Universitat Autònoma de Barcelona

Array Processing

2016/2017

Code: 42844
ECTS Credits: 6

Degree	Type	Year	Semester
4313797 Telecommunications Engineering	OT	2	1

Contact

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Use of languages

Principal working language: english (eng)

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"). Basic knowledge on Matlab programming is also required.

Objectives and Contextualisation

The objective of this course is to introduce traditional methods of array signal processing for multi-antenna transceivers, including spatial filtering (beamforming), direction of arrival estimation and multiple-input multiple-output (MIMO) communication systems.

The use of transmitters and/or receiver with multiple antennas is nowadays widespread in modern wireless communications, localization and radar systems. The trend of increasing the number of antenna in any device will likely continue in the next years. After this course, the student will have the understanding of the fundamental concepts of array signal processing and the capability to apply them to the design of future telecommunications and positioning systems.

Skills

- 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 for developing radio communications systems: design of antennas, equipment and subsystems, channel modelling, calculation of links and planning.
- 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 antenna arrays in different applications.
2. Apply the principal techniques of smart beam conformation, estimation of the direction multichannel arrival and MIMO communications.
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. Classify the different algorithms in array signal processing and use them to describe the main characteristics of multichannel techniques.
5. Describe the different ways of modeling the signals received in an array.
6. Design in array processing algorithms that solve specific problems in the field of communications or other related telecommunications engineering fields.
7. Evaluate the advantages of using multiple antennas for the reception and/or transmission of radionavegation and radar systems.
8. 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
9. Put into practice different techniques using real or synthetic signal samples.
10. Student should possess the learning skills that enable them to continue studying in a way that is largely student led or independent
11. 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
12. 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

1. Introduction to array processing

    1.1. Baseband signal model and analytic signal.

    1.2. Far field and near field models. Narrowband approximation.

    1.3. Direction of arrival. Spatial covariance matrix. Source coherence.

2. Spatial filtering

    2.1. Space-time filtering and beamforming.

    2.2. Design of time reference beamformers. Communication applications.

    2.3. Design of spatial reference beamformers. Radar/sonar applications.

    2.4. Other training methods for spatial filtering.

3. Direction of arrival (DoA) estimation

    3.1. Main principles in DoA estimation.

    3.2. Phased arrays and spatial periodogram.

    3.3. Subspace-based techniques. MUSIC.

    3.4. Spatial prediction: ESPRIT.

    3.5. High resolution methods: maximum likelihood and approximations.

4. Multiple-input Multiple-output processing: spatial diversity and multiplexing

4.1. Spatial diversity at the transmitter and at the receiver.

4.2. Space-time coding.

4.3. Introduction to Information Theory for multi-antenna system. MIMO capacity.

4.4. Optimum spatial processing. Waterfilling.

5. Examples of array signal processing in 5G wireless communications systems, MIMO radar, and positioning systems.

Methodology

Lectures: development of the theoretical concepts of the course. Written evaluation tests, including a mid-term exam and a final one.

Laboratory: development of Matlab-based exercises covering the theoretical contents of the course.

Student self-learning activities: Study of the material presented during the lectures. Preparation of lab exercises, other homework and exams.

Activities

Title	Hours	ECTS	Learning outcomes
Type: Directed			
Lectures	30	1.2	1, 2, 7, 4, 5, 6, 9, 11, 10, 8
Study, preparations of problems and laboratori sessions	86	3.44	1, 2, 7, 3, 4, 5, 6, 9, 11, 12, 10, 8
Type: Supervised			
Laboratory and problem sessions	15	0.6	1, 2, 7, 3, 4, 5, 6, 9, 11, 12, 10, 8

Evaluation

The final evaluation will take into account the lab exercises (30%), a mid-term exam (30%) and the final exam (40%).

FinalGrade = max (Final Exam, 0.7*Final Exam + 0.3*Lab Exercises, 0.4*Final Exam + 0.3*Lab Exercises + 0.3*Mid-Term Exam).

The course will be declared to be passed when FinalGrade >= 5.

If FinalGrade < 5, students will have a second chance to pass the course by doing a second final exam. The FinalGrade will be the grade of this exam.

Students missing both the Final Exam and the Mid-Term Exam will be declared to be "Not Graded" in the final mark of this course.

Evaluation activities

Title	Weighting	Hours	ECTS	Learning outcomes

Final exam	40%	2	0.08	1, 2, 7, 3, 4, 5, 6, 9, 11, 12, 10, 8
Mid-term exam	30%	2	0.08	1, 2, 7, 4, 5, 6, 9
Reports from laboratory sessions and problem solutions	30%	15	0.6	1, 2, 7, 3, 4, 5, 6, 9, 11, 12, 10, 8

Bibliography

H. Van Trees, Optimum Array Processing, part IV of Detection, Estimation and Modulation Theory, New York, Wiley 2002.

Don H. Johnson, Dan E. Dudgeon, Array Signal Processing, Concepts and Techniques, Prentice Hall, 1993.

E. Larsson, P. Stoica, Space-time block coding for wireless communications, Cambridge University Press, UK, 2003.

S. Haykin, Array signal processing, Prentice Hall, Englewood Cliffs, NJ, 1985.

P. Stoica and R. Moses, Spectral Analysis of Signals, Prentice Hall, NJ, 2005.

Steven M. Kay, Fundamentals of Statistical Signal Processing, Prentice Hall, 1993.