

Course guide

230381 - QCC - Quantum Communication and Computation

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). (Optional subject).
MASTER'S DEGREE IN ADVANCED TELECOMMUNICATION TECHNOLOGIES (Syllabus 2019). (Optional subject).

Academic year: 2025 **ECTS Credits:** 3.0 **Languages:** English

LECTURER

Coordinating lecturer: JAVIER RODRIGUEZ FONOLLOSA

Others: Primer quadrimestre:
ALBA MARIA PAGES ZAMORA - 10
JAVIER RODRIGUEZ FONOLLOSA - 10

PRIOR SKILLS

Solid knowledge of linear algebra and probability theory.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:

CE1. 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.

TEACHING METHODOLOGY

- Lectures.
- Problems solved individually or in groups by the student.

LEARNING OBJECTIVES OF THE SUBJECT

This subject combines two of the most important branches of science of the 20th century, the quantum theory developed in the 1920s and 1930s by scientists such as Planck, Einstein, Bohr, Heisenberg, Schrödinger, Pauli, Dirac and von Neumann, and the information theory, born after the work of Shannon in 1948. The basic postulates of quantum systems as well as their mathematical model will be presented. The concept of entropy and channel will also be generalized to establish the capacity of the quantum channels to transmit information, thus extending the emblematic Shannon theorem to the quantum context.

STUDY LOAD

Type	Hours	Percentage
Self study	51,0	68.00
Hours large group	24,0	32.00

Total learning time: 75 h

CONTENTS

Introduction.

Description:

- a) The EPR paper and course outline.
- b) Quantum states: the Bloch sphere, spectral decomposition, reversible evolution, measurement and the Born rule, the Stern-Gerlach experiment and measurement based on POVM.
- c) Composite quantum systems: Kronecker product description, the no-cloning theorem, separable and entangled states, the Schmidt decomposition, partial trace, purification, entanglement as a resource and the violation of the CHSH inequality.

Full-or-part-time: 18h

Theory classes: 6h

Self study : 12h

Quantum protocols and channels

Description:

- a) Quantum protocols: Entanglement distribution, super-dense coding and quantum teleportation.
- b) Quantum channels: Axiomatic definition, the Choi-Kraus theorem and the Choi rank, unitary and isometric channels, examples of quantum channels.
- c) The Classical-to-Classical channel, the Classical-to-Quantum channel, the Quantum-to-Classical channel.
- d) Entanglement-breaking channels.
- e) Purification of Quantum channels.

Full-or-part-time: 18h

Theory classes: 6h

Self study : 12h

Quantum entropy and information

Description:

- a) Quantum entropy and joint entropy.
- b) Conditional quantum entropy and coherent information.
- c) Quantum mutual information and conditional quantum mutual information.
- d) Quantum relative entropy.
- e) Quantum typicality and conditional typicality.

Full-or-part-time: 12h

Theory classes: 4h

Self study : 8h

Classical Communication.

Description:

- a) Accessible information.
- b) The information of quantum channels.
- c) The HSW theorem.
- d) Capacity examples.

Full-or-part-time: 12h

Theory classes: 4h

Self study : 8h



Quantum Computing

Description:

- a) Quantum Fourier Transform.
- b) Phase estimation.

Full-or-part-time: 12h

Theory classes: 4h

Self study : 8h

GRADING SYSTEM

- Attendance is mandatory.
- Participation in class (20%)
- Problems and/or group or individual presentation (80%)

EXAMINATION RULES.

There is no final exam.

BIBLIOGRAPHY

Basic:

- Wilde, M.M. Quantum information theory. Second edition. Cambridge, UK: Cambridge University Press, 2017. ISBN 9781107176164.

Complementary:

- Nielsen, M.A.; Chuang, I.L. Quantum computation and quantum information. 10th anniversary ed. Cambridge, UK: Cambridge University Press, 2010. ISBN 9781107002173.