

Curs 13

2019/2020

# Dispozitive și circuite de microunde pentru radiocomunicații

# Disciplina 2019/2020

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

# Disciplina 2019/2020

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

# Documentatie

■ <http://rf-opto.etti.tuiasi.ro>

Laboratorul de Microunde si Optica

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

RF-OPTO

English | Romana

Start **Didactic** Master Colectiv Cercetare Studenti Admin

Microunde Comunicatii Optice Optoelectronica Internet Antene Practica Retele Soft didactic

## Dispozitive si circuite de microunde pentru radiocomunicatii

### Disciplina: DCMR (2017-2018)

**Coordonator Disciplina:** conf. dr. Radu-Florin Damian  
**Cod:** DOS412T  
**Tip Disciplina:** DOS; Disciplina Optionala, Disciplina de Specialitate  
**Credite:** 4  
**An de Studiu:** 4, Sem. 7

### Activitati

**Curs:** Cadru Didactic: conf. dr. Radu-Florin Damian, 2 Ore/Saptamana, Sectie Specializare, Orar:  
**Laborator:** Cadru Didactic: conf. dr. Radu-Florin Damian, 1 Ore/Saptamana, Grupa, Orar:

### Evaluare

Tip: **Examen**

**A:** 50%, (Examen/Colocviu)  
**B:** 25%, (Activitate Seminar/Laborator/Proiect)  
**D:** 25%, (Teme de casa/Lucrari de specialitate)

### Note

[Rezultate totale](#)

### Prezenta

[Curs](#)  
[Laborator](#)

### Liste

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



# Bibliografie

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

# Examen: Reprezentare logaritmică

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

# Examen: Operatii cu numere complexe

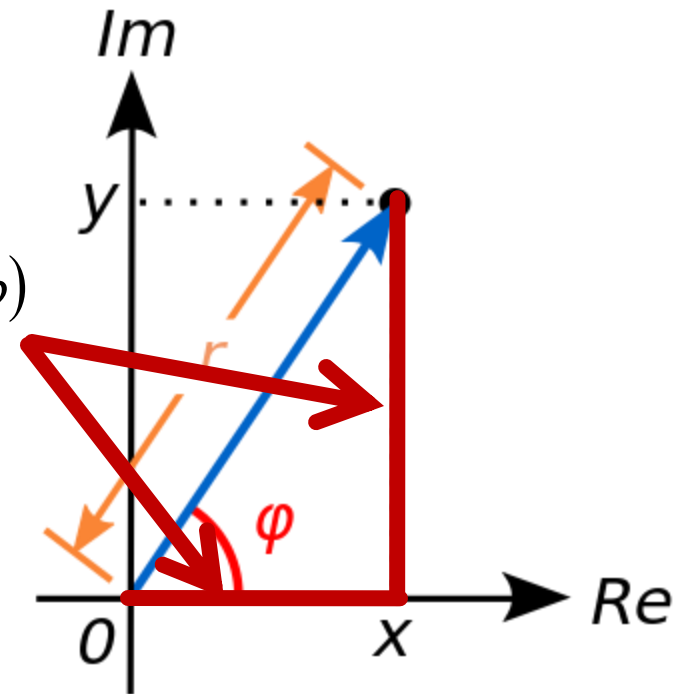
## ■ Reprezentare polara

- modul
- faza

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

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

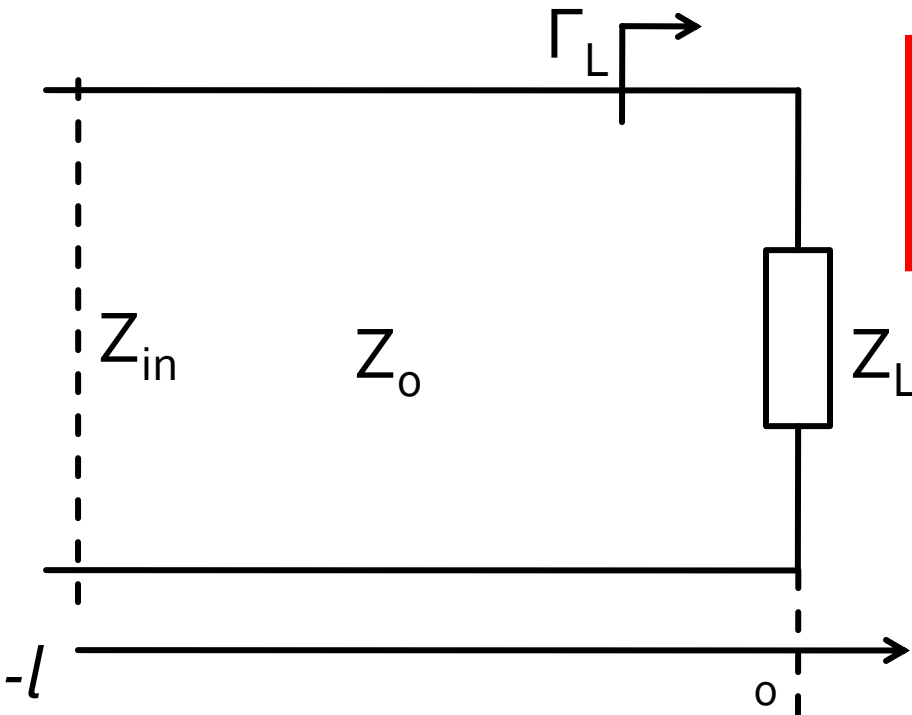
$$\varphi = \arg(z) = \begin{cases} \arctan\left(\frac{b}{a}\right), & a > 0 \\ \arctan\left(\frac{b}{a}\right) + \pi, & a < 0, b \geq 0 \\ \arctan\left(\frac{b}{a}\right) - \pi, & a < 0, b < 0 \\ \frac{\pi}{2}, -\frac{\pi}{2}, \text{ nedefinit} & a = 0 \end{cases}$$



# Linii de transmisie in mod TEM

# Linie fara pierderi

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

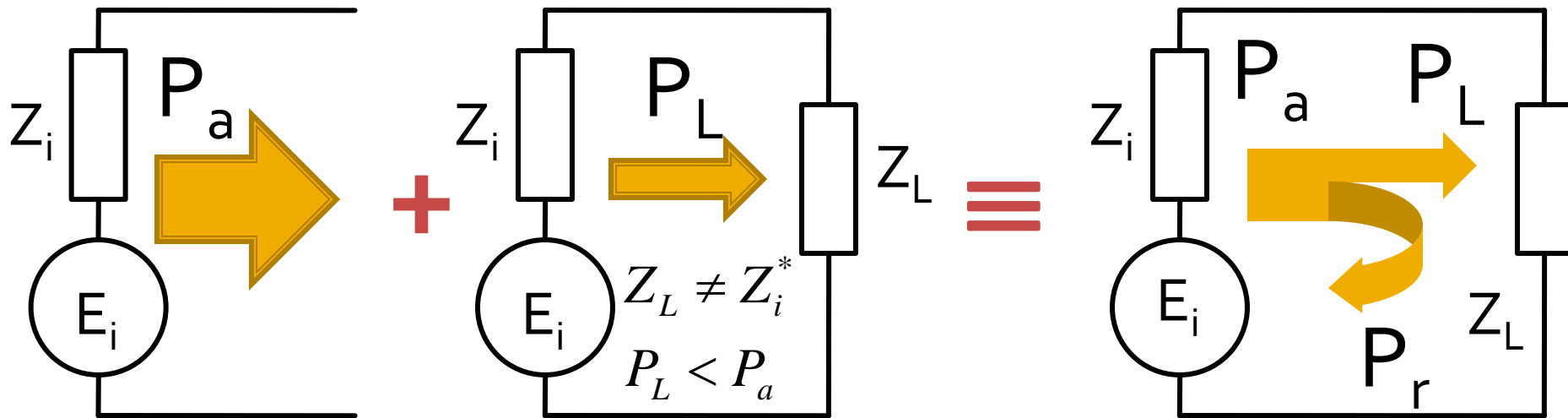


$$Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan \beta \cdot l}{Z_0 + j \cdot Z_L \cdot \tan \beta \cdot l}$$

Transfer de putere

# Adaptarea de impedanță

# Reflexie de putere / Model

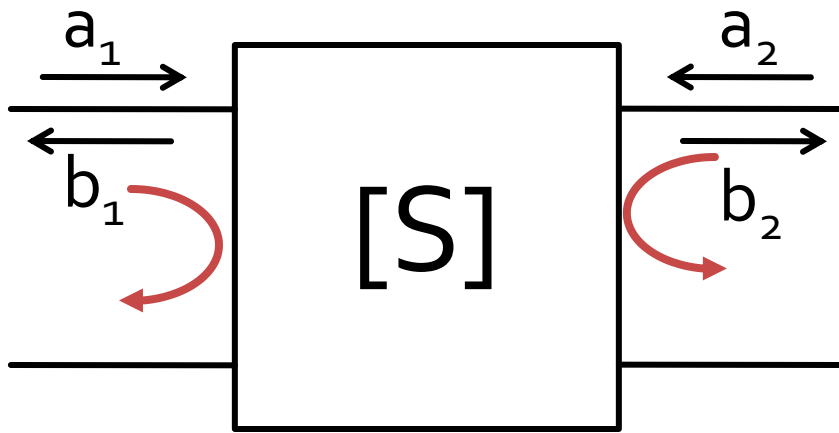


- Generatorul are posibilitatea de a oferi o anumita putere maxima de semnal  $P_a$
- Pentru o sarcina oarecare, acestuia i se ofera o putere de semnal mai mica  $P_L < P_a$
- Se intampla **"ca si cum"** (model) o parte din putere se reflecta  $P_r = P_a - P_L$
- Puterea este o marime **scalara!**

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



# Matricea S (repartitie)

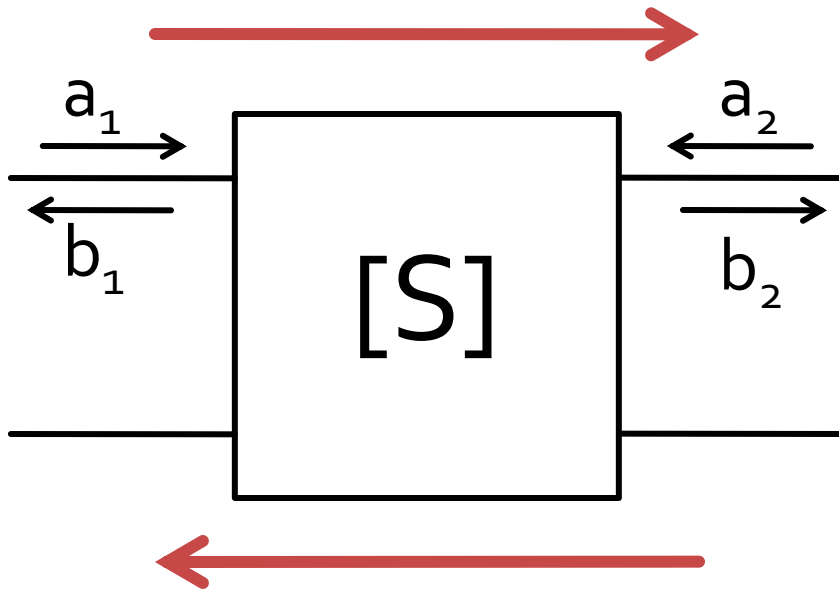


$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

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

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

# Matricea S (repartitie)

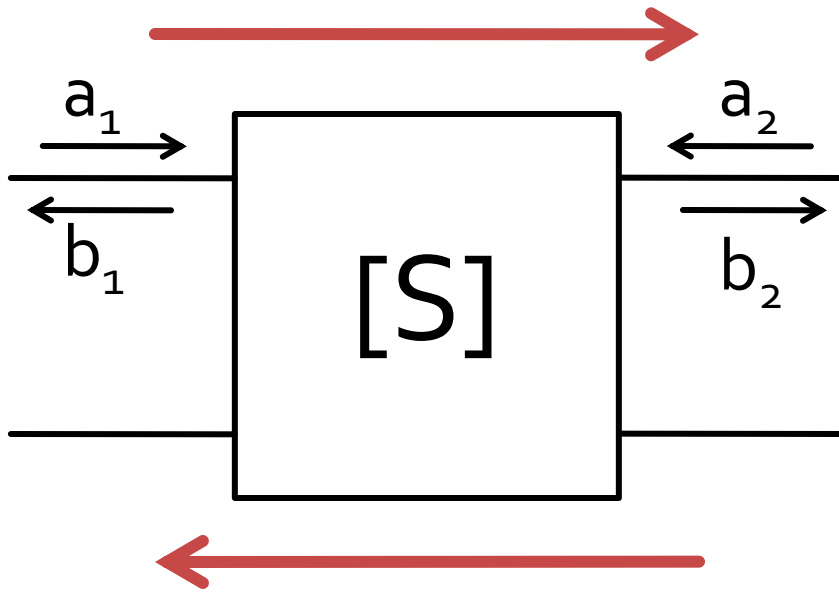


$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

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

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

# Matricea S (repartitie)



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

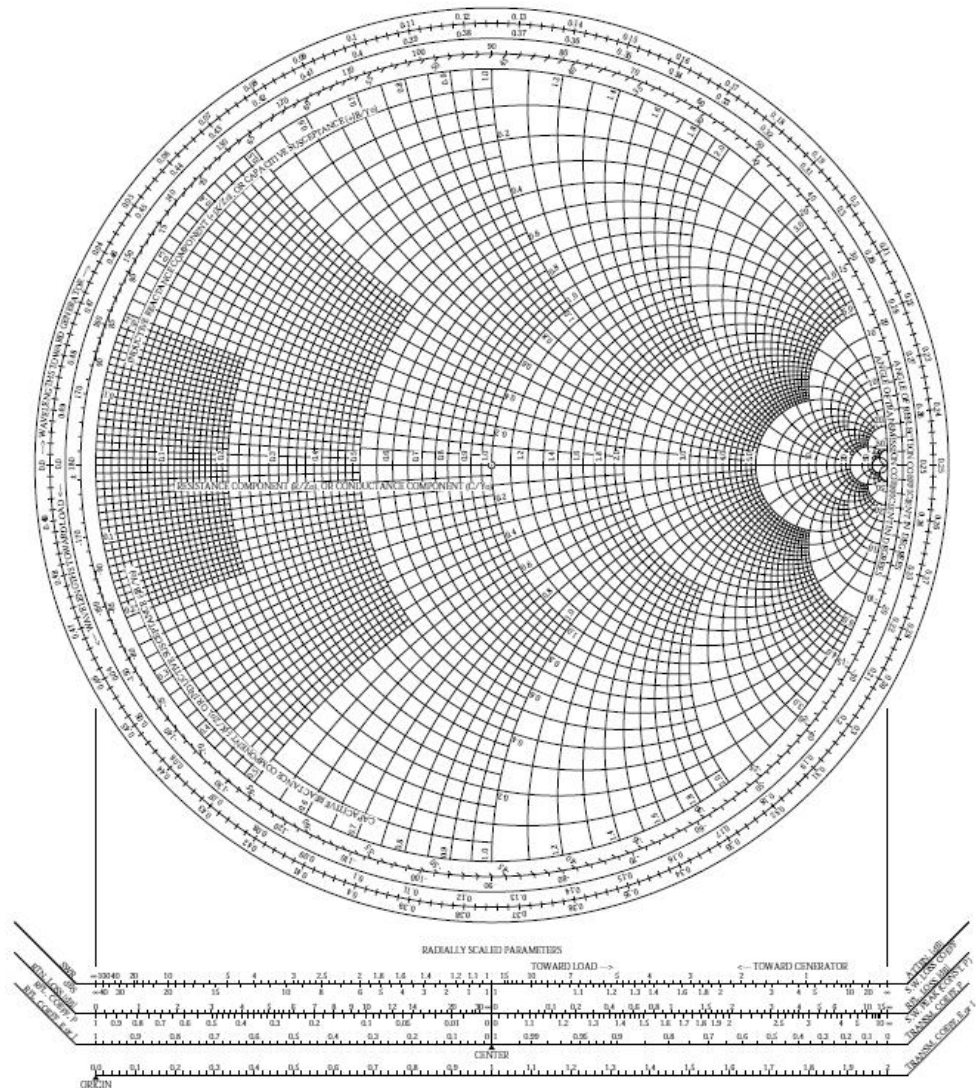
$$|S_{21}|^2 = \frac{\text{Putere sarcina } Z_0}{\text{Putere sursa } Z_0}$$

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

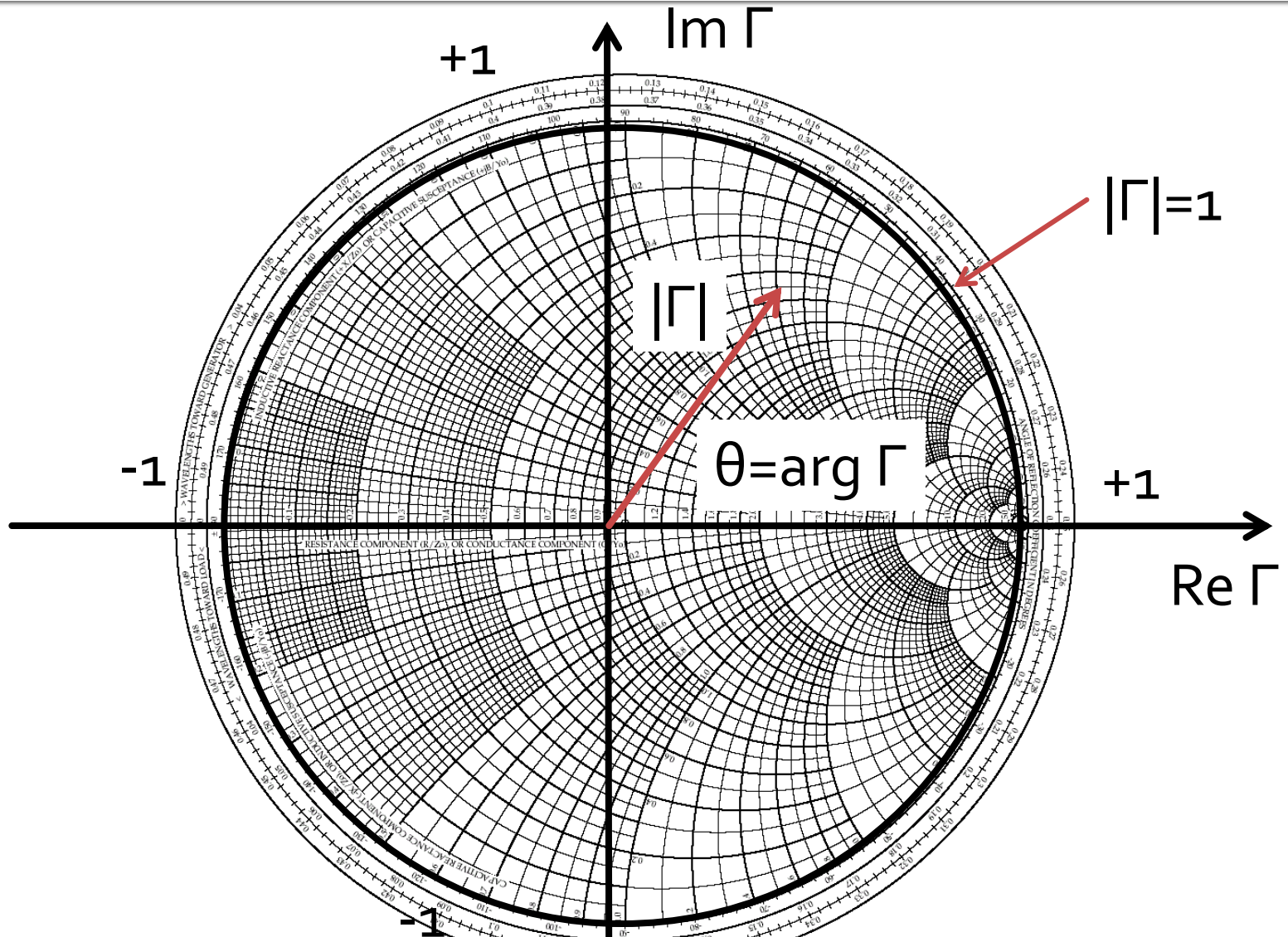
Adaptarea de impedanță

# Diagrama Smith

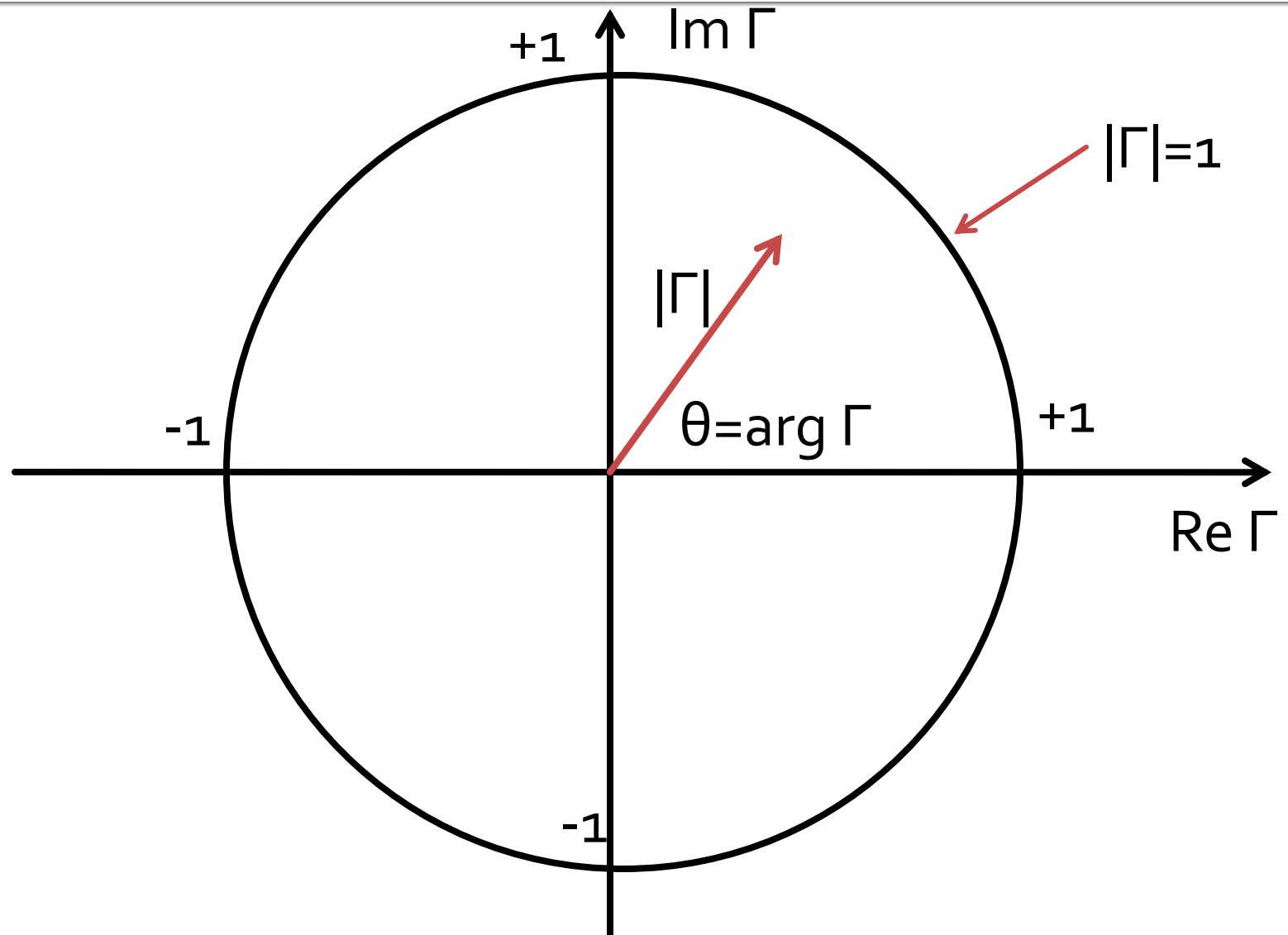
# Diagrama Smith



# Diagrama Smith



# Diagrama Smith



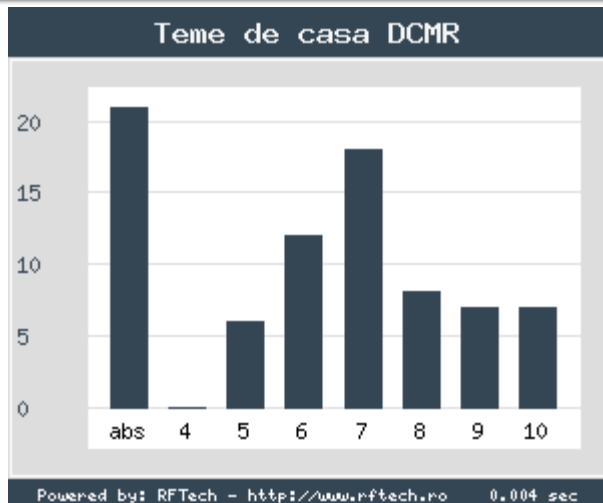
Adaptarea cu sectiuni de linii (stub)

# Adaptarea de impedanță

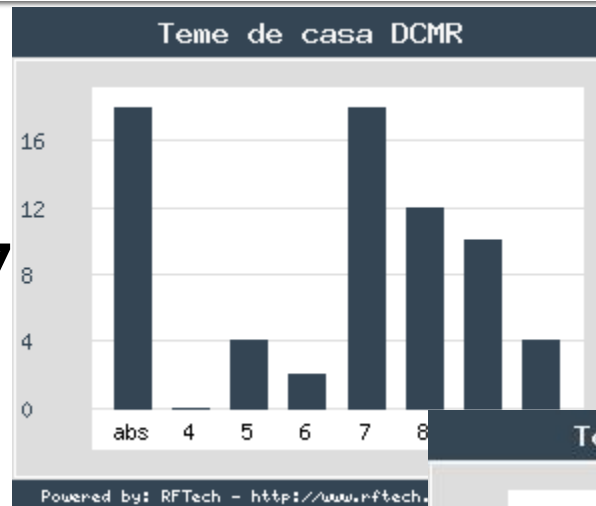


# Efect? – factorul “andrei”

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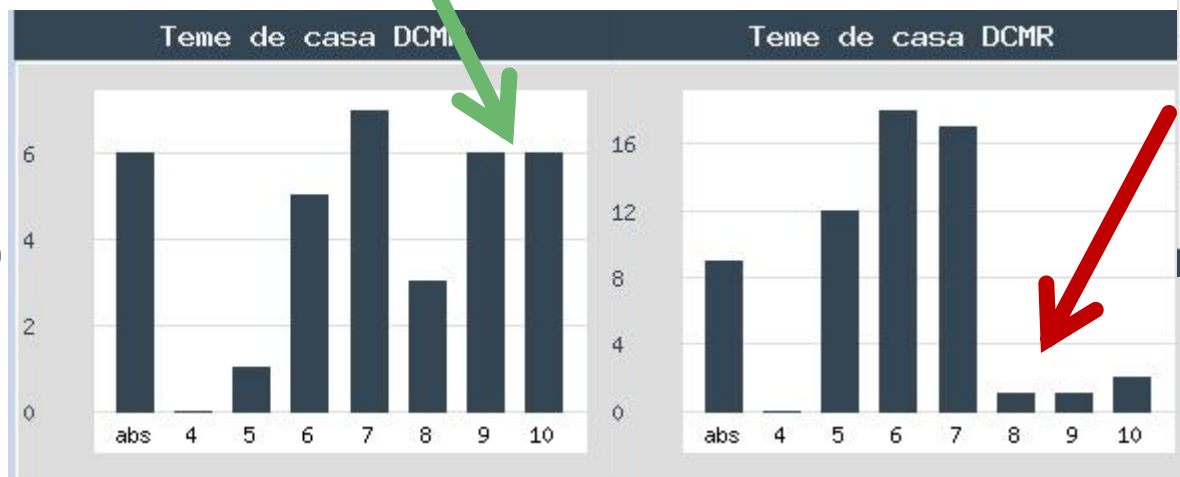
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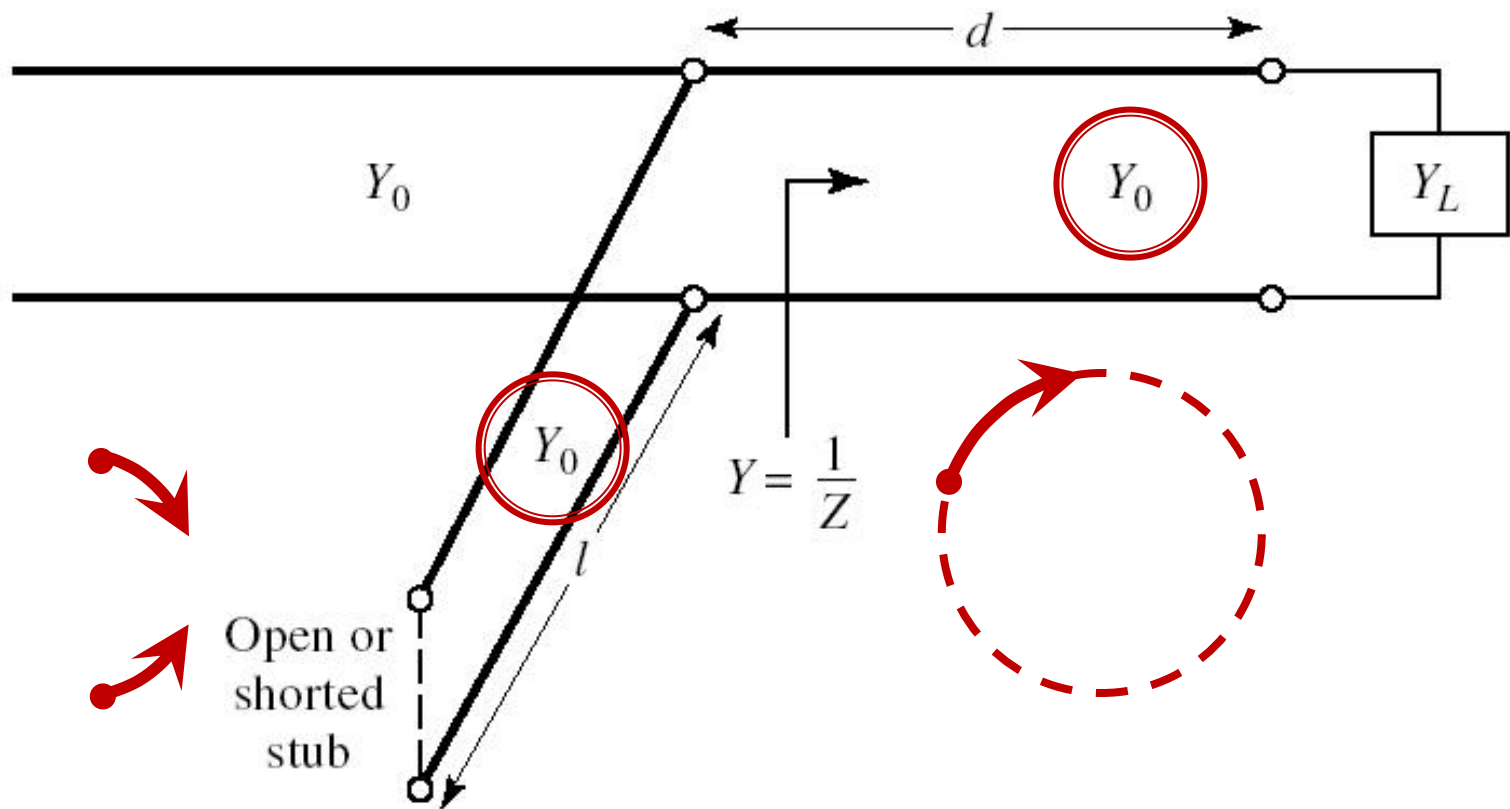


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# Caz 1, Shunt Stub

- Shunt Stub (sectiune de linie in paralel)



# Calcul analitic (calcul efectiv)

$$\cos(\varphi + 2\theta) = -|\Gamma_S|$$

$$\Gamma_S = 0.593 \angle 46.85^\circ$$

$$\theta_{sp} = \beta \cdot l = \tan^{-1} \frac{\mp 2 \cdot |\Gamma_S|}{\sqrt{1 - |\Gamma_S|^2}}$$

$$|\Gamma_S| = 0.593; \quad \varphi = 46.85^\circ \quad \cos(\varphi + 2\theta) = -0.593 \Rightarrow (\varphi + 2\theta) = \pm 126.35^\circ$$

- **Semnul** (+/-) solutiei alese la ecuatia **liniei serie** impune **semnul** solutiei utilizate la ecuatia **stub-ului paralel**

- **solutia "cu +"** ↓

$$(46.85^\circ + 2\theta) = +126.35^\circ \quad \theta = +39.7^\circ \quad \text{Im } y_s = \frac{-2 \cdot |\Gamma_S|}{\sqrt{1 - |\Gamma_S|^2}} = -1.472$$

$$\theta_{sp} = \tan^{-1}(\text{Im } y_s) = -55.8^\circ (+180^\circ) \rightarrow \theta_{sp} = 124.2^\circ$$

- **solutia "cu -"** ↓

$$(46.85^\circ + 2\theta) = -126.35^\circ \quad \theta = -86.6^\circ (+180^\circ) \rightarrow \theta = 93.4^\circ$$

$$\text{Im } y_s = \frac{+2 \cdot |\Gamma_S|}{\sqrt{1 - |\Gamma_S|^2}} = +1.472 \quad \theta_{sp} = \tan^{-1}(\text{Im } y_s) = 55.8^\circ$$

# Filtre pentru microunde

# Metoda pierderilor de insertie

$$P_{LR} = \frac{P_S}{P_L} = \frac{1}{1 - |\Gamma(\omega)|^2}$$

- $|\Gamma(\omega)|^2$  este o functie para de  $\omega$

$$|\Gamma(\omega)|^2 = \frac{M(\omega^2)}{M(\omega^2) + N(\omega^2)}$$

$$P_{LR} = 1 + \frac{M(\omega^2)}{N(\omega^2)}$$

- Alegerea corespunzatoare a polinoamelor M si N determina comportarea filtrului

# FTJ prototip Maxim plat/Echiriplu

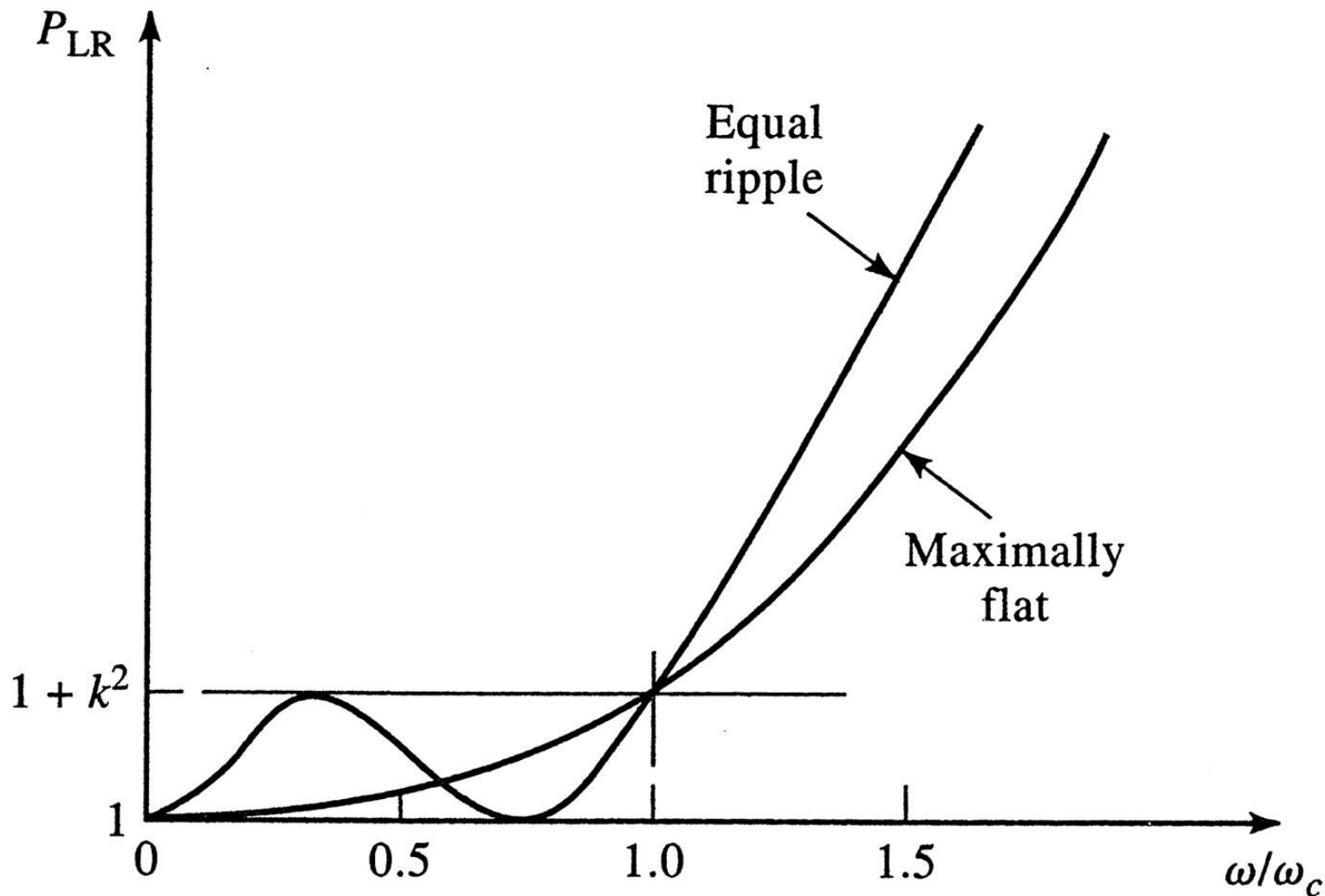


Figure 8.21

# Metoda pierderilor de insertie

- Se aleg polinoamele pentru implementarea unui FTJ (prototip)
- Acest filtru poate fi convertit la alte functii, scalat in frecventa pentru a obtine alte tipuri de functii

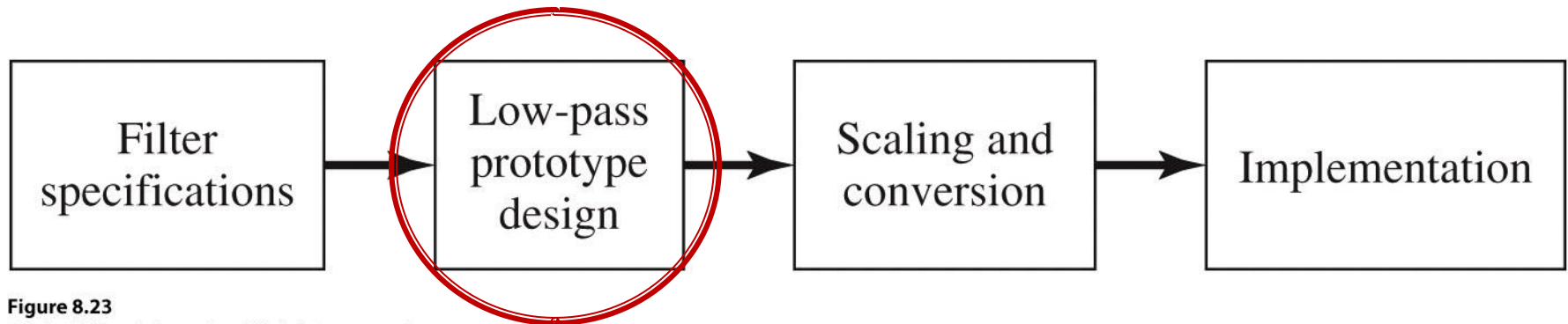


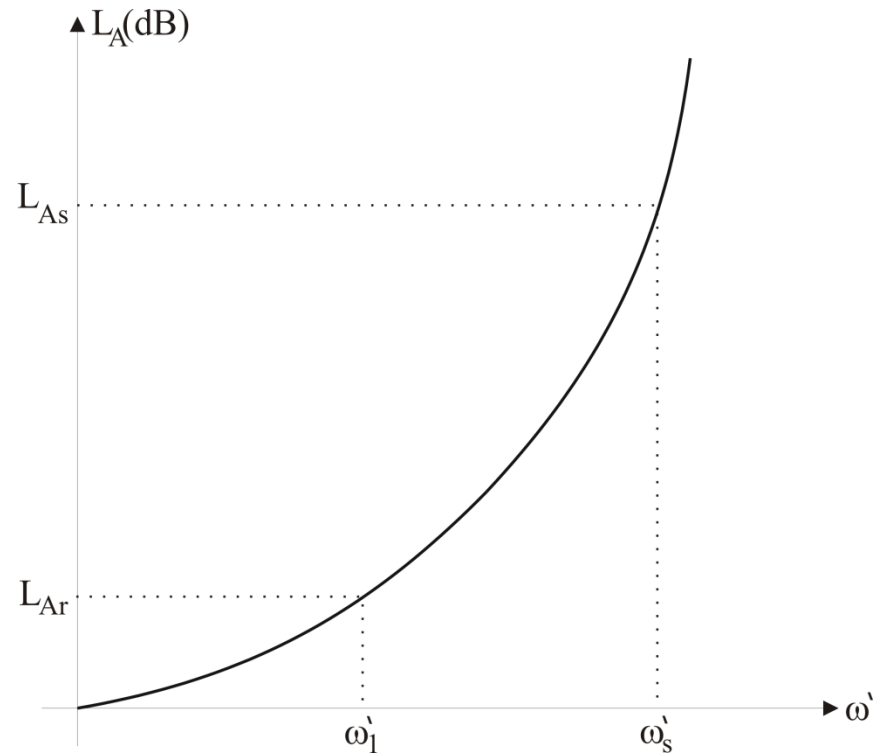
Figure 8.23

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# Calculul ordinului filtrului maxim plat

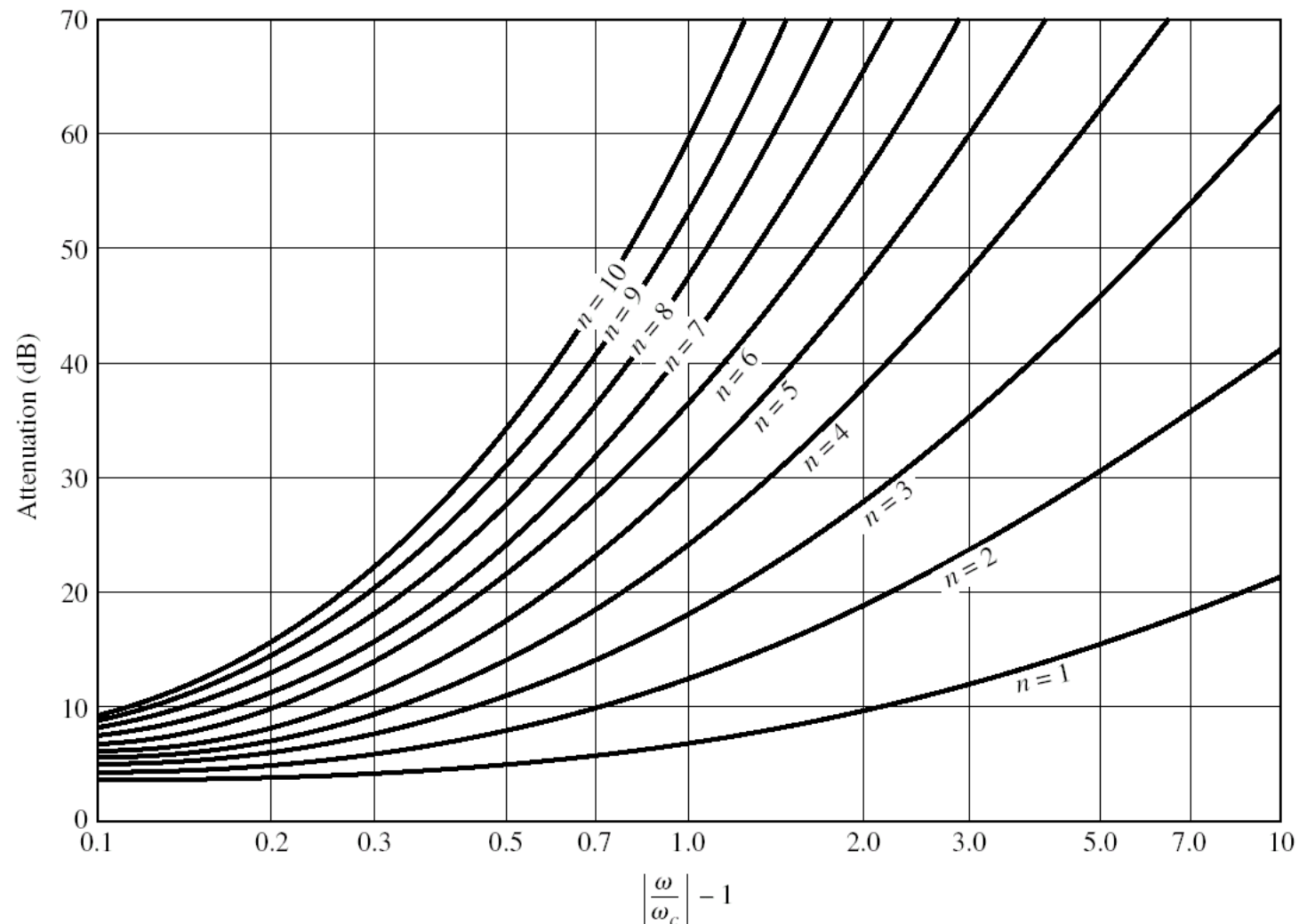
$$n \geq \frac{\log \left( \frac{10^{\frac{L_{As}}{10}} - 1}{10^{\frac{L_{Ar}}{10}} - 1} \right)}{2 \cdot \log \frac{\omega'_s}{\omega'_1}}$$

- cu atenuarile in **dB**

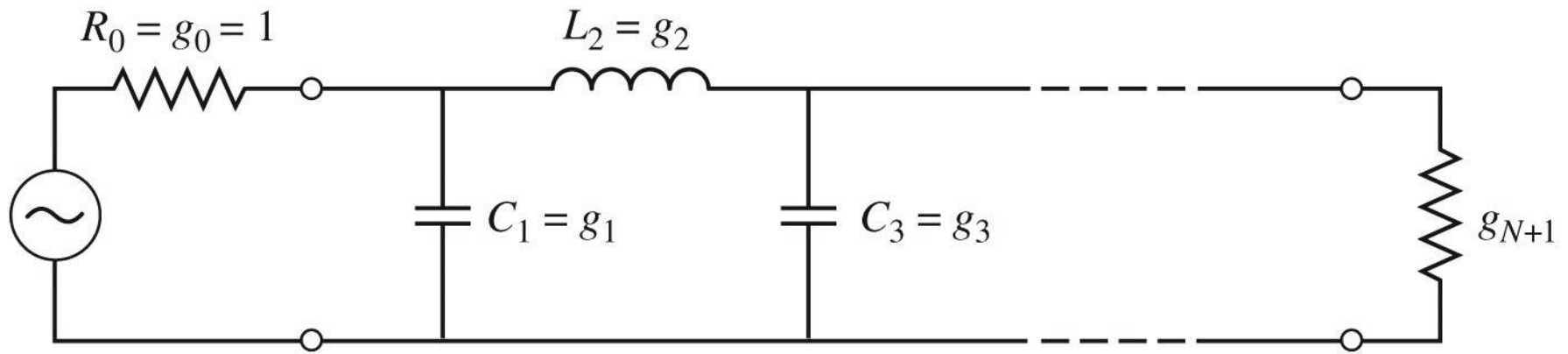




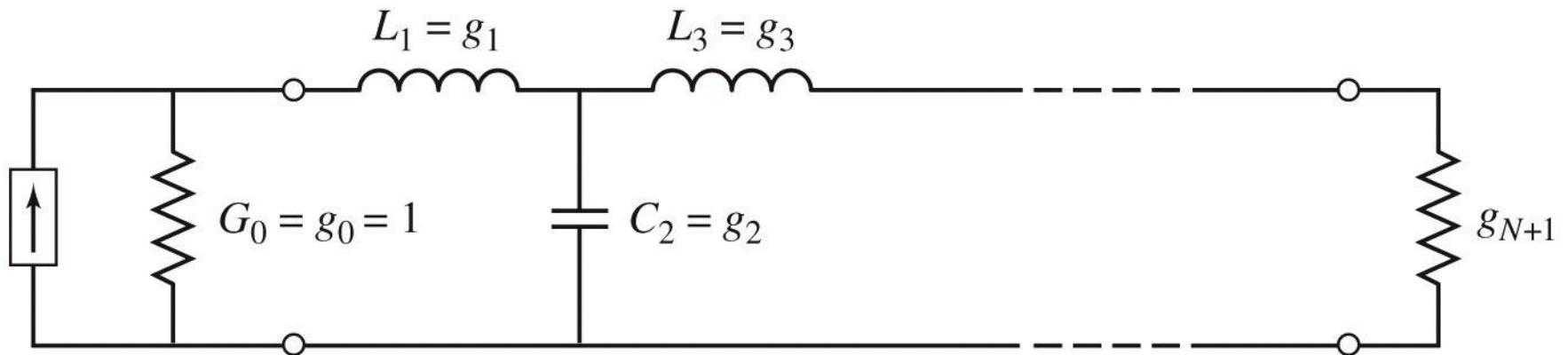
# Raspunsul filtrului maxim plat



# Filtre prototip



(a)



(b)

# Filtru prototip echiriplu

- Calculul elementelor filtrului (iterativ)

$$a_k = \sin\left[\frac{(2 \cdot k - 1) \cdot \pi}{2 \cdot N}\right], \quad k = 1, N \qquad \beta = \ln\left(\coth \frac{L_{Ar}}{17,37}\right)$$

$$\gamma = \sinh\left(\frac{\beta}{2 \cdot N}\right) \qquad b_k = \gamma^2 + \sin^2\left(\frac{k \cdot \pi}{N}\right), \quad k = 1, N$$

$$g_1 = \frac{2 \cdot a_1}{\gamma}$$

$$g_k = \frac{4 \cdot a_{k-1} \cdot a_k}{b_{k-1} \cdot g_{k-1}}, \quad k = 1, N$$

$$g_{N+1} = \begin{cases} 1 & \text{pentru } N = \text{impar} \\ \coth^2\left(\frac{\beta}{4}\right) & \text{pentru } N = \text{par} \end{cases}$$

TABLE 8.4 Element Values for Equal-Ripple Low-Pass Filter Prototypes ( $g_0 = 1, \omega_c = 1, N = 1$  to 10, 0.5 dB and 3.0 dB ripple)

0.5 dB Ripple											
$N$	$g_1$	$g_2$	$g_3$	$g_4$	$g_5$	$g_6$	$g_7$	$g_8$	$g_9$	$g_{10}$	$g_{11}$
1	0.6986	1.0000									
2	1.4029	0.7071	1.9841								
3	1.5963	1.0967	1.5963	1.0000							
4	1.6703	1.1926	2.3661	0.8419	1.9841						
5	1.7058	1.2296	2.5408	1.2296	1.7058	1.0000					
6	1.7254	1.2479	2.6064	1.3137	2.4758	0.8696	1.9841				
7	1.7372	1.2583	2.6381	1.3444	2.6381	1.2583	1.7372	1.0000			
8	1.7451	1.2647	2.6564	1.3590	2.6964	1.3389	2.5093	0.8796	1.9841		
9	1.7504	1.2690	2.6678	1.3673	2.7239	1.3673	2.6678	1.2690	1.7504	1.0000	
10	1.7543	1.2721	2.6754	1.3725	2.7392	1.3806	2.7231	1.3485	2.5239	0.8842	1.9841

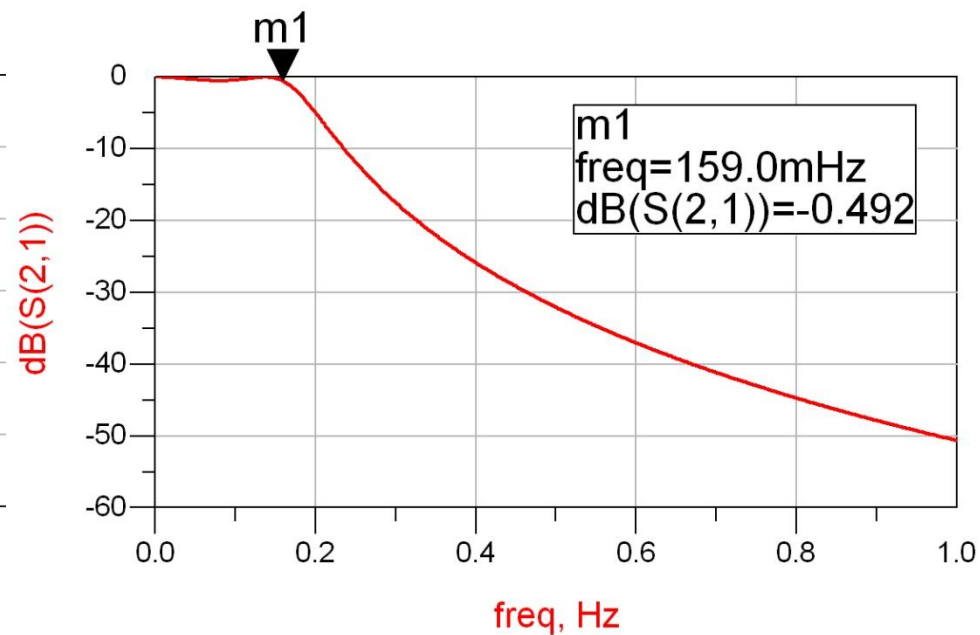
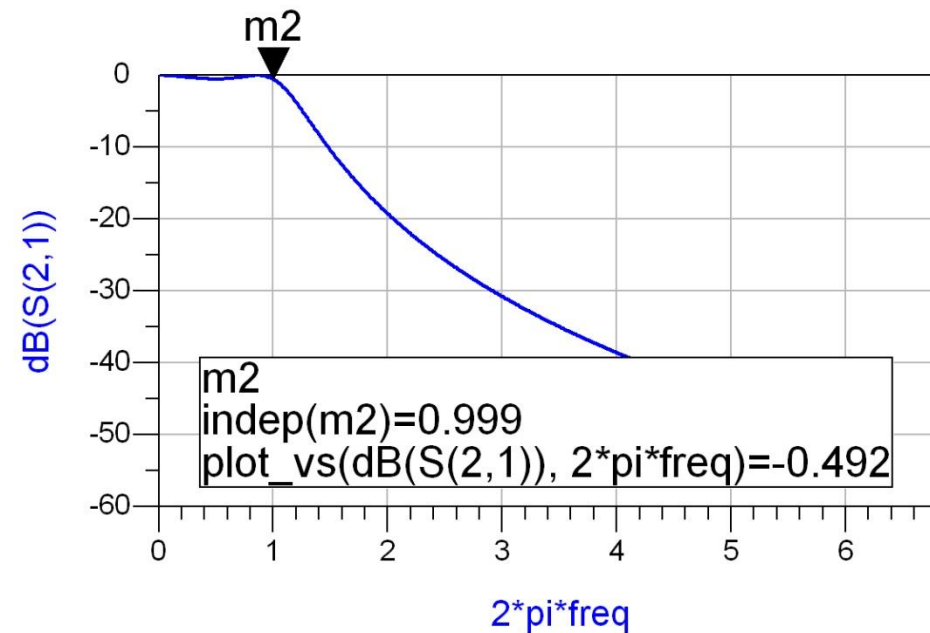
3.0 dB Ripple											
$N$	$g_1$	$g_2$	$g_3$	$g_4$	$g_5$	$g_6$	$g_7$	$g_8$	$g_9$	$g_{10}$	$g_{11}$
1	1.9953	1.0000									
2	3.1013	0.5339	5.8095								
3	3.3487	0.7117	3.3487	1.0000							
4	3.4389	0.7483	4.3471	0.5920	5.8095						
5	3.4817	0.7618	4.5381	0.7618	3.4817	1.0000					
6	3.5045	0.7685	4.6061	0.7929	4.4641	0.6033	5.8095				
7	3.5182	0.7723	4.6386	0.8039	4.6386	0.7723	3.5182	1.0000			
8	3.5277	0.7745	4.6575	0.8089	4.6990	0.8018	4.4990	0.6073	5.8095		
9	3.5340	0.7760	4.6692	0.8118	4.7272	0.8118	4.6692	0.7760	3.5340	1.0000	
10	3.5384	0.7771	4.6768	0.8136	4.7425	0.8164	4.7260	0.8051	4.5142	0.6091	5.8095

Source: Reprinted from G. L. Matthaei, L. Young, and E. M. T. Jones, *Microwave Filters, Impedance-Matching Networks, and Coupling Structures*, Artech House, Dedham, Mass., 1980, with permission.

- Pentru ordin par al filtrului ( $N = 2, 4, 6, 8 \dots$ ) filtrele echiriplu **trebuie** sa fie inchise pe o impedanta de terminatie diferita de cea standard  **$g_{N+1} \neq 1$**
- Daca aplicatia nu suporta aceasta comportare, e necesara introducerea unei adaptari de impedanta suplimentare (transformator in sfert de lungime de unda, binomial ...)

# Filtru prototip

- $\omega_o = 1 \text{ rad/s}$  ( $f_o = \omega_o / 2\pi = 0.159 \text{ Hz}$ )



# Scalare si conversie

- FTJ (prototip) are utilitate doar ca pas intermediar
  - filtru FTJ
  - frecventa de taiere  $\omega_o = 1 \text{ rad/s}$  ( $f_o = 0.159 \text{ Hz}$ )
  - conectate la intrare la o rezistenta  $R = 1$

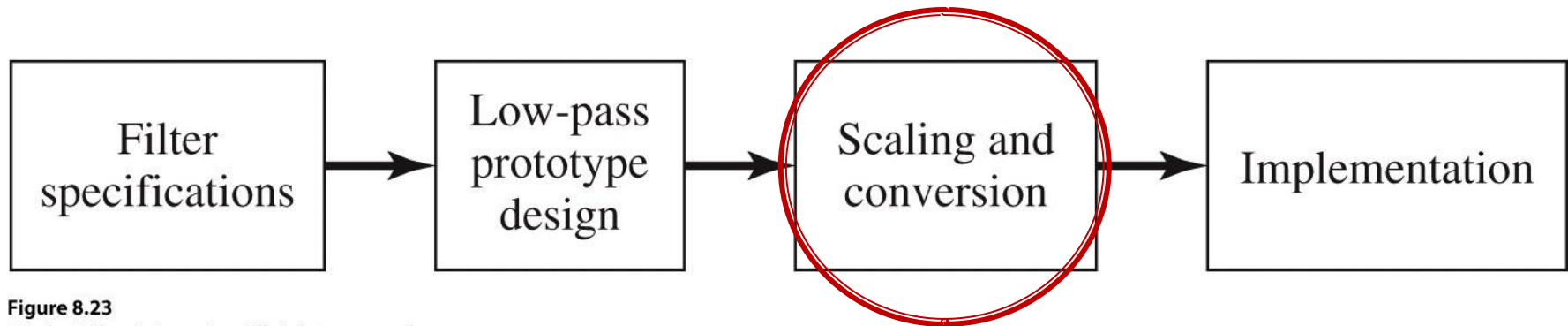


Figure 8.23

# Transformari ale filtrului prototip


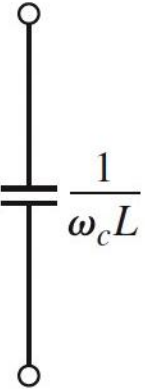
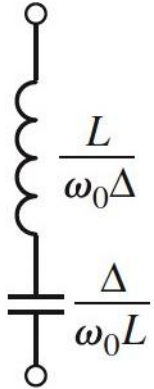
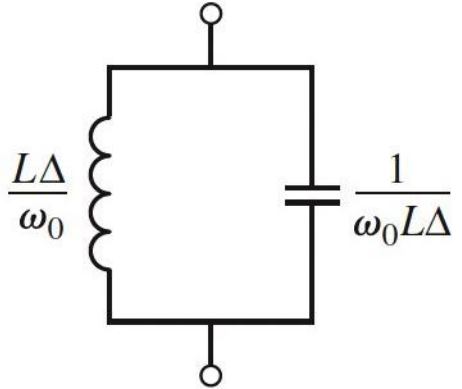
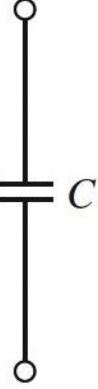
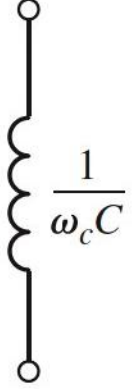
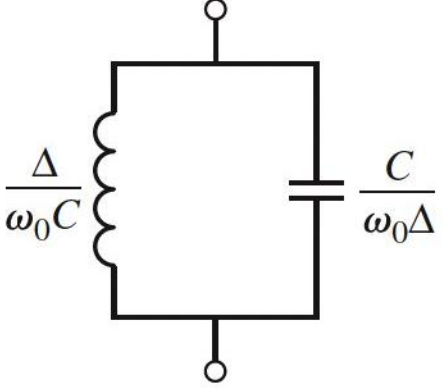
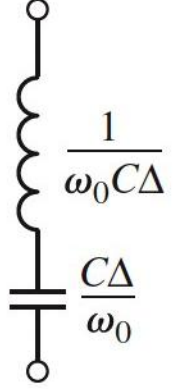
Low-pass	High-pass	Bandpass	Bandstop
			
			

Table 8.6

# Implementare filtre pentru microunde

- Implementarea cu elemente concentrate (L, C) este utilizabila mai ales in zona frecventelor ceva mai reduse (RF) datorita:
  - dificultatii de implementare a valorilor rezultante pentru componente
  - dificultatii de a asigura toleranta (foarte mica) necesara pentru componente

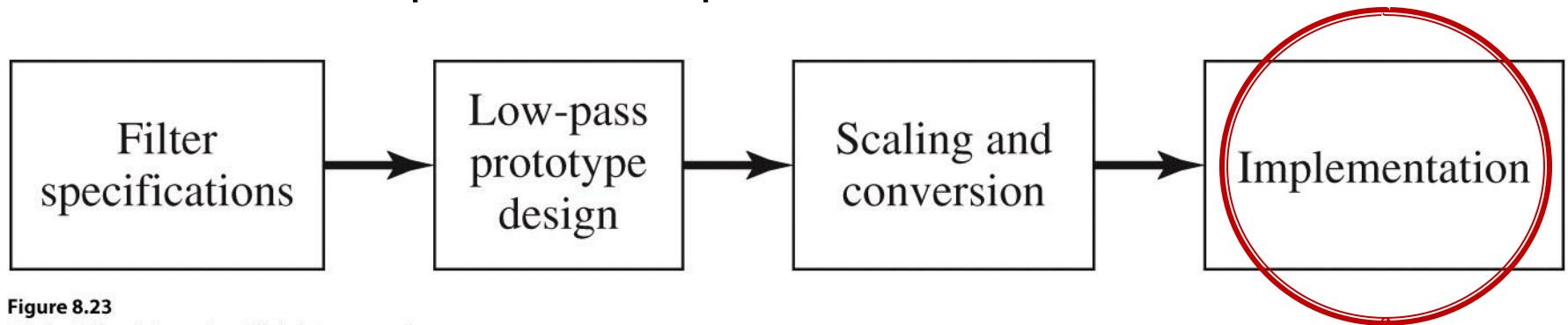
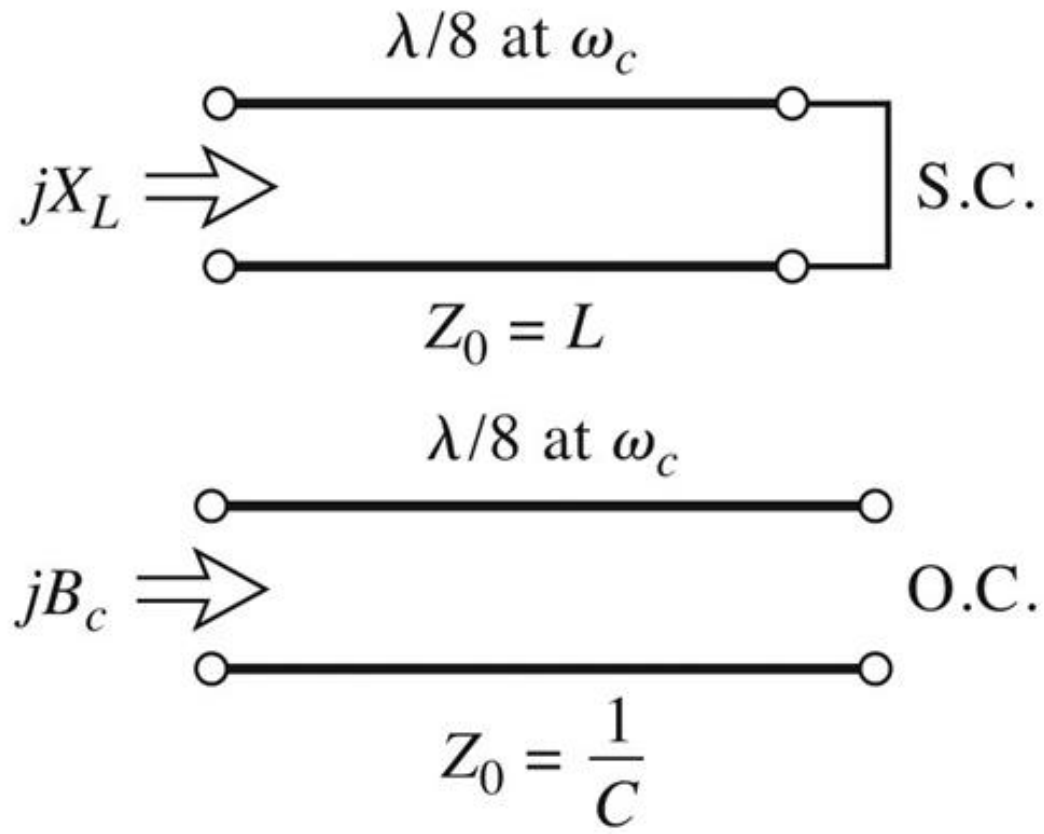
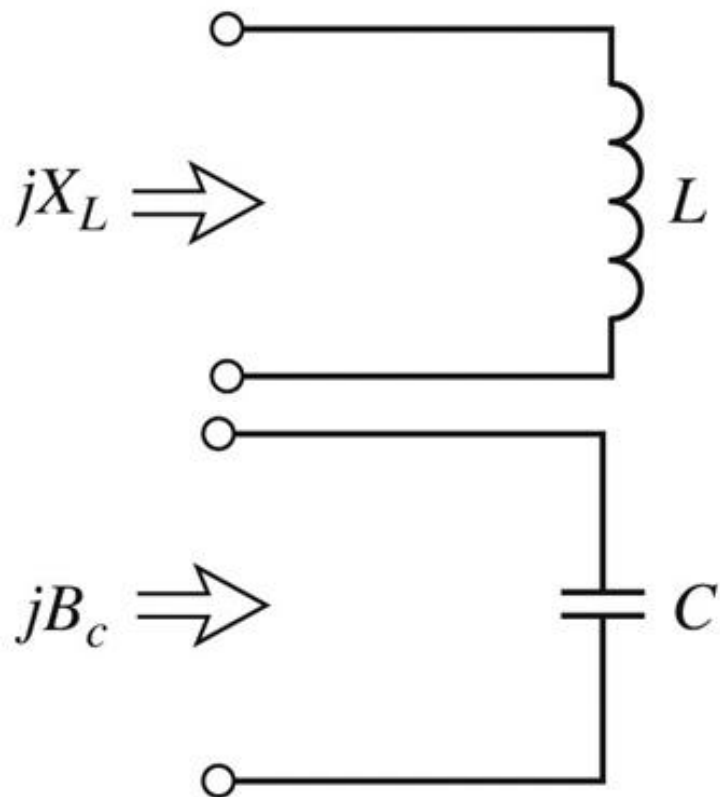


Figure 8.23

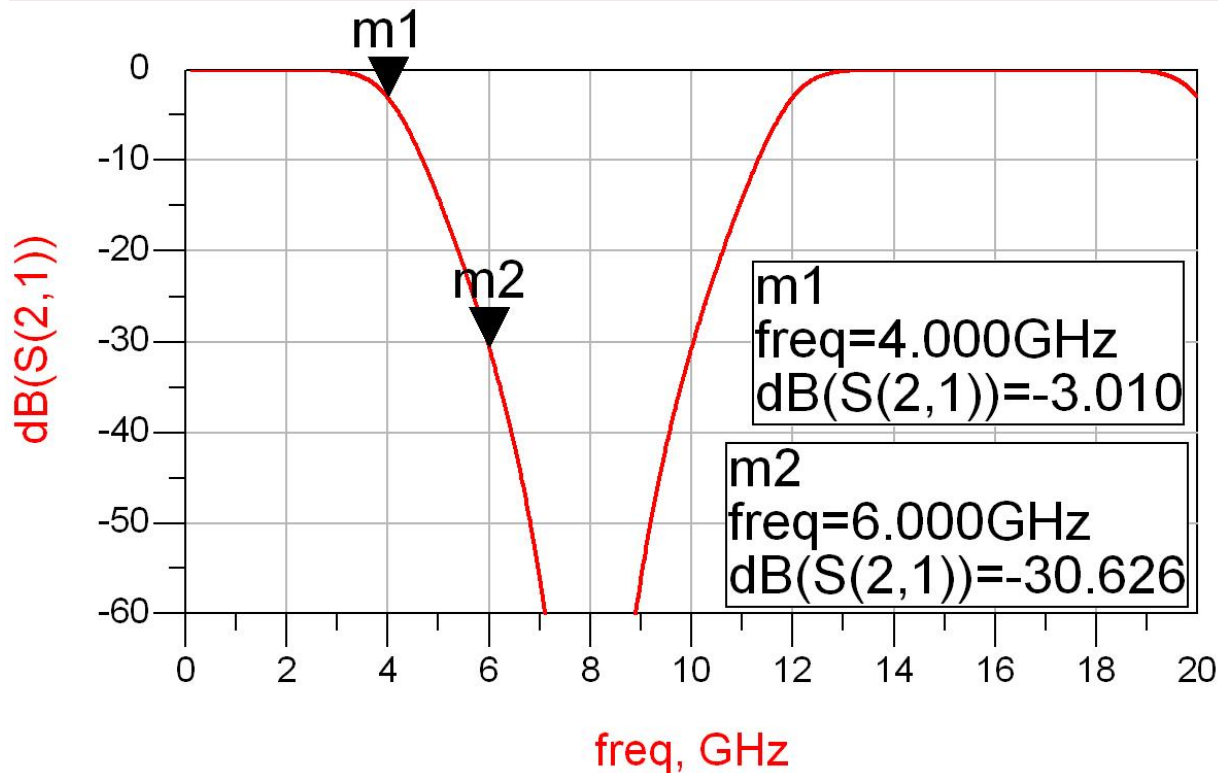
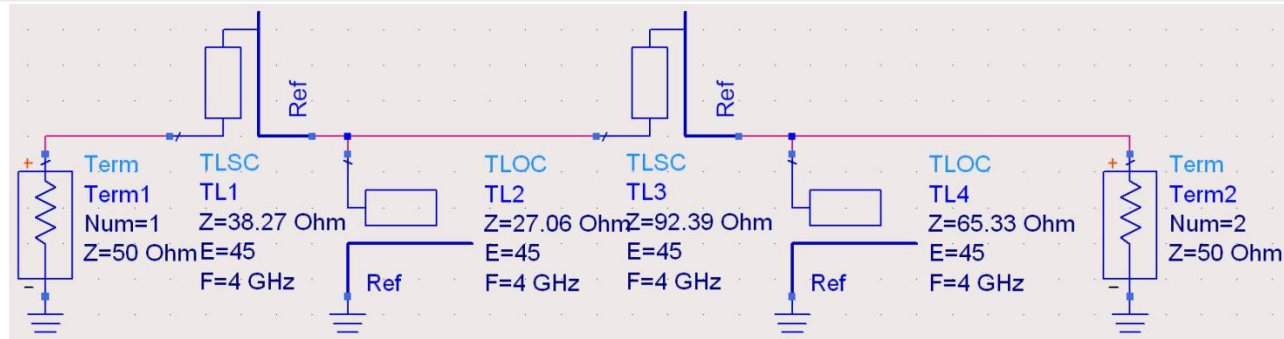


# Transformarea Richards

- permite obtinerea cu sectiuni de linii a inductantelor si capacitatilor **dupa** scalarea prototipului pentru functia corespunzatoare (FTJ/FTS/FTB /FOB)

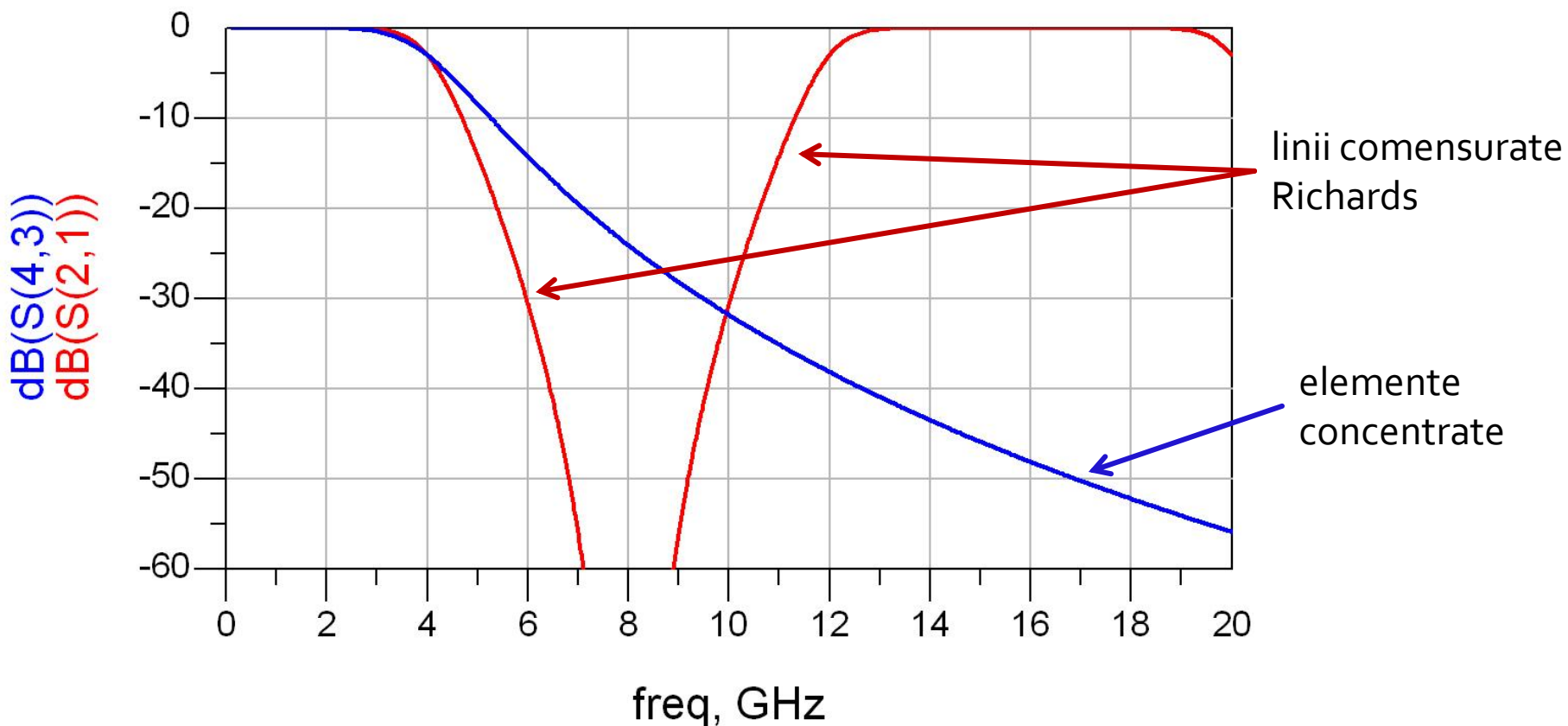


# Transformarea Richards – ADS



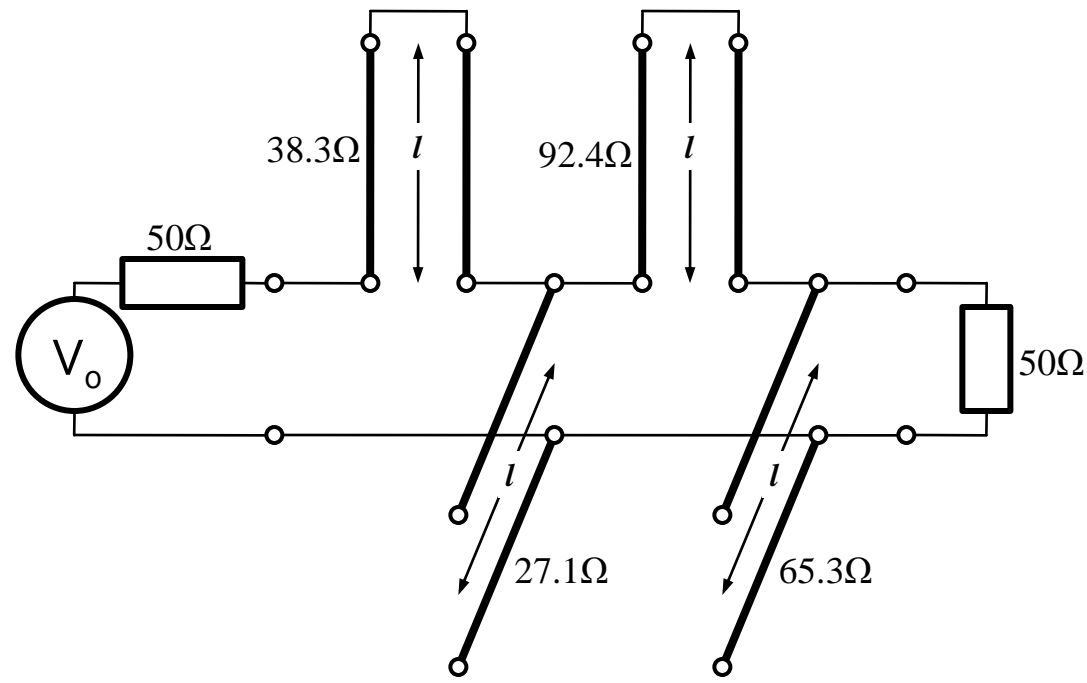
# Transformarea Richards

- Filtre realizate cu transformarea Richards
  - beneficiaza de polul suplimentar de atenuare  $2 \cdot \omega_c$
  - au dezavantajul periodicitatii in frecventa, de obicei se prevede un filtru trece jos suplimentar neperiodic daca e necesar



# Identitatile Kuroda

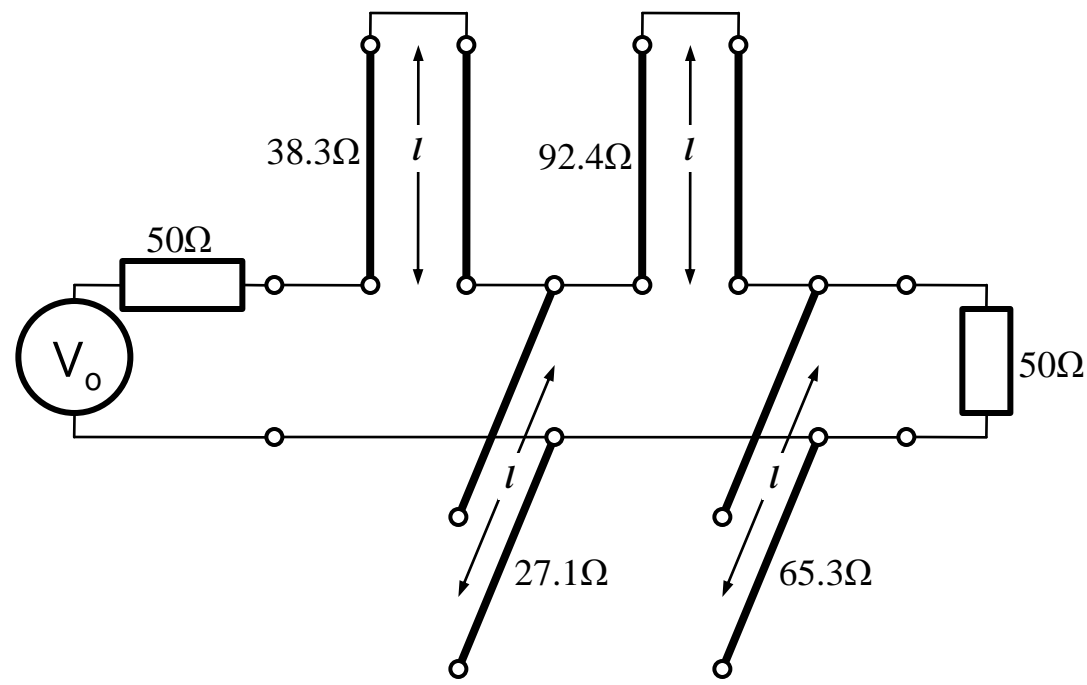
- Filtre implementate cu transformarea Richards au anumite dezavantaje in ceea ce priveste implementarea practica
- Identitatile/Transformarile Kuroda pot fi utilizate pentru a elimina o parte din aceste dezavantaje
- Se utilizeaza sectiuni de linie suplimentare pentru a obtine sisteme mai simplu de implementat in practica
- Liniile suplimentare se numesc elemente unitare si au lungimi de  $\lambda/8$  la frecventa de taiere dorita ( $\omega c$ ) fiind comensurate cu celelalte sectiuni de linie



# Identitatile Kuroda

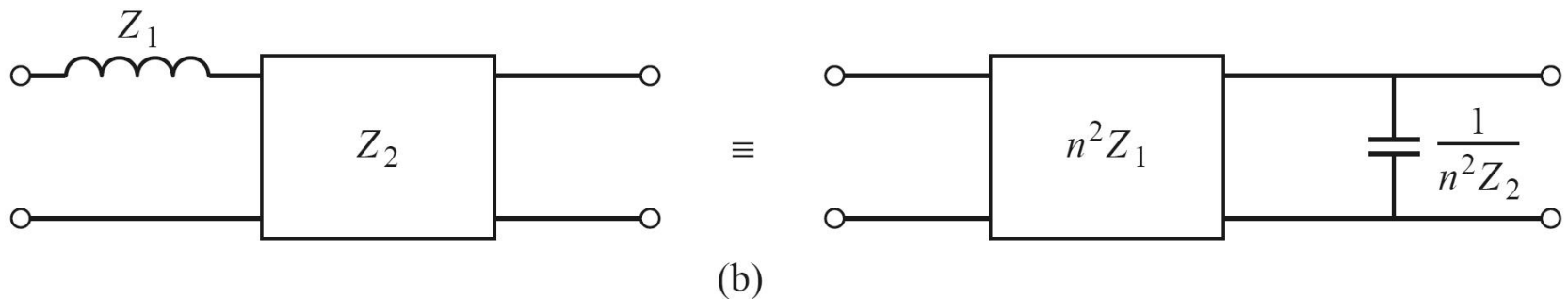
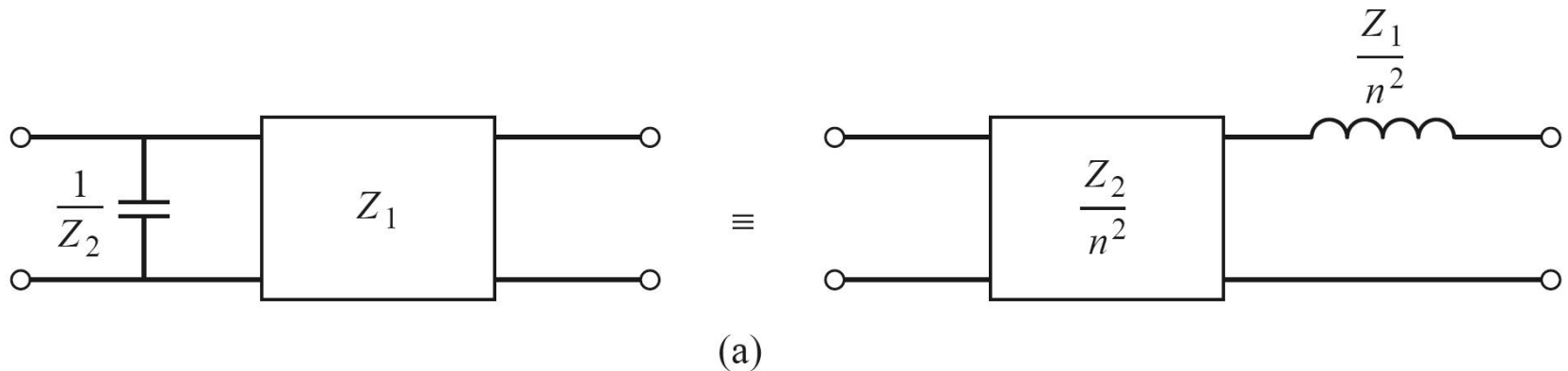
- Identitatile Kuroda pot fi utilizate pentru a realiza urmatoarele operatii:

- Separarea fizica a diferitelor stub-uri
- Transformarea stub-urilor serie in stub-uri paralel sau invers
- Obtinerea unor impedante caracteristice mai "realizabile" pentru linii ( $\sim 50\Omega$ )



# Identitățile Kuroda

- 4 echivalente de circuit



# (Acelasi) Exemplu

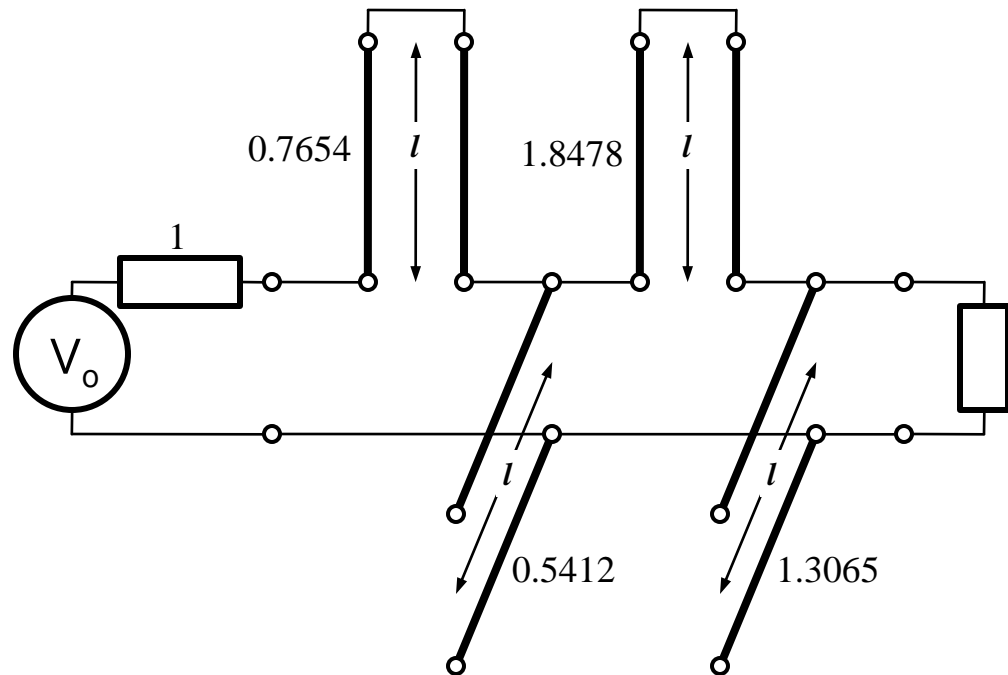
- Filtru trece jos de ordinul 4, cu frecventa de taiere de 4 GHz, de tip maxim plat (care sa functioneze pe  $50\Omega$  la intrare si iesire)
- Tabel maxim plat sau relatii de calcul:
  - $g_1 = 0.7654 = L_1$
  - $g_2 = 1.8478 = C_2$
  - $g_3 = 1.8478 = L_3$
  - $g_4 = 0.7654 = C_4$
  - $g_5 = 1$  (**nu** are nevoie de adaptare suplimentara la iesire – apare la filtrele de ordin par echiriplu)

# Exemplu

## ■ Se aplica transformarea Richards

### ■ Probleme:

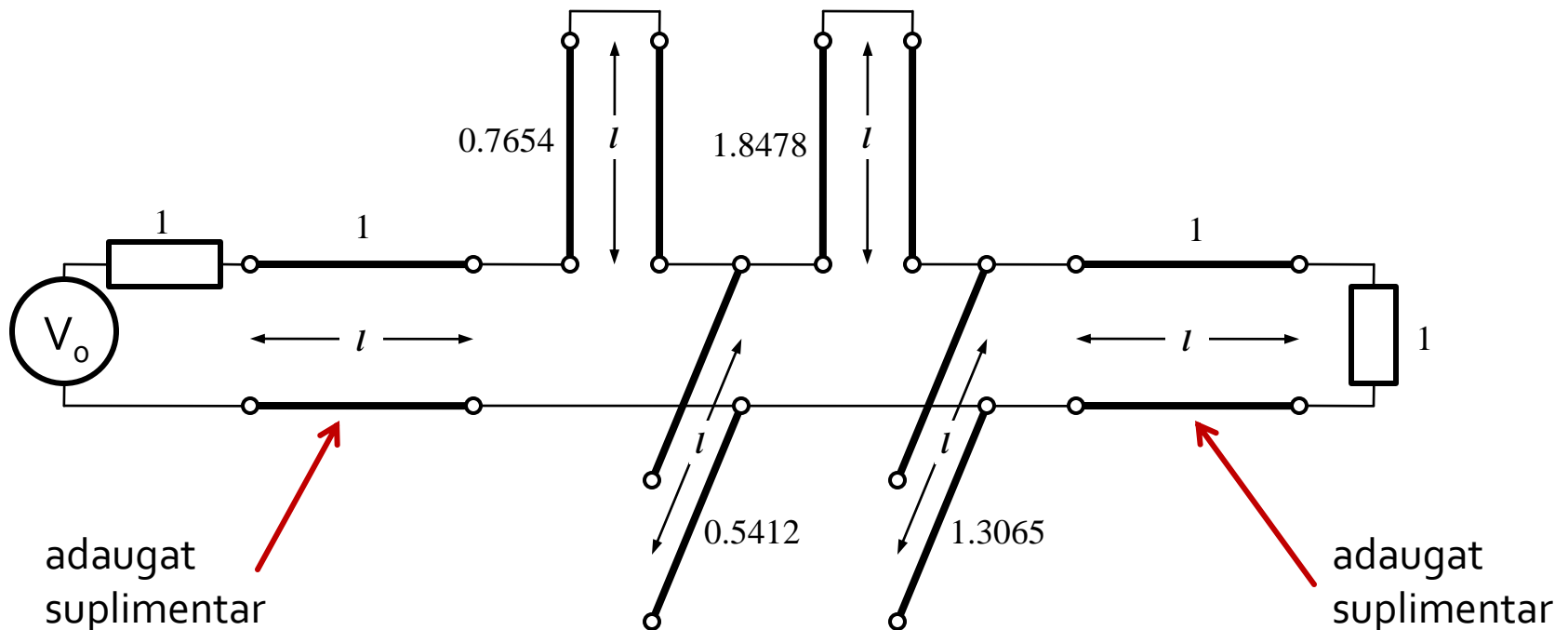
- stub-urile in serie sunt **extrem de dificil** de implementat in tehnologie microstrip
- cu tehnologia microstrip e preferabil sa avem stub-uri in gol (scurtcircuit necesita un **via-hole** spre planul de masa)
- cele 4 stub-uri sunt conectate in acelasi punct, o implementare care sa elimine/micsoreze **cuplajul** intre aceste linii e imposibila
- nu e cazul aici, dar pot aparea situatii cand impedantele raportate sunt mult diferite de 1. Majoritatea tehnologiilor sunt concepute pentru linii cu impedante caracteristice in jur de  $50\Omega$





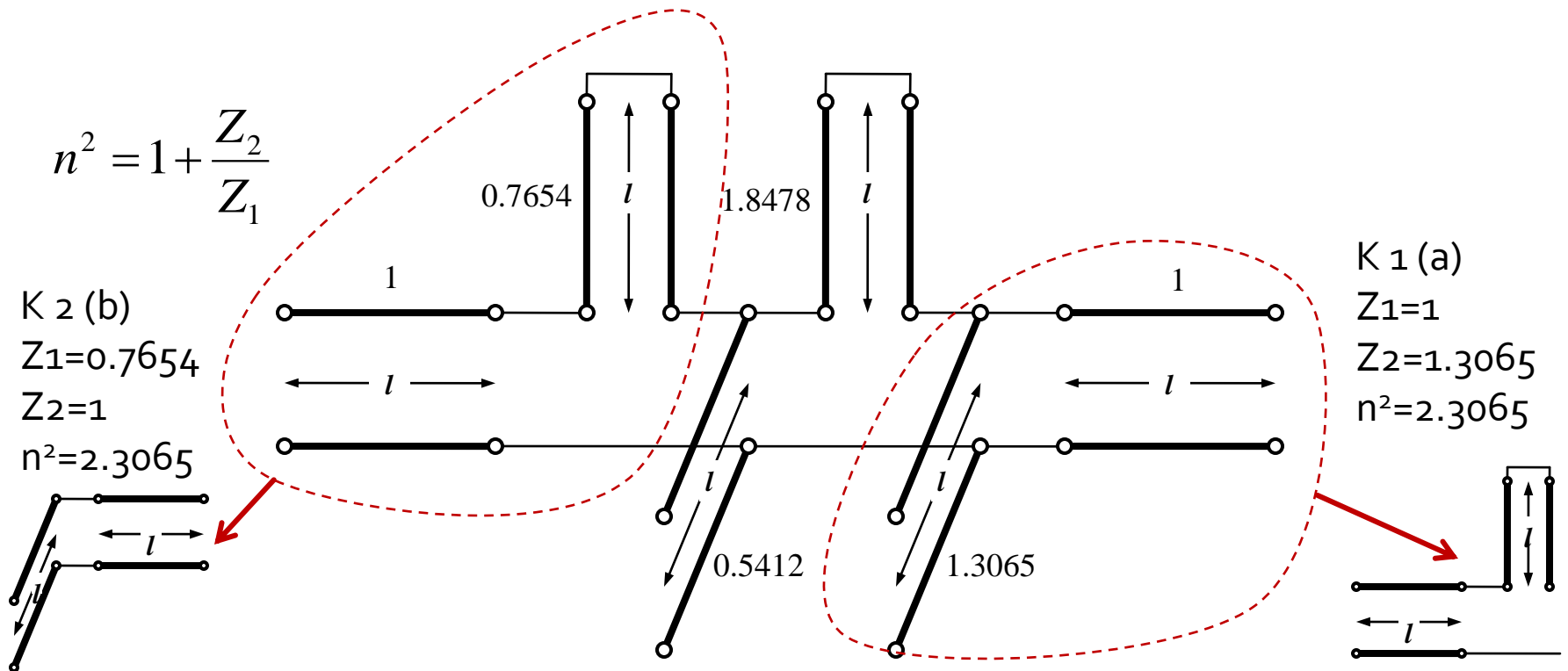
# Exemplu

- Identitățile Kuroda se referă **intotdeauna** la o schema cu o secțiune de linie în serie:
  - se **adauga** elementele unitare ( $z = 1, l = \lambda/8$ ) la fiecare capăt al circuitului (adaugarea nu modifică proprietățile filtrului acesta fiind adaptat la  $z = 1$  la fiecare capăt)
  - se **aplica** una din identitățile Kuroda la fiecare capăt și se **continua**
  - un indicator al **opririi** procedurii este apariția unei secțiuni de linie între toate stub-urile obținute cu transformarea Richards



# Exemplu

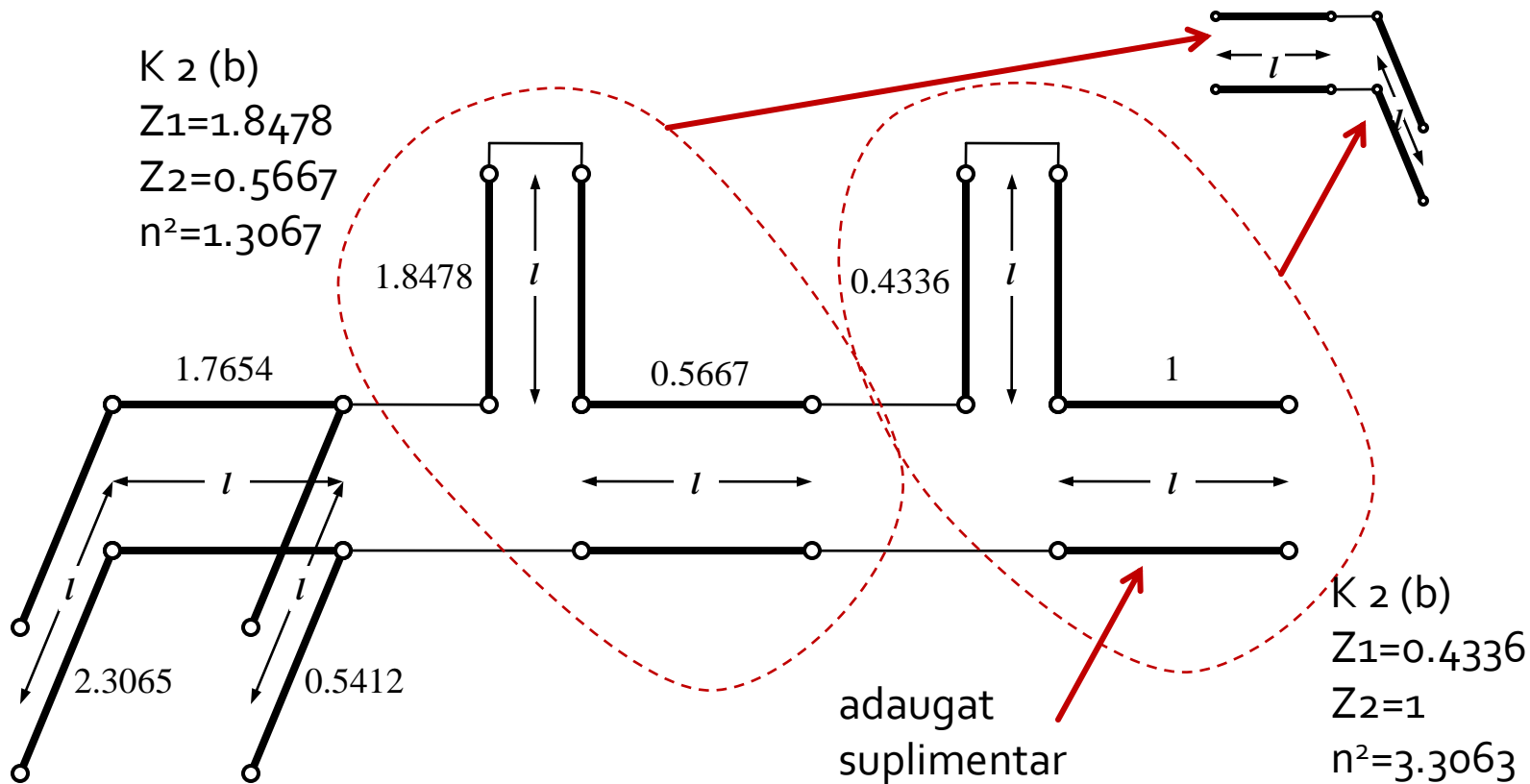
- Se aplica :
  - Kuroda 2 ( $L, Z$  cunoscut  $\rightarrow C, Z$ ) in partea stanga
  - Kuroda 1 ( $C, Z$  cunoscut  $\rightarrow L, Z$ ) in partea dreapta



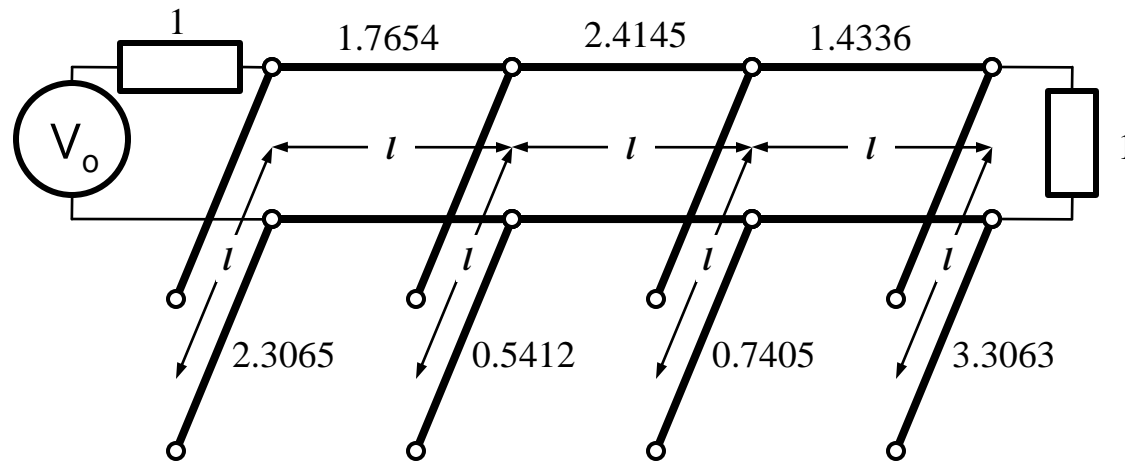
# Exemplu

- Se mai adauga un element unitar in partea dreapta si se aplica Kuroda 2 de doua ori

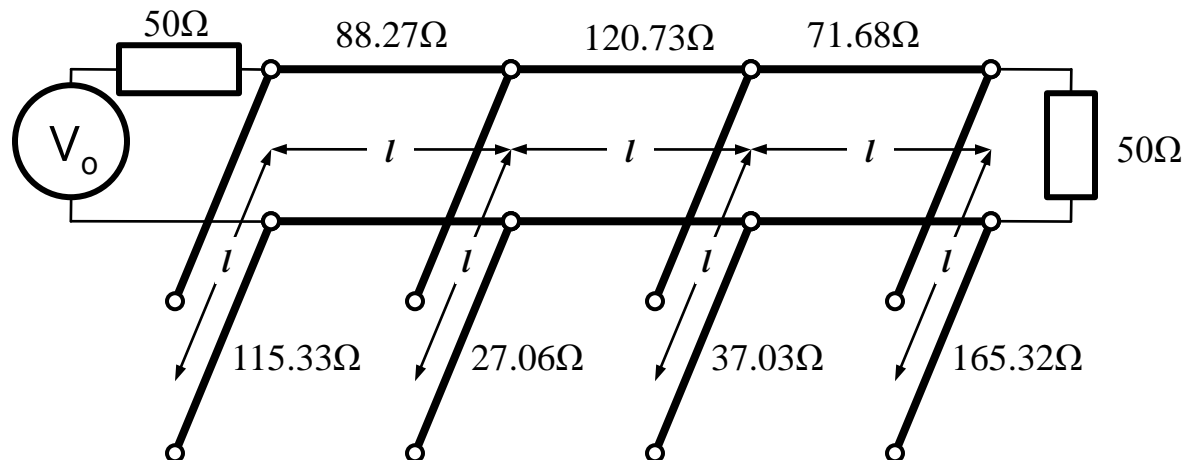
$$n^2 = 1 + \frac{Z_2}{Z_1}$$



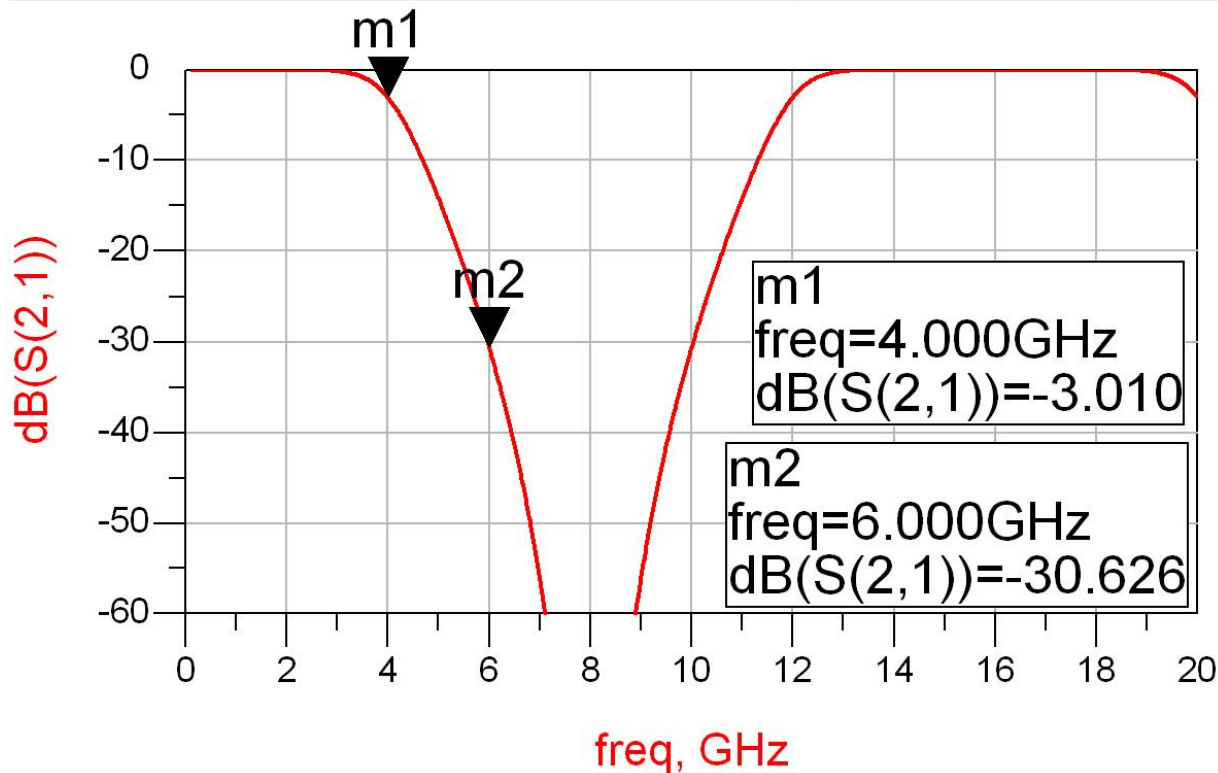
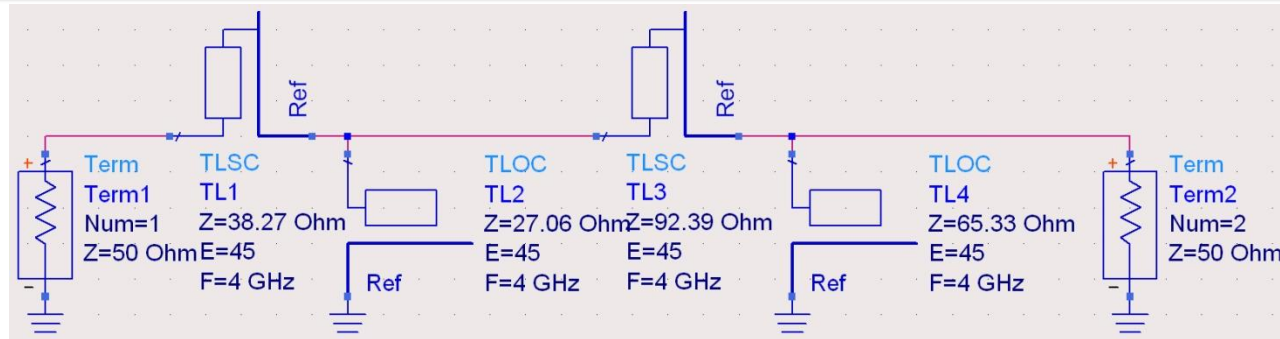
# Exemplu



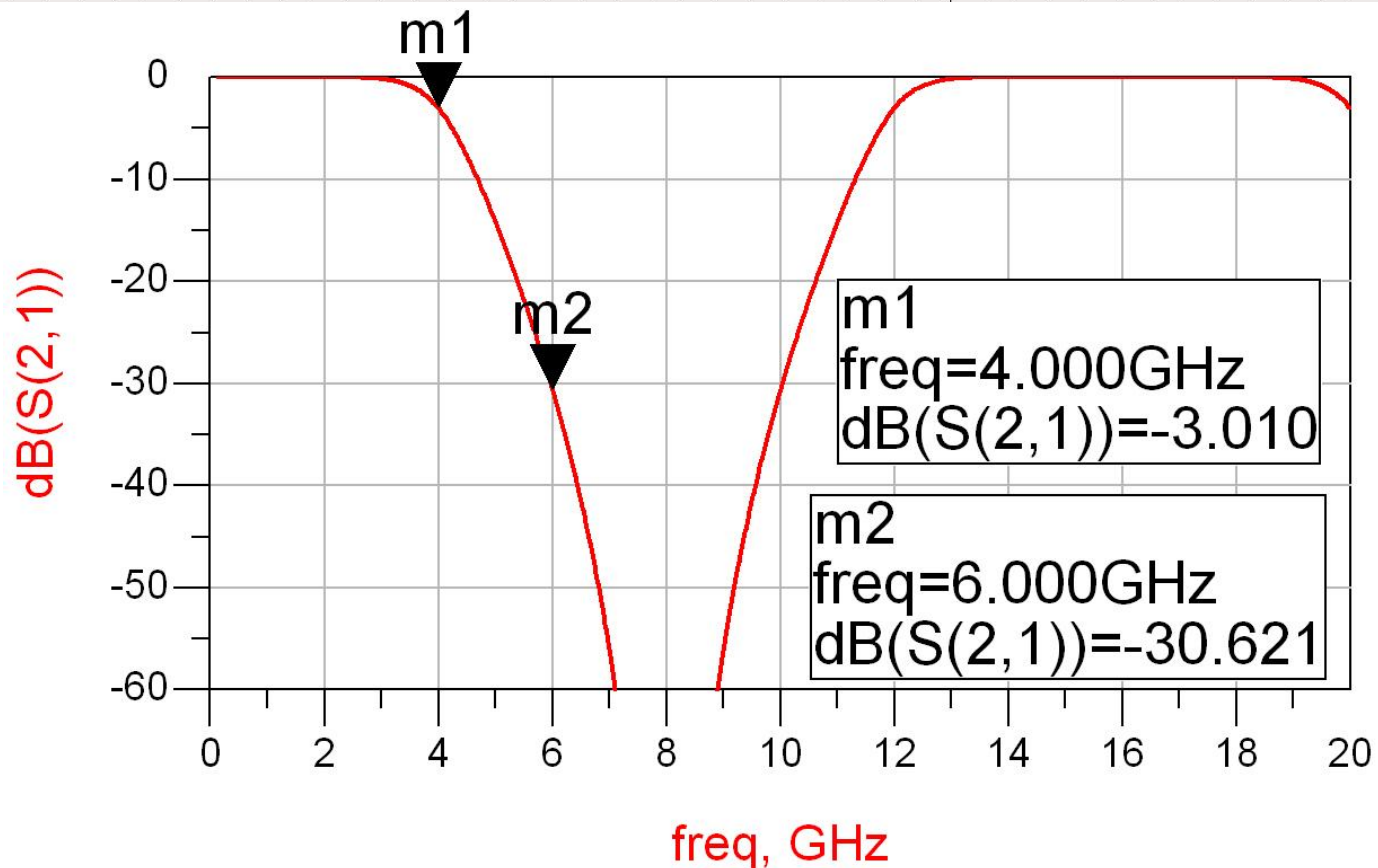
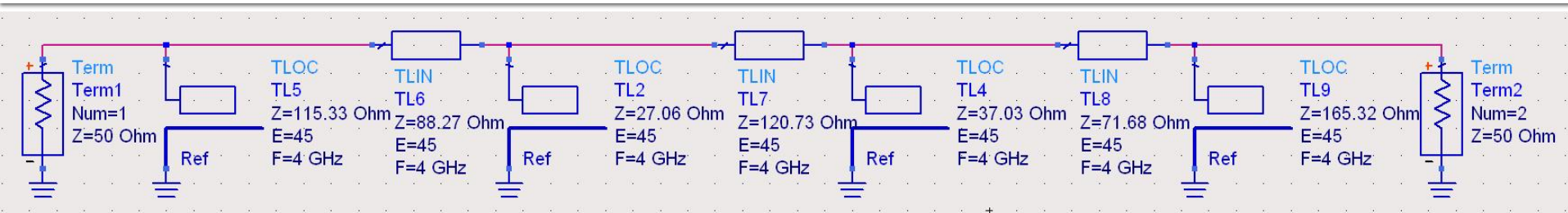
- Scalare la  $50\Omega$



# Transformarea Richards – ADS



# Identitatile Kuroda – ADS



# Example

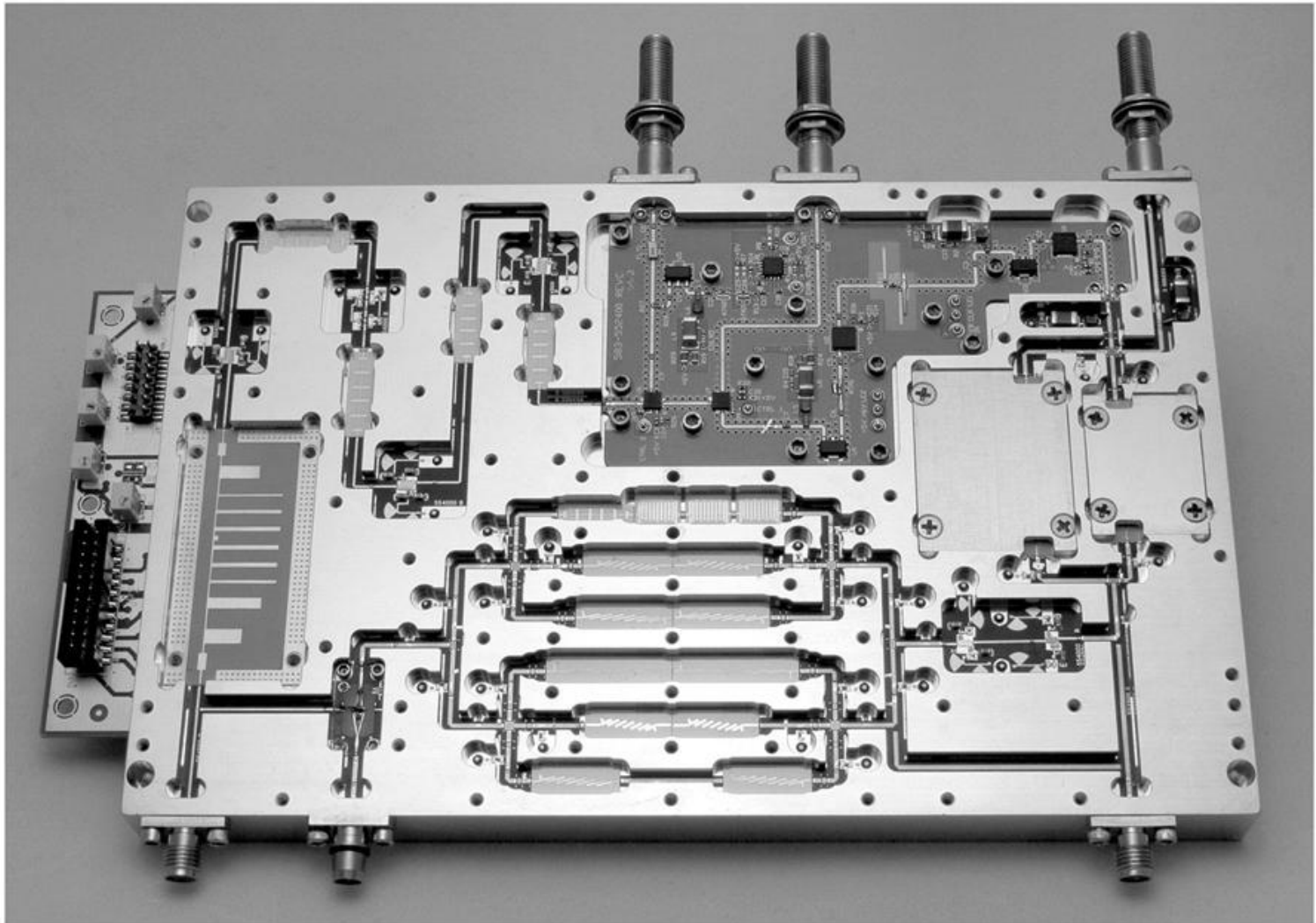


Figure 8.55  
Courtesy of LNX Corporation, Salem, N.H.



# Example

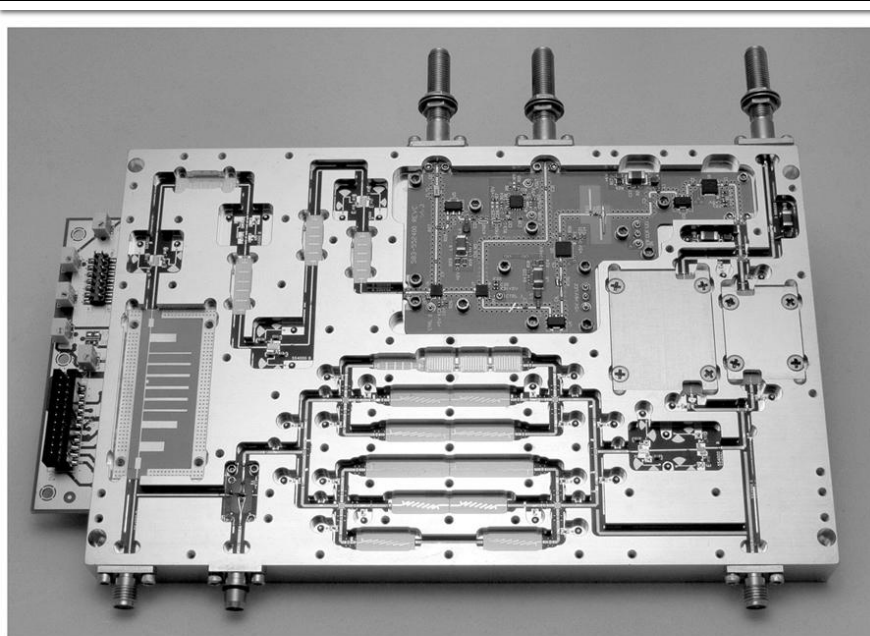
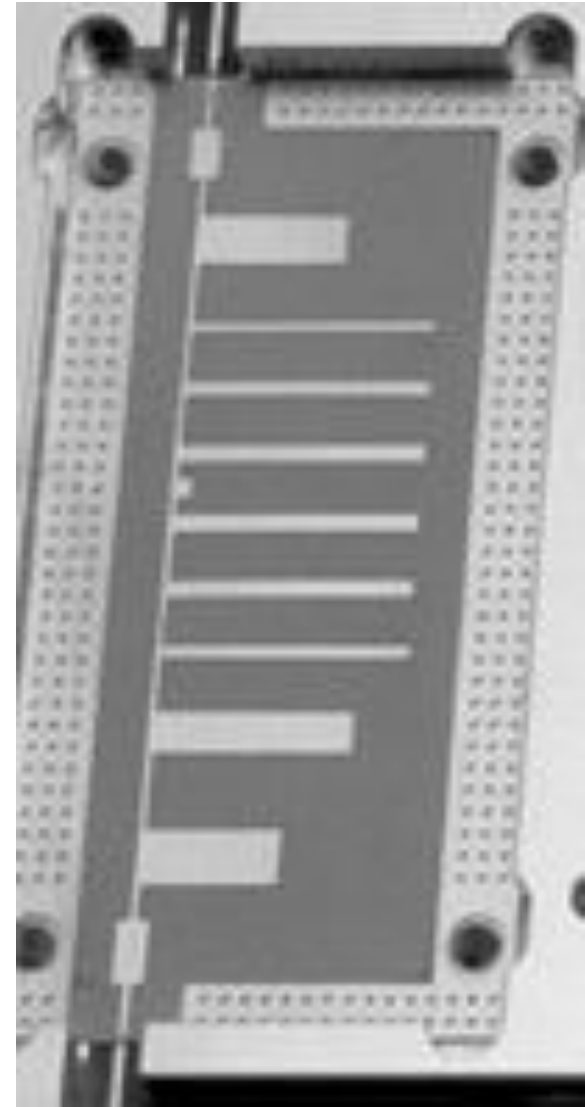
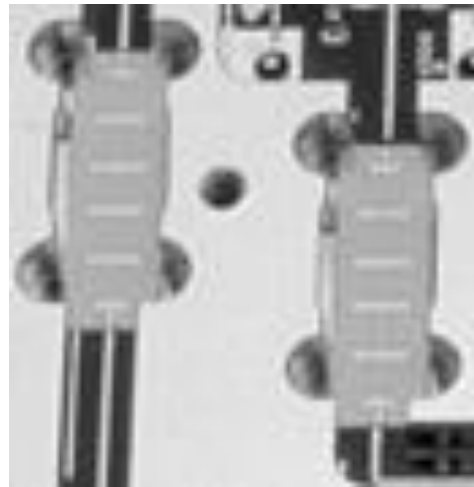
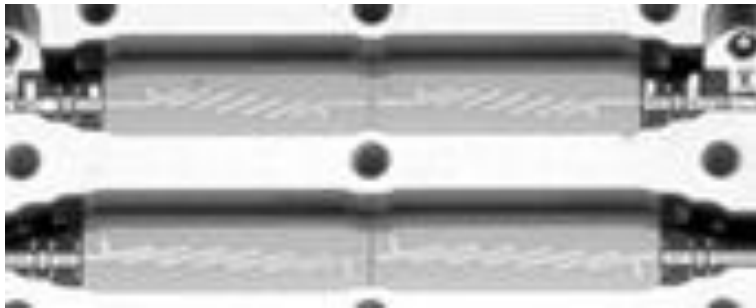


Figure 8.55  
Courtesy of LNX Corporation, Salem, N.H.





# Inversoare de impedanta si admitanta

- Transformarea Richard si identitatile Kuroda sunt utile mai ales pentru filtrele trece jos in tehnologiile in care stub-urile serie sunt dificil/imposibil de realizat (microstrip)
- De exemplu in cazul filtrului trece banda de ordinul 3:
  - se poate implementa inductanta serie utilizand K1-K2
  - capacitatea serie in schimb nu poate fi echivalata cu un stub paralel

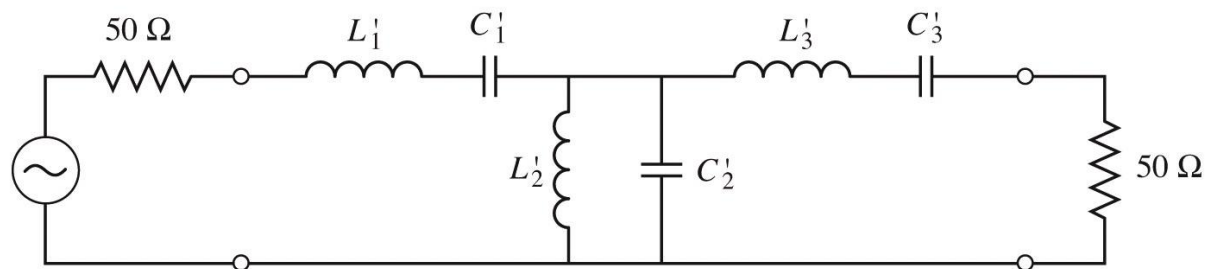


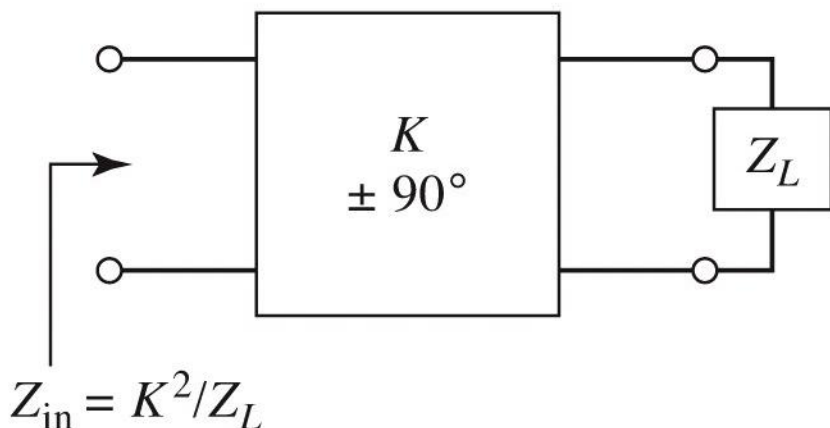
Figure 8.32  
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# Inversoare de impedanta si admitanta

- Pentru situatiile in care implementarea cu Richards + Kuroda nu ofera solutii practice se folosesc structuri de circuit numite **inversoare de impedanta si admitanta**

$$Z_{in} = \frac{K^2}{Z_L}$$

Impedance inverters



$$Y_{in} = \frac{J^2}{Y_L}$$

Admittance inverters

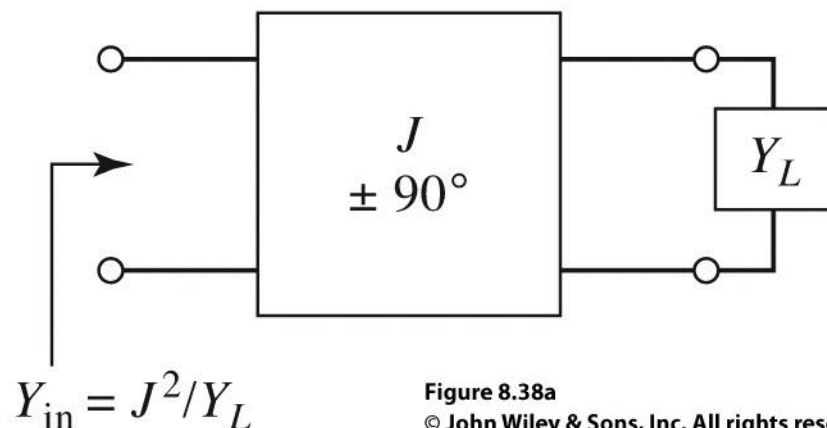


Figure 8.38a

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# Inversoare de impedanta si admitanta

- Cel mai simplu exemplu de inversor de impedanta/admitanta este **transformatorul in sfert de lungime de unda (C2)**

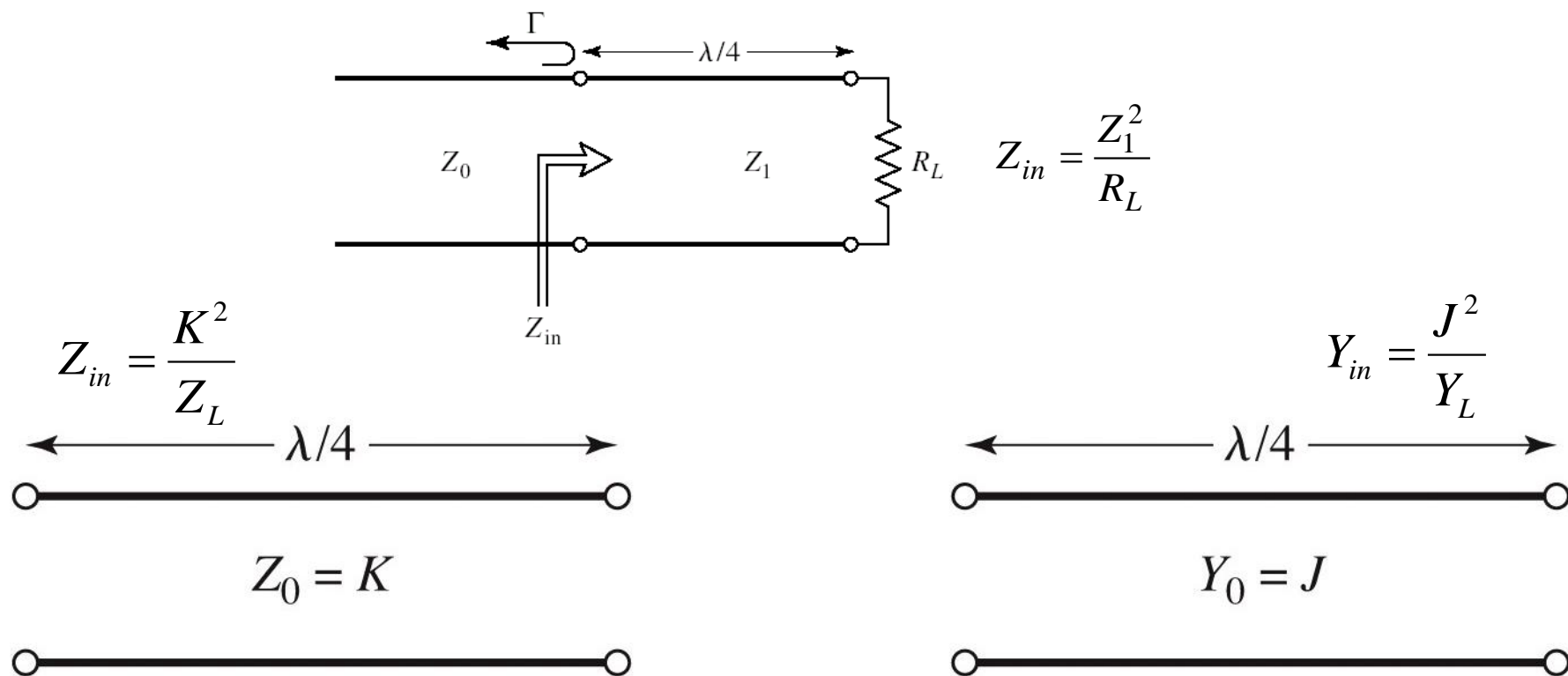
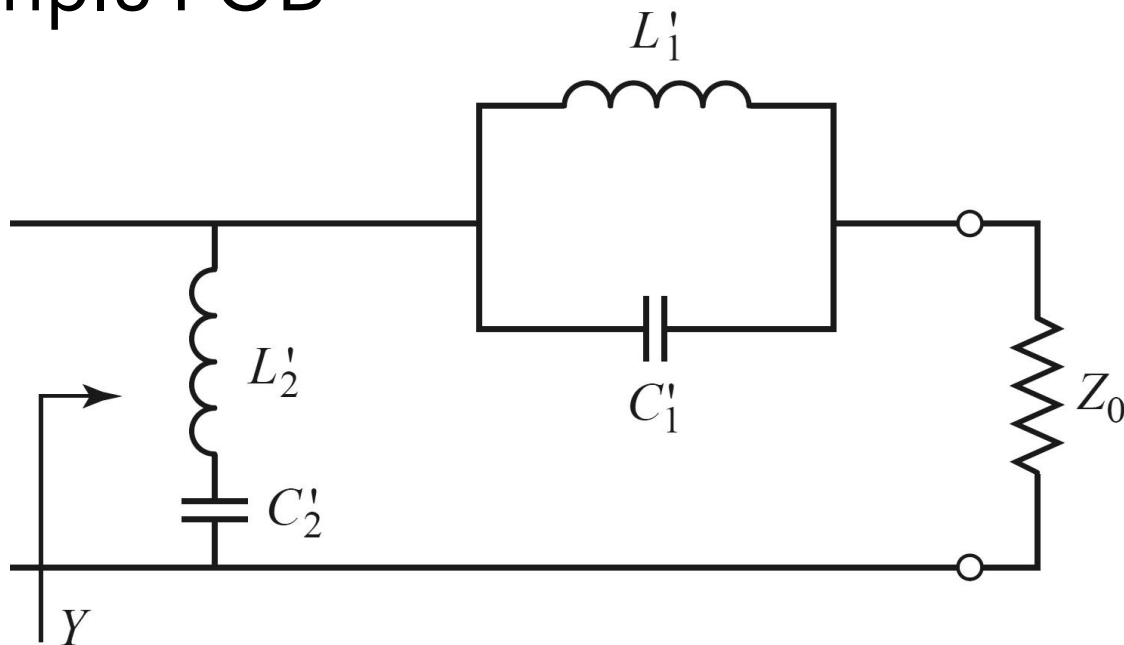


Figure 8.38b

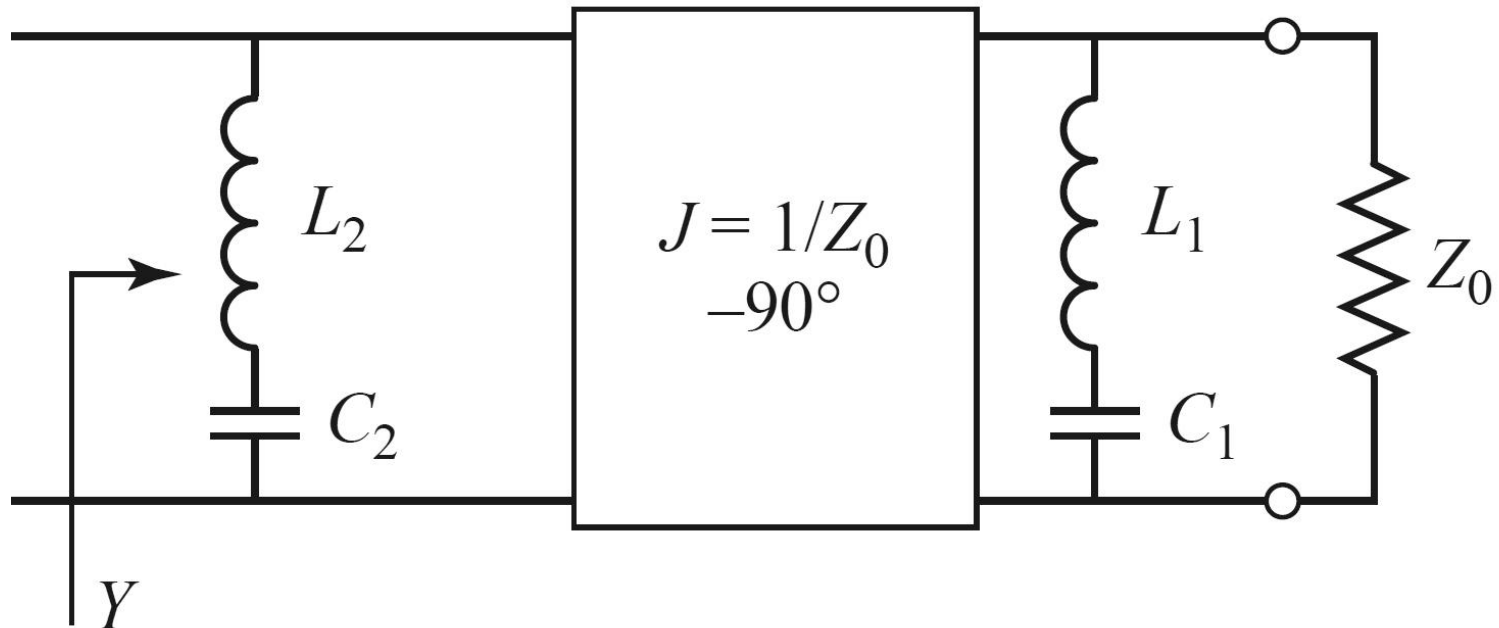
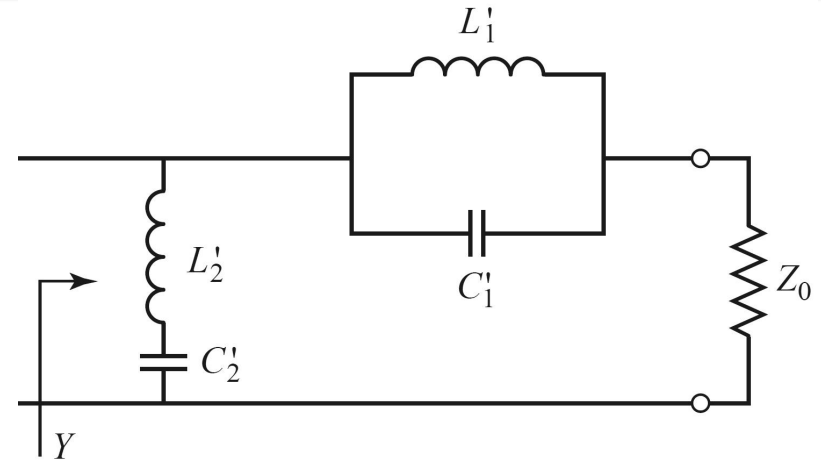
# Inversoare de impedanta si admitanta

- Inversoarele de impedanta/admitanta pot fi utilizate pentru a schimba structura filtrelor in forme realizabile
- Exemplu FOB



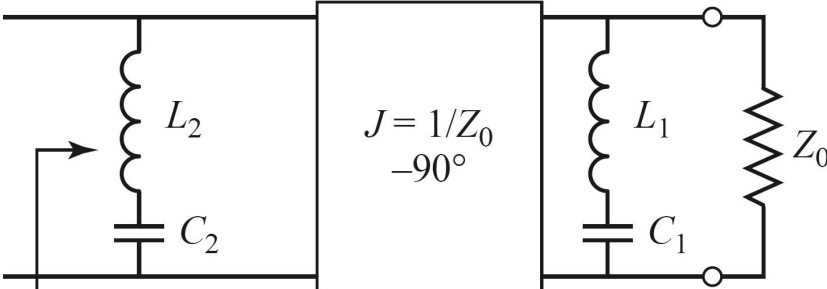
# Inversoare de impedanta si admitanta

- Elementele serie pot fi eliminate prin introducerea unui inversor de admitanta



# Inversoare de impedanta si admitanta

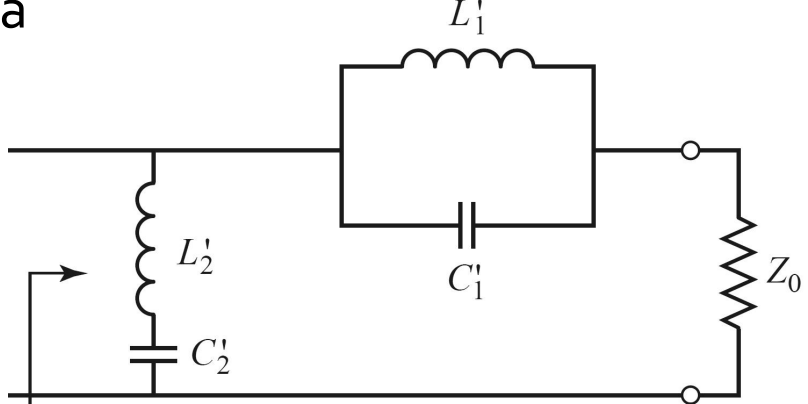
- Echivalenta celor doua scheme se demonstreaza prin obtinerea aceleiasi admitante de intrare
- Echivalenta completa se obtine prin incadrarea grupului simulat intre doua invertoare de admitanta



$$Y = \frac{1}{j \cdot \omega \cdot L_2 + \frac{1}{j \cdot \omega \cdot C_2}} + \frac{1}{Z_0} \cdot \left( \frac{1}{j \cdot \omega \cdot L_1 + \frac{1}{j \cdot \omega \cdot C_1}} + \frac{1}{Z_0} \right)^{-1}$$

$$L_n \cdot C_n = L'_n \cdot C'_n = \frac{1}{\omega_0^2} \Rightarrow \frac{1}{Z_0^2} \cdot \sqrt{\frac{L_1}{C_1}} = \sqrt{\frac{C'_1}{L'_1}} \Rightarrow Y = Y'$$

$$\sqrt{\frac{L_2}{C_2}} = \sqrt{\frac{L'_2}{C'_2}}$$

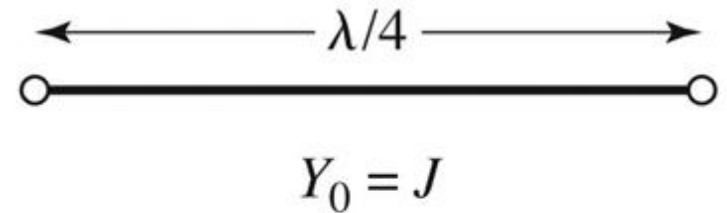
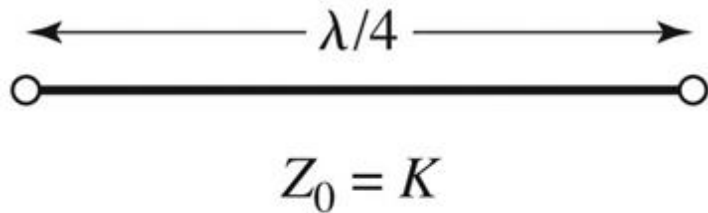


$$Y' = \frac{1}{j \cdot \omega \cdot L'_2 + \frac{1}{j \cdot \omega \cdot C'_2}} + \left( \frac{1}{j \cdot \omega \cdot C'_1 + \frac{1}{j \cdot \omega \cdot L'_1}} + Z_0 \right)^{-1}$$

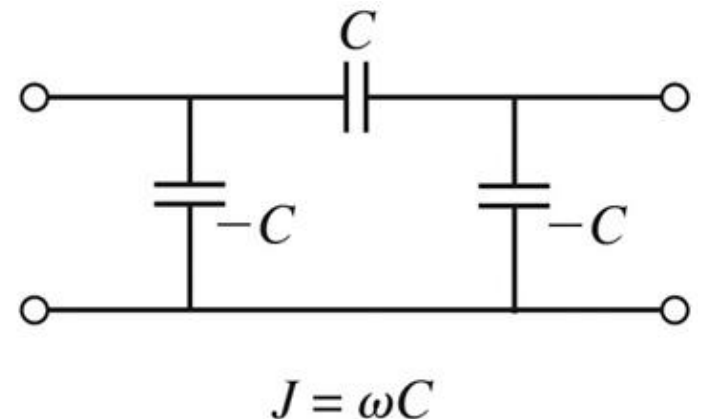
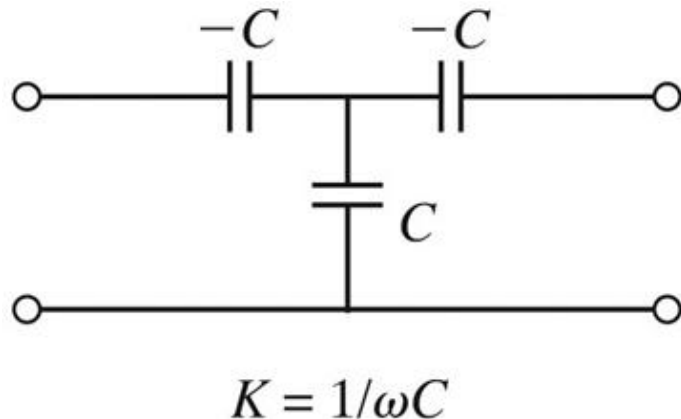
- Rezultat similar se obtine si pentru filtrul trece banda
- Un grup **LC serie** introdus in serie se poate inlocui cu un grup **LC paralel** introdus in paralel incadrat de doua invertoare de admitanta

# Realizari practice de inversoare de impedanta/admitanta

- Cel mai uzual se foloseste transformatorul in sfert de lungime de unda

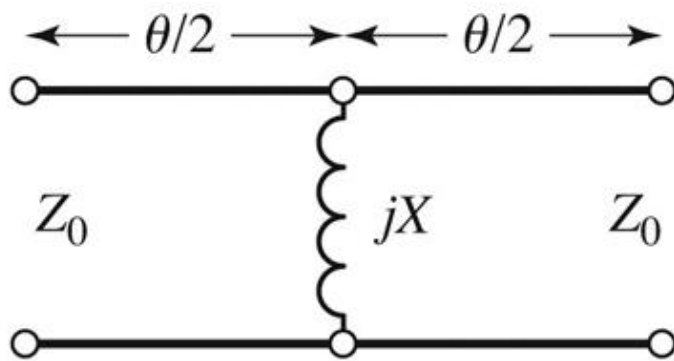


- Realizare cu elemente concentrate

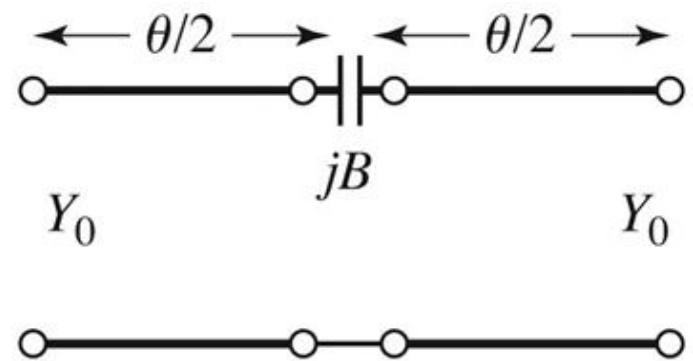


# Realizari practice de inversoare de impedanta/admitanta

## ■ Realizare cu linii



$$K = Z_0 \cdot \tan \left| \frac{\theta}{2} \right|$$
$$X = \frac{K}{1 - \left( \frac{K}{Z_0} \right)^2}$$
$$\theta = -\tan^{-1} \frac{2 \cdot X}{Z_0}$$



$$J = Y_0 \cdot \tan \left| \frac{\theta}{2} \right|$$
$$B = \frac{J}{1 - \left( \frac{J}{Y_0} \right)^2}$$
$$\theta = -\tan^{-1} \frac{2 \cdot B}{Y_0}$$

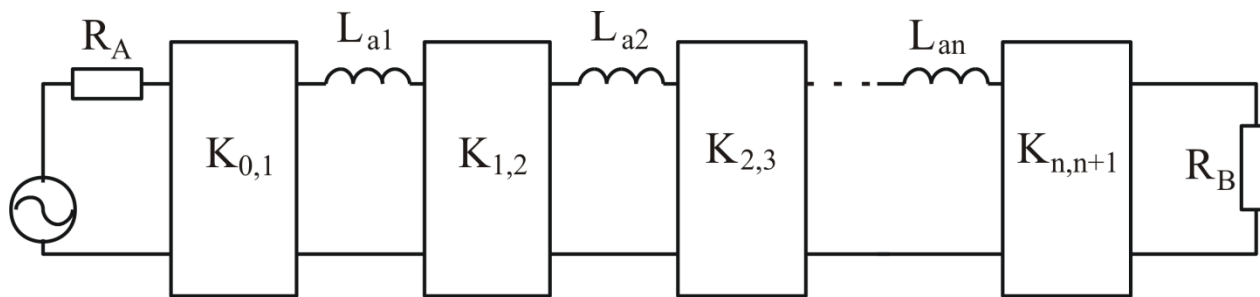
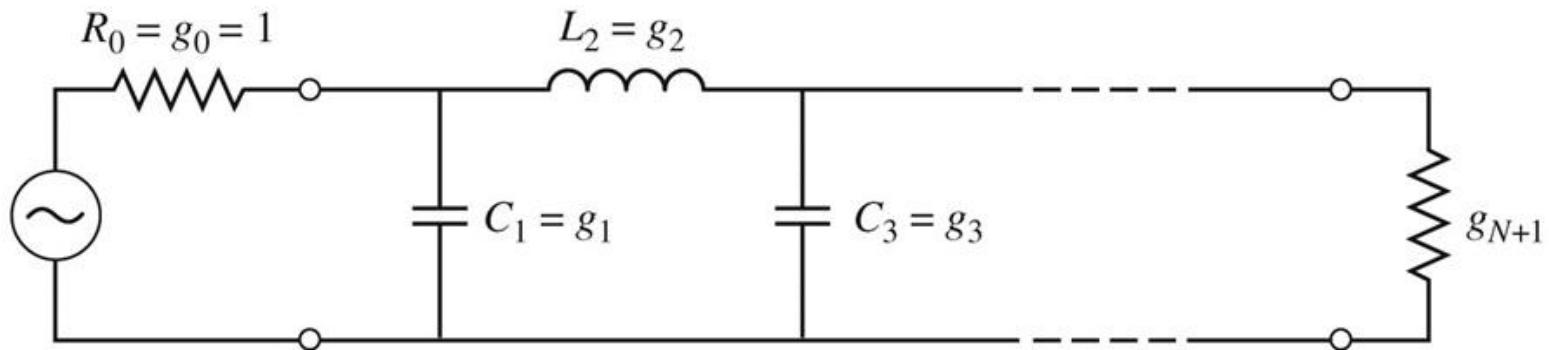
Red arrows point from the two diagrams above to the equation below.

$$\theta < 0$$



# Filtre prototip cu inversoare

- Utilizand inversoare de admitanta se pot implementa filtrele prototip utilizand un singur tip de element



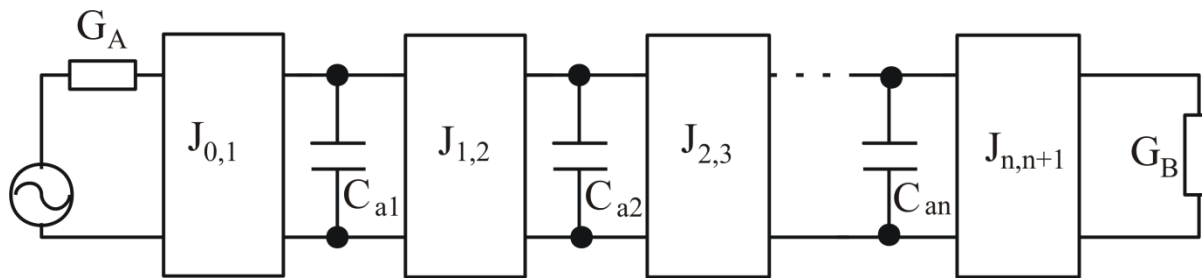
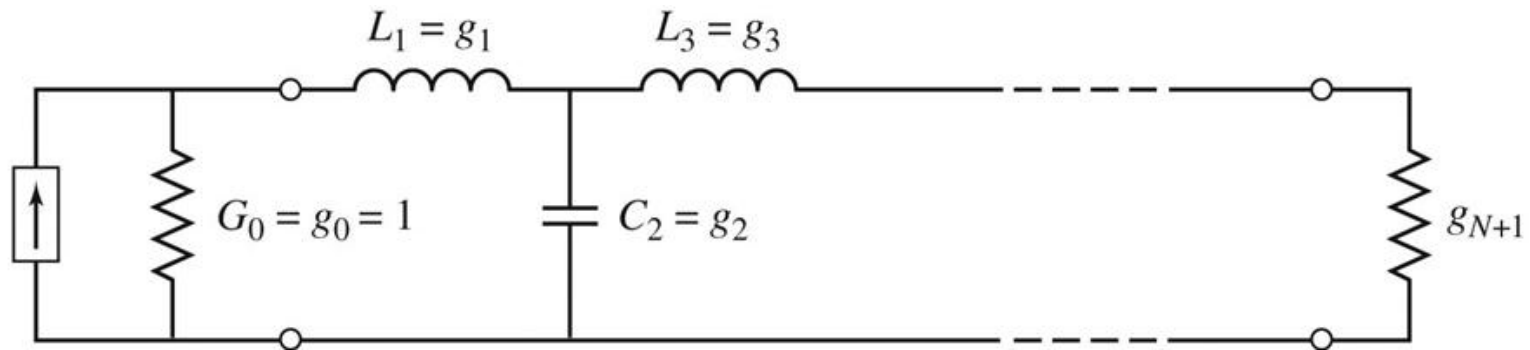
$$K_{0,1} = \sqrt{\frac{R_A \cdot L_{a,1}}{g_0 \cdot g_1}}$$

$$K_{k,k+1} \Big|_{k=1, n-1} = \sqrt{\frac{L_{a,k} \cdot L_{a,k+1}}{g_k \cdot g_{k+1}}}$$

$$K_{n,n+1} = \sqrt{\frac{L_{a,n} \cdot R_B}{g_n \cdot g_{n+1}}}$$

# Filtre prototip cu inversoare

- Utilizand inversoare de admitanta se pot implementa filtrele prototip utilizand un singur tip de element



$$J_{0,1} = \sqrt{\frac{G_A \cdot C_{a,1}}{g_0 \cdot g_1}}$$

$$J_{k,k+1} \Big|_{k=1, n-1} = \sqrt{\frac{C_{a,k} \cdot C_{a,k+1}}{g_k \cdot g_{k+1}}}$$

$$J_{n,n+1} = \sqrt{\frac{C_{a,n} \cdot g_B}{g_n \cdot g_{n+1}}}$$

# Filtre prototip cu inversoare

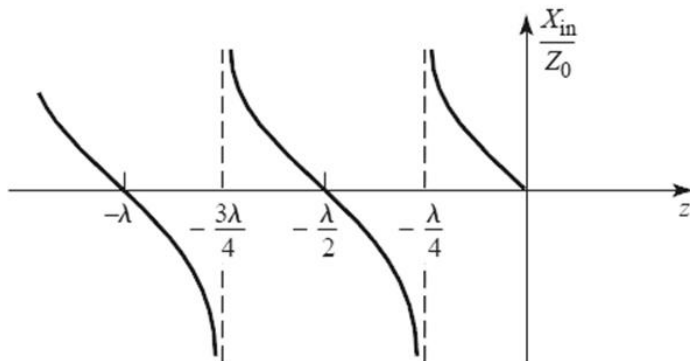
- Pentru filtrele prototip cu inversoare exista  $2 \cdot N + 1$  parametri si  $N + 1$  ecuatii care asigura echivalenta raspunsului deci  $N$  parametri pot fi alesi din considerente oarecare
  - se pot alege valorile reactantelor, urmand ca parametrii inversoarelor sa rezulte din calcul
  - se pot alege convenabil inversoarele, urmand ca reactantele sa rezulte din ecuatiile de echivalare
- Principiul se poate aplica si pentru filtrele trece banda/opreste banda, acestea putand fi realizate din  $N + 1$  inversoare si  $N$  rezonatori (grupuri LC serie sau paralel cu frecventa de rezonanta  $\omega_0$ ) conectate fie in serie fie in paralel intre inversoare
  - FTB se realizeaza cu
    - grup LC serie conectat in serie intre inversoare
    - grup LC paralel conectat in paralel intre inversoare
  - FOB se realizeaza cu
    - grup LC paralel conectat in serie intre inversoare
    - grup LC serie conectat in paralel intre inversoare

# Linii ca rezonatoare

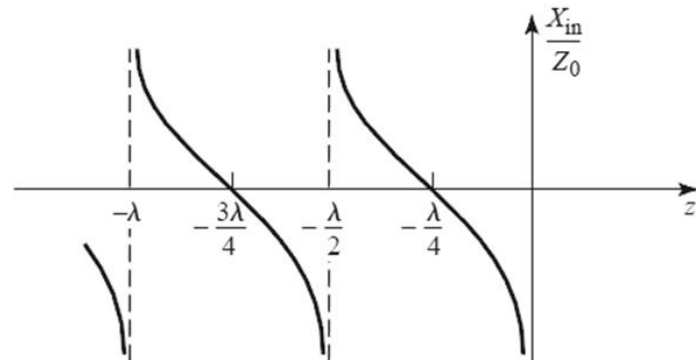
- Impedanta de intrare intr-o linie (stub) scurtcircuitata sau lasata in gol la capat manifesta comportament rezonant care poate fi utilizat pentru implementarea rezonatoarelor

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

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

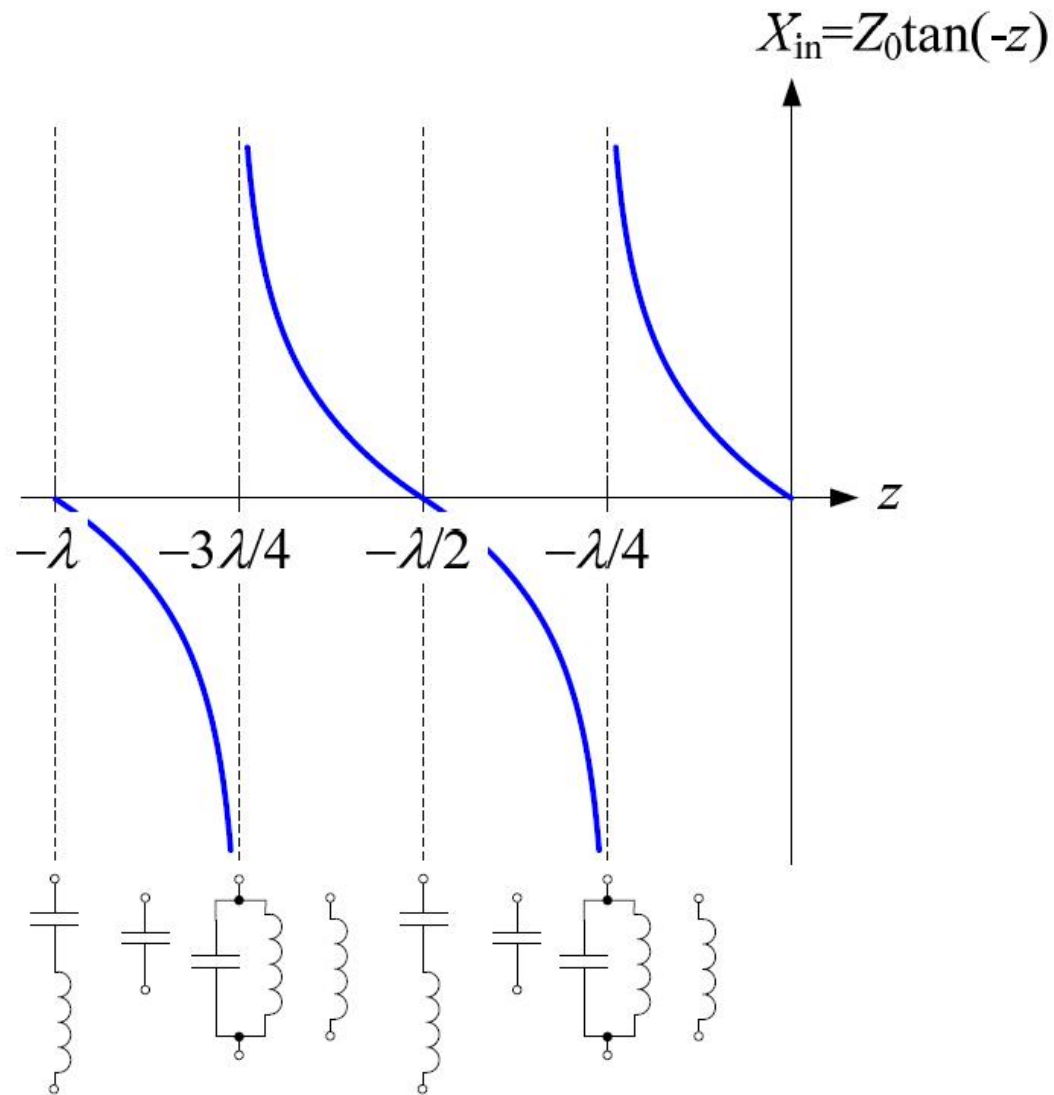


$$Z_{in,g} = -j \cdot Z_0 \cdot \cot \beta \cdot l$$



# Linii ca rezonatoare

- Linie in scurtcircuit
- Pentru frecventa ( $\omega_0$ ) la care  $l = \lambda/4$  se obtine un circuit rezonant LC paralel
  - linia are comportament capacitiv pentru frecvente mai mici ( $l > \lambda/4$ )
  - linia are comportament inductiv pentru frecvente mai mari ( $l < \lambda/4$ )
- Discutie similara pentru linia in gol (LC serie la frecventa la care  $l = \lambda/4$ )



# FTB/FOB relatii de proiectare

- Pentru cazul particular in care se implementeaza inversoarele de admitanta cu transformatoare in sfert de lungime de unda si impedanta caracteristica  $Z_0$

- FTB – stub-uri paralel scurtcuite la  $l = \lambda/4$

$$Z_{0n} \approx \frac{\pi \cdot Z_0 \cdot \Delta}{4 \cdot g_n}$$

- FOB – stub-uri paralel in gol de lungime  $l = \lambda/4$

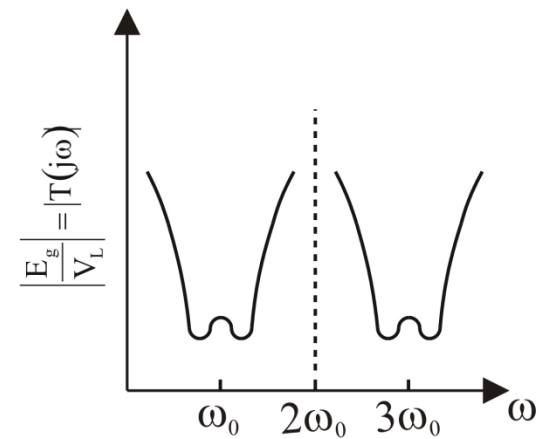
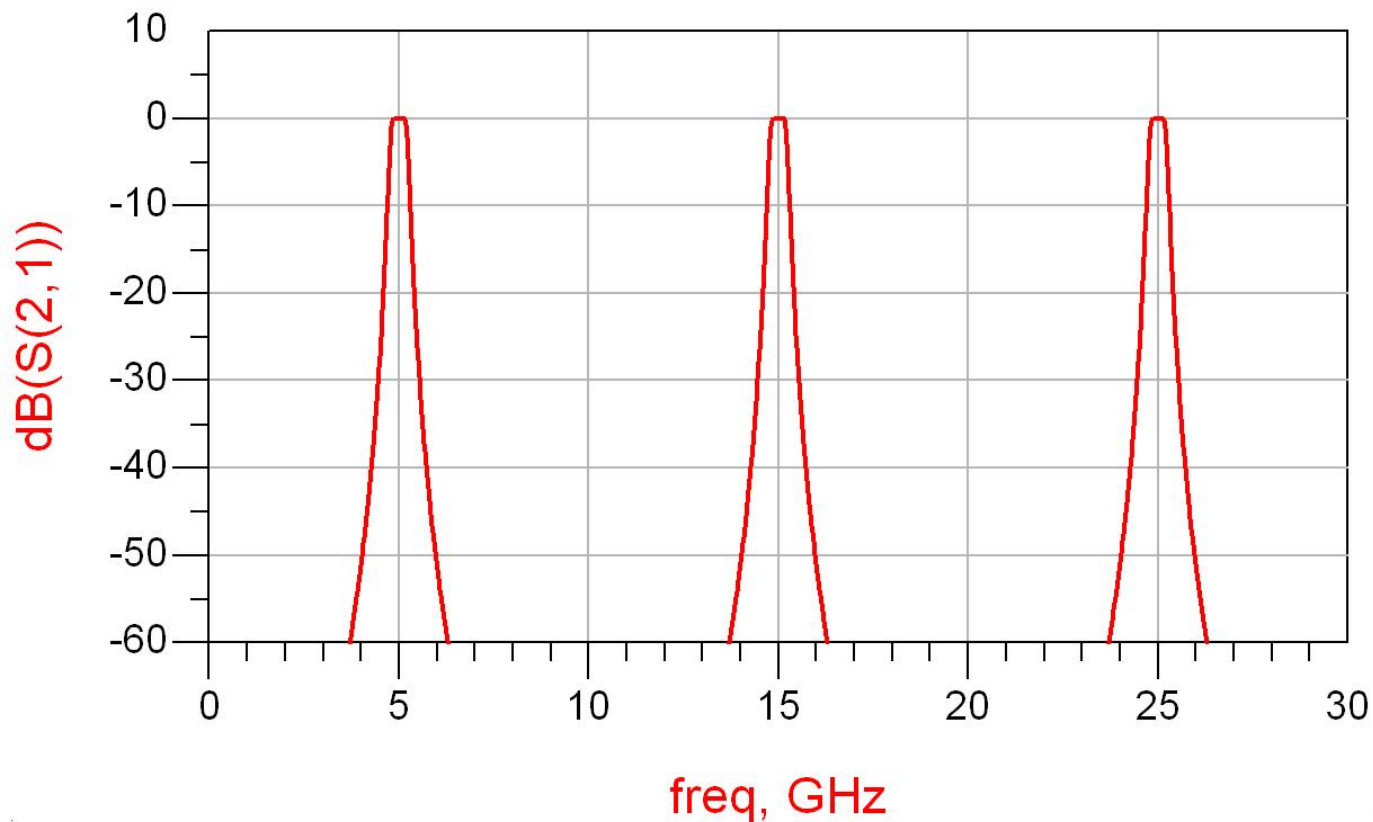
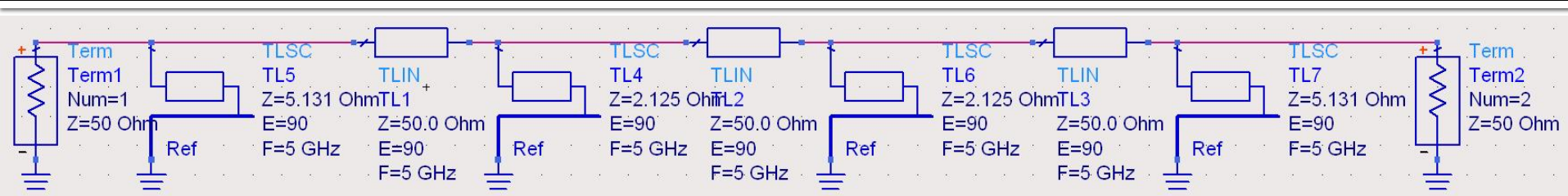
$$Z_{0n} \approx \frac{4 \cdot Z_0}{\pi \cdot g_n \cdot \Delta}$$

# Exemplu

- Similar cu o tema de proiect
- Continuarea amplificatorului C10
- Filtru trece banda de ordinul 4,  $f_0 = 5\text{GHz}$ , banda 10 %
- Tabel maxim plat sau relatii de calcul:

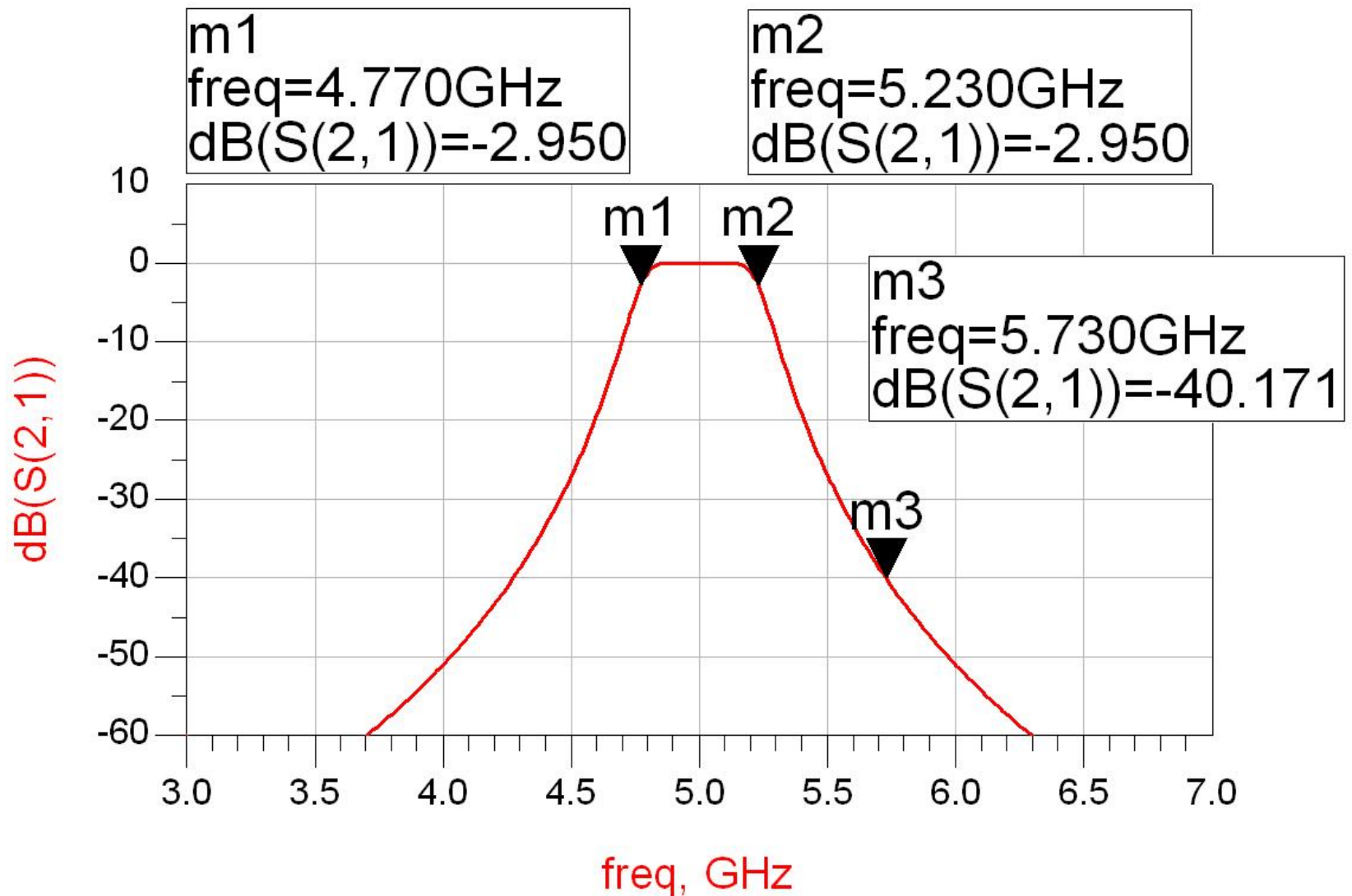
n	$g_n$	$Z_{on}(\Omega)$
1	0.7654	5.131
2	1.8478	2.125
3	1.8478	2.125
4	0.7654	5.131

# ADS – FTB

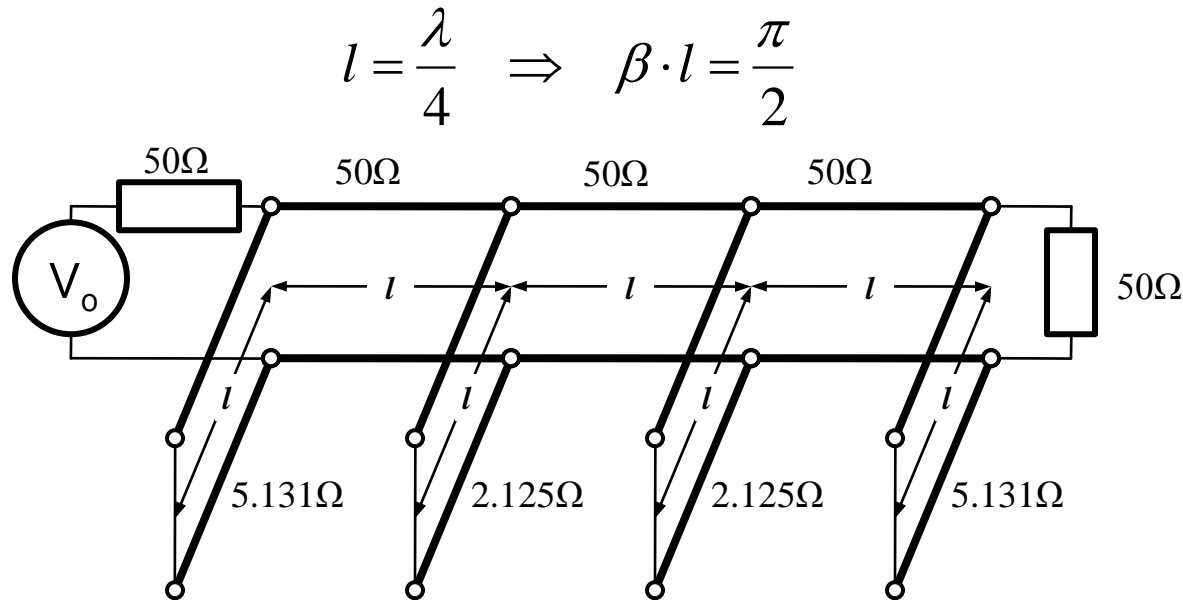




# ADS – FTB



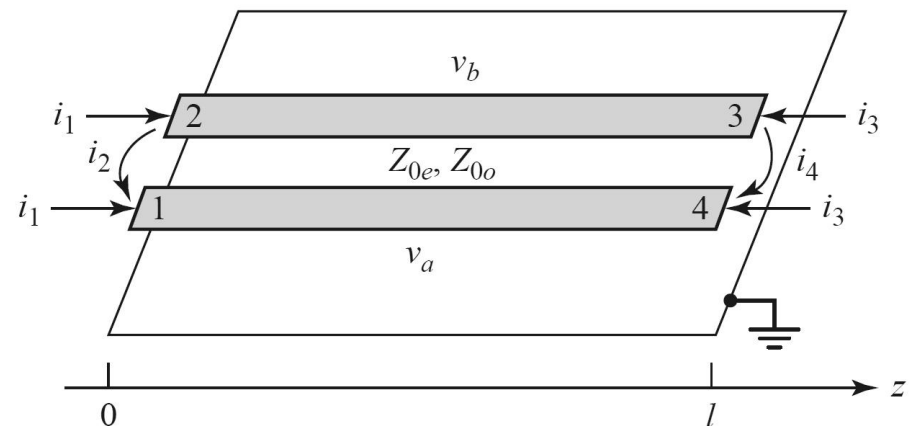
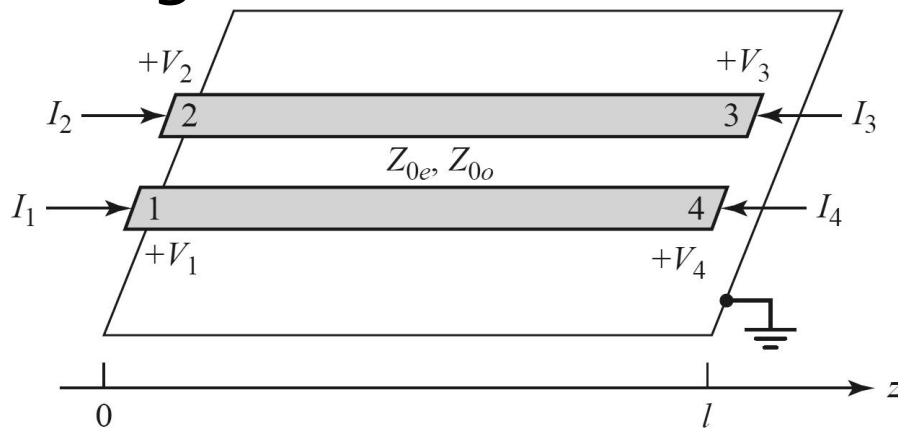
# Exemplu



- Problemele filtrelor realizate cu linii ca rezonatoare si invertoare de impedanta
  - stub-uri in scurtcircuit (via-hole) pentru FTB
  - deseori impedantele caracteristice pentru stub-uri rezulta de **valori** dificil de realizat in practica (2.125Ω)

# Filtre cu linii cuplate

- Analiza sectiunilor de linii cuplate se face punand in evidenta comportarea pe modul par si pe modul impar
- Aceste moduri sunt caracterizate de impedantele caracteristice de mod par/impar a caror valoare va impune in functie de tehnologia utilizata geometria liniilor (latime/distanta dintre linii)



# Linii cuplate

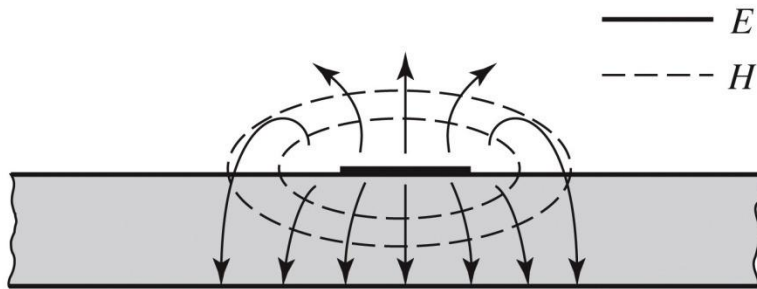
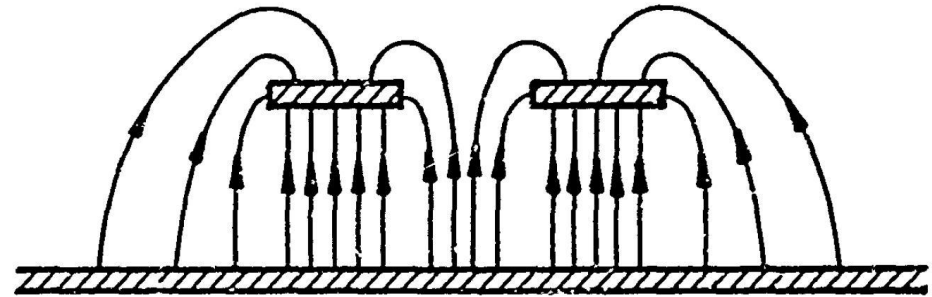
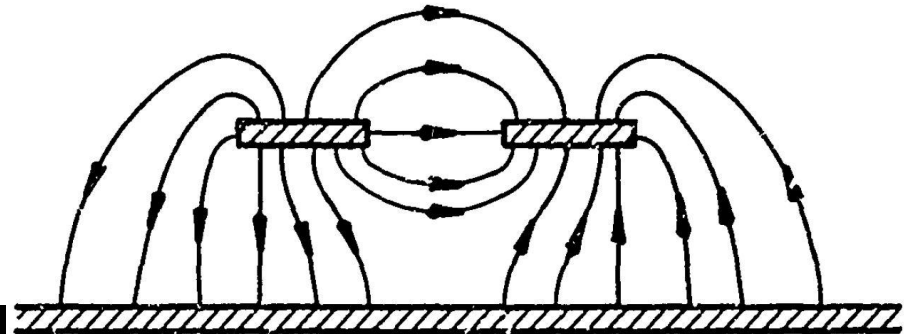


Figure 3.25b  
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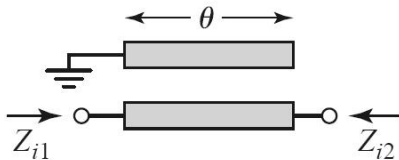
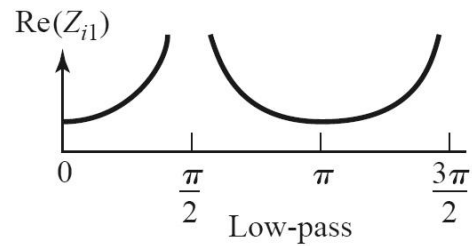
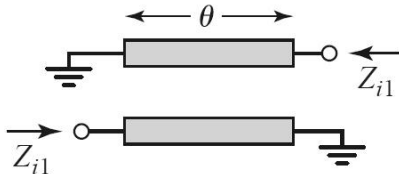
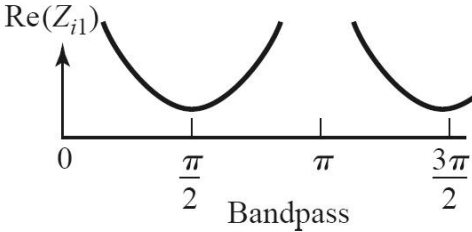
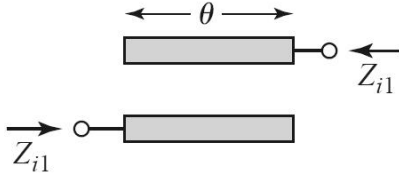
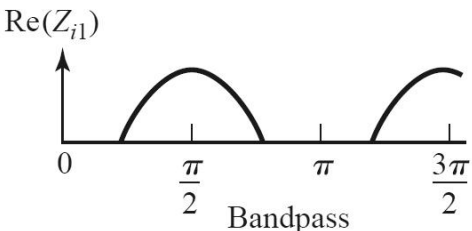
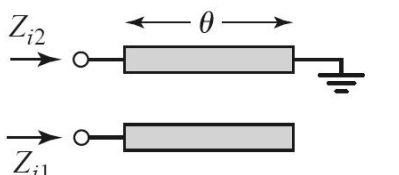
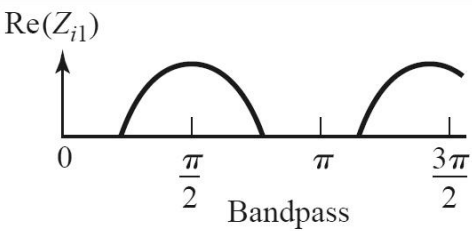
b) EVEN MODE ELECTRIC FIELD PATTERN (SCHEMATIC)



c) ODD MODE ELECTRIC FIELD PATTERN (SCHEMATIC)

- Mod par – caracterizeaza semnalul de mod comun de pe cele doua linii
- Mod impar – caracterizeaza semnalul de mod diferential dintre cele doua linii

# Filtre cu linii cuplate

Circuit	Image Impedance	Response
	$Z_{i1} = \frac{2Z_{0e}Z_{0o} \cos \theta}{\sqrt{(Z_{0e} + Z_{0o})^2 \cos^2 \theta - (Z_{0e} - Z_{0o})^2}}$ $Z_{i2} = \frac{Z_{0e}Z_{0o}}{Z_{i1}}$	 <p>Low-pass</p>
	$Z_{i1} = \frac{2Z_{0e}Z_{0o} \sin \theta}{\sqrt{(Z_{0e} - Z_{0o})^2 - (Z_{0e} + Z_{0o})^2 \cos^2 \theta}}$	 <p>Bandpass</p>
	$Z_{i1} = \frac{\sqrt{(Z_{0e} - Z_{0o})^2 - (Z_{0e} + Z_{0o})^2 \cos^2 \theta}}{2 \sin \theta}$	 <p>Bandpass</p>
	$Z_{i1} = \frac{\sqrt{Z_{0e}Z_{0o}} \sqrt{(Z_{0e} - Z_{0o})^2 - (Z_{0e} + Z_{0o})^2 \cos^2 \theta}}{(Z_{0e} + Z_{0o}) \sin \theta}$ $Z_{i2} = \frac{Z_{0e}Z_{0o}}{Z_{i1}}$	 <p>Bandpass</p>

# Filtre cu linii cuplate

- Filtru trece banda cu rezonanta la  $\theta = \pi/2$  ( $l = \lambda/4$ )

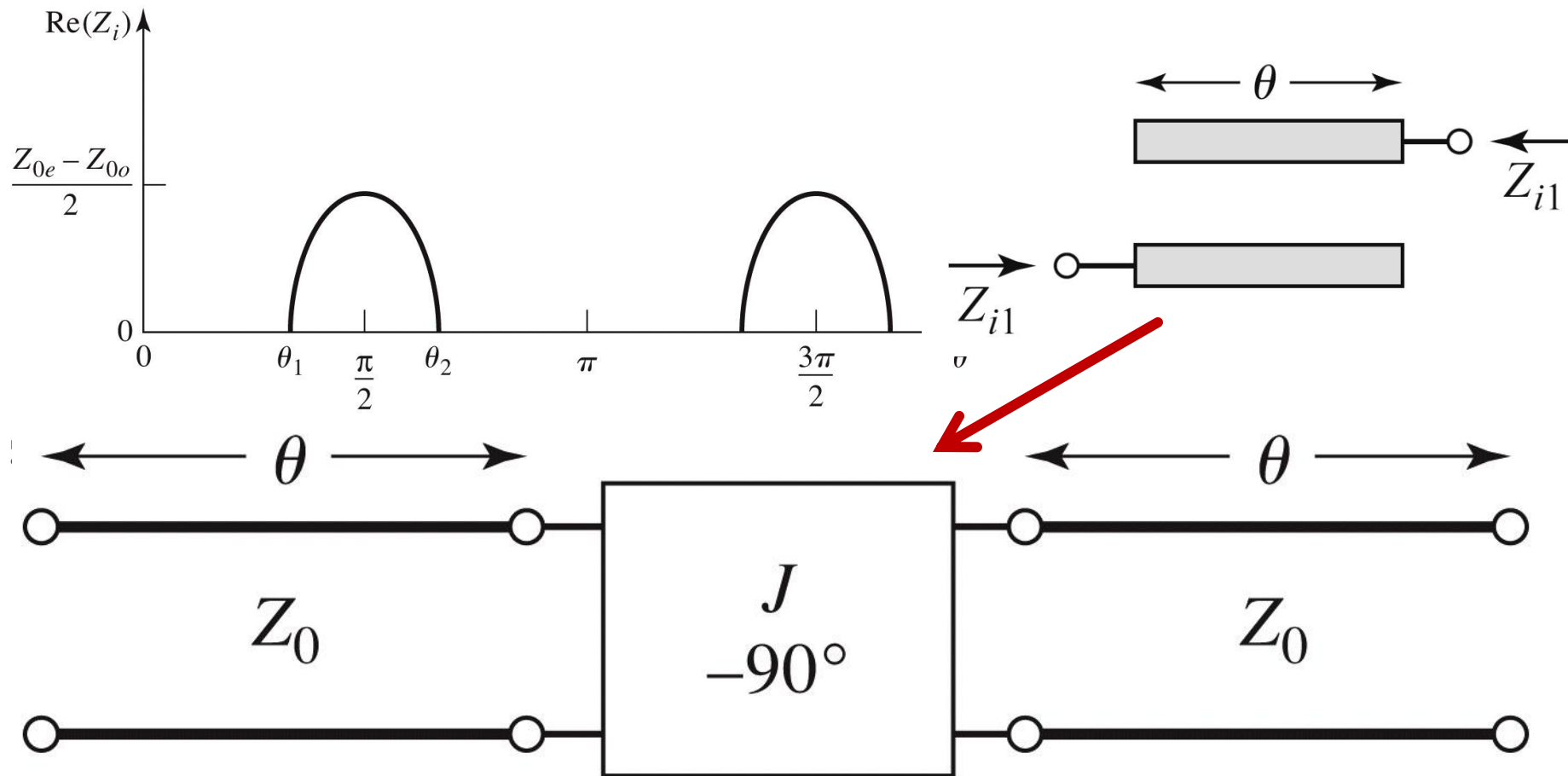
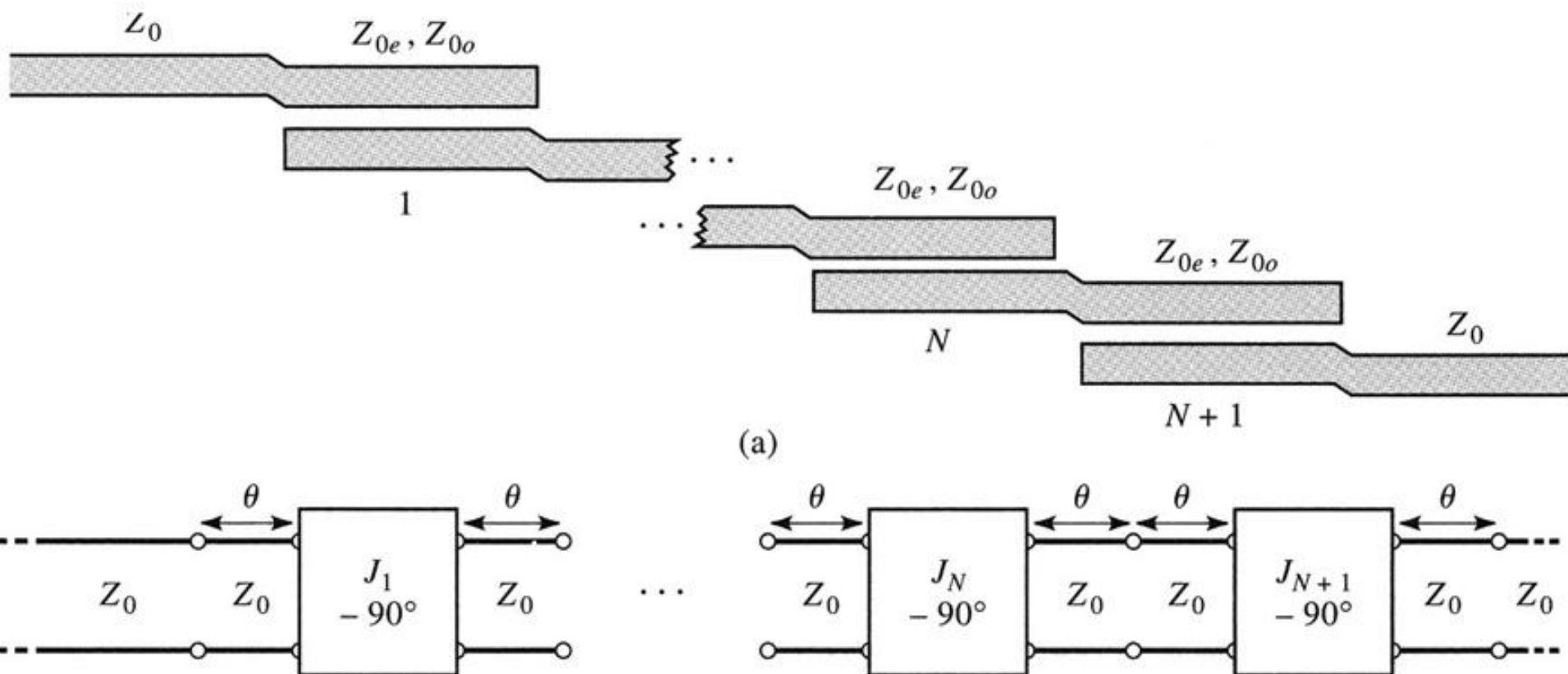


Figure 8.44

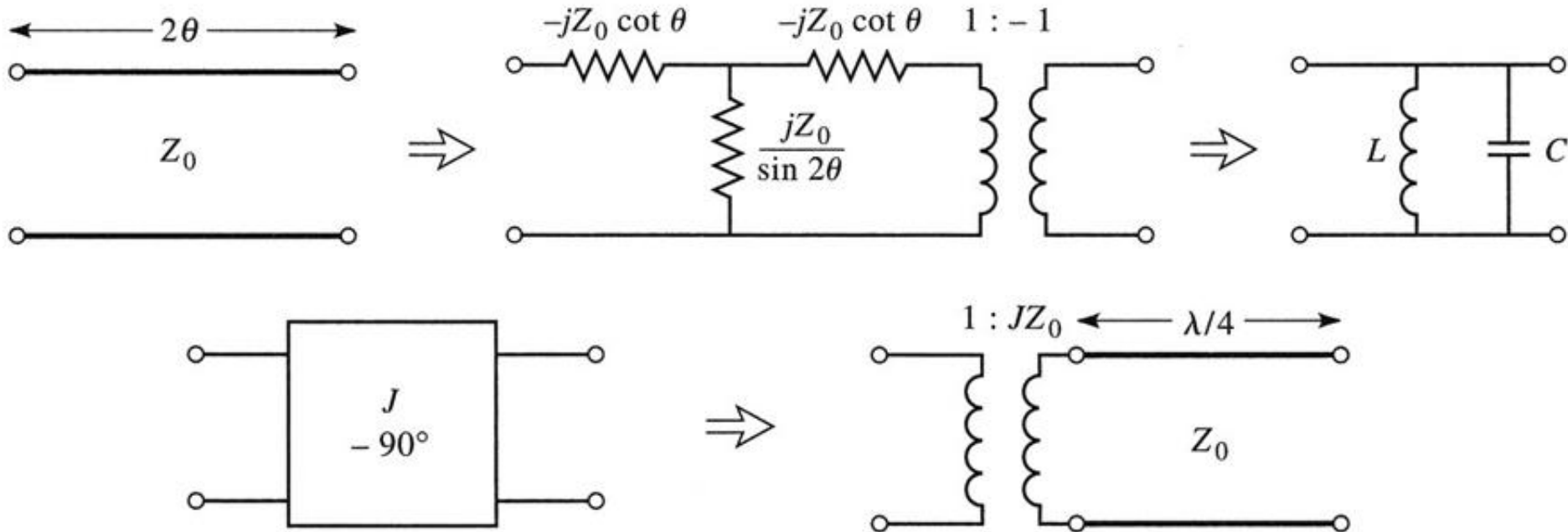
# Filtre cu linii cuplate

- Un filtru cu  $N+1$  sectiuni de linii cuplate



# Filtre cu linii cuplate

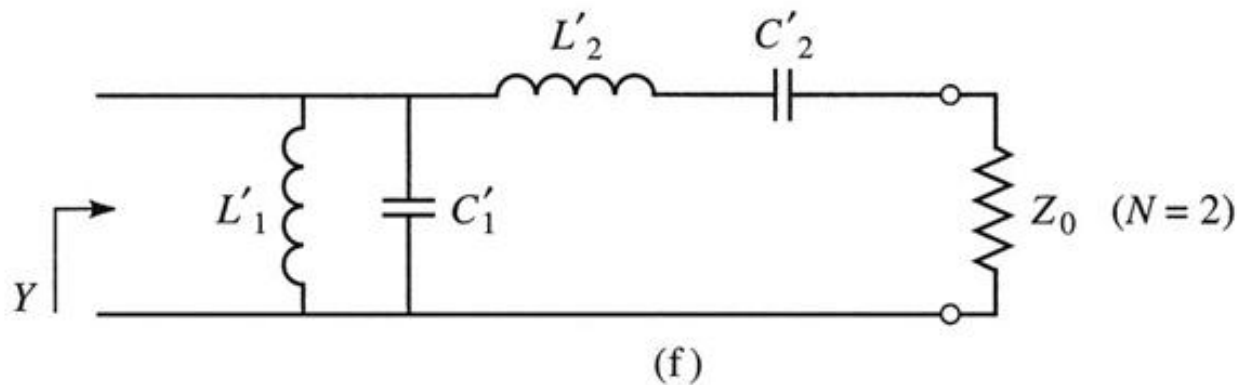
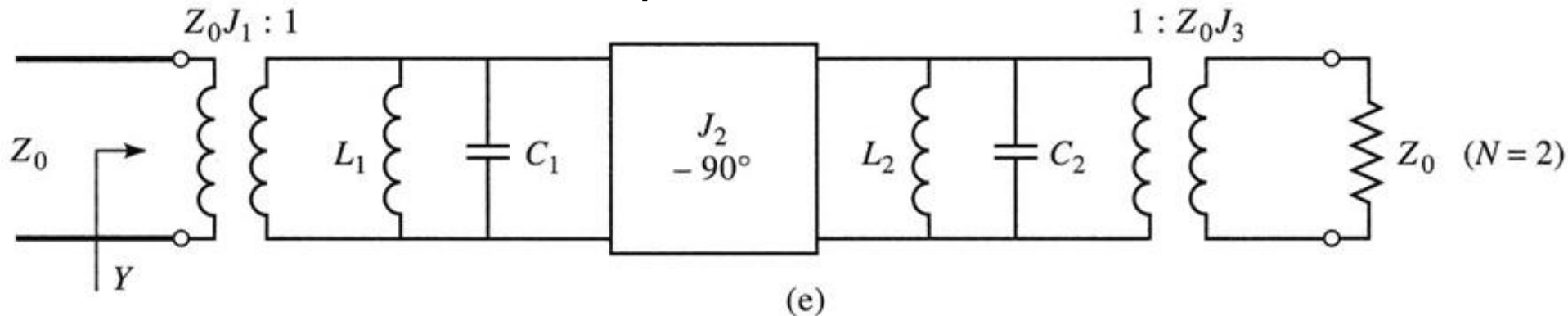
- Se modeleaza
  - liniile
  - inversoarele





# Filtre cu linii cuplate N=2

- Se obtine comportare de tip FTB de ordin 2 cu 3 sectiuni de linii cuplate



# Proiectare filtre cu linii cuplate

- Se calculeaza inversoarele

$$Z_0 \cdot J_1 = \sqrt{\frac{\pi \cdot \Delta}{2 \cdot g_1}} \quad Z_0 \cdot J_n = \frac{\pi \cdot \Delta}{2 \cdot \sqrt{g_{n-1} \cdot g_n}}, n = \overline{2, N} \quad Z_0 \cdot J_{N+1} = \sqrt{\frac{\pi \cdot \Delta}{2 \cdot g_N \cdot g_{N+1}}}$$

- Se calculeaza liniile cuplate (toate de lungime  $l = \lambda/4$ )

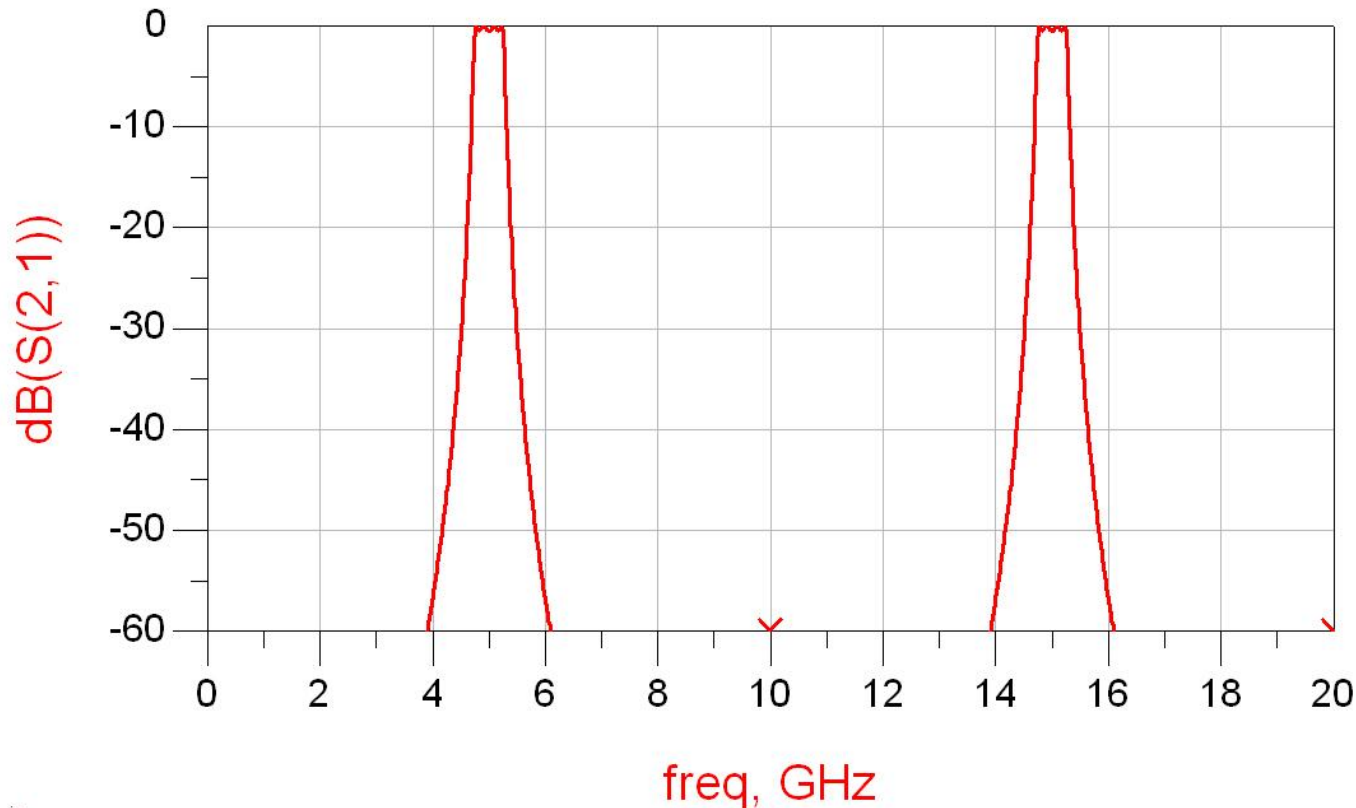
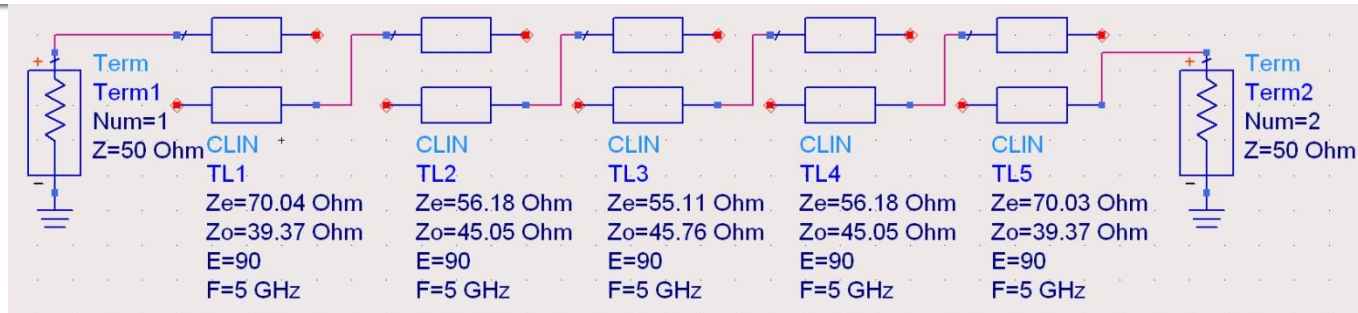
$$\begin{aligned} Z_{0e,n} &= Z_0 \cdot \left[ 1 + J_n \cdot Z_0 + (J_n \cdot Z_0)^2 \right] \\ Z_{0o,n} &= Z_0 \cdot \left[ 1 - J_n \cdot Z_0 + (J_n \cdot Z_0)^2 \right] \end{aligned} \quad n = \overline{1, N+1}$$

# Exemplu

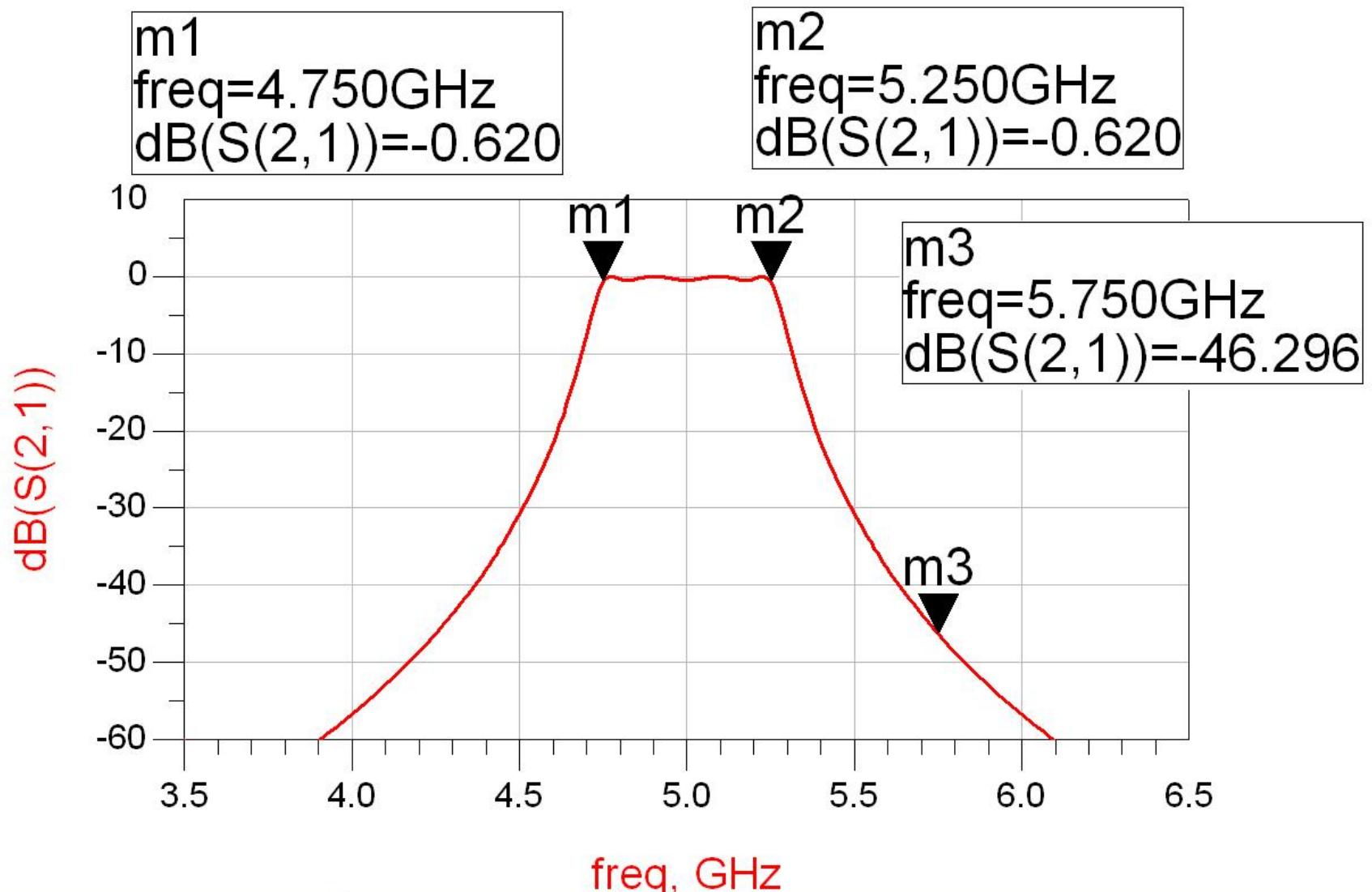
- Similar cu o tema de proiect
- Continuarea amplificatorului C10
- Filtru trece banda de ordinul 4,  $f_0 = 5\text{GHz}$ , banda 10 %
- Tabel echiriplu 0.5dB ( $g_i$ ) plus relatii de calcul:

n	g	$Z_0 J_n$	$Z_{0e}$	$Z_{0o}$
1	1.6703	0.306664	70.04	39.37
2	1.1926	0.111295	56.18	45.05
3	2.3661	0.09351	55.11	45.76
4	0.8419	0.111294	56.18	45.05
5	1.9841	0.306653	70.03	39.37

# ADS – FTB coupled line



# ADS – FTB coupled line



# Example

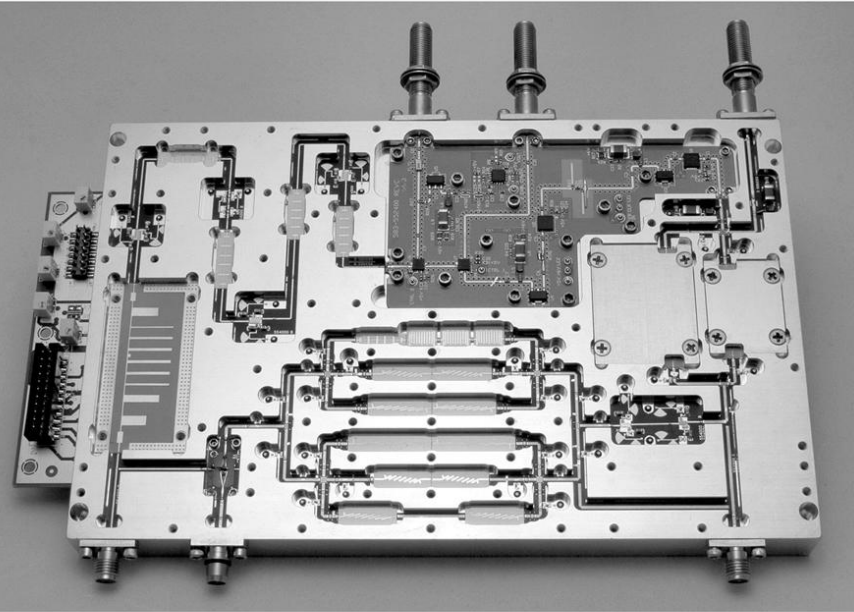
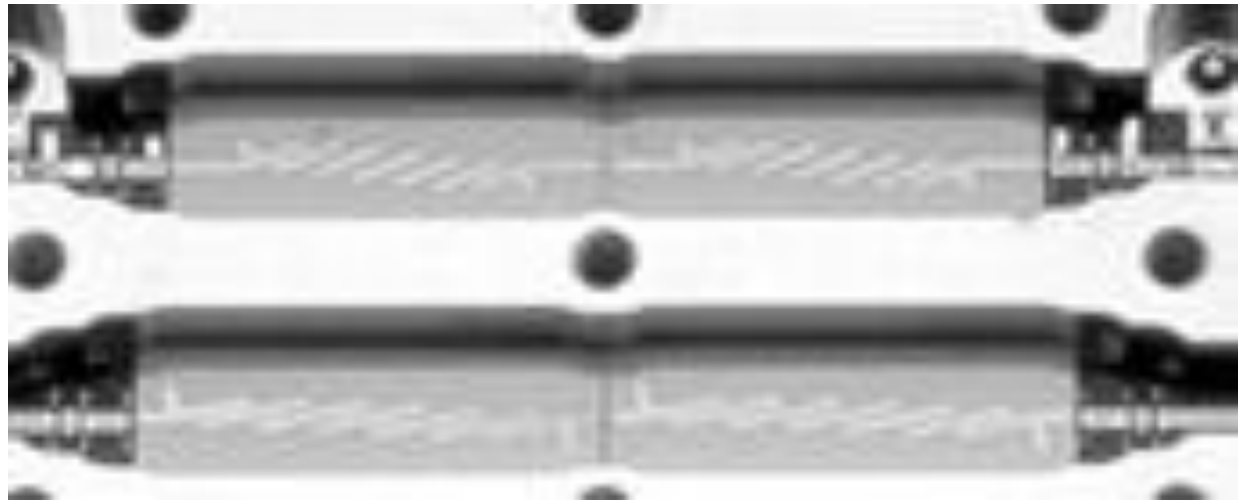
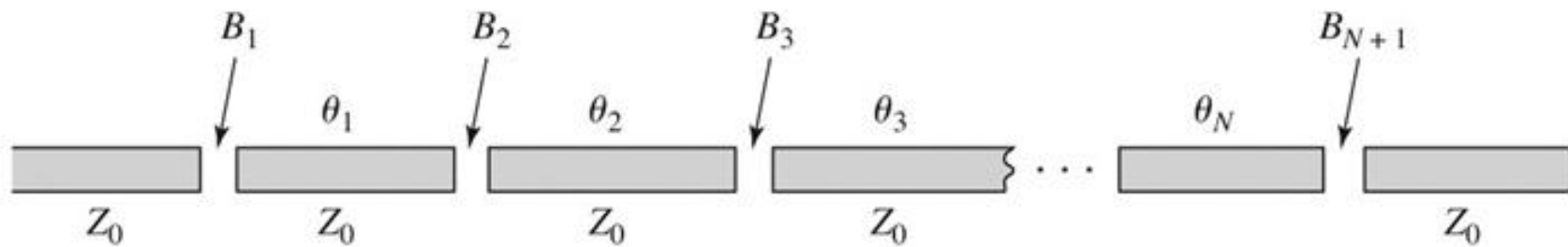


Figure 8.55  
Courtesy of LNX Corporation, Salem, N.H.

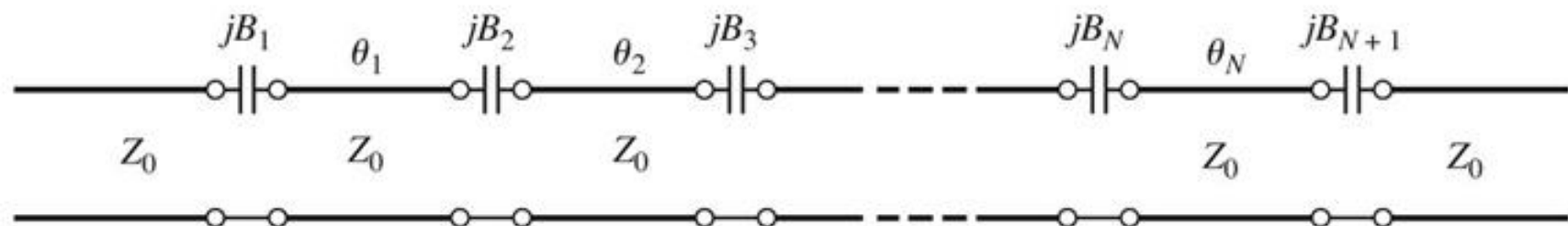


# Filtru cu rezonatoare serie cuplate capacitiv

- Separarea fizica a doua sectiuni de linie produce un cuplaj capacitiv intre cele doua linii



(a)



(b)

# Filtru cu rezonatoare serie cuplate capacitiv

- Din lungimea fizica a rezonatoarelor o portiune se foloseste pentru a crea schema de inversor (ramane  $\phi = \pi$ ,  $l = \lambda/2$ )

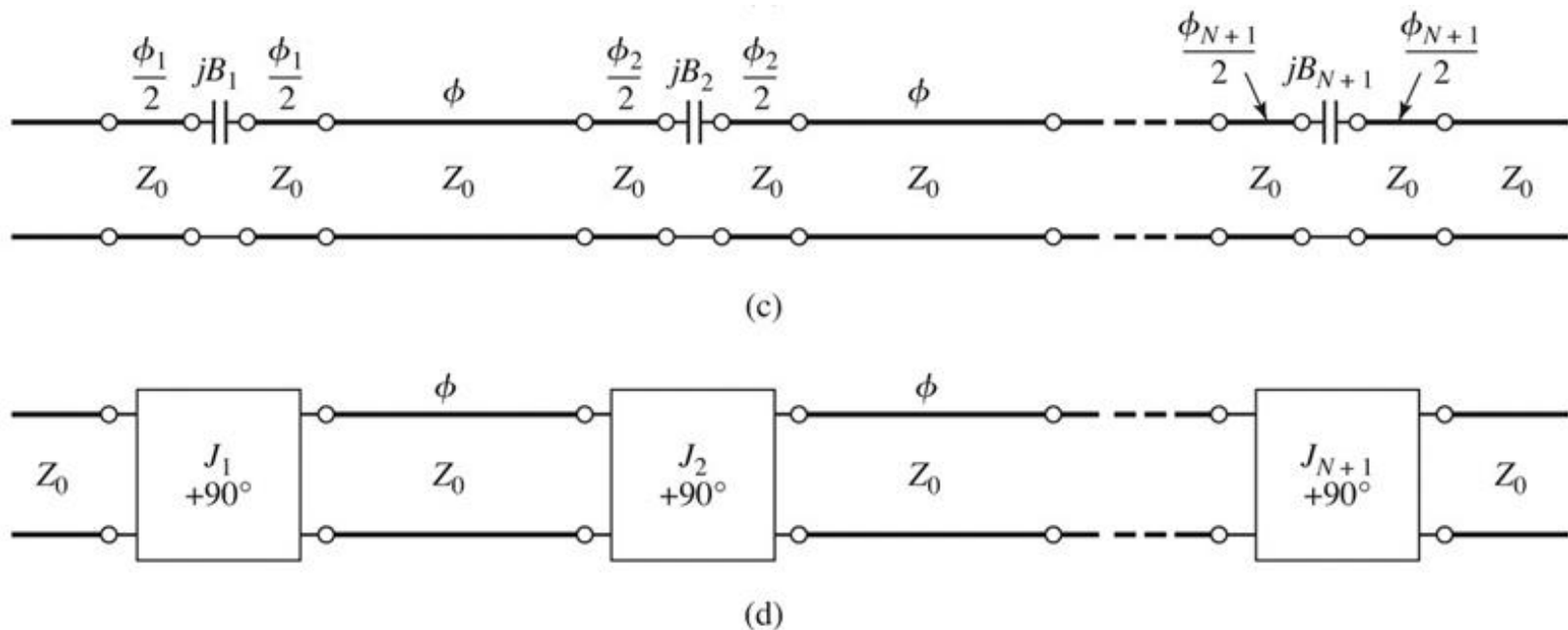


Figure 8.50



# Proiectare filtru cu rezonatoare serie cuplate capacitiv

- Se calculeaza inversoarele (similar linii cuplate)

$$Z_0 \cdot J_1 = \sqrt{\frac{\pi \cdot \Delta}{2 \cdot g_1}} \quad Z_0 \cdot J_n = \frac{\pi \cdot \Delta}{2 \cdot \sqrt{g_{n-1} \cdot g_n}}, n = \overline{2, N} \quad Z_0 \cdot J_{N+1} = \sqrt{\frac{\pi \cdot \Delta}{2 \cdot g_N \cdot g_{N+1}}}$$

- Se calculeaza susceptantele cuplajului

$$B_n = \frac{J_n}{1 - (Z_0 \cdot J_n)^2}, n = \overline{1, N+1}$$

- Se calculeaza lungimile de linii care trebuie “imprumutate” pentru realizarea inversoarelor

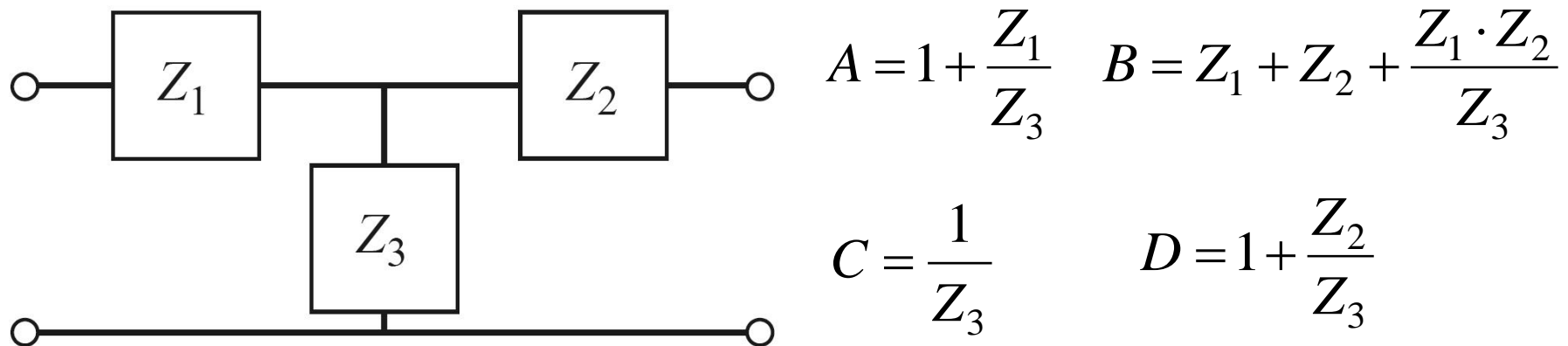
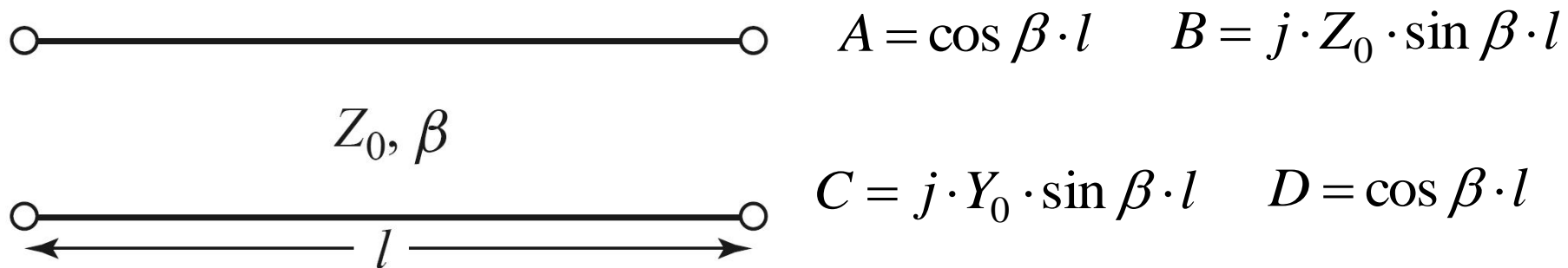
$$\phi_n = -\tan^{-1}(2 \cdot Z_0 \cdot B_n), n = \overline{1, N+1} \quad \phi_n < 0, n = \overline{1, N+1}$$

- Se calculeaza lungimile electrice ale liniilor

$$\theta_i = \pi + \frac{1}{2} \cdot (\phi_i + \phi_{i+1}) = \pi - \frac{1}{2} \cdot [\tan^{-1}(2 \cdot Z_0 \cdot B_i) + \tan^{-1}(2 \cdot Z_0 \cdot B_{i+1})], i = \overline{1, N}$$

# Circuite echivalente pentru sectiuni scurte de linii

- Parametri ABCD ( $C_4$ )
- linie scurta, model cu elemente concentrate valid



# Circuite echivalente pentru sectiuni scurte de linii

- Element paralel capacitiv

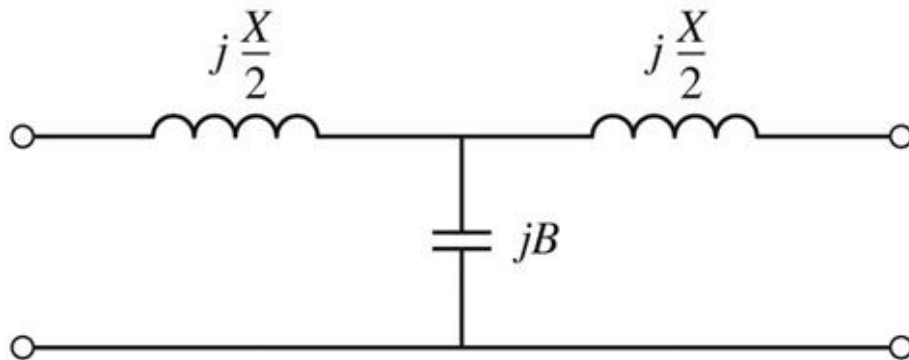
$$Z_3 = \frac{1}{j \cdot Y_0 \cdot \sin \beta \cdot l}$$

- Elementele in serie egale, inductive

$$\cos \beta \cdot l = 1 + \frac{Z_1}{Z_3} = 1 + \frac{Z_2}{Z_3}$$

$$Z_1 = Z_2 = Z_3 \cdot (\cos \beta \cdot l - 1) = -j \cdot Z_0 \cdot \frac{\cos \beta \cdot l - 1}{\sin \beta \cdot l} = j \cdot Z_0 \cdot \tan \frac{\beta \cdot l}{2}$$

- Schema echivalenta

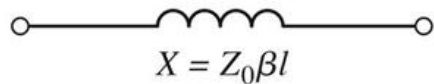


$$\frac{X}{2} = Z_0 \cdot \tan \frac{\beta \cdot l}{2}$$
$$B = \frac{1}{Z_0} \cdot \sin \beta \cdot l$$

# Circuite echivalente pentru sectiuni scurte de linii

- In functie de valoarea impedantei caracteristice

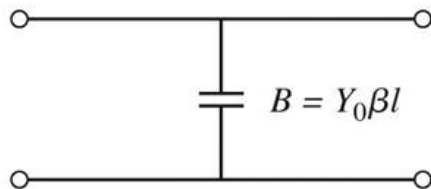
- impedanta ridicata  $Z_0 \gg$



$$X \cong Z_0 \cdot \beta \cdot l \quad \beta \cdot l < \frac{\pi}{4} \quad Z_0 = Z_h$$



- impedanta scazuta  $Z_0 \ll$



$$B \cong Y_0 \cdot \beta \cdot l \quad \beta \cdot l < \frac{\pi}{4} \quad Z_0 = Z_l$$

# Filtre cu variatii treapta a impedantei

- Se pot crea filtre trece jos
- Se utilizeaza
  - linii cu impedanta caracteristica mare pentru a implementa o inductanta

$$\beta \cdot l = \frac{L \cdot R_0}{Z_h}$$

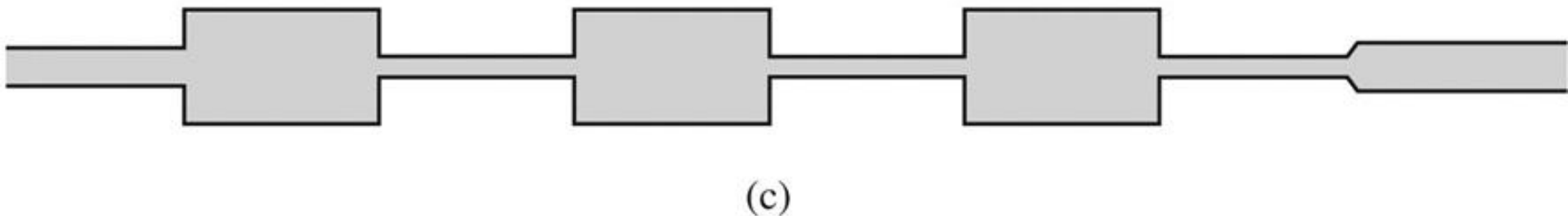
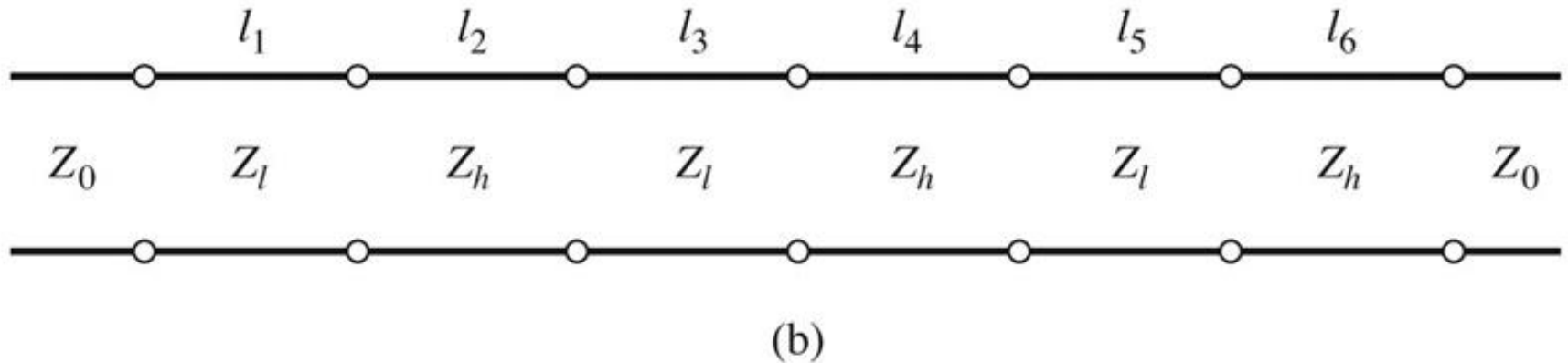
- linii cu impedanta caracteristica mica pentru a implementa o capacitate

$$\beta \cdot l = \frac{C \cdot Z_l}{R_0}$$

- De obicei se utilizeaza cea mai mare si cea mai mica impedanta permisa de tehnologie

# Filtre cu variatii treapta a impedantei

- Nu toate liniile au aceeași lungime deci problema periodicității în frecvență a răspunsului este mai puțin importantă

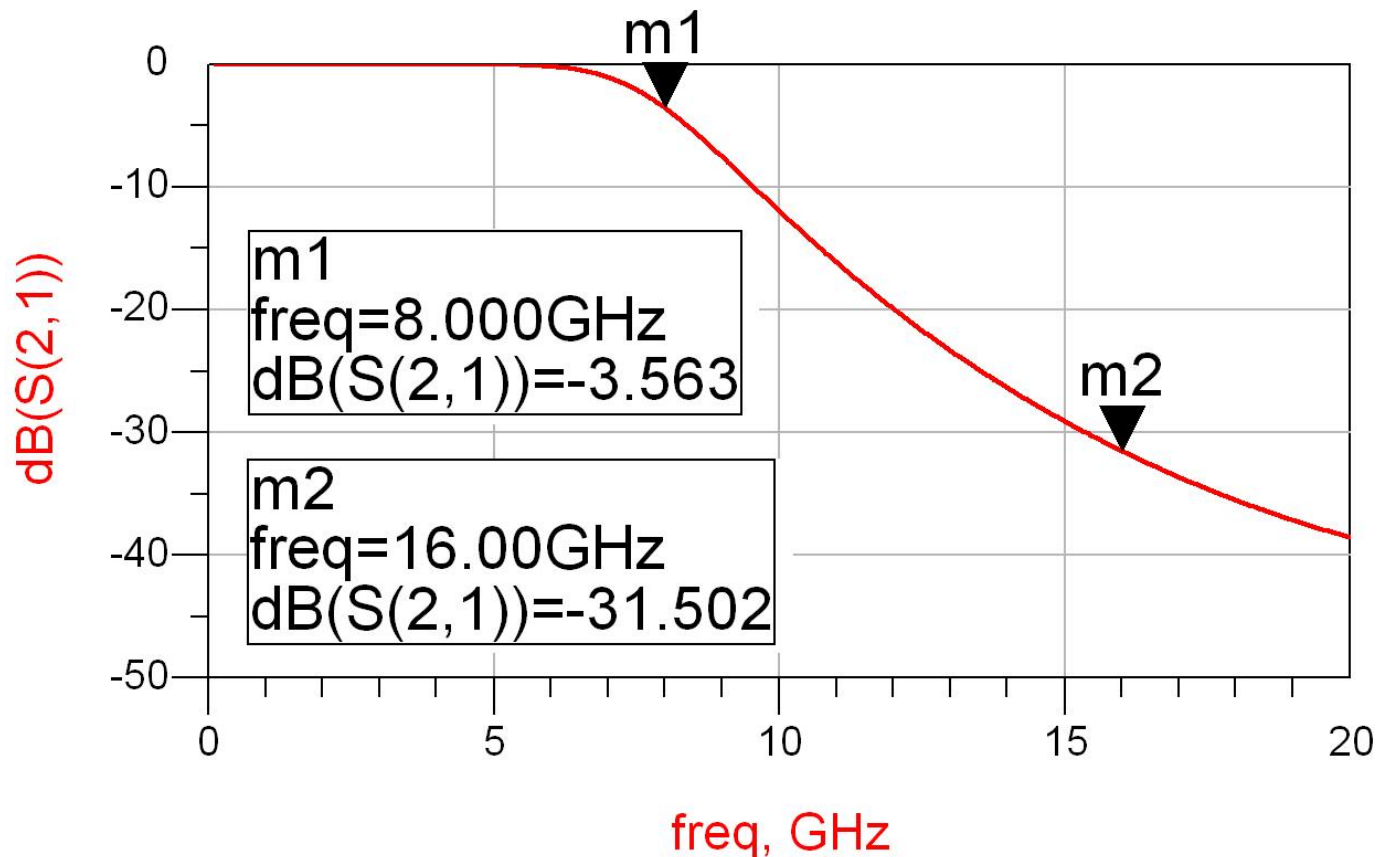
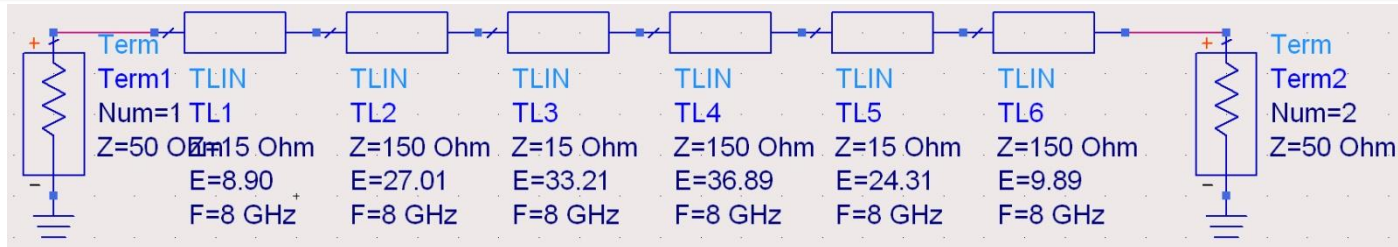


# Exemplu

- FTJ cu frecventa de taiere 8GHz, de ordinul 6. Impedanta maxima realizabila este  $150\Omega$  iar cea minima  $15\Omega$ .

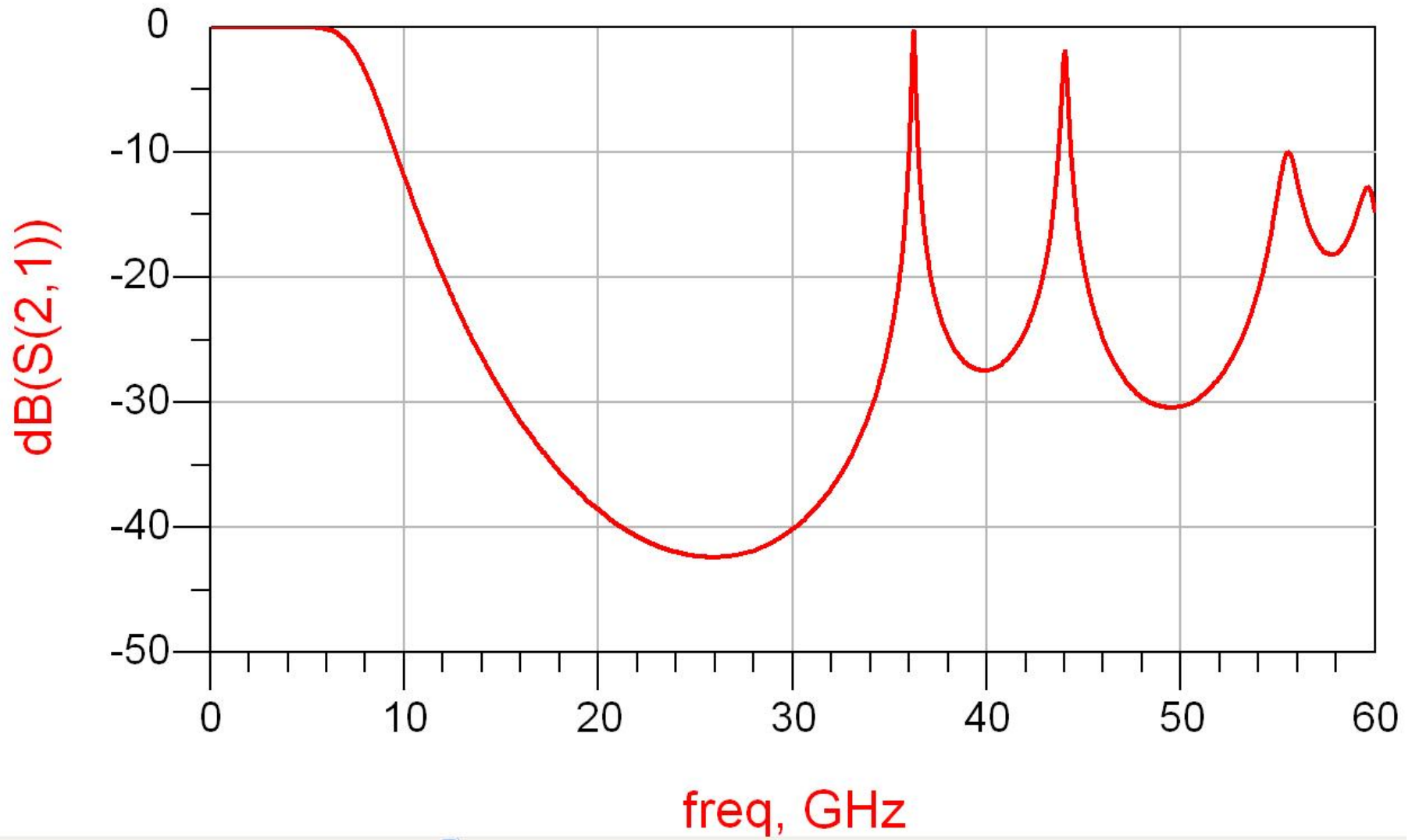
n	$g_n$	$L/C_n$	Z	$\theta_n[\text{rad}]$	$\theta_n[^\circ]$
1	0.5176	0.206pF	15	0.155	8.90
2	1.4142	1.407nH	150	0.471	27.01
3	1.9318	0.769pF	15	0.580	33.21
4	1.9318	1.922nH	150	0.644	36.89
5	1.4142	0.563pF	15	0.424	24.31
6	0.5176	0.515nH	150	0.173	9.89

# ADS – FTJ stepped impedance

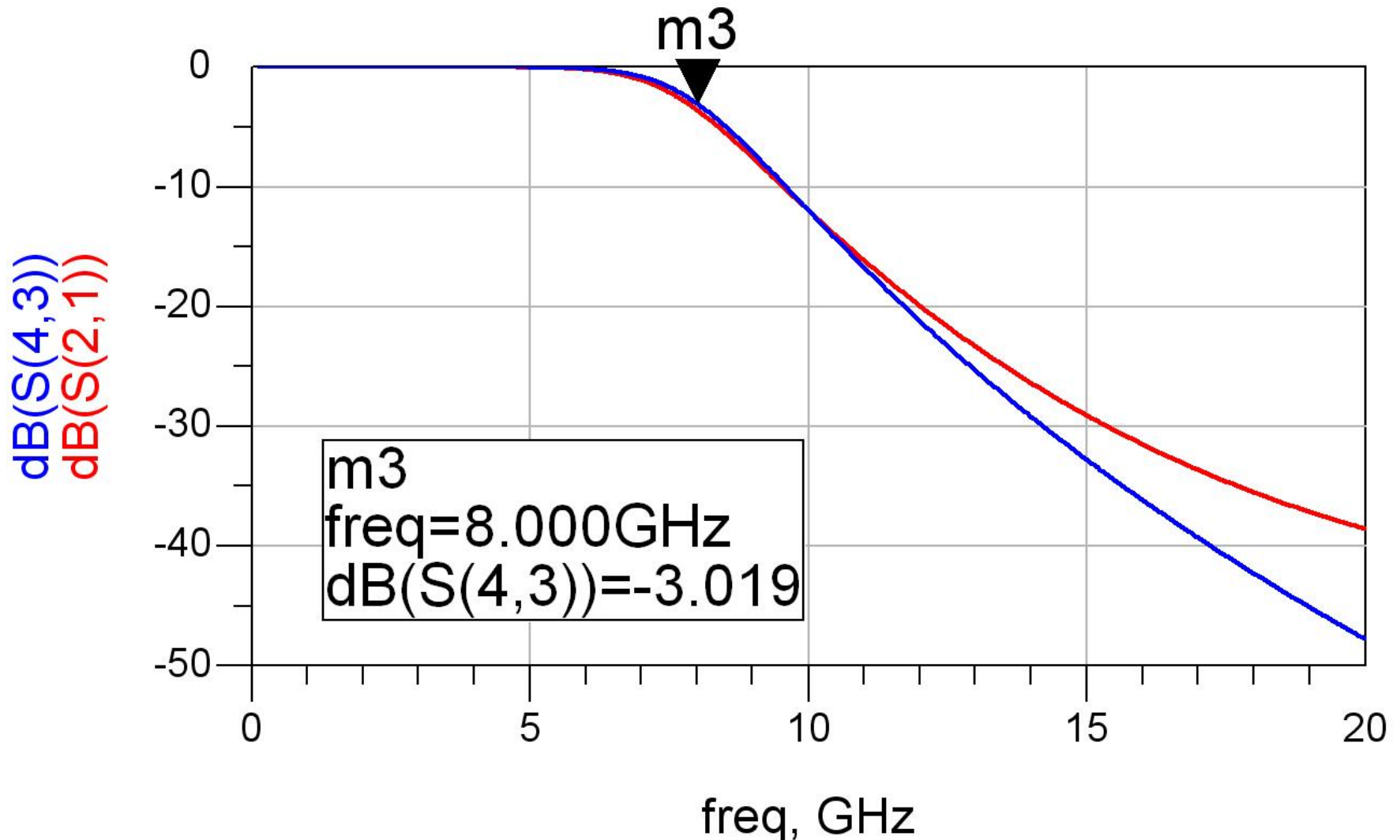




# ADS – FTJ stepped impedance



# ADS – FTJ comparatie cu elemente concentrate



# Example

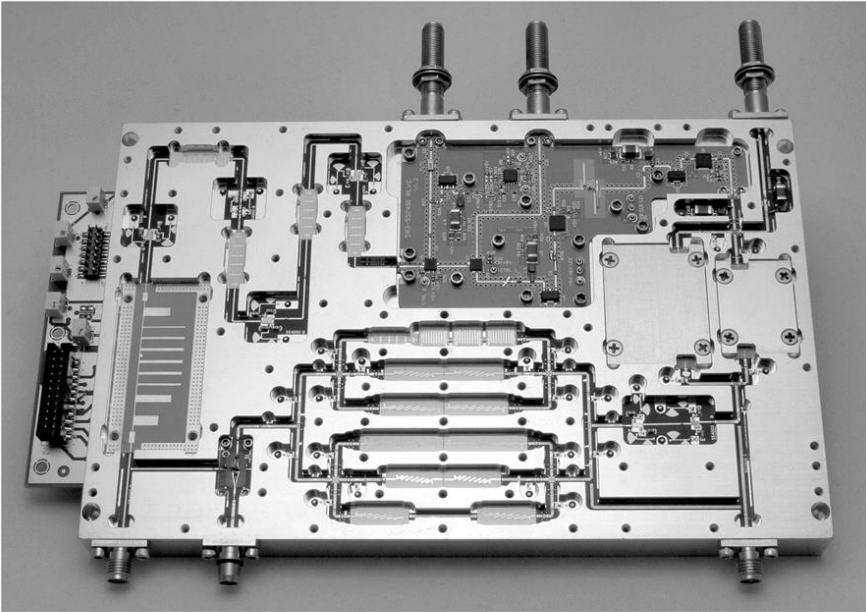
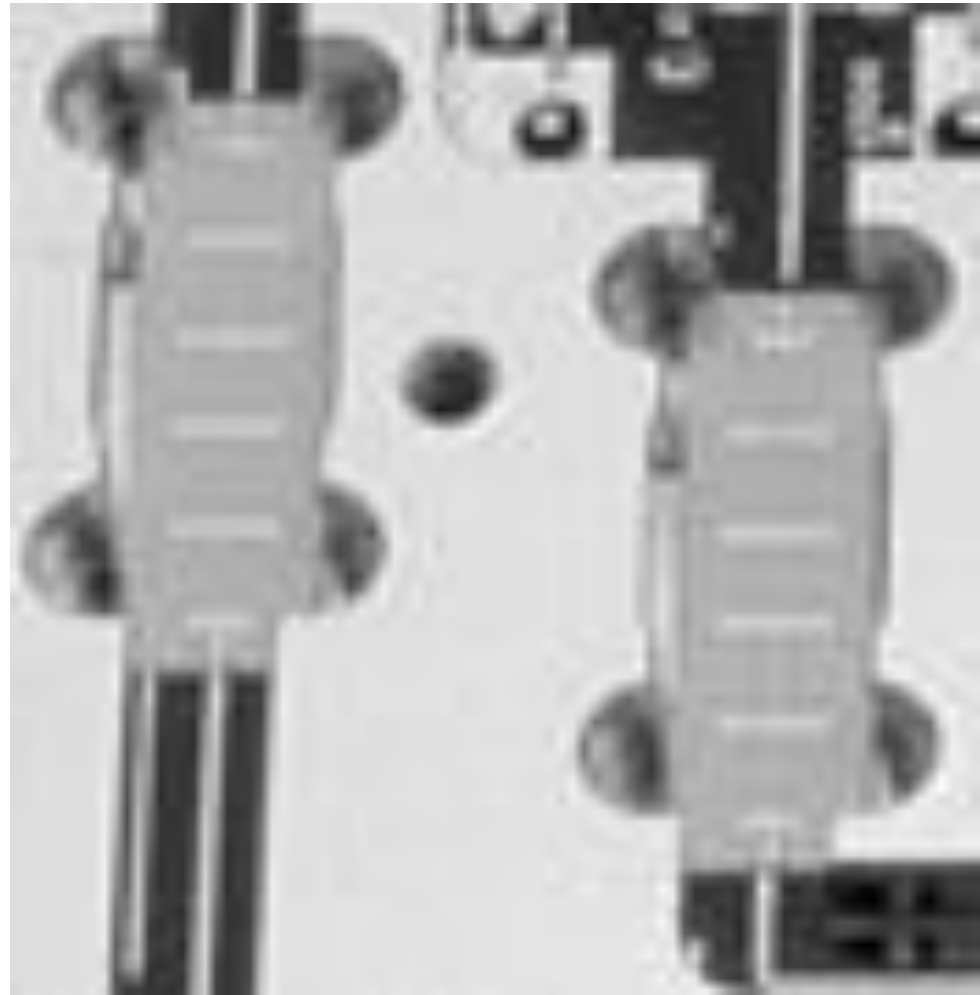


Figure 8.55  
Courtesy of LNX Corporation, Salem, N.H.



# Supliment Mini Proiect

# Implementare cu linii microstrip

- linii microstrip
  - strat dielectric
  - metalizare totala (plan de masa)
  - trasee care fixeaza
    - impedanta caracteristica
    - lungime fizica/electrica

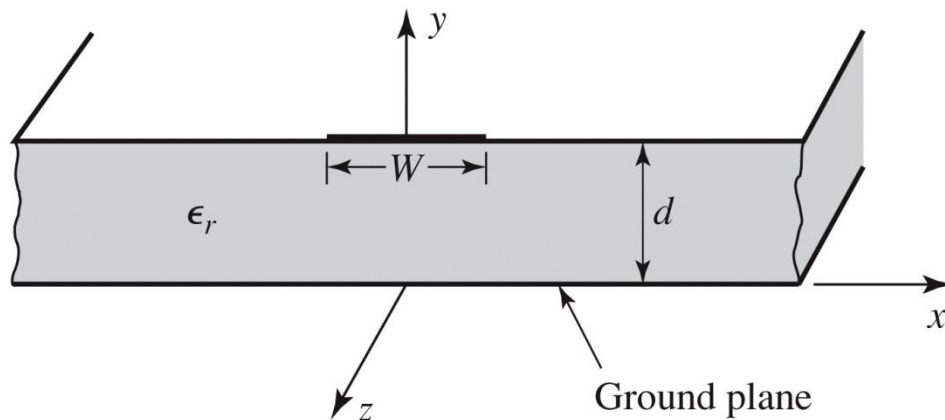


Figure 3.25a  
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# Implementare cu linii microstrip

- Linie quasi TEM

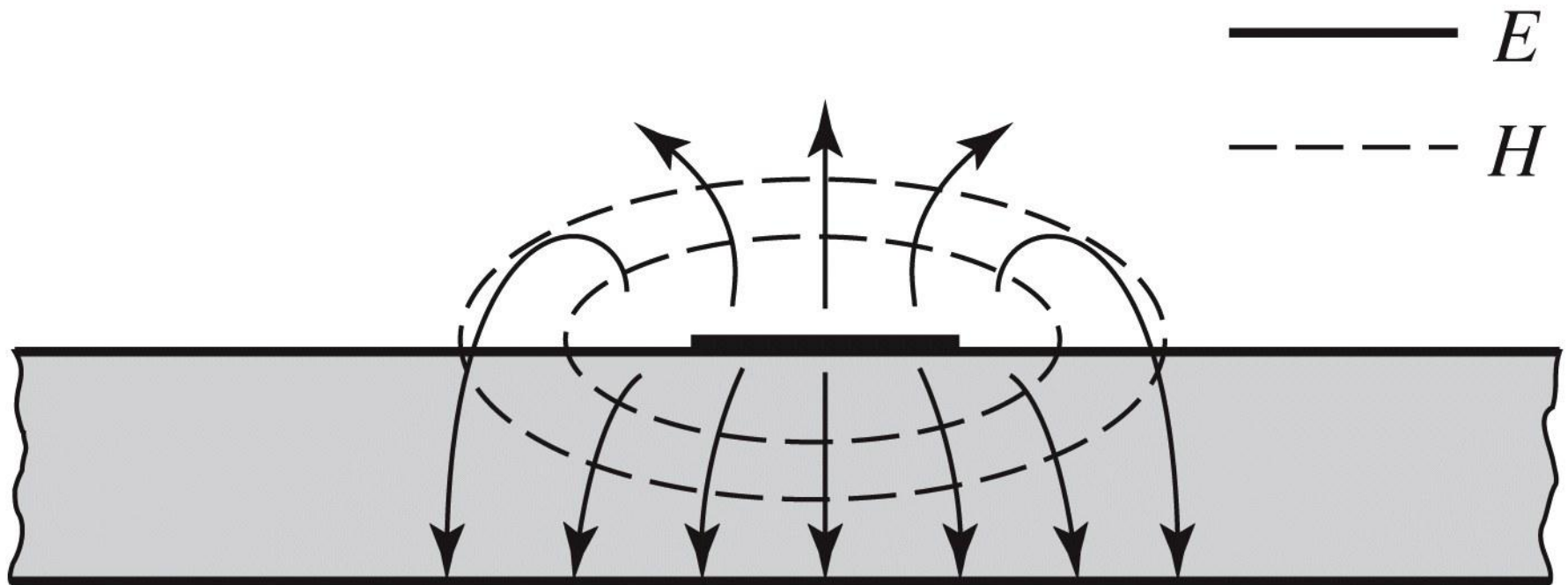
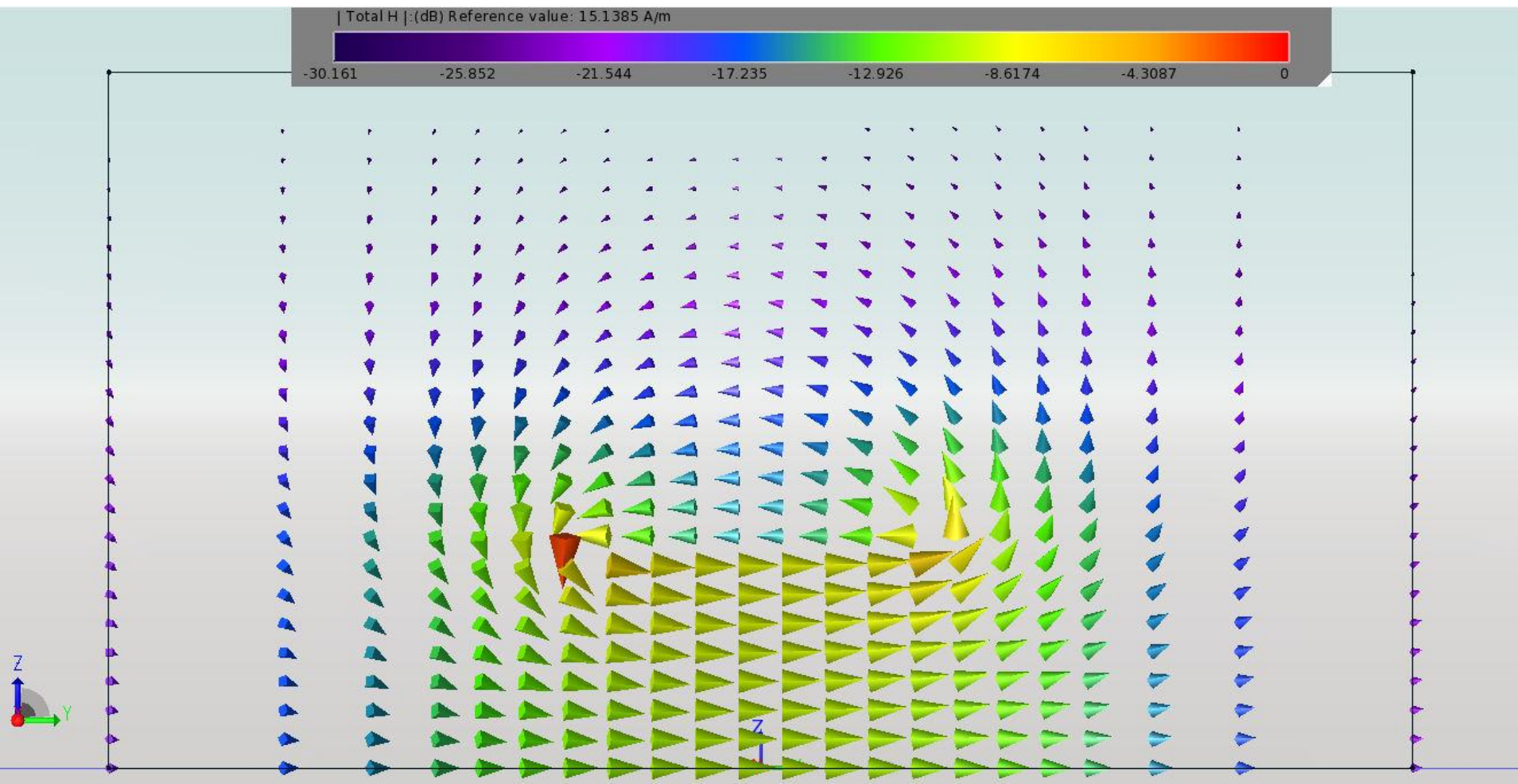


Figure 3.25b

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# Implementare cu linii microstrip

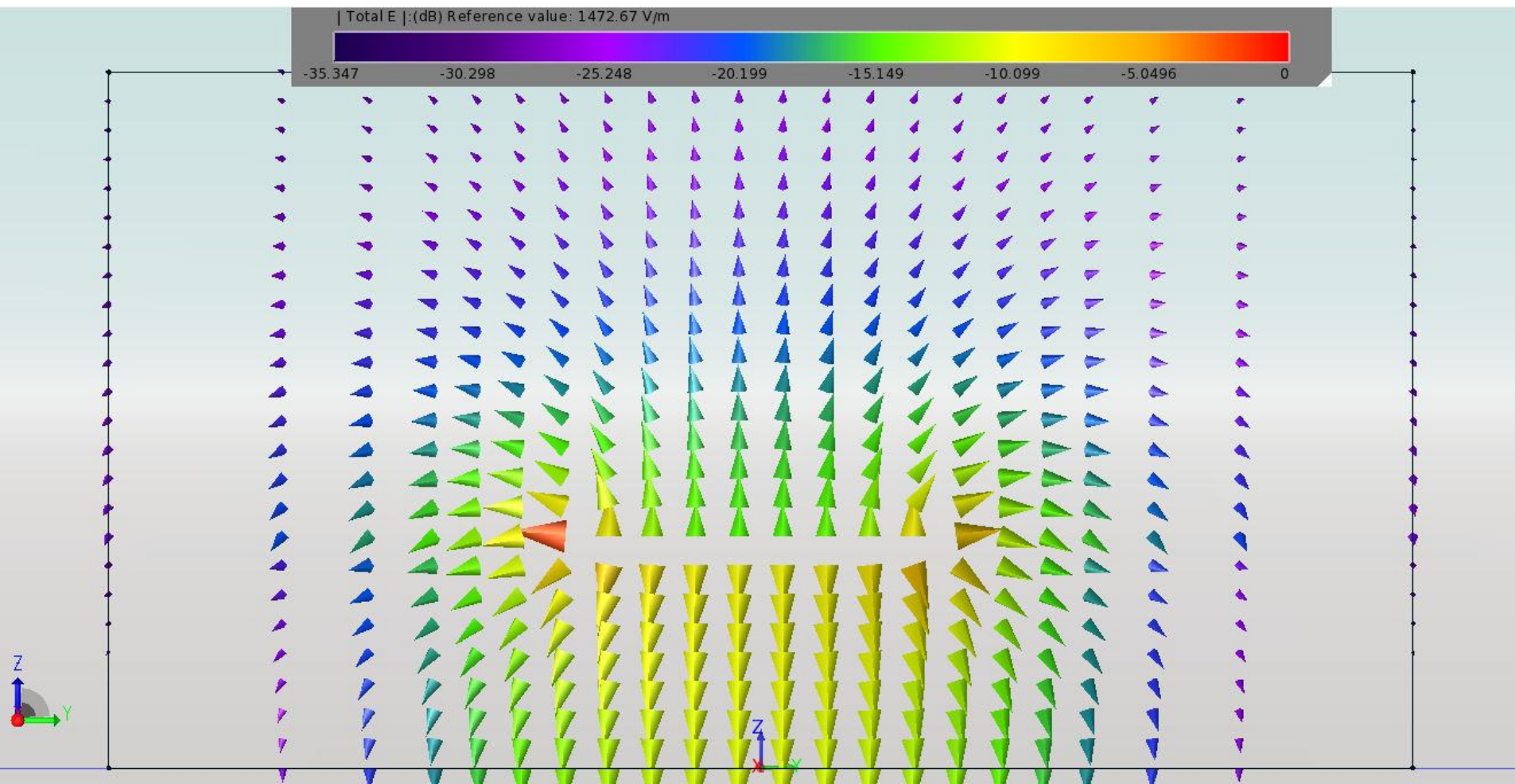
- Linie quasi TEM, EmPro





# Implementare cu linii microstrip

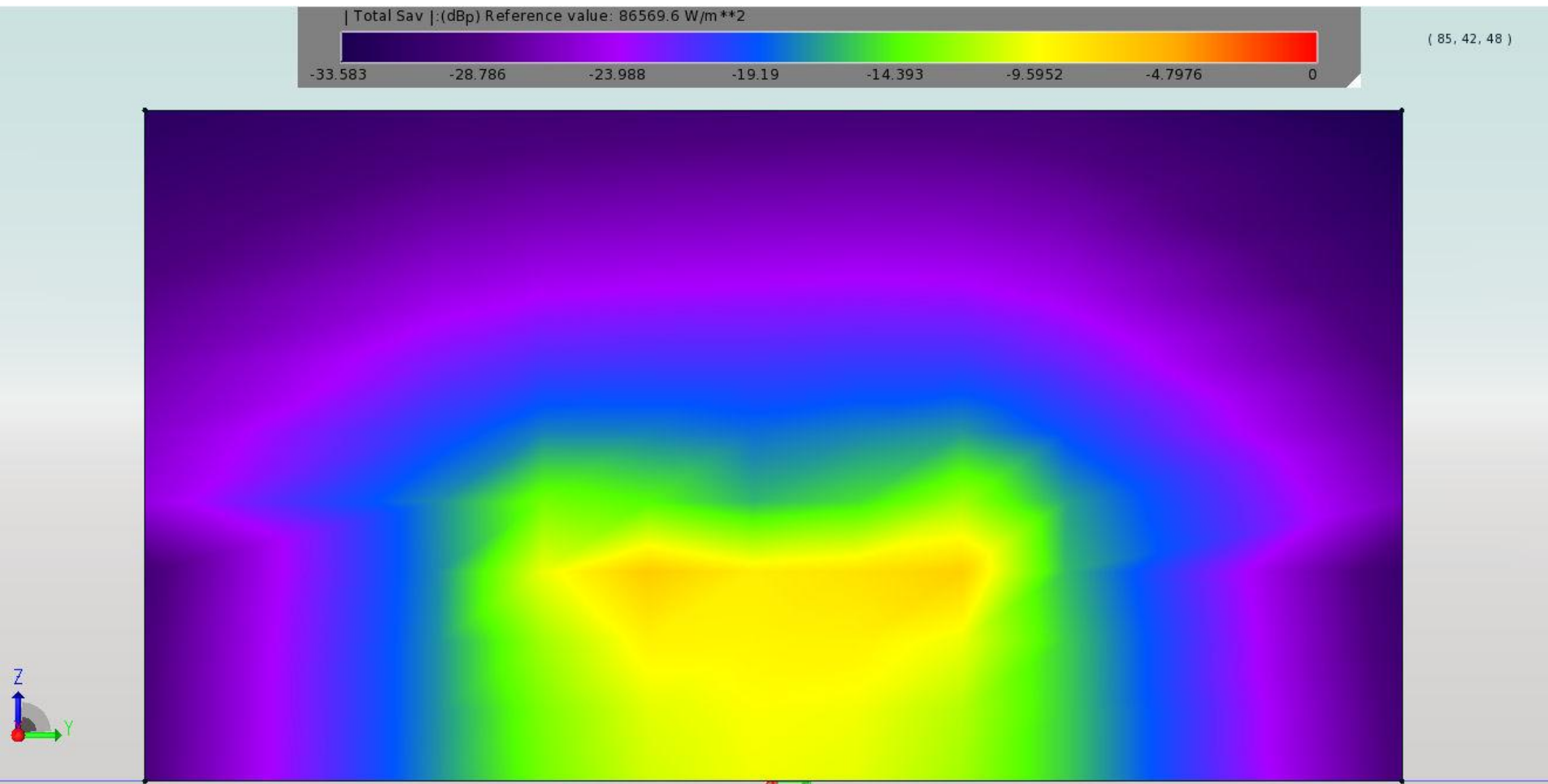
- Linie quasi TEM, EmPro





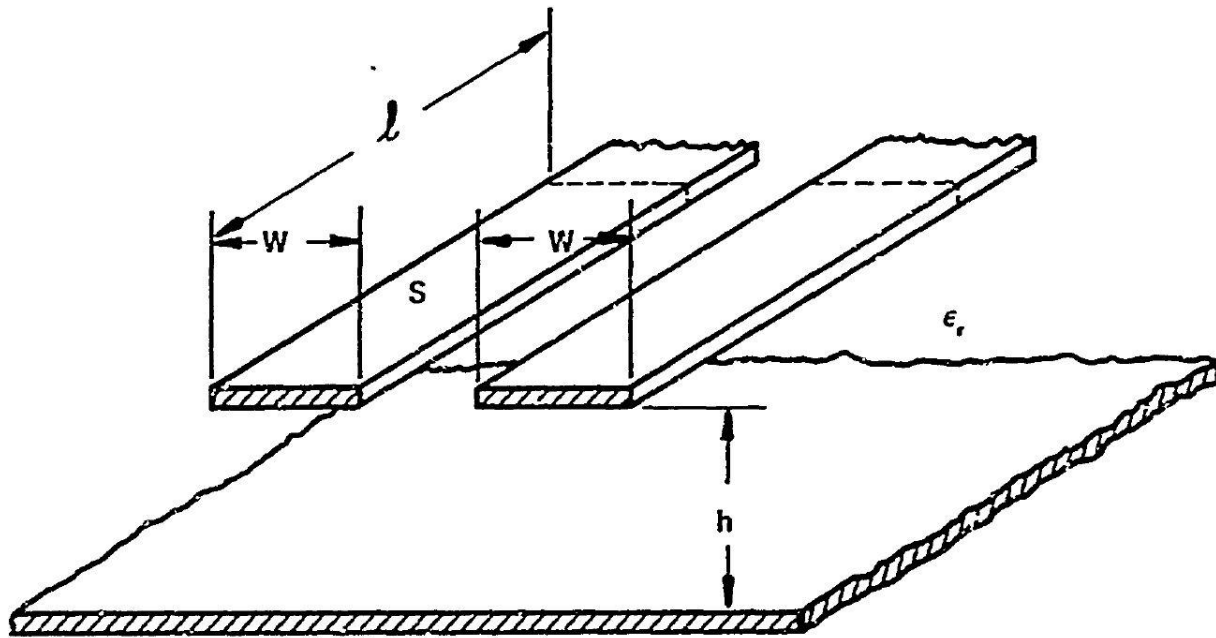
# Implementare cu linii microstrip

- Linie quasi TEM, EmPro



# Implementare cu linii microstrip

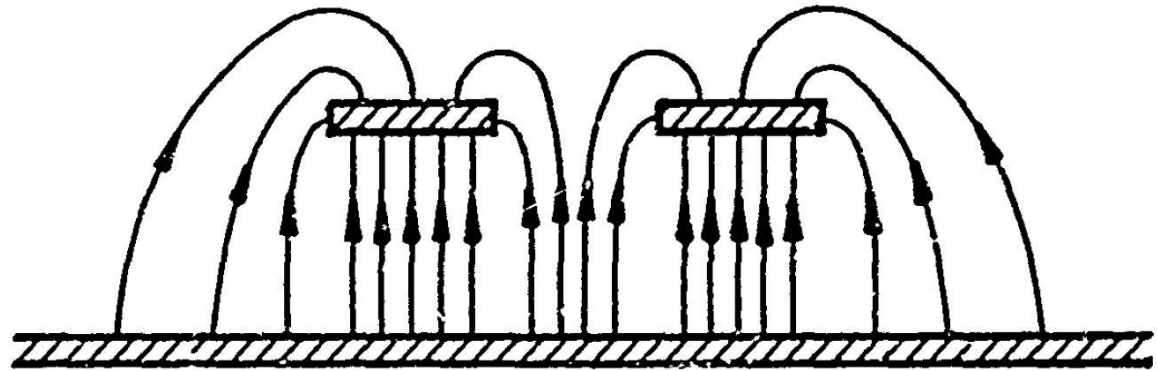
- ~ Aproximativ TEM



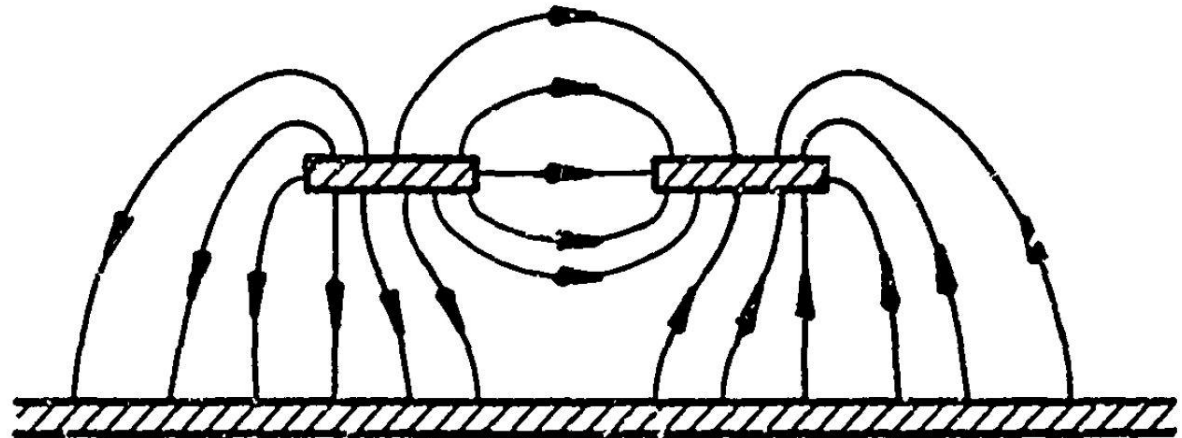
a) COUPLED STRIP GEOMETRY

# Implementare cu linii microstrip

- ~ Aproximativ TEM



b) EVEN MODE ELECTRIC FIELD PATTERN (SCHEMATIC)



c) ODD MODE ELECTRIC FIELD PATTERN (SCHEMATIC)

# Implementare cu linii microstrip

- Se echivaleaza linia cu o linie cu dielectric omogen echivalent

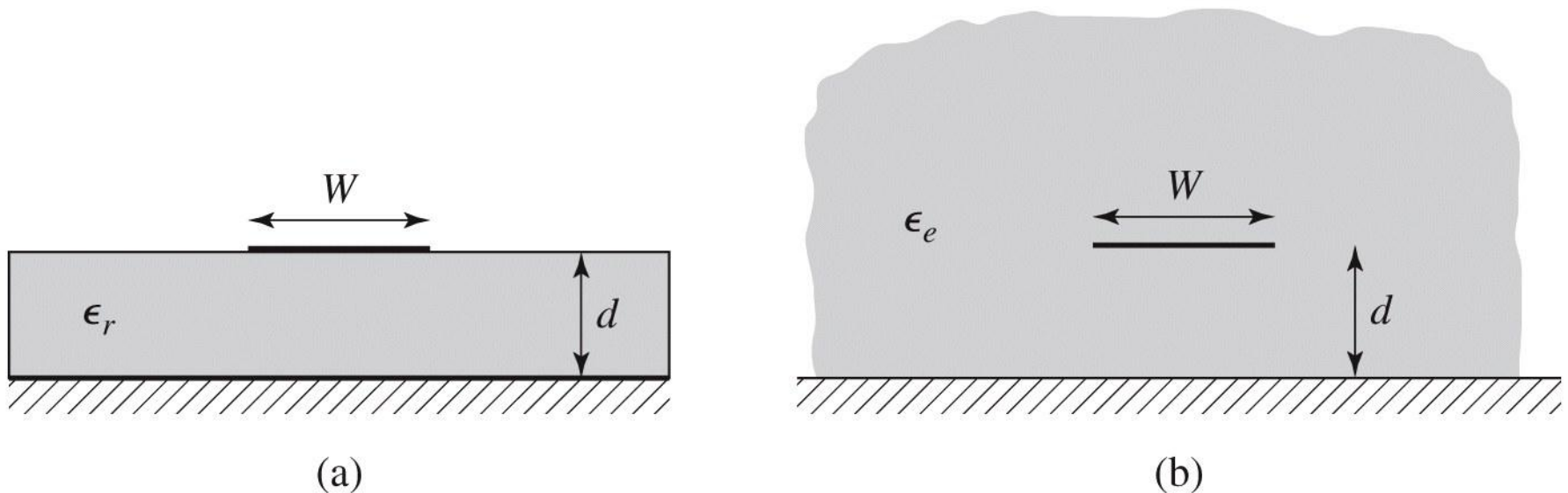


Figure 3.26  
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# Calcul

## ■ Calcul empiric

$$v_p = \frac{c}{\sqrt{\epsilon_e}},$$

$$\beta = k_0 \sqrt{\epsilon_e},$$

$$\epsilon_e = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \frac{1}{\sqrt{1 + 12d/W}}.$$

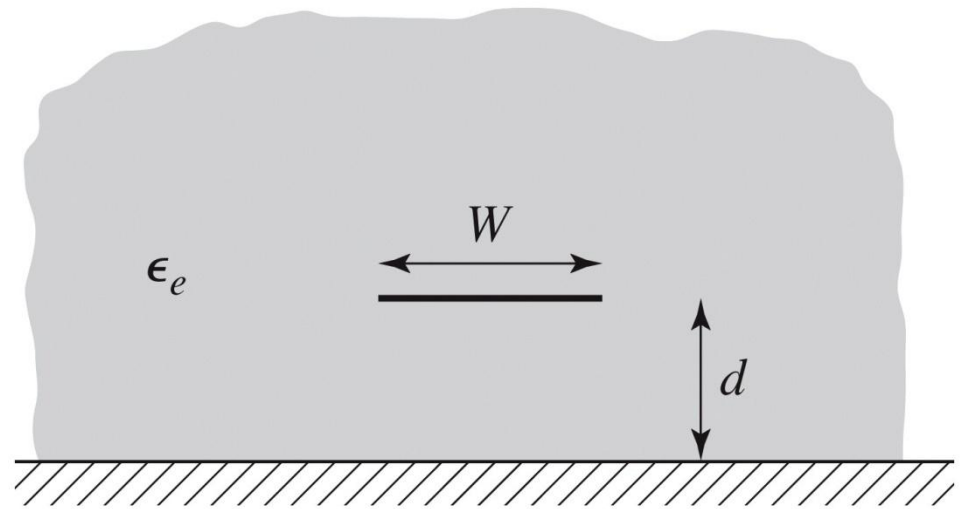


Figure 3.26b  
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$$Z_0 = \begin{cases} \frac{60}{\sqrt{\epsilon_e}} \ln \left( \frac{8d}{W} + \frac{W}{4d} \right) & \text{for } W/d \leq 1 \\ \frac{120\pi}{\sqrt{\epsilon_e} [W/d + 1.393 + 0.667 \ln (W/d + 1.444)]} & \text{for } W/d \geq 1. \end{cases}$$

# Calcul

## ■ Calcul empiric

$$A = \frac{Z_0}{60} \sqrt{\frac{\epsilon_r + 1}{2}} + \frac{\epsilon_r - 1}{\epsilon_r + 1} \left( 0.23 + \frac{0.11}{\epsilon_r} \right)$$

$$B = \frac{377\pi}{2Z_0\sqrt{\epsilon_r}}$$

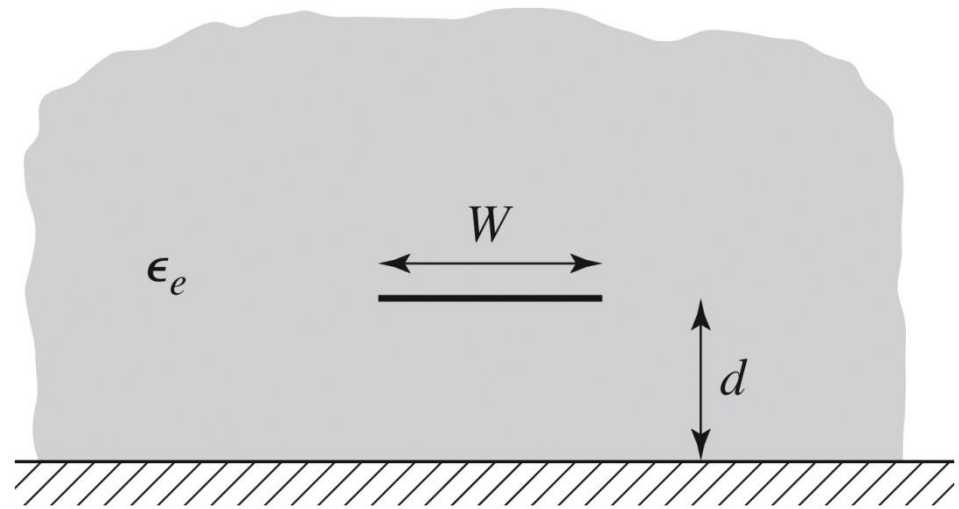
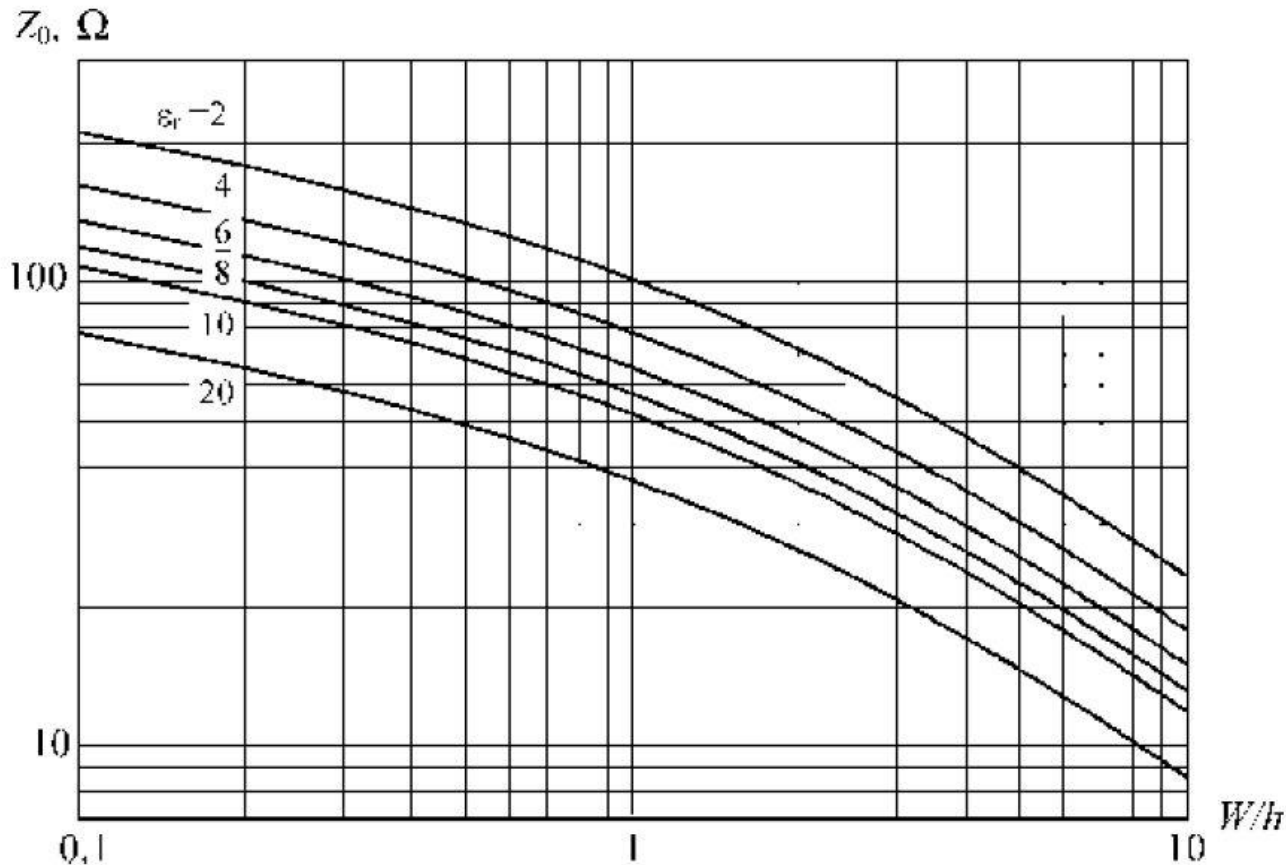


Figure 3.26b  
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$$\frac{W}{d} = \begin{cases} \frac{8e^A}{e^{2A} - 2} & \text{for } W/d < 2 \\ \frac{2}{\pi} \left[ B - 1 - \ln(2B - 1) + \frac{\epsilon_r - 1}{2\epsilon_r} \left\{ \ln(B - 1) + 0.39 - \frac{0.61}{\epsilon_r} \right\} \right] & \text{for } W/d > 2, \end{cases}$$

# Impedanta caracteristica

- Pentru **impedante mari** e nevoie de **latimi mici** ale traseelor
- Pentru **impedante mici** e nevoie de **latimi mari** ale traseelor



$$k_0 = \frac{2\pi f}{c}$$
$$\beta \ell = \sqrt{\epsilon_e} k_0 \ell,$$

# Microstrip standardizare

- Standardizare
  - dimensiuni in **mil**
  - 1 mil =  $10^{-3}$  inch
  - 1 inch = 2.54 cm
- Inaltimea conductoarelor
  - in functie de greutatea cuprului
  - uncii / picioare pătrate (oz/ft<sup>2</sup>)
  - 10z=28.35g și 1ft=30.48cm

Greutatea cuprului depus		Grosimea stratului	
oz/ft <sup>2</sup>	g/ft <sup>2</sup>	inch	mm
0.5	14.175	0.0007	0.0178
1.0	28.35	0.0014	0.0356
2.0	56.7	0.0028	0.0712



# Microstrip standardizare

- Tipic inaltimea straturilor de dielectric de asemenea standardizat in mil

Standard Thickness
<b>RO4003C:</b> 0.008" (0.203mm), 0.012 (0.305mm), 0.016" (0.406mm), 0.020" (0.508mm) 0.032" (0.813mm), 0.060" (1.524mm) <b>RO4350B:</b> *0.004" (0.101mm), 0.0066" (0.168mm) 0.010" (0.254mm), 0.0133 (0.338mm), 0.0166 (0.422mm), 0.020" (0.508mm) 0.030" (0.762mm), 0.060" (1.524mm)

# Microstrip, materiale substrat

	Constanta dielectrică relativă	Factorul de pierderi dielectrice	Conductivitate termică	Coeficient liniar de expansiune	Coeficient de temperatură a lui $\epsilon_r$
Material	-	-	W/cm/K	ppm/K	ppm/K
Al <sub>2</sub> O <sub>3</sub> (99.5%)	9.8	0.0001	0.37	6.3	+136
Al <sub>2</sub> O <sub>3</sub> (96%)	9.4	0.001	0.35	6.4	-
Safir	9.4;11.6	0.0001	0.42	6.0	+110-+140
Sticlă cuarț	3.78	0.0001	0.017	0.55	+13
Sticlă Corning 7059	5.75	0.0036	0.012	4.6	-
BeO Ceramic (98%)	6.3	0.006	2.1	6.1	+107
TiO <sub>2</sub>	85	0.004	0.05	7.5	-575
Tetratitanat de Ba (BaTi <sub>4</sub> O <sub>9</sub> )	37	0.0005	0.02	9.4	-26
Zirconat	20-40	0.002	-	5.0	-130-+100
GaAs	12.9	0.002	0.46	5.7	-
Si	11.9	0.015	1.45	4.2	-
Ferită	9-16	0.001	-	-	-

# ADS linecalc

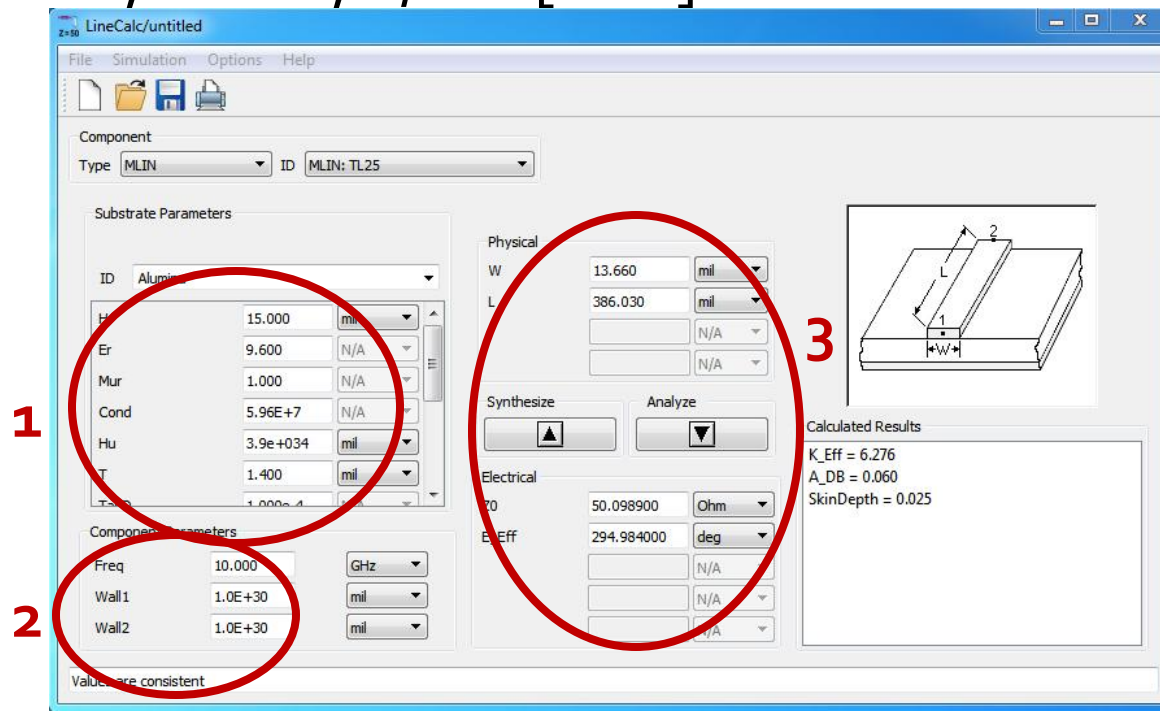
- In scheme:
  - >Tools>LineCalc>Start
  - Pentru linii Microstrip >Tools>LineCalc>Send to Linecalc

The screenshot shows the ADS LineCalc/untitled window with the following settings:

- Component:** Type: MLIN, ID: MLIN: TL25
- Substrate Parameters:**
  - ID: Alumina
  - H: 15.000 mil
  - Er: 9.600 N/A
  - Mur: 1.000 N/A
  - Cond: 5.96E+7 N/A
  - Hu: 3.9e+034 mil
  - T: 1.400 mil
  - TanD: 1.00e-4 N/A
- Physical:**
  - W: 13.660 mil
  - L: 386.030 mil
- Synthesize:** [Up Arrow]
- Analyze:** [Down Arrow]
- Electrical:**
  - Z0: 50.098900 Ohm
  - E\_Eff: 294.984000 deg
- Component Parameters:**
  - Freq: 10.000 GHz
  - Wall1: 1.0E+30 mil
  - Wall2: 1.0E+30 mil
- Calculated Results:**
  - K\_Eff = 6.276
  - A\_DB = 0.060
  - SkinDepth = 0.025
- Diagram:** A 3D perspective view of a microstrip line on a substrate, with dimensions W (width), L (length), and H (height) indicated.
- Status:** Values are consistent

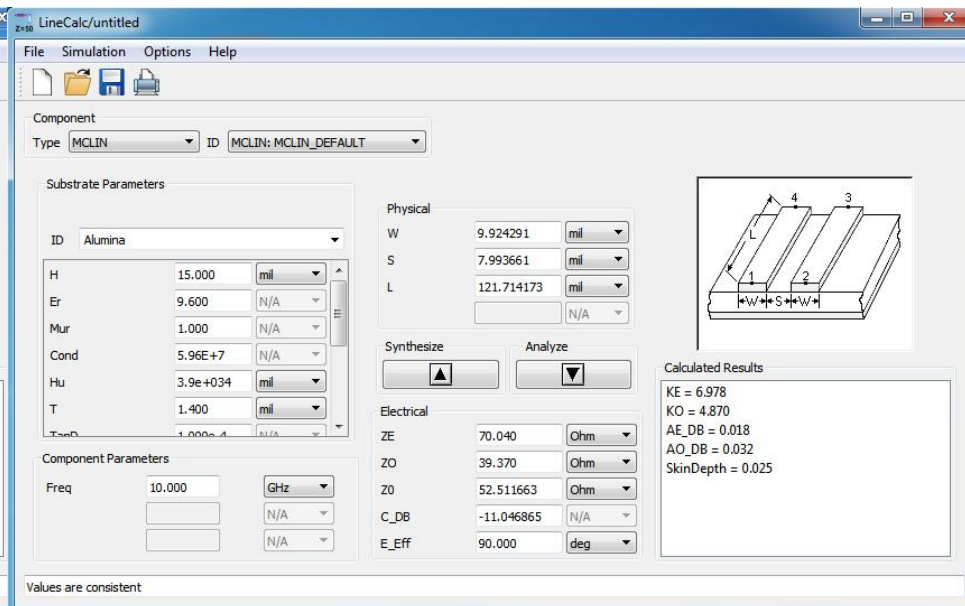
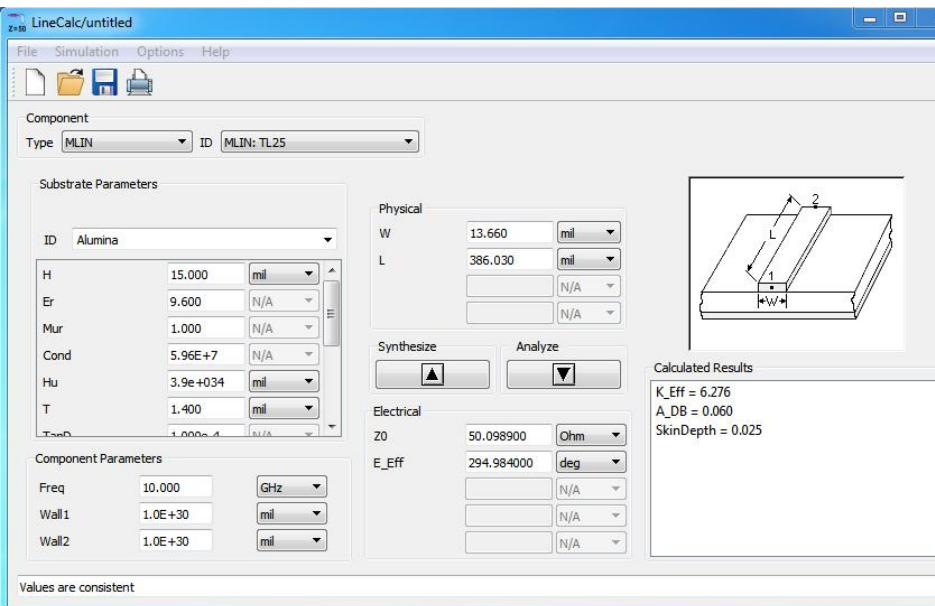
# ADS linecalc

- 1. Definire (receptie din schema) substrat
- 2. Introducere frecventa
- 3. Introducere date de intrare
  - Analiza:  $W, L \rightarrow Z_0, E$  sau  $Z_e, Z_0, E / la f [GHz]$
  - Sinteza:  $Z_0, E \rightarrow W, L / la f [GHz]$



# ADS linecalc

- Se poate utiliza pentru:
  - linii microstrip MLIN:  $W, L \Leftrightarrow Z_0, E$
  - linii cuplate microstrip MCLIN:  $W, L \Leftrightarrow Z_e, Z_0, E$



# ADS linecalc

LineCalc/untitled

File Simulation Options Help

Component  
Type: MCLIN ID: MCLIN: MCLIN\_DEFAULT

Substrate Parameters

ID	Alumina
H	15.000 mil
Er	9.600 N/A
Mur	1.000 N/A
Cond	5.96E+7 N/A
Hu	3.9e+034 mil
T	1.400 mil
TanD	1.000e-4 N/A

Component Parameters

Freq	10.000 GHz
	N/A
	N/A

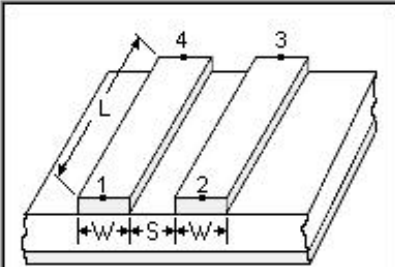
Physical

W	9.924291 mil
S	7.993661 mil
L	121.714173 mil
	N/A

Synthesize Analyze

Electrical

ZE	70.040 Ohm
ZO	39.370 Ohm
Z0	52.511663 Ohm
C_DB	-11.046865 N/A
E_Eff	90.000 deg



Calculated Results

KE = 6.978  
KO = 4.870  
AE\_DB = 0.018  
AO\_DB = 0.032  
SkinDepth = 0.025

Values are consistent

# Linii de transmisie

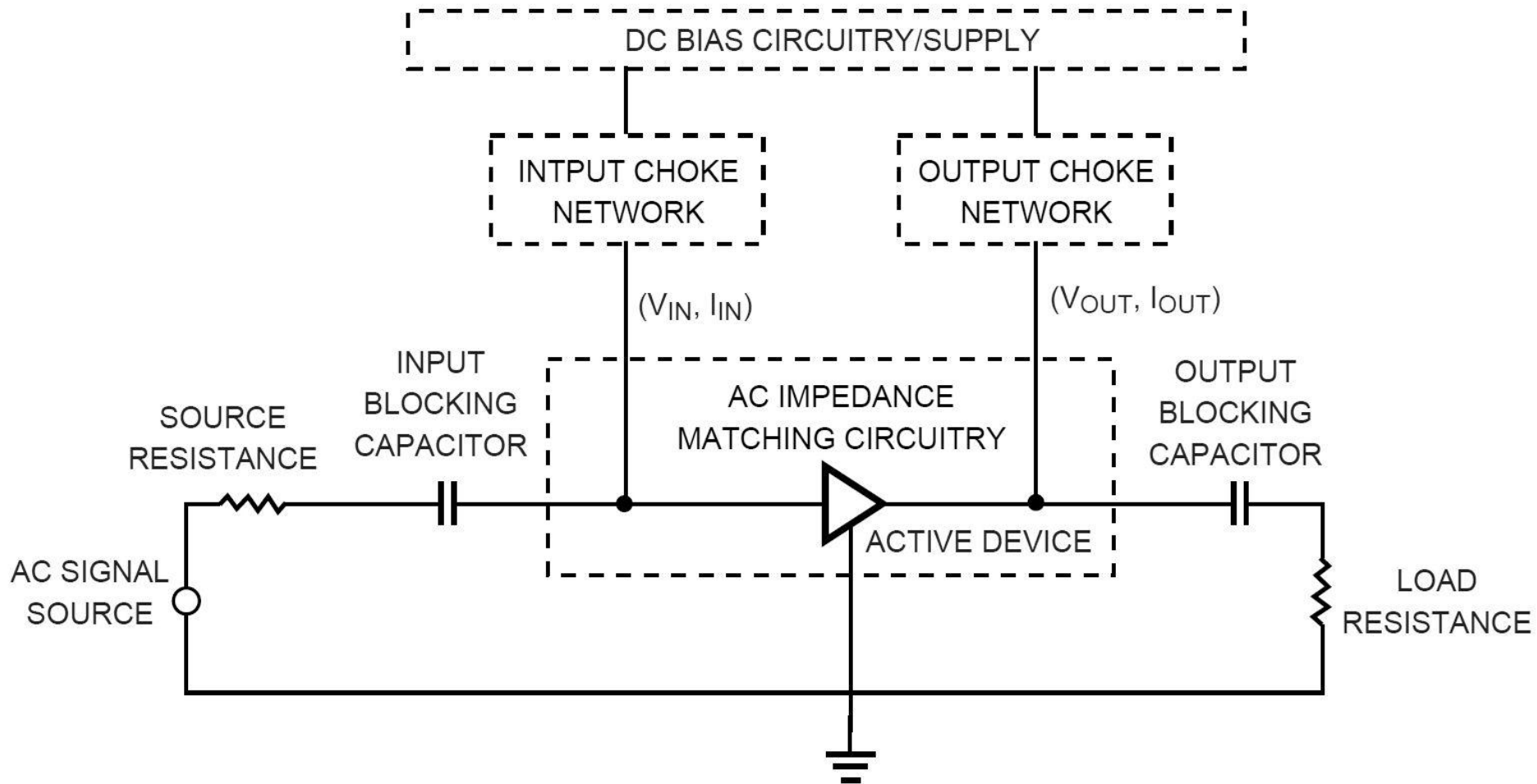
- <http://rf-opto.etti.tuiasi.ro>
- linii de transmisie Rogers
  - relatii dependente de
    - $t$ , inaltimea metalizarilor
    - $f$ , frecventa
  - relatii pentru
    - microstrip
    - strip
    - linii cuplate

# Polarizare

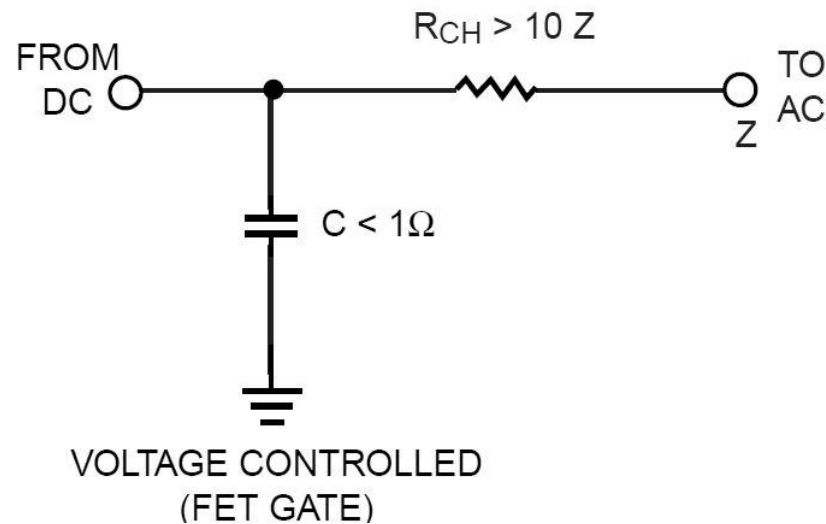
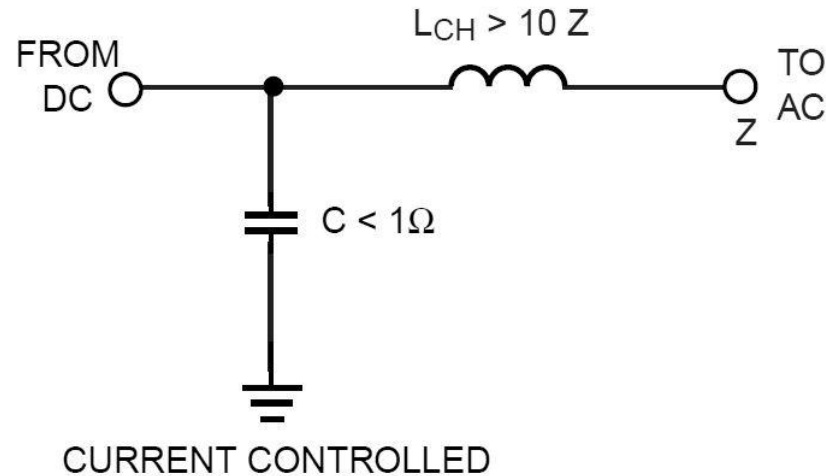
- <http://rf-opto.etti.tuiasi.ro>
- note de aplicatii importante Agilent
  - decuplarea circuit de semnal/circuit de polarizare
  - detalii de implementare a circuitelor de polarizare pentru tranzistoarele cu microunde
- Appcad contine instrumente pentru calculul schemelor de polarizare



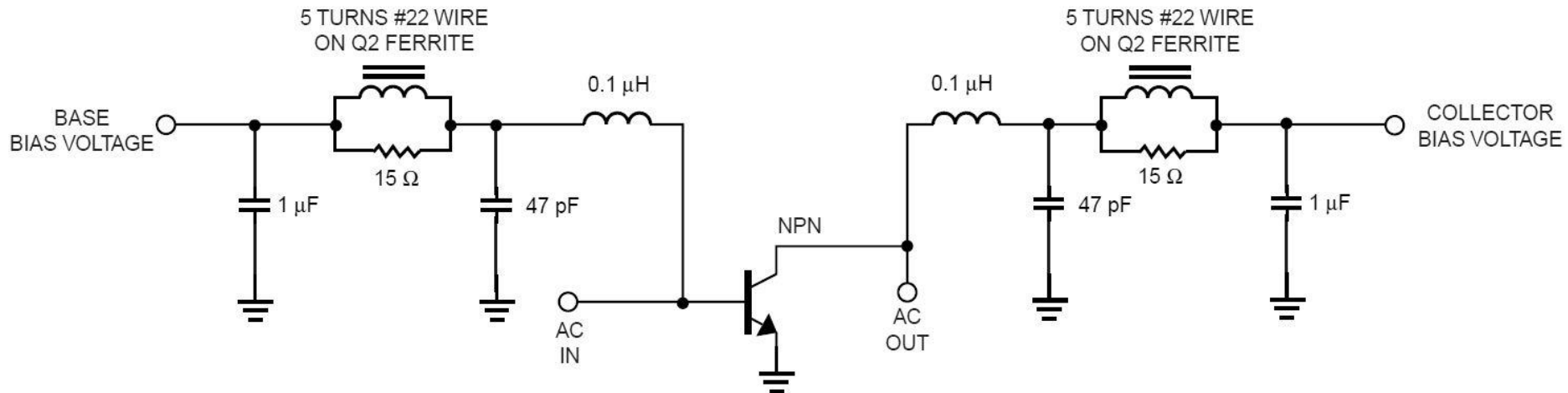
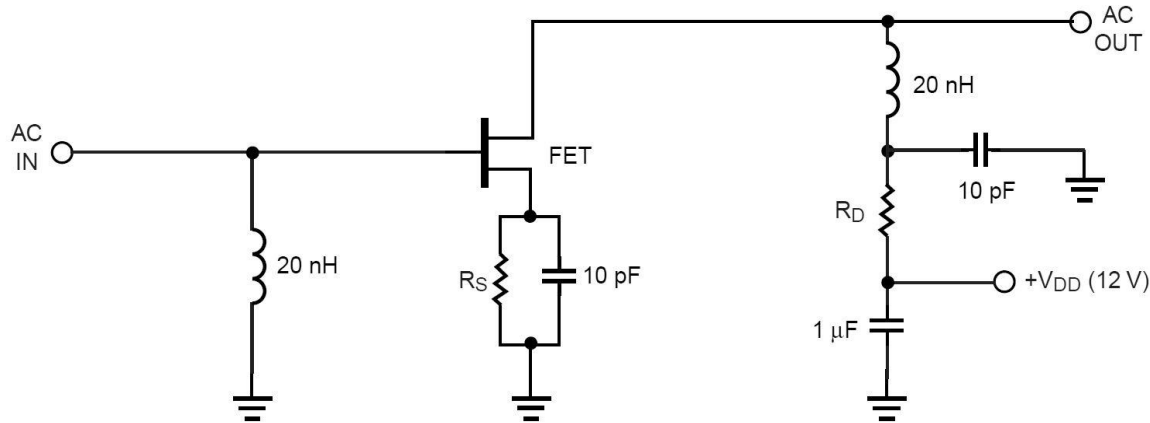
# Polarizare



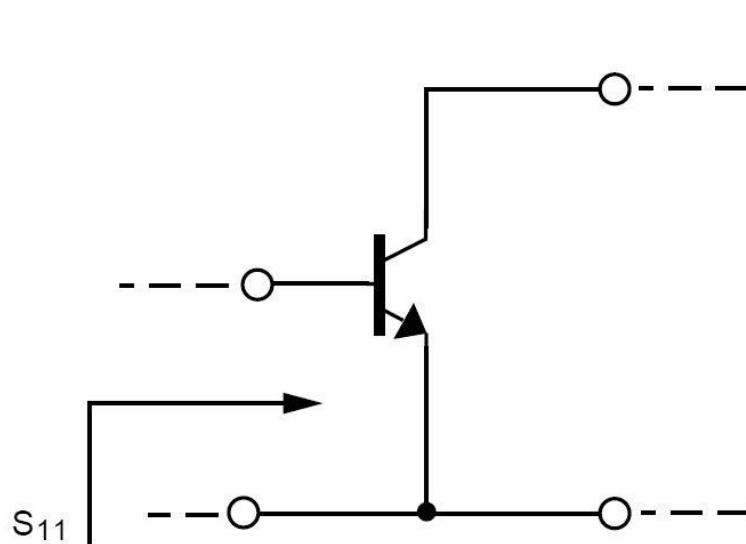
# Polarizare, soc tipic



# Polarizare, scheme/valori tipice

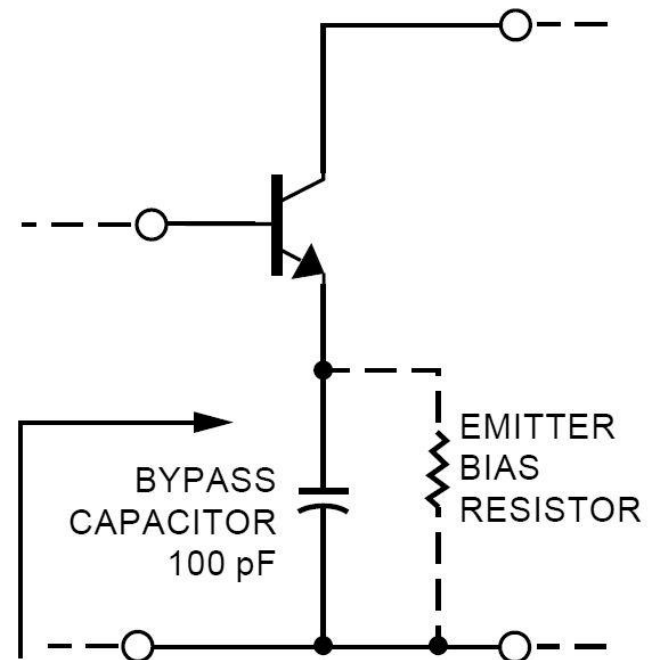


# Polarizare, problema elementelor conectate in E/S



$$S_{11} \text{ (AT 4 GHz)} = 0.52 \angle 154^\circ$$

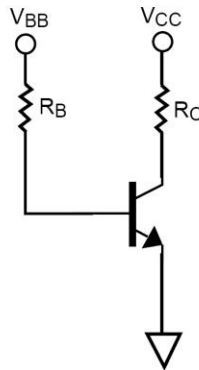
$$S_{11} \text{ (AT 0.1 GHz)} = 0.901 \angle -14.9^\circ$$



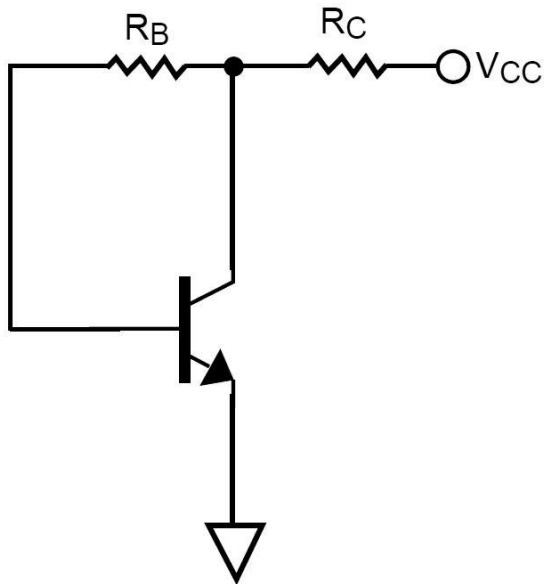
$$S'_{11} \text{ (AT 4 GHz)} = 0.52 \angle 154^\circ \text{ UNCHANGED AT 4 GHz}$$

$$S'_{11} \text{ (AT 0.1 GHz)} = 1.066 \angle -8.5^\circ \quad |S_{11}| > 1 \text{ AT 0.1 GHz}$$

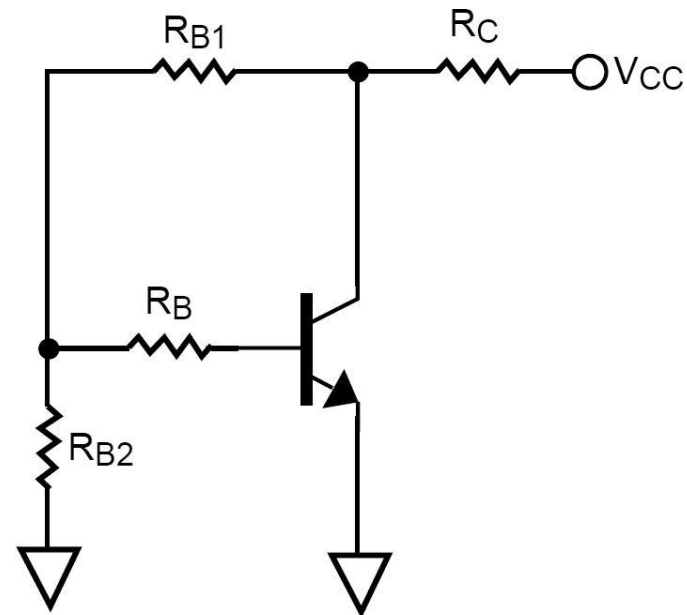
# Polarizare TB scheme de polarizare



NON-STABILIZED



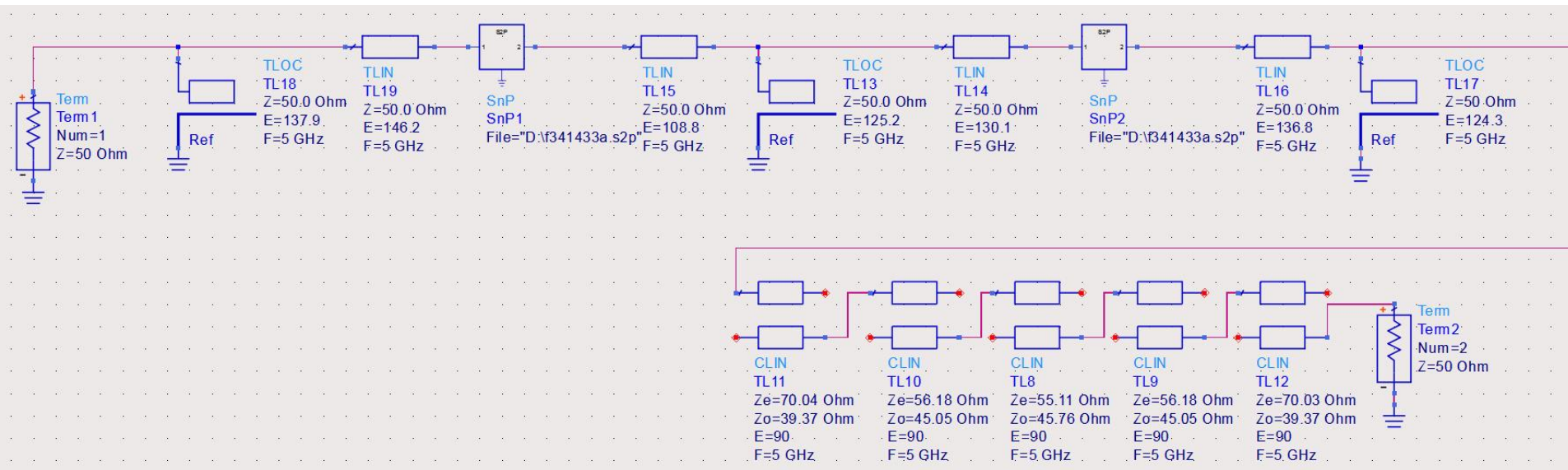
VOLTAGE FEEDBACK



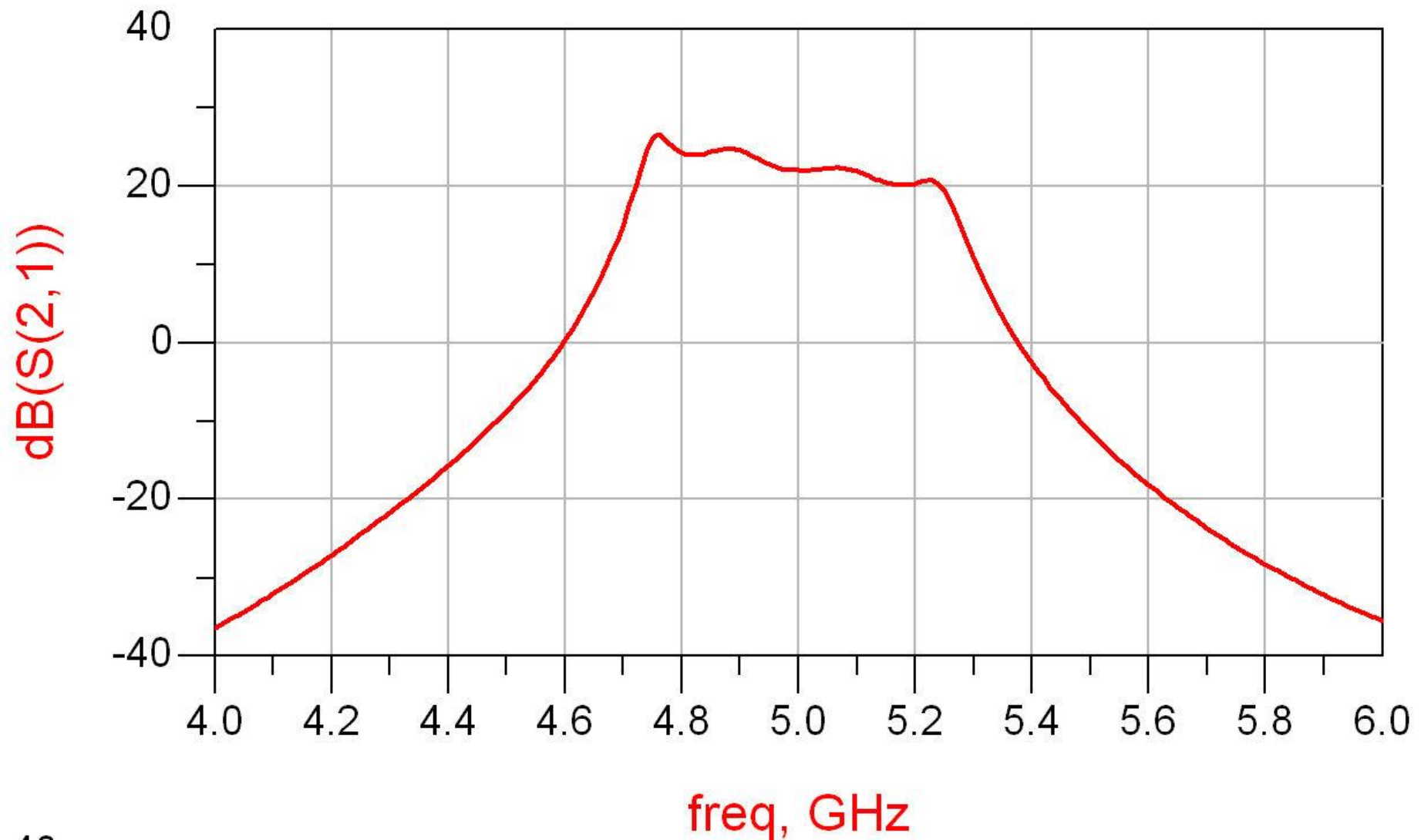
VOLTAGE FEEDBACK AND CONSTANT  
BASE CURRENT SOURCE

# Exemplu proiect

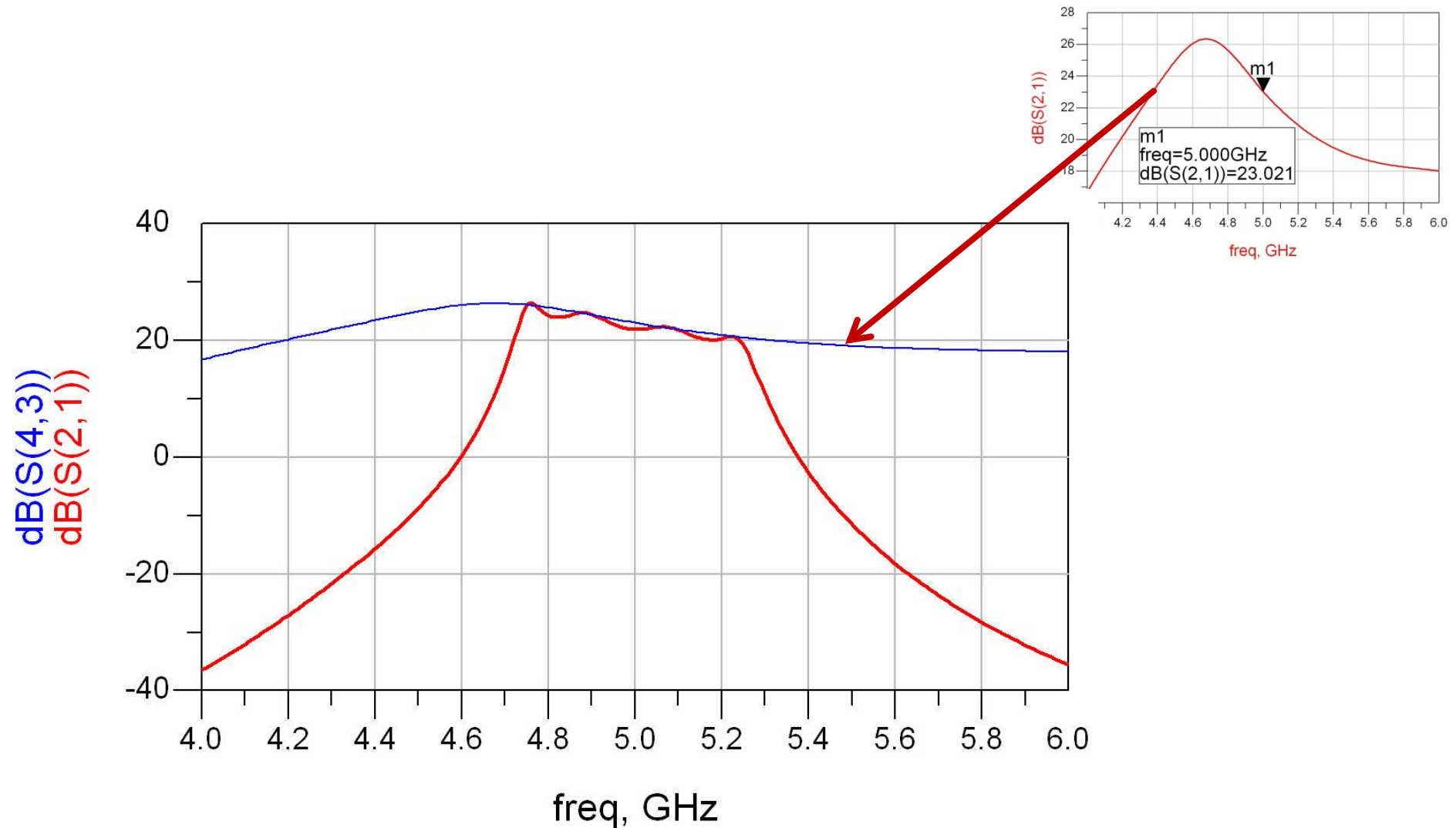
- Unirea celor doua scheme
  - C10 – amplificator
  - C13 – filtre



# Rezultat (dezechilibrat)

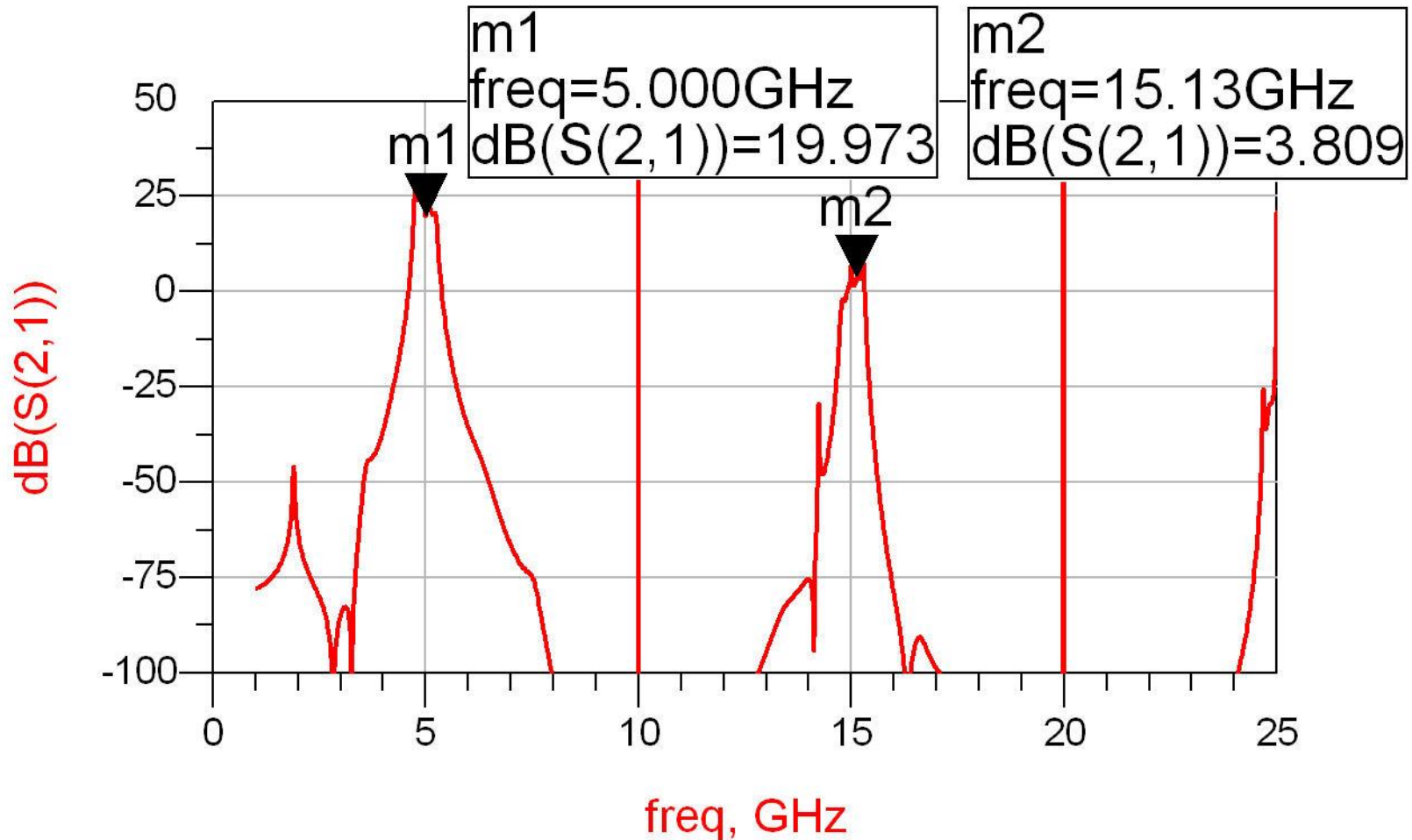


# Rezultat (dezechilibrat)



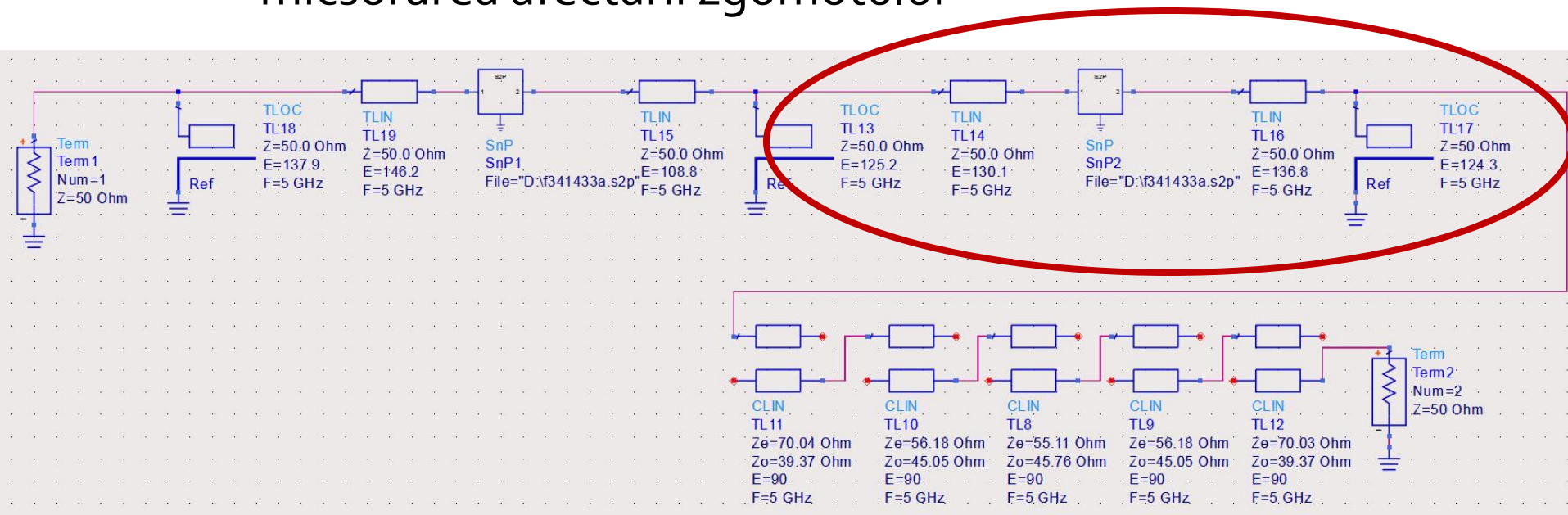


# Rezultat (periodic in frecventa)

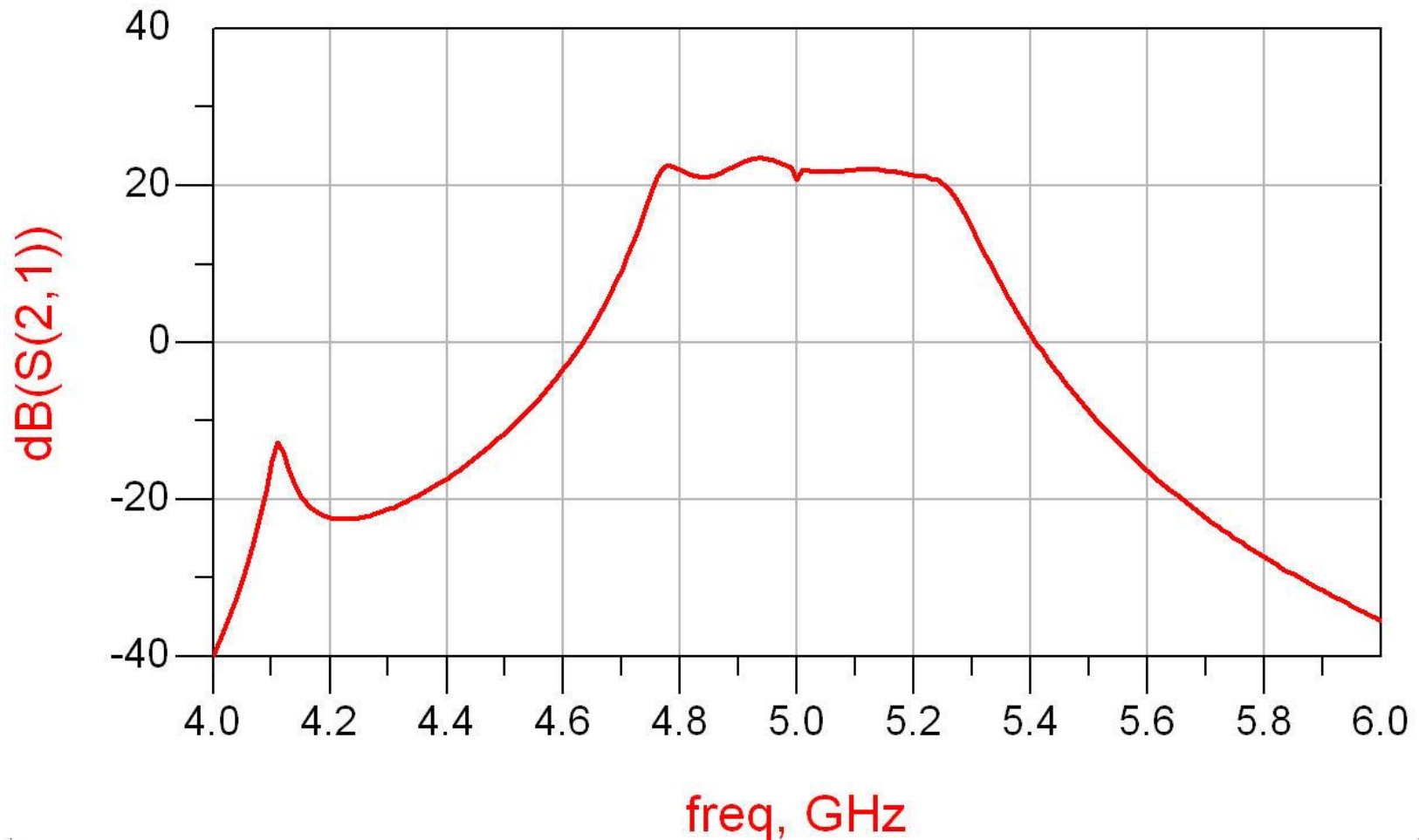


# Reglaj -> echilibrare

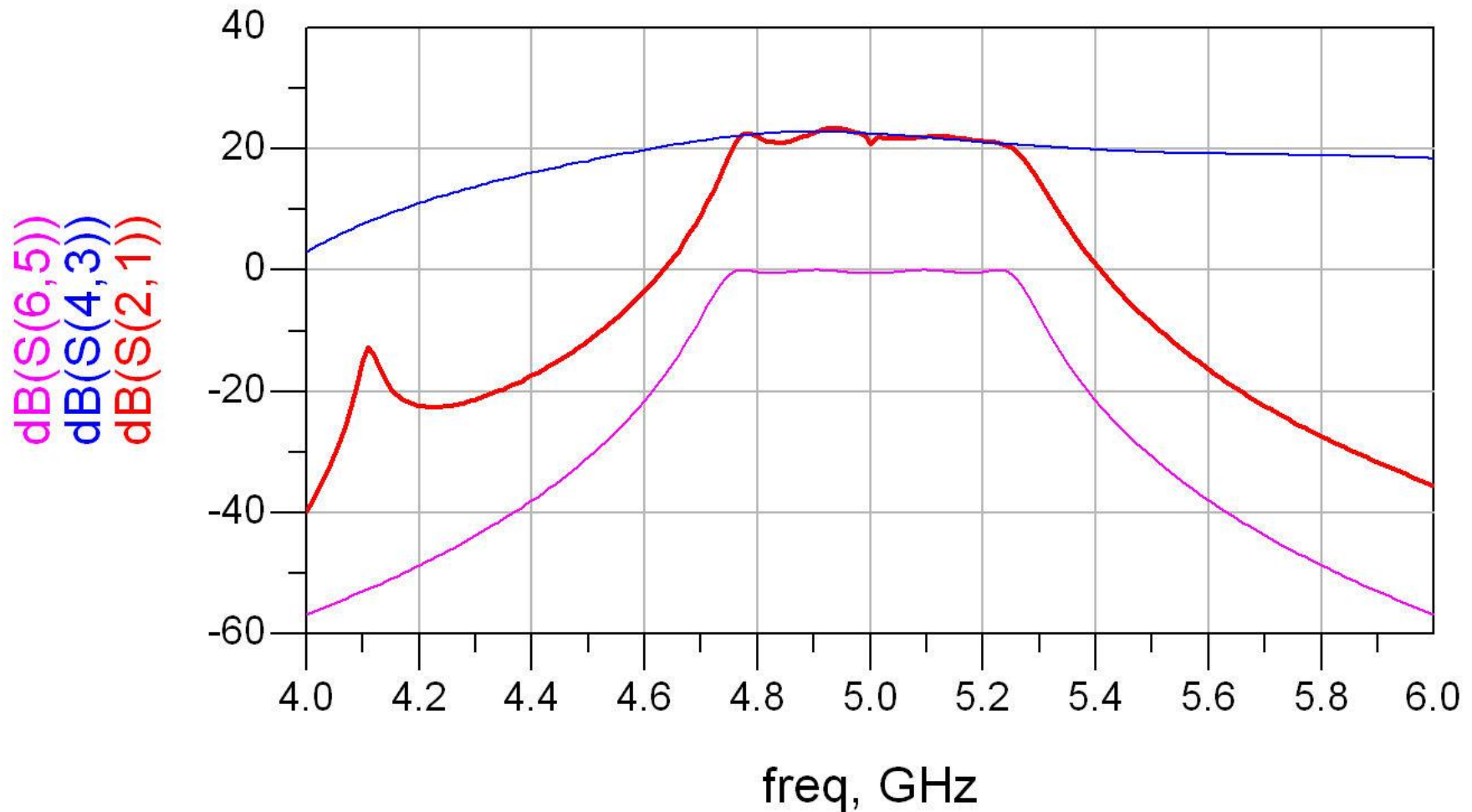
- scopul: echilibrarea caracteristicii amplificatorului (maxim la frecventa centrala)
  - se prefera reglarea lungimii liniilor de la iesirea amplificatorului
    - micsorarea afectarii zgomotului



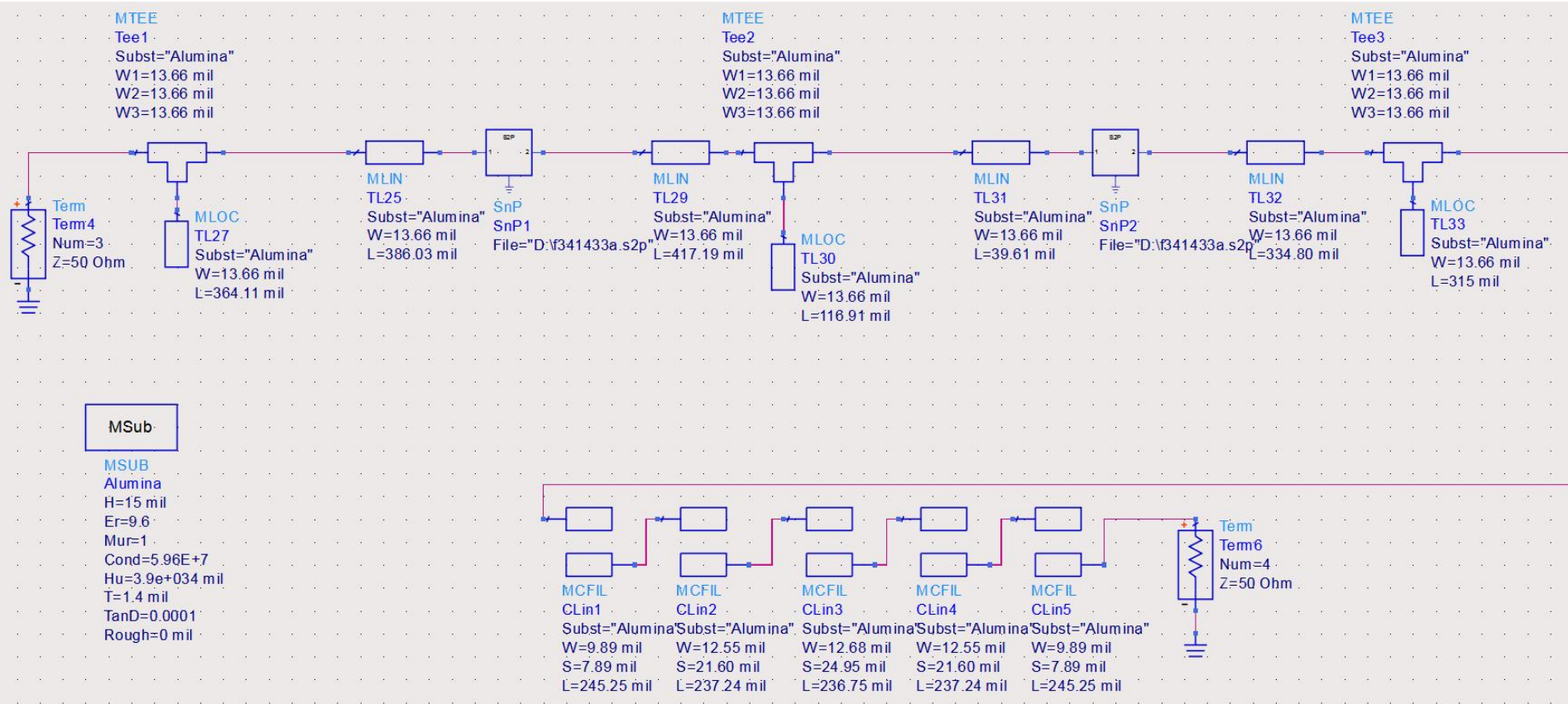
# Reglaj -> echilibrare, efect



# Amplificator, Filtru, Total



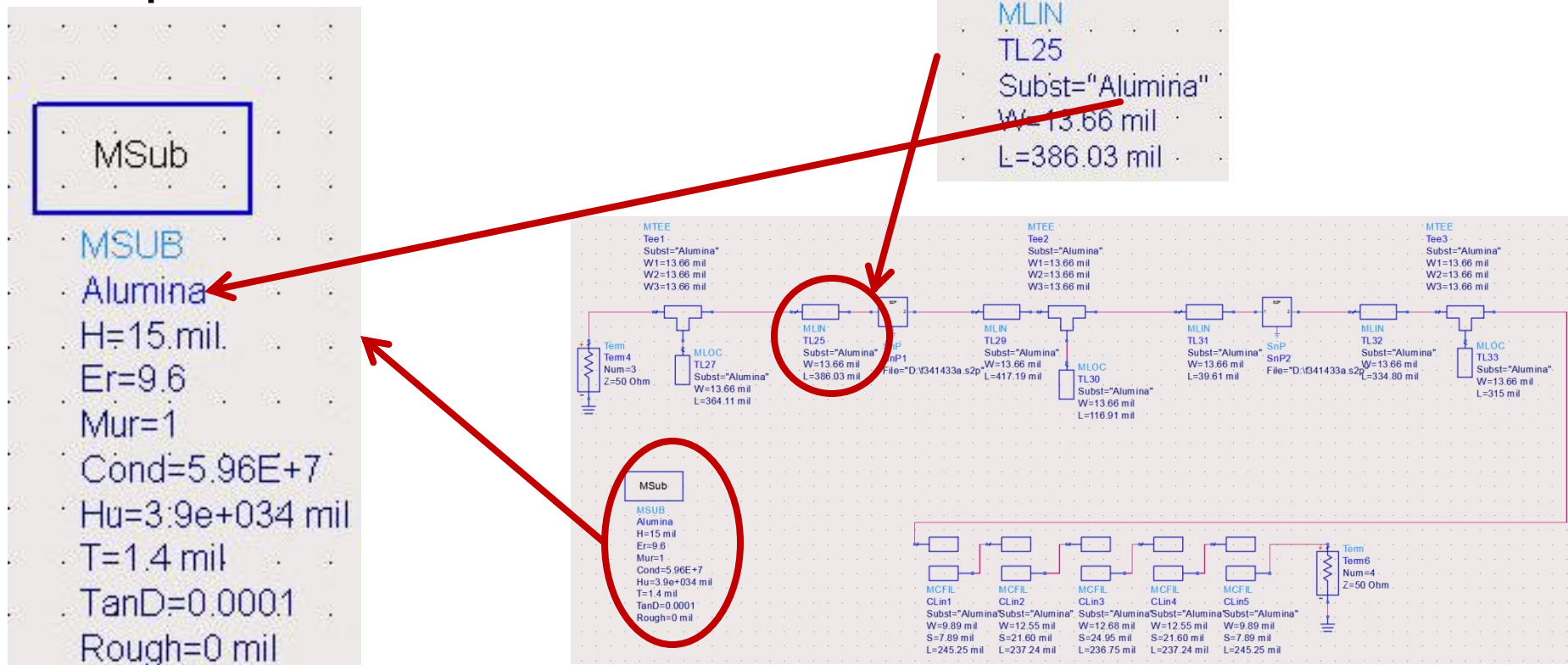
# Implementare cu linii microstrip





# Implementare cu linii microstrip

- Se introduce modelul de substrat
- Liniile/liniile cuplate se calculeaza cu Linecalc pentru acelasi substrat

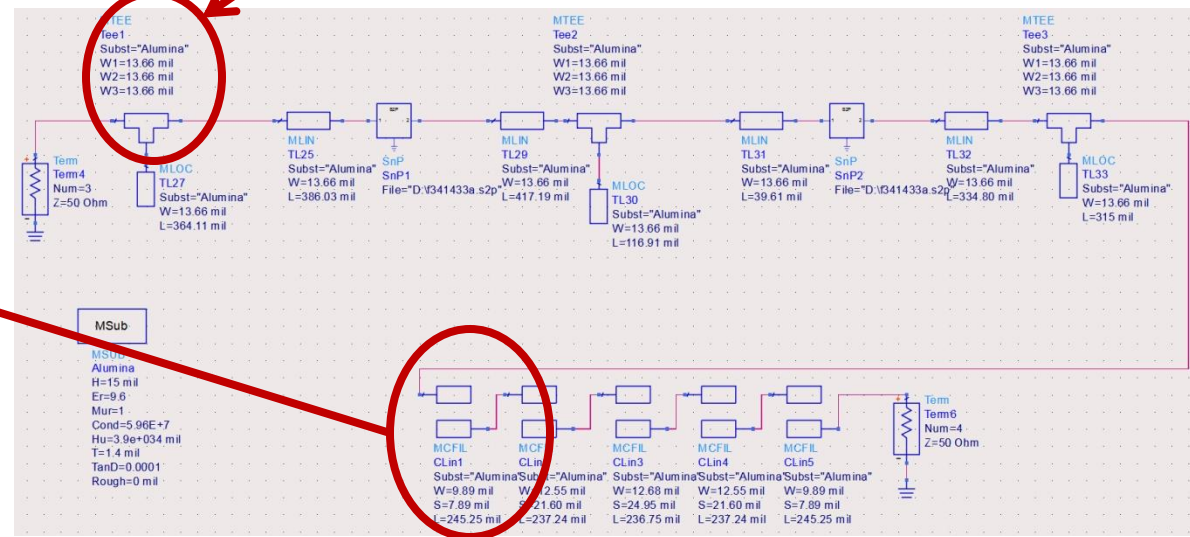
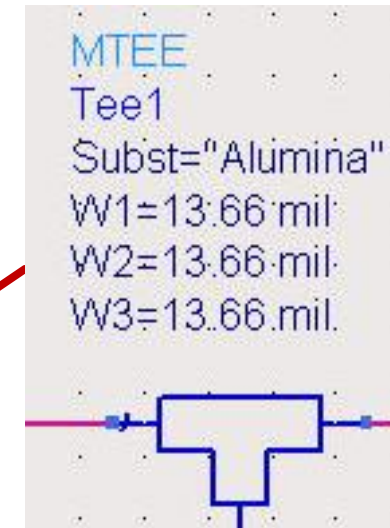


# Implementare cu linii microstrip

- Se folosesc componente din paleta Transmission Lines – Microstrip
  - MSUB - substrat
  - MLIN – linie serie
  - MLOC – stub paralel in gol
  - MTEE – modelare conexiune cu stub in paralel
  - MCFIL – sectiune de filtru cu linii cuplate  
(alternativa mai precisa decat MCLIN – se tine cont de faptul ca doua sectiuni succesive sunt in fizic alaturate)

# Implementare cu linii microstrip

- E necesara atentie la completarea parametrilor pentru MTEE si MCFIL prin verificarea in schema a latimii liniilor conectate la fiecare terminal

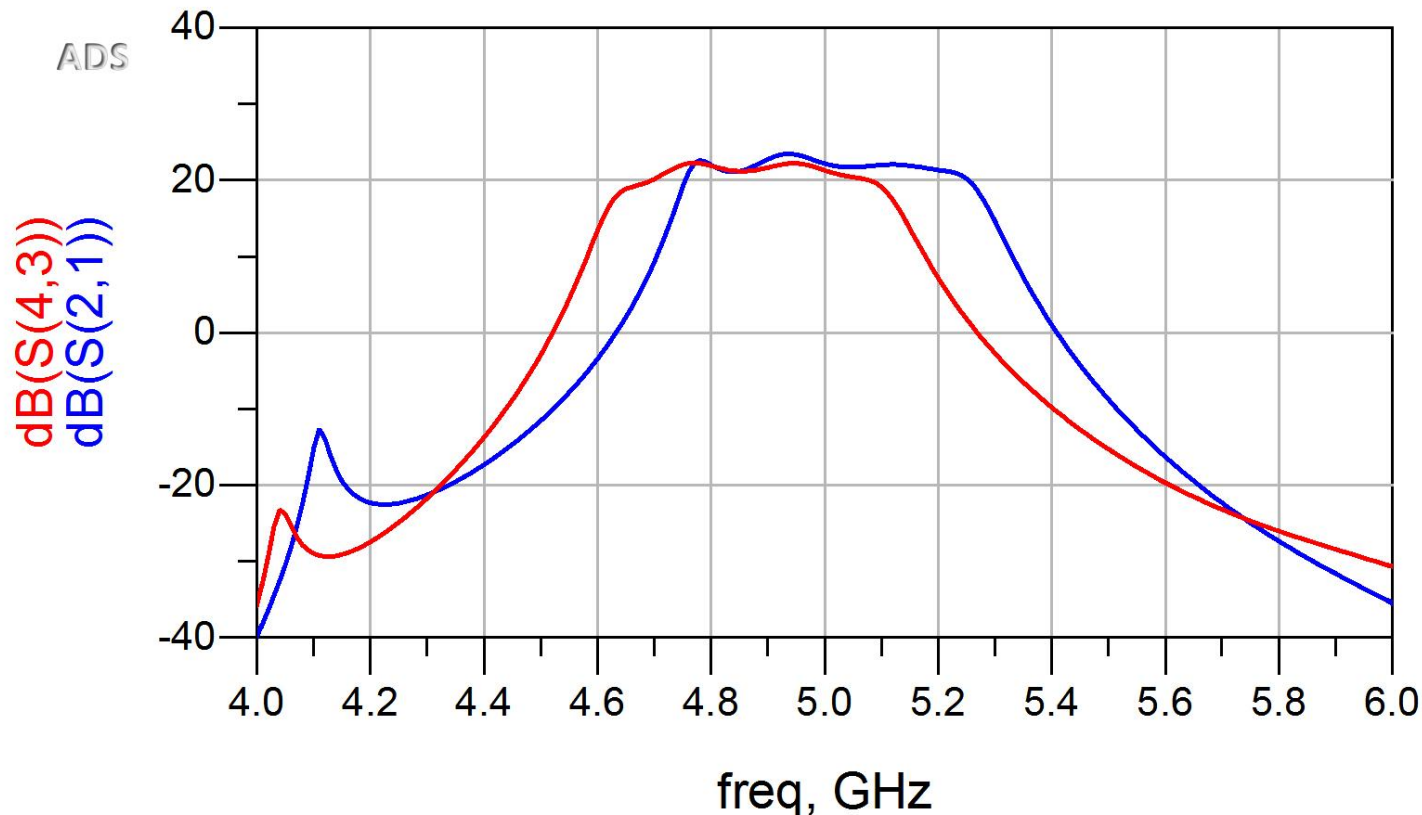




# Implementare cu linii microstrip

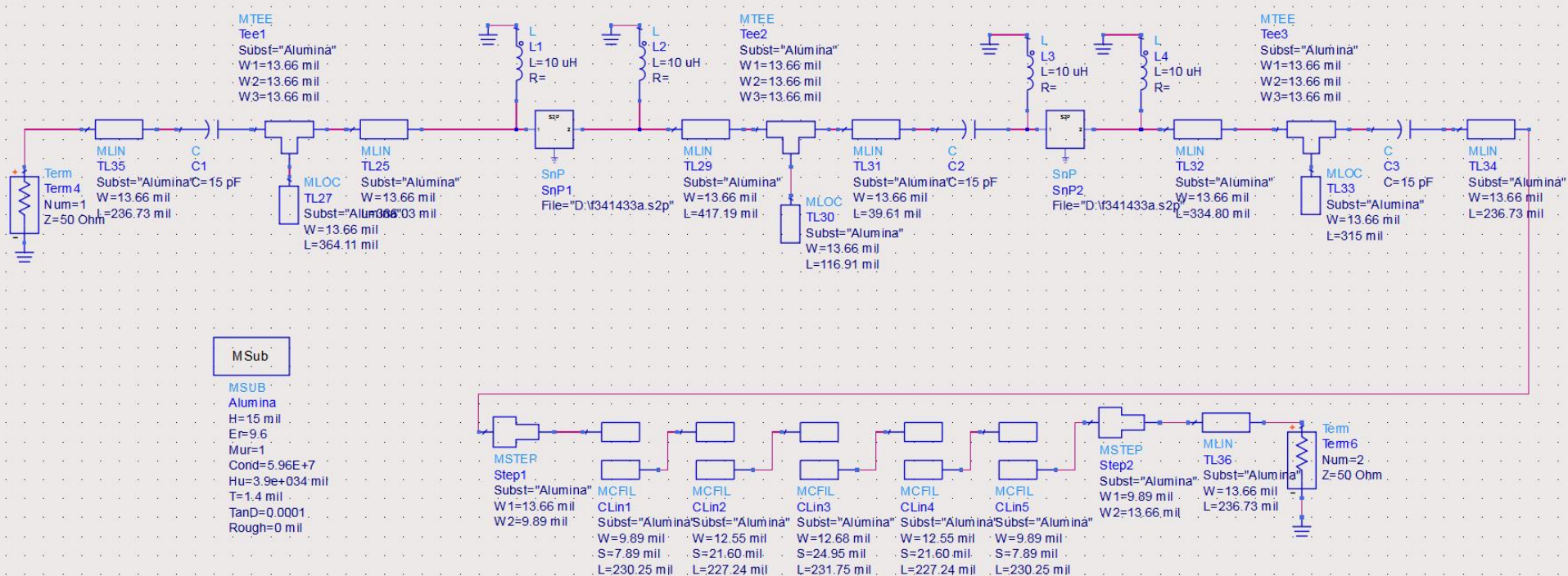
## Rezultat

- Se constata o deplasare a benzii obtinute (albastru) spre frecvente mai mici fata de modelele ideale (rosu)
  - datorat diferentei MCFIL / MCLIN

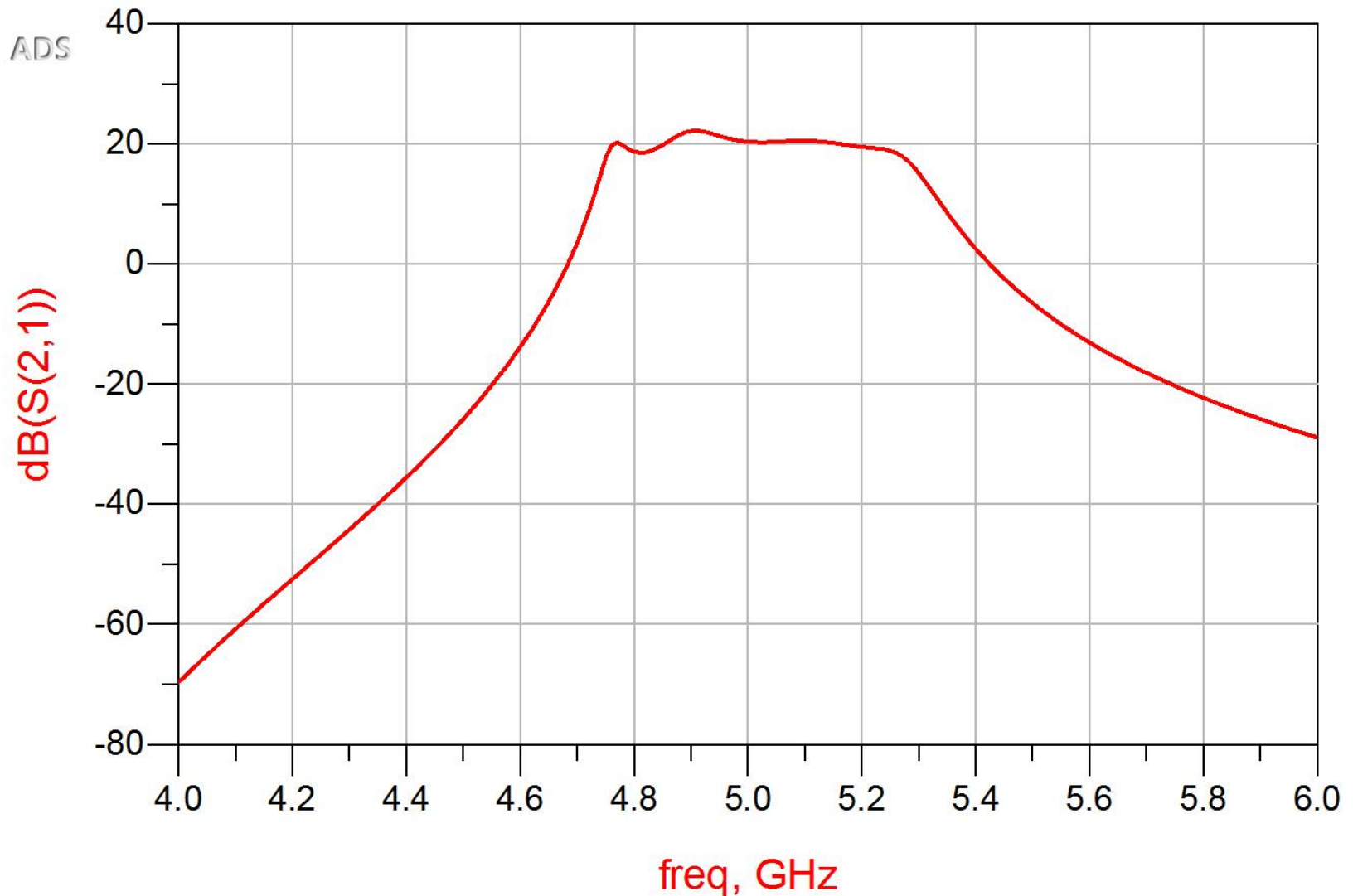


# Introducere elemente de polarizare

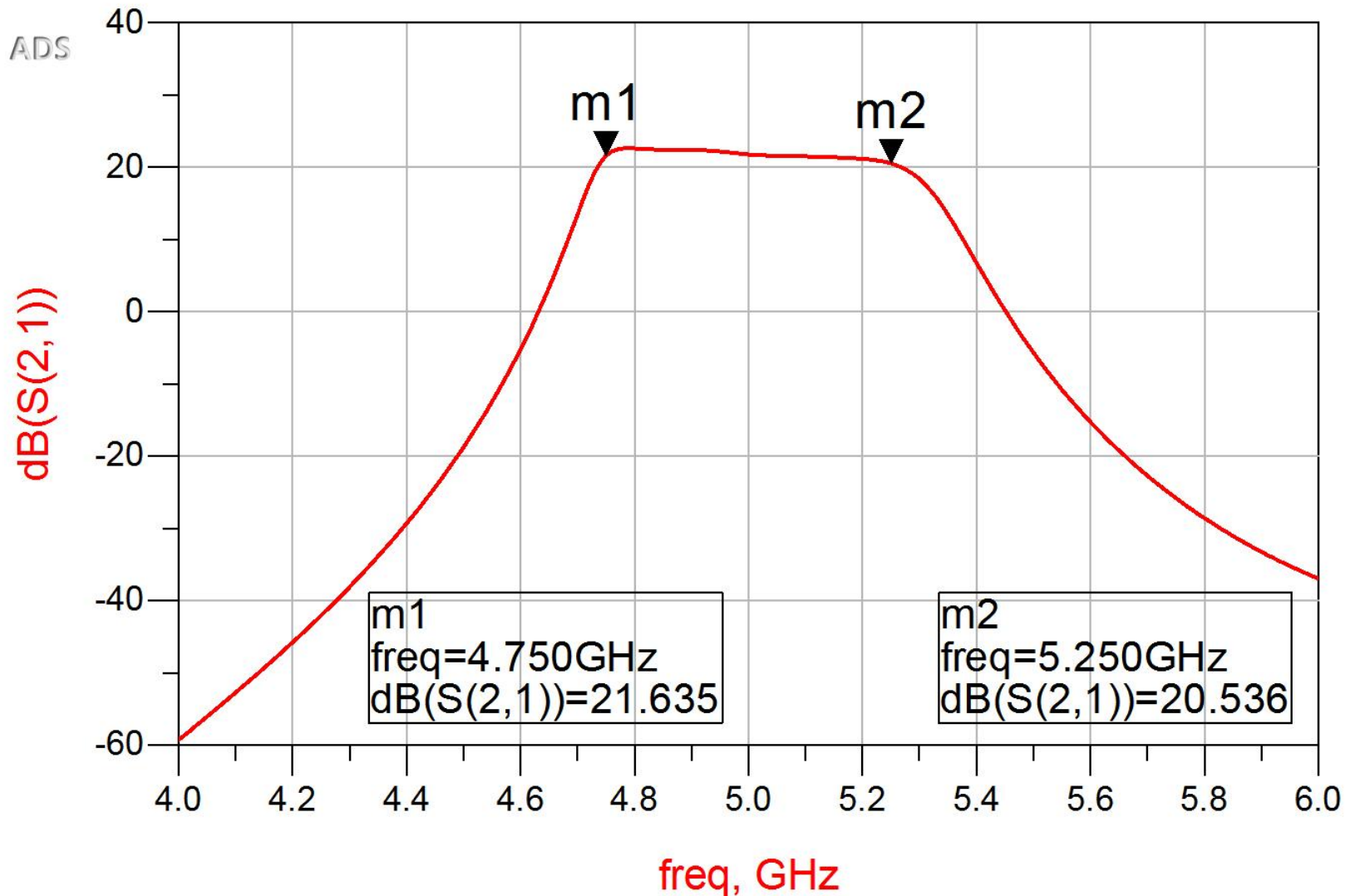
- Reglaj de lungimi la elementele filtrului pentru reglarea frecventelor in jurul  $f_0 = 5\text{GHz}$
- Introducere L (soc RF) si C (decuplare)



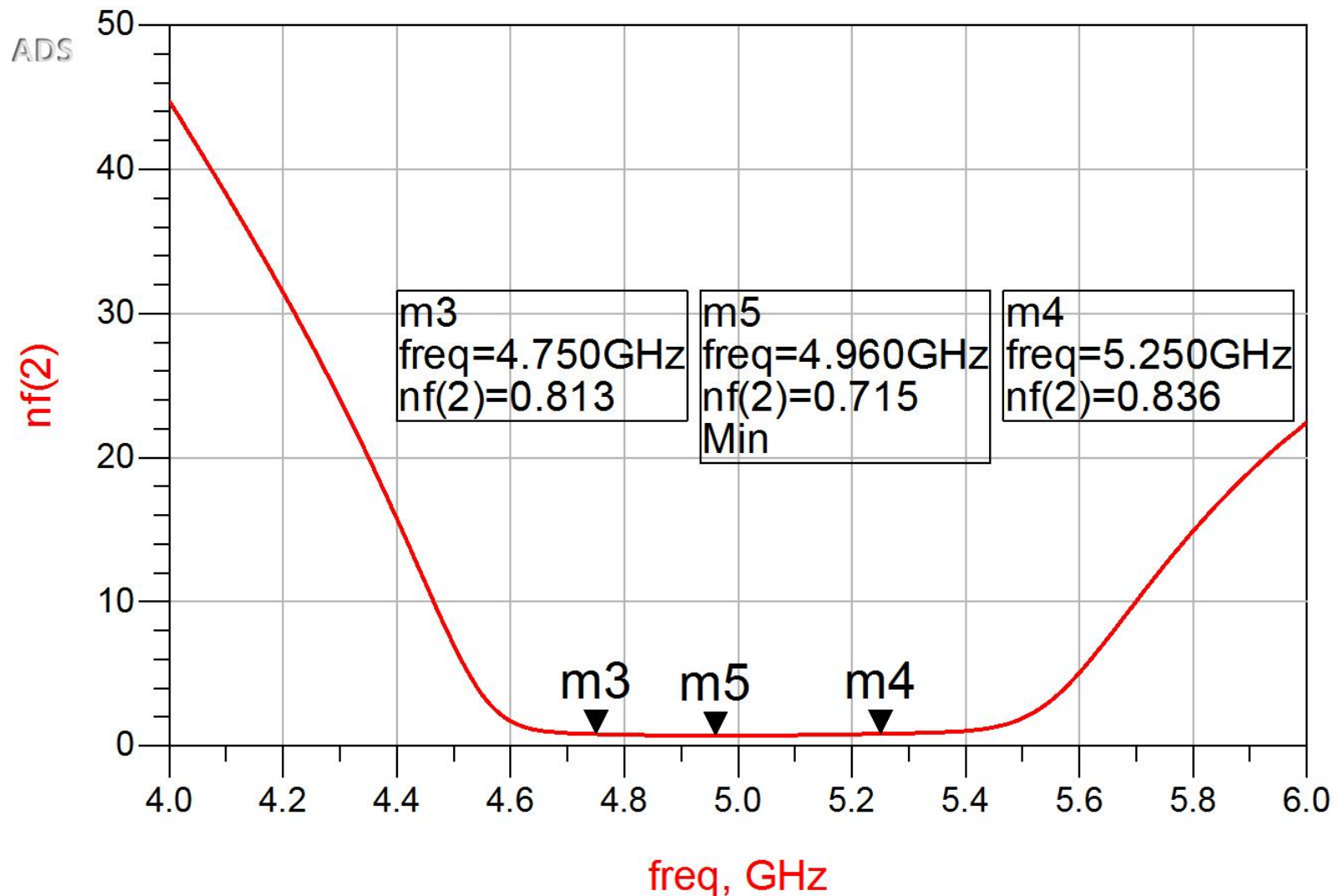
# Castig -> Reglaj/Optimizare



# Rezultat final (Castig)



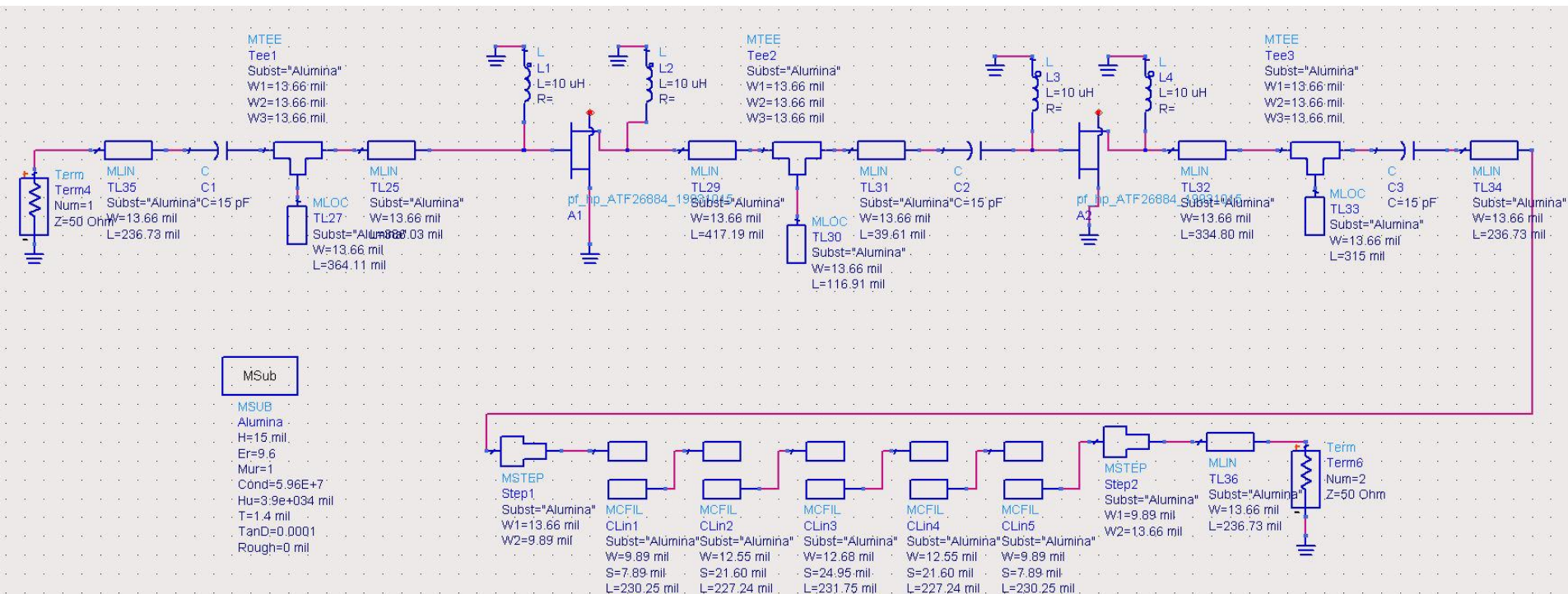
# Rezultat final (Zgomot)



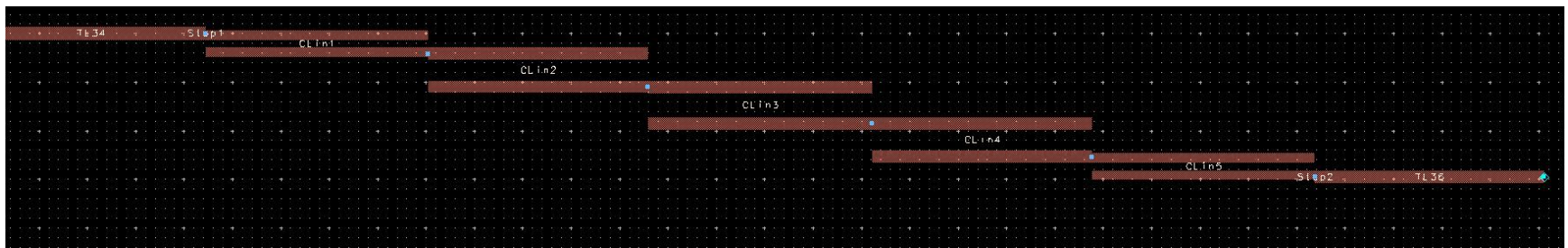
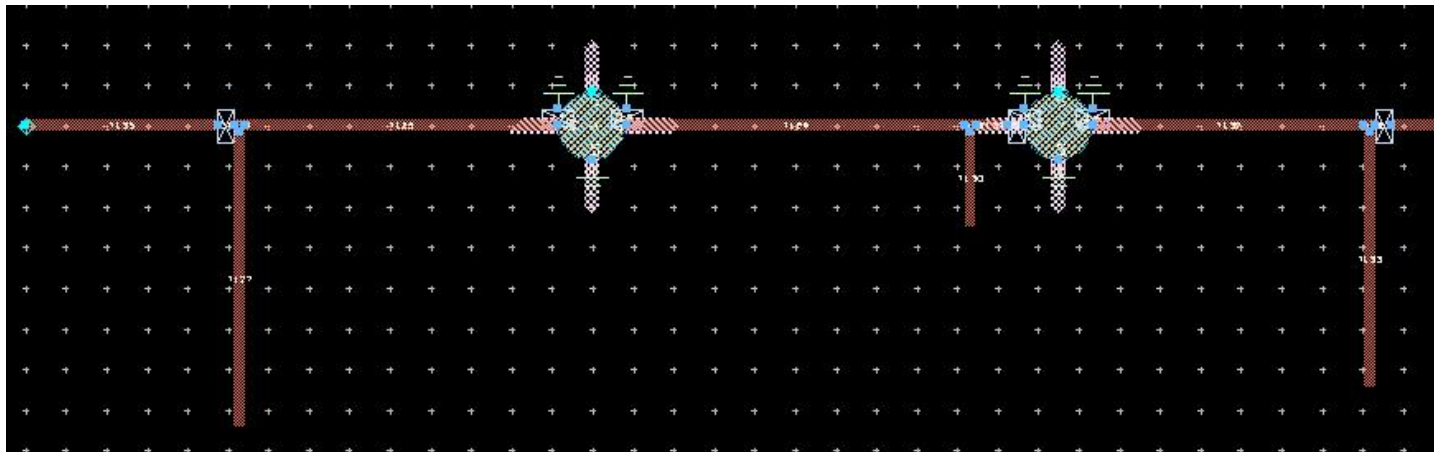
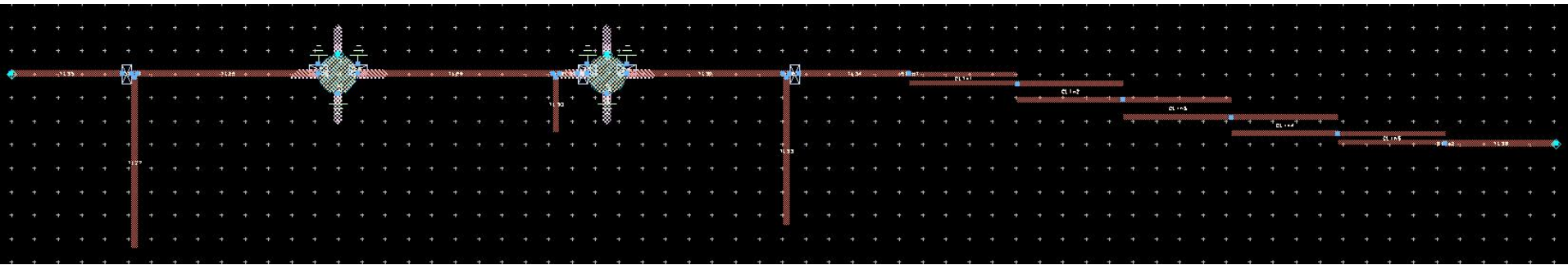


# Layout (Exemplu)

- Inlocuirea (fictiva) a tranzistoarelor si elementelor concentrate (LC) cu elemente pentru care ADS are informatii despre capsule



# Layout (Exemplu)



# Contact

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- Laboratorul de microunde si optoelectronica
- <http://rf-opto.etti.tuiasi.ro>
- [rdamian@etti.tuiasi.ro](mailto:rdamian@etti.tuiasi.ro)