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 doctoral students.
  - Is given in English in all sessions.
  - Has specific engineering applications of radiowaves in mind, i.e., radio communications, remote sensing 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.

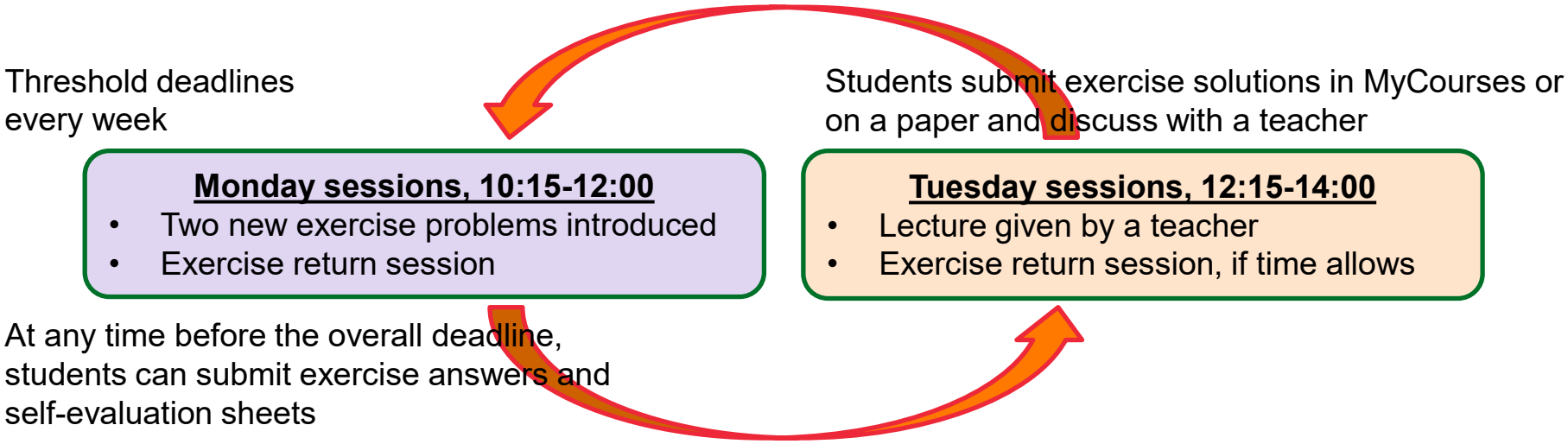
Alignment of LOs of the Present Course with Those of the Microwave Engineering Major

- Microwave engineering is the basis of everything that transmits, receives or manipulates radio waves, such as wireless communications devices, radars, or wireless sensors. This major provides you with the ability to design, analyze and characterize microwave components and systems using the state-of-the-art computer-aided design tools and equipment. The major offers a solid basis for deepening your knowledge through doctoral studies.
- In this major, you will learn fundamentals of electromagnetic fields and analysis and design of electronic circuits, as well as practical tools to solving mathematical problems. You will further learn to design and analyze passive and active microwave components and systems both using analytical models and state-of-the-art circuit and electromagnetic simulation and design tools. You will learn the basics of antennas and you will learn to perform microwave measurements using common laboratory equipment. Elective studies allows you to further specialize in many additional topics including radiowave scattering and propagation, electromagnetic fields or circuits, computational electromagnetics, terahertz techniques, antennas, and metamaterials and nanophotonics.

https://into.aalto.fi/display/enelenano/Microwave+Engineering+2020-2022

Course Implementation

- Responsible teacher: Katsuyuki Haneda, teachers: MSc. Mar Francis de Guzman
- The course is organized in 11 topics, one topic per week
- All sessions are on-site and in-person mode; NO remote options available according to Aalto's guideline of teaching for 2022-2023.



Students' activities during contact sessions

- Attending lectures
- Asking help from the teachers when needed
- Discussing with a teacher to agree on points (teachers ask questions to know students' understanding) 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 and transmission (Ch. 3, Ch. 3)
  - Exercise 1: Frequency dependency of reflection and transmission
  - Exercise 2: Estimating material parameters through wave reflection and transmission
- Topic 4: Material measurement and analysis
  - Exercise 1: Material measurement
  - Exercise 2: Analysis and reporting
- Topic 5: Diffraction (Ch. 3, Ch. 5)
  - Exercise 1: Diffraction due to an absorbing knife edge
  - Exercise 2: Modeling the human blockage
- Topic 6: Scattering (Ch. 3, Ch. 3.2.1)
  - Exercise 1: Scattering in remote sensing
  - Exercise 2: Simulation of scattering from a rough surface
- Topic 7: Terrestrial and satellite links (Ch. 5 and 7, Ch. 4)
  - Exercise 1: Two-ray multipath model
  - Exercise 2: Rain attenuation

Books, Topics and Exercises (3)

- Topic 8: Cellular links (Ch. 12, Ch. 2)
  - Exercise 1: Physical propagation modeling in microcells
  - Exercise 2: Pathloss and small-scale fading
- Topic 9: Radio channel characterization (Molisch Ch. 5 and 13, Ch. 10)
  - Exercise 1: Characterization of small-scale fading
  - Exercise 2: Capacity and bit error rate of fading channels
- Topic 10: Fading measurement and analysis (Ch. 8, Ch. 19)
  - Exercise 1: Radio channel measurements
  - Exercise 2: Characterization of small-scale fading
- Topic 11: Multiple-antenna radios (Ch. 13 and 20, Ch. 16 and 18)
  - Exercise 1: Antenna diversity
  - Exercise 2: Capacity of MIMO channels

Schedule

Wk	Date	Location	Lectures, exercises and deadlines
37	Mon. 12 Sep.	Simlab	Introduction
	Tue. 13 Sep.		Lecture 1: prerequisite
38	Mon. 19 Sep.		Exercise return session 1
	Tue. 20 Sep.		Lecture 2: reflection and transmission
39	Mon. 26 Sep.		Exercise return session 2
	Tue. 27 Sep.		Lecture 3: reflection and transmission 2
40	Mon. 03 Oct.		Exercise return session 3
	Tue. 04 Oct.	ELE lab	Lecture 4: material measurement
41	Mon. 10 Oct.	Simlab	Exercise return session 4
	Tue. 11 Oct.		Lecture 5: diffraction

Schedule

Wk	Date	Location	Lectures, exercises and deadlines
42	Mon. 17 Oct.	Simlab	Exercise return session 5
	Tue. 18 Oct.		Lecture 6: scattering
43	Mon. 24 Oct.		Exercise return session 6
	Tue. 25 Oct.		Lecture 7: terrestrial and satellite links
44	Mon. 31 Oct.		Exercise return session 7
	Tue. 01 Nov.		Lecture 8: cellular links
45	Mon. 07 Nov.		Exercise return session 8
	Tue. 08 Nov.		Lecture 9: radio channel characterization
46	Mon. 14 Nov.		Exercise return session 9
	Tue. 15 Nov.	ELE lab	Lecture 10: fading measurements

Schedule

Wk	Date	Location	Lectures, exercises and deadlines
47	Mon. 21 Nov.	Simlab	Exercise return session 10
	Tue. 22 Nov.		Lecture 11: multiple-antenna radios
48	Mon. 28 Nov.		Exercise return session 11
	Tue. 29 Nov.		Exercise return session 12
49	Mon. 05 Dec.		Exercise return session 13; deadline of all exercise submissions

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 sessions	2 hours x 25 sessions = 50 hours
Individual study for exercises	3 hours x 11 topics x 2 problems = 66 hours
Self-evaluation	1 hour x 3 self-evaluation = 3 hours
Total	119 hours

Evaluation Method (1/2)

- Total points (91 p) = Exercise points (88 p) + Self-evaluation points (3 p)
- Exercises points: Max 88 points
  - Max 4 points x 11 topics x 2 problems
- 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 91 points)
  - Total 45-53 points → Grade 1
  - Total 54-62 points→ Grade 2
  - Total 63-71 points → Grade 3
  - Total 72-80 points → Grade 4
  - Total above 81 points → Grade 5

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 on September 19th.
- *Overall deadline* of exercise problem completion
  - Monday, December 5th 10:15 am (when the last exercise return session starts) for topics 1-11. 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 on 19th September</u>.