

Curs 3
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 + (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
DCMR Dispozitive si circuite de microunde pentru radiocomunicații					
	Nota	19/06/2009	Nota finală	10	
	Exam	19/06/2009	Examen DCMR	9	
	Tema	05/06/2009	Proiect DCMR	10	

FLORESCU DAN-CONSTANȚĂ



Date:

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Detalii

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

Fotografii

http://if-opto.eti.tuiasi.ro/presenza.php?act=153&nru=14&ext_supliz=26

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		<input type="checkbox"/> Prezent	2	ANTIGHIN FLORIN-RAZVAN		Fotografia nu există	<input type="checkbox"/> Prezent
		Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> <input type="button" value="■"/>			Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> <input type="button" value="■"/>			Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> <input type="button" value="■"/>
		Nota: 0			Nota: 0			Nota: 0
		Obs: <input type="text"/>			Obs: <input type="text"/>			Obs: <input type="text"/>
4	APOSTOL PAVEL-MANUEL		Fotografia nu există		<input type="checkbox"/> Prezent	5	BALASCA TUDIAN-PETRU	
		Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> <input type="button" value="■"/>			Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> <input type="button" value="■"/>			
		Nota: 0			Nota: 0			
		Obs: <input type="text"/>			Obs: <input type="text"/>			
7	BOTEZAT EMANUEL				<input type="checkbox"/> Prezent	8	BUTUNOI GEORGE-MADALIN	
		Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> <input type="button" value="■"/>			Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> <input type="button" value="■"/>			
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10	CHIRITOIU CATERINA			11	CODOC MARIUS			
		Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> <input type="button" value="■"/>			Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> <input type="button" value="■"/>			
		Nota: 0			Nota: 0			
		Obs: <input type="text"/>			Obs: <input type="text"/>			

Nr. Student

Prezent

2 ANTIGHIN
FLORIN-RAZVAN

Prezent

Fotografia nu există

Puncte: 0

Nota: 0

Obs:

Reprezentare logarithmică

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Recapitulare

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

$$D = \epsilon \cdot E$$

$$B = \mu \cdot H$$

$$J = \sigma \cdot E$$

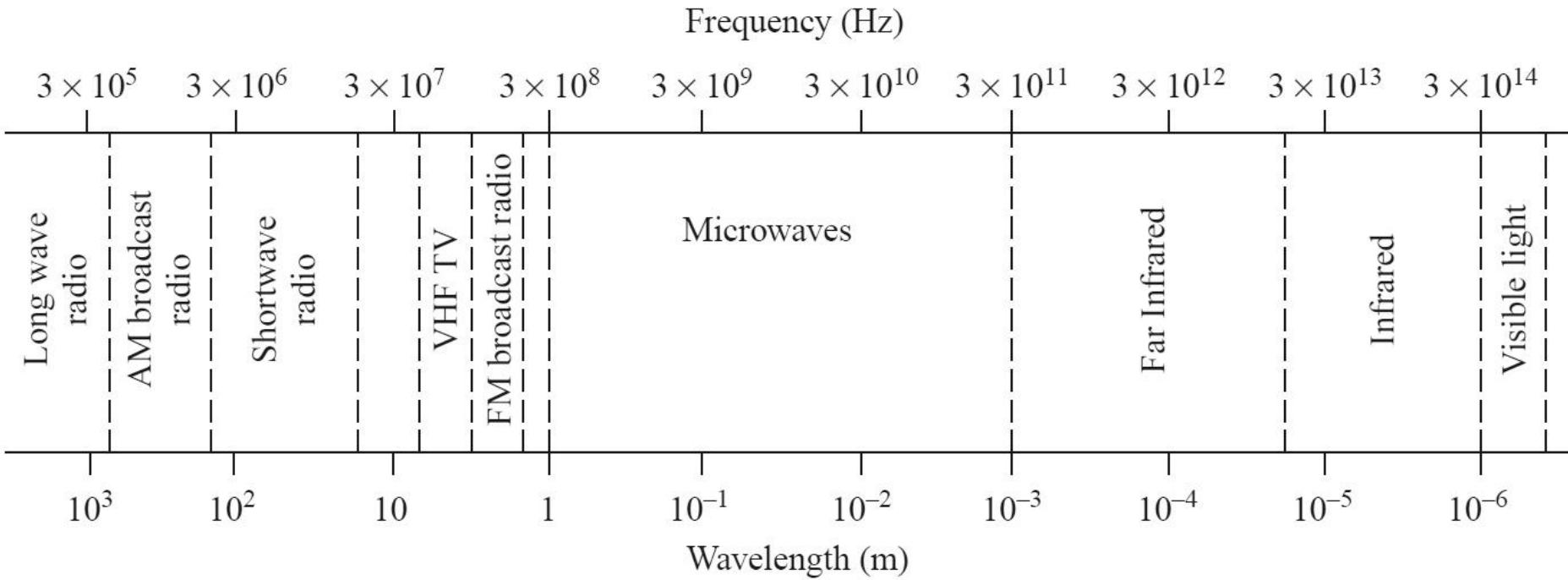
- În vid

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

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

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

Microunde



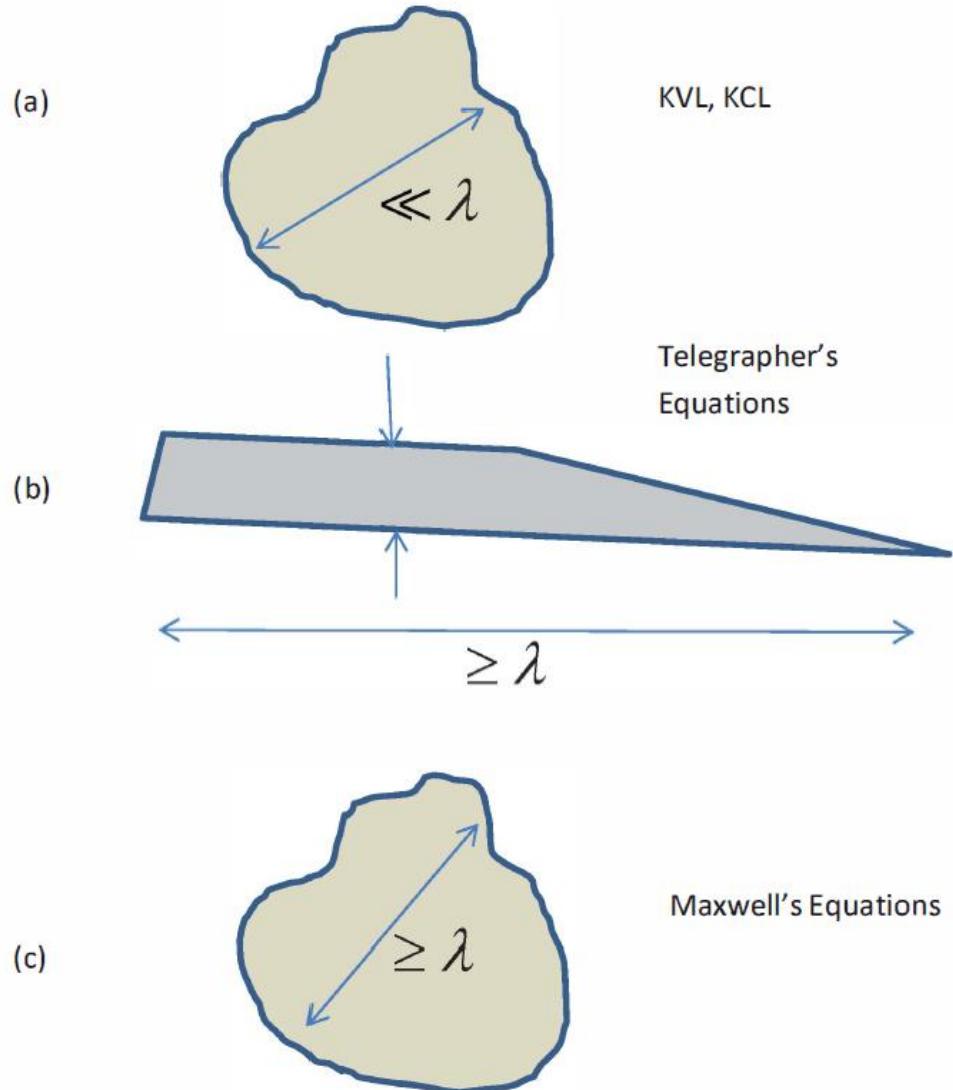
- tipic
 - $f \approx 1\text{--}3\text{GHz} - 300\text{GHz}$
 - $\lambda \approx 1\text{mm} - 10\text{cm}$

Lungimea electrică

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

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

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



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

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

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

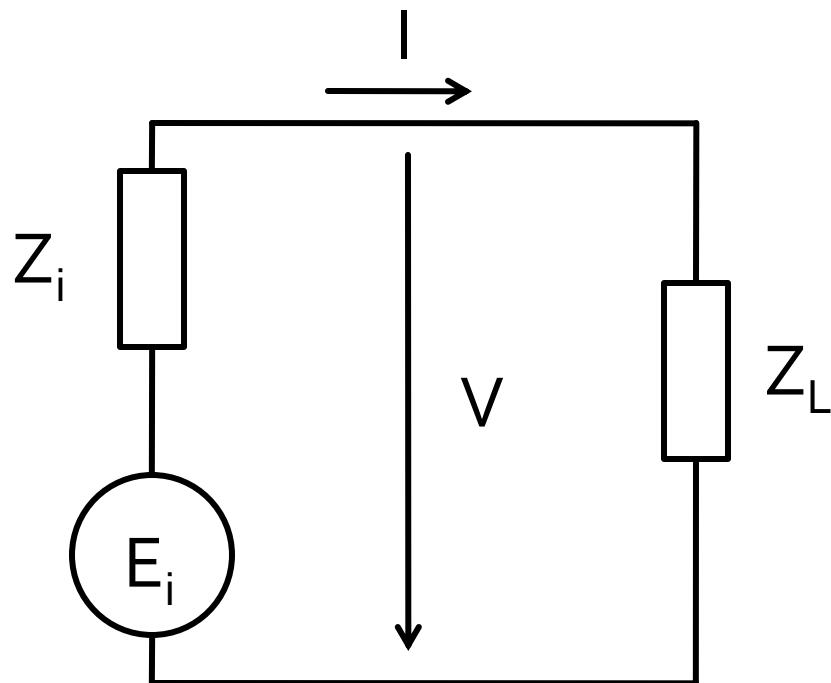
$$V(z) = V^+ \cdot e^{j(\omega \cdot t - \beta \cdot z)} + V^- \cdot e^{j(\omega \cdot t + \beta \cdot z)}$$

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

Continuare

Adaptare

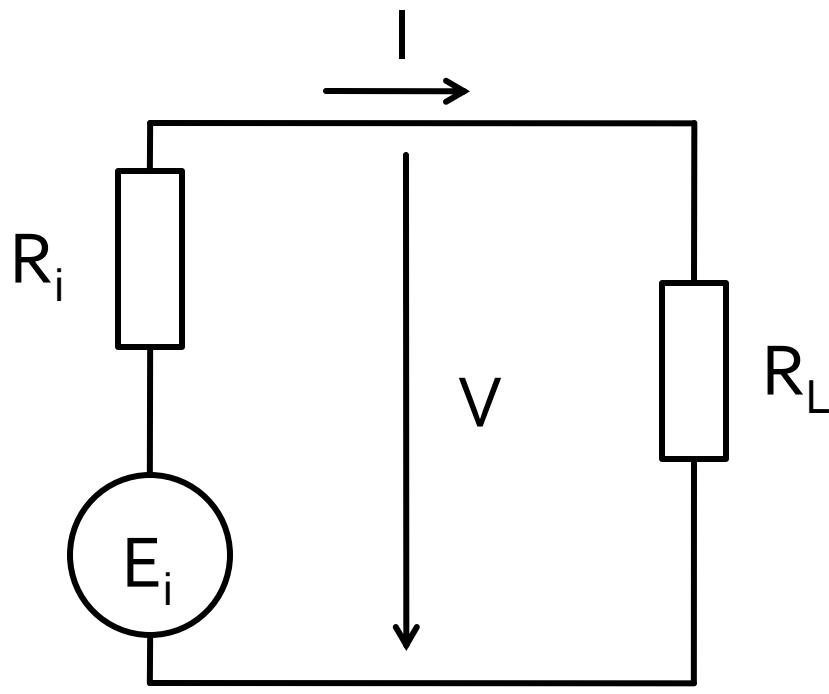
- Generator adaptat la sarcina ?



- valori impedanta ?
- reflexii ?

Adaptare, impedante reale

- Generator adaptat la sarcina



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

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

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

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

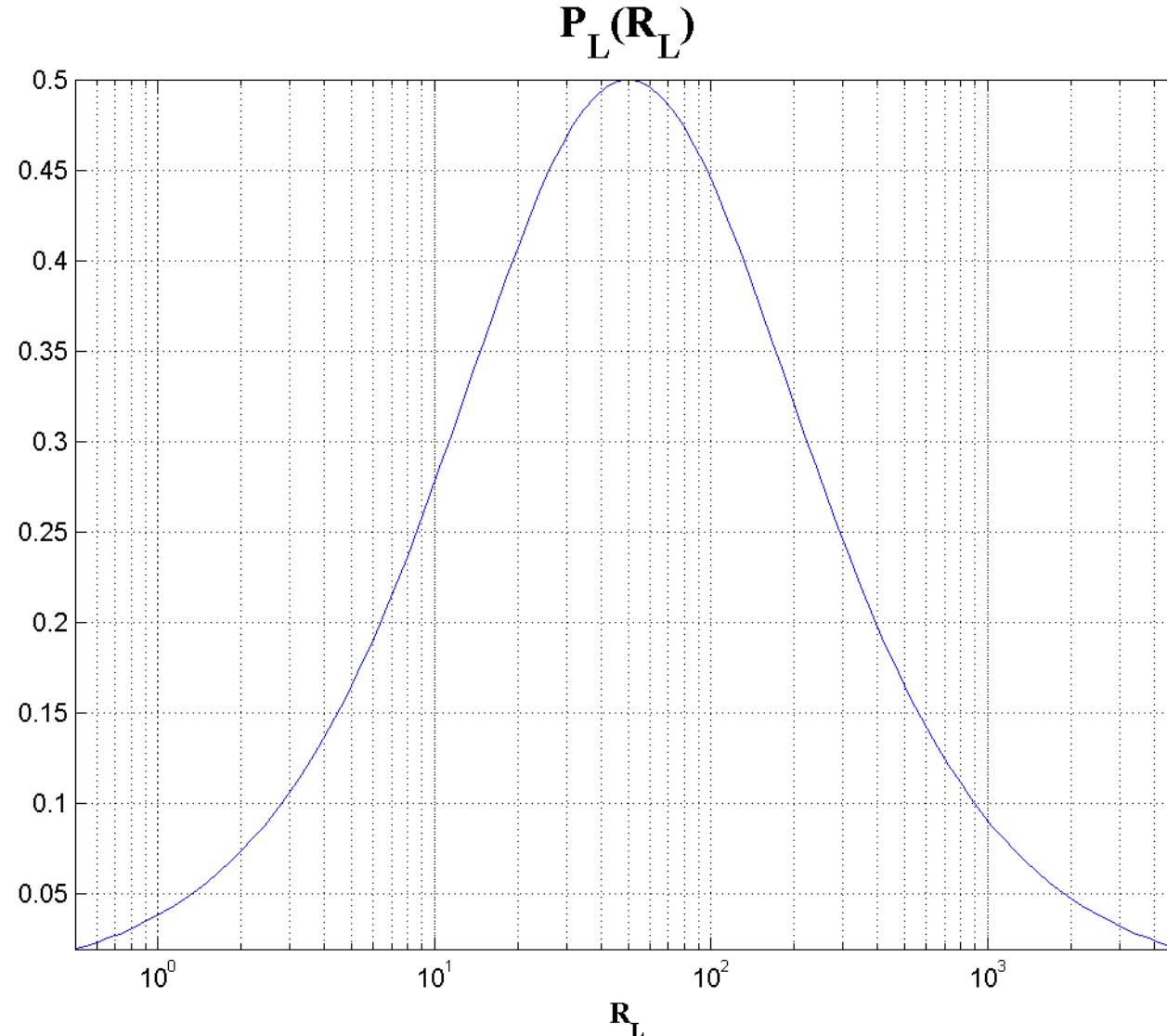
Adaptare , impedante reale

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

■ Putere pe sarcina

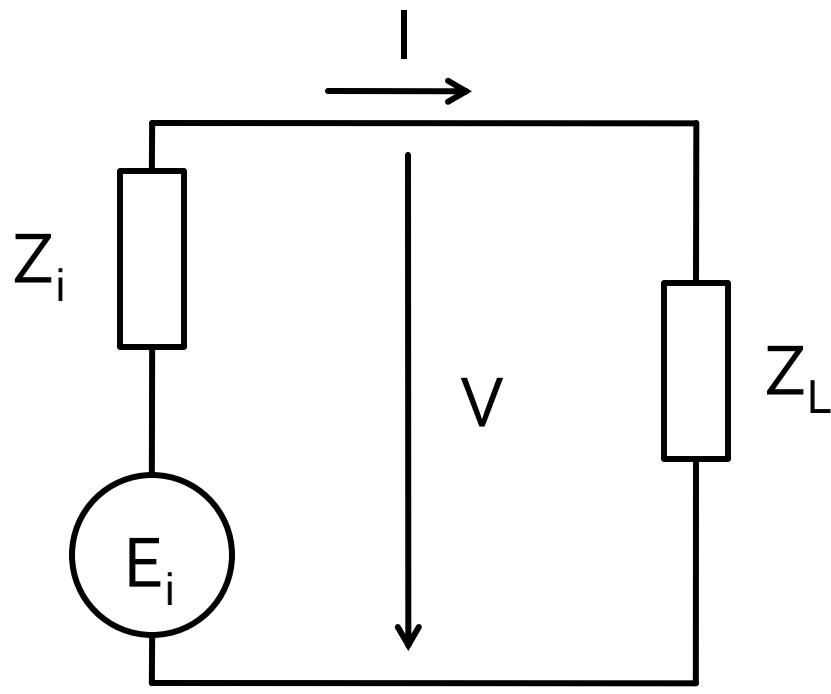
- $R_i = 50\Omega$
- $R_L = 0 \rightarrow P_L = 0$
- $R_L = \infty \rightarrow P_L = 0$

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

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

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

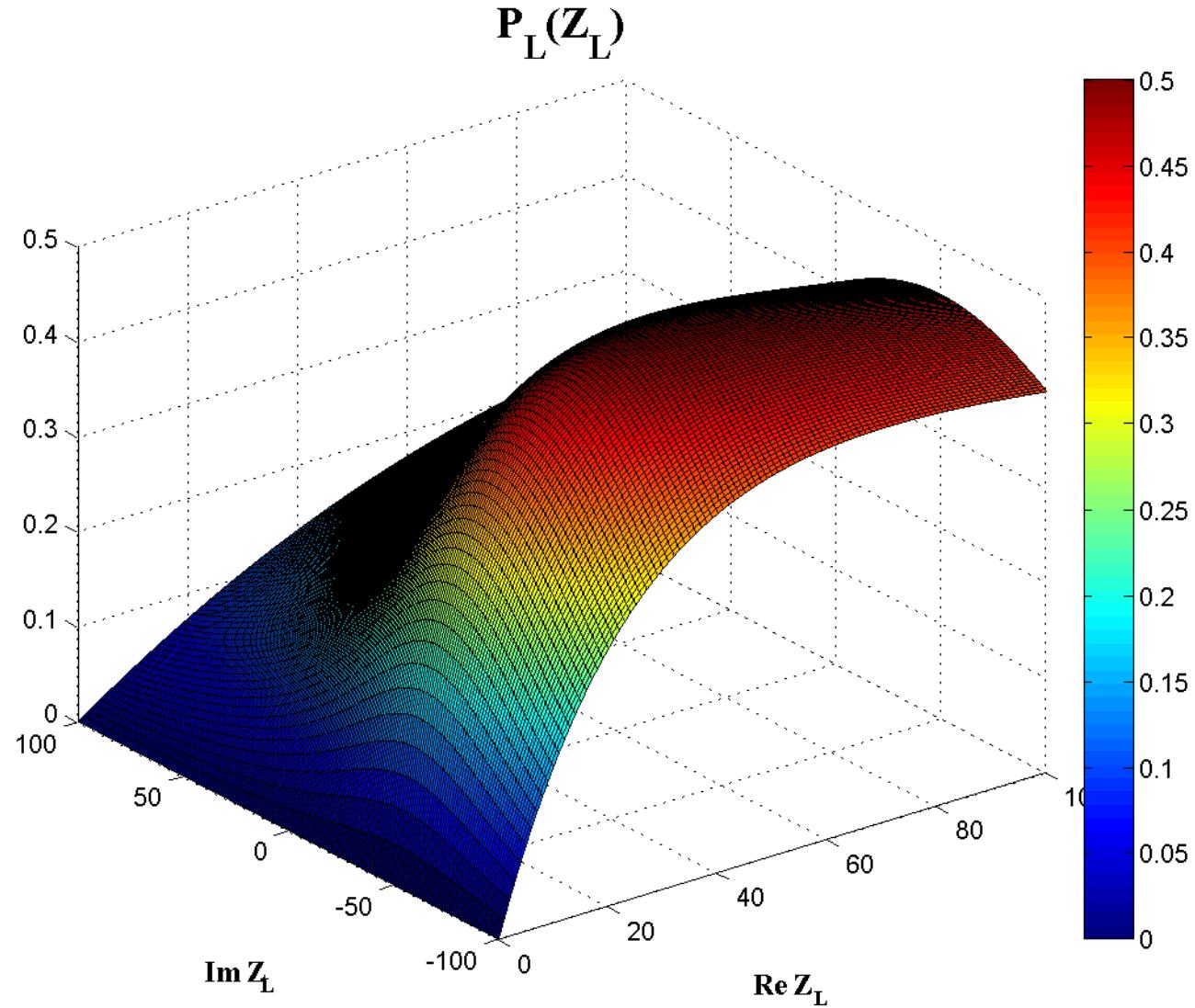
$$P_L = \frac{R_L \cdot |E_i|^2}{(R_i + R_L)^2 + (X_i + X_L)^2}$$

- Adaptare
 - putere maxima transmisa sarcinii
 - conditie?

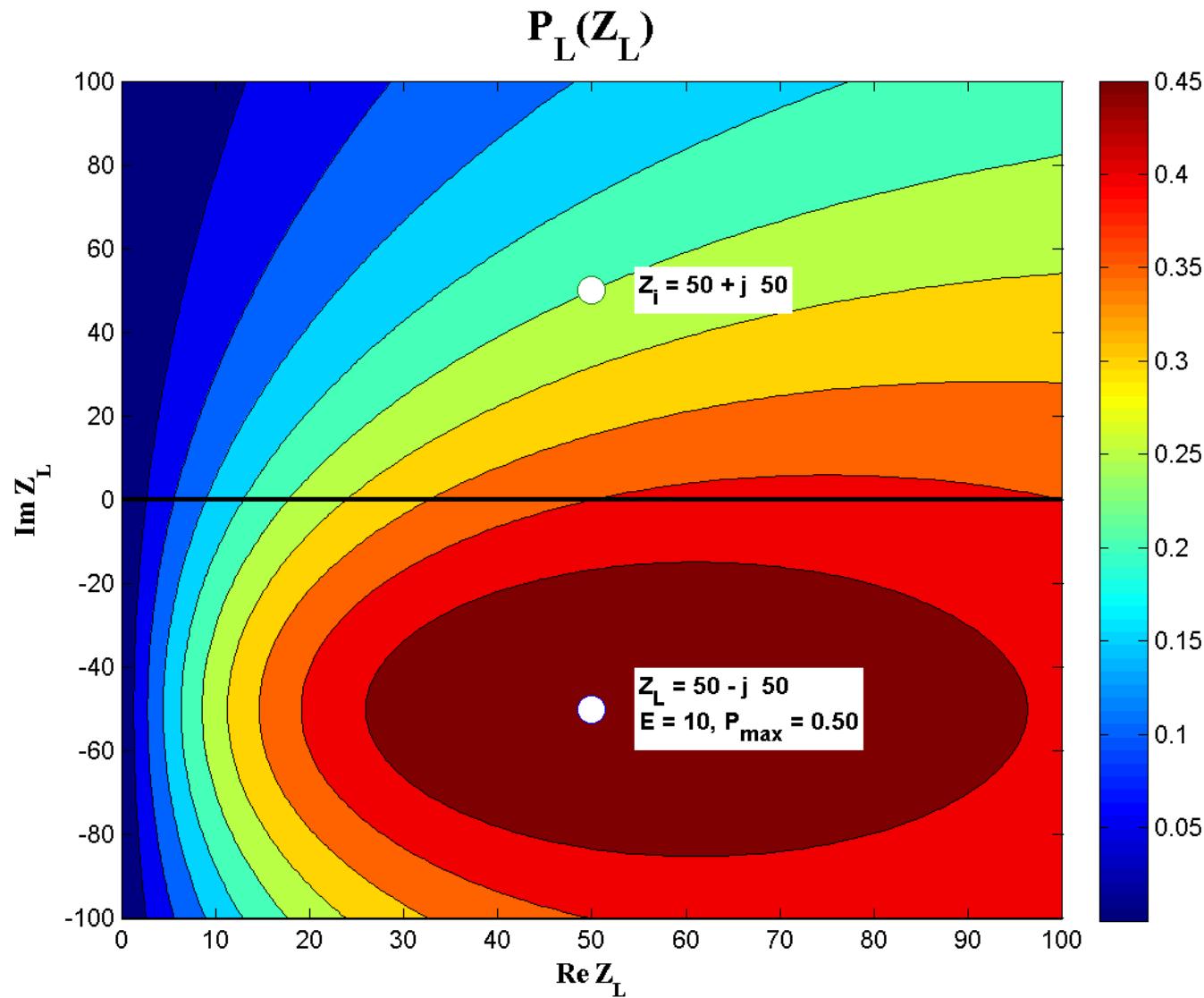
Adaptare, exemplu

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

Adaptare, exemplu



Adaptare, exemplu



Adaptare dpdv al puterii

$$R_i > 0, R_L > 0$$

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

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

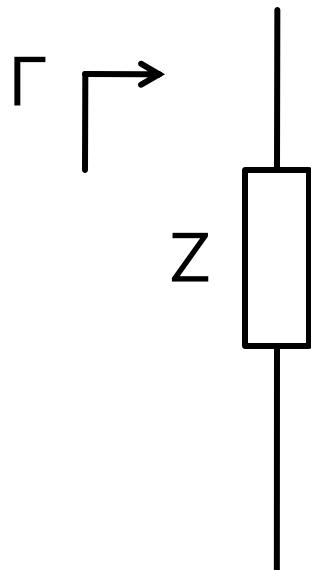
$$R_L = R_i, X_L = -X_i$$

- Puterea disponibila (available)

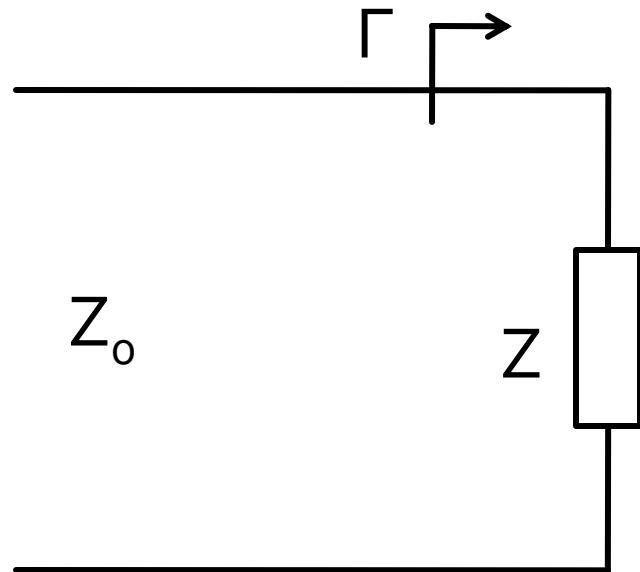
$$Z_L = Z_i^*$$

Coeficient de reflexie

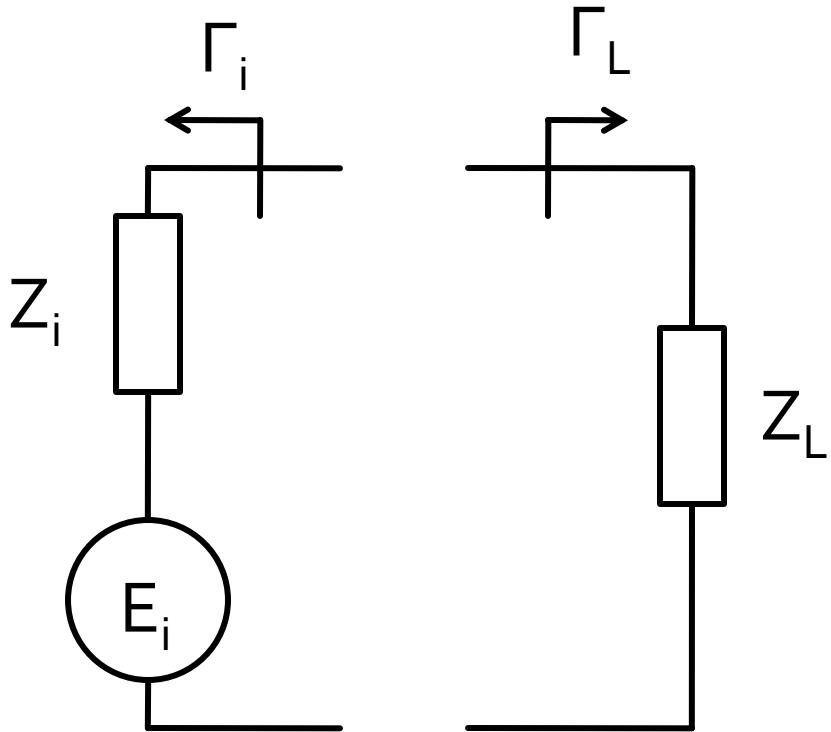
- Un Z_0 oarecare ales ca referinta



$$\Gamma = \frac{Z - Z_0^*}{Z + Z_0}$$



Adaptare dpdv al puterii



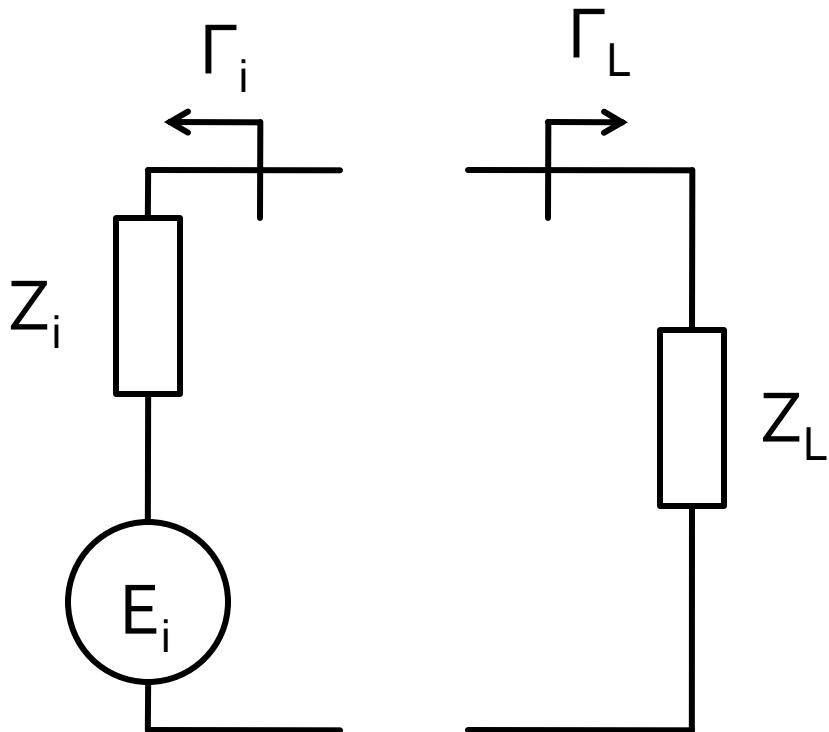
$$\Gamma_i = \frac{Z_i - Z_0^*}{Z_i + Z_0}$$

$$\Gamma_i = \frac{(R_i - R_0) + j \cdot (X_i + X_0)}{(R_i + R_0) + j \cdot (X_i + X_0)}$$

$$\Gamma_L = \frac{Z_L - Z_0^*}{Z_L + Z_0}$$

$$\Gamma_L = \frac{(R_L - R_0) + j \cdot (X_L + X_0)}{(R_L + R_0) + j \cdot (X_L + X_0)}$$

Adaptare dpdv al puterii



$$\Gamma_i = \frac{Z_i - Z_0^*}{Z_i + Z_0^*} = 1 - \frac{Z_0 + Z_0^*}{Z_i + Z_0}$$

$$\Gamma_L = \frac{Z_L - Z_0^*}{Z_L + Z_0^*} = 1 - \frac{Z_0 + Z_0^*}{Z_L + Z_0}$$

$$\Gamma_i^* = 1 - \frac{Z_0^* + Z_0}{Z_i^* + Z_0} = 1 - \frac{Z_0^* + Z_0}{Z_L + Z_0^*}$$

Adaptare dpdv al puterii

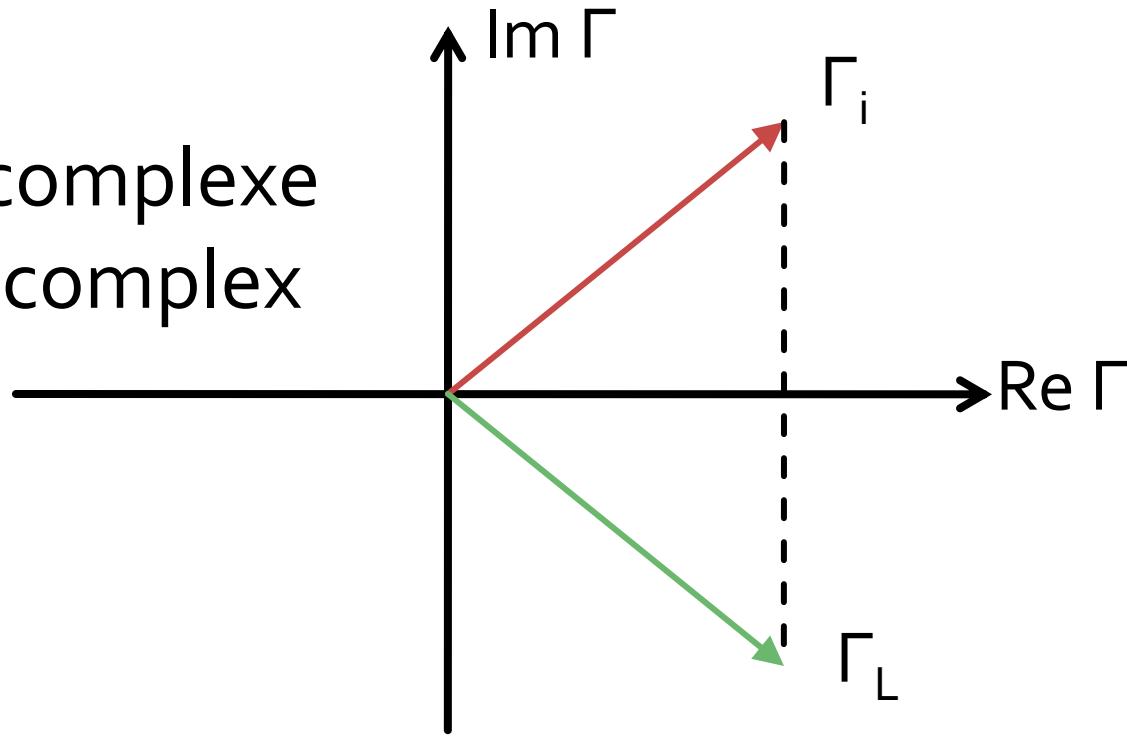
$$Z_L = Z_i^*$$

Daca se alege un Z_0 real

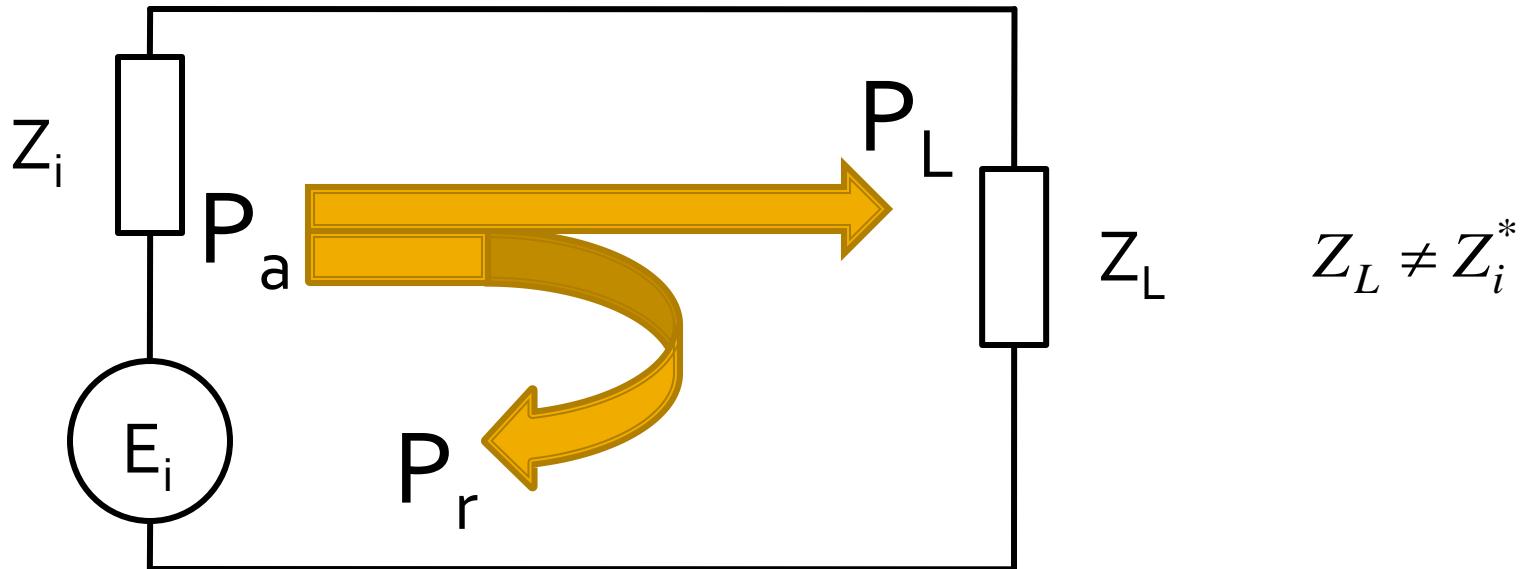
$$\Gamma = \frac{Z - Z_0}{Z + Z_0}$$

$$\Gamma_L = \Gamma_i^*$$

- numere complexe
- in planul complex

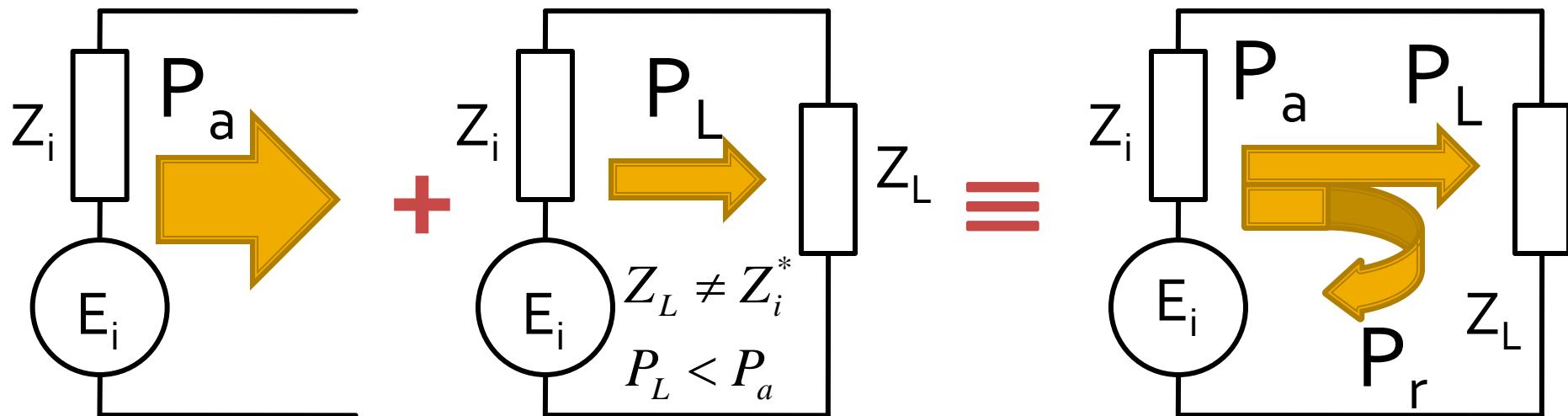


Reflexie de putere / Model



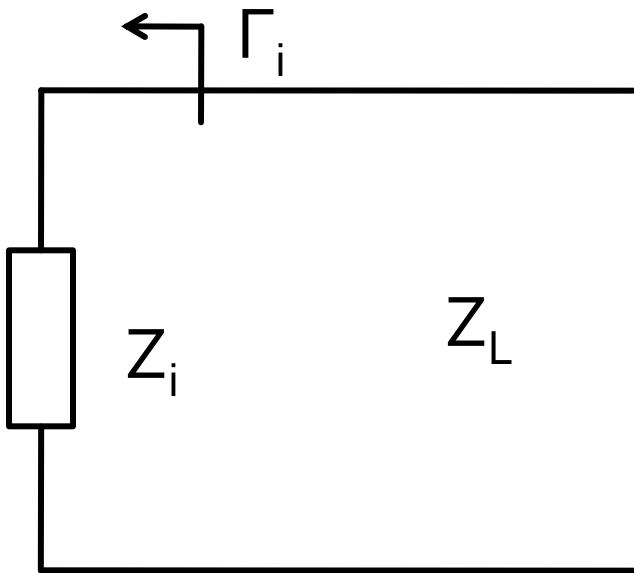
- Putere reflectată
- Putere a undei reflectate

Reflexie de putere / Model

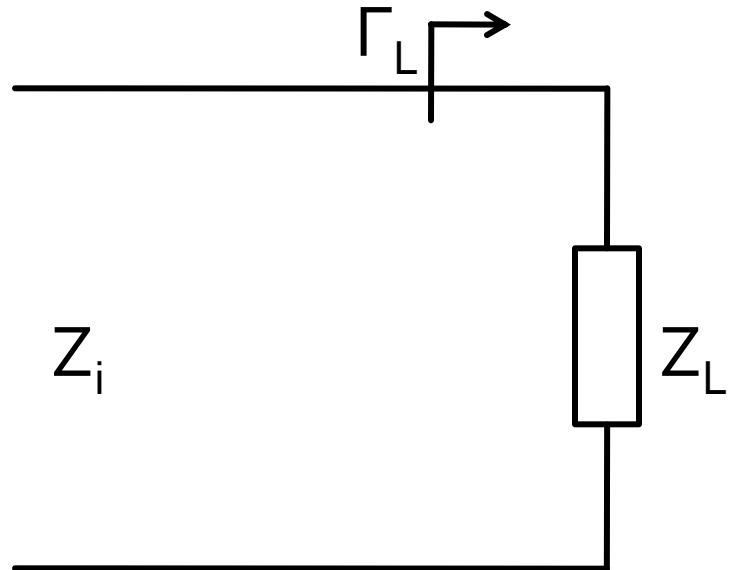


- Generatorul are posibilitatea de a oferi o anumita putere maxima de semnal P_a
- Pentru o sarcina oarecare, acesteia i se ofera o putere de semnal mai mica $P_L < P_a$
- Se intampla "ca si cum" (model) o parte din putere se reflecta $P_r = P_a - P_L$
- Puterea este o marime **scalara!**

Coeficienti de reflexie



$$\Gamma_i = \frac{Z_i - Z_L^*}{Z_i + Z_L}$$



$$\Gamma_L = \frac{Z_L - Z_i^*}{Z_L + Z_i}$$

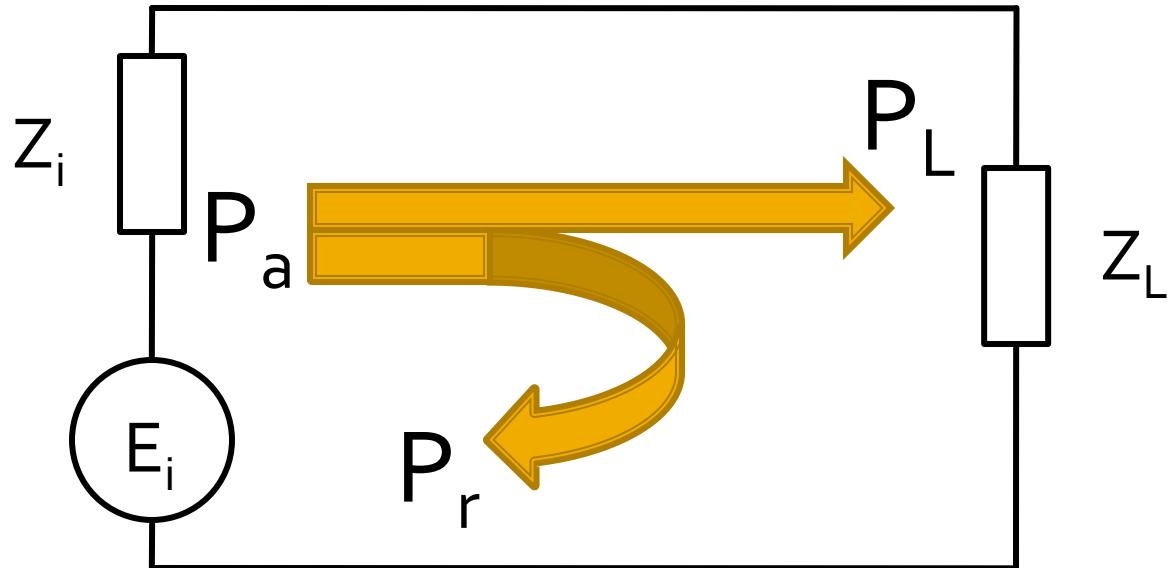
Coeficienti de reflexie

$$\Gamma_i = \frac{(R_i - R_L) + j \cdot (X_i + X_L)}{(R_i + R_L) + j \cdot (X_i + X_L)} \quad \Gamma_L = \frac{(R_L - R_i) + j \cdot (X_L + X_i)}{(R_L + R_i) + j \cdot (X_L + X_i)}$$

$$|\Gamma_i| = \frac{|(R_i - R_L) + j \cdot (X_i + X_L)|}{|(R_i + R_L) + j \cdot (X_i + X_L)|} = \frac{\sqrt{(R_i - R_L)^2 + (X_i + X_L)^2}}{\sqrt{(R_i + R_L)^2 + (X_i + X_L)^2}} = |\Gamma_L|$$

$$|\Gamma_i| = |\Gamma_L| \equiv |\Gamma|$$

Reflexie de putere / Model



$$P_a = \frac{|E_i|^2}{4R_i}$$

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

$$P_r = P_a - P_L = \frac{|E_i|^2}{4R_i} - \frac{R_L \cdot |E_i|^2}{(R_i + R_L)^2 + (X_i + X_L)^2} = \frac{|E_i|^2}{4R_i} \cdot \left[1 - \frac{4R_L \cdot R_i}{(R_i + R_L)^2 + (X_i + X_L)^2} \right]$$

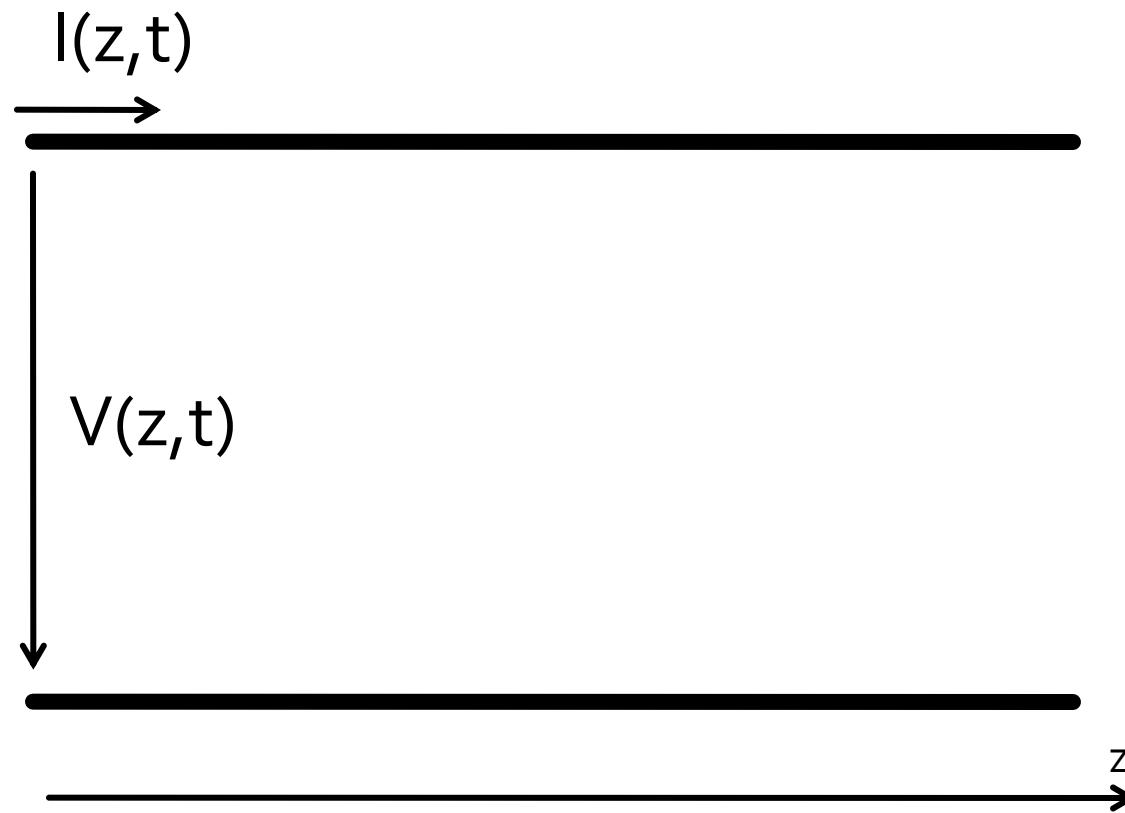
$$P_r = \frac{|E_i|^2}{4R_i} \cdot \left[\frac{(R_i - R_L)^2 + (X_i + X_L)^2}{(R_i + R_L)^2 + (X_i + X_L)^2} \right] = P_a \cdot |\Gamma|^2$$

- coeficient de reflexie in putere

Linii de transmisie in mod TEM

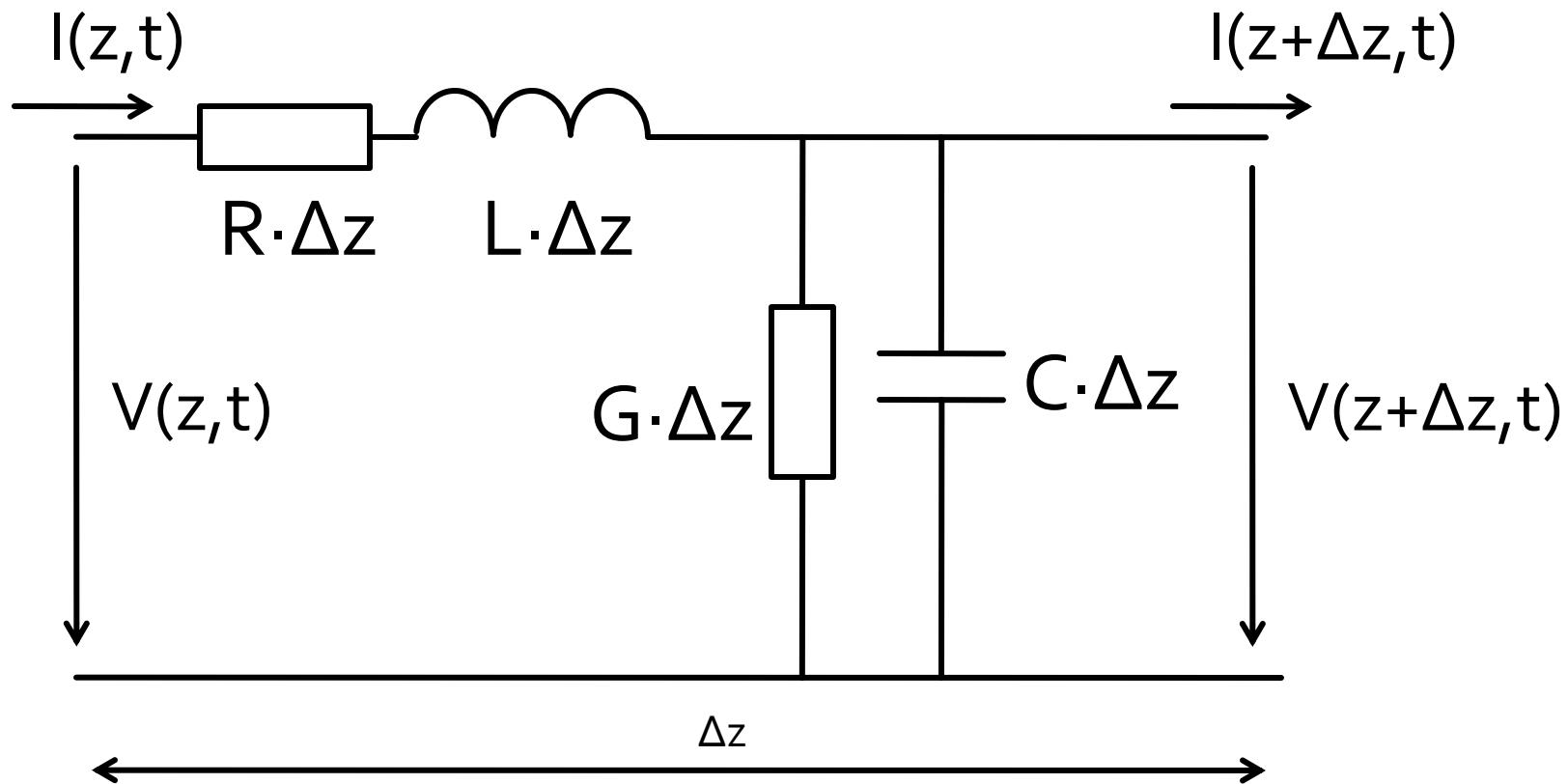
Linie de transmisie

- mod TEM, doi conductori



Linie de transmisiem model echivalent

- mod TEM, doi conductori



Ecuatiile telegrafistilor

- domeniu timp

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

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

- semnale sinusoidale

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

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

Rezolvare

$$\frac{d^2V(z)}{dz^2} - \gamma^2 \cdot V(z) = 0$$

$$\frac{d^2I(z)}{dz^2} - \gamma^2 \cdot I(z) = 0$$

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

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

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

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

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

Solutiile

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

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

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

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

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

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

- Impedanta caracteristica a liniei

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

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

Linie 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_o real

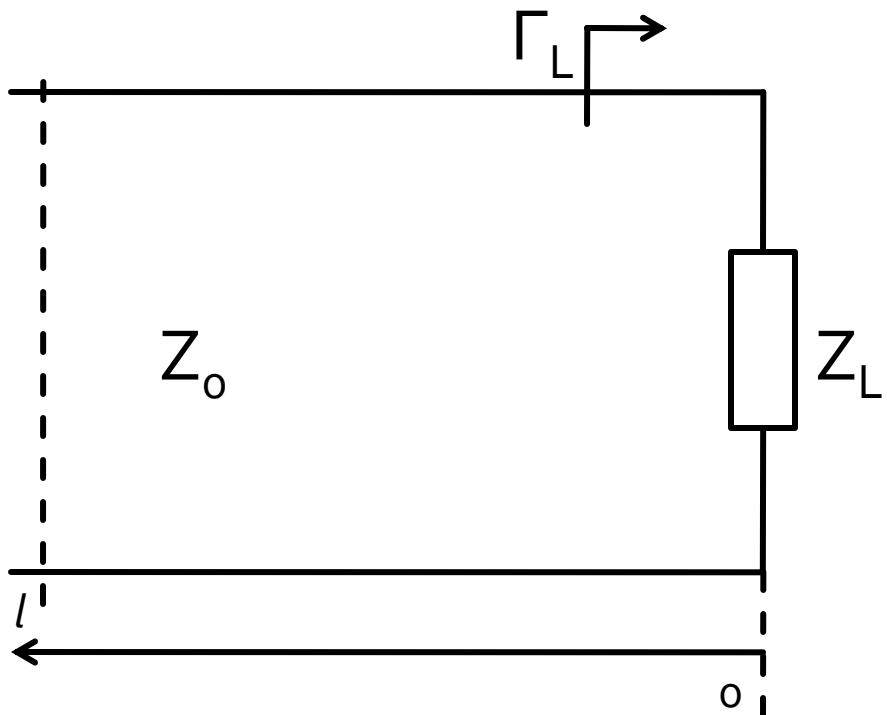
$$V(z) = V_0^+ e^{-j \cdot \beta \cdot z} + V_0^- e^{j \cdot \beta \cdot z}$$

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

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

$$v_f = \frac{1}{\sqrt{LC}}$$

Linie fara pierderi



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

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

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

- coeficient de reflexie in tensiune

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

- Z_0 real

Linie fara pierderi

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

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

■ Puterea medie

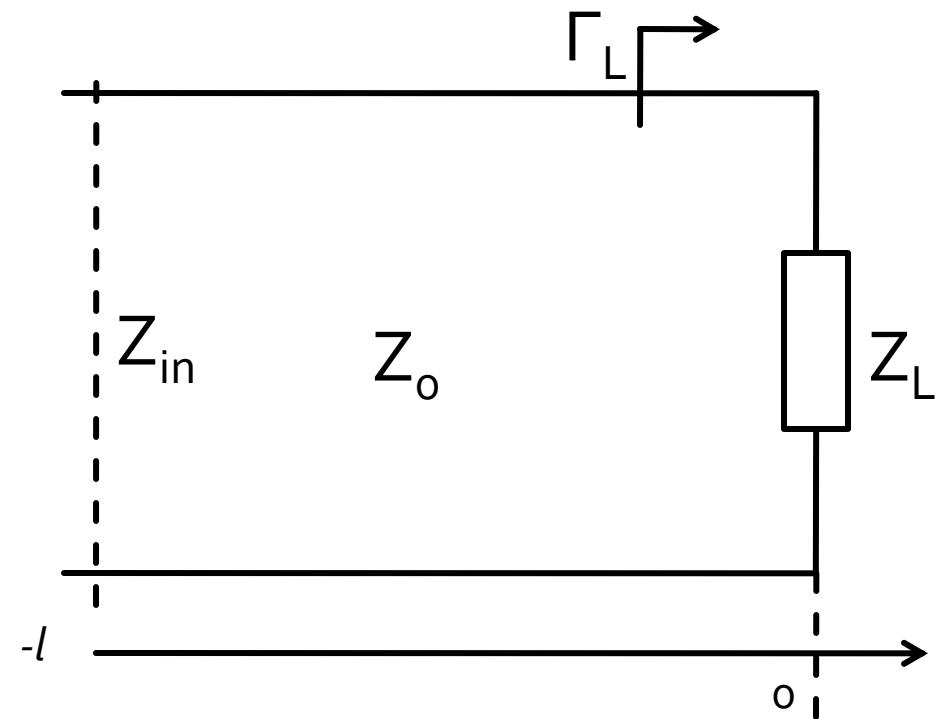
$$P_{\text{avg}} = \frac{1}{2} \operatorname{Re}\{V(z)I(z)^*\} = \frac{1}{2} \frac{|V_o^+|^2}{Z_0} \operatorname{Re}\{1 - \Gamma^* e^{-2j\beta z} + \Gamma e^{2j\beta z} - |\Gamma|^2\}$$

$$P_{\text{avg}} = \frac{1}{2} \frac{|V_o^+|^2}{Z_0} (1 - |\Gamma|^2)$$

■ Puterea transmisa sarcinii = Puterea incidenta - Puterea "reflectata"

■ Return Loss $RL = -20 \log |\Gamma| \text{ dB},$

Linie fara pierderi



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

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

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

- impedanta la intrarea liniei

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

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

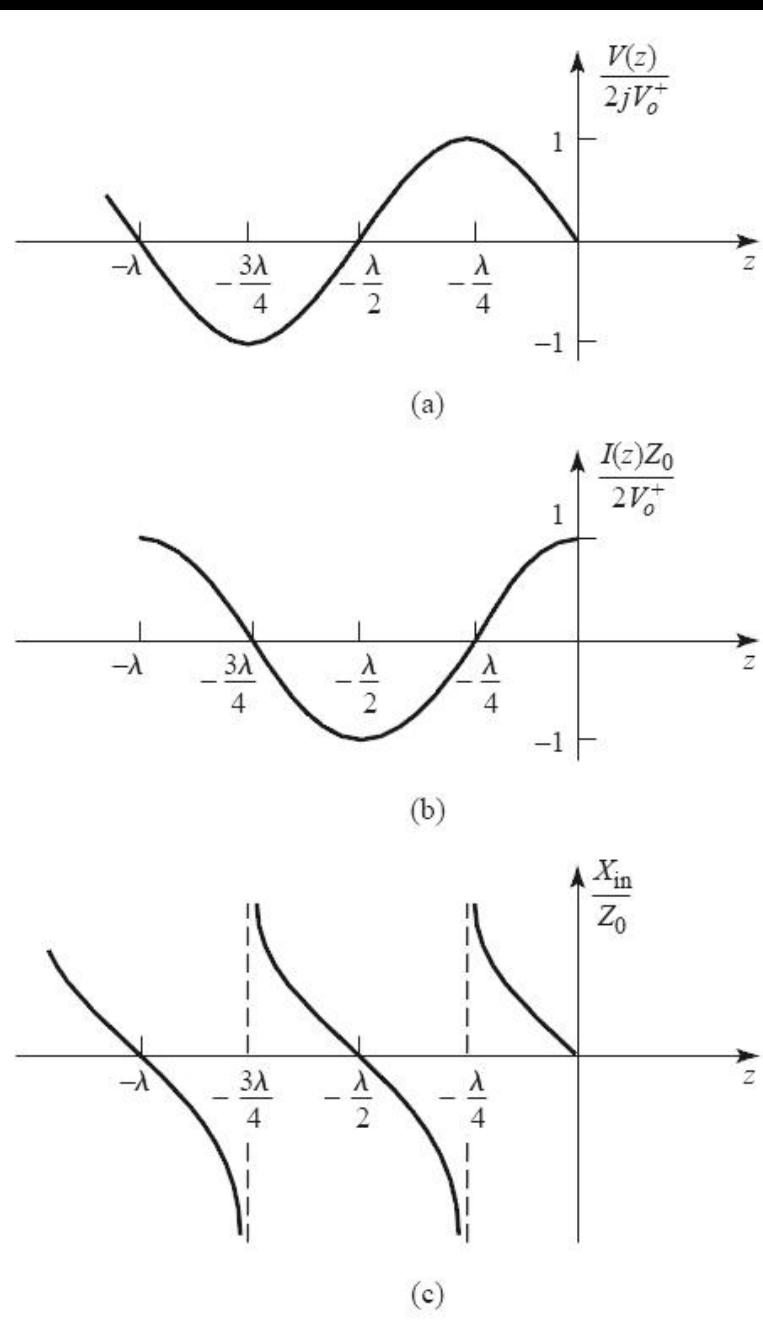
Linie fara pierderi

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

Linie in scurtcircuit

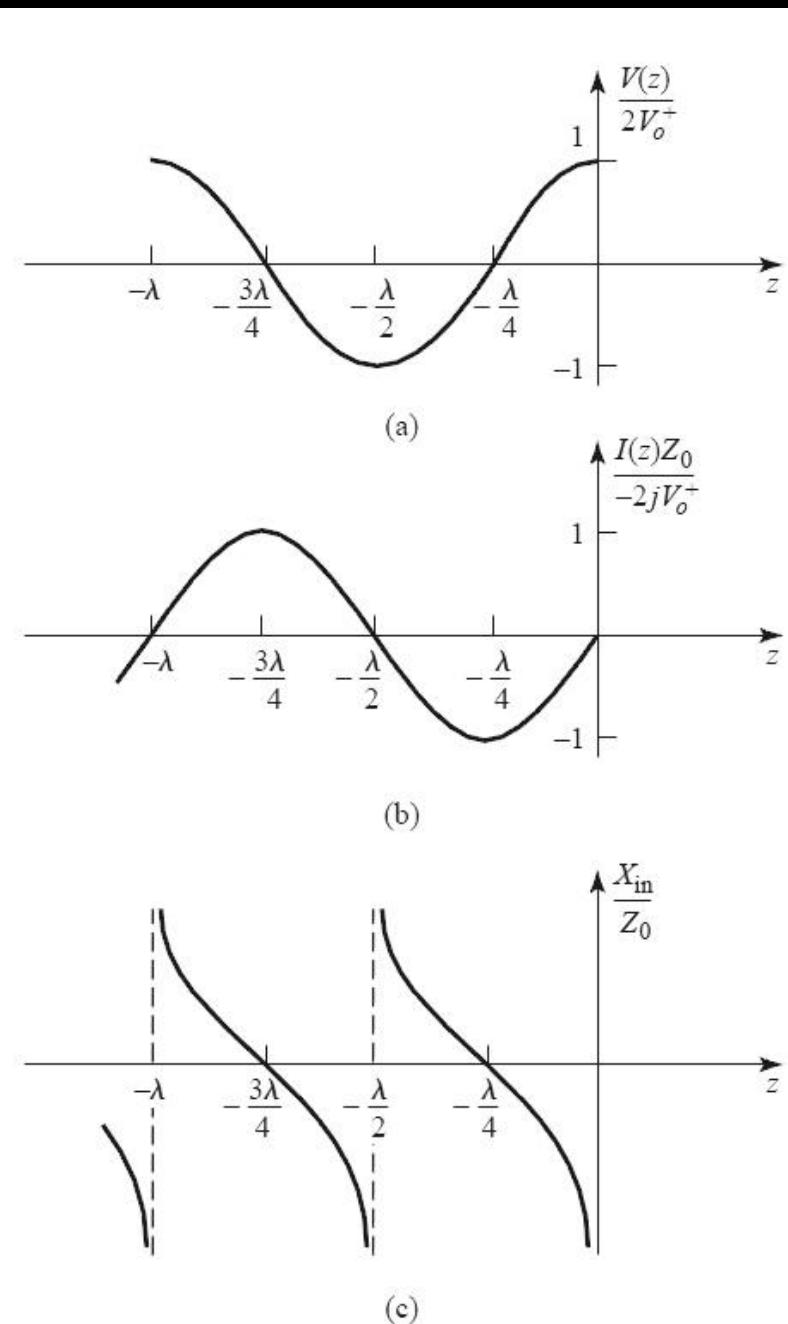


$$Z_{in} = j \cdot Z_0 \cdot \tan \beta \cdot l$$



Linie in gol

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



Factor de unda stationara

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

$$\Gamma = |\Gamma| \cdot e^{j\theta}$$

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

$$\max \quad e^{\theta + 2j\beta z} = 1 \quad V_{\max} = |V_0^+| \cdot (1 + |\Gamma|)$$

$$\min \quad e^{\theta + 2j\beta z} = -1 \quad V_{\min} = |V_0^+| \cdot (1 - |\Gamma|)$$

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

Contact

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