Curs 2

2026/2027

Dispozitive şi circuite de microunde pentru radiocomunicații

Disciplina 2026/2027

- 2C/1L/1P, **DCMR (CDM)**
- **Minim 14 prezente (curs+laborator+proiect)**
- Curs - **conf. Radu Damian**
  - Vineri 8-10/**Video (istoric)**, C1, corp C
  - E – **40%** din nota
  - **probleme** + (2p prez. curs) + (3 teste) + (bonus activitate)
    - primul test L1: ~01.10.2025 (t2 si t3 neanuntate la **curs**)
    - 3pz (C) ≈ +0.5p (**2p** max)
  - **toate materialele permise**

Disciplina 2026/2027

- 2C/1L/1P, **DCMR (CDM)**
- Laborator – **conf. Radu Damian**
  - Miercuri 08-16, **II.13**
  - Joi 12-20, **I.08**
  - L – **30%** din nota
    - ADS, tema personala
    - prezenta + **rezultate personale!**
  - P – **30%** din nota
    - ADS, tema personala
  - S1÷14: 3P, 7L, 4P
    - prezenta cu alte grupe **permisa** in limita numarului de calculatoare disponibile

Documentatie

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



Scop curs 4





Sinapse "inginerești"

Cuprins

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

Bibliografie

- https://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)

Examen: Reprezentare logaritmică

- $\boldsymbol{X[dB] = 10 \cdot log_{10}(X[lin])}$
- $X[B] = log_{10}(X[lin])$
- X[lin] – adimensional
- $log(A \cdot B) = log(A) + log(B)$

- $\boldsymbol{X[lin] = 10^{X[dB]/10}}$

Examen: Reprezentare logaritmică

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]

Calculul atenuarii/amplificarii

$$\text{Atenuare} = \frac{P_{out}}{P_{in}} < 1 \qquad \text{Pierderi[dB]} = 10 \cdot \log_{10}\left(\frac{P_{out}}{P_{in}}\right) < 0$$

$$\text{Pierderi/Atenuare[dB]} = [-]\ 10 \cdot \log_{10}\left(\frac{P_{out}}{P_{in}}\right)$$

$$\text{Castig} = \frac{P_{out}}{P_{in}} > 1$$

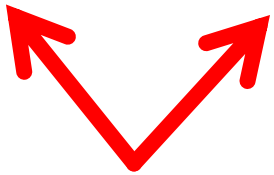
$$\text{Castig/Amplificare[dB]} = 10 \cdot \log_{10}\left(\frac{P_{out}}{P_{in}}\right) > 0$$

$$\text{Atenuare[dB/km]} = \frac{\text{Pierderi[dB]}}{\text{Lungime[km]}}$$

Calculul atenuarii/amplificarii

Pierderi/Atenuare $\rightarrow P_{out} < P_{in} \rightarrow P_{out}[\text{dBm}] < P_{in}[\text{dBm}]$

$$P_{out}[\text{dBm}] = P_{in}[\text{dBm}] - \text{Pierderi/Atenuare}[\text{dB}]$$



Castig/Amplificare $\rightarrow P_{out} > P_{in} \rightarrow P_{out}[\text{dBm}] > P_{in}[\text{dBm}]$

$$P_{out}[\text{dBm}] = P_{in}[\text{dBm}] + \text{Castig/Amplificare}[\text{dB}]$$



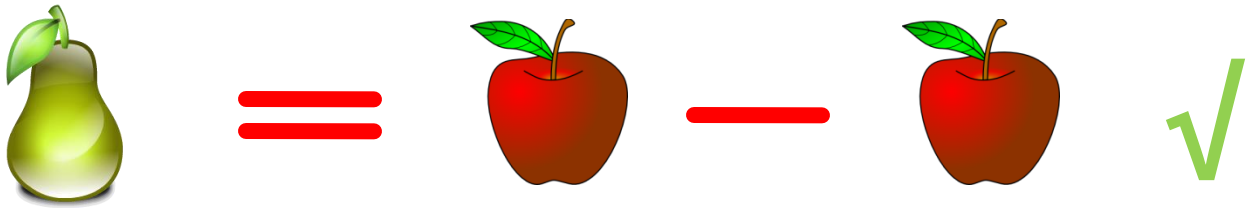
Calculul atenuarii/amplificarii

$$\text{Pierderi/Castig} = \frac{P_{out}}{P_{in}}$$

$$\text{Pierderi}[\text{dB}] = [-]10 \cdot \log_{10}\left(\frac{P_{out}}{P_{in}}\right)$$

$$\text{Pierderi}[\text{dB}] = [-]10 \cdot \log_{10}\left(\frac{P_{out}}{P_0} \cdot \frac{P_0}{P_{in}}\right) = [-]10 \cdot \left[\log_{10}\left(\frac{P_{out}}{P_0}\right) - \log_{10}\left(\frac{P_{in}}{P_0}\right)\right]$$

$$\text{Pierderi}[\text{dB}] = [-]\left(P_{out}[\text{dBm}] - P_{in}[\text{dBm}]\right)$$

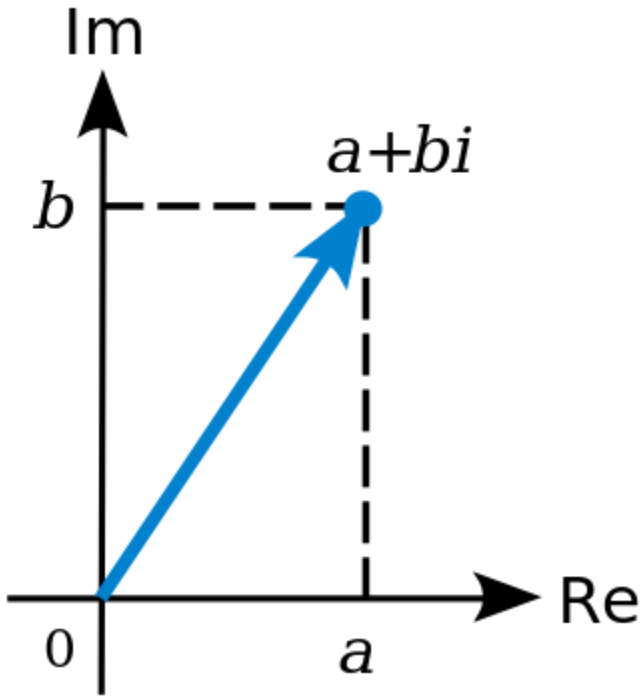


Examen

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

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

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

Complex Conjugat

- z $z = a + j \cdot b$
- z^* $z^* = a - j \cdot b$
- Simetric fata de axa **reala**

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

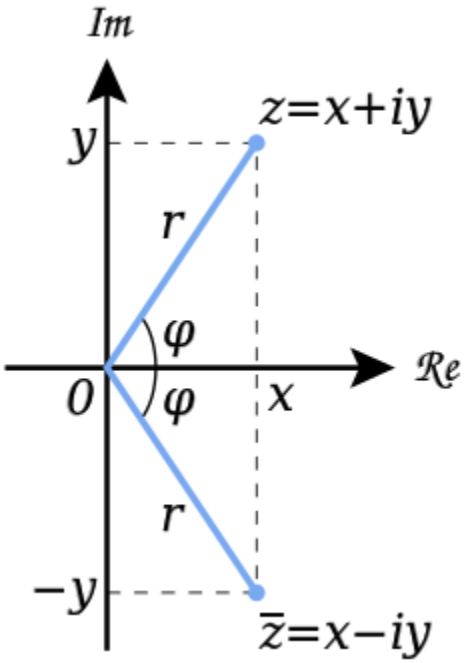
$$\mathrm{Im}(z) = b = \frac{1}{2 \cdot j} \cdot (z - z^*) = \frac{j}{2} \cdot (z^* - z)$$

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

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

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

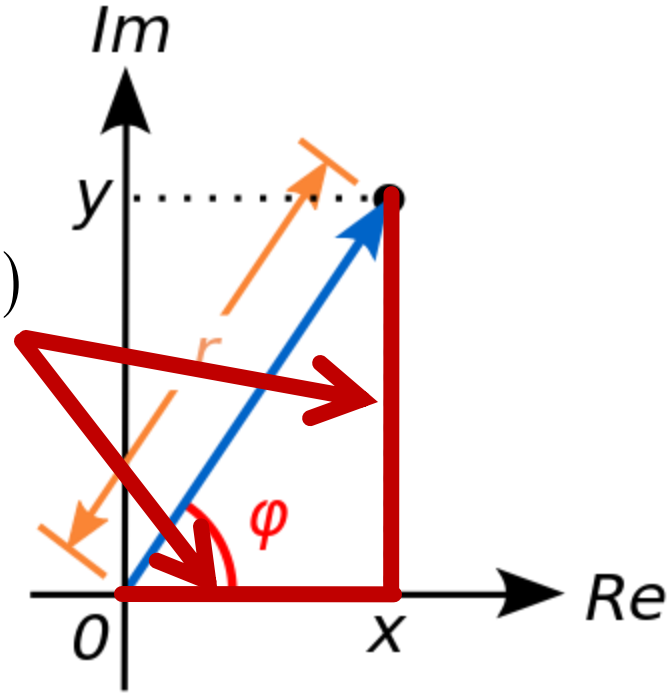
$$(z / w)^* = z^* / w^*$$



Reprezentare polara

- Reprezentare polara
  - modul
  - faza

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



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

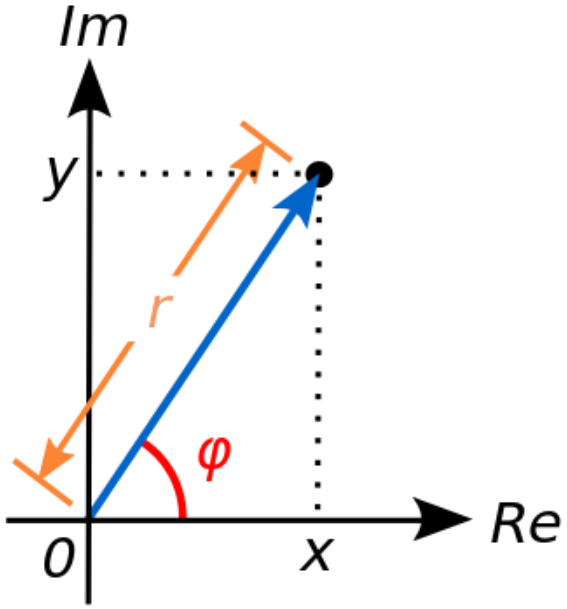
$$\varphi = \arg(z) = \begin{cases} \arctan\left(\frac{b}{a}\right), & a > 0 \\ \arctan\left(\frac{b}{a}\right) + \pi, & a < 0, b \geq 0 \\ \arctan\left(\frac{b}{a}\right) - \pi, & a < 0, b < 0 \\ \frac{\pi}{2}, -\frac{\pi}{2}, nedefinit & a = 0 \end{cases}$$

Reprezentare polara

- Formula lui Euler

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

- Reprezentare polara



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

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

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

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

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

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

Reprezentare polara

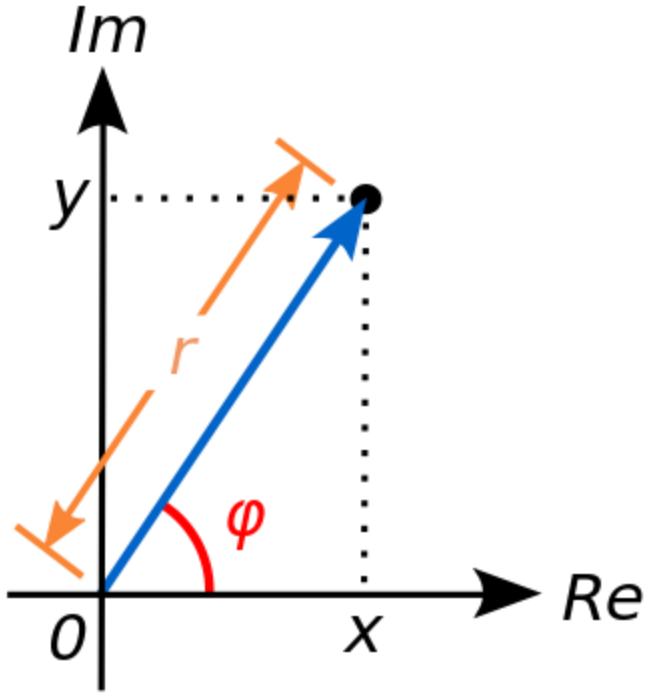
- Reprezentare polara

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

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

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

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



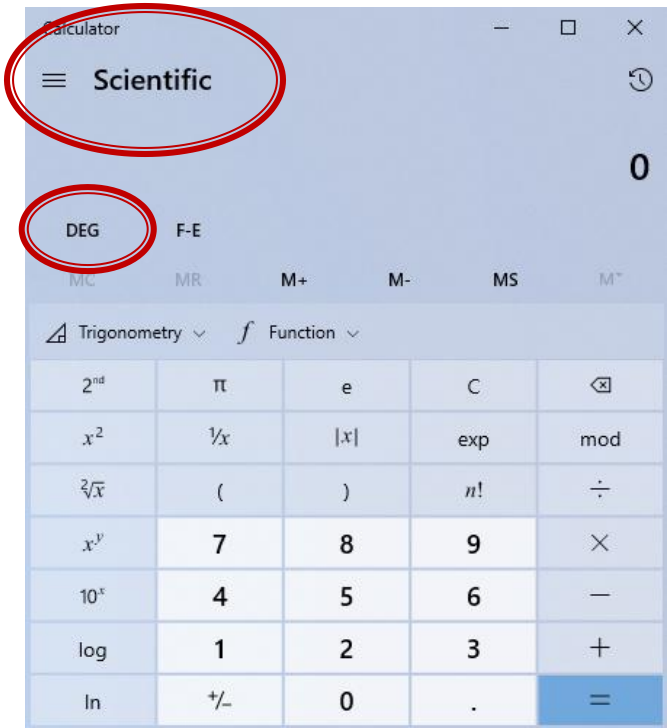
$$z^* = \left(|z| \cdot e^{j \cdot \varphi}\right)^* = |z| \cdot \left(\cos\varphi + j \cdot \sin\varphi\right)^* = |z| \cdot \left(\cos\varphi - j \cdot \sin\varphi\right) =$$

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

Reprezentare polara

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

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



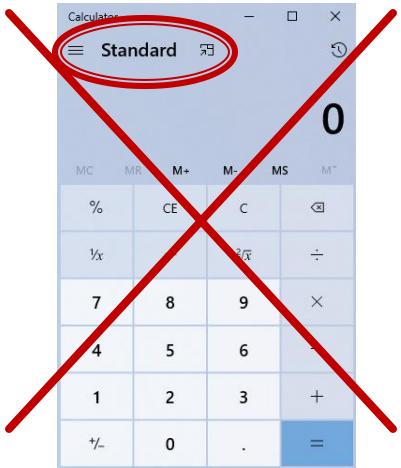
$$\varphi[^\circ] = 180^\circ \cdot \frac{\varphi[rad]}{\pi} \qquad \varphi[rad] = \pi \cdot \frac{\varphi[^\circ]}{180^\circ}$$

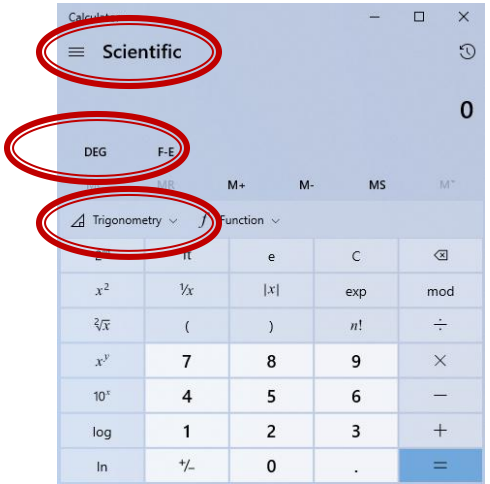
Reprezentare polara

- **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

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

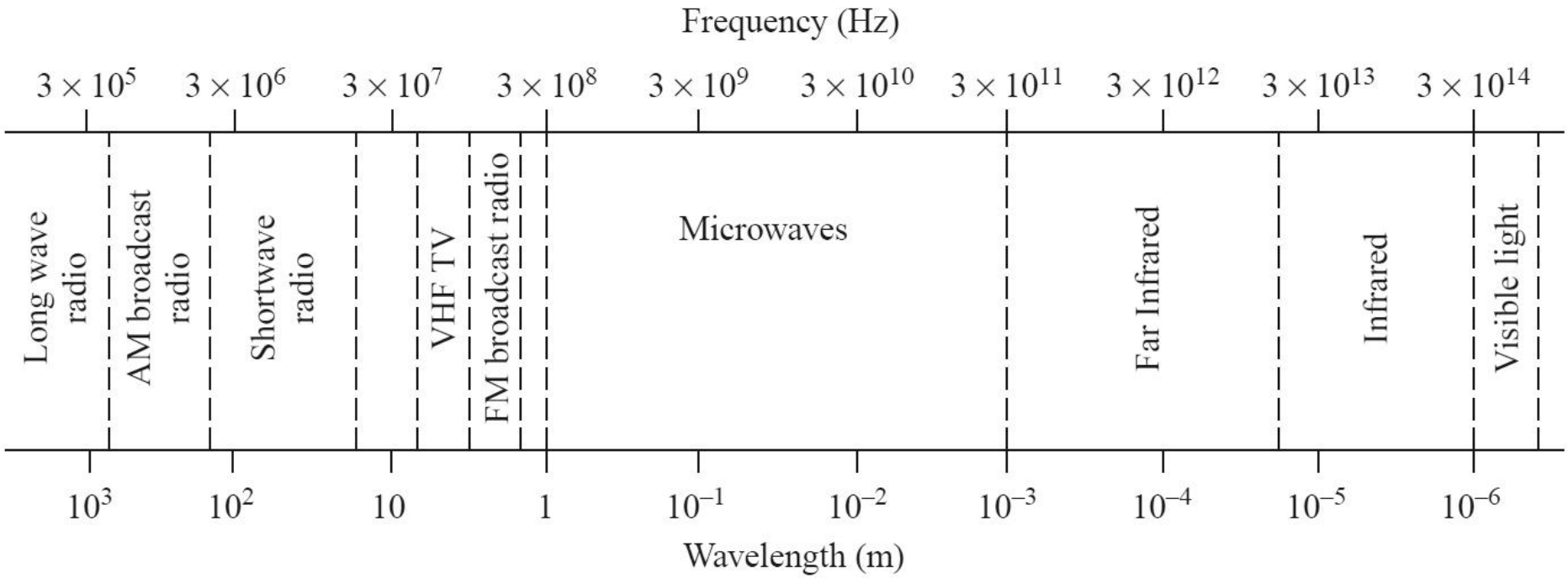
$$\varphi[rad] = \pi \cdot \frac{\varphi[^\circ]}{180^\circ}$$





Introducere

Microunde



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

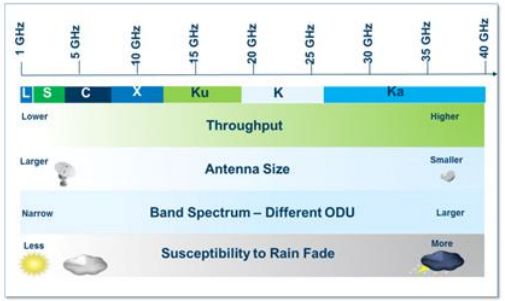
Microunde

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



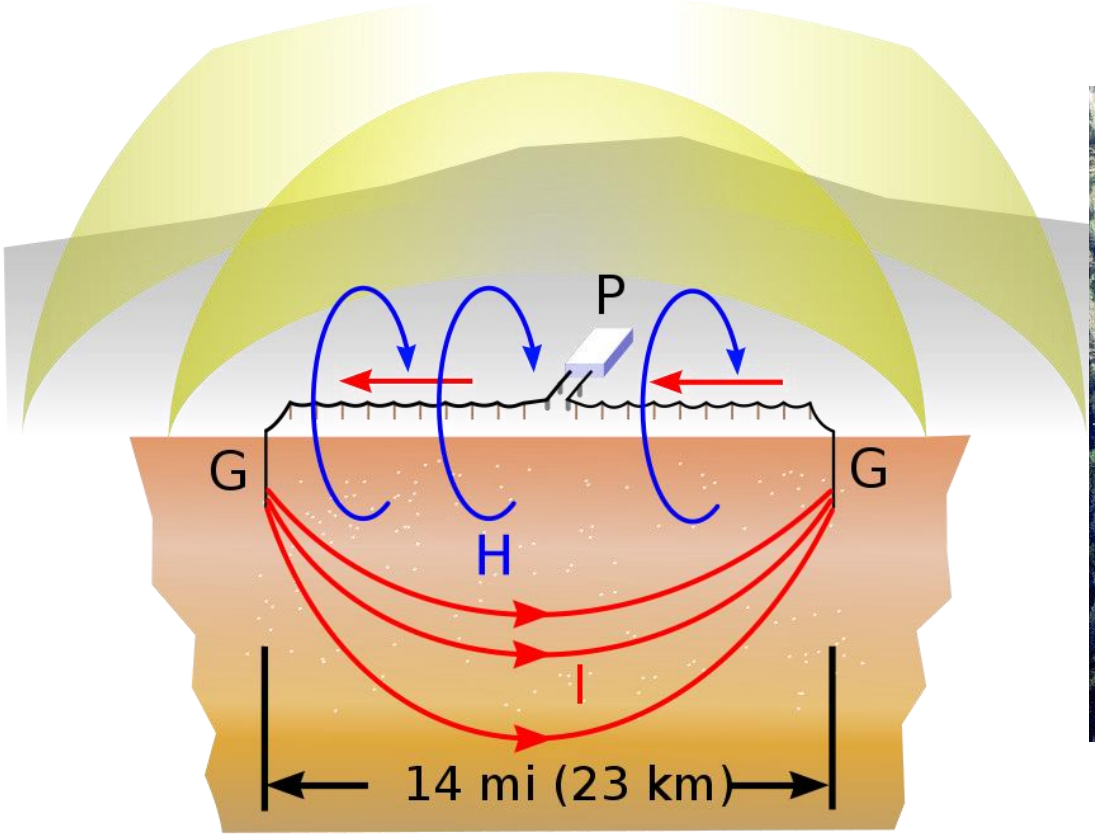
CPU

- Intel® Core™ 14th Gen i9-14900KS
- 6.2 GHz
- overclock 9.13 GHz



ELF, VLF

- Extremely low frequency, 3 - 30 Hz
- Very low frequency, 3 - 30 kHz





~ Microunde

- Lungimea electrica a unui circuit
  - l – lungimea fizica
  - E = β·l – lungimea electrica

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

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

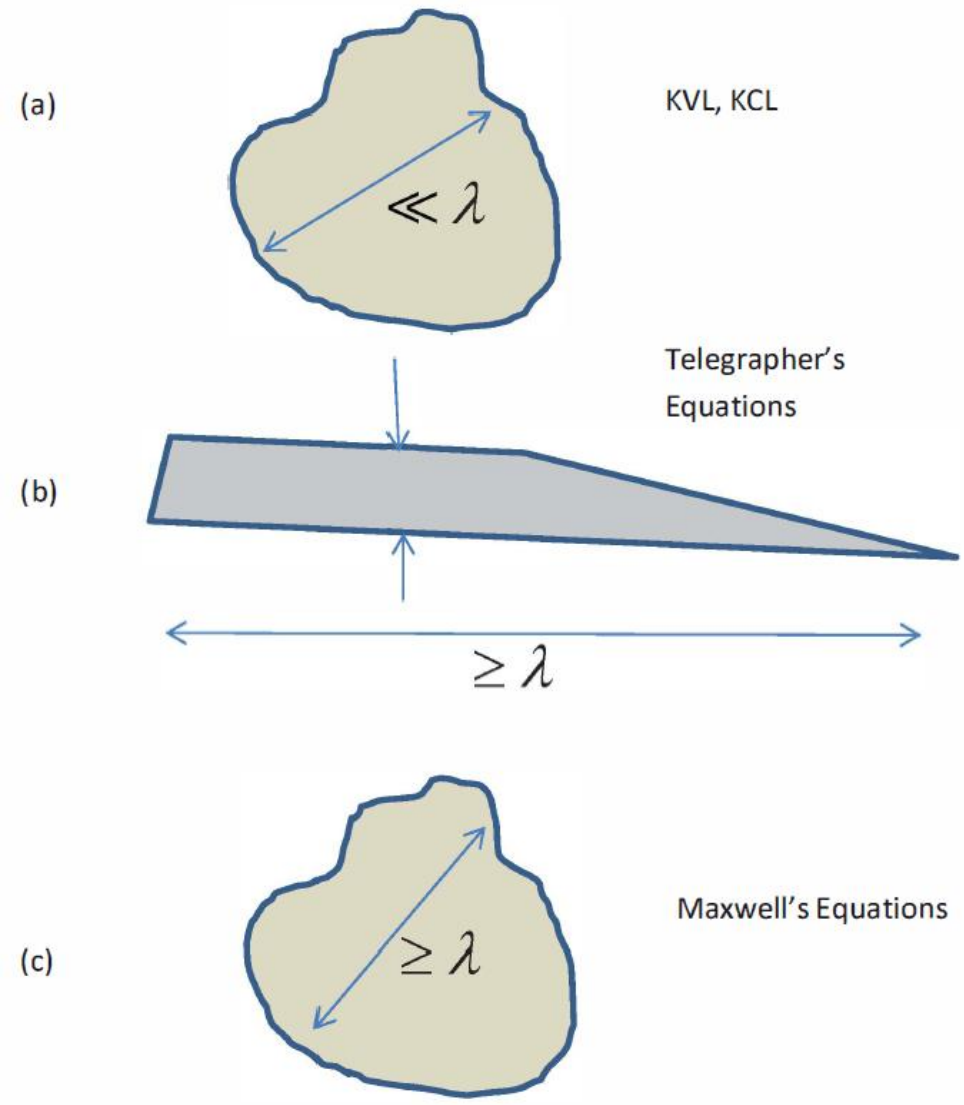
V, I variabile
~ inutile

- Dependenta
  - castigul antenei
  - imaginea unui obiect pe radar

Lungime electrica

- Comportarea (descrierea) unui circuit depinde de lungimea sa electrica la frecventele de interes
  - E≈0 → Kirchhoff
  - E>0 → Maxwell

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



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

$$D = \varepsilon \cdot E$$

$$B = \mu \cdot H$$

$$J = \sigma \cdot E$$

- In vid

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

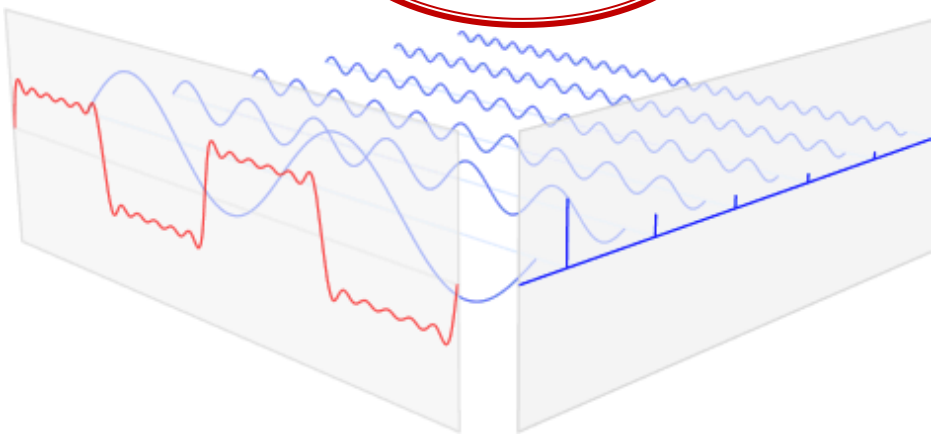
$$\varepsilon_0 = 8{,}854 \times 10^{-12}\ F/m$$

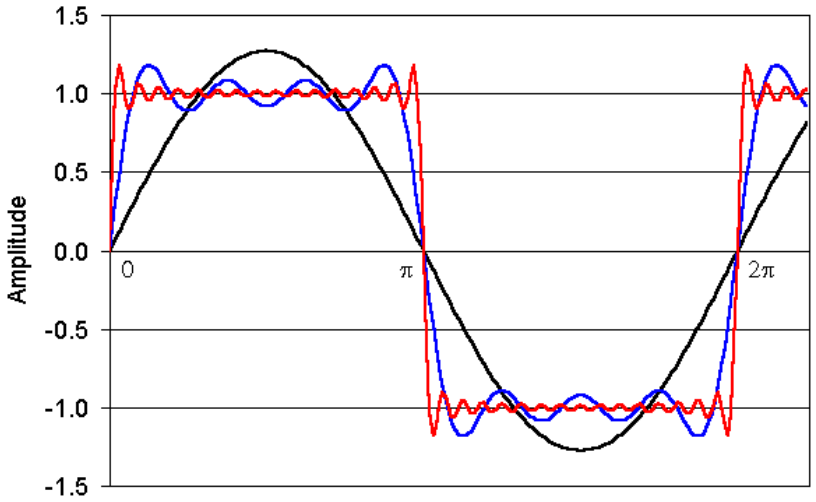
$$c_0 = \frac{1}{\sqrt{\varepsilon_0 \cdot \mu_0}} = 2{,}99790 \cdot 10^8\ m/s$$

Modele matematice

- cazuri particulare in care exista rezolvare analitica
  - semnale cu variație armonică în timp, transformata Fourier, spectru

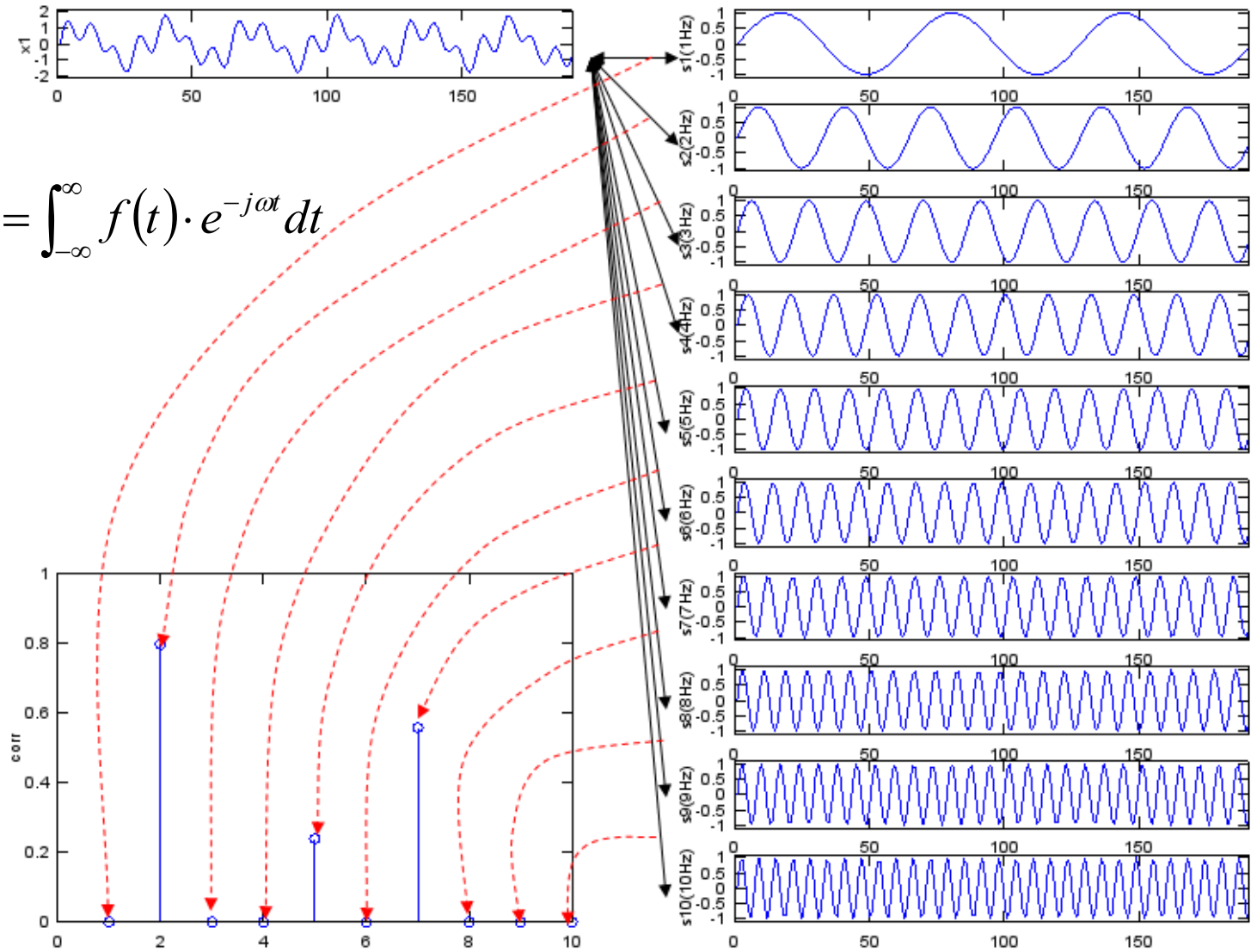
$$X = X_0 e^{j\cdot\omega\cdot t} \qquad \frac{\partial X}{\partial t} = j\cdot\omega\cdot X \qquad g(\omega) = \int_{-\infty}^{\infty} f(t)\cdot e^{-j\omega t}\,dt \qquad f(t) = \int_{-\infty}^{\infty} g(\omega)\cdot e^{j\omega t}\,d\omega$$



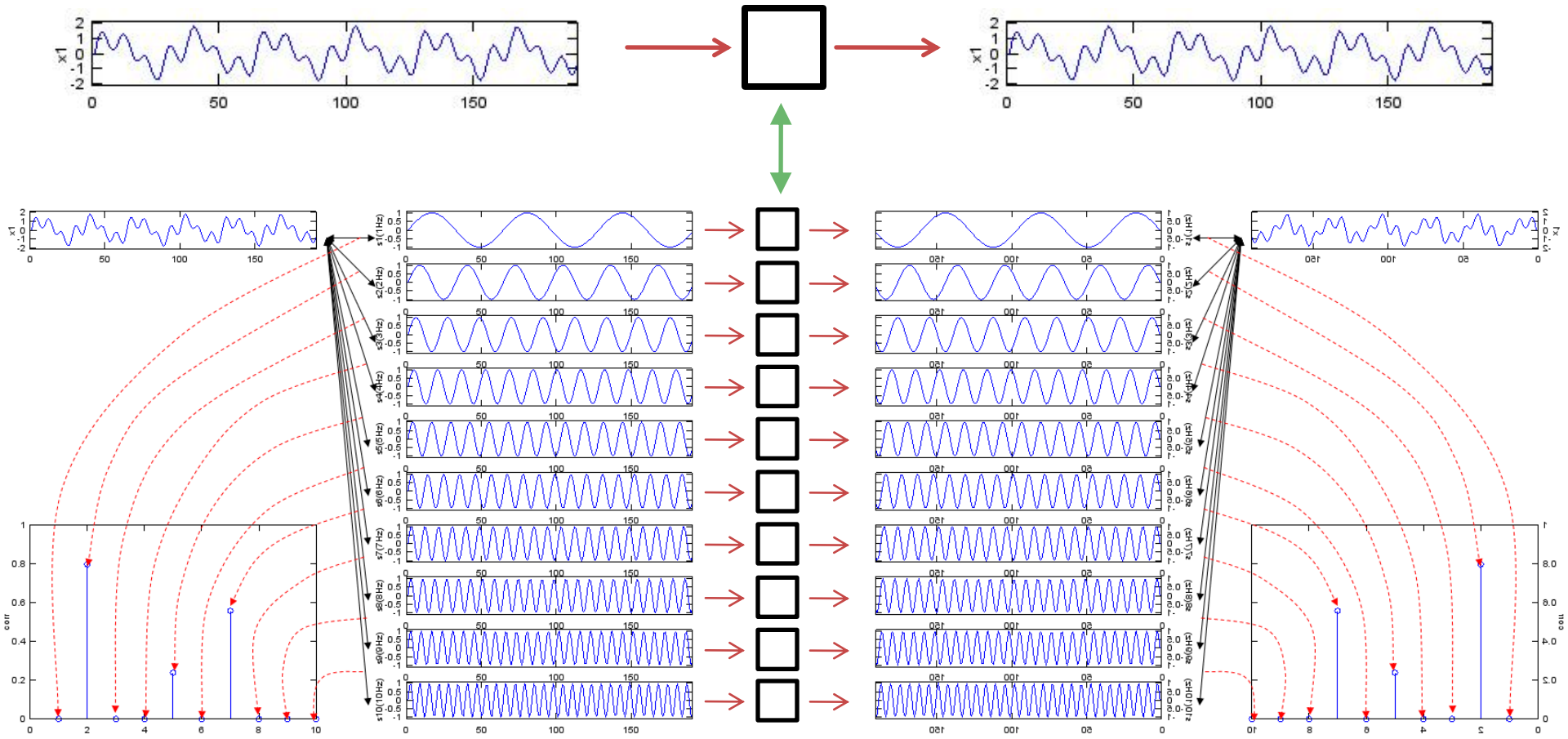


Modele matematice

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



Modele matematice



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

$$G(\omega)[F(\omega)]$$

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

Câmpuri electromagnetice cu variație armonică în timp

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

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

- Simplificarea ecuatiilor lui Maxwell

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

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

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

$$\nabla\cdot H = 0$$

Ecuațiile de propagare

- Ecuațiile Helmoltz sau ecuațiile de propagare

Mediu lipsit de sarcini electrice

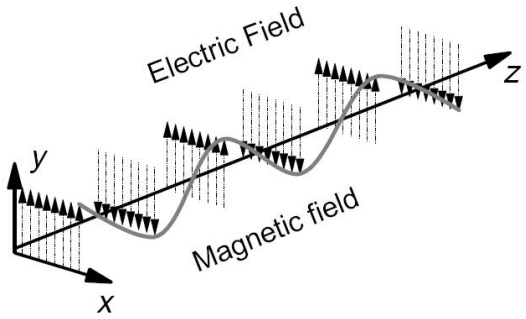
$$\nabla^2 E - \gamma^2 E = 0$$

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

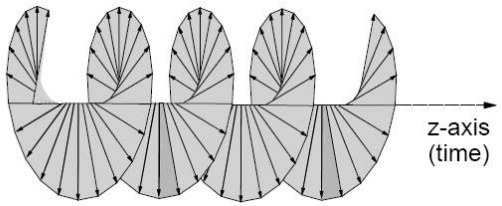
$$\gamma^2 = -\omega^2 \varepsilon \mu + j\omega\mu\sigma$$

γ – Constanta de propagare

Solutia ecuatiilor de propagare



Propagare



Polarizare circulara

Camp electric dupa directia Oy, ← prin alegerea judicioasa
propagare dupa directia Oz ← a sistemului de referinta

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

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

Exista numai unda progresiva E_+=> A

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

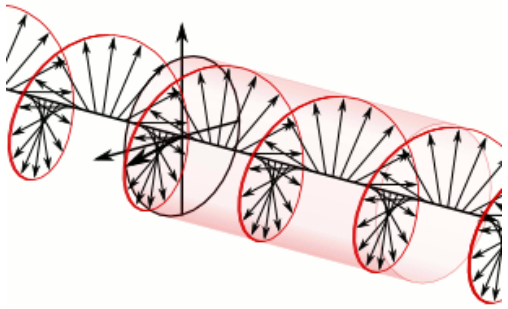
Camp armonic

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

Amplitudine

Atenuare

Propagare
(variatie in timp si spatiu)



Solutia ecuatiilor de propagare

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

Camp electric dupa directia Oy, propagare dupa directia Oz

← prin alegerea judicioasa
← a sistemului de referinta

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

- 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
- unda
  - directa
  - inversa

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

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

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

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

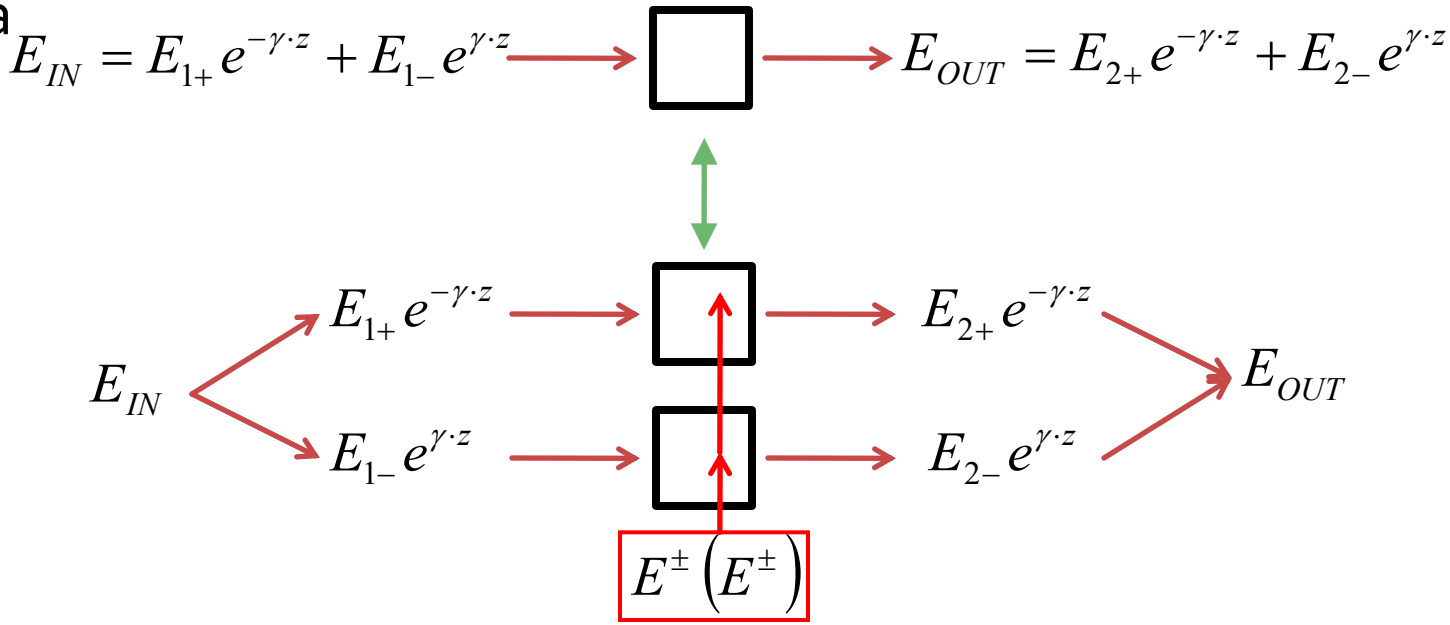
$$V(z) = V^+ \cdot e^{j(\omega \cdot t - \beta \cdot z)} + V^- \cdot e^{j(\omega \cdot t + \beta \cdot z)}$$

Modele matematice

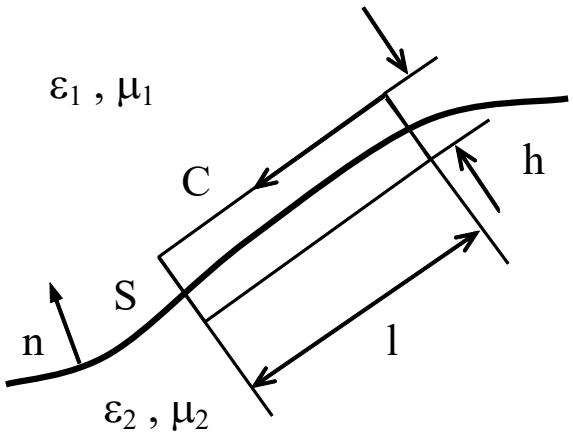
- cazuri particulare in care exista rezolvare analitica
  - Exista unda in o singura directie $E^+\left(E^+\right),\quad E^-\left(E^-\right)$
  - unda
    - incidenta
    - reflectata

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

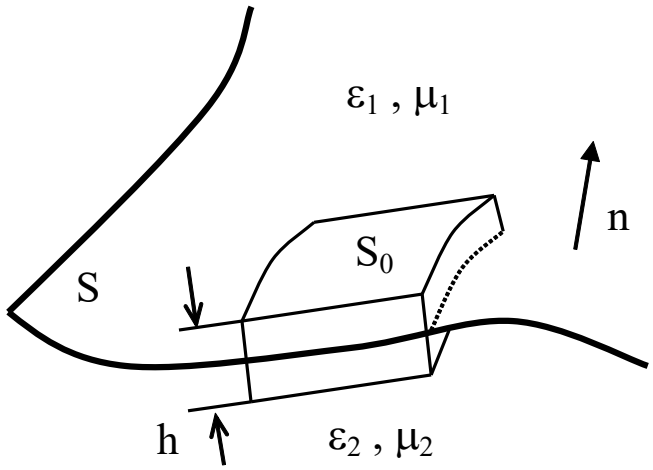
  - unda
    - directa
    - inversa



Condiții la limita de separație între două medii



a)



b)

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

$$n \times \left(H_1 - H_2\right) = J_S$$

$$n \cdot \left(D_1 - D_2\right) = \rho_S$$

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

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

Moduri in medii delimitate

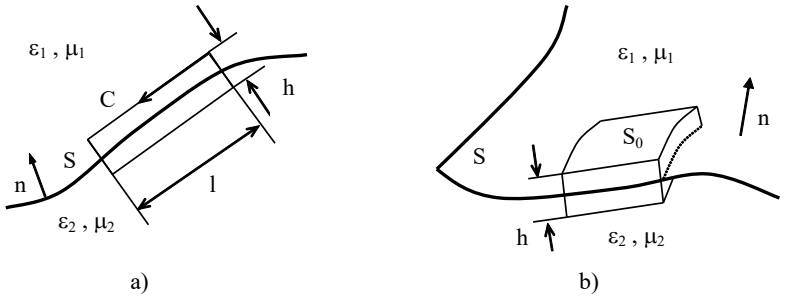
- Câmpuri electromagnetice cu variație armonică în timp
  - simplificarea ecuatiilor lui Maxwell

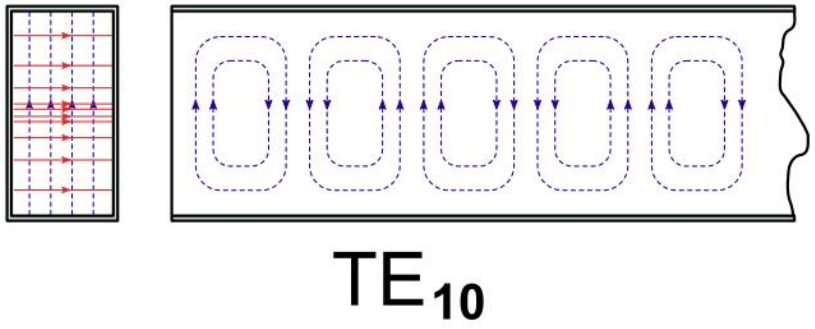
$$X = X_0 e^{j\cdot\omega\cdot t} \qquad \frac{\partial X}{\partial t} = j\cdot\omega\cdot X \qquad g(\omega) = \int_{-\infty}^{\infty} f(t)\cdot e^{-j\omega t}\,dt \qquad f(t) = \int_{-\infty}^{\infty} g(\omega)\cdot e^{j\omega t}\,d\omega$$

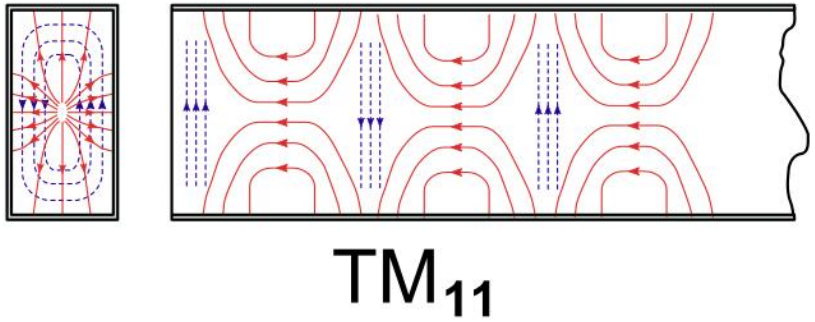
- In medii delimitate solutiile ecuatiilor lui Maxwell trebuie sa verifice conditiile la limita
  - solutiile trebuie sa respecte anumite conditii suplimentare

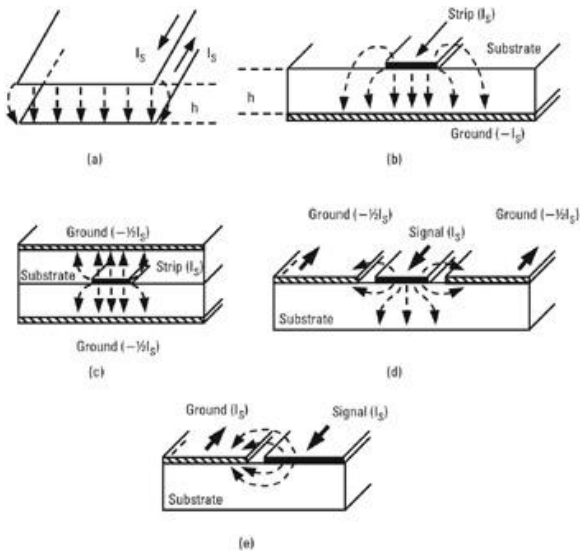
Moduri in medii delimitate

- Campul electric **trebuie** sa fie perpendicular pe un perete metalic, sau nul
- Campul magnetic **trebuie** sa fie tangent la un perete metalic, sau nul

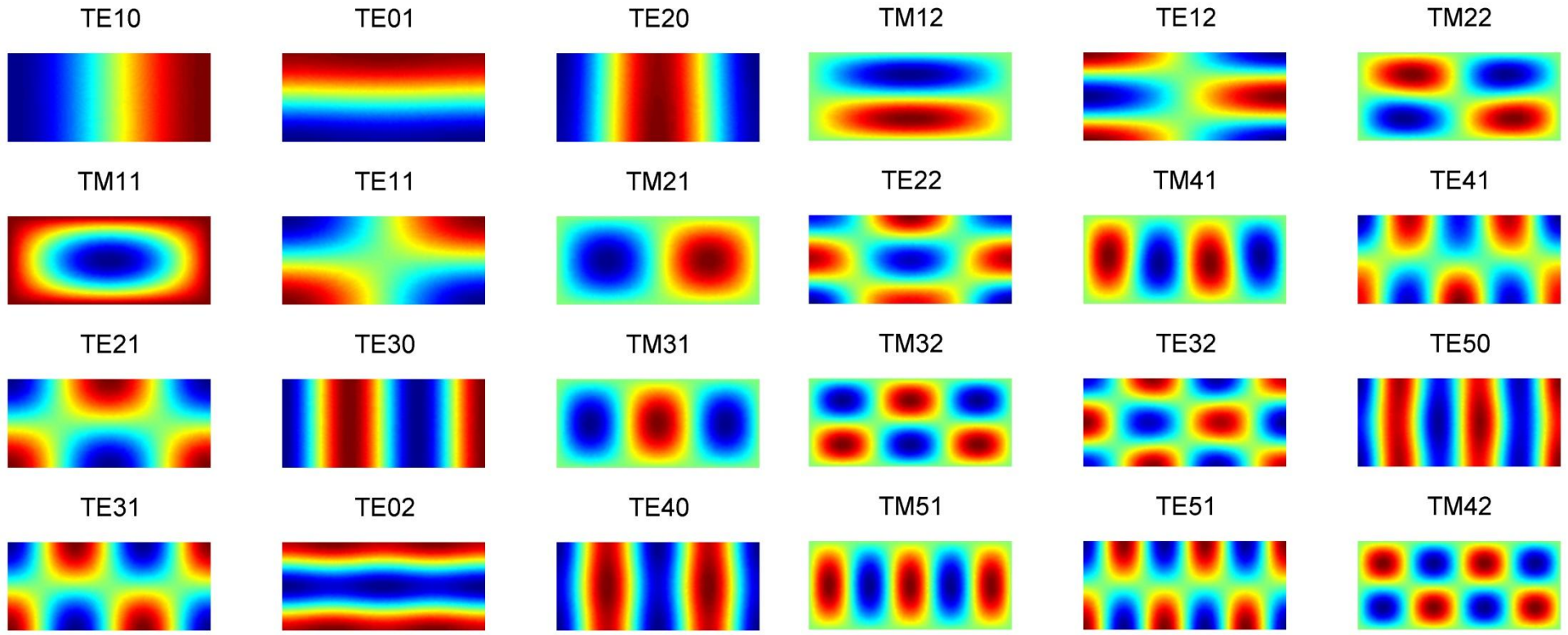








Moduri in medii delimitate



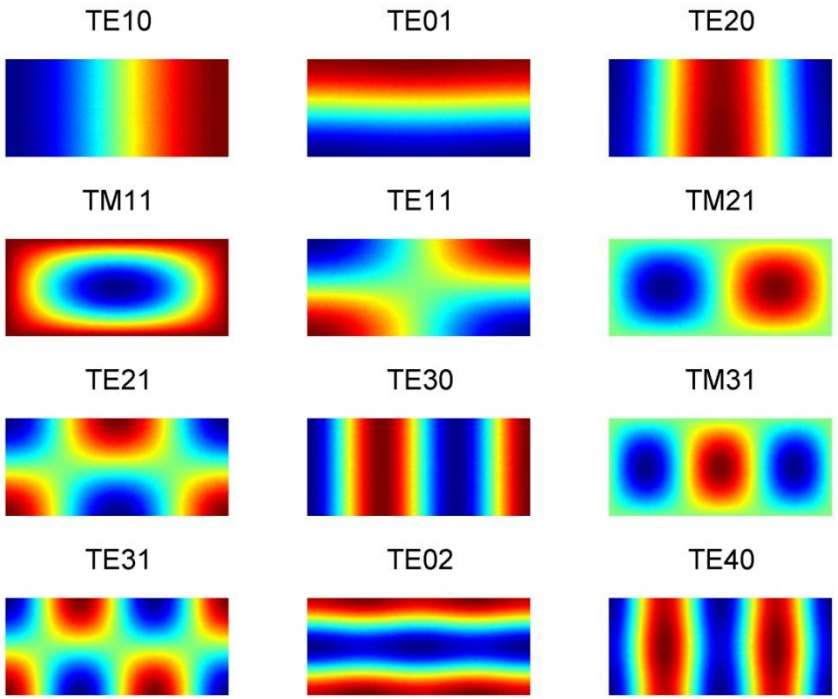
- Similar cu transformata Fourier

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

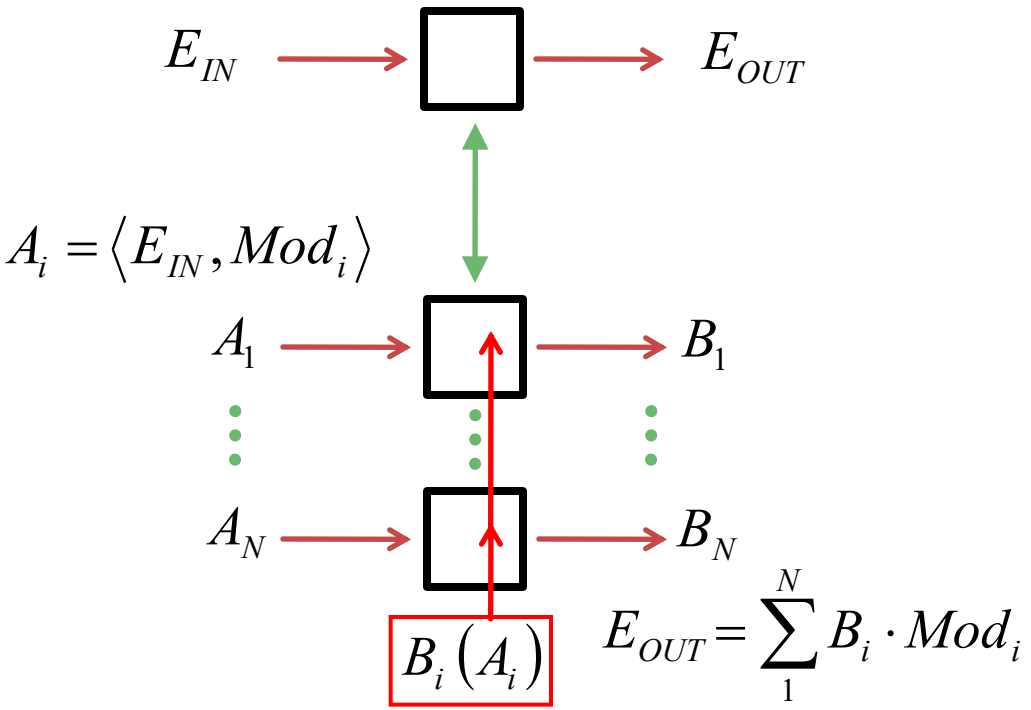
$$E^{+},E^{-}=\sum_{1}^{\infty} A_i\cdot Mod_i \qquad A_i=\langle E,Mod_i\rangle$$

Modele matematice

- cazuri particulare in care exista rezolvare analitica
  - moduri in medii delimitate $B_i(A_i)$



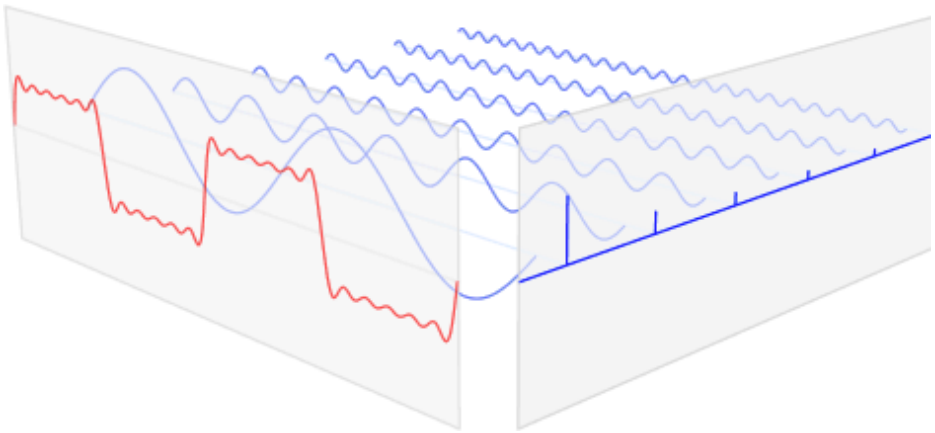
$$E = \sum_{1}^{\infty} A_i \cdot Mod_i \qquad A_i = \langle E, Mod_i \rangle$$

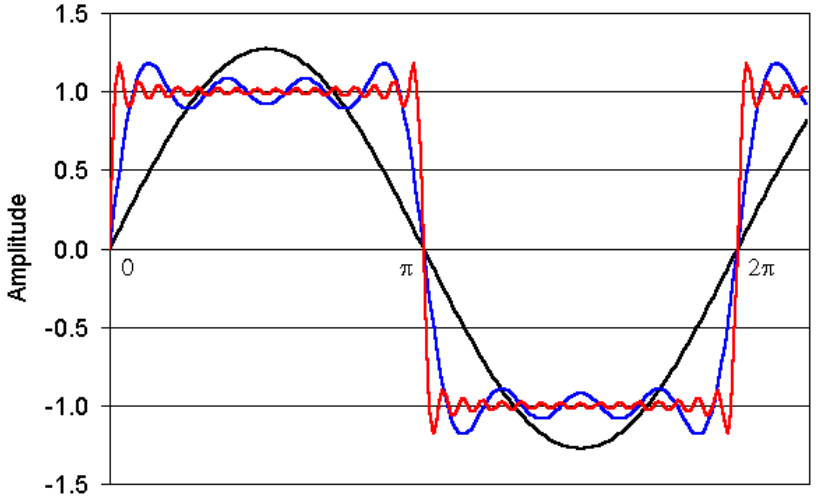


Modele matematice

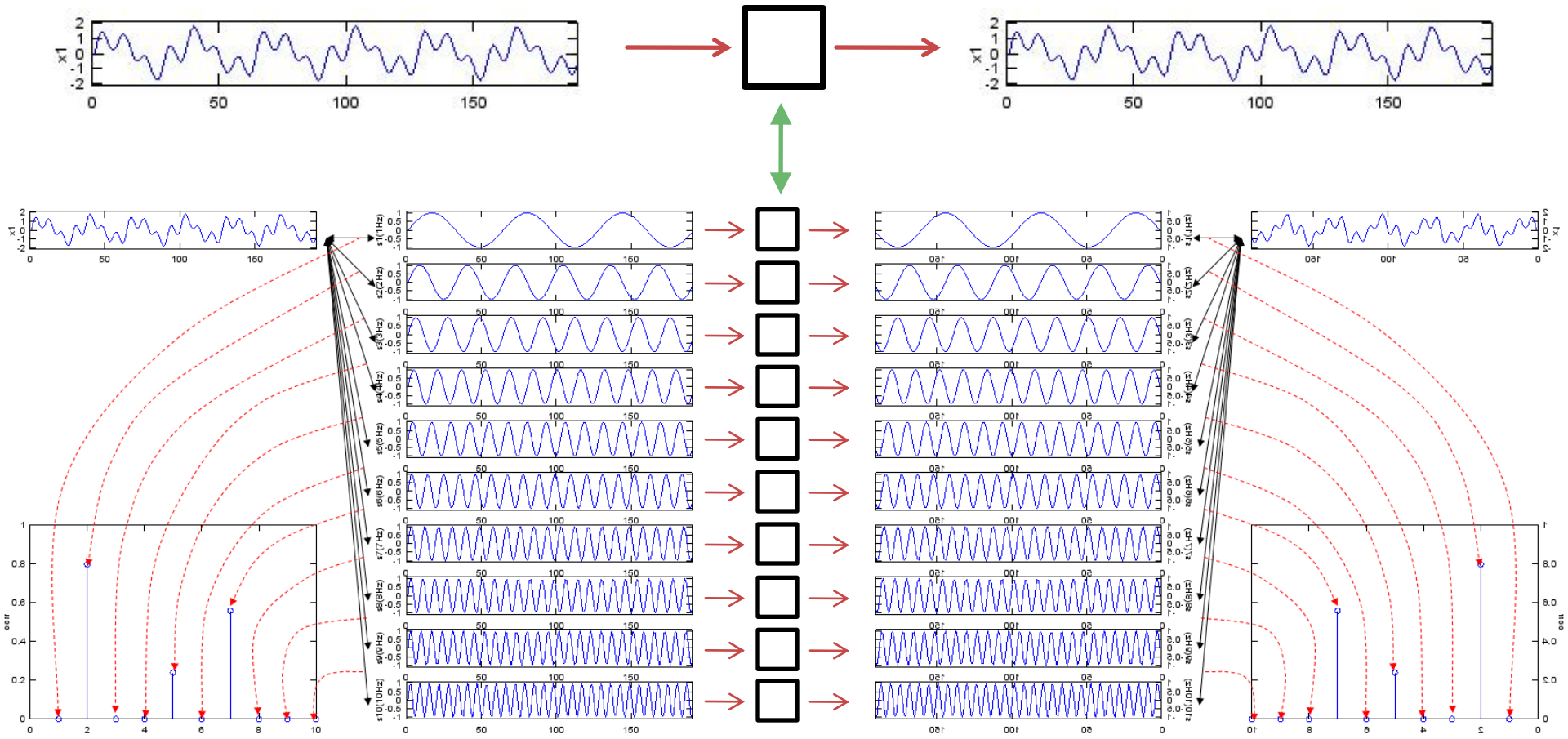
- cazuri particulare in care exista rezolvare analitica
  - semnale cu variație armonică în timp, transformata Fourier, spectru

$$X = X_0 e^{j\cdot\omega\cdot t} \qquad \frac{\partial X}{\partial t} = j\cdot\omega\cdot X \qquad g(\omega) = \int_{-\infty}^{\infty} f(t)\cdot e^{-j\omega t}\,dt \qquad f(t) = \int_{-\infty}^{\infty} g(\omega)\cdot e^{j\omega t}\,d\omega$$





Modele matematice



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

$$G(\omega)[F(\omega)]$$

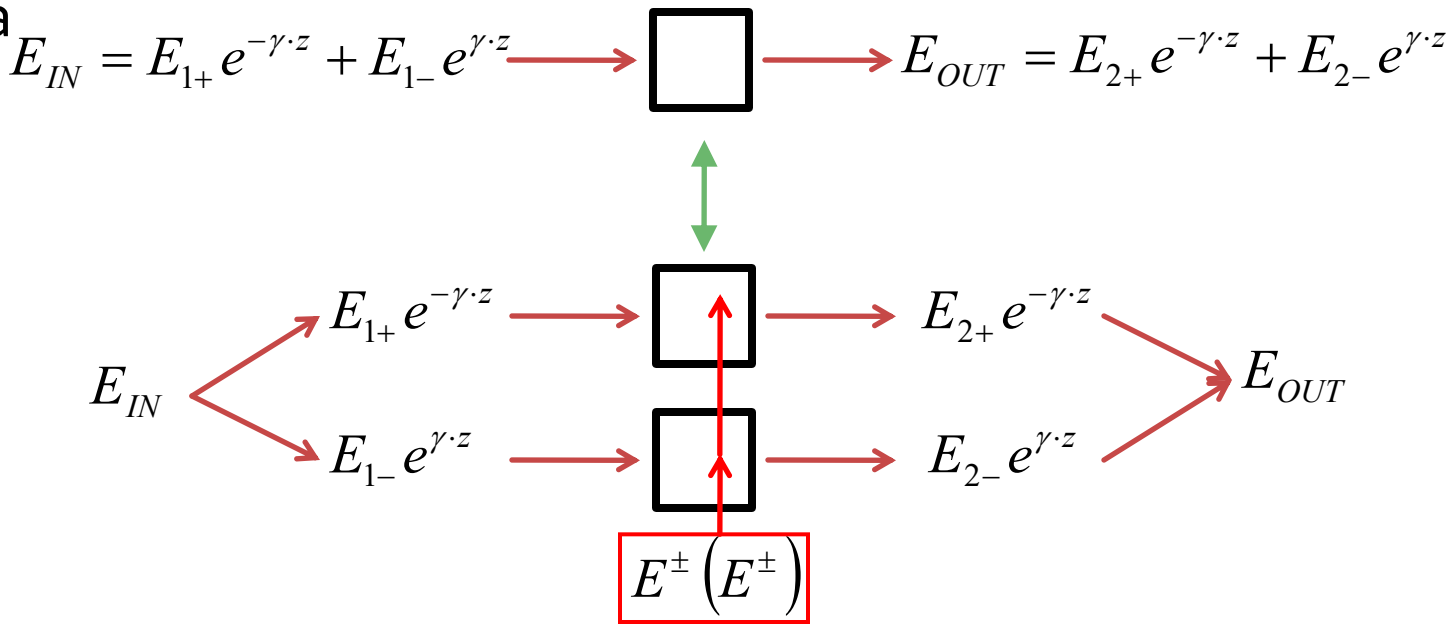
$$g(t)=\int_{-\infty}^{\infty} G(\omega)\cdot e^{j\omega t}d\omega$$

Modele matematice

- cazuri particulare in care exista rezolvare analitica
  - Exista unda in o singura directie $E^+\left(E^+\right),\quad E^-\left(E^-\right)$
  - unda
    - incidenta
    - reflectata

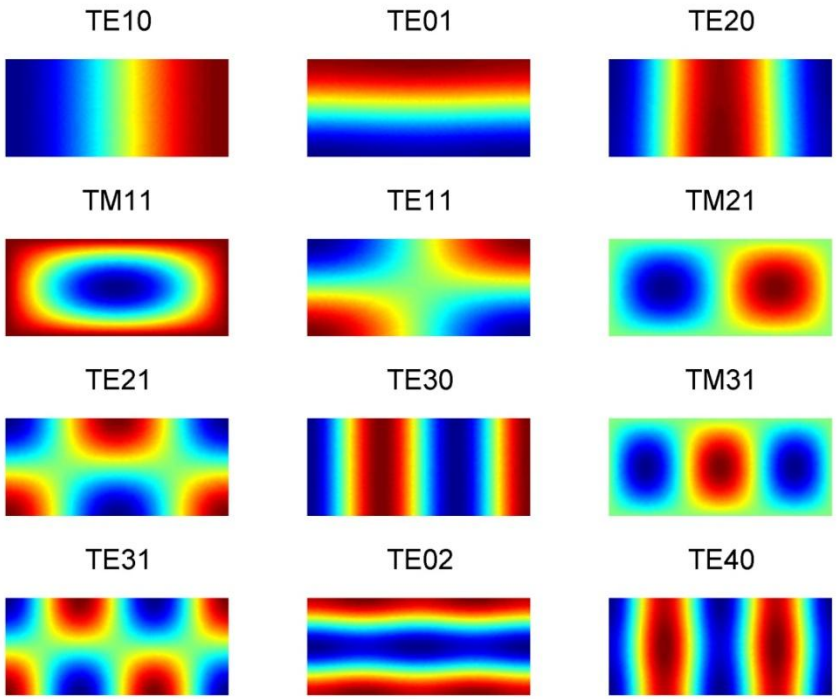
$$E_y = E^+ \cdot e^{-\alpha \cdot z} \cdot e^{j(\omega \cdot t - \beta \cdot z)} + E^- \cdot e^{-\alpha \cdot z} \cdot e^{j(\omega \cdot t + \beta \cdot z)}$$

  - unda
    - directa
    - inversa

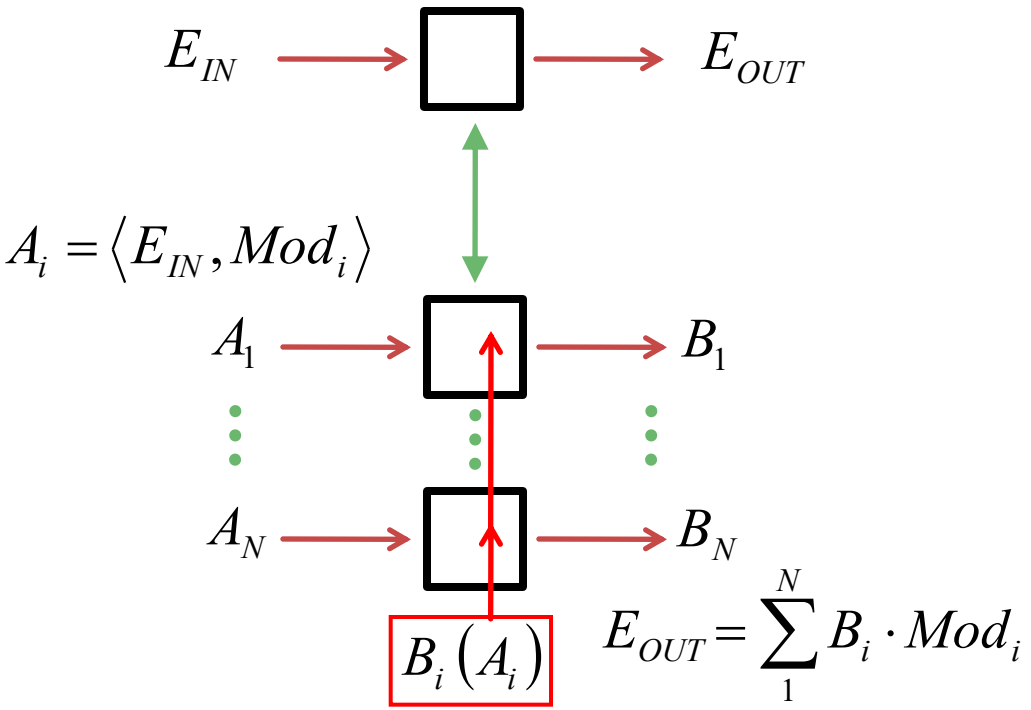


Modele matematice

- cazuri particulare in care exista rezolvare analitica
  - moduri in medii delimitate $B_i(A_i)$



$$E = \sum_{1}^{\infty} A_i \cdot Mod_i \qquad A_i = \langle E, Mod_i \rangle$$



Linii de transmisie in mod TEM

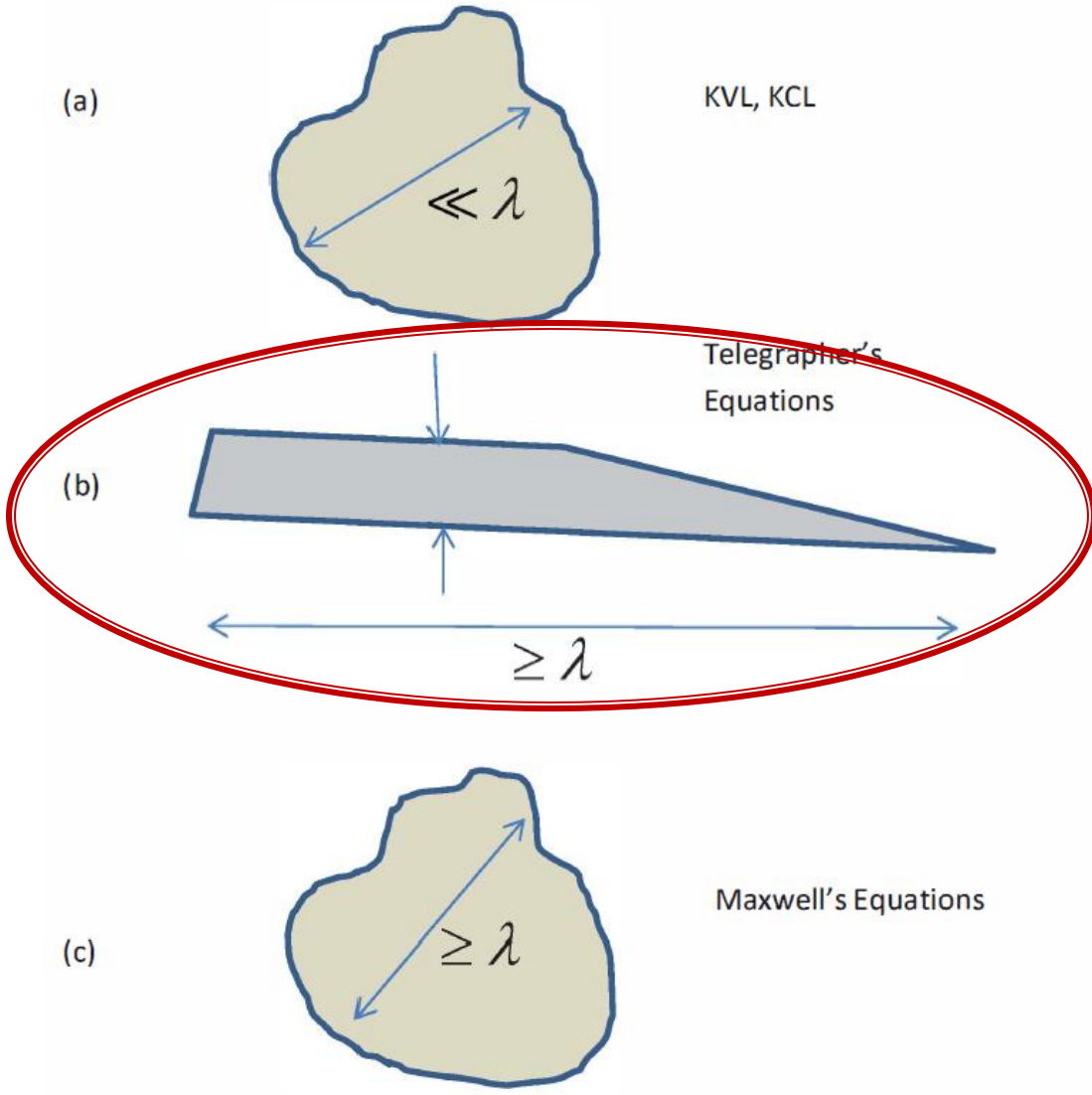
Cuprins

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

Lungime electrica

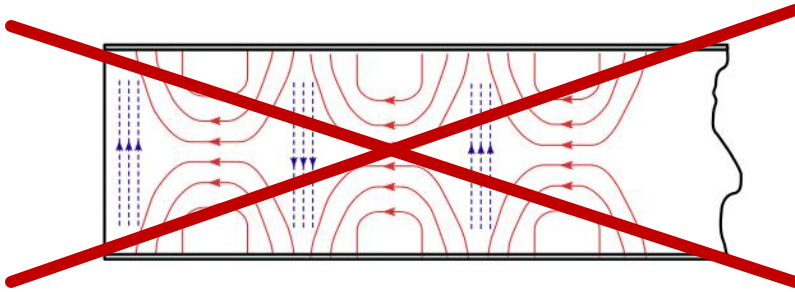
- Comportarea (descrierea) unui circuit depinde de lungimea sa electrica la frecventele de interes
  - E≈o → Kirchhoff
  - E>o → propagare

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



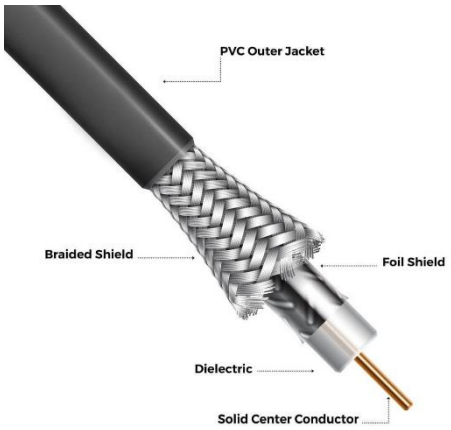
Linie de transmisie

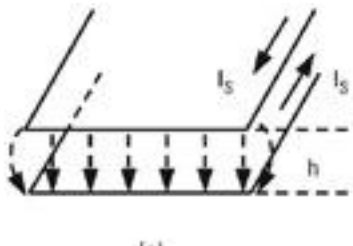
- mod TEM, doi conductori

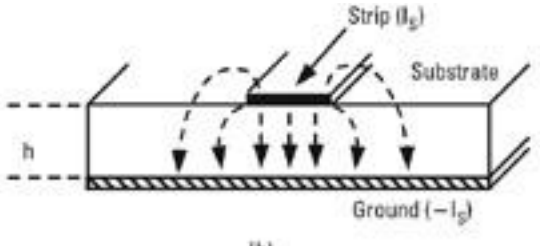


I(z,t)

V(z,t)



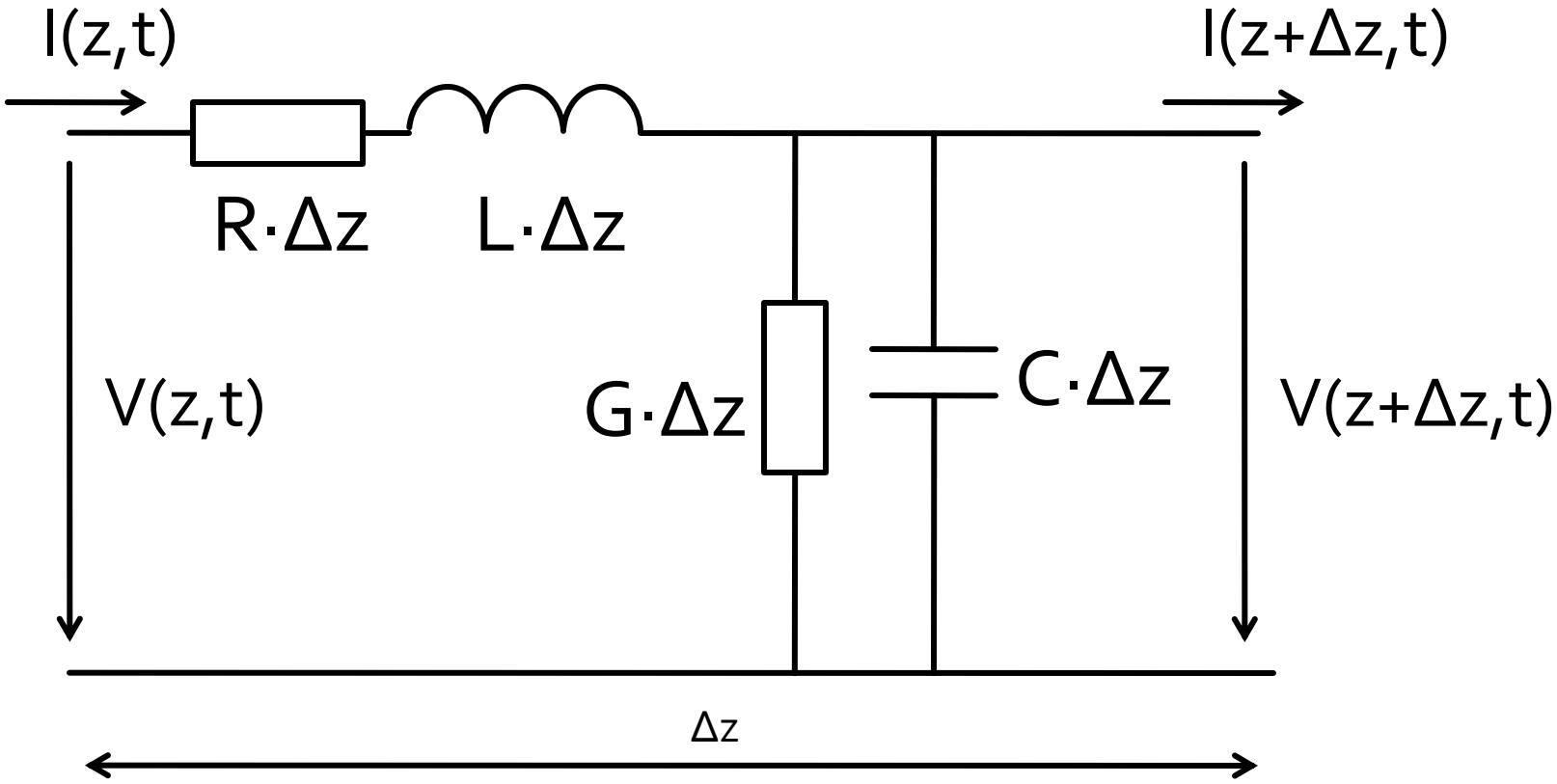




z

Linie de transmisie model echivalent

- mod TEM, doi conductori, parametri **lineici**



- parametri **lineici, distribuiti** R, L, G, C (Ω/m, H/m ...)

Contact

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- rdamian@etti.tuiasi.ro