Universidad de Alcalá

TEACHING GUIDE

Digital Signal Processing in Communications

Master in
Telecommunication Engineering (MUIT)

Universidad de Alcalá

Academic Year 2023/2024

1st Year - 2nd Semester (MUIT)

Approved by the School Board on June 12th, 2023

TEACHING GUIDE

Course Name:	**Digital Signal Processing in Communications**
Code:	**201811 (MUIT)**
Master in:	**Telecommunication Engineering (MUIT)**
Department and area:	**Teoría de la Señal y Comunicaciones** **Teoría de la Señal y Comunicacicones**
Type:	**Compulsory (MUIT)**
ECTS Credits:	**3.0**
Year and semester:	**1st Year - 2nd Semester (MUIT)**
Teachers:	Por definir
Tutoring schedule:	Consultar al comienzo de la asignatura
Language:	Spanish / English Friendly

1. COURSE SUMMARY

Digital signal processing has clearly advanced in Telecommunications in the last decades. The parallel development in Electronics Technology and Computer Architecture and the advances in Digital Signal Processing theory were aligned to create a suitable technology background that allows the creation of new telecommunication systems and services.
This course includes the study of some of the most extended digital signal processing techniques applied to communications, namely:

- Signal decomposition using orthogonal and biorthogonal transformations and filter banks, to be applied in multimedia processing and multicarrier digital communications.
- Adaptive filtering applied in communication interference suppression and systems modeling (e.g., of communications channels).
- Signal codification using different domain transforms with perceptual quality criteria used in the development of standards like MPEG (audio and video), which have enabled the development of communications systems such as Digital Broadcasting Television or Digital Radio.
- Model based codification used in digital mobile telephony (GSM, UMTS) and Voice over IP

This course is fundamentaly practical, where most of the teaching part is carried out in the laboratory in combination with theoretical and software simulation.

Although no prerequisites are requested, basics on digital signal processing are recommended to follow the course, such as analysis, signal and systems characterization, digital filters design, spectral estimation.

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_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_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_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_CTecTel4 - Ability to design and dimension transport, broadcast and distribution networks of multimedia signals.

en_EURACE - Link to the correlation table between the Learning Outcomes, according to the ENAEE (European Network for Accreditation of Engineering Education) standards, and the Master's subjects where the corresponding skills are acquired.

Learning Outcomes

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

RA1. Design and build multirate systems and usuful orthogonal and biorthogonal transforms.

RA2. Develop algorithms such as LMS and RMLS in adaptive filtering.

RA3. Apply multirate systems to signal decomposition for coding purposes.

RA4. Apply adaptive filters to problems like interference cancelation or channel equalization in communications.

RA5. Design non linear processing systems and the necessary learning algorithms.

RA6. Build, compare and evaluate the main lossy and lossless coders of multimedia signals (image, speech, audio, video).

3. CONTENTS

Contents Blocks	Total number of hours
Module 1. Multirate processing and usuful transforms. Trigonometric trnasforms (DCT, DST, MDCT, LOT, MLT). Time-frequency analysis and filter banks. Wavelet transform. Bidimensional transforms.	7 hours
Module 2. Adaptive filtering. Minimum mean squared error linear estimators. Wiener filter. Introduction to adaptive filtering. Error surface. Stepest descent algorithm. LMS algorithm. RLS algorithm. Application to interferences estimation.	7 hours
Module 3. Data compression. Source coding techniques Lossless coding: entropic coding, Run-Length coding, arithmetic coding. Lossy coding: transform coding, differential coding, vector coding, analysis by synthesis coding.	7 hours
Module 4. Audiovisual signals coding standards. Speech coding standards, Audio coding standards, Image coding standards, Video coding standards.	7 hours

4. TEACHING - LEARNING METHODOLOGIES. FORMATIVE ACTIVITIES.

4.1. Credits Distribution

Number of on-site hours:	30 hours (28 hours on-site +2 exams hours)
Number of hours of student work:	45 (including study, activities and exams preparation)
Total hours	75

4.2. Methodological strategies, teaching materials and resources

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

Lectures in combination with practices in the laboratory:

Large group theory classes consist of lectures, where the main concepts of the subject will be exposed. The goal is to introduce the fundamentals in a guided and thoughtful way. To promote reflection and to avoid monotony of the master class, short application examples will be proposed in both, the classroom and the laboratory. These examples, along with the necessary discussion are prone to generate critical learning environments. The learning process will be complemented with a meaningful learning with practical implementations in the laboratory and solving problems in the classroom.

In laboratory sessions, students will have to work in a computational and programming framework (either individually or in groups, depending on the availability of computeres) to develop algorithms where the theoretical concepts for the resolution of real problems are applied. A manual of the laboratory activities will be provided, describing the objectives and characteristics of the algorithms to be implemented. Before each session, the student will prepare the activity, to understand the theoretical fundations. In the

laboratory, the student will implement the algorithms and analize the results from a critical point of view, drawing the relevant conclussions. This work is supervised by the theacher, who will advise the student in the best solving strategy, pursuing a thoughtful and creative attitude. During the session, the teacher can ask a round of questions to each student on the way in which the problem has been posed, to perform an evaluation and follow-up, and to suggests improvements. Finally, the student will have to deliver the result of the practise, namely, algorithm implementation, discusion and conclusions, using the virtual platform.

Group and cooperative work

Finally, the student's work and personal study are key elements in learning. Time dedicated to personal work should be, on average, twice the time dedicated to face-to-face teaching, so as to succeed. For personal study, students must consult the recommended bibliography and the available teaching material set by the teachers. Personal study is to understand the theoretical concepts and to learn how to implement systems based on them in a practical way. The objective for the students is to develop skills related to find valuable information, to deal with bibliography, and to write reports related to the proposed topics. In the same way, the work is intended to promote 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 proposed evaluation process is inspired by continuous evaluation, although, respecting the regulations of the University of Alcalá, the student may take the final evaluation. To qualify for the final evaluation, students of the Master's Degree will have to request it in writing to the director of the Master's Degree in the first two weeks of teaching the subject, explaining the reasons that prevent them from following the continuous evaluation system. The evaluation of the learning process of all students who do not submit an application in this regard or see it denied will be carried out, by default, according to the continuous evaluation model described below. The student has two calls to pass the subject, one ordinary and one extraordinary.

Ordinary Call

Continous Assessment:

Since the subject matter has, mainly, a practical utility in the environments of transmission of multimedia signals, the evaluation will be focussed on the implementation of techniques and algorithms explained, in obtaining results and analyzing them. The practical implementation will be based on the use of specific software for signal processing (such as Matlab), for which the licenses that the University makes available to students will be used. The following elements will be used for the evaluation:

1. Laboratory Deliverables (EL). Deliveries of results and conclusions of the practices proposed throughout the course.

2. Evaluation exams (PE). Carrying out written exams focused on both, practical and theoretical aspects of the subject.

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

1. Laboratory exam (EL).

2. Final evaluation exams (EF). A single exam with the same characteristics as the EEs, but that should only be done by students who choose the final evaluation.

Students are recommended to make the laboratory practices during the semester, thus replacing the practical laboratory exam with the evaluation of the reports corresponding to the different practices.

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 following criteria will be used for subject evaluation, which are related to the learning outcomes:

CE1. The student is able of designing and implementing multirate systems, and knows how to apply useful orthogonal and biorthogonal transforms.

CE2. The student is able of applying algorithms like LMS and RLMS in adaptive filtering.

CE3. Faced with a specific problem of cancellation of interference or equalization of communication channels, the student knows how to apply adaptive filters when appropriate.

CE4. The student is able to apply, depending on the specific application, lossy and lossless encoders to signals of audiovisual origin.

CE5. The student knows and identifies the main image, audio and video formats, including their main characteristics.

CE6. The student is able to present and evaluate, in an orderly manner, the results of the application of the different algorithms presented during the course.

GRADING TOOLS

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

- **Laboratory deliverables (EL):** Deliveries of results and conclusions of the practices proposed throughout the course. At most, one deliverable per subject is considered.
- **Evaluation exam (PE):** Short exams to be made along the course. There will be two exams, in which modules 1 and 2, and 3 and 4, respectively, will be evaluated.
- **Laboratory exam (PL):** To be made only by students who choose the final evaluation.
- **Final evaluaton exam (EF)**: Only one exam with the same characteristics of EE, to be made only by students who choose the final evaluation.

GRADING CRITERIA

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
CB6, CB7, CB9, CGT1, CT5, CtecTel1, CtecTel4	RA1, RA2, RA3, RA4, RA5, RA6	CE1, CE6, CE3, CE4, CE5, CE6	EL	40%
CB6, CB7, CB9, CGT1, CT5, CtecTel1, CtecTel4	RA1, RA3, RA3, RA4, RA5, RA6	CE1, CE2, CE3, CE4, CE5, CE6	PE	60 % (two exams with 30% each)

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 among the competences, learning outcomes, criteria and evaluation instruments is as follows.

Skill	Learning Outcomes	Evaluation criteria	Grading Tool	Contribution to the final mark
CtecTel1, CTecTel4	RA1, RA2, RA3, RA4, RA5, RA6	CE1, CE2, CE3, CE4, CE5, CE6	PL	40%
CtecTel1, CTecTel4	RA1, RA2, RA3, RA4, RA5, RA6	CE1, CE2, CE3, CE4, CE5, CE6	PEF	60%

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, giving the option of making the PL or maintaining the mark obtained in the EL (continuous evaluation) or in the PEF (final evaluation), according to the student's decision. In any case, the PL will be made by those students who have not done it in the final exam option in the ordinary call.

6. BIBLIOGRAPHY

6.1. Basic Bibliography

- P. P. Vaidyanathan, Multirate Systems and Filter Banks. Englewood Cliffs, N.J.: Prentice Hall, 1993.
- K. R. Rao and P. Yip, Discrete Cosine Transforms, Academic Press, New York, 1990.
- G. Strang and T. Nguyen, Wavelets and Filter Banks, Wellesley-Cambridge Press, Wellesley, MA, 1996.
- M. Vetterli and J. Kovacevic, Wavelets and Subband Coding, Englewood Cliff, N.J. Prentice Hall, 1995.
- S. Haykin, Adaptive Filter Theory. Prentice Hall, 2002.
- B. Widrow, S. Stearns, Adaptive Signal Processing. Englewood Cliffs, N.J. Prentice Hall, 1985.
- N.S. Jayant and P. Noll, Digital Coding of Waveforms, Prentice Hall, Inc. 1984.
- G. Wade, Signal Coding and Processing. Cambridge University Press (Second Edition), 2004.

- P.S. Diniz, E.A.B. da Silva, S.L. Netto, Digital Signal Processing, System Analysis and Design (2nd Edition), Cambridge 2011.

6.2. Additional Bibliography

Books

- H.S. Malvar, Signal Processing with Lapped Transform, Artech House, Norwood, MA, 1992.
- M. Hayes, Statistical Signal Processing and Modeling, Wiley, 1996.
- Christopher M. Bishop, Neural Networks for Pattern Recognition, Clarendon Press, Oxford, UK, 1995.
- Richard O. Duda, Peter E. Hart, David G. Stork, Pattern Recognition (2nd Edition), Wilie-Interscience, 2000.
- Harry L. Van Trees, Detection, Estimation, and Modulation Theory (Part I), 1968.

Scientific journals

- IEEE Transactions on Signal Processing.
- IEEE Communications Magazine
- IEEE Journal on Selected Areas in Communications
- IEEE Transactions on Image Processing
- IEEE Transactions on Audio, Speech and Language Processing
- Proceedings of the IEEE
- Signal Processing

Disclosure Note

During the evaluation tests, the guidelines set out in the Regulations establishing the Rules of Coexistence of the University of Alcalá must be followed, as well as the possible implications of the irregularities committed during said tests, including the consequences for committing academic fraud according to the Regulation of Disciplinary Regime of the Students of the University of Alcalá.