Lecture 1

2018/2019

Microwave Devices and Circuits for Radiocommunications

2017/2018

- 2C/1L, **MDCR**
- **Attendance at minimum 7 sessions (course + laboratory)**
- Lectures- **associate professor Radu Damian**
  - Friday 09-11, ?
  - E – 50% final grade
  - **problems** + (2p atten. lect.) + (3 tests) + (bonus activity)
    - 3p=+0.5p
  - **all materials/equipments authorized**
- Laboratory – **associate professor Radu Damian**
  - Monday 18-20 II.12 even weeks
  - Thursday 8-14 odd weeks II.12 **?**
  - L – 25% final grade
  - P – 25% final grade

Materials

- http://rf-opto.etti.tuiasi.ro

Materials

- RF-OPTO
  - http://rf-opto.etti.tuiasi.ro
- David Pozar, "Microwave Engineering", Wiley; 4th edition , 2011
  - 1 exam problem ← Pozar
- Photos
  - sent by email: rdamian@etti.tuiasi.ro
  - used at lectures/laboratory

Photos

Studentii care au trimis fotografiile

Grupa: 5402

Nr.	Nume
1	APETRII MARIA

Grupa: 5403

Nr.	Nume
1	ALEXANDRESCU SEBASTIAN

Grupa: 5404

Nr.	Nume
1	APERGHIS MIHAI-ALIN

Grupa: 5405

Nr.	Nume
1	ANGHELUS MARIL

Studentii care inca nu au trimis fotografiile

Grupa: 5304

Nr.	Nume

Grupa: 5402

Nr.	Nume

Grupa: 5403

Nr.	Nume

Grupa: 5404

Nr.	Nume

Photos

Date:

Grupa	5304 (2015/2016)
Specializarea	Tehnologii si sisteme de telecomunicatii
Marca	5184

Trimite email acestui student | Adauga acest student la lista (0)

Detalii curente **Observatii**

Finantare	Buget
Bursa	Fara Bursa

Date:

Grupa	5304 (2015/2016)
Specializarea	Tehnologii si sisteme de telecomunicatii
Marca	5244

Trimite email acestui student | Adauga acest student la lista (0)

Detalii curente **Observatii**

Finantare	Buget
Bursa	Bursa de Studii

Date:

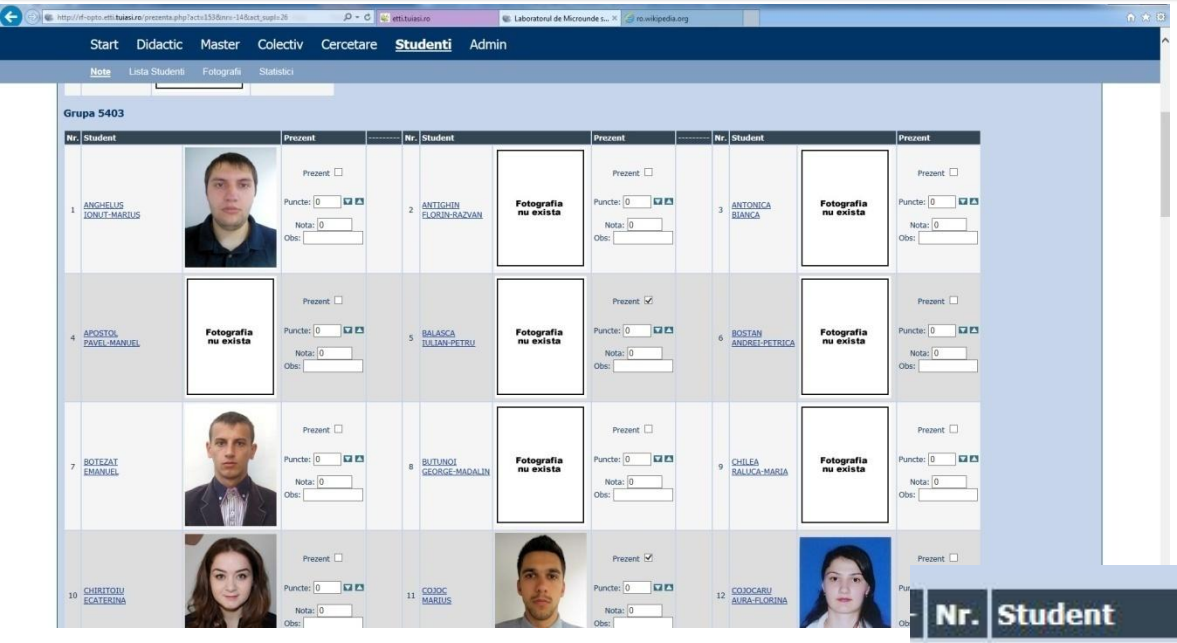
Grupa	5304 (2015/2016)
Specializarea	Tehnologii si sisteme de telecomunicatii
Marca	5184

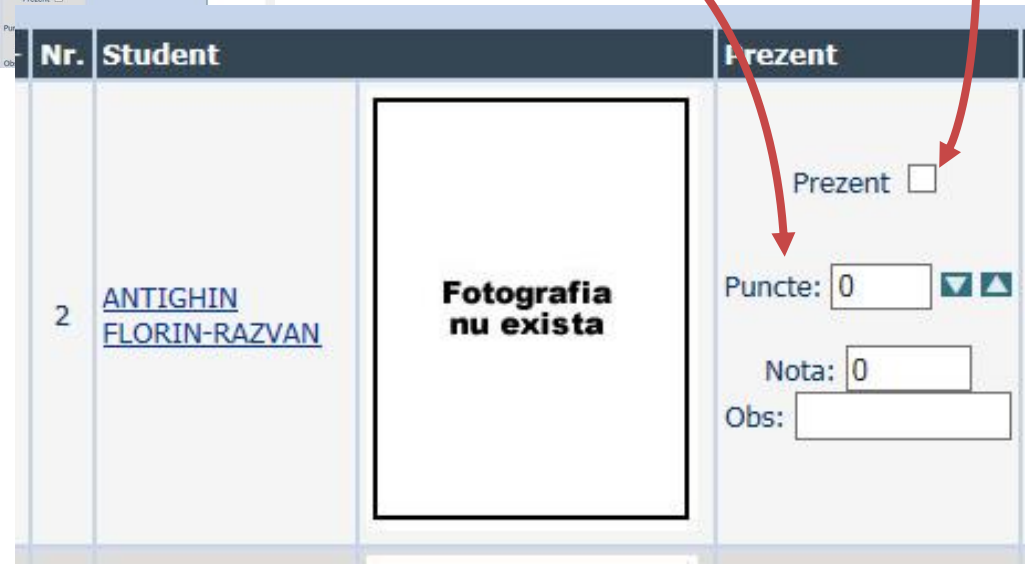
Acceseaza ca acest student

Note obtinute

Disciplina	Tip	Data	Descriere	Nota	Puncte	Obs.
TW	**Tehnologii Web**					
	N	17/01/2014	Nota finala	10	-	
	A	17/01/2014	Colocviu Tehnologii Web 2013/2014	10	7.55	
	B	17/01/2014	Laborator Tehnologii Web 2013/2014	9	-	
	D	17/01/2014	Tema Tehnologii Web 2013/2014	9	-	

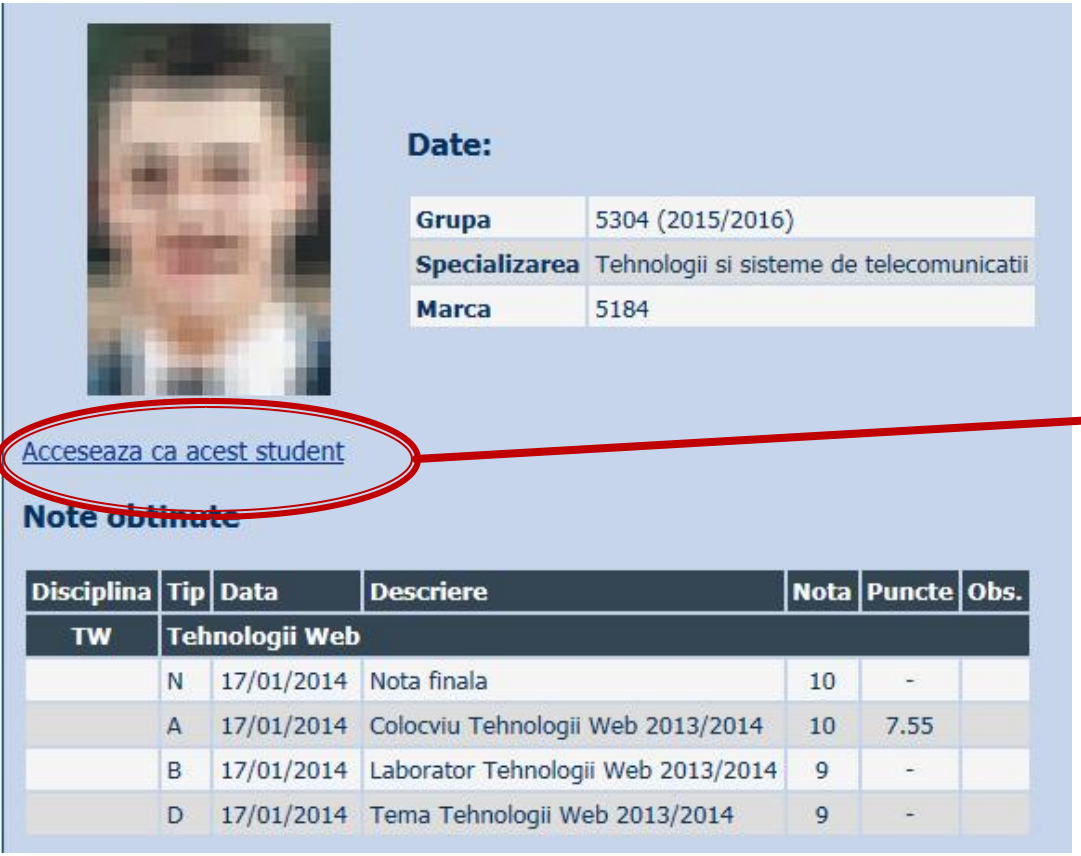
Photos


Start
Didactic
Master
Colectiv
Cercetare
Studenti
Admin
Note
Lista Studenti
Fotografii
Statistici
Grupa 5403
Nr.
Student
Prezent
ANGHELUS IONUT-MARIUS
ANTIGHIN FLORIN-RAZVAN
ANTONICA BIANCA
APOSTOL PAVEL-MANUEL
BALASCA IULIAN-PETRU
BOSTAN ANDREI-PETRICA
BOTEZAT EMANUEL
BUTUNOI GEORGE-MADALIN
CHILEA RALUCA-MARIA
CHIRITOIU ECATERINA
COJOC MARIUS
COJOCARU AURA-FLORINA
Fotografia nu exista
Puncte:
Nota:
Obs:


Nr.
Student
Prezent
2
ANTIGHIN FLORIN-RAZVAN
Fotografia nu exista
Prezent
Puncte: 0
Nota: 0
Obs:

Access

- ~~Not customized~~



Date:

Grupa	5304 (2015/2016)
Specializarea	Tehnologii si sisteme de telecomunicatii
Marca	5184

Acceseaza ca acest student

Note obtinute

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	D	17/01/2014	Tema Tehnologii Web 2013/2014	9	-	

MOTTO (RO)

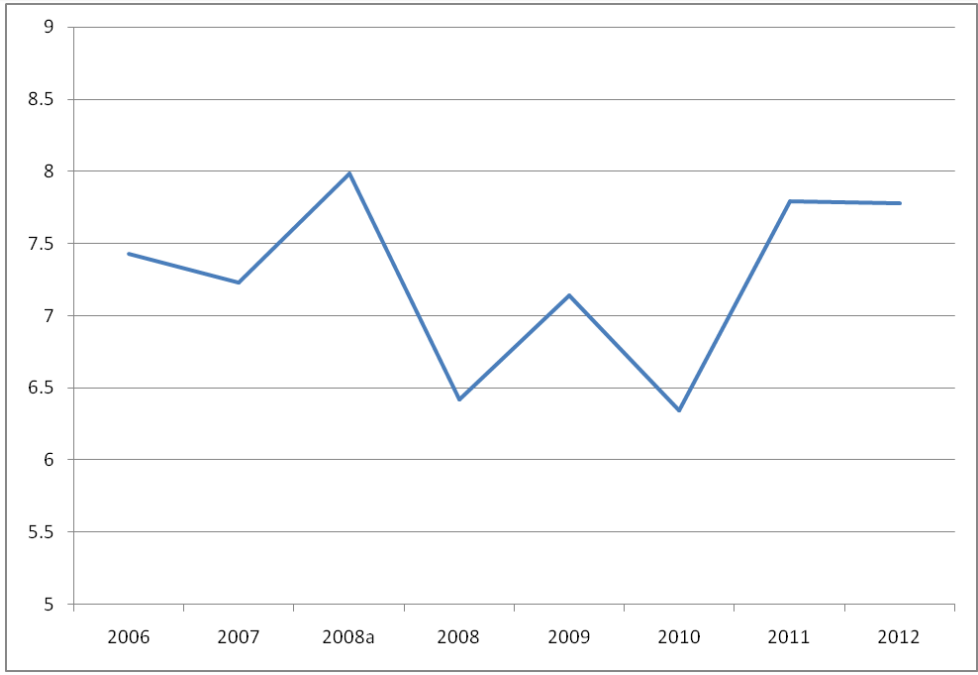
- “Universitatea nu e pentru mase locul de unde emana cunoasterea, ci un obstacol intre individ si diploma pe care i-a harazit-o destinul”

- “Universitatea fiind ceva care se interpune in mod imoral intre individ si dreptul lui natural de a fi diplomat, individul are obligatia morala sa triumfe asupra universitatii prin orice mijloace”

  - Sursa citat: Internet, user: ”un student batran si plesuv”

Examen

- individual topics
- Grades
  - 2006: 7.43
  - 2007: 7.23
  - 2008: 7.98
  - 2008: 6.42
  - 2009: 7.14
  - 2010: 6.34
  - 2011: 7.79
  - 2012: 7.77



- First time (unannounced)
  - 50% of the students left the exam in the first 10 minutes
  - 50% of those who stayed did not pass
  - overall passing percentage 25%, litigation rate: 0%
- Next examinations (announced)
  - litigation rate : 0%

Examen

Grades

- 2017/2018

Start **Didactic** Master Colectiv Cercetare Studenti Admin

Microunde Comunicatii Optice Optoelectronica Internet Antene Practica Retele Soft didactic

Dispozitive si circuite de microunde pentru radiocomunicatii

Disciplina: DCMR (2017-2018)

Coordonator Disciplina: conf. dr. Radu-Florin Damian
Cod: DOS412T
Tip Disciplina: DOS; Disciplina Optionala, Disciplina de Specialitate
Credite: 4
An de Studiu: 4, **Sem.** 7

Activitati

Curs: Cadru Didactic: conf. dr. Radu-Florin Damian, 2 Ore/Saptamana, Sectie Specializare, Orar:
Laborator: Cadru Didactic: conf. dr. Radu-Florin Damian, 1 Ore/Saptamana, Grupa, Orar:

Evaluare

Tip: **Examen**

A: 50%, (Examen/Colocviu)
B: 25%, (Activitate Seminar/Laborator/Proiect)
D: 25%, (Teme de casa/Lucrari de specialitate)

Note

Rezultate totale

Prezenta

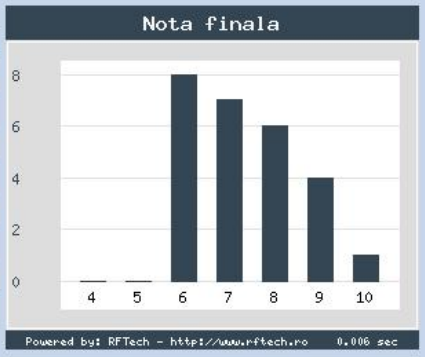
Curs
Laborator

Liste

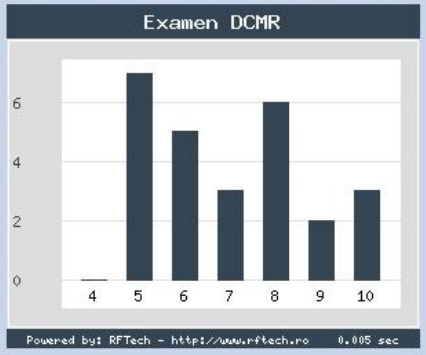
Bonus-uri acumulate (final)
Studenti care nu pot intra in examen

Statistici

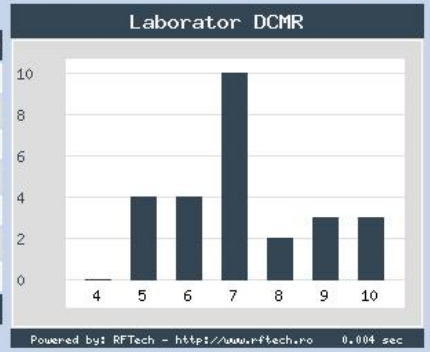
Nota.	Numar
4	0
5	0
6	8
7	7
8	6
9	4
10	1
TOTAL	26



Exam.	Numar
4	0
5	7
6	5
7	3
8	6
9	2
10	3
TOTAL	26

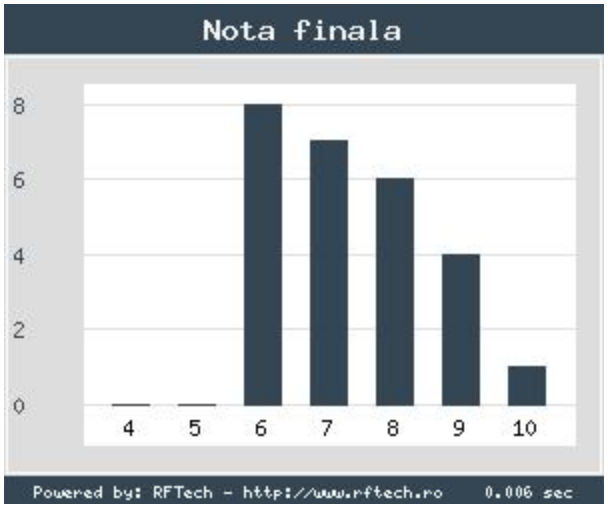


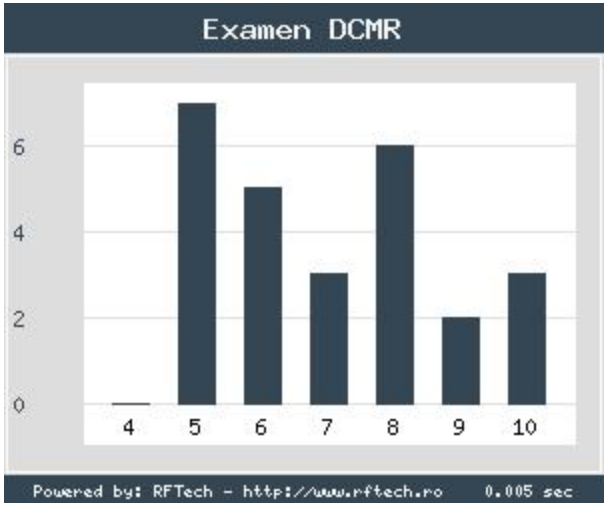
Labo.	Numar
4	0
5	4
6	4
7	10
8	2
9	3
10	3
TOTAL	26

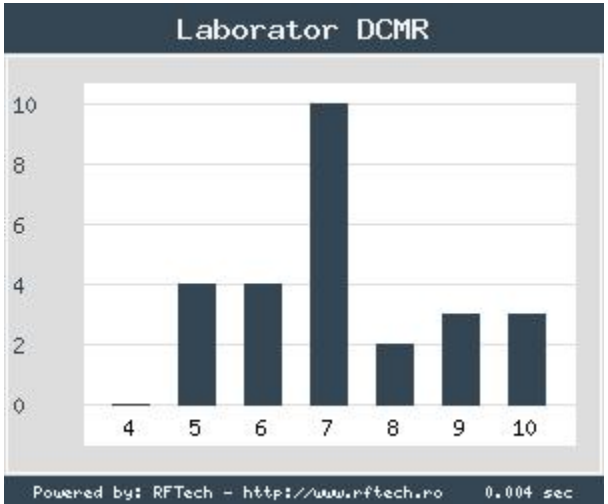


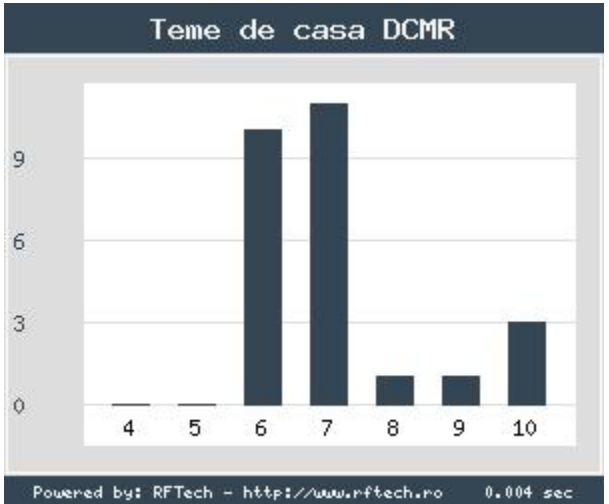
Grades

- 2017/2018

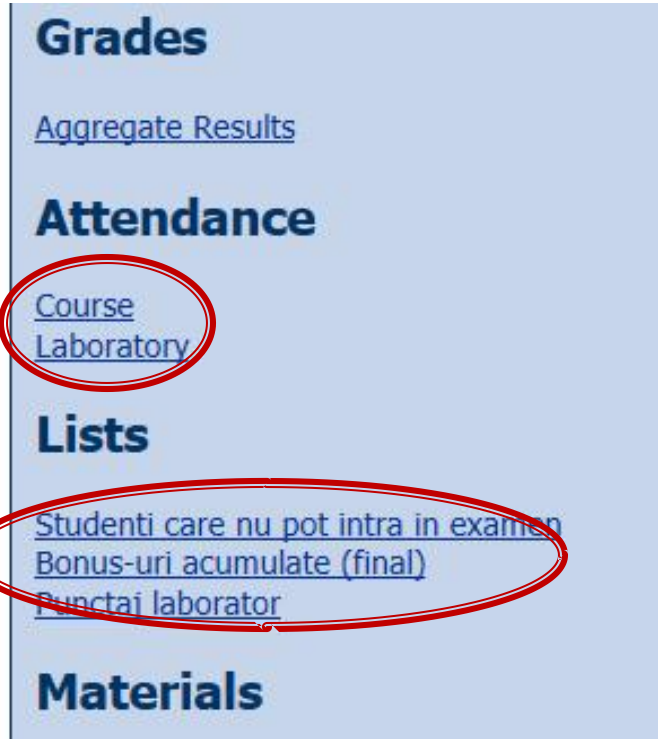








Attendance, Lists



- Attendance
- minimum 7 sessions
- Activity bonus
- Homework individual data
- etc.

L 2017 - Job opportunity

- Temporary **employment** available
- Salary equivalent to **2790** €/month

L 2017 - Job opportunity

- Students qualitative review (2017):
  - RO: "70% dintre studenti au platit un student de an mai mare sa le faca proiectul, intre 30 si 50 de lei"
- Computation

$$50\ stud \times 70\% \times 40\ lei = 1400\ lei$$

$$50\ stud \times 70\% \times 30\ \min = 17.5\ h$$

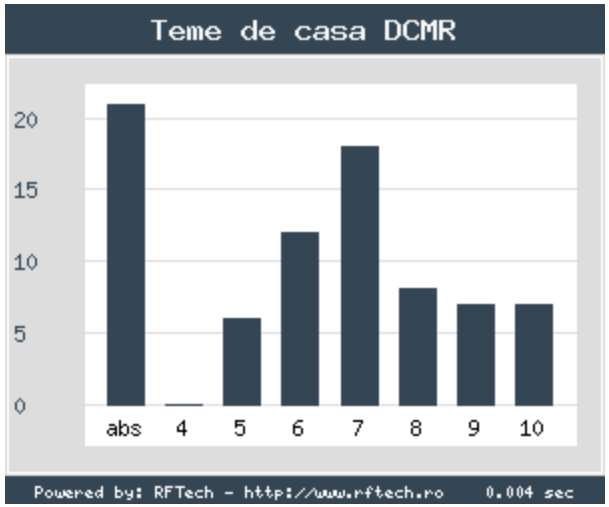
$$1\ month = 4\ weeks \times 5\ days \times 8\ h = 160\ h$$

$$\frac{1400\ lei}{17.5\ h} = \frac{12800\ lei}{160\ h} = \frac{12800\ lei}{1\ month} = \frac{2790\ Euro}{1\ month}$$

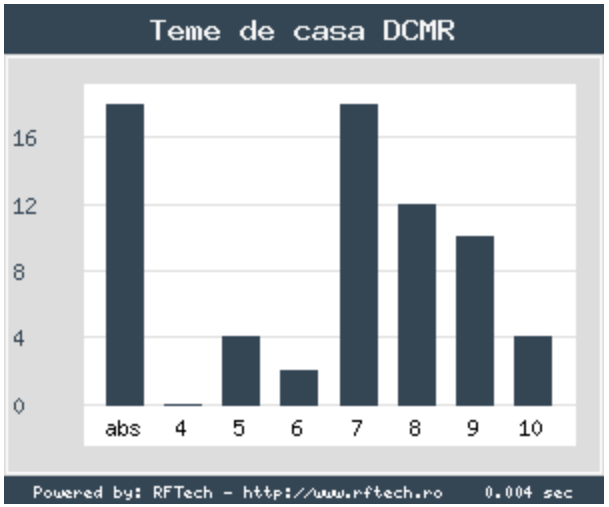
Efect?

- factorul “andrei”

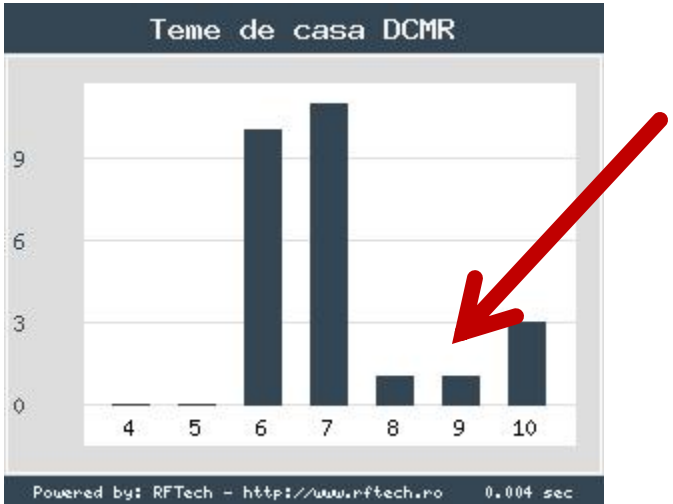
2015/6



2016/7



2017/8



Morala 2017/2018

- Diferența între:
  - un hoț harnic
  - un hoț leneș

Morala 2017/2018

- Hoțul harnic se duce la magazin, cumpăra o rangă, după care se duce personal la locația "crimei" și comite spargerea
- Hoțul leneș își achită ranga prin Internet Banking, și se așteaptă ca proprietarul magazinului de scule să ia ranga, să comită spargerea, să vândă prada și să îi vireze banii in cont

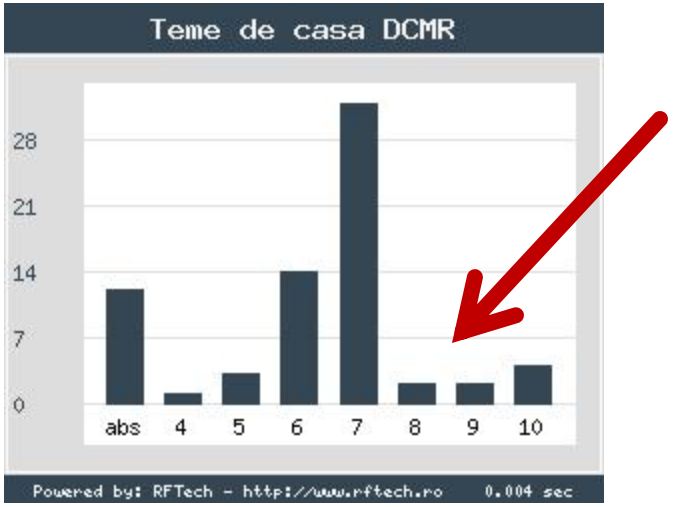
Morala 2017/2018

- Diferența între:
  - un hoț harnic : factorul “andrei” = +1p
  - un hoț leneș : factorul “andrei” = -1p

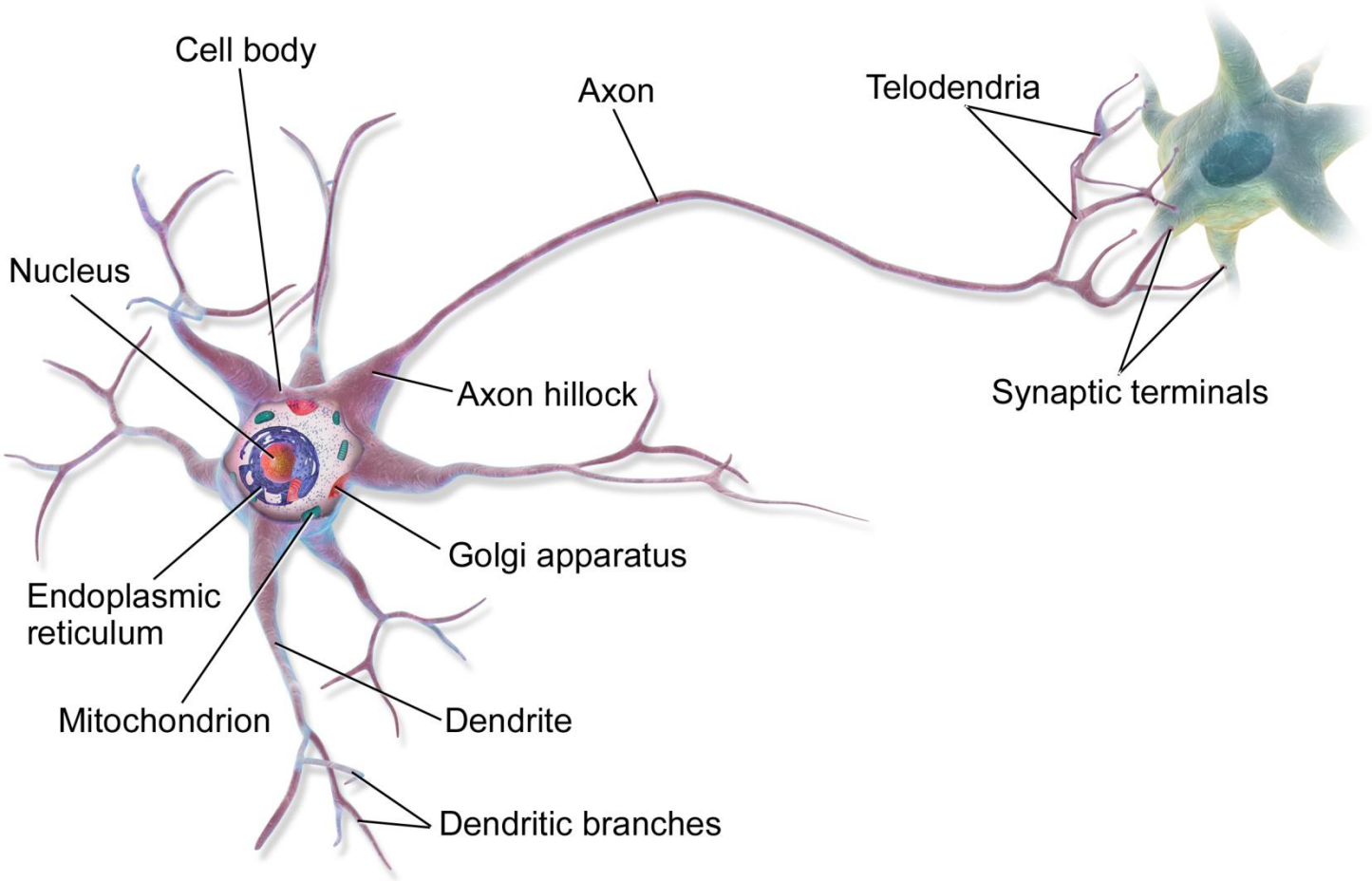
Proiect 2018/2019

- factorul “andrei” = -2p

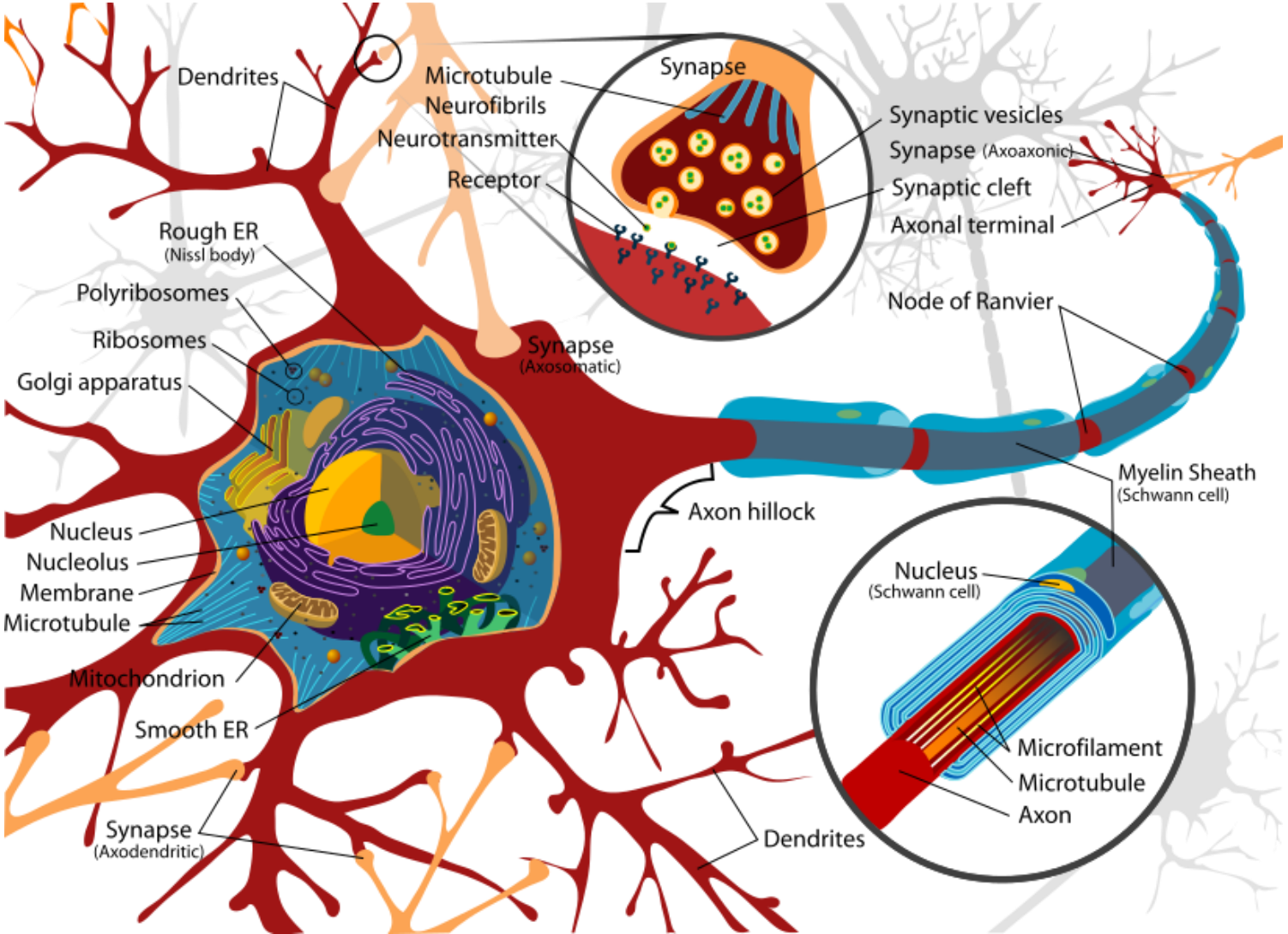
2017/8



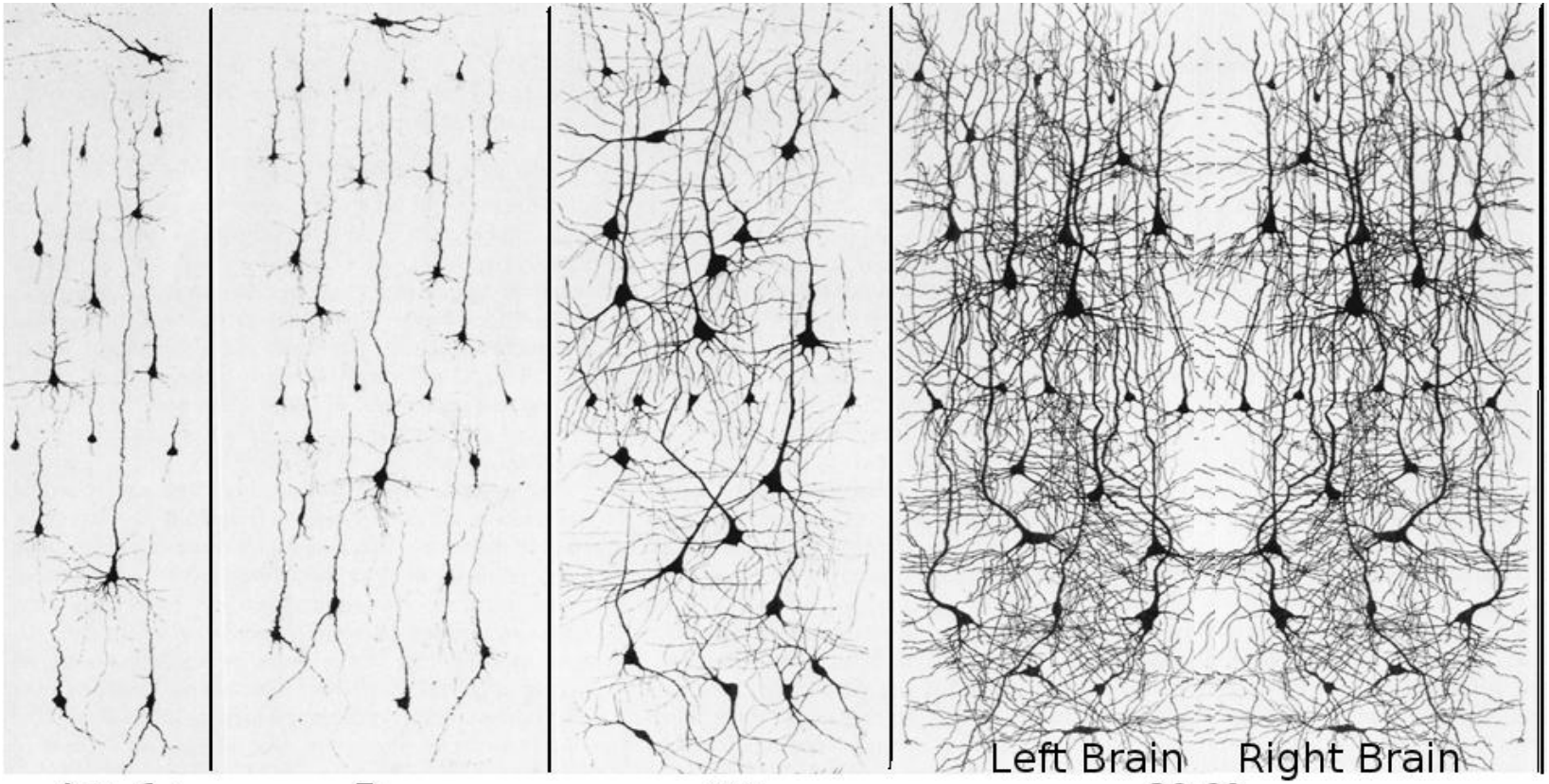
Course Objectives 1



Course Objectives 2



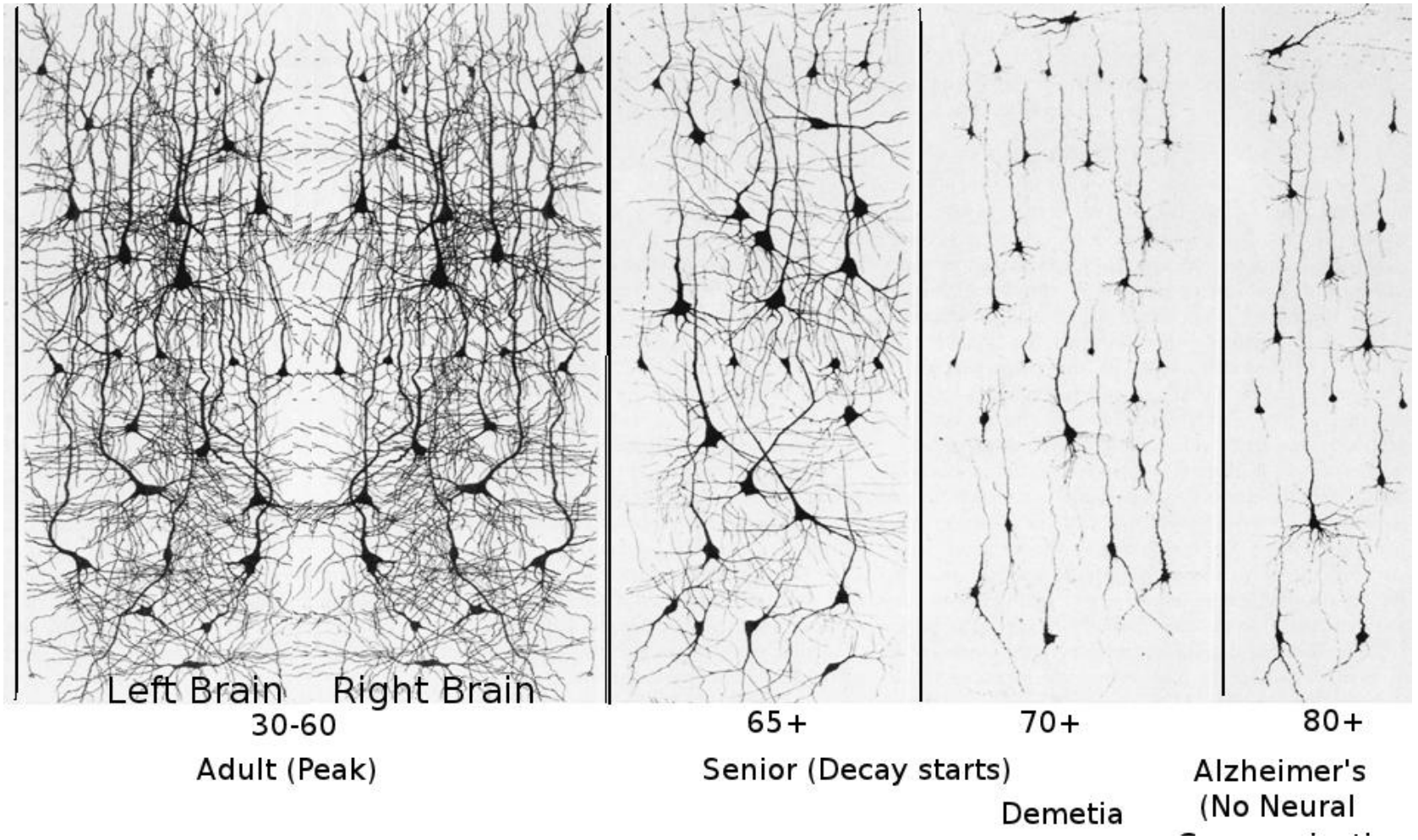
Course Objectives 3



Course Objectives 4

"Engineering" Sinapses

Deadline


Left Brain
Right Brain
30-60
Adult (Peak)
65+
Senior (Decay starts)
70+
Demetia
80+
Alzheimer's
(No Neural

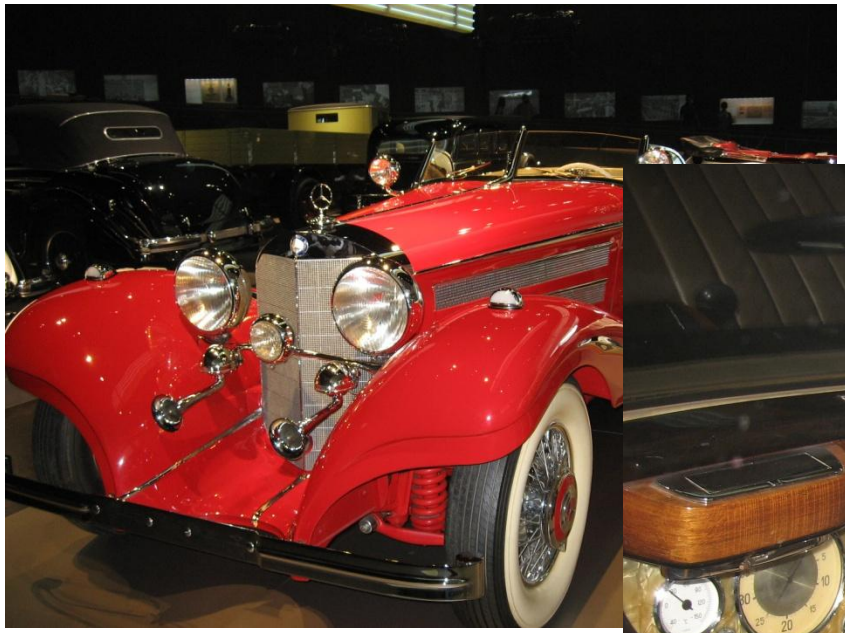
Course Topics

- Transmission lines
- Impedance matching and tuning
- Directional couplers
- Power dividers
- Microwave amplifier design
- Microwave filters
- Oscillators and mixers ?

Textbooks

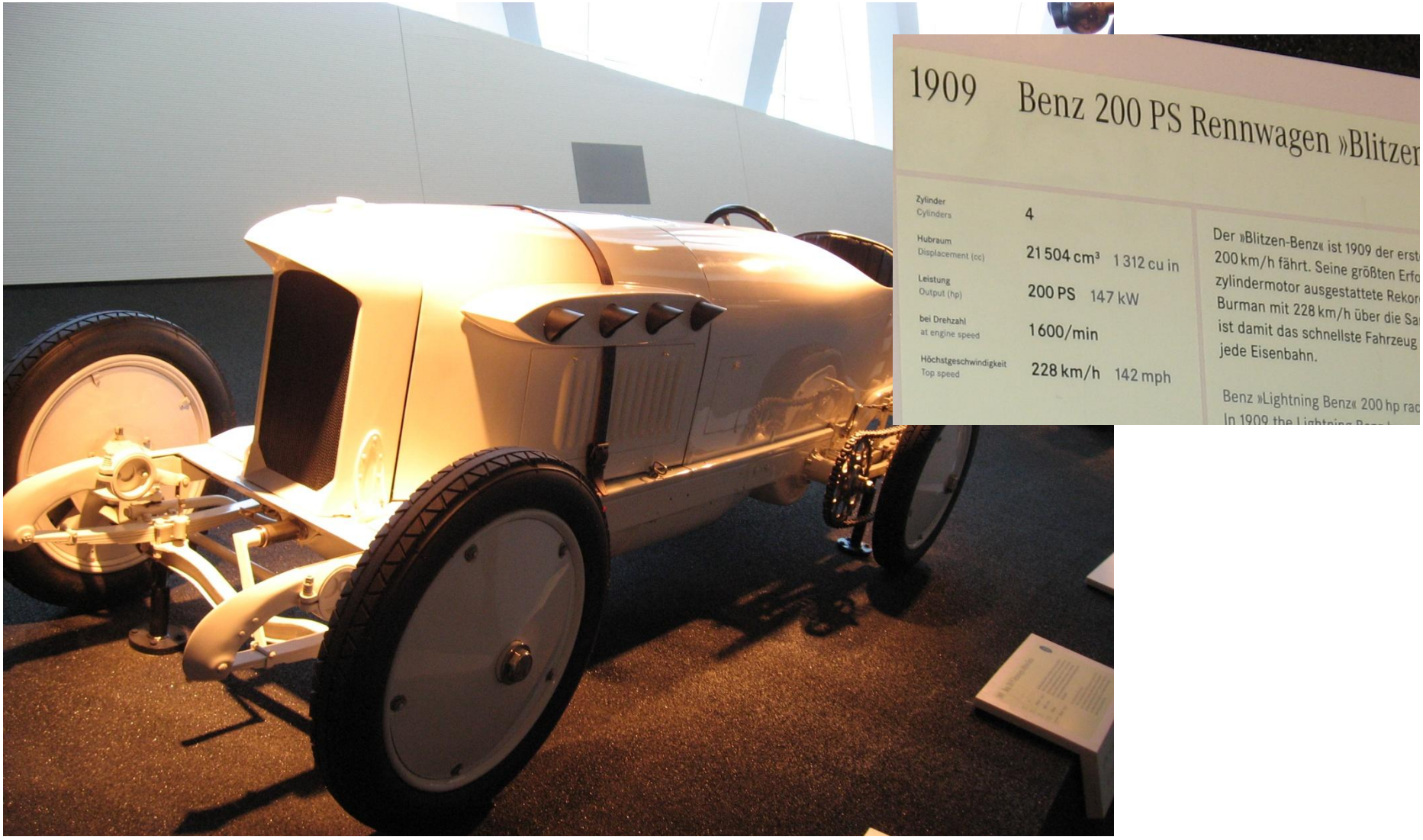
- http://rf-opto.etti.tuiasi.ro
- Irinel Casian-Botez: "Microunde vol. 1: Proiectarea de circuit", Ed. TEHNOPRES, 2008
- David Pozar, Microwave Engineering, Wiley; 4th edition , 2011, ISBN : 978-1-118-29813-8 (E), ISBN : 978-0-470-63155-3 (P)

~1930



~1930

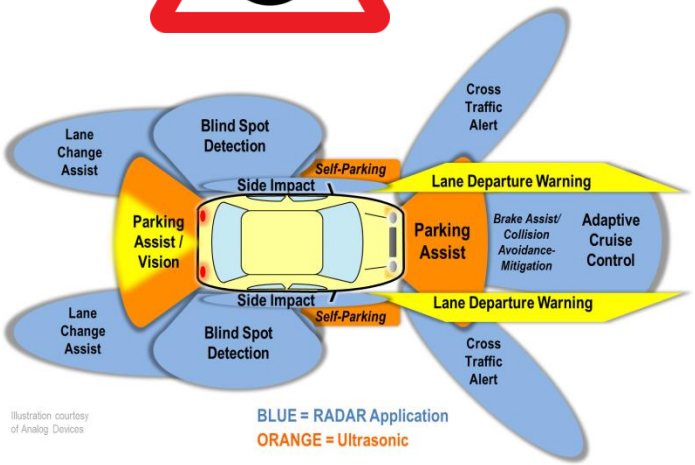
1909


1909 Benz 200 PS Rennwagen »Blitzen
Zylinder
Cylinders
4
Hubraum
Displacement (cc)
21 504 cm³ 1 312 cu in
Leistung
Output (hp)
200 PS 147 kW
bei Drehzahl
at engine speed
1 600/min
Höchstgeschwindigkeit
Top speed
228 km/h 142 mph
Der »Blitzen-Benz« ist 1909 der erst
200 km/h fährt. Seine größten Erfo
zylindermotor ausgestattete Rekor
Burman mit 228 km/h über die Sa
ist damit das schnellste Fahrzeug
jede Eisenbahn.
Benz »Lightning Benz« 200 hp rac

1930-1950

Technology

> 2010



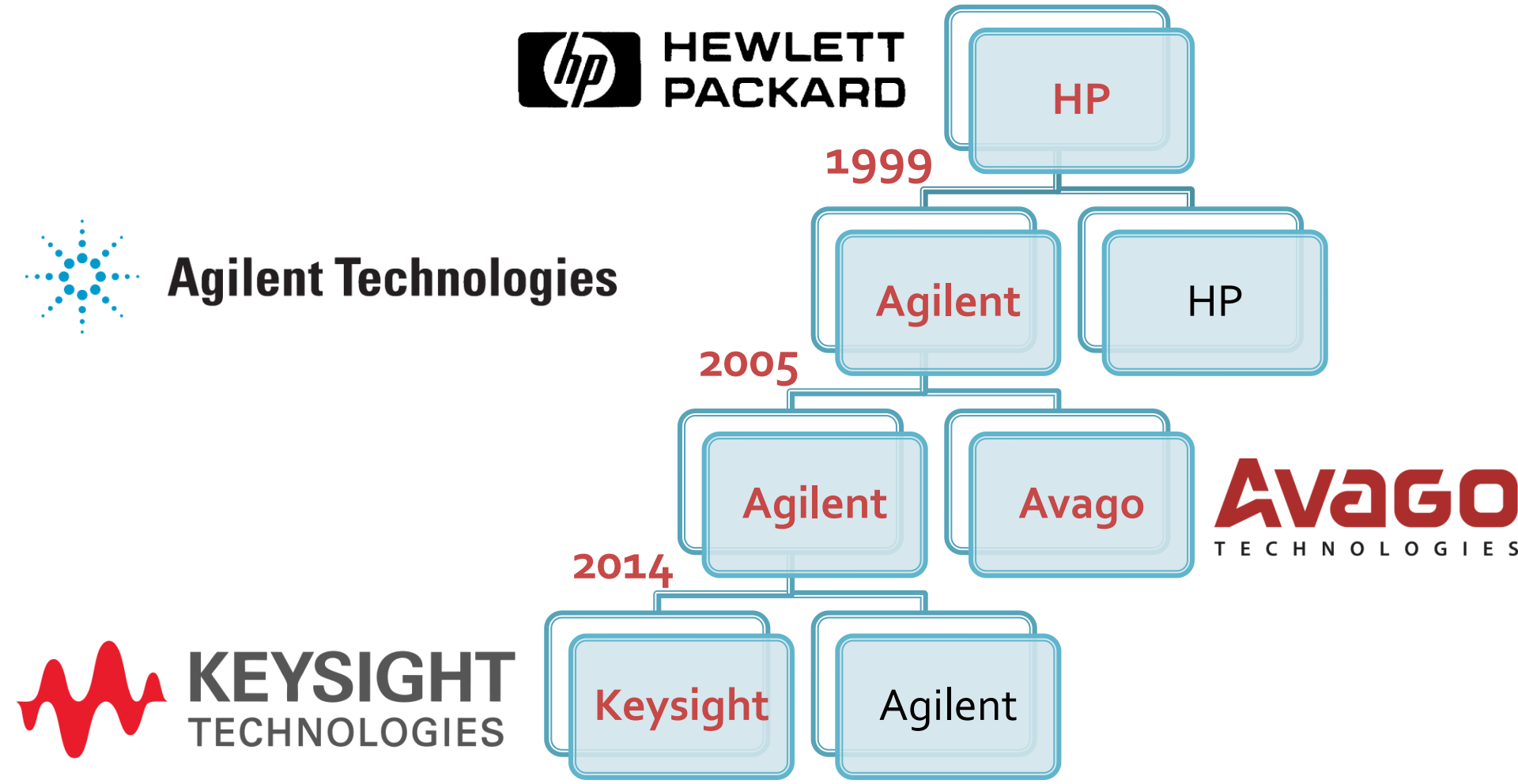
< 1950

Technology

1x1 = 1 1x2 = 2 1x3 = 3 1x4 = 4 1x5 = 5 1x6 = 6 1x7 = 7 1x8 = 8 1x9 = 9 1x10 = 10	2x1 = 2 2x2 = 4 2x3 = 6 2x4 = 8 2x5 = 10 2x6 = 12 2x7 = 14 2x8 = 16 2x9 = 18 2x10 = 20	3x1 = 3 3x2 = 6 3x3 = 9 3x4 = 12 3x5 = 15 3x6 = 18 3x7 = 21 3x8 = 24 3x9 = 27 3x10 = 30	4x1 = 4 4x2 = 8 4x3 = 12 4x4 = 16 4x5 = 20 4x6 = 24 4x7 = 28 4x8 = 32 4x9 = 36 4x10 = 40	5x1 = 5 5x2 = 10 5x3 = 15 5x4 = 20 5x5 = 25 5x6 = 30 5x7 = 35 5x8 = 40 5x9 = 45 5x10 = 50
6x1 = 6 6x2 = 12 6x3 = 18 6x4 = 24 6x5 = 30 6x6 = 36 6x7 = 42 6x8 = 48 6x9 = 54 6x10 = 60	7x1 = 7 7x2 = 14 7x3 = 21 7x4 = 28 7x5 = 35 7x6 = 42 7x7 = 49 7x8 = 56 7x9 = 63 7x10 = 70	8x1 = 8 8x2 = 16 8x3 = 24 8x4 = 32 8x5 = 45 8x6 = 48 8x7 = 56 8x8 = 64 8x9 = 72 8x10 = 80	9x1 = 9 9x2 = 18 9x3 = 27 9x4 = 36 9x5 = 45 9x6 = 54 9x7 = 63 9x8 = 72 9x9 = 81 9x10 = 90	10x1 = 10 10x2 = 20 10x3 = 30 10x4 = 40 10x5 = 50 10x6 = 60 10x7 = 70 10x8 = 80 10x9 = 90 10x10 = 100

Most used!!

2x1 = 2
2x2 = 4
2x3 = 6
2x4 = 8
2x5 = 10
2x6 = 12
2x7 = 14
2x8 = 16
2x9 = 18
2x10 = 20

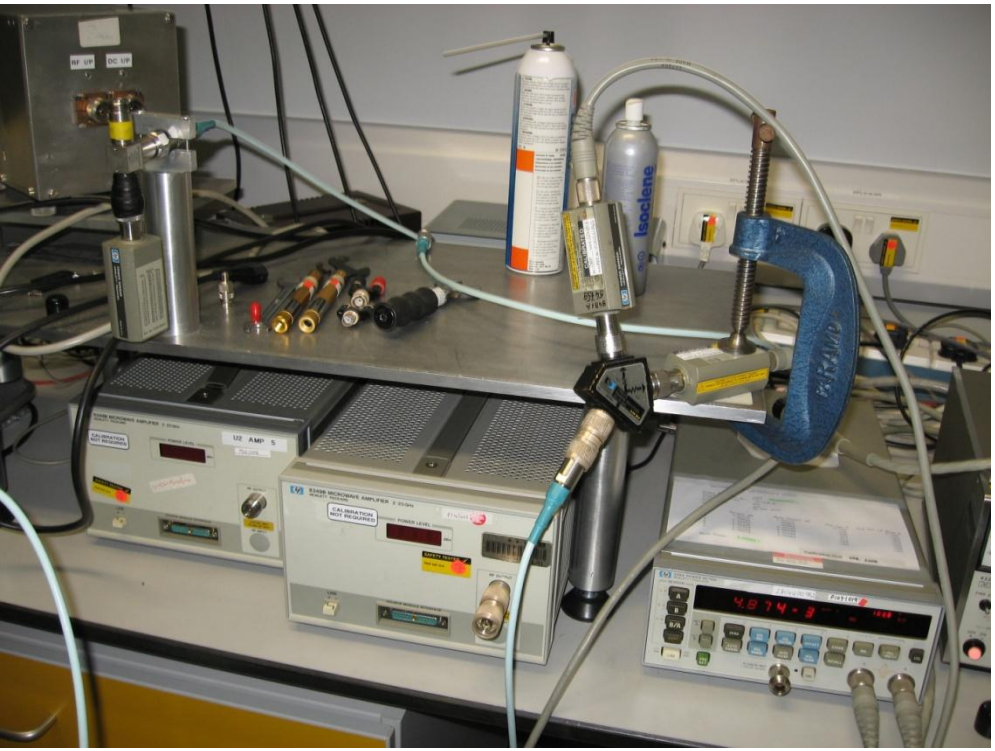

HEWLETT PACKARD
HP
1999
Agilent Technologies
Agilent
HP
2005
Agilent
Avago
AVAGO TECHNOLOGIES
2014
KEYSIGHT TECHNOLOGIES
Keysight
Agilent

NPL, Londra

HEWLETT PACKARD 8510

NATIONAL PHYSICAL LABORATORY
HEWLETT PACKARD
NETWORK ANALYZER
8510
SAFETY TESTED

NPL, Londra


Isoclene

8349B MICROWAVE AMPLIFIER 2-20 GHz
HEWLETT-PACKARD
CALIBRATION NOT REQUIRED
POWER LE

438A POWER METER
HEWLETT-PACKARD
SENSOR
A
B

8349B MICROWAVE AMPLIFIER 2-20 GHz
HEWLETT PACKARD
CALIBRATION NOT REQUIRED
POWER LEVEL

Examen: Logarithmic scales

dB $= 10 \cdot \log_{10}(P_2 / P_1)$

0 dB	= 1
+ 0.1 dB	= 1.023 (+2.3%)
+ 3 dB	= 2
+ 5 dB	= 3
+ 10 dB	= 10
-3 dB	= 0.5
-10 dB	= 0.1
-20 dB	= 0.01
-30 dB	= 0.001

dBm $= 10 \cdot \log_{10}(P / 1\ mW)$

0 dBm	= 1 mW
3 dBm	= 2 mW
5 dBm	= 3 mW
10 dBm	= 10 mW
20 dBm	= 100 mW
-3 dBm	= 0.5 mW
-10 dBm	= 100 µW
-30 dBm	= 1 µW
-60 dBm	= 1 nW

[dBm] + [dB] = [dBm]

[dBm/Hz] + [dB] = [dBm/Hz]

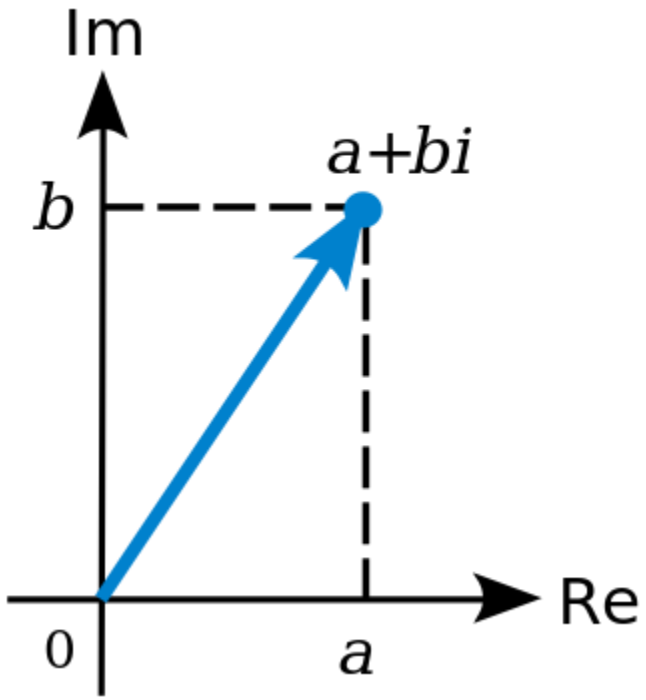
[x] + [dB] = [x]

Examen

- Complex numbers arithmetic!!!!
- $z = a + j \cdot b$; $j^2 = -1$

Complex plane

- abscissa – real part
- ordinate – imaginary part
- any of them can be negative, whole plane, 4 quadrants



Elementary operations

- Addition

$$z+w=(a+j\cdot b)+(c+j\cdot d)=(a+c)+j\cdot(b+d)$$

- Subtraction

$$z-w=(a+j\cdot b)-(c+j\cdot d)=(a-c)+j\cdot(b-d)$$

- Multiplication

$$z\cdot w=(a+j\cdot b)\cdot(c+j\cdot d)=(a\cdot c-b\cdot d)+j\cdot(b\cdot c+a\cdot d)$$

- Division

$$z/w=\frac{a+j\cdot b}{c+j\cdot d}=\frac{(a+j\cdot b)\cdot(c-j\cdot d)}{(c+j\cdot d)\cdot(c-j\cdot d)}=\left(\frac{a\cdot c+b\cdot d}{c^2+d^2}\right)+j\cdot\left(\frac{b\cdot c-a\cdot d}{c^2+d^2}\right)$$

Conjugate

- z $z = a + j \cdot b$
- z^* $z^* = a - j \cdot b$
- Symmetry over the real axis

$$\mathrm{Re}(z) = a = \frac{1}{2} \cdot (z + z^*)$$

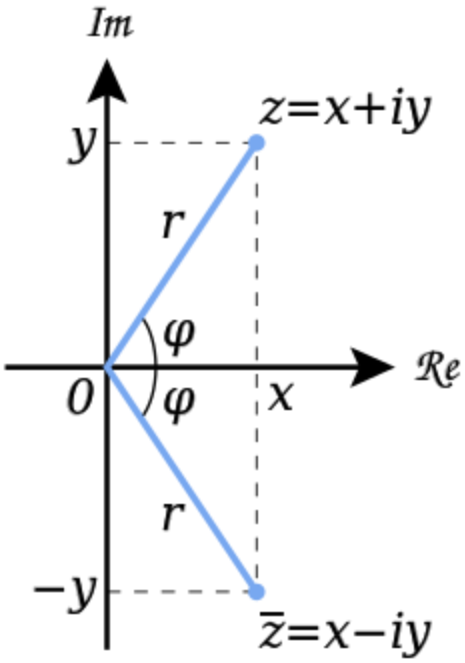
$$\mathrm{Im}(z) = b = \frac{1}{2 \cdot j} \cdot (z - z^*) = \frac{j}{2} \cdot (z^* - z)$$

$$(z + w)^* = z^* + w^*$$

$$(z - w)^* = z^* - w^*$$

$$(z \cdot w)^* = z^* \cdot w^*$$

$$(z / w)^* = z^* / w^*$$



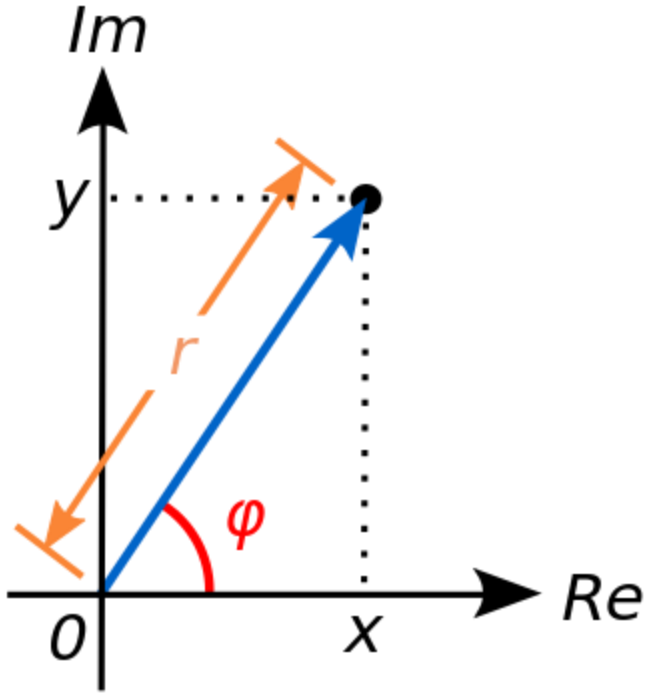
Polar representation

- Polar representation
  - modulus
  - phase relative to the real axis

$$z = a + j \cdot b = |z| \cdot (\cos\varphi + j \cdot \sin\varphi)$$

$$|z| = \sqrt{a^2 + b^2}$$

$$\varphi = \arg(z) = \begin{cases} \arctan\left(\frac{b}{a}\right), & a > 0 \\ \arctan\left(\frac{b}{a}\right) + \pi, & a < 0, b \geq 0 \\ \arctan\left(\frac{b}{a}\right) - \pi, & a < 0, b < 0 \\ \frac{\pi}{2}, -\frac{\pi}{2}, nedefinit & a = 0 \end{cases}$$

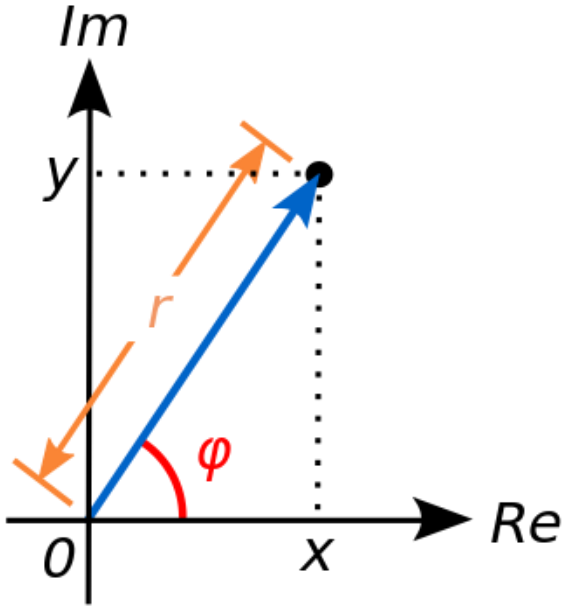


Polar representation

- Euler's formula

$$e^{j\cdot x} = \cos x + j\cdot \sin x; \forall x \in R$$

- Polar representation



$$z = a + j\cdot b = |z|\cdot e^{j\cdot\varphi}$$

$$z = a + j\cdot b = |z|\cdot(\cos\varphi + j\cdot\sin\varphi)$$

$$z^n = \left(|z|\cdot e^{j\cdot\varphi}\right)^n = |z|^n \cdot e^{j\cdot n\cdot\varphi} = |z|^n \cdot [\cos(n\cdot\varphi) + j\cdot\sin(n\cdot\varphi)]$$

$$\sqrt{z} = \left(|z|\cdot e^{j\cdot\varphi}\right)^{1/2} = \sqrt{|z|}\cdot e^{j\cdot\frac{\varphi}{2}} = \sqrt{|z|}\cdot\left(\cos\frac{\varphi}{2} + j\cdot\sin\frac{\varphi}{2}\right)$$

$$z\cdot w = |z|\cdot e^{j\cdot\varphi}\cdot|w|\cdot e^{j\cdot\theta} = |z|\cdot|w|\cdot e^{j\cdot(\varphi+\theta)} = |z|\cdot|w|\cdot[\cos(\varphi+\theta) + j\cdot\sin(\varphi+\theta)]$$

$$z/w = \frac{|z|\cdot e^{j\cdot\varphi}}{|w|\cdot e^{j\cdot\theta}} = \frac{|z|}{|w|}\cdot e^{j\cdot\varphi}\cdot e^{-j\cdot\theta} = \frac{|z|}{|w|}\cdot[\cos(\varphi-\theta) + j\cdot\sin(\varphi-\theta)]$$

Polar representation

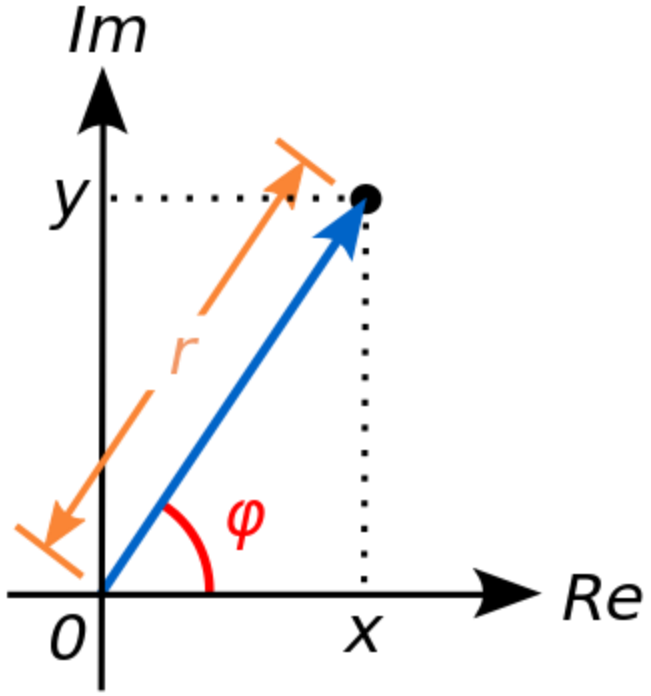
- Polar representation

$$|z| = \sqrt{a^2 + b^2}$$

$$|z|^2 = z \cdot z^*$$

$$\left|e^{j \cdot x}\right| = \left|\cos x + j \cdot \sin x\right| = \sqrt{\cos^2 x + \sin^2 x} = 1$$

$$\left|e^{j \cdot x}\right| = 1; \quad \forall x \in R$$



$$z^* = \left(|z| \cdot e^{j \cdot \varphi}\right)^* = |z| \cdot \left(\cos\varphi + j \cdot \sin\varphi\right)^* = |z| \cdot \left(\cos\varphi - j \cdot \sin\varphi\right) =$$

$$= |z| \cdot \left[\cos(-\varphi) + j \cdot \sin(-\varphi)\right] = |z| \cdot e^{-j \cdot \varphi}$$

Polar representation

- standard unit for angles – radians
- microwaves traditional unit for angles – **degrees in decimal form** (55.89°)

$$\varphi = \arg(z) = \begin{cases} \arctan\left(\frac{b}{a}\right), & a > 0 \\ \arctan\left(\frac{b}{a}\right) + \pi, & a < 0, b \geq 0 \\ \arctan\left(\frac{b}{a}\right) - \pi, & a < 0, b < 0 \\ \frac{\pi}{2}, -\frac{\pi}{2}, nedefinit & a = 0 \end{cases}$$

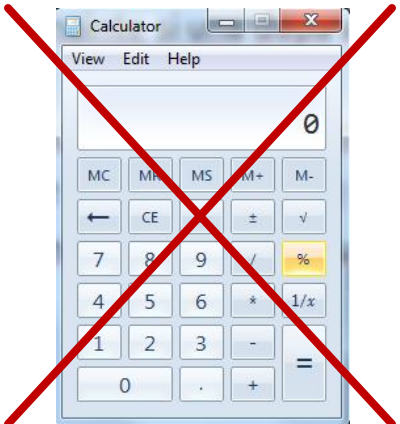
$$\varphi[^\circ] = 180^\circ \cdot \frac{\varphi[rad]}{\pi} \qquad \varphi[rad] = \pi \cdot \frac{\varphi[^\circ]}{180^\circ}$$

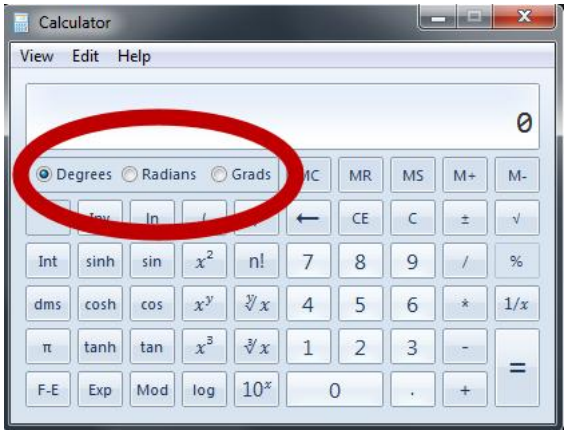
Polar representation

- **Attention to angle numerical values!!**
  - math software – work in standard unit: radians
    - a **conversion** is necessary before and after using a trigonometric function (sin, cos, tan, atan, tanh)
  - scientific calculators have the built-in option of choosing the angle unit
    - always **double check** current working unit

$$\varphi[^\circ] = 180^\circ \cdot \frac{\varphi[rad]}{\pi}$$

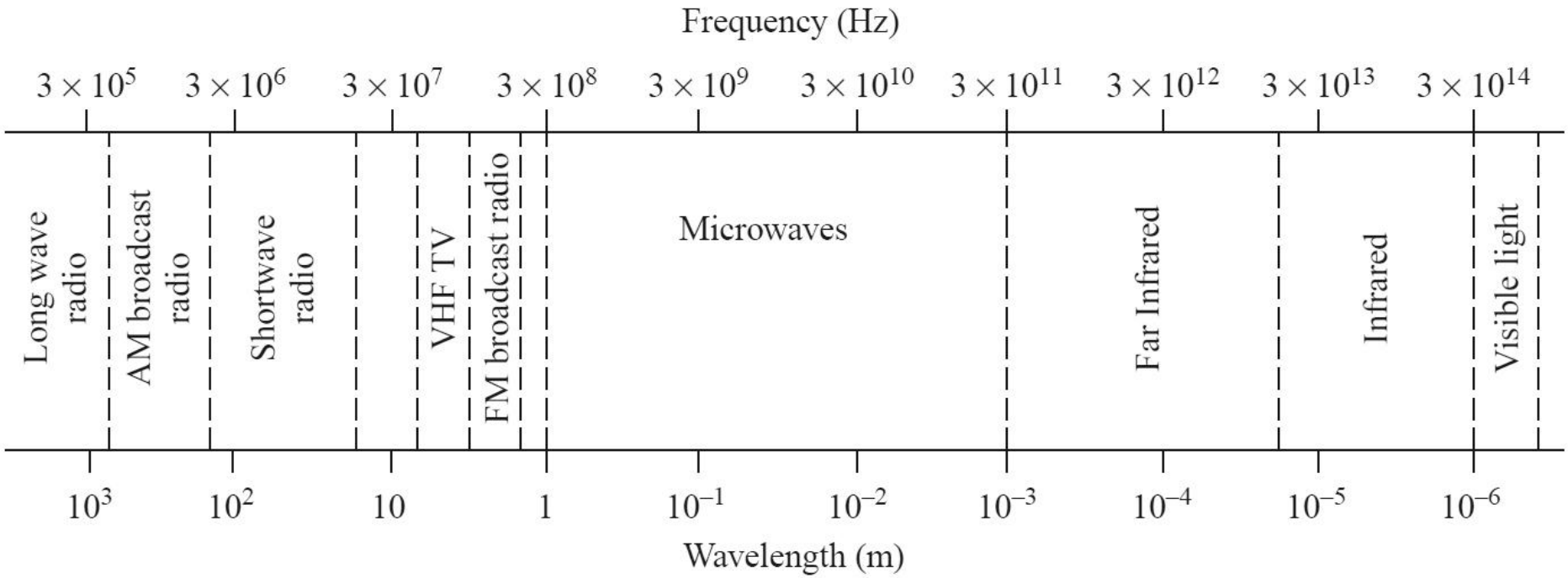
$$\varphi[rad] = \pi \cdot \frac{\varphi[^\circ]}{180^\circ}$$





Introduction

Microwaves



- typically
  - f ≈ 1÷3GHz – 300GHz
  - λ ≈ 1mm – 10cm

Microwaves

Typical Frequencies

AM broadcast band	535–1605 kHz
Short wave radio band	3–30 MHz
FM broadcast band	88–108 MHz
VHF TV (2–4)	54–72 MHz
VHF TV (5–6)	76–88 MHz
UHF TV (7–13)	174–216 MHz
UHF TV (14–83)	470–890 MHz
US cellular telephone	824–849 MHz
	869–894 MHz
European GSM cellular	880–915 MHz
	925–960 MHz
GPS	1575.42 MHz
	1227.60 MHz
Microwave ovens	2.45 GHz
US DBS	11.7–12.5 GHz
US ISM bands	902–928 MHz
	2.400–2.484 GHz
	5.725–5.850 GHz
US UWB radio	3.1–10.6 GHz

Approximate Band Designations

Medium frequency	300 kHz–3 MHz
High frequency (HF)	3 MHz–30 MHz
Very high frequency (VHF)	30 MHz–300 MHz
Ultra high frequency (UHF)	300 MHz–3 GHz
L band	1–2 GHz
S band	2–4 GHz
C band	4–8 GHz
X band	8–12 GHz
Ku band	12–18 GHz
K band	18–26 GHz
Ka band	26–40 GHz
U band	40–60 GHz
V band	50–75 GHz
E band	60–90 GHz
W band	75–110 GHz
F band	90–140 GHz

~ Microwaves

- Electrical Length (Phase Length)
  - l – physical length
  - E = β·l – electrical Length

$$E = \beta \cdot l = \frac{2\pi}{\lambda} \cdot l = 2\pi \cdot \left(\frac{l}{\lambda} \right)$$

$$E = \beta \cdot l = \frac{2\pi}{c_0} \cdot \left(l \cdot f \cdot \sqrt{\varepsilon_r} \right)$$

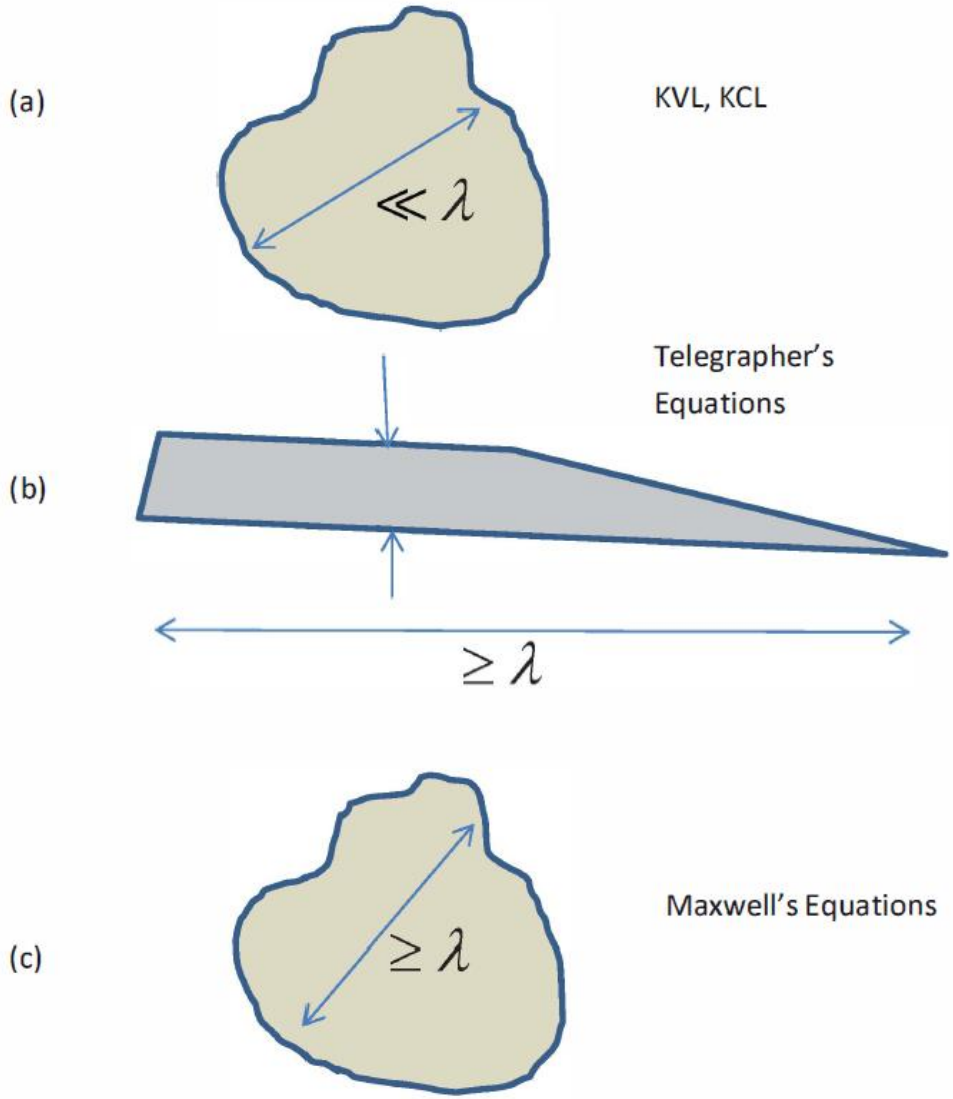
V, I vary
~ useless

- Dependency
  - antenna gain
  - Radar cross-section

Electrical Length

- Behavior (and description) of any circuit depends on his electrical length at the particular frequency of interest
  - E≈o → Kirchhoff
  - E>o → wave propagation

$$E = \beta \cdot l = \frac{2\pi}{\lambda} \cdot l = 2\pi \cdot \left(\frac{l}{\lambda} \right)$$



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