Introduction to quantum communications and computing

Academic Year: (2019 / 2020) **Review date: 15-05-2020**

Department assigned to the subject: Department of Signal and Communications Theory

Coordinating teacher: VAZQUEZ VILAR, GONZALO

Type: Electives ECTS Credits : 3.0

Year : Semester :

STUDENTS ARE EXPECTED TO HAVE COMPLETED

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.

COMPETENCES AND SKILLS THAT WILL BE ACQUIRED AND LEARNING RESULTS.

- 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 of a quantum system.
- Know and use the axioms that govern the measurement of a quantum state.
- Model and analyze simple quantum communication channels.
- Interpret a quantum computing protocol and understand the resources that it requires.

DESCRIPTION OF CONTENTS: PROGRAMME

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. The new quantum theory of probability will then be used to analyze several simple problems, including the transmission of information, the distribution of quantum entanglement and the teleportation protocol. Finally, the current state of the technology and its future perspectives will be discussed.

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Contents

Unit 1. Introduction: bits versus qubits
1.1. What is a qubit?
1.2. Quantum states
1.3. Experiments and quantum systems

Unit 2. Axioms of quantum mechanics
2.1. Principles of quantum mechanics
2.2. Combining systems: quantum entanglement
2.3. Experimental verification: Bell¿s inequality
2.4. Time and evolution of a system

Unit 3. Quantum communications
3.1. Modeling quantum channels
3.2. Classical versus quantum information
3.3. Communication protocols: polarization and entanglement
3.4. Secure link Alice-Bob-Eve

Unit 4. Quantum computation
4.1. Resources and tasks
4.2. Teleportation
4.3. Protocols: entanglement distribution and super-dense coding
4.4. Quantum computers: state of the art

LEARNING ACTIVITIES AND METHODOLOGY

- 8 theoretical sessions presenting the generalization of the classical probability theory, basic concepts of quantum mechanics and illustrative examples.
- 4 practical sessions to simulate simple quantum systems and quantum protocols.
- 2 sessions in which it will be presented and evaluated the experimental setup of a secure

communications link.
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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 the best understanding of the session. Exercises will also be given, some of which will be solved in practical sessions.

ASSESSMENT SYSTEM

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

The evaluation in the ordinary call will consist on the continuous assesment of the student work. To this end, homework deliverables and quizzes will contribute to the 50% of the final grade and lab reports to the other 50%.

The evaluation in the extra-ordinary period will consist on a 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