Aalto University
School of Electrical
Engineering

ELEC-E4750
Radiowave Propagation and Scattering
Session 0: Introduction

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The "Radiowave Propagation and Scattering" Course

- This course
  - Is within the framework of the Microwave Engineering Major of the Electronics and Nanotechnology master's program.
  - Is an elective course given in even years of periods I-II (autumn).
  - Is for 5 credits, and mainly for master's and phd students.
  - Is given in English in all sessions.
  - Has specific engineering applications of radiowaves in mind, i.e., radio communications and radar.
  - Includes practical hands-on experience, e.g., numerical simulations and data analysis to deepen understanding about learnt theories.
- Related courses covering pre-knowledge
  - ELEC-E4130 Electromagnetic fields (periods I-II)
  - ELEC-E3150 Mathematical methods (periods I-II)
  - ELEC-E4420 Microwave engineering I (periods III-IV)
  - It is advantageous to take these courses prior to the present course, but not mandatory.

Leaning Outcomes (LOs) of the Course

After the course, participants will be

1. Able to discuss and analyze radio propagation mechanisms for a frequency range between 10 MHz and 100 GHz;
2. Capable of identifying relevant radio wave propagation mechanisms in terrestrial, satellite and cellular links;
3. Getting familiar with analytical, numerical and experimental approaches of analyzing the radio wave propagation, and finally,
4. Getting used to basic scientific activities, e.g., making short reports, discussing results with teachers and peers and performing numerical simulations.

Alignment of LOs of the Present Course with Those of the Microwave Engineering Major

- This major provides you with the ability to do high-level scientific research on new electromagnetic phenomena and to develop components and systems, or to invent new wireless gadgets, for the present and future wireless world.

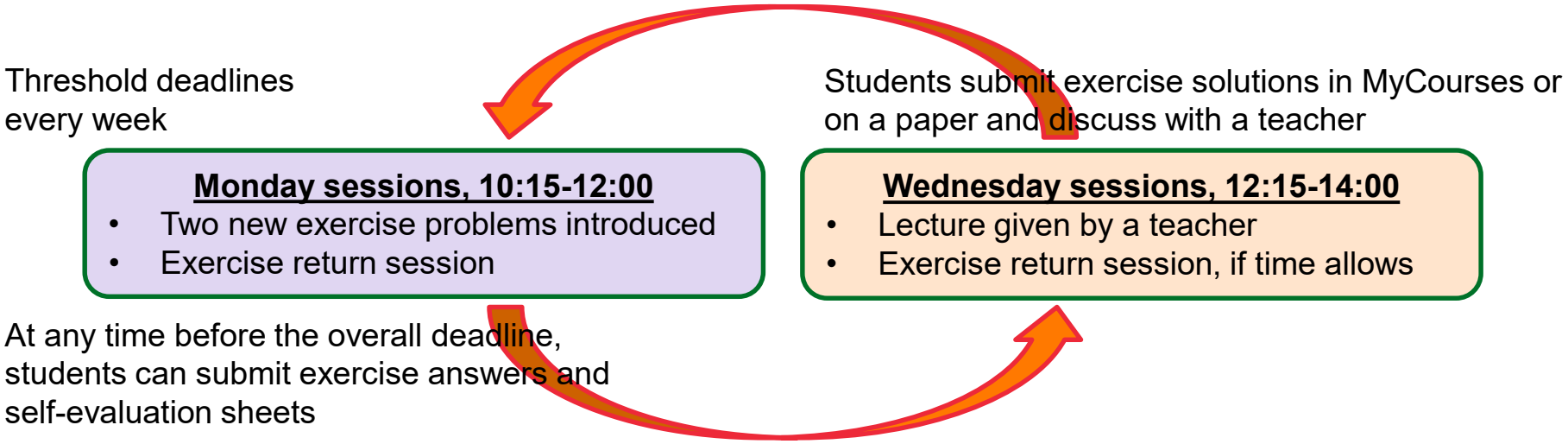
- Upon successfully finalizing the Radio Science major you will possess thorough knowledge of fundamental and applied electromagnetics, wireless devices and systems, and the related mathematical tools. This includes thorough understanding of radiowave propagation and interactions of electromagnetic fields and matter.

- Furthermore, you will gain the ability to use this understanding for creating new components and systems for future wireless sensing and communications applications that are superior in their operation and have novel functionalities. This includes the ability to use analytical methods and numerical tools in the design of new components and circuits and to measure and evaluate the performance of components, devices and systems. So, you will have the proficiency to translate your expertise into new technological solutions for environmental, well-being, and communications challenges in the industry and academia.

https://into.aalto.fi/pages/viewpage.action?pageId=4859800

Course Implementation

- Responsible teacher: Katsuyuki Haneda, teachers: Dr. Clemens Icheln and MSc. Lauri Vähä-Savo
- The course is organized in 12 topics, one topic per week
- All sessions are provided in remote mode, except for the measurement session (lecture 9). Video recording of lectures will be available in MyCourses.



Students' activities during contact sessions

- Attending lectures
- Asking help from the teachers when needed
- Discussing with a teacher to justify their points (teachers "challenge" students for their suggested points) for every submission of exercise answers

Books, Topics and Exercises (1)

- Books
  - Main books
    - S. Saunders, *Antennas and Propagation for Wireless Communication Systems*, Chapters 3, 5, 6-8, 10, 12 15, Wiley.
    - H. L. Bertoni, *Radio propagation for modern wireless systems*, Chapters 2-6, Prentice Hall.
    - A. F. Molisch, *Wireless Communications*, Chapters 1, 5 and 8, Wiley.
    - R. Vaughan and J. B. Andersen, Channels, propagation and antennas for mobile communications, Chapter 3.2.1, IEE Press.
  - Supplemental book
    - D. M. Pozar, Microwave Engineering, Chapters 1 and 14, Wiley.
- Topic 1: Prerequisite (Saunders Ch. 5 and Bertoni Ch. 4)
  - Exercise 1: Free space pathloss
  - Exercise 2: Link budget
- Topic 2: Reflection and transmission (Ch. 3, Ch. 3)
  - Exercise 1: Signal incidence and boundary conditions
  - Exercise 2: Simulation of reflection and transmission

Books, Topics and Exercises (2)

- Topic 3: Reflection, transmission and diffraction (Ch. 3, Ch. 5)
  - Exercise 1: Frequency dependency of reflection and transmission
  - Exercise 2: Diffraction due to an absorbing knife edge
- Topic 4: Diffraction (Ch. 3, Ch. 5)
  - Exercise 1: Modeling the human blockage
  - Exercise 2: Diffraction due to a building corner
- Topic 5: Scattering (Ch. 3, Ch. 3.2.1)
  - Exercise 1: Scattering in remote sensing
  - Exercise 2: Simulation of scattering from a rough surface
- Topic 6: Terrestrial and satellite links (Ch. 5 and 7, Ch. 4)
  - Exercise 1: Two-ray multipath model
  - Exercise 2: Rain attenuation
- Topic 7: Cellular links (Ch. 12, Ch. 2)
  - Exercise 1: Physical propagation modeling in microcells
  - Exercise 2: Pathloss and small-scale fading

Books, Topics and Exercises (3)

- Topic 8: Radio channel characterization (Ch. 5, Ch. 10)
  - Exercise 1: Rayleigh fading
  - Exercise 2: Characterization of small-scale fading
- Topic 9: Measurements and analysis (Ch. 8, Ch. 19)
  - Exercise 1: Radio channel measurements
  - Exercise 2: Characterization of small-scale fading
- Topic 10: Fading and radio link performance (Ch. 13 and 20, Ch. 15)
  - Exercise 1: Capacity and bit error rate of fading channels
  - Exercise 2: Spatial diversity
- Topic 11: Multiple-antenna radios (Ch. 20, Ch. 18)
  - Exercise 1: Antenna diversity in correlated channels
  - Exercise 2: Representation and capacity of MIMO channels
- Topic 12: Multiple-antenna radios (Ch. 20, Ch. 18)
  - Exercise 1: Guest lecture
  - Exercise 2: Literature study on wireless systems that use multiple-antenna radios

Schedule

Wk	Date	Session location	Lectures, exercises and deadlines
37	Mon. 07 Sep.	Online	Introduction
	Wed. 09 Sep.		Lecture 1: prerequisite
38	Mon. 14 Sep.		Exercise return session 1
	Wed. 16 Sep.		Lecture 2: reflection and transmission
39	Mon. 21 Sep.		Exercise return session 2
	Wed. 23 Sep.		Lecture 3: reflection and transmission and diffraction
40	Mon. 28 Sep.		Exercise return session 3
	Wed. 30 Sep.		Lecture 4: diffraction
41	Mon. 05 Oct.		Exercise return session 4
	Wed. 07 Oct.		Lecture 5: scattering

Schedule

Wk	Date	Location	Lectures, exercises and deadlines
42	Mon. 12 Oct.	Online	Exercise return session 5
	Wed. 14 Oct.		Lecture 6: terrestrial and satellite links
43	Mon. 19 Oct.		Exercise return session 6
	Wed. 21 Oct.		Lecture 7: cellular links
44	Mon. 26 Oct.		Exercise return session 7
	Wed. 28 Nov.		Lecture 8: radio channel characterization
45	Mon. 02 Nov.		Exercise return session 8
	Wed. 04 Nov.	ELE lab	Lecture 9: measurements and analysis
46	Mon. 09 Nov.	Online	Exercise return session 9
	Wed. 11 Nov.		Lecture 10: fading and radio link performance

Schedule

Wk	Date	Location	Lectures, exercises and deadlines
47	Mon. 16 Nov.	Online	Exercise return session 10
	Wed. 18 Nov.		Lecture 11: multiple-antenna radios
48	Mon. 23 Nov.		Exercise return session 11
	Wed. 25 Nov.		Lecture 12: guest lecture Prof. Pekka Kyosti from University of Oulu, Tentative title TBD
49	Mon. 30 Dec.		Exercise return session 12
	Wed. 02 Dec.		No session
50	Mon. 07 Dec.		Exercise return session 13
	Wed. 09 Dec.		Exercise return session 14; deadline of all exercise returns

Allocation of Study Hours

- 1 credit = approx. 27 hours of study
- 5 credits in total = approx. 135 hours
- On average 5 hours to solve one problem (2 hours face-to-face + 3 hours individual)
  - ✓ Including reading books, solving equations, implementing/debugging codes, plotting results and making reports

Activity	Efforts
Guided learning through contact (online) sessions	2 hours x 27 sessions = 54 hours
Individual study for exercises	3 hours x 12 topics x 2 problems = 72 hours
Self-evaluation	1 hour x 3 self-evaluation = 3 hours
Total	129 hours

Evaluation Method (1/2)

- Total points (99 p) = Exercise points (96 p) + Self-evaluation points (3 p)
- Exercises points: Max 96 points
  - Max 4 points x 12 topics x 2 problems
  - Note that exercise problems for topic 9, i.e., “Measurements and analysis” require on-site participation to perform measurements, while keeping safety guidelines of Aalto. Otherwise all exercise problems can be solved and returned online.
- Self-evaluation and feedback points: Max 3 points
  - Max 1 point x 3 self-evaluation
  - For each self-evaluation and feedback, we ask you to analyze to which extent the intended learning outcomes of the covered topics are achieved. You get one point when you submit the self-evaluation and feedback.

Evaluation Method (2/2)

- Grading is based on the total points (max 99 points)
  - Total 50-59 points → Grade 1
  - Total 59-68 points→ Grade 2
  - Total 68-77 points → Grade 3
  - Total 77-86 points → Grade 4
  - Total above 86 points → Grade 5
- It is possible to get grade 5 entirely by remote participation to this course.
  - The measurement exercises (lecture 9) cannot be completed for fully-remote students, which amount to total of 8 exercise points. So, fully remote students have max 91 points to start.

Deadlines

- Deadline is set every week!
  - It is **required for getting a credit**, to complete at least *n* exercise problems in the *n*-th exercise return session. For example, you are required to complete at least one exercise problem by the end of next Monday session in September 14th.
- *Overall deadline* of exercise problem completion
  - Wednesday, December 9th 10:15 am (when the last exercise return session starts) for topics 1-12. You can get points out of exercise problems of any topics if you complete them until this deadline.

IMPORTANT! The exercise points are valid ONLY AFTER you discuss with a teacher about your exercise answers in the contact sessions. Only submitting the answers through, e.g., MyCourses, and not having discussions with teachers do NOT entitle you to get points!

Forthcoming Contact Sessions

- Learning outcomes of exercise problems for topic 1 are to
  - Be aware of the assumptions behind the Friis' free-space transmission formula (problem 1)
  - Be able to analyze the link budget (problem 2)
- During the contact sessions, you are
  - solving the exercise problems by referring to relevant parts of the course books.
    - A limited number of course books are available.
  - encouraged to discuss with other students and teachers, but do NOT copy others' answers – explain by your own words!
  - asked to contact a teacher once your solutions are ready.
    - If you prepare exercise solutions in an electronic format (recommended), upload the solution to MyCourses first and then contact a teacher.
  - not given exercise points without discussing with a teacher.
    - The discussions to happen in the contact sessions.
  - reminded that <u>one exercise problem must be completed before the end of the next Monday session in 14th September</u>.

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