

Curs 4

2019/2020

Dispozitive și circuite de microunde pentru radiocomunicații

Disciplina 2019/2020

- 2C/1L, DCMR (CDM)
- Minim 7 prezente (curs+laborator)
- Curs - **conf. Radu Damian**
 - Marti 14-16, P7
 - E – 50% din nota
 - probleme + (2p prez. curs) + (3 teste) + (bonus activitate)
 - primul test L1 (t2 si t3 neanuntate)
 - 3pz (C) = +0.5p
 - toate materialele permise

Disciplina 2019/2020

- 2C/1L, **DCMR (CDM)**
- Laborator – **conf. Radu Damian**
 - Miercuri 10-14 impar II.12 (par eng.)
 - Joi 14- 16 par
 - L – **25%** din nota
 - prezenta + rezultate personale
 - P – **25%** din nota
 - tema personala

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](#)

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)

Fotografii

Grupa 5403

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

Nr.	Student	Prezent
2	ANTIGHIN FLORIN-RAZVAN	☐ Puncte: 0 Nota: 0 Obs:

Acces

■ Personalizat



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	-	

Nume

Email

Cod de verificare

Trimite

Examen: Reprezentare logaritmică

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

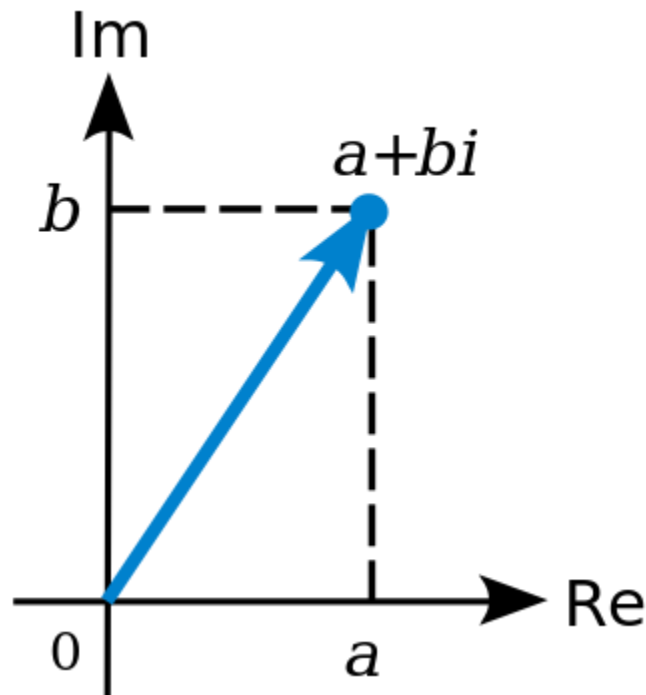
$$[x] + [\text{dB}] = [x]$$

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



Reprezentare polara

■ Reprezentare polara

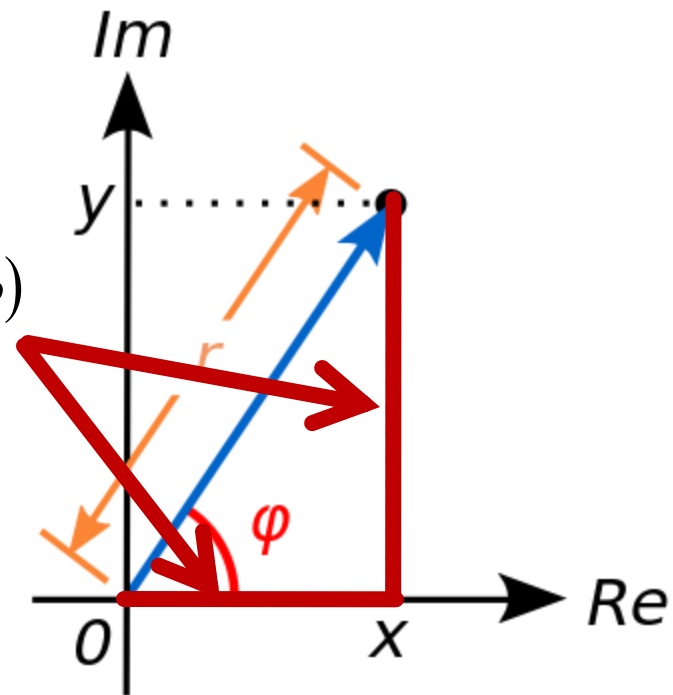
■ modul

■ faza

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

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

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

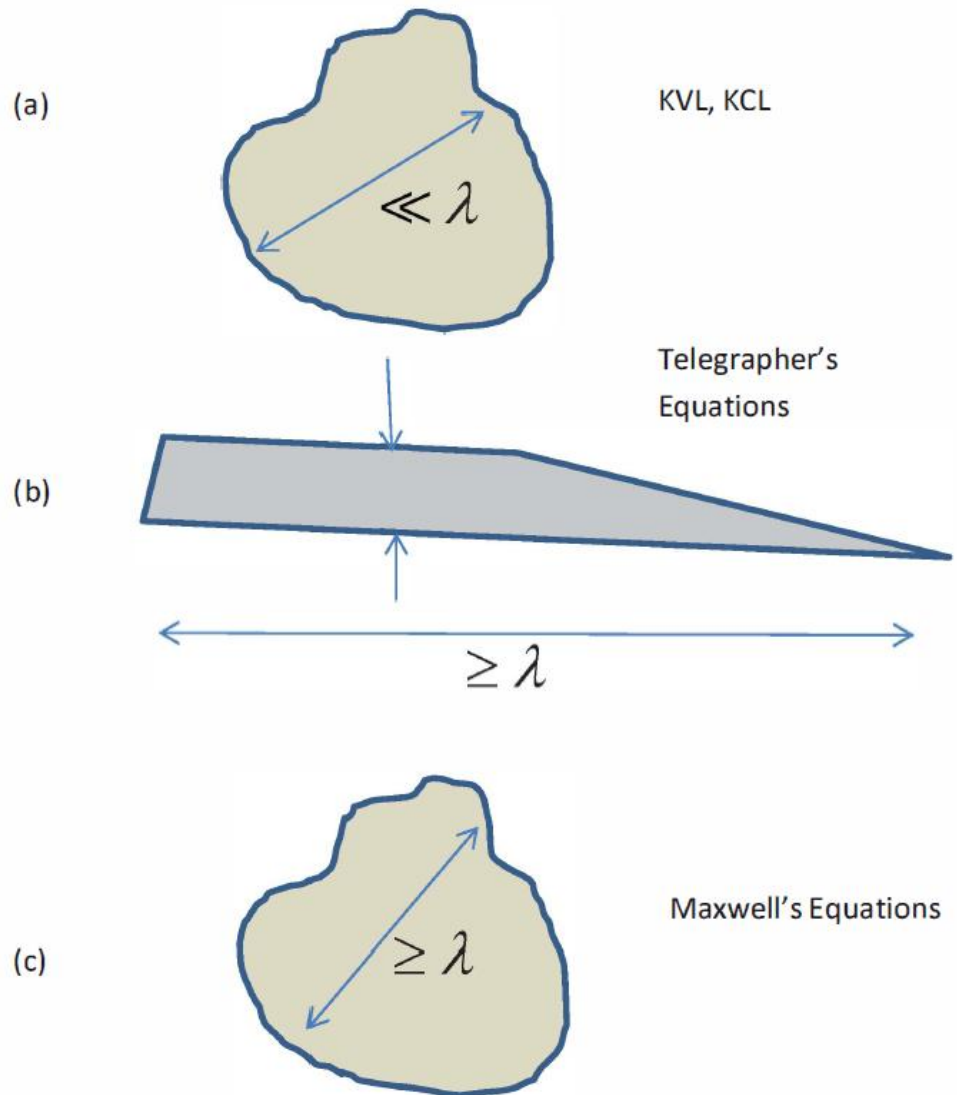


Lungime electrica

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

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

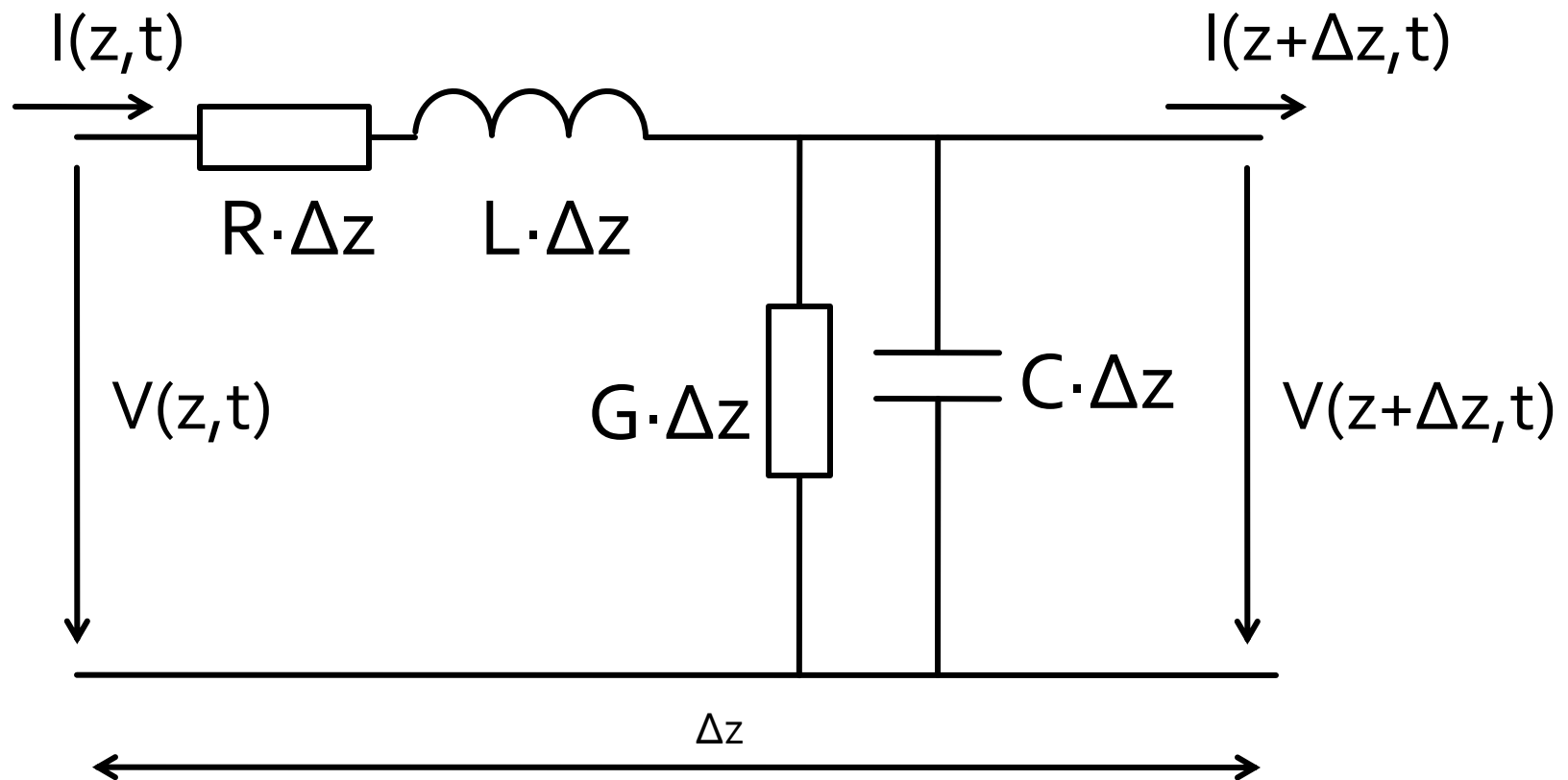
$$E = \beta \cdot l = \frac{2\pi}{\lambda} \cdot l = 2\pi \cdot \left(\frac{l}{\lambda} \right)$$



Linii de transmisie in mod TEM

Linie de transmisie model echivalent

- mod TEM, doi conductori



Soluliile

$$\begin{cases} V(z) = V_0^+ e^{-\gamma \cdot z} + V_0^- e^{\gamma \cdot z} \\ I(z) = I_0^+ e^{-\gamma \cdot z} + I_0^- e^{\gamma \cdot z} \end{cases} \quad \gamma = \alpha + j \cdot \beta = \sqrt{(R + j \cdot \omega \cdot L) \cdot (G + j \cdot \omega \cdot C)}$$

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

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

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

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

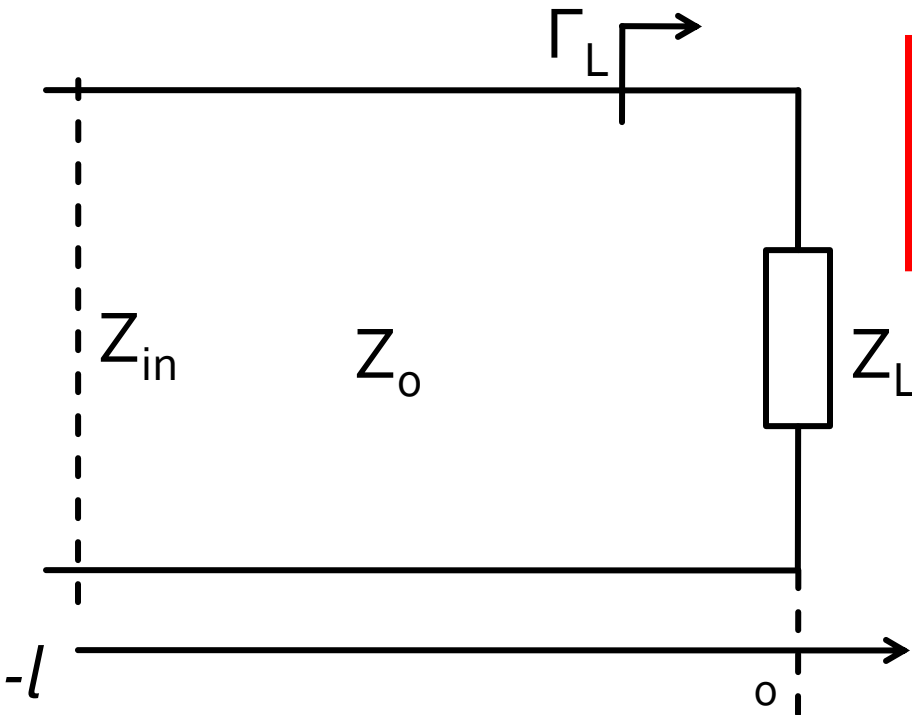
$$I(z) = \frac{\gamma}{R + j \cdot \omega \cdot L} (V_0^+ e^{-\gamma \cdot z} - V_0^- e^{\gamma \cdot z})$$

- Impedanta caracteristica a liniei

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

Linie fara pierderi

- impedanta la intrarea liniei de impedanta caracteristica Z_0 , de lungime l , terminata cu impedanta Z_L



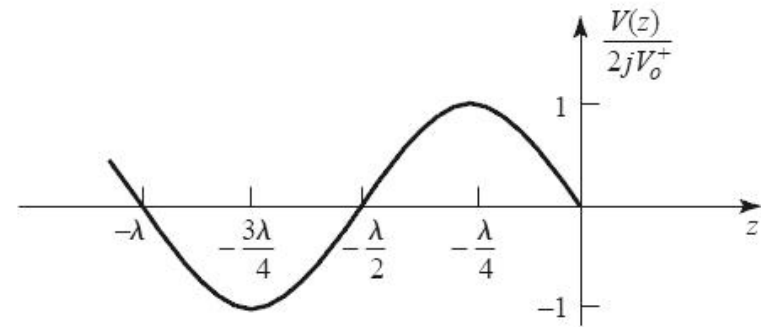
$$Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan \beta \cdot l}{Z_0 + j \cdot Z_L \cdot \tan \beta \cdot l}$$

Linie în scurtcircuit

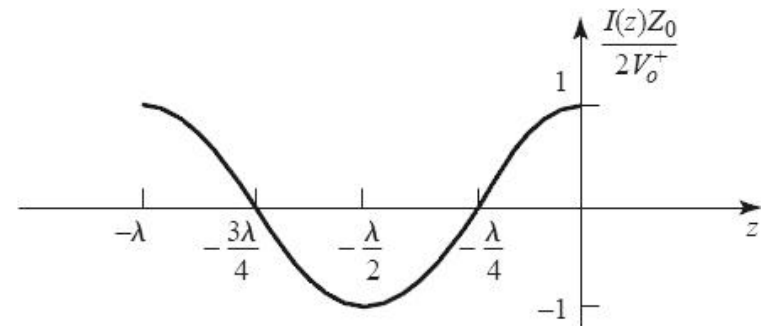
- $Z_L = 0$
- reactanța pură
 - +/- → în funcție de l

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

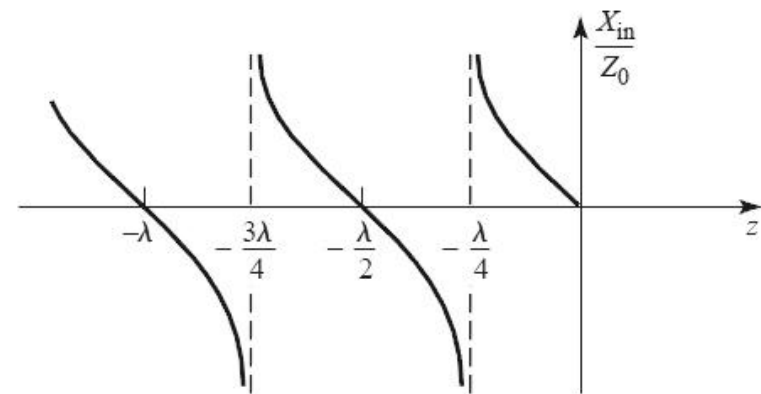
$$Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan(\beta \cdot l)}{Z_0 + j \cdot Z_L \cdot \tan(\beta \cdot l)}$$



(a)



(b)



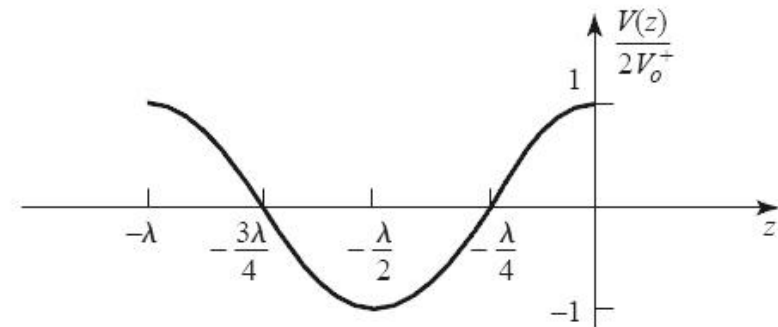
(c)

Linie în gol

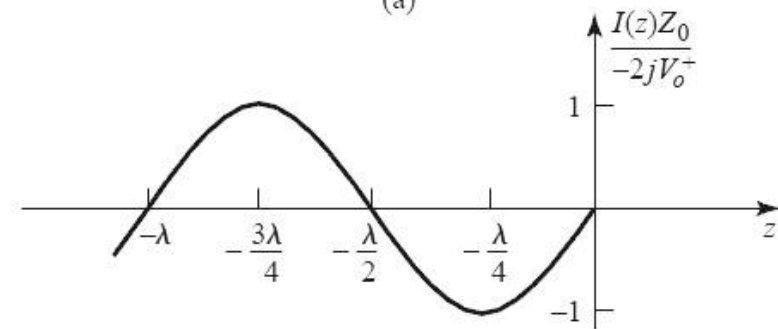
- $Z_L = \infty \rightarrow 1/Z_L = 0$
- reactanța pură
 - +/- $\rightarrow$ în funcție de l

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

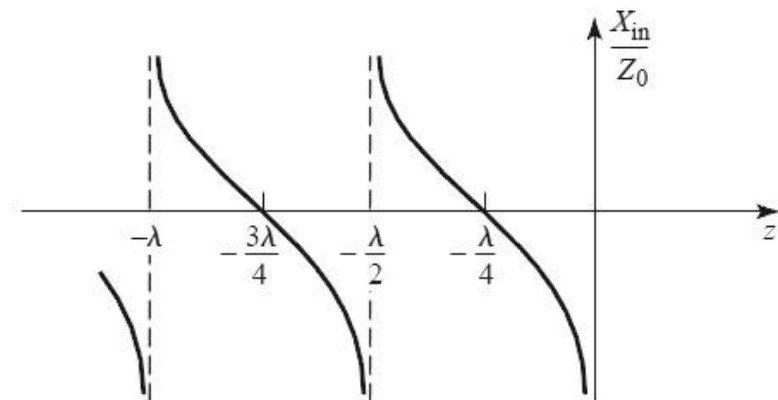
$$Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan(\beta \cdot l)}{Z_0 + j \cdot Z_L \cdot \tan(\beta \cdot l)}$$



(a)

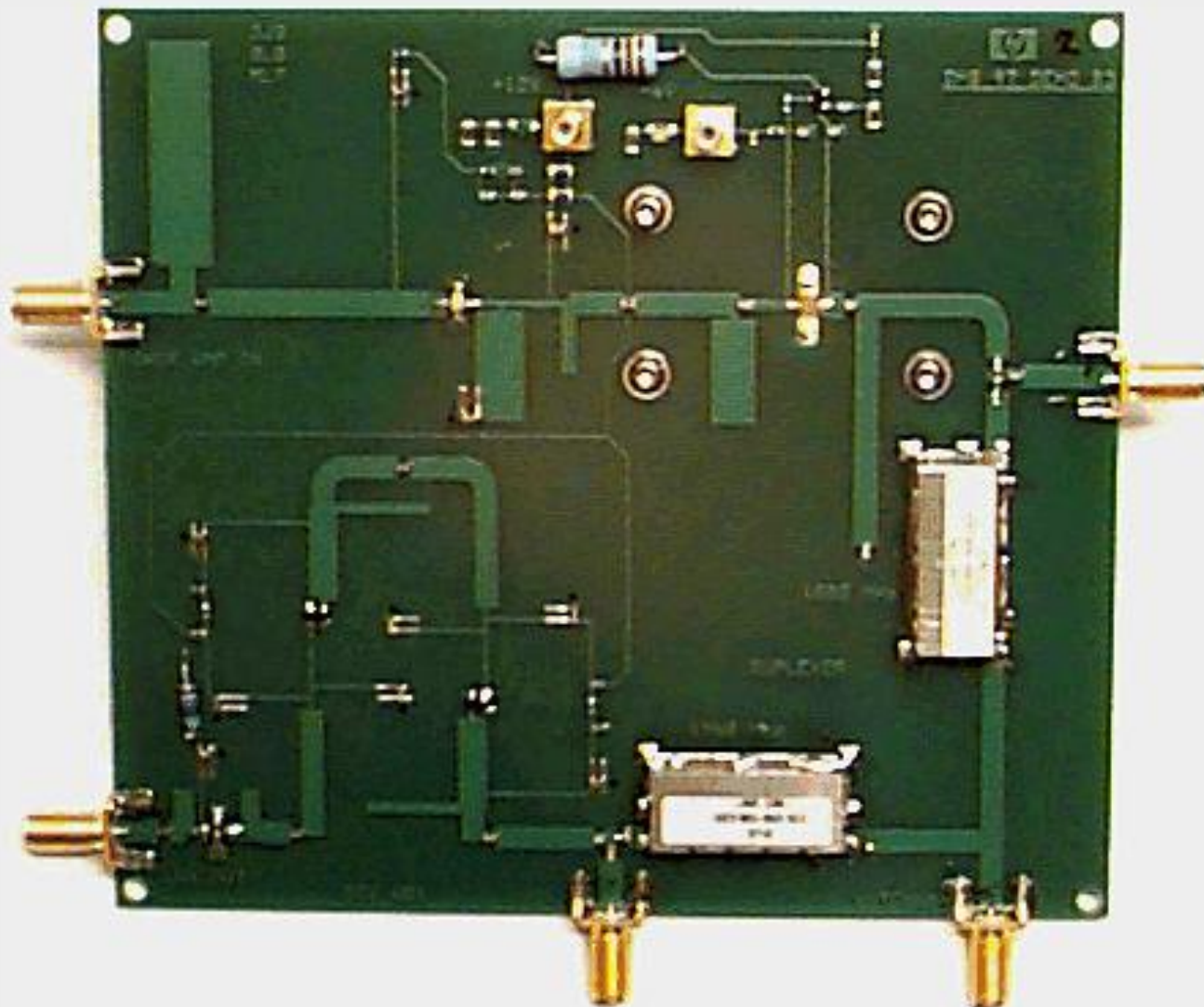


(b)

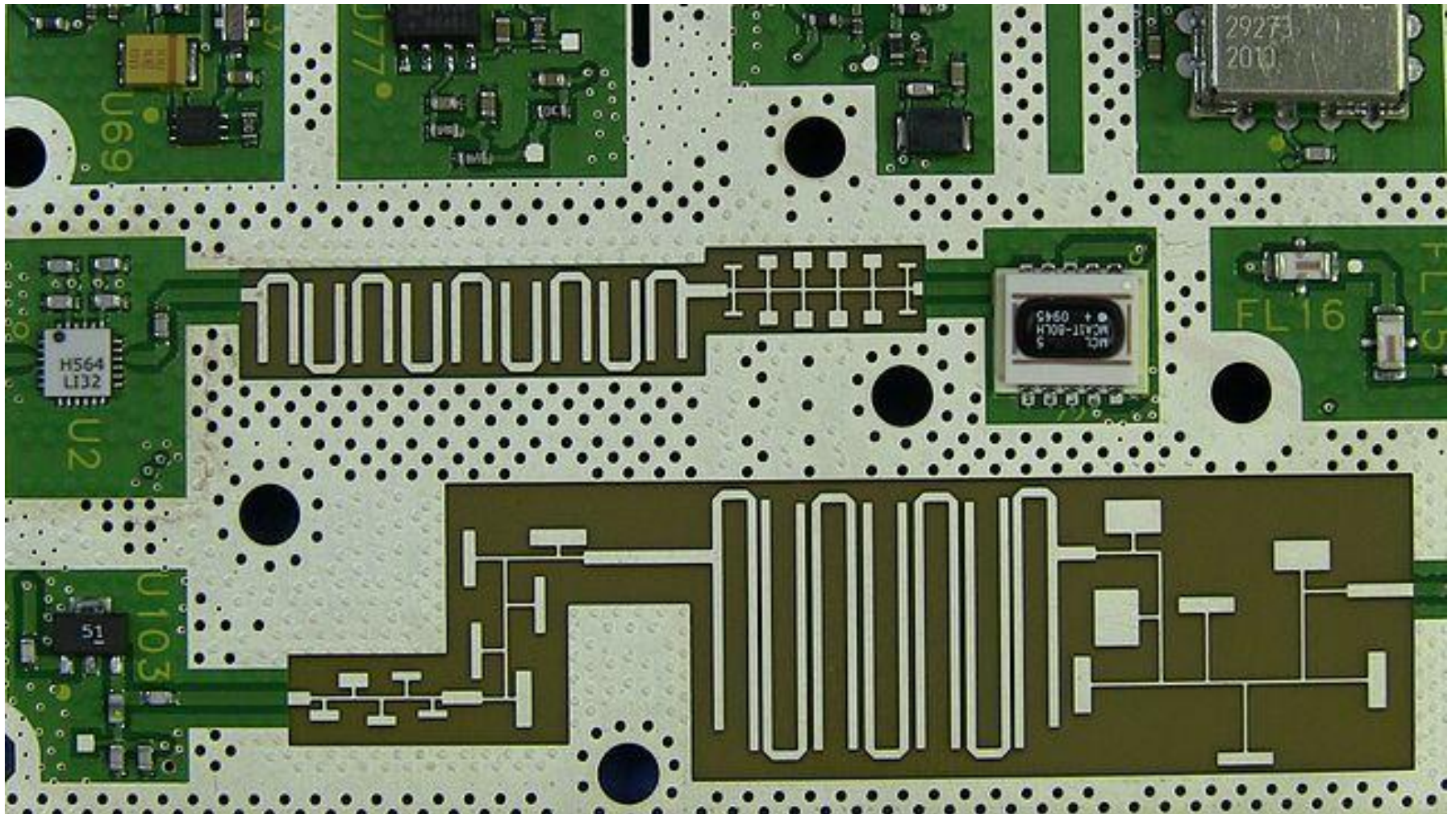


(c)

Example



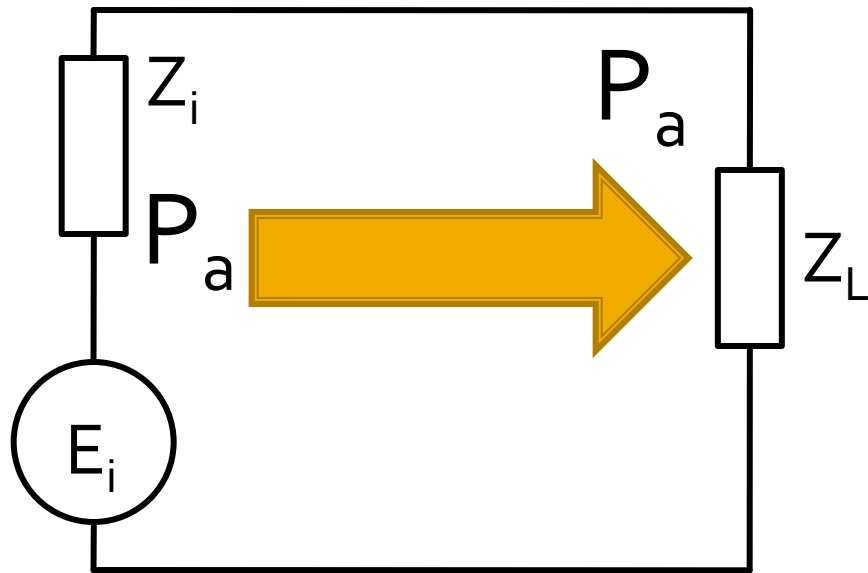
Example



Transfer de putere

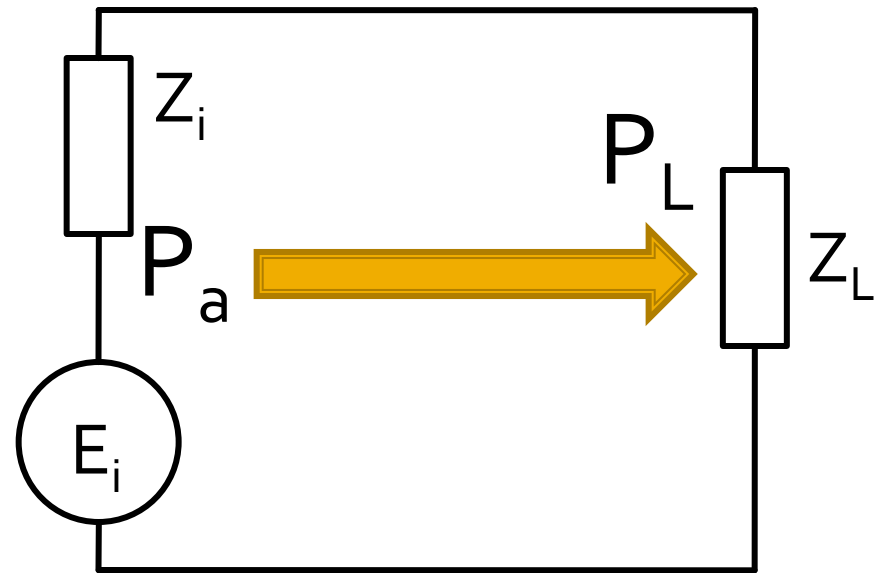
Adaptarea de impedanță

Reflexie de putere / Model



$$Z_L = Z_i^*$$

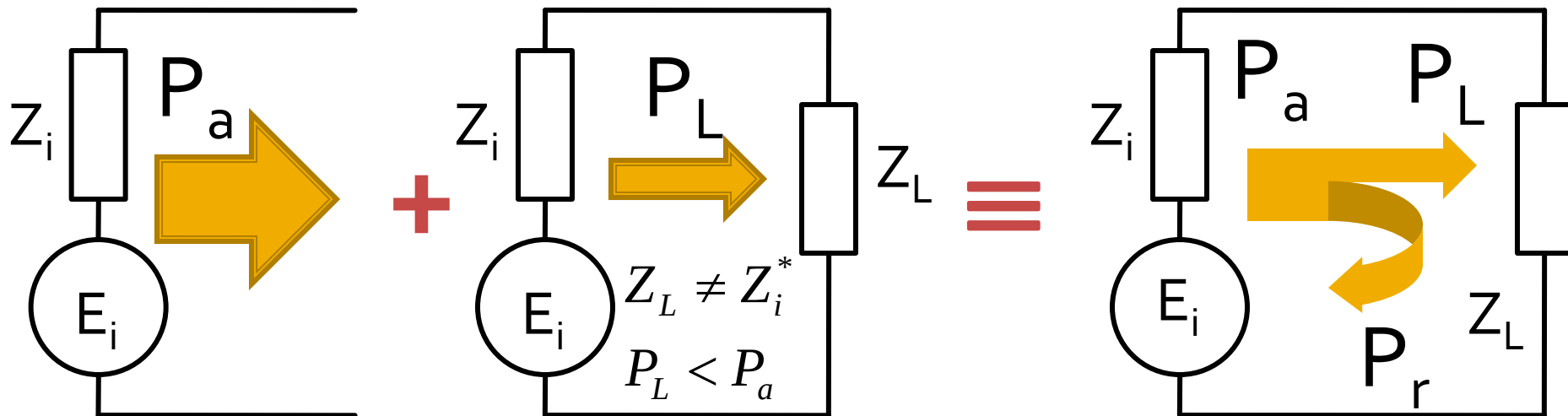
$$P_L = P_a$$



$$Z_L \neq Z_i^*$$

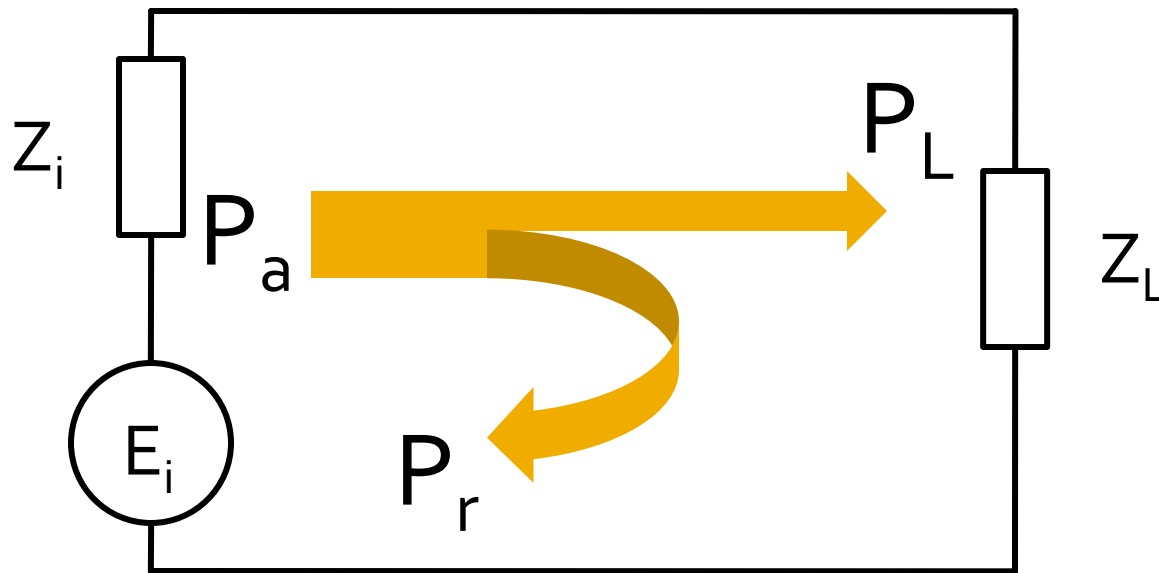
$$P_L < P_a$$

Reflexie de putere / Model



- Generatorul are posibilitatea de a oferi o anumita putere maxima de semnal P_a
- Pentru o sarcina oarecare, acestuia 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!**

Reflexie de putere / Model



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

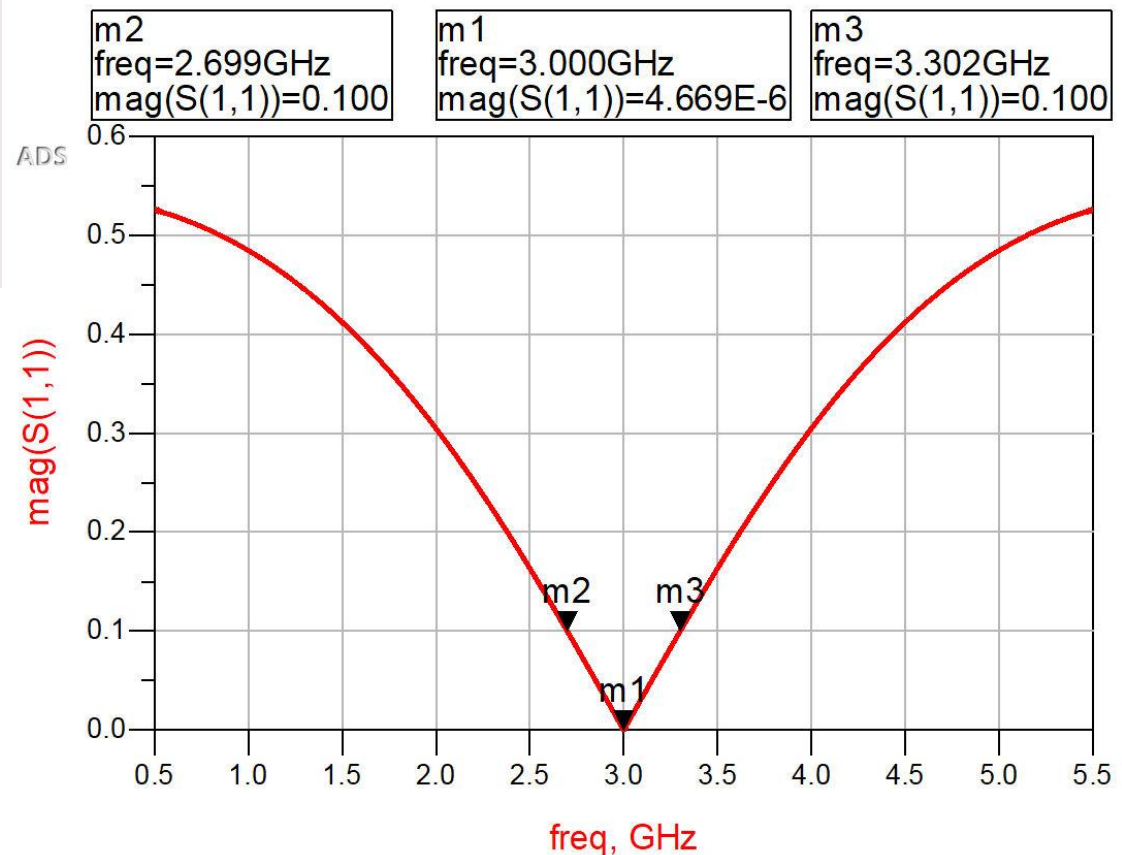
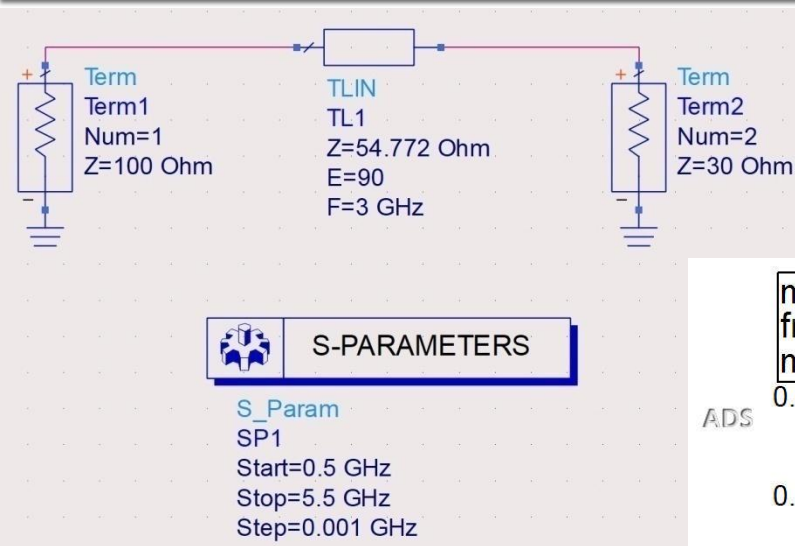
$$P_L = \frac{R_L \cdot |E_i|^2}{(R_i + R_L)^2 + (X_i + X_L)^2}$$

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

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

- $|\Gamma|^2$ **este** un coeficient de reflexie in putere

Sfert de lungime de unda

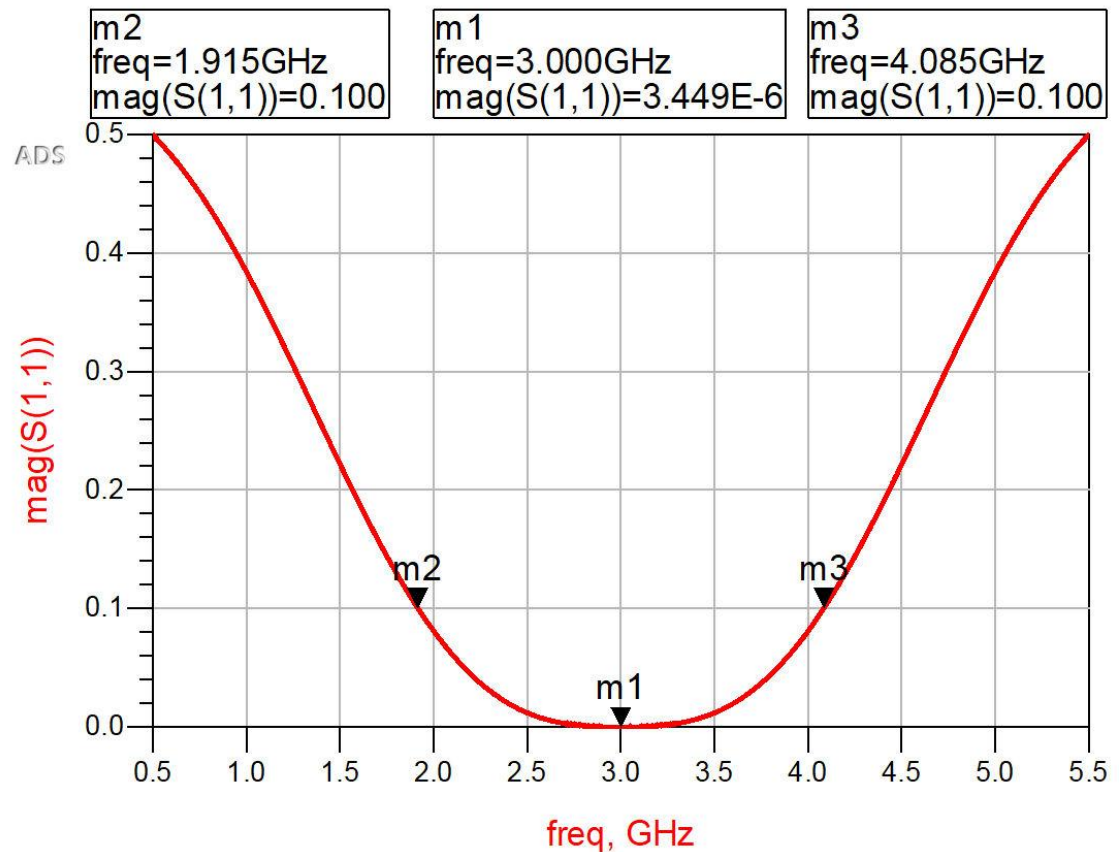


Binomial

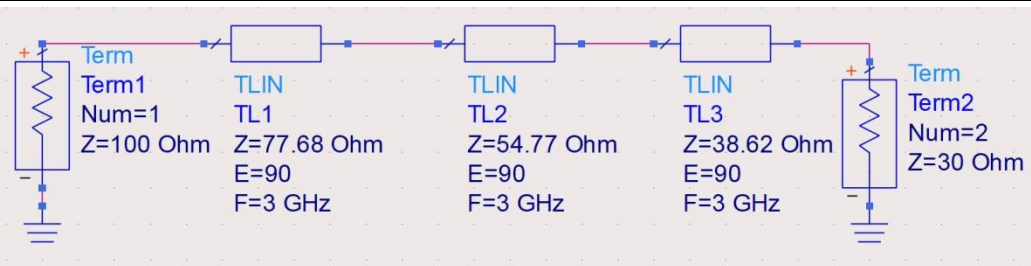


 **S-PARAMETERS**

S_Param
SP1
Start=0.5 GHz
Stop=5.5 GHz
Step=0.001 GHz

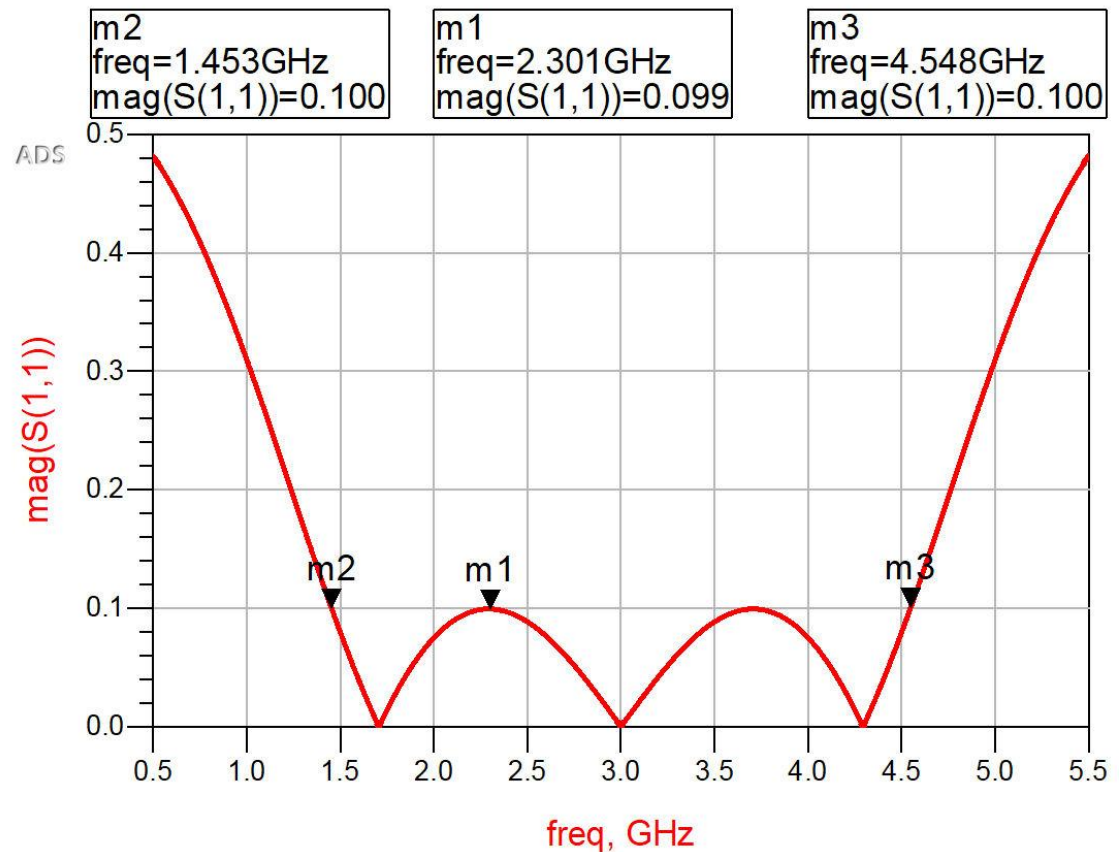


Cebâşev



 **S-PARAMETERS**

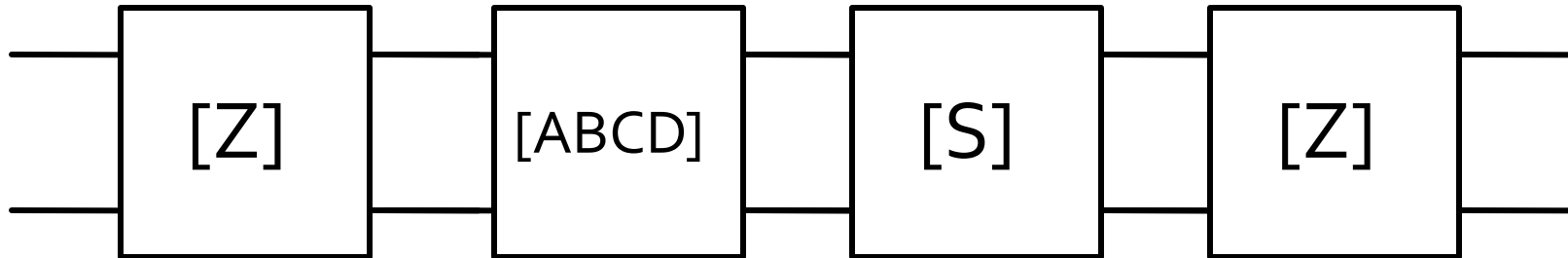
S_Param
SP1
Start=0.5 GHz
Stop=5.5 GHz
Step=0.001 GHz



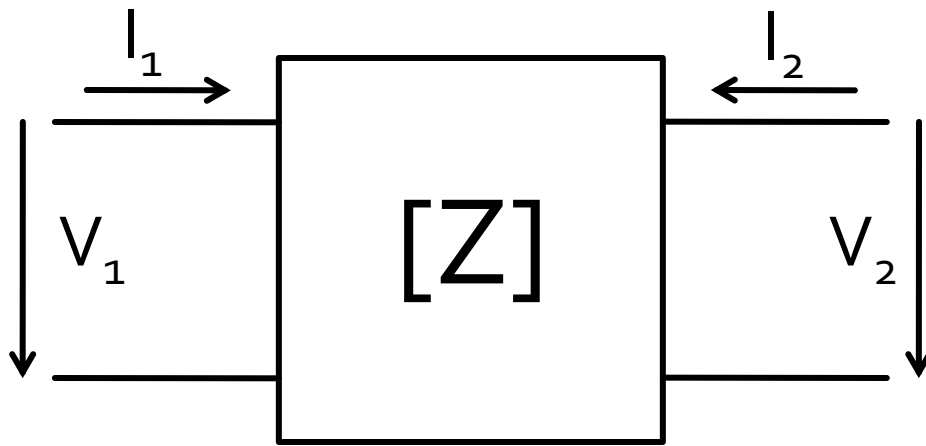
**Analiza la nivel de rețea a
circuitelor de microunde**

Analiza la nivel de bloc

- are ca scop separarea unui circuit complex in blocuri individuale
- acestea se analizeaza separat (decuplate de restul circuitului) si se caracterizeaza doar prin intermediul porturilor (**cutie neagra**)
- analiza la nivel de retea permite cuplarea rezultatelor individuale si obtinerea unui rezultat total pentru circuit



Matricea impedanta



$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \cdot \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

$$V_1 = Z_{11} \cdot I_1 + Z_{12} \cdot I_2$$

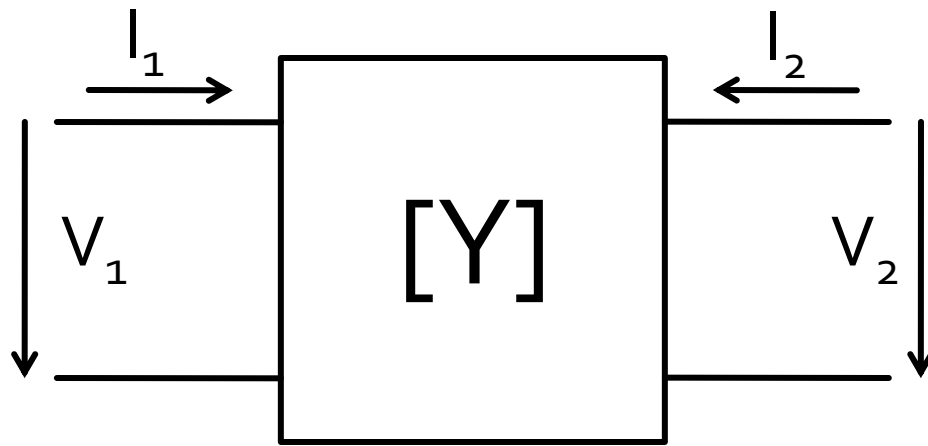
$$V_2 = Z_{21} \cdot I_1 + Z_{22} \cdot I_2$$

$$V_1 = Z_{11} \cdot I_1 \Big|_{I_2=0} \quad Z_{11} = \frac{V_1}{I_1} \Big|_{I_2=0}$$

- Z_{11} – impedanta de intrare cu iesirea in gol

$$Z_{11} = \frac{V_1}{I_1} \Big|_{I_2=0} \quad Z_{12} = \frac{V_1}{I_2} \Big|_{I_1=0} \quad Z_{21} = \frac{V_2}{I_1} \Big|_{I_2=0} \quad Z_{22} = \frac{V_2}{I_2} \Big|_{I_1=0}$$

Matricea admitanta



$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} \cdot \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

$$I_1 = Y_{11} \cdot V_1 + Y_{12} \cdot V_2$$

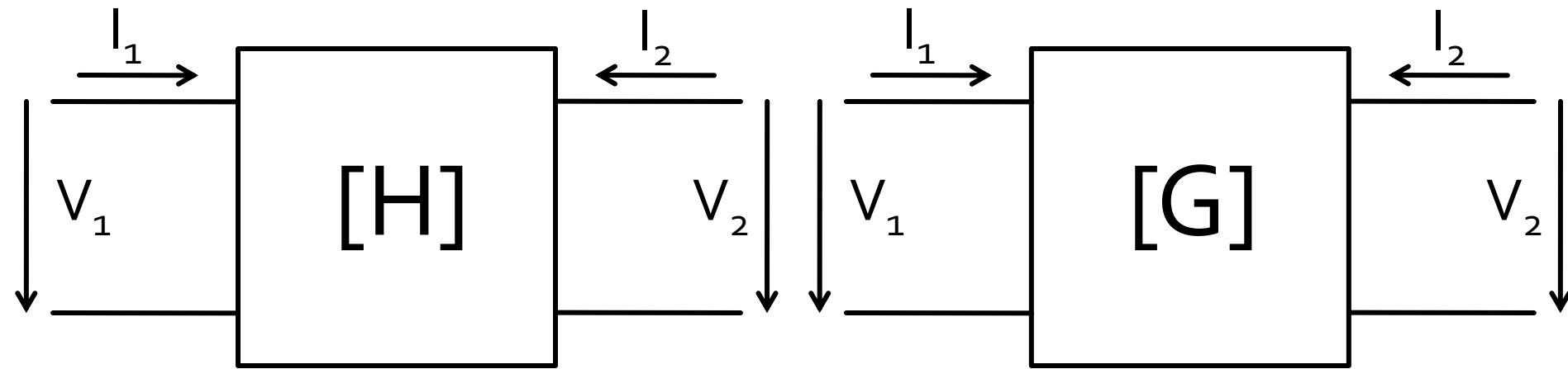
$$I_2 = Y_{21} \cdot V_1 + Y_{22} \cdot V_2$$

$$I_1 = Y_{11} \cdot V_1 \Big|_{V_2=0} \quad Y_{11} = \frac{I_1}{V_1} \Big|_{V_2=0}$$

- Y_{11} – admitanta de intrare cu iesirea in scurtcircuit

$$Y_{11} = \frac{I_1}{V_1} \Big|_{V_2=0} \quad Y_{12} = \frac{I_1}{V_2} \Big|_{V_1=0} \quad Y_{21} = \frac{I_2}{V_1} \Big|_{V_2=0} \quad Y_{22} = \frac{I_2}{V_2} \Big|_{V_1=0}$$

Matrici hibride



$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{bmatrix} \cdot \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$

$$\begin{bmatrix} I_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} G_{11} & G_{12} \\ G_{21} & G_{22} \end{bmatrix} \cdot \begin{bmatrix} V_1 \\ I_2 \end{bmatrix}$$

$$H_{21} = \left. \frac{I_2}{I_1} \right|_{V_2=0 \text{ sau } H_{22} \rightarrow \infty}$$

- h_{21E} utilizat la TB, conexiune Emitor comun (β , h_{22} este foarte mare)

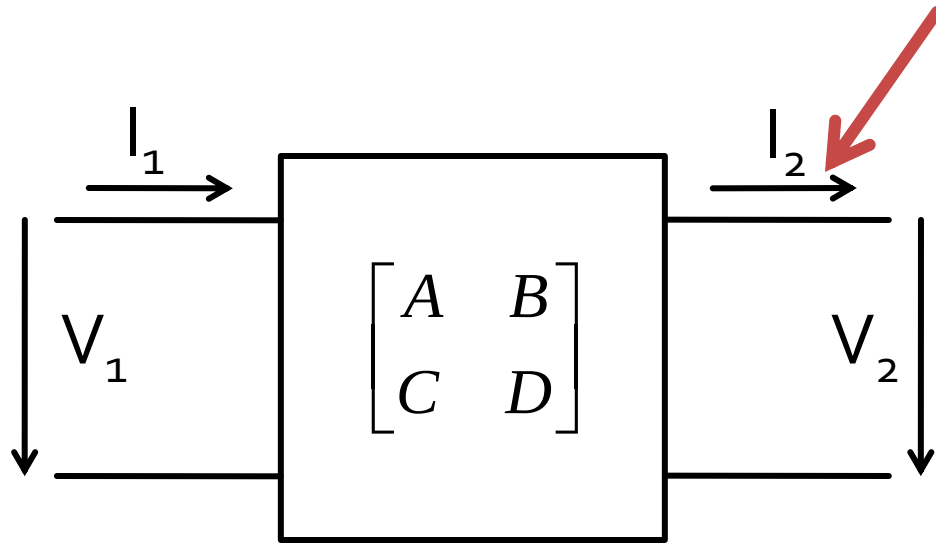
Analiza la nivel de bloc

- fiecare matrice este potrivita pentru un anumit mod de excitare a porturilor (V,I)
 - matricea H in conexiune emitor comun pentru TB: I_B, V_{CE}
 - matricile ofera marimile asociate in functie de marimile de "atac"
- traditional parametrii Z, Y, G, H sunt notati cu litera mica (z, y, g, h)
- In microunde se prefera notatia cu litera mare pentru a nu exista confuzie cu parametrii raportati la o valoare de referinta

$$z = \frac{Z}{Z_0} \qquad y = \frac{Y}{Y_0} = \frac{1/Z}{1/Z_0} = \frac{Z_0}{Z} = Z_0 \cdot Y$$

$$z_{11} = \frac{Z_{11}}{Z_0} \qquad y_{11} = \frac{Y_{11}}{Y_0} = Z_0 \cdot Y_{11}$$

Matricea ABCD – de transmisie



$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \cdot \begin{bmatrix} V_2 \\ I_2 \end{bmatrix}$$

$$V_1 = A \cdot V_2 + B \cdot I_2$$

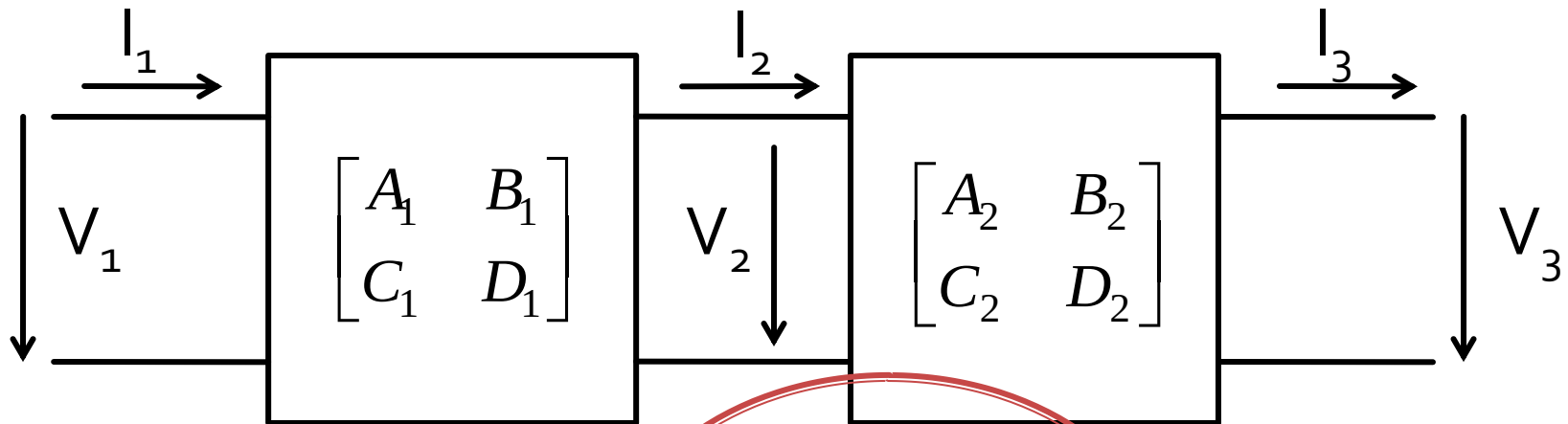
$$I_1 = C \cdot V_2 + D \cdot I_2$$

$$\begin{bmatrix} V_2 \\ I_2 \end{bmatrix} = \frac{1}{A \cdot D - B \cdot C} \cdot \begin{bmatrix} D & -B \\ -C & A \end{bmatrix} \cdot \begin{bmatrix} V_1 \\ I_1 \end{bmatrix}$$

$$A = \left. \frac{V_1}{V_2} \right|_{I_2=0} \quad B = \left. \frac{V_1}{I_2} \right|_{V_2=0} \quad C = \left. \frac{I_1}{V_2} \right|_{I_2=0} \quad D = \left. \frac{I_1}{I_2} \right|_{V_2=0}$$

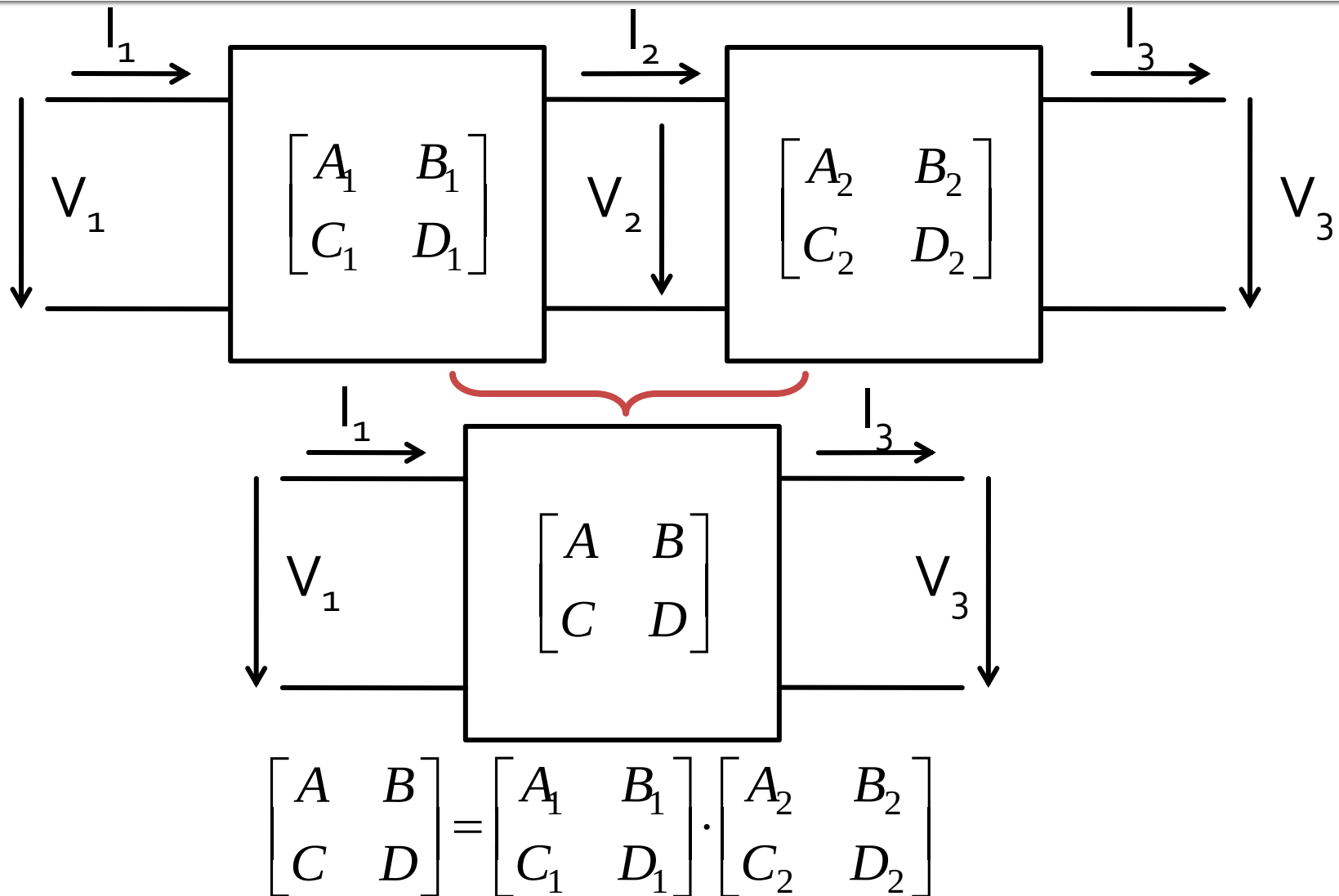
Matricea ABCD – de transmisie

- introduce o legatura intre "intrare" si "iesire"
- permite inlatuirea usoara intre mai multe blocuri



$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \cdot \begin{bmatrix} V_2 \\ I_2 \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \cdot \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \cdot \begin{bmatrix} V_3 \\ I_3 \end{bmatrix}$$

Matricea ABCD – de transmisie

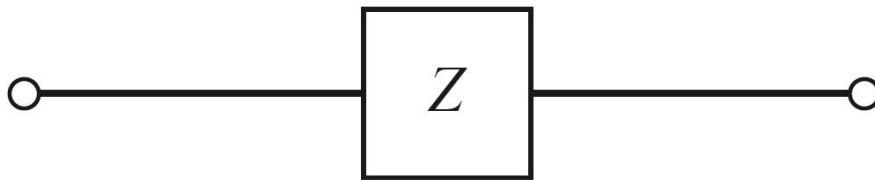


Matricea ABCD – de transmisie

- potrivita **numai** pentru diporti (Z, Y pot fi usor extinse pentru multiporti/n-porturi)
- permite cuplarea facila a mai multor elemente
- permite calculul unor circuite complexe cu o intrare si o iesire prin spargerea in blocuri individuale componente
- se pot crea "biblioteci" de matrici pentru blocuri mai des utilizate

Matrici ABCD

- Impedanza serie



$$A = 1$$

$$B = Z$$

$$C = 0$$

$$D = 1$$



$$\begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix}$$

$$A = \left. \frac{V_1}{V_2} \right|_{I_2=0} = 1$$

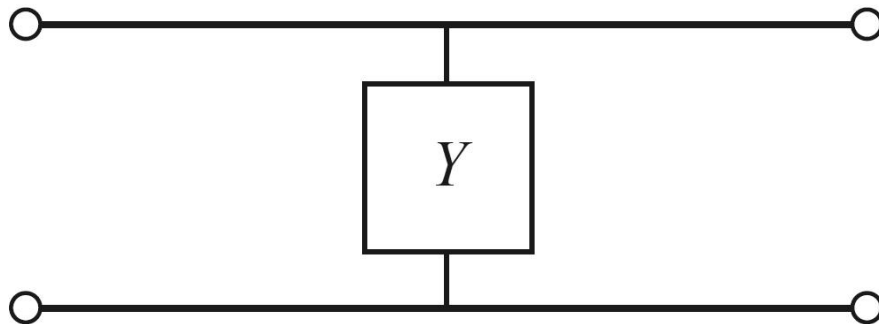
$$B = \left. \frac{V_1}{I_2} \right|_{V_2=0} = \frac{V_1}{V_1/Z} = Z$$

$$C = \left. \frac{I_1}{V_2} \right|_{I_2=0} = 0$$

$$D = \left. \frac{I_1}{I_2} \right|_{V_2=0} = \frac{I_1}{I_1} = 1$$

Matrici ABCD

- Admitanta paralel



$$A=1$$

$$B=0$$

$$C=Y$$

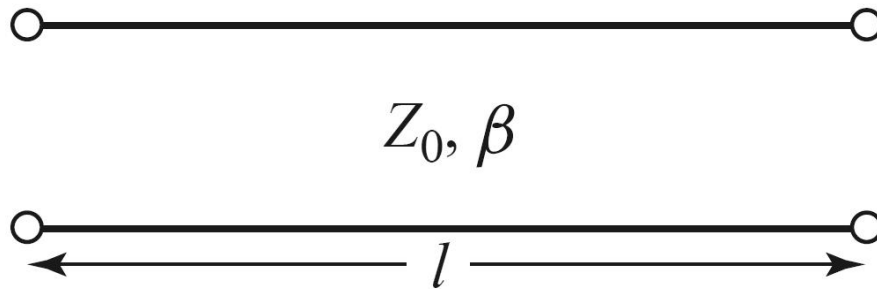
$$D=1$$

$$\begin{bmatrix} 1 & 0 \\ Y & 1 \end{bmatrix}$$

Verificare - tema!

Matrici ABCD

- Sectiune de linie de transmisie



$$A = \cos \beta \cdot l$$

$$B = j \cdot Z_0 \cdot \sin \beta \cdot l$$

$$C = j \cdot Y_0 \cdot \sin \beta \cdot l$$

$$D = \cos \beta \cdot l$$

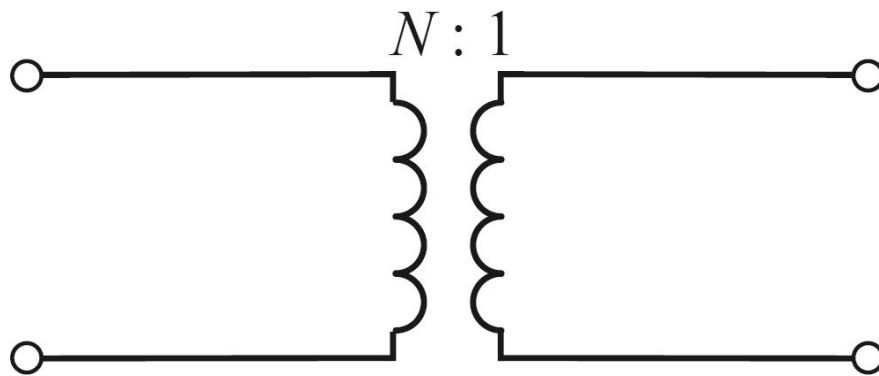
Verificare - tema!

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

$$\begin{bmatrix} \cos \beta \cdot l & j \cdot Z_0 \cdot \sin \beta \cdot l \\ j \cdot Y_0 \cdot \sin \beta \cdot l & \cos \beta \cdot l \end{bmatrix}$$

Matrici ABCD

- Transformator



$$A = N$$

$$B = 0$$

$$C = 0$$

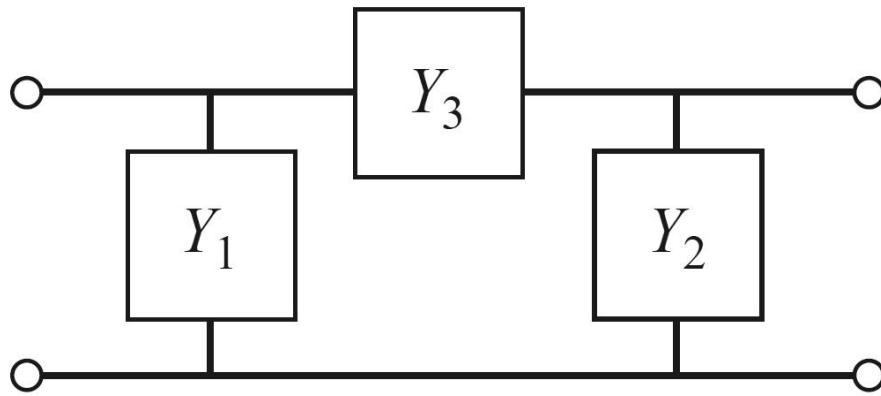
$$D = \frac{1}{N}$$

$$\begin{bmatrix} N & 0 \\ 0 & \frac{1}{N} \end{bmatrix}$$

Verificare - tema!

Matrici ABCD

- diport π



$$A = 1 + \frac{Y_2}{Y_3}$$

$$B = \frac{1}{Y_3}$$

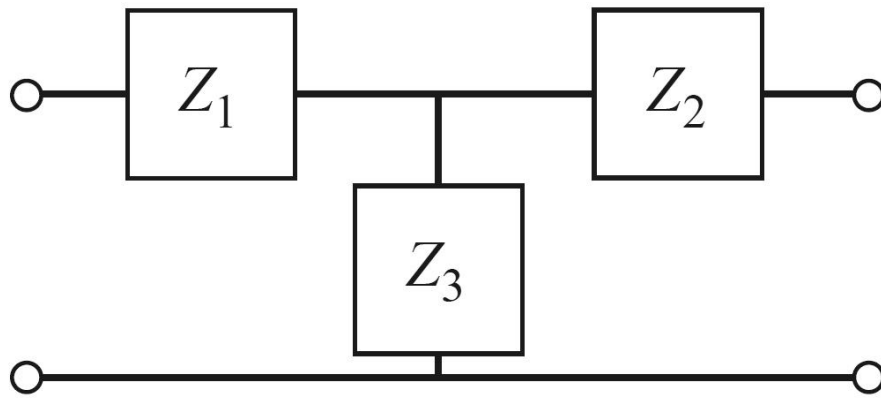
$$C = Y_1 + Y_2 + \frac{Y_1 \cdot Y_2}{Y_3}$$

$$D = 1 + \frac{Y_1}{Y_3}$$

Verificare - tema!

Matrici ABCD

- diport T



$$A = 1 + \frac{Z_1}{Z_3}$$

$$B = Z_1 + Z_2 + \frac{Z_1 \cdot Z_2}{Z_3}$$

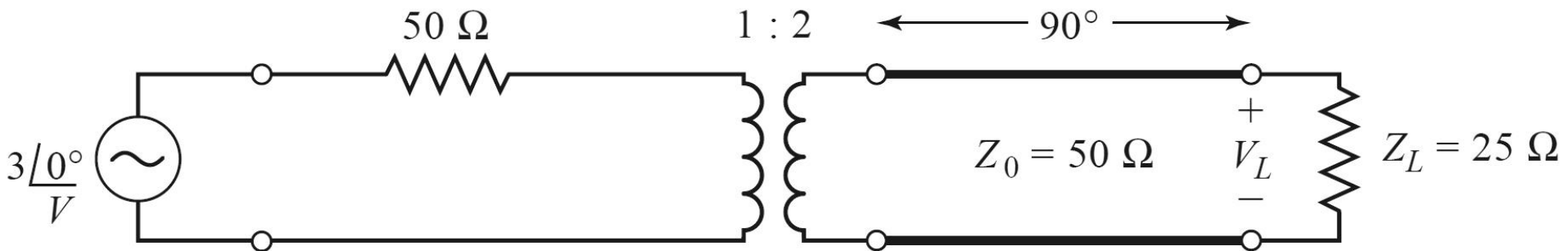
$$C = \frac{1}{Z_3}$$

$$D = 1 + \frac{Z_2}{Z_3}$$

Verificare - tema!

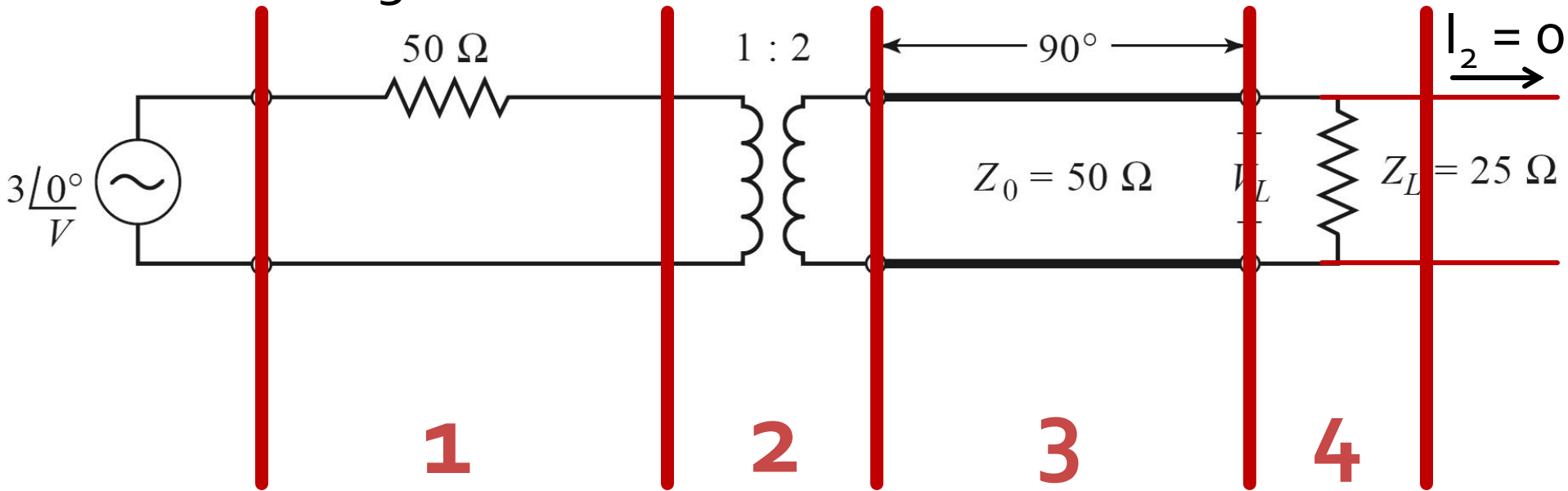
Exemplu utilizare matrice ABCD

- Determinati tensiunea pe sarcina in circuitul urmator



Exemplu utilizare matrice ABCD

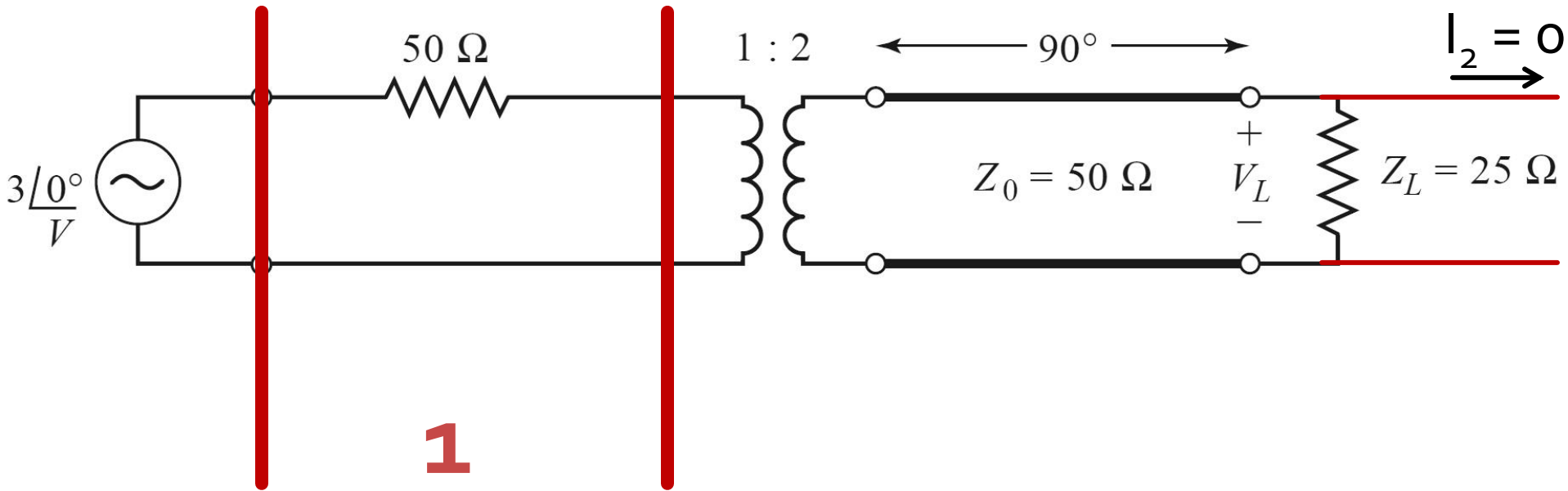
- Sectionare circuit in elemente simple
- Generatoarele raman in exterior
- Daca e necesar, se creaza porturi de intrare si iesire lasate in gol



$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = M_1 \cdot M_2 \cdot M_3 \cdot M_4 \quad V_1 = A \cdot V_2 + B \cdot I_2 \Big|_{I_2=0} \quad V = A \cdot V_L \rightarrow V_L = \frac{V}{A}$$

Exemplu utilizare matrice ABCD

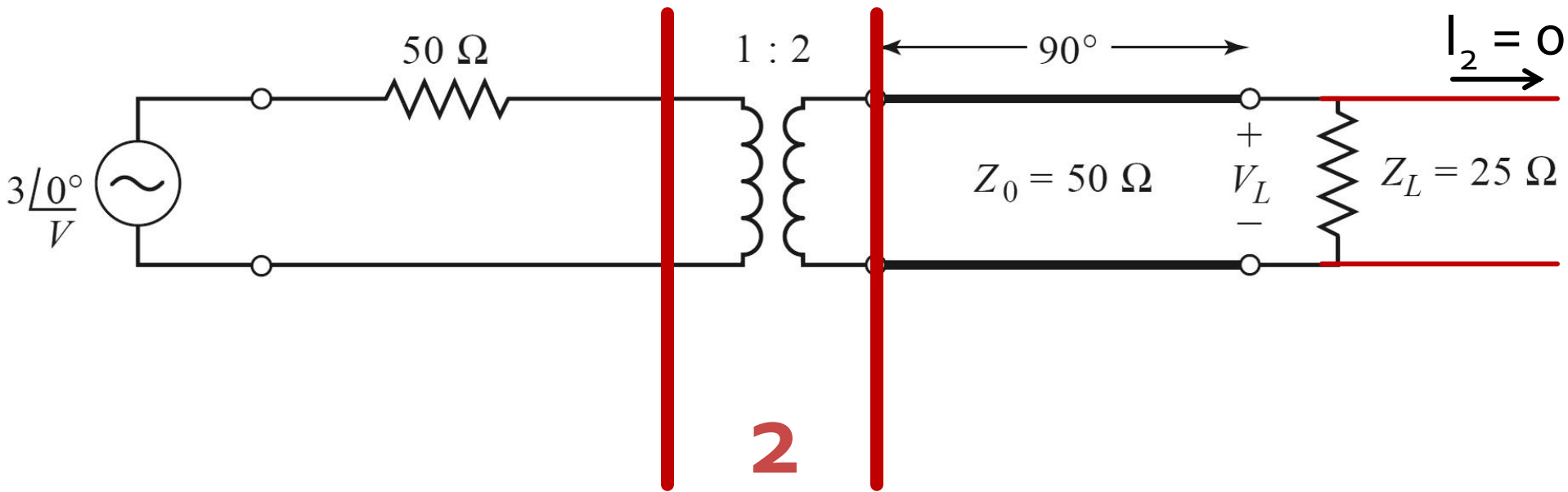
- M_1 , impedanta serie



$$M_1 = \begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 50 \\ 0 & 1 \end{bmatrix}$$

Exemplu utilizare matrice ABCD

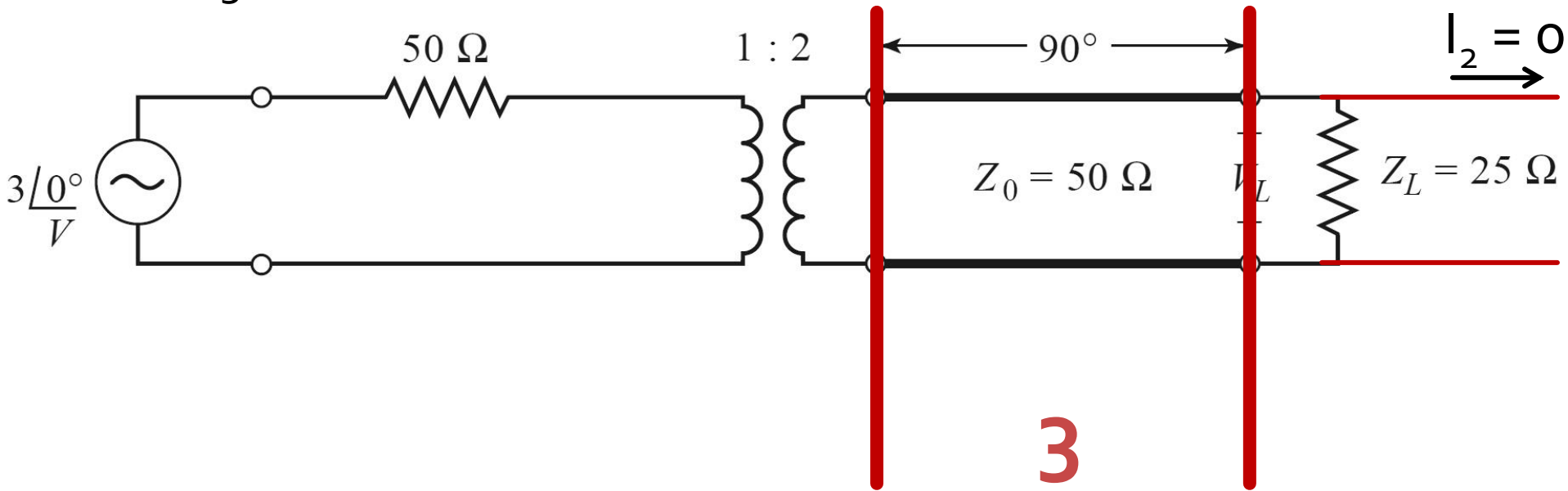
- M_2 , transformator 1:2



$$M_2 = \begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1/2 & 0 \\ 0 & 2 \end{bmatrix}$$

Exemplu utilizare matrice ABCD

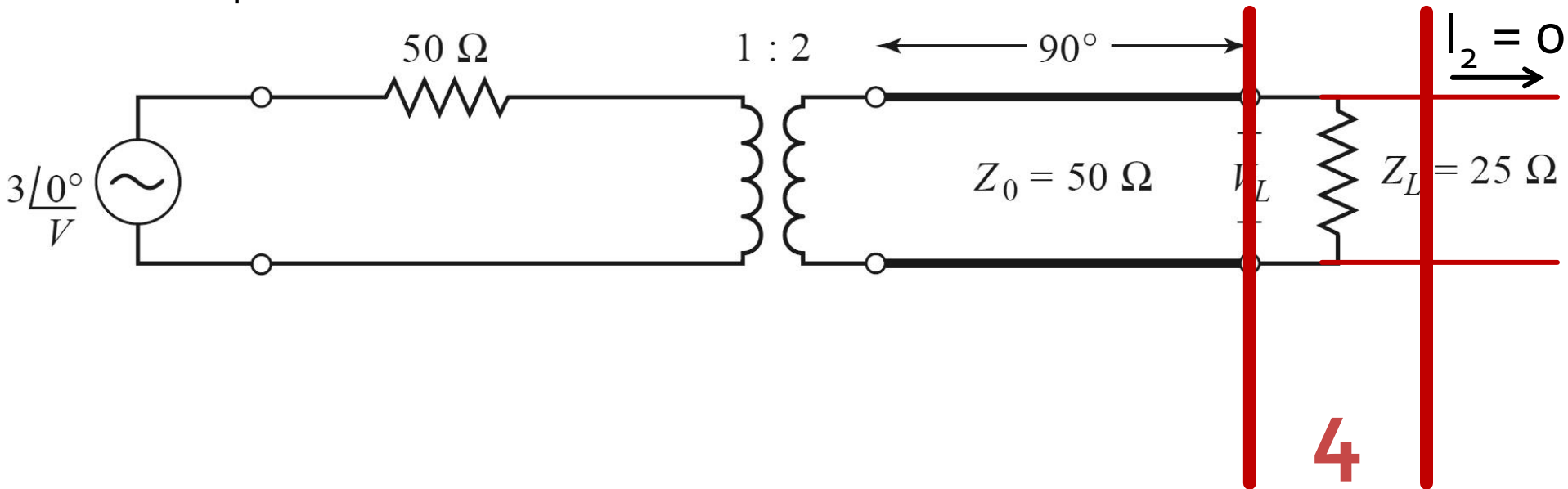
- M_3 , linie serie, $E = 90^\circ$



$$M_3 = \begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 0 & 50 \cdot j \\ \frac{j}{50} & 0 \end{bmatrix}$$

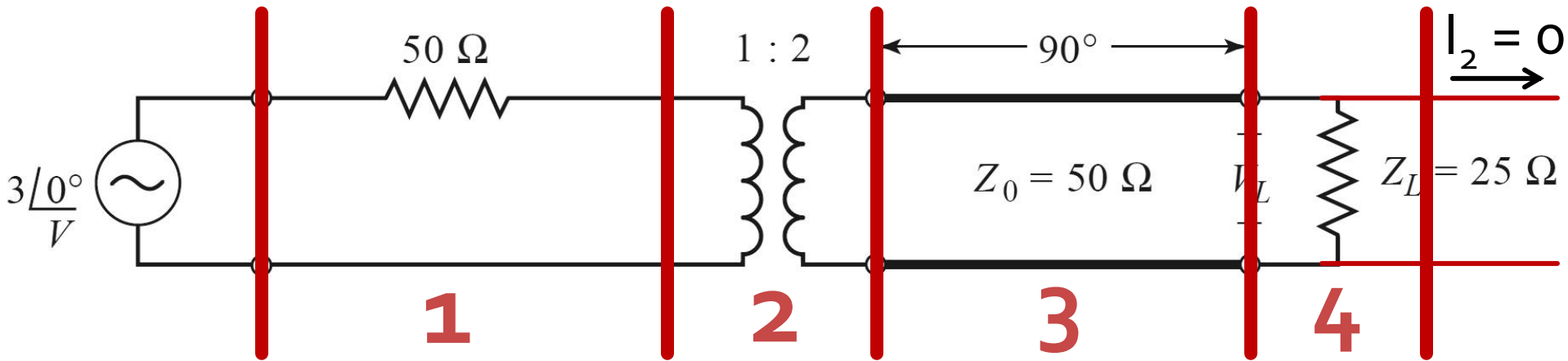
Exemplu utilizare matrice ABCD

- M_4 , impedanta/admitanta paralel



$$M_4 = \begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ \frac{1}{25} & 1 \end{bmatrix}$$

Exemplu utilizare matrice ABCD

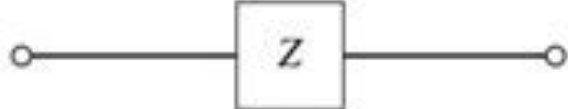
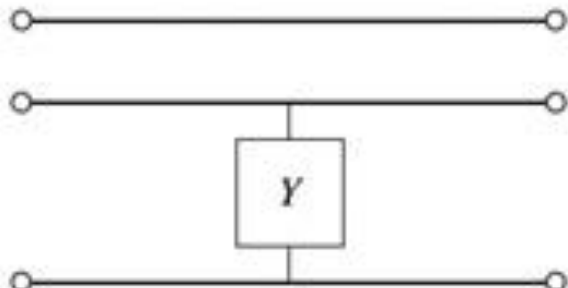
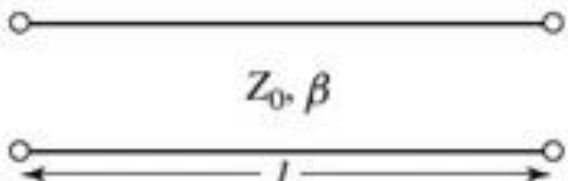


$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 50 \\ 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} \frac{1}{2} & 0 \\ 0 & 2 \end{bmatrix} \cdot \begin{bmatrix} 0 & 50 \cdot j \\ \frac{j}{50} & 0 \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 \\ \frac{1}{25} & 1 \end{bmatrix} = \begin{bmatrix} 3 \cdot j & 25 \cdot j \\ \frac{j}{25} & 0 \end{bmatrix}$$

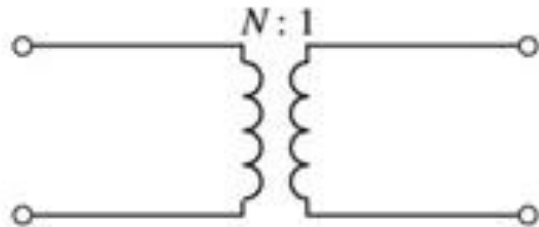
$$V_L = \frac{V}{A} = \frac{3\angle 0^\circ}{3 \cdot j} = 1\angle 90^\circ$$

Bibliotece de matrici ABCD

TABLE 4.1 *ABCD* Parameters of Some Useful Two-Port Circuits

Circuit	<i>ABCD</i> Parameters	
	$A = 1$ $C = 0$	$B = Z$ $D = 1$
	$A = 1$ $C = Y$	$B = 0$ $D = 1$
	$A = \cos \beta \ell$ $C = jY_0 \sin \beta \ell$	$B = jZ_0 \sin \beta \ell$ $D = \cos \beta \ell$

Bibliotece de matrici ABCD

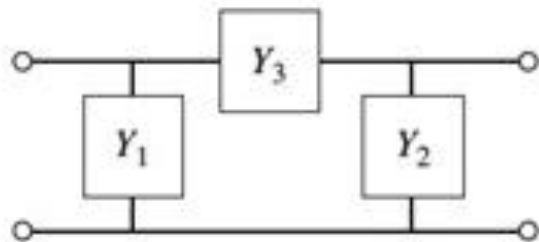


$$A = N$$

$$C = 0$$

$$B = 0$$

$$D = \frac{1}{N}$$

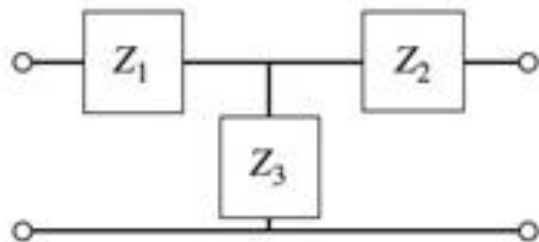


$$A = 1 + \frac{Y_2}{Y_3}$$

$$C = Y_1 + Y_2 + \frac{Y_1 Y_2}{Y_3}$$

$$B = \frac{1}{Y_3}$$

$$D = 1 + \frac{Y_1}{Y_3}$$



$$A = 1 + \frac{Z_1}{Z_3}$$

$$C = \frac{1}{Z_3}$$

$$B = Z_1 + Z_2 + \frac{Z_1 Z_2}{Z_3}$$

$$D = 1 + \frac{Z_2}{Z_3}$$

Table 4.1

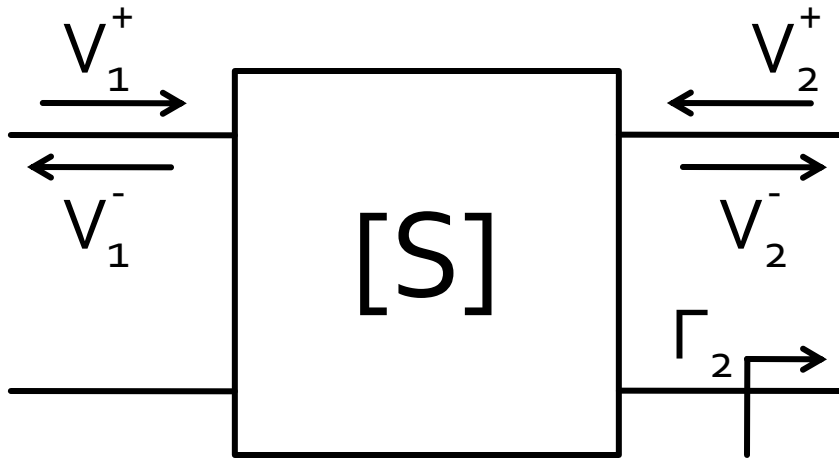
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Continuare

Analiza la nivel de rețea a circuitelor de microunde

Matricea S (repartitie)

- Scattering parameters



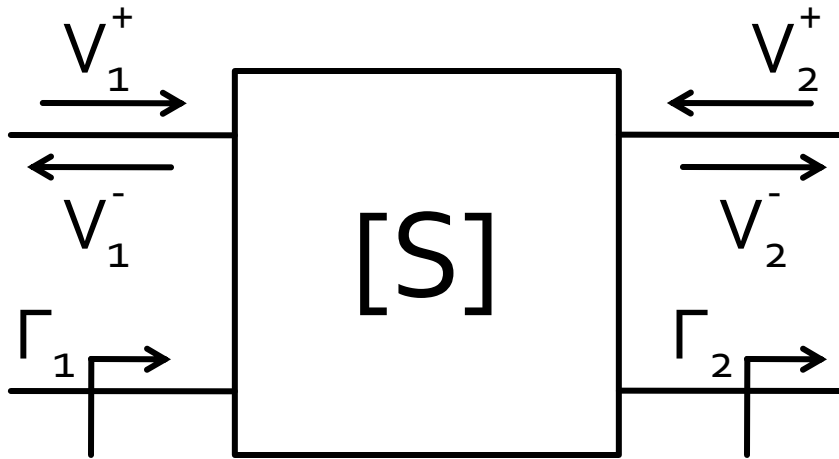
$$\begin{bmatrix} V_1^- \\ V_2^- \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} V_1^+ \\ V_2^+ \end{bmatrix}$$

$$S_{11} = \left. \frac{V_1^-}{V_1^+} \right|_{V_2^+ = 0} \quad S_{21} = \left. \frac{V_2^-}{V_1^+} \right|_{V_2^+ = 0}$$

- $V_2^+ = 0$ are semnificatia: la portul 2 este conectata impedanta care realizeaza conditia de adaptare (complex conjugat)

$$\Gamma_2 = 0 \rightarrow V_2^+ = 0$$

Matricea S (repartitie)



$$\begin{bmatrix} V_1^- \\ V_2^- \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} V_1^+ \\ V_2^+ \end{bmatrix}$$

$$S_{11} = \left. \frac{V_1^-}{V_1^+} \right|_{V_2^+=0} = \Gamma_1|_{\Gamma_2=0}$$

$$S_{21} = \left. \frac{V_2^-}{V_1^+} \right|_{V_2^+=0} = T_{21}|_{\Gamma_2=0}$$

- S_{11} este coeficientul de reflexie la portul **1** cand cand portul **2** este terminat pe impedanta care realizeaza adaptarea
- S_{21} este coeficientul de transmisie de la portul **1** (**al doilea** indice!) la portul **2** (**primul** indice!) cand se depune semnal la portul **1** portul **2** este terminat pe impedanta care realizeaza adaptarea

Matricea S (repartitie)

- Matricea S poate fi extinsa (generalizata) pentru multiporti (n-porturi)

$$S_{ii} = \left. \frac{V_i^-}{V_i^+} \right|_{V_k^+ = 0, \forall k \neq i} \quad S_{ij} = \left. \frac{V_i^-}{V_j^+} \right|_{V_k^+ = 0, \forall k \neq j}$$

- S_{ii} este coeficientul de reflexie la portul i cand toate celelalte porturi sunt conectate la impedanta care realizeaza adaptarea
- S_{ij} este coeficientul de transmisie de la portul j (**al doilea** indice!) la portul i (**primul** indice!) cand se depune semnal la portul j si toate celelalte porturi sunt conectate la impedanta care realizeaza adaptarea

Proprietati [S]

- Daca portul i este conectat la o linie cu impedanta caracteristica Z_{0i}
- Curs 2

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

In planul de
referinta al
portului, $z=0$

$$V_i = V_i^+ + V_i^-$$

$$I_i = \frac{V_i^+}{Z_{0i}} - \frac{V_i^-}{Z_{0i}}$$

$$[Z_0] = \begin{bmatrix} Z_{01} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & Z_{0n} \end{bmatrix}$$

- Legatura cu matricea Z $[Z] \cdot [I] = [V]$

$$[Z] \cdot [I] = [Z_0]^{-1} \cdot [Z] \cdot [V^+] - [Z_0]^{-1} \cdot [Z] \cdot [V^-] \quad [V] = [V^+] + [V^-]$$

$$[Z_0]^{-1} \cdot [Z] \cdot [V^+] - [Z_0]^{-1} \cdot [Z] \cdot [V^-] = [V^+] + [V^-] \quad ([Z] - [Z_0]) \cdot [V^+] = ([Z] + [Z_0]) \cdot [V^-]$$

$$[V^-] = [S] \cdot [V^+]$$

$$[S] = ([Z] - [Z_0]) \cdot ([Z] + [Z_0])^{-1}$$

Deplasare a planului de referinta

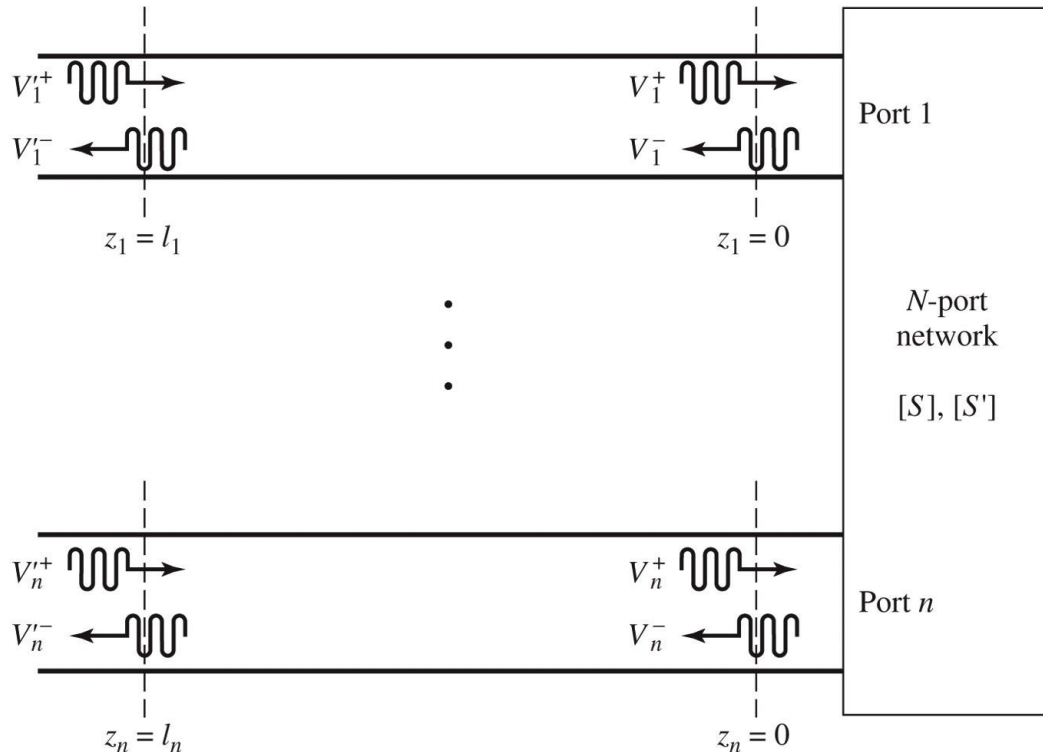


Figure 4.9
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$$[S'] = \begin{bmatrix} e^{-j\theta_1} & 0 & \dots & 0 \\ 0 & e^{-j\theta_2} & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & \dots & \dots & e^{-j\theta_N} \end{bmatrix} \cdot [S] \cdot \begin{bmatrix} e^{-j\theta_1} & 0 & \dots & 0 \\ 0 & e^{-j\theta_2} & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & \dots & \dots & e^{-j\theta_N} \end{bmatrix}$$

Proprietati [S]

- Circuite reciproce (fara circuite active, ferite)

$$Z_{ij} = Z_{ji}, \forall j \neq i$$

$$Y_{ij} = Y_{ji}, \forall j \neq i$$

$$S_{ij} = S_{ji}, \forall j \neq i \quad [S] = [S]^t$$

- Circuite fara pierderi

$$\operatorname{Re}\{Z_{ij}\} = 0, \forall i, j$$

$$\operatorname{Re}\{Y_{ij}\} = 0, \forall i, j$$

$$\sum_{k=1}^N S_{ki} \cdot S_{kj}^* = \delta_{ij}, \forall i, j$$

$$[S]^* \cdot [S]^t = [1]$$

$$\sum_{k=1}^N S_{ki} \cdot S_{ki}^* = 1$$

$$\sum_{k=1}^N S_{ki} \cdot S_{kj}^* = 0, \forall i \neq j$$

Matricea S generalizata

- Amplitudinile totale ale tensiunii si curentului in functie de amplitudinile undelor incidenta si reflectate pentru o linie

$$V = V_0^+ + V_0^- \quad I = \frac{1}{Z_0} \cdot (V_0^+ - V_0^-) \quad \text{planul de referinta al portului, } z=0$$

- Aflam amplitudinile undelor de tensiune

$$V_0^+ = \frac{V + Z_0 \cdot I}{2} \quad V_0^- = \frac{V - Z_0 \cdot I}{2}$$

- Puterea oferita sarcinii la iesirea din linie:

$$P_L = \frac{1}{2} \cdot \text{Re}\{V \cdot I^*\} = \frac{1}{2 \cdot Z_0} \cdot \text{Re}\left\{|V_0^+|^2 - \underbrace{V_0^+ \cdot V_0^{-*} + V_0^{+*} \cdot V_0^-}_{(z - z^*) = \text{Im}} - |V_0^-|^2\right\}$$

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

Matricea S generalizata

- Definim unde de putere

$$a = \frac{V + Z_R \cdot I}{2 \cdot \sqrt{R_R}} \quad \text{unda incidenta de putere}$$

$$b = \frac{V - Z_R^* \cdot I}{2 \cdot \sqrt{R_R}} \quad \text{unda reflectata de putere}$$

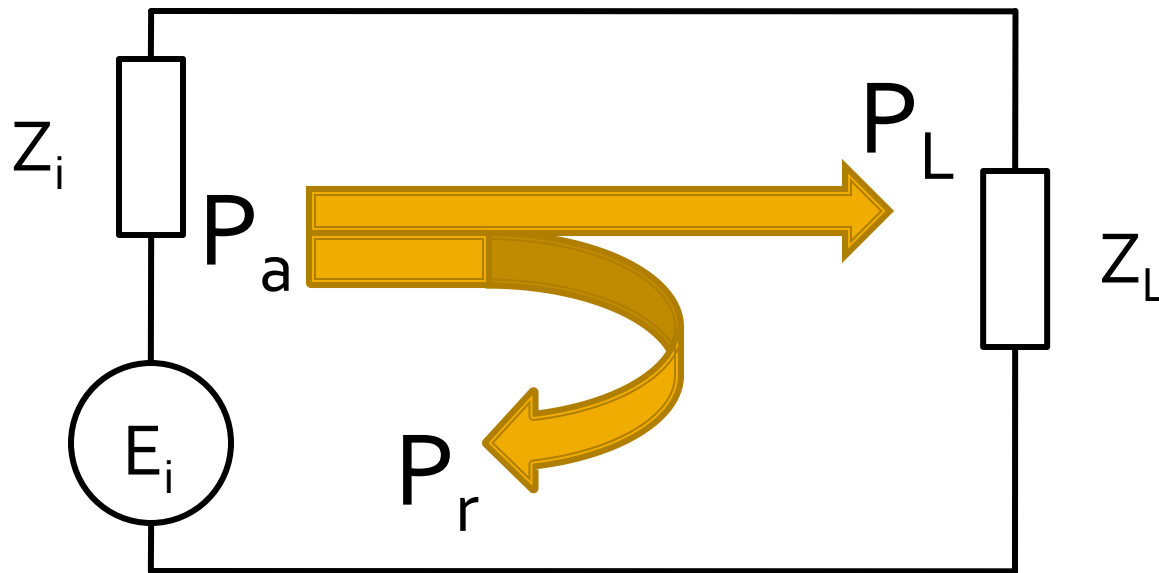
$Z_R = R_R + j \cdot X_R$
O impedanta de referinta
oarecare, complexa

- Tensiuni si curenti

$$V = \frac{Z_R^* \cdot a + Z_R \cdot b}{\sqrt{R_R}}$$

$$I = \frac{a - b}{\sqrt{R_R}}$$

Reflexie de putere / Model / C3



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

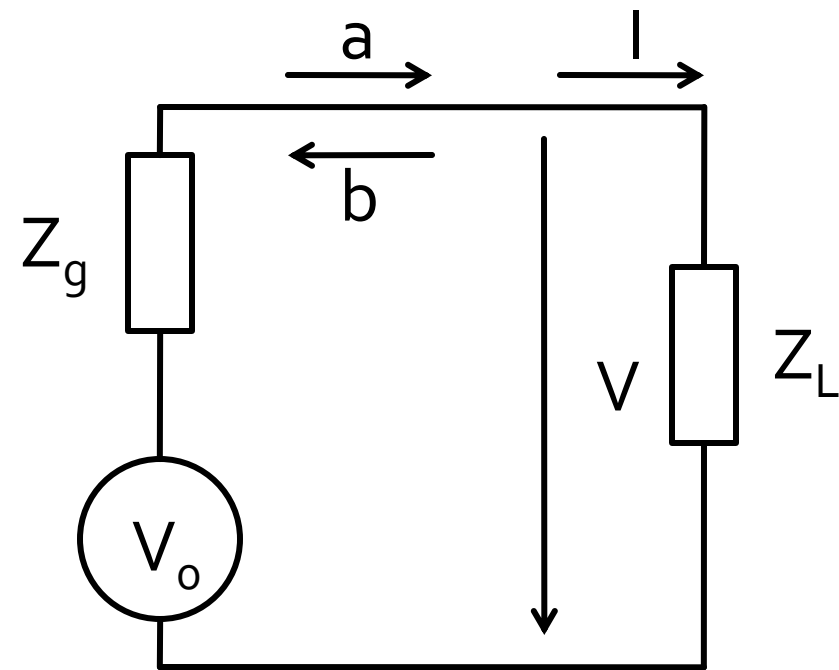
$$P_L = \frac{R_L \cdot |E_i|^2}{(R_i + R_L)^2 + (X_i + X_L)^2}$$

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

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

- coeficient de reflexie in putere

Unde de putere



$$P_L = \frac{1}{2} \cdot \text{Re}\{V \cdot I^*\}$$

$$P_L = \frac{1}{2} \cdot \text{Re}\left\{ \frac{Z_R^* \cdot a + Z_R \cdot b}{\sqrt{R_R}} \cdot \left(\frac{a-b}{\sqrt{R_R}} \right)^* \right\}$$

$$P_L = \frac{1}{2R_R} \cdot \text{Re}\{Z_R^* \cdot |a|^2 - Z_R^* \cdot a \cdot b^* + Z_R \cdot a^* \cdot b - Z_R \cdot |b|^2\}$$

$$P_L = \frac{1}{2} \cdot |a|^2 - \frac{1}{2} \cdot |b|^2$$

$$\Gamma_p = \frac{b}{a} = \frac{V - Z_R^* \cdot I}{V + Z_R \cdot I} = \frac{Z_L - Z_R^*}{Z_L + Z_R}$$

Unde de putere

$$V = \frac{V_0 \cdot Z_L}{Z_g + Z_L} \quad I = \frac{V_0}{Z_g + Z_L} \quad P_L = \frac{V_0^2}{2} \cdot \frac{R_L}{|Z_g + Z_L|^2}$$

- Daca aleg $Z_R = Z_L^*$

$$a = \frac{V + Z_R \cdot I}{2 \cdot \sqrt{R_R}} = V_0 \cdot \frac{\frac{Z_L}{Z_g + Z_L} + \frac{Z_L^*}{Z_g + Z_L}}{2 \cdot \sqrt{R_L}} = V_0 \cdot \frac{\sqrt{R_L}}{Z_g + Z_L}$$

$$b = \frac{V - Z_R^* \cdot I}{2 \cdot \sqrt{R_R}} = V_0 \cdot \frac{\frac{Z_L}{Z_g + Z_L} - \frac{Z_L}{Z_g + Z_L}}{2 \cdot \sqrt{R_L}} = 0$$

$$P_L = \frac{1}{2} \cdot |a|^2 = \frac{V_0^2}{2} \cdot \frac{R_L}{|Z_g + Z_L|^2}$$

Unde de putere

- Daca in plus generatorul este adaptat conjugat cu sarcina

$$Z_g = Z_L^* \quad P_{L\max} = \frac{1}{2} \cdot |a|^2 = \frac{V_0^2}{8 \cdot R_L}$$

- Reflexie in putere C₃

$$\begin{aligned} Z_L = Z_i^* \quad P_{L\max} &\equiv P_a & \Gamma &= \frac{Z - Z_0^*}{Z + Z_0} \\ Z_L \neq Z_i^* \quad P_r &= P_a \cdot |\Gamma|^2 & P_L &= P_a - P_r = P_a - P_a \cdot |\Gamma|^2 = P_a \cdot (1 - |\Gamma|^2) \end{aligned}$$

- Reflexie in putere C₄

$$\begin{aligned} P_{L\max} &\equiv P_a = \frac{1}{2} \cdot |a|^2 & P_L &= \frac{1}{2} \cdot |a|^2 - \frac{1}{2} \cdot |b|^2 & \Gamma_p &= \frac{b}{a} = \frac{V - Z_R^* \cdot I}{V + Z_R \cdot I} = \frac{Z_L - Z_R^*}{Z_L + Z_R} \\ P_L &= \frac{1}{2} \cdot |a|^2 - \frac{1}{2} \cdot |a|^2 \cdot |\Gamma_p|^2 & P_L &= P_a \cdot (1 - |\Gamma_p|^2) & P_r &= P_a \cdot |\Gamma_p|^2 = \frac{1}{2} \cdot |b|^2 \end{aligned}$$

Unde de putere

- Definitii de unde pentru n-porti

$$[Z_R] = \begin{bmatrix} Z_{R1} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & Z_{Rn} \end{bmatrix} \quad [F] = \begin{bmatrix} 1/2\sqrt{R_{R1}} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 1/2\sqrt{R_{Rn}} \end{bmatrix}$$

$$[a] = [F] \cdot ([V] + [Z_R] \cdot [I])$$

$$[b] = [F] \cdot ([V] - [Z_R]^* \cdot [I])$$

$$[Z] \cdot [I] = [V]$$

Unde de putere pentru multiporti

$$[b] = [F] \cdot ([Z] - [Z_R]^*) \cdot ([Z] + [Z_R])^{-1} \cdot [F]^{-1} \cdot [a]$$

- legatura intre undele de putere incidenta si reflectata

$$[b] = [S_p] \cdot [a]$$

$$[S_p] = [F] \cdot ([Z] - [Z_R]^*) \cdot ([Z] + [Z_R])^{-1} \cdot [F]^{-1}$$

$$[S] = ([Z] - [Z_0]) \cdot ([Z] + [Z_0])^{-1}$$

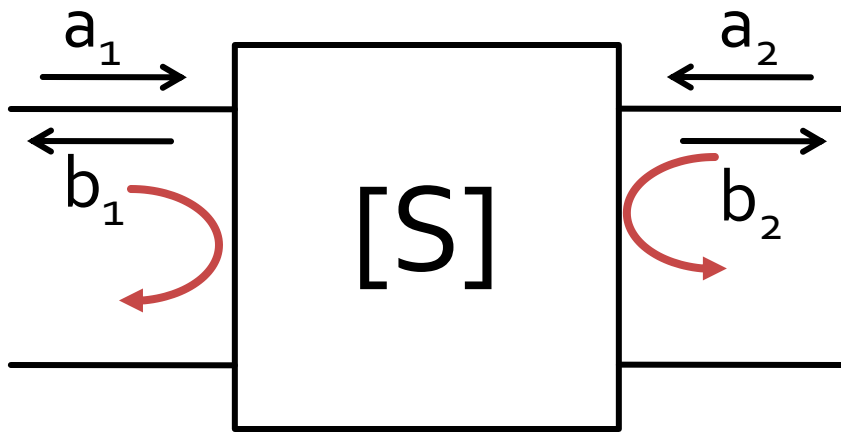
- tipic

$$Z_{0i} = Z_{Ri} = R_0, \forall i$$

$$R_0 = 50\Omega$$

$$\boxed{[S_p]} \equiv [S] \quad \blacksquare \text{ coincid!!!}$$

Matricea S (repartitie)

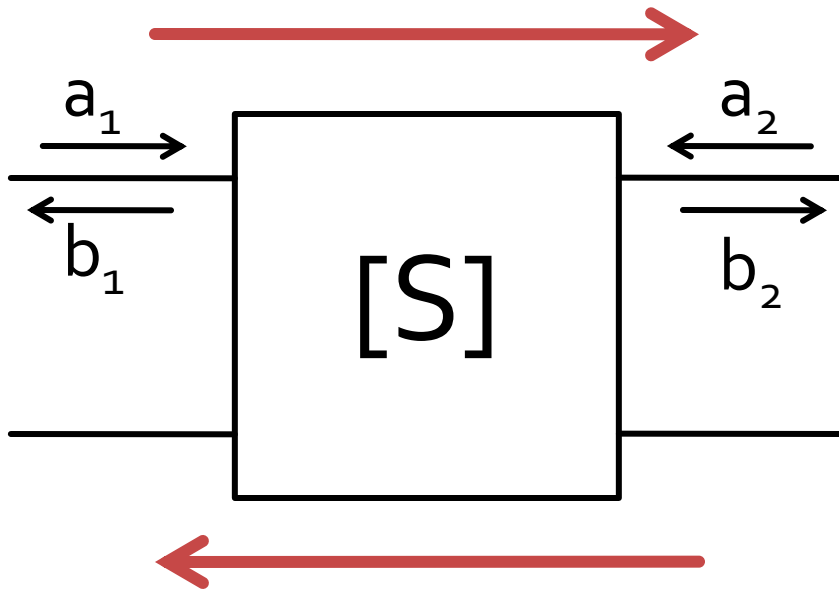


$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

$$S_{11} = \left. \frac{b_1}{a_1} \right|_{a_2=0} \quad S_{22} = \left. \frac{b_2}{a_2} \right|_{a_1=0}$$

- S_{11} si S_{22} sunt coeficienti de reflexie la intrare si iesire cand celalalt port este adaptat

Matricea S (repartitie)

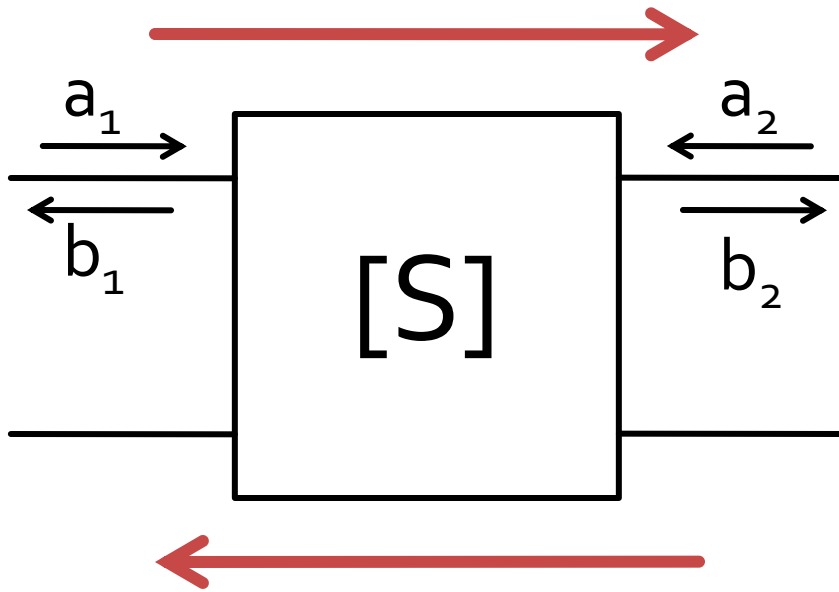


$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

$$S_{21} = \left. \frac{b_2}{a_1} \right|_{a_2=0} \quad S_{12} = \left. \frac{b_1}{a_2} \right|_{a_1=0}$$

- S_{21} si S_{12} sunt amplificari de semnal cand celalalt port este adaptat

Matricea S (repartitie)



$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

$$|S_{21}|^2 = \frac{\text{Putere sarcina } Z_0}{\text{Putere sursa } Z_0}$$

- a, b
 - informatia despre putere **SI** faza
- S_{ij}
 - influenta circuitului asupra puterii semnalului incluzand informatiile relativ la faza

Masurare S - VNA

- Vector Network Analyzer

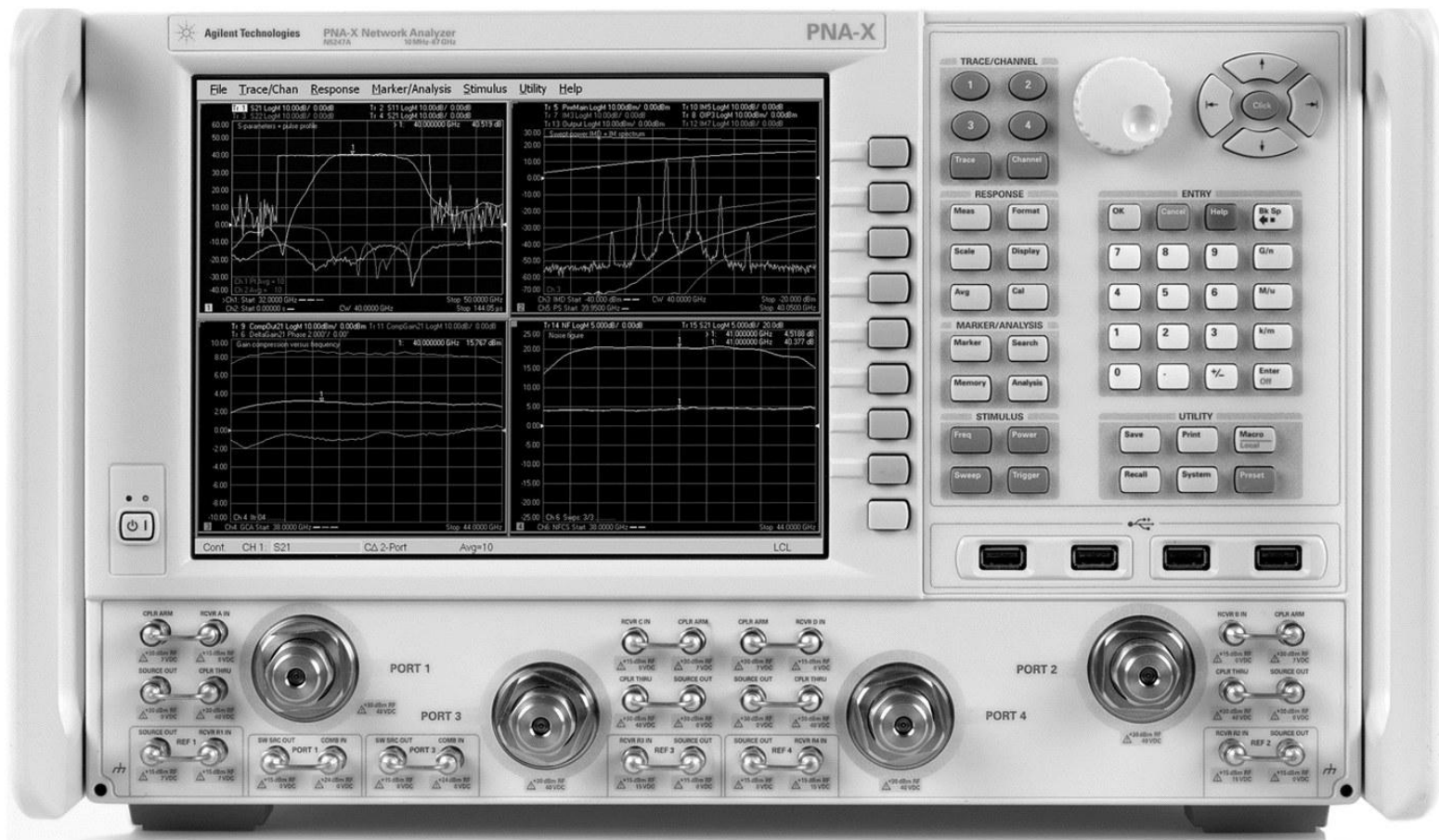


Figure 4.7
Courtesy of Agilent Technologies

Legatura dintre parametrii S si parametrii ABCD

$$A = \sqrt{\frac{Z_{01}}{Z_{02}}} \frac{(1 + S_{11} - S_{22} - \Delta S)}{2S_{21}}$$

$$B = \sqrt{Z_{01}Z_{02}} \frac{(1 + S_{11} + S_{22} + \Delta S)}{2S_{21}}$$

$$C = \frac{1}{\sqrt{Z_{01}Z_{02}}} \frac{1 - S_{11} - S_{22} + \Delta S}{2S_{21}}$$

$$D = \sqrt{\frac{Z_{02}}{Z_{01}}} \frac{1 - S_{11} + S_{22} - \Delta S}{2S_{21}}$$

$$\Delta S = S_{11}S_{22} - S_{12}S_{21}$$

$$S_{11} = \frac{AZ_{02} + B - CZ_{01}Z_{02} - DZ_{01}}{AZ_{02} + B + CZ_{01}Z_{02} + DZ_{01}}$$

$$S_{12} = \frac{2(AD - BC)\sqrt{Z_{01}Z_{02}}}{AZ_{02} + B + CZ_{01}Z_{02} + DZ_{01}}$$

$$S_{21} = \frac{2\sqrt{Z_{01}Z_{02}}}{AZ_{02} + B + CZ_{01}Z_{02} + DZ_{01}}$$

$$S_{22} = \frac{-AZ_{02} + B - CZ_{01}Z_{02} + DZ_{01}}{AZ_{02} + B + CZ_{01}Z_{02} + DZ_{01}}$$

Contact

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