Introduction to quantum communications and computing

Academic Year: (2023 / 2024) **Review date: 14-04-2023**

Department assigned to the subject: Signal and Communications Theory Department

Coordinating teacher: VAZQUEZ VILAR, GONZALO

Type: Electives ECTS Credits : 3.0

Year : Semester :

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Students are expected to have a basic background in probability theory and linear algebra. Therefore, having passed the 1st year courses 'Statistics' and 'Lineal Algebra' is highly recommended.

OBJECTIVES

This course introduces the fundamental concepts of quantum communication and computing. Starting from an experimental basis, we will motivate why the classical theory of probability is not able to model certain real physical systems. We will present a generalization of the concept of probability that allows us to model these experiments, as well as their (unexpected) consequences. Among the applications in communications are quantum cryptography, the use of quantum entanglement and the teleportation protocol. We will study the underlying principles of quantum computers and we will learn to program them exploiting the quantum parallelism. Finally, the current state and the future perspectives of quantum technology will be discussed.

Some of the specific objectives are to:
- Understand the fundamental differences between classical and quantum probability theories.
- Describe mathematically a quantum state of a single qubit and that of several qubits.
- Know and use the axioms that govern the evolution and measurement of a quantum state.
- Model and analyze simple quantum communication channels and their cryptographic guarantees.
- Implement and analyze a quantum computing algorithm.

DESCRIPTION OF CONTENTS: PROGRAMME

Unit 1. Introduction
1.1. Historical remarks
1.2. The polarization of a photon

Unit 2. Axioms of quantum mechanics
2.1. Binary quantum states and superposition
2.2. Combining systems: quantum entanglement
2.3. Evolution of a quantum system
2.4. Bell¿s theorem

Unit 3. Quantum communications
3.1. Classical and quantum information
3.2. Modeling quantum channels
3.3. Communication protocols: teleportation
3.4. Quantum cryptography

Unit 4. Quantum computing
4.1. Quantum computers and their programming paradigm
4.2. Quantum computing algorithms
4.3. Programming a quantum computer
4.4. Perspectives and future

LEARNING ACTIVITIES AND METHODOLOGY

· 10 sessions motivating the generalization of the classical probability theory, studying the model for quantum systems with illustrative examples, and presenting the different technologies and applications of the quantum paradigm.
· 2 practical sessions to simulate simple quantum systems and quantum protocols.

· 1 practical session in which it will be presented and evaluated the experimental setup of a secure communications link.
· 1 practical session in which the students will develop and implement an quantum computing algorithm in a real quantum computer.

Teaching material
The material used in the course sessions will be uploaded to the platform Aula Global in electronic format. Before each session, the students will have available all the information and recommended reading for best understanding of the topic. Exercises will also be given to delve into the behavior of simple quantum systems and protocols. Some of the proposed exercises will be solved in the course sessions.

ASSESSMENT SYSTEM

· Homework and quizzes: 50%
· Lab projects: 50%

The course evaluation will be based on the continuous assessment of the student work. To this end, homework deliverables and quizzes will contribute to the 50% of the final grade and reports of the practical assignments will sum up the remaining 50%.

The evaluation in the extra-ordinary period will consist of one single exam covering both theoretical questions and practical problems.

% end-of-term-examination:	0
% of continuous assessment (assigments, laboratory, practicals…):	100

ADDITIONAL BIBLIOGRAPHY

- Eleanor Rieffel, Wolfgang Polak Quantum Computing: A Gentle Introduction, The MIT Press, 2011