

Curs 5

2023/2024

# Dispozitive și circuite de microunde pentru radiocomunicații

# Disciplina 2023/2024

- 2C/1L (+1), **DCMR (CDM)**
- Minim 7 prezente (curs+laborator)
- Curs - **conf. Radu Damian**
  - Miercuri 08(:**15**)-17, ~~Online~~/**Video (istoric)**, P5
  - E – **50%** din nota
  - probleme + (2p prez. curs) + (3 teste) + (bonus activitate)
    - primul test L1: 04.10.2023 (t2 si t3 neanuntate la **curs**)
    - 3pz (C)  $\approx$  +0.5p (**2p** max)
  - toate materialele permise

# Disciplina 2023/2024

- 2C/1L, **DCMR (CDM)**
- Laborator – **conf. Radu Damian**
  - Miercuri/Joi/Vineri, par/impar, **II.13**
  - L – **25%** din nota
    - ADS, 4 sedinte aplicatii
    - prezenta + **rezultate personale!**
  - P – **25%** din nota
    - ADS, 3 sedinte aplicatii (-1? 21-22.12.2022)
    - tema personala

# Documentatie

## ■ <http://rf-opto.etti.tuiasi.ro>

Laboratorul de Microunde si Opti x +

← → ↻ ⚠ Not secure | rf-opto.etti.tuiasi.ro/microwave\_cd.php?chg\_lang=1



English | Romana

Start **Didactic** Master Colectiv Cercetare Studenti

Microunde Comunicatii Optice Optoelectronica Internet Antene Tehnologie/Zgomote Practica Soft didactic

### Dispozitive si circuite de microunde pentru radiocomunicatii

#### Disciplina: DCMR (2021-2022)

**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


[Studenti care nu pot intra in examen \(final\)](#)  
[Bonus-uri acumulate \(final\)](#)

# Istoric

## Alte informatii

[Online Exam manual](#) (pdf, 2.56 MB, en, )

[Exam Simulation \(video\)](#) (mp4, 41.96 MB, en, )

[Important Agilent Application Notes](#) (rar, 2.36 MB, ro, )

## Ani anteriori

2020-2021

2019-2020

2018-2019

2017-2018

2016-2017

Mai mult...

## Dispozitive si circuite de microunde pentru radiocomunicatii

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**Coordonator Disciplina:** conf. dr. Radu-Florin Damian

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**Credite:** 4

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### 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:

# Fotografii (S4+S6)



## Date:

Grupa	5304 (2015/2016)
Specializarea	Tehnologii si sisteme de telecomunicatii
Marca	5184

[Trimite email acestui student](#) | [Adauga acest student la lista \(0\)](#)

## Detalii curente

## Observatii

Finantare	Buget
Bursa	Fara Bursa



## Date:

Grupa	5304 (2015/2016)
Specializarea	Tehnologii si sisteme de telecomunicatii
Marca	5244

[Trimite email acestui student](#) | [Adauga acest student la lista \(0\)](#)

## Detalii curente

## Observatii

Finantare	Buget
Bursa	Bursa de Studii



## Date:

Grupa	5304 (2015/2016)
Specializarea	Tehnologii si sisteme de telecomunicatii
Marca	5184


[Acceseaza ca acest student](#)

## Note obtinute

Disciplina	Tin	Data	Descriere	Nota	Puncte	Obs.
TW			Tehnologii Web			
	N	17/01/2014	Nota Finala	10	-	
	A	17/01/2014	Coloana Tehnologii Web 2013/2014	10	7.55	
	B	17/01/2014	Laborator Tehnologii Web 2013/2014	9	-	
	B	17/01/2014	Tema Tehnologii Web 2013/2014	9	-	

# Acces

- Personalizat (parola), Generic (email)



**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	-	

**Identificare**

Introduceti numele si adresa de email

Nume

E-mail/Parola

Introduceti codul afisat mai jos

ff769c3

Trimite





# Manual examen online

- Aplicatia de examen online utilizata intens la:
  - ~~curs (prezenta)~~
  - **laborator (rezultate)**
  - **proiect (predare)**
  - ~~examen~~

## Materials

### Other data

[Manual examen on-line](#) (pdf, 2.65 MB, ro, )

[Simulare Examen](#) (video) (mp4, 65.12 MB, ro, )

## Microwave Devices and Circuits (Englis



# Examen online

- intotdeauna **contratimp**
  - **perioada lunga** (rezultate laborator)
  - perioada scurta (teste: 15min, examen: 2h)

Start Didactic Master Colectiv Cercetare **Studenti**

Note Lista Studenti **Examene** Fotografii

**Anunț**  
17:28 (29/04/2020)

**Material suport**  
17:30 (29/04/2020)

**Subiecte**  
17:32 (29/04/2020)

**Rezultate**  
17:35 (29/04/2020)

**Finalizare**  
17:45 (29/04/2020)

**Confirmare**  
17:45 (30/04/2020)

urmatorul interval de timp in:  
**01 m 08 s**  
[Reincarca acum](#)

## Anunț

In acest examen se verifica diverse actiuni ale studentilor pentru examen

## Ora pe server

Toate examenele sunt bazate pe fusul orar al server-ului (ar putea sa fie diferit de timpul local). Pentru referinta ora pe server este acum:

**29/04/2020 17:28:51**

# Examen online laborator 1

**Examene online: 2023/2024**

**Disciplina: DCMR (Dispozitive si circuite de microunde pentru ra**

**Pas 3**

Nr.	Titlu	Start	Stop	Text
1	Fotografii profil	18/10/2023; 08:00	20/01/2024; 08:00	"Examen on-line" creat .
2	Laborator 2 (s5-6)	01/11/2023; 07:00	23/11/2023; 23:00	Temele individuale pent .
3	Laborator 1 (s3-5)	18/10/2023; 08:00	09/11/2023; 23:00	Temele individuale pent .
4	Tema curs 4 Adaptare	25/10/2023; 10:00	08/11/2023; 15:00	Testul curent consta in ..

# Cuprins

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

# 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)

# 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!
- $z = a + j \cdot b ; j^2 = -1$

# Linii de transmisie in mod TEM



# Cuprins

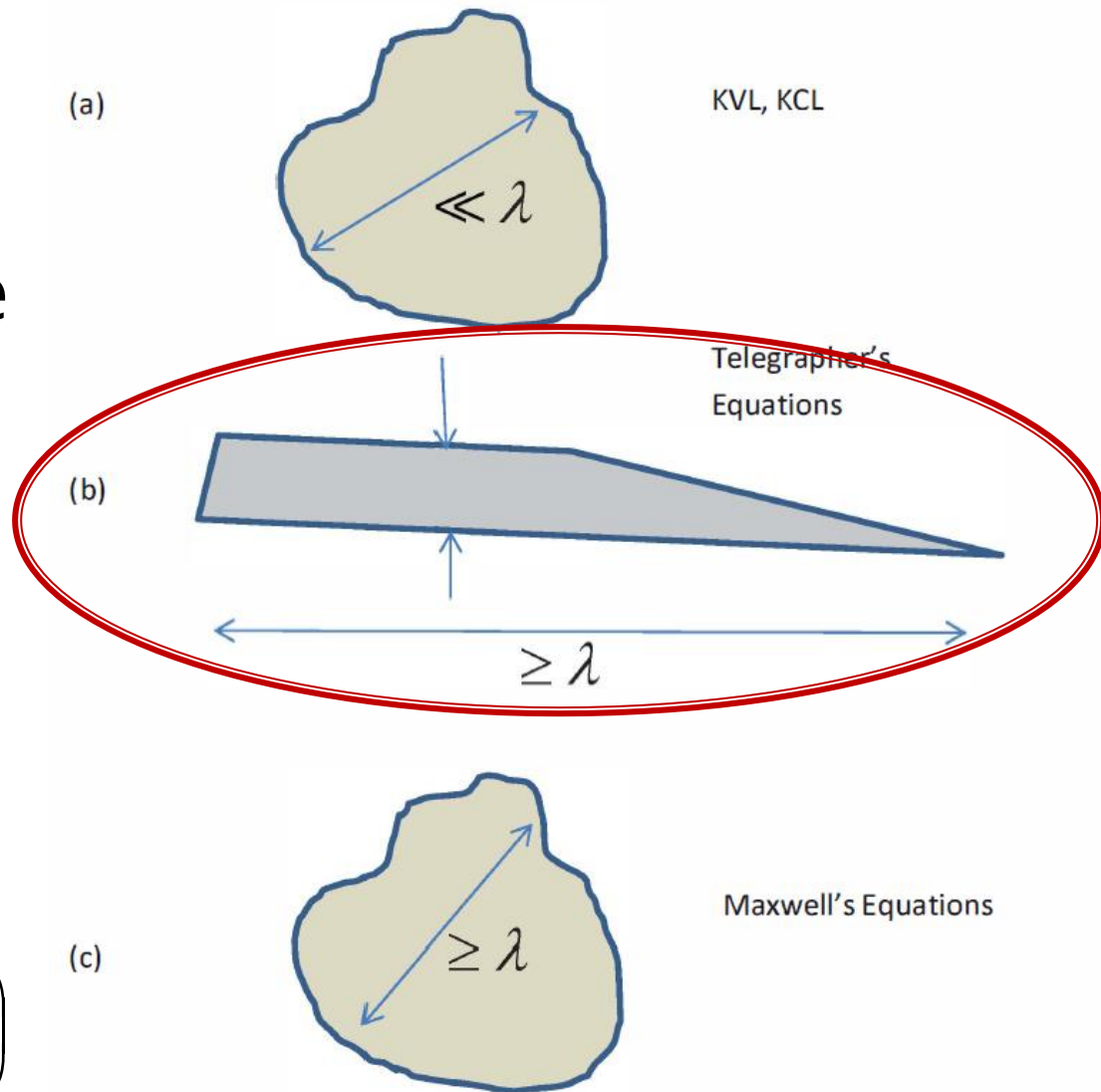
- **Linii de transmisie**
- **Adaptarea de impedanță**
- **Cuploare direcționale**
- **Divizoare de putere**
- **Amplificatoare de microunde**
- **Filtre de microunde**
- **Oscilatoare de microunde ?**

# Lungime electrica

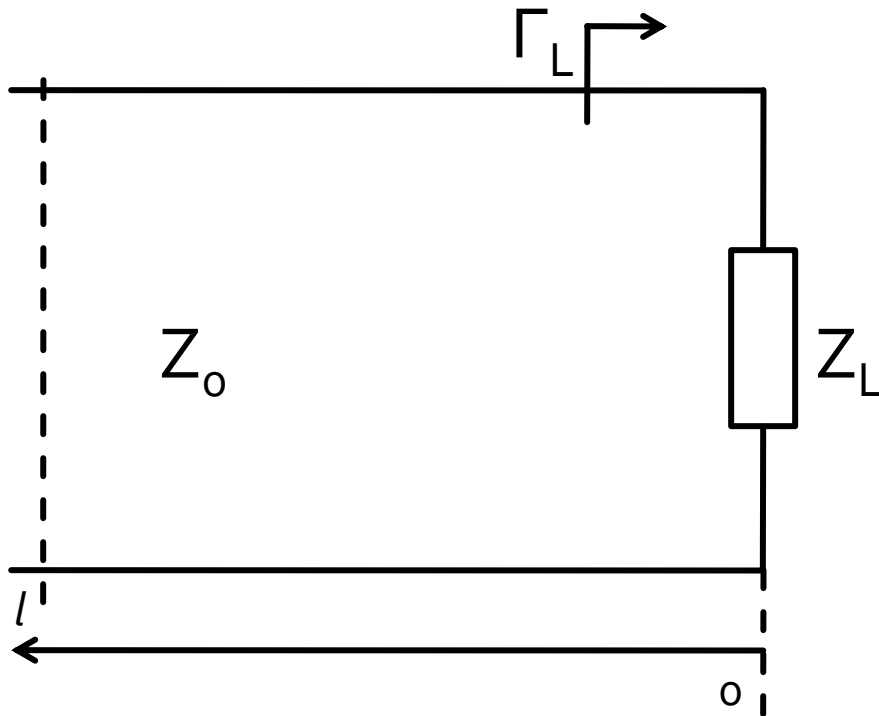
- Comportarea (descrierea) unui circuit depinde de lungimea sa electrica la frecventele de interes

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

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



# Linie fara pierderi



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

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

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

- 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

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

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

## ■ Puterea medie

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

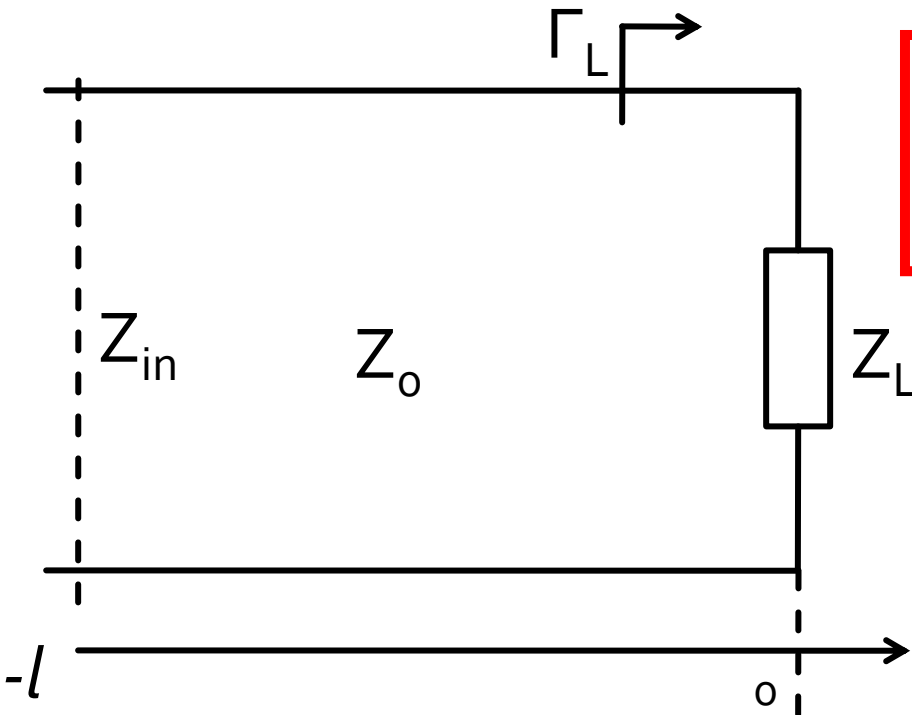
■ Puterea transmisa sarcinii = Puterea incidenta - Puterea "reflectata"

■ Return Loss [dB]

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

# Linie fara pierderi

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



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

# Cuprins

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

# Adaptare dpdv al puterii

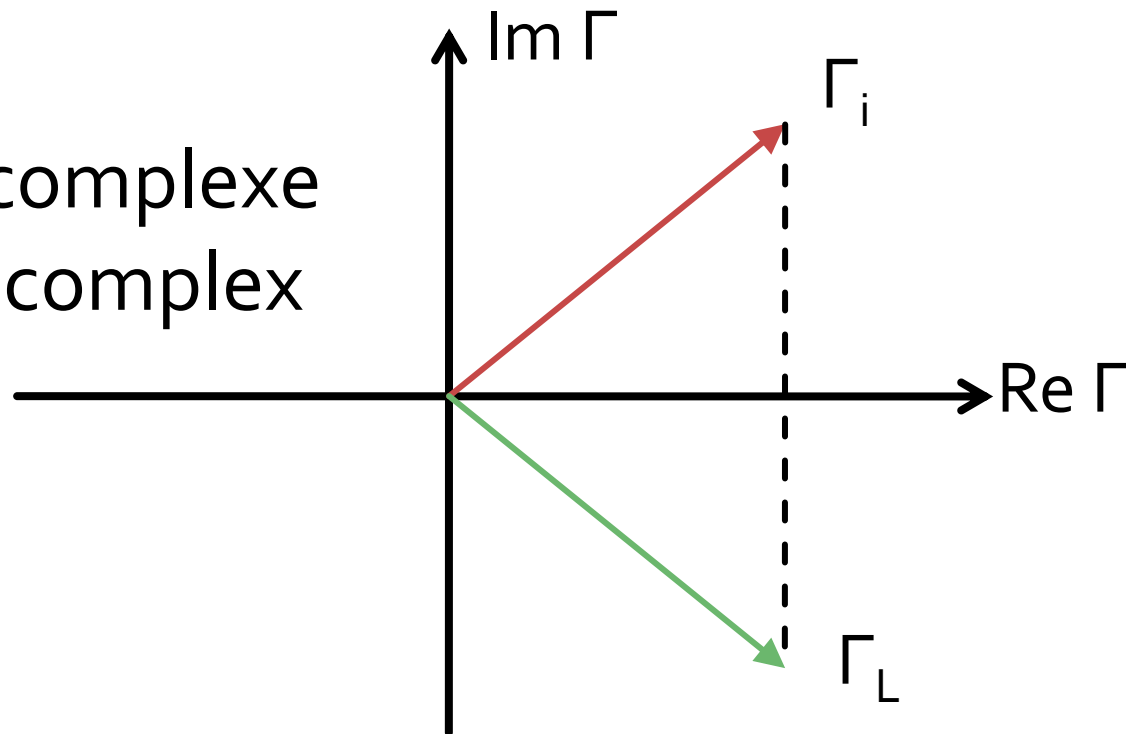
Daca se alege un  $Z_0$  real

$$Z_L = Z_i^*$$

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

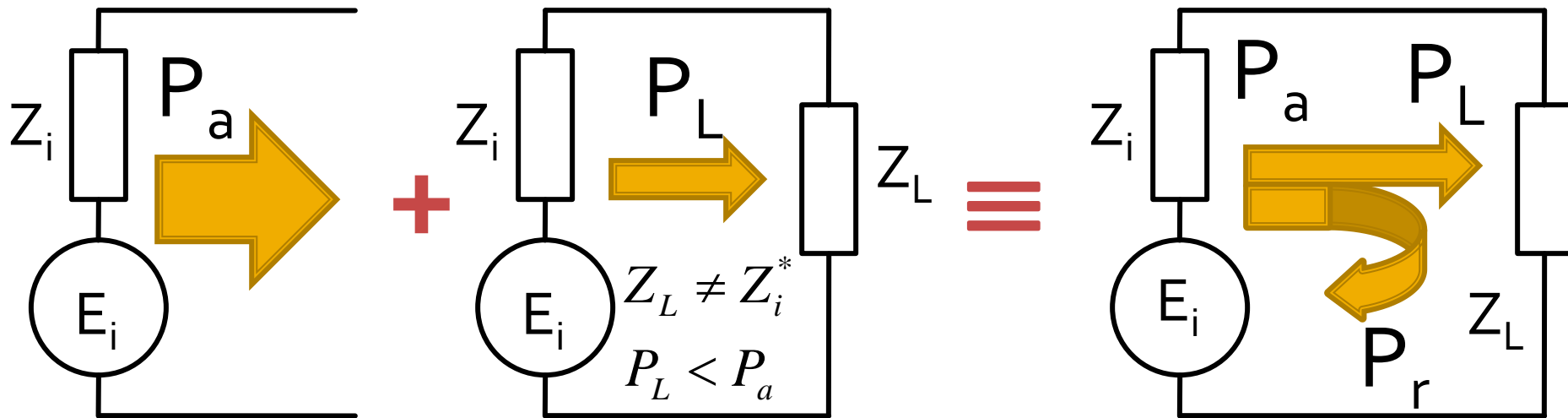
$$\Gamma_L = \Gamma_i^*$$

- numere complexe
- in planul complex



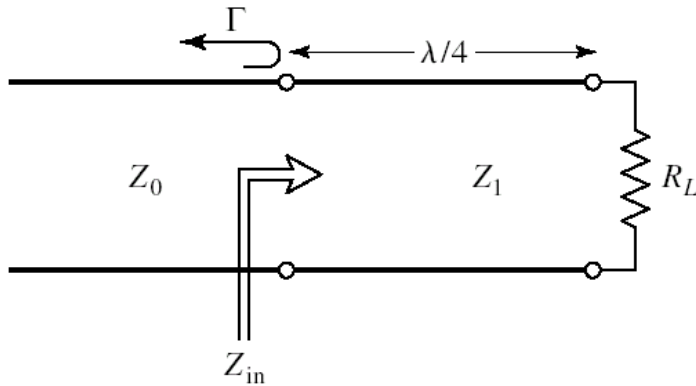


# Reflexie de putere / Model



- 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!**

# Transformatorul in sfert de lungime de unda



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

$$\beta \cdot l = \frac{2\pi}{\lambda} \cdot \frac{\lambda}{4} = \frac{\pi}{2}$$

$$Z_{in} = \frac{Z_1^2}{R_L}$$

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

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

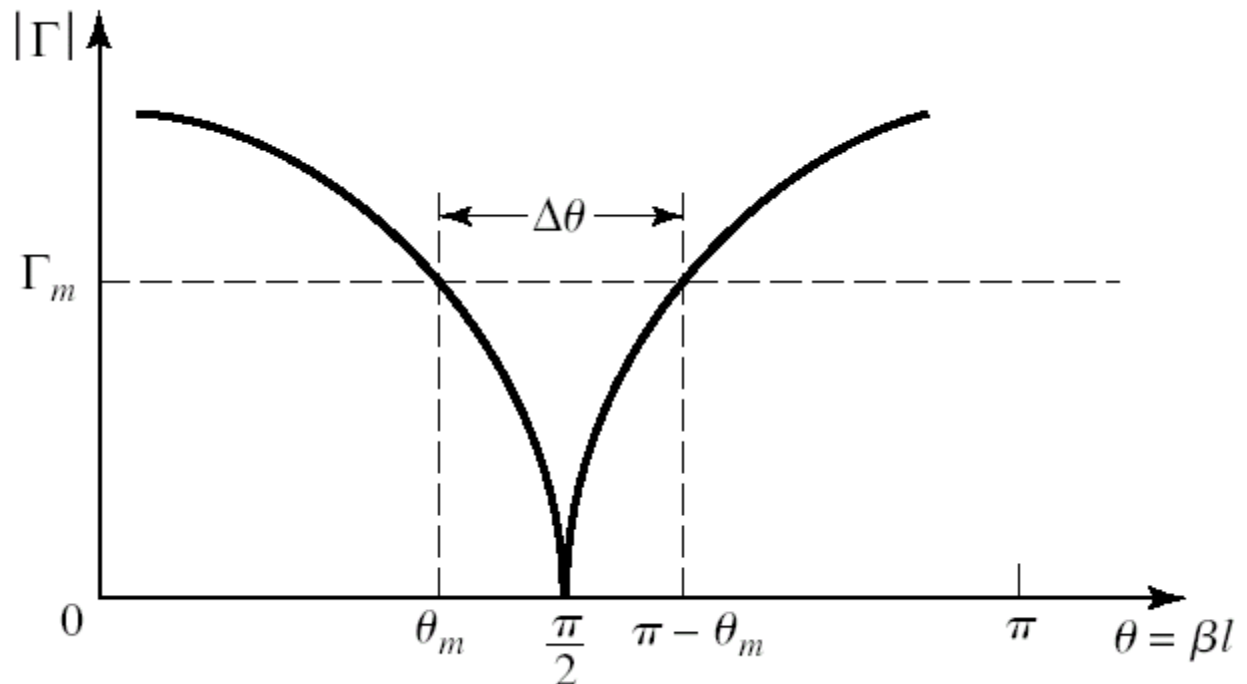
- Pe fider ( $Z_0$ ) avem doar unda progresiva
- Pe linia in sfert de lungime de unda ( $Z_1$ ) avem unda stationara

# Transformatorul in sfert de lungime de unda

- ne intereseaza frecventa in jurul frecventei la care facem adaptarea (banda ingusta)

$$f \approx f_0 \quad l \approx \frac{\lambda_0}{4} \quad \theta \approx \frac{\pi}{2} \quad \sec^2 \theta = 1 + \tan^2 \theta \gg 1$$

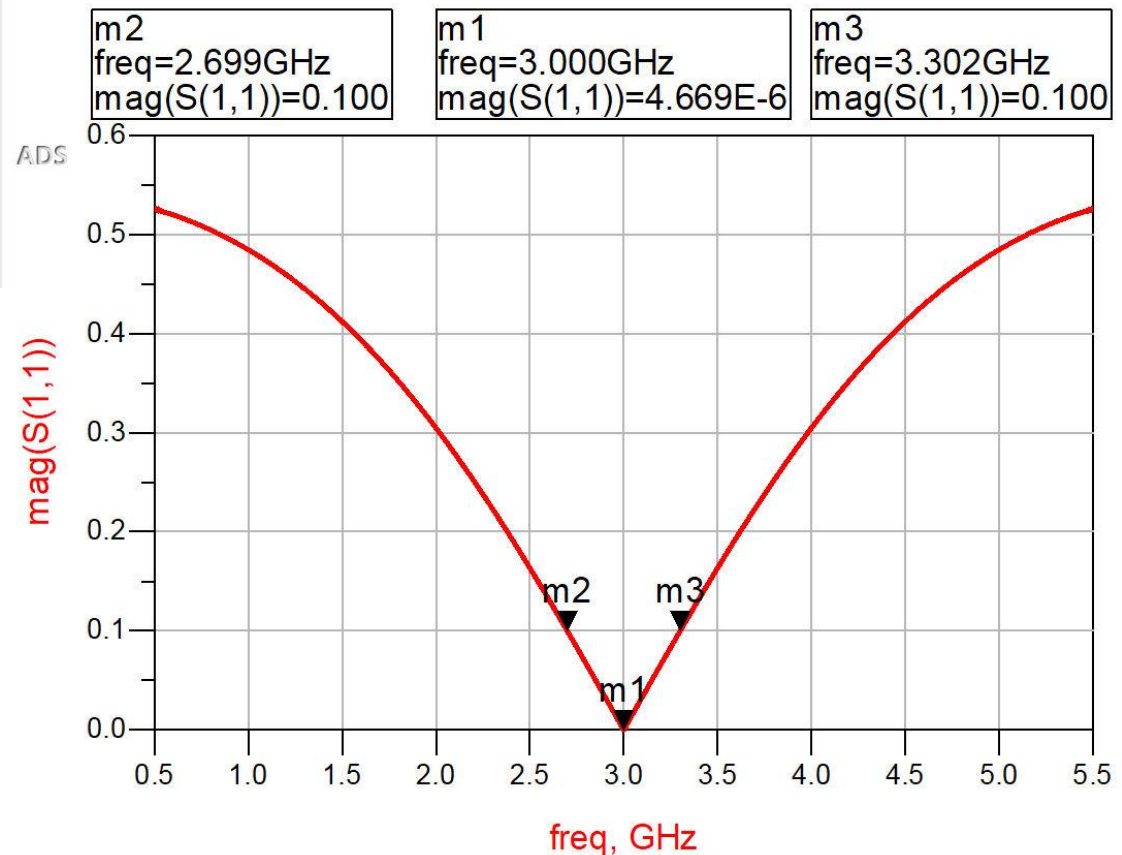
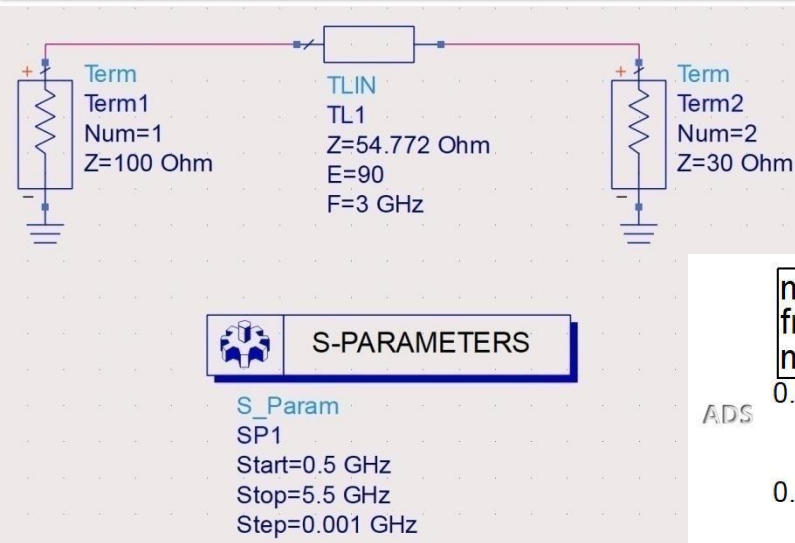
$$|\Gamma| \cong \frac{|Z_L - Z_0|}{2 \cdot \sqrt{Z_0 \cdot Z_L}} \cdot |\cos \theta|$$



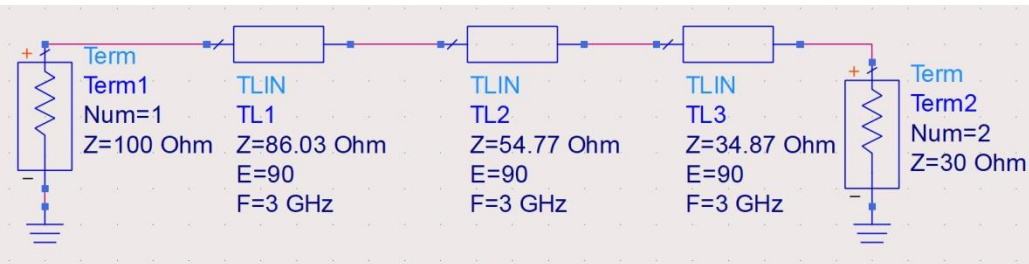
Lab. 1


# Adaptarea de impedanță

# Sfert de lungime de unda

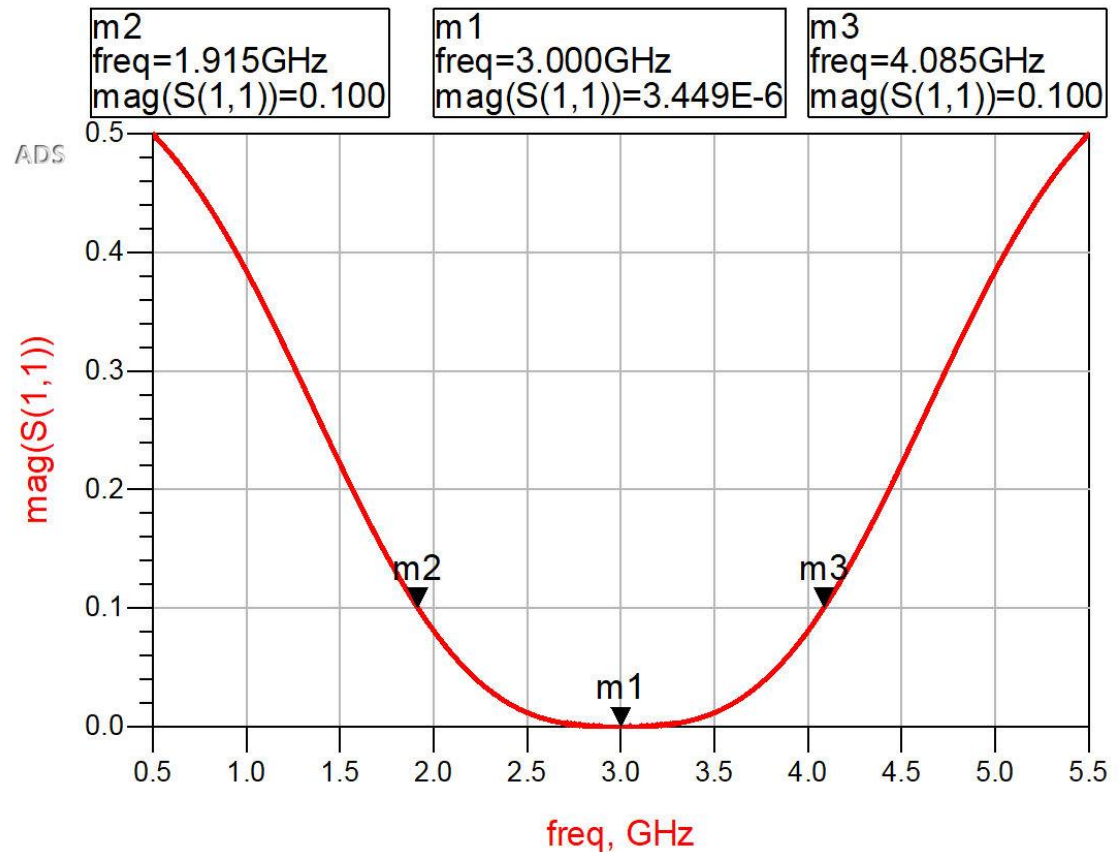


# Binomial

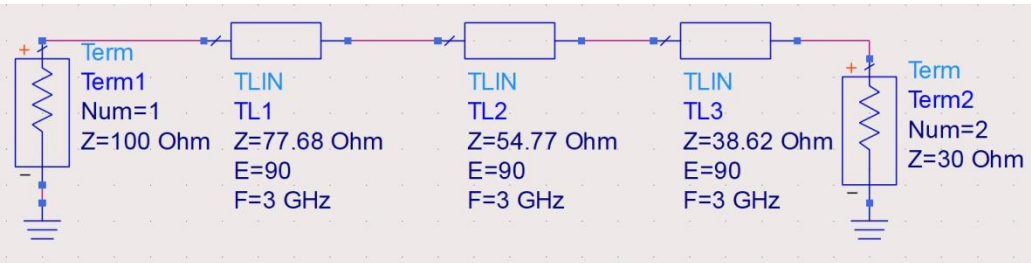



 **S-PARAMETERS**

S\_Param  
SP1  
Start=0.5 GHz  
Stop=5.5 GHz  
Step=0.001 GHz

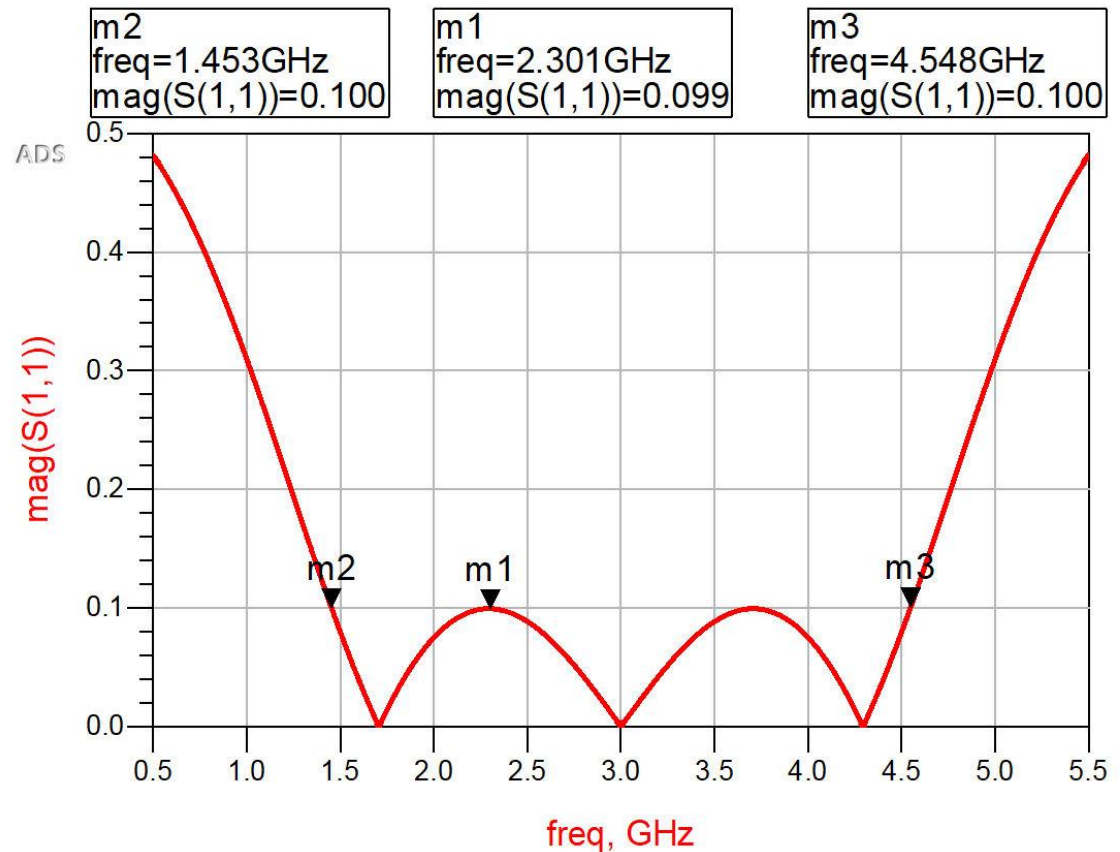


# Cebâşev



 **S-PARAMETERS**

S\_Param  
SP1  
Start=0.5 GHz  
Stop=5.5 GHz  
Step=0.001 GHz





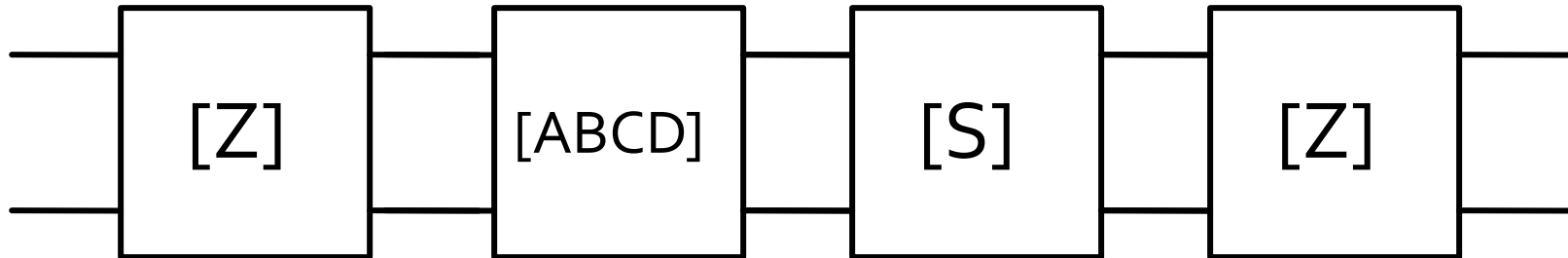
# **Analiza la nivel de rețea a circuitelor de microunde**

# Cuprins

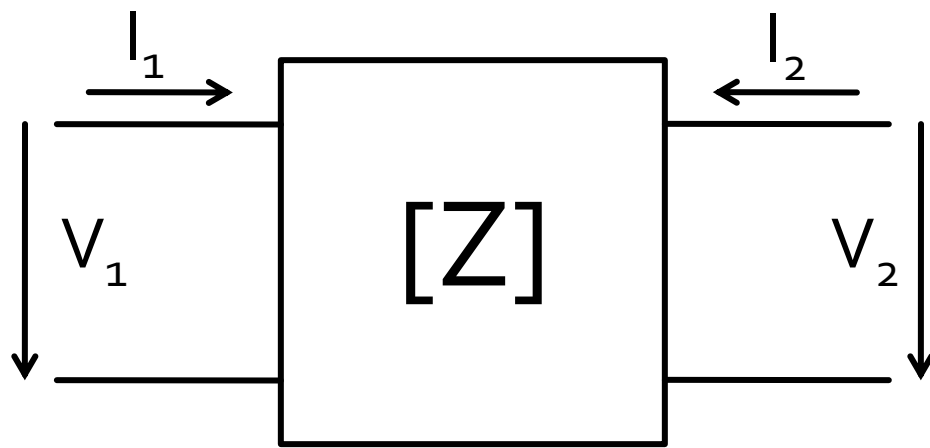
- Linii de transmisie
- Adaptarea de impedanță
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# Analiza la nivel de bloc

- 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



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

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

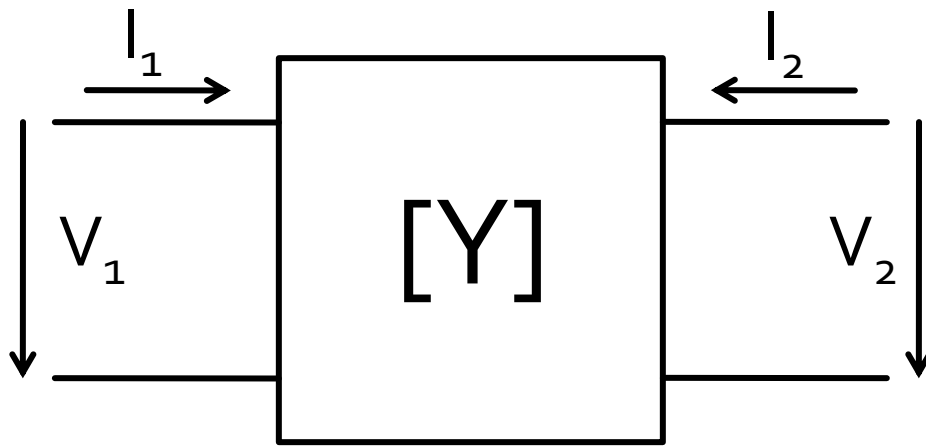
$$V_2 = Z_{21} \cdot I_1 + Z_{22} \cdot I_2$$

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

- $Z_{11}$  – 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



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

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

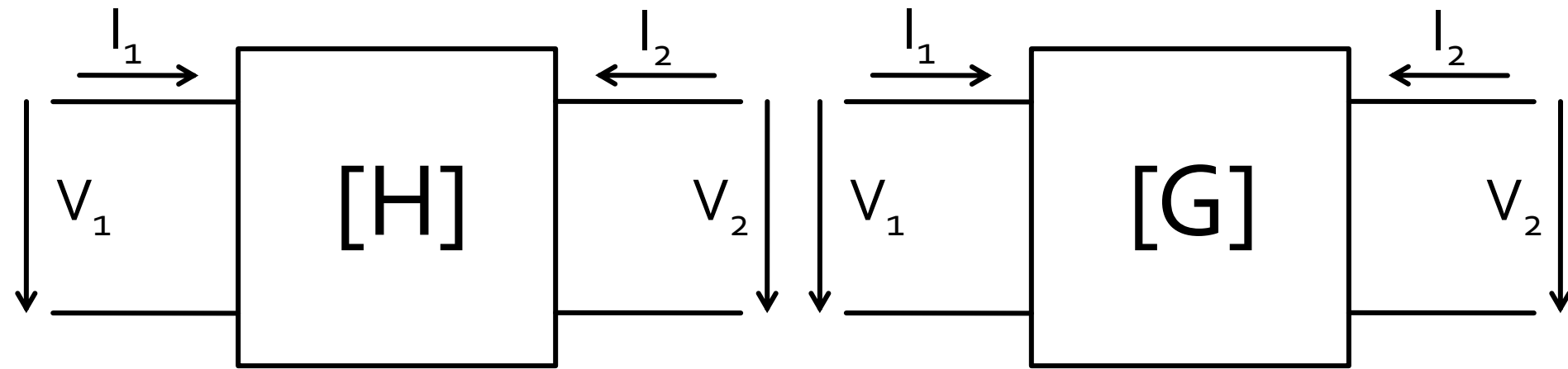
$$I_2 = Y_{21} \cdot V_1 + Y_{22} \cdot V_2$$

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

- $Y_{11}$  – 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 Emitter comun ( $\beta$ ,  $h_{22}$  este foarte mare)

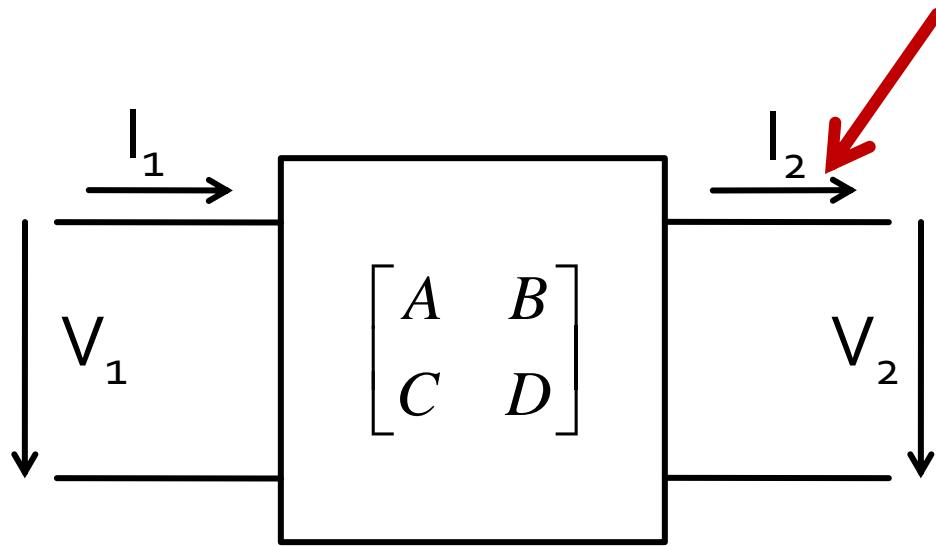
# Analiza la nivel de bloc

- 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



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

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

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

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

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

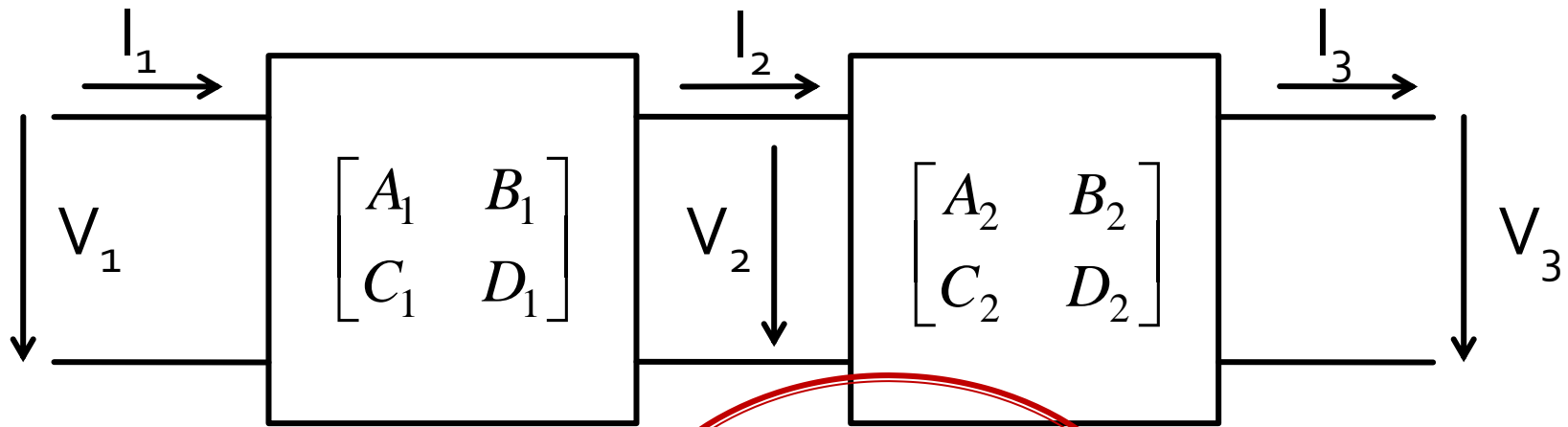
$$B = \left. \frac{V_1}{I_2} \right|_{V_2=0}$$

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

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

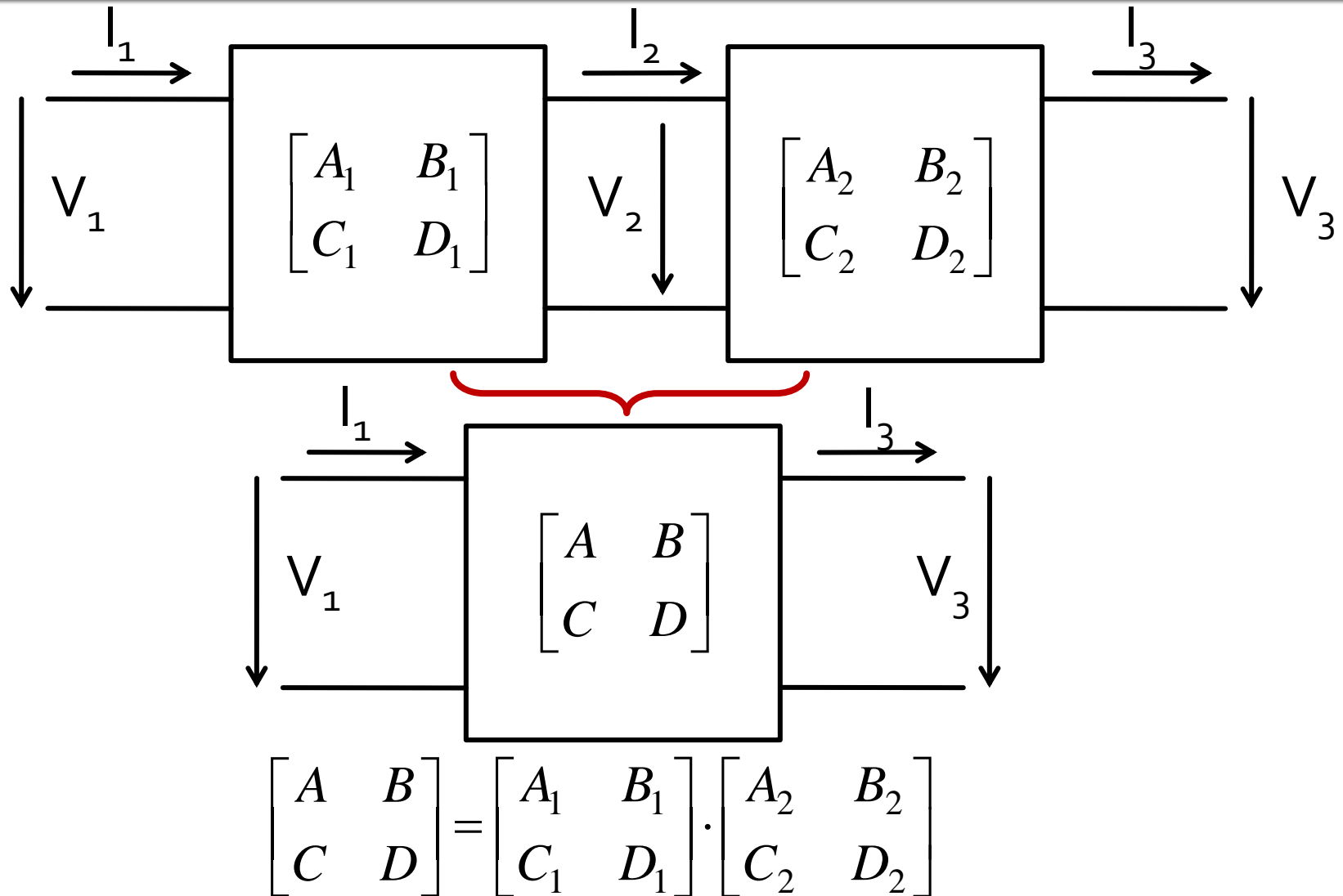
# Matricea ABCD – de transmisie

- 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

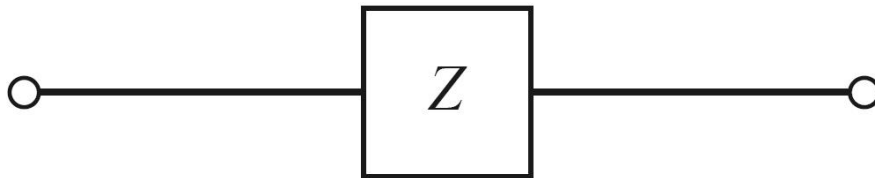


# Matricea ABCD – de transmisie

- 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



$$A = 1$$

$$B = Z$$

$$C = 0$$

$$D = 1$$



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

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

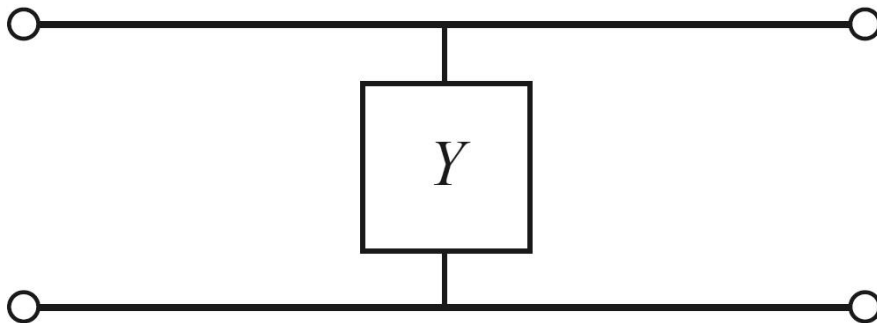
$$B = \left. \frac{V_1}{I_2} \right|_{V_2=0} = \frac{V_1}{V_1/Z} = Z$$

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

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

# Matrici ABCD

- Admitanta paralel



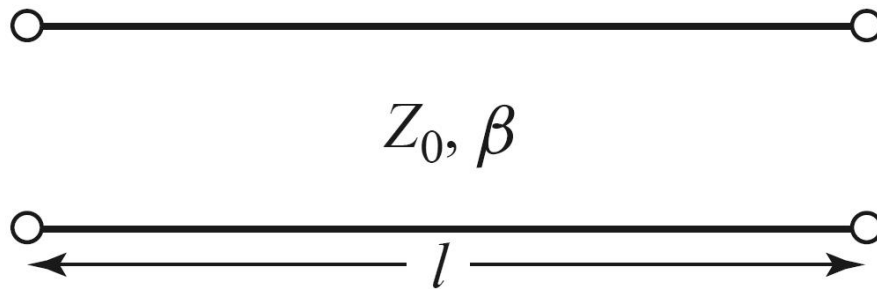
$$\begin{array}{ll} A = 1 & B = 0 \\ C = Y & D = 1 \end{array}$$

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

Verificare - tema!

# Matrici ABCD

- Sectiune de linie de transmisie



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

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

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

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

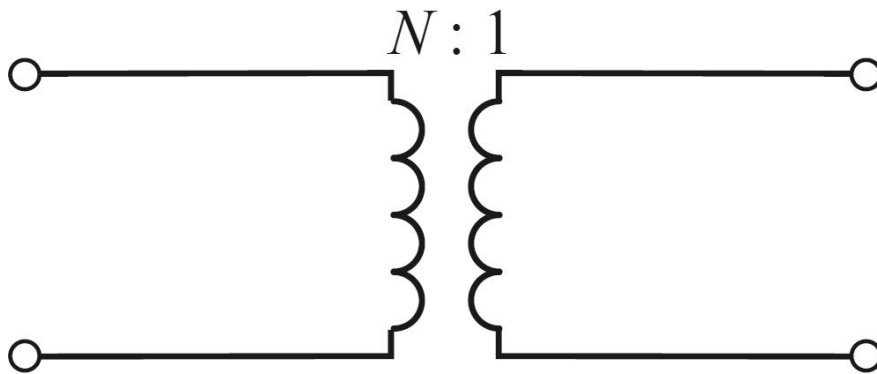
Verificare - tema!

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

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

# Matrici ABCD

- Transformator



$$A = N$$

$$B = 0$$

$$C = 0$$

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

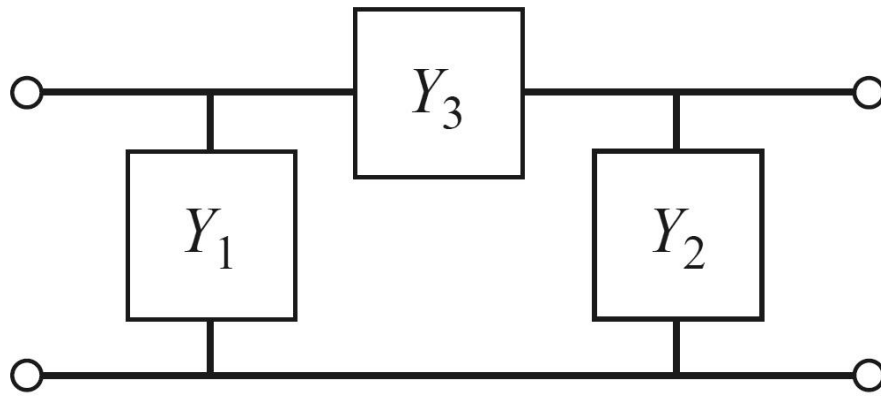
$$\begin{bmatrix} N & 0 \\ 0 & \frac{1}{N} \end{bmatrix}$$

Verificare - tema!



# Matrici ABCD

- diport  $\pi$



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

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

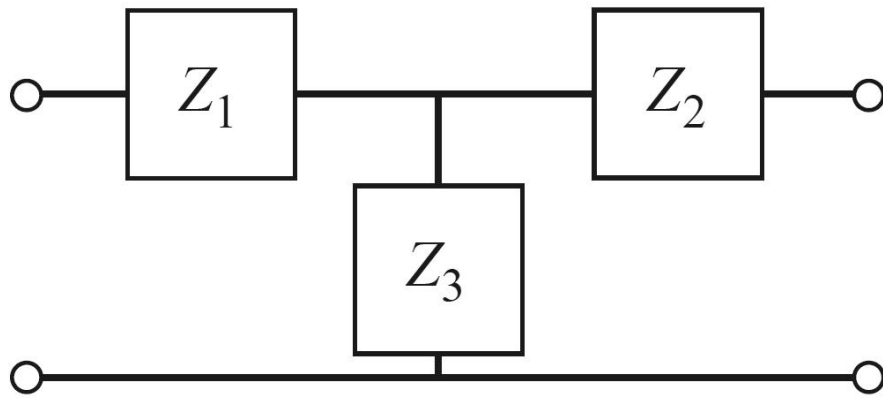
$$C = Y_1 + Y_2 + \frac{Y_1 \cdot Y_2}{Y_3}$$

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

Verificare - tema!

# Matrici ABCD

- diport T



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

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

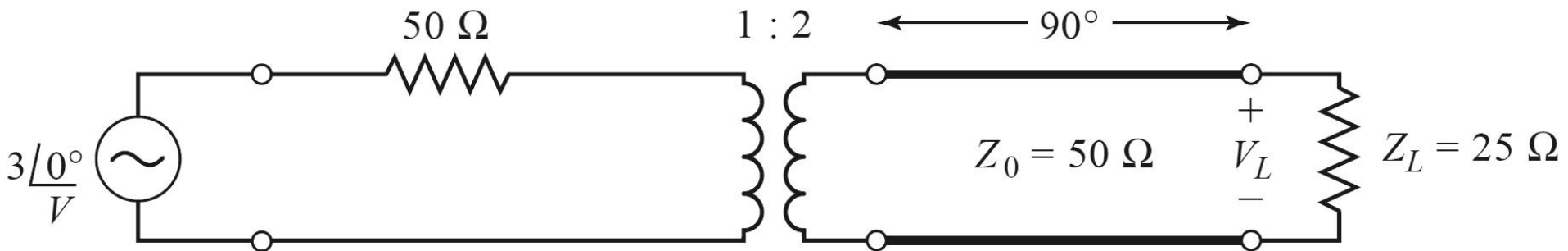
$$C = \frac{1}{Z_3}$$

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

Verificare - tema!

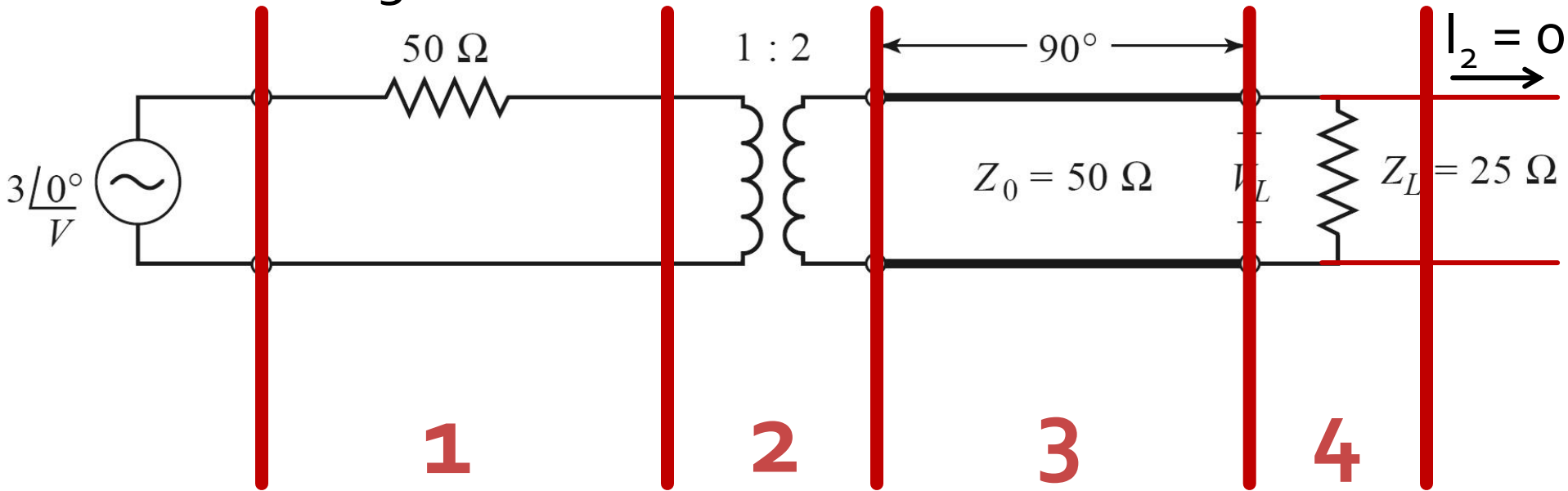
# Exemplu utilizare matrice ABCD

- Determinati tensiunea pe sarcina in circuitul urmator



# Exemplu utilizare matrice ABCD

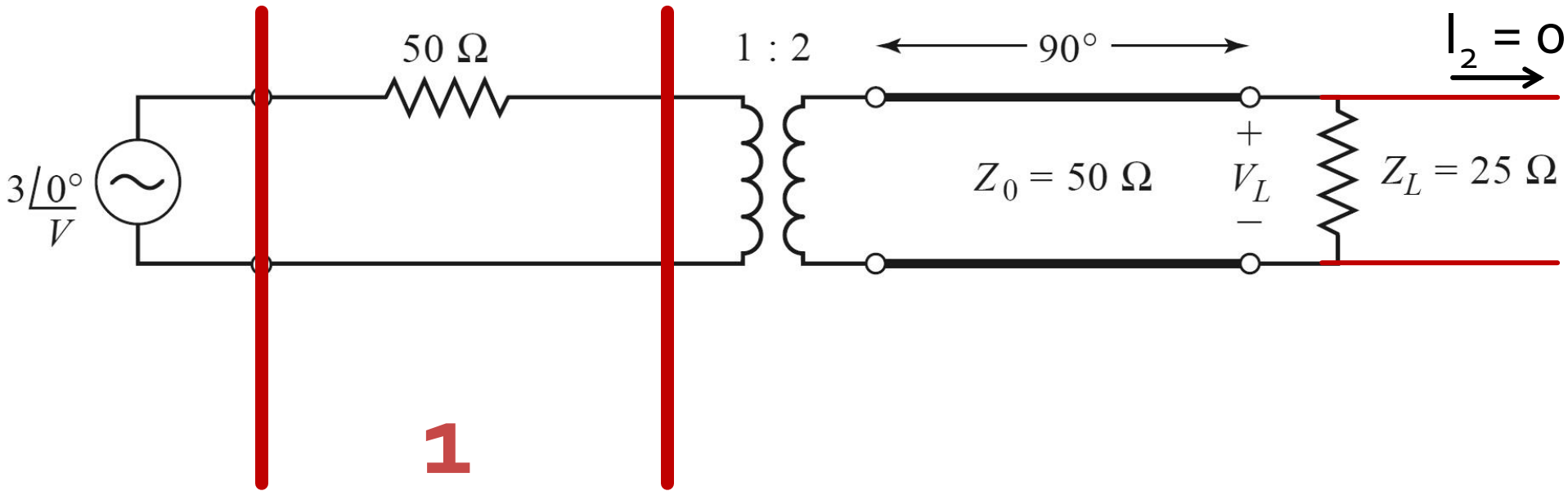
- Sectionare circuit in elemente simple
- Generatoarele raman in exterior
- Daca e necesar, se creaza porturi de intrare si iesire lasate in gol



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

# Exemplu utilizare matrice ABCD

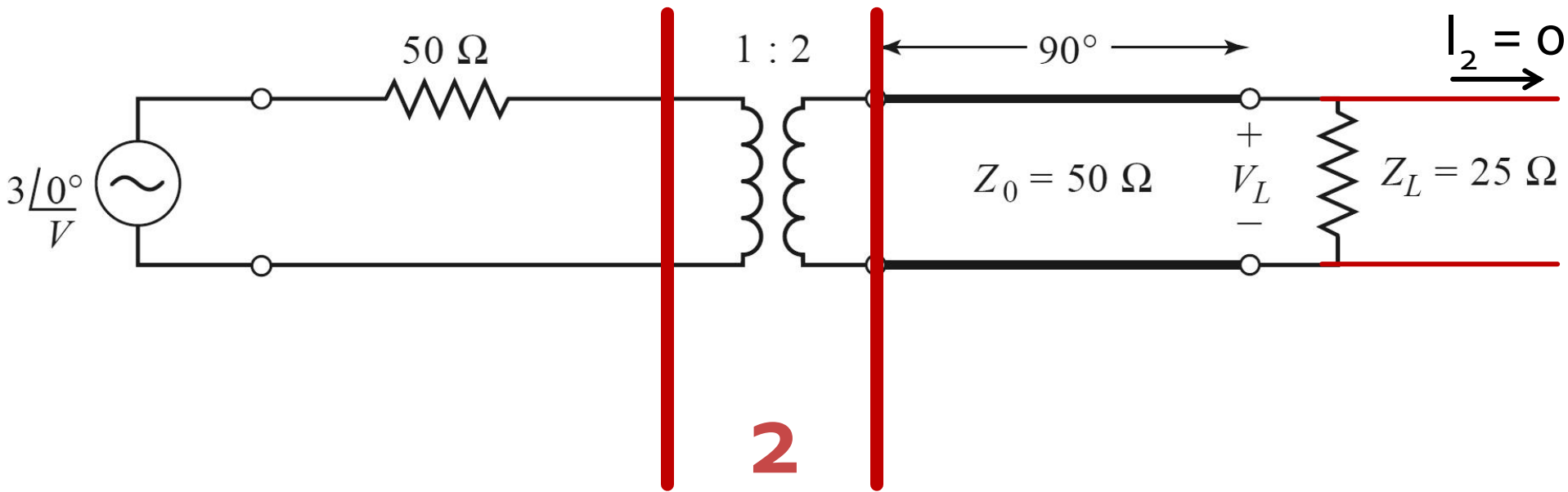
- $M_1$ , impedanta serie



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

# Exemplu utilizare matrice ABCD

- $M_2$ , transformator 1:2

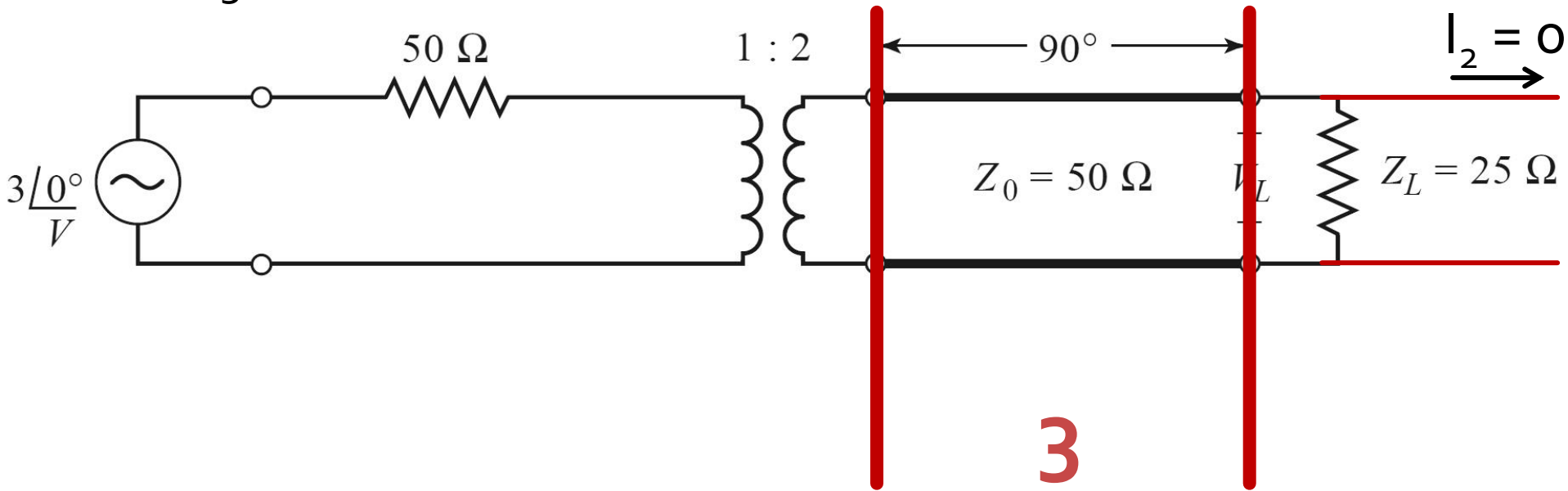


$$M_2 = \begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1/2 & 0 \\ 0 & 2 \end{bmatrix}$$

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

# Exemplu utilizare matrice ABCD

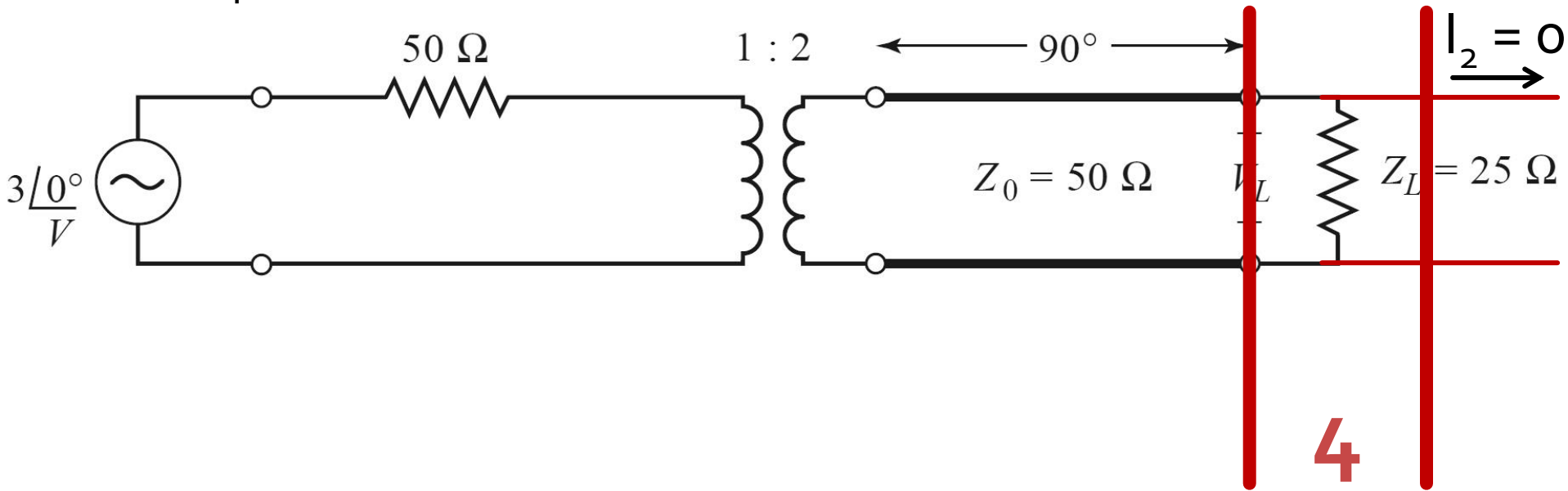
- $M_3$ , linie serie,  $E = 90^\circ$



$$M_3 = \begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 0 & 50 \cdot j \\ \frac{j}{50} & 0 \end{bmatrix} \quad \begin{bmatrix} \cos \beta \cdot l & j \cdot Z_0 \cdot \sin \beta \cdot l \\ j \cdot Y_0 \cdot \sin \beta \cdot l & \cos \beta \cdot l \end{bmatrix}$$

# Exemplu utilizare matrice ABCD

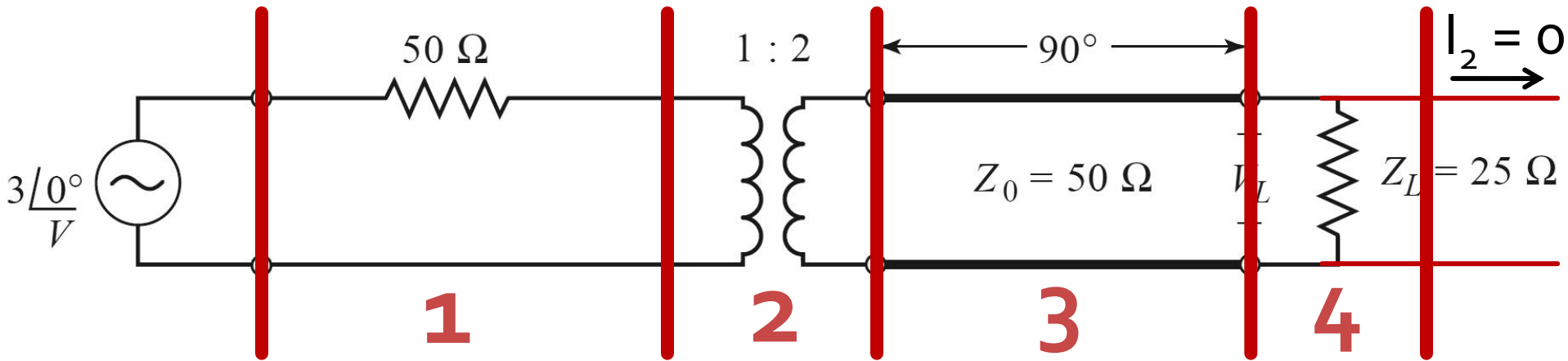
- $M_4$ , impedanta/admitanta paralel



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



# Exemplu utilizare matrice ABCD

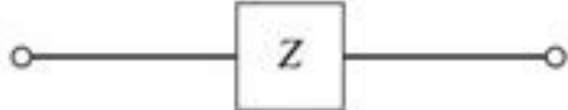
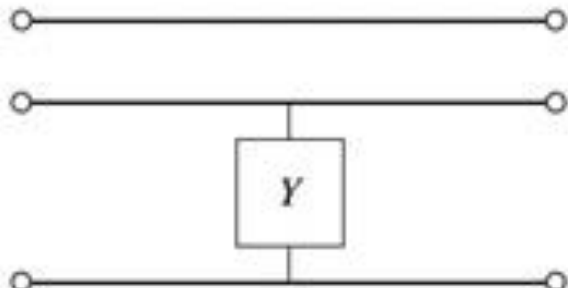
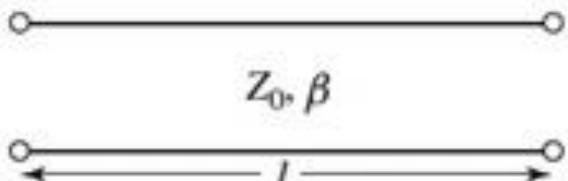


$$\begin{bmatrix} \textcircled{A} & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 50 \\ 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} \frac{1}{2} & 0 \\ 0 & 2 \end{bmatrix} \cdot \begin{bmatrix} 0 & 50 \cdot j \\ \frac{j}{50} & 0 \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 \\ \frac{1}{25} & 1 \end{bmatrix}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

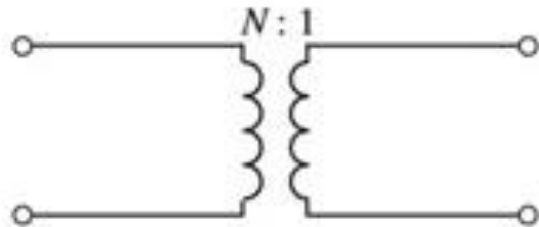
$$V_L = \frac{V}{\textcircled{A}} = \frac{3\angle 0^\circ}{\textcircled{3 \cdot j}} = 1\angle -90^\circ$$

# 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

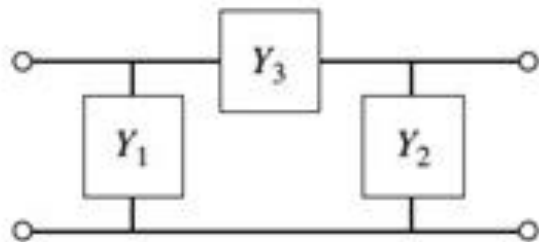


$$A = N$$

$$C = 0$$

$$B = 0$$

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

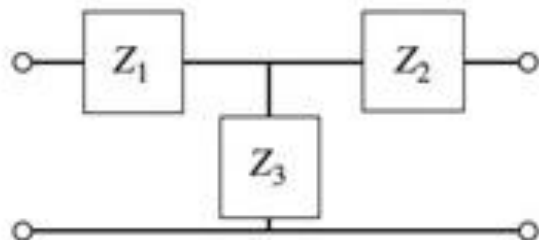


$$A = 1 + \frac{Y_2}{Y_3}$$

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

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

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



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

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

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

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

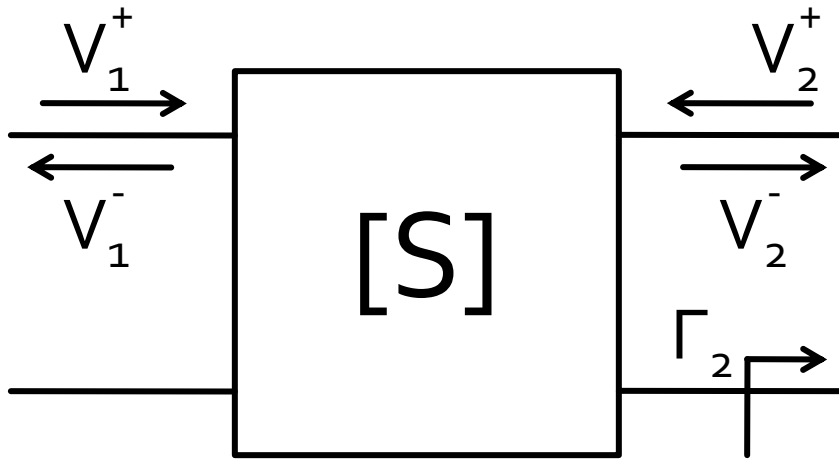
Table 4.1

Matricea S

# Analiza la nivel de rețea a circuitelor de microunde

# Matricea S (repartitie)

- Scattering parameters



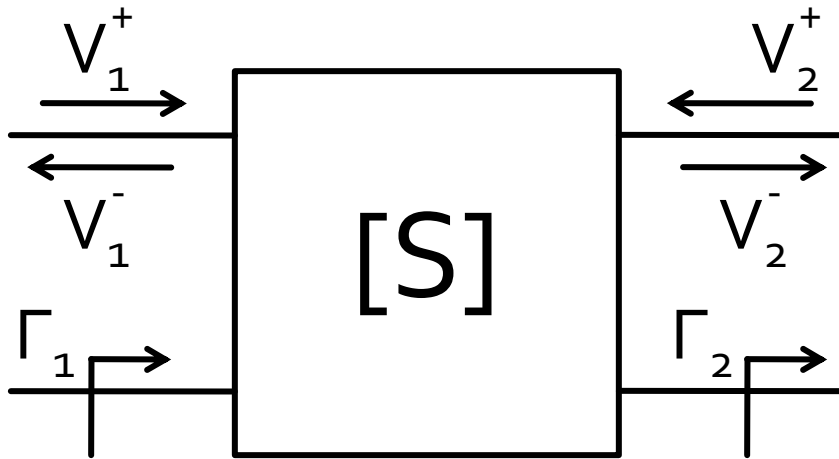
$$\begin{bmatrix} V_1^- \\ V_2^- \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} V_1^+ \\ V_2^+ \end{bmatrix}$$

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

- $V_2^+ = 0$  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** si portul **2** este terminat pe impedanta care realizeaza adaptarea

# Matricea S (repartitie)

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

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

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

- $S_{ii}$  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 3

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

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

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

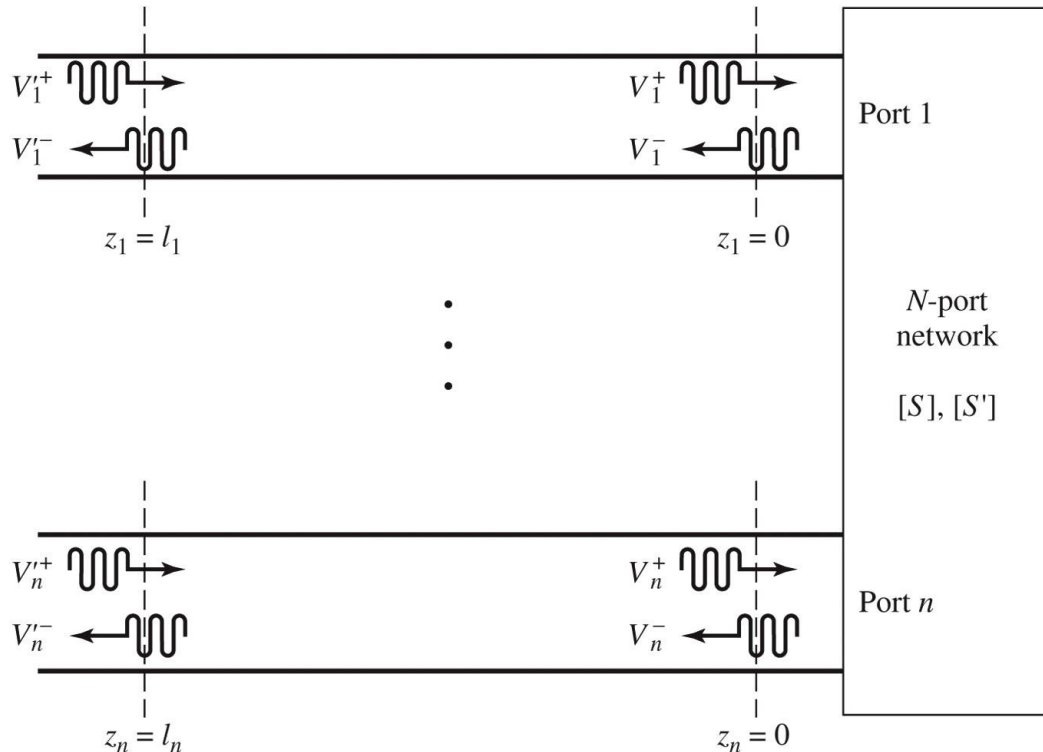
$$[Z_0]^{-1} \cdot [Z] \cdot [V^+] - [Z_0]^{-1} \cdot [Z] \cdot [V^-] = [V^+] + [V^-] \quad ([Z] - [Z_0]) \cdot [V^+] = ([Z] + [Z_0]) \cdot [V^-]$$

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

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



# Deplasare a planului de referinta



- De-Embedding
- Decapsulare

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:

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

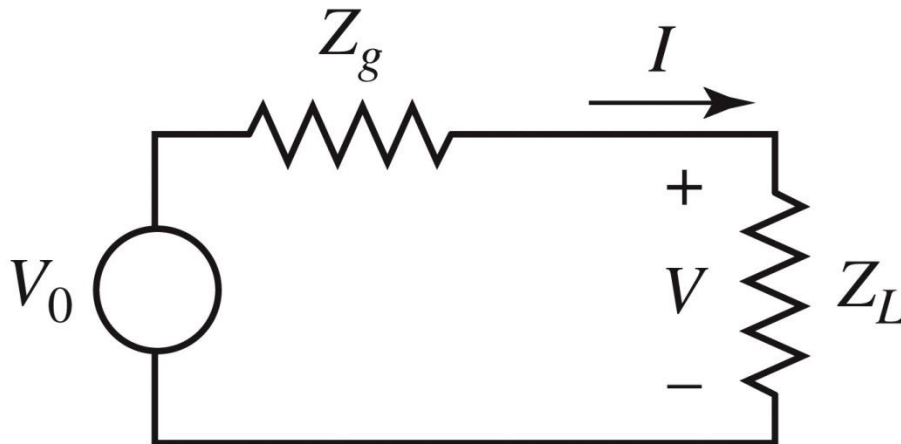
$$P_L = \frac{1}{2 \cdot Z_0} \cdot \left(|V_0^+|^2 - |V_0^-|^2\right)$$

# Matricea S generalizata

- Puterea oferita sarcinii la iesirea din linie:

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

- Restrictii
  - Rezultat valid pentru  $Z_0$  real
  - Necesita prezenta unei linii cu impedanta caracteristica  $Z_0$  intre generator si sarcina



# Matricea S generalizata

- Definim undele de putere

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

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

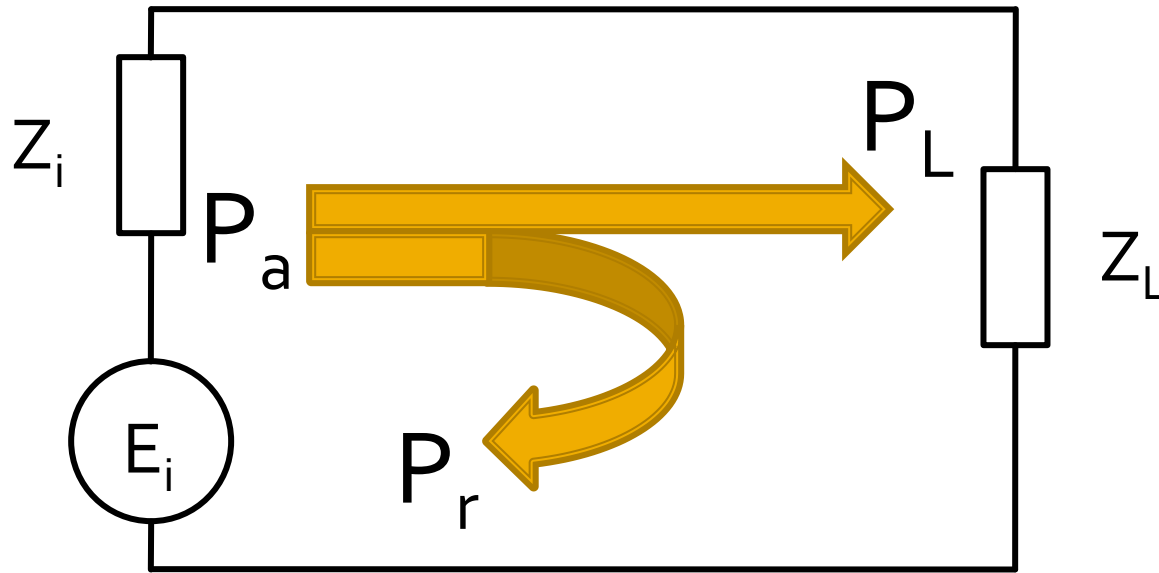
$Z_R = R_R + j \cdot X_R$   
O impedanta de referinta  
oarecare, complexa

- 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 / C4



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

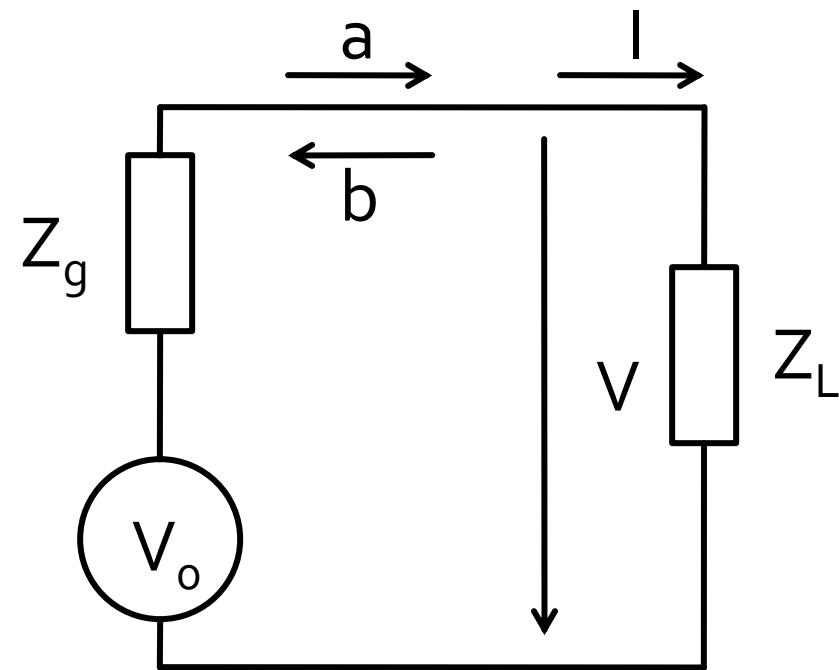
$$P_L = \frac{R_L \cdot |E_i|^2}{(R_i + R_L)^2 + (X_i + X_L)^2}$$

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

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

- coeficient de reflexie in putere

# Unde de putere



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

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

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

$$P_L = \frac{1}{2} \cdot |a|^2 - \frac{1}{2} \cdot |b|^2 \quad \underbrace{(z - z^*)}_{\text{Im}} \quad \boxed{\forall Z_R \in \mathbb{C}}$$

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

# 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 C4

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

- Reflexie in putere C5

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

# 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

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

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

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

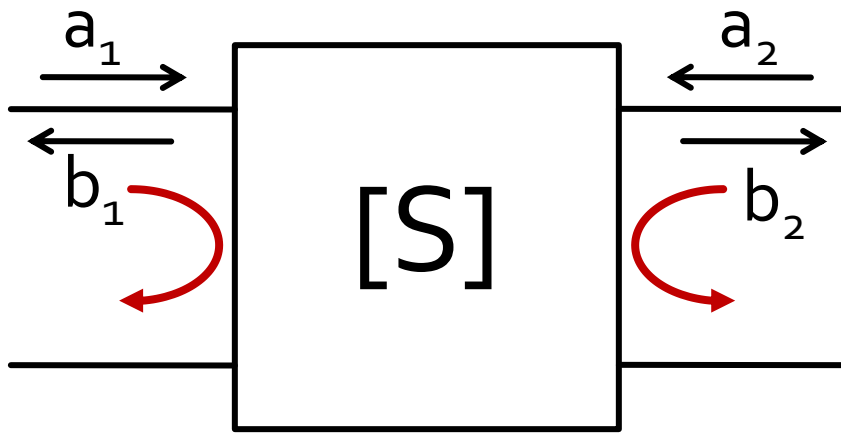
- tipic

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

$$R_0 = 50\Omega$$

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

# Matricea S (repartitie)

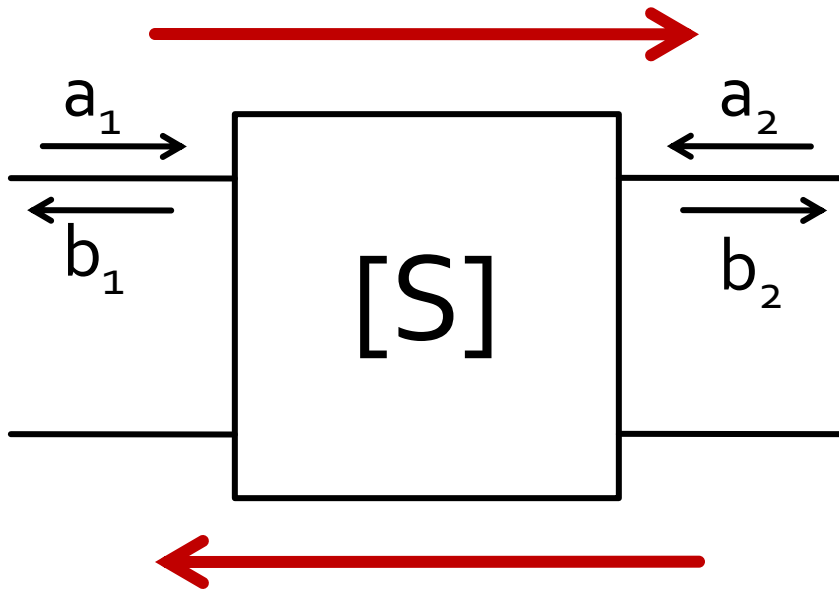


$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

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

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

# Matricea S (repartitie)

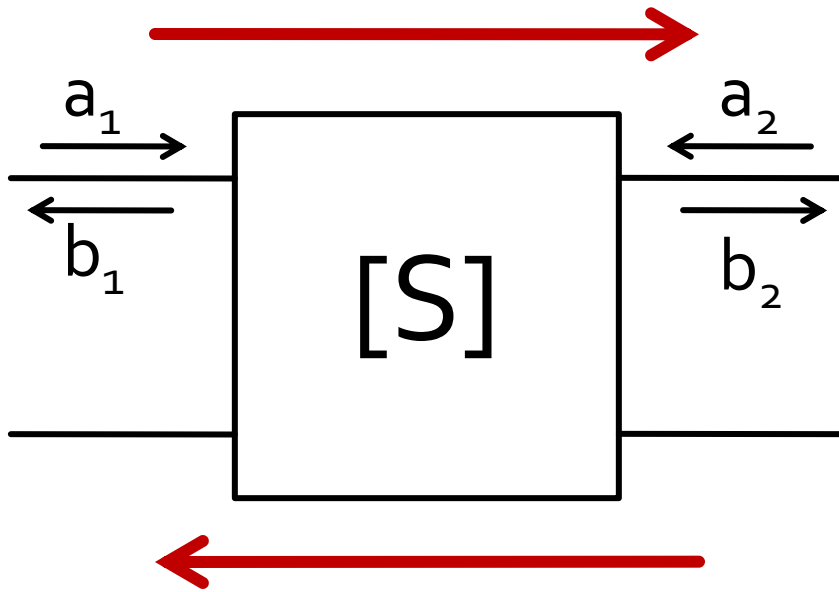


$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

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

- $S_{21}$  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

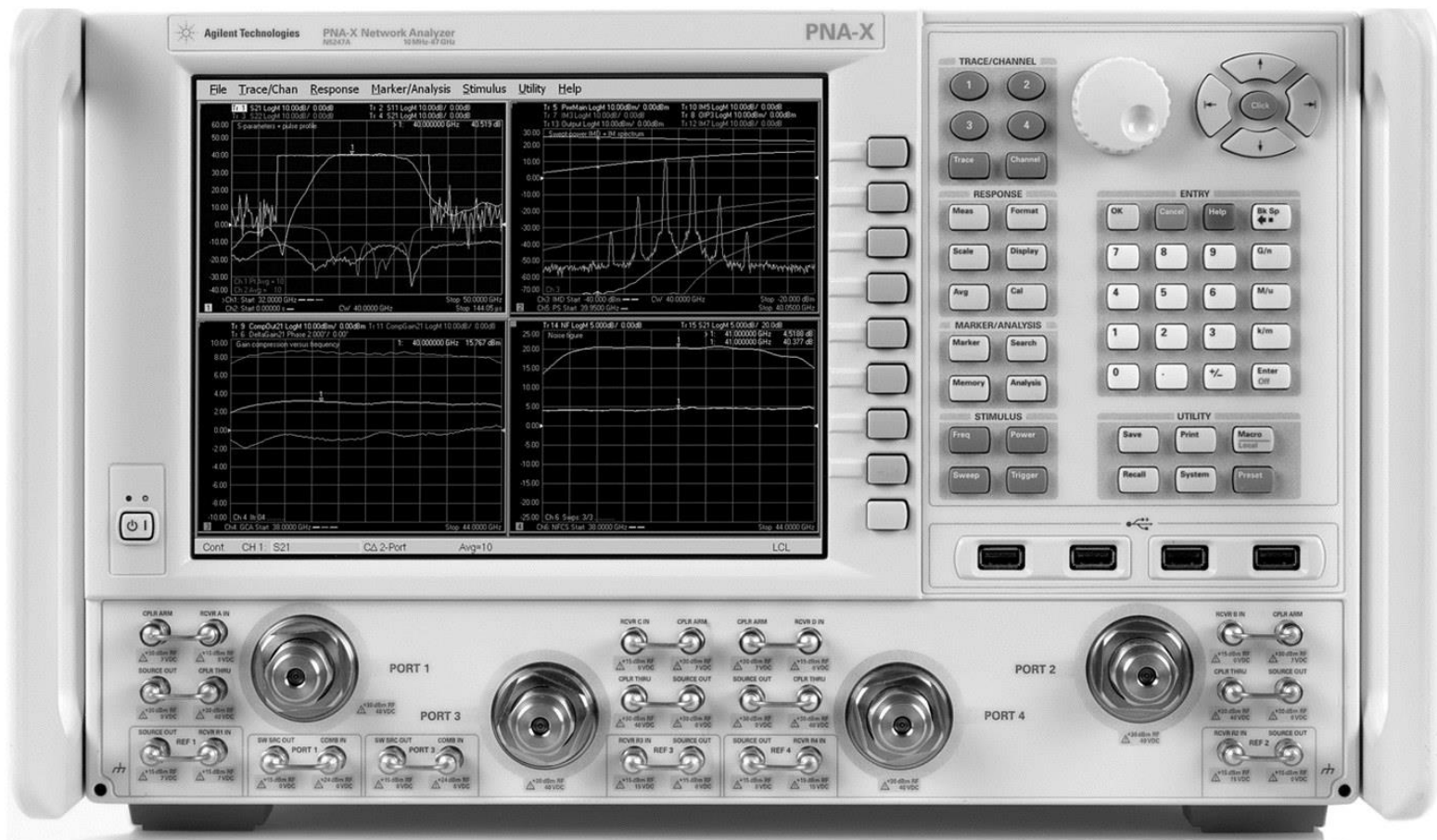


Figure 4.7  
Courtesy of Agilent Technologies

# Legatura dintre parametrii S si parametrii ABCD

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

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

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

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

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

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

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

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

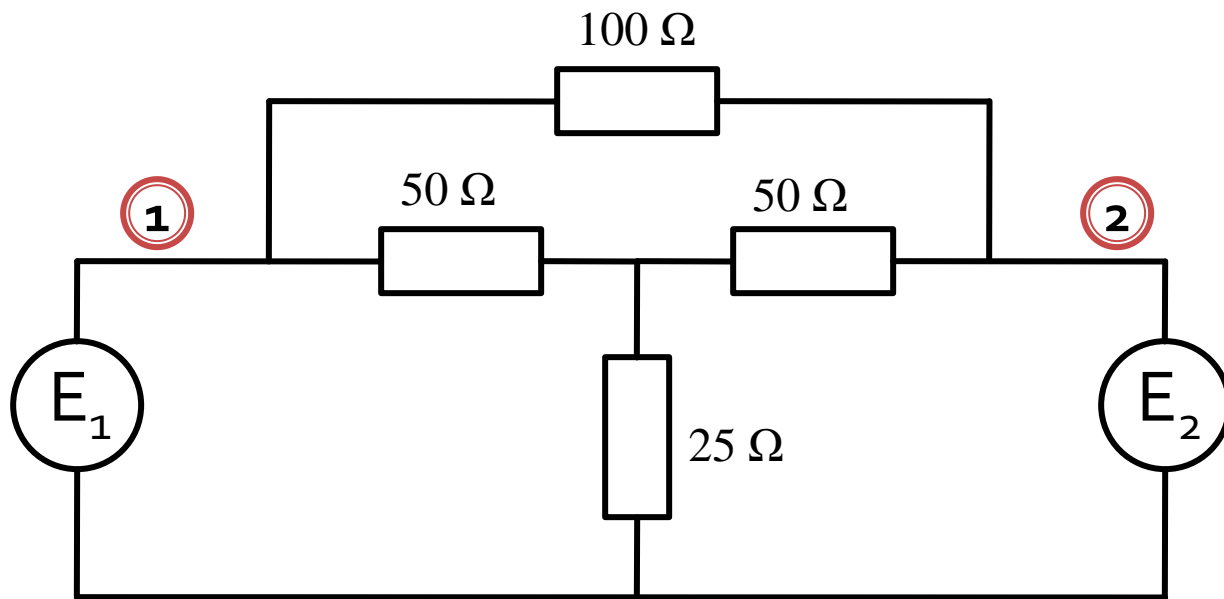
$$S_{22} = \frac{-AZ_{02} + B - CZ_{01}Z_{02} + DZ_{01}}{AZ_{02} + B + CZ_{01}Z_{02} + DZ_{01}}$$



# Analiza pe mod par/impar

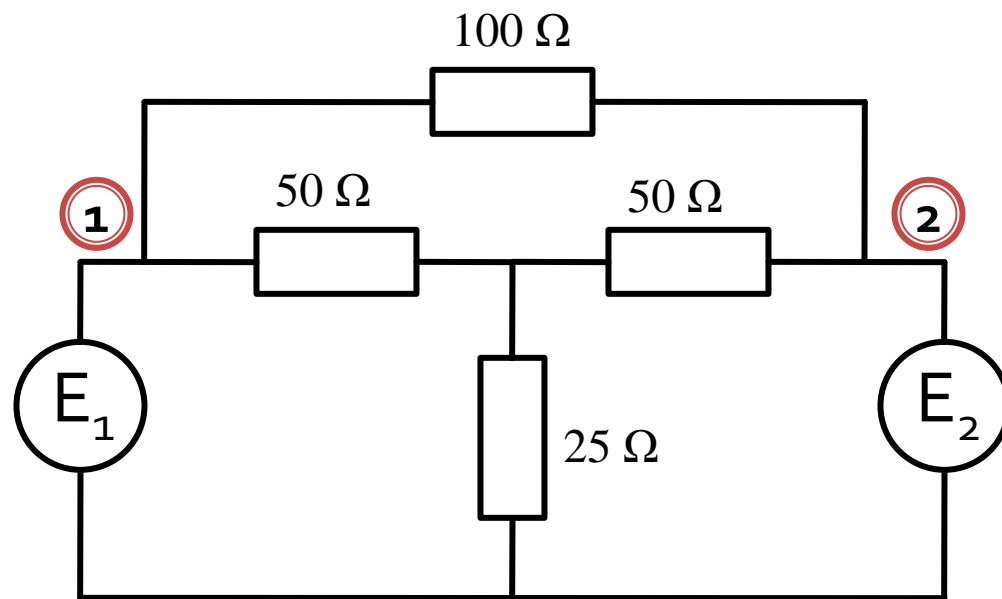
# Analiza pe mod par/impar (even/odd)

- utila/necesara pentru multiporti
- exemplu, rezistori, circuit cu 2 porturi



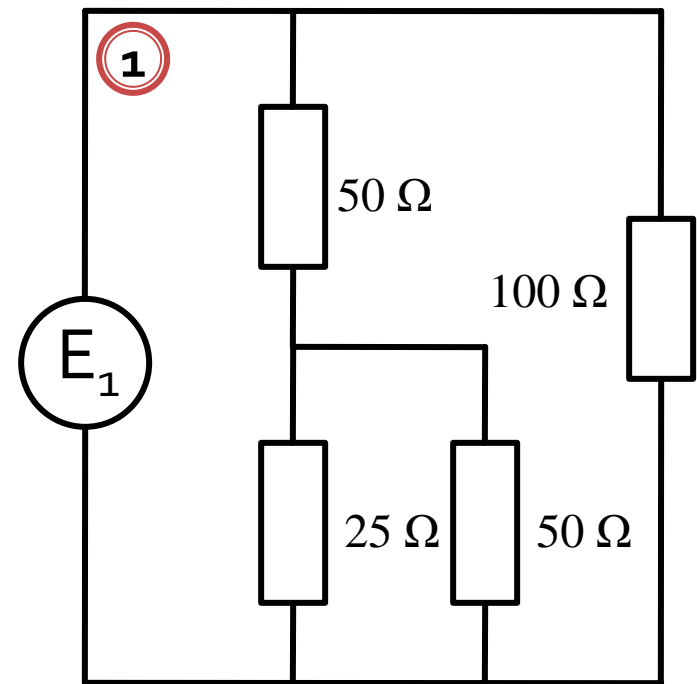
# Analiza pe mod par/impar (even/odd)

- presupunem ca doresc  $Y_{11}$   $Y_{11} = \frac{I_1}{V_1} \Big|_{V_2=0}$
- $E_2 = 0$



$$R_{ech} = 100\Omega \parallel (50\Omega + 25\Omega \parallel 50\Omega) =$$

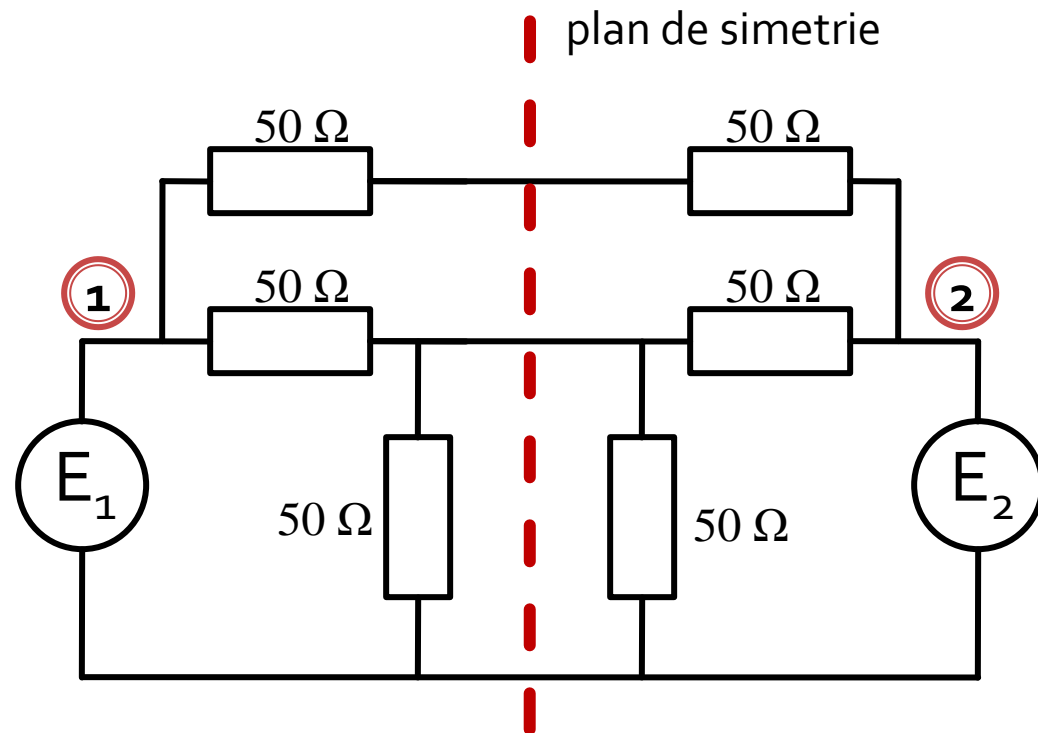
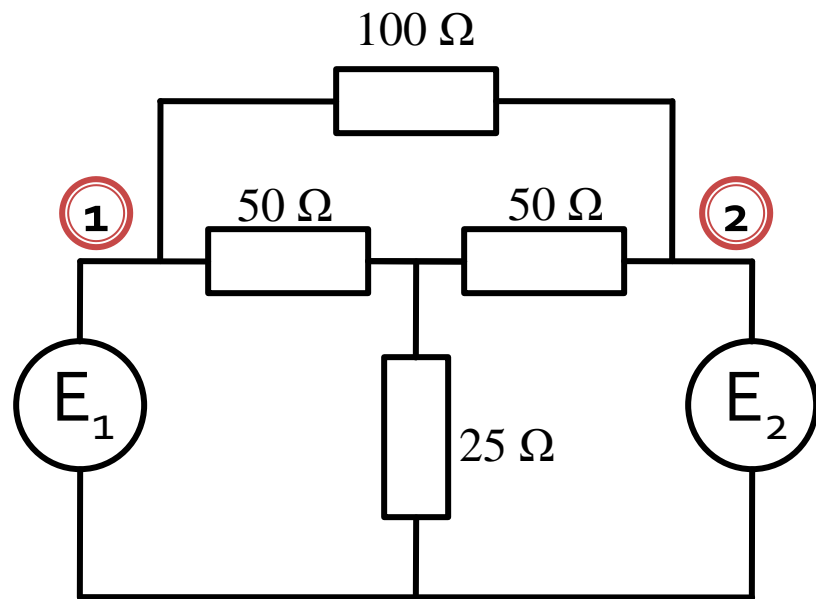
$$= 100\Omega \parallel (50\Omega + 16.67\Omega) = 100\Omega \parallel 66.67\Omega = 40\Omega$$



$$Y_{11} = \frac{I_1}{V_1} \Big|_{V_2=0} = 0.025S$$

# Analiza pe mod par/impar (even/odd)

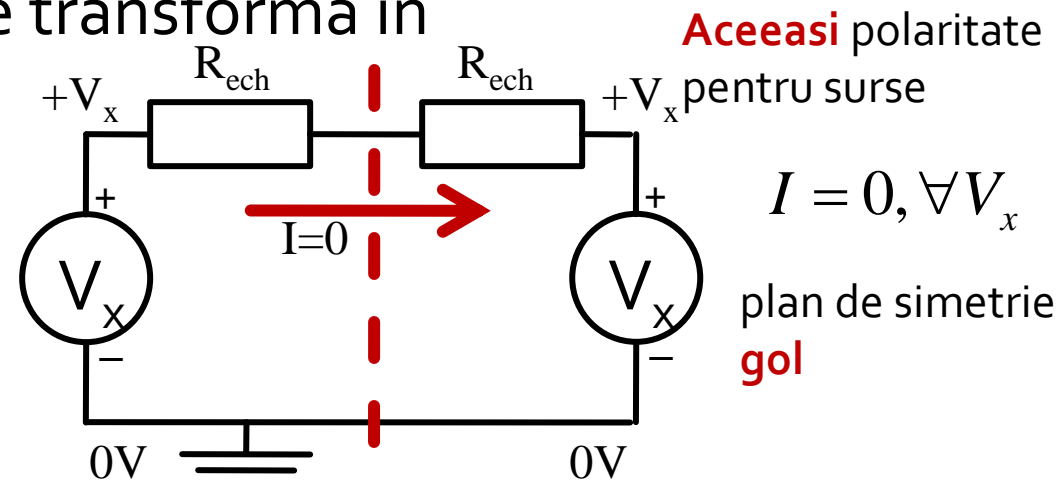
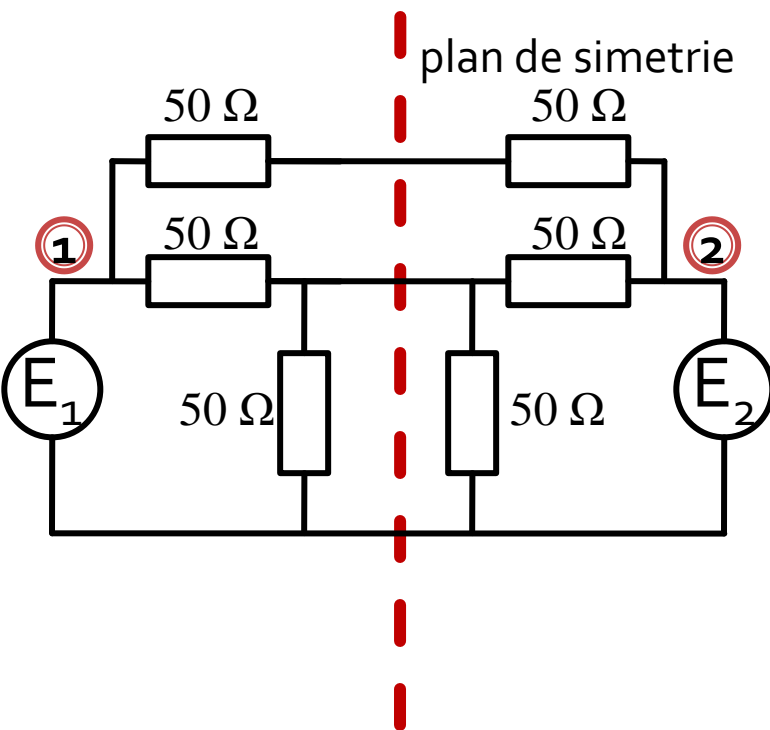
- analiza pe mod par/impar beneficiaza de existenta in circuit a unor plane de simetrie
  - initiale
  - create



# Analiza pe mod par/impar (even/odd)

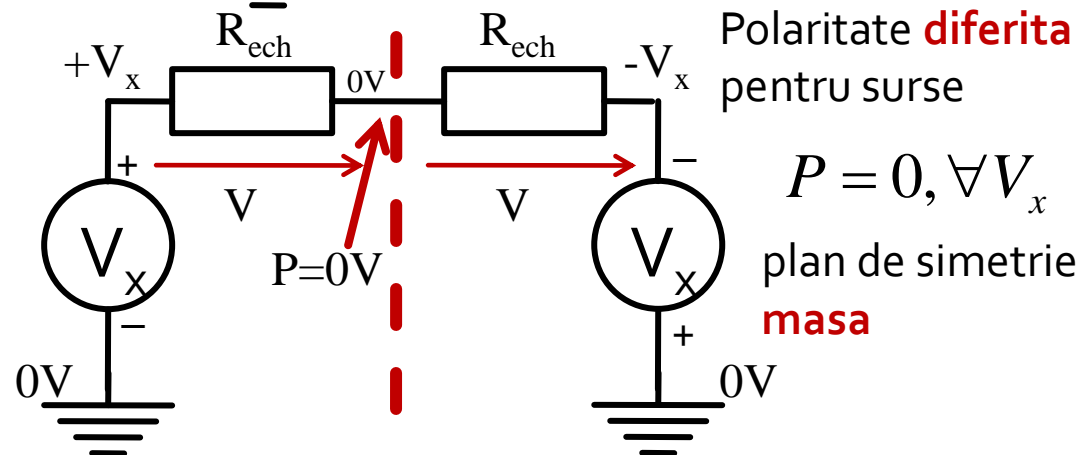
- la atacul porturilor cu surse simetrice/antisimetrice  
planele de simetrie se transforma in

- gol virtual
- masa virtuala



$$I = 0, \forall V_x$$

plan de simetrie  
gol



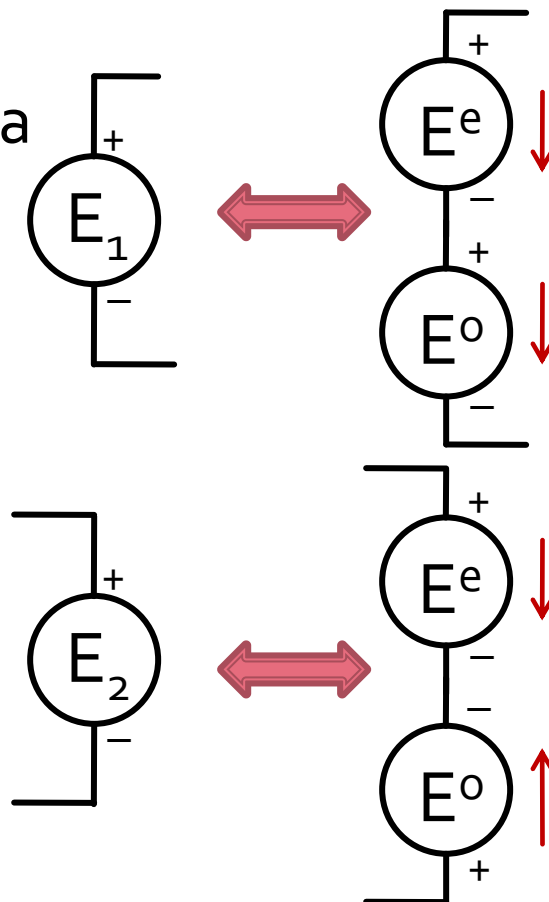
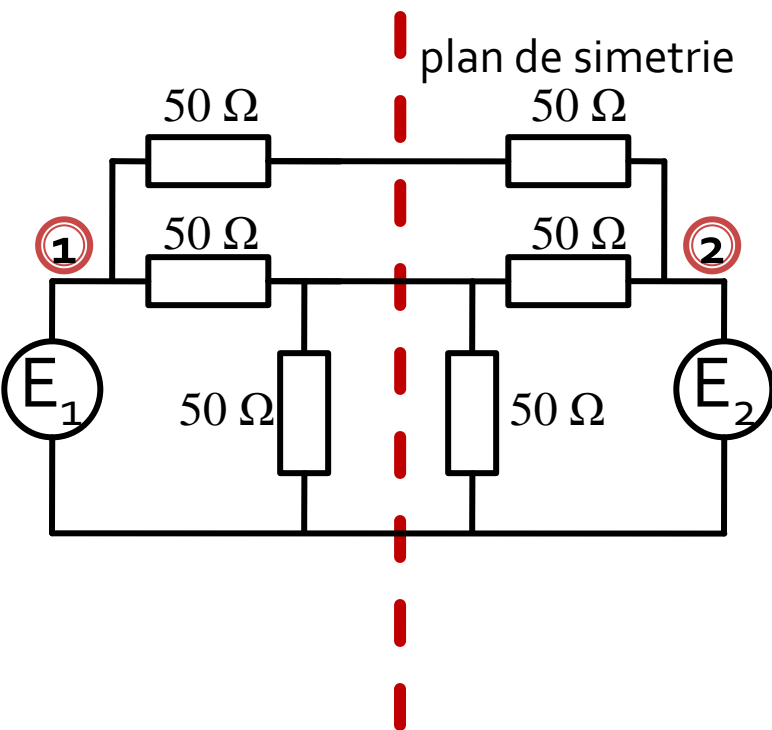
$$P = 0, \forall V_x$$

plan de simetrie  
masa

# Analiza pe mod par/impar (even/odd)

- orice combinatie de 2 surse poate fi echivalata pentru circuitele liniare cu o suprapunere:

- o sursa simetrica
- o sursa antisimetrica



$$E_1 = E^e + E^o$$

$$E_2 = E^e - E^o$$

$$E^e = \frac{E_1 + E_2}{2}$$

$$E^o = \frac{E_1 - E_2}{2}$$

# Analiza pe mod par/impar (even/odd)

- In circuite liniare putem aplica suprapunerea efectelor

$$\text{Efect} ( \text{Sursa1} + \text{Sursa2} ) = \text{Efect} ( \text{Sursa1} ) + \text{Efect} ( \text{Sursa2} )$$

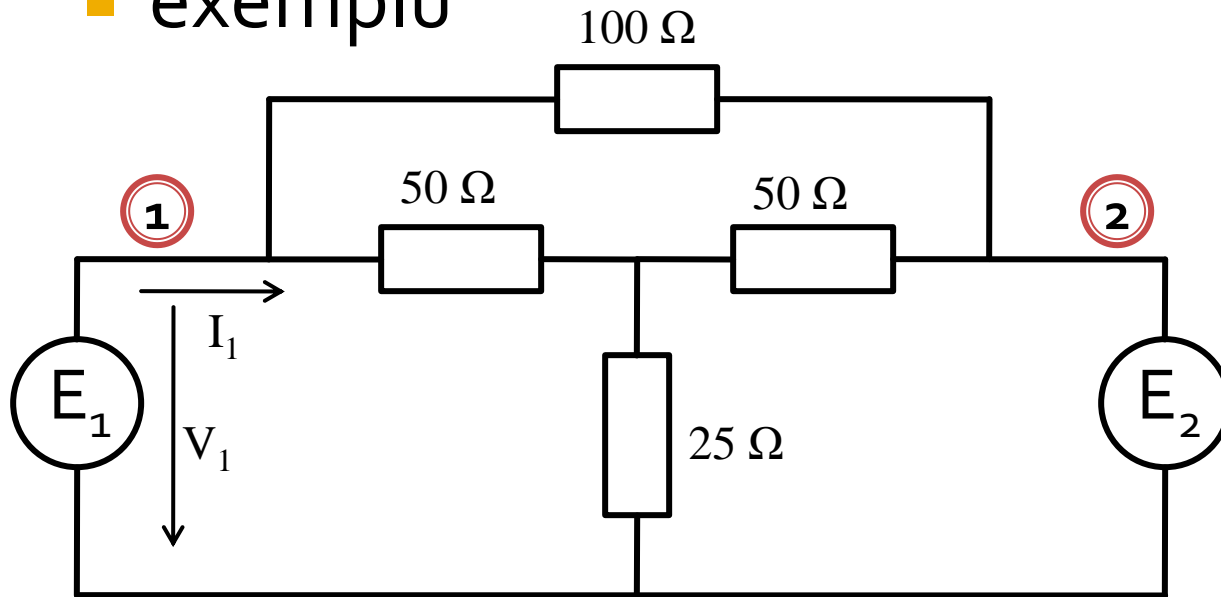
$$\text{Efect} ( \text{PAR} + \text{IMPAR} ) = \text{Efect} ( \text{PAR} ) + \text{Efect} ( \text{IMPAR} )$$

  
OARECARE

  
Putem beneficia de avantajele simetriilor!!

# Analiza pe mod par/impar (even/odd)

## ■ exemplu

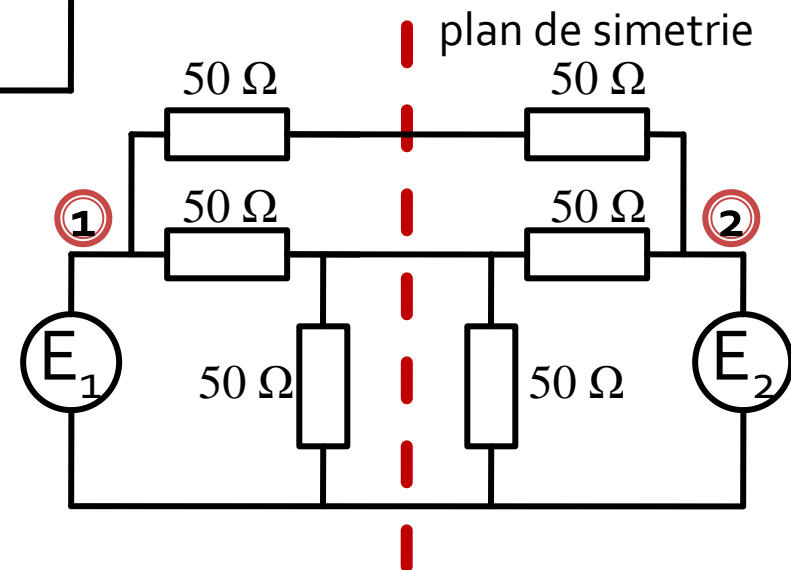


$$Y_{11} = \left. \frac{I_1}{V_1} \right|_{V_2=0}$$

$$V_2 \equiv E_2 = 0 \Rightarrow$$

$$E^e = \frac{E_1}{2}$$

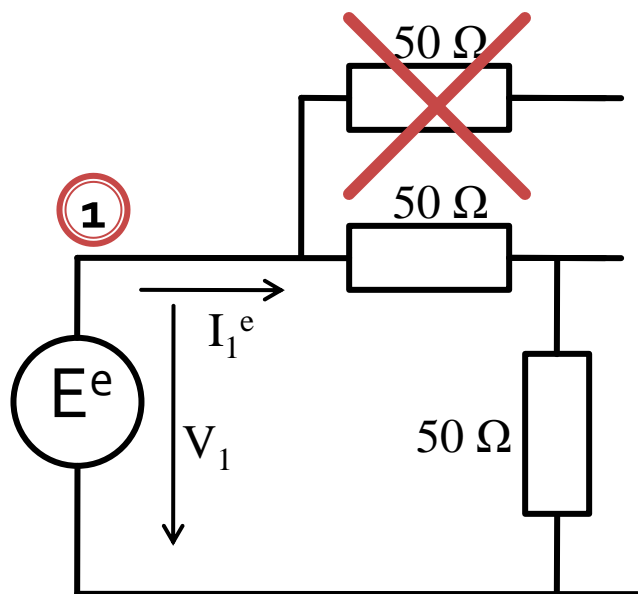
$$E^o = \frac{E_1}{2}$$





# Analiza pe mod par/impar (even/odd)

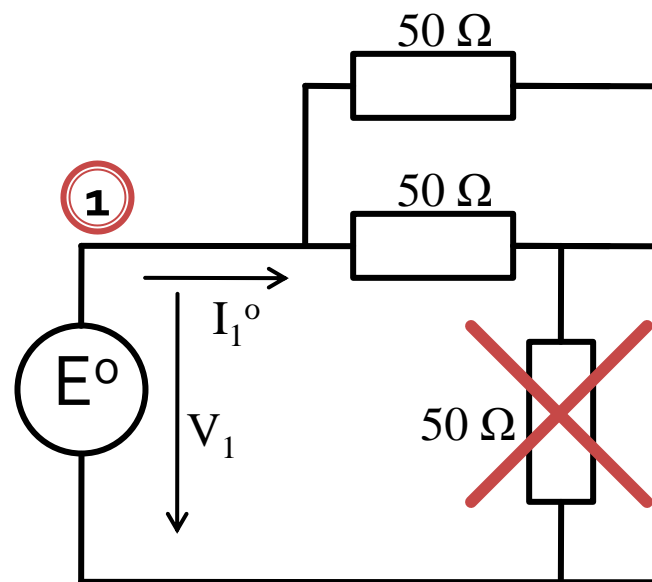
## ■ analiza pe mod par/impar



$$R_{ech}^e = 50\ \Omega + 50\ \Omega = 100\ \Omega$$

$$I_1^e = \frac{E^e}{R_{ech}^e} = \frac{E_1/2}{100\ \Omega} = \frac{E_1}{200\ \Omega}$$

**PAR** → plan de simetrie **gol**



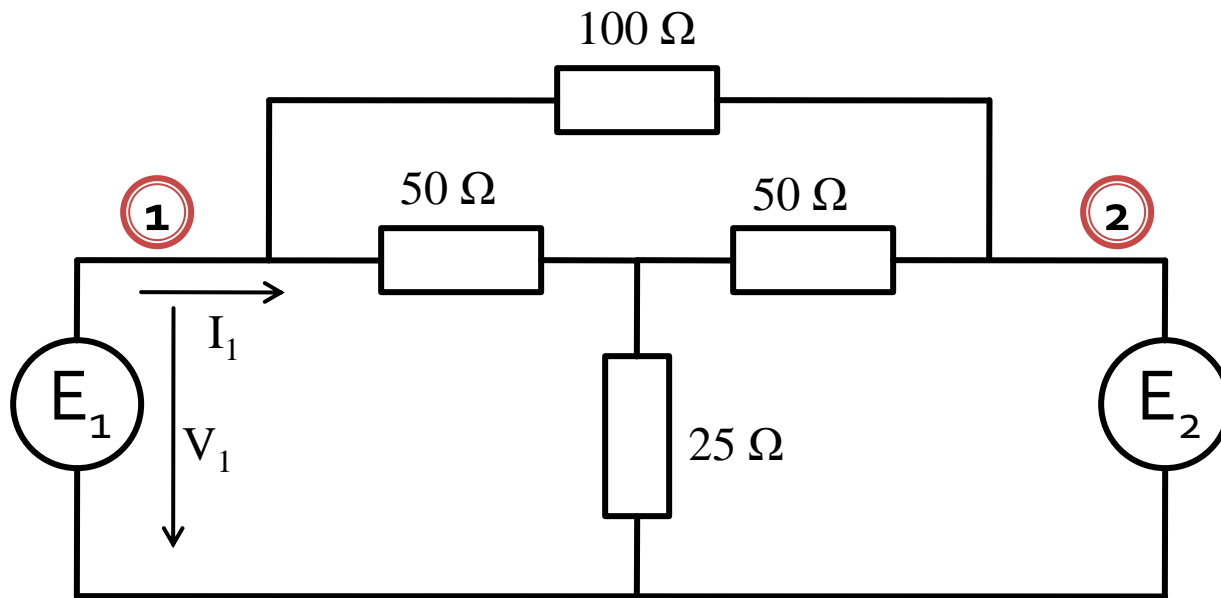
$$R_{ech}^o = 50\ \Omega || 50\ \Omega = 25\ \Omega$$

$$I_1^o = \frac{E^o}{R_{ech}^o} = \frac{E_1/2}{25\ \Omega} = \frac{E_1}{50\ \Omega}$$

**IMPAR** → plan de simetrie **masa**

# Analiza pe mod par/impar (even/odd)

- suprapunerea efectelor



$$I_1 = I_1^e + I_1^o$$

$$V_1 = V_1^e + V_1^o$$

$$I_1 = I_1^e + I_1^o = \frac{E_1}{200\Omega} + \frac{E_1}{50\Omega} = \frac{E_1}{40\Omega}$$

$$V_1 = V_1^e + V_1^o = E_1$$

$$Y_{11} = \frac{I_1}{V_1} = \frac{1}{40\Omega} = 0.025S$$

# Analiza pe mod par/impar (even/odd)

- In circuite liniare putem aplica suprapunerea efectelor
- avantaje
  - reducerea complexitatii circuitului
  - reducerea numarului de porturi (**principalul** avantaj)

$$\text{Efect} ( \text{PAR} + \text{IMPAR} ) = \text{Efect} ( \text{PAR} ) + \text{Efect} ( \text{IMPAR} )$$



Putem beneficia de avantajele simetriilor!!

Puncte suplimentare

# Tema

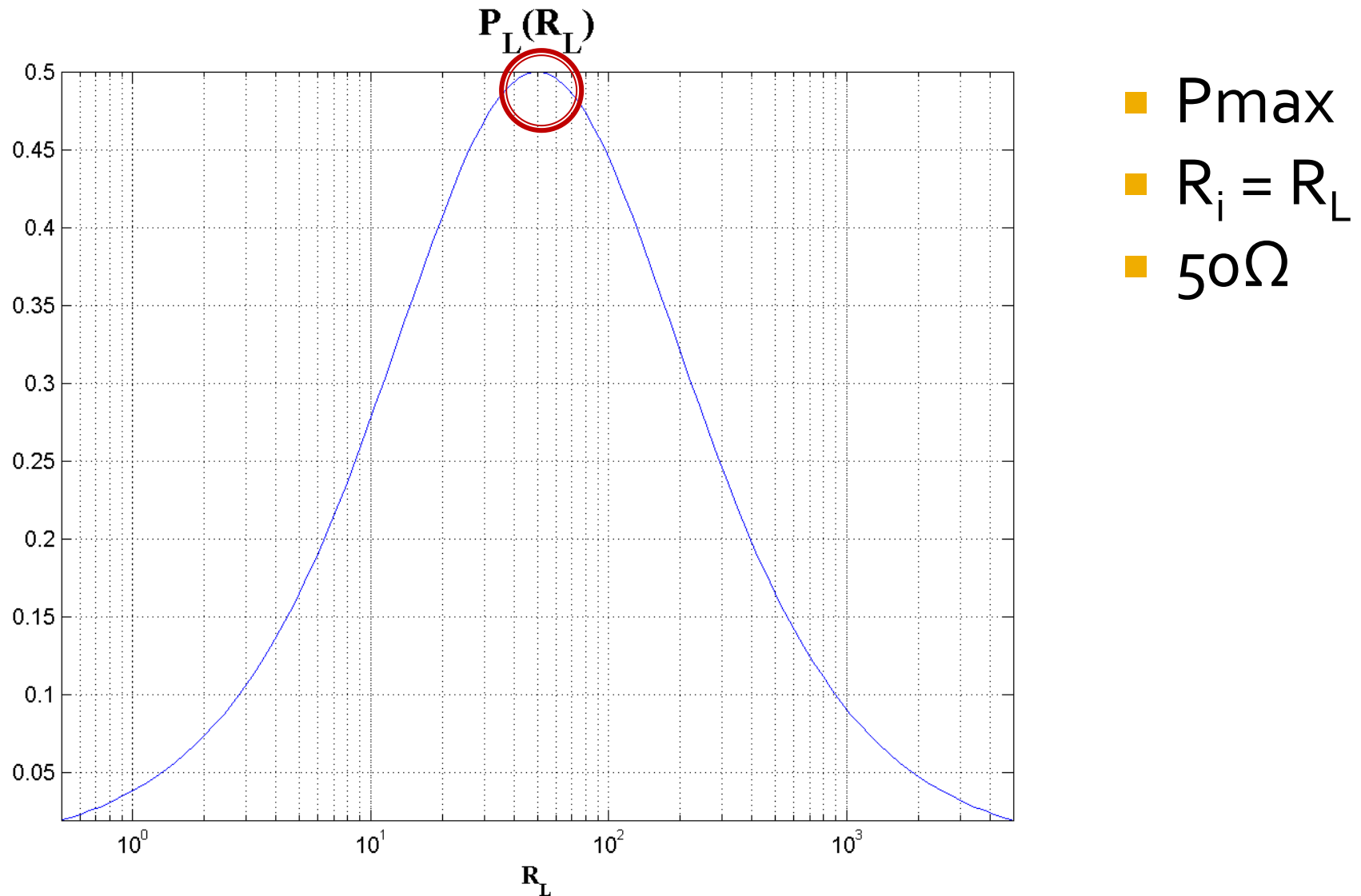
# Tema

- Scrieti pe o foaie de hartie (si scanati/foto) relatiile pentru modalitatea de determinare a matricii ABCD pentru:
  - admitanță paralel
  - linie de transmisie
  - transformator
  - diport  $\pi$
  - diport T

Cuploare directionale

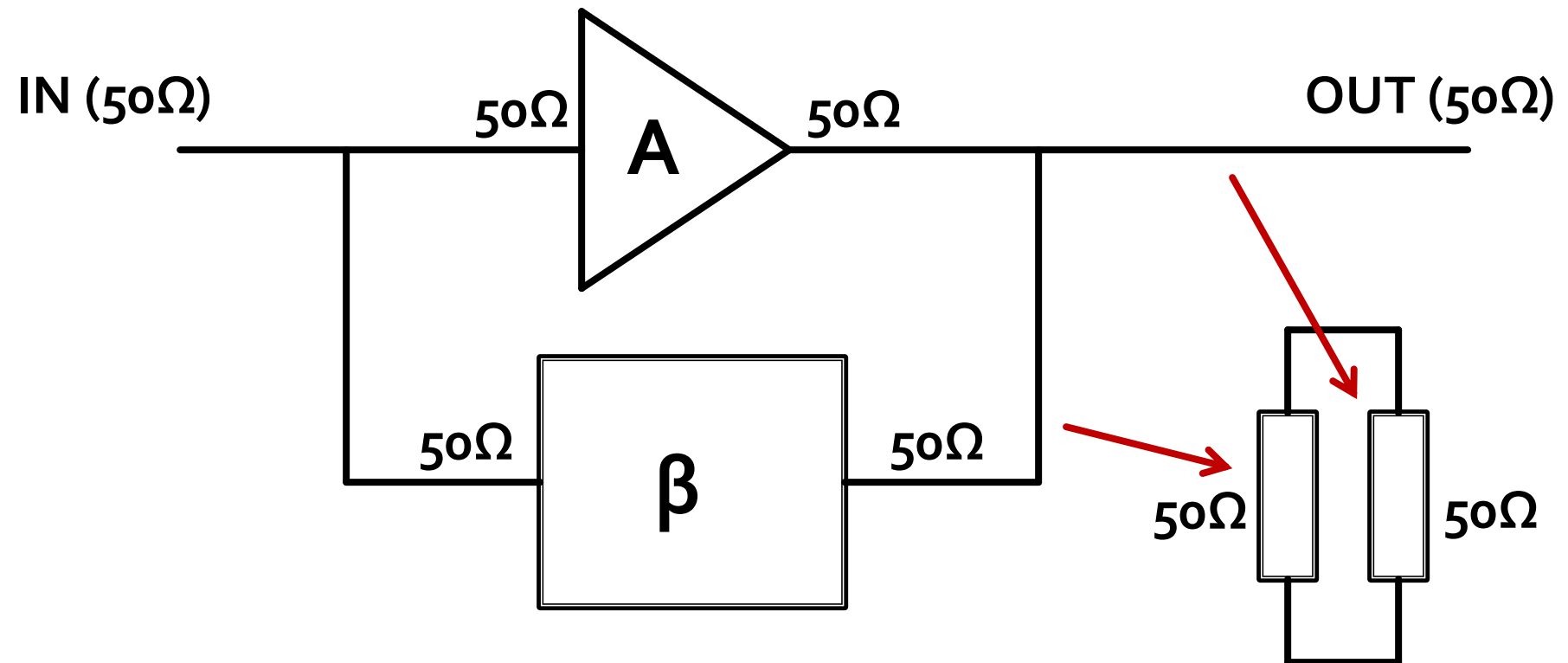
# Laborator 2

# Adattare , impedenza reale



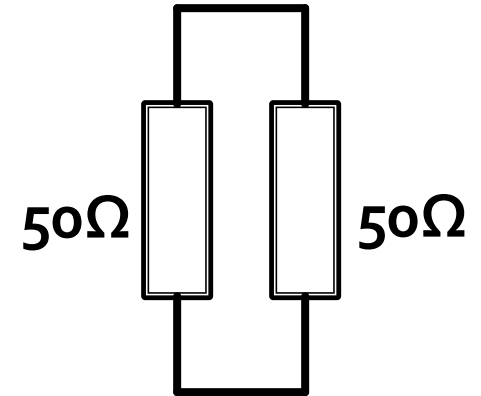
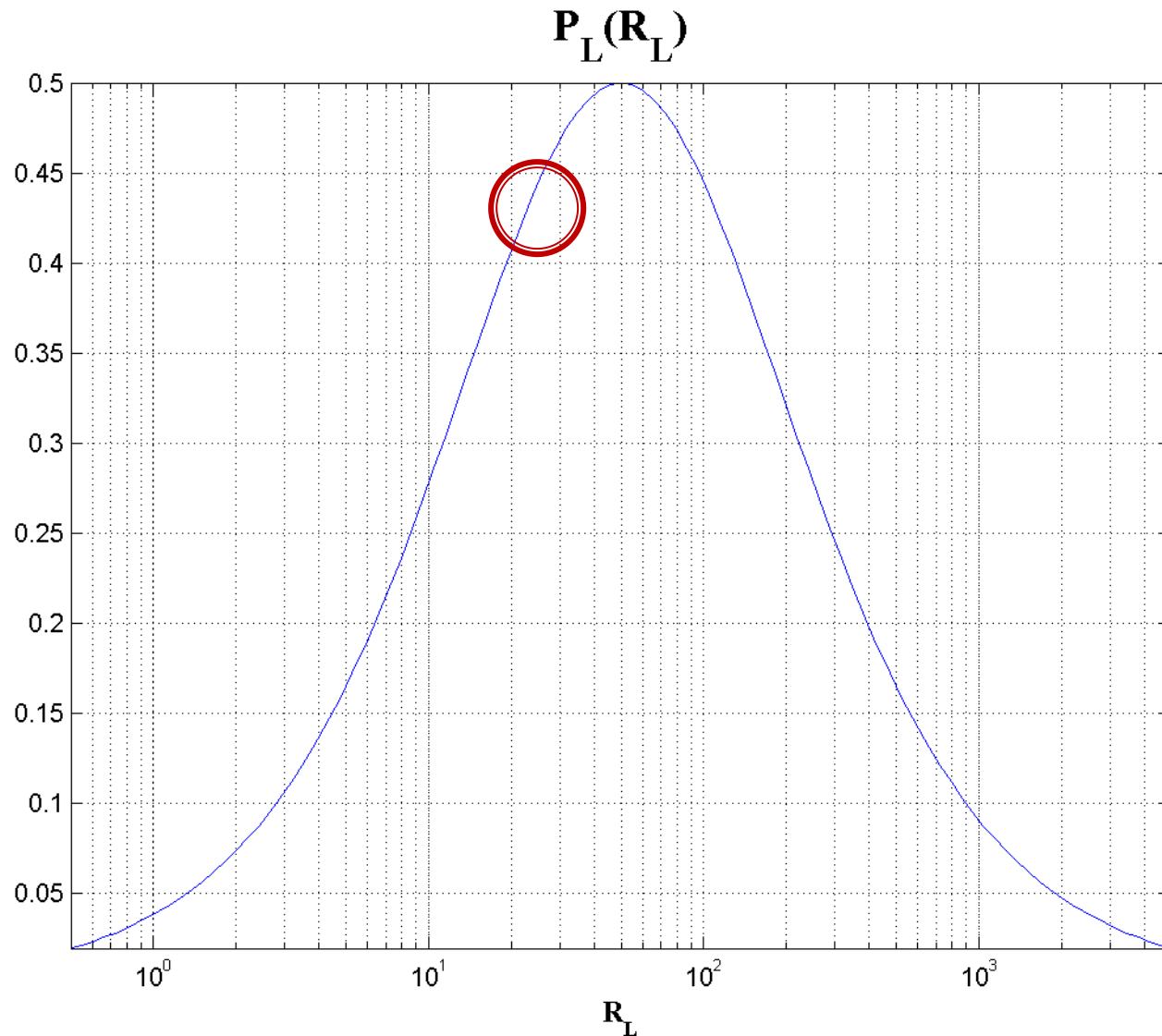
# Adaptare

- amplificator cu reactie





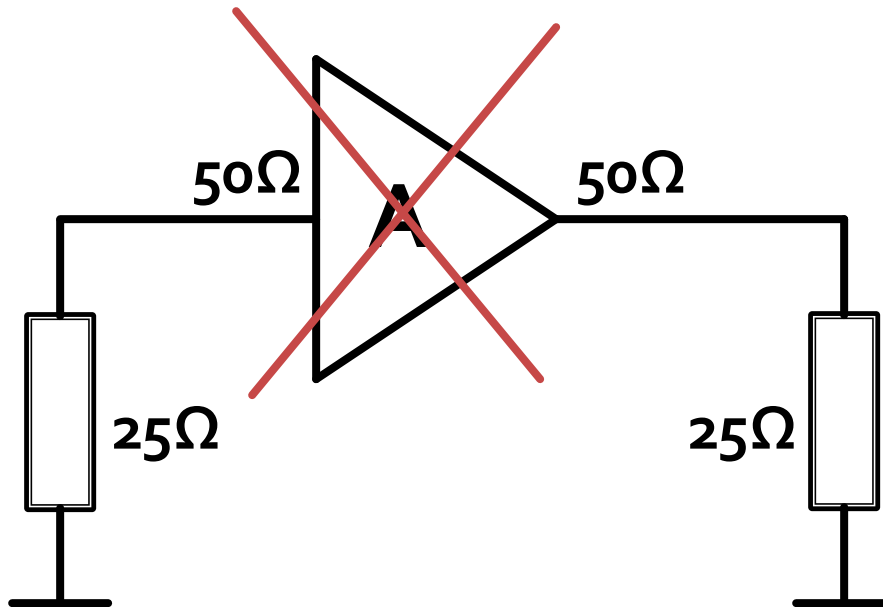
# Adattare , impedante reale



- $50\Omega$
- $50\Omega || 50\Omega = 25\Omega$

# Adaptare

- amplificator cu reactie



# Cuploare directionale si divizoare de putere

# Cuploare/Divizoare

- Funcționalitatea dorită:
  - divizarea
  - combinarea
- puterii semnalului

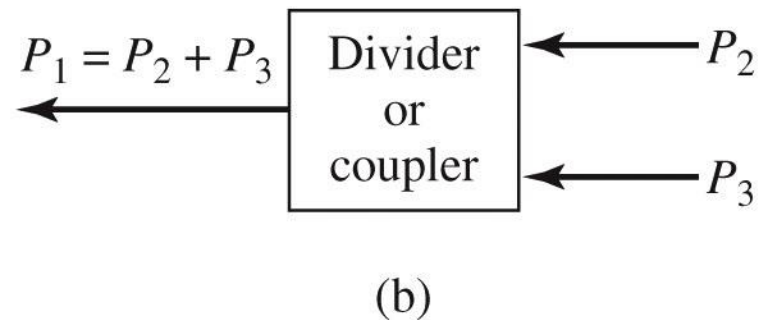
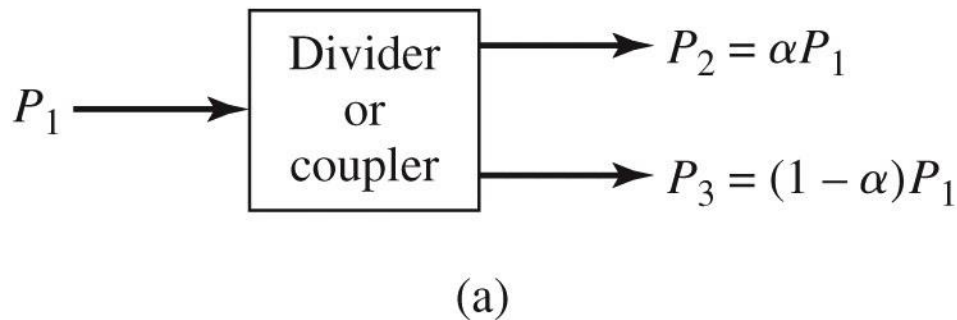


Figure 7.1  
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# Circuite cu trei porți

- numite si joncțiune in T
- caracterizate de o matrice  $\mathbf{S}$  3x3

$$[\mathbf{S}] = \begin{bmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{bmatrix}$$

- circuitul este **reciproc** dacă **nu** conține:
  - materiale anizotrope (de obicei ferite)
  - circuite active
- e de dorit să obținem funcționalitatea dorită de divizare/combinare de putere **fără pierderi** interne
- e de dorit sa obținem circuitul **adaptat simultan la toate porțile**
  - evitarea unor pierderi externe de putere

# Circuite cu trei porți

$$[S] = \begin{bmatrix} 0 & S_{12} & S_{13} \\ S_{12} & 0 & S_{23} \\ S_{13} & S_{23} & 0 \end{bmatrix}$$

- 6 ecuații / 3 necunoscute
  - **nici o soluție posibilă**
- Un circuit cu 3 porți **NU** poate fi simultan:
  - reciproc
  - fara pierderi
  - adaptat simultan la toate cele 3 porți

# Circuite cu patru porți

- caracterizate de o matrice  $S_{4 \times 4}$

$$[S] = \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{34} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix}$$

- circuitul este **reciproc** dacă nu conține:
  - materiale anizotrope (de obicei ferite)
  - circuite active
- e de dorit să obținem funcționalitatea dorită de divizare/combinare de putere **fără pierderi** interne
- e de dorit să obținem circuitul **adaptat simultan la toate porțile**
  - evitarea unor pierderi externe de putere

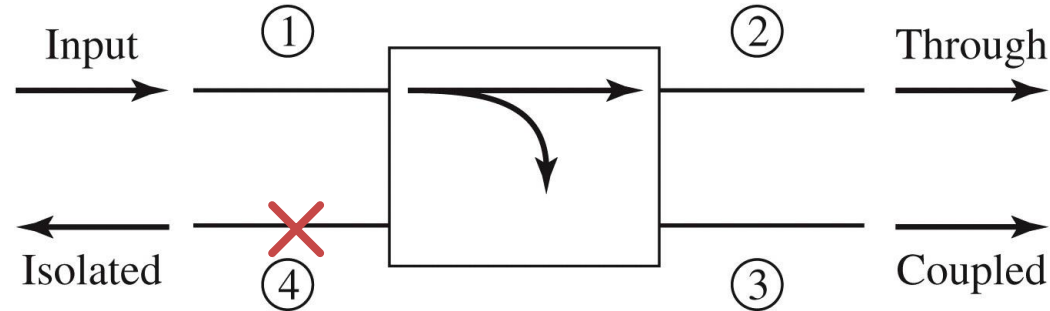
# Circuite cu patru porți

- Un circuit cu 4 porți care este simultan:
  - adaptat la toate portile
  - reciproc
  - fara pierderi
- este **intotdeauna** **directional**
  - puterea de semnal introdusa pe un port este trimisa **numai spre doua** din celelalte trei porturi

$$[S] = \begin{bmatrix} 0 & \alpha & \beta \cdot e^{j\theta} & 0 \\ \alpha & 0 & 0 & \beta \cdot e^{j\phi} \\ \beta \cdot e^{j\theta} & 0 & 0 & \alpha \\ 0 & \beta \cdot e^{j\phi} & \alpha & 0 \end{bmatrix}$$



# Cuplor directional



$$|S_{12}|^2 = \alpha^2 = 1 - \beta^2$$

$$|S_{13}|^2 = \beta^2$$

**Cuplaj**

$$C = 10 \log \frac{P_1}{P_3} = -20 \cdot \log(\beta) [\text{dB}]$$

**Directivitate**

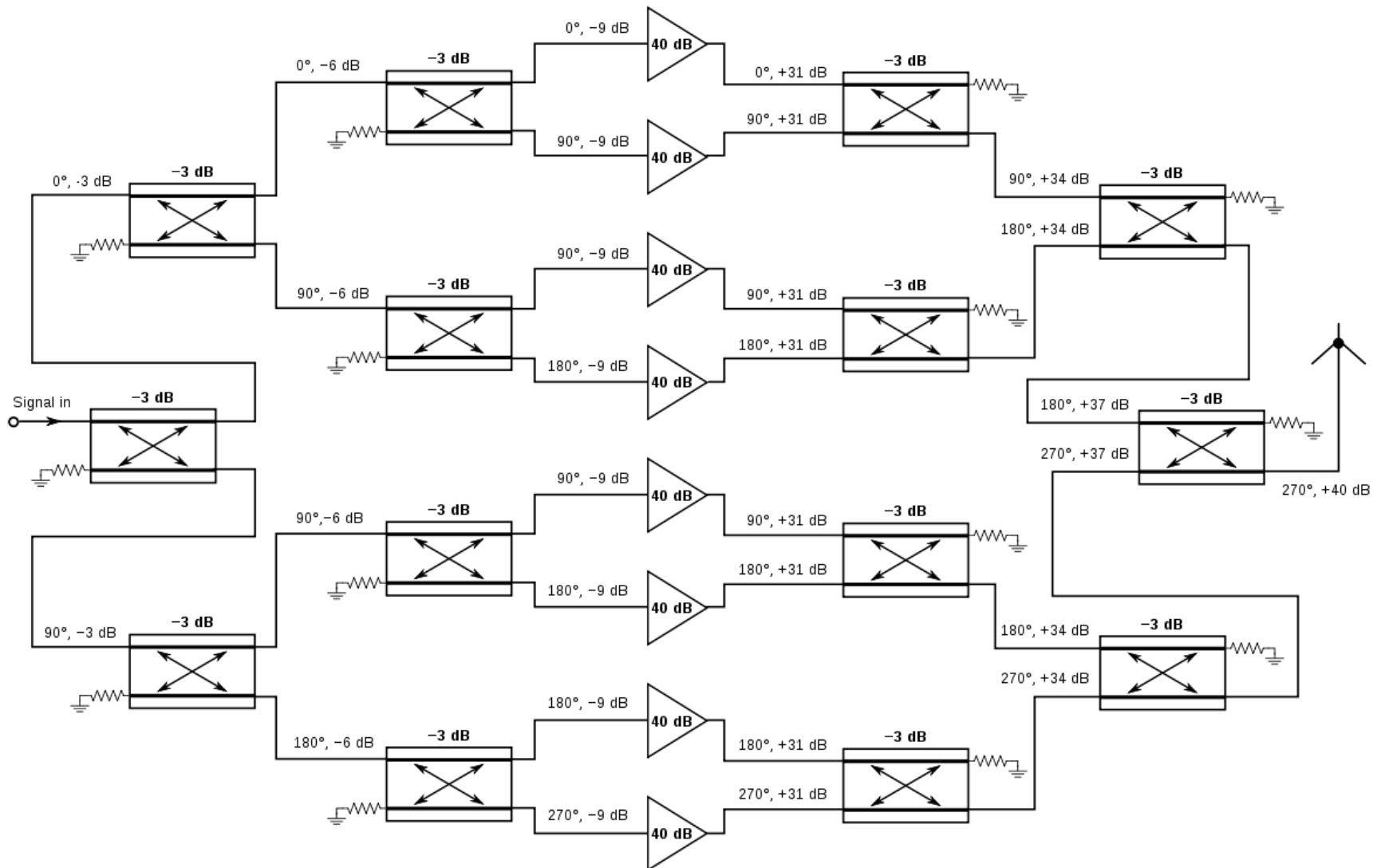
$$D = 10 \log \frac{P_3}{P_4} = 20 \cdot \log \left( \frac{\beta}{|S_{14}|} \right) [\text{dB}]$$

**Izolare**

$$I = 10 \log \frac{P_1}{P_4} = -20 \cdot \log |S_{14}| [\text{dB}]$$

$$I = D + C, \text{ dB}$$

# Amplificatoare echilibrate



# Cuplorul hibrid în cuadratură (90°)

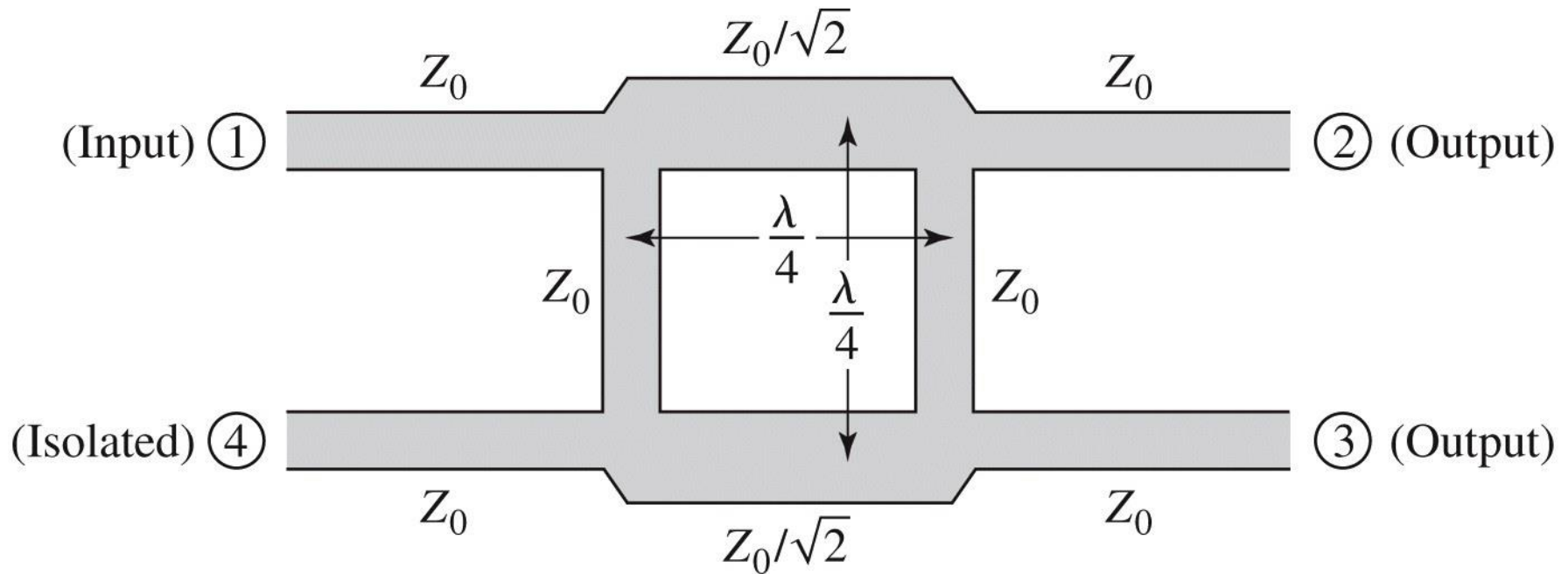
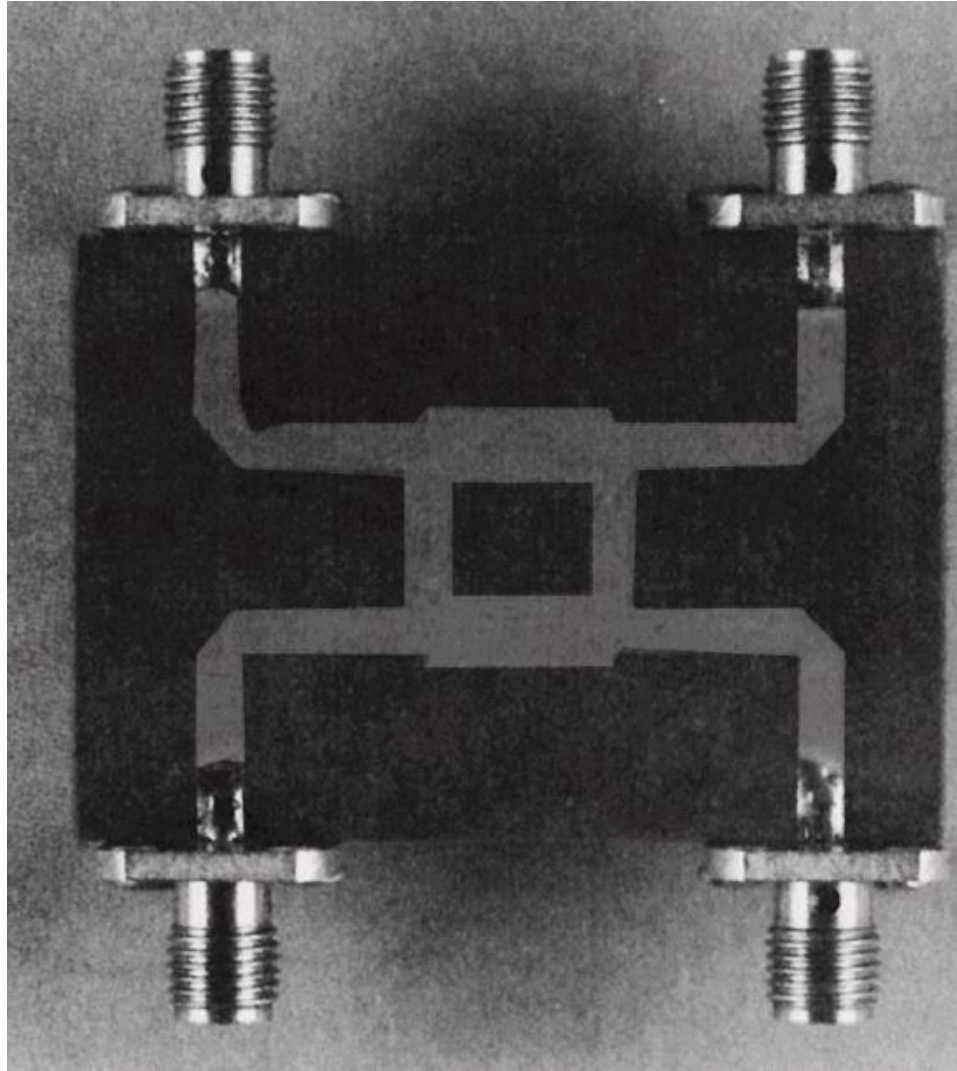


Figure 7.21  
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$$[S] = \frac{-1}{\sqrt{2}} \begin{bmatrix} 0 & j & 1 & 0 \\ j & 0 & 0 & 1 \\ 1 & 0 & 0 & j \\ 0 & 1 & j & 0 \end{bmatrix}$$



# Cuplorul in cuadratura

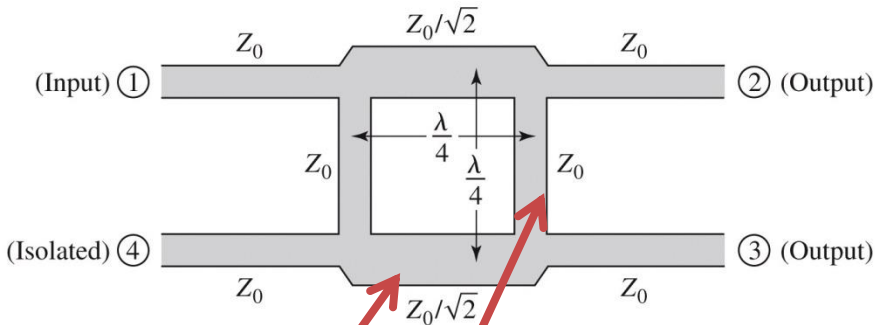


Figure 7.21  
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$$y_2^2 = 1 + y_1^2$$

$$|\beta| = \frac{\sqrt{y_2^2 - 1}}{y_2}$$

$$C[\text{dB}] = -20 \cdot \log_{10} \frac{\sqrt{y_2^2 - 1}}{y_2}$$

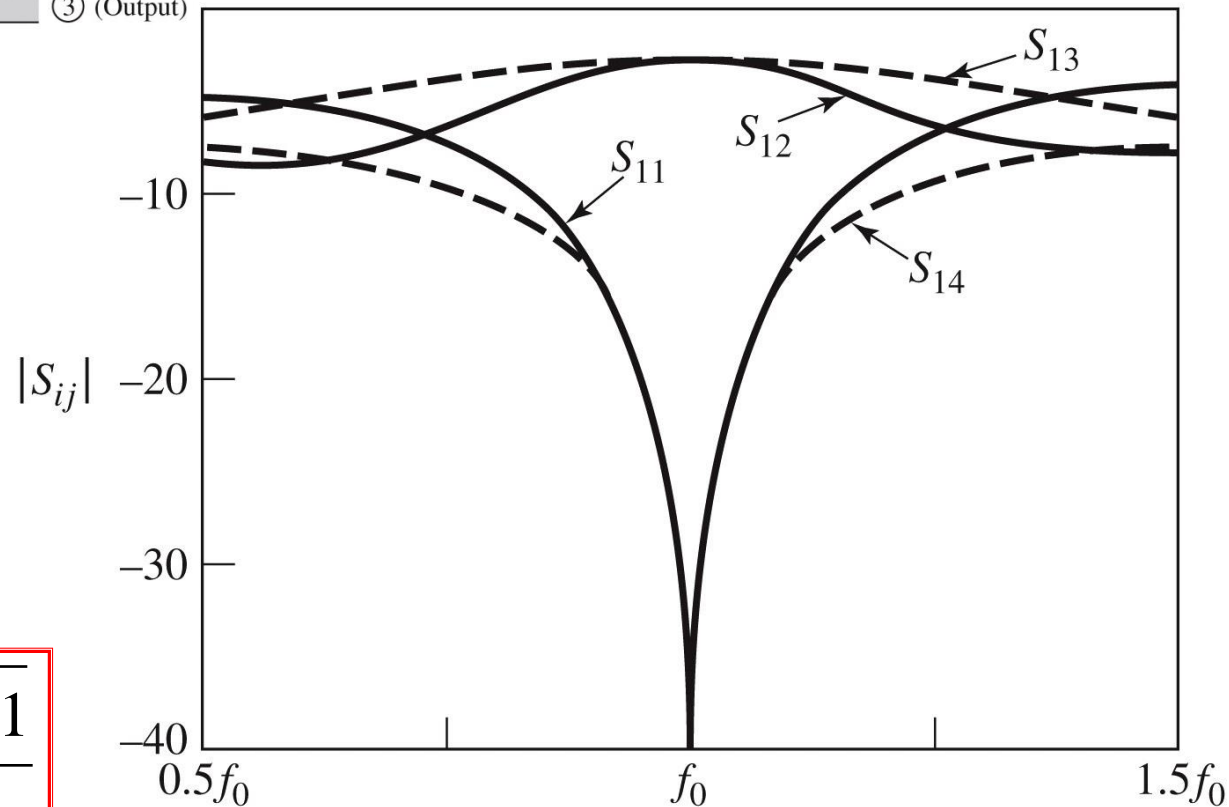
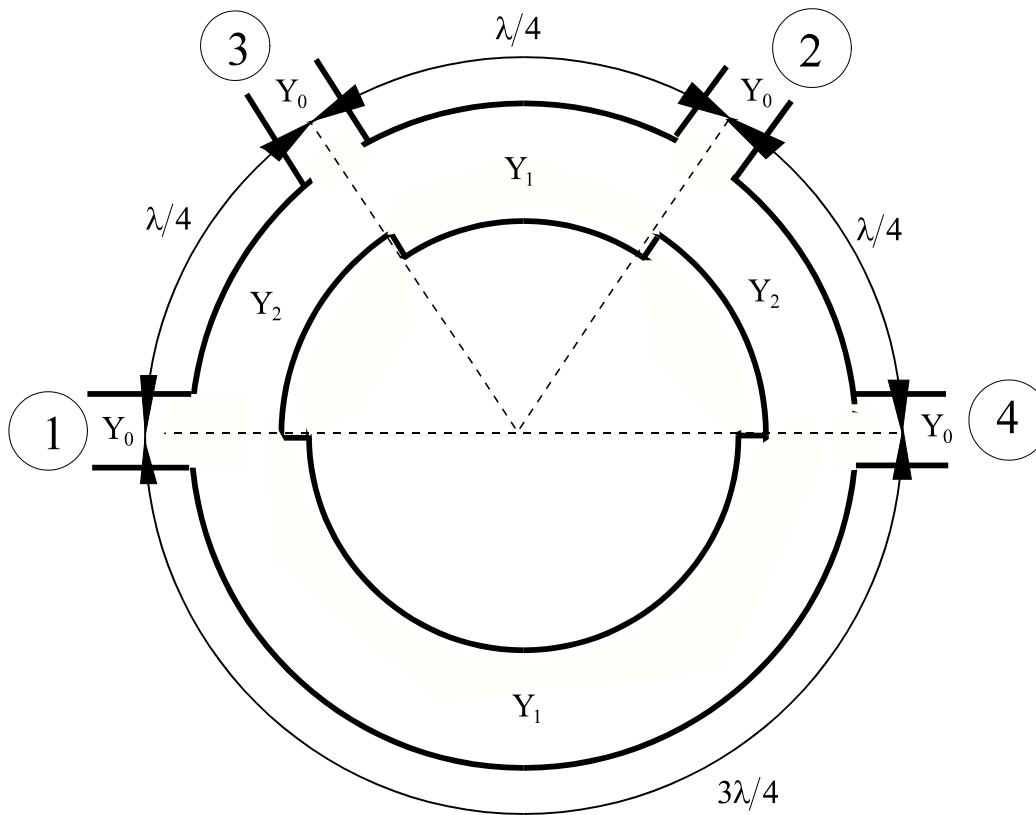


Figure 7.25  
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# Cuplorul in inel



# Cuplor în inel

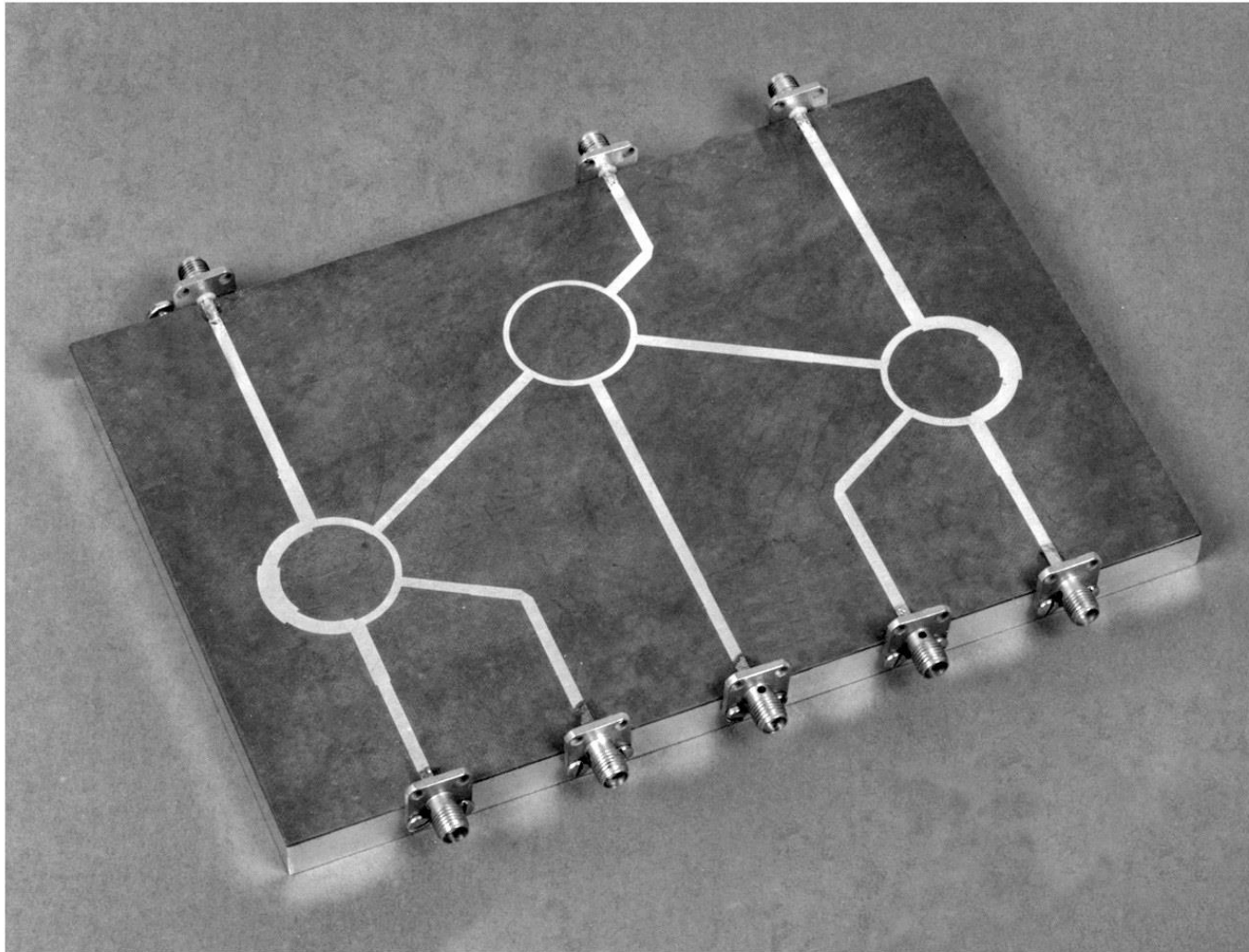
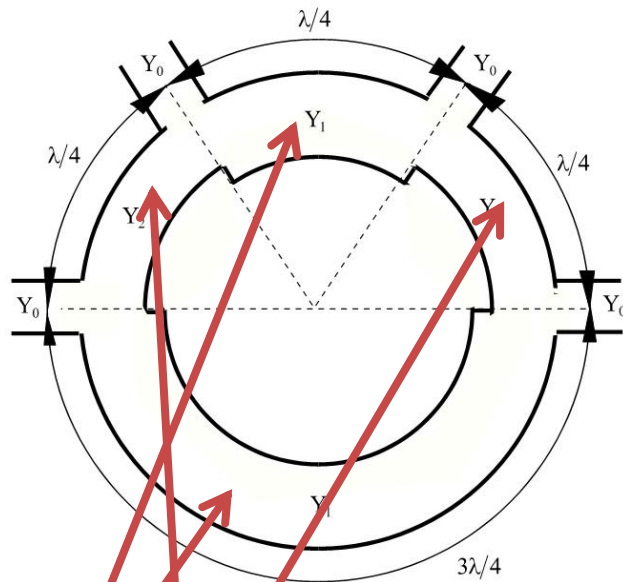


Figure 7.43  
Courtesy of M. D. Abouzahra, MIT Lincoln Laboratory, Lexington, Mass.

# Cuplorul în inel



$$y_1^2 + y_2^2 = 1$$

$$|\beta| = y_1$$

$$C \text{ [dB]} = -20 \cdot \log_{10}(y_1)$$

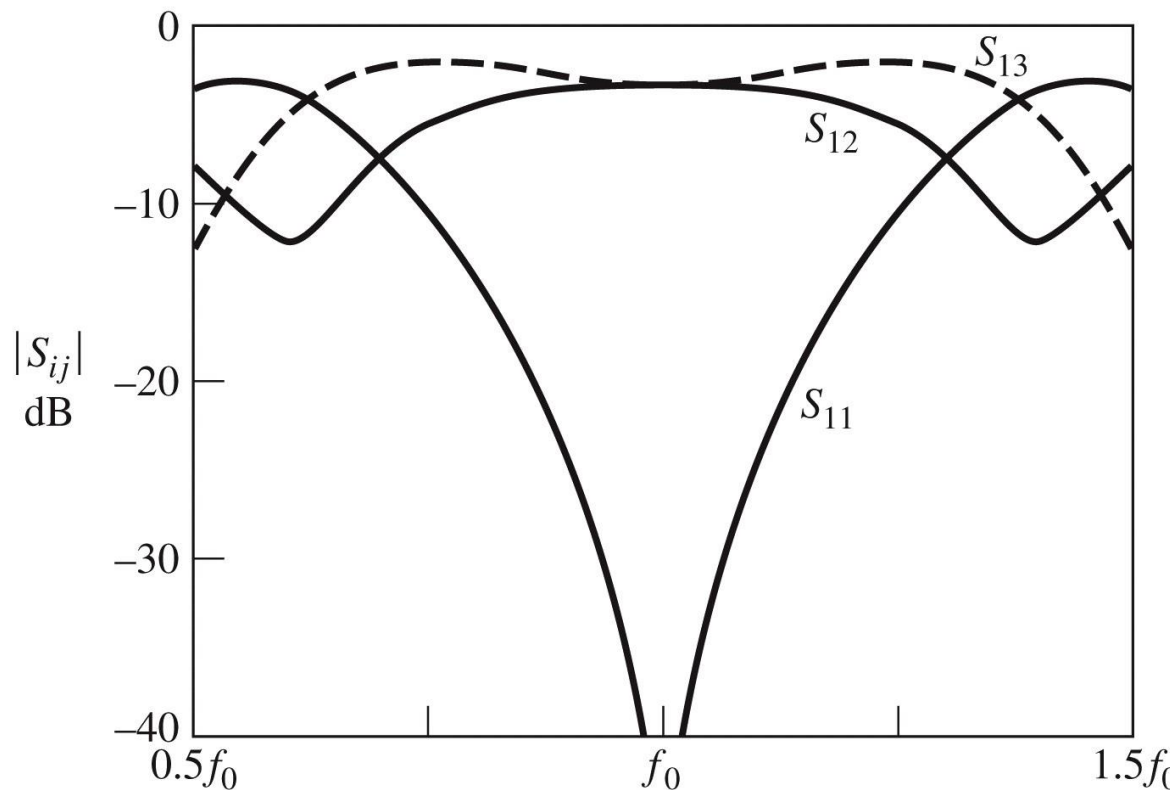
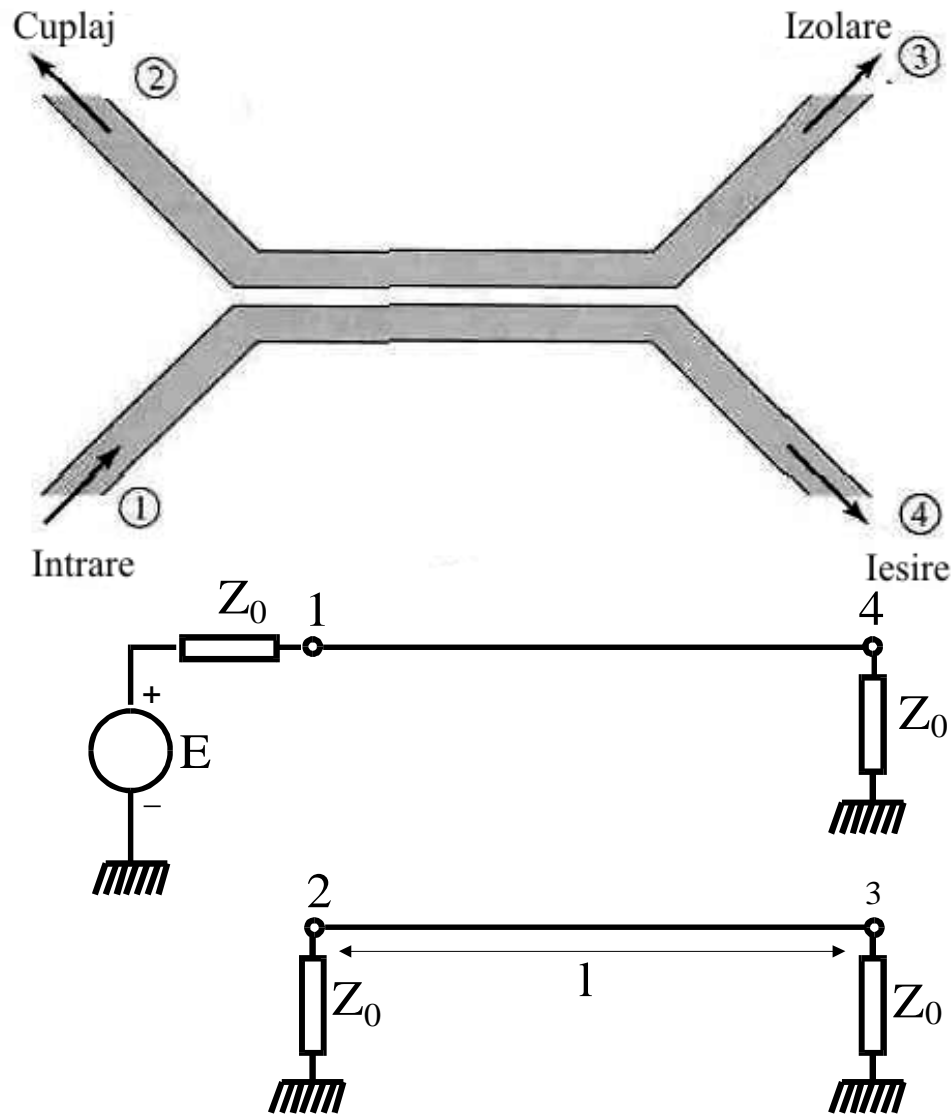


Figure 7.46  
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# Cuplorul prin proximitate



# Linii cuplate

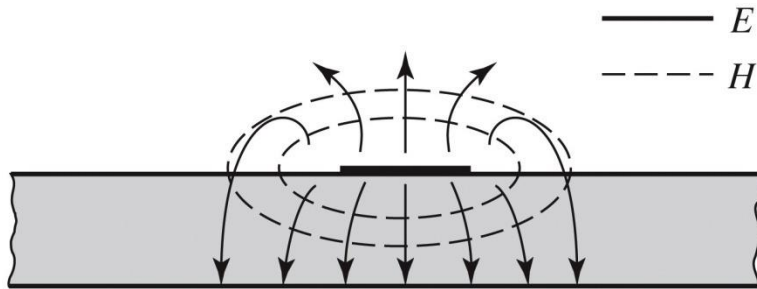
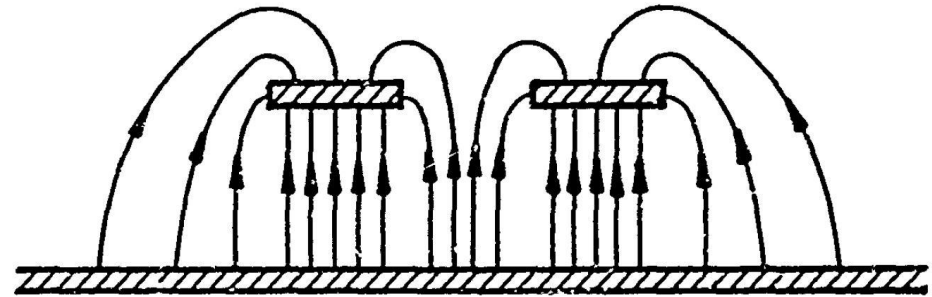
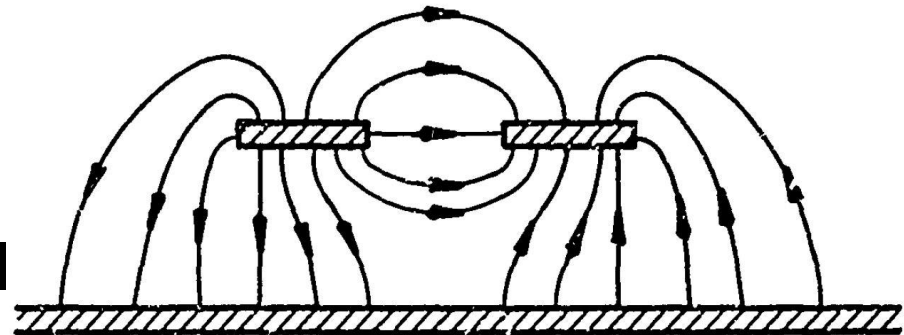


Figure 3.25b  
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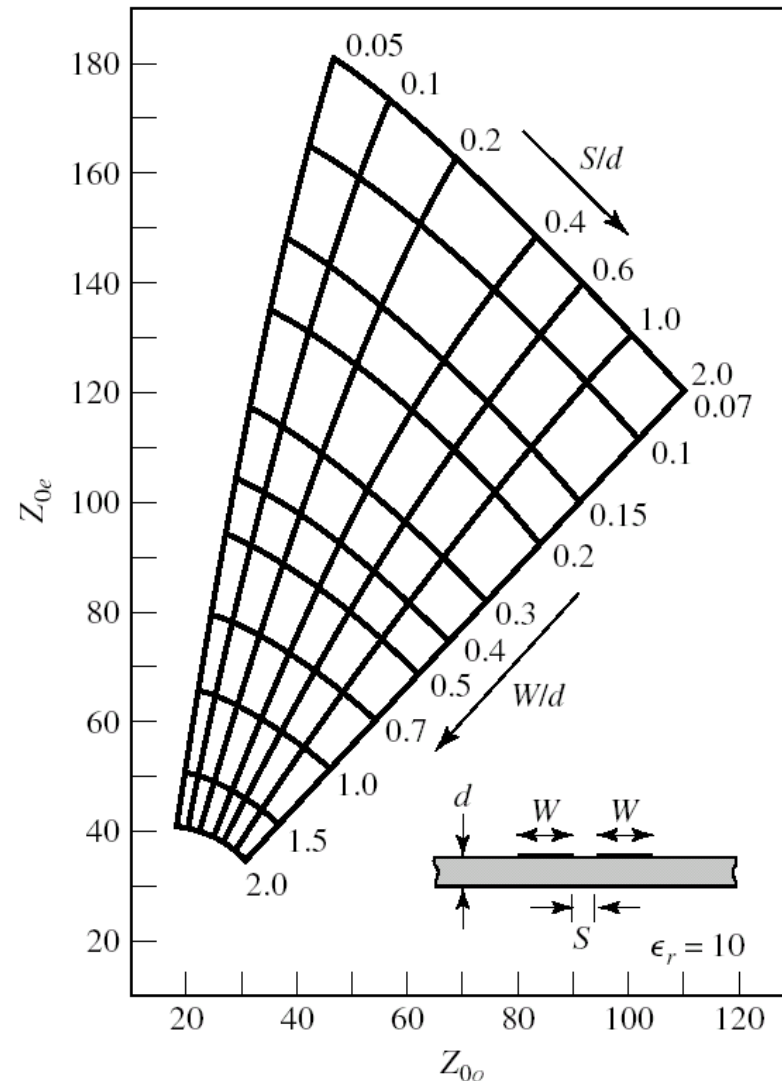
b) EVEN MODE ELECTRIC FIELD PATTERN (SCHEMATIC)

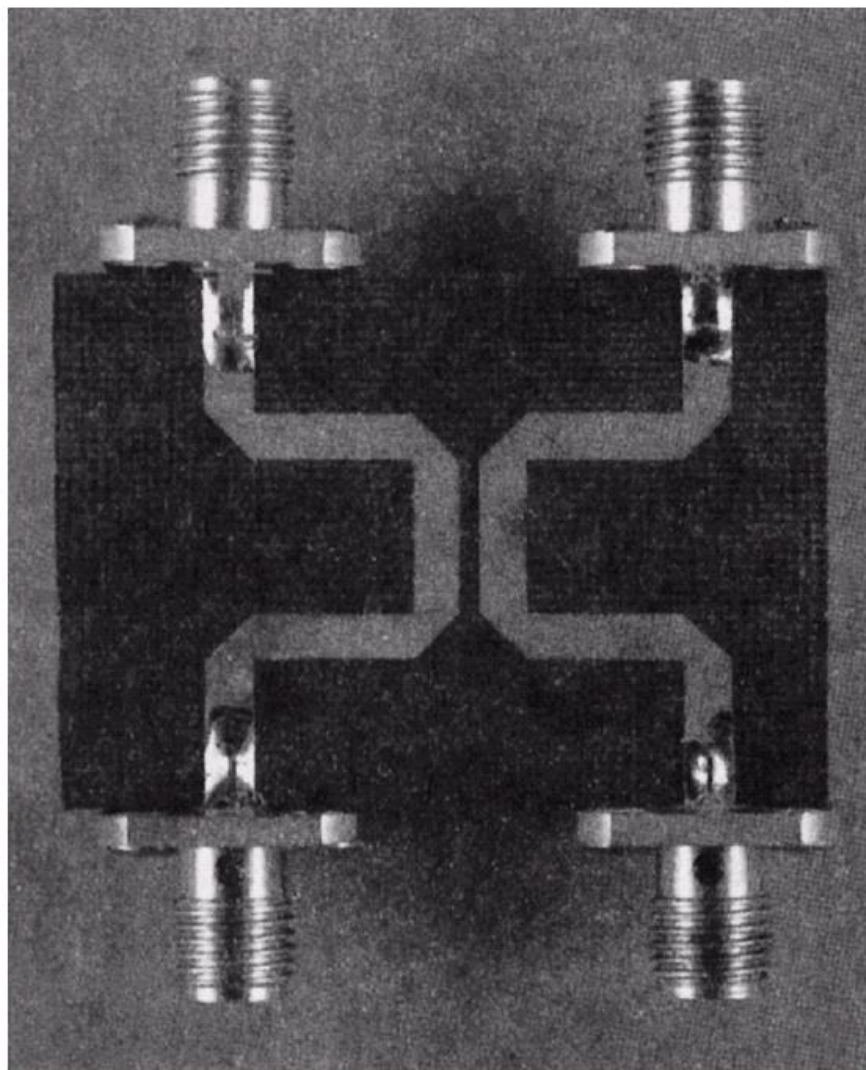


c) ODD MODE ELECTRIC FIELD PATTERN (SCHEMATIC)

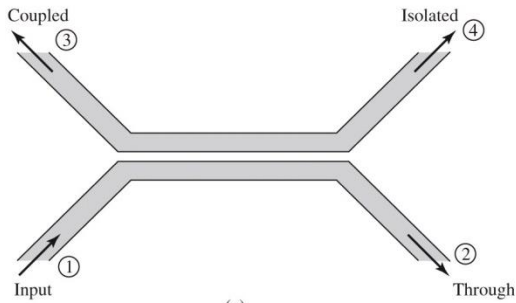
- Mod par – caracterizeaza semnalul de mod comun de pe cele doua linii
- Mod impar – caracterizeaza semnalul de mod diferential dintre cele doua linii
- Fiecare din cele doua moduri e caracterizat de impedante caracteristice **diferite**

# Even- and odd-mode characteristic impedance design data for coupled microstrip lines on a substrate with $\epsilon_r = 10$ .





# Cuplor prin proximitate



Coupling, Directivity (dB)

$$Z_{ce} Z_{co} = Z_0^2$$

$$|\beta| = \frac{Z_{ce} - Z_{co}}{Z_{ce} + Z_{co}}$$

$$C \text{ [dB]} = -20 \cdot \log_{10} \left( \frac{Z_{ce} - Z_{co}}{Z_{ce} + Z_{co}} \right)$$

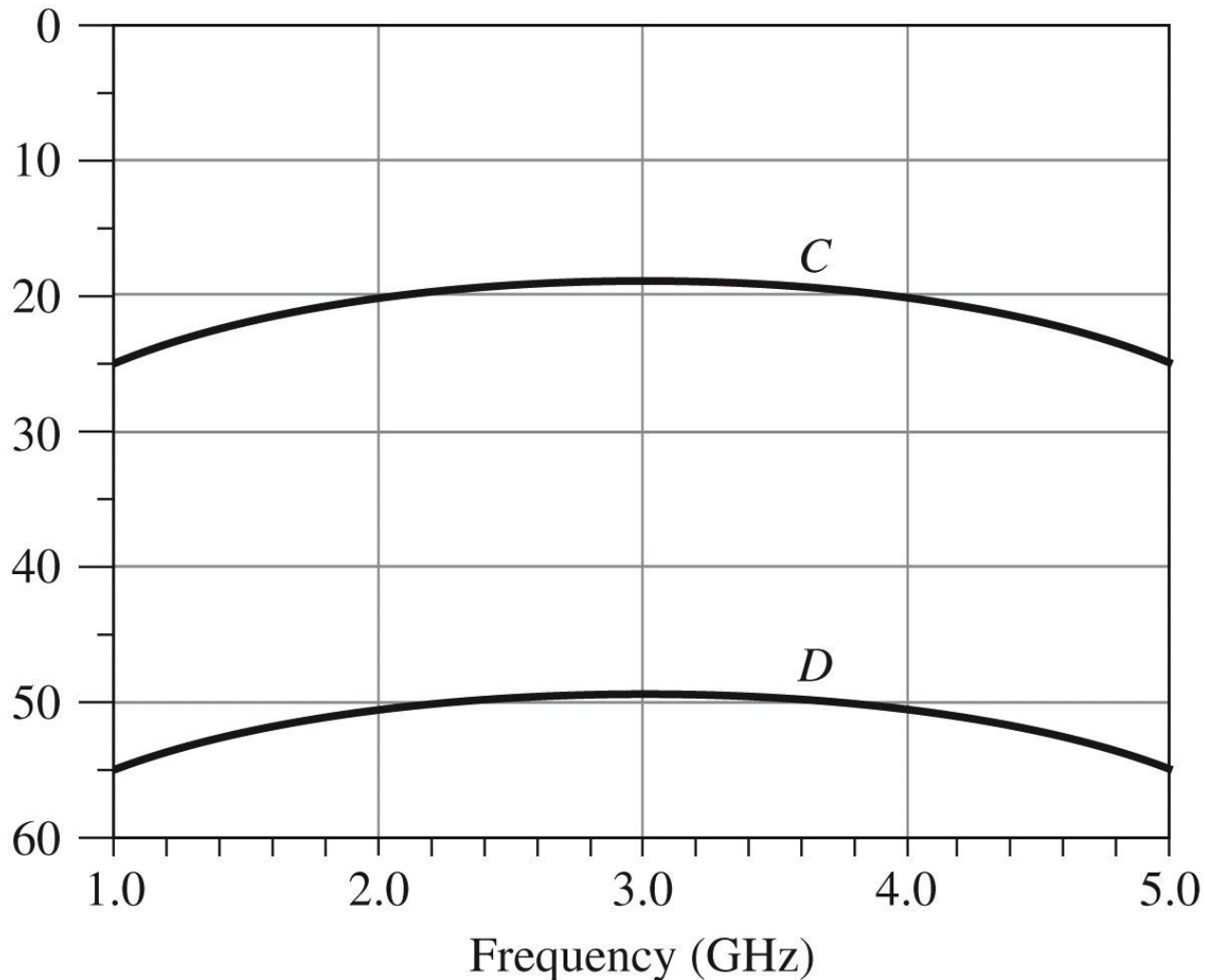


Figure 7.34

# Contact

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