

**Curs 2**

**2015/2016**

# **Dispozitive și circuite de microunde pentru radiocomunicații**

# Disciplina 2015/2016

- 2C/1L, DCMR (CDM)
- **Minim 7 prezente (curs+laborator)**
- Curs - **sl. Radu Damian**
  - Marti 18-20, P2
  - E – 60% din nota
  - probleme + (**? 1 subiect teorie**) + (2p prez. curs)
    - 3p=+0.5p
  - **toate materialele permise**
- Laborator – **sl. Radu Damian**
  - Miercuri 8-14 impar (14.10.2015 – prez. obligatorie)
  - L – 25% din nota
  - P – 15% din nota

# Fotografii

## FLORESCU DAN-CONSTANȚĂ



Date:

Grupa	5405 (2008)
Specializarea	Tehnologii si sisteme
Marca	3275

### Note obtinute

Disciplina	Tip	Data	Descriere	Nota	Obiectiv
<b>DCMR Dispozitive si circuite de microunde pentru radiocomunicații</b>					
	Nota	19/06/2009	Nota finală	10	
	Exam	19/06/2009	Examen DCMR	9	
	Tema	05/06/2009	Proiect DCMR	10	

## FLORESCU DAN-CONSTANȚĂ



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### Detalii

Finanțare	Buget
Bursa	Bursa de Studii
Domiciliu	Iasi, judet Iasi
Promovare	Promovare Integrala
Credite	60
Media	8.86

# Fotografii

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Start Didactic Master Colectiv Cercetare Studenti Admin

Note Lista Studenti Fotografi Statistici

Grupa 5403

Nr.	Student	Prezent	Nr.	Student	Prezent	Nr.	Student	Prezent
1	ANGHELUS IONUT-MARCUS		Prezent: <input type="checkbox"/>	2	ANTIGHIN FLORIN-RAZVAN		<b>Fotografia nu exista</b>	Prezent: <input type="checkbox"/>
		Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/>			Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/>			Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/>
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4	APOSTOL PAVEL-MANUEL		Prezent: <input type="checkbox"/>	5	BALASCA TUDIAN-PETRU		<b>Fotografia nu exista</b>	Prezent: <input checked="" type="checkbox"/>
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		Obs: <input type="text"/>			Obs: <input type="text"/>			Obs: <input type="text"/>
7	BOTEZAT EMANUEL		Prezent: <input type="checkbox"/>	8	BUTUNOI GEORGE-MADALIN		<b>Fotografia nu exista</b>	Prezent: <input type="checkbox"/>
		Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/>			Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/>			Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/>
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		Obs: <input type="text"/>			Obs: <input type="text"/>			Obs: <input type="text"/>
10	CHIRITOIU CATERINA		Prezent: <input type="checkbox"/>	11	CODOC MARIUS		<b>Fotografia nu exista</b>	Prezent: <input type="checkbox"/>
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		Obs: <input type="text"/>			Obs: <input type="text"/>			Obs: <input type="text"/>

Nr. Student

Prezent

2 ANTIGHIN  
FLORIN-RAZVAN

**Fotografia  
nu exista**

Prezent:

Puncte: 0

Nota: 0

Obs:

# Introducere

# Ecuatiile lui Maxwell

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

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

$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \cdot J = -\frac{\partial \rho}{\partial t}$$

## ■ Ecuatii constitutive

$$D = \epsilon \cdot E$$

$$B = \mu \cdot H$$

$$J = \sigma \cdot E$$

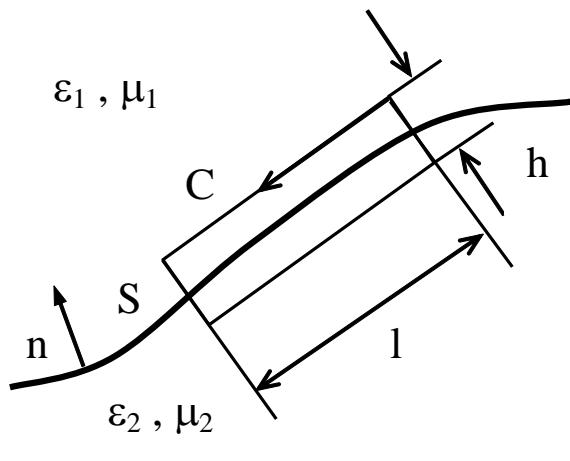
- În vid

$$\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$$

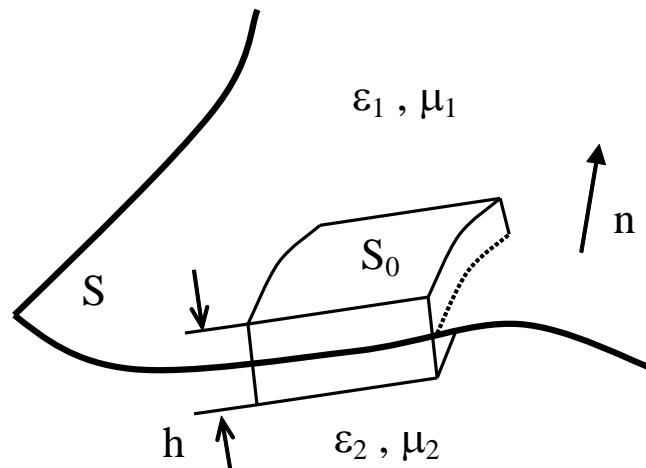
$$\epsilon_0 = 8,854 \times 10^{-12} \text{ F/m}$$

$$c_0 = \frac{1}{\sqrt{\epsilon_0 \cdot \mu_0}} = 2,99790 \cdot 10^8 \text{ m/s}$$

# Condiții la limita de separație între două medii



a)



b)

$$n \times (E_1 - E_2) = 0$$

$$n \cdot (D_1 - D_2) = \rho_s$$

$$n \times (H_1 - H_2) = J_s$$

$$n \cdot (B_1 - B_2) = 0$$

- Daca un mediu este metal ideal toate campurile se anuleaza in interior

# Câmpuri electromagnetic cu variație armonică în timp

$$X = X_0 e^{j \cdot \omega \cdot t} \quad \frac{\partial X}{\partial t} = j \cdot \omega \cdot X$$

$$g(\omega) = \int_{-\infty}^{\infty} f(t) \cdot e^{-j\omega t} dt \quad f(t) = \int_{-\infty}^{\infty} g(\omega) \cdot e^{j\omega t} d\omega$$

- Simplificarea ecuațiilor lui Maxwell

$$\nabla^2 E + \omega^2 \epsilon \mu E = j \omega \mu J + \frac{1}{\epsilon} \nabla \rho$$

$$\nabla^2 H + \omega^2 \epsilon \mu H = -\nabla \times J$$

$$\nabla \cdot E = \frac{\rho}{\epsilon}$$

$$\nabla \cdot H = 0$$

# Ecuățiile de propagare

- Ecuățiile Helmholtz sau ecuațiile de propagare

Mediu lipsit de sarcini electrice

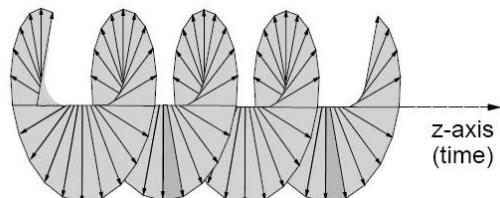
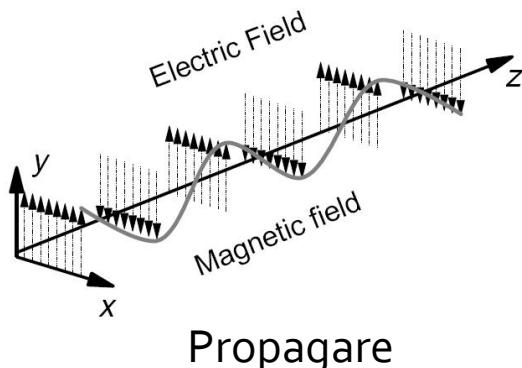
$$\nabla^2 E - \gamma^2 E = 0$$

$$\nabla^2 H - \gamma^2 H = 0$$

$$\gamma^2 = -\omega^2 \epsilon \mu + j \omega \mu \sigma$$

$\gamma$  – Constanta de propagare

# Solutia ecuatiilor de propagare



Polarizare circulara

Camp electric dupa directia Oy,  
propagare dupa directia Oz

$$E_y = E_+ e^{-\gamma \cdot z} + E_- e^{\gamma \cdot z}$$

$$\gamma = \sqrt{-\omega^2 \epsilon \mu + j \omega \mu \sigma} = \alpha + j \cdot \beta$$

Exista numai unda progresiva  $E_+ \Rightarrow A$

$$E_y = A e^{-(\alpha + j \cdot \beta) \cdot z}$$

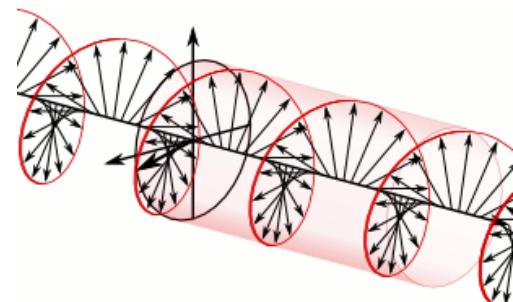
Camp armonic

$$E_y = A \cdot e^{-\alpha \cdot z} \cdot e^{j(\omega \cdot t - \beta \cdot z)}$$

Amplitudine

Atenuare

Propagare  
(variatie in timp si spatiu)



# Atenuare

$$E_y(z_1) = Ct \cdot e^{-\alpha \cdot z_1} \cdot e^{j(\omega t - \beta \cdot z_1)}$$

$$E_y(z_2) = Ct \cdot e^{-\alpha \cdot z_2} \cdot e^{j(\omega t - \beta \cdot z_2)}$$

$$W, P \sim \int E^2$$

$$A = \frac{P_2}{P_1} = \frac{Ct^2 \cdot e^{-2\alpha \cdot z_2}}{Ct^2 \cdot e^{-2\alpha \cdot z_1}} = e^{-2\alpha \cdot (z_2 - z_1)}$$

$$A[dB] = 10 \log_{10} \frac{P_2}{P_1} = 10 \log_{10} [e^{-2\alpha \cdot (z_2 - z_1)}]$$

$$A[dB] = -20 \cdot \alpha \cdot (z_2 - z_1) \log_{10} e = -8.686 \cdot \alpha \cdot (z_2 - z_1)$$

$$A / L[dB / km] = -8.686 \cdot \alpha < 0$$

- ▶ Atenuarea se exprima de obicei in **dB/km**
  - ▶ de obicei valori pozitive
  - ▶ semnul = **implicit**

# Reprezentare logarithmică

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$-20 \text{ dBm} = 1 \mu\text{W}$$

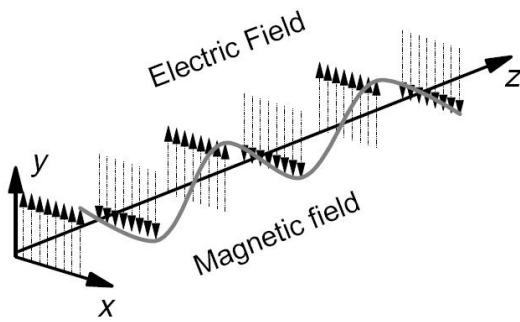
$$-30 \text{ dBm} = 1 \text{ nW}$$

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

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

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

# Parametri de propagare



$$\nabla \times E = -j\omega\mu \cdot H$$

$$H_x = \frac{j\gamma \cdot E_y}{\omega\mu}$$

Mediu fara pierderi,  $\sigma = 0$

$$\gamma = j\omega \cdot \sqrt{\epsilon\mu}$$

$$\eta = \frac{E_y}{H_x} = \sqrt{\frac{\mu}{\epsilon}} \quad \text{Impedanta intrinseca a mediului}$$

$$E_y = A \cdot e^{-\alpha \cdot z} \cdot e^{j(\omega \cdot t - \beta \cdot z)} \quad \text{punctele de faza constante:} \quad (\omega \cdot t - \beta \cdot z) = \text{const}$$

Viteza de faza

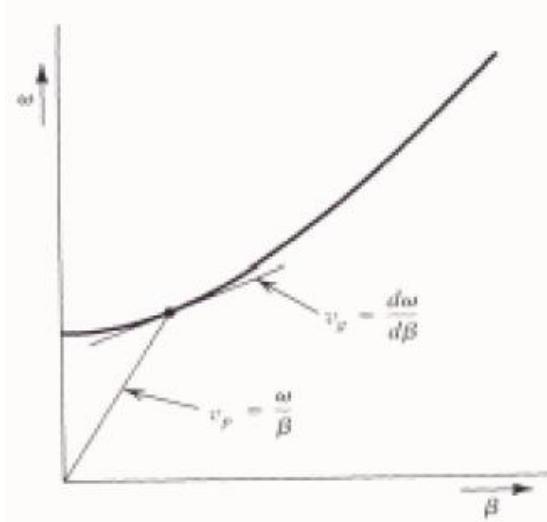
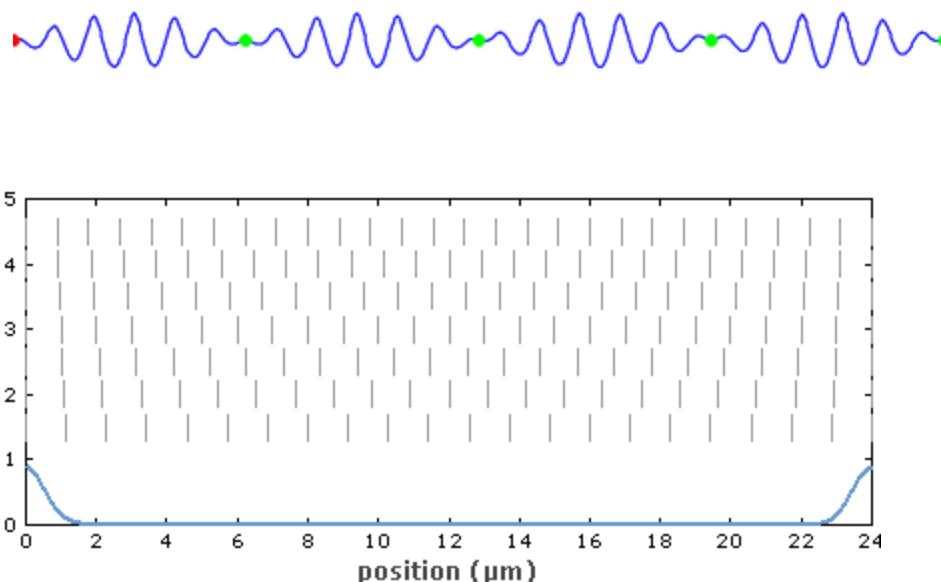
$$v = \frac{dz}{dt} = \frac{\omega}{\beta} = \frac{1}{\sqrt{\epsilon\mu}}$$

Viteza de grup

$$v_g = \frac{dz}{dt} = \frac{d\omega}{d\beta} \quad \text{in medii dispersive unde } \beta = \beta(\omega)$$

# Viteze de grup și fază

- Viteza de fază – viteza virtuală cu care circula punctul cu o anumita fază
- Viteza de grup – viteza cu care circula informația (energia)



# Parametri de propagare

## ■ În vid

$$\eta_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} = 377\Omega \quad v = v_g = c_0 \quad c_0 = \frac{1}{\sqrt{\epsilon_0 \cdot \mu_0}} = 2,99790 \cdot 10^8 \text{ m/s}$$

$$\lambda_0 = \frac{2\pi}{\beta} = \frac{c_0}{f}$$

Periodicitate în spațiu

$$T = \frac{2\pi}{\omega} = \frac{1}{f}$$

Periodicitate în timp

## ■ În mediu nedispersiv $\epsilon_r$

$$c = \frac{1}{\sqrt{\epsilon \cdot \mu_0}} = \frac{1}{\sqrt{\epsilon_0 \epsilon_r \cdot \mu_0}} = \frac{c_0}{\sqrt{\epsilon_r}}$$

$$n = \sqrt{\epsilon_r} \quad \text{Indice de refractie al mediului}$$

$$c = \frac{c_0}{n}$$

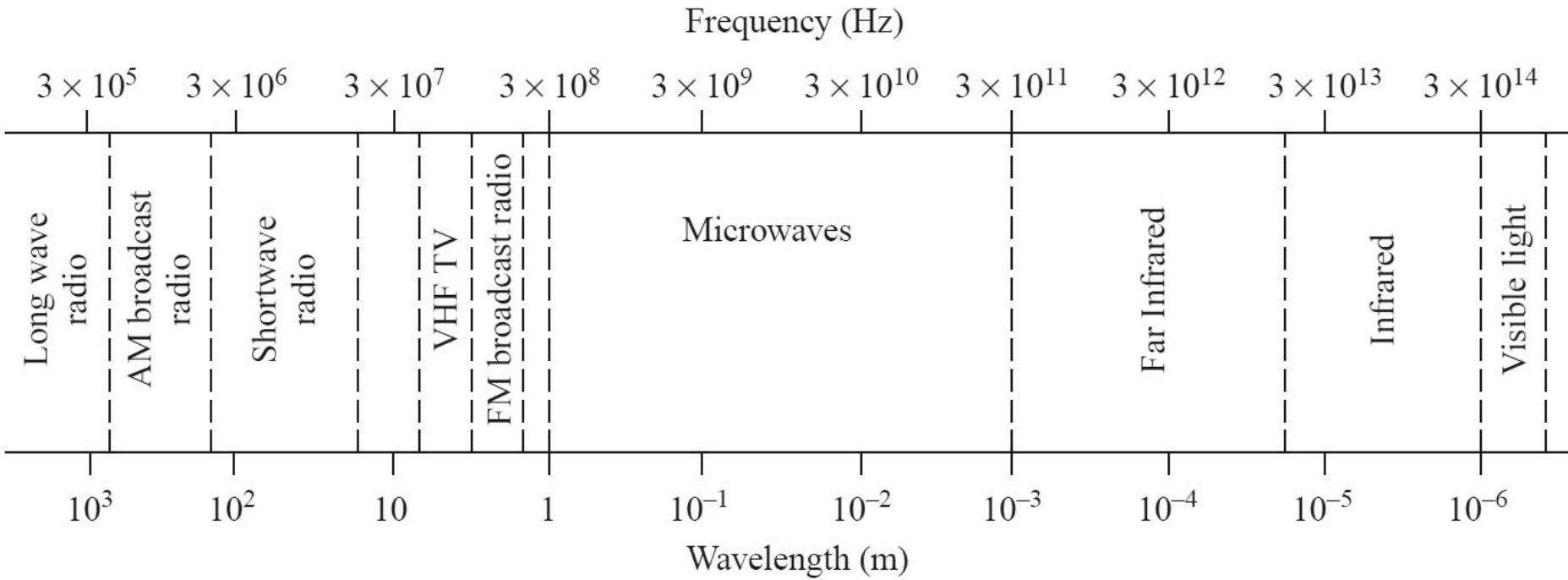
$$T = \frac{2\pi}{\omega} = \frac{1}{f}$$

$$\lambda = \frac{2\pi}{\beta} = \frac{c}{f}$$

$$\lambda = \frac{c_0}{\sqrt{\epsilon_r \cdot f}} = \frac{\lambda_0}{\sqrt{\epsilon_r}}$$



# Microunde



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

# 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

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

V, l variabile  
~ inutile

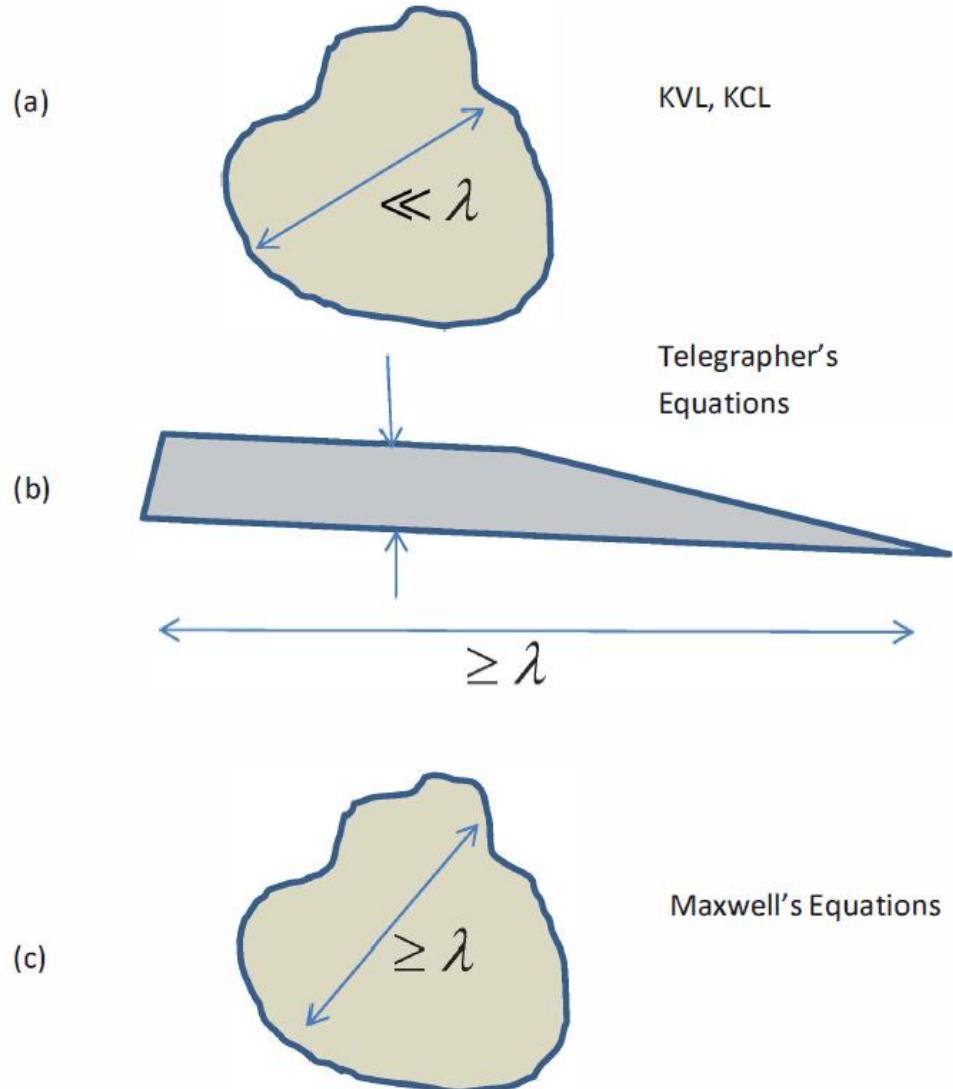
$$E = \beta \cdot l = \frac{2\pi}{c_0} \cdot \left( l \cdot f \cdot \sqrt{\epsilon_r} \right)$$

- Dependenta
  - castigul antenei
  - imaginea unui obiect pe radar

# Lungimea electrică

- Comportarea (descrierea) unui circuit depinde de lungimea sa electrică la frecvențele de interes

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



# Solutia ecuatiilor de propagare

$$E_y = E^+ e^{-\gamma \cdot z} + E^- e^{\gamma \cdot z}$$

$$\gamma = \sqrt{-\omega^2 \epsilon \mu + j\omega \mu \sigma} = \alpha + j \cdot \beta$$

Camp electric dupa directia Oy,  
propagare dupa directia Oz

## ■ unda

- incidenta
- reflectata

## ■ unda

- directa
- inversa

$$E_y = E^+ \cdot e^{-\alpha \cdot z} \cdot e^{j(\omega \cdot t - \beta \cdot z)}$$

$$(\omega \cdot t - \beta \cdot z) = \text{const}$$

$$E_y = E^- \cdot e^{\alpha \cdot z} \cdot e^{j(\omega \cdot t + \beta \cdot z)}$$

$$(\omega \cdot t + \beta \cdot z) = \text{const}$$

punctele  
de faza  
constanta:

# Solutia ecuatiilor de propagare

## ■ unda

- incidenta
- reflectata

$$E_y = E^+ \cdot e^{-\alpha \cdot z} \cdot e^{j(\omega \cdot t - \beta \cdot z)} + E^- \cdot e^{-\alpha \cdot z} \cdot e^{j(\omega \cdot t + \beta \cdot z)}$$

$$H_z = H^+ \cdot e^{-\alpha \cdot z} \cdot e^{j(\omega \cdot t - \beta \cdot z)} + H^- \cdot e^{-\alpha \cdot z} \cdot e^{j(\omega \cdot t + \beta \cdot z)}$$

## ■ unda

- directa
- inversa

$$V(z) = V^+ \cdot e^{-\alpha \cdot z} \cdot e^{j(\omega \cdot t - \beta \cdot z)} + V^- \cdot e^{-\alpha \cdot z} \cdot e^{j(\omega \cdot t + \beta \cdot z)}$$

$$I(z) = I^+ \cdot e^{-\alpha \cdot z} \cdot e^{j(\omega \cdot t - \beta \cdot z)} + I^- \cdot e^{-\alpha \cdot z} \cdot e^{j(\omega \cdot t + \beta \cdot z)}$$

$$V(z) = V^+ \cdot e^{j(\omega \cdot t - \beta \cdot z)} + V^- \cdot e^{j(\omega \cdot t + \beta \cdot z)}$$

# Contact

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