Course guide
19901 - ADSPAA - Analogue and Digital Signal Processing for Aerospace Applications

Last modified: 19/05/2025

Unit in charge: Castelldefels School of Telecommunications and Aerospace Engineering
Teaching unit: 739 - TSC - Department of Signal Theory and Communications.

Degree: MASTER'S DEGREE IN AEROSPACE SCIENCE AND TECHNOLOGY (Syllabus 2015). (Compulsory subject).
MASTER'S DEGREE IN AEROSPACE SCIENCE AND TECHNOLOGY (Syllabus 2021). (Optional subject).

Academic year: 2025 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: Defined in the course webpage at the EETAC website.

Others: Defined in the course webpage at the EETAC website.

PRIOR SKILLS

- Basic operational capacity of infinitesimal calculation including derivation, integration and series.
- Operations with complex numbers. Product and summation of complex numbers, calculation of module and phase of a complex number.
- Probability and statistics: Probability concepts, random variables, probability density function.
- Operations with matrices.
- Operations with trigonometric functions.
- Basic circuit analysis.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE3 MAST21. Carry out, present and publicly defend a research work carried out in a group, on a research topic in the aerospace field.

Generical:
CG2 MAST. Identify and apply the fundamental theoretical, experimental and numerical analyzes currently used in aerospace engineering.

Transversal:
CT5. FOREIGN LANGUAGE: Achieving a level of spoken and written proficiency in a foreign language, preferably English, that meets the needs of the profession and the labour market.

Basic:
CB10. Students will acquire learning skills that allow them to continue studying in a way that will be largely self-directed or autonomous.

TEACHING METHODOLOGY

Thanks to the work material prepared by the lecturers, i.e. slides, class notes, solved exercises, etc. available at the digital campus (ATENEA), the student has enough available tools to work autonomously, both individually and in group. The student will take advantage of this material to consolidate in class the main concepts of the subject and solve doubts that he/she may have.
The course is divided in two kinds of sessions: Sessions done at the theory class (theory and exercises) and lab sessions. Theoretical/exercise classes combine formal explanations done by the lecturer and informal questions made to the students which favours the comprehension of the basic concepts of the subject. The work material prepared for the student allows him to stay in class focusing on learning the subject concepts instead of just taking notes. Moreover, several proposed exercises will be solved in these sessions to illustrate the concepts presented at the theoretical sessions. The lecturer will propose exercises to be solved by the students in the hours of autonomous learning.

In the lab sessions, the activity will be done in groups of two students. Each group will have to do a previous work before the beginning of the lab exercise. After the lab work, the students will have to elaborate and present a document that should briefly describe the work developed in the lab and highlight the relationship between the lab work and the concepts previously seen in the theoretical classes. The main conclusions of the lab work should also be included in the final document.

LEARNING OBJECTIVES OF THE SUBJECT

- Understand the advantages and disadvantages of digital signal processing compared to the analog tehcniques. Know the applications of digital signal processing.
- Understand the concepts of signal and systems and its characterization.
- Know the processes of A/D and D/A conversion.
- Understand the concept of transfer function in a discrete linear and invariant system. Calculate poles and zeros.
- Understand the concepts related to Laplace transform, Z-transform and Fourier transform.
- Know the concepts of correlation and spectral density.
- Know some applicability examples of the correlation and spectrum concepts, such as the Wiener filtering.
- Know the Least Squares methodology for system identification.
- Know the Least Mean Squares algorithm for system identification.
- Know the funcitonal blocks of a communications system.
- Operate with modulated signals in the time and frequency domain.
- Study and calculate the main parameters of a communication system.
- Study the main quaility criteria in communications system (signal to noise ratio and error probability).
- Know the basic channel coding techniques (error detection and correction systems).

STUDY LOAD

Type	Hours	Percentage
Self study	80,0	64.00
Hours large group	45,0	36.00

Total learning time: 125 h

CONTENTS

Analog and Digital Signal Processing

Description:
An overview of the basic concepts related to analog and digital signal processing is provided.

Specific objectives:
In this sessions we provide an overview of the following topics:
- Signals and Systems
- Laplace Transform
- Fundamental of Analog Linear Systems
- Sinusoidal Steady State Responses
- Fourier Series-Transform
- Analog Filtering
- Sampling Theorem/Nyquist
- Discrete Linear Systems
- Z-Transform
- Discrete-time Fourier Transform
- Windowing

Related activities:
1 Individual deliverables/exercises
2 Laboratory Sessions:
- Simulation of Acoustic Echoes
- Dual Tone Multi-Freq. (DTMF) Detect.
- Interfering Tone Suppression

Full-or-part-time: 34h 20m
Theory classes: 12h 20m
Self study : 22h

Optimum and Adaptive Filters for System Identification

Description:
An overview of optimum and adaptive filter is provided and the basic concepts of system identification are explained.

Specific objectives:
In this sessions we provide an overview of the following topics:
- Deterministic and stocastic signal filtering.
- Digital FIR and IIR signal desing.
- Linear phase filtering.
- Cross correlation and autocorrelation of deterministic and stocastic signals. Signal power and energy.
- Energy and power spectral densitiy. Example: White noise.
- Cross correlation and autocorrelation of a signal at the input/output of a linear filter.
- Optimum Wiener filtering. Application examples (identifying systems and correlation receivers).
- Least Squares methodology.
- Least Mean Squares methodology.

Related activities:
1 Individual deliverables/exercises
2 Laboratory Sessions:
- Echoes Identifier
- The Wiener Filter (unknown disturbance)
- Technical paper on a noise canceller estimated using the LMS algorithm.

Full-or-part-time: 34h
Theory classes: 12h
Self study : 22h

Analog and digital communications

Description:
- Initially, an introduction of the concept of communications system is provided, highlitghting the main sub-systems that belong to the transmitter and receiver, and a characterization of the propagation channel (delay, attenuation, interference, noise, distortion). Then, an overview of the main quality parameters in a communication system is presented.
On the other hand, the main amplitude analog modulations (AM, DSB, SSB) and angular analog modulations (PM and FM) are described, highlighting aspects such as signal bandwidth, transmit power, demodulator scheme, signal to noise ratio, etc.
Moreover, an overview of the main concepts of digital signal transmission is provided. These topics will be presented: Baseband digital transmission, PAM modulation. Line coding (NRZ, RZ, etc.). Pulse shaping. PAM signal spectrum. Detection of PAM signal in presence of AWGN noise. Receiver scheme. Matched filter. Error probability. In-phase and quadrature components in band pass modulated signals. Digital modulations (ASK, FSK, PSK, QAM). Constellation.
Finally, the main concepts concerning channel coding will be presented. ARQ and FEC techniques. Block and convolutional coding.

Specific objectives:
- Know the funcitonal blocks of a communications system.
- Operate with modulated signals in the time and frequency domain.
- Study and calculate the main parameters of a communication system.
- Study the main quaility criteria in communications system (signal to noise ratio and error probability).
- Know the basic channel coding techniques (error detection and correction systems).

Related activities:
Exercise/exam done in a class sesison.

Full-or-part-time: 34h
Theory classes: 12h
Self study : 22h

Digital Radio

Description:
The explained theoretical concepts are used to explaing the performance of a digital communications transmitter and receiver. An overview of the basics of Green Radio will be provided, i.e. techniques that reduce the energy consumption in a communication system.

Specific objectives:
- Block diagram of a transmitter.
- Block diagram of a receiver.
- Hardware components for implementing a digital communication system.
- Energy efficient RF amplifiers.

Related activities:
Activity 3: Experimentation with a digital communications transceiver.

Full-or-part-time: 22h 40m
Theory classes: 8h
Self study : 14h 40m

ACTIVITIES

Laboratory Sessions

Description:
Laboratory Sessions to put into practice the theoretical concepts given in the master classes.

Specific objectives:
- Laboratory Sessions:
- Echoes Identifier
- Simulation of Acoustic Echoes
- Dual Tone Multi-Freq. (DTMF) Detect.
- Interfering Tone Suppression
- The Wiener Filter (unknown disturbance)

Material:
PC running Matlab

Full-or-part-time: 8h
Theory classes: 8h

Exercise/exam done in class

Description:
The student has to do an exercise/exam in which he/she must demonstrate the knowledge that he/she should have acquired in the theoretical/exercise classes before the exam.

Material:
The exercise will be done with the possibility of using the notes taken in class.

Delivery:
At the end of the exercise session.

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

Experimentation with a digital communications transceiver

Description:
The student can access remotely to a transceiver working in a research lab. By using Matlab software real signals can be transmitted and received.

Material:
PC running MATLAB

Full-or-part-time: 2h
Theory classes: 2h

GRADING SYSTEM

Defined in the course webpage at the EETAC website.

EXAMINATION RULES.

Attendance to the lab sessions, realization of the previous work and the final document of the lab work is mandatory. Not doing all of this will represent a zero mark in the corresponding activity.

BIBLIOGRAPHY

Basic:
- Proakis, John G.; Manolakis, Dimitris G. Introduction to digital signal processing. New York : London: MacMillan ; Collier MacMillan, 1988. ISBN 0023968109.
- Oppenheim, Alan V.; Schafer, Ronald W. Discrete-time signal processing. 3rd. Upper Saddle River (N.J.): Prentice-Hall, 2010. ISBN 9780131988422.
- Carlson, A. Bruce; Rutledge, Janet C.; Crilly, Paul B. Communication systems : an introduction to signals and noise in electrical communication. 4th. New York [etc.]: McGraw-Hill, 2002. ISBN 0070111278.
- Proakis, John G.; Salehi, Masoud. Communication systems engineering. 2nd. Upper Saddle River, New Jersey: Prentice Hall, 2002. ISBN 0130617938.
- Sklar, Bernard. Digital communications : fundamentals and applications [on line]. 2nd. Upper Saddle River: Prentice Hall, 2001 [Consultation: 30/09/2024]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=5185638. ISBN 0130847887.
- Haykin, Simon S.; Van Veen, Barry. Signals and systems. 2nd. New York ; [Chichester]: Wiley, 2003. ISBN 0471378518.
- Oppenheim, Alan V.; Willsky, Alan S.; Nawab, Syed Hamid. Signals and systems. 2nd. Essex: Pearson, 2014. ISBN 9781292025902.

RESOURCES

Audiovisual material:
- Transparències. Slides
- Col·lecció d'exercicis. Resource

Computer material:
- Matlab. Matlab to carry out the lab exercises