

Course guide

300038 - LCSF - Wireless Communications Laboratory

Last modified: 01/06/2023

Unit in charge:	Castelldefels School of Telecommunications and Aerospace Engineering	
Teaching unit:	739 - TSC - Department of Signal Theory and Communications.	
Degree:	BACHELOR'S DEGREE IN TELECOMMUNICATIONS SYSTEMS ENGINEERING (Syllabus 2009). (Compulsory subject).	
Academic year: 2023	ECTS Credits: 6.0	Languages: Catalan, Spanish

LECTURER

Coordinating lecturer: Definit a la infoweb de l'assignatura.

Others: Definit a la infoweb de l'assignatura.

PRIOR SKILLS

- Operation with complex numbers, matrices, random variables and processes.
- Analysis of signals and systems, analog and digital, in the temporal and frequency domain. Fourier analysis.
- Single and multi-carrier modulations. Operation with complex baseband notation and phasor representations.
- Basic electromagnetic theory: free space propagation, polarization, reflection coefficient, Doppler effect ...
- Channel coding strategies.
- Basic knowledge of communications, antennas and transmitters and receivers.
- Basic teletraffic theory. Erlang-B and Erlang-C formulas.

REQUIREMENTS

WIRELESS COMMUNICATIONS - Prerequisite

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:

7. CE 22 SIS. Capacidad para aplicar las técnicas en que se basan las redes, servicios y aplicaciones de telecomunicación tanto en entornos fijos como móviles, personales, locales o a gran distancia, con diferentes anchos de banda, incluyendo telefonía, radiodifusión, televisión y datos, desde el punto de vista de los sistemas de transmisión. (CIN/352/2009, BOE 20.2.2009.)

Generical:

5. EFFICIENT USE OF EQUIPMENT AND INSTRUMENTS - Level 2: Use the correct instruments, equipment and laboratory software for specific or specialized knowledge of their benefits. A critical analysis of the experiments and results. Correctly interpret manuals and catalogs. Working independently, individually or in groups, in the laboratory.

Transversal:

1. SELF-DIRECTED LEARNING - Level 2: Completing set tasks based on the guidelines set by lecturers. Devoting the time needed to complete each task, including personal contributions and expanding on the recommended information sources.
2. EFFICIENT ORAL AND WRITTEN COMMUNICATION - Level 2. Using strategies for preparing and giving oral presentations. Writing texts and documents whose content is coherent, well structured and free of spelling and grammatical errors.
3. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
4. TEAMWORK - Level 1. Working in a team and making positive contributions once the aims and group and individual responsibilities have been defined. Reaching joint decisions on the strategy to be followed.
6. EFFECTIVE USE OF INFORMATION RESOURCES - Level 2. Designing and executing a good strategy for advanced searches using specialized information resources, once the various parts of an academic document have been identified and bibliographical references provided. Choosing suitable information based on its relevance and quality.

TEACHING METHODOLOGY

The course combines the following teaching methodologies:

- Autonomous learning: the students will work on self-learning material at home and reserving the lab for extra practice out of class time.
- The students will develop different team projects where they must organize the work autonomously to achieve certain milestones with the teacher's guidance.
- Master lectures: part of the theoretical lectures should be concentrated at the beginning of the semester. The projects will not start until the students have the necessary theoretical content.

LEARNING OBJECTIVES OF THE SUBJECT

LCSF aims to provide students a complete overview of the problems that arise in wireless communications systems. Not only from a detailed knowledge of the radio medium but also placing a lot of emphasis on system design.

The course is divided into 4 main modules: (a) propagation, (b) cellular radio engineering, (c) planning of mobile communication networks, (d) broadcasting systems (digital TV). After completing the course, the student should be able to:

1. Characterize the statistical behavior of the radio signal (first and second moments) and to model it for coverage calculations and predict the bit error rate. The student must be able to do it both from a theoretical and experimental viewpoint, in this last case from measurement campaigns. Differentiate the characteristics of different operating environments: urban, rural, indoor, roads and tunnels.
2. Explain the advantages of cellular deployments and the main procedures that govern them. To measure experimentally parameters controlling these procedures. Know the characteristics of a base station equipment in operation.
3. Design cellular systems to achieve a degree of service in terms of coverage (SINR and throughput probability), blocking probability and monthly data consumption done by users. Students should know all the steps to plan a network both theoretically and by means of planning and simulation computing tools. The student will be able to explain the main features of 4G and 5G systems.
4. Do simple designs of digital broadcasting (digital video broadcasting, DVB) based on OFDM. Perform measurements and understand the effects of the radio channel on the OFDM signal as well as strategies to compensate them. Understand the characteristics of planning single frequency networks, and the process of setting internal transmission delays. The student will be able to explain the PHY features of DVB-T systems of 1st and 2nd generation.

Thanks to the organization of the course in projects:

- Students will acquire social and cooperative skills for the proper functioning of the group work. Specifically, they will work in groups towards the implementation of projects looking at all stages: project planning, information search, choice of solutions, implementation, distribution of tasks, integration of results, writing of technical reports and presentation, defense and argumentation of final decisions and results achieved.
- Learn to plan and lead a project and take responsibility within the group.
- Improve self-learning ability.
- Agility in the use of wireless communications laboratory equipment for calibration, measurements, processing and analysis of data

STUDY LOAD

Type	Hours	Percentage
Guided activities	26,0	17.33
Self study	84,0	56.00
Hours large group	14,0	9.33
Hours small group	26,0	17.33

Total learning time: 150 h



CONTENTS

- Course presentation

Description:

Make the student know:

- The contents of the course and recommended bibliography per topic.
- Description of projects and guidelines on how groups should work.
- Establishment of project schedules for each group.

Specific objectives:

Look at description

Full-or-part-time: 0h 30m

Theory classes: 0h 30m

- Characterization of the radio signal

Description:

At the end of this section the student should be able to:

- List and calculate the effect of a radio channel with few reflectors: propagation in free space, reflection against the ground, variations of the refractive index, diffraction effect, attenuation by hydro-meteors, gases and clutter. The student should be able to find models of n-ray propagation, calculate diffraction losses from the result of Fresnel integrals, implications of blocking different percentages of the 1st Fresnel zone. Anticipate the effect in the direction of the wave front under the effect of atmospheres with different refractive gradients.
- Characterize the statistical behavior of the radio signal in multipath conditions and with many reflectors:
 - Calculation of the average attenuation based on statistical propagation models in different environments: outdoor (rural, urban), indoor and tunnels. The student should be able to explain the differences between free space, Flat Earth, Egli, Okumura-Hata, Cost231-Hata, and Cost231-Walfish-Ikegami models.
 - Characterization of the standard deviation of attenuation in the presence of shadowed areas. At the end of this lesson, the student should be able to perform coverage calculations with any propagation model and ensure perimeter coverage with any degree of service that is defined. It should be able to calculate the margins required to account for fading with log-Normal statistics, identify the limiting link, analyze the differences between link budgets in different environments (urban, rural, communication routes, indoor and tunnel implementations) and for different services. Calculate the number of nodes required to provide service in a target area
 - Statistical characterization of attenuation deviations due to multipath propagation:
 1. Identify broadband and narrowband conditions. Students should be able to interpret a power delay profile (PDP), select an appropriate tap model in the evaluated environment, and calculate the spread delay. It should be able to predict the type of impulse response in different environments (rural, urban, mountain...).
 2. Efficiently analyze the consequences of the Doppler effect: at the time level: Calculate the channel coherence time, predict the presence of slow or fast fades. Differentiate between Rayleigh and Rice channels (vs. Gaussians) and its effects on the signal (module and phase) and the probability of error in the bit. You will need to be able to find the minimum distance between two antennas to ensure spatial diversity and evaluate variations in diversity gain depending on the number of antennas, as well as explain the different methods of signal combination. Frequency level: Calculate frequency deviation, and power spectral density according to Jakes model.
 3. Efficiently analyze the consequences of multipath propagation in high delay dispersion environments and assess whether the channel is selective or plane in frequency. They must be able to estimate the coherence bandwidth.
- List the different steps to follow in a measurement campaign to correctly fit a propagation model and propose alternatives by minimizing the mean square error between prediction and measurement. Understand and apply Lee's criterion for short-term fading removal. To be able to enunciate and calculate the main merit factors of a propagation model from measurements: first and second order moments of error, Pearson correlation factor, etc. Obtain the standard deviation caused by shadowing from measurements.
- Describe the particularities of leaky coaxial deployments and calculate attenuation in these scenarios. Correctly interpret the specifications of these elements to establish communications in tunnels and railway communication channels

Specific objectives:

Look at description

Related activities:

- A.1. Project 1. Introduction to campaigns of measures and adjustment of propagation models
- A.5. Evaluation of the behaviour of the radio medium with Matlab.
- A.6. Mid-term theoretical examination.

Full-or-part-time: 44h

Theory classes: 5h 30m

Laboratory classes: 13h 30m

Self study : 25h

- Cellular radio-communications engineering

Description:

- Students should be able to justify the advantages of cellular deployments, as well as the different typologies that exist.
- They must be able to describe the architecture of a cellular system of any generation (2-5G) as well as the functions of the elements that compose them, back and fronthaul circuits, architectural changes with cloud RAN, etc.
- They must be able to describe and calculate the parameters that conform to the main procedures governing cellular systems, and the basic modes of operation associated with users: (de)attach, handover and handover events, with special emphasis on LTE systems, Open and closed loop power control, paging process, the need for localization/routing areas and lists of tracking areas, timing advance, types of scheduling, link adaptation and utilization of multiantenna systems for transmission diversity and spatial multiplexing. The student must be able to explain the frequency-time grid of OFDMA systems and the different types of signal located there
- Interact with a real mobile phone network and measure different KPIs, understand their impact on radio resource management procedures. Spectral measurements and identification of commercial networks and the different technologies currently operational in sub 6 GHz cellular bands.

Specific objectives:

Look at description

Related activities:

- A.2. Project 2. Procedures and management of radio resources in mobile communications systems
- A.6. Mid-term theoretical examination.

Full-or-part-time: 33h 30m

Theory classes: 6h

Laboratory classes: 7h 30m

Self study : 20h

- Engineering, design and planning of cellular systems

Description:

- Students should be able to design cellular systems to achieve a degree of service in terms of coverage (SINR and throughput probability), blocking probability and monthly data consumption done by users. Students should know all the steps to plan a network both theoretically and by means of planning and simulation computing tools. The main characteristics and specificities of 5G systems must be known:
 - Calculation of interferences. They should know how to calculate CIR in theoretical cellular deployments and communication pathways under different interference reduction and coordination configurations: basic frequency reuse and co-channel distances, multiple reuse patterns, fractional reuse options, etc. Explain the impact of radiant system configuration on azimuth and elevation... They will also need to show how to proceed with actual calculations with simulation tools.
 - Dimensioning studies to ensure a certain probability of blocking and to ensure a certain volume of monthly data. Dimensioning of control channels.
 - Choice of equipment from specifications and to achieve design quality criteria.

Specific objectives:

Look at description

Related activities:

- A.3. Project 3. Planning of a cellular system with a coverage calculation tool
- A.6. Theoretical exam at the end of the semester.

Full-or-part-time: 52h

Theory classes: 8h

Laboratory classes: 12h

Self study : 32h

- Introduction to broadcasting systems engineering. Digital Video Broadcasting.

Description:

The objectives of this module are:

- Do simple designs of digital broadcasting (digital video broadcasting, DVB) based on OFDM.
- The student should be able to explain the PHY features of DVB-T systems of 1st and 2nd generation.
- Perform measurements with commercial equipment and understand the effects of radio channel on the OFDM signal as well as strategies to compensate them.
- Understand the characteristics of planning single frequency networks, and the process of setting internal transmission delays.

Specific objectives:

Look at description

Related activities:

- A.4. Optional Project 4. Experimental analysis of the DVB-T signal in the radio medium.
- A.6. Theoretical exam at the end of the semester.

Full-or-part-time: 17h

Theory classes: 4h

Laboratory classes: 3h

Self study : 10h

ACTIVITIES

A.1. PROJECT 1. INTRODUCTION TO CAMPAIGNS OF MEASURES AND ADJUSTMENT OF PROPAGATION MODELS

Description:

Project of the propagation module. The project will involve the analysis of a campaign of measures, evaluation of existing propagation models, learning to create new models and extraction of the typical deviation of the attenuation caused by shadowing. Analysis of multipath effects. Measurements on radiant cable.

Specific objectives:

- The first objective is for the student to learn the steps to follow in a campaign of measures to correctly adjust an existing propagation model.
- Likewise, it must be able to propose alternatives through regression techniques and minimizing the mean square error between prediction and measurement. They must process with solvency the captured measures and be able to enunciate and calculate the main merit factors of a propagation model from the measurements: first and second order moments of error, Pearson correlation factor, etc.
- Know how to apply Lee's criteria and also statistically characterize long-term fades to use the conclusions in system design.
- Another goal is for the student to become familiar with common measurement software in wireless local area network environments.
- The student must be able to analyze the first-order effects of multipath propagation
- The student must be able to explain the performance of a radiant cable in terms of propagation and deployment of radio systems versus propagation with classical antennas, as well as predict its range in a complete communications system.

Material:

- Measuring software and hardware.
- Software developed in Matlab to import measurements and ease its processing
- Specifications of transmitting equipment, antennas and radiating cable.
- Project guide and milestones

Delivery:

- Report based on project objectives and preliminar studies.

Full-or-part-time: 18h 45m

Laboratory classes: 7h 30m

Self study: 11h 15m

A.2. PROJECT 2. PROCEDURES AND MANAGEMENT OF RADIO RESOURCES IN MOBILE COMMUNICATIONS SYSTEMS

Description:

Project associated to the module on cellular engineering. With the help of Matlab, the student will analyze the physical layer of LTE and create a full grid step by step. Different configurations will be compared and its impact on the user throughput, it will be analyzed the impact of the propagation on the grid and the direct consequences on the procedures of handover, scheduling, PCI planning. The impact of the terminal category on the quality of service will also be evaluated. Vertical handovers will be performed and spectral analysis will be done and also quality measurements on real networks with net monitoring tools as well as visualization of the parameters necessary to (de)attach (from)into the network and guaranteeing mobility in idle mode. It will also be analyzed the problems in the integration of air terminals in the network.

Specific objectives:

See description of module 2

Material:

- Software Matlab
- Software for net monitoring in Android i IOS
- Forms and templates for result sharing among working groups.
- Measurement campaign done in EETAC facilities with specific software.
- Equipment to perform spectral analysis
- Project description.

Delivery:

Same as in Project 1

Full-or-part-time: 18h 45m

Laboratory classes: 7h 30m

Self study: 11h 15m

A.3. PROJECT 3. PLANNING OF A CELLULAR SYSTEM WITH A TOOL FOR COVERAGE CALCULATIONS

Description:

Project associated with the planning module. The student has to do the planning of a realistic system using simulation tools. The deployment will be over an area of Catalonia with at least three environments to be considered: urban, rural and communication ways. Students should be able to execute all design stages typical of a radio planning engineer.

Specific objectives:

They are directly the first point of the third module of contents

Material:

- Link budget to calibrate the ones student have to prepare.
- Manual of planning tool and tutorial to get started.
- Project guide and milestones

Delivery:

View Project 1

Full-or-part-time: 27h

Laboratory classes: 9h

Self study: 18h

A.4. PROJECT 4. EXPERIMENTAL ANALYSIS OF THE DVB-T SIGNAL IN THE RADIO MEDIUM.

Description:

Project associated with Module 4. Optional. With professional laboratory instrumentation (generators and specific analyzers). The student will carry out an advanced experimental study of the OFDM signal in the digital video broadcasting terrestrial (DVB-T).

Specific objectives:

They are directly the contents of the fourth module.

Material:

- Specification of equipment, antennas.
- Project guide and milestones

Delivery:

Oral presentation with experiment results.

Full-or-part-time: 12h

Laboratory classes: 4h

Self study: 8h

A.5. ASSESSMENT OF RADIO MEDIUM BEHAVIOUR WITH MATLAB

Description:

The student will experience and evaluate variations of behavior for different realistic input parameters.

- Impact of antenna separation in a two ray environment (flat earth).
- Power spectral density of the signal in a Doppler environment.
- Phasor representation and frequency selective fading in a doppler environment.

Specific objectives:

Strengthen the knowledge of the propagation module.

Material:

Already programmed scripts in Matlab

Full-or-part-time: 3h

Guided activities: 1h

Self study: 2h

MID SEMESTER EXAM

Description:

Evaluation activity

Full-or-part-time: 1h 30m

Theory classes: 1h 30m

FINAL EXAM

Description:

Evaluation activity

Full-or-part-time: 1h 30m

Theory classes: 1h 30m



GRADING SYSTEM

Evaluation criteria that are defined in the course infoweb will be applied.

EXAMINATION RULES.

- Attendance at laboratory sessions is mandatory.
- At the end of the project, the group should write a report based on the objective index. Likewise, a self-analysis of group work must be done. Both documents will be delivered within the established limits.
- Some project tasks will be done cooperatively between different groups.

BIBLIOGRAPHY

Basic:

- Goldsmith, A. Wireless communications. New York: Cambridge University Press, 2005. ISBN 9780521837163.
- Rappaport, Theodore S. Wireless communications : principles and practice. 2nd. ed. Upper Saddle River, NJ: Prentice Hall, 2002. ISBN 0130422320.
- Molisch, Andreas F. Wireless communications. West Sussex, England: John Wiley & Sons, cop. 2005. ISBN 047084888X.

Complementary:

- Mishra, Ajay R. Advanced cellular network planning and optimisation : 2G/2.5G/3G ... evolution to 4G. Chichester: John Wiley, 2007. ISBN 97804700174714.
- Artés Rodríguez, Antonio; Pérez González, Fernando. Comunicaciones digitales. Madrid: Pearson Educación/Prentice Hall, cop. 2007. ISBN 9788483223482.