Curs 3

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 ?

Examen: Reprezentare logaritmică

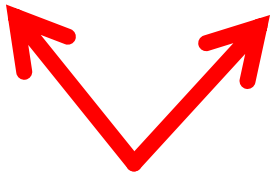
- $\boldsymbol{X[dB] = 10 \cdot log_{10}(X[lin])}$
- $X[B] = log_{10}(X[lin])$
- X[lin] – adimensional
- $log(A \cdot B) = log(A) + log(B)$

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

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

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



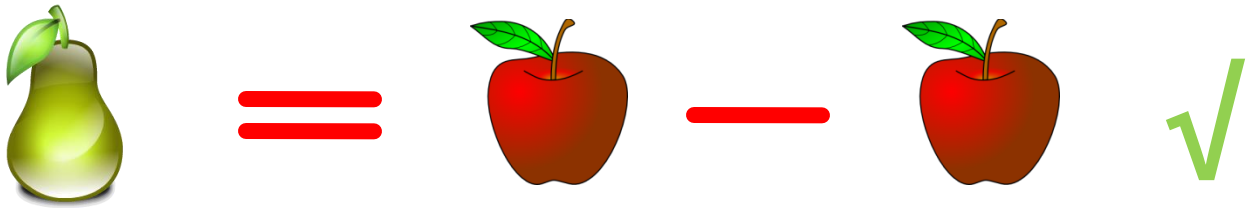
Calculul atenuarii/amplificarii

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

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

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

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



Examen

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

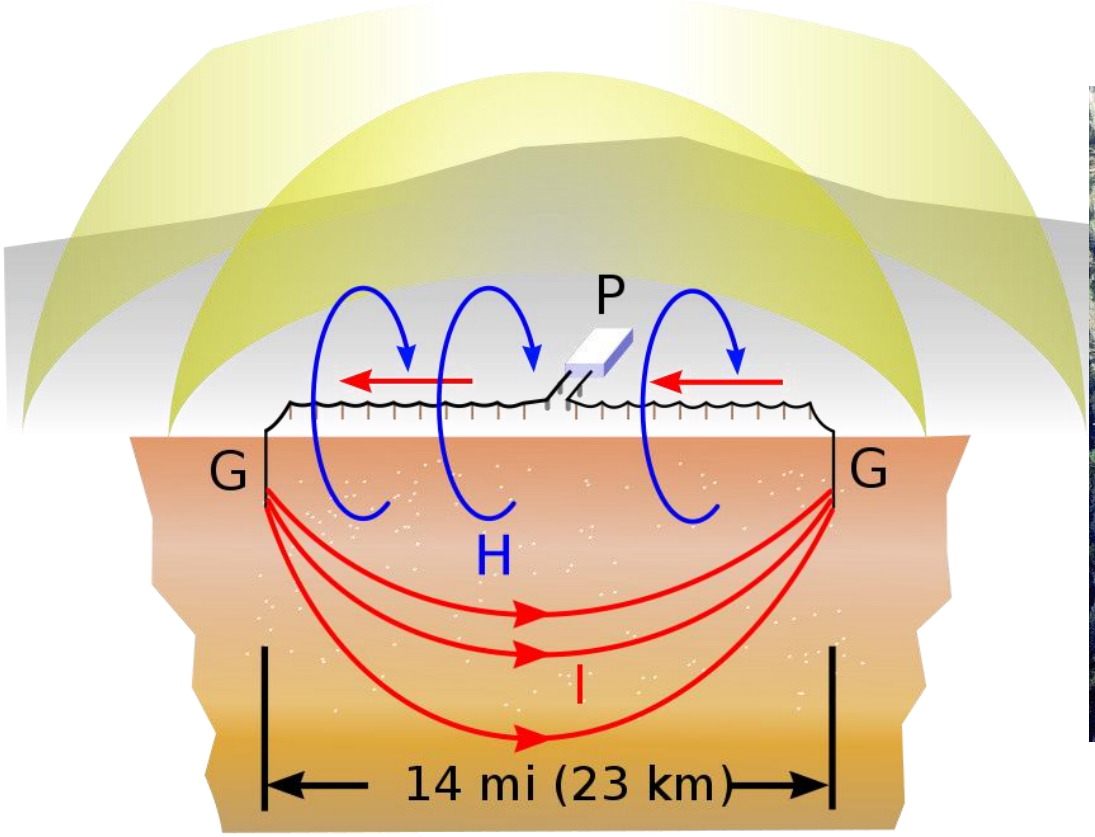
CPU

- 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

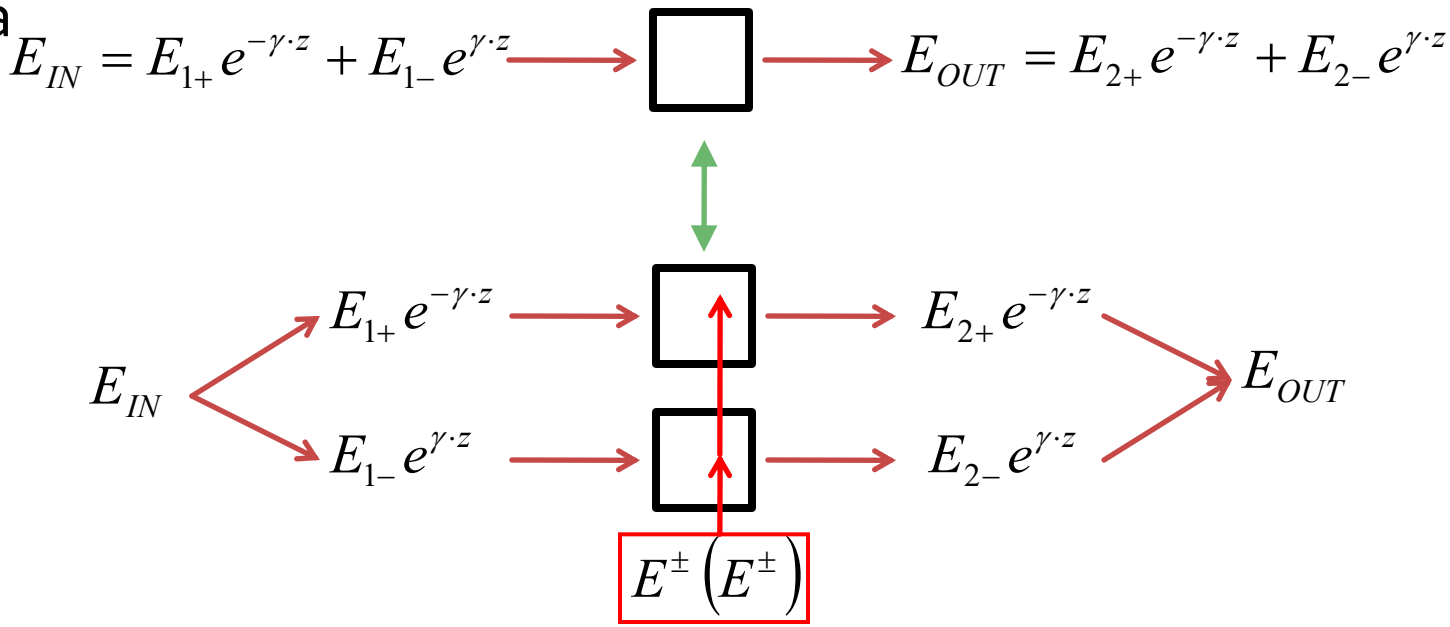
- Dependenta
  - castigul antenei
  - imaginea unui obiect pe radar

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

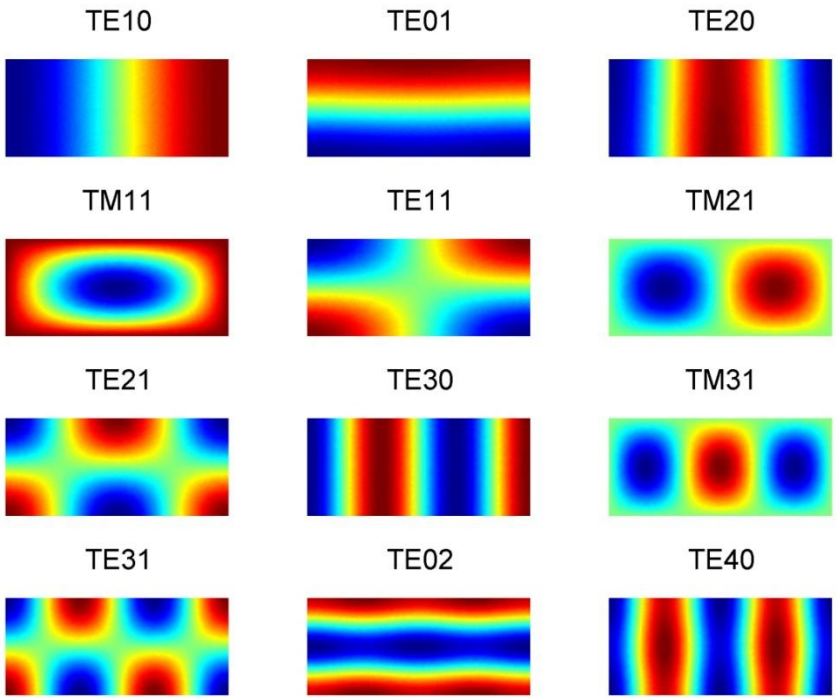
$$E_y = E^+ \cdot e^{-\alpha \cdot z} \cdot e^{j(\omega \cdot t - \beta \cdot z)} + E^- \cdot e^{-\alpha \cdot z} \cdot e^{j(\omega \cdot t + \beta \cdot z)}$$

  - unda
    - directa
    - inversa

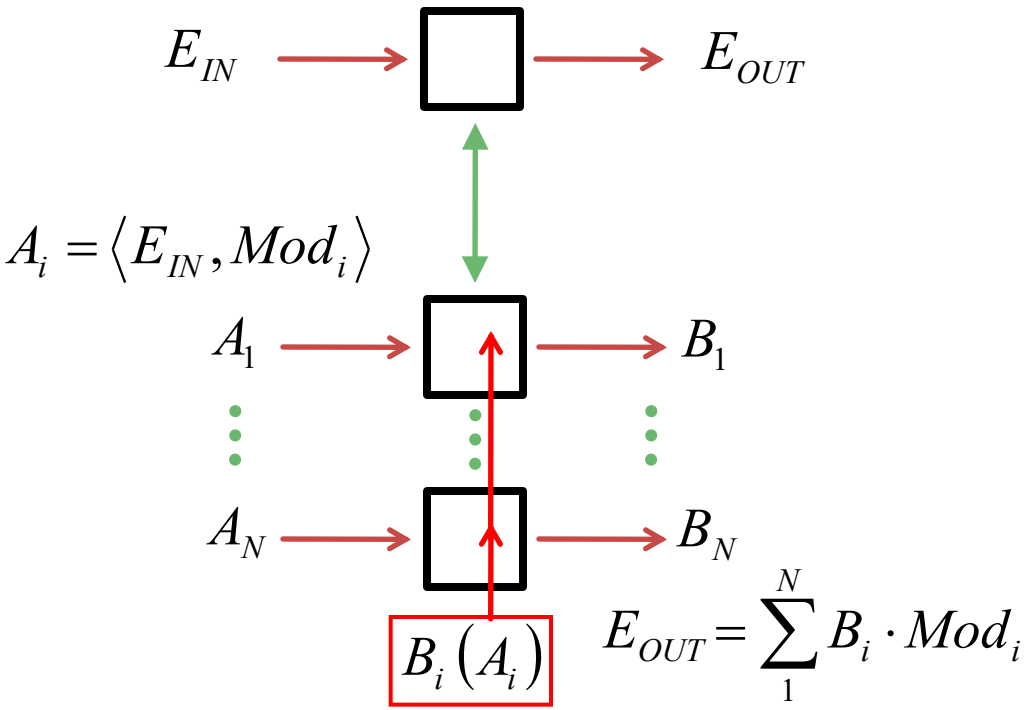


Modele matematice

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



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



Continuare

Linii de transmisie in mod TEM

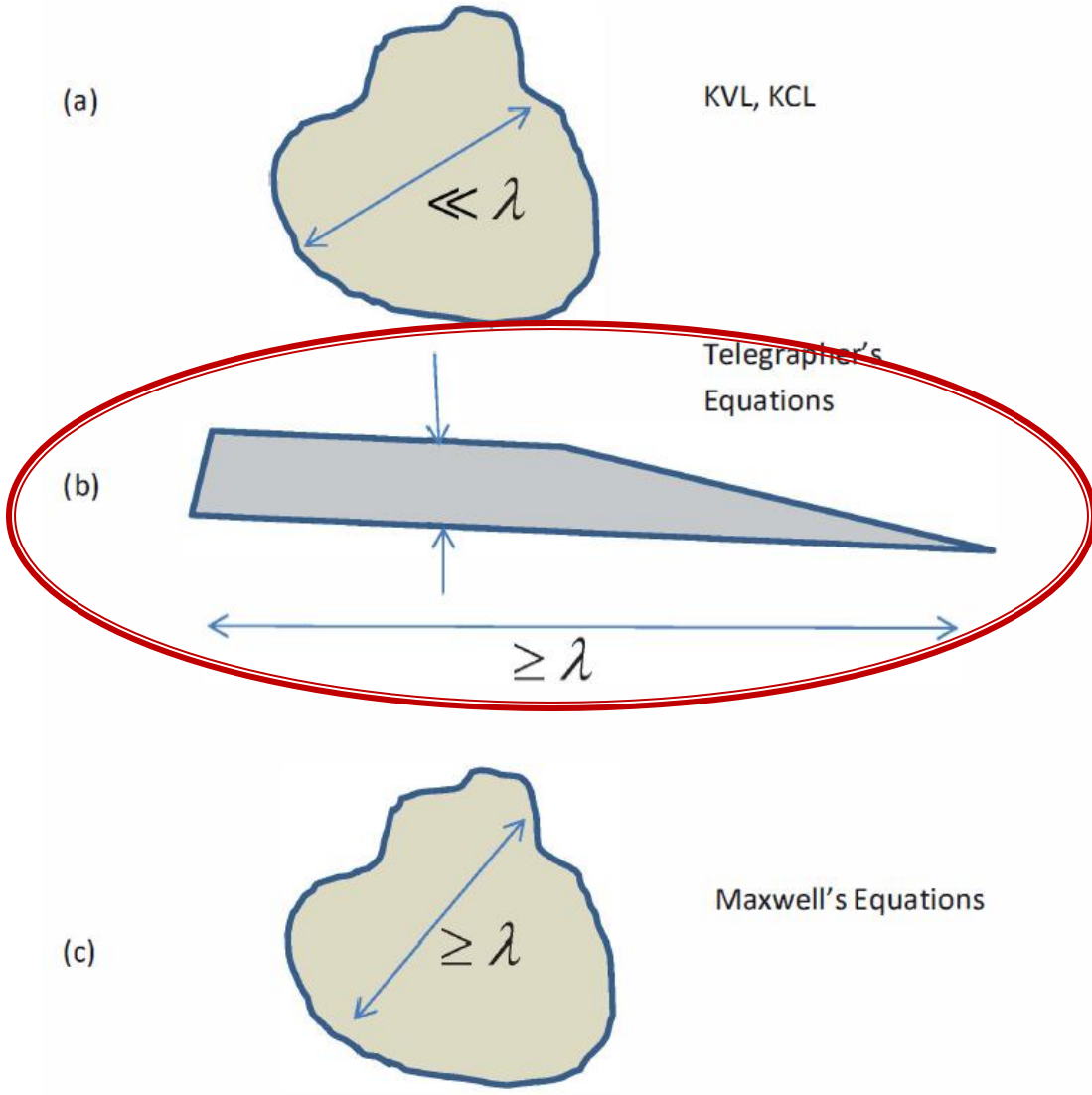
Cuprins

- Linii de transmisie
- Adaptarea de impedanța
- Cuploare direcționale
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- Filtre de microunde
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Lungime electrica

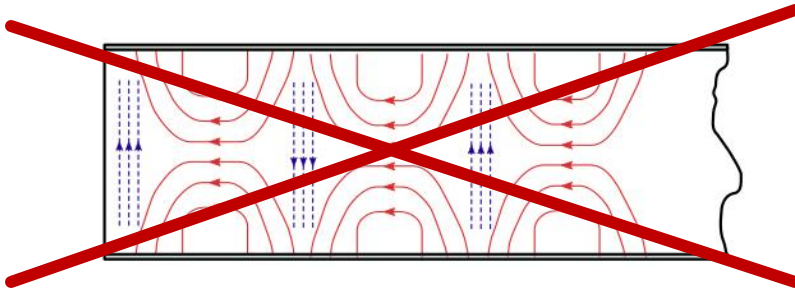
- Comportarea (descrierea) unui circuit depinde de lungimea sa electrica la frecventele de interes
  - E≈o → Kirchhoff
  - E>o → propagare

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



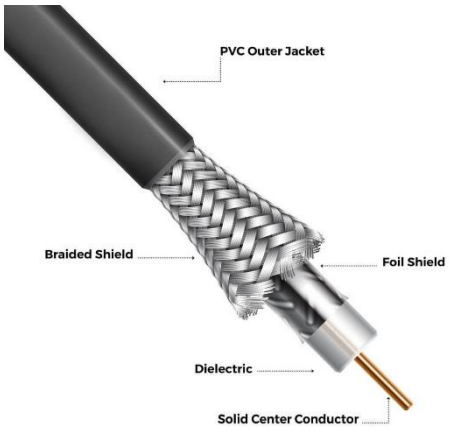
Linie de transmisie

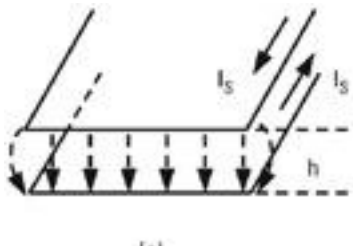
- mod TEM, doi conductori

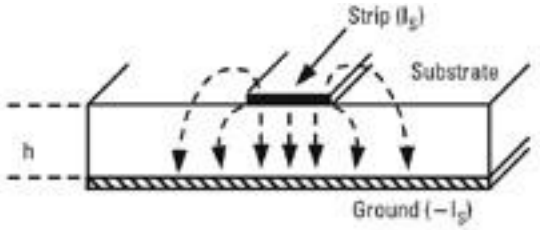


I(z,t)

V(z,t)



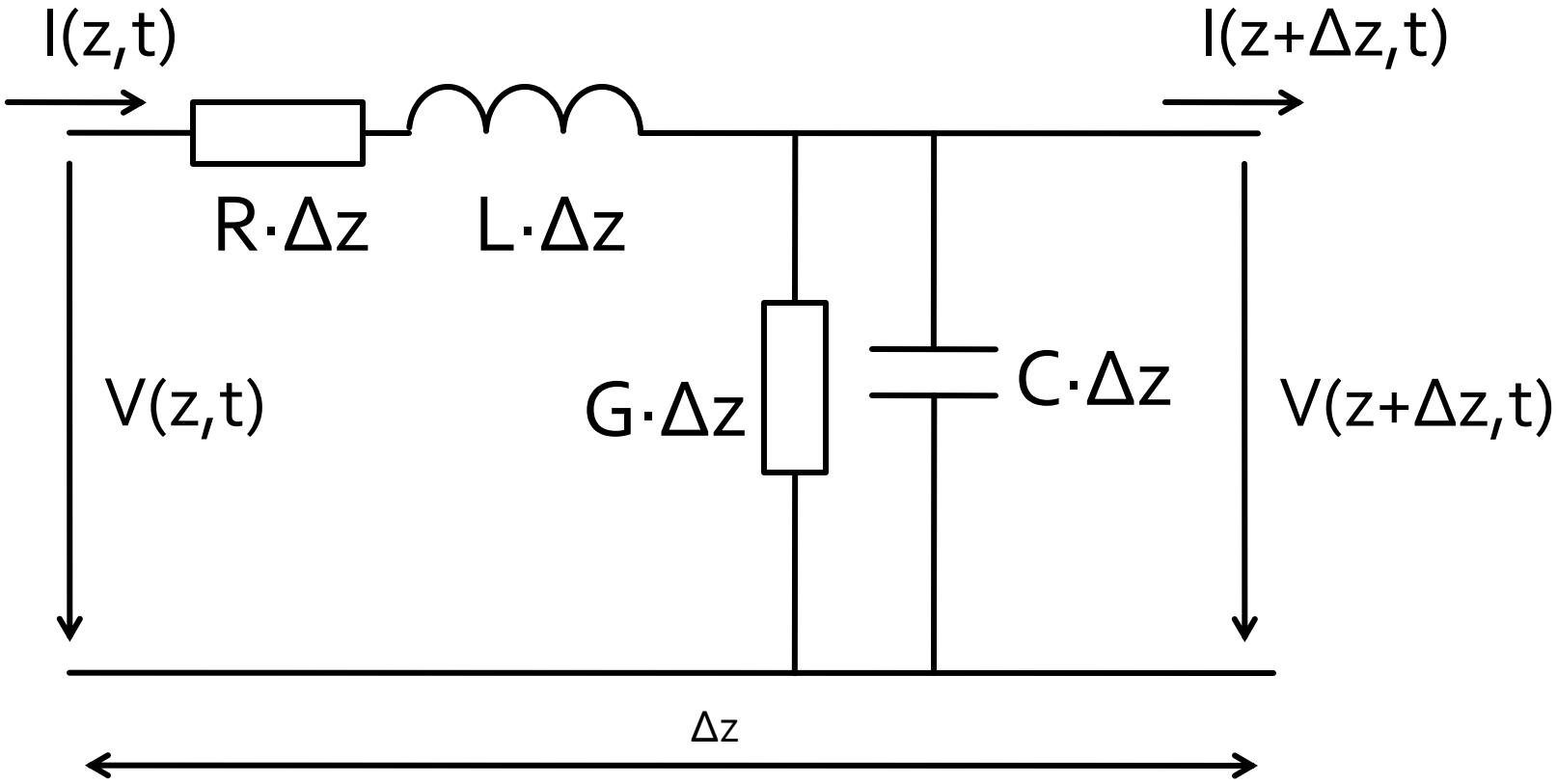




z

Linie de transmisie model echivalent

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



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

Ecuatiile telegrafistilor

- domeniu timp

$$\frac{\partial v(z,t)}{\partial z} = -R \cdot i(z,t) - L \cdot \frac{\partial i(z,t)}{\partial t} \qquad \text{K II}$$

$$\frac{\partial i(z,t)}{\partial z} = -G \cdot v(z,t) - C \cdot \frac{\partial v(z,t)}{\partial t} \qquad \text{K I}$$

- semnale sinusoidale

$$\frac{dV(z)}{dz} = -(R + j \cdot \omega \cdot L) \cdot I(z)$$

$$\frac{dI(z)}{dz} = -(G + j \cdot \omega \cdot C) \cdot V(z)$$

$$\Big/ \frac{d}{dz}(\ldots)$$

Rezolvare

$$\begin{cases} \dfrac{d^2V(z)}{dz^2} - \gamma^2 \cdot V(z) = 0 \\ \dfrac{d^2I(z)}{dz^2} - \gamma^2 \cdot I(z) = 0 \end{cases}$$

$$\gamma = \alpha + j \cdot \beta = \sqrt{(R + j \cdot \omega \cdot L) \cdot (G + j \cdot \omega \cdot C)}$$



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

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

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

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

Solutiile

$$\begin{cases} V(z) = V_0^+ e^{-\gamma \cdot z} + V_0^- e^{\gamma \cdot z} \\ I(z) = I_0^+ e^{-\gamma \cdot z} + I_0^- e^{\gamma \cdot z} \end{cases}$$

$$\gamma = \alpha + j \cdot \beta = \sqrt{(R + j \cdot \omega \cdot L) \cdot (G + j \cdot \omega \cdot C)}$$

$$V(z) = V_0^+ e^{-\gamma \cdot z} + V_0^- e^{\gamma \cdot z}$$

$$\frac{dV(z)}{dz} = -(R + j \cdot \omega \cdot L) \cdot I(z)$$

$$I(z) = \frac{\gamma}{R + j \cdot \omega \cdot L} \left(V_0^+ e^{-\gamma \cdot z} - V_0^- e^{\gamma \cdot z} \right)$$

$$Z_0 \equiv \frac{R + j \cdot \omega \cdot L}{\gamma} = \sqrt{\frac{R + j \cdot \omega \cdot L}{G + j \cdot \omega \cdot C}}$$

- Impedanta caracteristica a liniei

$$\frac{V_0^+}{I_0^+} = Z_0 = -\frac{V_0^-}{I_0^-}$$

$$\lambda = \frac{2\pi}{\beta} \qquad v_f = \frac{\omega}{\beta} = \lambda \cdot f$$

Linie fara pierderi

- **Fara pierderi**: R=G=0

$$\gamma = \alpha + j \cdot \beta = \sqrt{(R + j \cdot \omega \cdot L) \cdot (G + j \cdot \omega \cdot C)} = j \cdot \omega \cdot \sqrt{L \cdot C}$$

$$\alpha = 0 \quad ; \quad \beta = \omega \cdot \sqrt{L \cdot C}$$

$$Z_0 = \sqrt{\frac{R + j \cdot \omega \cdot L}{G + j \cdot \omega \cdot C}} = \sqrt{\frac{L}{C}}$$

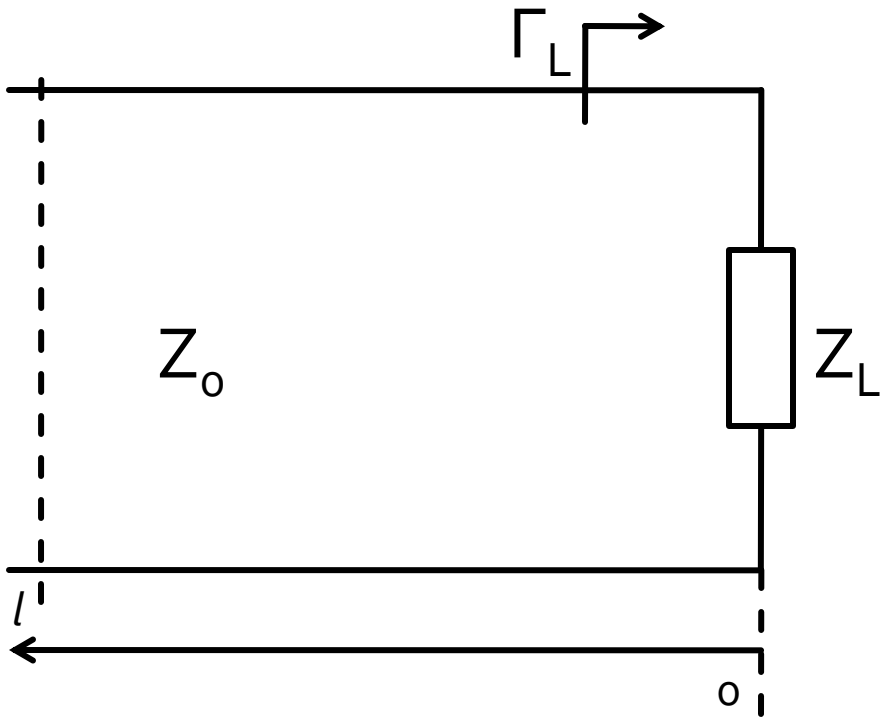
- Z_0 **real**

$$\begin{cases} V(z) = V_0^+ e^{-j \cdot \beta \cdot z} + V_0^- e^{j \cdot \beta \cdot z} \\ I(z) = \frac{V_0^+}{Z_0} e^{-j \cdot \beta \cdot z} - \frac{V_0^-}{Z_0} e^{j \cdot \beta \cdot z} \end{cases}$$

$$\lambda = \frac{2\pi}{\omega \cdot \sqrt{LC}} \qquad v_f = \frac{1}{\sqrt{LC}}$$

$$e^{-\gamma \cdot z} + e^{\gamma \cdot z} \Rightarrow e^{-j \cdot \beta \cdot z} + e^{j \cdot \beta \cdot z}$$

Linie fara pierderi



$$V(z) = V_0^+ e^{-j\cdot\beta\cdot z} + V_0^- e^{j\cdot\beta\cdot z}$$

$$I(z) = \frac{V_0^+}{Z_0} e^{-j\cdot\beta\cdot z} - \frac{V_0^-}{Z_0} e^{j\cdot\beta\cdot z}$$

$$Z_L = \frac{V(0)}{I(0)} \qquad Z_L = \frac{V_0^+ + V_0^-}{V_0^+ - V_0^-}\cdot Z_0$$

- coeficient de reflexie in tensiune

$$\Gamma = \frac{V_0^-}{V_0^+} = \frac{Z_L - Z_0}{Z_L + Z_0}$$

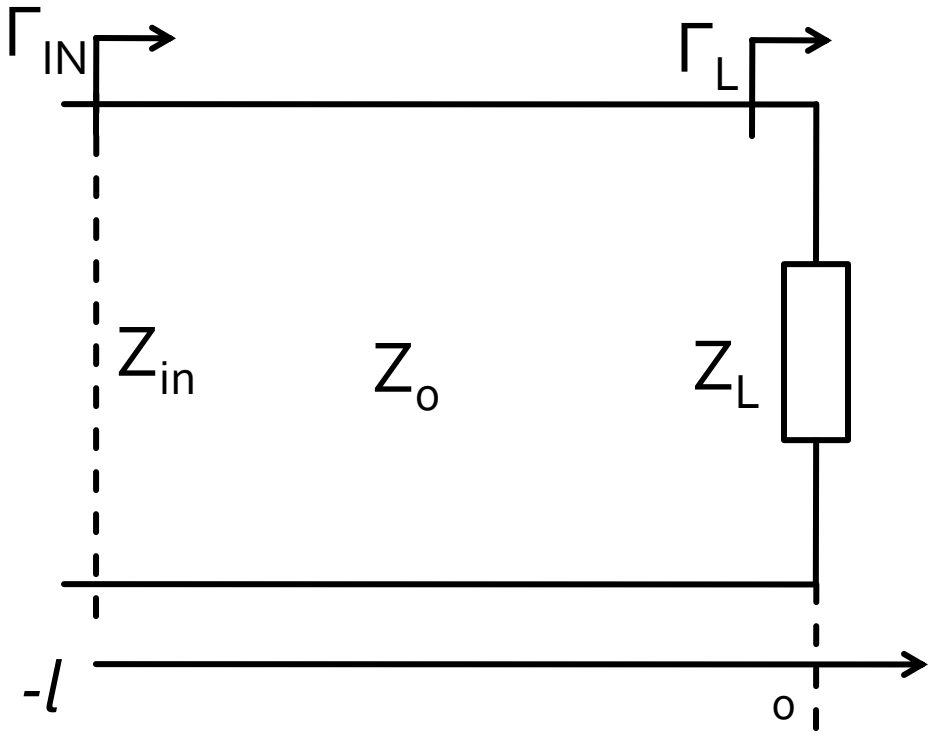
  - Z_o real

Linie fara pierderi

- coeficientul de reflexie la intrarea liniei

$$V(z) = V_0^+ e^{-j\cdot\beta\cdot z} + V_0^- e^{j\cdot\beta\cdot z}$$

$$\Gamma = \Gamma(z) = \frac{V_0^-(z)}{V_0^+(z)}$$



$$V(0) = V_0^+ + V_0^- \qquad \Gamma(0) = \Gamma_L = \frac{V_0^-}{V_0^+}$$

$$V(-l) = V_0^+ e^{j\cdot\beta\cdot l} + V_0^- e^{-j\cdot\beta\cdot l}$$

$$\Gamma(-l) = \Gamma_{IN} = \frac{V_0^- \cdot e^{-j\cdot\beta\cdot l}}{V_0^+ \cdot e^{j\cdot\beta\cdot l}} = \Gamma(0)\cdot e^{-2j\cdot\beta\cdot l}$$

$$|\Gamma(-l)| = |\Gamma(0)|\cdot|e^{-2j\cdot\beta\cdot l}| = |\Gamma(0)|$$

$$\Gamma_{IN} = \Gamma_L \cdot e^{-2j\cdot\beta\cdot l} \qquad |\Gamma_{IN}| = |\Gamma_L|$$

Linie fara pierderi

$$V(z) = V_0^+ \cdot \left(e^{-j\cdot\beta\cdot z} + \Gamma \cdot e^{j\cdot\beta\cdot z}\right) \qquad I(z) = \frac{V_0^+}{Z_0} \cdot \left(e^{-j\cdot\beta\cdot z} - \Gamma \cdot e^{j\cdot\beta\cdot z}\right)$$

- Puterea medie

$$P_{avg} = \frac{1}{2} \cdot \mathrm{Re}\left\{V(z)\cdot I(z)^*\right\} = \frac{1}{2} \cdot \frac{\left|V_0^+\right|^2}{Z_0} \cdot \mathrm{Re}\left\{1 - \Gamma^* \cdot e^{-2j\cdot\beta\cdot z} + \Gamma \cdot e^{2j\cdot\beta\cdot z} - \left|\Gamma\right|^2\right\}$$

$$\left(z - z^*\right) = \mathrm{Im}$$

$$P_{avg} = \frac{1}{2} \cdot \frac{\left|V_0^+\right|^2}{Z_0} \cdot \left(1 - \left|\Gamma\right|^2\right)$$

- Puterea transmisa sarcinii = Puterea incidenta - Puterea "reflectata"
- Return Loss [dB]

$$\mathrm{RL} = -20 \cdot \log\left|\Gamma\right| \quad [\mathrm{dB}]$$

Linie fara pierderi

$$P_{avg} = \frac{1}{2} \cdot \frac{\left|V_0^+\right|^2}{Z_0} \cdot \left(1 - \left|\Gamma\right|^2\right)$$

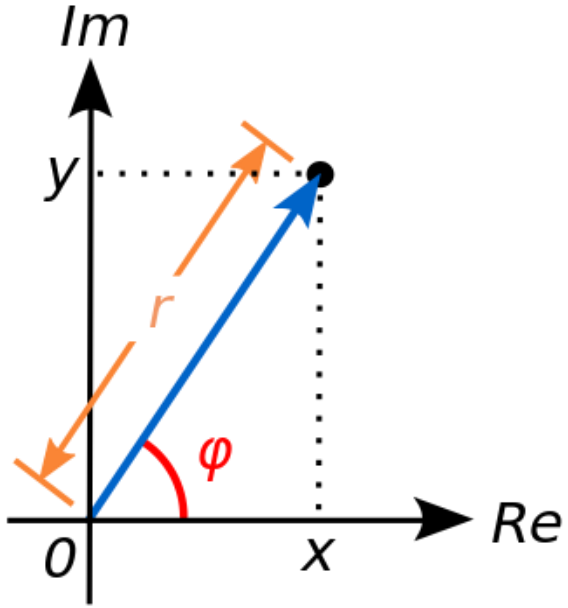
- Puterea medie e constanta in lungul liniei
  - (**fara** P_{avg}(~~≠~~))
  - poate fi masurata
- Se utilizeaza puterea pentru a caracteriza amplitudinea semnalului
  - un punct de vedere "energetic" (fizica)
  - energie mai mare = semnal "mai mare"

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

- Formula lui Euler

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

$$e^{j\cdot x} + e^{-j\cdot x} = \cos x + j\cdot \sin x + \cos(-x) + j\cdot \sin(-x)$$

$$e^{j\cdot x} + e^{-j\cdot x} = \cos x + j\cdot \sin x + \cos x - j\cdot \sin x = 2\cdot \cos x$$

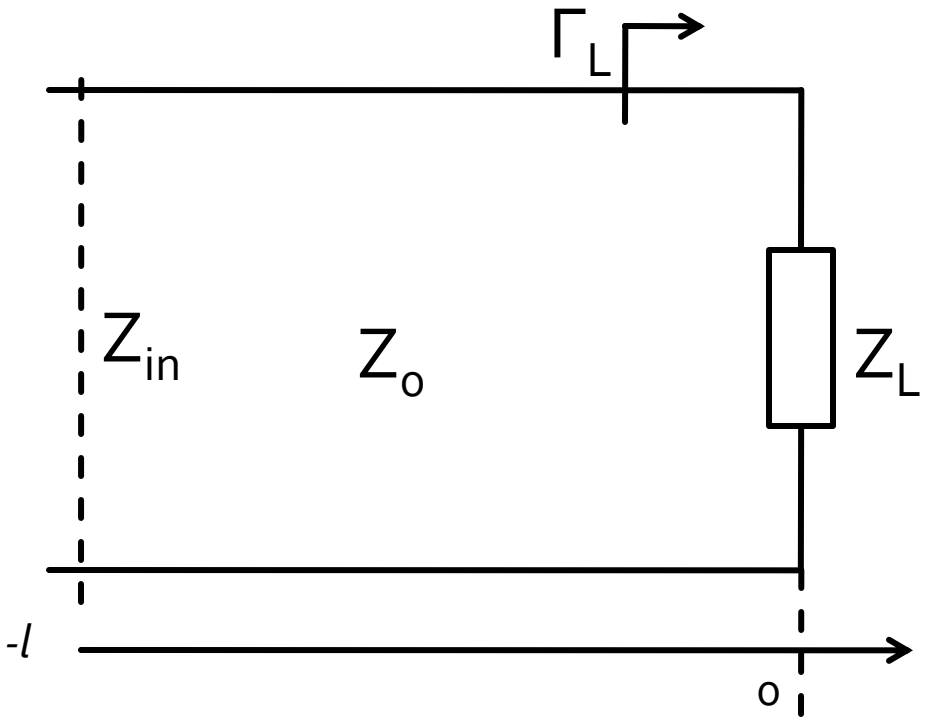
$$\rightarrow \quad \cos x = \frac{e^{j\cdot x} + e^{-j\cdot x}}{2}$$

$$e^{j\cdot x} - e^{-j\cdot x} = \cos x + j\cdot \sin x - \cos(-x) - j\cdot \sin(-x)$$

$$e^{j\cdot x} - e^{-j\cdot x} = \cos x + j\cdot \sin x - \cos x + j\cdot \sin x = 2j\cdot \sin x$$

$$\rightarrow \quad \sin x = \frac{e^{j\cdot x} - e^{-j\cdot x}}{2j}$$

Linie fara pierderi



$$V(-l) = V_0^+ e^{j\cdot\beta\cdot l} + V_0^- e^{-j\cdot\beta\cdot l}$$

$$I(-l) = \frac{V_0^+}{Z_0} e^{j\cdot\beta\cdot l} - \frac{V_0^-}{Z_0} e^{-j\cdot\beta\cdot l}$$

$$Z_{in} = \frac{V(-l)}{I(-l)} \qquad Z_{in} = Z_0 \cdot \frac{1+\Gamma\cdot e^{-2j\cdot\beta\cdot l}}{1-\Gamma\cdot e^{-2j\cdot\beta\cdot l}}$$

- **impedanta la intrarea liniei**

$$Z_{in} = Z_0 \cdot \frac{(Z_L+Z_0)\cdot e^{j\cdot\beta\cdot l} + (Z_L-Z_0)\cdot e^{-j\cdot\beta\cdot l}}{(Z_L+Z_0)\cdot e^{j\cdot\beta\cdot l} - (Z_L-Z_0)\cdot e^{-j\cdot\beta\cdot l}}$$

$$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot\tan(\beta\cdot l)}{Z_0 + j\cdot Z_L\cdot\tan(\beta\cdot l)}$$

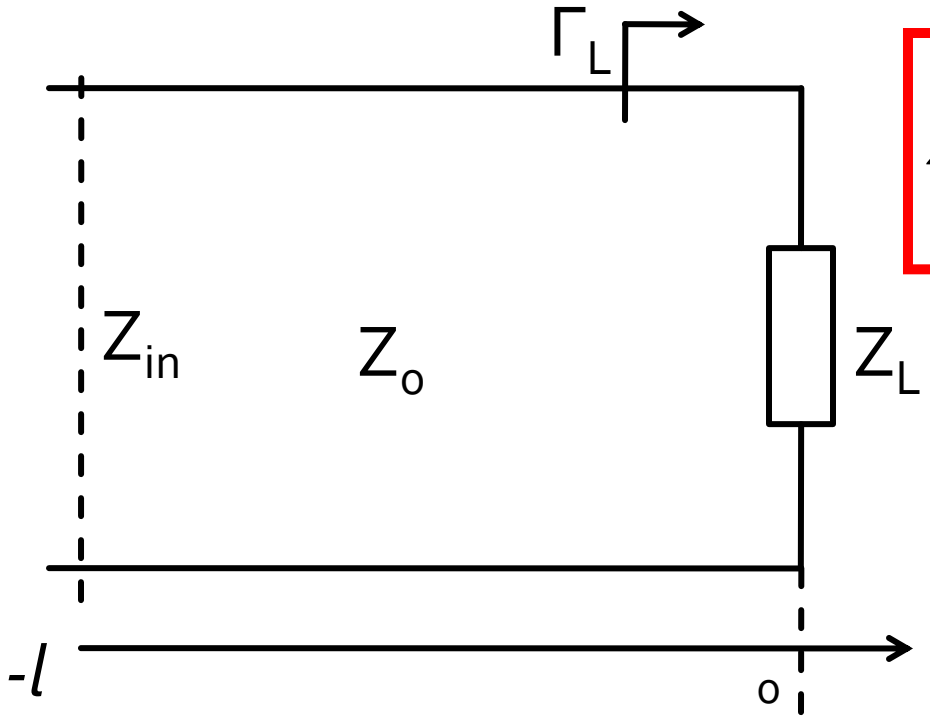
Linie fara pierderi

- **impedanta la intrarea liniei**

$$Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan \beta \cdot l}{Z_0 + j \cdot Z_L \cdot \tan \beta \cdot l}$$

Linie fara pierderi

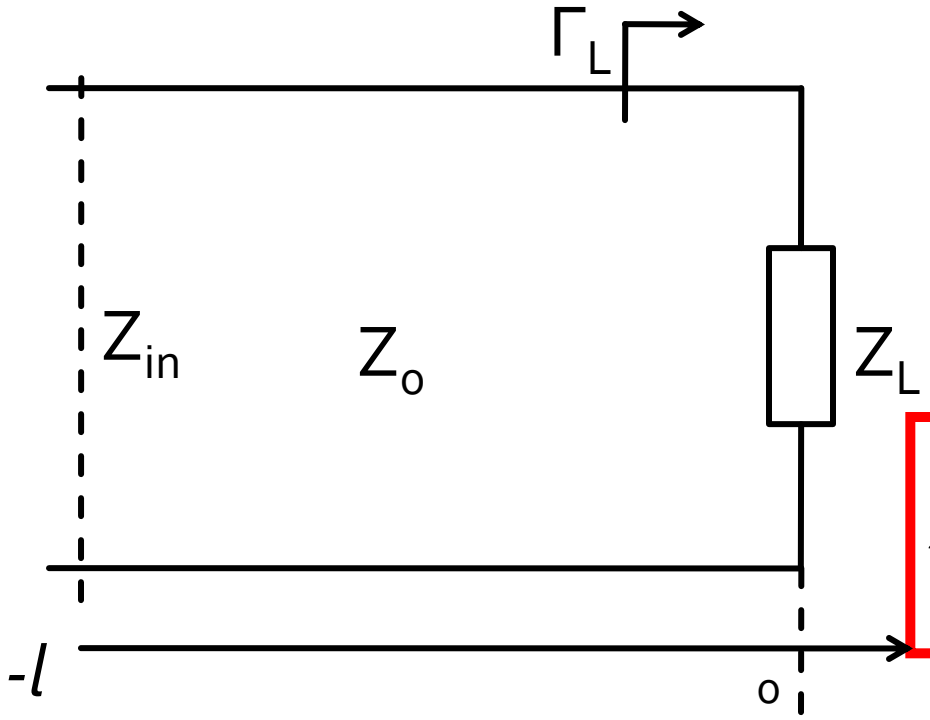
- impedanta la intrarea liniei de impedanta caracteristica Z_o, de lungime l, terminata cu impedanta Z_L



$$Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan \beta \cdot l}{Z_0 + j \cdot Z_L \cdot \tan \beta \cdot l}$$

Linie fara pierderi

- relatia este **dependenta de frecventa** prin valoarea $\beta \cdot l$



$$v_f = \frac{\omega}{\beta} = \lambda \cdot f \qquad \lambda = \frac{2\pi}{\beta}$$

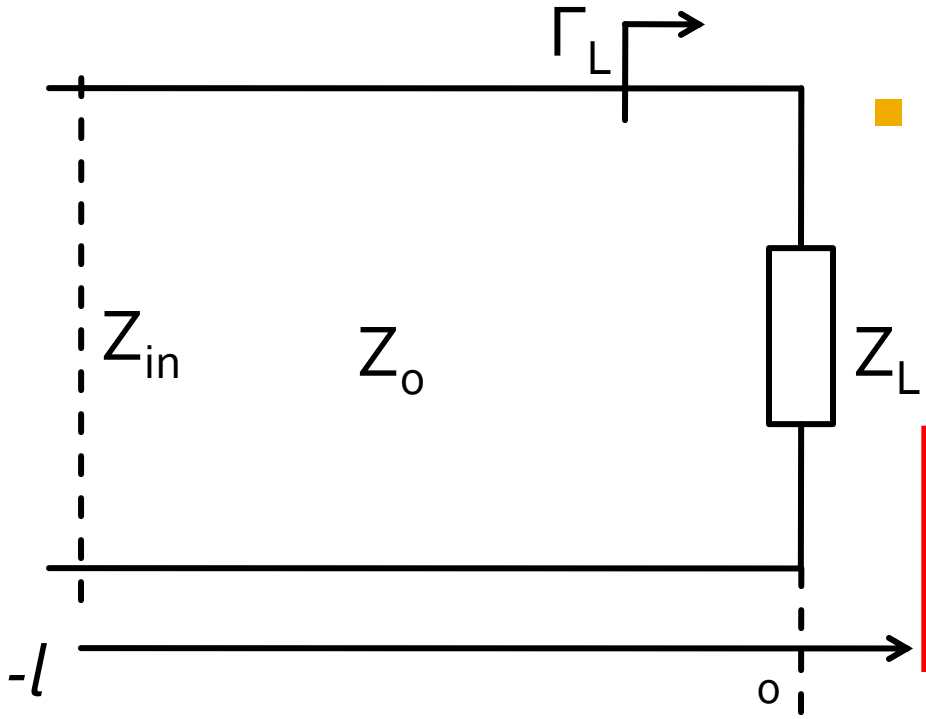
$$\beta \cdot l = \frac{2\pi}{\lambda} \cdot l = \frac{2\pi \cdot f}{v_f} \cdot l = \frac{2\pi \cdot l}{v_f} \cdot f$$

dependenta de frecventa este **periodica**, impusa de functia tangenta

$$Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan \beta \cdot l}{Z_0 + j \cdot Z_L \cdot \tan \beta \cdot l}$$

Linie fara pierderi, cazuri particulare

- $l = k \cdot \lambda/2$ $\quad \beta \cdot l = \frac{2\pi}{\lambda} \cdot l = k \cdot \pi \quad \tan \beta \cdot l = 0$ $\quad Z_{in} = Z_L$
- $l = \lambda/4 + k \cdot \lambda/2$ $\quad \tan \beta \cdot l \to \infty$ $\quad Z_{in} = \frac{Z_0^2}{Z_L}$



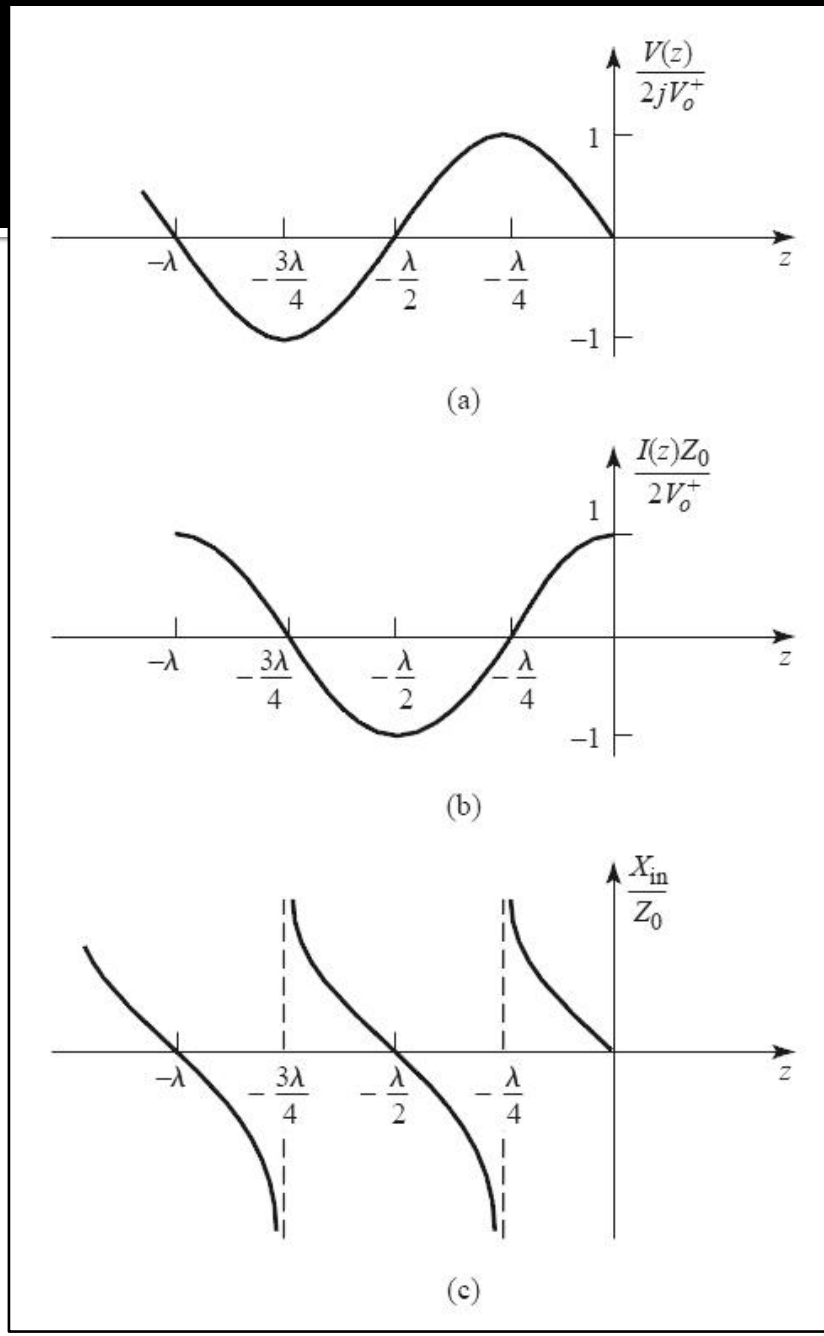
- Transformatorul in sfert de lungime de unda

$$Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan \beta \cdot l}{Z_0 + j \cdot Z_L \cdot \tan \beta \cdot l}$$

Linie in scurtcircuit

- Z_L = o
- reactanța pură
  - +/- → in funcție de *l*

$$Z_{in} = j \cdot Z_0 \cdot \tan \beta \cdot l$$



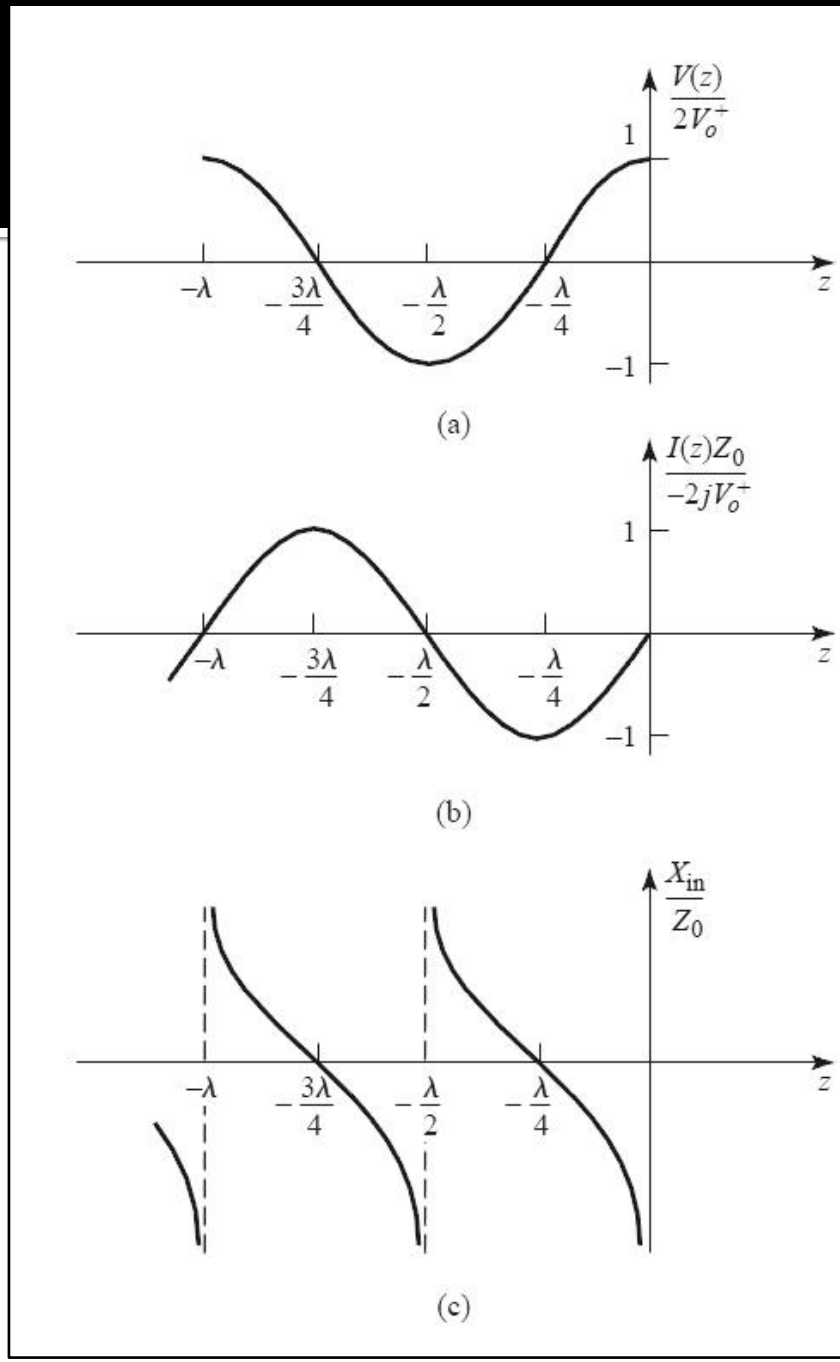
$$Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan(\beta \cdot l)}{Z_0 + j \cdot Z_L \cdot \tan(\beta \cdot l)}$$

Linie in gol

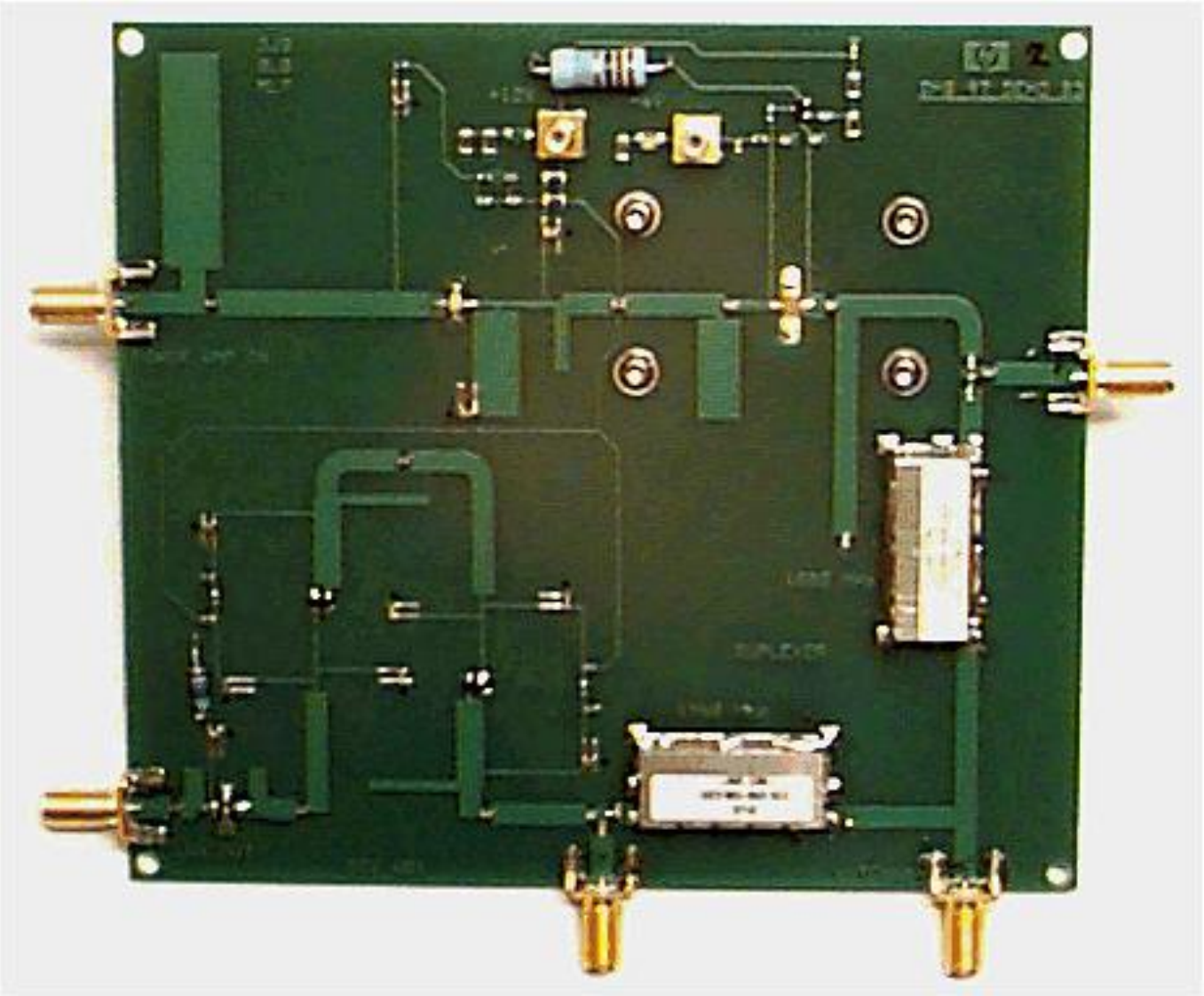
- $Z_L = \infty \longrightarrow 1 / Z_L = 0$
- reactanța pură
  - +/- → in funcție de *l*

$$Z_{in} = -j \cdot Z_0 \cdot \cot \beta \cdot l$$

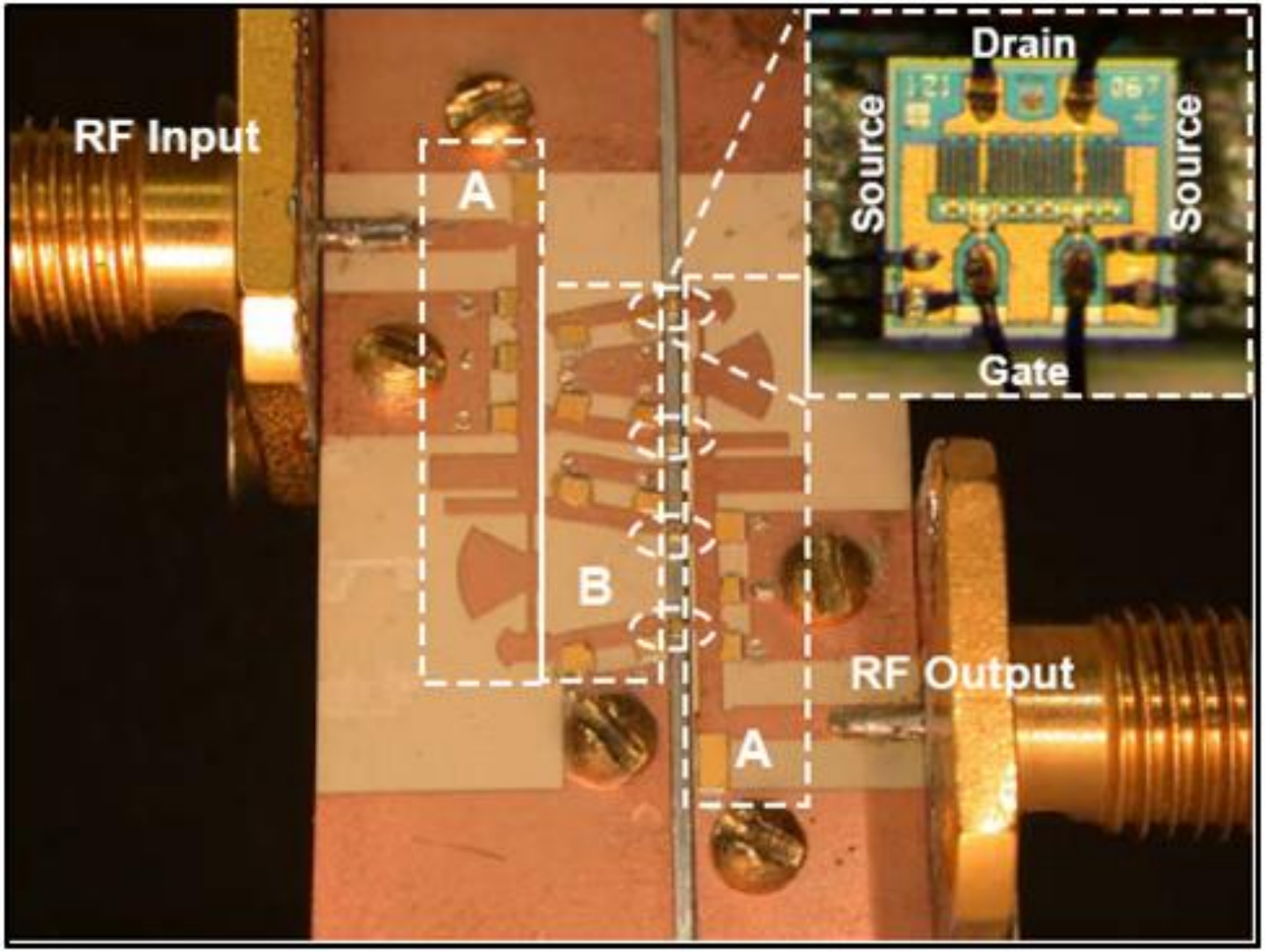
$$Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan(\beta \cdot l)}{Z_0 + j \cdot Z_L \cdot \tan(\beta \cdot l)}$$



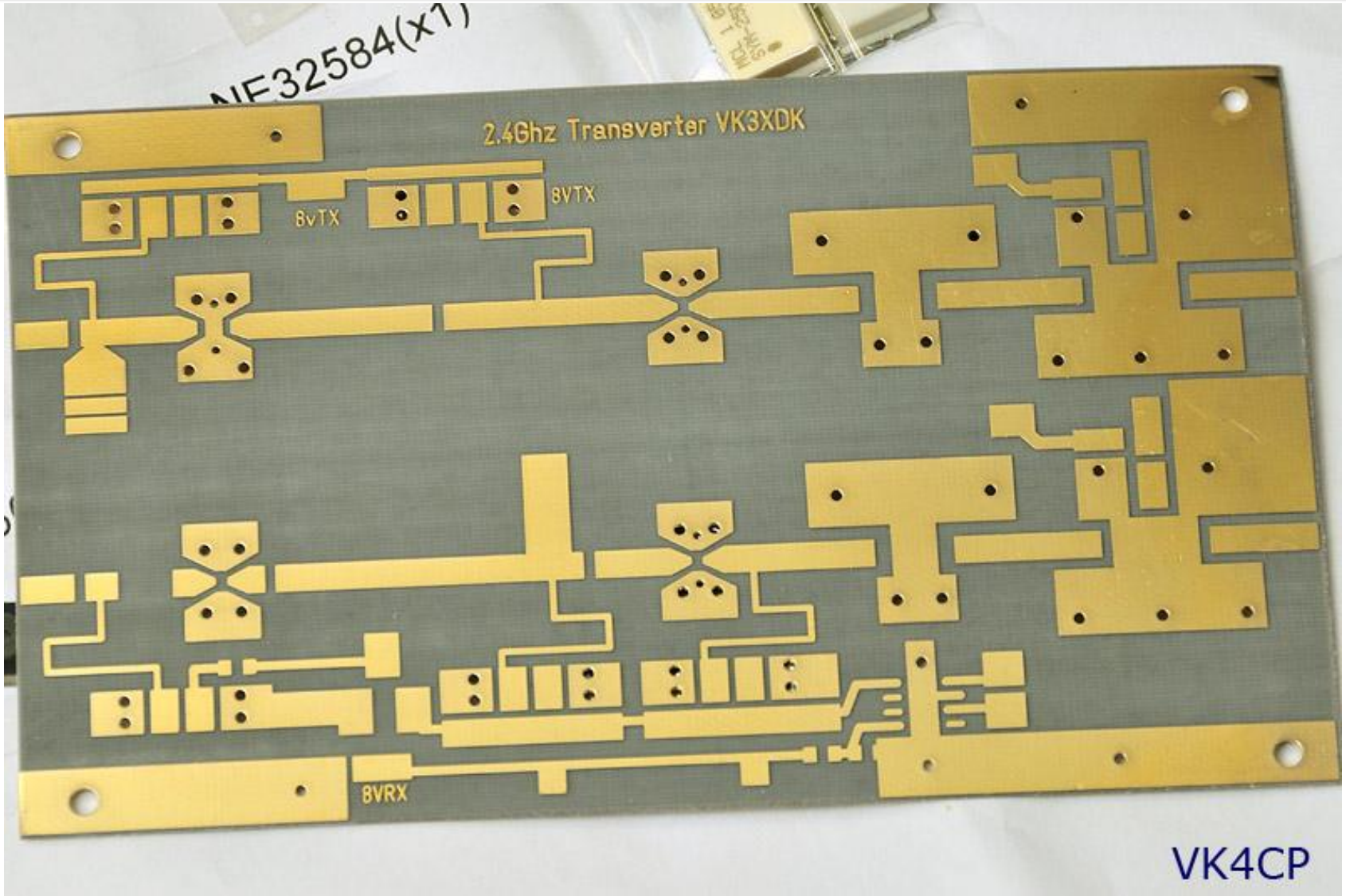
Exemple



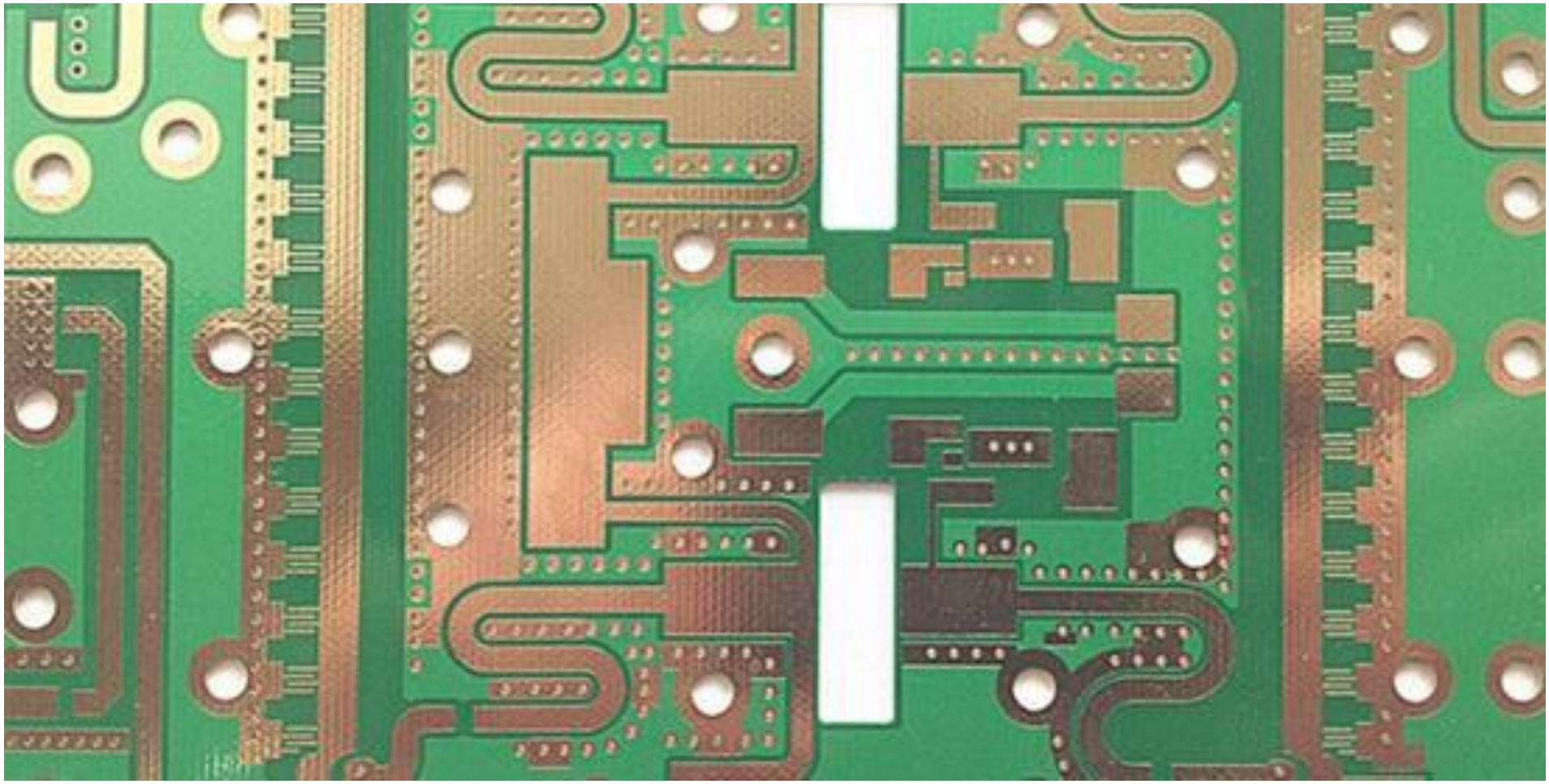
Exemple



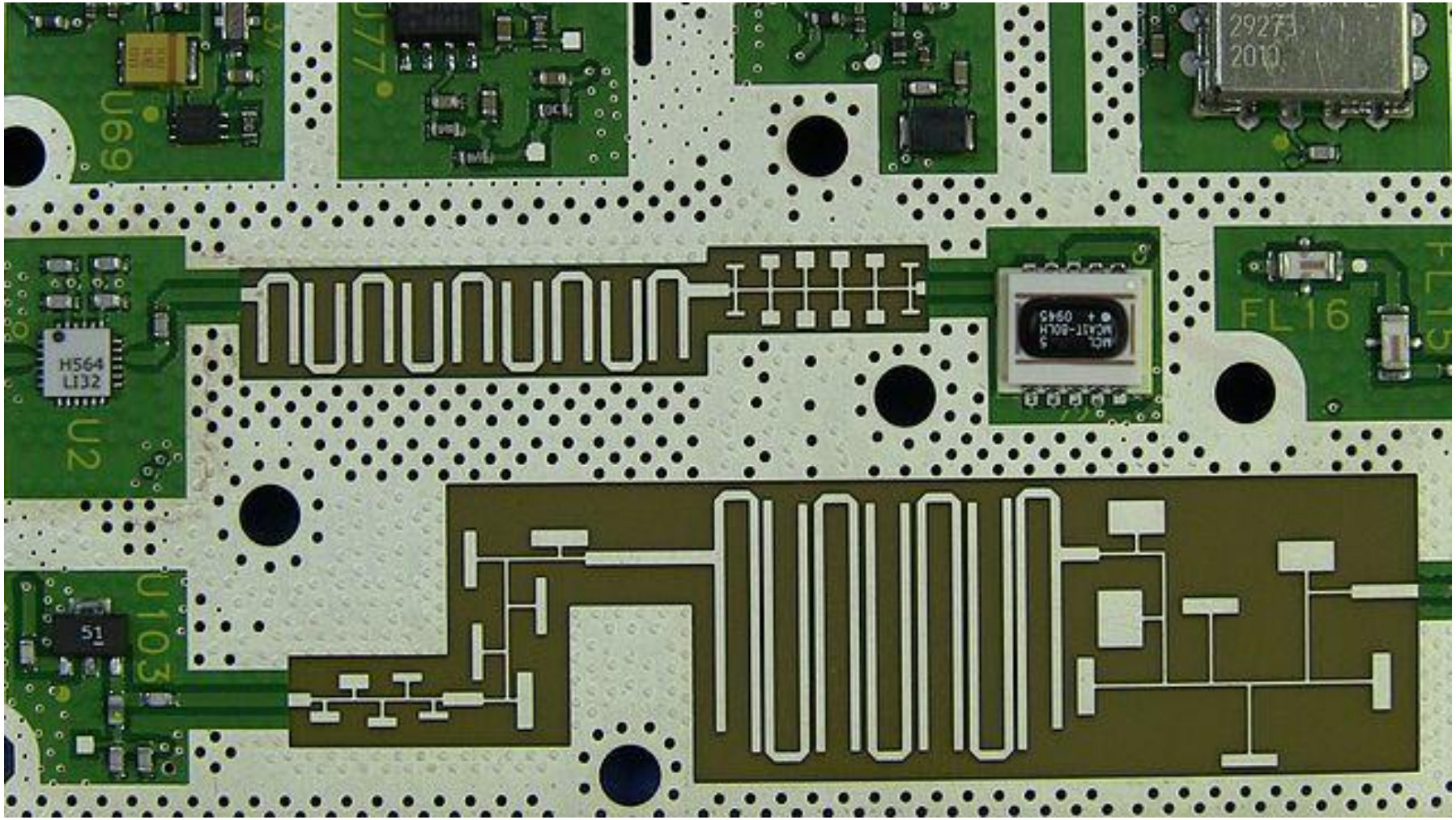
Exemple



Exemple



Exemple



Factor de unda stationara

$$V(z) = V_0^+ \cdot \left(e^{-j\cdot\beta\cdot z} + \Gamma \cdot e^{j\cdot\beta\cdot z}\right) \qquad |V(z)| = \left|V_0^+\right| \cdot \left|e^{-j\cdot\beta\cdot z}\right| \cdot \left|1 + \Gamma \cdot e^{2j\cdot\beta\cdot z}\right| \qquad \Gamma = |\Gamma| \cdot e^{j\theta}$$

$$|V(z)| = \left|V_0^+\right| \cdot \left|1 + |\Gamma| \cdot e^{\theta + 2j\cdot\beta\cdot z}\right|$$

amplitudine maxima pentru $e^{\theta+2j\cdot\beta\cdot z} = 1$ $\qquad V_{\max} = \left|V_0^+\right| \cdot \left(1 + |\Gamma|\right)$

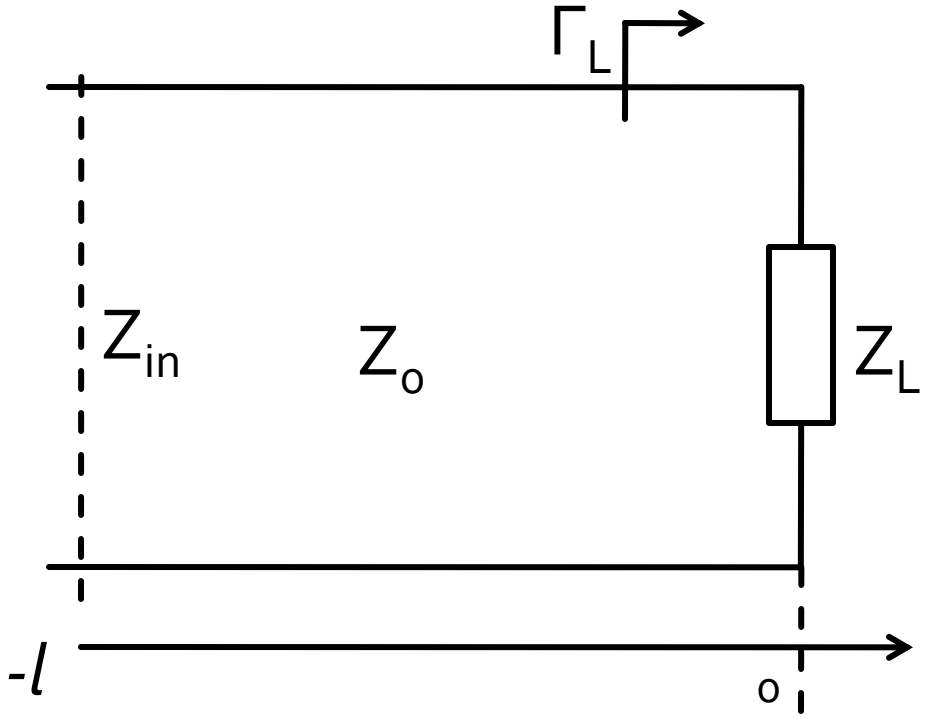
amplitudine minima pentru $e^{\theta+2j\cdot\beta\cdot z} = -1$ $\qquad V_{\min} = \left|V_0^+\right| \cdot \left(1 - |\Gamma|\right)$

- se defineste factorul de unda stationara
  - (Voltage) Standing Wave Ratio

$$VSWR = \frac{V_{\max}}{V_{\min}} = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

  - numar real $1 \le VSWR < \infty$
  - o masura a dezadaptarii (SWR = 1 semnifica adaptare)

Linie fara pierderi +/-



$$Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan \beta \cdot l}{Z_0 + j \cdot Z_L \cdot \tan \beta \cdot l}$$

$$V(z) = V_0^+ e^{-\gamma \cdot z} + V_0^- e^{\gamma \cdot z}$$

$$I(z) = I_0^+ e^{-\gamma \cdot z} + I_0^- e^{\gamma \cdot z}$$

$$\Gamma(-l) = \Gamma(0) \cdot e^{-2j \cdot \beta \cdot l}$$

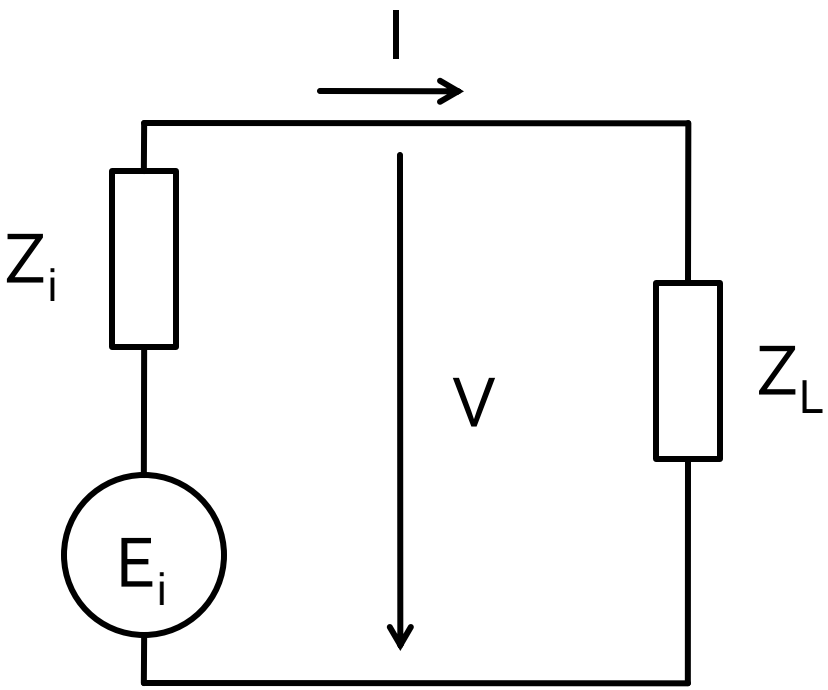
$$\Gamma_{in} = \Gamma_L \cdot e^{-2j \cdot \beta \cdot l}$$

Transfer de putere

Adaptarea de impedanța

Adaptare

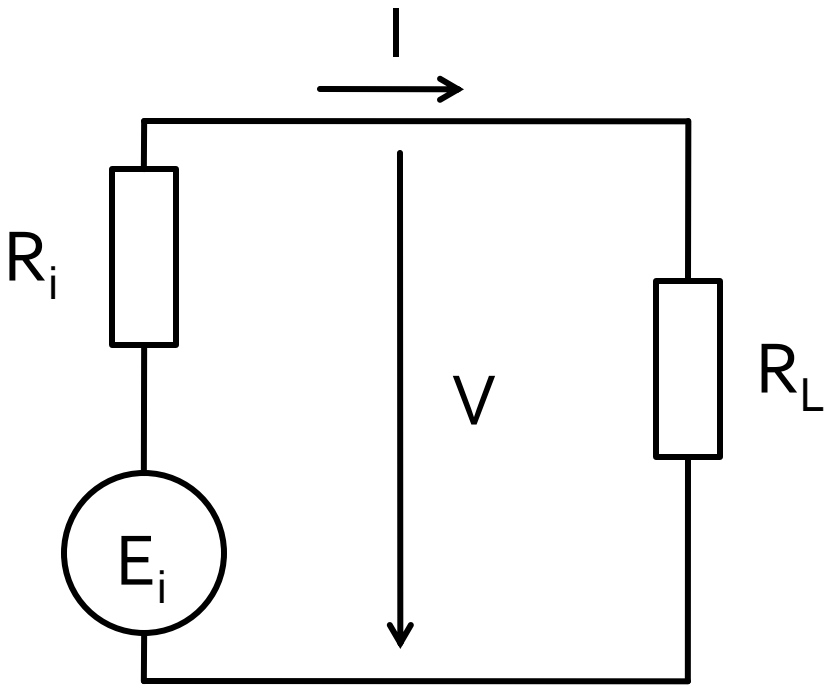
- Generator **adaptat** la sarcina ?



- valori impedanta ?
- reflexii ?

Adaptare, impedante reale

- Generator adaptat la sarcina



$$I = \frac{E_i}{R_i + R_L}$$

$$V = \frac{E_i \cdot R_L}{R_i + R_L}$$

$$P_L = R_L \cdot I^2$$

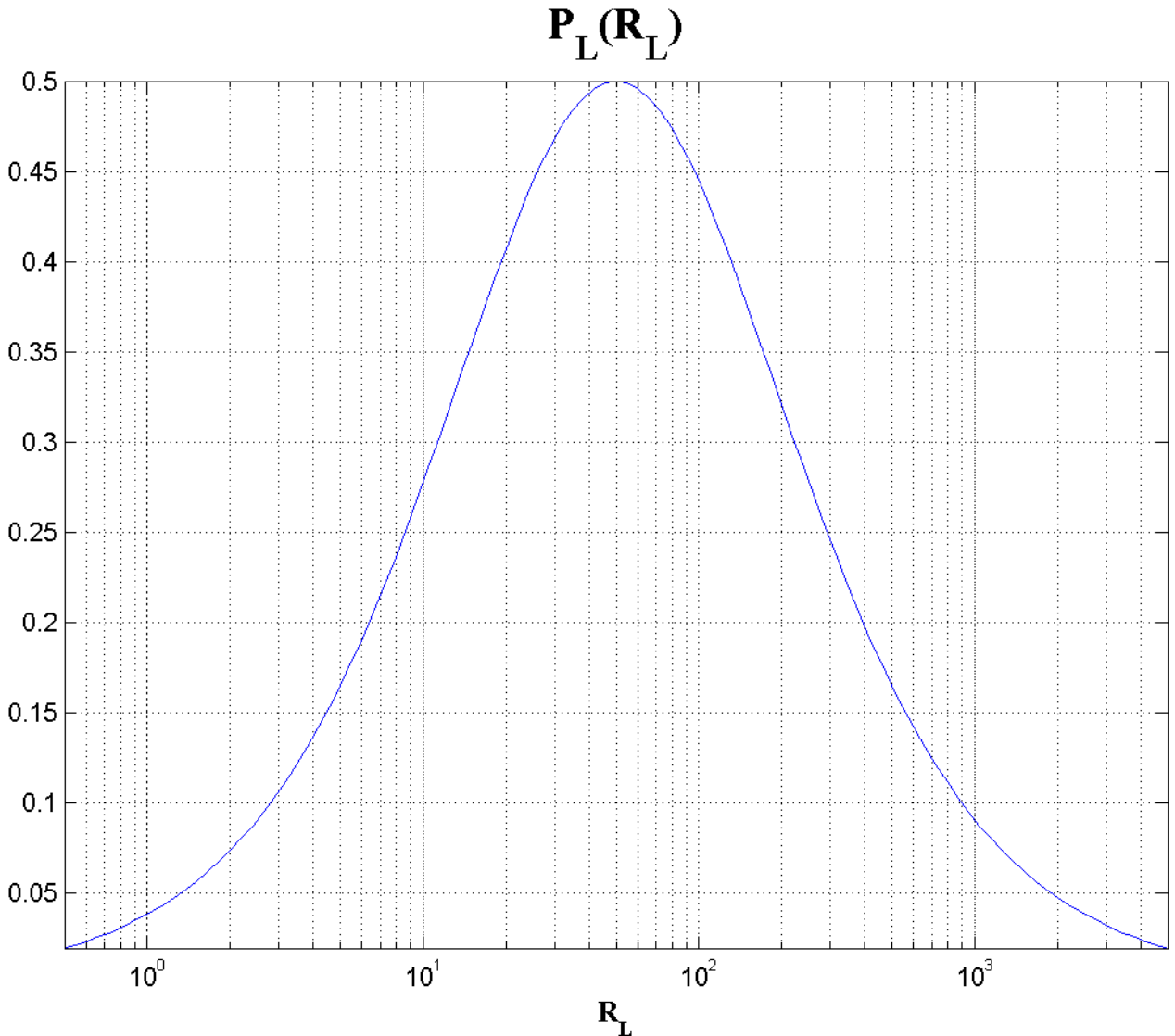
$$P_L = \frac{R_L \cdot E_i^2}{(R_i + R_L)^2}$$

Adaptare , impedante reale

$$P_L = R_L \cdot I^2 \qquad P_L = \frac{R_L \cdot E_i^2}{(R_i + R_L)^2}$$

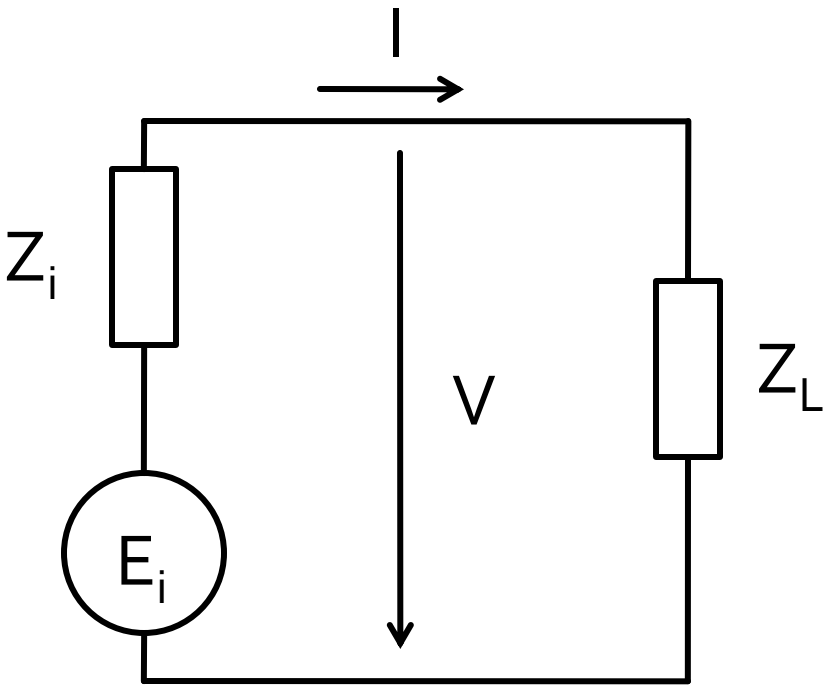
- Putere pe sarcina
  - $R_i = 50\Omega$
  - $R_L = 0 \rightarrow P_L = 0$
  - $R_L = \infty \rightarrow P_L = 0$

Adaptare , impedante reale



Adaptare, impedante complexe

- Generator adaptat la sarcina



$$I = \frac{E_i}{Z_i + Z_L}$$

$$V = \frac{E_i \cdot Z_L}{Z_i + Z_L}$$

$$P_L = \operatorname{Re} Z_L \cdot |I|^2$$

$$P_L = \operatorname{Re} Z_L \cdot \left| \frac{E_i}{Z_i + Z_L} \right|^2$$

Adaptare

$$P_L = \frac{R_L \cdot |E_i|^2}{|Z_i + Z_L|^2} = \frac{R_L \cdot |E_i|^2}{|(R_i + R_L) + j \cdot (X_i + X_L)|^2}$$

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

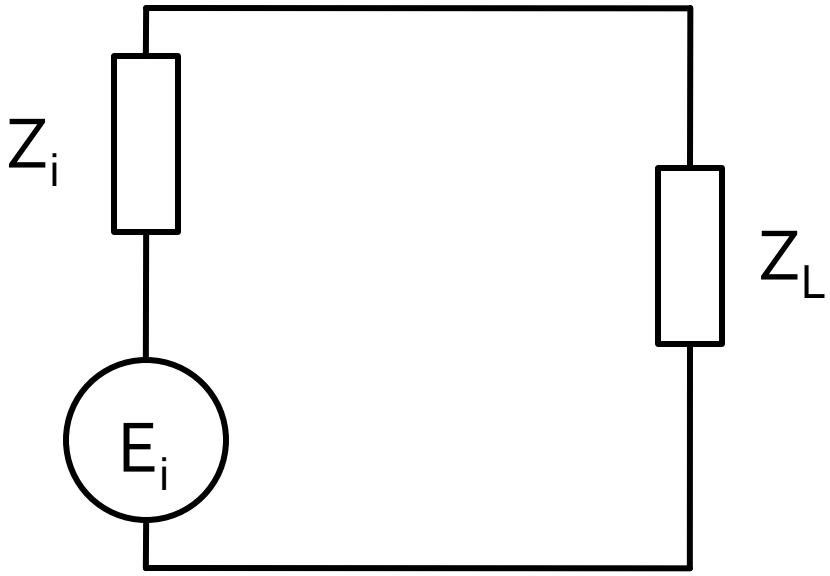
$$P_L = \frac{R_L \cdot |E_i|^2}{(R_i + R_L)^2 + (X_i + X_L)^2}$$

- Adaptare
  - putere maxima transmisa sarcinii
  - conditie?

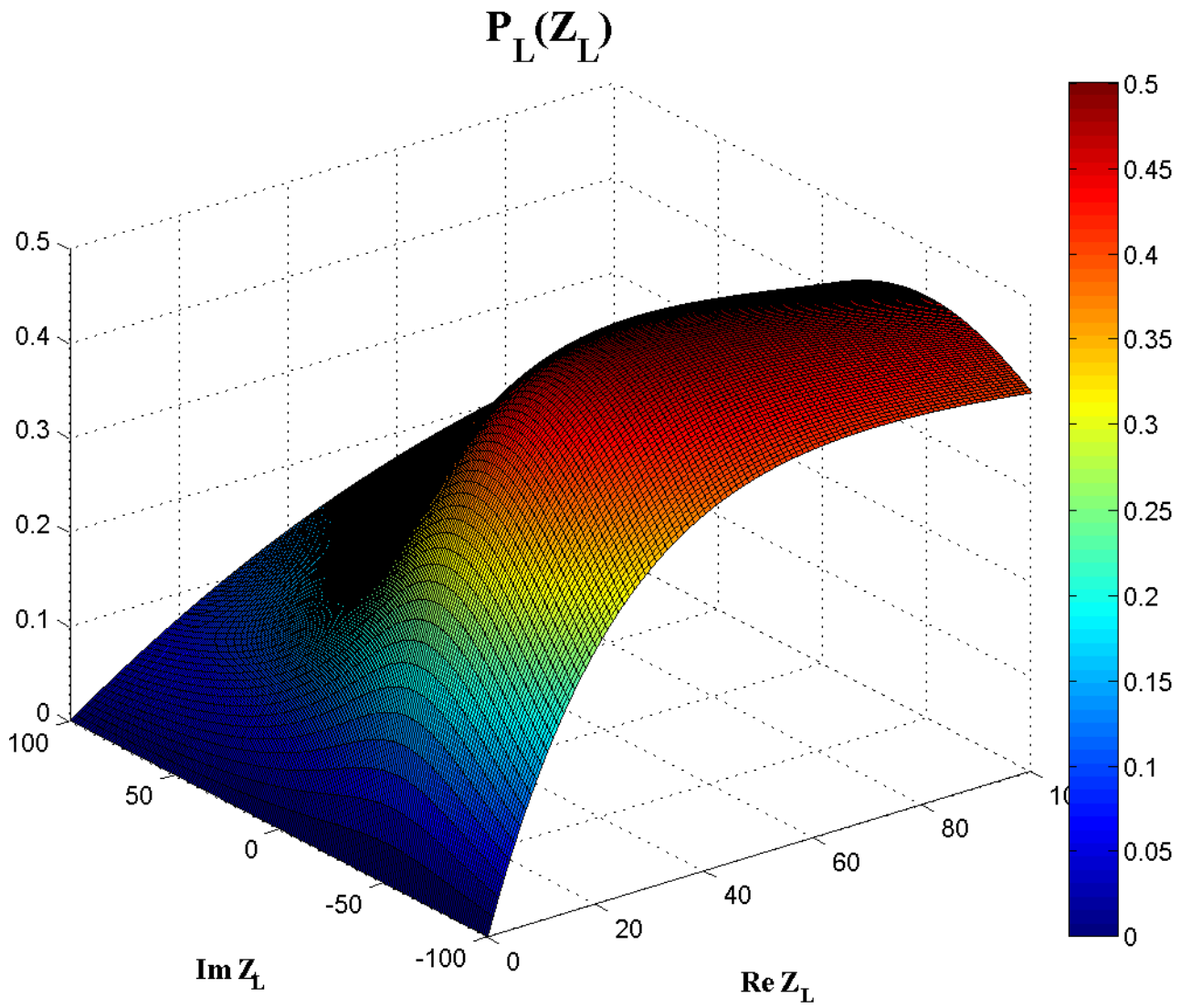
Adaptare, exemplu

- E = 10V
- $Z_i = 50\,\Omega + j \cdot 50\Omega$
- $P_L(Z_L)$?

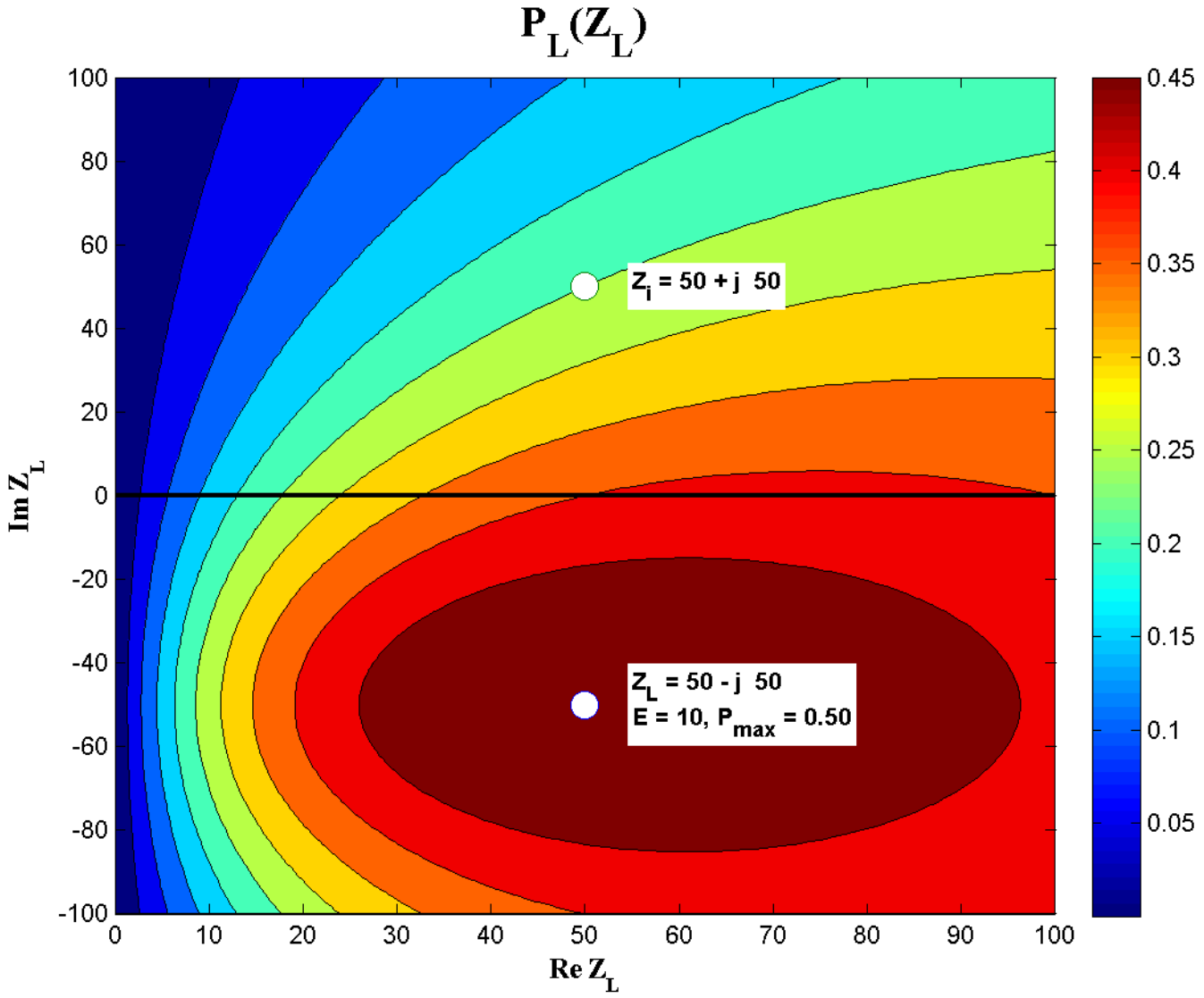
$$P_L = \frac{R_L \cdot |E_i|^2}{(R_i + R_L)^2 + (X_i + X_L)^2}$$



Adaptare, exemplu



Adaptare, exemplu



Adaptare dpdv al puterii

$$R_i > 0, R_L > 0$$

$$P_L = \frac{|E_i|^2}{4R_i + \frac{(R_i - R_L)^2}{R_L} + \frac{(X_i + X_L)^2}{R_L}}$$

$$P_{L\max} = \frac{|E_i|^2}{4R_i} \equiv P_a$$

$$R_L = R_i, X_L = -X_i$$

- P_a : Puterea disponibila (**available**)

$$Z_L = Z_i^*$$

Puncte suplimentare

Tema

Tema

- Scrieti pe o foaie de hartie (si scanati/foto) relatiile pentru:
  - determinarea conditiei de maxim de putere utilizand derivate partiale (impedante complexe)

$$\frac{\partial P_L}{\partial R_L} = 0 \qquad \frac{\partial P_L}{\partial X_L} = 0$$

Laborator 1

2026/2027

Dispozitive şi circuite de microunde pentru radiocomunicații

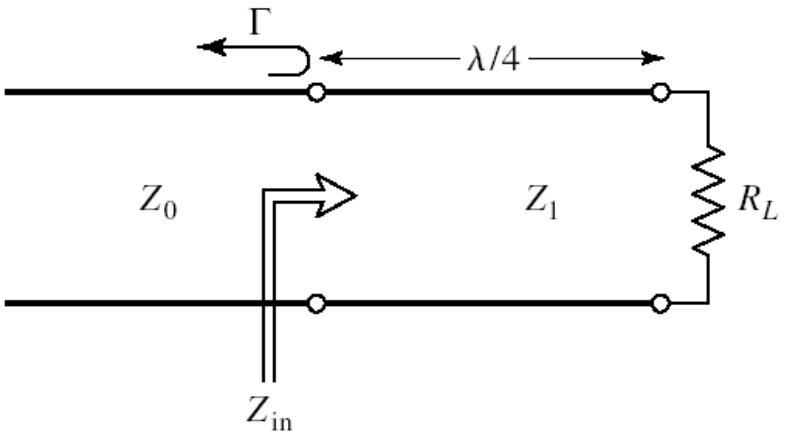
Scurta teorie

Adaptare de impedanta

- Adaptarea de impedanta este necesara atunci cand are loc o variatie in salt a impedantei/impedantei caracteristice
- Se caracterizeaza prin valoarea coeficientului de reflexie (Γ)
  - $|\Gamma|=0$ adaptare perfecta
  - $|\Gamma|\approx 0$, $|\Gamma|<\Gamma_{max}$ adaptare "suficienta"
- in simulare $|\Gamma|==|S11|$

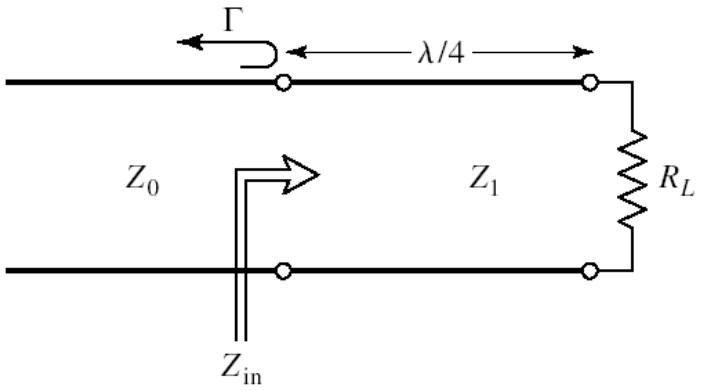
Transformatorul in sfert de lungime de unda

- Feed line – linie de intrare cu impedanta caracteristica Z_0
- Sarcina cu impedanta (**rezistiva!**) R_L
- Dorim adaptarea sarcinei la fider cu o linie de lungime **λ/4** si impedanta caracteristica Z_1



$$\Gamma_{in} = 0 \quad \Rightarrow \quad Z_1 = \sqrt{Z_0 R_L}$$

Transformatorul in sfert de lungime de unda



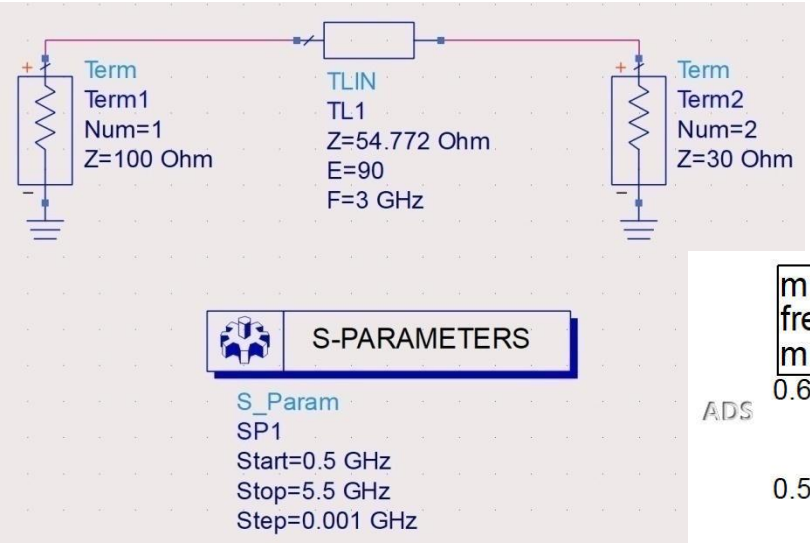
$$\Gamma_{in} = \frac{Z_{in} - Z_0}{Z_{in} + Z_0}$$

$$\beta \cdot l = \frac{2\pi}{\lambda} \cdot \frac{\lambda}{4} = \frac{\pi}{2} \qquad Z_{in} = \frac{Z_1^2}{R_L}$$

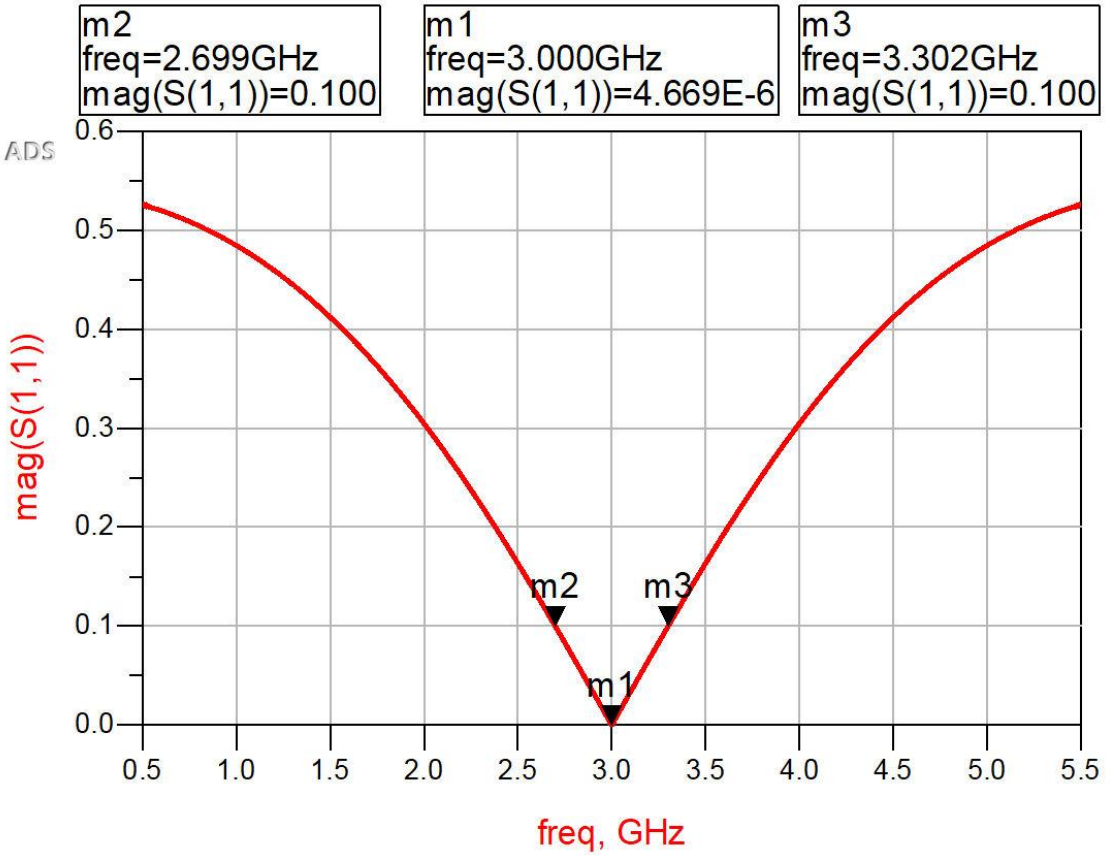
$$\Gamma_{in} = \frac{Z_1^2 - Z_0 \cdot R_L}{Z_1^2 + Z_0 \cdot R_L} \qquad \Gamma_{in} = 0 \Rightarrow Z_1 = \sqrt{Z_0 R_L}$$

- Pe fider (Z_0) avem doar unda progresiva
- Pe linia in sfert de lungime de unda (Z_1) avem unda stationara

Sfert de lungime de unda



$$P_{avg} = \frac{1}{2} \cdot \frac{\left|V_0^+\right|^2}{Z_0} \cdot \left(1 - \left|\Gamma\right|^2\right)$$



Contact

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- rdamian@etti.tuiasi.ro