Course guide
230647 - ACWS - Advanced Communications for Wireless Systems

Last modified: 11/04/2025

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

Degree: MASTER'S DEGREE IN TELECOMMUNICATIONS ENGINEERING (Syllabus 2013). (Compulsory subject).
MASTER'S DEGREE IN ADVANCED TELECOMMUNICATION TECHNOLOGIES (Syllabus 2019). (Optional subject).

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

LECTURER

Coordinating lecturer: JAUME RIBA SAGARRA - GREGORIO VAZQUEZ GRAU

Others: Primer quadrimestre:
GREGORIO VAZQUEZ GRAU - 10

PRIOR SKILLS

Students are required to certify that they have previously followed courses on digital communications with similar technical contents than the master adaptation course 'Digital Communications' (http://infoteleco.upc.edu/documents/guia_docent/assignatures/all/ang/230600.pdf) or as for the undergraduate subjects 'Introduction to Communications' (https://www.upc.edu/content/grau/guiadocent/pdf/ing/230018) and 'Advanced Digital Communications' (http://infoteleco.upc.edu/documents/guia_docent/assignatures/all/ang/230051.pdf).
Concepts on signal and systems:
- Time domain and frequency domain analysis of deterministic and random signals and linear systems.
- Random signals (stochastic processes). Stationarity and Ergodicity. Thermal noise.
- Power spectral density. Pass-band random signals. Base-band equivalent representation. In-phase and quadrature components.
Concepts on digital communications:
- Signal Space and optimal detection in Additive White Gaussian Noise (AWGN) channels.
- Time and frequency domain Nyquist's criterions. Band-limited pulse shaping. Nyquist's pulses.
- Digital modulations: PAM, QAM, ASK, PSK, FSK and orthogonal modulations.
- Discrete and continuous Bello's Model.
- Frequency-Flat Fading and Frequency Selective channels: Coherence-Time, Coherence-Bandwidth, Delay-Spread and Doppler-Spread.
- Channel models: Rayleigh and Rician Channels.
- Multicarrier modulations: OFDM.
- Space diversity techniques: Beamforming and Maximum-Ratio Combining.
- Space-Time diversity techniques: Alamouti's Code.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
1. Ability to apply information theory methods, adaptive modulation and channel coding, as well as advanced techniques of digital signal processing to communication and audiovisual systems.

Transversal:
2. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

3. 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.

TEACHING METHODOLOGY

- Lectures
- Application classes
- Exercises
- Mid-Term Exam
- Final Exam

LEARNING OBJECTIVES OF THE SUBJECT

Learning objectives of the subject:

The aim of this course is to present advanced concepts on digital communication systems. The course is divided in two main sections, that is, the point-to-point communication theory and the extension to multiuser scenarios. From a definition and a measure of information, the course develops the theory associated to the important concept of channel capacity. Impact of frequency-flat fading channels and frequency selective channels are analyzed. Performance degradations are mitigated through the use of transmission and reception diversity techniques. The extension of all the former concepts to a multiuser framework is done, providing a more rich and interesting context for current and future communication networks.

Learning results of the subject:

- To achieve a solid background on fundamental concepts of digital communications and information theory.
- Ability to understand the physical layers of modern advanced communication systems in point-to-point and multiuser networks.
- Ability to analyze, characterize and develop the physical layers of modern advanced communication systems in point-to-point and multiuser networks.

STUDY LOAD

Type	Hours	Percentage
Hours large group	39,0	31.20
Self study	86,0	68.80

Total learning time: 125 h

CONTENTS

1. Introduction: A Definition of Information.

Description:
- Discrete memoryless sources and source entropy.
- Discrete memoryless channels, mutual Information and channel capacity.
- Continuous time-amplitude channels. The Gaussian channel.
- Water-pouring and bit-loading approaches.

Full-or-part-time: 42h
Theory classes: 12h
Self study : 30h

2. Additive White Gaussian Channel (AWGN).

Description:
Signalling and optimal detection.
Performance bounds and case studies.

Full-or-part-time: 7h
Theory classes: 3h
Self study : 4h

3. Frequency-Flat-Fading Channels: the wireless channel.

Description:
- Statistical Models.
- Performance degradation and diversity schemes.
- Use of the channel-state information.
- Slow-fading: Outage Probability and Outage Capacity.
- Fast-fading: Ergodic Capacity.

Full-or-part-time: 16h
Theory classes: 6h
Self study : 10h

4. Frequency-Selective Channels: the multipath channel.

Description:
- Bello's channel model and channel transfer matrix.
- SVD and optimal communication schemes.
- OFDMA: Orthogonal Frequency Division Multiple Access.
- Hybrid SVD on OFDM solutions.

Full-or-part-time: 20h
Theory classes: 6h
Self study : 14h

5. Multiple-Access Channel.

Description:
- Ahiswede-Liao multiple-access capacity region.
- Multiple-access schemes and capacity regions: TDMA, FDMA-OFDMA, CDMA.
- Multiuser detection.
- Uplink fading channel.
- Downlink fading channel.
- Multiuser diversity.

Full-or-part-time: 40h
Theory classes: 12h
Self study : 28h

ACTIVITIES

EXERCISES

EXTENDED ANSWER TEST (MID TERM EXAMINATION)

EXTENDED ANSWER TEST (FINAL EXAMINATION)

GRADING SYSTEM

Mid-Term examination: 40 %
Final examination: 60 %
Final Grade: The final grade is the maximum between the Final Exam mark and the weighted former mark.

BIBLIOGRAPHY

Basic:
- Viterbi, A.J.; Omura, J.K. Principles of digital communication and coding. New York: Dover, 2009. ISBN 9780486469010.
- Tse, D.; Viswanath, P. Fundamentals of wireless communication. Cambridge: Cambridge University Press, 2005. ISBN 9780521845274.

Complementary:
- Benedetto, S.; Biglieri, E. Principles of digital transmission: with wireless applications [on line]. New York: Kluwer Acad./Plenum PWB, 1999 [Consultation: 22/09/2020]. Available on: http://link.springer.com/book/10.1007/b117711/page/1. ISBN 0306457539.
- Goldsmith, A. Wireless communications [on line]. Cambridge ; New York: Cambridge University Press, 2005 [Consultation: 08/07/2025]. Available on: https://www-cambridge-org.recursos.biblioteca.upc.edu/core/books/wireless-communications/800BA8A8211FBECB133A7BB77CD2E2BD. ISBN 0521837162.
- Gallager, R.G. Information theory and reliable communication. New York: John Wiley & Sons, 1968. ISBN 0471290483.
- Cover, T.M.; Thomas, J.A. Elements of information theory. 2nd ed. New York: John Wiley & Sons, 2006. ISBN 0471241954.