Degree competences to which the subject contributes

- To plan and use the needed information in order to develop a project or academic work, based on a critical appraisal of the used information resources.
- To apply the acquired skills to carry out a task. To identify the need for continuous learning and for the design of an strategy to carry out that task.
- To identify, model and raise problems from open situations. To explore and apply alternatives for its resolution, and to use approximate solutions when necessary.
- To identify and model complex systems. To perform analysis and qualitative approaches, establishing the uncertainty of the results. To pose hypotheses and validate them experimentally. To identify the major components and to establish commitments and priorities.
Learning outcomes.

At the end of the course, the students will have acquired advanced knowledge in:

- characterizing signals as realizations of stochastic processes.
- estimation theory.
- time-frequency signal analysis.
- optimal filtering.
- adaptive filtering.
- applying all above concepts to the development of signal processing subsystems for voice, audio, image, video and communication signals.

**Study load**

<table>
<thead>
<tr>
<th>Total learning time: 150h</th>
<th>Hours large group:</th>
<th>65h</th>
<th>43.33%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self study:</td>
<td>85h</td>
<td></td>
<td>56.67%</td>
</tr>
</tbody>
</table>
## Content

### Lecture 1. Introduction

#### Learning time: 11h 30m

- Theory classes: 4h
- Guided activities: 1h
- Self study: 6h 30m

#### Description:
- Notation of vector and random variables.
- Characterization of stochastic processes (stationary and ergodic), correlation matrix and its properties, power spectral density, and linear discrete processes and systems.

#### Related activities:
- Modeling AR processes.
- Identification of nonlinearities using the spectral coherence function.

### Lesson 2. Detection

#### Learning time: 14h 30m

- Theory classes: 4h 30m
- Guided activities: 1h 30m
- Self study: 8h 30m

#### Description:
- The decision problem: hypothesis testing, terminology and examples.
- Decision criteria: MAP and Neyman-Pearson.
- Detection of deterministic signals and the Receiver Operating Characteristic (ROC) curve.

#### Related activities:
- Application to the detection of radar signals.

### Lesson 3. Estimation Theory

#### Learning time: 33h

- Theory classes: 11h
- Guided activities: 2h
- Self study: 20h

#### Description:
- Parameter estimation and MVUE estimator.
- Cramer-Rao limit and efficient estimator.
- Maximum Likelihood estimation, MAP estimation and MMSE estimation.

#### Related activities:
- CRLB in signal delay, frequency and angle of arrival estimation.
- ML estimation of channel, signal delay, frequency, power and SNR.
### Lesson 4. Optimum Filtering

**Description:**
- Linear least mean square estimation.
- Filtering problems: system identification, equalisation, cancelation, prediction and interpolation.
- Wiener filter in the frequency domain.
- Linear Regression and Least Squares design.

**Related activities:**
- Interference cancellation, deconvolution and channel equalization, predicting processes over time.
- Estimation of the channel impulse response.

**Learning time:** 29h
- Theory classes: 5h
- Guided activities: 4h
- Self study: 20h

### Lesson 5. Adaptive filtering

**Description:**
- Gradient method for linear regression.
- Stochastic gradient methods. LMS algorithm.
- LMS convergence and mismatch. Normalized LMS algorithm.

**Related activities:**
- Active noise cancellation.
- Hands-free telephone.
- Adaptive differential coding (ADPCM).

**Learning time:** 25h 46m
- Theory classes: 6h
- Guided activities: 5h
- Self study: 14h 46m

### Lesson 6. Spectral estimation

**Description:**
- Periodogram and tradeoff between bias and variance.
- Filter banks and Capon estimator.
- Detectors spectral lines.

**Related activities:**
- Characterisation of biologic signals. Spectrum sensing.
- Non-parametric spectral estimation. Detection of spectral lines.

**Learning time:** 24h 50m
- Theory classes: 7h
- Guided activities: 4h
- Self study: 13h 50m
Planning of activities

<table>
<thead>
<tr>
<th>Midterm exam</th>
<th>Hours: 6h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description: Midterm exam</td>
<td></td>
</tr>
</tbody>
</table>

**Qualification system**

Midterm and Final Exam.

The final mark will be computed as:

\[
\text{max}(\text{Final\_exam}, \ 0.55 \cdot \text{Nota\_examen\_final} + 0.3 \cdot \text{Midterm\_exam}) + 0.15 \ (\text{Lab\_work})
\]

The re-assessed final mark of the course is computed from a final exam (85%) and from the non-re-assessed laboratory part (15%).

This course will assess the following generic skills:

- Self Learning (Middle Level)
- Ability to identify, formulate and solve engineering problems (Middle level)

**Regulations for carrying out activities**

Neither notes nor any kind of electronic devices are allowed.

**Bibliography**

**Basic:**


**Complementary:**


**Others resources:**

1. Problems publication
2. Course slides