ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

593000602 - Mobile Communication Systems

DEGREE PROGRAMME

59AI - Master Universitario En Comunicaciones Inalámbricas

ACADEMIC YEAR & SEMESTER

2022/23 - Semester 1

Index

Learning guide

1. Description

1.1. Subject details

Name of the subject	593000602 - Mobile Communication Systems
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	59AI - Master Universitario en Comunicaciones Inalámbricas
Centre	59 - Escuela Tecnica Superior De Ingenieria Y Sistemas De Telecomunicacion
Academic year	2022-23

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
Antonio Perez Yuste (Subject coordinator)	8304	antonio.perez@upm.es	Sin horario.
Yolanda Blanco Archilla	8203	yolanda.blanco@upm.es	Sin horario.
Juan Anton Moreno Garcia-Loygorri	8418	juan.moreno.garcia-loygorri@upm.es	Sin horario.

Angel Martinez Jimenez	7010	angel.martinez.jimenez@upm.es	Sin horario.

* 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

- Operation of RF instrumentation

- Management of technical information

- Programming in MATLAB and SIMULINK

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

CEM03 - Analizar y diseÃ±ar la arquitectura, servicios y protocolos de la red de acceso radio de un sistema de comunicaciones mÃ³viles 4G y 5G

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

RA8 - RA05.- Interpret data derived from empirical observations and measurements in terms of their importance and relate them.

RA10 - Distinguish between the different signal processes that take place in a modern radio access network for mobile communications

RA11 - Identify the social and economic impact of mobile communications in a global context

RA12 - Apply the knowledge acquired to the solution of qualitative and quantitative problems related to personal mobile communications

RA6 - RA02.- Choose the computer methods and tools necessary to tackle a problem and finds the solution.

* 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

Mobile communications have become an impressive worldwide service extended to the point of achieving outstanding coverage figures close to one hundred percent penetration nowadays. Socially speaking, that makes mobile communications an indispensable element for modern lifestyle; and economically speaking, it provides an essential global enabler for many world businesses as well.

LTE represents the fourth generation of mobile communications technologies, currently representing the most successful wireless mobile broadband technology across the globe. Although LTE is a very capable technology which is still evolving and expected to be used for many years to come, a new 5G radio access known as New Radio (NR) has been introduced to meet future requirements.

A higher mobile broadband is, without a doubt, the main objective but, more and more, future wireless networks will also be about a wider range of new use cases. That includes, among others, mission critical communications, intelligent energy distribution, smart vehicles and roads, ubiquitous transport solutions, remote healthcare and telesurgery, expanded industrial IoT, etc.

This course is aimed to gain a clear understanding on present and future mobile communication systems, particularly 4G-LTE and 5G-NR, and mainly focused to both the Radio Access Network (RAN) and to the Physical Layer (PHY). Both generations will be jointly presented, moving from the former key features to the latter?s new enhancements, although paying more attention to the latter one.

5.2. Syllabus

1. LTE and 5G overview
    1.1. Standardization activities: 3GPP
    1.2. Key capabilities and usage scenarios
    1.3. LTE key features and 5G enhancements
    1.4. LTE-5G interoperation
2. Architecture of the Radio Access Network
    2.1. The Evolved UMTS Terrestrial Radio Access Network
    2.2. The next generation Node B
    2.3. Architectural options
    2.4. Network Areas and Identities
    2.5. RRC State Diagram
    2.6. Signaling Protocols
3. PHY transmission structure
    3.1. Transmission scheme
    3.2. Time-domain structure
    3.3. Frequency-domain structure
    3.4. Bandwidth parts
    3.5. Carrier aggregation
    3.6. Supplementary uplink
    3.7. Duplex schemes
    3.8. Antenna ports
    3.9. Quasi-colocation
4. PHY signal processing: multi-antenna transmission
    4.1. Beamforming
    4.2. Spatial multiplexing
    4.3. Massive MIMO
    4.4. Downlink and uplink precoding

4.5. Beam management

5. PHY signal processing: modulation and channel coding

5.1. Radio transmission in a mobile cellular network

5.2. OFDMA

5.3. Cyclic prefix insertion

5.4. Code block segmentation

5.5. Turbo and LDPC encoding

5.6. Rate matching

5.7. Scrambling

5.8. Hybrid ARQ functionality

6. Air Interface L1

6.1. Air interface protocol stack

6.2. Frequency bands and combinations

6.3. Frequency domain structure

6.4. Time domain structure

6.5. Multiple antennas

6.6. Data transmission

7. Cell Acquisition

7.1. Acquisition procedure

7.2. Resource mapping

7.3. Acquisition of the SS/PBCH block

7.4. System information

8. Link Adaptation

8.1. CSI reference signals

8.2. Channel state information

8.3. Physical Uplink Control Channel

8.4. Sounding

9. Mm-wave for wireless communications

9.1. Radio wave propagation for Mm-wave

9.2. Mm-wave standardization

9.3. Antennas and Arrays for Mm-Wave applications

9.4. Mm-wave RF and analog devices and circuits

9.5. Multi-Gbps digital baseband circuits

6. Schedule

6.1. Subject schedule*

Week	Classroom activities	Laboratory activities	Distant / On-line	Assessment activities
1	**LTE and 5G overview** Duration: 04:00 **Architecture of the Radio Access Network** Duration: 04:00			**Architecture of the Radio Access Network** Continuous assessment and final examination Not Presential Duration: 01:00
2	**PHY transmission structure** Duration: 06:00	**PHY transmission structure** Duration: 02:00		**PHY transmission structure** Continuous assessment and final examination Presential Duration: 02:00
3	**PHY signal processing: multi-antenna transmission** Duration: 06:00	**PHY signal processing: multi-antenna transmission** Duration: 02:00		**PHY signal processing: multi-antenna transmission** Continuous assessment and final examination Presential Duration: 02:00
4	**PHY signal processing: modulation and channel coding** Duration: 06:00	**PHY signal processing: modulation and channel coding** Duration: 02:00		
5	**Air Interface L1** Duration: 06:00	**PHY signal processing: modulation and channel coding** Duration: 02:00		**PHY signal processing: modulation and channel coding** Continuous assessment and final examination Presential Duration: 02:00
6	**Cell Acquisition** Duration: 03:00 **Link Adaptation** Duration: 02:00	**Air Interface L1** Duration: 02:00 **Cell Acquisition** Duration: 01:00		**Air Interface L1** Continuous assessment and final examination Not Presential Duration: 01:00
7	**Link Adaptation** Duration: 01:00 **Mm-wave for wireless communications** Duration: 06:00	**Link Adaptation** Duration: 01:00		**Cell Acquisition and Link Adaptation** Continuous assessment and final examination Presential Duration: 02:00 **Mm-wave for wireless communications** Continuous assessment and final

				examination Presential Duration: 01:00
8				
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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
1	Architecture of the Radio Access Network		No Presential	01:00	10%	5 / 10	UPM5 UPM1 CEM03 CGI03 CGI04
2	PHY transmission structure		Face-to-face	02:00	20%	5 / 10	UPM5 UPM1 CEM03 CGI03 CB7
3	PHY signal processing: multi-antenna transmission		Face-to-face	02:00	20%	5 / 10	UPM4 UPM1 CEM03 CGI04 CB8
5	PHY signal processing: modulation and channel coding		Face-to-face	02:00	20%	5 / 10	UPM4 CGI02 UPM1 CEM03 CGI03 CB6 CB7
6	Air Interface L1		No Presential	01:00	10%	5 / 10	CEM03 UPM5 UPM1 CGI04 CB6 CB7
7	Cell Acquisition and Link Adaptation		Face-to-face	02:00	10%	5 / 10	UPM4 CGI02 UPM1 CEM03 CGI03 CB8

7	Mm-wave for wireless communications		Face-to-face	01:00	10%	5 / 10	UPM4 UPM5 UPM1 CGI03 CGI04 CB6

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
1	Architecture of the Radio Access Network		No Presential	01:00	10%	5 / 10	UPM5 UPM1 CEM03 CGI03 CGI04
2	PHY transmission structure		Face-to-face	02:00	20%	5 / 10	UPM5 UPM1 CEM03 CGI03 CB7
3	PHY signal processing: multi-antenna transmission		Face-to-face	02:00	20%	5 / 10	UPM4 UPM1 CEM03 CGI04 CB8
5	PHY signal processing: modulation and channel coding		Face-to-face	02:00	20%	5 / 10	UPM4 CGI02 UPM1 CEM03 CGI03 CB6 CB7
6	Air Interface L1		No Presential	01:00	10%	5 / 10	CEM03 UPM5 UPM1 CGI04 CB6 CB7
7	Cell Acquisition and Link Adaptation		Face-to-face	02:00	10%	5 / 10	UPM4 CGI02 UPM1 CEM03 CGI03 CB8
7	Mm-wave for wireless communications		Face-to-face	01:00	10%	5 / 10	UPM4 UPM5 UPM1 CGI03 CGI04 CB6

7.1.3. Referred (re-sit) examination

No se ha definido la evaluación extraordinaria.

7.2. Assessment criteria

The type of course and the approach described above make more convenient to select an assessment mechanism different to the traditional final exam. A continuous evaluation methodology is here proposed for this course, based on a set of short quizzes, or on a short project, or on both. This way, main concepts could be properly set up while the attractive of the contents are increased.

The assessment of lab practices based on the realization of a report will be also considered in addition to the former one, in order to get the final grade.

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
Slide shows	Web resource	Moodle LMS
Lab scripts	Web resource	Moodle LMS
3GPP	Web resource	The 3rd Generation Partnership Project, http://www.3gpp.org/
The 3G4G Blog	Web resource	https://blog.3g4g.co.uk
Cox, 2021	Bibliography	Cox, C., "An Introduction to 5G. The New Radio, 5G Network and Beyond", Ed. John Wiley & Sons, 2021
Cox, 2014	Bibliography	Cox, C., "An Introduction to LTE. LTE-Advanced, SAE, VoLTE and 4G Mobile Communications", 2nd ed, Ed. John Wiley & Sons, 2014
Dahlman, 2018	Bibliography	Dahlman, E. et al, "5G NR: The Next Generation Wireless Access Technology", Academic Press, Elsevier, 2018

Dahlman, 2011	Bibliography	Dahlman, E. et al, "4G: LTE/LTE-Advanced for Mobile Broadband", Academic Press, 2011