Universidad de Alcalá

TEACHING GUIDE

High Capacity Digital Communications

Master in
Telecommunication Engineering

Universidad de Alcalá

Academic Year 2022/2023

1st Year - 2nd Semester

Approved by the School Board on June 3, 2022

TEACHING GUIDE

Course Name:	**High Capacity Digital Communications**
Code:	**201810**
Master in:	**Telecommunication Engineering**
Department and area:	**Teoría de la Señal y Comunicaciones** **Teoría de la Señal y Comunicaciones**
Type:	**Compulsory**
ECTS Credits:	**4.5**
Year and semester:	**1st Year, 2nd Semester**
Teachers:	Por definir
Tutoring schedule:	Consultar al comienzo de la asignatura
Language:	Spanish / English Friendly

1. COURSE SUMMARY

In recent years, an increasing number of users demands innovative services with high requirements in terms of data rate or bandwidth. Examples of such services include High-Definition Television (HDTV), multimedia communications, or access to high speed Internet. This trend is due, among other factors, to the tremendous boost in mobile devices, which is pulling the telecommunication market and exerting great pressure to improve the capacity of access networks. In addition, due mainly to social networks, more capacity is highly demanded. Residential users require even greater capacities, since a set of devices (Smart TV, HDTV, video games, domotics, etc., all networked) converges at the current digital home, that gain access to the outside world through a fixed network, which should have a high capacity.

The described dynamic is possible thanks to the development of digital communication techniques that at their physical layers exhibit very high capacity to carry information. In this context, the aim of this course is to provide the students a set of skills to implement, among others, techniques of single- and multi-carrier modulations that, in combination with advanced techniques of adaptive coding and modulation, estimation and channel equalization, allow them to design the physical layer of networks and systems with very high capacity which can transport and/or distribute signals containing multimedia information.

In order to motivate and better understand how these techniques work, each technique is presented by means of case studies: technique/ application or case study. Following this approach, practice classes are proposed in order to enable students to simulate the behavior of these techniques in realistic digital communication systems.

Students should have studied subjects related to the fundamentals of signal processing and digital communications to follow the course properly.

2. SKILLS

Basic, Generic and Cross Curricular Skills.

This course contributes to acquire the following generic skills, which are defined in the Section 3 of the Annex to the Orden CIN/355/2009:

en_CB6 - To have and understand knowledges that provide a basis or opportunity to be original in the development and/or application of ideas, often in a research context

en_CB7 - That students know how to apply the acquired knowledge and problem-solving abilities in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their area of study.

en_CB8 - That students be able to integrate knowledge and face the complexity of making judgements based on incomplete or limited information that includes reflections on the social and ethical responsibilities linked to the application of their knowledge and judgements.

en_CB9 - That students be able to communicate their findings and the ultimate knowledge and reasons behind them to specialized and non-specialized audiences in a clear and unambiguous manner.

en_CB10 - That students have the learning skills that will enable them to continue studying in a way that will be largely self-directed or autonomous.

en_CGT1 - Skill of analysis and synthesis.

en_CGT2 - Skill of organization and planning.

en_CGT3 - Skill to analyze and search for information from diverse sources

en_CGT4 - Skill to make decisions.

en_CGT5 - Skill to adapt to new situations.

en_CT1 - Troubleshooting skill

en_CT2 - Ethical commitment to work

en_CT3 - Skill to work in a team

en_CT4 - Working in a pressure environment

en_CT5 - Motivation for quality

Professional Skills

This course contributes to acquire the following professional skills, which are defined in the Section 5 of the Annex to the Orden CIN/355/2009:

en_CTecTel1 - Skill to apply methods of information theory, adaptive modulation and channel coding, as well as advanced digital signal processing techniques to communications and audiovisual systems.

en_CTecTel3 - Skill to implement wireline, satellite systems in fixed and mobile communications environments

Learning Outcomes

After succeeding in this subject the students will be able to:

RA1. To use mathematical models of communications systems, evaluating the fundamental limits in communications.

RA2. To apply channel coding techniques appropriate for the techniques considered in the course.

RA3. To correctly apply single and multiusers medium access techniques in digital communications systems.

RA4. To develop and correctly apply channel estimation and equalization techniques in digital communications systems.

RA5. To implement adaptive coding and modulation techniques.

RA6. To use MIMO techniques to increase the capacity and to implement systems with spatial diversity.

3. CONTENTS

Contents Blocks	Total number of hours
Unit 1. Motivation and Introduction Need for high-capacity digital communications. Characteristics of the transmission medium. Medium access techniques. Overview of equalizing techniques. Primary modulation (Mapping). Presentation of cases study.	3 hours
Unit 2. Single carrier and multicarrier modulations Multi-tone modulation: Basic idea, non-overlapping and overlapping channels, channel partitioning. Vector coding: Matrix formulation, definition. OFDM and DMT modulations: Block diagram, cyclic prefix, zero padding, matrix notation, OFDM and DMT differences. Windowed OFDM. SC-FDE: definition, matrix notation, comparison with OFDM. Multi-carrier modulation with other transformed blocks: System model, motivation, DCT-MCM. Multi-carrier modulation with filter banks. Practical aspects of implementation.	9 hours
Unit 3. Multiple access techniques OFDMA: Basic idea, differences with OFDM. Single Carrier-FDMA. Definition, differences with SC-FDE. Practical aspects of implementation: Channel coding, spectral shaping, PAPR, synchronization. Application cases, standards.	4 hours
Unit 4. Channel estimation and equalization techniques System model and motivation. Channel estimation: Pilot structure, estimation based on training symbols, LS, MMSE, and DFT-based methods. Equalization in the time domain: Introduction, MMSE and MSSNR techniques, Zero-Forcing. Adaptive channel estimation and equalization techniques.	8 hours
Unit 5. Adaptive techniques Motivation. Introduction to adaptive techniques. Adaptive bit-loading algorithms: constant power bitrate maximization (variable bitrate techniques) and constant bitrate energy minimization (variable energy techniques). Adaptive coding and modulation.	8 hours
Unit 6. MIMO Wireless MIMO channels. Capacity of SISO, SIMO, MISO and MIMO systems with fading. Decomposition of the MIMO channel into parallel independent channels: maximizing capacity. Spatial Multiplexing and Spatial Diversity. Transmission diversity: Space-time codes or STBC. MIMO/OFDM schemes. Practical implementation issues: IEEE 802.11n standard.	10 hours

4. TEACHING - LEARNING METHODOLOGIES. FORMATIVE ACTIVITIES.

4.1. Credits Distribution

Number of on-site hours:	45 hours
Number of hours of student work:	68
Total hours	113

4.2. Methodological strategies, teaching materials and resources

The teaching strategy of the course is divided into 3 sections: classroom learning, learning in small groups and finally the working sessions in the laboratory.

Sessions of large group in the classroom:

Working sessions in the classroom, in large groups, will consist of lectures where the main concepts of the theory of circuits will be presented. The aim is to introduce students to the theoretical foundations of circuit analysis in a guided and reflective way. The understanding of these concepts will culminate with the use of them in both the laboratory and the problem solving sessions in small groups.

Teaching materials will be essential to create reflective learning environments, where students and teachers can undertake a critical analysis that allows the student to autonomously relate concepts.

The order of presentation of the contents will evolve from the simple to the complex, in order to avoid a high degree of abstraction that might cause a student lack of interest in the course. In any case, it is very convenient, during the working sessions in the classroom, to establish linkages with other subjects in the curriculum, and to provide possible experience on the contents, which will help to attract students' attention and will encourage their interest in the subject.

Sessions of problems in small groups

The purpose of these sessions is to create a suitable atmosphere to participate and apply the theoretical concepts as well as encouraging the capacity of analysis and synthesis. The student must interpret the problems, recognize the implicit or explicit concepts, be able to handle the tools for resolution, and analyze the results from a critical standpoint. The teacher will solve basic problems and will propose the students to solve problems individually to test their knowledge and taking feedback to improve their comprehension. Participation will be promoted through several strategies, such as discussions, set of questions, quiz, etc. Special attention must be paid to the analysis and resolution of problems to learn how to solve problem from different perspectives and also checking its consistency. In these sessions, the teacher will observe the student activity to determine the level of learning achieved and the difficulties found as a mean to adapt the explanations to the degree of understanding. The continuous assessment tests will be carried out during these sessions in order to achieve a formative evaluation. Information and Communication Technologies will be used during the course to support the formative activities: Internet, forums, wikis, email, available material in “Aula Virtual” (virtual classroom), etc.

Sessions of laboratory in small groups

This is the third learning scenario. The students will work individually (or in groups, depending on computer availability) to write the algorithms where the theoretical concepts to solve problems are applied using a computer and a programming platform such as Matlab. Guide notes with the objectives

and the characteristics of the algorithms will be provided. Before every session, the student has to prepare the work starting from the theoretical foundations. In the lab, the student will write the algorithms and will analyze the results from a critical standpoint to infer relevant conclusions. This work is carried out under the teacher supervision who will advice the student on the solution strategy, pursuing a thoughtful and creative attitude. During the session, the teacher can make a set of questions to each student to check how the problem has been faced and with the aim to make an oral assessment, monitoring and suggestion for improvement that are considered opportune. Finally, the student will deliver the solution (algorithms and results analysis) through Aula Virtual. The report must summarize the conclusions arisen from the implementation.

Seminars

Conferences and seminars are an important part of teaching in postgraduate studies. In them, presentations will be made that will go deeper into the concepts explained. As far as possible, conferences and seminars will be organized in the course, offered by prestigious professors from within and outside the University of Alcalá.

Group and cooperative work

Another learning scenario is the performance of work related to the techniques and concepts developed in the classroom. The objective is for the student to develop skills related to the search for information, the handling of bibliography and the preparation of reports on the subjects proposed to them. In the same way, the aim is to encourage teamwork.

5. ASSESSMENT: procedures, evaluation and grading criteria

Preferably, students will be offered a continuous assessment model that has characteristics of formative assessment in a way that serves as feedback in the teaching-learning process.

5.1. PROCEDURES

The evaluation must be inspired by the criteria of continuous evaluation (Learning Assesment Guidelines, LAG, art 3). However, in compliance with the regulations of the University of Alcalá, an alternative process of final evaluation is made available to the student in accordance with the Learning Assesment Guidelines (last modified in the Governing Board of October 31, 2019) as indicated in Article 10, students will have a period of fifteen days from the start of the course to request in writing to the Director of the Polytechnic School their intention to take the non-continuous evaluation model adducing the reasons that they deem convenient. The evaluation of the learning process of all students who do not apply for it or are denied it will be done, by default, according to the continuous assessment model. The student has two calls to pass the subject, one ordinary and one extraordinary.

Ordinary Call

Continous Assessment:

The main assessment tools will be:

1. **Problems (EP**). Solving practical problems individually or in small groups. Solving practical problems individually or in small groups.
2. **Laboratory Exercises (EL)**. Performance of laboratory practices and delivery of the corresponding reports. The evaluation will consider systematic observation, where the teacher will record the main difficulties and skills observed in each student, and the realization of a single memory by practice, by each of the groups of students who have done it.
3. **Assessment** Tests (PE). Performing written tests focused on both practical and theoretical aspects of the subject.

Students must attend 100% of the laboratory sessions and deliver the corresponding reports to all laboratory practices. Recovery sessions will be enabled for those students who have not attended any of the sessions and justify it documentarily.

The students, as a group, will deliver the reports of the laboratory practices following the established schedule. These practices will be evaluated by the professor responsible for the laboratory group, to assess if the objectives indicated in the script of the same have been met.

Assessment through final exam:

In the case of evaluation by means of a final exam, the evaluation elements to be used will be the following:

1. **Final assessment** Tests (PEF). Performing written tests focused on both practical and theoretical aspects of the subject.

Extraordinary Call

The procedure will be the same as that described for the assessment by means of a final exam in the ordinary call.

5.2. EVALUATION

EVALUATION CRITERIA

The assessment criteria measure the level in which the competences have been acquired by the student. For that purpose, the following are defined::

CE1. The student demonstrates a deep knowledge of the theoretical concepts explained in the course.

CE2. The student correctly applies the knowledge acquired to the design of high-capacity digital communications systems.

CE3. The student chooses the most suitable medium access technique, depending on the parameters and design requirements of the communications system.

CE4. The student adequately and efficiently implements algorithms that allow the development of the techniques explained in the course.

CE5. The student solves practical problems related to the subject with rigor and order.

GRADING TOOLS

The work of the student is graded in terms of the assessment criteria above, through the following tools:

1. Ordinary call
   a. Continuous assessment, with the previously described assessment tools (problems (EP), Laboratory Exercises (EL), and two assessment exams (PE)).
   b. Final assessment (PEF)
2. Extraordinary call. Final assessment (PEF)

GRADING CRITERIA

Ordinary call

In the ordinary call-continuous assessment the relationship between the competences, learning outcomes, criteria and evaluation instruments is as follows.

Skill	Learning Outcomes	Evaluation criteria	Grading Tool	Contribution to the final mark
CtecTel1, CTecTel3, CB6-CB10, CT1-CT5	RA1, RA2, RA3, RA4	CE1, CE2, CE3, CE4, CE5	EL	15%
			PE	35%
CtecTel1, CTecTel3, CB6-CB10, CT1-CT5	RA1, RA2, RA3, RA4, RA5, RA6	CE1, CE2, CE3, CE4, CE5	EP	10%
			EL	15%
			PE	25%

The grade of "Not presented" will be awarded to the student who, having opted for the continuous evaluation procedure, meets any of the following requirements:

- When the student has failed to attend, at least, 60% of the classes in small groups.
- When the student has not delivered, at least, 60% of the requested work.

In the ordinary call-final evaluation, the relationship between the competences, learning outcomes, criteria and evaluation instruments is as follows.

Skill	Learning Outcomes	Evaluation criteria	Grading Tool	Contribution to the final mark
CtecTel1, CTecTel3, CB6-CB10, CT1-CT5	RA1, RA2, RA3, RA4, RA5, RA6	CE1, CE2, CE3, CE4, CE5, CE6	PEF	100%

Extraordinary call

In the case of the extraordinary call, the same percentages that have been established in the case of the evaluation by means of a final exam will be maintained.

6. BIBLIOGRAPHY

6.1. Basic Bibliography

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6.2. Additional Bibliography

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- A. Goldsmith, Wireless Communications. Cambridge University Press, 2006.
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- Revistas científico técnicas: IEEE Communications Magazine, IEEE Journal on Selected Areas in Communications, IEEE Transactions on Communications…

Disclosure Note

The University of Alcalá guarantees to its students that, if due to health requirements the competent authorities do not allow the total or partial attendance of the teaching activities, the teaching plans will achieve their objectives through a teaching-learning and evaluation methodology in online format, which will return to the face-to-face mode as soon as these impediments cease.