School of Electrical Engineering and Telecommunications

Term 3, 2020
Course Outline

TELE4651
Wireless Communication Technologies

COURSE STAFF

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Consultations: You are encouraged to ask questions on the course material, after the lecture class times in the first instance, rather than via email. Lecturer consultation times will be advised during lectures. You are welcome to email the tutor or laboratory demonstrator, who can answer your questions on this course and can also provide you with consultation times. ALL email enquiries should be made from your student email address with TELE4651 in the subject line; otherwise they will not be answered.

Keeping Informed: Announcements may be made during classes, via email (to your student email address) and/or via online learning and teaching platforms – in this course, we will use Moodle https://moodle.telt.unsw.edu.au/login/index.php. Please note that you will be deemed to have received this information, so you should take careful note of all announcements.

COURSE SUMMARY

Contact Hours

The course consists of 2-3-hour lectures per week, 1-hour tutorial per week, and a 3-hour laboratory session per fortnight (except the first two weeks when you have one lab session per week).

	Day	Time	Location
Lectures	Tuesday	9 - 12 (week 1- 4) 9 - 11 (week 5-10)	
Tutorials	Tuesday	12 - 13 (week 1-4,6-9) 12 - 14 (week 5, 10)	
	Tuesday	15 - 16 (week 1-4,6-9) 15 - 17 (week 5, 10)	
Labs			
	Wednesday	09 - 12	EE426
	Wednesday	12 - 15	EE426
	Wednesday	15 - 18	EE426
	Thursday	09 - 12	EE426
	Thursday	15 - 18	EE426
	Friday	09 - 12	EE426

Context and Aims

This is an advanced course in telecommunications, providing detailed knowledge of the fundamental concepts in wireless communications and in-depth discussions on several selected areas, namely, digital transmission and receiving techniques, error control methods, antenna diversity techniques and wideband transmissions. This course is a professional elective offered in the Telecommunication option. It assumes basic competency in the

second year electronics and systems courses and the third year TELE3113 Introduction of Analogue and Digital Communications, and requires a mathematical ability of at least up to second year.

Aims: This course aims to:

a. Make the student familiar with the basic principles of information transmission in wireless channels.
b. Make the student familiar with wireless transmission techniques and their applications.
c. Enable the student to do analysis and design transmission and receiving algorithms.

Course Objectives

At the end of this course the student will:

- be familiar with wireless channel models and the effects of fading on the transmitted signals.
- have developed an understanding of various diversity techniques.
- have developed an understanding of error control methods for wireless channels.
- have developed an understanding of wideband transmission technologies.

Indicative Lecture Schedule

Period	Summary of Lecture Program
Week 1	Introduction to wireless communications and digital communications overview
Week 2	**LabVIEW Test** Review of signal processing fundamentals I: signals and stochastic processes, Fourier transforms, sampling theorem, discrete-time processing of continuous-time signals
Week 3	Review of signal processing fundamentals II: frequency response of random signals, power spectrum, bandwidth, complex envelope notation, up/down conversion, complex baseband representation, complex baseband equivalent channel
Week 4	Quadrature pulse amplitude, modulation, PAM, QAM, transmit energy, transmit bandwidth, additive white Gaussian noise channels Optimal pulse shapes for AWGN, Nyquist pulse shapes, implementing optimal pulse shapes using multi-rate identities Maximum likelihood detection with additive white Gaussian noise, probability of error analysis, Sample timing offset, algorithms for sample timing
Week 5	**Mid-Term Test** Narrowband frame synchronization, channel estimation, linear least squares estimation Frequency selective channels, least squares channel estimation, direct least squares equalizer estimation
Week 6	Revision:
Week 7	Frequency offset estimation and correction, requency domain equalization, DFT Single carrier frequency domain equalization (SC-FDE), OFDM, the cyclic prefix
Week 8	Single carrier frequency domain equalization (SC-FDE), OFDM, the cyclic prefix Comparison between SC-FDE and OFDM, carrier frequency offset estimation and channel estimation in OFDM
Week 9	Introduction to propagation, large-scale fading, link budgets, path loss Small-scale fading, coherence time, coherence bandwidth, Rayleigh fading
Week 10	Probability of error in fading channels, receive diversity, selection diversity and maximum ratio combining, probability of error with diversity Sources of diversity, Alamouti space-time code, transmit beamforming
Optional	Introduction to MIMO wireless communication, spatial multiplexing Receivers for spatial multiplexing, performance analysis Dealing with practical impairments in MIMO communication systems, channel estimation and synchronization Introduction to MIMO-OFDM, highlights of the IEEE 802.11n standard

Indicative Laboratory Schedule

Period	Summary of Laboratory Program
Week 1	Self-paced training of LabView on your own PC/Laptop. Lab0: LabVIEW (Lab starts from this week.)
Week 2	Lab1: Part 1 Introduction to NI LabVIEW Lab1: Part 2 Introduction to NI RF Hardware
Week 4	Lab 2: Part 1 Modulation and Detection Lab 2: Part 2 Pulse Shaping and Matched Filtering
Week 7	Lab 3: Synchronization
Week 8	Lab 4: Channel Estimation & Equalization
Week 10	Lab 5: Frame Detection & Frequency Offset Correction
Optional	Lab 6: OFDM Modulation & Frequency Domain Equalization
Optional	Lab 7: Synchronization in OFDM Systems
Optional	Lab 8: Channel Coding in OFDM Systems

Assessment

The assessment scheme in this course reflects the intention to assess your learning progress through the term. Ongoing assessment occurs through the lab checkpoints (see lab manual), lab exams and the mid-term exam.

LabVIEW Test and Pre-Labs	**10%**
Lab Experiments and Lab Report	**40%**
Mid-Term Test	**20%**
Final Test	**30%**

Important Health Related Notice

Your health and the health of those in your class is critically important. You must stay at home if you are sick or have been advised to self-isolate by NSW health or government authorities. Current alerts and a list of hotspots can be found here. **You will not be penalised for missing a face-to-face activity due to illness or a requirement to self-isolate**. We will work with you to ensure continuity of learning during your isolation and have plans in place for you to catch up on any content or learning activities you may miss. Where this might not be possible, an application for fee remission may be discussed.

If you are required to self-isolate and/or need emotional or financial support, please contact the Nucleus: Student Hub. If you are unable to complete an assessment, or attend a class with an attendance or participation requirement, please let your teacher know and apply for special consideration through the Special Consideration portal. To advise the University of a positive COVID-19 test result or if you suspect you have COVID-19 and are being tested, please fill in this form.

UNSW requires all staff and students to follow NSW Health advice. Any failure to act in accordance with that advice may amount to a breach of the Student Code of Conduct. Please refer to the Safe Return to Campus guide for students for more information on safe practices.

COURSE DETAILS

Credits

This is a 6 UoC course and the expected workload is 15 hours per week throughout the 10 week term.

Relationship to Other Courses

This is a 4th year course in the School of Electrical Engineering and Telecommunications. It is an elective course for students following a BE (Electrical) or (Telecommunications) program and other combined degree programs, and an elective for Computer Engineering students.

This course provides advanced knowledge of wideband wireless communication techniques to enable the students to design advanced wireless communication systems. It includes the topics of digital transmission and receiving technologies, channel impairments and the associated mitigation techniques, diversity techniques, Wideband OFDM transmission and multiple-input/multiple-output communications. It serves as an excellent basis from which to commence research in the area. Various aspects of the course bring students up to date with the very latest developments in the field, as seen in recent international conferences and journals, and some of the laboratory work is designed in the style of an empirical research investigation.

Pre-requisites and Assumed Knowledge

The pre-requisite for this course is TELE3113 Introduction of Analogue and Digital Communications (or equivalent). Knowledge from TELE4653 is highly desirable. It is essential that you are familiar with digital signal, modulation and detection before this course is attempted. It is further assumed that students are familiar with LabView and Matlab, and have good computer literacy. Students who are not confident in their knowledge from previous digital communications courses (especially the topics mentioned) are strongly advised to revise their previous course materials as quickly as possible to avoid difficulties in this course.

Learning outcomes

After successful completion of this course, you should be able to:

1. Understand of the principles, algorithms and technologies used in transmission information in wireless mobile channels
2. Derive expressions for error performance and capacity for various transmission schemes
3. Explain the operation of example algorithms covered in lectures, and discuss the effects of varying parameter values within these;
4. Analyse the performance of a wireless communication systems
5. Apply the principles and technique to communication systems design or undertake further research

The course delivery methods and course content address a number of core UNSW graduate attributes, include:

a. The capacity for analytical and critical thinking and for creative problem-solving, which is addressed by the tutorial exercises and laboratory work.
b. The ability to engage in independent and reflective learning, which is addressed by tutorial exercises together with self-directed study.
c. The skills of effective communication, which are addressed by the viva-style verbal assessment in the laboratory.
d. Information literacy, which is addressed by the homework.

This course is designed to provide the above learning outcomes which arise from targeted graduate capabilities listed in ***Appendix A***. The targeted graduate capabilities broadly support the UNSW and Faculty of Engineering graduate capabilities (listed in ***Appendix B***). This course also addresses the Engineers Australia (National Accreditation Body) Stage I competency standard as outlined in ***Appendix C***.

Syllabus

Digital wireless transmission and receiving technologies: modulation, demodulation, symbol synchronization and time recovery, frame synchronization, channel estimation and equalization. Wireless Communications Channels: time-variant multipath fading, Doppler shift, shadowing effect, time selective channel, frequency selective channel, the effects of fading on wireless transmission, performance analysis. Digital Transmission over Fading Channels:

performance analysis, burst-error correcting codes for fading channels, convolutional codes, soft output Viterbi algorithm, coded modulation, turbo principles, iterative processing, space diversity, time diversity and frequency diversity techniques. Wideband Transmissions: spread-spectrum communications, DS-CDMA, frequency hopping, OFDM techniques, their applications.

TEACHING STRATEGIES

Delivery Mode

The teaching in this course aims at establishing a good fundamental understanding of the areas covered using:

- Formal lectures, which provide you with a focus on the core analytical material in the course, together with qualitative, alternative explanations to aid your understanding;
- Tutorials, which allow for exercises in problem solving and allow time for you to resolve problems in understanding of lecture material;
- Laboratory sessions, which support the formal lecture material and also provide you with practical construction, measurement and debugging skills;
- Video lectures, small periodic quizzes (non-assessed), etc.

Learning in this course

You are expected to attend all lectures, tutorials, labs, and mid-term exams in order to maximize learning. You must prepare well for your laboratory classes and your lab work will be assessed. In addition to the lecture notes/video, you should read relevant sections of the recommended text. Reading additional texts will further enhance your learning experience. Group learning is also encouraged. UNSW *assumes* that self-directed study of this kind is undertaken in addition to attending face-to-face classes throughout the course.

Tutorial classes

You should attempt all of your problem sheet questions in advance of attending the tutorial classes. The importance of adequate preparation prior to each tutorial cannot be overemphasized, as the effectiveness and usefulness of the tutorial depends to a large extent on this preparation. Group learning is encouraged. Answers for these questions will be discussed during the tutorial class and the tutor will cover the more complex questions in the tutorial class. In addition, during the tutorial class, 1-2 new questions that are not in your notes may be provided by the tutor, for you to try in class. These questions and solutions may not be made available on the web, so it is worthwhile for you to attend your tutorial classes to gain maximum benefit from this course.

Laboratory program

The laboratory schedule is deliberately designed to provide practical, hands-on exposure to the concepts conveyed in lectures soon after they are covered in class. You are required to attend laboratory from Week 4 to Week 12. Laboratory attendance WILL be kept, and you MUST attend at least 80% of labs.

Laboratory Exemption

There is no laboratory exemption for this course. Regardless of whether equivalent labs have been completed in previous courses, all students enrolled in this course must take the labs. If, for medical reasons, (note that a valid medical certificate must be provided) you are unable to attend a lab, you will need to apply for a catch-up lab during another lab time, as agreed by the laboratory coordinator.

ASSESSMENT

The assessment scheme in this course reflects the intention to assess your learning progress through the term. Ongoing assessment occurs through the lab checkpoints (see lab manual), lab exams and the mid-term exam.

Laboratory Assessment

Laboratories are primarily about learning, and the laboratory assessment is designed mainly to check your knowledge as you progress through each stage of the laboratory tasks. You are required to maintain a lab book for recording your observations. A lab book is an A4 size notebook containing a mix of plain pages and graph sheets. You have to purchase your own lab book from any stores.

It is essential that you complete the laboratory preparation before coming to the lab. You are required to write the aim of the experiment and draw the circuit diagram if any in your lab book. This will be verified and signed by your demonstrators in the lab. You will be recording your observations/readings in your lab book first and then completing and submitting the results sheet before leaving the lab.

Prelabs:

Every lab session will have prelab that should be completed and handed in before you starting the associated lab session in room EE426 (You must hand in the prelab in the first 15 minutes of your lab session). The prelab includes a mixture of problems and programming to prepare you for that week's experiment. You may work on the prelab with your lab partner but not with other students but all work must be your own. You may not participate in the lab without a prelab. Copying another student's prelab is considered cheating and the appropriate action will be taken. Prelabs, homework assignments, tests, and solutions from previous offerings of this course or offerings of related courses on the Internet are off limits. Use of these materials will be considered cheating and appropriate action according to the Academic Dishonesty Policy listed below will be taken. All prelab assignments will be due at the beginning of each lab. No late prelabs will be accepted as you need to be prepared for the lab.

After completing each experiment, your work will be assessed by the laboratory demonstrator. Both the results sheet and your lab book will be assessed by the laboratory demonstrator.

Assessment marks will be awarded according to your preparation (completing set preparation exercises and correctness of these or readiness for the lab in terms of pre-reading), how much of the lab you were able to complete, your understanding of the experiments conducted during the lab, the quality of the code you write during your lab work (according to the guidelines given in lectures), and your understanding of the topic covered by the lab.

Laboratory Report

The purpose of the lab report is to discuss what was observed in the lab and to answer several questions related to wireless communication engineering. The lab report is an opportunity to synthesize what was learned. The questions will be based on what you have learned/observed in your laboratory classes and lectures, and marks will be awarded for the correct understanding of practical and relevant theoretical concepts, correct operation of laboratory equipment, and correct interpretation of measured results. The report for each lab is due at the beginning of the next lab

Laboratory Exam

To check that you have achieved the practical learning outcomes for the course, you will be examined in the laboratory. Laboratory Exams are closed book practical exams that include answering questions and analytical calculations. The exam questions will be based on what you have learned in your laboratory classes and lectures, and marks will be awarded for the correct understanding of practical and relevant theoretical concepts, correct operation of laboratory equipment, and correct interpretation of measured results.

Mid-Term Test

The mid-session examination tests your general understanding of the course material, and is designed to give you feedback on your progress through the analytical components of the course. Questions may be drawn from any course material up to the end of week 6. It may contain questions requiring some (not extensive) knowledge of laboratory material, and will definitely contain numerical and analytical questions. Marks will be assigned according to the correctness of the responses.

Assignment

The assignment allows self-directed study leading to the solution of partly structured problems. NO marks will be assigned to the assignments. However, you are encouraged to do the assignments as the mid-term test and the final test might be highly related to the assignments. You do NOT need to hand in your assignments.

Final Test

The test in this course is a standard closed-book 2 hour written examination, comprising five or upto five compulsory questions. University approved calculators are allowed. The examination tests analytical and critical thinking and general understanding of the course material and lab material in a controlled fashion. Questions may be drawn from any aspect of the course (including laboratory), unless specifically indicated otherwise by the lecturer. Marks will be assigned according to the correctness of the responses. *Please note that you must pass the final exam in order to pass the course.*

Relationship of Assessment Methods to Learning Outcomes

	Learning outcomes						
Assessment	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Laboratory experiment and report	✓	✓	-	✓	✓	✓	-
LabVIEW Test and Pre-Labs	✓	-	✓	✓	-	✓	✓
Mid-Term exam	-	✓	✓	-	✓	✓	✓
Final exam	-	✓	✓	✓	✓	-	✓

COURSE RESOURCES

Textbooks

Prescribed textbook

- Andrew Goldsmith, Wireless communications, Cambridge University Press, 2005.

You may want to check the coverage of this text before purchasing, as some topics in the syllabus are not featured. Unfortunately there is no single text that covers all topics in a satisfactory depth. Additional references, listed below and at the end of some lecture note sets, will in combination provide complete coverage of the course. Lecture notes will be provided, however note that these do not treat each topic exhaustively and additional reading is required.

Reference books

- B. Vucetic and J. Yuan: *Space-time coding: John Wiley and Sons*, 2003.
- Simon Heykin and Michael Moher, "Modern Wireless Communications", Pearson Prentice Hall, 2005.
- Gordon L. Stuber, Principles of Mobile Communication, Boston, MA: Kluwer Academic Publishers, 1996.
- Theodore S. Rappaport, Wireless Communications: Principles and Practice. Upper Saddle River, NJ: Prentice-Hall, 1996.

On-line resources

Moodle

As a part of the teaching component, Moodle will be used to disseminate teaching materials, host forums and occasionally quizzes. Assessment marks will also be made available via Moodle: https://moodle.telt.unsw.edu.au/login/index.php.

Mailing list

Announcements concerning course information will be given in the lectures and/or on Moodle and/or via email (which will be sent to your student email address).

OTHER MATTERS

Dates to note

Important Dates available at: https://student.unsw.edu.au/dates

Academic Honesty and Plagiarism

Plagiarism is the unacknowledged use of other people's work, including the copying of assignment works and laboratory results from other students. Plagiarism is considered a form of academic misconduct, and the University has very strict rules that include some severe penalties. For UNSW policies, penalties and information to help you avoid plagiarism, see https://student.unsw.edu.au/plagiarism. To find out if you understand plagiarism correctly, try this short quiz: https://student.unsw.edu.au/plagiarism-quiz.

Student Responsibilities and Conduct

Students are expected to be familiar with and adhere to all UNSW policies (see https://student.unsw.edu.au/guide), and particular attention is drawn to the following:

Workload

It is expected that you will spend at least **ten to twelve hours per week** studying a 6 UoC course, from Week 1 until the final assessment, including both face-to-face classes and *independent, self-directed study*. In periods where you need to need to complete assignments or prepare for examinations, the workload may be greater. Over-commitment has been a common source of failure for many students. You should take the required workload into account when planning how to balance study with employment and other activities.

Attendance

Regular and punctual attendance at all classes is expected. UNSW regulations state that if students attend less than 80% of scheduled classes they may be refused final assessment.

General Conduct and Behaviour

Consideration and respect for the needs of your fellow students and teaching staff is an expectation. Conduct which unduly disrupts or interferes with a class is not acceptable and students may be asked to leave the class.

Work Health and Safety

UNSW policy requires each person to work safely and responsibly, in order to avoid personal injury and to protect the safety of others.

Special Consideration and Supplementary Examinations

You must submit all assignments and attend all examinations scheduled for your course. You should seek assistance early if you suffer illness or misadventure which affects your course progress. All applications for special consideration must be **lodged online through myUNSW within 3 working days of the assessment**, not to course or school staff. For more detail, consult https://student.unsw.edu.au/special-consideration.

Continual Course Improvement

This course is under constant revision in order to improve the learning outcomes for all students. Please forward any feedback (positive or negative) on the course to the course convener or via the online student survey myExperience. You can also provide feedback to ELSOC who will raise your concerns at student focus group meetings. As a result of previous feedback obtained for this course and in our efforts to provide a rich and meaningful learning experience, we have continued to evaluate and modify our delivery and assessment methods.

Administrative Matters

On issues and procedures regarding such matters as special needs, equity and diversity, occupational health and safety, enrolment, rights, and general expectations of students, please refer to the School and UNSW policies:
https://student.unsw.edu.au/guide
https://www.engineering.unsw.edu.au/electrical-engineering/resources

APPENDICES

Appendix A: Targeted Graduate Capabilities

Electrical Engineering and Telecommunications programs are designed to address the following targeted capabilities which were developed by the school in conjunction with the requirements of professional and industry bodies:

- The ability to apply knowledge of basic science and fundamental technologies;
- The skills to communicate effectively, not only with engineers but also with the wider community;
- The capability to undertake challenging analysis and design problems and find optimal solutions;
- Expertise in decomposing a problem into its constituent parts, and in defining the scope of each part;
- A working knowledge of how to locate required information and use information resources to their maximum advantage;
- Proficiency in developing and implementing project plans, investigating alternative solutions, and critically evaluating differing strategies;

- An understanding of the social, cultural and global responsibilities of the professional engineer;
- The ability to work effectively as an individual or in a team;
- An understanding of professional and ethical responsibilities;
- The ability to engage in lifelong independent and reflective learning.

Appendix B: UNSW Graduate Capabilities

The course delivery methods and course content directly or indirectly addresses a number of core UNSW graduate capabilities, as follows:

- Developing scholars who have a deep understanding of their discipline, through lectures and solution of analytical problems in tutorials and assessed by assignments and written examinations.
- Developing rigorous analysis, critique, and reflection, and ability to apply knowledge and skills to solving problems. These will be achieved by the laboratory experiments and interactive checkpoint assessments and lab exams during the labs.
- Developing capable independent and collaborative enquiry, through a series of tutorials spanning the duration of the course.
- Developing digital and information literacy and lifelong learning skills through assignment work.

Appendix C: Engineers Australia (EA) Professional Engineer Competency Standard

	Program Intended Learning Outcomes	
PE1: Knowledge and Skill Base	PE1.1 Comprehensive, theory-based understanding of underpinning fundamentals	✓
	PE1.2 Conceptual understanding of underpinning maths, analysis, statistics, computing	✓
	PE1.3 In-depth understanding of specialist bodies of knowledge	✓
	PE1.4 Discernment of knowledge development and research directions	
	PE1.5 Knowledge of engineering design practice	✓
	PE1.6 Understanding of scope, principles, norms, accountabilities of sustainable engineering practice	
PE2: Engineering Application Ability	PE2.1 Application of established engineering methods to complex problem solving	✓
	PE2.2 Fluent application of engineering techniques, tools and resources	✓
	PE2.3 Application of systematic engineering synthesis and design processes	
	PE2.4 Application of systematic approaches to the conduct and management of engineering projects	
PE3: Professional and Personal Attributes	PE3.1 Ethical conduct and professional accountability	
	PE3.2 Effective oral and written communication (professional and lay domains)	✓
	PE3.3 Creative, innovative and pro-active demeanour	✓
	PE3.4 Professional use and management of information	✓
	PE3.5 Orderly management of self, and professional conduct	
	PE3.6 Effective team membership and team leadership	✓