Microwave engineering I (MiWE I)

10 January – 17 March 2022, 5 ECTS

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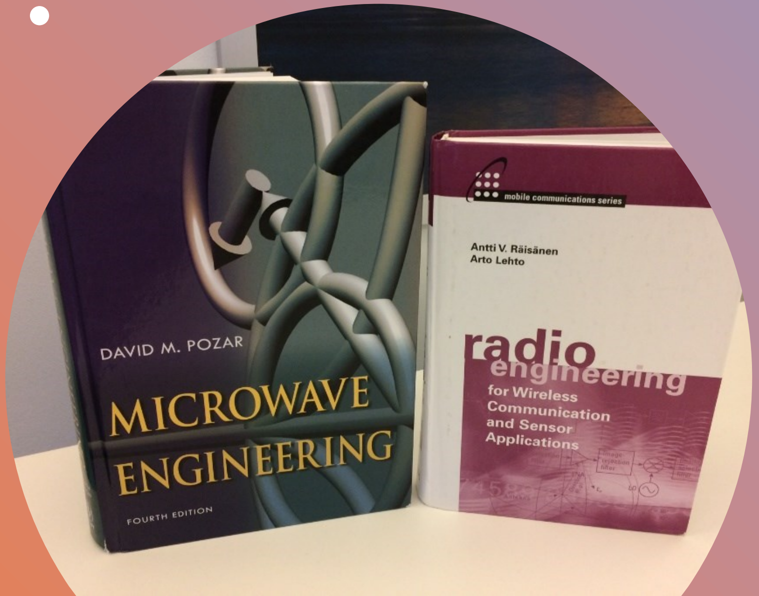
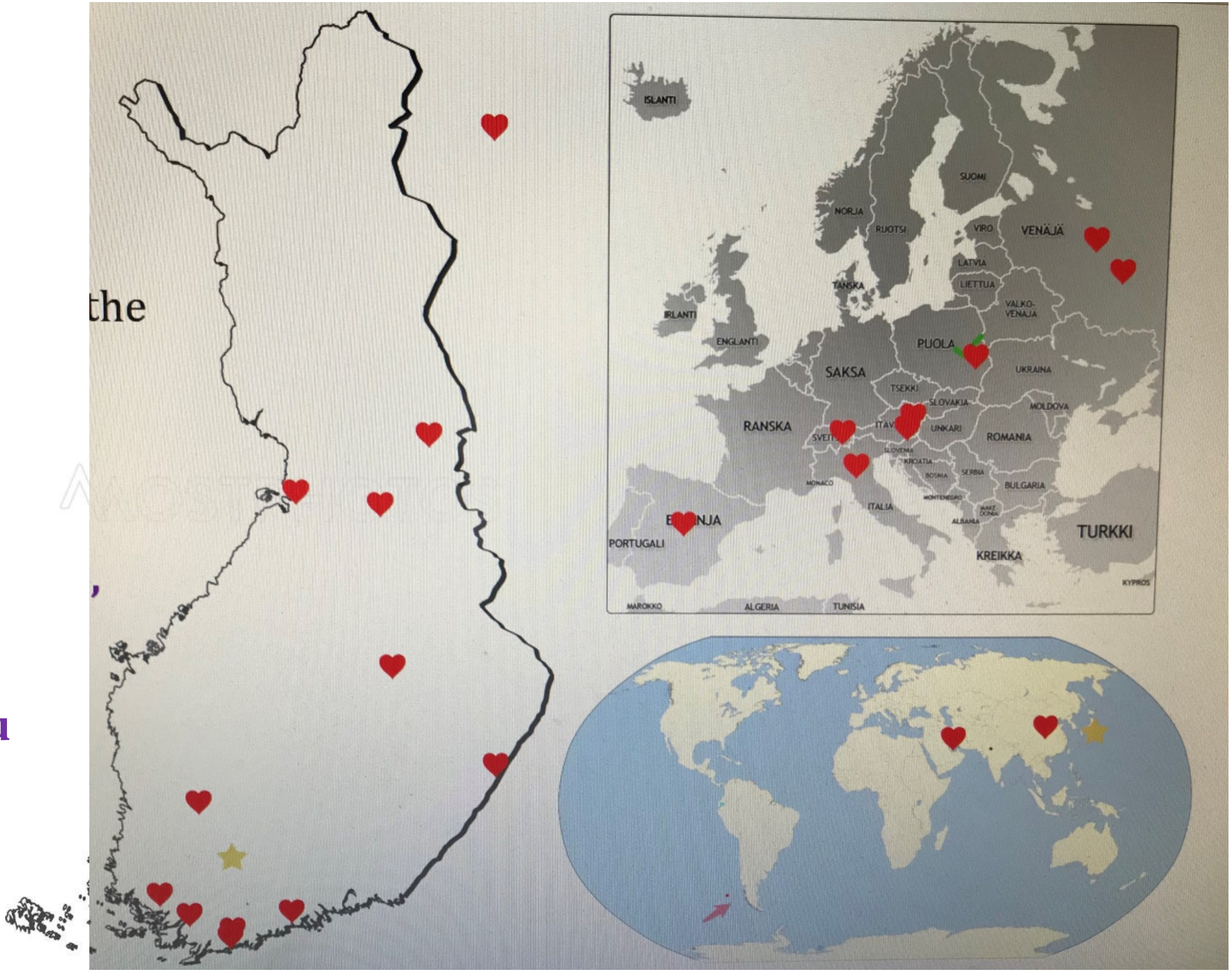


The main learning outcome is to create readiness to work in microwave engineering related tasks and projects and enable further studies and continuous learning in microwave engineering.

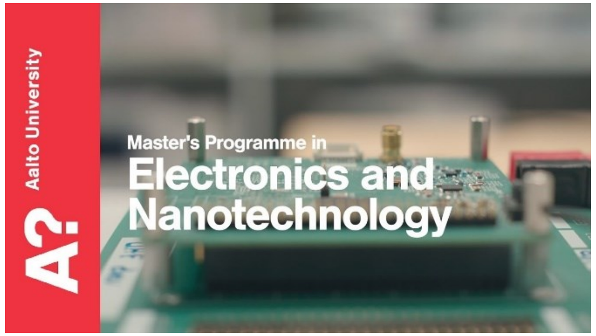
Where are we from?

In up- or downside bar of the Zoom window select **“View options”→ “Annotate” → “Stamp”**.

Mark in one of the maps, where are you from.



What is your current study programme?



- Select the **best** alternative. The questionnaire is anonymous.

7/31 1. microwave engineering major of the ELE master's programme
10/31 2. other major of the ELE master's programme
3/31 3. other master's programme of Aalto University
0/31 4. EST bachelor's studies of Aalto University
6/31 5. doctoral studies in Aalto University (any school)
6/31 6. ERASMUS exchange studies
1/31 7. Other → select "*I do not know*" within the polling

Select those pre knowledge of the course that you master in your opinion?

- Select **multiple** alternatives. The questionnaire is anonymous.

100% 1. **bachelor's level engineering mathematics**
   - e.g., algebra, trigonometry, linear algebra, complex numbers, complex vectors, differential and integral calculus, differential equations etc.

74% 2. **circuit theory**
   - e.g., ELEC-C4110 *Piirianalyysi I* and ELEC-C4120 *Piirianalyysi II* **or** ELEC-E3120 *Analysis and design of electronic circuits*

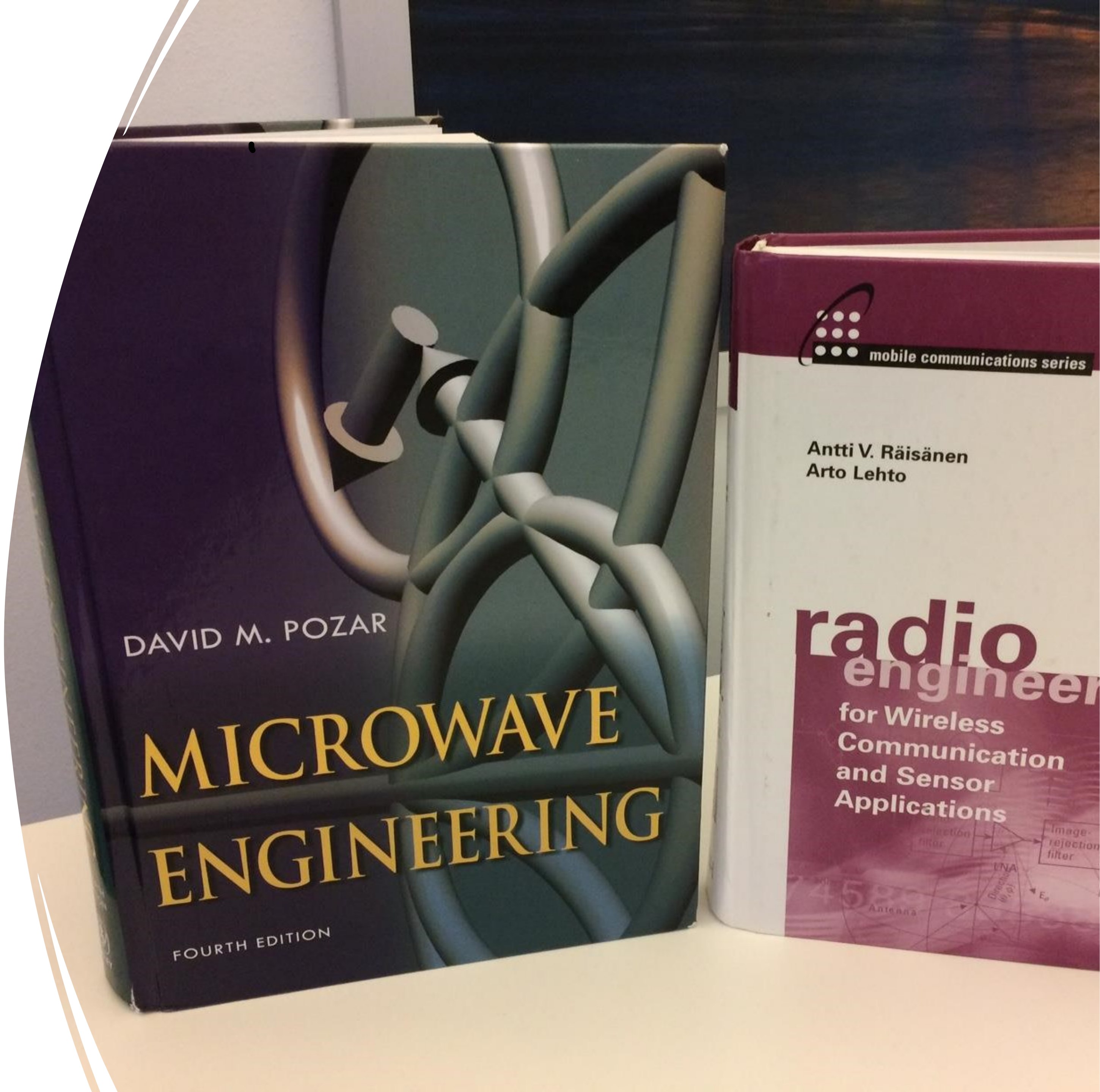
71% 3. **electromagnetic field theory**
   - e.g., ELEC-C4140 *Kenttäteoria* or ELEC-E4130 *Electromagnetic fields*

90% 4. **some mathematical software, for instance, Matlab or Wolfram Mathematica**
   - e.g., ELEC-C4140 *Matematiikkaohjelmistot* or ELEC-E9111 *Mathematical computing*

32% 5. **circuit simulations, for example, with AWR Design Environment**
   - e.g., you participate in Period III in the course ELEC-E4410 *Electromagnetic and circuit simulations*

You need a course book for studying already this week!

- **Pozar: Microwave engineering**
  - editions 2-4 are okay!
  - 11+ hard copies available in the learning centre
  - e-book available through lib.aalto.fi
  - the same book used in MiWE II
- Alternative book: Räisänen/Lehto - Radio engineering for wireless communication or the same in Finnish: Radiotekniikan perusteet



We will study half of Pozar book in this course

Pozar book chapters (edition 4)   Räisänen/Lehto book chapters

- Today: introduction of the course and the topic(Ch. 1 and 14, Ch. 1 and 13)
- Topic 1: **transmission line theory and waveguides** (Ch. 2 and 3, Ch. 3 and 4)
  - Related interactive lectures on Thu 13 and 20 January
- Topic 2: **Smith chart and impedance matching** (Ch. 2 and 5, Ch. 4)
  - Thu 27 January and 3 February
- Topic 3: **analysis of microwave circuits** (Ch. 4 and 6, Ch. 5 and 7)
  - Thu 10 and 17 February
- Topic 4: **radio systems** (Ch. 10 and 14, Ch. 11)
  - Thu 24 February and 3 March
- Topic 5: (teaser of) **radiowave propagation** (Ch. 14, Ch. 10)
  - Thu 10 March (only one lecture), Thu 18 March reserved for exercise returning

Intended learning outcomes

- The student is able to **identify** the types of radio waves and **discuss** usage of radio spectrum and typical applications in microwave engineering.
- The student can **discuss** the biological effects and safety issues of radio waves.
- The student is able to **explain** the behaviour of a radio signal in typical transmission lines, **calculate** and **simulate** related circuit parameters, and **design** transmission lines. (*Topic 1*)
- The student can **design** impedance matching circuits and **explain** the design principles. (*Topic 2*)
- The student is able to **model** basic microwave circuits and resonators with suitable circuit parameters and **analyse** their operation based on calculations and simulations. (*Topic 3*)
- The student can **explain** the operational principles of basic microwave systems and **calculate** relevant system parameters. (*Topic 4*)
- The student can **explain** the radio wave propagation. He/she is able to **calculate** basic characteristics of radio links based on propagation models. (*Topic 5*)

Taking the course requires active learning

- **Preliminary tasks** related to each interactive lecture
  - Returned in MyCourses before the Thursday interactive lecture
  - The main idea is that you are *prepared* for the lecture

- **Interactive lectures** every Thursday at 9
  - The first week will in Zoom, next weeks will be informed separately
  - "Interactive" means that there are activating tasks integrated to the session

- **Exercise problems** with soft deadlines
  - There will be 18 exercise problems – i.e., 2 – 4 per topic (+ some extras)
  - The soft deadline system: one problem return per week is a must, but two per week would be optimal return rate
  - The hard deadline: at the end of the course – i.e., March 17
  - Monday session at 10-12 is reserved for exercises, we will communicate details during the Thursday session and in MyCourses

Continuous assessment is in use

- **Preliminary tasks** (nine times)
  - each graded 0−2 points, maximum 9 x 2 points = **18 points (22%)**

- **Interactive lectures** (ten times)
  - each graded 0–1 points, maximum 10 x 1 points = **10 points (12%)**
  - 1 point = ”active participation” during the lecture – i.e., actively and successfully participating in all in-class quizzes and tasks

- **Exercise problems** (18 regular problems + some extras)
  - each problem graded 0–3 points
  - typically, 4 problems per topic, 18 x 3 points = **54 points (66%)**

- All points have **equal** weight on the final grade
- The grading of the course is **individual**, any misconduct of academic integrity is forbidden
- Grading plan: 50% of the maximum points → passed (1), 60%→2, 70%→3, 80%→4, 90%→5

Last time students' feedback was very positive

“The course was one the best courses that I have attended in this university. Quizzes were good and kept me awake during lectures. It was very nice that we were able to talk about assignments with teachers.”

“The course arrangements were really suited for the remote teaching. The Quiz were keeping my focus to the lecture and the point system kept me motivated. It was easy to follow my progress towards the final grade. The homework return system was educational. I really learned from my mistakes because they were told me in person and I was receiving a lot of feedback. I also think that the system kept my stress levels low since there were no strict dead lines. Talking with the teachers also helped my motivation since I think it was much easier to ask help if I did not understand something.”

“The course worked very well in my opinion. The pre-assignment - lecture - homework - explain (- revise) loop was excellent! I'm quite sure that compared to the time spent on working, I learned more than on most other courses. By that I mean that the efficiency of my studying was much higher on this course than on many other ones.”

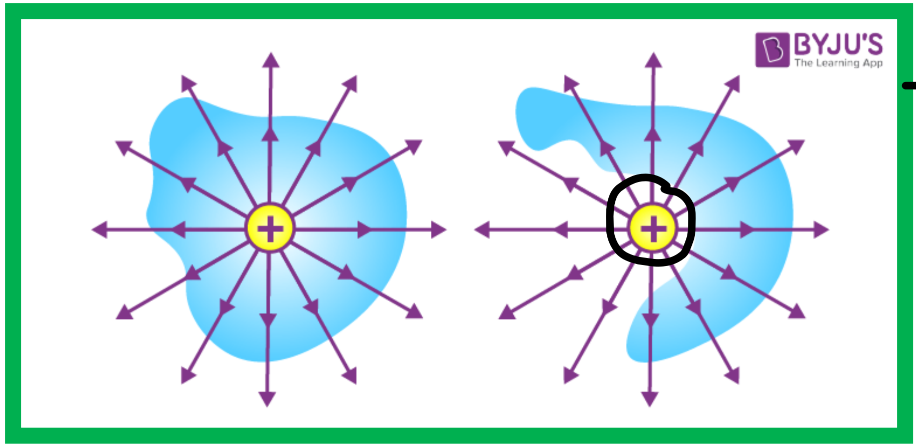
"Soft-deadlines exercise returns format was bold and new. It allowed a student who is a bit slow on the uptake, such as myself, to keep up in my own pace.”

“The course organization was excellent, and I feel like I learned a lot. Initially, I was a bit skeptical as to how much freedom was given to the students with managing deadlines, but the flexible schedule for submissions worked really well at least in my case. The workload was well-balanced - at least it didn't feel like there was too much work at any point during the course. In the beginning of the course, doing the exercises took a bit more time than later in the course, but I appreciated the fact that there were a lot of simulation problems among the exercises. Also, the pre-lecture problems really make a difference as to how much one can get out of the corresponding lecture.”

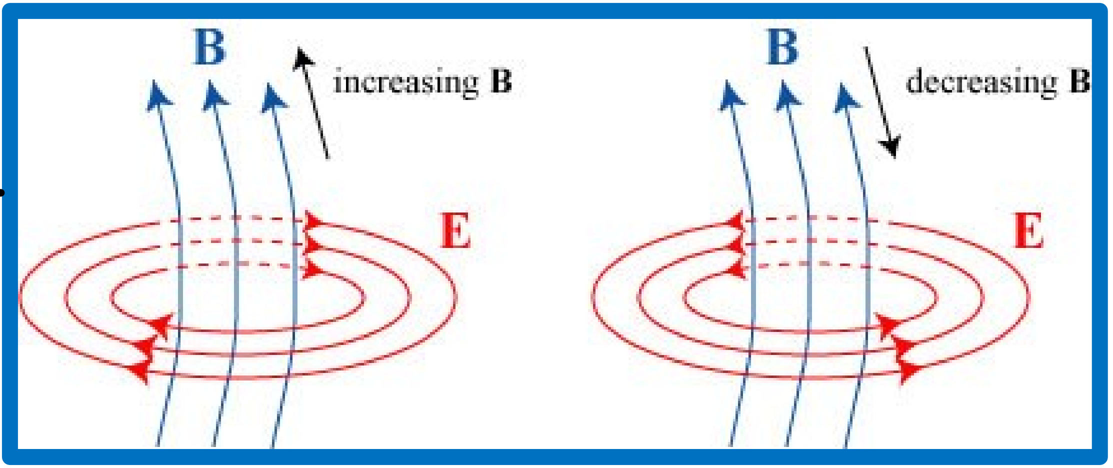
“Polls during the lectures were very good and homework return system worked very well.”

“Maybe more exercises with AWR and some simulations related to the wave propagation if possible.”

Maxwell introduced the famous equations in 1865

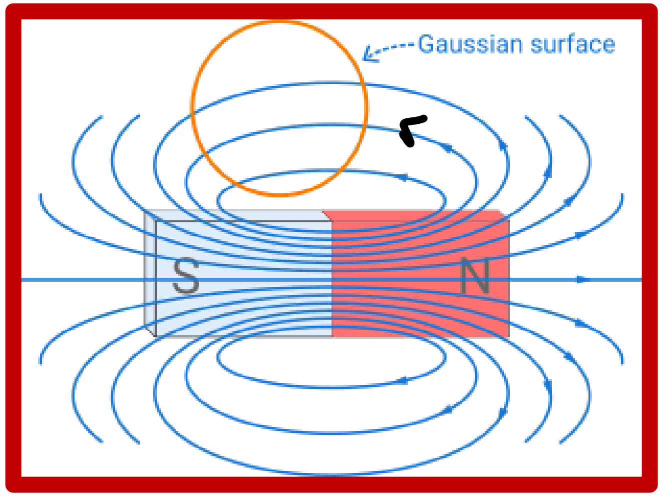


$$\nabla \cdot \bar{D} = \rho$$



$$\nabla \times \bar{E} = -\frac{\partial \bar{B}}{\partial t}$$

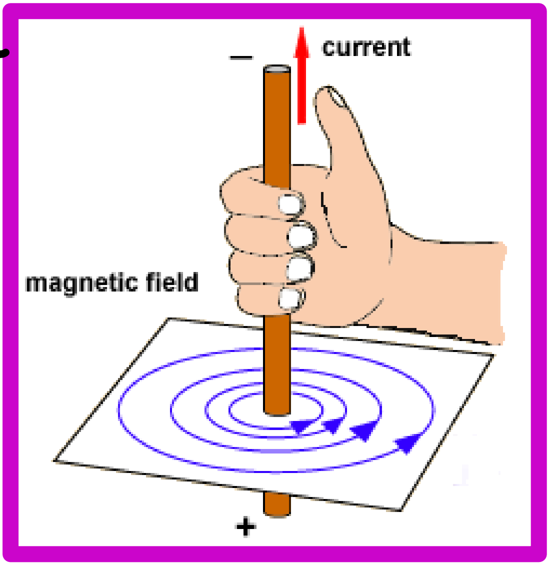
$$\nabla \times \bar{E} = -j\omega \bar{B}$$



$$\nabla \cdot \bar{B} = 0$$

$$\nabla \times \bar{H} = \bar{J} + \frac{\partial \bar{D}}{\partial t}$$

$$\nabla \times \bar{H} = \bar{J} + j\omega \bar{D}$$



Maxwell predicted the existence of electromagnetic waves purely based on the equations

Gauss′s law	Gauss′s law for magn. field	Faraday′s law	Ampère′s law
$\nabla \cdot \mathbf{D} = \rho$	$\nabla \cdot \mathbf{B} = 0$	$\nabla \times \mathbf{E} = -j\omega\mathbf{B}$	$\nabla \times \mathbf{H} = \mathbf{J} + j\omega\mathbf{D}$

$\nabla^2 \bar{E} + k^2 \bar{E} = 0$ Helmholtz equation

k = wave number

$k^2 = \omega^2 \varepsilon_0 \mu_0$

one solution $\bar{E} = \bar{u}_x E_0 e^{-jkz}$

time-domain solution $\bar{E}(z,t) = \mathrm{Re}\{\bar{E}(z)\, e^{j\omega t}\} = \bar{u}_x E_0 \cos(\omega t - kz)$

Maxwell noticed that these "new" waves propagate at the same speed as the light

$$\mathbf{E}(z,t) = \mathbf{u}_x\, E_0 \cos(\omega t - kz)$$

$$E_0 \cos(\omega t - kz) = \frac{E_0}{2}$$

$$\omega t - kz = \text{constant} \quad \Big| \frac{d}{dt}$$

$$\frac{d}{dt}(\omega t - kz) = 0$$

$$\omega - k\frac{dz}{dt} = 0 \quad \leftarrow v = \frac{dz}{dt} = \text{velocity}$$

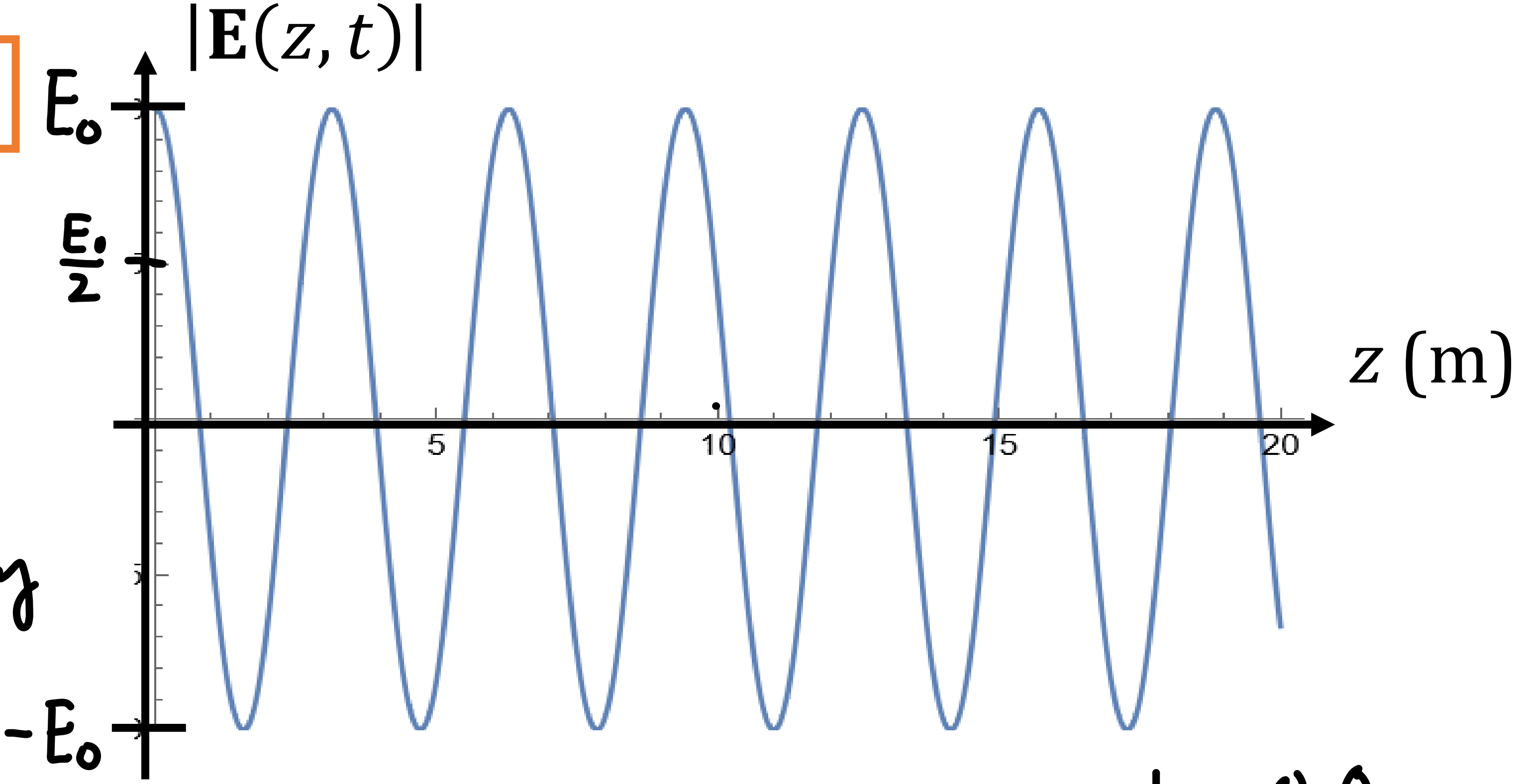
$$\omega - kv = 0$$

$$v = \frac{\omega}{k} = \frac{\omega}{\omega\sqrt{\varepsilon_0 \mu_0}} = \frac{1}{\sqrt{\varepsilon_0\mu_0}} \simeq 3 \cdot 10^8 \ \frac{m}{s}$$

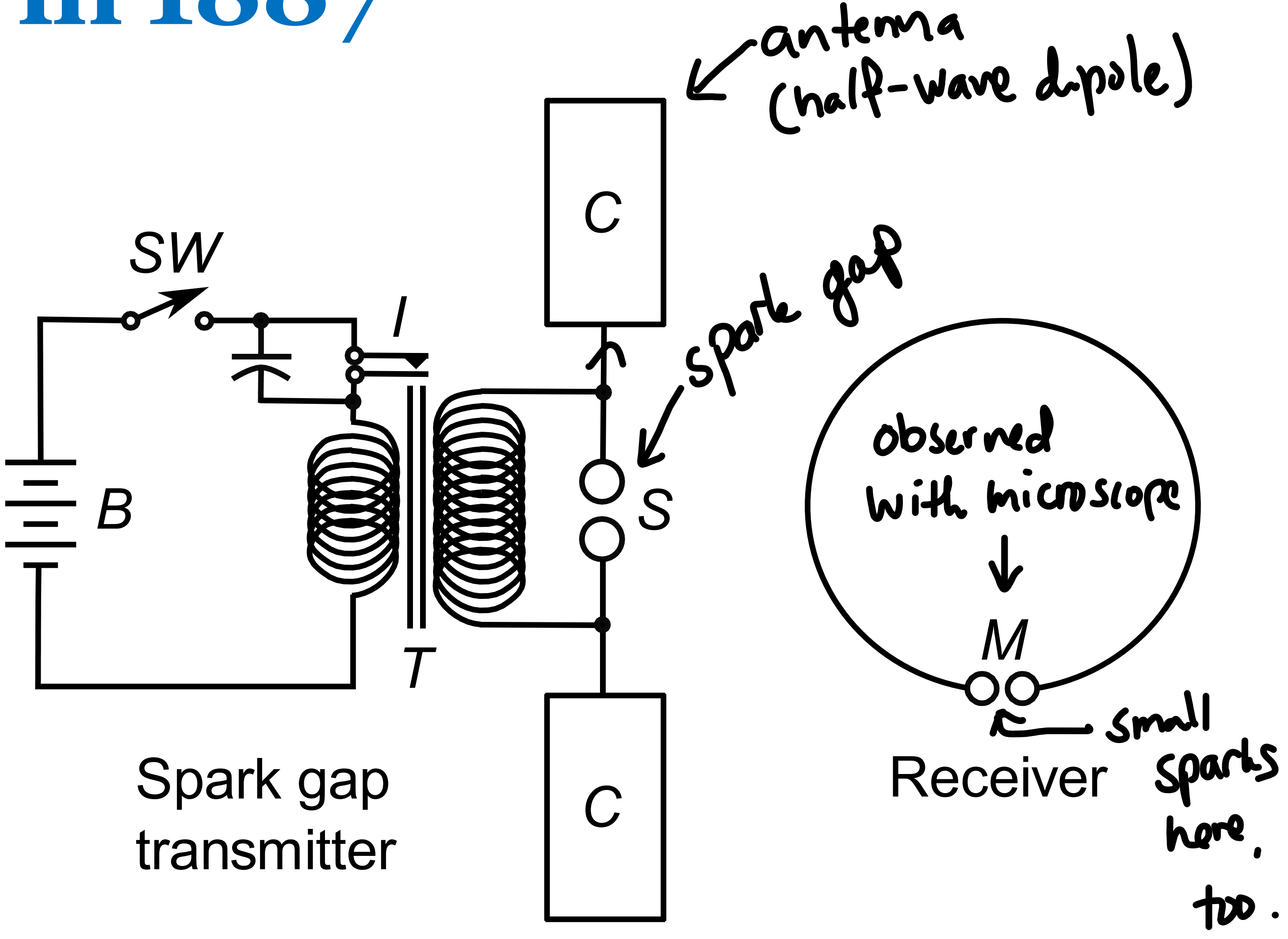
THE SAME VALUE AS THE SPEED OF LIGHT

$$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}$$

$$F = \frac{\mu_0}{4\pi}\frac{I_1 I_2}{r}$$



Hertz proved the existence of EM waves in 1887



Karlsruhe, Germany

Radio wave spectrum: 3 Hz – 3 THz (3000 GHz)

radio waves

long waves
(3 Hz – 300 MHz)
$\lambda \geq 1m$

- long-range communication

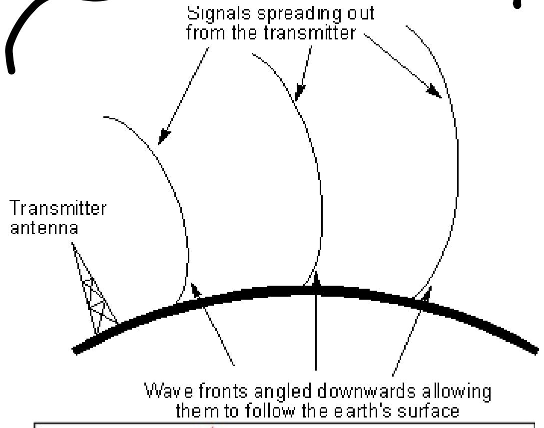
micro waves
300 MHz – 300 GHz
(λ = 1m .. 1mm)

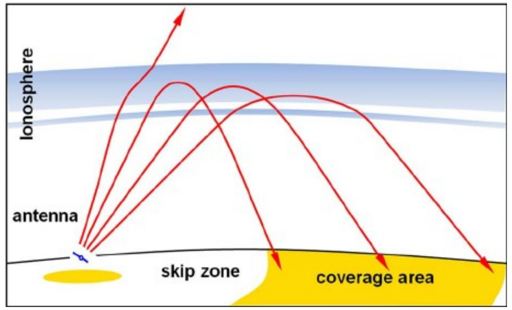
mm waves
30 GHz – 300 GHz
(λ = 10 mm – 1mm)

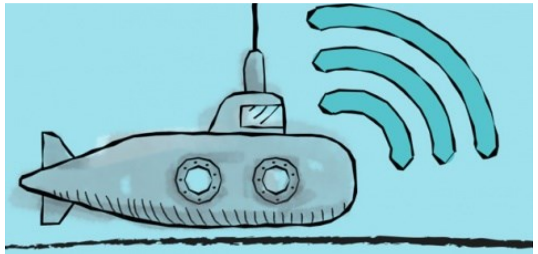
THz / sub-mm frequencies
300 GHz ... 3 THz
(λ < 1mm)

Application of radio waves

long waves ("small" freq.)





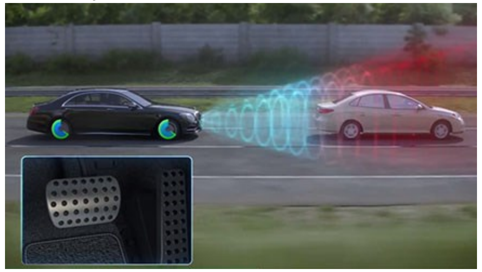


~ 100 MHz

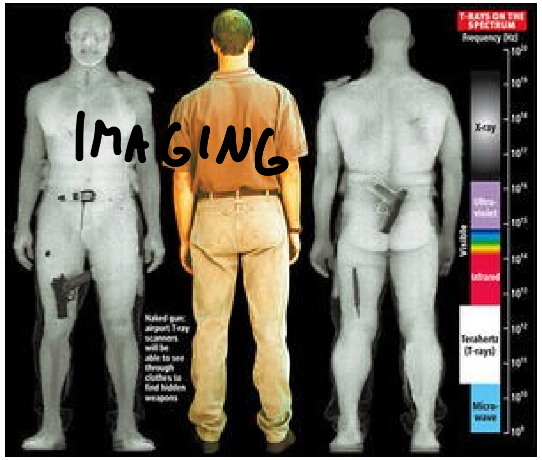
a few GHz

tens of GHz

AUTOMOTIVE RADAR



hundreds of GHz



In-class task: we use Zulip forum for discussions

- Zulip is a forum intended for questions and discussions of any issue, especially the exercise problems

1. During the last minutes of this session, go to Zulip forum (https://miwe1.zulip.aalto.fi) and sign-in
2. Go to #*general* stream and open topic "*introduction*"
3. Write an introduction of your
   - study background, current studies, expectations and goals for the course
   - if possible, add a profile picture in Zulip
4. By writing your introduction (no later than today), you will get the activity point of this first lecture

What to do before the Thursday session

- Write your introduction in Zulip
- Get a book to enable studying
- Read through the MyCourses pages for further information of the course content, learning outcomes and the arrangements
- Answer the preliminary tasks in MyCourses before the Thursday interactive lecture
- Join the interactive lecture on Thursday, the session starts at 9.
    - ➢ Sign-in Zoom using the Aalto domain