Course-PM

SSY135 Wireless Communications

2019/20

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Abstract

This document describes the course *SSY135Wireless Communications*, 7.5 credit units spring semester 2020. Any changes to the information in this document will be posted on the course web, which is found at

https://chalmers.instructure.com/courses/8763

Contents

General Information

Literature
Andrea Goldsmith, Wireless Communications, Cambridge University Press, 2005, ISBN-13: 9780521837163, ISBN-10: 0521837162. The book is available in printed form from many sources, including Cremona. It is also available as an e-book through Chalmers library. An errata list is available for download at the course web page.

Additional printed material
Additional material will be made available for download from the course web.

Exam
Exam dates are found on page 8. Allowed materials on the exam are

- Chalmers-approved calculator
- L. Råde, B. Westergren. *Beta, Mathematics Handbook,* any edition.
- One A4 page with your own *handwritten* notes. Both sides of the page can be used. Photocopies or printouts of other material or other student's notes are not allowed.

As a general Chalmers' rule, it is allowed to bring a dictionary to the exam. Electronic dictionaries are not allowed. Furthermore, another general Chalmers' rule states that answers to exam problems should be in English, answers in any other language will be ignored when grading the exam.

Projects
There are two mandatory projects in the course; details are found on page 5.

Quizzes
There are six quizzes in the course; details are found below on page 7.

Email subject line
Please include the string "[SSY135]" in the subject line of all course-related emails.

Lecturers

- Henk Wymeersch, phone 772 1765, room 6408, henkw@chalmers.se
- Thomas Eriksson, phone 772 1745, room 6330, thomase@chalmers.se
- Giuseppe Durisi, phone 772 18 02, room 6312, durisi@chalmers.se

Teaching Assistants

- Yasaman Ettefagh, phone 031 772 1815 room 6331, ettefagh@chalmers.se
- Nima Hajiabdolrahim, phone 031 7721724, room 6329, nimahaj@chalmers.se

Office hours: Thursday mornings, 9:00-10:00

E2 Student Administration Office
The office is in E2 Administration (3rd floor of EDIT building), madeleine.persson@chalmers.se.

Prerequisites

A passing grade in SSY125 Digital Communications, or a similar course, is required. This implies working knowledge of basic concepts in signal processing (linear filtering, convolution, impulse response, frequency response, Fourier transforms), probability and random processes (probability density functions, conditional probabilities, expectation, power spectral density), modulation (pulse-amplitude modulation, quadrature modulation, inter-symbol interference), error-control coding (block codes, convolutional codes), error probability analysis for additive white Gaussian channels, power efficiency, and spectral efficiency, and channel capacity for AWGN channels. Basic MATLAB skills programming skills are required to complete the course projects.

Aims and Learning Outcomes

Aims

The course is concerned with the design of wireless communication systems. This includes link design (i.e., choice of modulation, channel coding, and possible use of multiple antenna techniques), channel access design (i.e., choice of multiple access, multiplexing, and duplexing techniques), and network design (e.g., choice of cell layout, power control, frequency and channel reuse strategies). The aim is that the students will acquire enough understanding of the wireless channel and the state of the technology to explain why today's systems are designed as they are and how they can be improved as technology evolves.

Learning Outcomes

After completion of this course, the student should be able to

- explain why small-scale and large-scale fading occurs
- describe the conditions under which the standard path loss and fading models accurately predicts real-world radio wave propagation
- define Doppler spread, delay spread, coherence time, and coherence bandwidth and explain how these parameters are related and affect the wireless physical layer design
- define the performance metrics instantaneous error probability, average error probability, and outage probability and understand which metric is appropriate for a given scenario
- define ergodic and outage channel capacity and explain under which conditions these concepts indicate the spectral efficiency of an optimum link design
- evaluate the performance of communication links over fading channels by analysis and computer simulations
- define the concepts of channel reuse, uplink, downlink, multiple access, multiplexing, frequency-division, time-division, code-division, and space-division
- define the concepts of time, frequency, and space diversity and explain how diversity can be achieved in practice
- explain the concept of spatial channels for multiple input, multiple output (MIMO) systems
- describe and compare complexity and performance of the following channel equalizations methods: zero-forcing, linear MMSE, maximum likelihood
- design and interpret power and rate allocation algorithm, including statistical and deterministic water-filling
- explain the effect of phase noise and power amplifier nonlinearities on the communication link
- describe the current knowledge of health effects of electromagnetic radiation and how this affects the design of wireless communication equipment via regulations, recommendations, and measurement methods for determining safe levels of exposure
- describe the foundations for ethical scientific research (e.g. related to dual use, data collection, plagiarism and authorship)

Tentative Week Plan

A tentative week plan follows below. Changes to the plan will be posted on the course web. All lectures and tutorials will take place in ES51.

Week 4 (Jan 20 – 24)	**Activity**	**Content**	**Comments**	**Teacher**
Tuesday 13:15-15:00 Tuesday 15:15-17:00	Lecture 1 Lecture 2	Introduction Path loss, shadowing		HW HW
Thursday 13:15-15:00 Thursday 15:15-17:00	Lecture 3 Inform. session	Narrowband fading Introduction to LaTeX		HW YE
Friday 13:15-15:00	Lecture 4	Wideband fading	Erik Ström will teach	ES
Week 5 (Jan 27 – Jan 31)				
Tuesday 13:15-15:00 Tuesday 15:15-17:00	Cancelled Exercise 1	Cancelled Path loss, shadowing	 Quiz 1	-- YE
Thursday 13:15-15:00 Thursday 15:15-17:00	Lecture 5 Exercise 2	Performance in fading Narrowband fading		HW YE / HW
Friday 13:15-15:00	Lecture 6	Diversity		HW
Week 6 (Feb 3 – 7)				
Tuesday 13:15-15:00 Tuesday 15:15-17:00	Lecture Exercise	No class No class		
Thursday 13:15-15:00 Thursday 15:15-17:00	Lecture 7 Exercise 3	Waterfilling Wideband fading		HW YE
Friday 13:15-15:00	Exercise 4	Performance in fading		YE
Friday	--		**Project 1 deadline**	
Week 7 (Feb 10 – 14)				
Tuesday 13:15-15:00 Tuesday 15:15-17:00	Lecture 8 Exercise 5	OFDM Diversity	 Quiz 2	HW NH
Thursday 13:15-15:00 Thursday 15:15-17:00	-- --	No class No class		
Friday 13:15-15:00	Exercise	No class		
Friday	Oral exam	Project 1 oral exam	E2 Room Landahlsrummet 7430	
Week 8 (Feb 17 – 21)				
Tuesday 13:15-15:00 Tuesday 15:15-17:00	Lecture 9 Exercise 6	Multiuser communication Waterfilling	 Quiz 3	HW YE
Thursday 13:15-15:00 Thursday 15:15-17:00	Guest Lecture Exercise 7	Hardware impairments in comm. OFDM	Thomas Eriksson	TE NH
Friday 13:15-15:00	Lecture 10	MIMO		HW
Week 9 (Feb 24 – 28)				
Tuesday 13:15-15:00 Tuesday 15:15-17:00	Lecture 11 Exercise 8	5G Communication – part I Multiuser communication	 Quiz 4	HW NH
Thursday 13:15-15:00 Thursday 15:15-17:00	Lecture 12 Exercise 9	5G Communication – part II MIMO		HW NH
Friday 13:15-15:00	--	No class	**Project 2 deadline**	HW
Week 10 (Mar 2 – 6)				
Tuesday 13:15-15:00 Tuesday 15:15-17:00	-- Exercise 10	No class 5G communications		 NH
Thursday 13:15-15:00 Thursday 15:15-17:00	Guest Lecture Exercise 11	Channel capacity Part I Capacity I	Giuseppe Durisi Quiz 5	GD NH
Friday 13:15-15:00	Oral exam	Project 2 oral exam	E2 Room Landahlsrummet 7430	HW
Week 11 (Mar 9 – 13)				
Tuesday 13:15-15:00 Tuesday 15:15-17:00	Lecture Exercise 12	Channel capacity Part II Capacity I&II	Giuseppe Durisi Quiz 6	GD NH
Thursday 13:15-15:00 Thursday 15:15-17:00	Lecture Lecture	Q&A Q&A		HW HW
Friday 13:15-15:00				

Lectures

The objective with the lectures is to highlight the most important parts of the course. However, it is not motivated (and there is not enough time) to cover all relevant parts in all details. Most of the learning takes place outside the lecture hall, and the number of lectures has therefore been reduced to free up more time for group and individual work.

In particular, material regarding health effects of electromagnetic radiation and research ethics are provided on the course homepage as reading material. They will be covered in the exam.

Tutorials

The tutorials will be conducted in a form that may feel unconventional. The purpose with the tutorials is not to solve a lot of standard problems at high speed. The purpose is to facilitate learning and understanding of the course material. The ability to solve standard problems does not imply understanding; however, understanding gives problem-solving skills.

It is important that you come prepared to the exercises, i.e., that you have read the relevant sections of the course book, and perhaps also solved some of the suggested exercise problems.

It is also important that you are active during the exercises. Always try to understand what aspects of wireless communications the problems are treating. If you cannot see the point with a certain problem, ask the assistant! There is a meaning behind every problem in this course.

A typical tutorial will be started with a short review of the theory and a motivation why the theory is of use for a communications engineer. The assistant solves the problems on the blackboard.

Projects

The course has a project with two mandatory parts. The project is carried out in groups of three to five students and it is marked via two reports (one for each part) and an oral exam. Cooperation between the groups is considered cheating and is subject to disciplinary actions. An assistant will be available for consultation, and the assistant will also approve and grade the project.

General instructions

The project work should be done according to the principles used in SSY120 Introduction to Communications Engineering. The principles are described in the document "Working in Projects," rev. B, by Pär Mattisson. The document is available for download at the course web and can be used free of charge in SSY135Wireless Communications. However, it is not allowed to share the document with anyone that is not a student in SSY135.

Program Code

The program code needed to solve the project should be carefully commented and be attached to the report. Writing program code is an efficient way to learn. Hence, all programs should be written from scratch. That is, it is not allowed to copy code from the Internet or other sources. Such practice will be caught by the anti-plagiarism system and will be treated accordingly.

Report guidelines

The project should be documented in a short report, which is due a few days before the oral exam. Reports handed in after the deadline will not be considered. The report for each part should be written in the IEEE Transactions format, following the IEEEtran LaTeX class (see for the package and a comprehensive example; to be able to use LaTeX see instructions in the project description). For each part of the project, the report may not exceed 5 double column pages and should:

- include title and names of the authors;
- state the problem addressed and outline its importance;
- describe briefly the milestones of the project;
- include the results from your simulations, along with thorough discussion and interpretation;
- explain how you would modify/change the design for better performance;
- add conclusions.

The results should be commented and checked that they are reasonable and consistent with each other and the relevant theory. Plots must be clearly labeled with units. Part I of the project deliverable should contain your explanation of how you implemented the two methods and what parameters you have used for verifying the generated channels. Part II of the project deliverable should include how the communication system was designed and implemented (Hint: *All team members should contribute equally towards accomplishing the tasks of both parts of the project. A section in the report of Part I and Part II should clearly state the members' contributions, including writing the report and MATLAB simulations*). It is important not to blindly use formulas from the book without checking that the formula is applicable for the situation at hand. Moreover, some of the formulas in the book are surely in error (as the case is for most books).

The report should not be longer than necessary. A too long or verbose report will not give full points. Do not spend a lot of space on background material. The purpose of the report is to document your work, not someone else's.

Report submission instructions and deadlines

The reports should be uploaded to the course web, which is found online.

- **File format:** unprotected pdf (hence, do not use encryption or passwords). Please review the file for conversion errors before submission. Use Adobe Acrobat for best conversion results.)
- **File name:** "P1-2020-project group number" or "P2-2020-project group number" for project Part 1 and Part 2, respectively.

Please do not send any messages to the teaching staff. **Note that late reports will not be graded, and no points will be awarded the group.** The oral exams are scheduled according to a separate schedule that your assistant will set. The deadlines are

- Project Part 1: February 7 at 23:59
- Project Part 2: February 28 at 23:59

Grading

There are two parts of the project carrying equal weightage in terms of the points.

For each part of the project, grading is based on the written report and an oral exam according to the following guidelines.

- The report should be concise, written in good English, easy to follow, and comply with the IEEE Transactions format. The results should be commented and checked that they are reasonable and consistent with theory. The maximum score is 8 points.
- All members of the group should be able to explain and defend all details about the project at the oral exam. Each group will be examined for 1 hour. The students are also expected to answer questions relating to the choice of parameters, simulation results and certain behaviors in the results, how some functions are implemented in MATLAB script etc. The maximum score is 15 points.

The report score is common to all group members, while the oral exam score is assigned individually. That is, the total project score can be different for the members in a group.

A minimum of 4 points for the report and an individual oral score of minimum 4 points are needed to pass that part of the project.

In case, students cannot get the required points to pass the oral exam, they are given a chance to redo the oral exam within one week after the planned oral exam for that part of the project. However, the maximum score for the evaluation will be reduced to 9 points (75% of initial points) but still with minimum of 4 points needed to pass the project. If a group has less than 4 points in the written report, they are also given a chance to re-submit the report within one week after the points are announced for the report. Maximum points for the report will be reduced to 5 points (60% of the initial points).

Students that fail a project even after the re-submission and/or the oral exam will have to redo the project in the next academic year. Since the projects are mandatory, this will also imply that the course cannot be completed until all projects have been approved.

Quizzes

Students can get points from the six quizzes that will be given at the exercises in LV2-7, see the Week Plan on pages 4-5 above for date, time, and rooms.

The quiz will have four multiple-choice questions that are to be answered in 10 minutes. Questions at the quiz can be from any part of the course (lectures, exercises, projects) that has been covered until the date of the quiz. A correct answer will give 1/4 point (there is no penalty for a wrong answer). The quiz points during the course are summed and rounded up to the nearest integer. Hence, the total quiz score is an integer in range from 0 to 6.

Topics of the quizzes:

- Quiz 1: Path loss, shadowing, fading.
- Quiz 2: Fading, performance in fading.

- Quiz 3: Performance in fading, diversity.
- Quiz 4: Diversity, waterfilling
- Quiz 5: OFDM, multiuser communication.
- Quiz 6: MIMO, hardware effects in wireless communication.

Written Exam

The course will be concluded with a written exam with four problems. Each problem can yield a maximum of 14 points. An erroneous answer, incomplete or badly motivated solutions give point reductions down to a minimum of 0 points. A minimum score of 12 is needed to pass the exam (max score is 48).

As a general rule, bad motivation or errors that relate to fundamental principles of the course will lead to large point reductions. Computational errors that do not lead to unreasonable answers generally give smaller reductions.

The purpose of all exam problems is to test to what degree the students have reached the aims and objectives (see Section *Aims and Learning Outcomes* on page 3). It will therefore not be possible to solve the exam problem by just finding the correct formula on the note sheet or by remembering and imitating the solution of one of the exercise problems. The course is about *understanding* not *remembering* wireless communications.

Exam dates

See the student portal. The exam review date will be communicated before the exam.

Final Grades

To pass the course, all projects and the exam must be passed. The exam is passed by securing at least 12 points. The project is passed by securing at least 8 points (4 for the report and 4 for the oral exam) in each part of the project. The final grade on the course will be decided by the project (max score 46), quizzes (max score 6), and final exam (max score 48). The sum of all scores will decide the grade according to the following table.

Total Score	0–39	40–59	60–79	≥80
Grade	Fail	3	4	5