Universitat Autònoma de Barcelona

2020/2021

Statistical Signal Processing

Code: 42845
ECTS Credits: 6

Degree	Type	Year	Semester
4313797 Telecommunications Engineering	OB	1	1

The proposed teaching and assessment methodology that appear in the guide may be subject to changes as a result of the restrictions to face-to-face class attendance imposed by the health authorities.

Contact

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Use of Languages

Principal working language: english (eng)

Teachers

Francesc Xavier Mestre Pons

Prerequisites

For students who have been admitted indirectly to the master (e.g. those who must attend complementary courses), they should have already passed the course on "Tractament digital del senyal" (TDS) offered within the B.Sc. degree on Telecommunication Systems Engineering (i.e. "Grau d'Enginyeria en Sistemes de Telecomunicació").

Objectives and Contextualisation

The goal of this course is to introduce advanced techniques in statistical signal processing with applications to telecommunication systems.

Competences

- Capacity for applying theory of information methods, adaptative modulation and channel coding as well as advanced techniques for digital signal processing in telecommunications and audiovisual systems.
- Capacity for critical reasoning and thought as means for originality in the generation, development and/or application of ideas in a research or professional context.
- Capacity for designing radionavegation, positioning systems and radar systems.
- Capacity to integrate new technologies and systems developed within telecommunications engineering in general and in broader, multidisciplinary contexts such as bioengineering, photovoltaic conversion, nanotechnology, telemedicine
- Possess and understand knowledge that provides a basis or opportunity for originality in the development and/or application of ideas, often in a research context
- Student should possess the learning skills that enable them to continue studying in a way that is largely student led or independent
- Students should know how to apply the knowledge they have acquired and their capacity for problem solving in new or little known fields within wider (or multidisciplinary) contexts related to the area of study

- Students should know how to communicate their conclusions, knowledge and final reasoning that they hold in front of specialist and non-specialist audiences clearly and unambiguously

Learning Outcomes

1. Analyse the implications at system level of the use of statistical signal processing techniques.
2. Apply advanced mathematical methods for the resolution of problems related to statistical signal processing.
3. Capacity for critical reasoning and thought as means for originality in the generation, development and/or application of ideas in a research or professional context.
4. Develop and evaluate signal detection techniques with applications in positioning and radar systems.
5. Develop statistical filtering systems aimed at synchronisation, equalisation and detection in communications receivers
6. Make a statistical classification of signals and random processes of telecommunications systems.
7. Possess and understand knowledge that provides a basis or opportunity for originality in the development and/or application of ideas, often in a research context
8. Student should possess the learning skills that enable them to continue studying in a way that is largely student led or independent
9. Students should know how to apply the knowledge they have acquired and their capacity for problem solving in new or little known fields within wider (or multidisciplinary) contexts related to the area of study
10. Students should know how to communicate their conclusions, knowledge and final reasoning that they hold in front of specialist and non-specialist audiences clearly and unambiguously

Content

0. Fundamentals of statistical signal processing

- Statistical reasoning.
- Random processes and probability distributions.
- Linear models.
- Estimation procedures and performance metrics.

1. Array signal model

- Baseband signal model and analytic signal.
- Far field wave front model. Narrowband approximation.
- Direction of arrival. Spatial covariance matrix.

2. Spatial filtering

- Space-time filtering and beamforming.
- Design of spatial reference beamformers.
- Capon beamformer. Direction of arrival estimation.
- Design of time reference beamformers.
- Adaptive filtering: LMS and RLS.

3. Source detection and tracking

- Detection theory (error probabilities, ROC).
- Detection criteria for completely known statistics (Neyman-Pearson).
- Detection criteria in the presence of unknown parameters (GLRT).
- Parameter tracking: Kalman filter

4. Multiple-input multiple-output (MIMO) processing: spatial diversity and multiplexing

- Array processing in multipath fading channels.
- Spatial diversity at the transmitter and at the receiver.

- Space-time coding.

Methodology

Lectures will be taught online.

Student self-learning activities:

- Study of the theoretical and practical contents of this course.
- Preparation of exercises and other homework.
- Preparation of the evaluation activities.

Activities

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Lectures	39	1.56	1, 2, 3, 6, 4, 5, 9, 10, 8, 7
Type: Supervised			
Tutorials	15	0.6	9, 10
Type: Autonomous			
Study	90	3.6	1, 2, 3, 6, 4, 5, 8

Assessment

Calculation of the continuous evaluation mark

The marks of the different evaluation tests are averaged to obtain the continuous evaluation mark according to:

Continuous evaluation mark (CE) = 0.33 x markExam1 + 0.33 x markExam2 + 0.34 x markCaseStudy

Calculation of the final course mark

If AC >= 5, the student has passed the continuous evaluation and the final mark of the course is the continuous evaluation mark.

If AC < 5, the student has failed the continuous evaluation. In this case, the student has the option of taking a second-chance exam that will take place within the period of exams planned by the degree in January / February. The second-chance exam is divided into two parts, each one corresponding to the syllabus of the exam1 and the exam2 of the subject. The student may decide to take the part of this exam that he/she considers appropriate based on the mark he/she would like to recover. The mark of the second-chance exam replaces the mark that the student had before the exam1 or the exam2, whatever this mark was, and the final mark of the course will be calculated following the same formula as for the continuous evaluation.

It must be borne in mind, however, that the case study cannot be recovered.

Students who do not participate in the exams will be declared "not evaluable" in the final grade of the course.

Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Case study	34%	2	0.08	1, 2, 5, 9, 10
Exam 1	33%	2	0.08	1, 2, 6, 8, 7
Exam 2	33%	2	0.08	1, 2, 3, 6, 4, 5, 9, 10, 8

Bibliography

- S. Kay, *Fundamentals of statistical signal processing. Estimation theory*, vol. I, Prentice-Hall, 1993.
- S. Kay, *Fundamentals of statistical signal processing. Detection theory*, vol. II, Prentice-Hall, 1998.
- Don H. Johnson, Dan E. Dudgeon, *Array signal processing, concepts and techniques*, Prentice Hall, 1993.
- S. Haykin, *Array signal processing*, Prentice Hall, Englewood Cliffs, 1985.
- H. L. Van Trees, *Optimum array processing, part IV: Detection, estimation and modulation theory*, New York,
  Wiley 2002.
- E. Larsson, P. Stoica, *Space-time block coding for wireless communications*, Cambridge University Press, UK,
  2003.