

Curs 1

2018/2019

Dispozitive și circuite de microunde pentru radiocomunicații

Disciplina 2018/2019

- 2C/1L, **DCMR (CDM)**
- Minim 7 prezente (curs+laborator)
- Curs - **conf. Radu Damian**
 - Vineri 11-13, P7
 - E – 50% din nota
 - probleme + (2p prez. curs) + (3 teste) + (bonus activitate)
 - 3pz=+0.5p
 - toate materialele permise
- Laborator – **conf. Radu Damian**
 - Joi 8-14 impar II.13
 - L – 25% din nota
 - P – 25% din nota

Documentatie

■ <http://rf-opto.etti.tuiasi.ro>

Laboratorul de Microunde si Opti

Not secure | rf-opto.etti.tuiasi.ro/microwave_cd.php?chg_lang=1

RF-OPTO

English | Romana

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](#)

Documentatie

- RF-OPTO
 - <http://rf-opto.etti.tuiasi.ro>
- Fotografie
 - de trimis prin email: rdamian@etti.tuiasi.ro
 - necesara la laborator/curs

Fotografii

Studentii care au trimis fotografiile 🙌👉

Grupa: 5402

Nr.	Nume
1	<u>APETRII MARIA</u>

Grupa: 5403

Nr.	Nume
1	<u>ALEXANDRESCU SEBASTIAN</u>

Grupa: 5404

Nr.	Nume
1	<u>APERGHIS MIHAI-ALIN</u>

Grupa: 5405

Nr.	Nume
1	<u>ANGHELUS MARIU</u>

Studentii care **inca** nu au trimis fotografiile 🙄🗨️

Grupa: 5304

Nr.	Nume

Grupa: 5402

Nr.	Nume

Grupa: 5403

Nr.	Nume

Grupa: 5404

Nr.	Nume

Fotografii



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	-	

Fotografii

Grupa 5403

Nr.	Student	Prezent	Nr.	Student	Prezent	Nr.	Student	Prezent
1	ANGHELUS DOMIT-MARIUS	<input type="checkbox"/> Puncte: 0 Nota: 0 Obs:	2	ANTIGHIN FLORIN-RAZVAN	<input type="checkbox"/> Puncte: 0 Nota: 0 Obs:	3	ANTONICA BIANCA	<input type="checkbox"/> Puncte: 0 Nota: 0 Obs:
4	APOSTOL PAVEL-MANUEL	<input type="checkbox"/> Puncte: 0 Nota: 0 Obs:	5	BALASCA TALIAN-PETRU	<input checked="" type="checkbox"/> Puncte: 0 Nota: 0 Obs:	6	BOSTAN ANDREI-PETRICU	<input type="checkbox"/> Puncte: 0 Nota: 0 Obs:
7	BOTEZAT EMANUEL	<input type="checkbox"/> Puncte: 0 Nota: 0 Obs:	8	BUTUNOI GEORGE-MADALIN	<input type="checkbox"/> Puncte: 0 Nota: 0 Obs:	9	CHILEA SALUCA-MARIA	<input type="checkbox"/> Puncte: 0 Nota: 0 Obs:
10	CHRISTOIU ECATERINA	<input type="checkbox"/> Puncte: 0 Nota: 0 Obs:	11	COJOC MARIUS	<input checked="" type="checkbox"/> Puncte: 0 Nota: 0 Obs:	12	COJOCARIU AUSA-FLORINA	<input type="checkbox"/> Puncte: 0 Nota: 0 Obs:

Nr.	Student	Prezent
2	ANTIGHIN FLORIN-RAZVAN	<input type="checkbox"/> Puncte: 0 Nota: 0 Obs:

Acces

■ Personalizat



Date:

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

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

Nume

Email

Cod de verificare

Trimite

MOTTO

- “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

- subiecte individuale

- Note

- 2006: 7.43

- 2007: 7.23

- 2008: 7.98

- 2008: 6.42

- 2009: 7.14

- 2010: 6.34

- 2011: 7.79

- 2012: 7.77

- La prima aplicare (neanuntata)

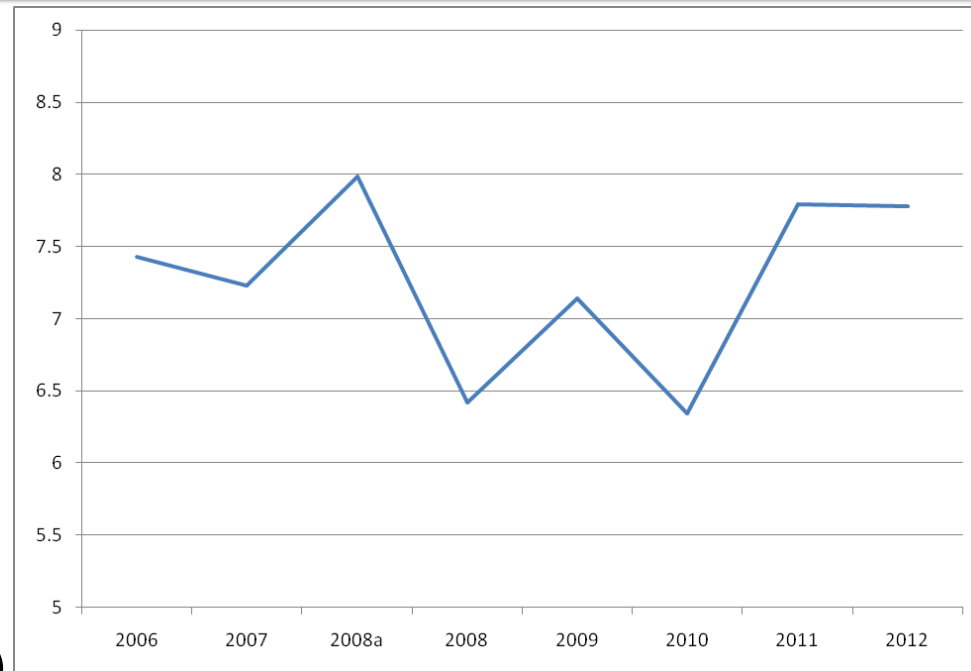
- 50% din studenti au parasit examenul in primele 10 minute

- 50% din cei ramasi nu au promovat

- promovabilitate totala 25%, rata contestatiilor: 0%

- Urmatoarele examinari (anuntate)

- rata contestatiilor: 0%



Examen

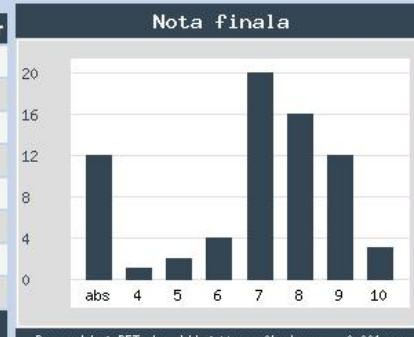


Note

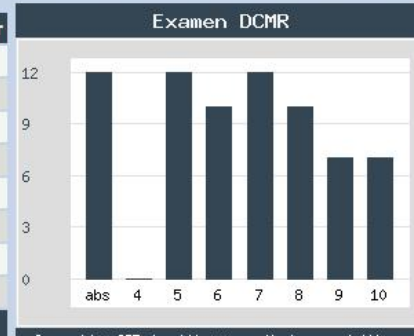
■ 2017/2018

Statistici

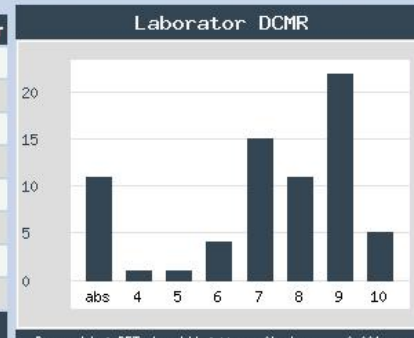
Nota.	Numar
abs	12
4	1
5	2
6	4
7	20
8	16
9	12
10	3
TOTAL	70



Exam.	Numar
abs	12
4	0
5	12
6	10
7	12
8	10
9	7
10	7
TOTAL	70



Labo.	Numar
abs	11
4	1
5	1
6	4
7	15
8	11
9	22
10	5
TOTAL	70



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[Laborator](#)

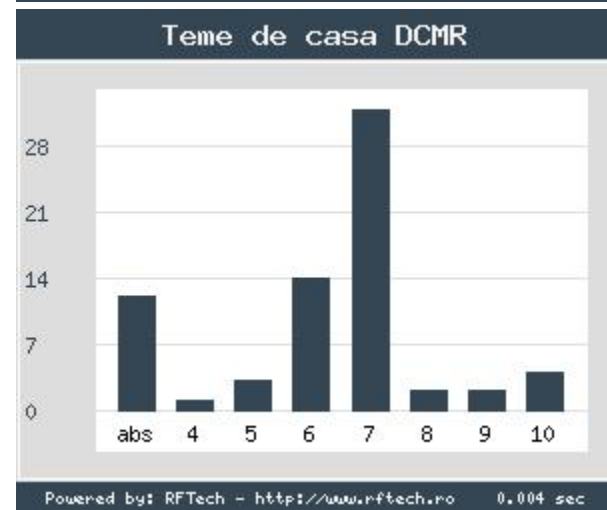
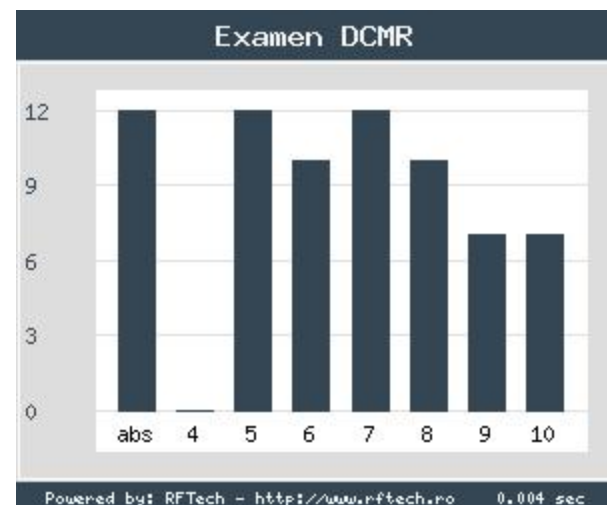
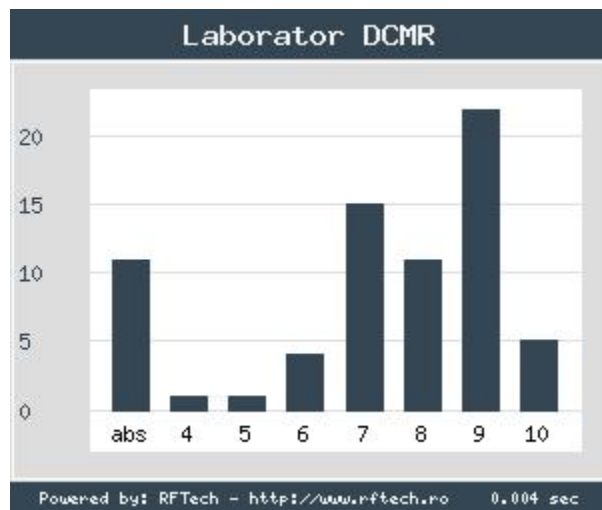
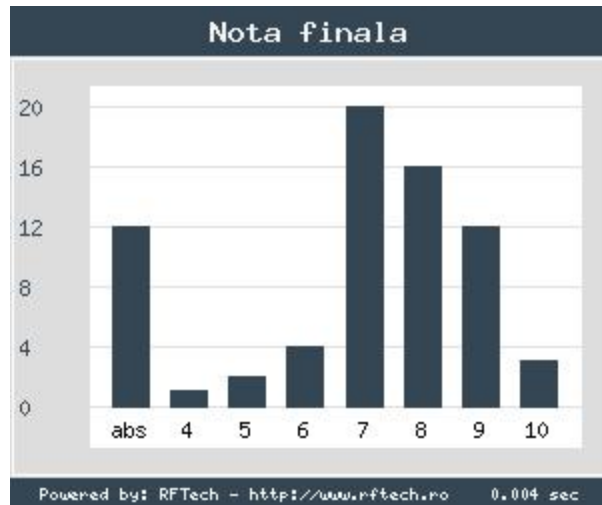
Liste

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Note

■ 2017/2018



Prezenta, Liste

D: 15%, (Teme de casa/Lucrari de specialitate)

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[Bonus-uri acumulate](#)

Materiale

- Prezenta
- Minim 7 prezente
- Bonus
- Teme proiect
- etc.

C 2017 Oportunitate de angajare

- Angajare **temporara** disponibila
- Salarizare lunara echivalenta **12800** lei/luna

C 2017 Oportunitate de angajare

- Extrase din evaluările calitative ale studenților (2017):
 - “70% dintre studenti au platit un student de an mai mare sa le faca proiectul, intre 30 si 50 de lei”
- Calcul

$$50 \text{ stud} \times 70\% \times 40 \text{ lei} = 1400 \text{ lei}$$

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

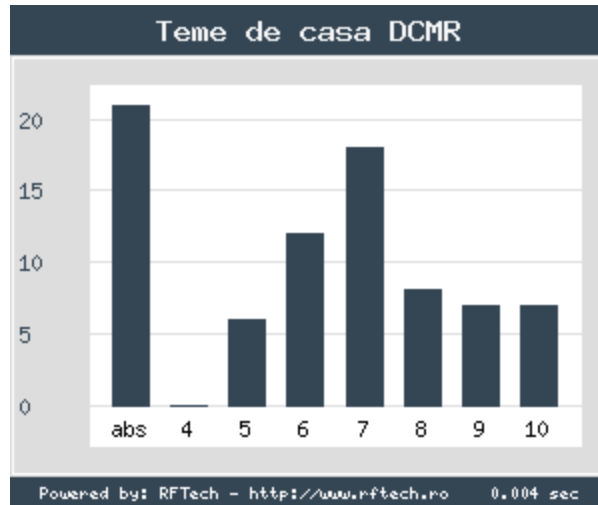
$$1 \text{ luna} = 4 \text{ sapt} \times 5 \text{ zile} \times 8 \text{ h} = 160 \text{ h}$$

$$\frac{1400 \text{ lei}}{17.5 \text{ h}} = \frac{12800 \text{ lei}}{160 \text{ h}} = \frac{12800 \text{ lei}}{1 \text{ luna}}$$

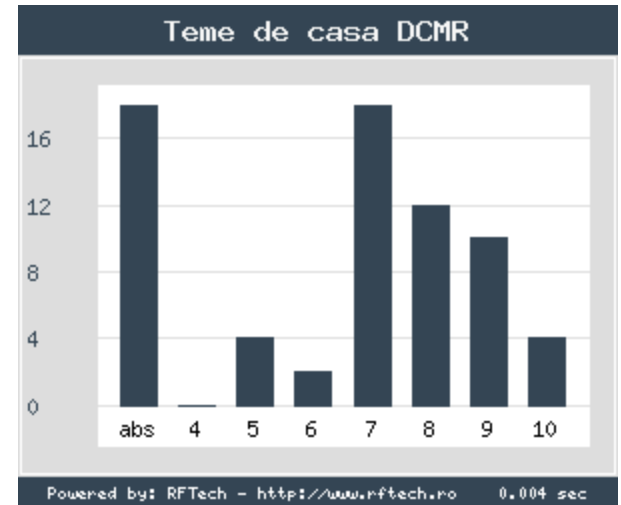
Efect?

■ factorul "andrei"

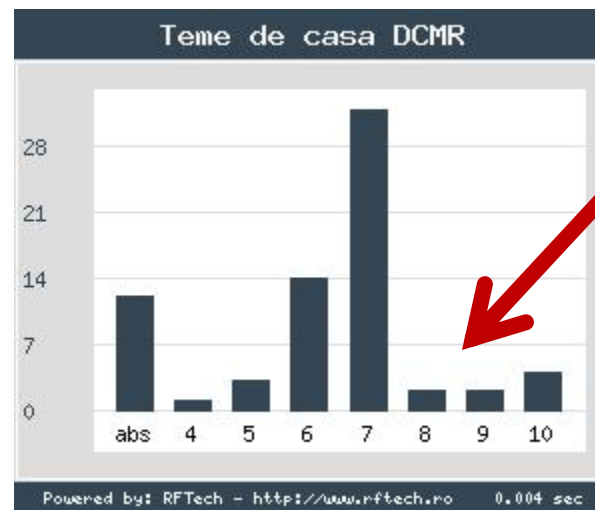
2015/6



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 în cont

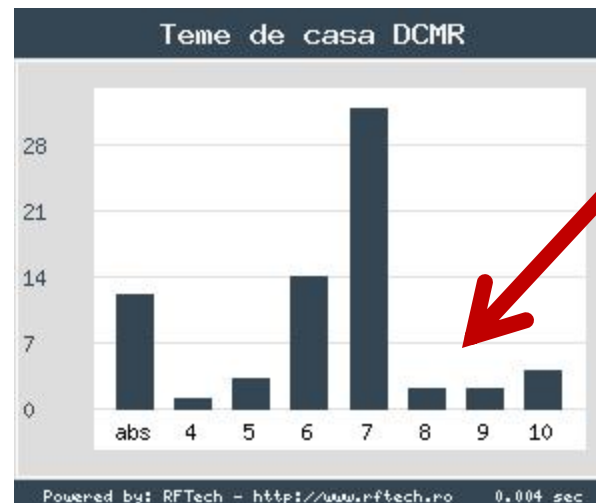
Morala 2017/2018

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

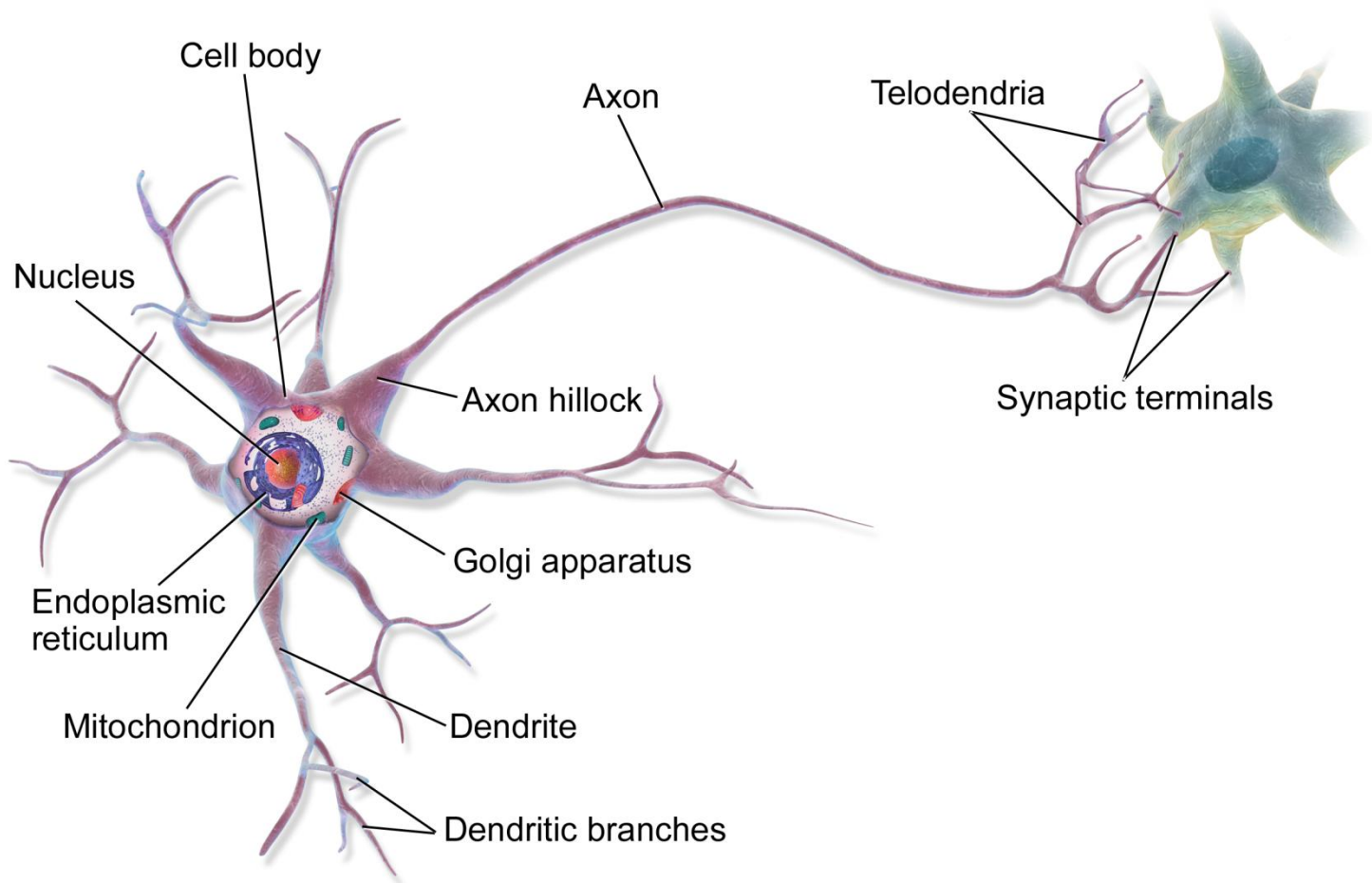
Proiect 2018/2019

- factorul "andrei" = $-2p$

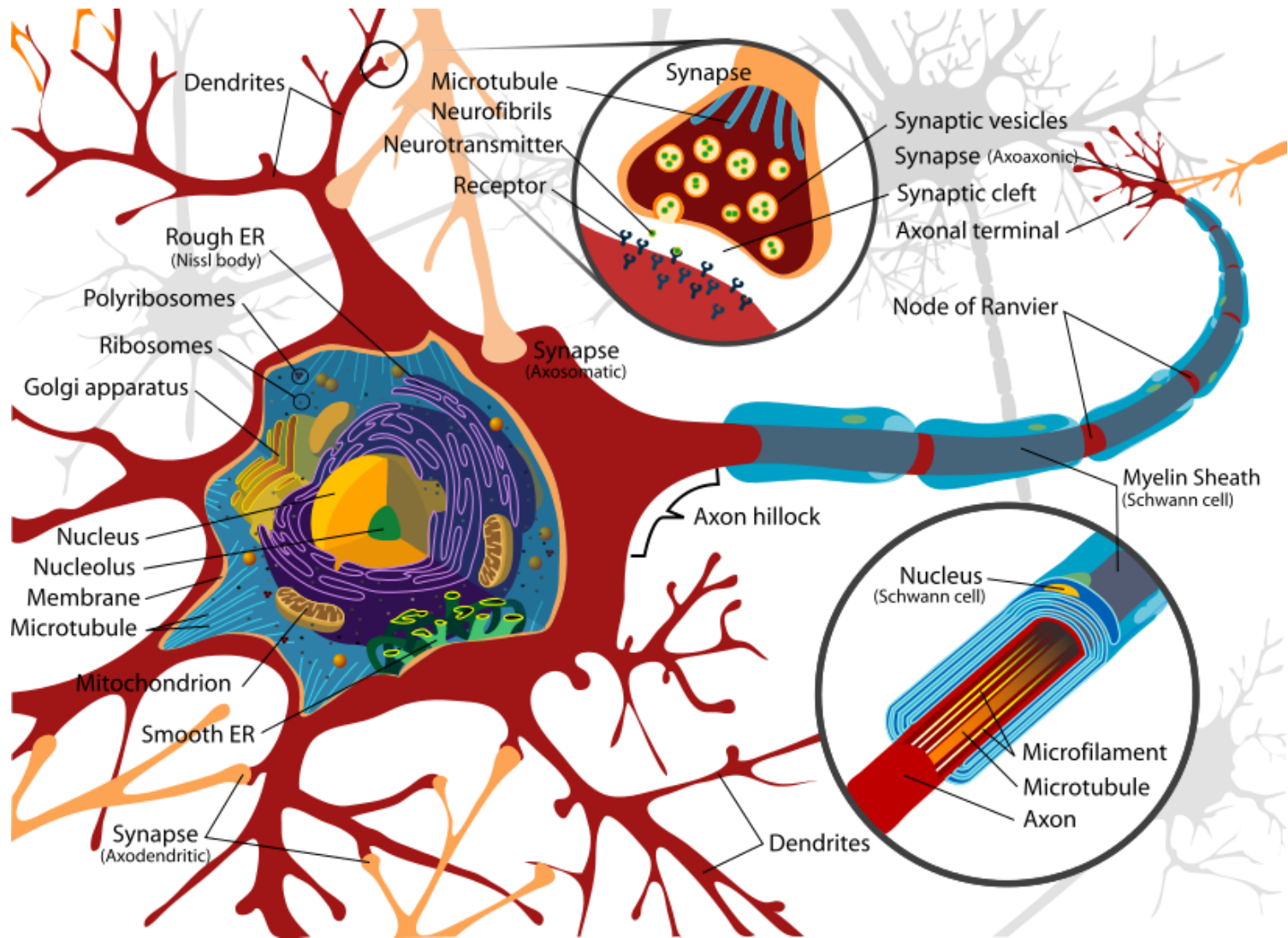
2017/8



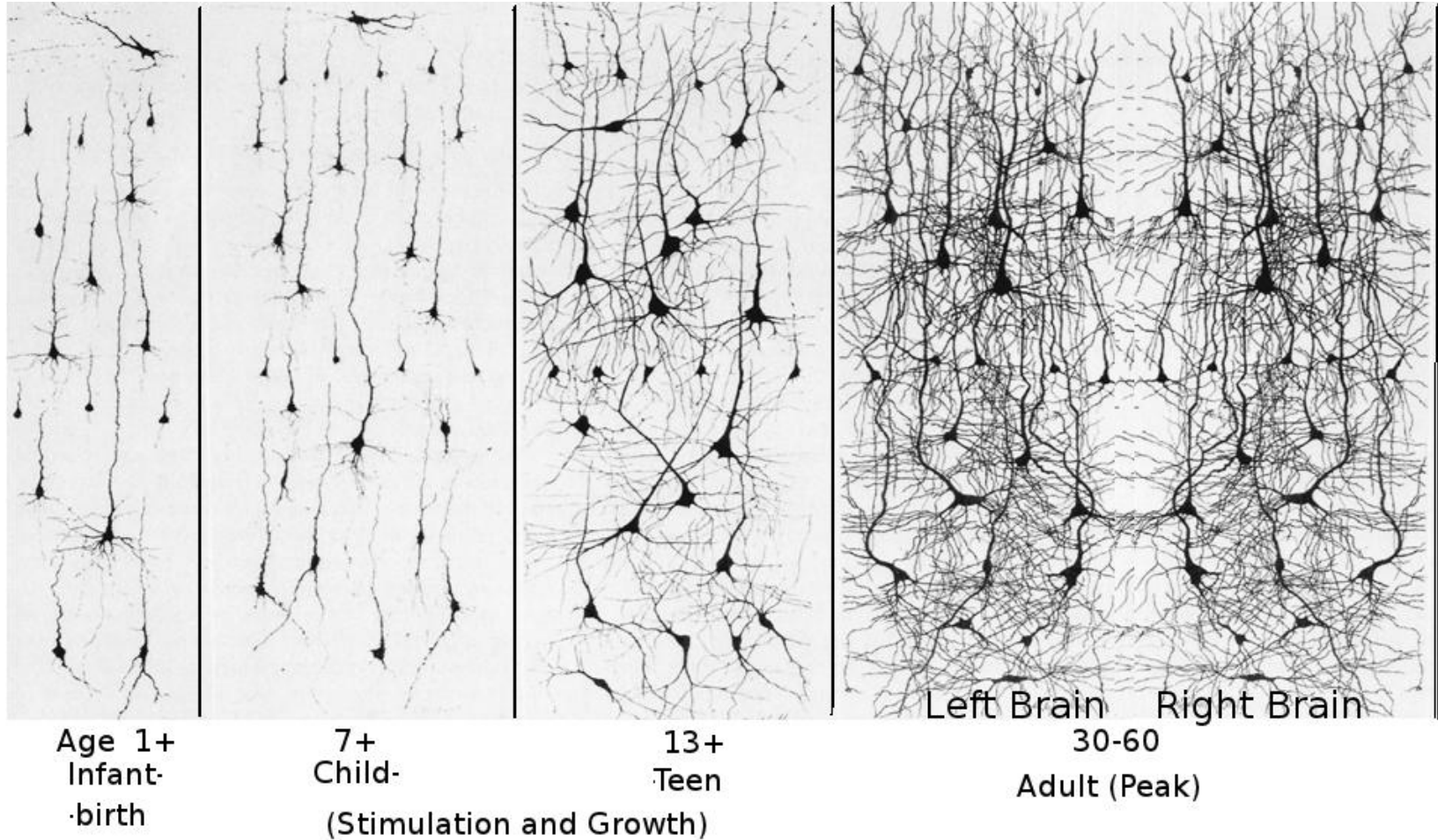
Scop curs 1



Scop curs 2



Scop curs 3



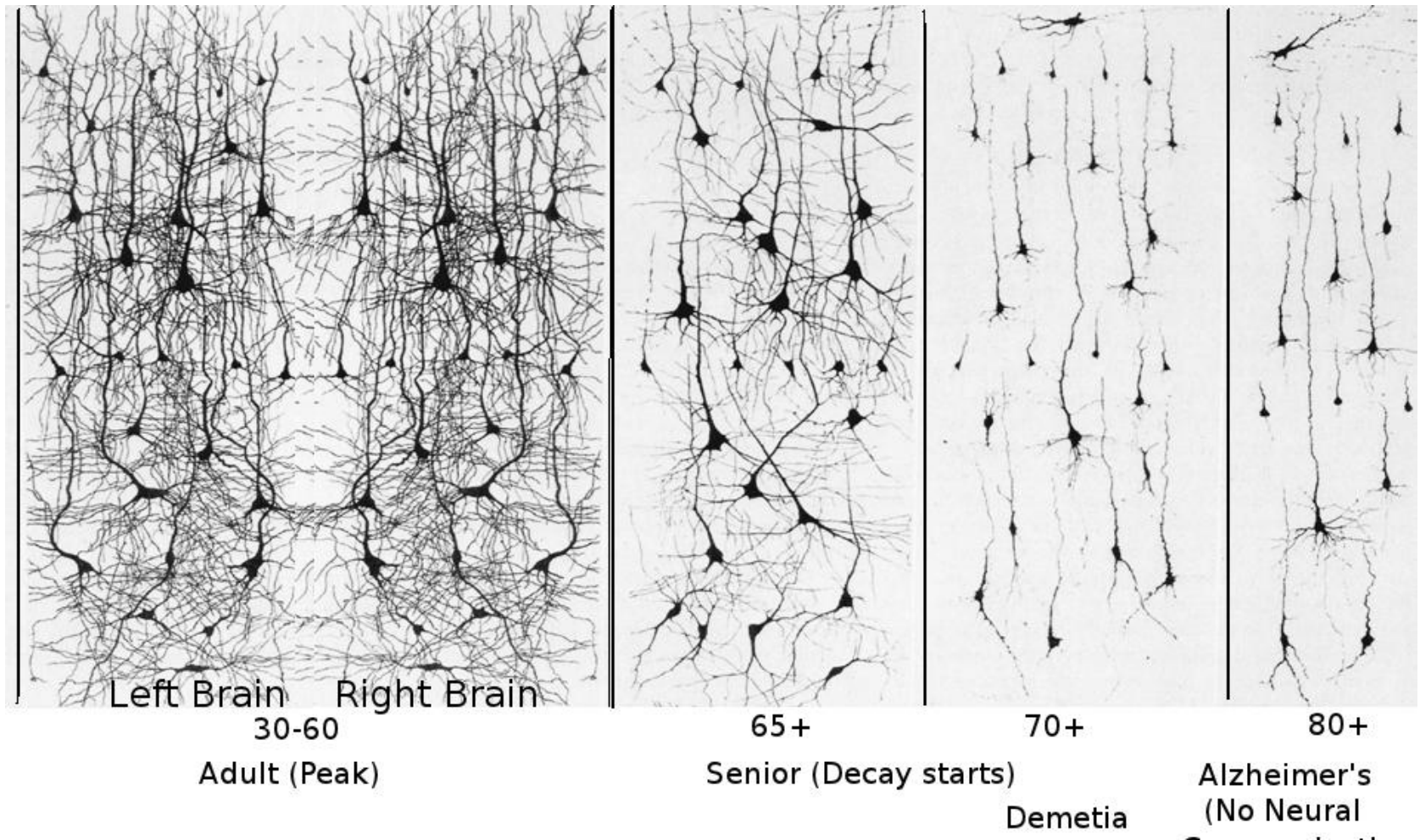
Scop curs 4



Sinapse
“înginerești”



Termen



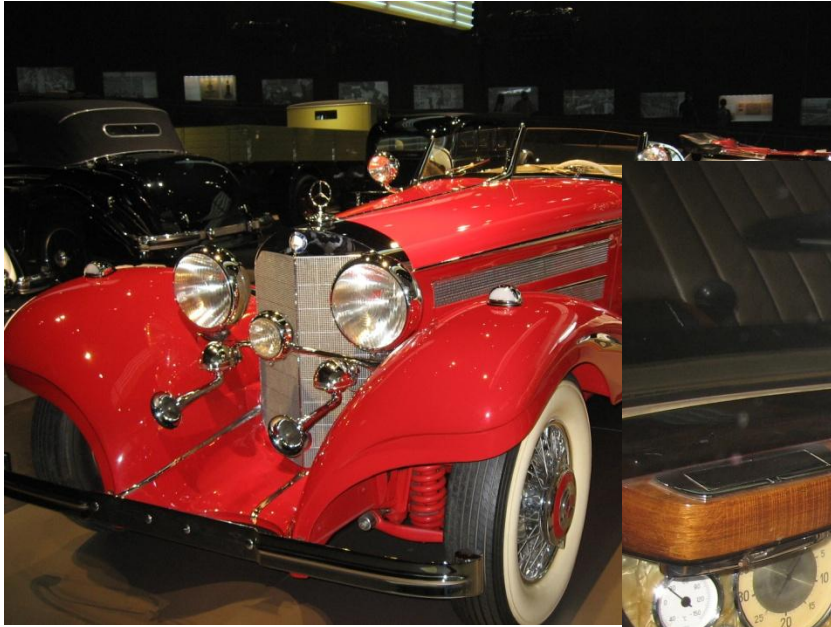
Cuprins

- Linii de transmisie
- Adaptarea de impedanță
- Cuploare direcționale
- Divizoare de putere
- Amplificatoare de microunde
- Filtre de microunde
- Oscilatoare de microunde ?

Bibliografie

- <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)

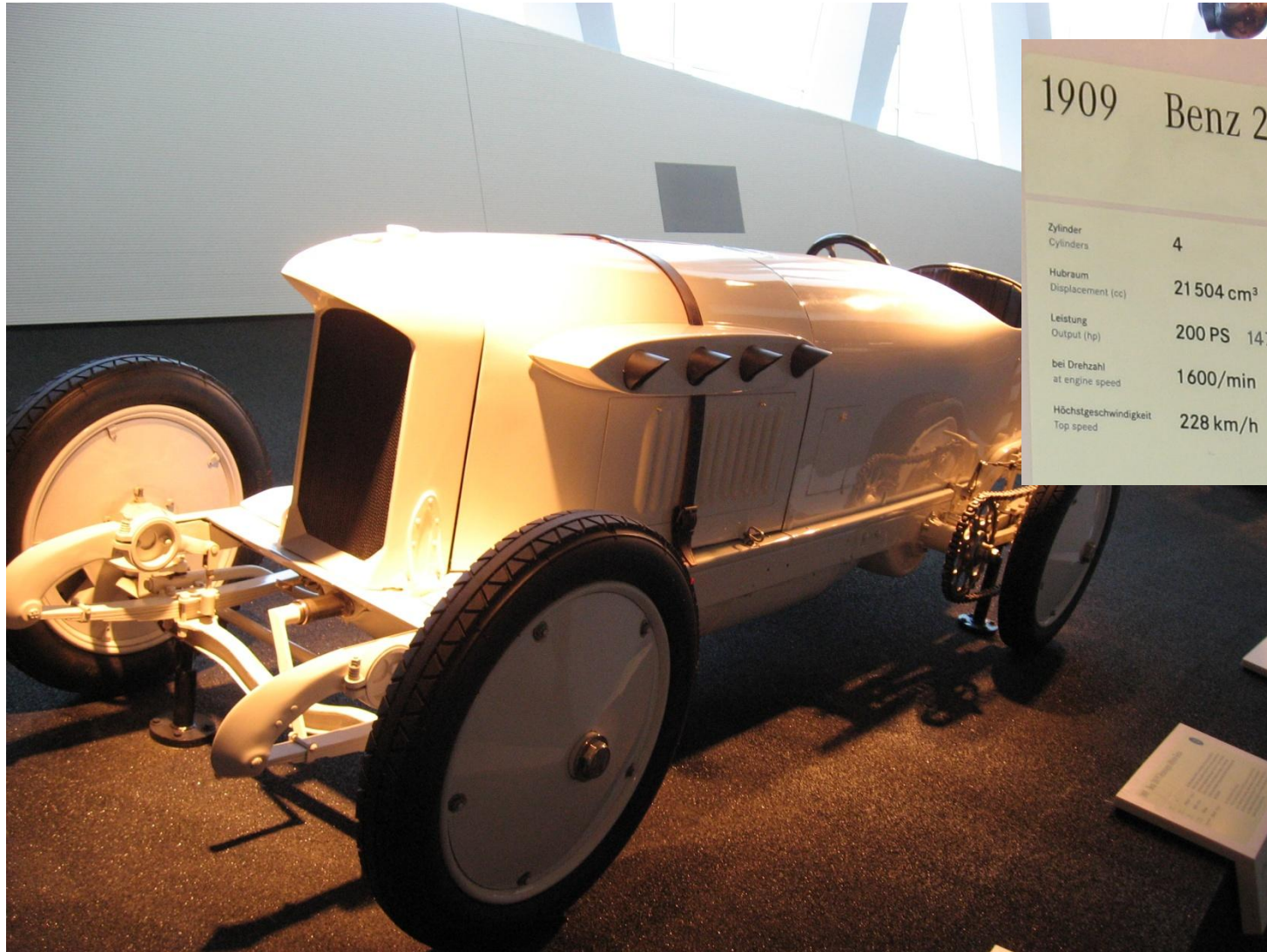
~1930



~1930



1909



1909 Benz 200 PS Rennwagen »Blitzen«

Zylinder Cylinders	4
Hubraum Displacement (cc)	21 504 cm ³ 1 312 cu in
Leistung Output (hp)	200 PS 147 kW
bei Drehzahl at engine speed	1600/min
Höchstgeschwindigkeit Top speed	228 km/h 142 mph

Der »Blitzen-Benz« ist 1909 der erste 200 km/h fähige. Seine größten Erfolge erzielt er mit dem 4-Zylinder-Motor ausgestattet. Rekordhalter Burman mit 228 km/h über die Sahara. Ist damit das schnellste Fahrzeug jeder Eisenbahn.

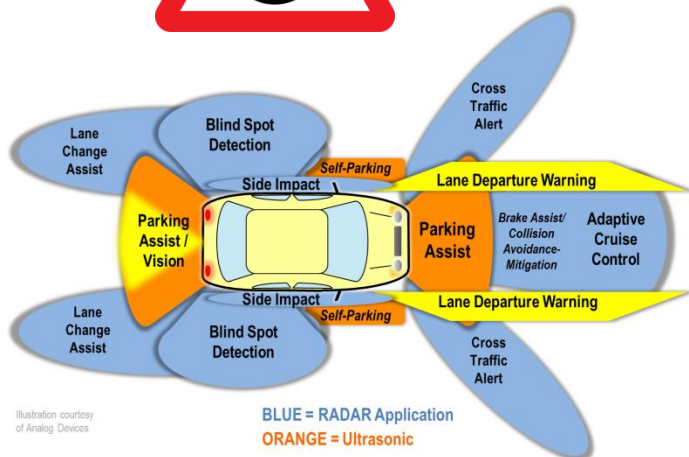
Benz »Lightning Benz« 200 hp racing car
In 1909 the Lightning Benz

1930-1950



Tehnologie

> 2010



< 1950



Tehnologie

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

$$2 \times 1 = 2$$

$$2 \times 2 = 4$$

$$2 \times 3 = 6$$

$$2 \times 4 = 8$$

$$2 \times 5 = 10$$

$$2 \times 6 = 12$$

$$2 \times 7 = 14$$

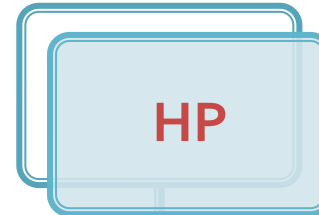
$$2 \times 8 = 16$$

$$2 \times 9 = 18$$

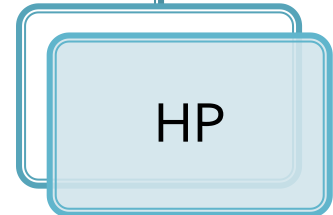
$$2 \times 10 = 20$$



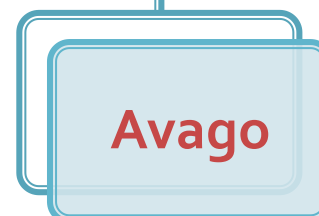
HEWLETT
PACKARD



1999



2005



Avago
TECHNOLOGIES

2014



 **Agilent Technologies**



KEYSIGHT
TECHNOLOGIES

NPL, Londra



NPL, Londra



Examen: Reprezentare logaritmică

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

$$0 \text{ dB} = 1$$

$$+ 0.1 \text{ dB} = 1.023 (+2.3\%)$$

$$+ 3 \text{ dB} = 2$$

$$+ 5 \text{ dB} = 3$$

$$+ 10 \text{ dB} = 10$$

$$-3 \text{ dB} = 0.5$$

$$-10 \text{ dB} = 0.1$$

$$-20 \text{ dB} = 0.01$$

$$-30 \text{ dB} = 0.001$$

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

$$0 \text{ dBm} = 1 \text{ mW}$$

$$3 \text{ dBm} = 2 \text{ mW}$$

$$5 \text{ dBm} = 3 \text{ mW}$$

$$10 \text{ dBm} = 10 \text{ mW}$$

$$20 \text{ dBm} = 100 \text{ mW}$$

$$-3 \text{ dBm} = 0.5 \text{ mW}$$

$$-10 \text{ dBm} = 100 \mu\text{W}$$

$$-30 \text{ dBm} = 1 \mu\text{W}$$

$$-60 \text{ dBm} = 1 \text{ nW}$$

$$[\text{dBm}] + [\text{dB}] = [\text{dBm}]$$

$$[\text{dBm/Hz}] + [\text{dB}] = [\text{dBm/Hz}]$$

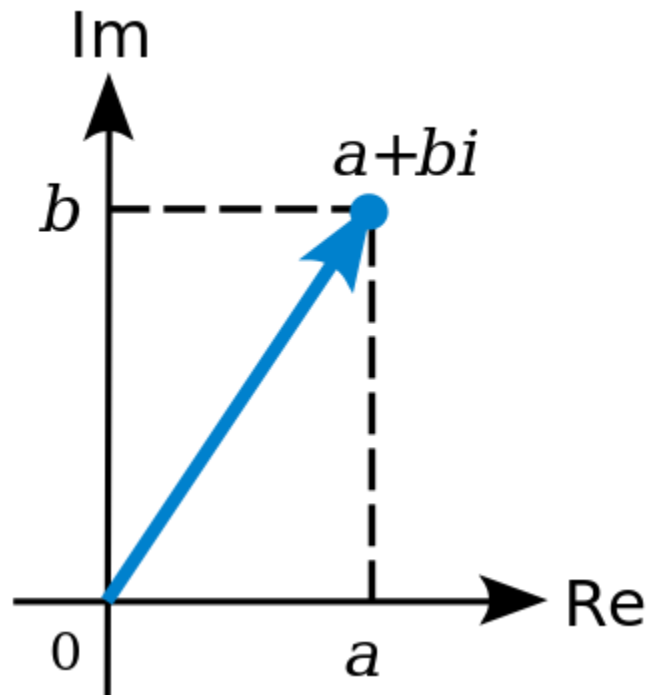
$$[x] + [\text{dB}] = [x]$$

Examen

- Operatii cu numere complexe!
- $z = a + j \cdot b ; j^2 = -1$

Plan complex

- abscisa – partea reala
- ordonata – partea imaginara
- oricare poate fi negativa, intregul plan, 4 cadrane



Operatii

- Adunare

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

- Scadere

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

- Inmultire

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

- Impartire

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

Complex Conjugat

- $z = a + j \cdot b$

- $z^* = a - j \cdot b$

- Simetric fata de axa **reala**

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

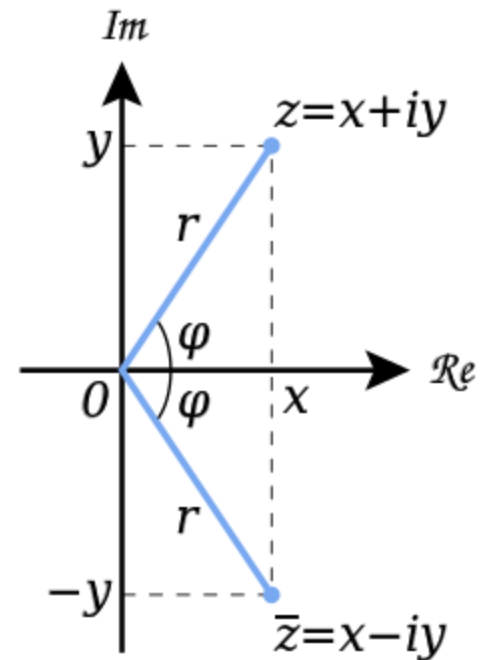
$$\operatorname{Im}(z) = b = \frac{1}{2 \cdot j} \cdot (z - z^*) = \frac{j}{2} \cdot (z^* - z)$$

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

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

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

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



Reprezentare polara

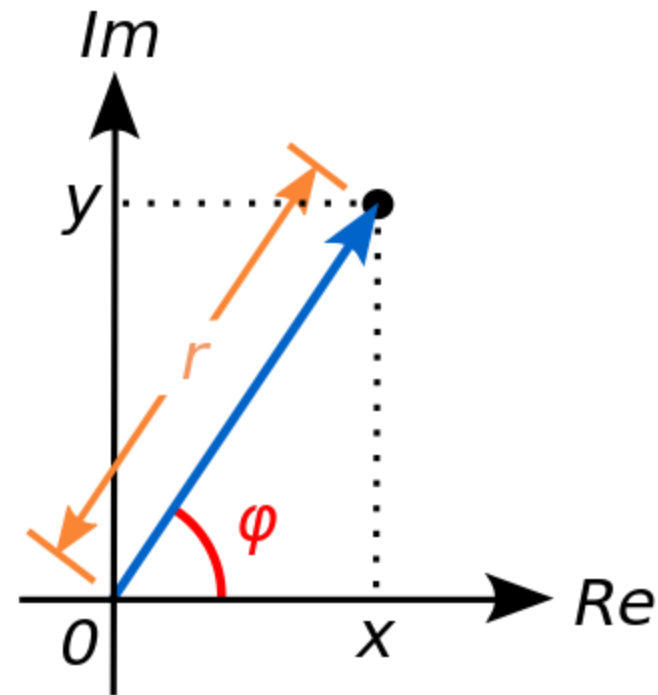
■ Reprezentare polara

- modul

- faza

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

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



Reprezentare polara

- Formula lui Euler

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

- Reprezentare polara

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

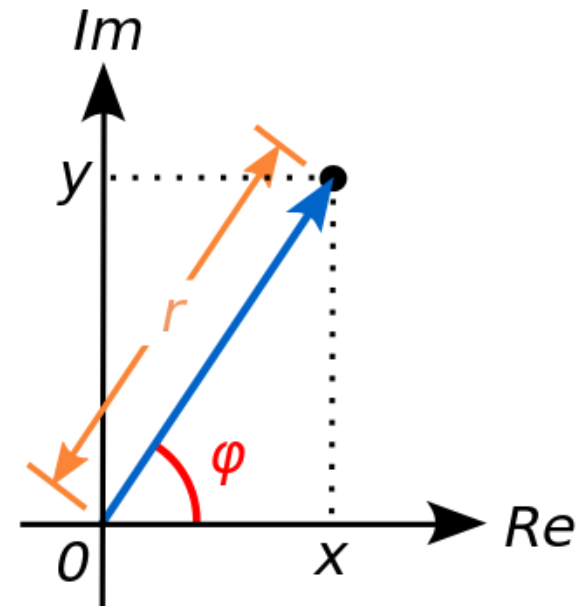
$$z = a + j \cdot b = |z| \cdot (\cos \varphi + j \cdot \sin \varphi)$$

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

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

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

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



Reprezentare polara

■ Reprezentare polara

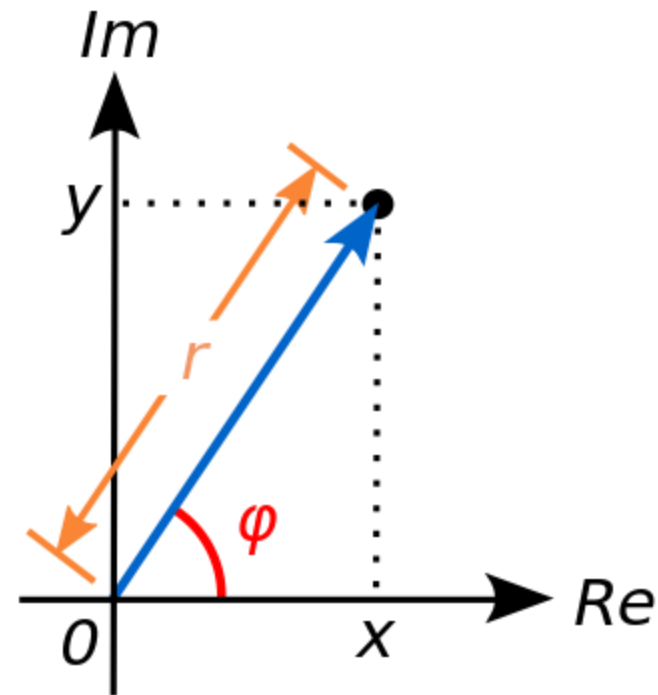
$$|z| = \sqrt{a^2 + b^2}$$

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

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

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

$$\begin{aligned} z^* &= (|z| \cdot e^{j \cdot \varphi})^* = |z| \cdot (\cos \varphi + j \cdot \sin \varphi)^* = |z| \cdot (\cos \varphi - j \cdot \sin \varphi) = \\ &= |z| \cdot [\cos(-\varphi) + j \cdot \sin(-\varphi)] = |z| \cdot e^{-j \cdot \varphi} \end{aligned}$$



Reprezentare polara

- unitate de masura standard – radiani
- unitate de masura traditionala in microunde – **grade format zecimal** (55.89°)

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

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

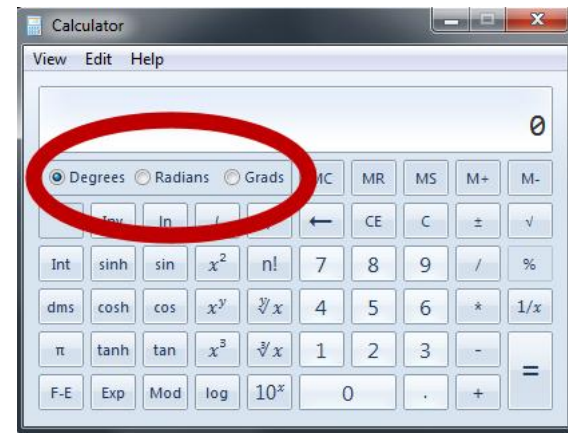
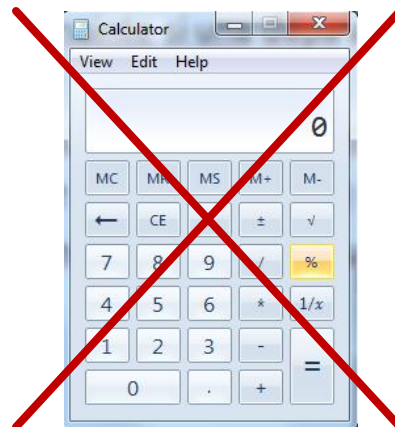


Reprezentare polara

- **Atentie la reprezentarea unghiurilor!!**
 - programele matematice – lucreaza standard in radiani
 - e necesara o **conversie** inainte si una dupa aplicarea unei functii trigonometrice
 - calculatoarele (stiintifice) au posibilitatea (de obicei) de a stabili unitatea de masura pentru unghiuri
 - e necesara **verificarea** unitatii de masura curente

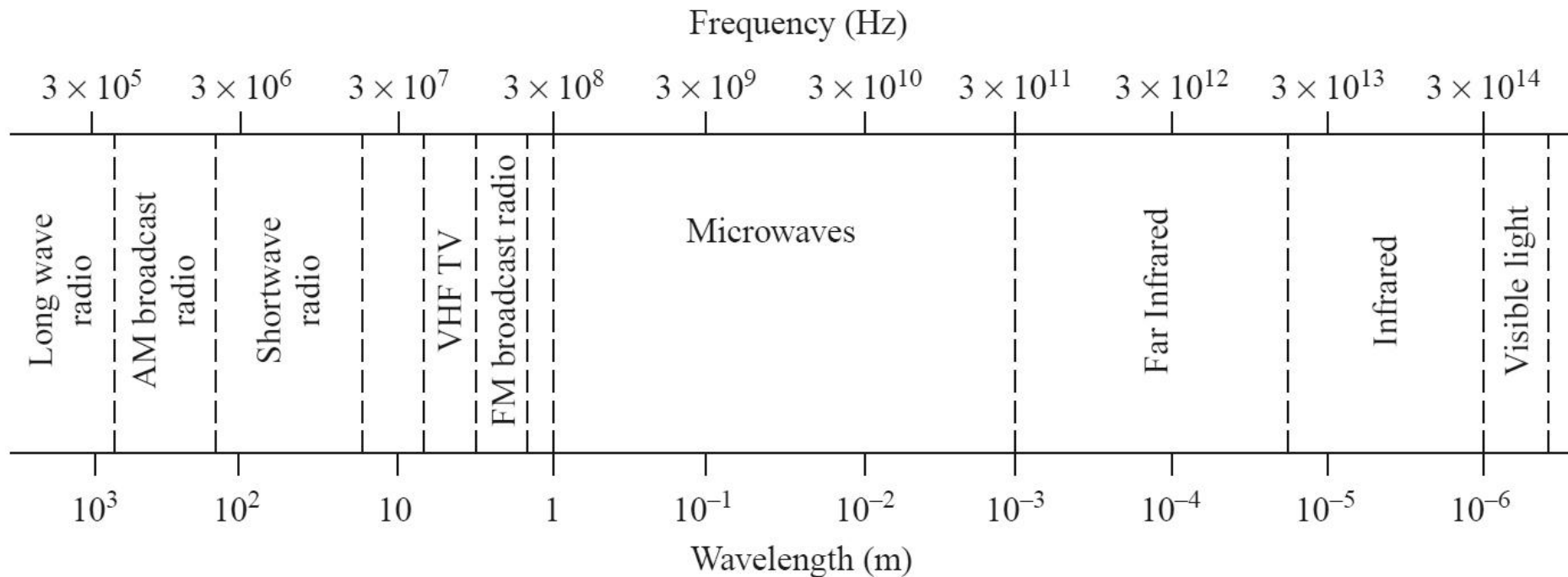
$$\varphi[^\circ] = 180^\circ \cdot \frac{\varphi[rad]}{\pi}$$

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



Introdurre

Microunde



- tipic
 - $f \approx 1 \div 3 \text{GHz} - 300 \text{GHz}$
 - $\lambda \approx 1 \text{mm} - 10 \text{cm}$

Microunde

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

~ Microunde

- Lungimea electrica a unui circuit
 - l – lungimea fizica
 - $E = \beta \cdot l$ – lungimea electrica

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

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

V, I variabile
~ inutile

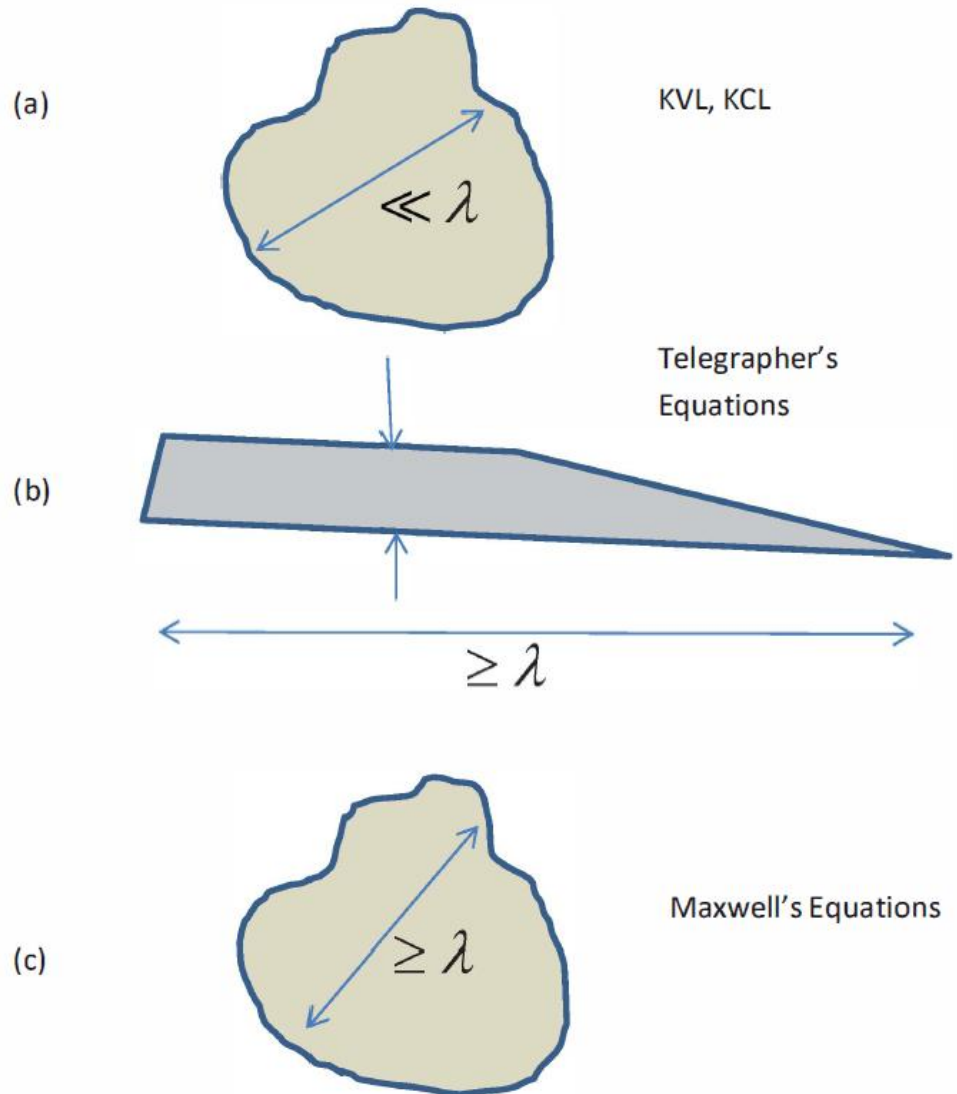
- Dependenta
 - castigul antenei
 - imaginea unui obiect pe radar

Lungime electrica

- Comportarea (descrierea) unui circuit depinde de lungimea sa electrica la frecventele de interes

- $E \approx 0 \rightarrow$ Kirchhoff
- $E > 0 \rightarrow$ propagare

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



Contact

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