Curs 5
2025/2026

Dispozitive şi circuite de microunde pentru radiocomunicații

Disciplina 2025/2026

- 2C/1L (+1), **DCMR (CDM)**

- **Minim 7 prezente (curs+laborator)**

- Curs - **conf. Radu Damian**
  - Vineri 10-12/**Video (istoric)**, C1, corp C
  - E – **50%** din nota
  - **probleme** + (2p prez. curs) + (3 teste) + (bonus activitate)
    - primul test L1: ~01.10.2025 (t2 si t3 neanuntate la **curs**)
    - 3pz (C) ≈ +0.5p (**2p** max)
  - **toate materialele permise**

Disciplina 2025/2026

- 2C/1L, **DCMR (CDM)**
- Laborator – **conf. Radu Damian**
  - 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

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

Microwave and Optoelectronics Laboratory
Faculty of Electronics, Telecommunications and Information Technology
Gheorghe Asachi Technical University of Iași

Main | **Courses** | Master | Staff | Research | Students

English
Romana

Microwave Devices and Circuits for Radiocommunicati

Course: DCMR (2024-2025)

Course Coordinator: Assoc.P. Dr. Radu-Florin Damian
Code: DOS412T
Discipline Type: DOS; Alternative, Specialty
Credits: 4
Enrollment Year: 4, **Sem.** 7

Activities

Course: Instructor: Assoc.P. Dr. Radu-Florin Damian, 2 Hours/Week, Specialization Section, Timetable:
Laboratory: Instructor: Assoc.P. Dr. Radu-Florin Damian, 1 Hours/Week, Group, Timetable:

Evaluation

Type: **Exam**

A: 50%, (Test/Colloquium)
B: 25%, (Seminary/Laboratory/Project Activity)
D: 25%, (Homework/Specialty papers)

Grades

Aggregate Results

Documentatie

- RF-OPTO
  - https://rf-opto.etti.tuiasi.ro ~~Moodle~~
- Fotografie
  - de trimis pe rf-opto
  - necesara la laborator/curs
  - bonus activitate 1p/0.5p (~~C4~~/**C6**)

Bibliografie

- https://rf-opto.etti.tuiasi.ro
- Irinel Casian-Botez: "Microunde vol. 1: Proiectarea de circuit", Ed. TEHNOPRES, 2008
- David Pozar, Microwave Engineering, Wiley; 4th edition , 2011, ISBN : 978-1-118-29813-8 (E), ISBN : 978-0-470-63155-3 (P)

Examen: Reprezentare logaritmică

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

0 dB	= 1
+ 0.1 dB	= 1.023 (+2.3%)
+ 3 dB	= 2
+ 5 dB	= 3
+ 10 dB	= 10
-3 dB	= 0.5
-10 dB	= 0.1
-20 dB	= 0.01
-30 dB	= 0.001

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

0 dBm	= 1 mW
3 dBm	= 2 mW
5 dBm	= 3 mW
10 dBm	= 10 mW
20 dBm	= 100 mW
-3 dBm	= 0.5 mW
-10 dBm	= 100 μW
-30 dBm	= 1 μW
-60 dBm	= 1 nW

[dBm] + [dB] = [dBm]

[dBm/Hz] + [dB] = [dBm/Hz]

[x] + [dB] = [x]

Examen

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

Linii de transmisie in mod TEM

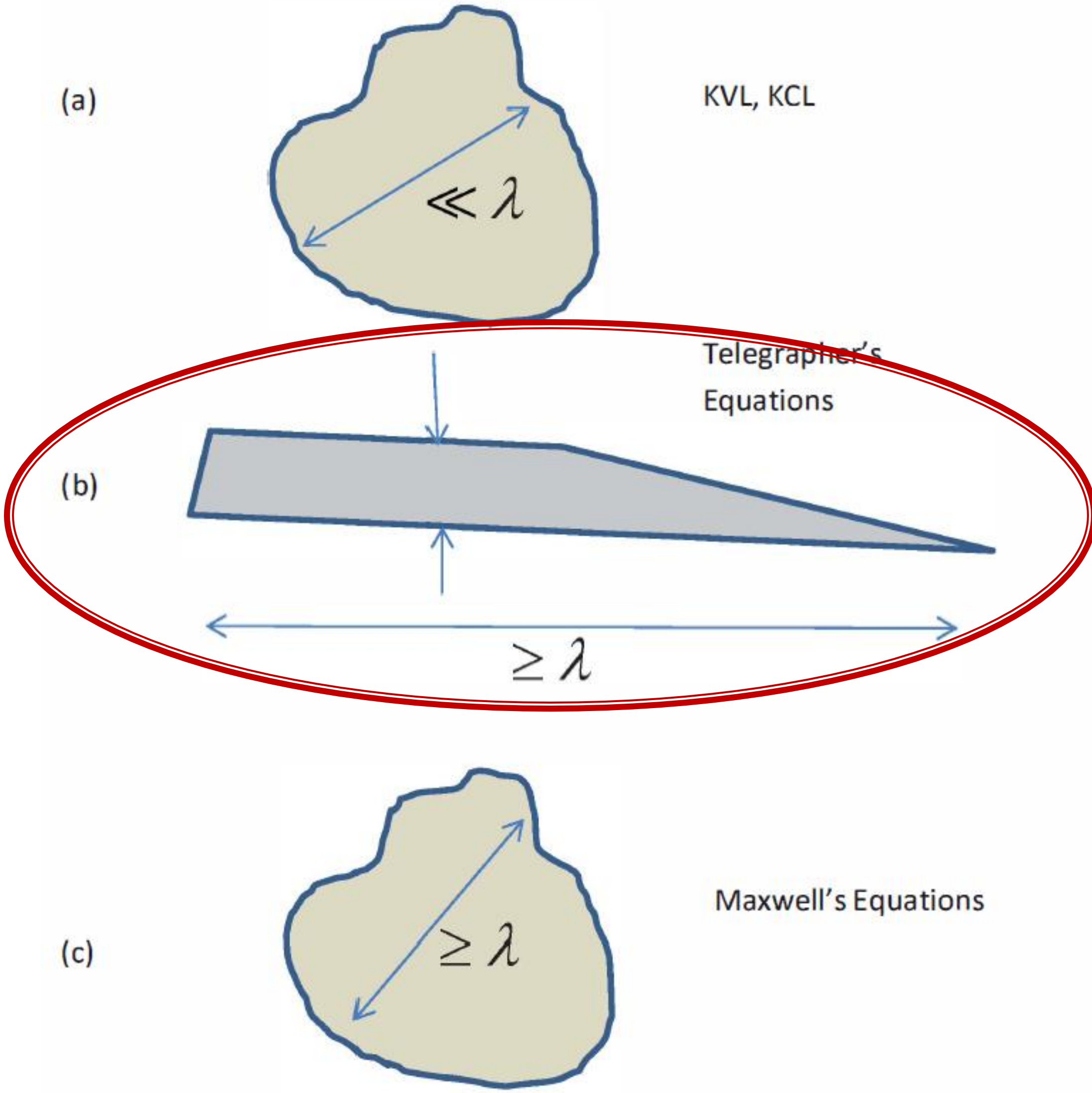
Cuprins

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

Lungime electrica

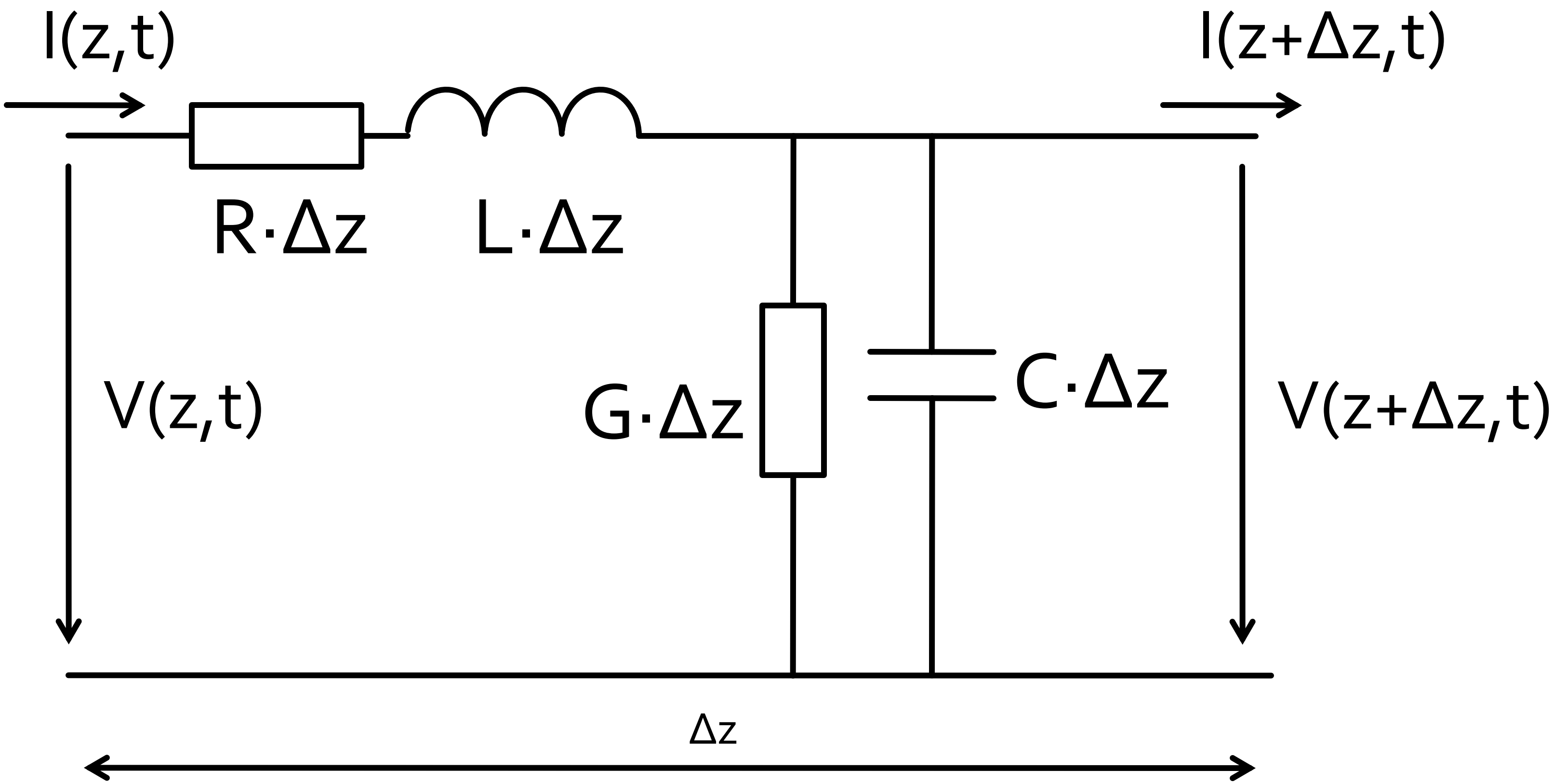
- Comportarea (descrierea) unui circuit depinde de lungimea sa electrica la frecventele de interes
  - E≈o → Kirchhoff
  - E>o → propagare

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



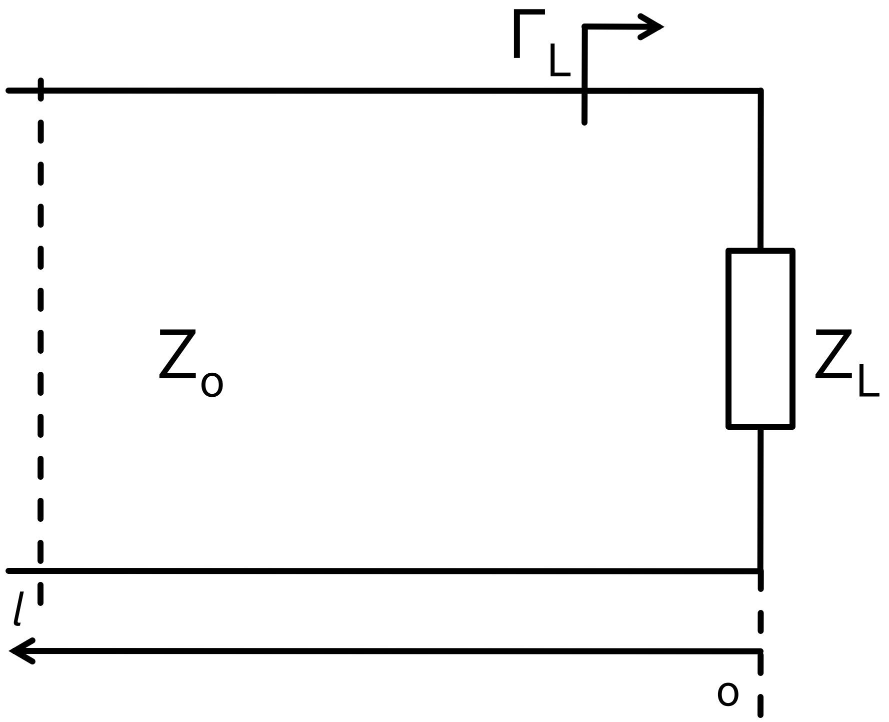
Linie de transmisie model echivalent

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



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

Linie fara pierderi



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

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

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

- coeficient de reflexie in tensiune

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

- Z_0 real

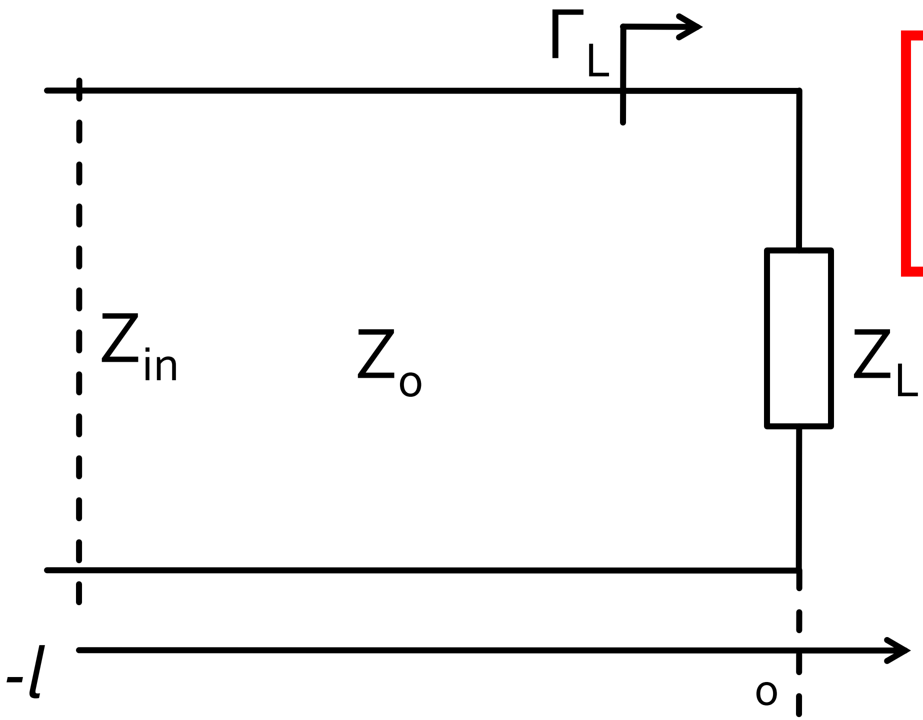
Linie fara pierderi

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

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

Linie fara pierderi

- impedanta la intrarea liniei de impedanta caracteristica $\boldsymbol{Z_o}$, de lungime $\boldsymbol{l}$, terminata cu impedanta $\boldsymbol{Z_L}$



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

Tema C4

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

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

  - determinarea expresiei pentru polinomul Cebîşev de ordinul 4

$$T_4(\sec\theta_m \cos\theta) = \sec^4\theta_m(\cos 4\theta + 4\cos 2\theta + 3) - 4\sec^2\theta_m(\cos 2\theta + 1) + 1$$

Continuare

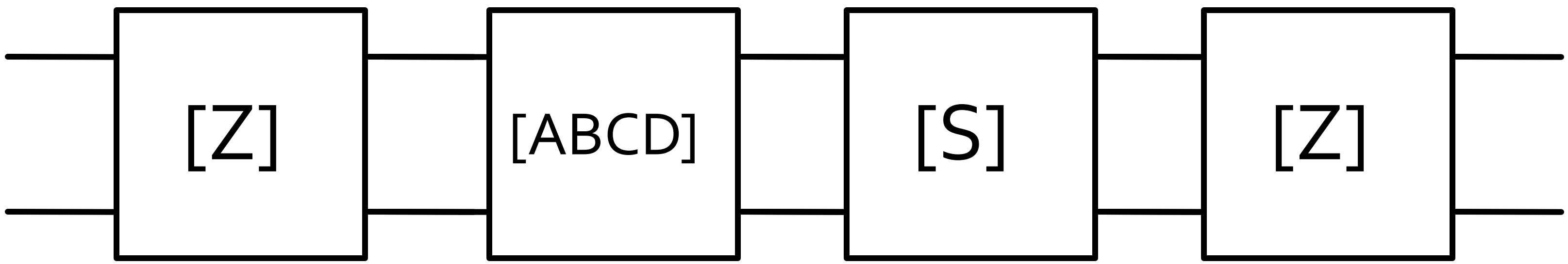
Analiza la nivel de rețea a circuitelor de microunde

Cuprins

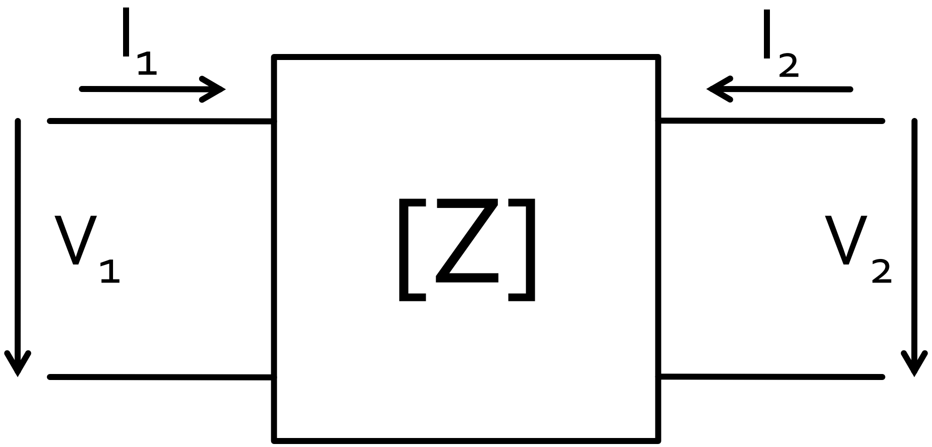
- Linii de transmisie
- Adaptarea de impedanța
- Cuploare direcționale
- Divizoare de putere
- Amplificatoare de microunde
- Filtre de microunde
- Oscilatoare de microunde ?

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



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

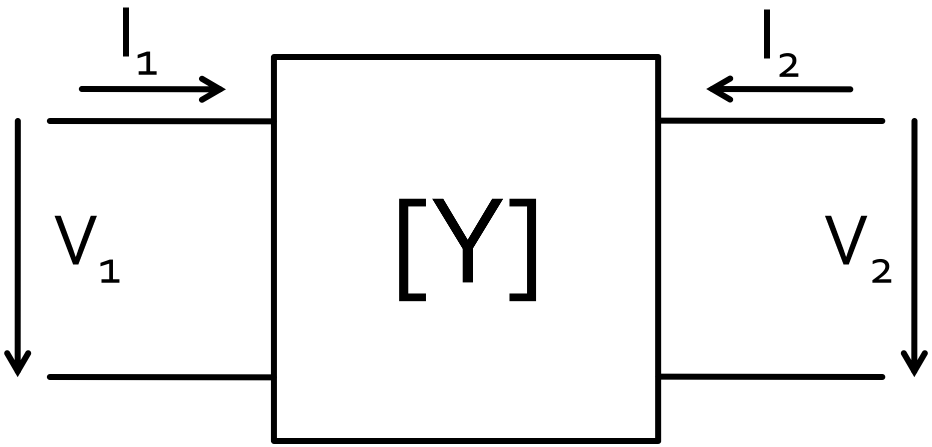
$$V_1 = Z_{11} \cdot I_1 + Z_{12} \cdot I_2$$
$$V_2 = Z_{21} \cdot I_1 + Z_{22} \cdot I_2$$

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

- Z11 – impedanta de intrare cu iesirea in gol

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

Matricea admitanta



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

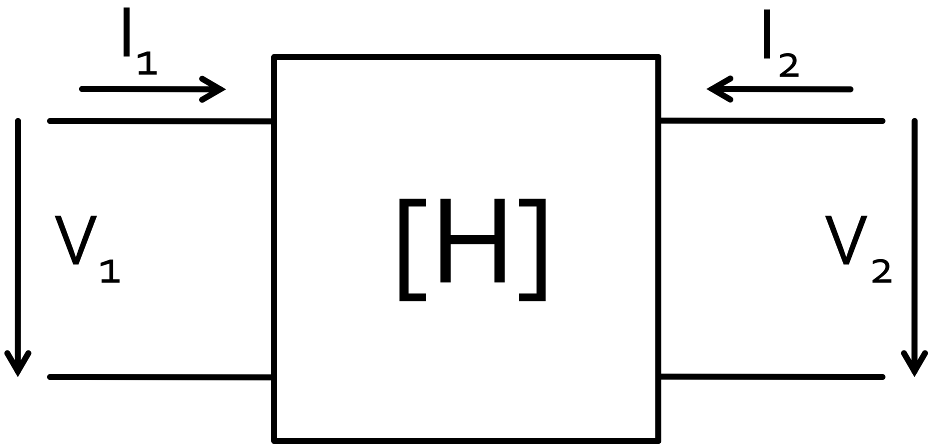
$$I_1 = Y_{11} \cdot V_1 + Y_{12} \cdot V_2$$
$$I_2 = Y_{21} \cdot V_1 + Y_{22} \cdot V_2$$

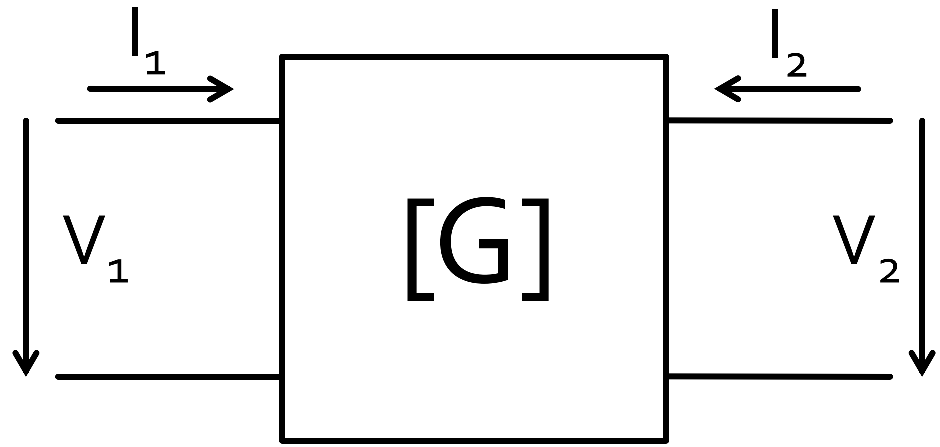
$$I_1 = Y_{11} \cdot V_1 \Big|_{V_2=0} \qquad Y_{11} = \frac{I_1}{V_1}\Big|_{V_2=0}$$

- Y11 – admitanta de intrare cu iesirea in scurtcircuit

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

Matrici hibride





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

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

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

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

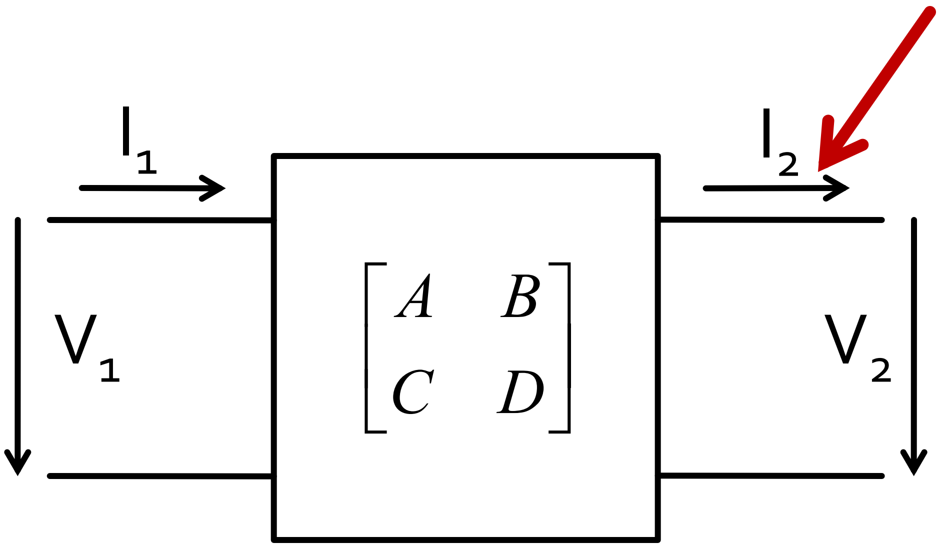
Analiza la nivel de bloc

- 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



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

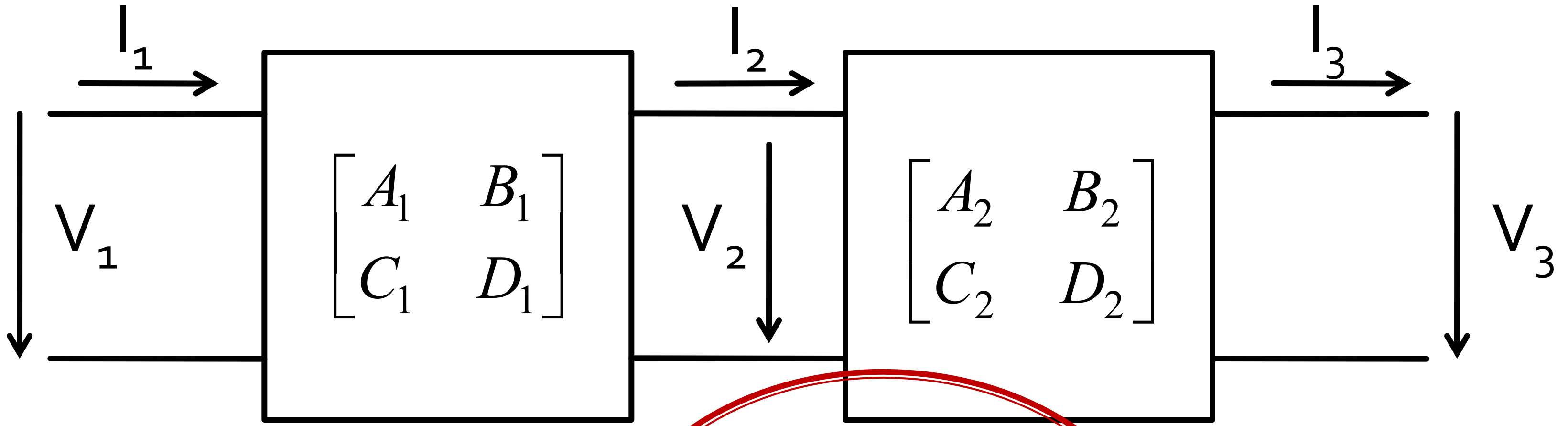
$$V_1 = A \cdot V_2 + B \cdot I_2$$
$$I_1 = C \cdot V_2 + D \cdot I_2$$

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

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

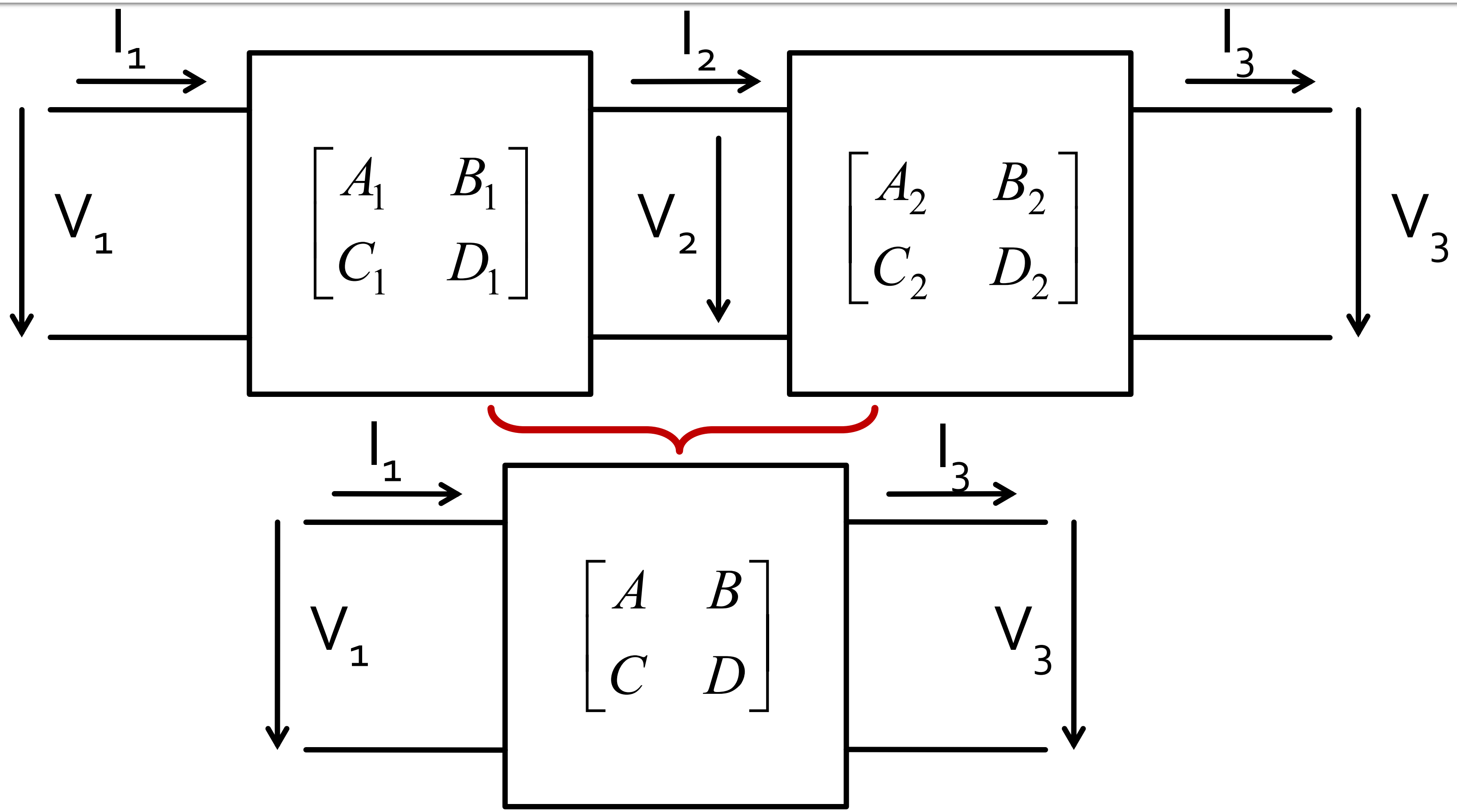
Matricea ABCD – de transmisie

- introduce o legatura intre "intrare" si "iesire"
- permite inlantuirea 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



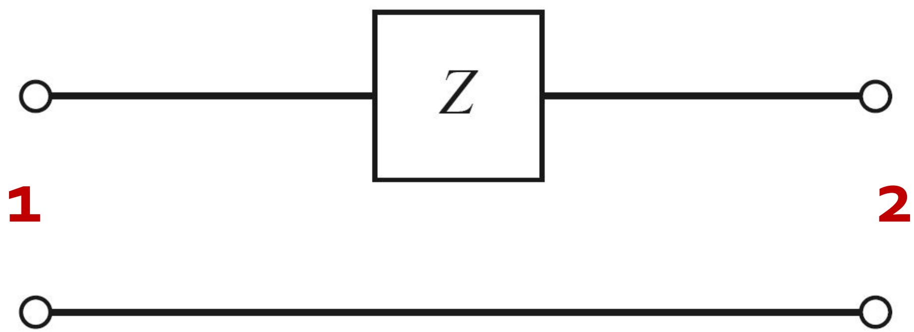
$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \cdot \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix}$$

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

- Impedanta serie



$$A = 1 \qquad B = Z$$

$$C = 0 \qquad D = 1$$

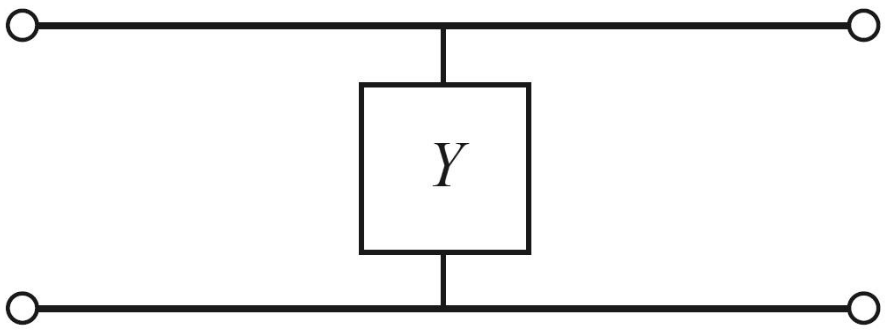
$$\begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix}$$

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

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

Matrici ABCD

- Admitanta paralel



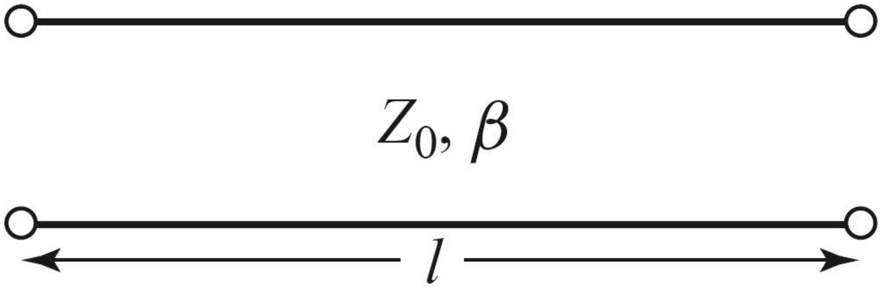
$$A = 1 \qquad B = 0$$
$$C = Y \qquad D = 1$$

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

Verificare - tema!

Matrici ABCD

- Sectiune de linie de transmisie



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

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

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

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

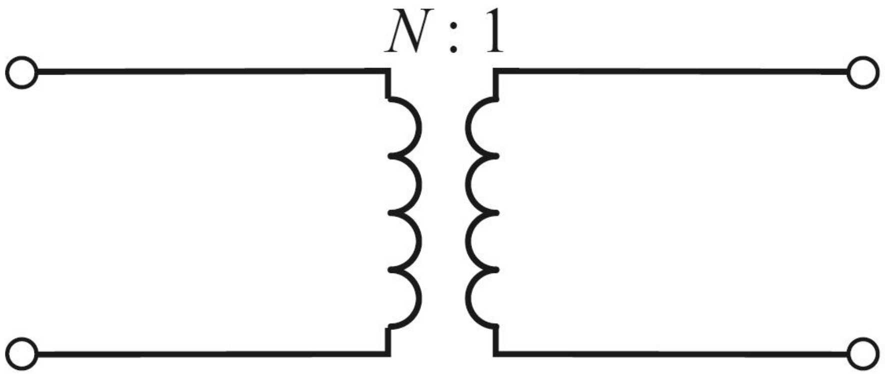
$$\begin{bmatrix} \cos\beta\cdot l & j\cdot Z_0\cdot\sin\beta\cdot l \\ j\cdot Y_0\cdot\sin\beta\cdot l & \cos\beta\cdot l \end{bmatrix}$$

Verificare - tema!

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

Matrici ABCD

- Transformator



$$A = N \qquad B = 0$$

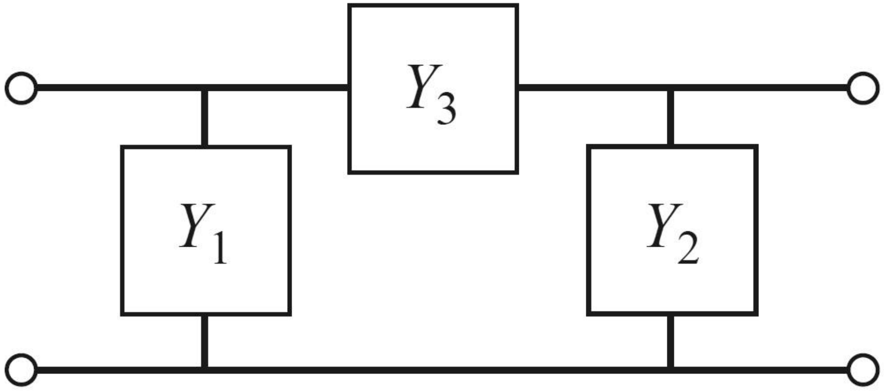
$$C = 0 \qquad D = \frac{1}{N}$$

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

Verificare - tema!

Matrici ABCD

- diport π



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

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

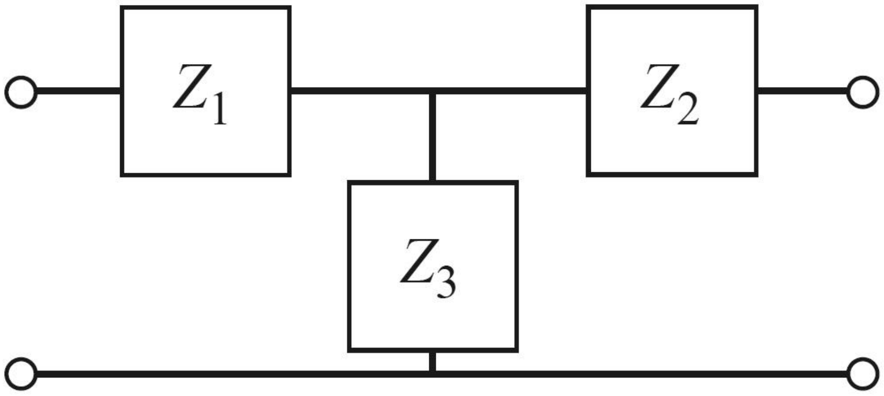
$$C = Y_1 + Y_2 + \frac{Y_1 \cdot Y_2}{Y_3}$$

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

Verificare - tema!

Matrici ABCD

- diport T



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

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

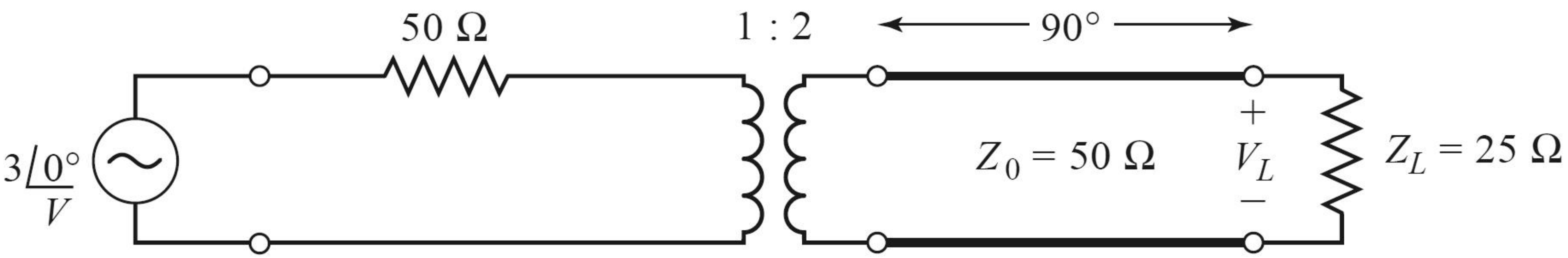
$$C = \frac{1}{Z_3}$$

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

Verificare - tema!

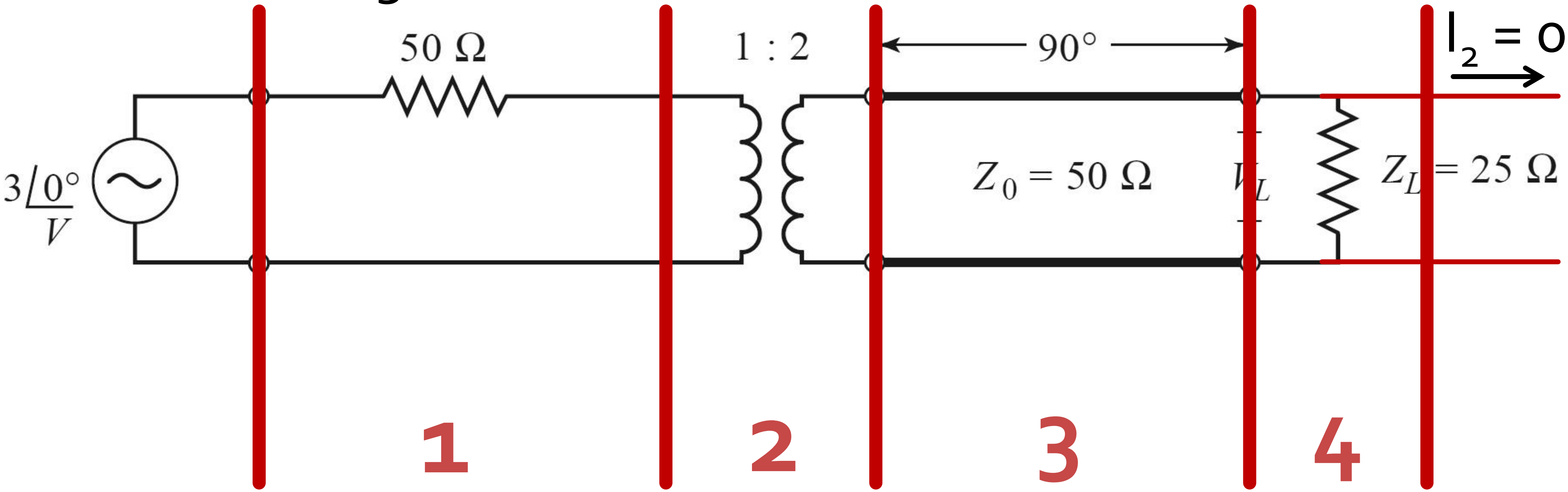
Exemplu utilizare matrice ABCD

- Determinati tensiunea pe sarcina in circuitul urmator



Exemplu utilizare matrice ABCD

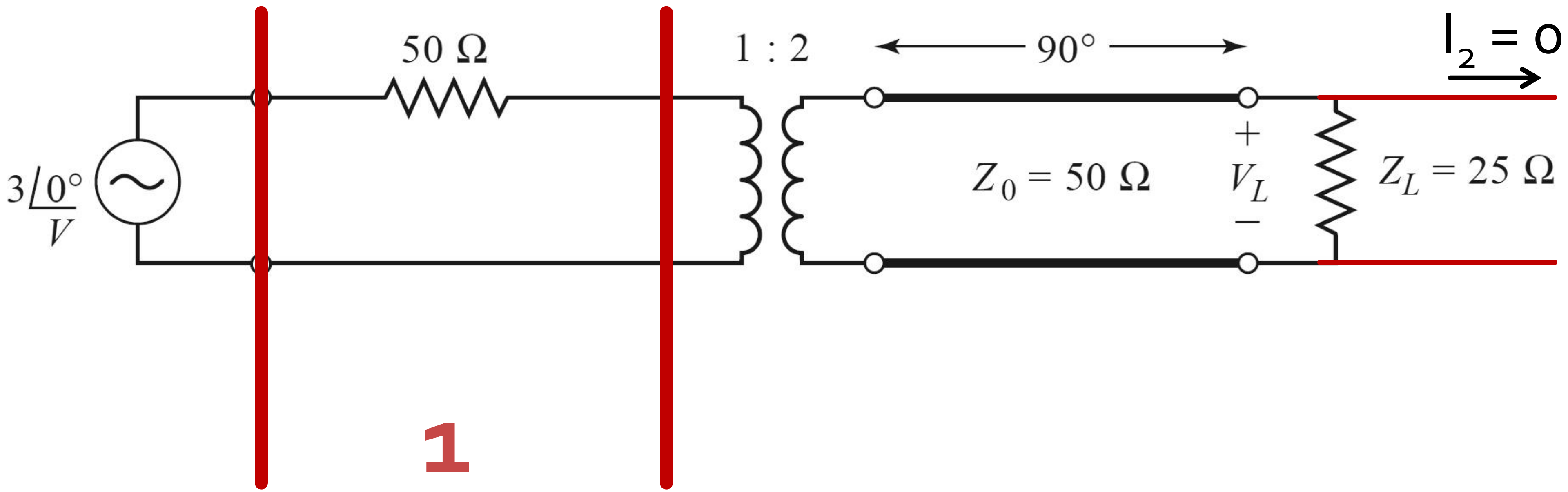
- Sectionare circuit in elemente simple
- Generatoarele raman in exterior
- Daca e necesar, se creaza porturi de intrare si iesire lasate in gol



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

Exemplu utilizare matrice ABCD

- M_1 , impedanta serie

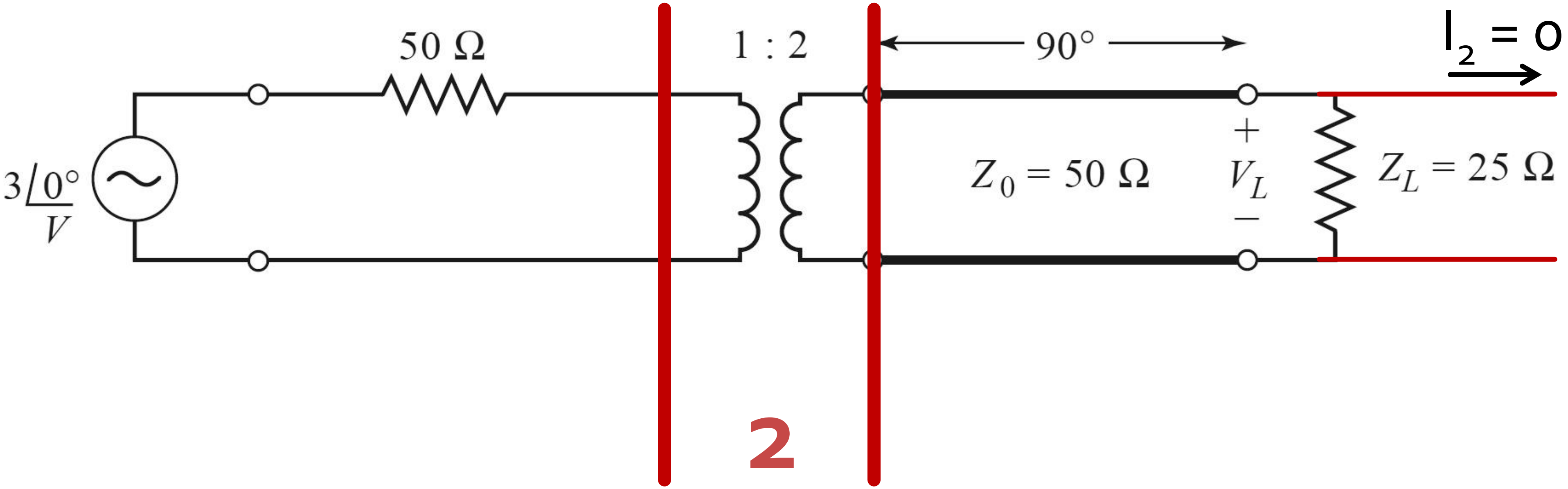


$$M_1 = \begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 50 \\ 0 & 1 \end{bmatrix}$$

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

Exemplu utilizare matrice ABCD

- M_2 , transformator 1:2

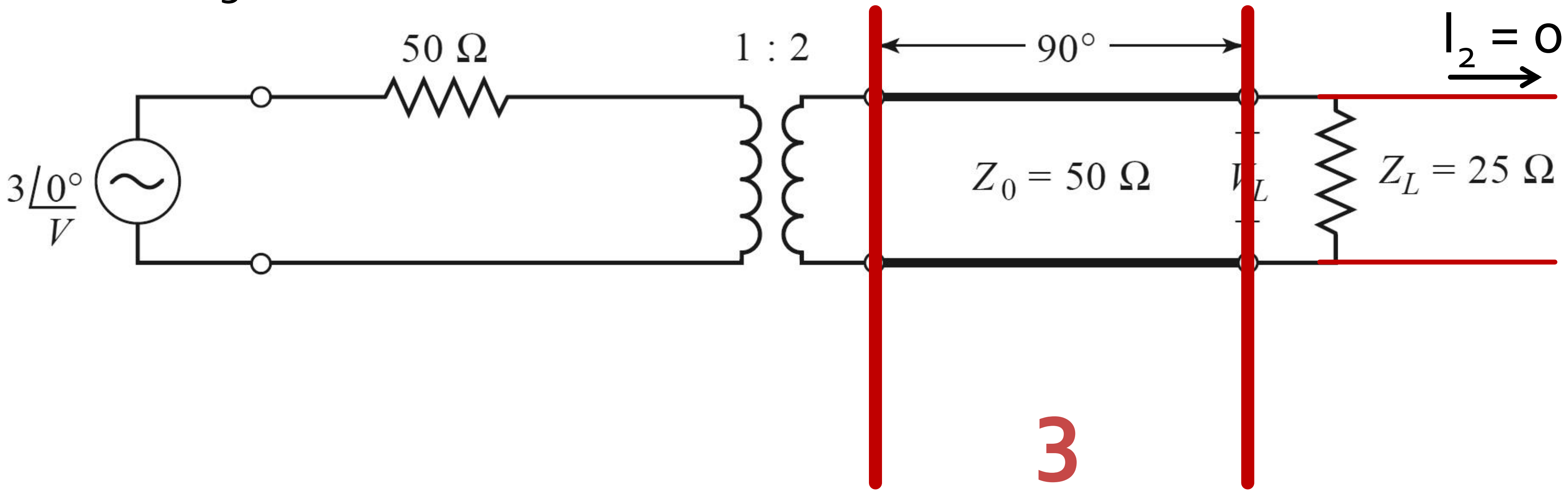


$$M_2 = \begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1/2 & 0 \\ 0 & 2 \end{bmatrix}$$

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

Exemplu utilizare matrice ABCD

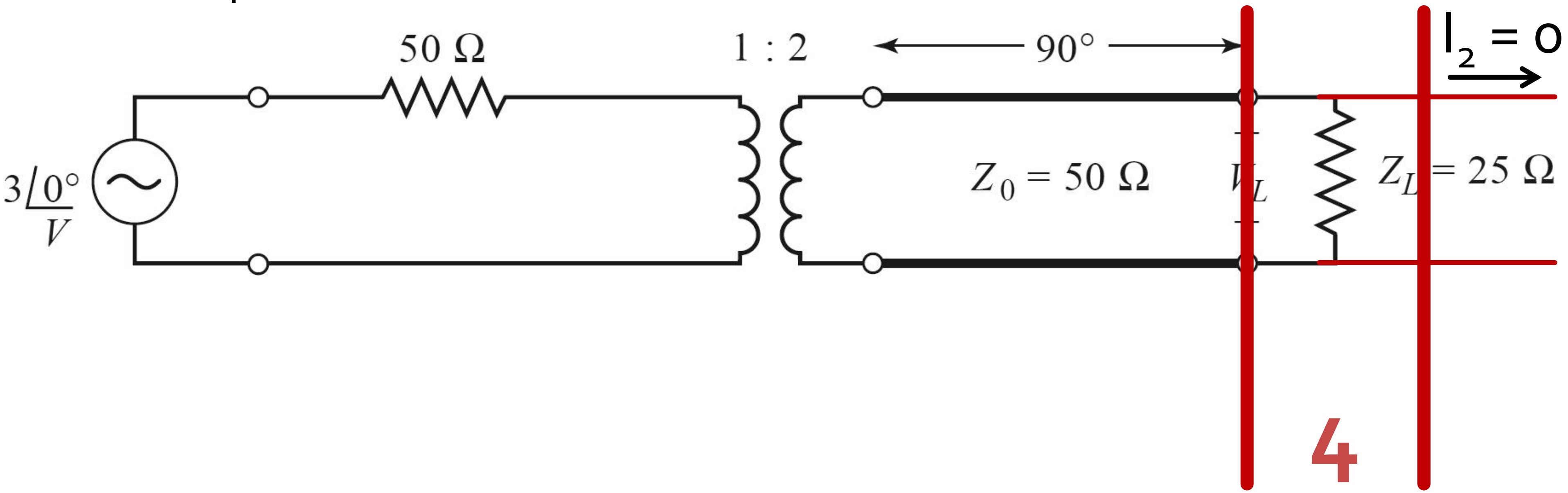
- M_3 , linie serie, E = 90°



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

Exemplu utilizare matrice ABCD

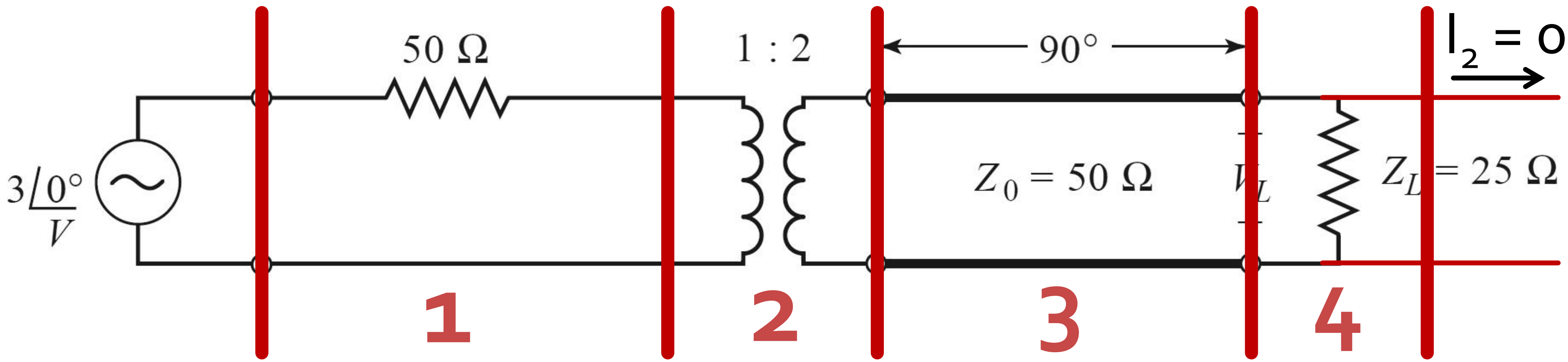
- M_4 , impedanta/admitanta paralel



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

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

Exemplu utilizare matrice ABCD

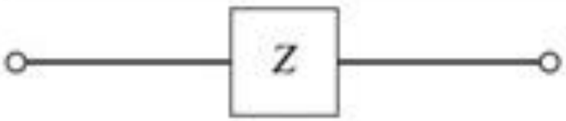
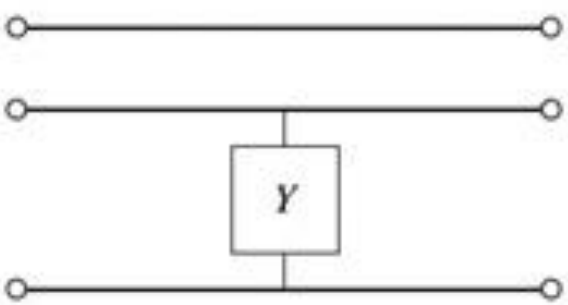
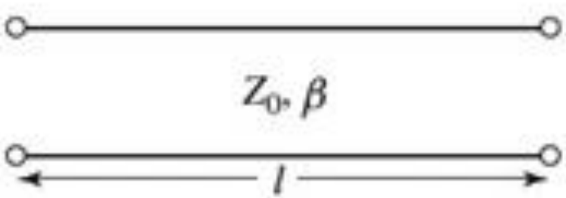


$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 50 \\ 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} \frac{1}{2} & 0 \\ 0 & 2 \end{bmatrix} \cdot \begin{bmatrix} 0 & 50 \cdot j \\ \frac{j}{50} & 0 \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 \\ \frac{1}{25} & 1 \end{bmatrix} = \begin{bmatrix}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

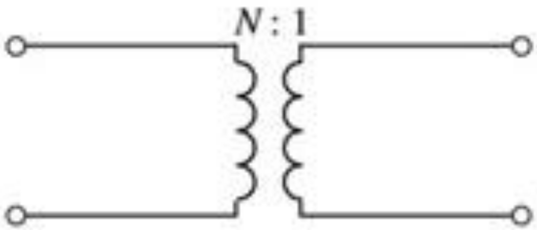
$$V_L = \frac{V}{A} = \frac{3\angle 0^\circ}{3 \cdot j} = 1\angle -90^\circ$$

Biblioteci de matrici ABCD

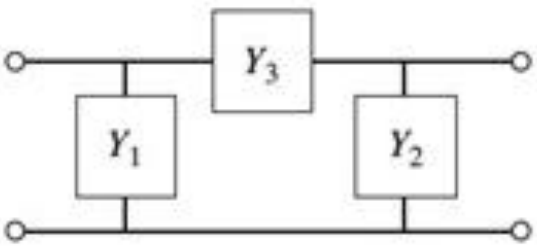
TABLE 4.1 ***ABCD* Parameters of Some Useful Two-Port Circuits**

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

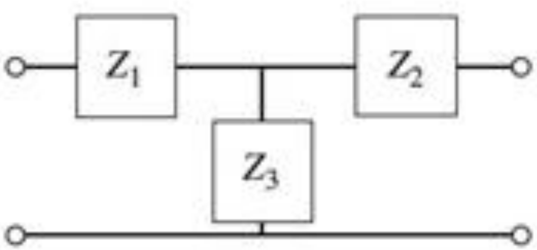
Biblioteci de matrici ABCD



$$A = N \qquad B = 0$$
$$C = 0 \qquad D = \frac{1}{N}$$



$$A = 1 + \frac{Y_2}{Y_3} \qquad B = \frac{1}{Y_3}$$
$$C = Y_1 + Y_2 + \frac{Y_1 Y_2}{Y_3} \qquad D = 1 + \frac{Y_1}{Y_3}$$



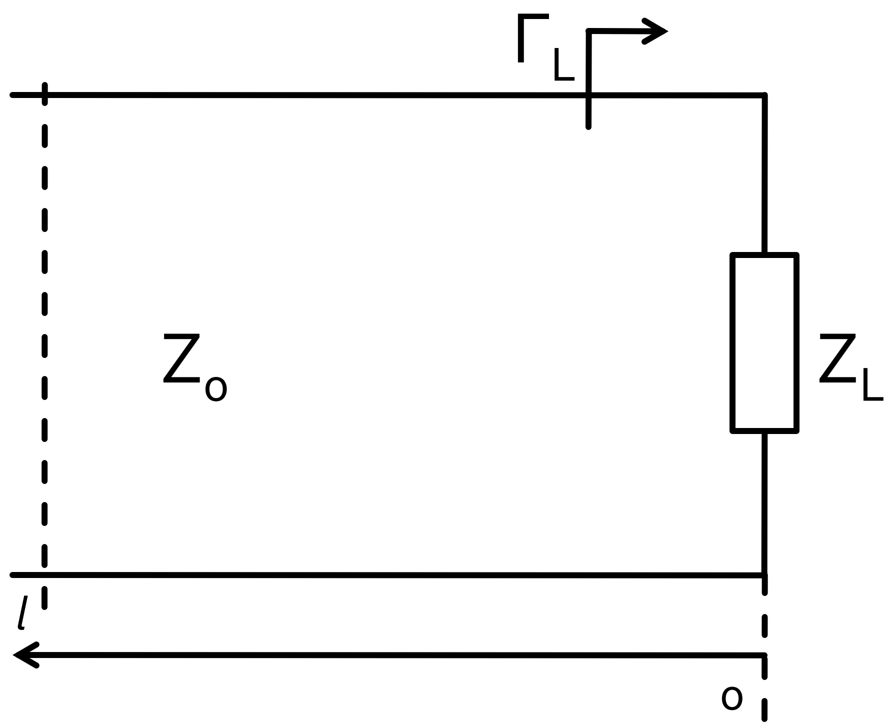
$$A = 1 + \frac{Z_1}{Z_3} \qquad B = Z_1 + Z_2 + \frac{Z_1 Z_2}{Z_3}$$
$$C = \frac{1}{Z_3} \qquad D = 1 + \frac{Z_2}{Z_3}$$

Table 4.1

Matricea S

Analiza la nivel de rețea a circuitelor de microunde

Linie fara pierderi – C3



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

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

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

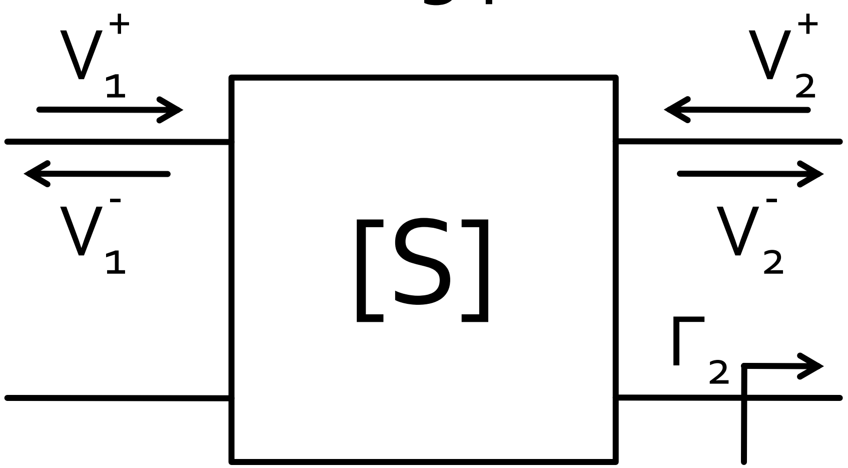
- coeficient de reflexie in tensiune

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

- Z_0 real

Matricea S (repartitie)

- Scattering parameters



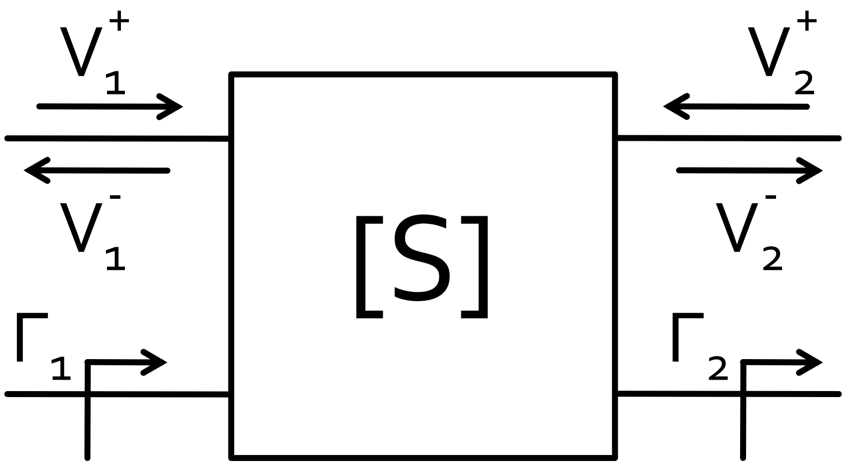
$$\begin{bmatrix} V_1^- \\ V_2^- \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} V_1^+ \\ V_2^+ \end{bmatrix}$$

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

- $V_2^+ = 0$ 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)



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

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

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

- S11 este coeficientul de reflexie la portul ***1*** cand cand portul ***2*** este terminat pe impedanta care realizeaza adaptarea
- S21 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)

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

- 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_{oi}
- Curs 3

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

In planul de referinta al portului, z=o

$$V_i = V_i^+ + V_i^- \qquad I_i = \frac{V_i^+}{Z_{0i}} - \frac{V_i^-}{Z_{0i}} \qquad [Z_0] = \begin{bmatrix} Z_{01} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & Z_{0n} \end{bmatrix}$$

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

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

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

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

Deplasare a planului de referinta

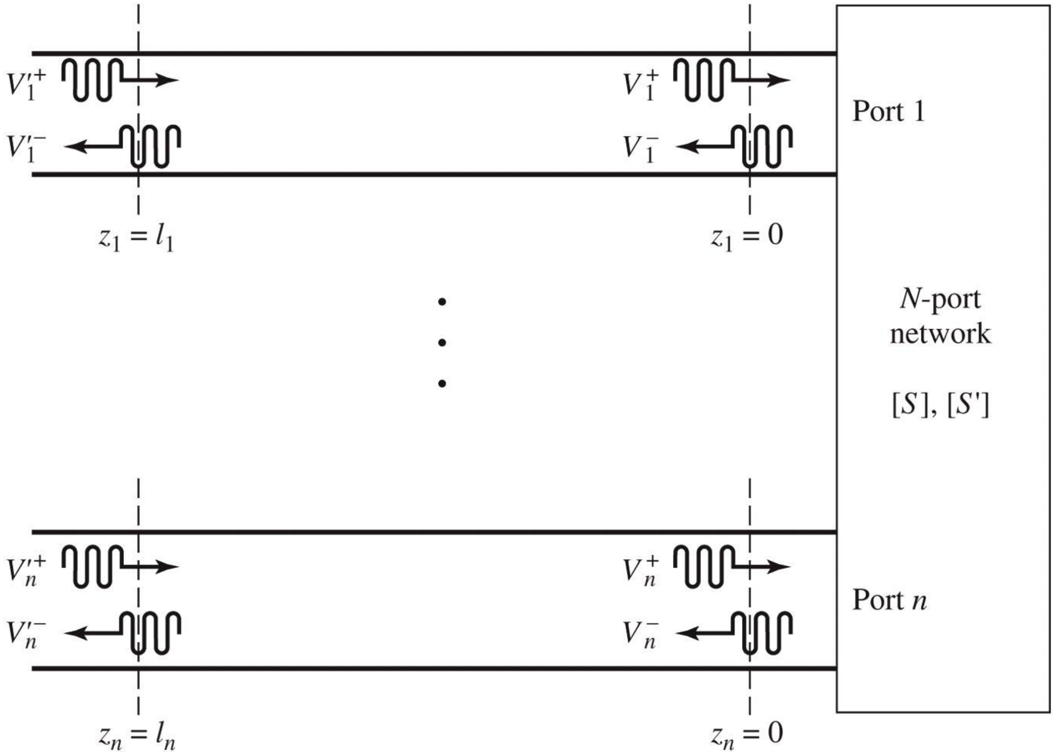


Figure 4.9

- De-Embedding
- Decapsulare

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

Proprietati [S]

- Circuite reciproce (fara circuite active, ferite)

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

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

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

- Circuite fara pierderi

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

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

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

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

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

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

Matricea S generalizata

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

$$V = V_0^+ + V_0^- \qquad I = \frac{1}{Z_0}\cdot\left(V_0^+ - V_0^-\right)$$

planul de referinta al portului, z=o

- Aflam amplitudinile undelor de tensiune

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

- Puterea oferita sarcinii la iesirea din linie:

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

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

Matricea S generalizata

- Puterea oferita sarcinii la iesirea din linie:

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

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

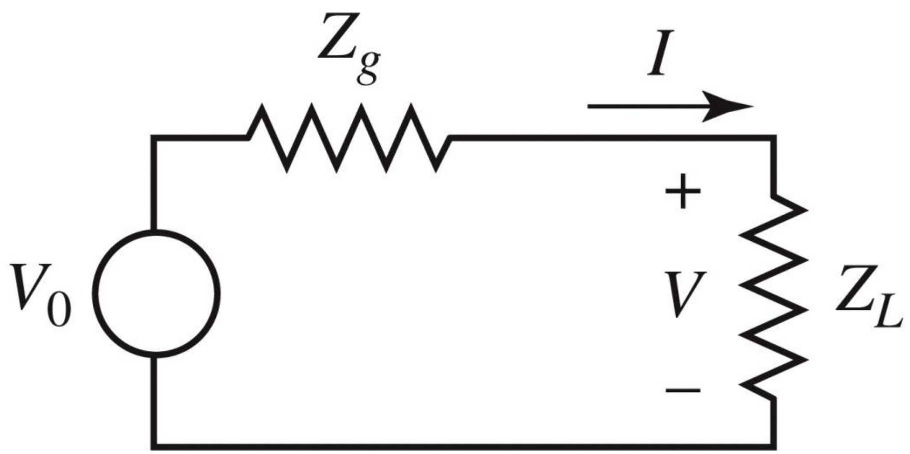


Figure 4.10

Matricea S generalizata

- Definim undele de putere

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

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

$$Z_R = R_R + j \cdot X_R$$

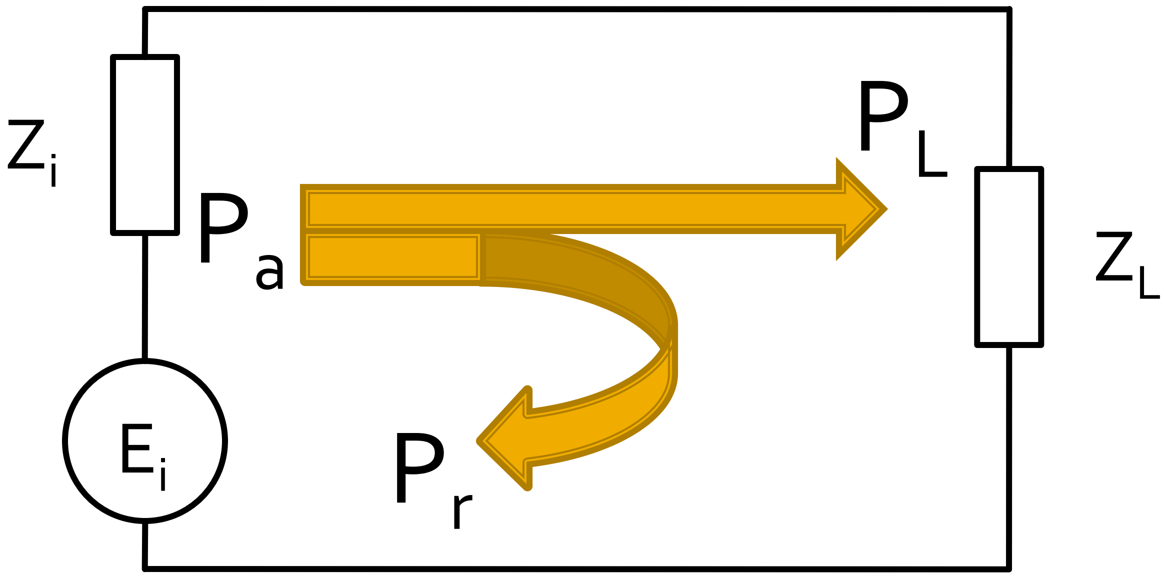
O impedanta de referinta oarecare, complexa

- 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



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

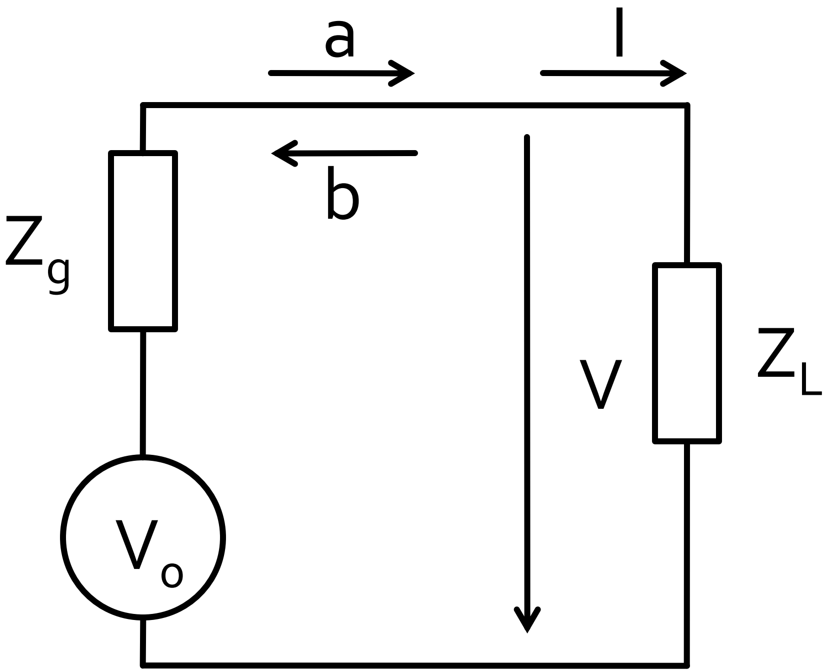
$$P_L = \frac{R_L \cdot |E_i|^2}{(R_i+R_L)^2 + (X_i+X_L)^2}$$

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

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

- coeficient de reflexie in putere

Unde de putere



$$P_L = \frac{1}{2}\cdot \mathrm{Re}\left\{V \cdot I^*\right\}$$

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

$$P_L = \frac{1}{2R_R}\cdot \mathrm{Re}\left\{Z_R^* \cdot |a|^2 - \underbrace{Z_R^* \cdot a \cdot b^* + Z_R \cdot a^* \cdot b}_{\left(z - z^*\right) = \mathrm{Im}} - Z_R \cdot |b|^2\right\}$$

$$\boxed{\forall Z_R \in C}$$

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

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

Unde de putere

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

- Daca aleg $Z_R = Z_L^*$

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

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

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

Unde de putere

- Daca in plus generatorul este adaptat conjugat cu sarcina

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

- Reflexie in putere C4

$$Z_L = Z_i^* \qquad P_{L\max} \equiv P_a \qquad \Gamma = \frac{Z - Z_0^*}{Z + Z_0}$$

$$Z_L \neq Z_i^* \qquad P_r = P_a\cdot|\Gamma|^2 \qquad P_L = P_a - P_r = P_a - P_a\cdot|\Gamma|^2 = P_a\cdot\left(1-|\Gamma|^2\right)$$

- Reflexie in putere C5

$$P_{L\max} \equiv P_a = \frac{1}{2}\cdot|a|^2 \qquad P_L = \frac{1}{2}\cdot|a|^2 - \frac{1}{2}\cdot|b|^2 \qquad \Gamma_p = \frac{b}{a} = \frac{V - Z_R^*\cdot I}{V + Z_R\cdot I} = \frac{Z_L - Z_R^*}{Z_L + Z_R}$$

$$P_L = \frac{1}{2}\cdot|a|^2 - \frac{1}{2}\cdot|a|^2\cdot|\Gamma_p|^2 \qquad P_L = P_a\cdot\left(1-|\Gamma_p|^2\right) \qquad P_r = P_a\cdot|\Gamma_p|^2 = \frac{1}{2}\cdot|b|^2$$

Unde de putere

- Definitii de unde pentru n-porti

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

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

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

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

Unde de putere pentru multiporti

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

- legatura intre undele de putere incidenta si reflectata

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

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

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

- tipic

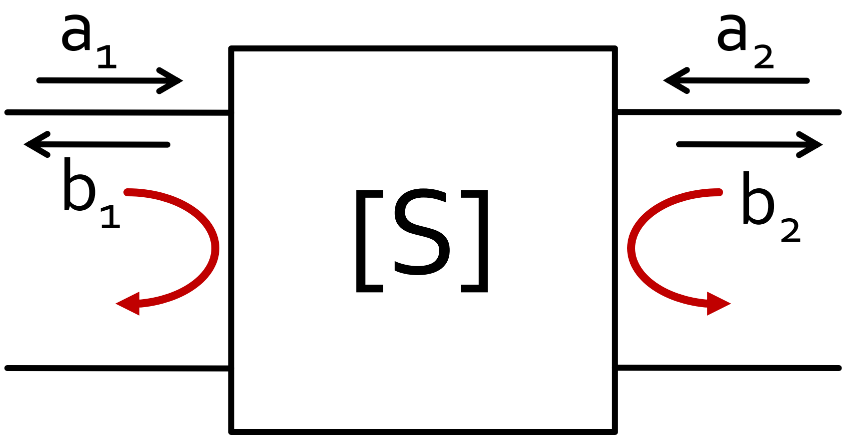
$$Z_{0i}=Z_{Ri}=R_0,\forall i$$

$$R_0=50\Omega$$

$$\boxed{\left[S_p\right]\equiv[S]}$$

- **coincid!!!**

Matricea S (repartitie)

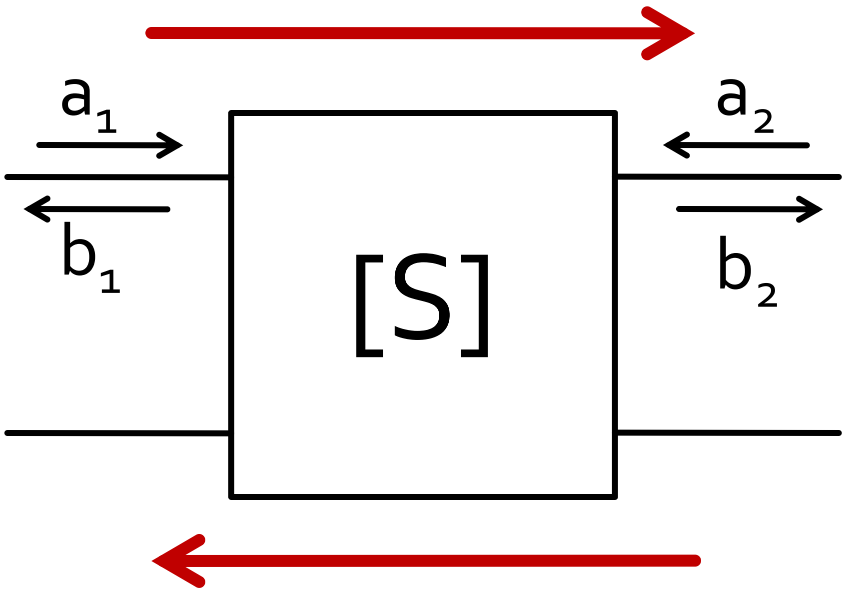


$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

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

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

Matricea S (repartitie)

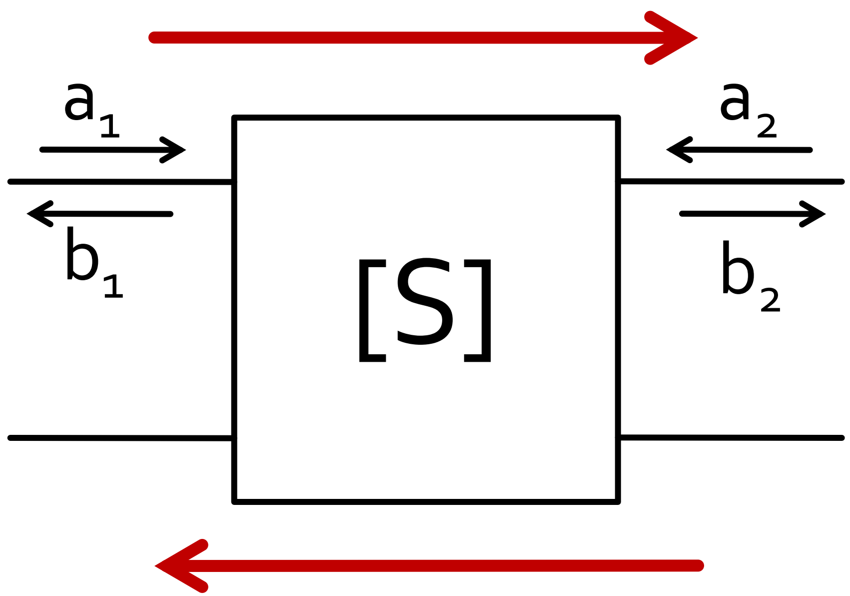


$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

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

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

Matricea S (repartitie)



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

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

- 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

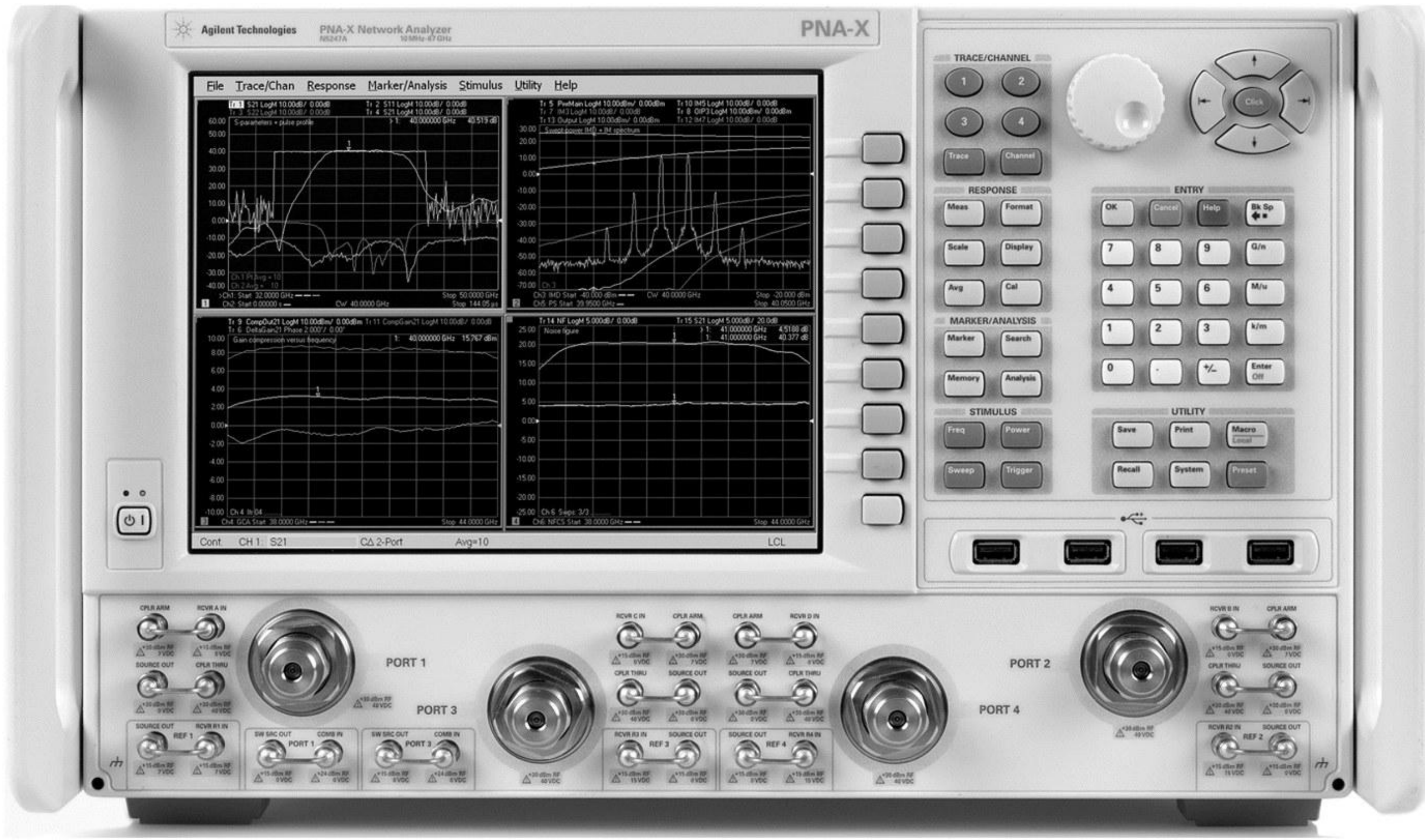


Figure 4.7
Courtesy of Agilent Technologies

Legatura dintre parametrii S si parametrii ABCD

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

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

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

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

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

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

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

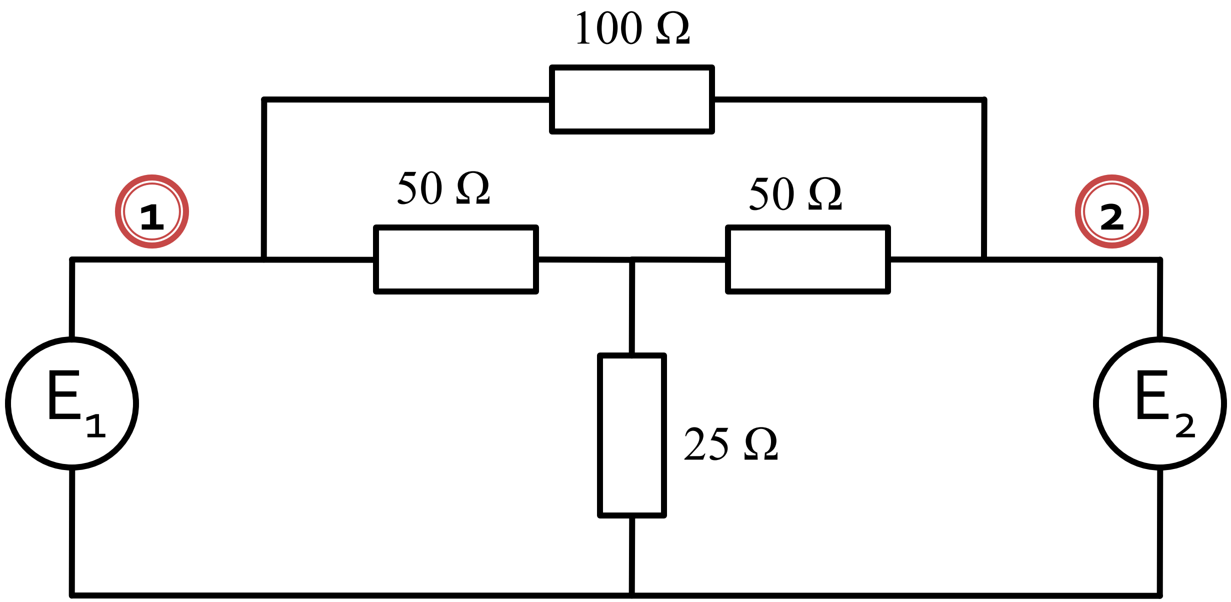
$$S_{21} = \frac{2\sqrt{Z_{01}Z_{02}}}{AZ_{02}+B+CZ_{01}Z_{02}+DZ_{01}}$$

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

Analiza pe mod par/impar

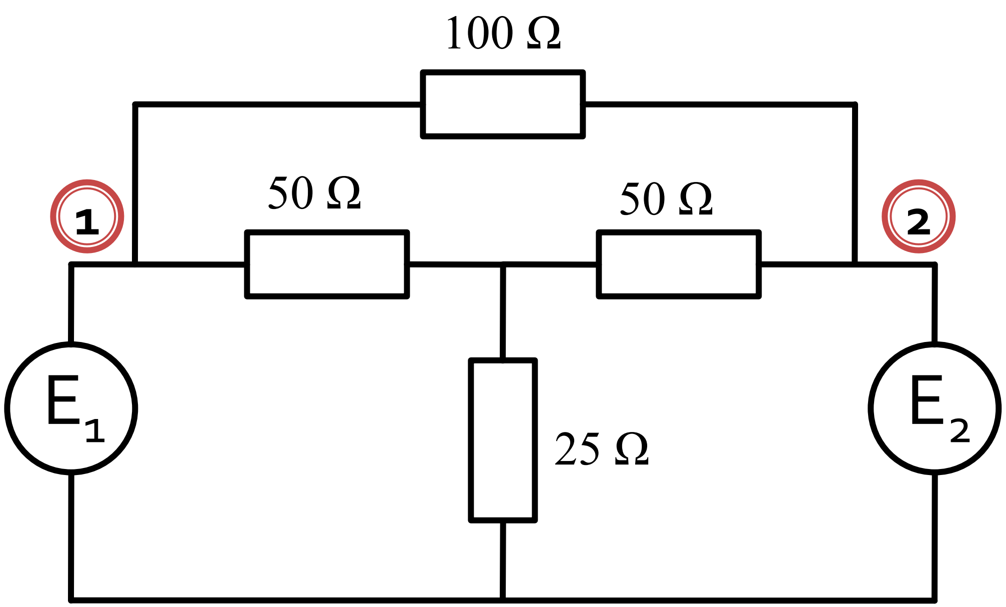
Analiza pe mod par/impar (even/odd)

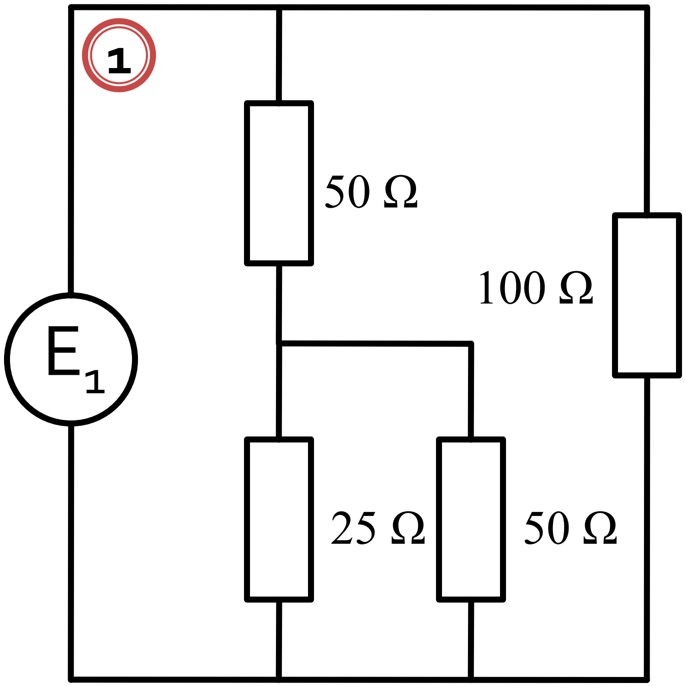
- utila/necesara pentru multiporti
- exemplu, rezistori, circuit cu 2 porturi



Analiza pe mod par/impar (even/odd)

- presupunem ca doresc Y_{11} $\quad Y_{11} = \left.\frac{I_1}{V_1}\right|_{V_2=0}$
- $E_2 = 0$



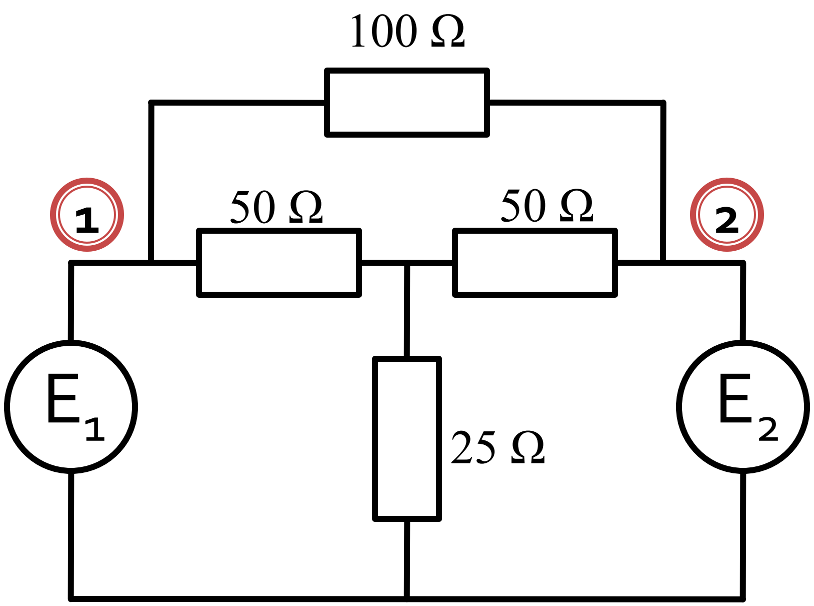


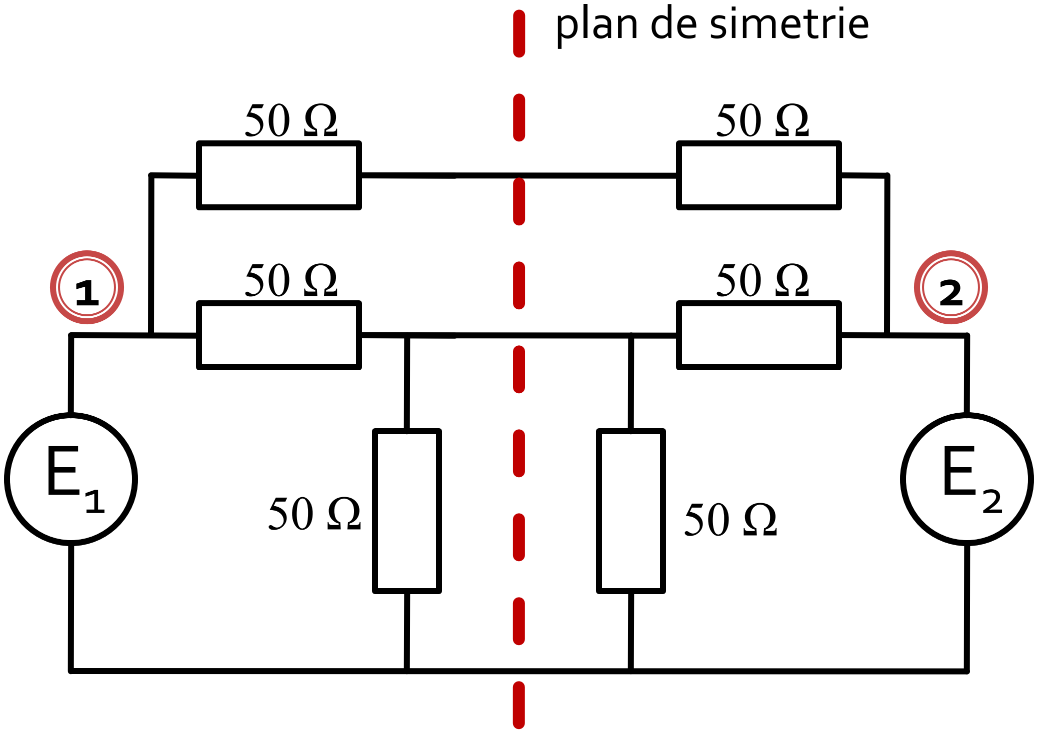
$$R_{ech} = 100\Omega \,||\, (50\Omega + 25\Omega \,||\, 50\Omega) =$$
$$= 100\Omega \,||\, (50\Omega + 16.67\Omega) = 100\Omega \,||\, 66.67\Omega = 40\Omega$$

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

Analiza pe mod par/impar (even/odd)

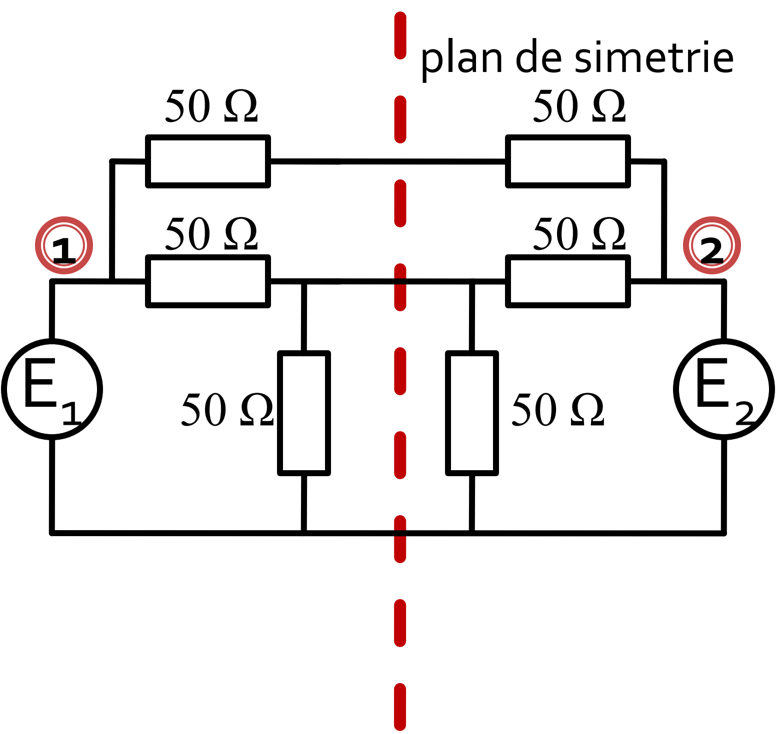
- analiza pe mod par/impar beneficiaza de existenta in circuit a unor plane de simetrie
  - initiale
  - create

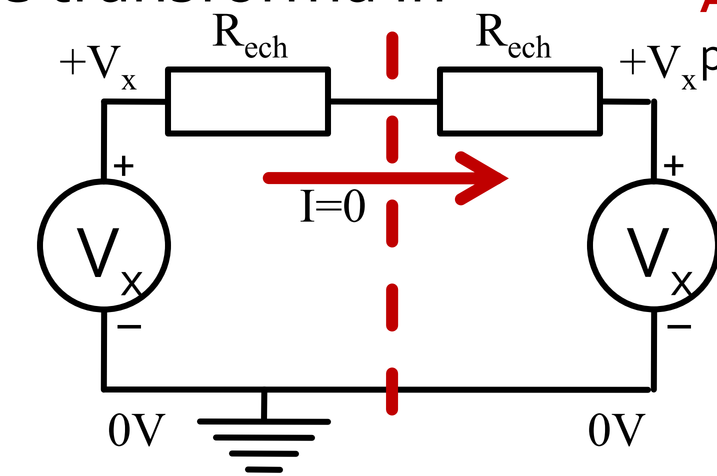




Analiza pe mod par/impar (even/odd)

- la atacul porturilor cu surse simetrice/antisimetrice planele de simetrie se transforma in
  - gol virtual
  - masa virtuala

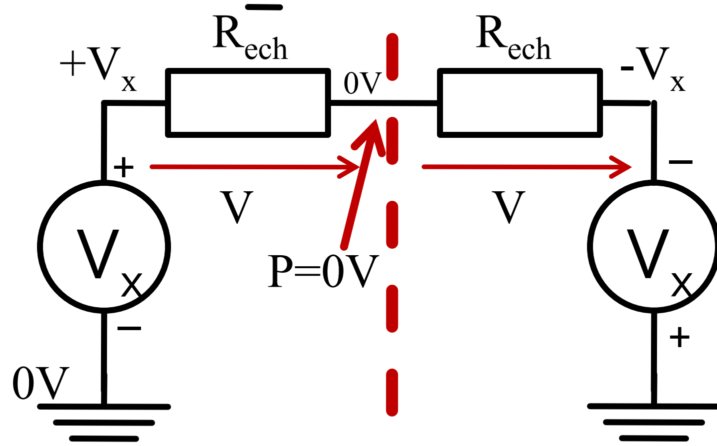




Aceeasi polaritate pentru surse

$$I = 0, \forall V_x$$

plan de simetrie **gol**



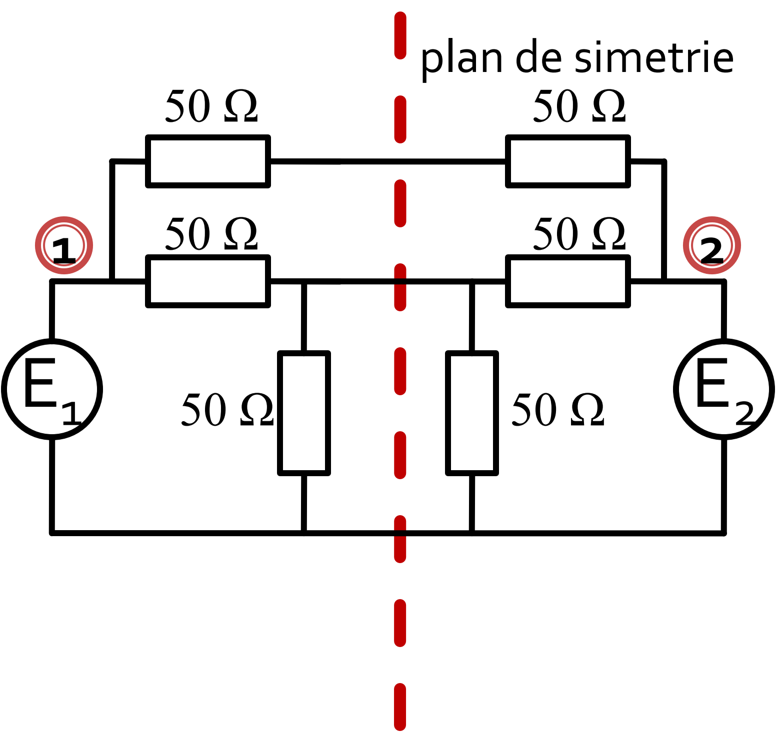
Polaritate **diferita** pentru surse

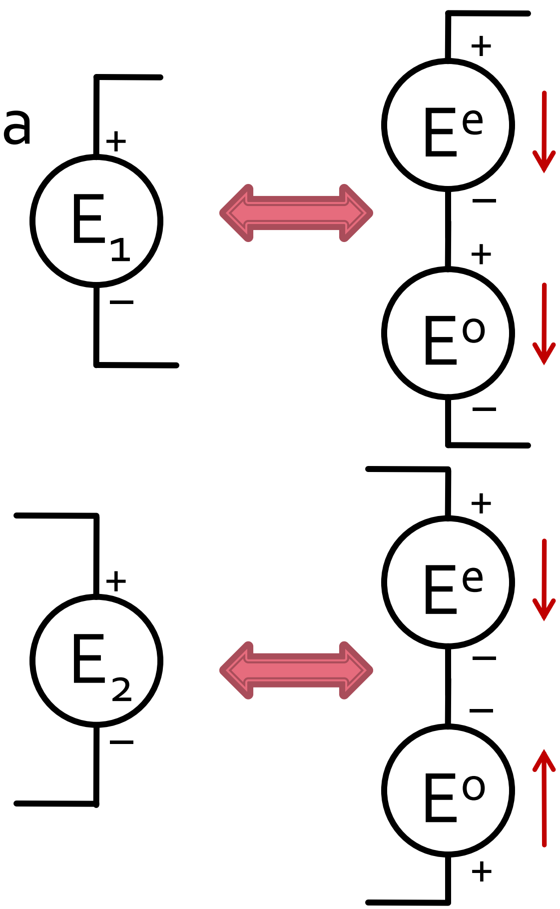
$$P = 0, \forall V_x$$

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

Efect (Sursa1 + Sursa2) = Efect (Sursa1) + Efect (Sursa2)

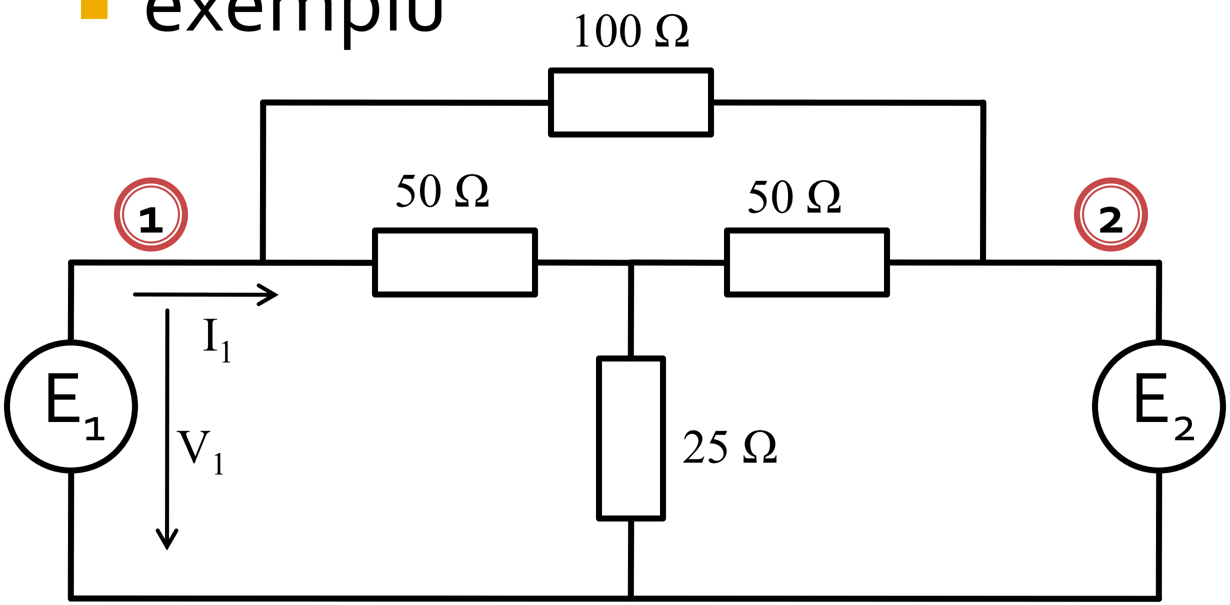
Efect (PAR + IMPAR) = Efect (PAR) + Efect (IMPAR)

$$\underbrace{\text{PAR + IMPAR}}_{\text{OARECARE}}$$

Putem beneficia de avantajele simetriilor!!

Analiza pe mod par/impar (even/odd)

- exemplu

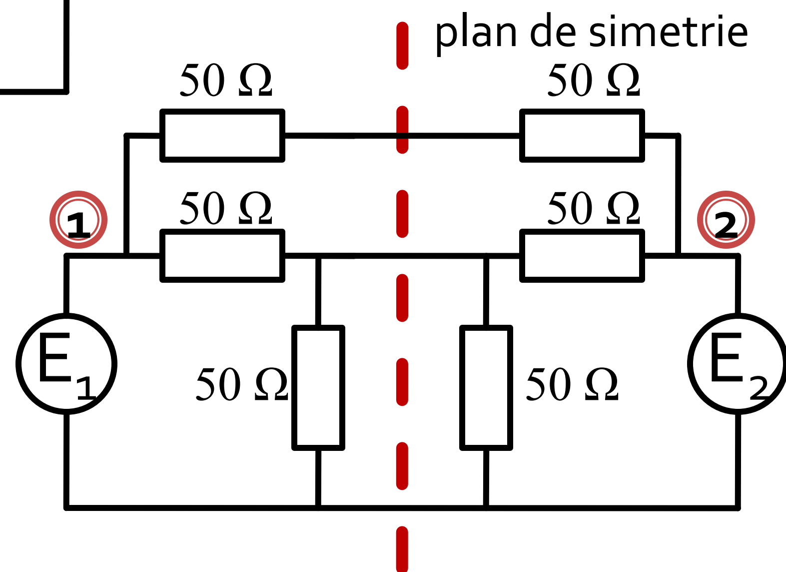


$$Y_{11} = \left.\frac{I_1}{V_1}\right|_{V_2=0}$$

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

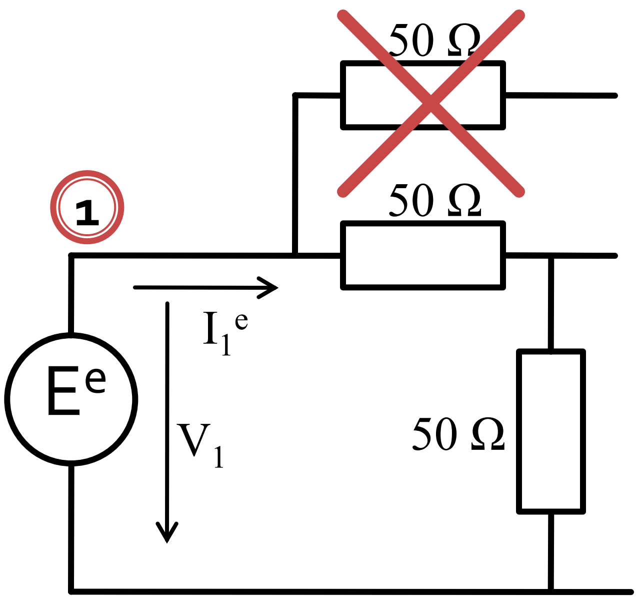
$$E^e = \frac{E_1}{2}$$

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



Analiza pe mod par/impar (even/odd)

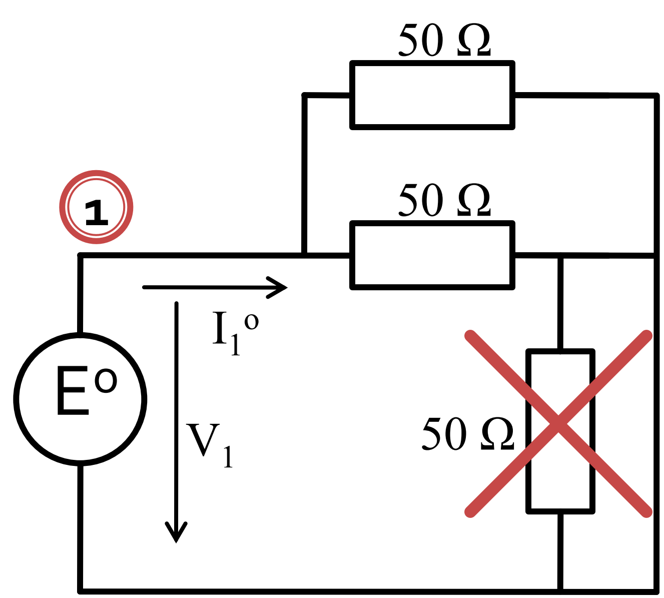
- analiza pe mod par/impar



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

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

PAR → plan de simetrie **gol**



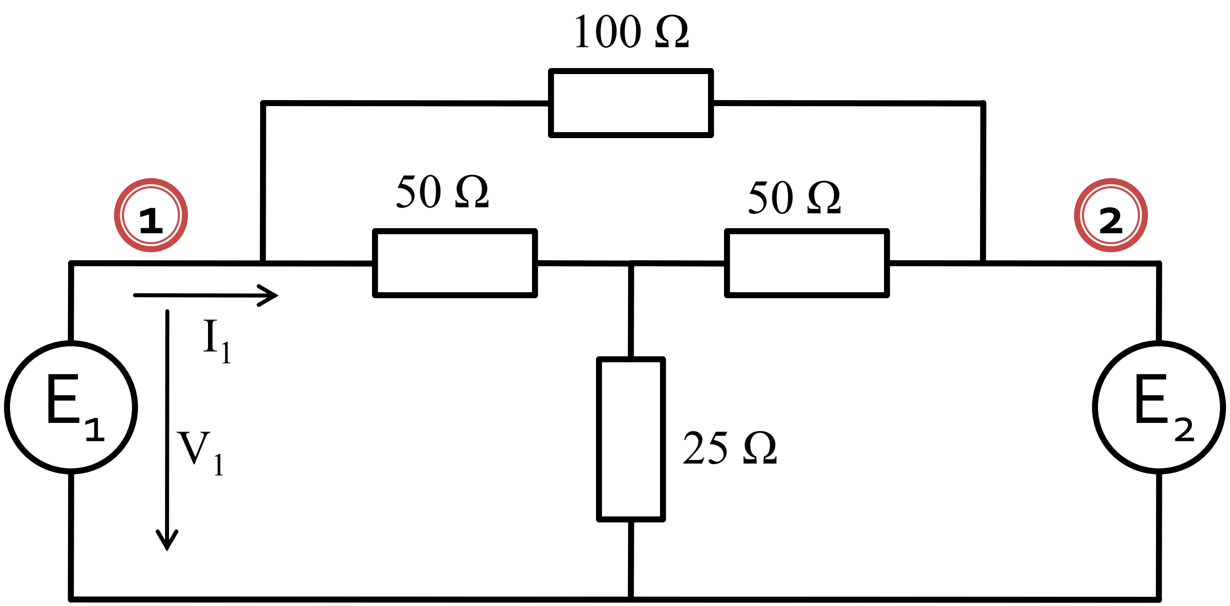
$$R^{o}_{ech} = 50\Omega \,||\, 50\Omega = 25\Omega$$

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

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)

Efect (PAR + IMPAR) = Efect (PAR) + Efect (IMPAR)

Putem beneficia de avantajele simetriilor!!

Puncte suplimentare

Tema

Tema C5

- Scrieți pe o foaie de hârtie (si scanați/foto) modalitatea de determinare a matricii ABCD pentru:
  - admitanță paralel
  - linie de transmisie
  - transformator
  - diport π
  - diport T

Cuploare directionale si divizoare de putere

Cuploare/Divizoare

- Funcționalitatea dorită:
  - divizarea
  - combinarea
- puterii semnalului

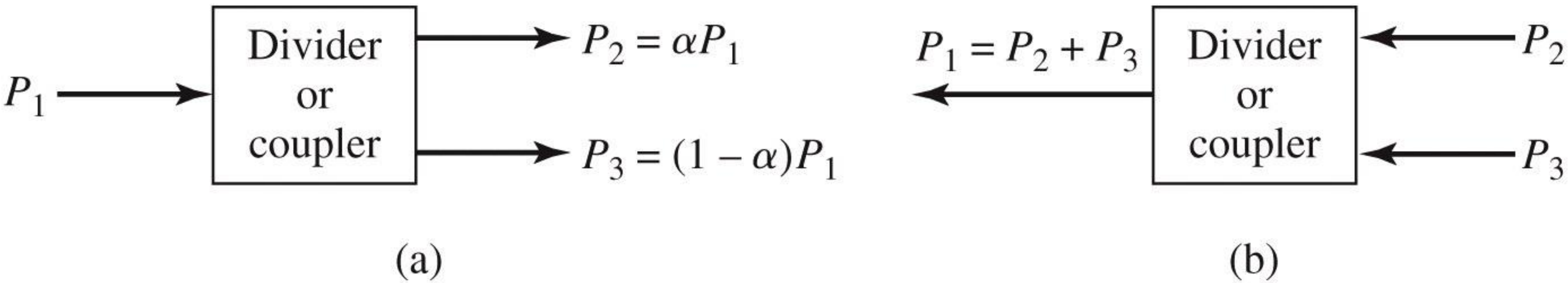


Figure 7.1

Circuite cu trei porți

- numite si joncțiune in T
- caracterizate de o matrice **S** 3x3

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

- 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 posibila**
- 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** 4x4

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

- 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 sa obținem circuitul **adaptat simultan la toate porțile**
  - evitarea unor pierderi externe de putere

Circuite cu patru porți

- Un circuit cu 4 porti 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

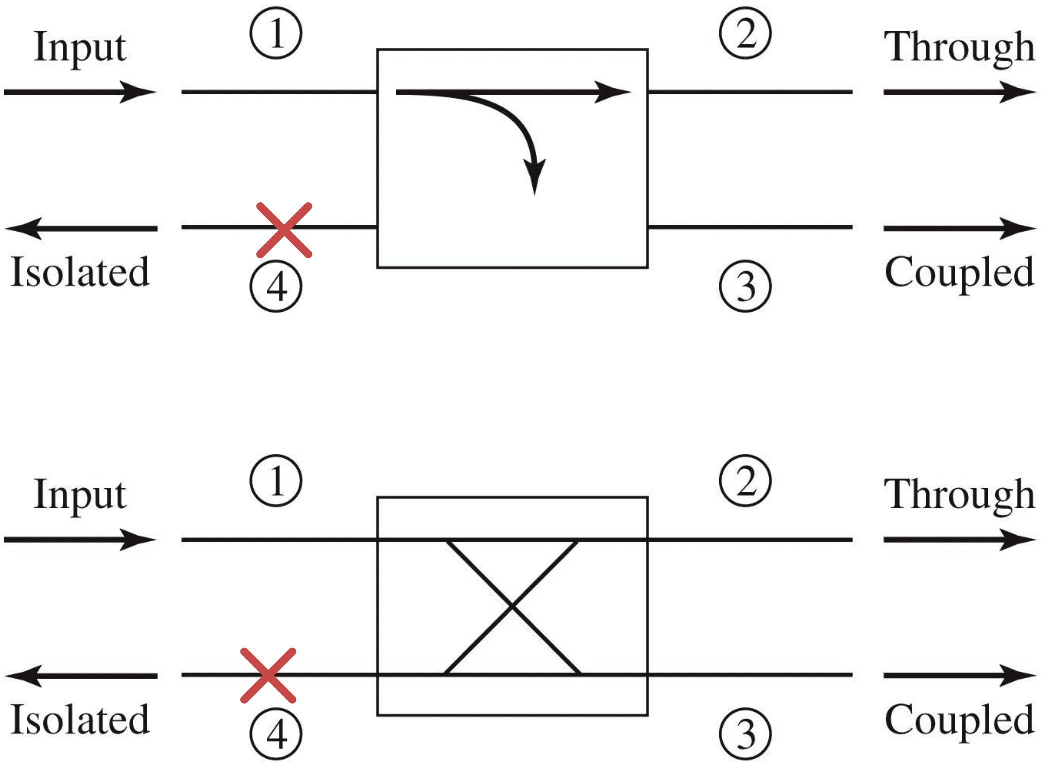


Figure 7.4

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

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

Cuplaj

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

Directivitate

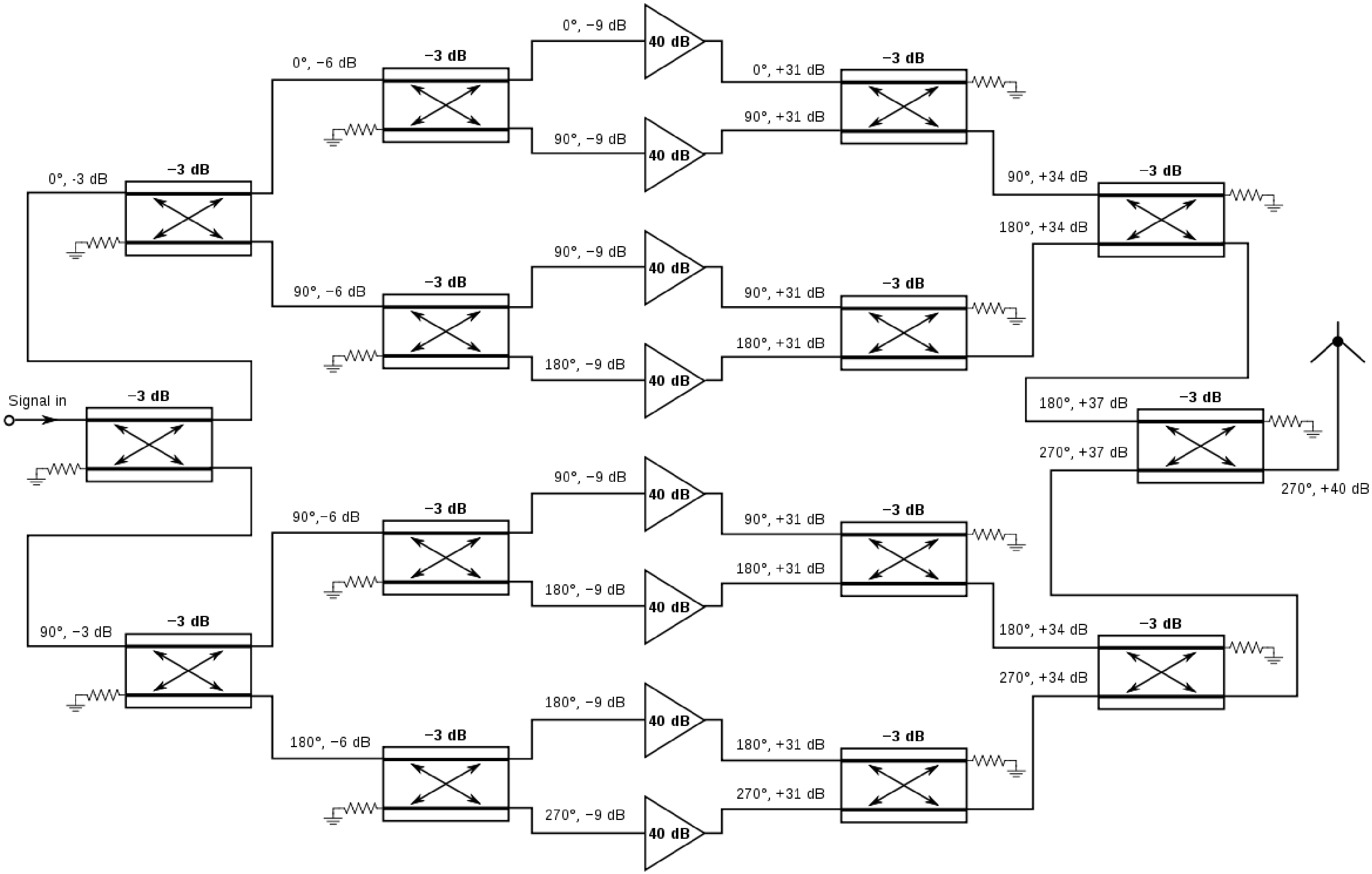
$$D = 10\log\frac{P_3}{P_4} = 20\cdot\log\left(\frac{\beta}{|S_{14}|}\right)[\text{dB}]$$

Izolare

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

$$I = D + C\;,\;\; dB$$

Amplificatoare echilibrate



Cuplorul hibrid în cuadratură (90°)

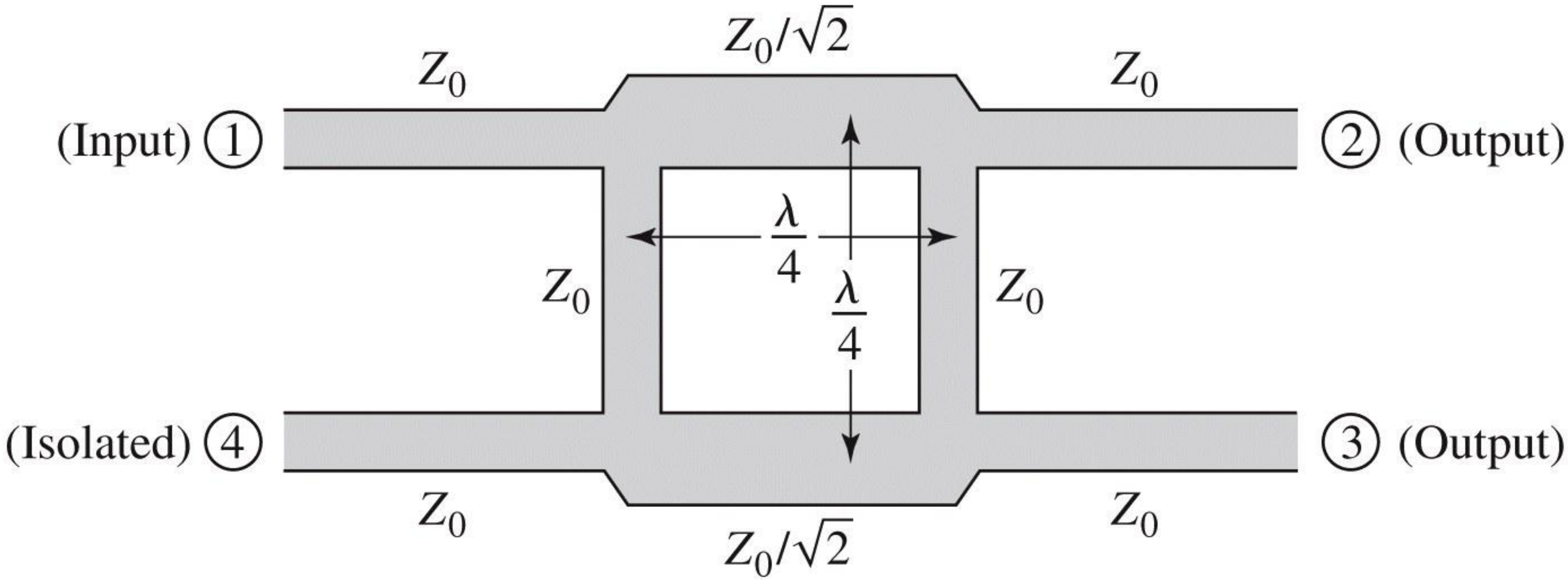
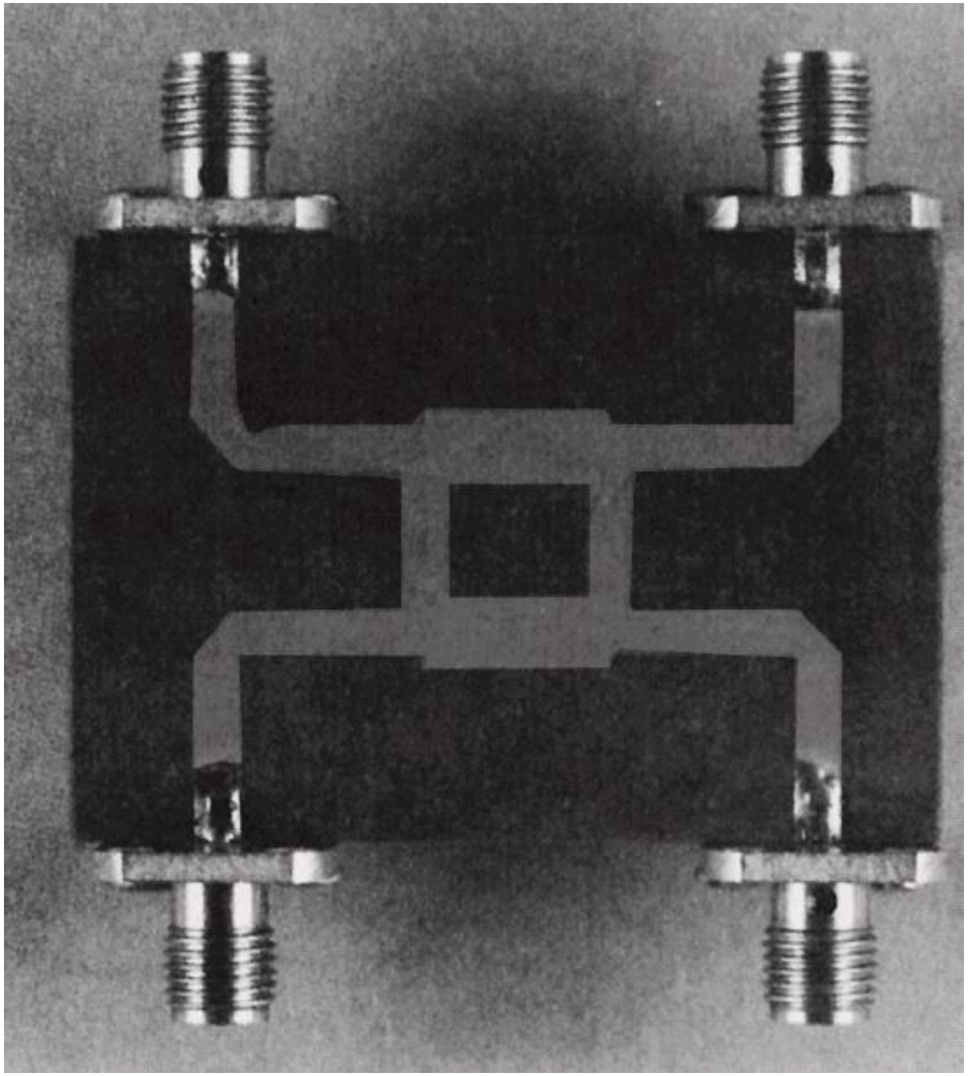


Figure 7.21

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



Cuplorul in cuadratura

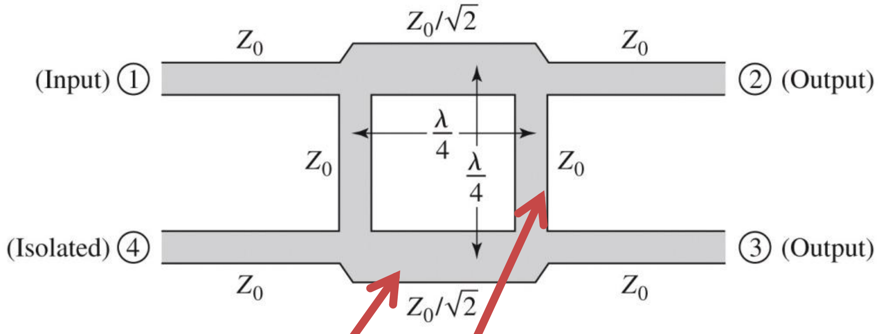


Figure 7.21

$$\boxed{y_2^2 = 1 + y_1^2}$$

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

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

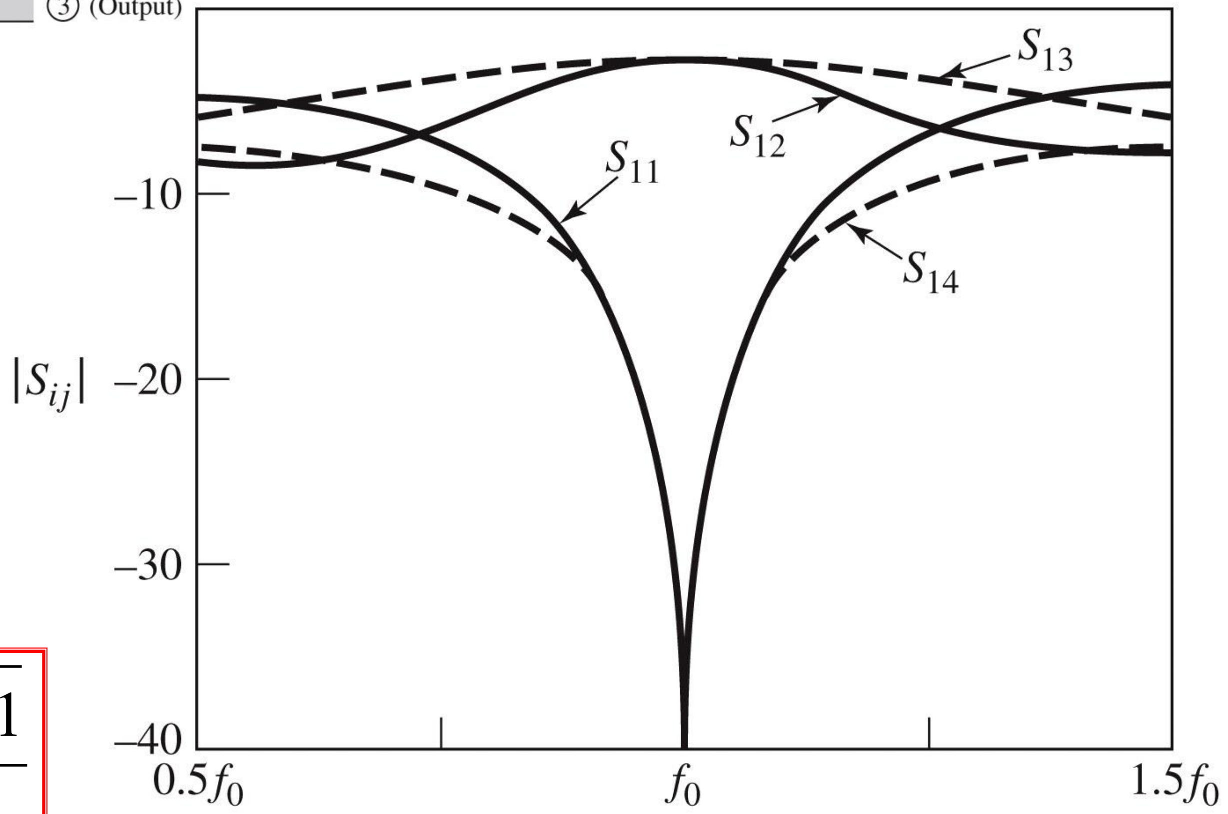
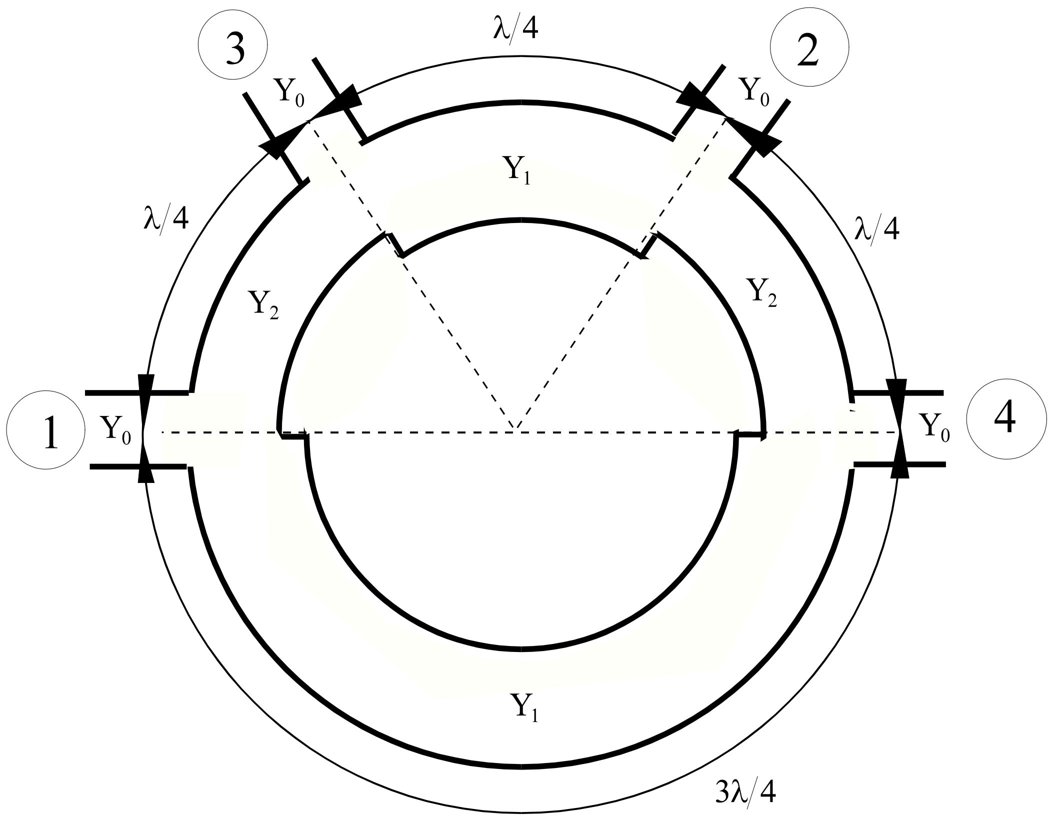


Figure 7.25

Cuplorul in inel



Cuplor în inel

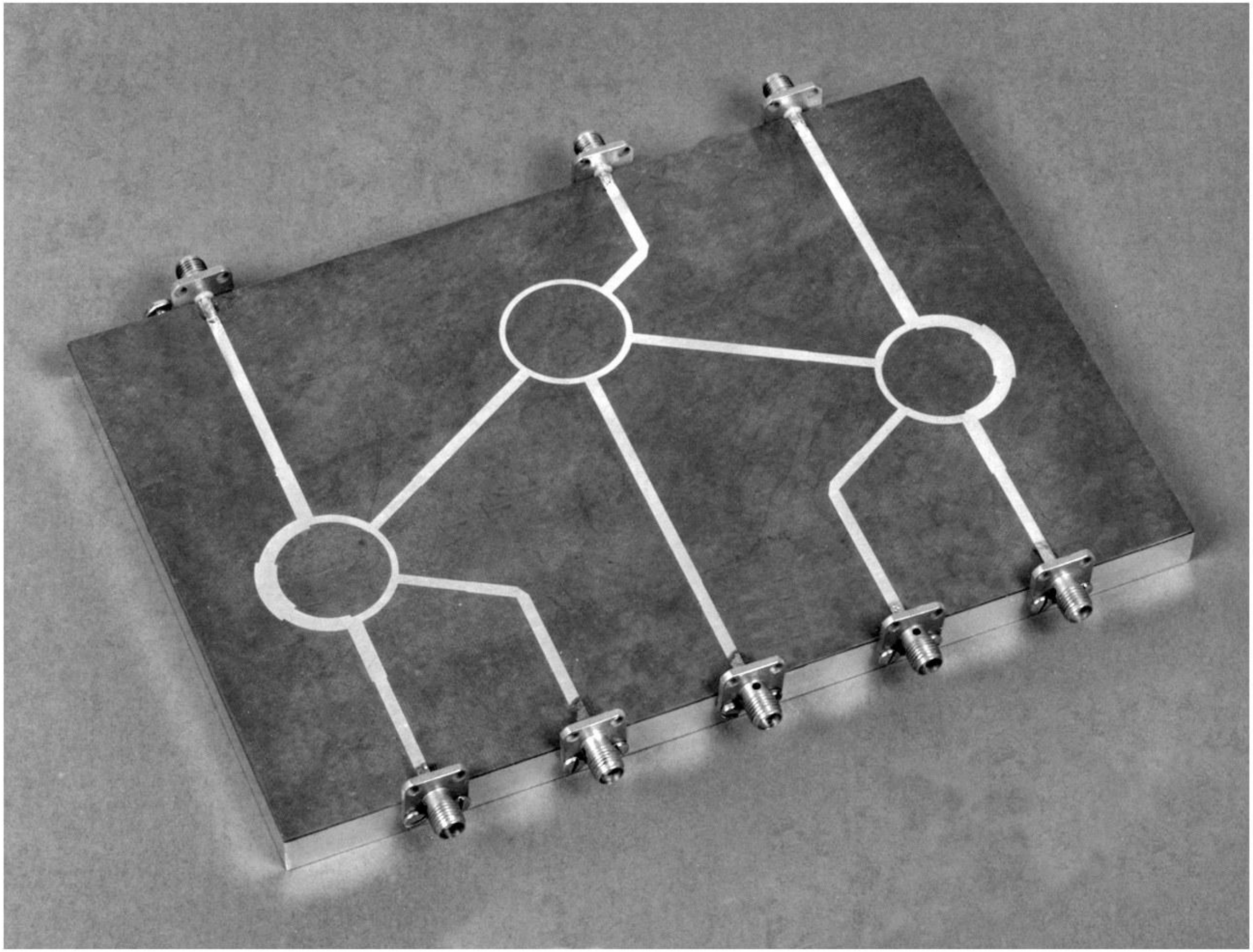
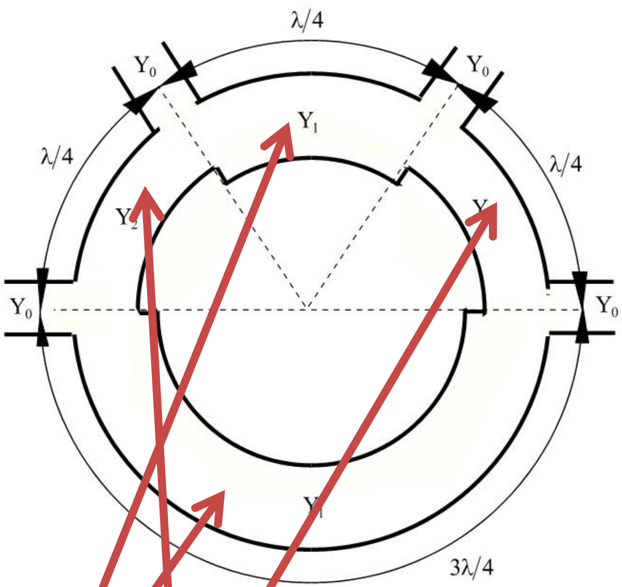


Figure 7.43
Courtesy of M. D. Abouzahra, MIT Lincoln Laboratory, Lexington, Mass.

Cuplorul în inel



$$\boxed{y_1^2 + y_2^2 = 1}$$

$$|\beta| = y_1$$

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

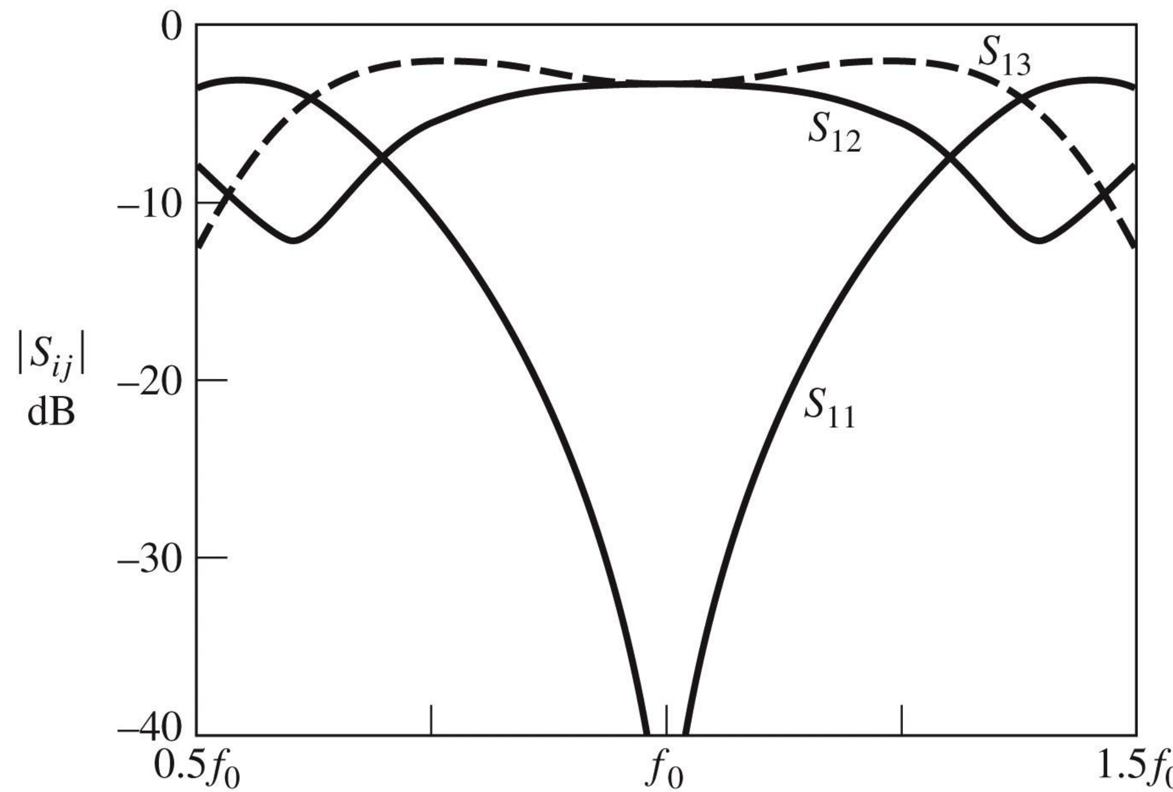
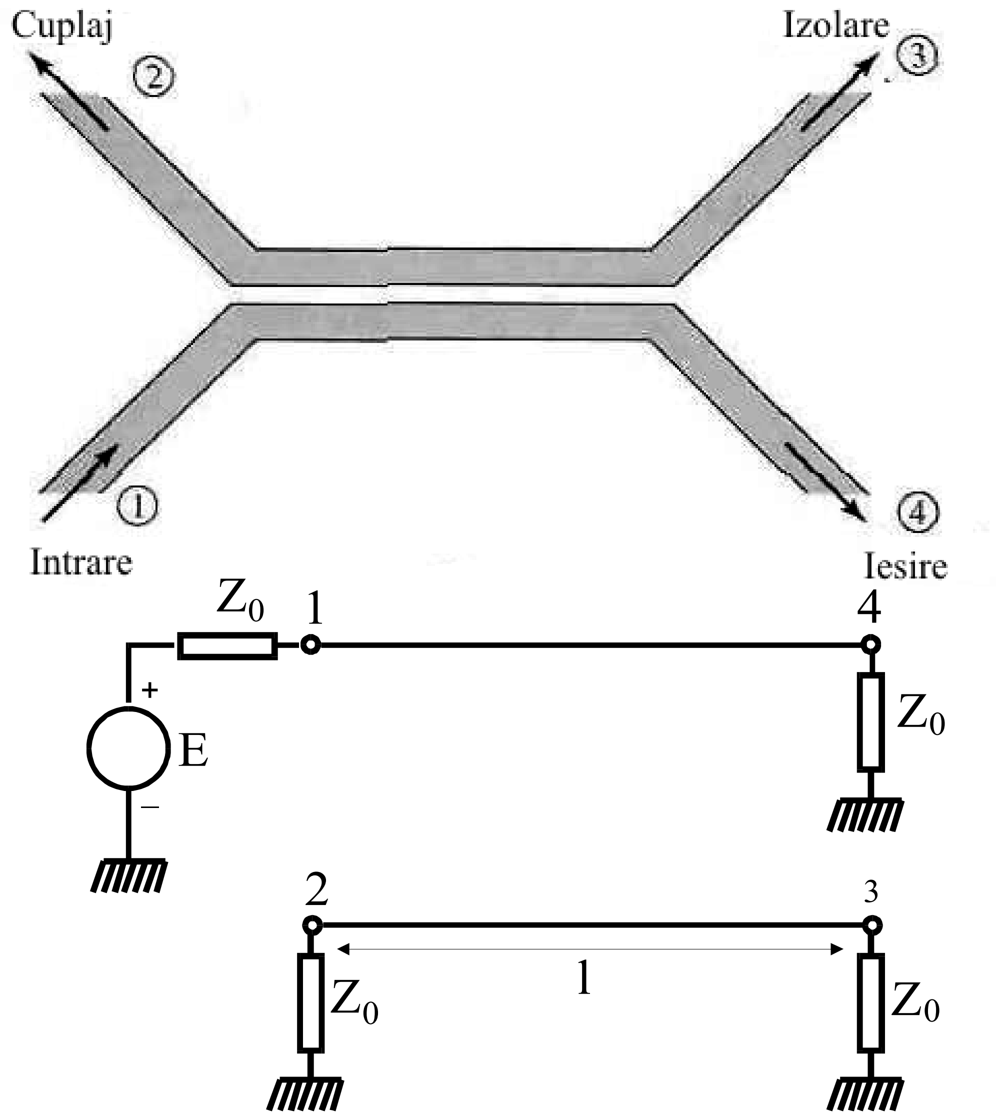


Figure 7.46

Cuplorul prin proximitate



Linii cuplate

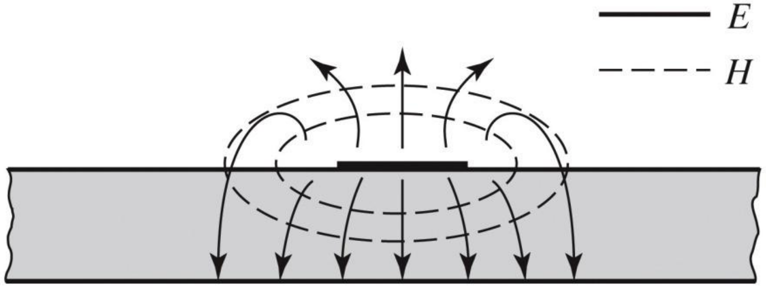
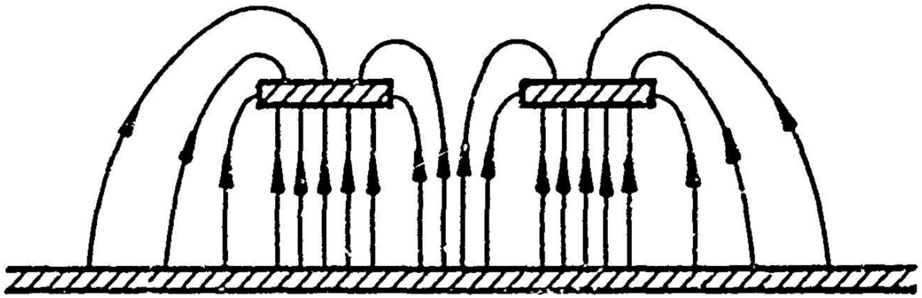
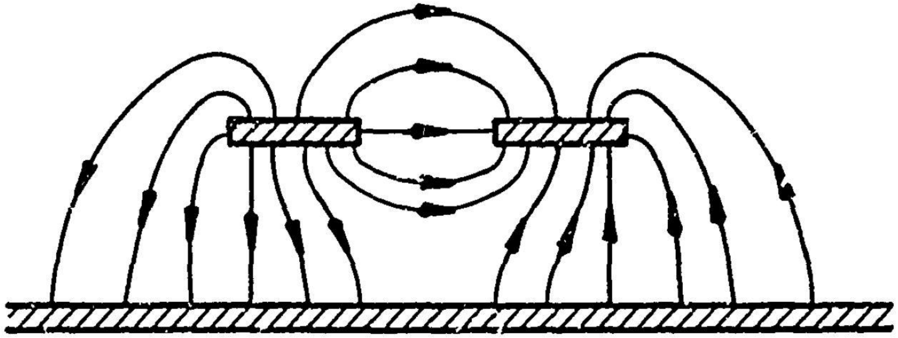


Figure 3.25b



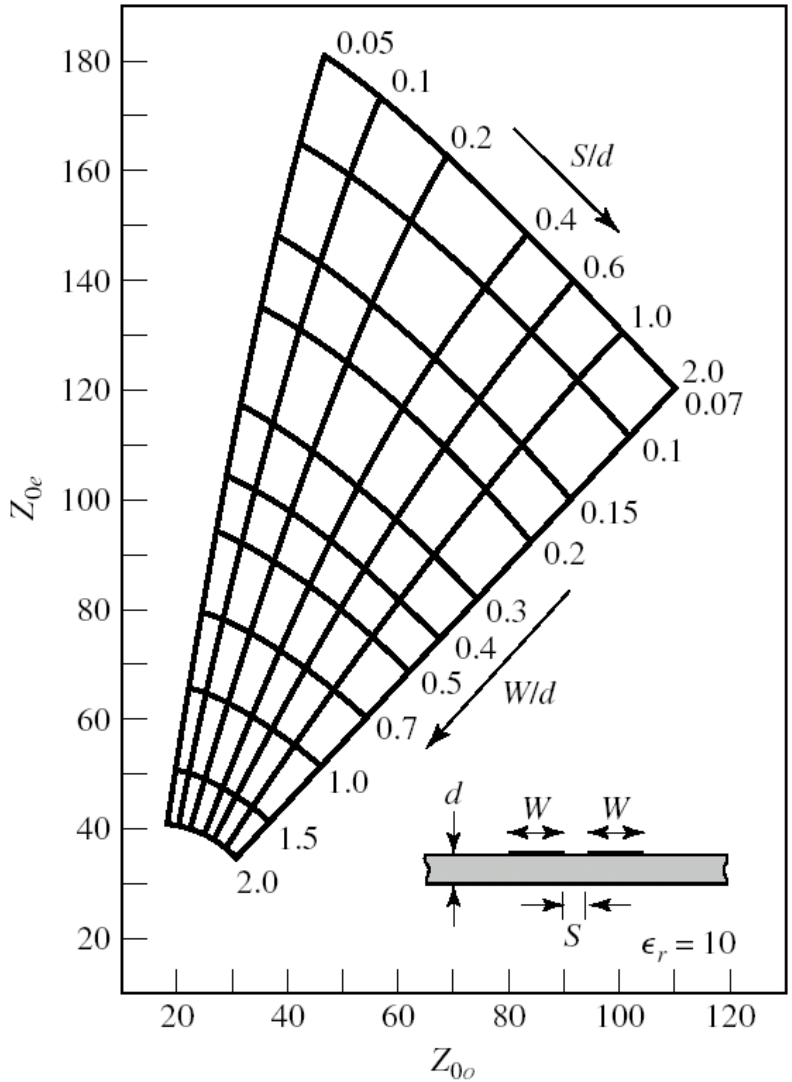
b) EVEN MODE ELECTRIC FIELD PATTERN (SCHEMATIC)

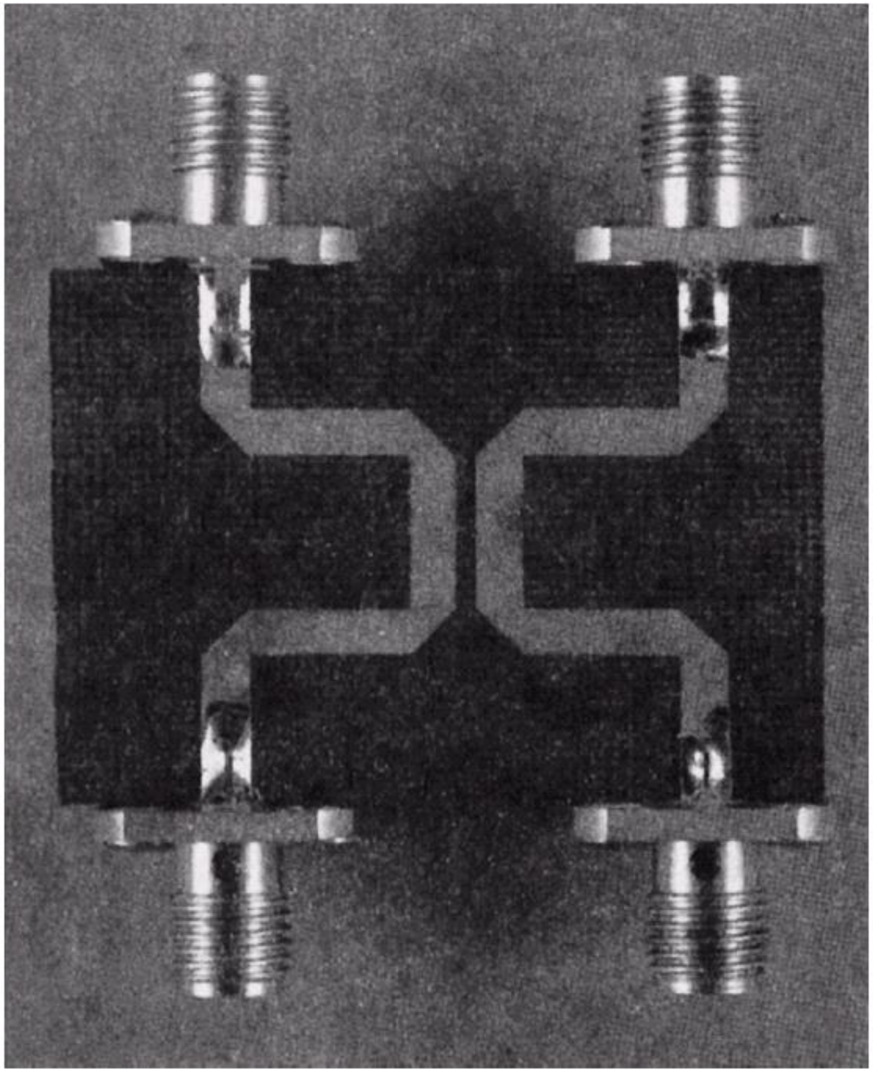


c) ODD MODE ELECTRIC FIELD PATTERN (SCHEMATIC)

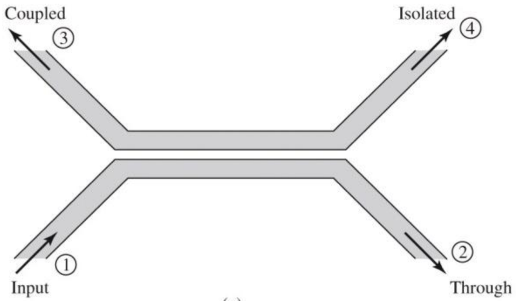
- Mod par – caracterizeaza semnalul de mod comun de pe cele doua linii
- Mod impar – caracterizeaza semnalul de mod diferential dintre cele doua linii
- Fiecare din cele doua moduri e caracterizat de impedante caracteristice **diferite**

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





Cuplor prin proximitate



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

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

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

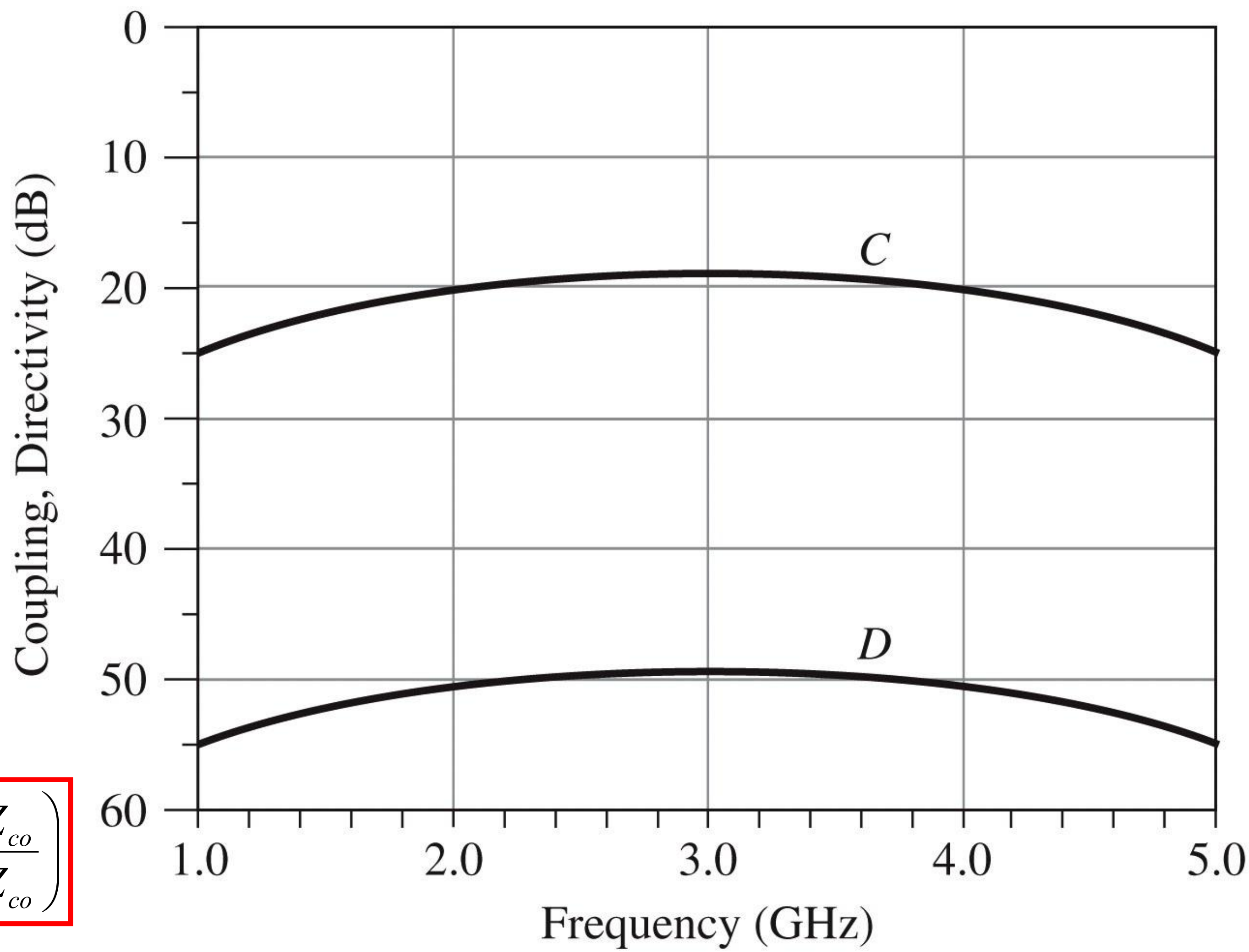


Figure 7.34

Contact

- Laboratorul de microunde si optoelectronica
- **https://rf-opto.etti.tuiasi.ro**
- **rdamian@etti.tuiasi.ro**