

Course guide

230742 - QOC - Quantum Optical Communications

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:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: JOAN MANUEL GENE BERNAUS

Others:

PRIOR SKILLS

Basic background on digital communications and signal processing.

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.

CE3. Ability to implement wired/wireless systems, in both fix and mobile communication environments.

Transversal:

CT5. 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.

CT4. 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.

TEACHING METHODOLOGY

- Theoretical lectures
- Exercises
- Tests

LEARNING OBJECTIVES OF THE SUBJECT

Quantum communications is a new research field while optical communications is the most used technology nowadays. The combination of the two seems to be the next natural step.

The main objective is to review the optical communications systems under the perspective of quantum mechanics which provides a much deeper understanding. In particular, quantum information theory provides new tools in designing a communications system being quantum key distribution (QKD) its most paradigmatic application.

The abilities to be acquired after the course's completion are:

- To be able to understand the fundamentals of quantum information theory.
- To be able to analyze a quantum optical communications system.
- To be able to design an optical quantum key distribution (QKD) system.

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

Description:

1. Introduction
 - 1.1. Course Objectives and Methodology
 - 1.2. Brief Introduction to the Quantum Realm

Full-or-part-time: 3h

Theory classes: 2h

Self study : 1h

2. Elements of Quantum Mechanics

Description:

2. Elements of Quantum Mechanics
 - 2.1. Dirac's Notation
 - 2.2. Hilbert Spaces
 - 2.3. Schrödinger Equation
 - 2.4. Quantum Measurements

Full-or-part-time: 22h

Theory classes: 7h

Self study : 15h

3. Discrete-Variable QOC

Description:

- 3. Discrete-Variable QOC
 - 3.1. Review of Classical Optical Communications
 - 3.2. Quantum Decision Theory
 - 3.2.1. Pure States: Kennedy's Theorem
 - 3.2.2. Mixed States: Holevo's Theorem
 - 3.3. Quantum Communications Systems
 - 3.3.1. Noiseless
 - 3.3.2. With Thermal Noise
 - 3.4. Quantum Optical Communications Systems
 - 3.4.1. Fiber-optic Communications
 - 3.4.2. Free-space Communications

Full-or-part-time: 50h

Theory classes: 15h

Self study : 35h

4. Continuous-Variable QOC

Description:

- 4. Continuous-Variable QOC
 - 4.1. Overview of Entanglement
 - 4.2. Fundamentals of Continuous Variables
 - 4.2.1. The Harmonic Oscillator
 - 4.2.2. Gaussian States
 - 4.3. Classical and Quantum Information Theory
 - 4.3.1. Classical and Quantum Entropies
 - 4.3.2. Shannon Capacity
 - 4.3.3. The Holevo Bound
 - 4.4. Applications
 - 4.4.1. Quantum Key Distribution (QKD)
 - 4.4.2. Quantum Internet

Full-or-part-time: 50h

Theory classes: 15h

Self study : 35h

GRADING SYSTEM

- Partial exams: 60%
- Final exam: 40%

BIBLIOGRAPHY

Basic:

- Cariolaro, Gianfranco. Quantum Communications [on line]. Cham: Springer, 2015 [Consultation: 13/11/2024]. Available on: <https://link-springer-com.recursos.biblioteca.upc.edu/book/10.1007/978-3-319-15600-2>. ISBN 9783319156002.

Complementary:

- J.J. Sakurai and Jim Napolitano. Modern Quantum Mechanics. 3rd ed. Cambridge: Cambridge University Press, 2021. ISBN 9798354925407.
- Nielsen, Michael A; Chuang, Isaac L.. Quantum Computation and Quantum Information. Cambridge: Cambridge University Press,



2010. ISBN 9781107002173.

- Desurvire, Emmanuel. Classical and Quantum Information Theory: An Introduction for the Telecom Scientist. Cambridge: Cambridge University Press, 2009. ISBN 9780521881715.

- Gerry, C.C.; Knight, P.L. Introductory quantum optics. 2nd ed. Cambridge: Cambridge University Press, 2024. ISBN 9781009415293.

- Loudon, Rodney. The Quantum Theory of Light. 3rd ed. Oxford University Press, 2000. ISBN 9780198501763.