2010-11 academic year

Data Transmission and Encoding (21606)

Degree/study: Bachelor's degree in Telematics Engineering and in Audiovisual Systems
Year: 2nd
Term: 2nd and 3rd
Number of ECTS credits: 8 credits
Hours of studi dedication: 200 hours
Teaching language or languages: Catalan and Spanish
Teaching Staff: Òscar Cámara (coordination), Gemma Piella, Blanca Mayayo and Eduard Gomà, Piots Holonowick

1. Presentation of the subject

Data transmission and Encoding (DTE) is a compulsory subject of the second year of the following degrees carried out by Polytechnic School in the Universitat Pompeu Fabra: bachelor's degree in Telematics Engineering and bachelor's degree in Audiovisual Systems.

This subject has been designed using a methodology adapted to the new European Higher Education Area (EHEA), also known as the Bologna Process, which aims to focus the learning process on the student. The main objective of this design is to involve continuously the student in the development of the subject by continuing assessment and individual study as a complement to the lectures. The difficulty of this subject makes this continuous two-term work essential to assume the minimum required knowledge.

The main objective of Data Transmission and Encoding (DTE) is introducing the fundamental concepts for analysis and design of a digital communications system, including the applied concepts of information theory to the compression and coding data as well as its codification and the correction of errors that are introduced by the channels of communication. Currently, digital communications systems are becoming indispensable to assume the increasing demand of quantity and quality in the data communication. The main reason of that is the flexibility and the different options of data processing provided by digital transmission, unlike analog transmission. Thus, the explained knowledge in this subject is fundamental for future engineers related to telecommunications.

Figure 1 shows the block diagram of a typical and general system of digital communications. Taking into account the skills that have been taught in other subjects, with a close relationship with Communication Systems, Principles of Communication and Network and Services Protocols, the DTE theoretical content will focus mainly on the stages of encoding, as both sources and channels, and modulation and digital demodulation stages in base band and carrier. When the different encodings have been explained, possible modulations and tools to evaluate, such as the calculation of probability of error, the last part of the subject is focused on the design and evaluation of all digital systems to put into practice the acquired skills. Finally, the basic concepts of some advanced modulations, which are used in such important areas such as mobile communications, will be introduced.

The theoretical elements are the basis of the lectures, but an equally important component in this subject is the resolution of activities, which is a big part of individual work of the student outside the classroom and it will be evaluated together in seminar sessions. In addition, students are required to develop teamwork, information search and oral and written communication skills from different activities to hand in and group practical activities during the subject.

2. Previous requirements to follow the formative itinerary

The DTE subject is a part of the set of subjects related to the "signal and communication theory", some of them are done in the bachelor's degree in Telematics such as Communication Systems (SDC), Network and Services Protocols (PXS) and Principles of Telecommunications

(PT). So, the objective of this set of subjects is to explain all the main elements of a digital communication system (SCD), as the system in Figure 1. In this figure, it can be observed the connection between the SCD subjects and the subjects of the set.

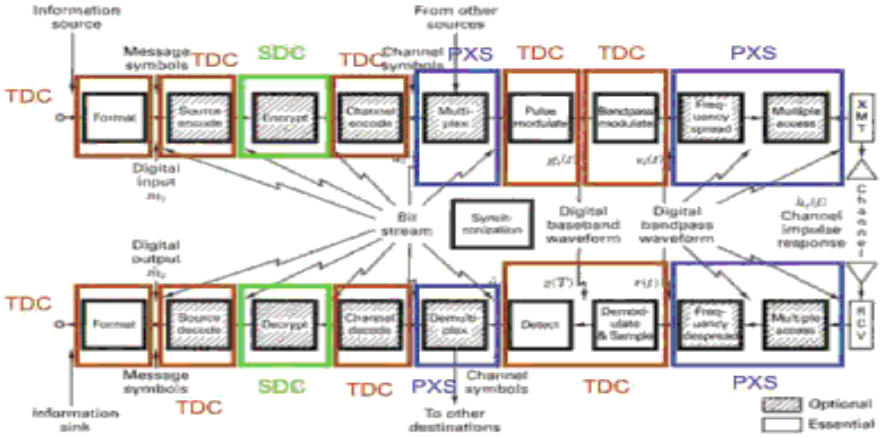

Figure 1: block diagram of a typical communication system and the connection between the related subjects: Data Transmission and Encoding (TDC), Communication Systems (SDC) and Network and Services Protocols (PXS).

DTE is a brief review of some concepts that have already presented in subjects such as Principles of Telecommunication and Communication Systems (for example, about signals and systems, transmitters and receivers, noise, sampling and quantification). These concepts represent the fundamentals on which students can make progress towards a deeper understanding of digital communications.

Finally, it is important to emphasize the importance of two mathematical tools of the DTE subject, Fourier and probability, which are introduced in the first year of the degree and are developed in the subjects of Signals and Systems and Probability and Stochastic Processes. DTE is not a basic math subject for engineers, because it requires a high knowledge of the commonly used Fourier properties, separation and the connection between time and frequency domains and the main axioms of probability. As it is a subject that deals with many equations, it will not be asked to memorize all them, and the necessary ones will be provided in the different exams, except those that are displayed continuously throughout the subject.

3. Competences to be obtained in the subject

Transferable skills	Specific competences
Instrumental 1. Oral and written communication in the own language 2. Capacity of analysis and synthesis 3. Knowledge of a second language, in this case, English. 4. Problems solving 5. Skills in the information management 6. Creativity Interpersonal 6. Planning and organization of the teamwork 7. Capacity of criticism and self-criticism. 8. Skill to work in an international context.	1. Capacity to use knowledge on mathematics, science and engineering. 2. Design and run experiments, as well as analyze and interpret the results. 3. Capacity of design a system which is a part or process of the Information and Communication Technologies area to achieve the required specifications. 4. Capacity to identify, formulate and solve engineering problems. 5. Capacity to use techniques and tools of the modern engineering that are necessary for the practice in engineering.

Systemic 9. Capacity to put the knowledge into practice 10. Capacity of the estimate and planning of work. 11. Continuous learning 12. Project design and management	6. Design, create, exploit and manage the network and the communication systems.

4. Learning aims

In this subject, the fundamental concepts are introduced for the analysis and the design of a typical system of digital communications, for instance, a satellite link, wireless or mobile telephony. More specifically, the following aims are tried to achieve:

• Find out the parts, the general operation and the purpose of a digital system of communications
• Identify the advantages of a digital system of communications beside an analog one
• Turn the input information into in a digital format
• Describe a receiver's information, enumerate and explain the sources of the mistakes to detect a signal
• Describe mathematically the discrete information sources and design the encoding diagram for them
• Identify the different diagrams of source coding and determine its properties
• Choose among different alternatives of source encoding following some specific criteria
• Design adapted filters for an ideal detection
• Represent signals in the space of the signal
• Design equalization filters
• Describe the different modulation diagrams with carriers that are used in digital communications.
• Classify the detection methods of the transmitted information (coherent / incoherent)
• Calculate the error probability related to different detection diagrams and evaluate its interest in different situations
• Differentiate the concepts of the amount of information of a source, mistake and joint information
• Calculate the error probability of reception for lineal, convolutional and cyclic diagrams of channel encoding
• Analyze (by the design and selection) the lineal, convolutional and cyclic diagrams of channel encoding following the different specifications of a transmission system
• Analyze the output data of a channel to quantify the information given related to the input
• Distinguish between the concepts of the channel capacity and the transmission rate, identifying its bounding factors
• Reproduce the proof of some fundamental theorems of the information and encoding theory with mathematical rigor
• Analyze the aims and limitations for the design of a digital communications system
• Determine which modulation and encoding diagrams are the most appropriate in the different systems that are limited in power or in bandwidth
• Analyze the advantages and disadvantages of the main spread spectrum modulations
• Connect the spread spectrum modulations with the multiple access techniques

5. Evaluation

5.1. General evaluation criteria

The evaluation of DTE is designed around a continuous learning of the student by means of work and continuing assessment, as well as the continuous feedback by the teaching staff about each student's work.

The weighting of the different types of the activities is the following:

- Activities to hand in à 20%
- Practical activities à 20% (10% Matlab + 10% "Shipping project")
- First partial test à 20% (Units 1 and 2)
- Second partial test à 20% (Unit 3)
- Final exam à 20% (Units 4 and 5 + global activities)

During the subject there is a set of **deliverables**, they are individual and group activities that students have to submit in a specific time and date uploading electronic documents in the subject's Moodle Web page. In addition, some of these deliverables will be oral presentations of some selected themes. The average grade of these activities represents 20% of the final mark and a minimum of 5.0 is required to pass the subject.

Two partial tests will be done (weeks 6 and 13 approximately), in which the acquired knowledge during the subject will be evaluated. One of the most important aims of these tests is to get a feedback about the situation of each student. Consequently, in the later seminar sessions to each test, a copy of his or her test will be given to the student and he or her will do a self-assessment and compare it with classmates to have a clearer idea if he is far or close to achieve the learning aims of the subject. Each test, which is a 20% of the final mark, is made up of questions about theoretical content (30%) and activities to solve (70%). The DTE subject's design is modular, so it is an essential requirement to pass (> 5.0) each unit to be able to pass the subject. So, each partial test will have specific units that, once they are passed, they will not be evaluated in the final exam. If a unit is failed, the student will have the opportunity to retake this unit in the final exam.

The **final exam** will count 20% and it will be made up of two parts: one part will be shared by all students with activities to solve related to the last units that they are not evaluated in two partial tests as well as problems that need the acquired knowledge during the subject to be solved; and the second part with specific problems of some units for the students that have to retake some of these units.

The **practical sessions** of the DTE subject will be made up of 8 sessions of 2 hours each and they are distinguished in two groups: Matlab practical activities (10%) and the "Shipping Project" (10%). In the first kind of practical activities (4 sessions), the students will come into contact with Matlab and they will use it to solve typical activities and practical examples using the handled concepts in lectures. For these practical activities, the students will have to hand in a previous study before each practical activity as well as solved activities at the end of the practical activity. The other practical sessions (the rest 4 sessions) will be about the introduction, solving doubts and the project's presentation of each group of students (from 2 to 4 students for a group). The winner of the "Shipping Project" will get 2 extra points of the 20% the practical sessions mark, the second one, 1 point of 20%; and the third one, 0.5 points of this 20%. More information about the "Shipping Project" will be given with the project's instructions.

The students, who wish to refuse the continuing assessment, can do the exam in September directly and the student's knowledge will be evaluated only according by the final exam. Obviously, the students, who are evaluated by the continuing assessment, will do a final exam in September which will be similar to the exam in June and they will be able to retake only the parts that they failed and their mark of the practical sessions and the deliverables in will be kept.

6. Contents

The design of the DTE subject is made up of five compulsory units. These five units meet a logic of discipline and curriculum.

6.1. Units

- Unit 1. Introduction to the digital communications

- Subunit 1. Introduction to the digital communications
- Subunit 2. Formatting

- Unit 2. Source coding

- Subunit 3. Introduction to the source coding
- Subunit 4. Codes and entropy

1st partial test

- Unit 3. Digital baseband and band-pass transmission. Tools to evaluate and modulations

- Subunit 5. Digital baseband transmission
- Subunit 6. Digital band-pass transmission

2nd partial test

- Unit 4. Channel coding and lineal codes

- Subunit 7. Channel coding
- Subunit 8. Lineal codes

- Unit 5. Design of an optimum digital system of communications. Advanced modulations

- Subunit 9. Agreement between modulation and encoding
- Subunit 10. Advanced modulations

6.2. Organization and precision of the contents

Unit 1. *Introduction to the digital communications*

Concepts	Processes	Attitudes
1. Diagram of digital communications system 2. Analog system vs. Digital one 3. Basic concepts of the analog and digital communications: sampling, quantification, and baseband transmission	1. Design of block diagram 2. Preparation of exposition 3. Important information extraction and a summarize of a text 4. Solution of problems about sampling, quantification and baseband transmission	1. Reasoning and use the previous knowledge 2. Work in pairs 3. Specificity and precision 4.Capacity of criticism related to the own and the others work 5. Active participation in lectures and seminar sessions

Unit 2. *Source coding*

Concepts	Processes	Attitudes
1. Discrete and conditional probability 2. Codes and encoding schemas 3. Information sources 4. Uniqueness and immediateness 5. Entropy 6. Source extension 7. Conditional entropy 8. Mutual information	1. Probability calculus 2. Use of the basic properties of probability 3. Codes and encoding schemas description 4. Information sources description 5. Classification of the univocal and instantaneous codes 6. Use of Kraft's inequality 7. Entropy and mutual information calculus 8. Calculus of source extension	1. Reasoning and use the previous knowledge 2. Work in pairs 3. Specificity and precision 4.Capacity of criticism related to the own and the others work 5. Active participation in lectures and seminar sessions

Unit 3. *Digital baseband and band-pass transmission. Tools to evaluate and modulations*

Concepts	Processes	Attitudes
1. Receiver's structure and optimum filters 2. Signal space 3. Detection of noisy channels 4. Symbol error probabilities 5. Intersymbol interference (ISI) 6.Techniques to reduce ISI: shaping filters and equalization 7.Moduling / demodulation with carrier and detection	1. Simulation with software of the concepts of baseband and band-pass transmission 2. Important information extraction and summary of a technical text in English 3. Problems solving about concepts of baseband and band-pass transmission 4.Explanation to the blackboard of solved problems 5. Representation of the signals in the signal space with or without the Gram-Schmidt method	1. Reasoning and use the previous knowledge 2. Work in pairs 3. Extract and summarize the most important concepts of a unit 4.Reason out and analyze the problems before using the most mechanical methods 5. Put the theory into practice 6. Analysis of technical texts in English 7.Autoevaluation and self-criticism of the own work

8.Diferent shapes of waves to the modulation and coherent detection 9. Incoherent detection 10. Complex surround 11. BPSK and BFSK error probabilities 12. Error probabilities for non-binary modulations	6. Error probabilities calculus 7. Design of shaping filters and equalization 8. Analysis of curves of error probabilities	8. Active participation in lectures and seminar sessions

Unit 4. *Channel coding and lineal codes*

Concepts	Processes	Attitudes
1. Information channel 2. Distance of the words in a code 3. Decoding rules 4. Redundancy 5. Capacity of channel 6. Lineal codes 7. Syndrome 8. Convolutional codes 9. Cyclic codes	1. Probability calculus of the conditional channels in the input or the output 2. Use of the decision rules 3. Calculus of the transmission rates and the capacity of channel 4. Design of generator matrixes and parity 5. Codes generation by means of these matrixes 6. Decoding for the Syndrome calculus 7. Identification of convolutional codes 8. Creation of cyclic codes and decoding	1. Reasoning and use the previous knowledge 2. Work in pairs 3. Extract and summarize the most important concepts of a unit 4. Reason out and analyze the problems before using the most mechanical methods 5. Put the theory into practice 6. Analysis of technical texts in English 7. Autoevaluation and self -criticism of the own work 8. Active participation in lectures and seminar sessions

Unit 5. *Design of an optimum digital system of communications*

Concepts	Processes	Attitudes
1. Aims and limitations of a digital communications system	1. Design of a digital communications systems with or without encoding,	1. Reasoning and use the previous knowledge

2. Planes of error probability and efficiency of bandwidth 3. Bounded systems in power and bandwidth 4. Systems with or without encoding 5. Modulation for direct sequence 6. Modulation for frequency hopping 7. Relation to the multiple access techniques	choosing and optimum option in different situations 2. Analysis of planes of error probability and efficiency of bandwidth 3. Solving problems about the design of a digital communications system 4. Preparation of an exposition about one theme of designing a digital communications system 5. Search and summarize the information about one theme of designing a digital communications system 6. Solving problems about advanced digital modulations	2. Work in pairs 3. Extract and summarize the most important concepts of a unit 4. Put the theory into practice 5. Recognition and interest about the work of important Scientifics of digital communications 6. Active participation in lectures and seminar sessions

7. Methodology

7.1. Methodological focus of the subject

The main objective of the subject design of DTE is to involve the student continuously in the development of the subject by continuing assessment and personal study as a complement to the lectures. The difficulty of this subject makes that this continuous work along these two terms is essential to acquire the minimum knowledge required.

The EHEA methodology involve a configuration of the learning cycle that divides the activities into face-to-face ones and virtual ones, representing the first 35% of the total work load of the subject and, consequently, 65% of student work outside the classroom. There are three types of classes: the **lectures**, **seminars** and **practical sessions**. The first ones are done with all students of the subject and represent 50% of the total (36 hours, 18 sessions of 2 hours per week), leaving 28% (20 hours, 20 sessions of one hour per week) of face-to-face sessions for seminars, where a small number of students (less than 15) and 22% for practical sessions (16 hours, 8 sessions of two hours, mostly twice-weekly).

<table>
<tr><td rowspan="2">BACHELOR'S DEGREE</td><td colspan="2">Student's work
65%</td></tr>
<tr><td>Teaching
35%</td><td>Lectures
70%
(big group)</td></tr>
</table>

		Seminar sessions 30% (small group)
		Practical sessions (big group)

Lectures (2 hours with a break of 10 minutes) are devoted mainly to the presentation of the context and the knowledge of the subject, as well as to show some demonstrations and examples of solving typical problems. Student's active participation will be asked in lectures by means of activities in pairs or individually to solve or complete the teacher's theoretical explanations. These explanations are based on slides in electronic format that will be provided for the students in the Moodle website of the subject since the beginning of the course.

The seminars (1h) are principally devoted to the correction in group and presentation of the different partial tests and activities to hand in for the subject, including solving problems, summaries of book chapters, group presentations or viewing scientific documentaries among other activities.

The practical sessions (2h) are divided into two types: those based on Matlab and those related to the "Shipping Project." The 4 practical sessions based on Matlab will be targeted to the use of Matlab as a tool to solve some easy activities about concepts that have been explained in the lectures. The remaining four practical sessions will be about the "Shipping Project", an activity that students will do in groups from 2 to 4 people. More information about the "Shipping project" will be provided with the basis of the project.