UNSW

School of Electrical Engineering and Telecommunications

Tele9757 Quantum Communications Course Outline 2009

Staff Contact: A/Prof Robert Malaney,
Email: r.malaney@unsw.edu.au

Course Aim

The main aim of this course is to develop amongst students from different backgrounds a solid understanding of the key concepts and principles that underpin the emerging and exciting new world of quantum communications.

Course Overview

This course is for 6 Units of Credit and aimed at Graduate Engineers and Physicists wishing to understand the exciting new world of Quantum Communications. Quantum Communications and Quantum Networks are anticipated to be the core networking technologies of the 21st century. In fact these communication systems have already appeared in the commercial world in many variations. This course introduces the keys concepts important for understanding, testing, analyzing and improving the performance of quantum communication networks. It will have particular focus on actual quantum networks currently being deployed and the use of such networks for secure information transfer. Designed from an engineering perspective the course will first introduce the basic quantum physics that underlies quantum communication principles. It will then introduce and explore the key concepts that drive quantum communications such as Quantum Entanglement, Quantum Teleportation, The No Cloning Theorem, Quantum Cryptography; Privacy Amplification and Error Correction for Quantum Keys.

Syllabus:

1. **[Week 1] Introductory Lecture**. Who wants to be a "Quantum Engineer"? Why study Quantum Communications and Quantum networks? What's wrong with classical networks? What Quantum physics will we cover in the course?
2. **[Week 1] Overview of Commercial Quantum Networks**. The future is now. What "real engineers" are now building. Overview of current Quantum networks both deployed commercially and those currently in prototype
3. **[Week 2] Photon Polarization.** Maxwell's equations revisited**.** Applications of polarization in Quantum Networks.
4. **[Week 2]General Quantum Variables and Qubits**. Applications of quantum variables in Quantum Networks
5. **[Week 3]Composite Quantum Systems**. Applications of quantum systems in Quantum Networks.
6. **[Week 4]Quantum Entanglement**. Why Einstein was wrong and right at same time. Why is entanglement important for Quantum Communications.
7. **[Week 4] Quantum Teleportation**. An application of composite qubits and entanglement
8. **[Week 5] Quantum Communications**. Superdense coding. Breaking the classical information barrier.
9. **[Week 6] Experimental Quantum Teleportation of Qubits**. Engineering sources of Entangled Photons. Why is this hard? What is state-of-the art. What does future predict?
10. **[Week 6]The No Cloning Theorem**. Copying classical information is easy, but try copying quantum information.
11. **[Week 7] Review of Classical Cryptography.** Algorithms and why classical encryption is defeated by Quantum Computers
12. **[Week 8] Quantum Cryptography**. The Bennett-Brassard Protocol for Quantum key distribution. Eckert's Protocol for Quantum key distribution using entanglement.
13. **[Week 9] Review of Classical Error Correcting Codes.** Hamming distance, Linear Codes, Generator Matrices, and all that jazz.
14. **[Week 10] Error Corrections for Quantum Keys.** Error correcting codes once quantum physics is thrown in
15. **[Week 11] Privacy Amplification.** Why error correction leaks information to a potential adversary and how to combat this with privacy amplification.
16. **[Week 12] Other Quantum Courses at UNSW.** Guest lectures by Andrew Dzurak and Arthur Ramer, outlining the Quantum Devices and the Quantum Computing & Information courses which will run in session 2.

Text(s) and Reference(s):

Main Text: Protecting Information: From Classical Error Correction to Quantum Cryptography, S. Loepp & W. K. Wooters, Cambridge Press, 2006

Secondary Text: Quantum Computation and Quantum Information, M. Nielsen and I. L. Chuang, Cambridge Press, 2006.

Other Background papers may be added

Course Objectives & Learning Outcomes

At the end of the course students should:

a) Understand the theory, concepts and challenges of quantum mechanics as applied to communications
b) Understand the theory, concepts and challenges of transferring quantum information over a network
c) Understand how applications actually operate over quantum a communication channel
d) Understand why quantum communications is a vital new technology that will only grow in importance within the engineering world
e) Understand and participate in discussions on the underlying principles of quantum networks
f) Be able to design and simulate the behavior of quantum networks
g) Be able to carry out calculations which determine the performance of a quantum network
h) Be able to read and understand quantum communication research papers appearing in engineering journals

Teaching Methods & Strategies

Lectures = 3*hrs/week*

The lectures will introduce the core concept and principles of quantum communications. Following the lecture a discussion session on the core material will take place in order to solidify your understanding. Tutorials and model solutions will be presented at the end of each lecture in order to re-enforce your ability to design quantum networks and to carry out detailed calculations relating to communication performance.

Relation to other Courses:

This course is related to other communication courses offered by Electrical Engineering in that it introduces a new physical layer communication technology, not previously covered. It compliments existing courses on physical layer *Photonics* and *Wireless Communications*. This new course also compliments existing courses in *Quantum Devices* for quantum computers. Quantum communications will be very important in construction of distributed quantum computers. Finally, the course also compliments a new course in *Quantum Algorithms & Information* being introduced by Computing Science and Engineering.

Graduate Attributes:

This course will impact on the following graduate attributes

1. Development of skills involved in scholarly enquiry
2. Capacity for analytical and critical thinking and for creative problem-solving
3. The ability to engage in independent and reflective learning
4. Information literacy - the skills to appropriately locate, evaluate and use relevant information
5. An appreciation of, and a responsiveness to, change

Attendance at Lectures

You are strongly encouraged to attend all class lectures. This is especially the case for this class as you will be presented with brand new concepts that you have likely never come across before. This makes the class very interesting for you – but it does require your participation in class. There will be no formal notes handed out that covers all the class material in detail, There will be power-points put on the class web site for download but these will not be sufficient for you to cover the class material. The lectures will consist of some power-point presentations, discussion of material in prescribed texts, and discussion of case studies. You are strongly encouraged to participate in class by interacting through questions and discussions of class material, and to prepare before class by reading relevant work packages ahead of time. There will be plenty of problem sets that will be reviewed in class. There may be guest lecturers.

Assessment Weighting

- **Final Examination (50%):** The examination is of two-hour duration, covering all aspects of the course that have been presented in lectures. This exam will assess both understanding and analytical skills. You must pass this exam to pass course.
- **Mid-Session Test (25%):** The mid-session test will last 45 minutes and will be held in week 6. It will cover material covered in the course in week 1 to 5, and will test your conceptual understanding of this material, as well as your ability to apply the concepts to solving problems. This is compulsory test.
- **Class Assignment (25%):** Each student will be charged with reviewing a research paper chosen from a list (to be given in class), or choosing a simulation which covers some aspects of the class work. This assignment is related to the learning outcome of being able to comprehend current research papers in the area. A formal 10 page report on the research paper or the simulation will be required by week 11. The assignment will be marked on the following criteria; Presentation (15%) depth of technical content (30%), independent critical thinking (40%). technical writing (15%). The student may present a power-point presentation on his/her report (although encouraged to do so the presentation is optional). The assignment will be due by end of week 11 – delivery will be electronic.
- **Bonus marks:** Some bonus marks may be available (max 5%) for additional class participation, – details in class.
- **Late reports and missed tests.** There will be zero marks awarded for late reports or missed tests.

Course Evaluation

All students will be given the opportunity to provide feedback on the course. You are strongly encouraged to participate in this, especially as this is the first time the course is offered. Teaching staff take such feedback seriously and use it to improve the course delivery for subsequent lectures.

Consultations

Please make an appointment for consultation at other times beyond standard class consultations through e-mail to r.malaney@unsw.edu.au (all email must be from a UNSW student account). Standard consultation time will be given in class.

Other Course Resources

Please see class web site **https://subjects.ee.unsw.edu.au/tele9757** for other material. It is expected and assumed that you will check this web site at least once per week for important class announcements.

Plagiarism is strictly prohibited.

Please refer to UNSW's plagiarism policy at

http://www.lc.unsw.edu.au/plagiarism/.