

Curs 4
2017/2018

Dispozitive și circuite de microunde pentru radiocomunicații

Documentatie

- RF-OPTO
 - <http://rf-opto.eti.tuiasi.ro>
- Fotografie
 - de trimis prin email: rdamian@etti.tuiasi.ro
 - necesara la laborator/curs

Fotografii

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

Start Didactic Master Colectiv Cercetare Studenti Admin

Note Lista Studenti Fotografi Statistici

Grupa 5403

| Nr. | Student | Prezent | Nr. | Student | Prezent | Nr. | Student | Prezent |
|-----|--------------------------|--|-----------------------------------|---------|--|-----|---------------------------------|--|
| 1 | ANGHELUS IONUT-MARCUS | | Prezent: <input type="checkbox"/> | 2 | ANTIGHIN FLORIN-RAZVAN | | Fotografia nu exista | Prezent: <input type="checkbox"/> |
| | | Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> | | | Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> | | | Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> |
| | | Nota: 0 | | | Nota: 0 | | | Nota: 0 |
| | | Obs: <input type="text"/> | | | Obs: <input type="text"/> | | | Obs: <input type="text"/> |
| 4 | APOSTOL PAVEL-MANUEL | | Prezent: <input type="checkbox"/> | 5 | BALASCA TUDIAN-PETRU | | Fotografia nu exista | Prezent: <input checked="" type="checkbox"/> |
| | | Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> | | | Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> | | | Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> |
| | | Nota: 0 | | | Nota: 0 | | | Nota: 0 |
| | | Obs: <input type="text"/> | | | Obs: <input type="text"/> | | | Obs: <input type="text"/> |
| 7 | BOTEZAT EMANUEL | | Prezent: <input type="checkbox"/> | 8 | BUTUNOI GEORGE-MADALIN | | Fotografia nu exista | Prezent: <input type="checkbox"/> |
| | | Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> | | | Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> | | | Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> |
| | | Nota: 0 | | | Nota: 0 | | | Nota: 0 |
| | | Obs: <input type="text"/> | | | Obs: <input type="text"/> | | | Obs: <input type="text"/> |
| 10 | CHIRITOIU CATERINA | | Prezent: <input type="checkbox"/> | 11 | CODOC MARIUS | | Fotografia nu exista | Prezent: <input type="checkbox"/> |
| | | Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> | | | Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> | | | Puncte: 0 <input type="button" value="▼"/> <input checked="" type="button" value="▲"/> |
| | | Nota: 0 | | | Nota: 0 | | | Nota: 0 |
| | | Obs: <input type="text"/> | | | Obs: <input type="text"/> | | | Obs: <input type="text"/> |

Nr. Student

Prezent

2 ANTIGHIN
FLORIN-RAZVAN

**Fotografia
nu exista**

Prezent:

Puncte: 0

Nota: 0

Obs:

Acces

Personalizat



Date:

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

[Acceseaza ca acest student](#)

Note obtinute

| Disciplina | Tip | Data | Descriere | Nota | Puncte | Obs. |
|------------|----------------|------------|------------------------------------|------|--------|------|
| TW | Tehnologii Web | | | | | |
| | N | 17/01/2014 | Nota finala | 10 | - | |
| | A | 17/01/2014 | Colocviu Tehnologii Web 2013/2014 | 10 | 7.55 | |
| | B | 17/01/2014 | Laborator Tehnologii Web 2013/2014 | 9 | - | |
| | D | 17/01/2014 | Tema Tehnologii Web 2013/2014 | 9 | - | |

Nume

Email

Cod de verificare

Trimite

Software

- ADS 2016
- EmPro 2015
- pe baza de IP din exterior

Date:

| | |
|---------------|------------------------------|
| Grupa | 5601 (2017/2018) |
| Specializarea | Master Retele de Comunicatii |
| Marca | 857 |

[Acceseaza ca acest student](#) | [Cere acces la licente](#)

Note obtinute

| Disciplina | Tip | Data | Descriere | Nota | Puncte | Obs. |
|------------|--|------|------------|-------------|--------|------|
| TMPAW | Tehnici moderne de proiectare a aplicatiilor web | N | 29/05/2017 | Nota finala | 10 | - |

Nume
MOOROUN

Email

Cod de verificare
344bd9f

Trimite

Software

Advanced Design System
Premier High-Frequency and High Speed Design Platform
2016.01

KEYSIGHT TECHNOLOGIES

© Keysight Technologies 1985-2016

JW License Setup Wizard for Advanced Design System 2016.01

Specify Remote License Server
Enter the name of the network license server you wish to add or replace.

Advanced Design System 2016.01
Enter the ne

Network li Examining your license server...
(e.g. 27001)

What is a ne
How do I know which network license server to use?
How do I specify a network license server name?
Can I find out the network license server name from the license file?

Details < Back Next > Exit

Update Availability Legend: License available License in use or not available << Hide D

ADS Inclusive

License is available

Number of licenses: Used: Version: Expires:

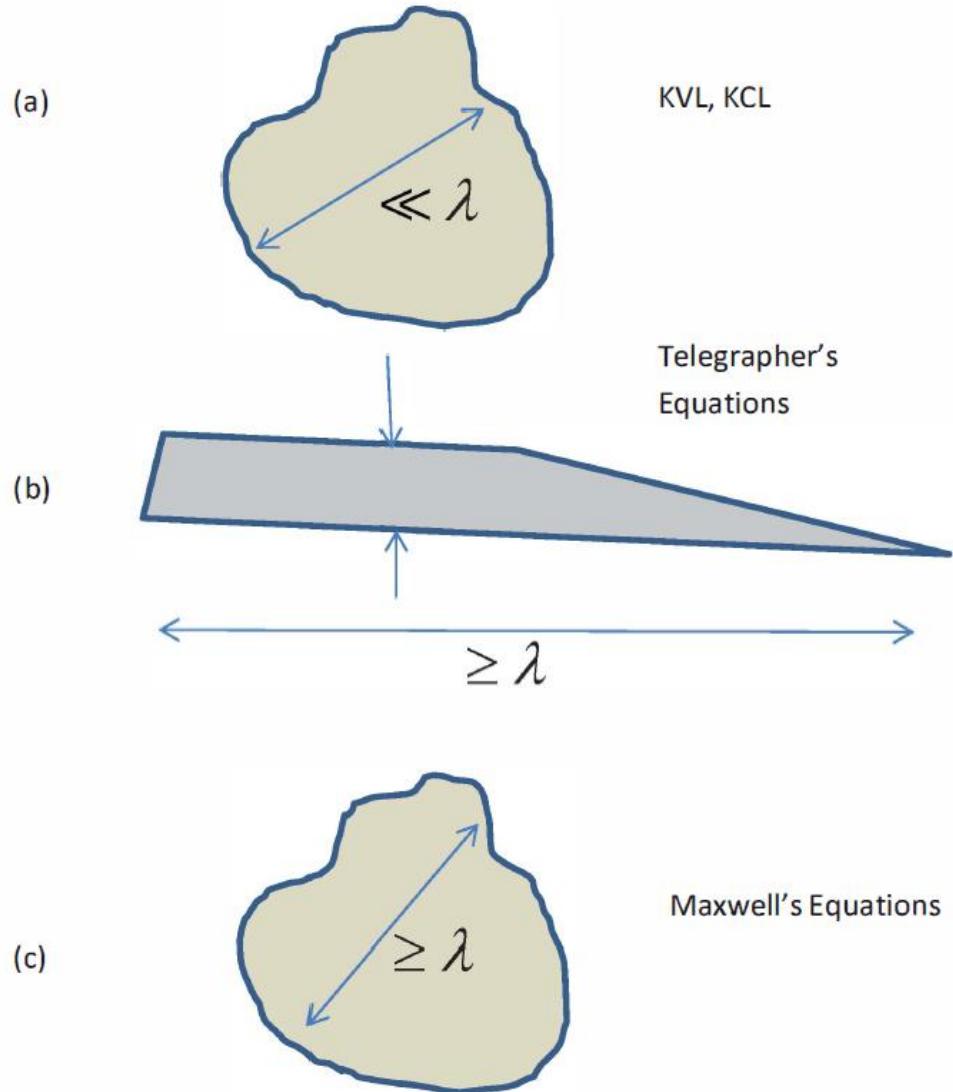
b_ads_i

Lungimea electrică

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

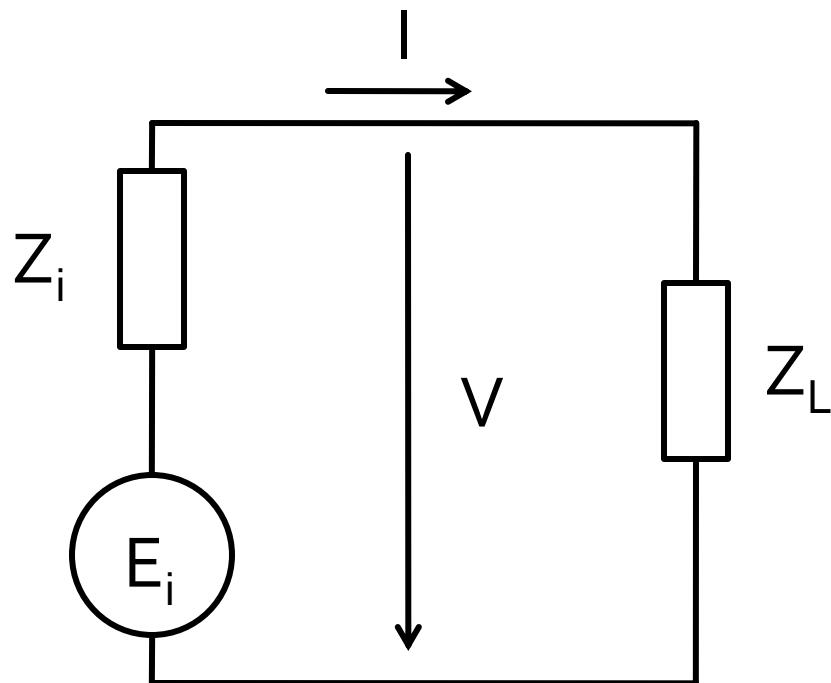
- $E \approx 0 \rightarrow$ Kirchhoff
- $E > 0 \rightarrow$ propagare

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



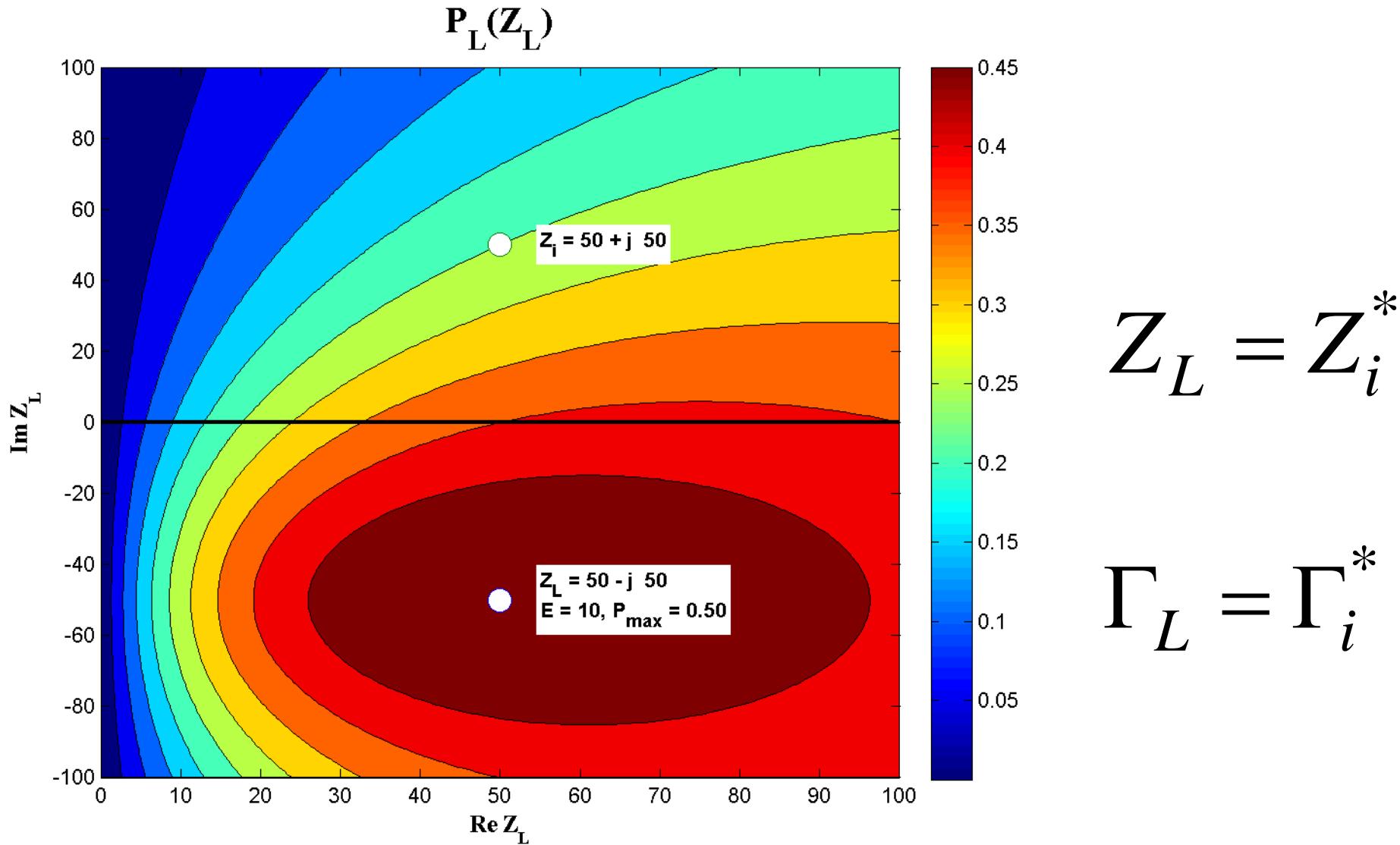
Adaptare

- Generator adaptat la sarcina ?

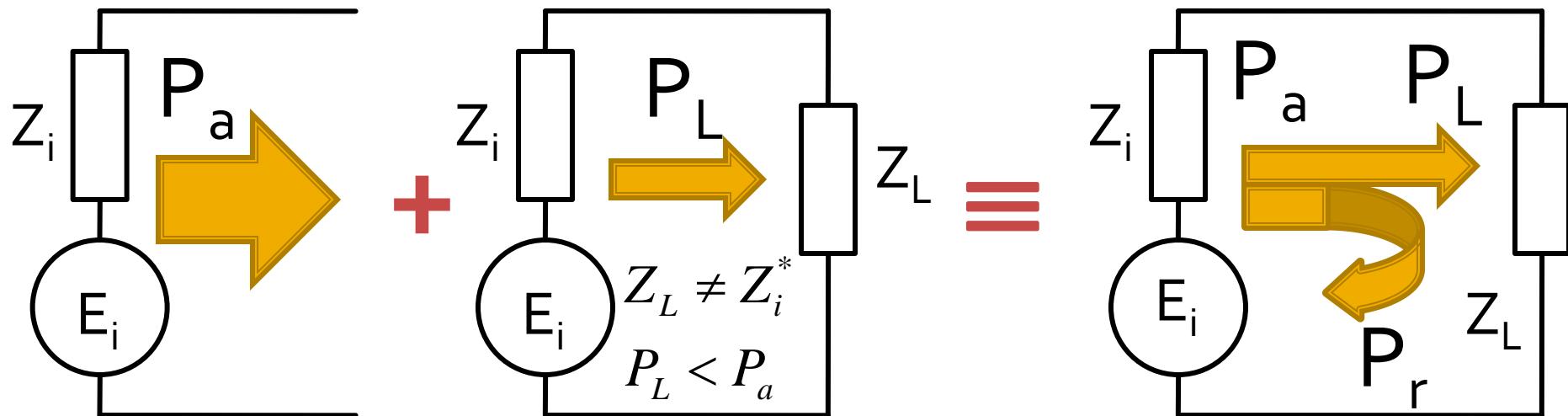


- valori impedanta ?
- reflexii ?

Adaptare, exemplu



Reflexie de putere / Model

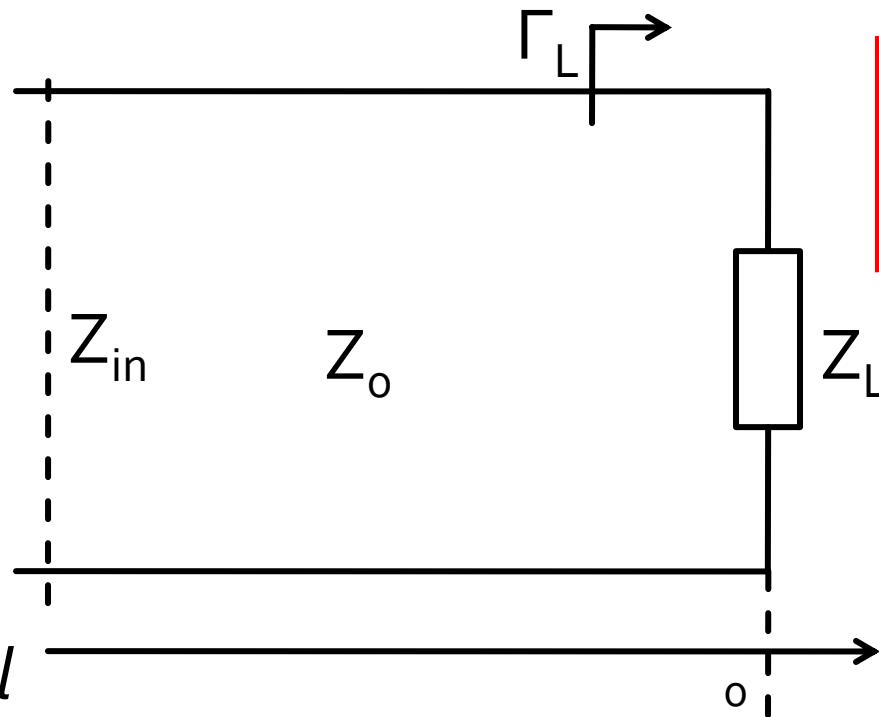


- Generatorul are posibilitatea de a oferi o anumita putere maxima de semnal P_a
- Pentru o sarcina oarecare, acesteia i se ofera o putere de semnal mai mica $P_L < P_a$
- Se intampla **“ca si cum”** (model) o parte din putere se reflecta $P_r = P_a - P_L$
- Puterea este o marime **scalara!**

Linii de transmisie in mod TEM

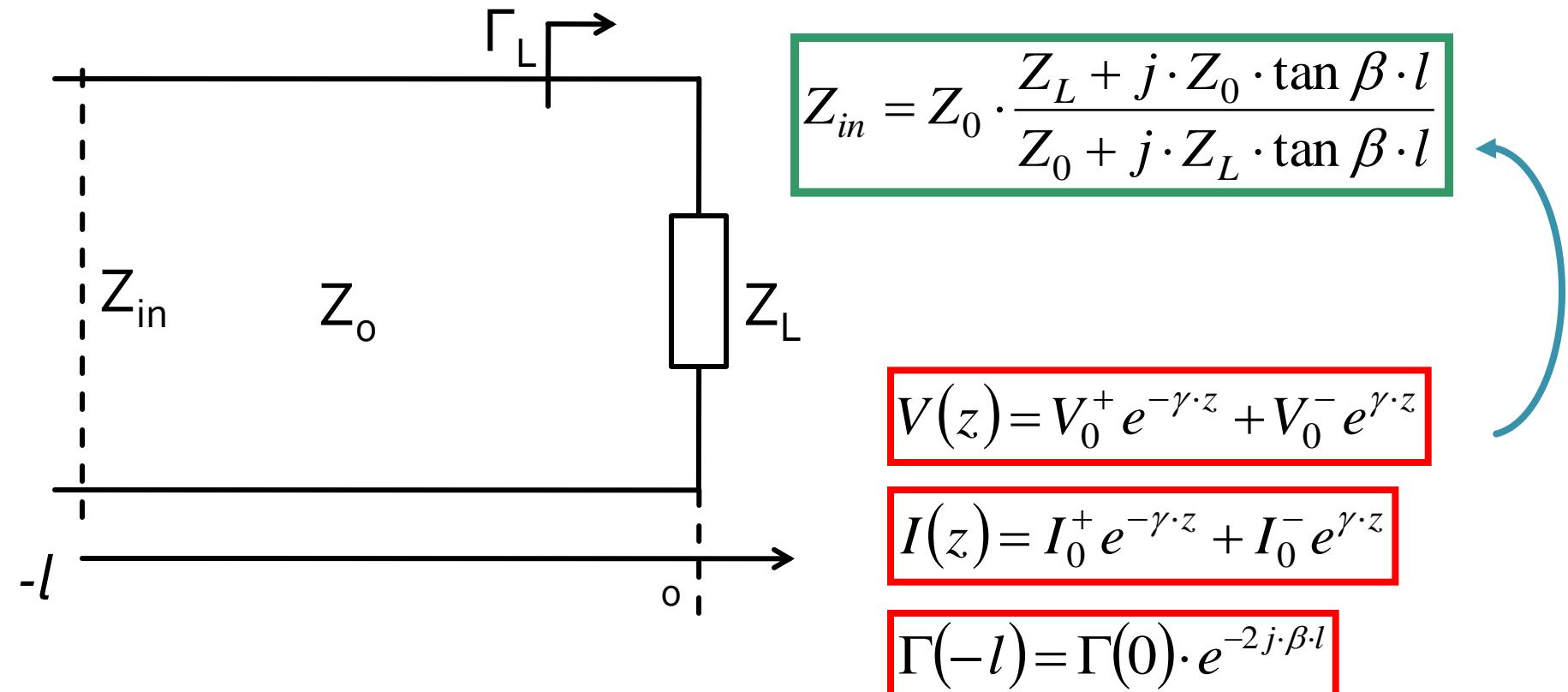
Linie fara pierderi

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



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

The lossless line +/-

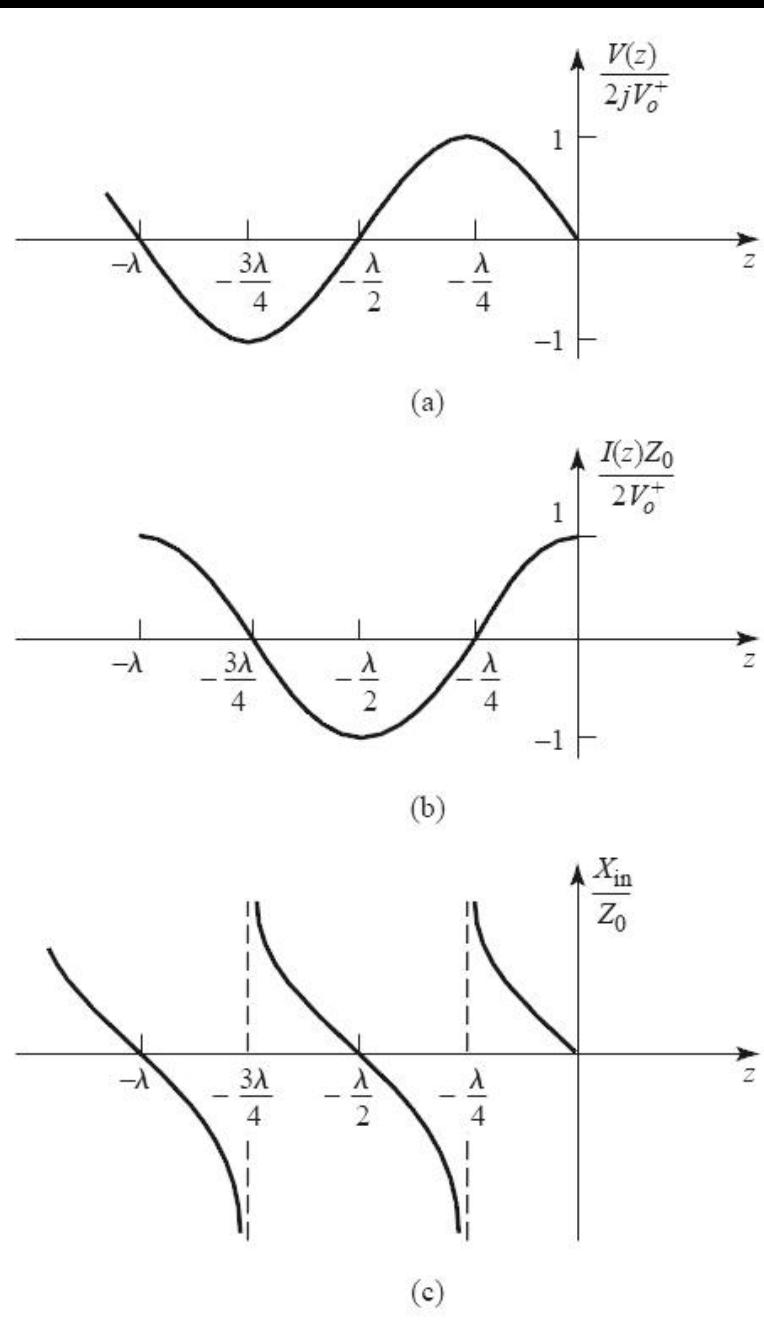


Linie în scurtcircuit

- reactanță pură
 - $+/- \rightarrow$ în funcție de l

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

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

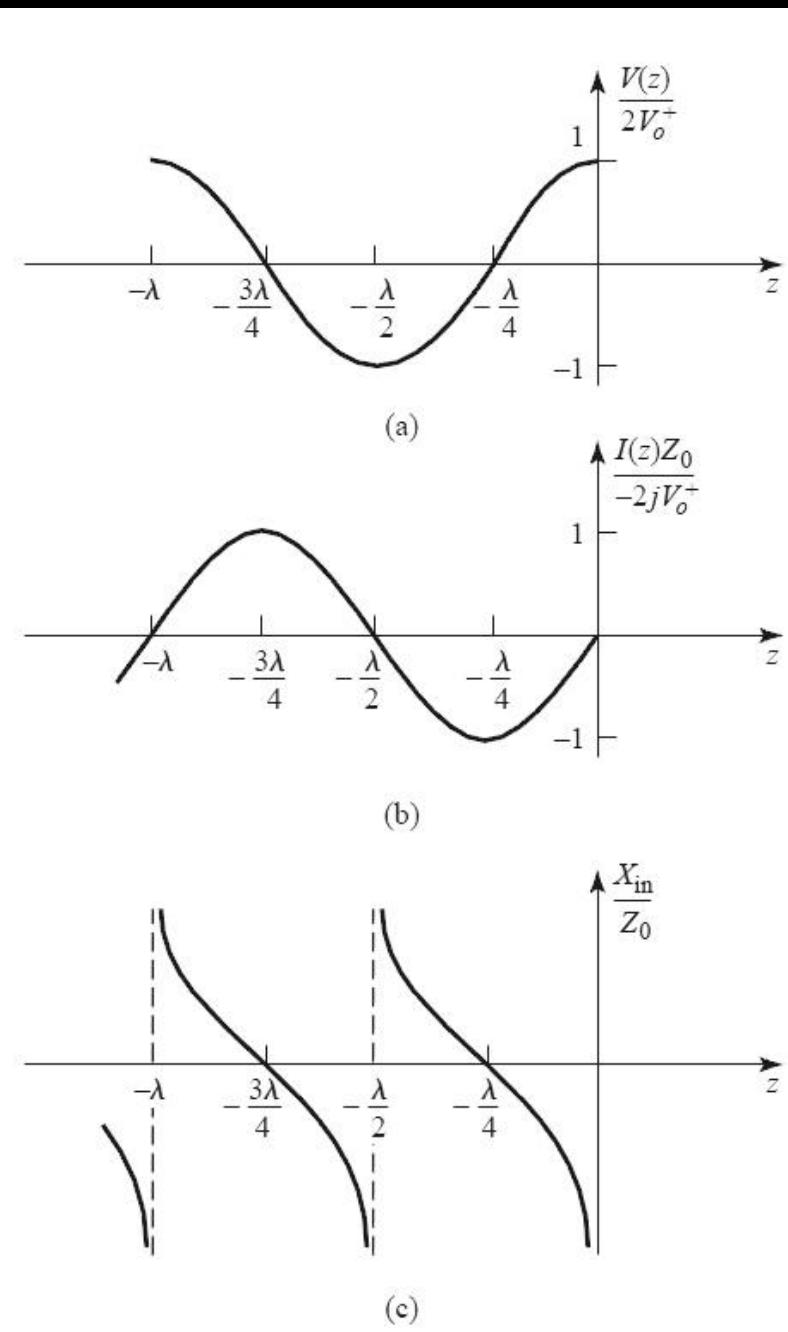


Linie în gol

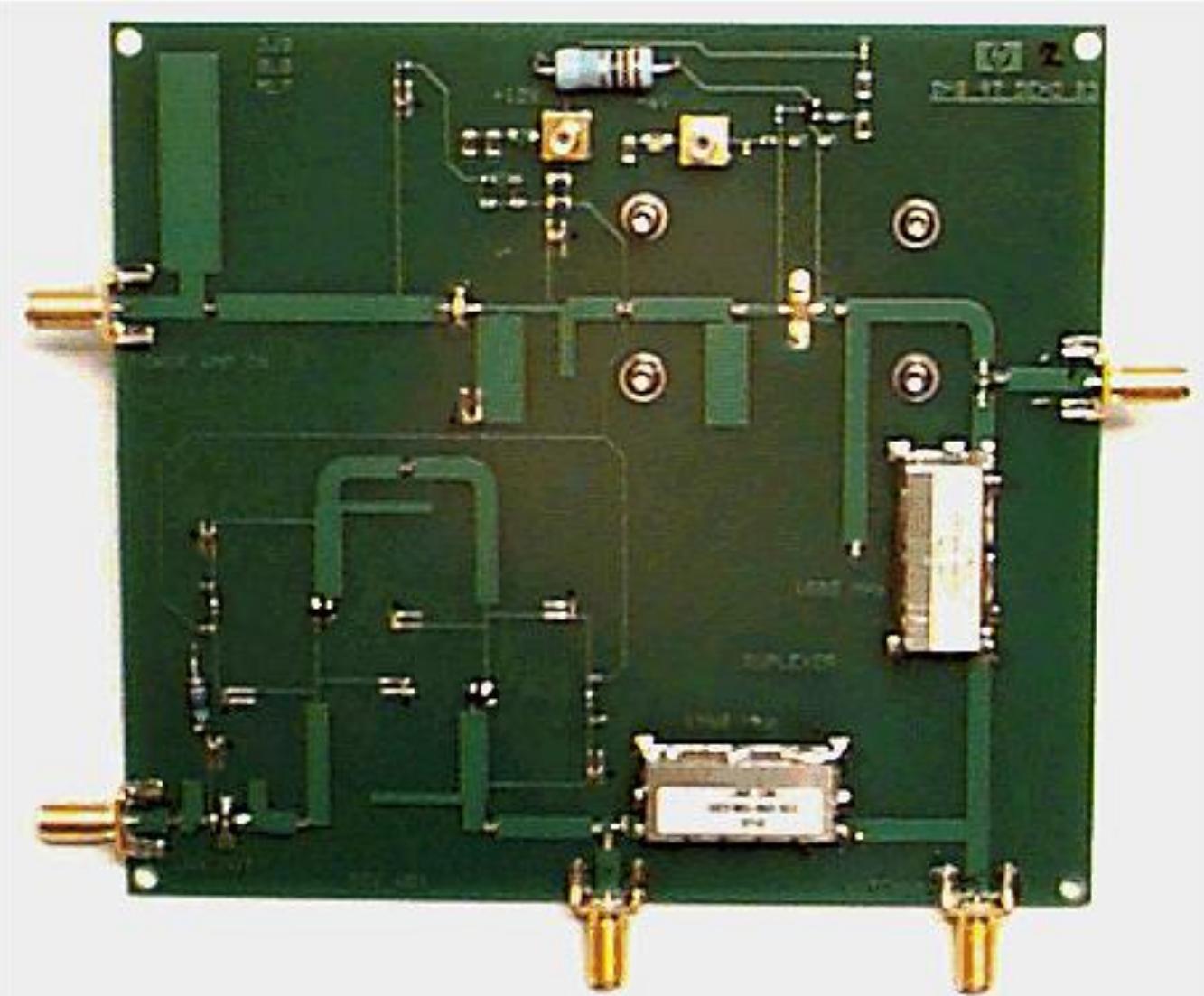
- reactanță pură
 - $+/- \rightarrow$ în funcție de l

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

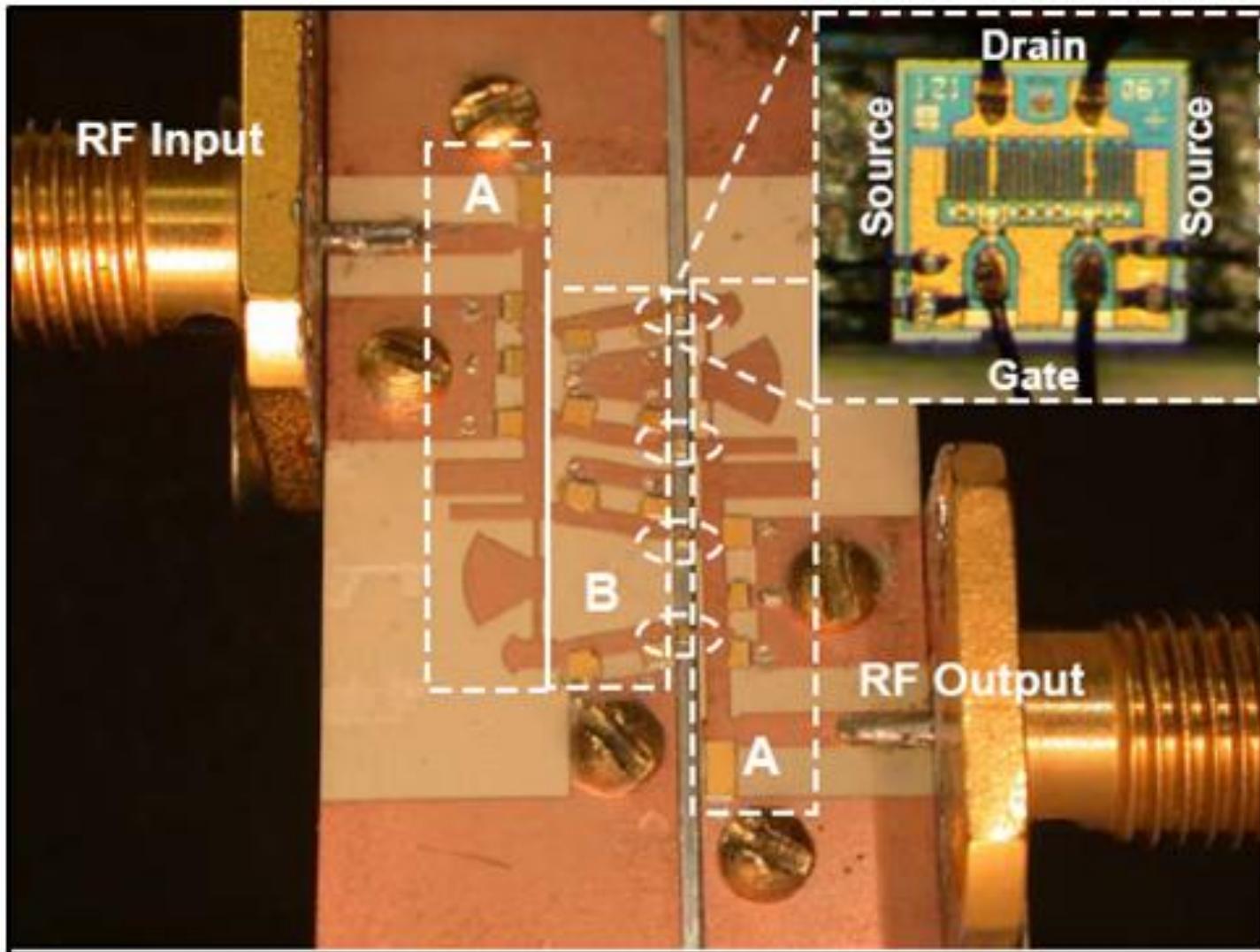
$$Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan(\beta \cdot l)}{Z_0 + j \cdot Z_L \cdot \tan(\beta \cdot l)}$$



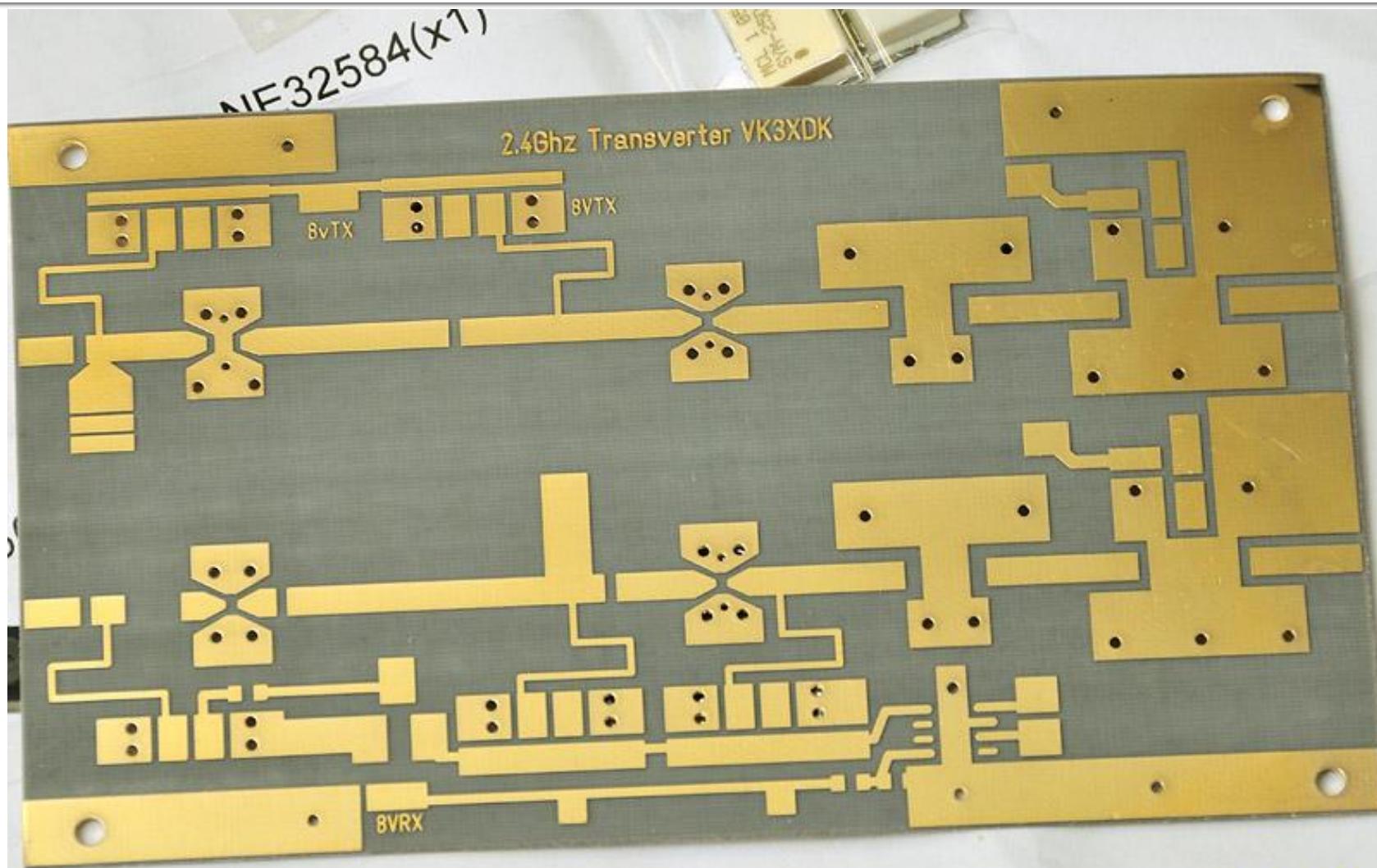
Exemple



Exemple

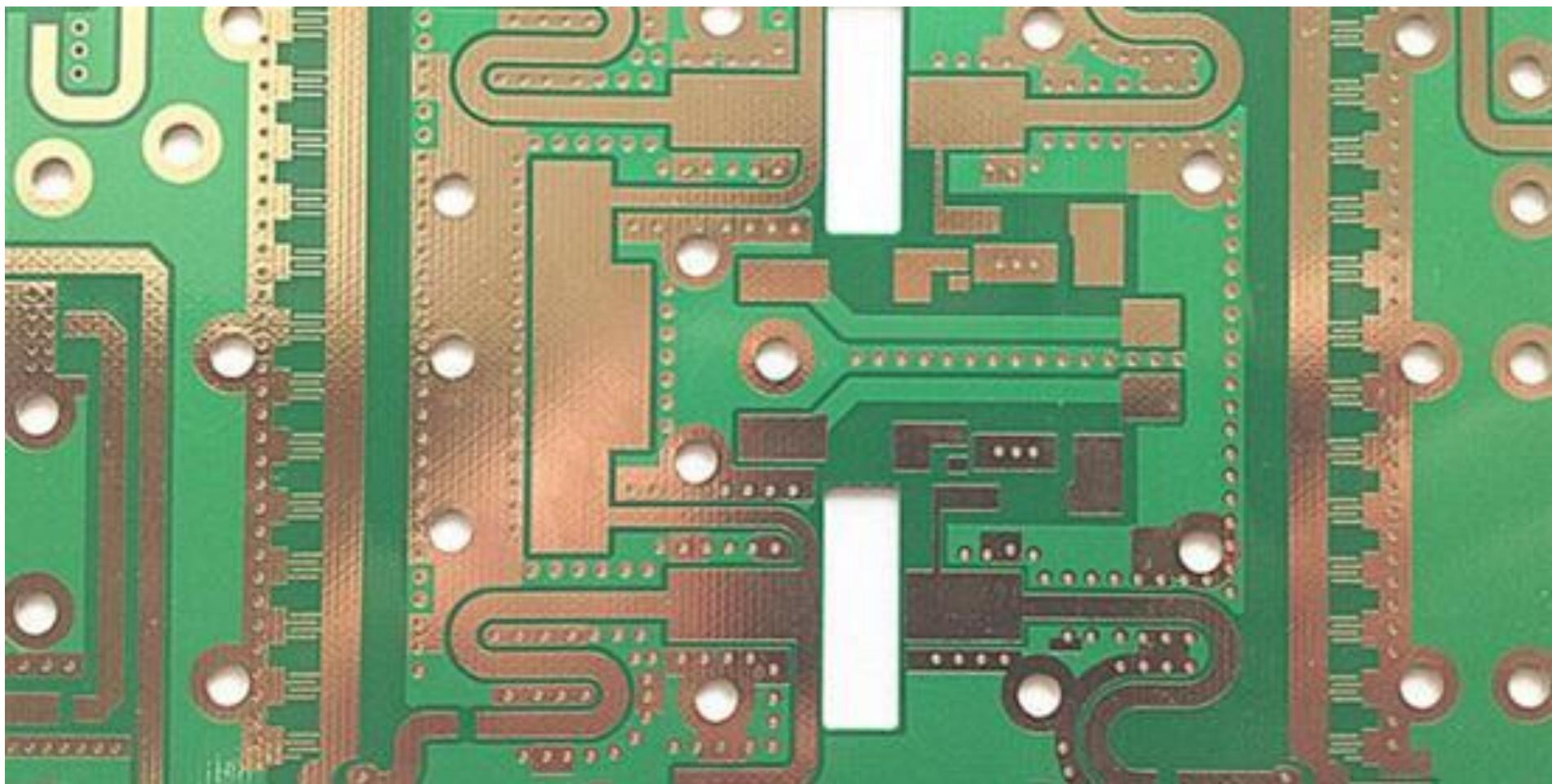


Exemple

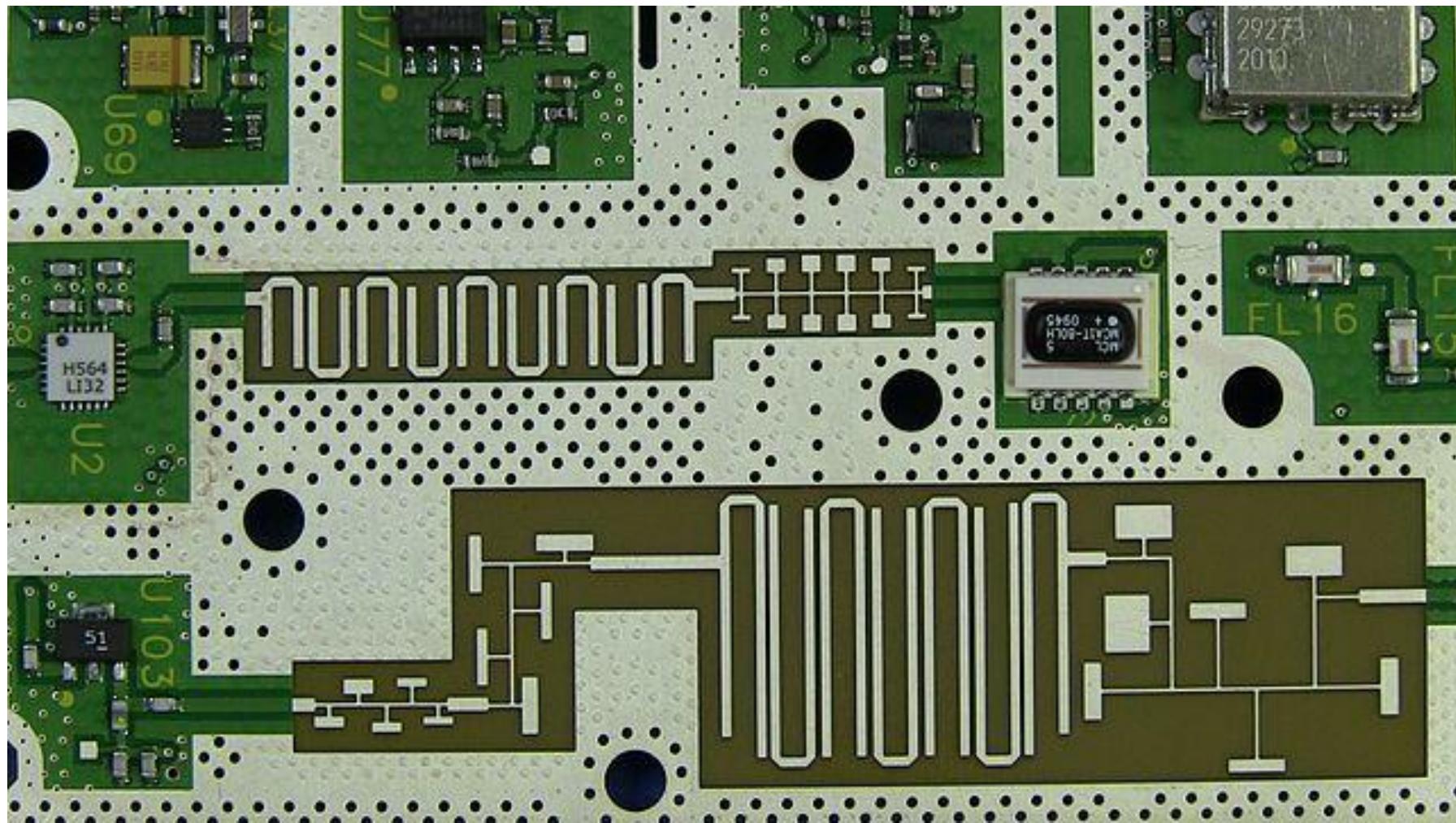


VK4CP

Exemple



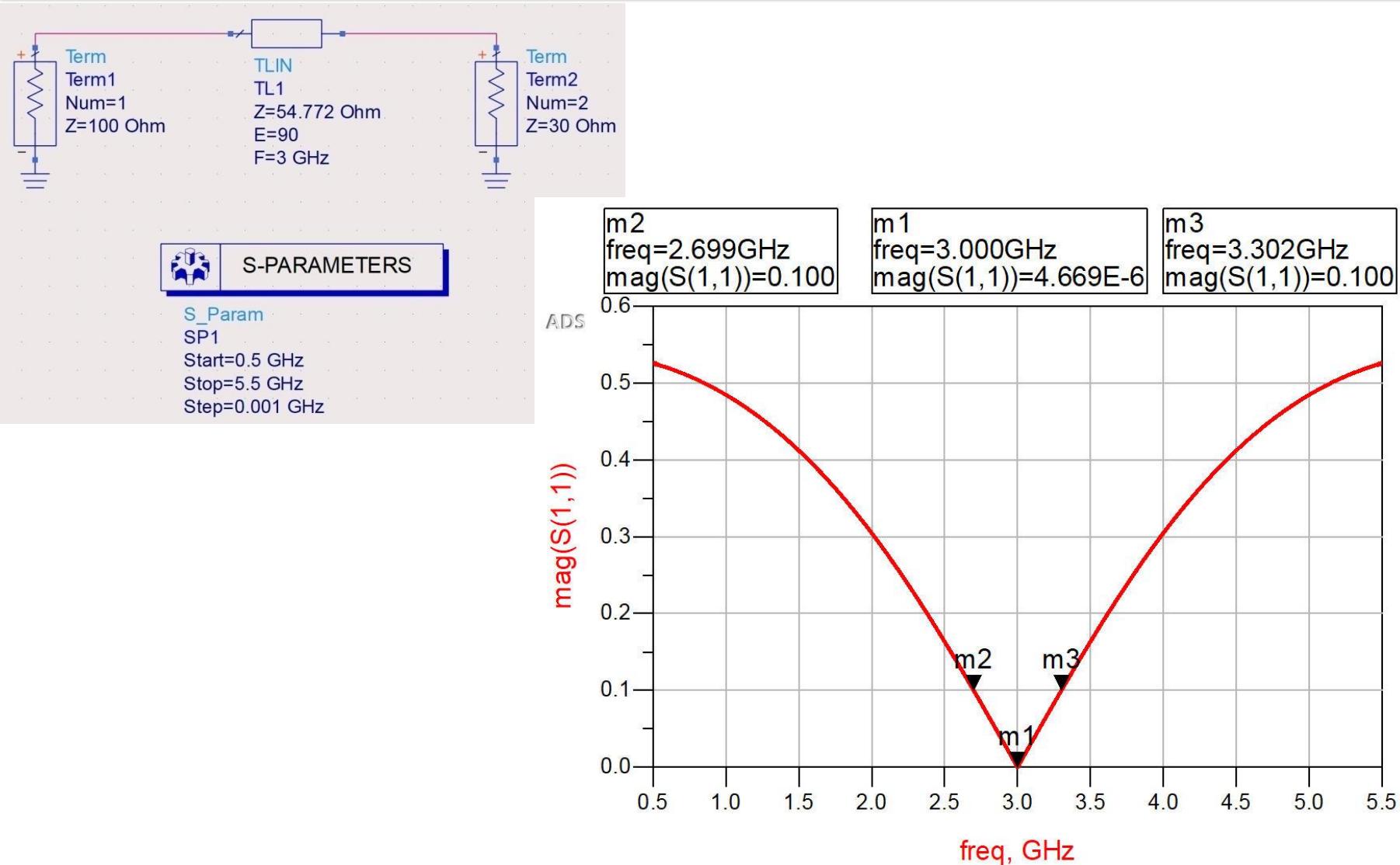
Exemple



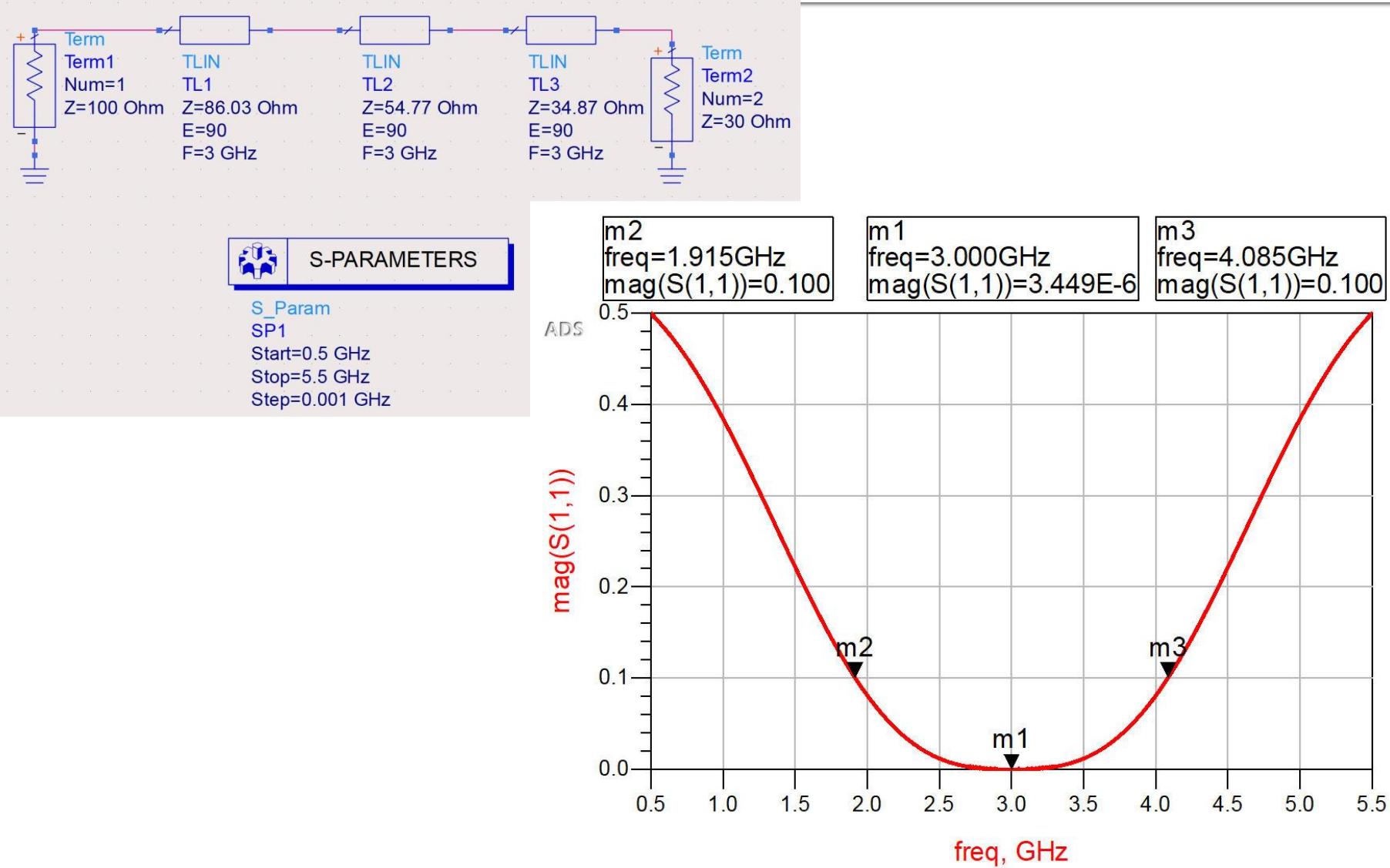
Adaptarea cu transformatoare de impedanta (Lab. 1)

Adaptarea de impedanță

Sfert de lungime de undă



Binomial



Cebâşev



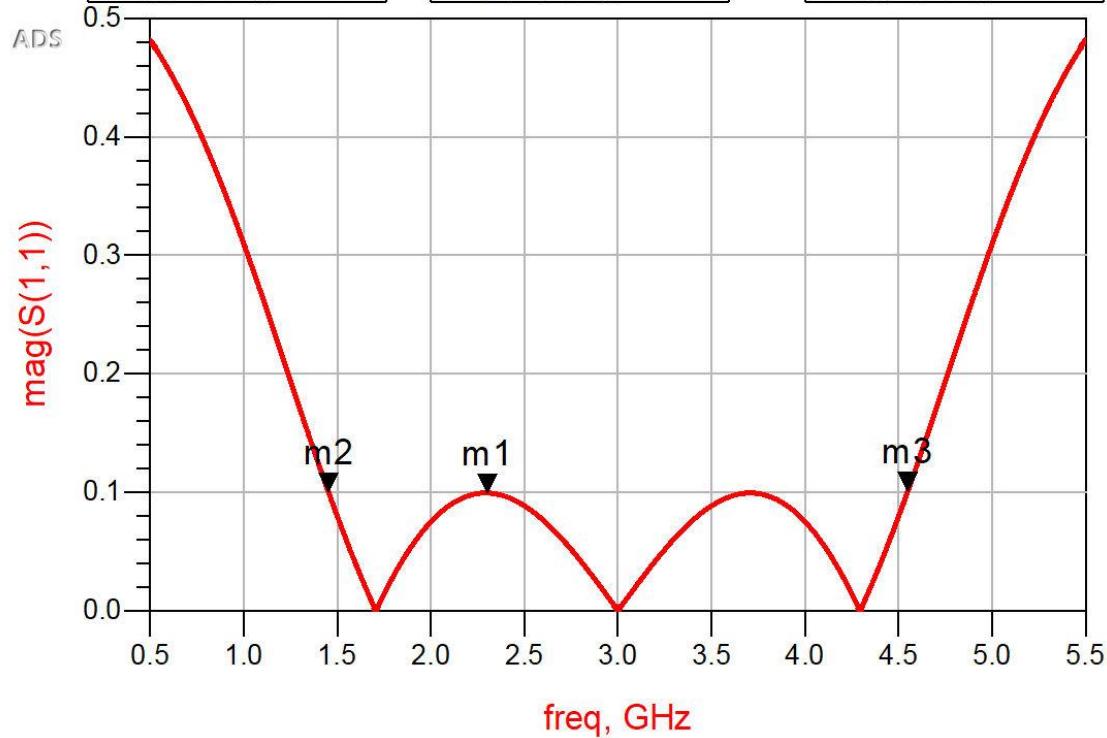
S-PARAMETERS

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

m2
freq=1.453GHz
mag(S(1,1))=0.100

m1
freq=2.301GHz
mag(S(1,1))=0.099

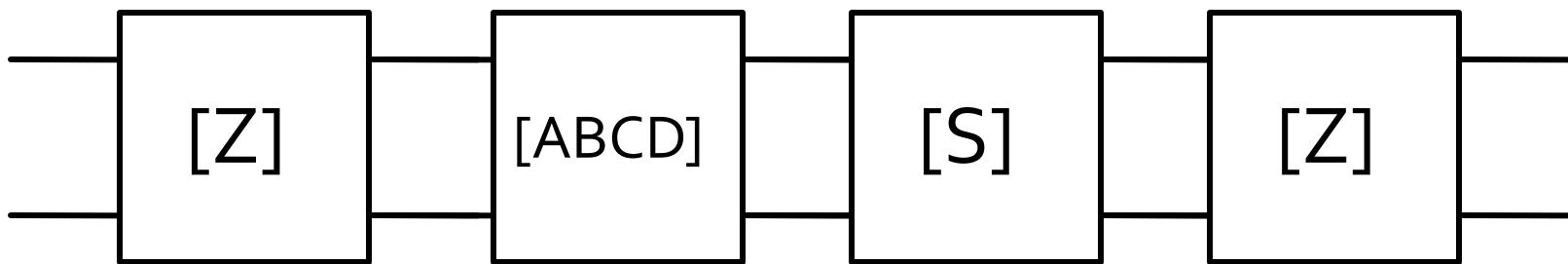
m3
freq=4.548GHz
mag(S(1,1))=0.100



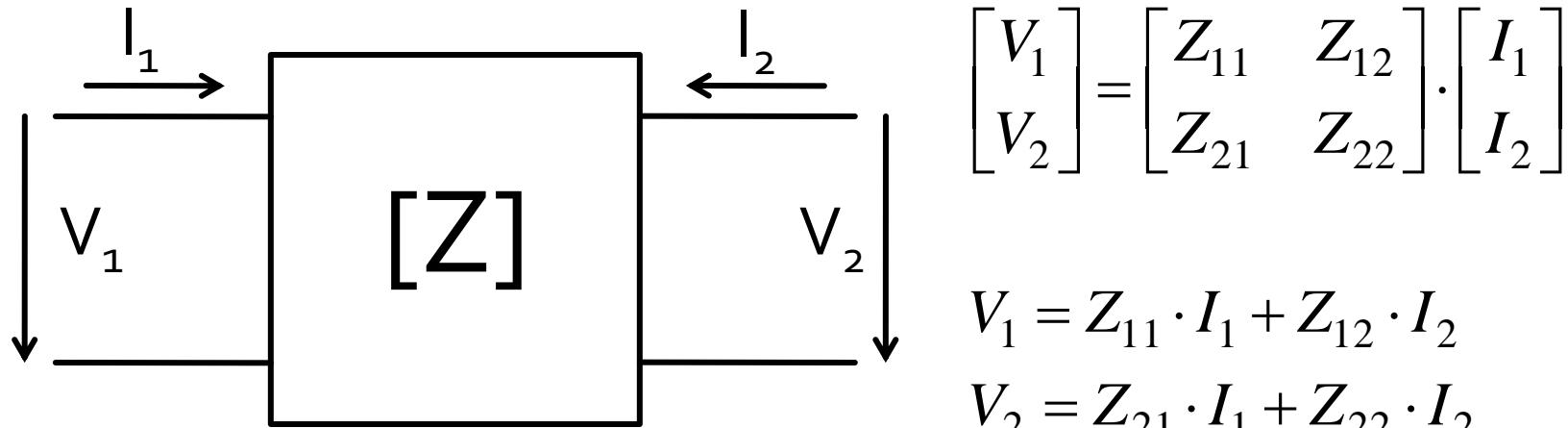
**Analiza la nivel de rețea a
circuitelor de microunde**

Analiza la nivel de bloc

- are ca scop separarea unui circuit complex în blocuri individuale
- acestea se analizează separat (decuplate de restul circuitului) și se caracterizează doar prin intermediul porturilor (**cutie neagră**)
- analiza la nivel de rețea permite cuplarea rezultatelor individuale și obținerea unui rezultat total pentru circuit



Matricea impedanta



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

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

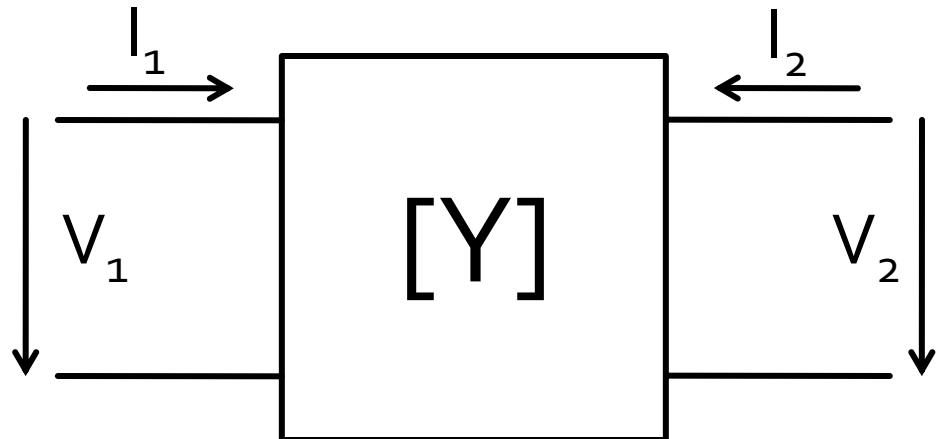
$$Z_{11} = \frac{V_1}{I_1} \Big|_{I_2=0}$$

$$Z_{12} = \frac{V_1}{I_2} \Big|_{I_1=0}$$

$$Z_{21} = \frac{V_2}{I_1} \Big|_{I_2=0}$$

$$Z_{22} = \frac{V_2}{I_2} \Big|_{I_1=0}$$

Matricea admitanta



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

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

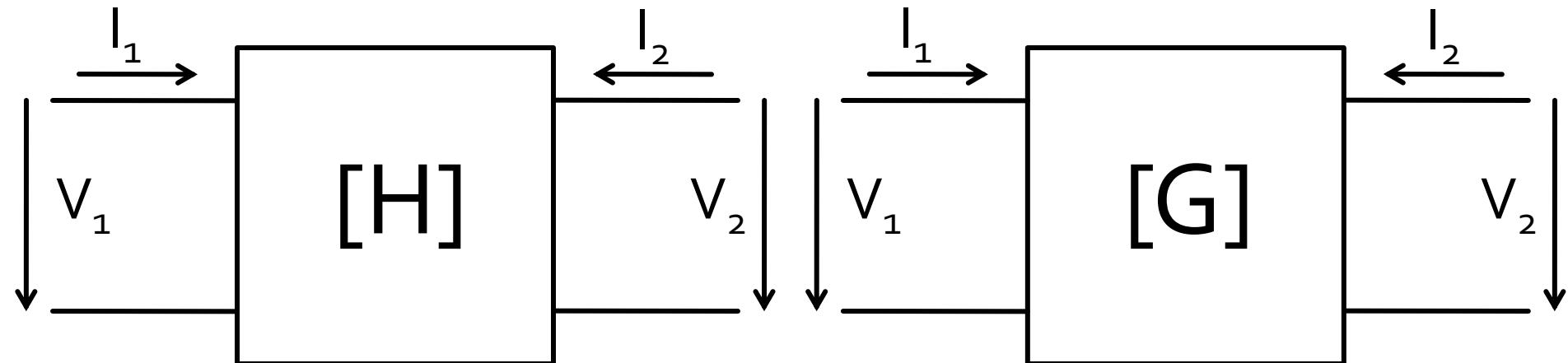
$$I_2 = Y_{21} \cdot V_1 + Y_{22} \cdot V_2$$

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

- **Y₁₁** – admitanta de intrare cu ieșirea în 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



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

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

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

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

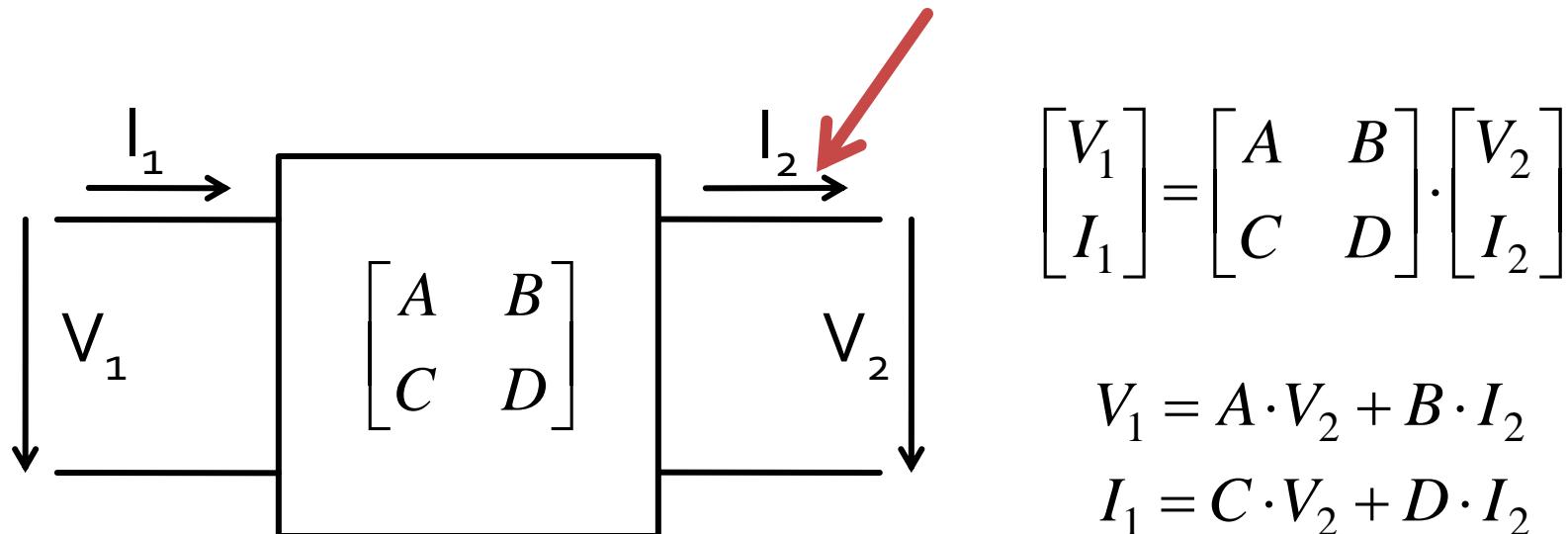
Analiza la nivel de bloc

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

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

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

Matricea ABCD – de transmisie



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

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

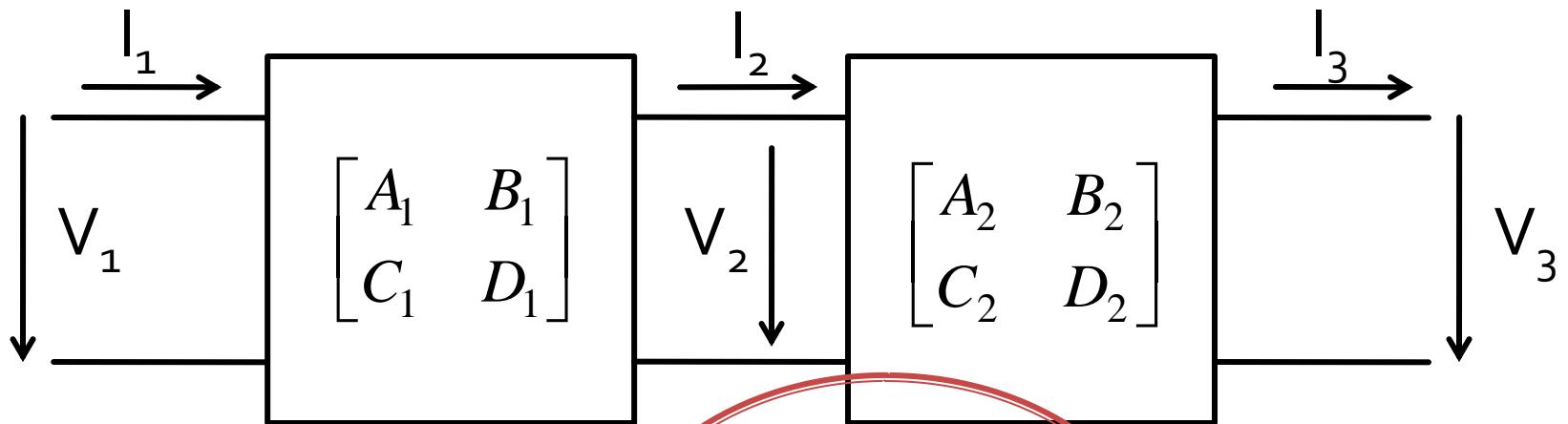
$$B = \left. \frac{V_1}{I_2} \right|_{V_2=0}$$

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

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

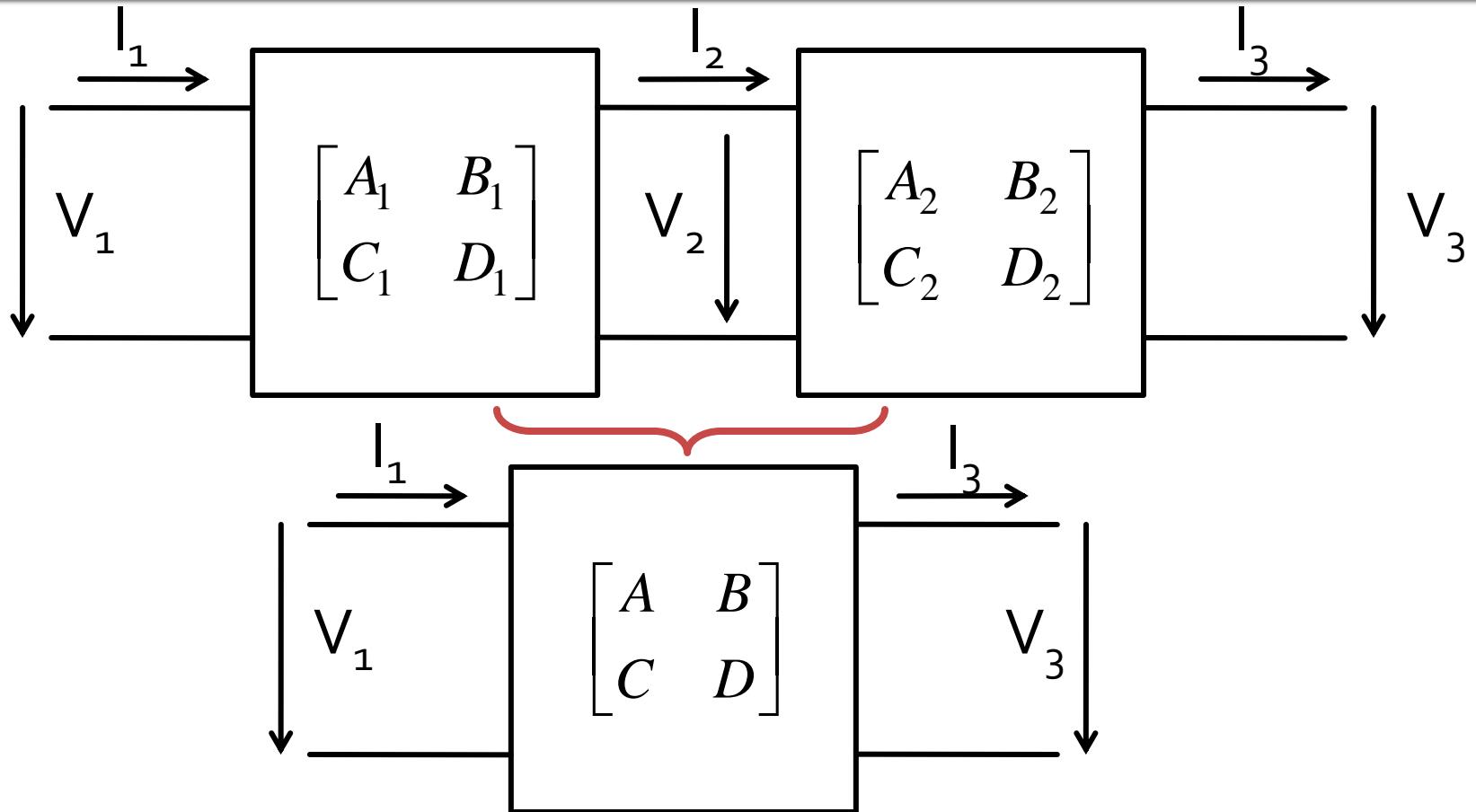
Matricea ABCD – de transmisie

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



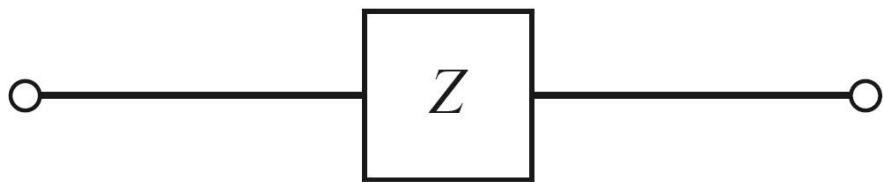
$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \cdot \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix}$$

Matricea ABCD – de transmisie

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

Matrici ABCD

■ Impedanza serie



$$A = 1$$

$$C = 0$$

$$B = Z$$

$$D = 1$$



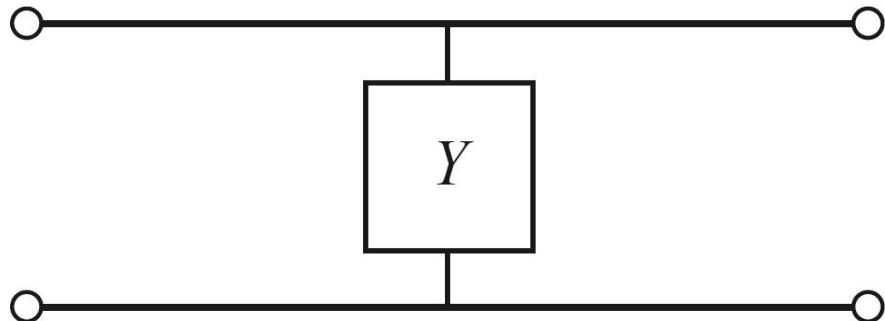
$$\begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix}$$

$$A = \frac{V_1}{V_2} \Big|_{I_2=0} = 1 \quad B = \frac{V_1}{I_2} \Big|_{V_2=0} = \frac{V_1}{V_1/Z} = Z$$

$$C = \frac{I_1}{V_2} \Big|_{I_2=0} = 0 \quad D = \frac{I_1}{I_2} \Big|_{V_2=0} = \frac{I_1}{I_1} = 1$$

Matrici ABCD

- Admitanta paralel



$$A = 1$$

$$B = 0$$

$$C = Y$$

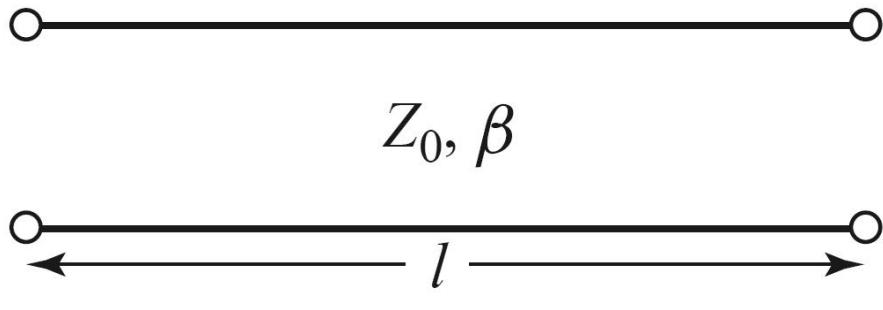
$$D = 1$$

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

Verificare - tema!

Matrici ABCD

■ Sectiune de linie de transmisie



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

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

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

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

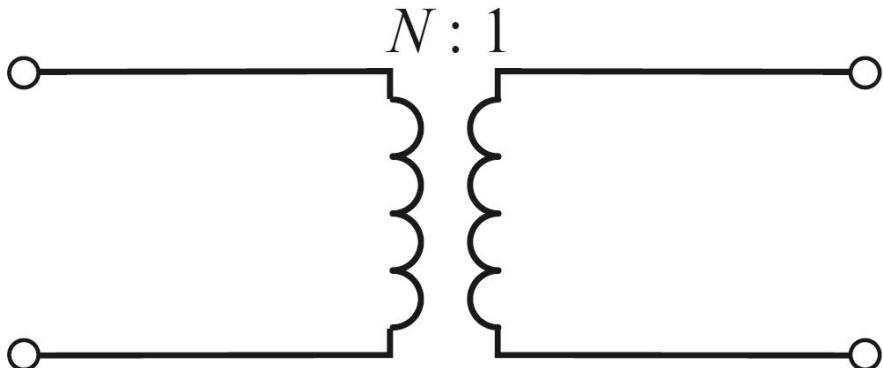
$$\begin{bmatrix} \cos \beta \cdot l & j \cdot Z_0 \cdot \sin \beta \cdot l \\ j \cdot Y_0 \cdot \sin \beta \cdot l & \cos \beta \cdot l \end{bmatrix}$$

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



$$A = N$$

$$C = 0$$

$$B = 0$$

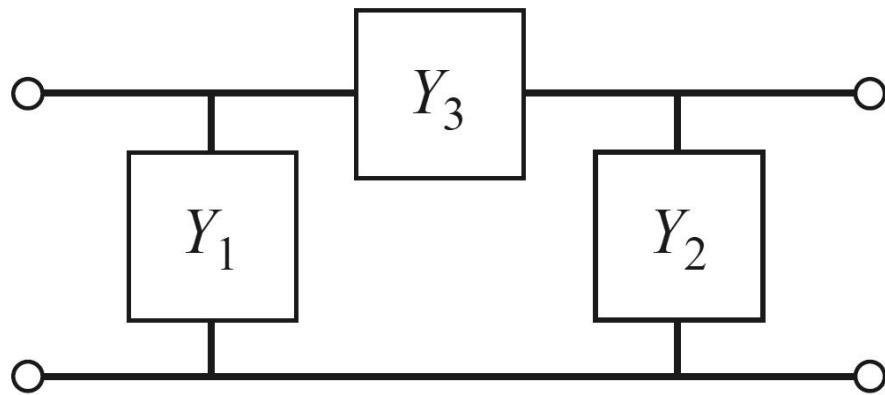
$$D = \frac{1}{N}$$

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

Verificare - tema!

Matrici ABCD

- diport π



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

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

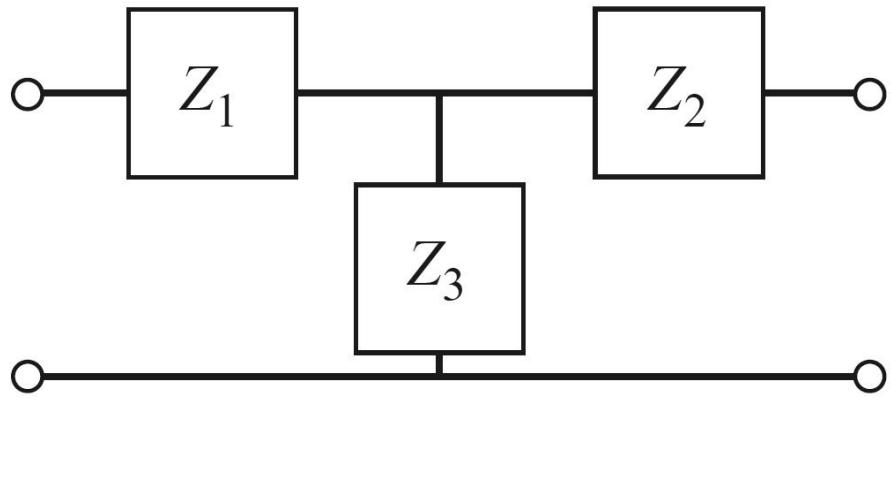
$$C = Y_1 + Y_2 + \frac{Y_1 \cdot Y_2}{Y_3}$$

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

Verificare - tema!

Matrici ABCD

- diport T



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

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

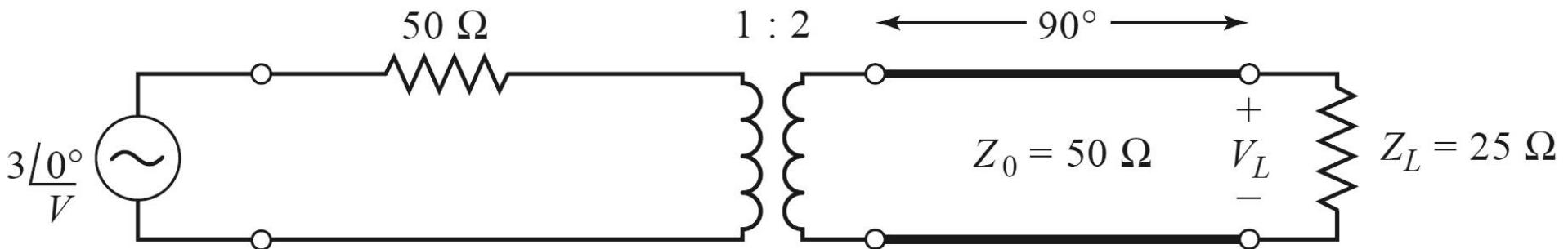
$$C = \frac{1}{Z_3}$$

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

Verificare - tema!

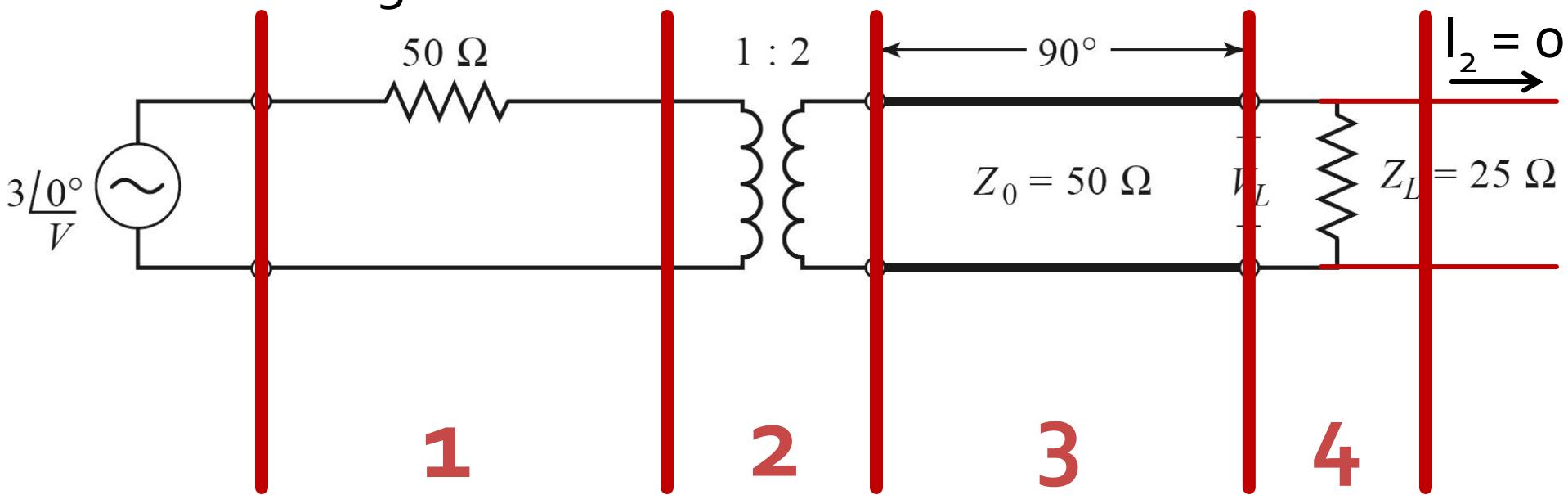
Exemplu utilizare matrice ABCD

- Determinati tensiunea pe sarcina in circuitul urmator



Exemplu utilizare matrice ABCD

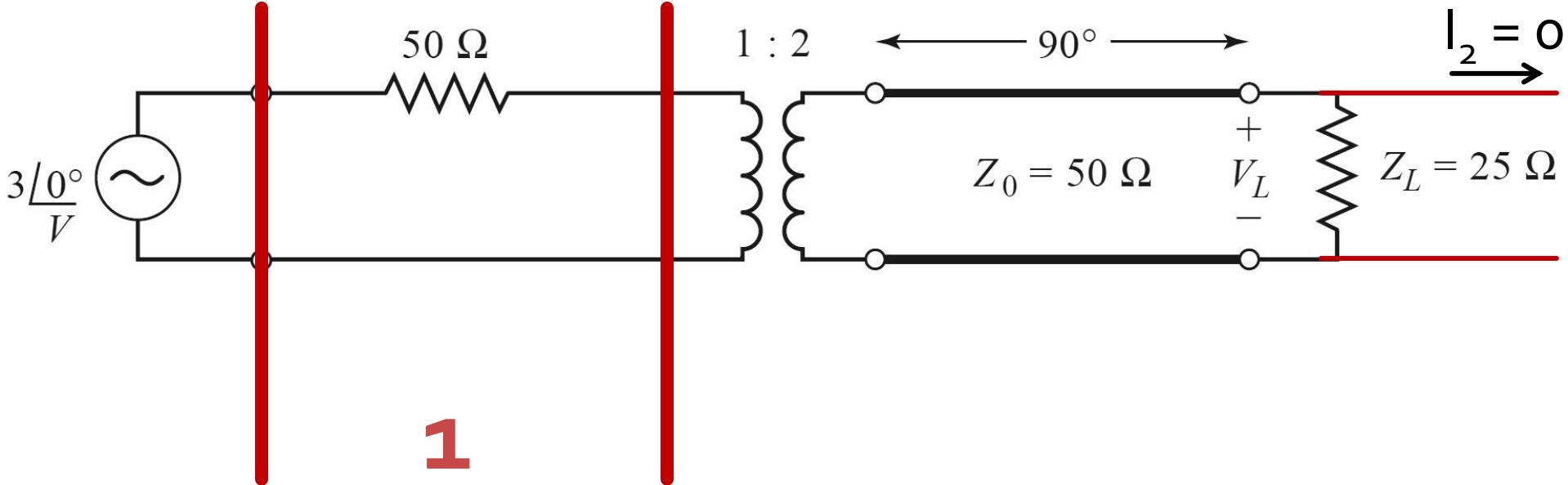
- Sectionare circuit in elemente simple
- Generatoarele raman in exterior
- Daca e necesar, se creaza porturi de intrare si iesire lasate in gol



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

Exemplu utilizare matrice ABCD

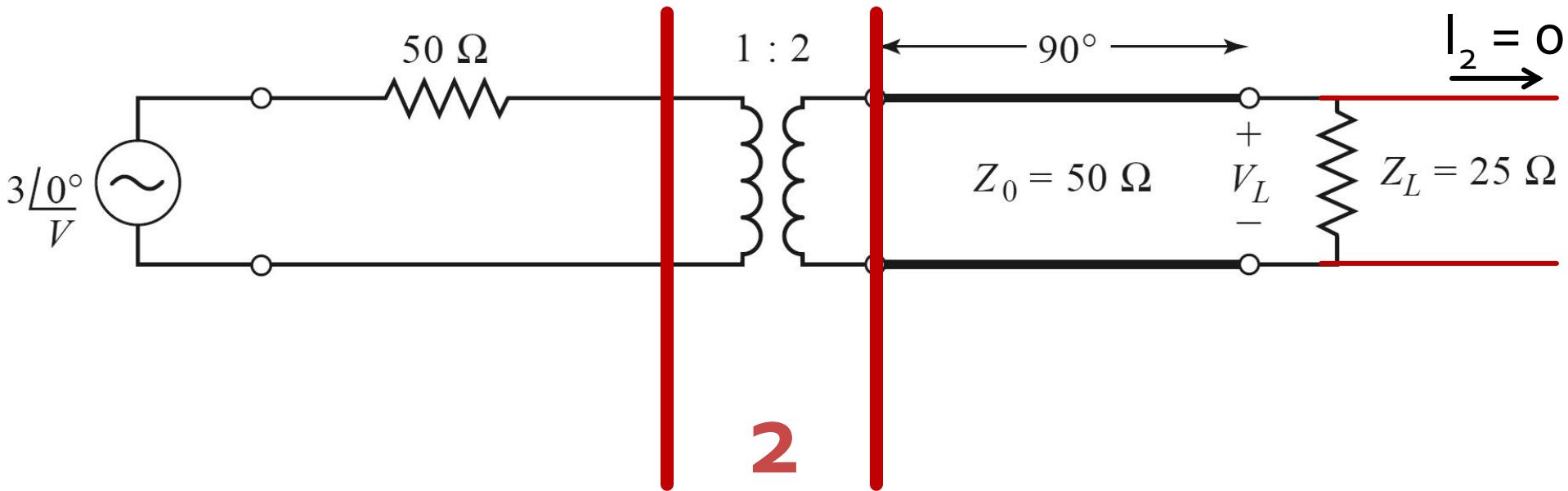
- M_1 , impedanta serie



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

Exemplu utilizare matrice ABCD

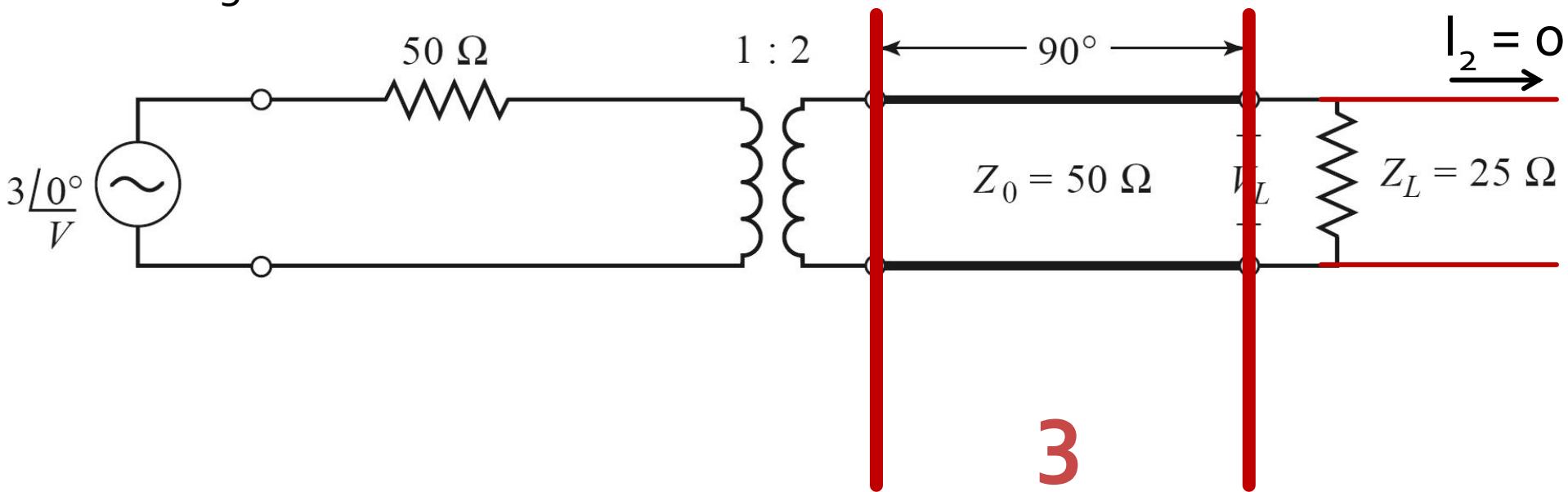
- M_2 , transformator 1:2



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

Exemplu utilizare matrice ABCD

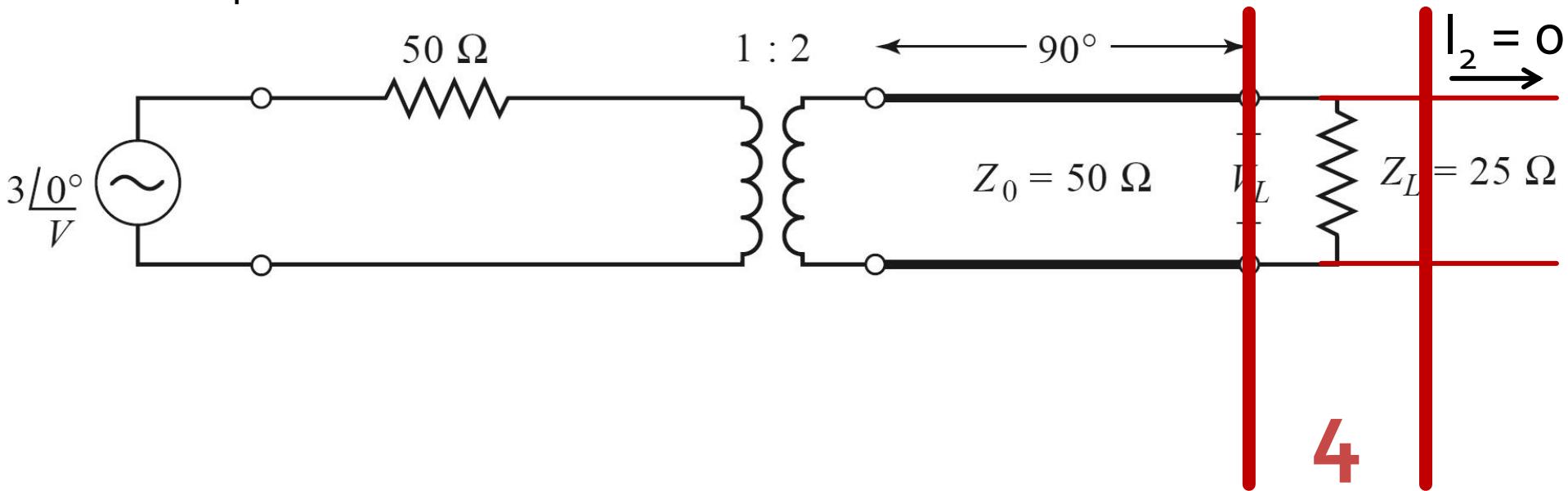
- M₃, linie serie, E = 90°



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

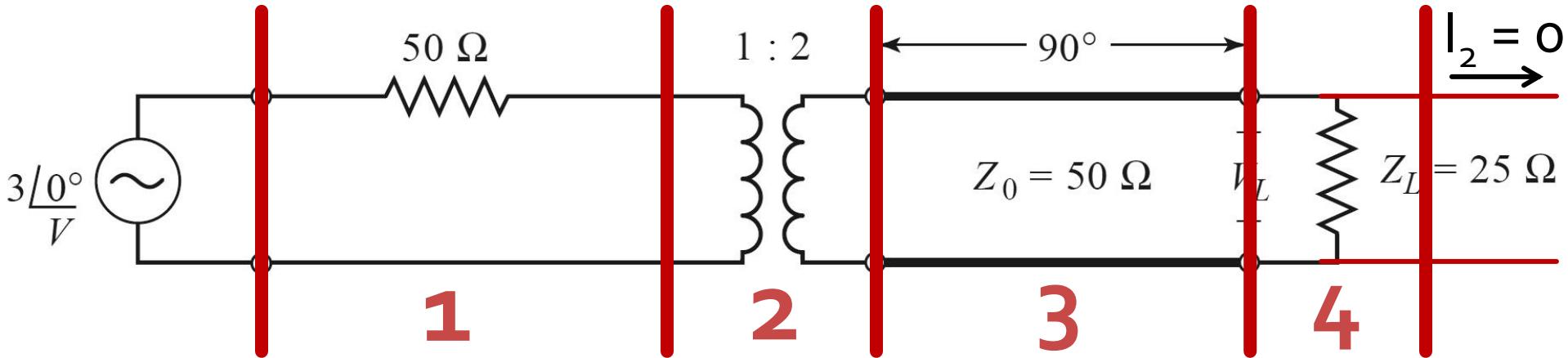
Exemplu utilizare matrice ABCD

- M_4 , impedanta/admitanta paralel



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

Exemplu utilizare matrice ABCD

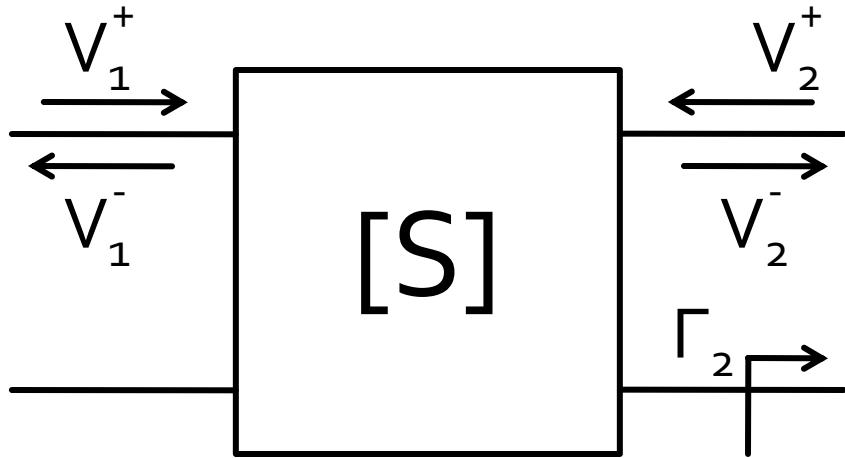


$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 50 \\ 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} \frac{1}{2} & 0 \\ 0 & 2 \end{bmatrix} \cdot \begin{bmatrix} 0 & 50 \cdot j \\ \frac{j}{50} & 0 \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 \\ \frac{1}{25} & 1 \end{bmatrix} = \begin{bmatrix}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

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

Matricea S (repartitie)

- Scattering parameters



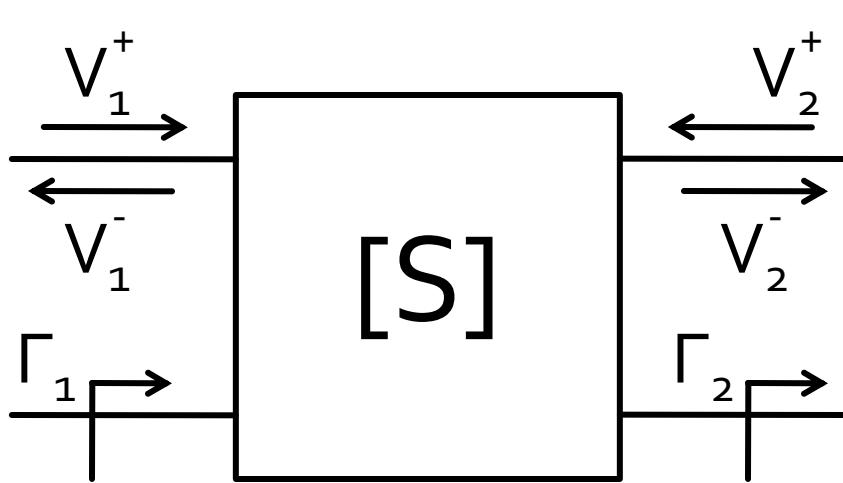
$$\begin{bmatrix} V_1^- \\ V_2^- \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} V_1^+ \\ V_2^+ \end{bmatrix}$$

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

- $V_2^+ = 0$ 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)



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

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

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

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

Matricea S (repartitie)

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

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

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

- 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

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

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

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

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

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

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

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

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

Deplasare a planului de referinta

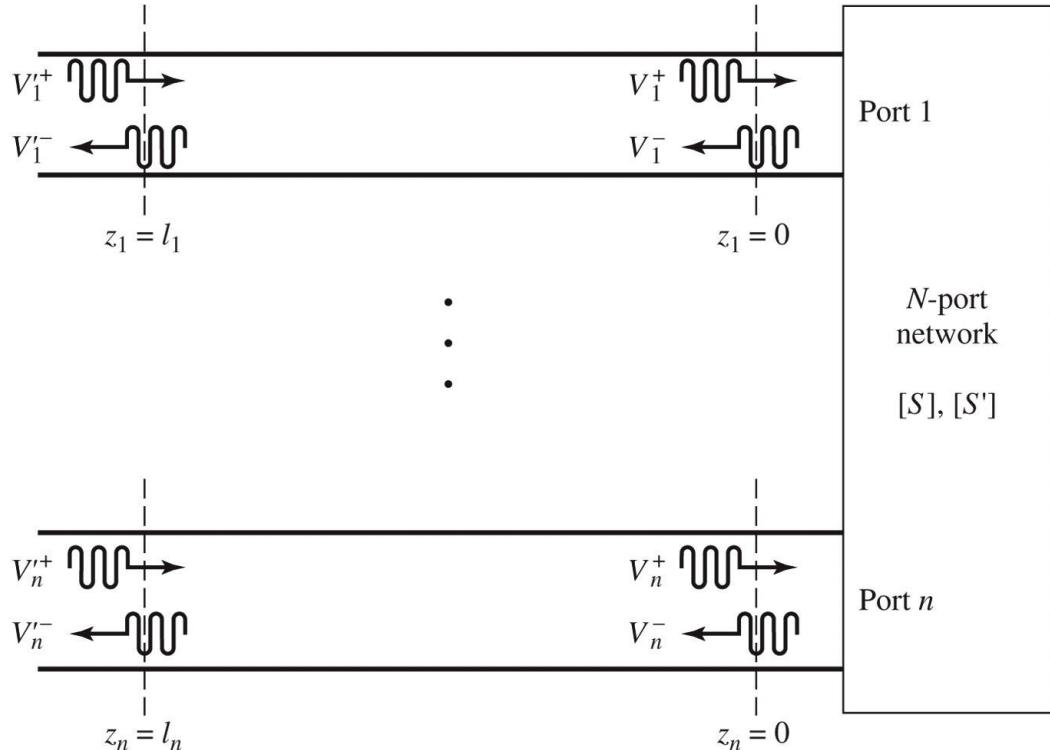


Figure 4.9
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$$[S'] = \begin{bmatrix} e^{-j\cdot\theta_1} & 0 & \dots & 0 \\ 0 & e^{-j\cdot\theta_2} & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & \dots & \dots & e^{-j\cdot\theta_N} \end{bmatrix} \cdot [S] \cdot \begin{bmatrix} e^{-j\cdot\theta_1}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

Proprietati [S]

- Circuite reciproce (fara circuite active, ferite)

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

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

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

- 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:

$$\begin{aligned} P_L &= \frac{1}{2} \operatorname{Re} \{ VI^* \} = \frac{1}{2Z_0} \operatorname{Re} \left\{ |V_0^+|^2 - V_0^+ V_0^{-*} + V_0^{+*} V_0^- - |V_0^-|^2 \right\} \\ &= \frac{1}{2Z_0} \left(|V_0^+|^2 - |V_0^-|^2 \right), \end{aligned}$$

Matricea S generalizata

- Definim undele de putere

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

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

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

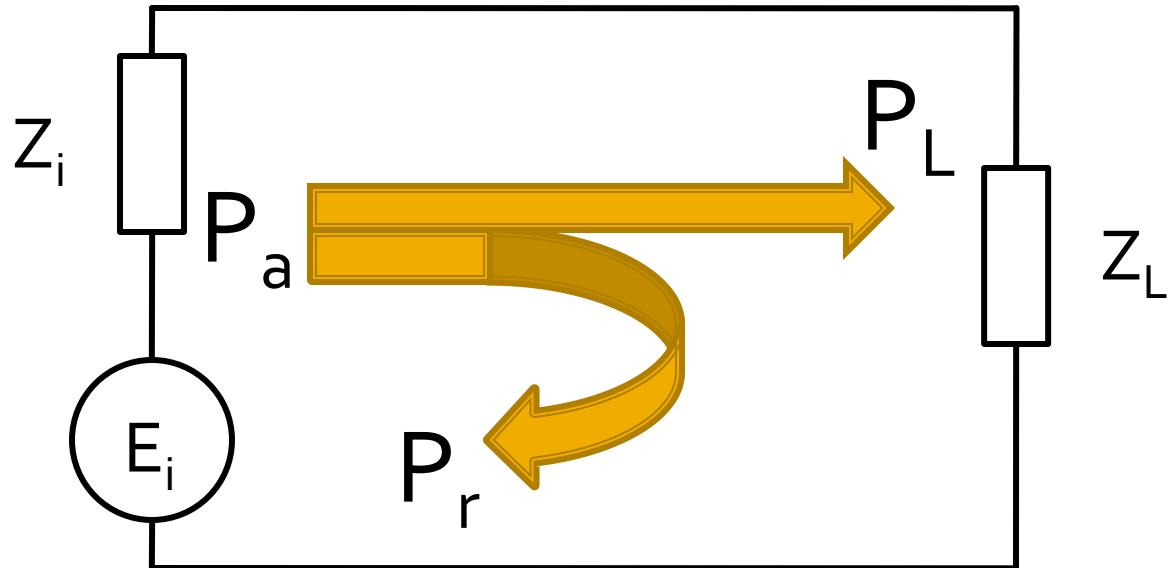
O impedanta de referinta
oarecare, complexa

- 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 / C2



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

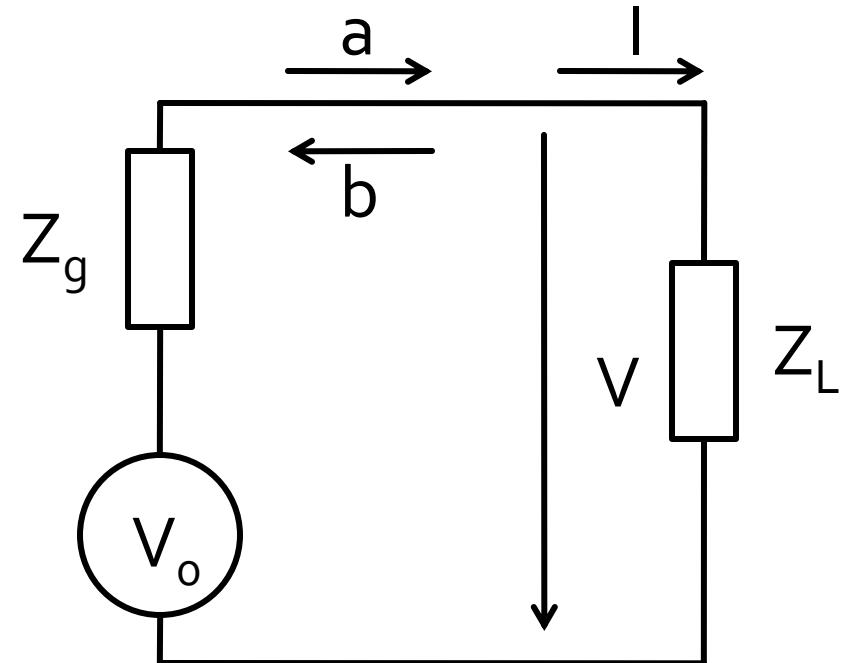
$$P_L = \frac{R_L \cdot |E_i|^2}{(R_i + R_L)^2 + (X_i + X_L)^2}$$

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

- coeficient de reflexie in putere

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

Unde de putere



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

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

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

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

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

Unde de putere

$$V = \frac{V_0 \cdot Z_L}{Z_g + Z_L}$$

$$I = \frac{V_0}{Z_g + Z_L}$$

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

■ 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 C2

$$Z_L = Z_i^* \quad P_{L\max} \equiv P_a$$

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

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

- Reflexie in putere C4

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

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

Unde de putere

- Definirile 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

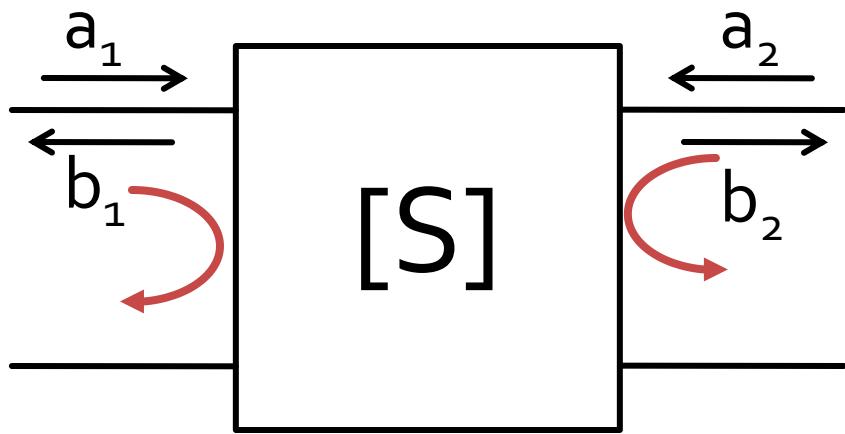
$$Z_{0i} = Z_{Ri} = R_0, \forall i$$

$$R_0 = 50\Omega$$

$$[S_p] \equiv [S]$$

■ coincid!!!

Matricea S (repartitie)

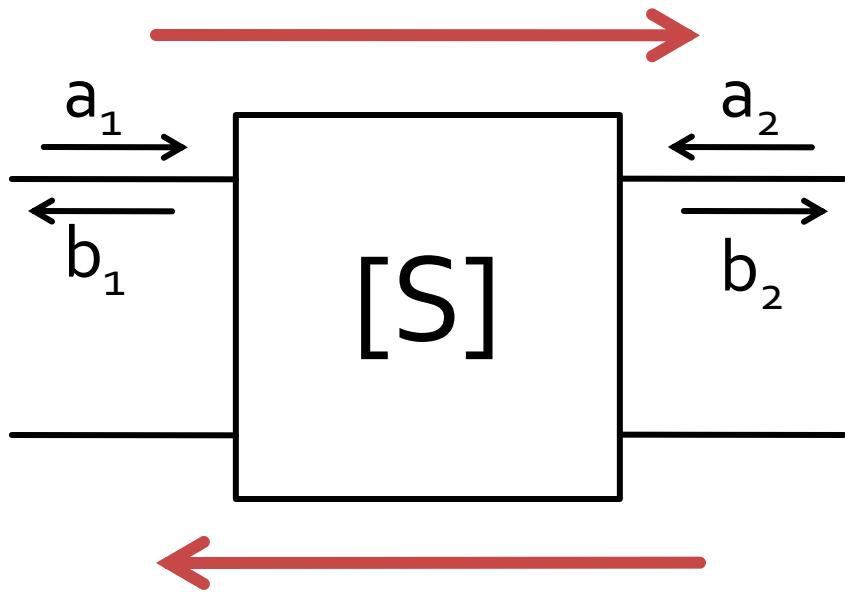


$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

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

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

Matricea S (repartitie)



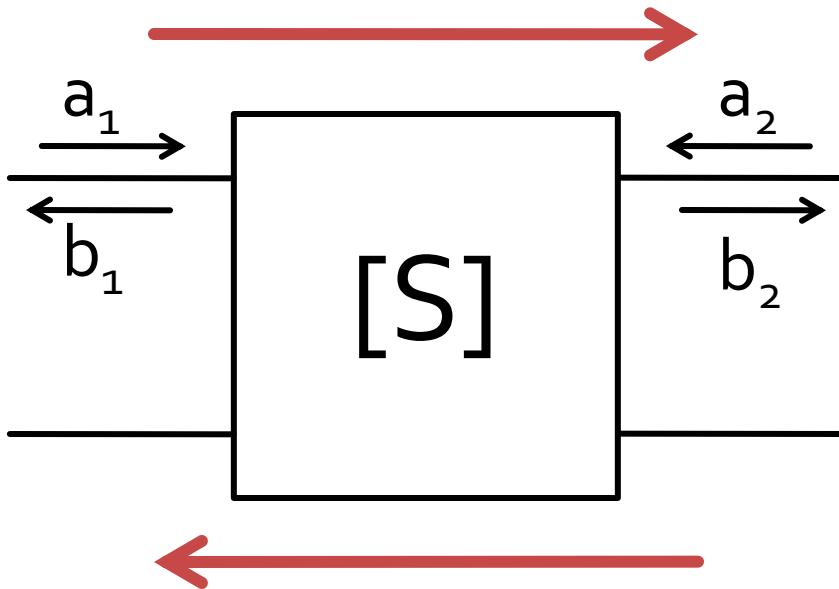
$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

$$S_{21} = \frac{b_2}{a_1} \Big|_{a_2=0}$$

$$S_{12} = \frac{b_1}{a_2} \Big|_{a_1=0}$$

- S_{21} și S_{12} sunt amplificări 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

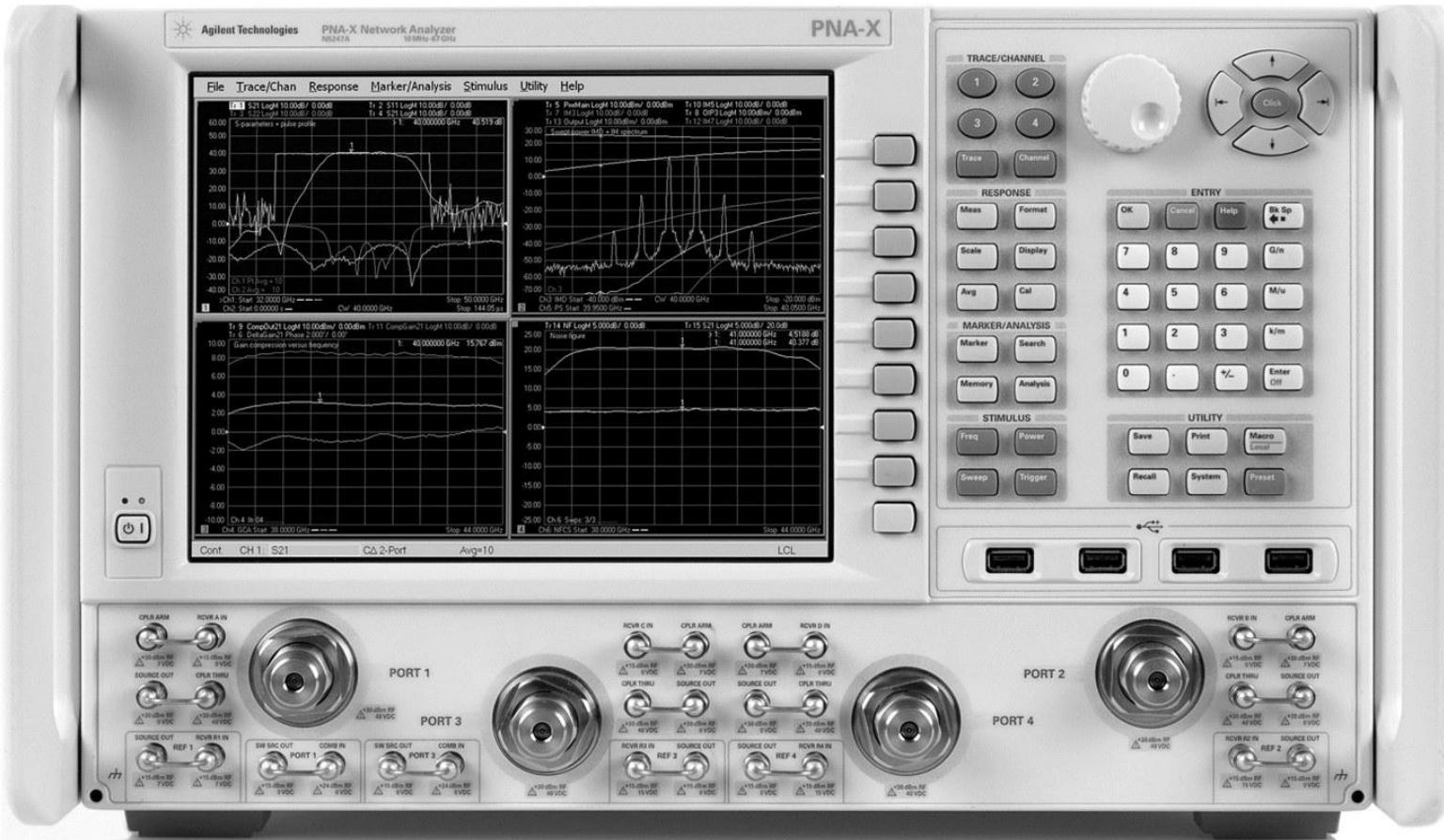


Figure 4.7
Courtesy of Agilent Technologies

Legatura dintre parametrii S si parametrii ABCD

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

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

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

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

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

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

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

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

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

**Cuploare directionale si
divizoare de putere**

Cuploare/Divizoare

- Funcționalitatea dorită:
 - divizarea
 - combinarea
- puterii semnalului

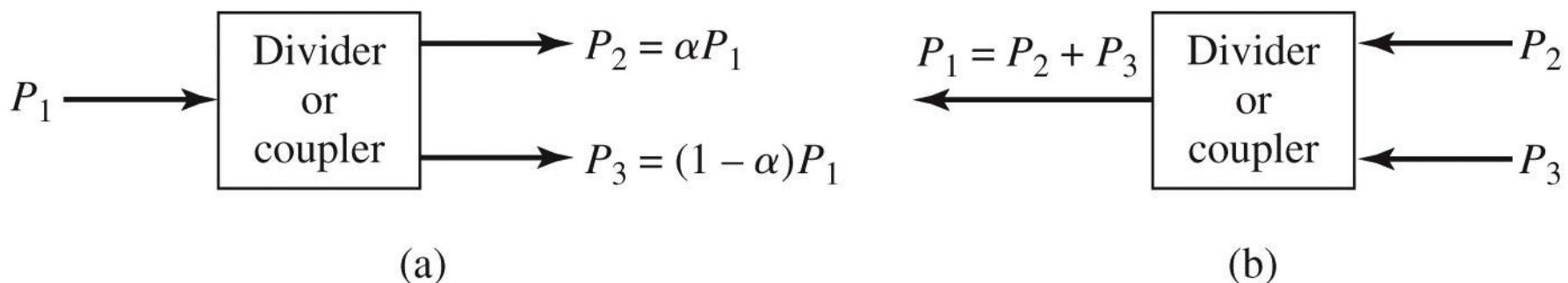


Figure 7.1
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Circuite cu trei porți

- numite și joncțiune în T
- caracterizate de o matrice S 3×3

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

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

Circuite cu trei porți

- circuit reciproc

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

$$S_{12} = S_{21}, S_{13} = S_{31}, S_{23} = S_{32}$$

- adaptat simultan la toate portile

$$S_{ii} = 0, \forall i \quad S_{11} = 0, S_{22} = 0, S_{33} = 0$$

- matricea S devine:

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

Circuite cu trei porți

- reciproc, adaptat, matricea S:

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

- circuit unitar (fără pierderi)

- toata puterea introdusa pe un port se regaseste la celelalte porturi

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

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

Circuite cu trei porți

- circuit unitar (fără pierderi)

$$[S] = \begin{bmatrix} 0 & S_{12} & S_{13} \\ S_{12} & 0 & S_{23} \\ S_{13} & S_{23} & 0 \end{bmatrix} \quad \sum_{k=1}^N S_{ki} \cdot S_{ki}^* = 1$$
$$\sum_{k=1}^N S_{ki} \cdot S_{kj}^* = 0, \forall i \neq j$$

- 6 ecuații / 3 necunoscute

$$|S_{12}|^2 + |S_{13}|^2 = 1 \quad S_{13}^* S_{23} = 0$$

$$|S_{12}|^2 + |S_{23}|^2 = 1 \quad S_{12}^* S_{13} = 0$$

$$|S_{13}|^2 + |S_{23}|^2 = 1 \quad S_{23}^* S_{12} = 0$$

- nici o soluție posibila

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
- Renunțarea la una din cele 3 condiții conduce la circuite realizabile

Circuit cu trei porți nereciproc

- de obicei cu materiale anizotrope, ferite
- **nereciproc**, dar adaptat simultan și fără pierderi

$$S_{ij} \neq S_{ji}$$

- matricea S

$$[S] = \begin{bmatrix} 0 & S_{12} & S_{13} \\ S_{21} & 0 & S_{23} \\ S_{31} & S_{32} & 0 \end{bmatrix}$$

- 6 ecuații / 6 necunoscute

$$|S_{12}|^2 + |S_{13}|^2 = 1 \quad S_{31}^* S_{32} = 0$$

$$|S_{21}|^2 + |S_{23}|^2 = 1 \quad S_{21}^* S_{23} = 0$$

$$|S_{31}|^2 + |S_{32}|^2 = 1 \quad S_{12}^* S_{13} = 0$$

Circuit cu trei porți nereciproc

- două solutii posibile
- circulatoare
 - în sens orar direct

$$S_{12} = S_{23} = S_{31} = 0$$

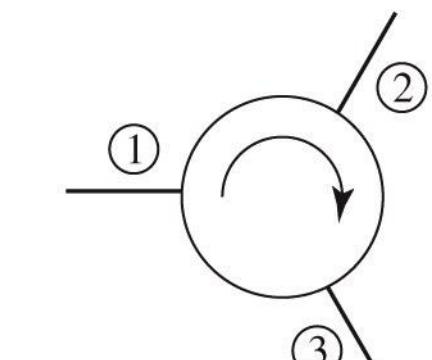
$$|S_{21}| = |S_{32}| = |S_{13}| = 1$$

- în sens orar invers

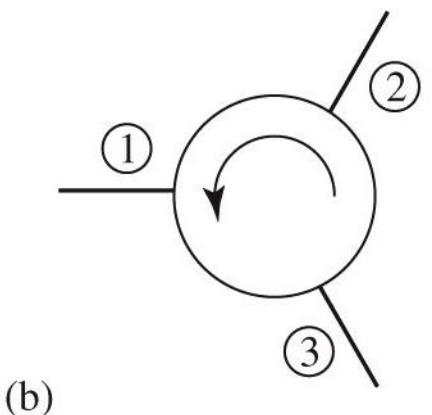
$$S_{21} = S_{32} = S_{13} = 0$$

$$|S_{12}| = |S_{23}| = |S_{31}| = 1$$

$$[S] = \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$



$$[S] = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix}$$



Circuit cu trei porți neadaptat

- Un circuit cu 3 porți reciproc și fără pierderi poate fi adaptat numai la 2 porți

$$[S] = \begin{bmatrix} 0 & S_{12} & S_{13} \\ S_{12} & 0 & S_{23} \\ S_{13} & S_{23} & S_{33} \end{bmatrix}$$

$$S_{13}^* S_{23} = 0$$

$$\begin{aligned} S_{12}^* S_{13} + S_{23}^* S_{33} &= 0 \\ S_{23}^* S_{12} + S_{33}^* S_{13} &= 0 \end{aligned}$$

$$\begin{aligned} S_{13} &= S_{23} = 0 \\ |S_{13}| &= |S_{23}| \end{aligned}$$

$$\begin{aligned} |S_{12}|^2 + |S_{13}|^2 &= 1 \\ |S_{12}|^2 + |S_{23}|^2 &= 1 \\ |S_{13}|^2 + |S_{23}|^2 + |S_{33}|^2 &= 1 \end{aligned}$$

$$|S_{12}| = |S_{33}| = 1$$

Circuit cu trei porți neadaptat

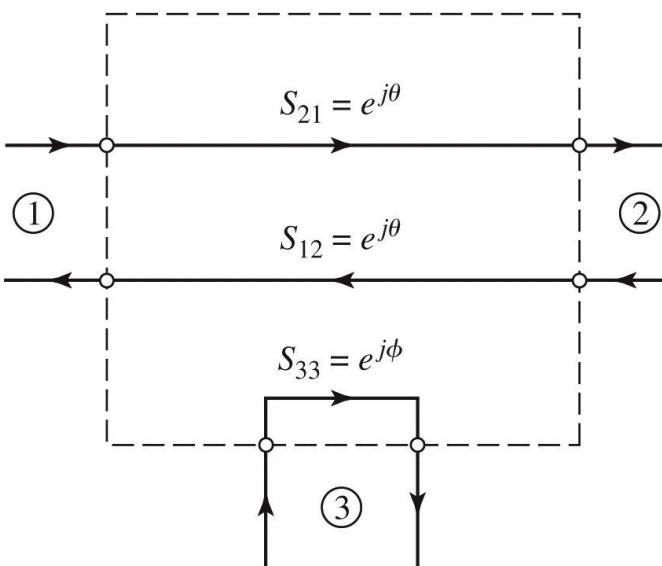
- Un circuit cu 3 porți reciproc și fără pierderi

$$[S] = \begin{bmatrix} 0 & S_{12} & S_{13} \\ S_{12} & 0 & S_{23} \\ S_{13} & S_{23} & S_{33} \end{bmatrix}$$

$$S_{13} = S_{23} = 0 \quad |S_{12}| = |S_{33}| = 1$$

$$S_{12} = e^{j\theta} \quad S_{33} = e^{j\varphi}$$

$$[S] = \begin{bmatrix} 0 & e^{j\theta} & 0 \\ e^{j\theta} & 0 & 0 \\ 0 & 0 & e^{j\varphi} \end{bmatrix}$$



- Un circuit cu 3 porți reciproc și fără pierderi **degenerează** în două componente separate:
 - **o linie** fără pierderi, adaptată, între două dintre porturi
 - **al treilea port** este **separat** și **dezadaptat**

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

- circuit reciproc

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

$$S_{12} = S_{21}, S_{13} = S_{31}, S_{23} = S_{32}$$

- adaptat simultan la toate portile

$$S_{ii} = 0, \forall i \quad S_{11} = 0, S_{22} = 0, S_{33} = 0, S_{44} = 0$$

- matricea S devine:

$$[S] = \begin{bmatrix} 0 & S_{12} & S_{13} & S_{14} \\ S_{12} & 0 & S_{23} & S_{24} \\ S_{13} & S_{23} & 0 & S_{34} \\ S_{14} & S_{24} & S_{34} & 0 \end{bmatrix}$$

Circuite cu patru porți

- reciproc, adaptat, matricea S :

$$[S] = \begin{bmatrix} 0 & S_{12} & S_{13} & S_{14} \\ S_{12} & 0 & S_{23} & S_{24} \\ S_{13} & S_{23} & 0 & S_{34} \\ S_{14} & S_{24} & S_{34} & 0 \end{bmatrix}$$

- circuit unitar (fără pierderi)

- toata puterea introdusa pe un port se regaseste la celelalte porturi

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

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

Circuite cu patru porți

$$S_{13}^* \cdot S_{23} + S_{14}^* \cdot S_{24} = 0 \quad / \cdot S_{24}$$

$$S_{14}^* \cdot S_{13} + S_{24}^* \cdot S_{23} = 0 \quad / \cdot S_{13}$$

$$\underline{S_{14}^* \cdot (|S_{13}|^2 - |S_{24}|^2) = 0}$$

$$S_{12}^* \cdot S_{23} + S_{14}^* \cdot S_{34} = 0 \quad / \cdot S_{12}$$

$$S_{14}^* \cdot S_{12} + S_{34}^* \cdot S_{23} = 0 \quad / \cdot S_{34}^*$$

$$\underline{S_{23} \cdot (|S_{12}|^2 - |S_{34}|^2) = 0}$$

- o solutie: $S_{14} = S_{23} = 0$
- cuploul rezulta **directional**

$$|S_{12}|^2 + |S_{13}|^2 = 1 \quad \rightarrow |S_{13}| = |S_{24}|$$

$$|S_{12}|^2 + |S_{24}|^2 = 1 \quad \rightarrow |S_{12}| = |S_{34}|$$

$$[S] = \begin{bmatrix} 0 & S_{12} & S_{13} & 0 \\ S_{12} & 0 & 0 & S_{24} \\ S_{13} & 0 & 0 & S_{34} \\ 0 & S_{24} & S_{34} & 0 \end{bmatrix}$$

Circuite cu patru porți

$$[S] = \begin{bmatrix} 0 & S_{12} & S_{13} & 0 \\ S_{12} & 0 & 0 & S_{24} \\ S_{13} & 0 & 0 & S_{34} \\ 0 & S_{24} & S_{34} & 0 \end{bmatrix} \quad |S_{12}| = |S_{34}| = \alpha \quad |S_{13}| = |S_{24}| = \beta$$

β – coeficientul de cuplaj în tensiune

- Alegem referintele de fază

$$S_{12} = S_{34} = \alpha \quad S_{13} = \beta \cdot e^{j\theta} \quad S_{24} = \beta \cdot e^{j\phi}$$

$$S_{12}^* \cdot S_{13} + S_{24}^* \cdot S_{34} = 0 \quad \rightarrow \quad \theta + \phi = \pi \pm 2 \cdot n \cdot \pi$$

$$|S_{12}|^2 + |S_{24}|^2 = 1 \quad \rightarrow \quad \alpha^2 + \beta^2 = 1$$

- Cealalta solutie posibila pentru ecuatiiile anterioare ofera fie aceeasi solutie (cu alta referinta de fază) fie un caz degenerat

$$S_{14}^* \cdot (|S_{13}|^2 - |S_{24}|^2) = 0 \quad S_{23} \cdot (|S_{12}|^2 - |S_{34}|^2) = 0$$

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

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

Circuite cu patru porți

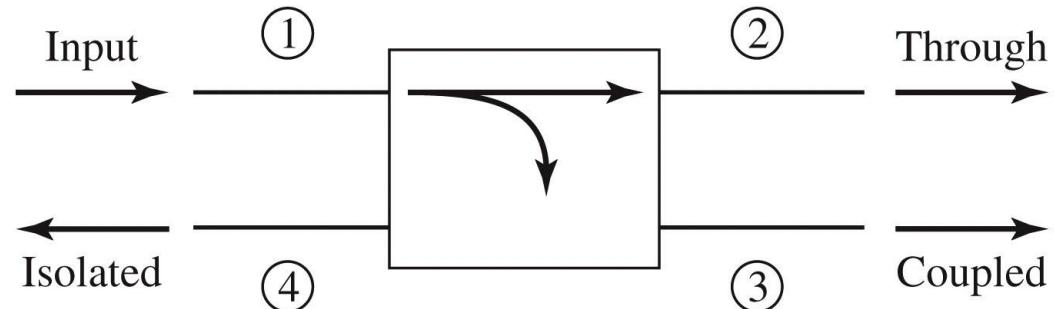
- 2 cazuri mai des întâlnite în practică
 - cupluri simetrie $\theta = \phi = \pi/2$

$$[S] = \begin{bmatrix} 0 & \alpha & j\beta & 0 \\ \alpha & 0 & 0 & j\beta \\ j\beta & 0 & 0 & \alpha \\ 0 & j\beta & \alpha & 0 \end{bmatrix}$$

- cupluri asymmetric $\theta = 0, \phi = \pi$

$$[S] = \begin{bmatrix} 0 & \alpha & \beta & 0 \\ \alpha & 0 & 0 & -\beta \\ \beta & 0 & 0 & \alpha \\ 0 & -\beta & \alpha & 0 \end{bmatrix}$$

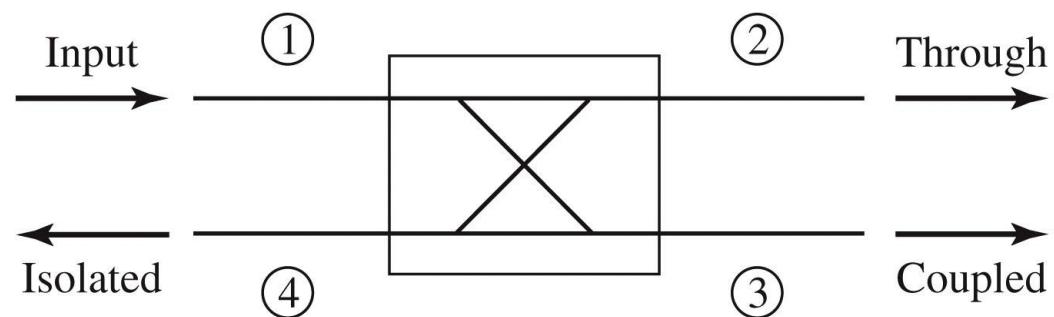
Cuplaj directional



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

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

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

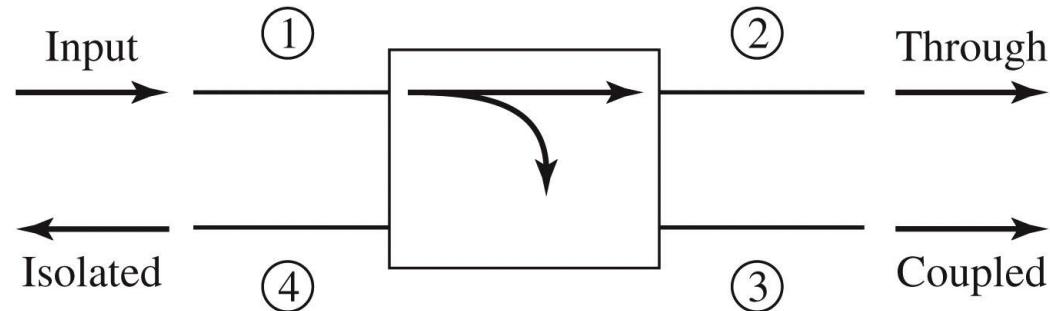
$$I = 10 \log \frac{P_1}{P_4} = -20 \cdot \log |S_{14}| [\text{dB}]$$

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

Cuploare directionale

Laborator 2

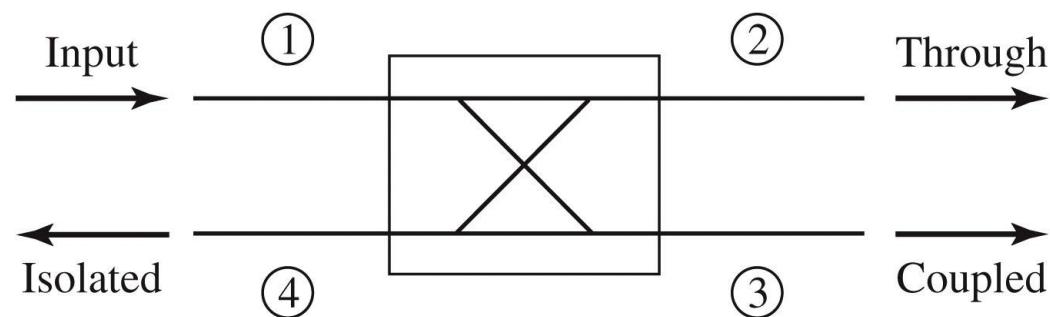
Cuplaj directional



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

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

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

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

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

Cuplорul in cuadratura

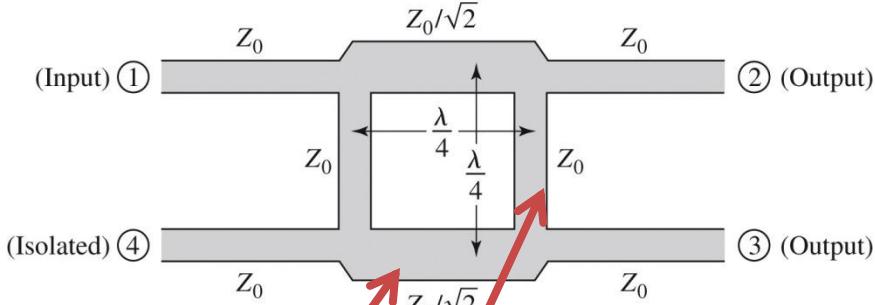


Figure 7.21
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$$y_2^2 = 1 + y_1^2$$

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

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

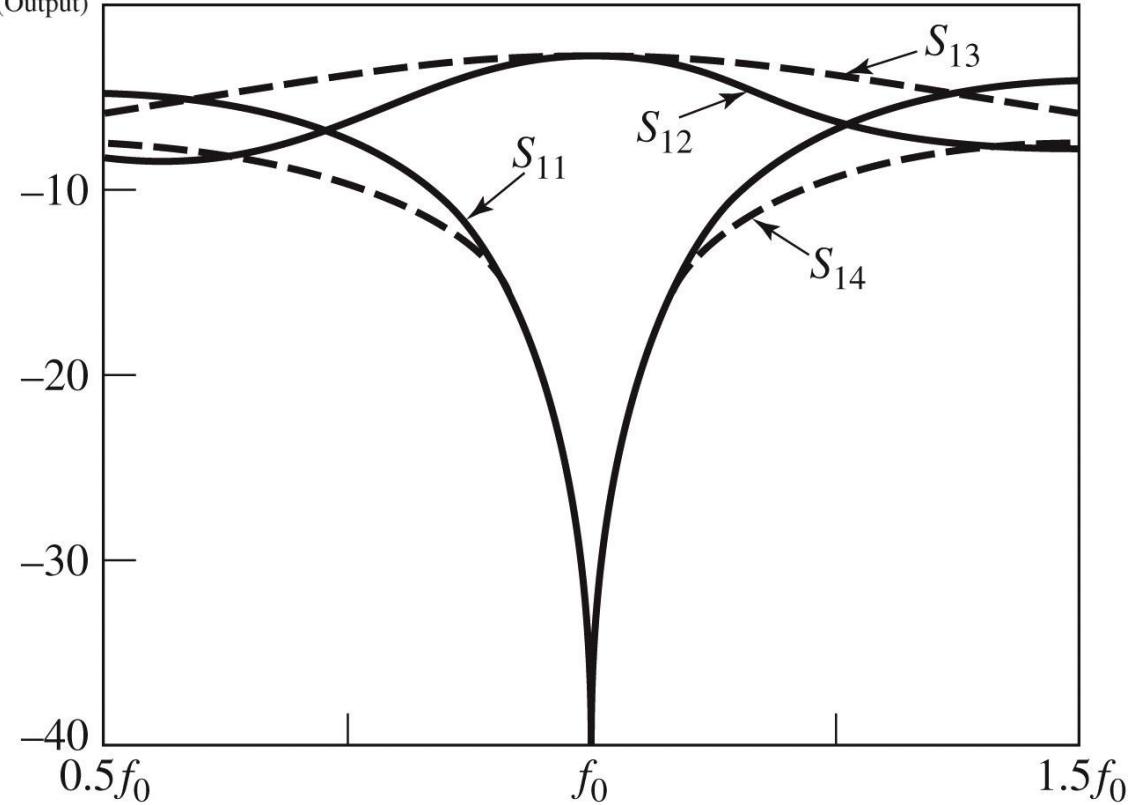
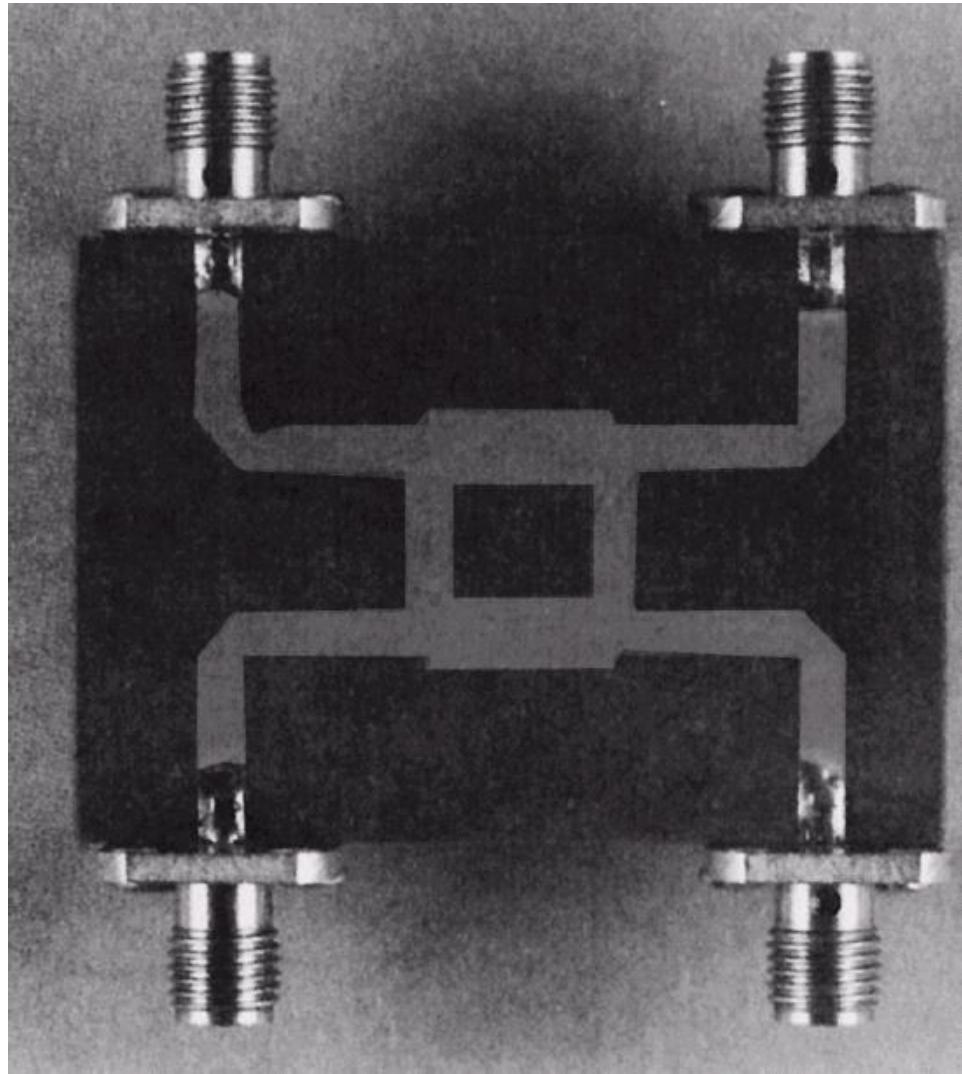
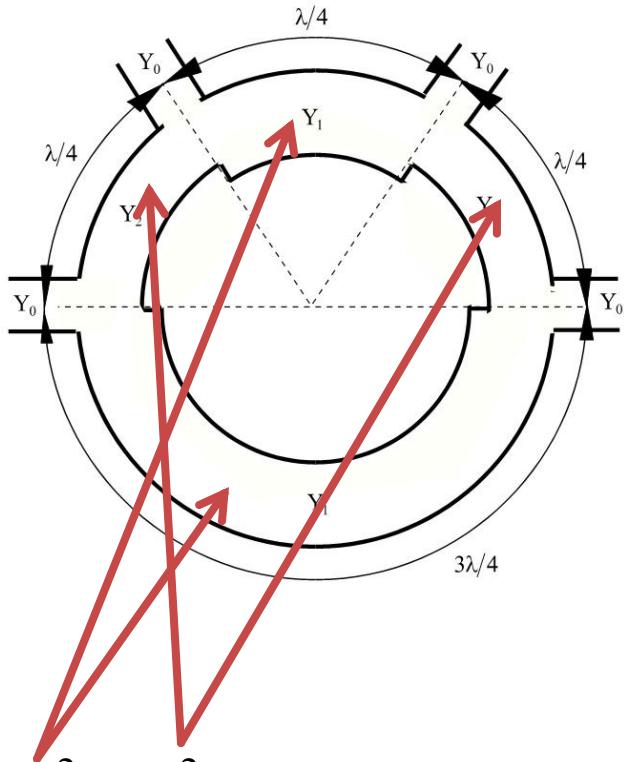


Figure 7.25
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Cuploul în inel



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

$$|\beta| = y_1$$

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

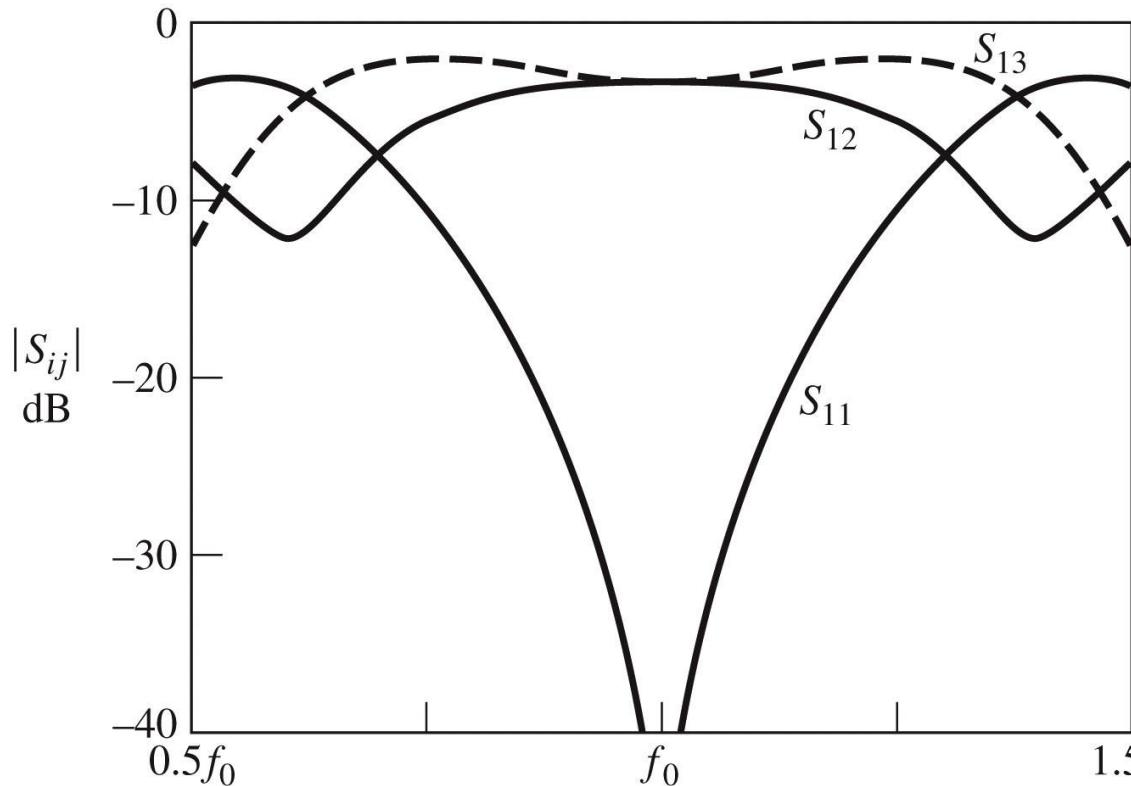


Figure 7.46
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Cupluri în inel

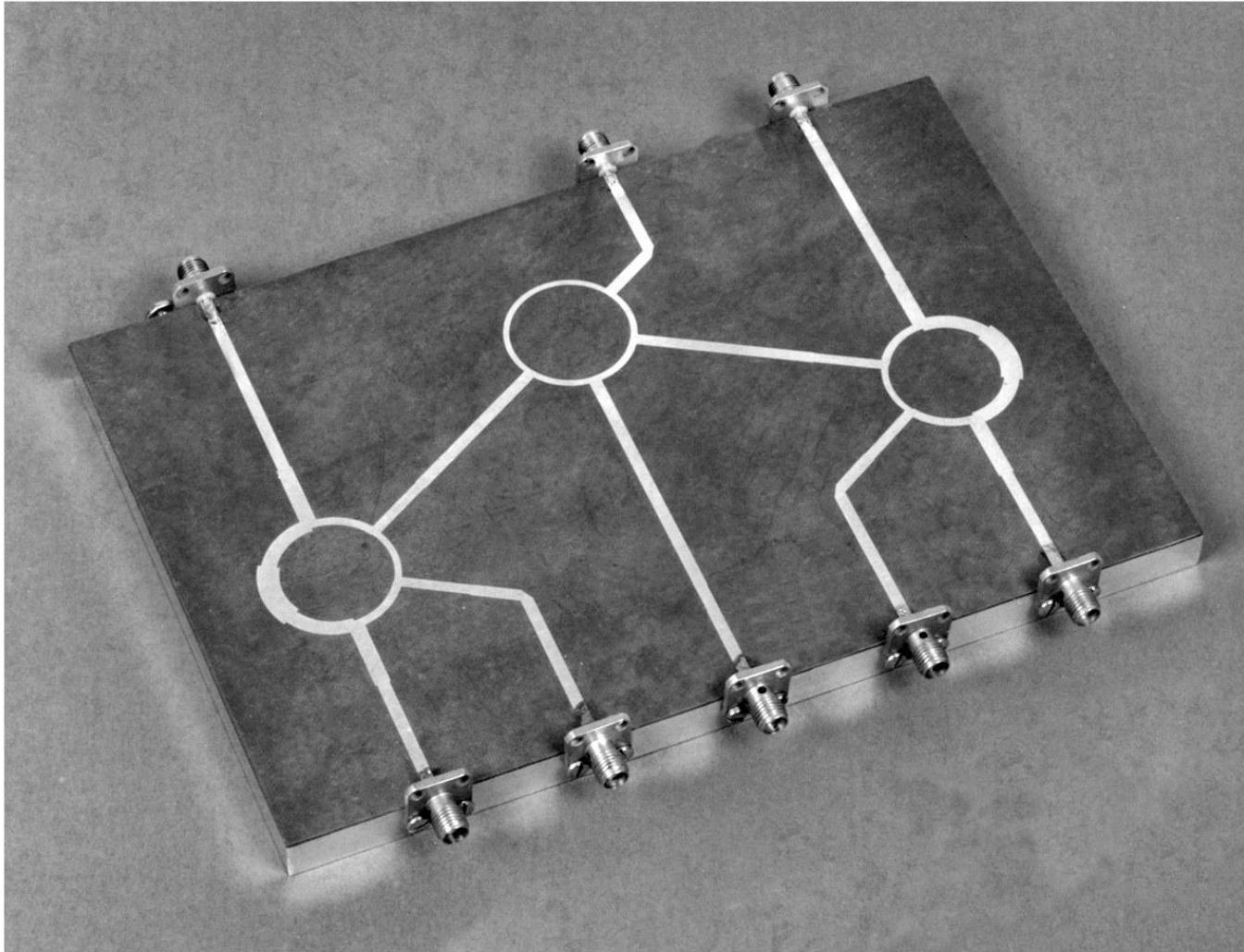
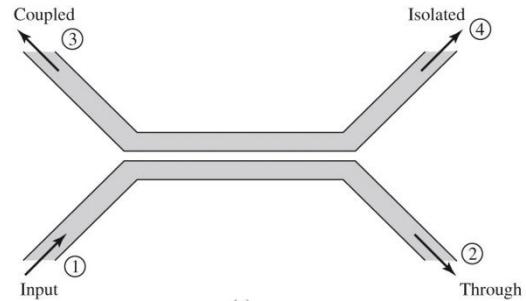


Figure 7.43
Courtesy of M. D. Abouzahra, MIT Lincoln Laboratory, Lexington, Mass.

Cuplă prin proximitate



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

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

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

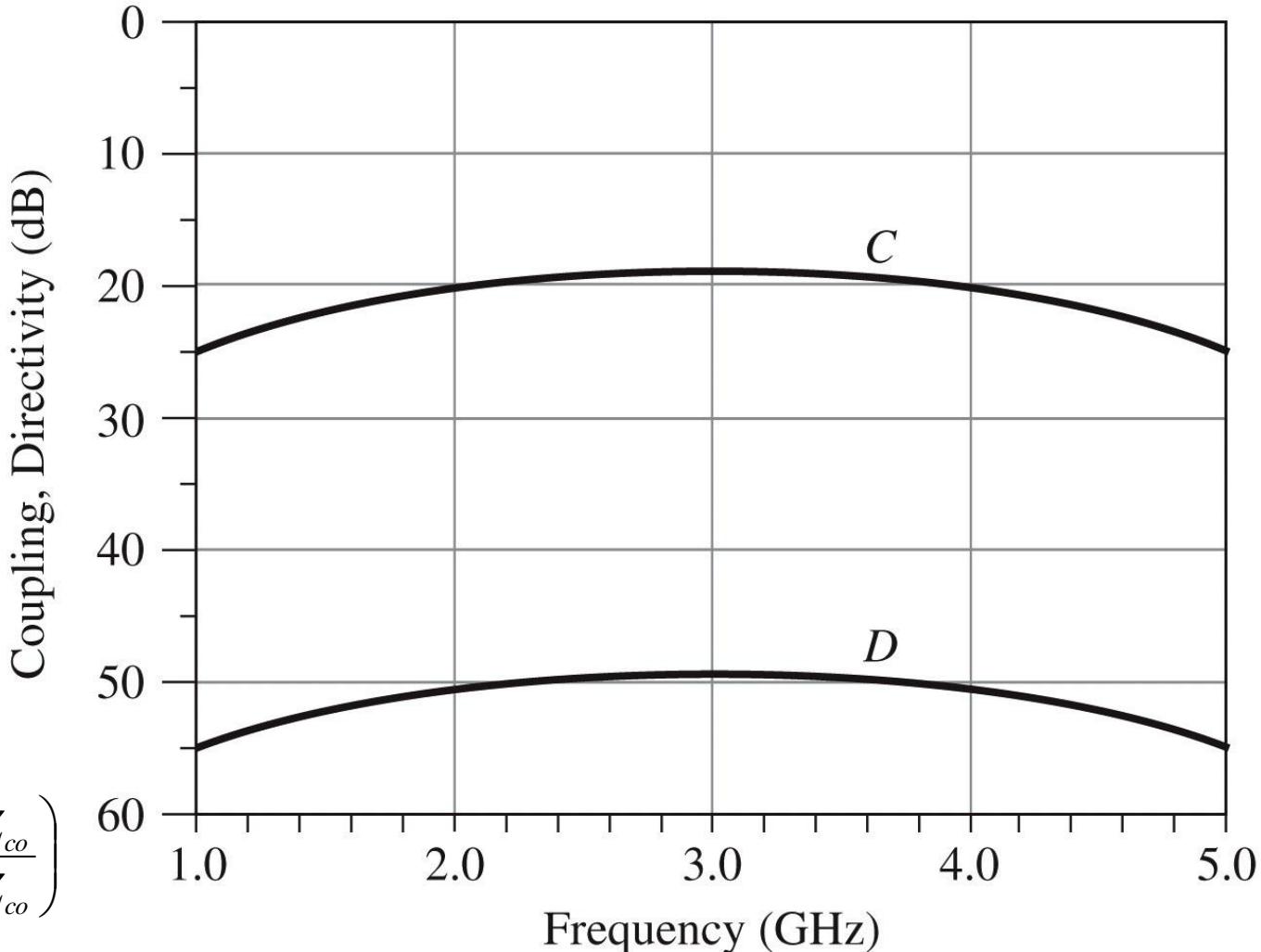
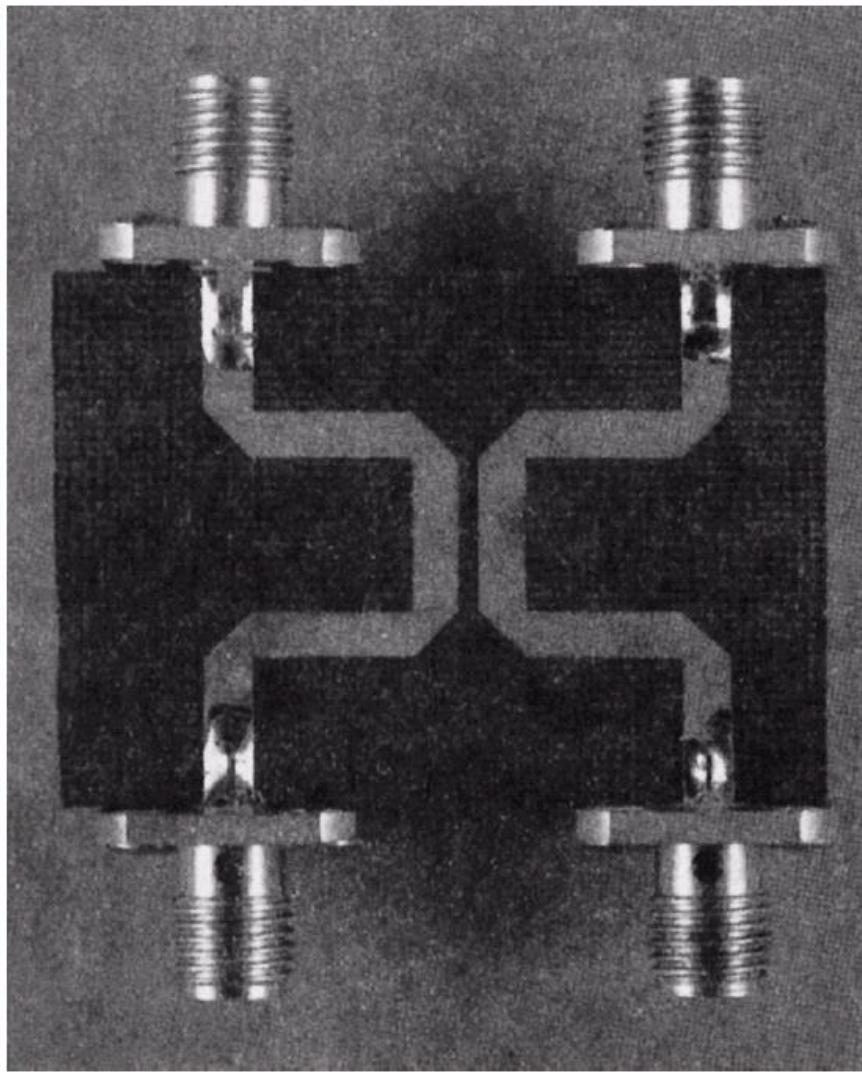


Figure 7.34

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