

Curs 9-10

2016/2017

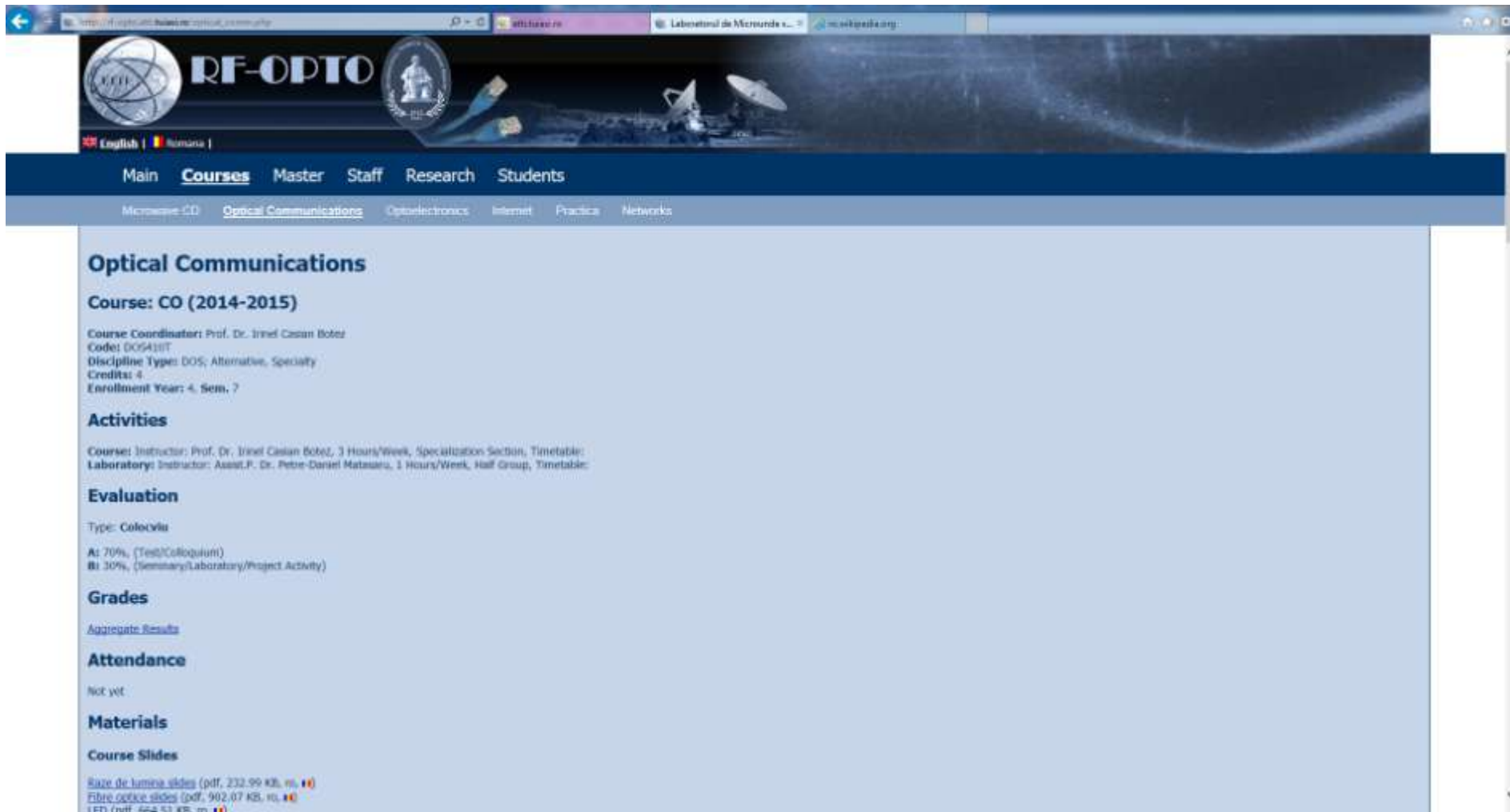
Dispozitive și circuite de microunde pentru radiocomunicații

Disciplina 2015/2016

- 2C/1L, **DCMR (CDM)**
- Minim 7 prezente (curs+laborator)
- Curs - **sl. Radu Damian**
 - Marti 18-20, P2
 - E – 50% din nota
 - probleme + (2p prez. curs)
 - 3prez.=+0.5p
 - toate materialele permise
- Laborator – **sl. Radu Damian**
 - Joi 8-14 impar II.13
 - L – 25% din nota
 - P – 25% din nota

Documentatie

■ <http://rf-opto.etti.tuiasi.ro>



The screenshot shows a web browser displaying the RF-OPTO website. The header features the RF-OPTO logo, a navigation menu with links to Main, Courses, Master, Staff, Research, and Students, and a secondary menu with links to Microwave CD, Optical Communications, Optoelectronics, Internet, Practice, and Networks. The main content area is titled "Optical Communications" and provides details for the "Course: CO (2014-2015)".

Optical Communications

Course: CO (2014-2015)

Course Coordinator: Prof. Dr. Irinel Casian Botez
Code: OC5410T
Discipline Types: DOS; Alternative; Specialty
Credits: 4
Enrollment Year: 4, Sem. 2

Activities

Course: Instructor: Prof. Dr. Irinel Casian Botez, 3 Hours/Week, Specialization Section, Timetable:
Laboratory: Instructor: Asist.P. Dr. Petre-Daniel Mateanu, 1 Hours/Week, Half Group, Timetable:

Evaluation

Type: Colocvii
At 70%, (Test/Colloquium)
B1 30%, (Seminary/Laboratory/Project Activity)

Grades

[Aggregate Results](#)

Attendance

Not yet

Materials

Course Slides

[Raze de lumina slides \(pdf, 232.99 KB, ro, 10\)](#)
[Fibre optice slides \(pdf, 902.07 KB, ro, 10\)](#)
[LED \(pdf, 424.53 KB, ro, 10\)](#)

Documentatie

- RF-OPTO
 - <http://rf-opto.etti.tuiasi.ro>
- Fotografie
 - de trimis prin email: rdamian@etti.tuiasi.ro
 - necesara la laborator/curs
 - ~~$\leq C_3 + 1p$~~
 - ~~$\leq C_5 + 0.5p$~~

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

Reprezentare logaritmică

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Filtre pentru microunde

Filtre pentru microunde

- In domeniul microundelor se utilizeaza doua strategii de implementare a filtrelor
 - structuri specifice microundelor (linii cuplate, rezonatori dielectrice, structuri periodice)
 - sinteza de filtre cu elemente concentrate urmate de implementare cu linii de transmisie
- prima strategie duce la obtinerea unor filtre mai eficiente dar e caracterizata de
 - generalitate mai mica
 - proiectare deseori dificila (lipsa relatiilor analitice)

Sinteza filtrelor

- Sinteza filtrelor cu elemente concentrate, urmata de implementarea acestora cu elemente distribuite (linii)
 - generala
 - relatii analitice usor de implementat pe calculator
 - eficienta
- Metoda preferata este metoda pierderilor de insertie

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 ω

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

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

- Alegerea corespunzatoare a polinoamelor M si N determina comportarea filtrului

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

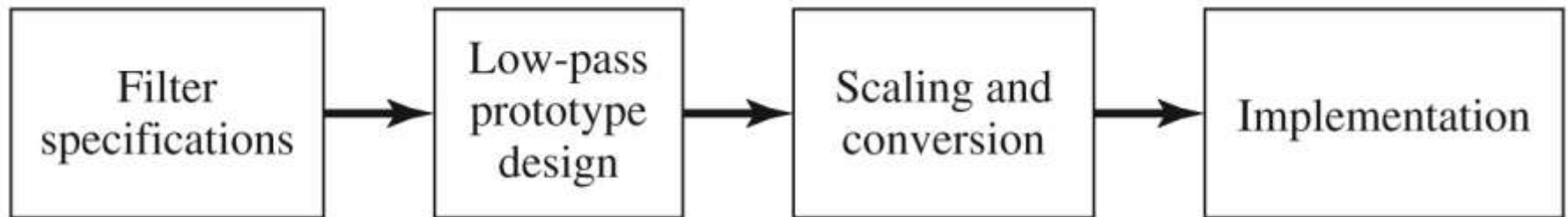


Figure 8.23

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Caracteristici de filtru trece jos prototip

- **Maxim plat** (Butterworth, binomial) ofera cea mai plata comportare in banda de trecere
- **Echiriplu** (Cebasev) ofera atenuare mai mare in banda de taiere cu dezavantajul existentei unor variatii (riplu) in banda de trecere
- **Filtre eliptice**, caracterizate de variatii (riplu) si in banda de taiere si in banda de trecere
- **Filtru cu raspuns liniar in faza**, ofera intarziere de grup de maxim plat, cu dezavantajul unei atenuari in putere mai mica, necesar in anumite aplicatii

FTJ prototip Maxim plat/Echiriplu

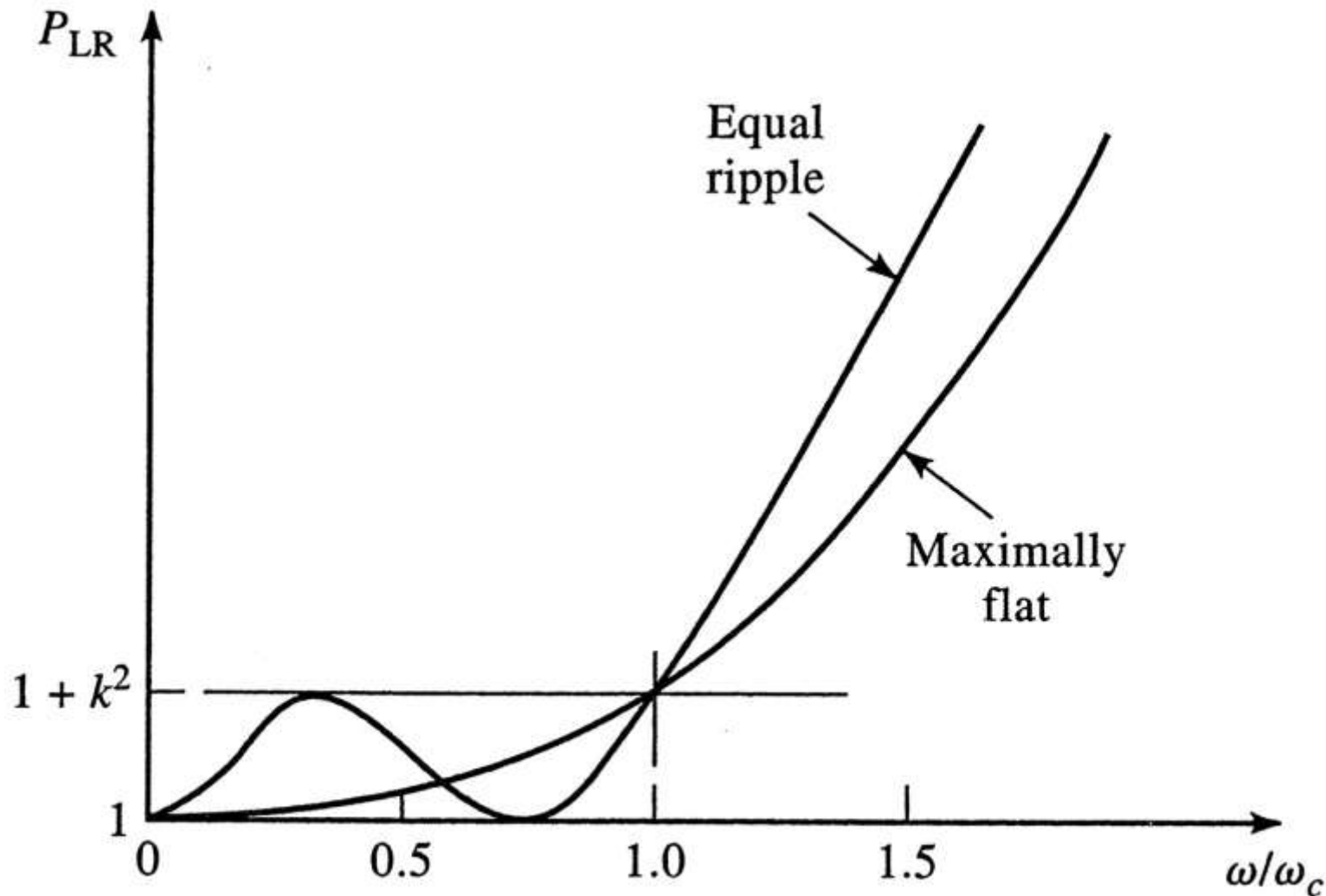


Figure 8.21

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FTJ elliptic prototip

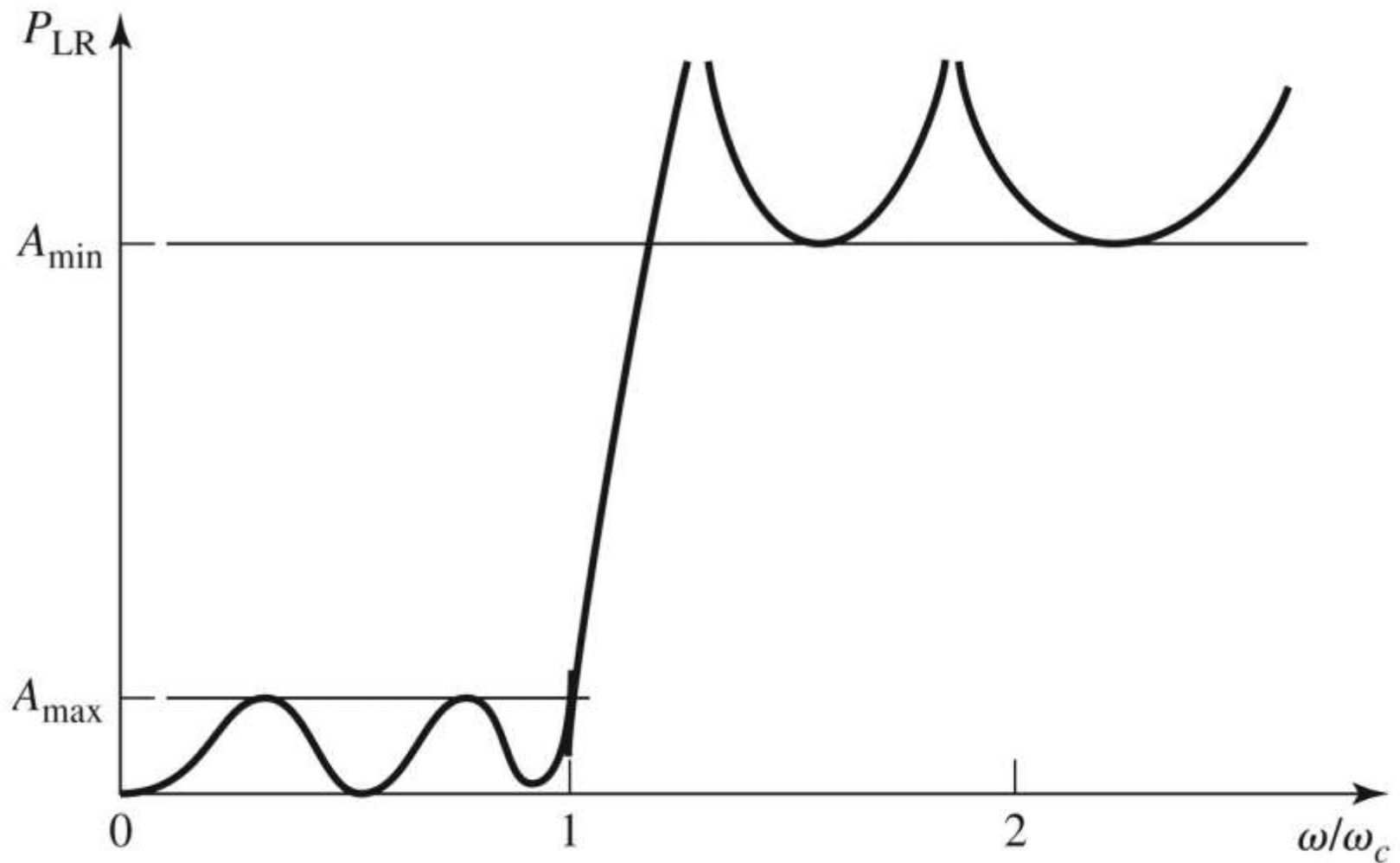


Figure 8.22
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FTJ de tip maxim plat

- Polinomul

$$P_{LR} = 1 + k^2 \cdot \left(\frac{\omega}{\omega_c} \right)^{2N}$$

- pentru $\omega \gg \omega_c$

$$P_{LR} \approx k^2 \cdot (\omega/\omega_c)^{2N}$$

- atenuarea creste cu 20N dB/decada

- k ofera atenuarea la limita benzii de trecere (3dB implica $k = 1$)

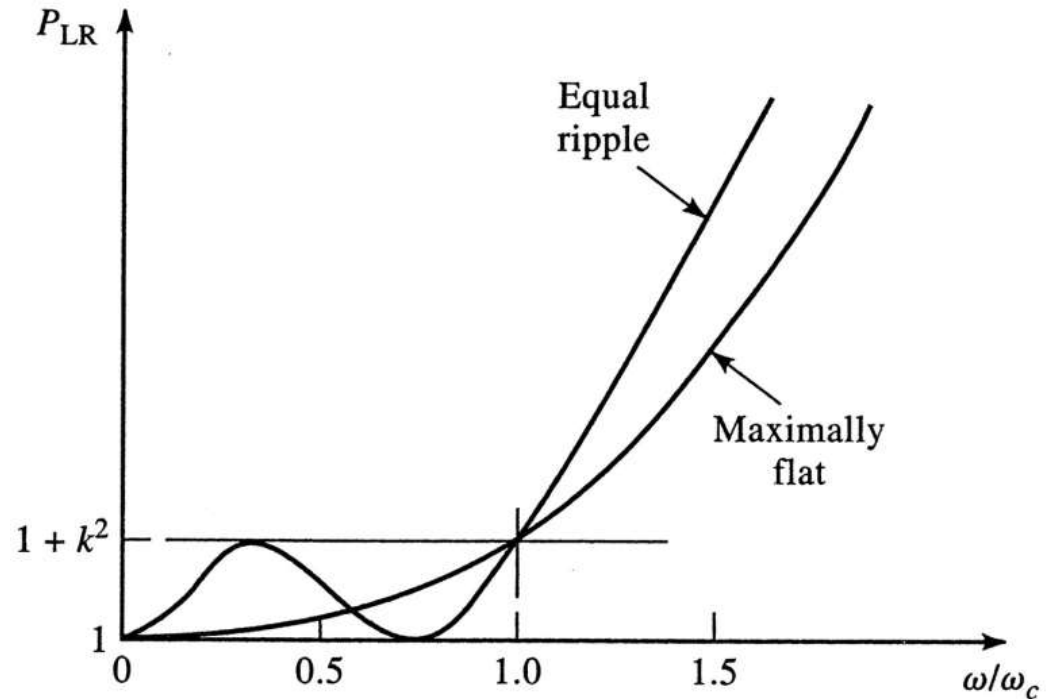


Figure 8.21
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FTJ de tip echiriplu

- Polinomul

$$P_{LR} = 1 + k^2 \cdot T_N^2\left(\frac{\omega}{\omega_c}\right)$$

- pentru $\omega \gg \omega_c$

$$P_{LR} \approx \frac{k^2}{4} \cdot \left(\frac{2 \cdot \omega}{\omega_c}\right)^{2N}$$

- atenuarea crește cu $20N$ dB/decada

- atenuarea este mai mare de $(2^{2N})/4$ decat cea a filtrului binomial la frecventele $\omega \gg \omega_c$

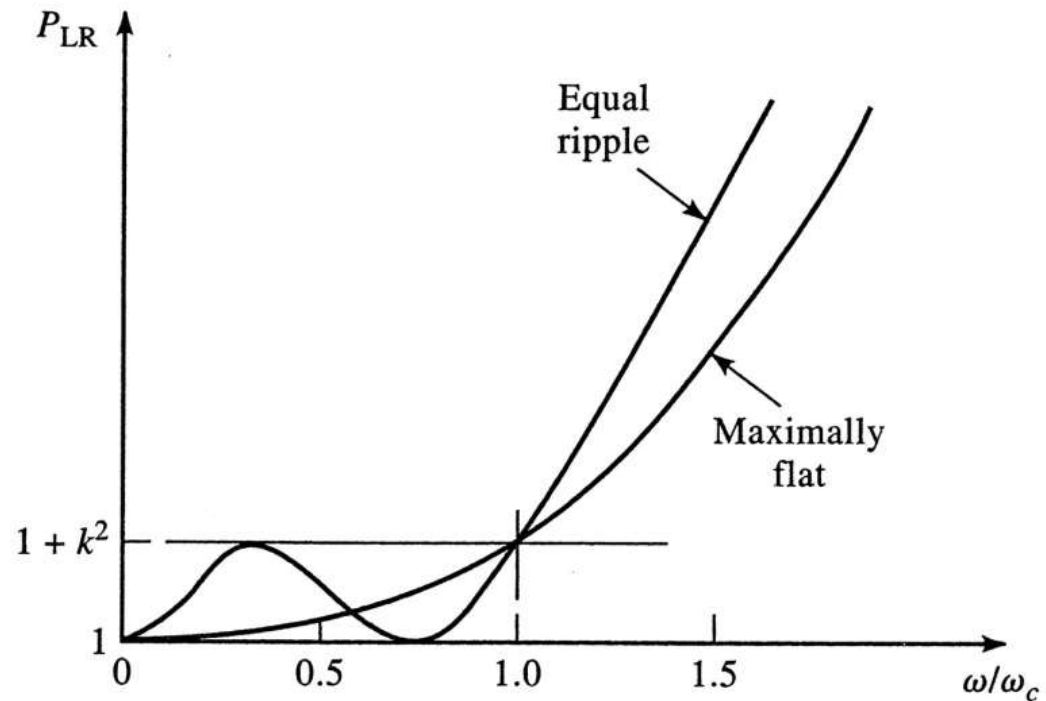
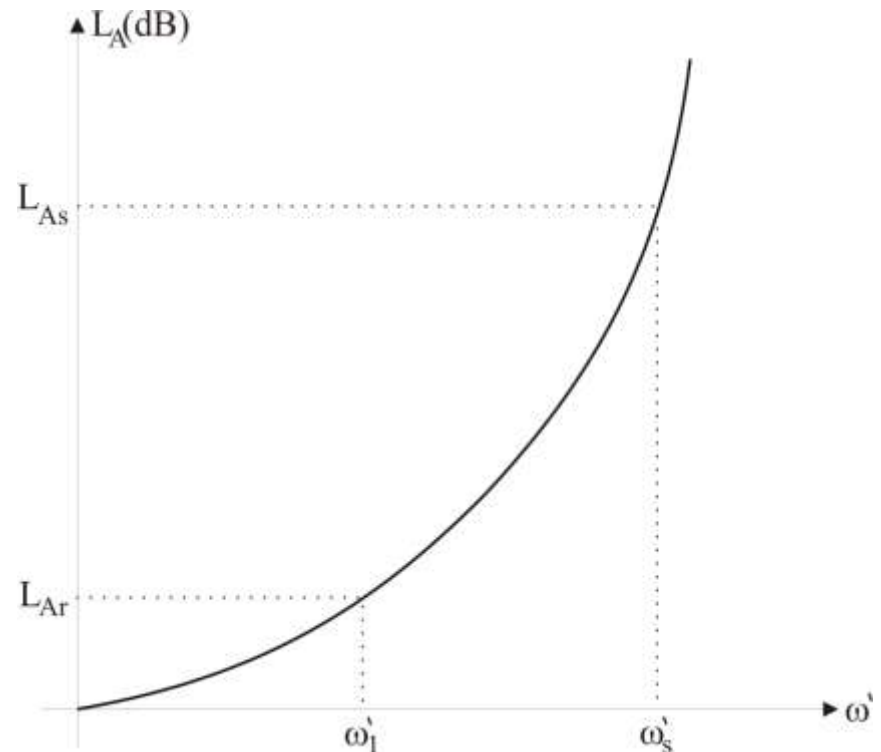


Figure 8.21
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Calculul ordinului filtrului maxim plat

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

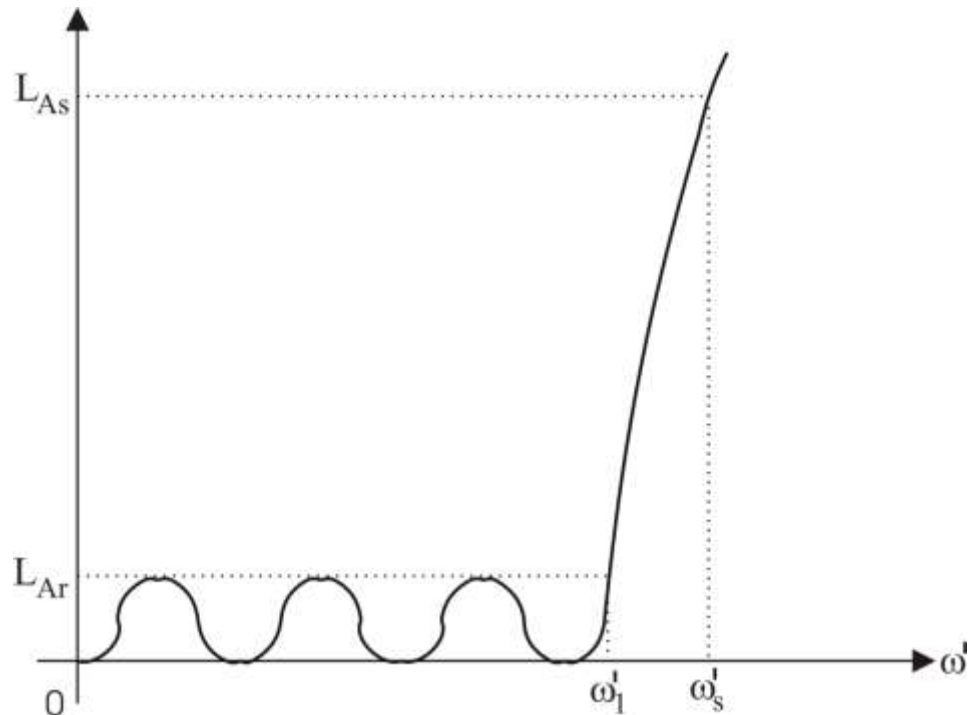
- cu atenuările in **dB**



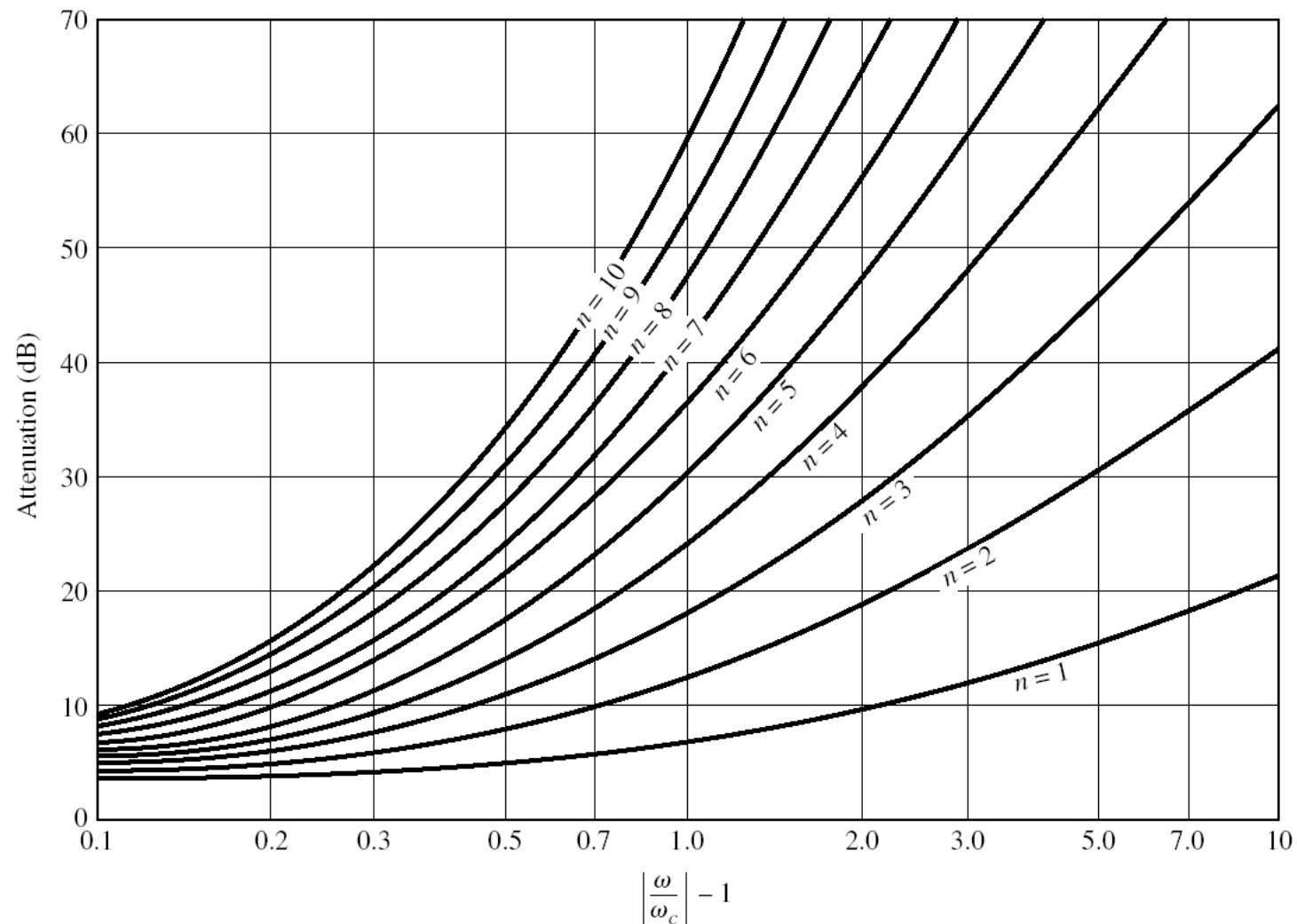
Calculul ordinului filtrului echiriplu

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

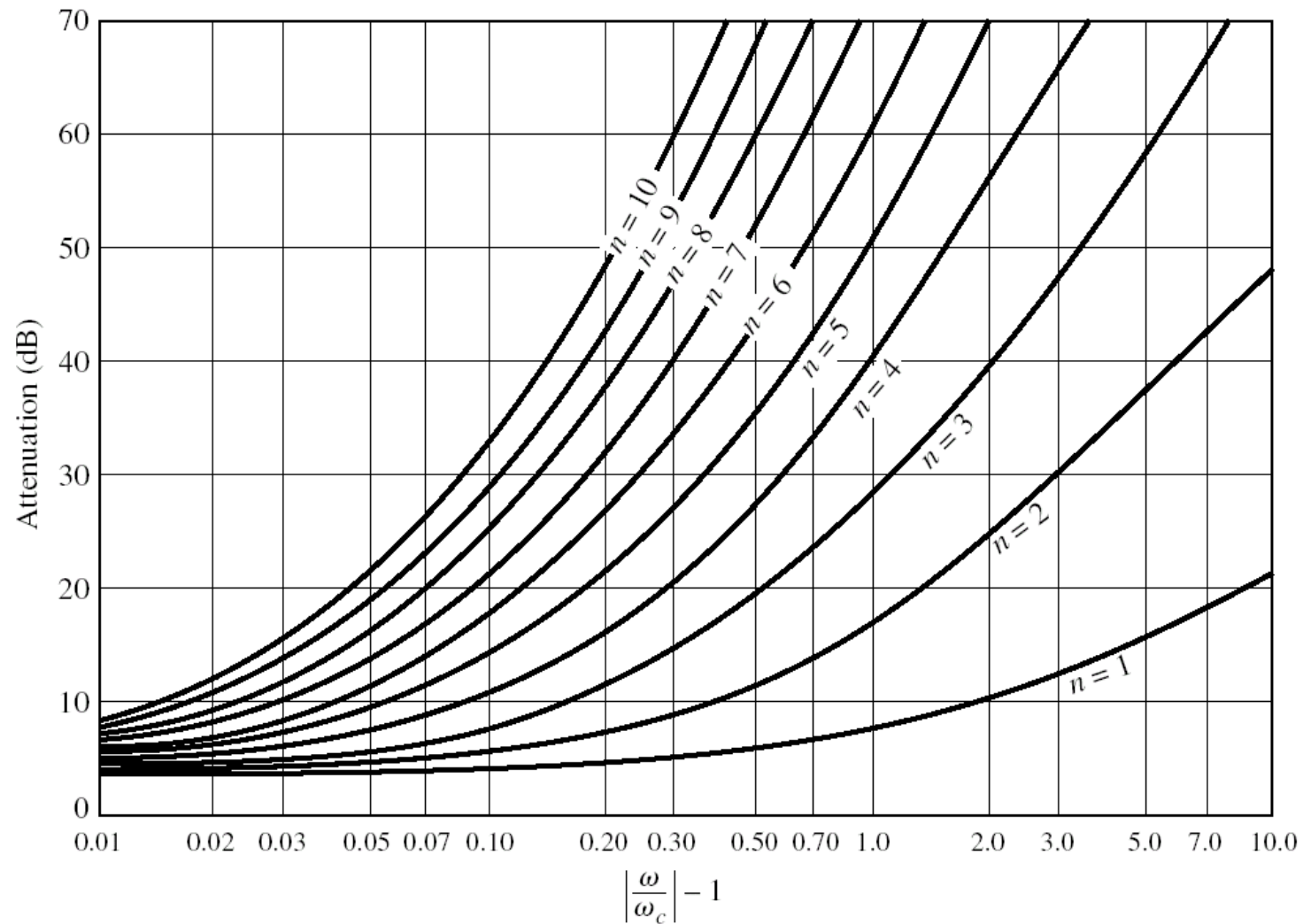
■ cu atenuările in **dB**



Raspunsul filtrului maxim plat

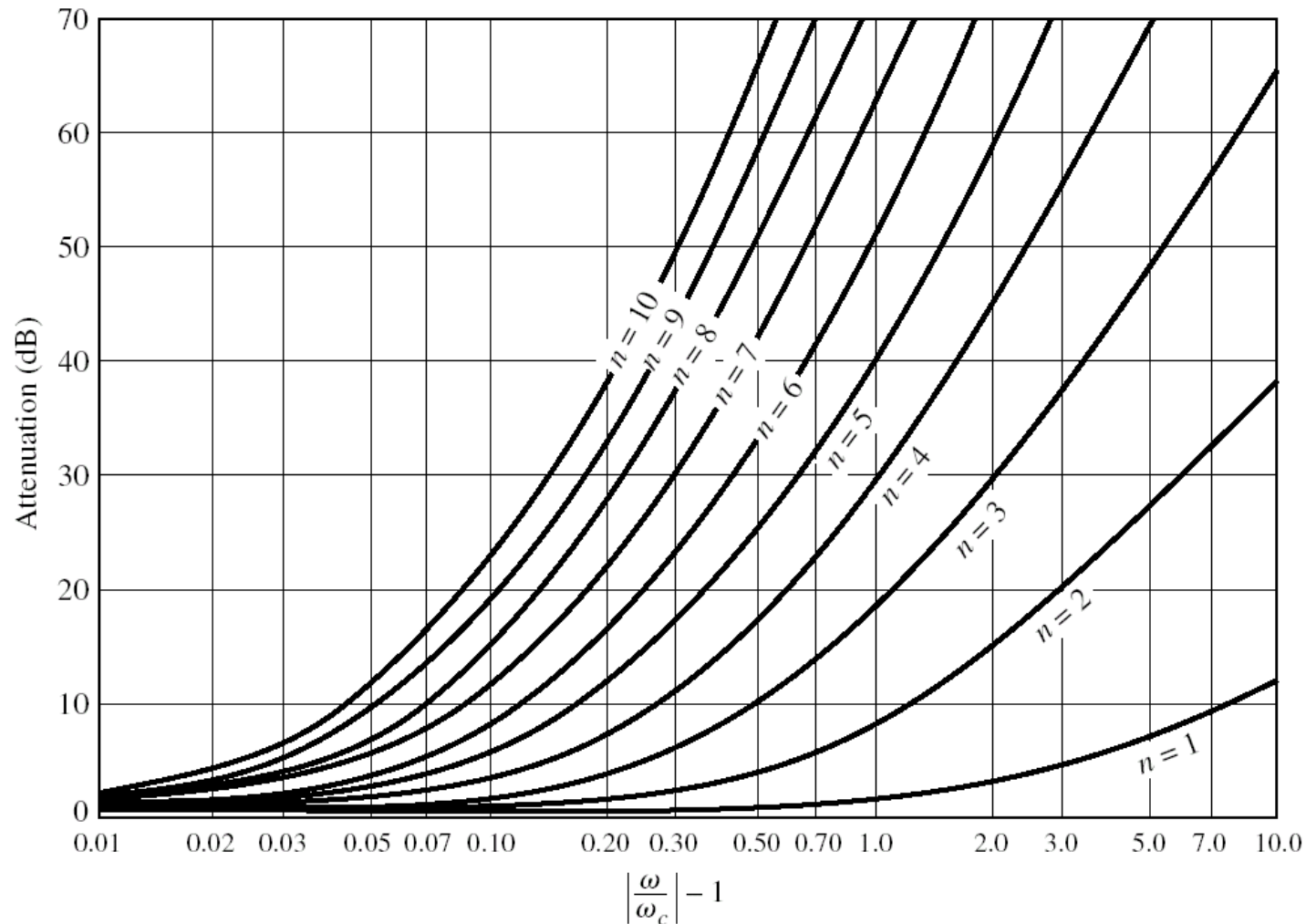


Raspunsul filtrului echiriplu 3 dB



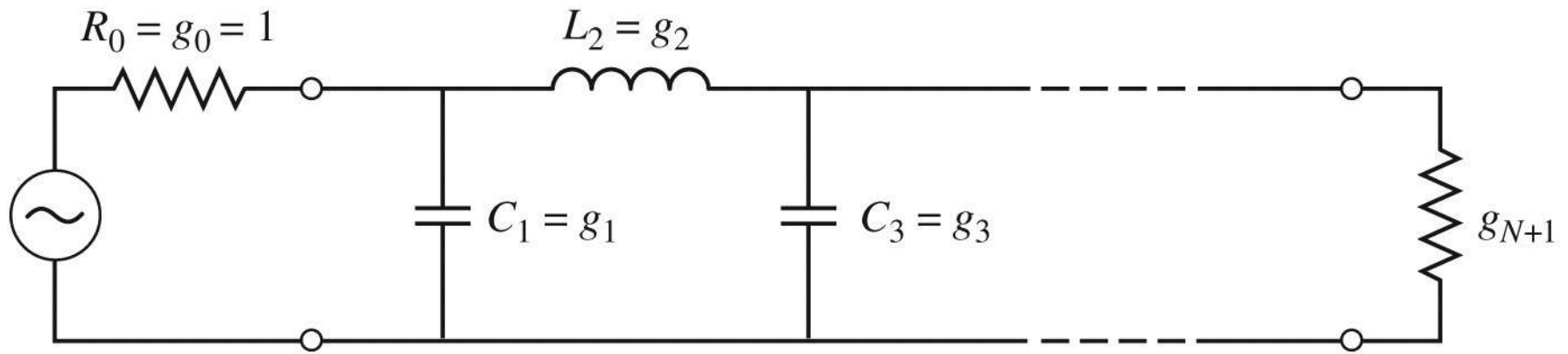
(b)

Raspunsul filtrului echiriplu 0.5 dB

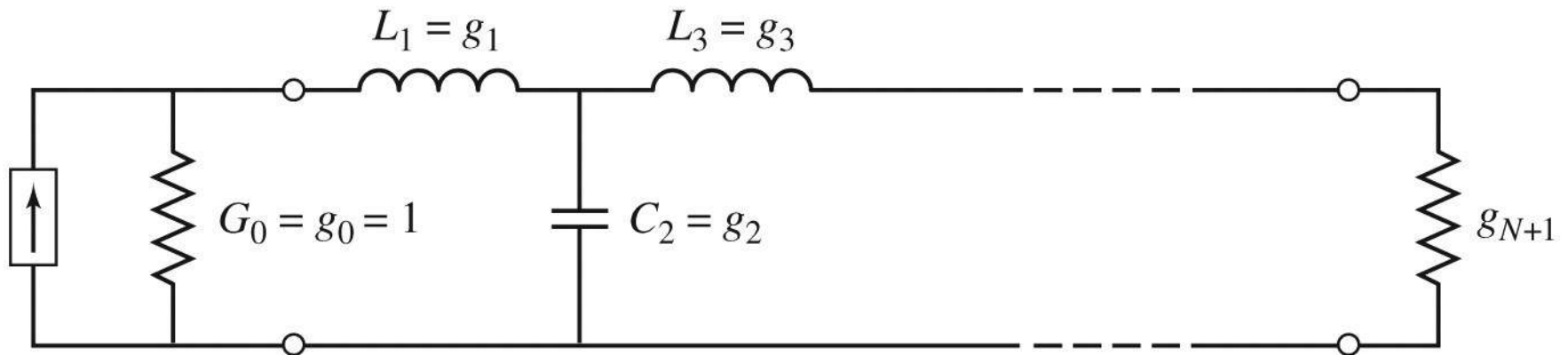


(a)

Filtre prototip



(a)



(b)

Filtre prototip

- Filtrele prototip sunt filtre care implementeaza :
 - filtru FTJ
 - frecventa de taiere $\omega_0 = 1 \text{ rad/s}$ ($f_0 = 0.159 \text{ Hz}$)
 - conectate la intrare la o rezistenta $R = 1$
- Numarul total de elemente reactive (L/C) este ordinul filtrului
- Elementele se introduc in alternanta L serie / C paralel
- Exista doua filtre prototip care ofera acelasi raspuns, o varianta care incepe cu C, o varianta care incepe cu L

Filtru prototip

- Se definesc parametrii g_i , $i=0, N+1$

$$g_0 = \begin{cases} \text{rezistenta generatorului } R'_0 & \text{daca } g_1 = C'_1 \\ \text{conductanta generatorului } G'_0 & \text{daca } g_1 = L'_1 \end{cases}$$

$$g_k|_{k=1, \overline{N}} = \begin{cases} \text{inductanta unei bobine serie} \\ \text{capacitate a unui condensator paralel} \end{cases}$$

$$g_{N+1} = \begin{cases} \text{rezistenta de sarcina } R'_{N+1} & \text{daca } g_N = C'_N \\ \text{conductanta de sarcina } G'_{N+1} & \text{daca } g_N = L'_N \end{cases}$$

Filtru prototip maxim plat

- Calculul elementelor filtrului

$$g_0 = 1$$

$$g_k = 2 \cdot \sin \left[\frac{(2 \cdot k - 1) \cdot \pi}{2 \cdot N} \right] , \quad k = 1, N$$

$$g_{N+1} = 1$$

Filtru prototip maxim plat

TABLE 8.3 Element Values for Maximally Flat Low-Pass Filter Prototypes ($g_0 = 1$, $\omega_c = 1$, $N = 1$ to 10)

N	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9	g_{10}	g_{11}
1	2.0000	1.0000									
2	1.4142	1.4142	1.0000								
3	1.0000	2.0000	1.0000	1.0000							
4	0.7654	1.8478	1.8478	0.7654	1.0000						
5	0.6180	1.6180	2.0000	1.6180	0.6180	1.0000					
6	0.5176	1.4142	1.9318	1.9318	1.4142	0.5176	1.0000				
7	0.4450	1.2470	1.8019	2.0000	1.8019	1.2470	0.4450	1.0000			
8	0.3902	1.1111	1.6629	1.9615	1.9615	1.6629	1.1111	0.3902	1.0000		
9	0.3473	1.0000	1.5321	1.8794	2.0000	1.8794	1.5321	1.0000	0.3473	1.0000	
10	0.3129	0.9080	1.4142	1.7820	1.9754	1.9754	1.7820	1.4142	0.9080	0.3129	1.0000

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.

Filtru prototip echiriplu

- Calculul elementelor filtrului (iterativ)

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

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

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

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

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

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.

Scalarea in impedanta si frecventa

- Dupa determinarea coeficientilor filtrului prototip
 - filtru FTJ
 - frecventa de taiere $\omega_o = 1 \text{ rad/s}$ ($f_o = 0.159 \text{ Hz}$)
 - conectate la intrare la o rezistenta $R = 1$
- Se pot calcula valorile necesare pentru componente pentru implementarea altor conditii

Scalarea in impedanta

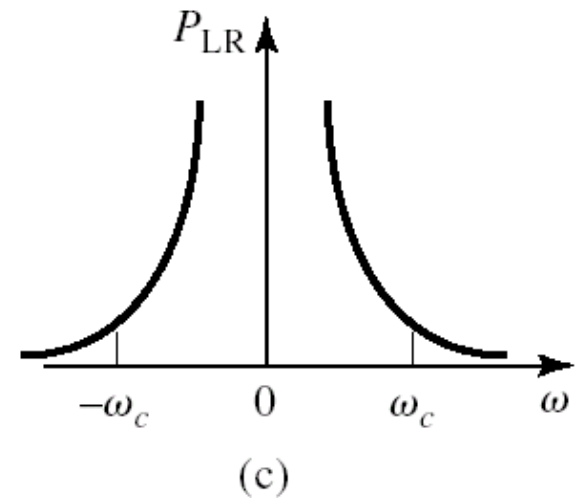
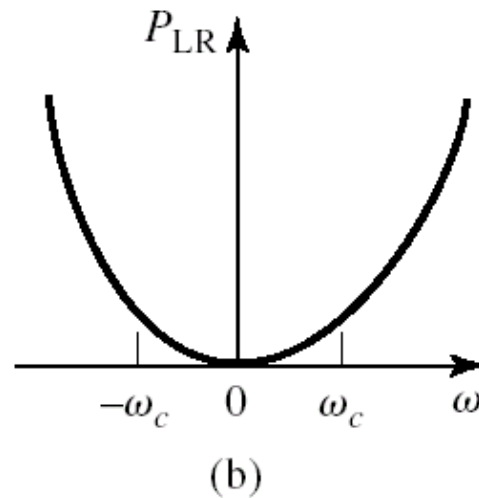
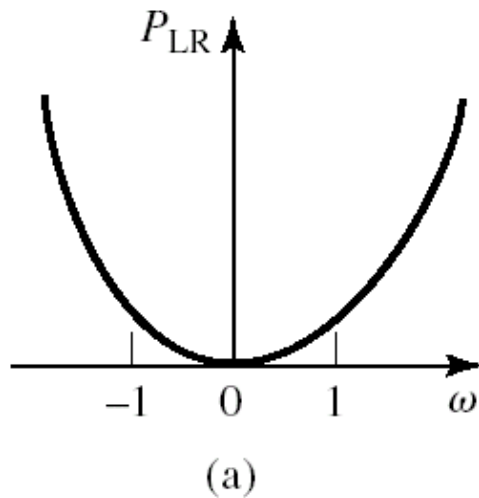
- Pentru a determina filtrul care lucreaza cu o alta rezistenta de intrare (R_0) se multiplica toate impedantele din circuit cu aceasta impedanta (cu " ' " se noteaza elementele noi)

$$R'_s = R_0 \quad R'_L = R_0 \cdot R_L$$

$$L' = R_0 \cdot L \quad C' = \frac{C}{R_0}$$

Scalarea in frecventa

- modificarea frecventei de taiere – (fig. b)
- modificarea caracteristicii de atenuare (de exemplu FTJ \rightarrow FTS – fig. c)



Scalarea in frecventa

- Pentru FTJ cu alta frecventa de taiere se face schimbarea de variabila:

$$\omega \leftarrow \frac{\omega}{\omega_c}$$

- Echivalent cu largirea caracteristicii de frecventa

$$P'_{LR}(\omega) = P_{LR}\left(\frac{\omega}{\omega_c}\right)$$

$$j \cdot X_k = j \cdot \frac{\omega}{\omega_c} \cdot L_k = j \cdot \omega \cdot L'_k$$

$$j \cdot B_k = j \cdot \frac{\omega}{\omega_c} \cdot C_k = j \cdot \omega \cdot C'_k$$

Scalarea FTJ \rightarrow FTJ

- Noile valori cu scalarea in frecventa

$$L'_k = \frac{L_k}{\omega_c} \quad C'_k = \frac{C_k}{\omega_c}$$

- Daca se aplica simultan si scalarea in impedanta

$$L'_k = \frac{R_0 \cdot L_k}{\omega_c} \quad C'_k = \frac{C_k}{R_0 \cdot \omega_c}$$

Scalarea FTJ \rightarrow FTS

- Se face schimbarea de variabila:

$$\omega \leftarrow -\frac{\omega_c}{\omega}$$

$$j \cdot X_k = -j \cdot \frac{\omega_c}{\omega} \cdot L_k = \frac{1}{j \cdot \omega \cdot C'_k} \quad j \cdot B_k = -j \cdot \frac{\omega_c}{\omega} \cdot C_k = \frac{1}{j \cdot \omega \cdot L'_k}$$

- Daca se aplica simultan si scalarea in impedanta

$$C'_k = \frac{1}{R_0 \cdot \omega_c \cdot L_k} \quad L'_k = \frac{R_0}{\omega_c \cdot C_k}$$

- In schema inductantele serie se transforma in capacitati serie, iar capacitatile paralel se transforma in inductante paralel

Scalarea FTJ \rightarrow FTB

- Se face schimbarea de variabila:

$$\omega \leftarrow \frac{\omega_0}{\omega_2 - \omega_1} \left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega} \right) = \frac{1}{\Delta} \left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega} \right)$$

- unde intervin banda fractionara si frecventa centrala

$$\Delta = \frac{\omega_2 - \omega_1}{\omega_0}$$

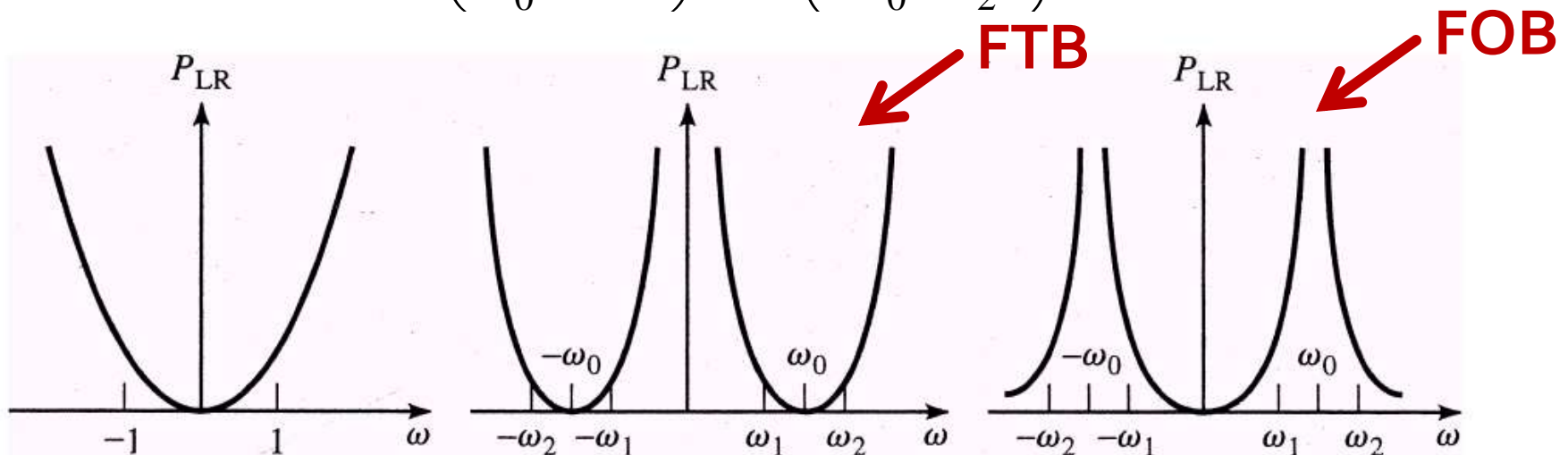
$$\omega_0 = \sqrt{\omega_1 \cdot \omega_2}$$

Scalarea FTJ \rightarrow FTB

$$\omega = \omega_0 \rightarrow \frac{1}{\Delta} \left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega} \right) = 0$$

$$\omega = \omega_1 \rightarrow \frac{1}{\Delta} \left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega} \right) = \frac{1}{\Delta} \left(\frac{\omega_1^2 - \omega_0^2}{\omega_0 \cdot \omega_1} \right) = -1$$

$$\omega = \omega_2 \rightarrow \frac{1}{\Delta} \left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega} \right) = \frac{1}{\Delta} \left(\frac{\omega_2^2 - \omega_0^2}{\omega_0 \cdot \omega_2} \right) = 1$$



Scalarea FTJ \rightarrow FTB

$$j \cdot X_k = \frac{j}{\Delta} \left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega} \right) \cdot L_k = j \cdot \frac{\omega \cdot L_k}{\Delta \cdot \omega_0} - j \cdot \frac{\omega_0 \cdot L_k}{\Delta \cdot \omega} = j \cdot \omega \cdot L'_k - j \frac{1}{\omega \cdot C'_k}$$
$$j \cdot B_k = \frac{j}{\Delta} \left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega} \right) \cdot C_k = j \cdot \frac{\omega \cdot C_k}{\Delta \cdot \omega_0} - j \cdot \frac{\omega_0 \cdot C_k}{\Delta \cdot \omega} = j \cdot \omega \cdot C'_k - j \frac{1}{\omega \cdot L'_k}$$

- O **inductanta** serie in filtrul prototip se transforma intr-un circuit **LC serie**

$$L'_k = \frac{L_k}{\Delta \cdot \omega_0} \quad C'_k = \frac{\Delta}{\omega_0 \cdot L_k}$$

- O **capacitate** paralel in filtrul prototip se transforma intr-un circuit **LC paralel**

$$L'_k = \frac{\Delta}{C_k \cdot \omega_0} \quad C'_k = \frac{C_k}{\omega_0 \cdot \Delta}$$

Scalarea FTJ \rightarrow FOB

$$\omega \leftarrow -\Delta \cdot \left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega} \right)^{-1}$$

- O **inductanta** serie in filtrul prototip se transforma intr-un circuit **LC paralel**

$$L'_k = \frac{\Delta \cdot L_k}{\omega_0} \quad C'_k = \frac{1}{\omega_0 \cdot \Delta \cdot L_k}$$

- O **capacitate** paralel in filtrul prototip se transforma intr-un circuit **LC serie**

$$L'_k = \frac{1}{\Delta \cdot \omega_0 \cdot C_k} \quad C'_k = \frac{\Delta \cdot C_k}{\omega_0}$$

Transformari ale filtrului prototip


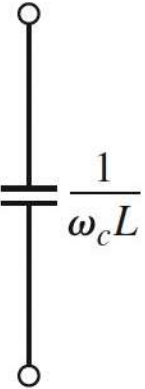
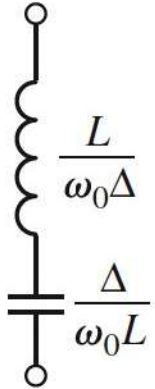
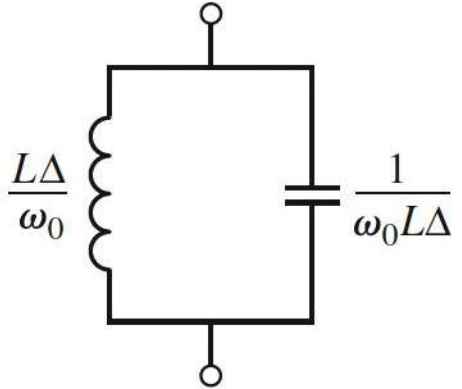
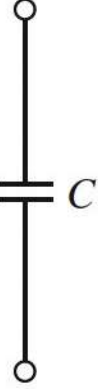
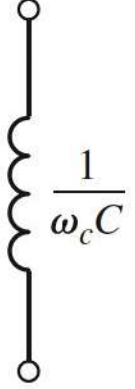
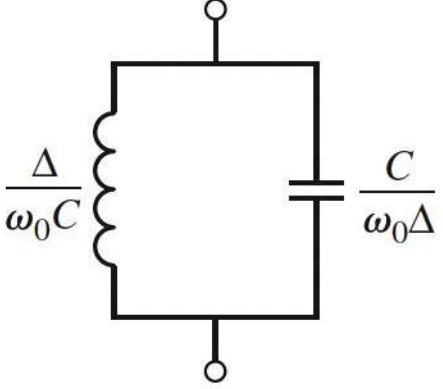
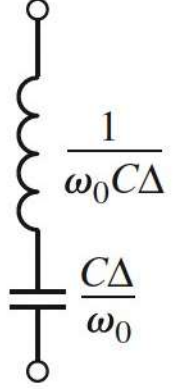
Low-pass	High-pass	Bandpass	Bandstop
			
			

Table 8.6

Exemplu

- Să se proiecteze un filtru trece-bandă de ordinul 3, avînd riplurile în bandă de 0.5 dB. Frecvența centrală a filtrului sa fie de 1 GHz. Banda să fie de 10%, și impedanța de 50 Ω .

Exemplu

- Să se proiecteze un filtru trece-bandă de ordinul 3, avînd riplurile în bandă de 0.5 dB. Frecvența centrală a filtrului sa fie de 1 GHz. Banda să fie de 10%, și impedanța de 50 Ω .

$$\omega_0 = 2 \cdot \pi \cdot 1 \text{ GHz} = 6.283 \cdot 10^9 \text{ rad} / \text{s}$$

$$\Delta = 0.1$$

Tabel echiriplu 0.5dB sau relatii de calcul:

$$g_1 = 1.5963 = L_1,$$

$$g_2 = 1.0967 = C_2,$$

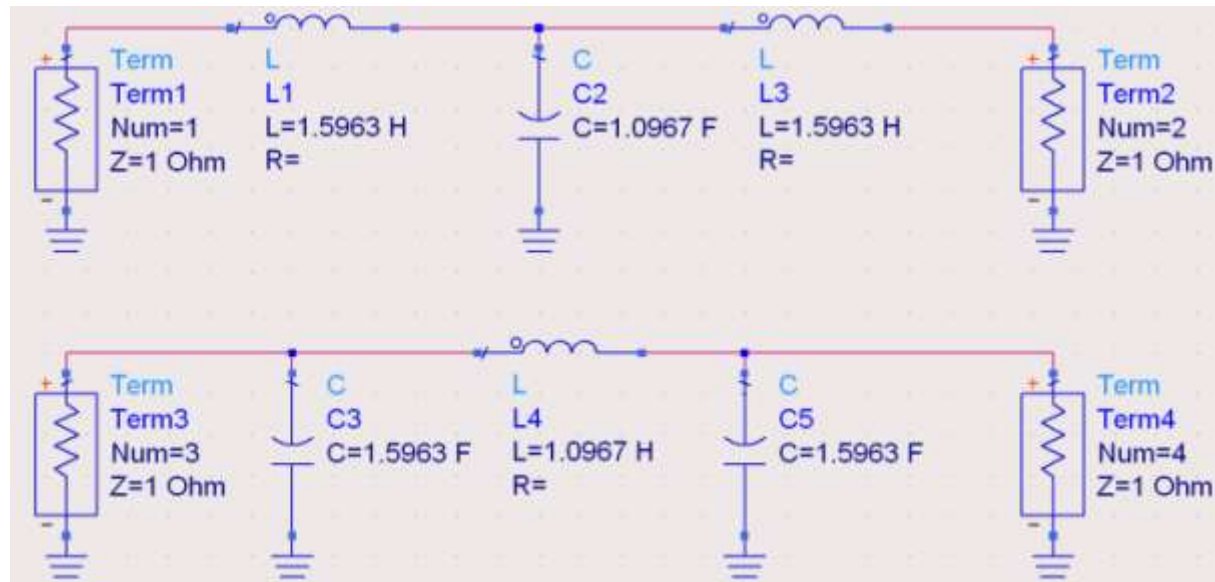
$$g_3 = 1.5963 = L_3,$$

$$g_4 = 1.000 = R_L$$

Filtru prototip

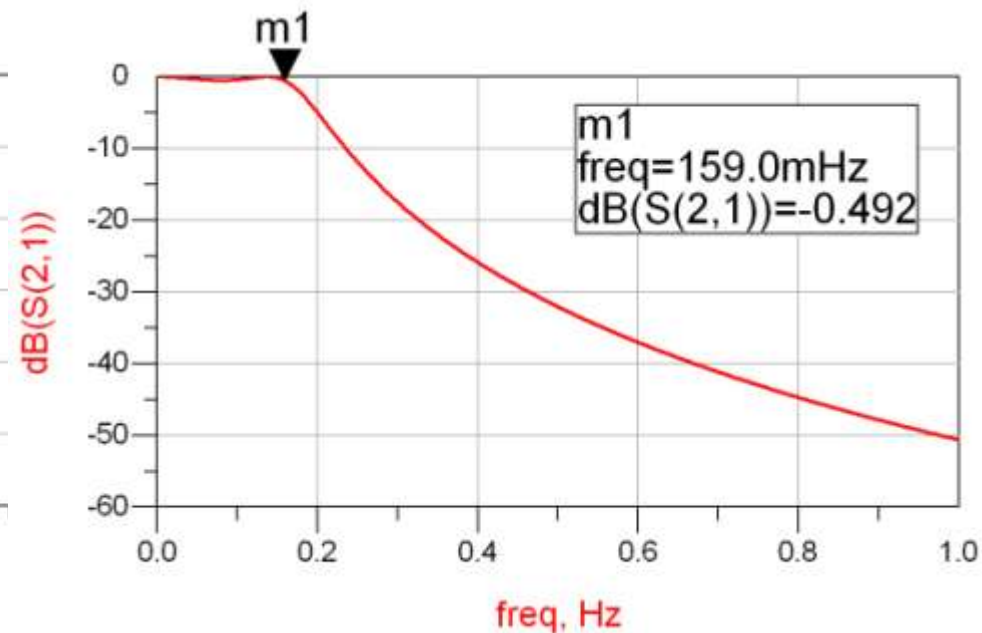
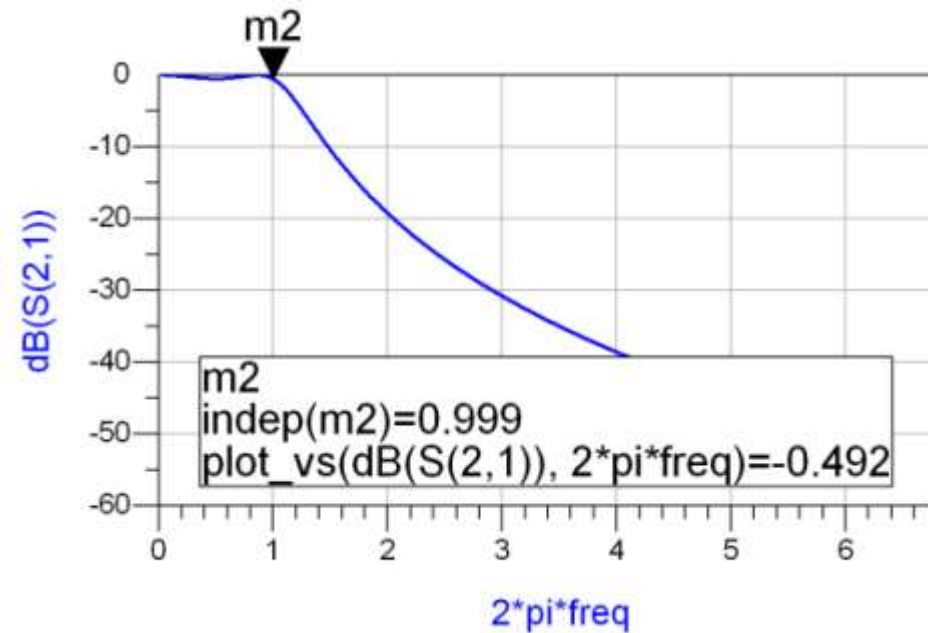
- Tabel echiriplu 0.5dB sau relatii de calcul:

- $g_1 = 1.5963 = L_1/C_3,$
- $g_2 = 1.0967 = C_2/L_4,$
- $g_3 = 1.5963 = L_3/C_5,$
- $g_4 = 1.000 = R_L$



Filtru prototip

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



Scalare frecventa / FTB

$$\omega_0 = 2 \cdot \pi \cdot 1 \text{GHz} = 6.283 \cdot 10^9 \text{ rad} / \text{s} \quad \Delta = \frac{\Delta \omega}{\omega_0} = \frac{\Delta f}{f_0} = 0.1 \quad R_0 = 50 \Omega$$

$$g_1 = 1.5963 = L_1,$$

$$g_2 = 1.0967 = C_2,$$

$$g_3 = 1.5963 = L_3,$$

$$g_4 = 1.000 = R_L$$

$$L'_1 = \frac{L_1 \cdot R_0}{\Delta \cdot \omega_0} = 127.0 \text{ nH}$$

$$C'_1 = \frac{\Delta}{\omega_0 \cdot L_1 \cdot R_0} = 0.199 \text{ pF}$$

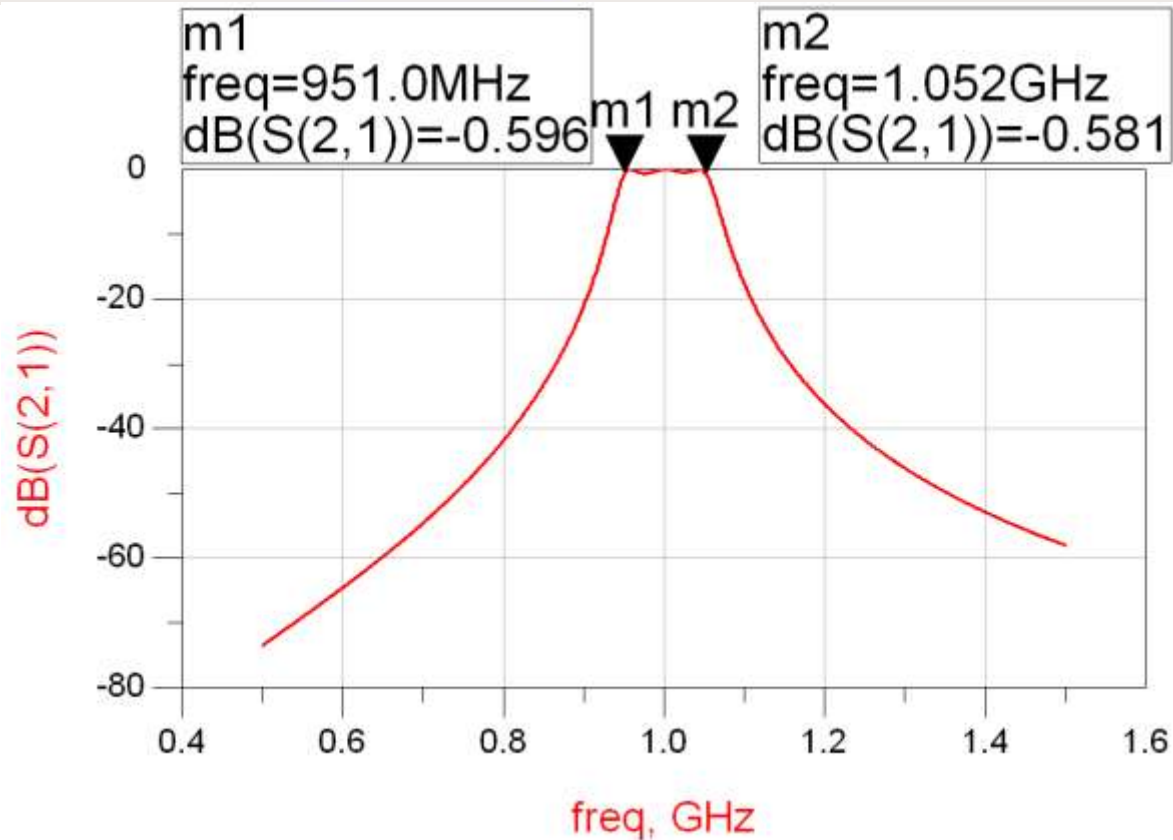
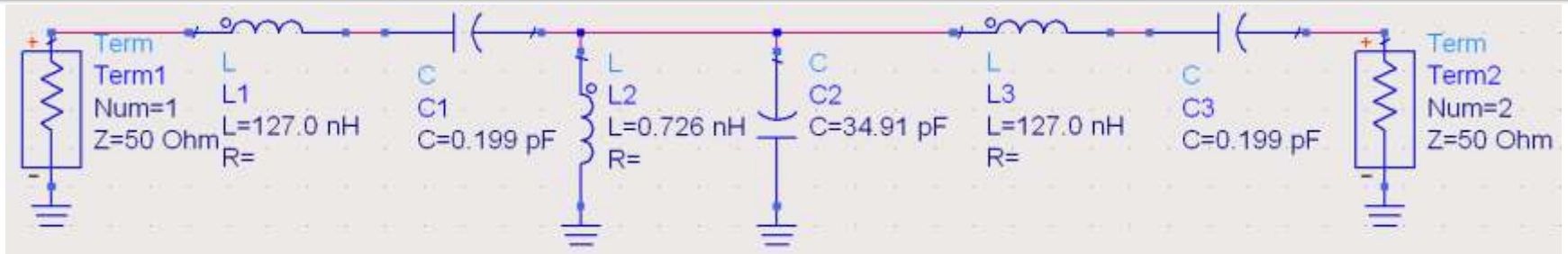
$$L'_2 = \frac{\Delta \cdot R_0}{\omega_0 \cdot C_2} = 0.726 \text{ nH}$$

$$C'_2 = \frac{C_2}{\Delta \cdot \omega_0 \cdot R_0} = 34.91 \text{ pF}$$

$$L'_3 = \frac{L_3 \cdot R_0}{\Delta \cdot \omega_0} = 127.0 \text{ nH}$$

$$C'_3 = \frac{\Delta}{\omega_0 \cdot L_3 \cdot R_0} = 0.199 \text{ pF}$$

ADS



Implementarea filtrelor pentru microunde

Transformarea Richards

- Impedanta vazuta la intrarea unei linii terminate cu Z_L

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

- Tehnologic e preferabil ca impedanta de capat sa fie:

- gol ($Z_L = \infty$) $Z_{in,g} = -j \cdot Z_0 \cdot \cot \beta \cdot l$

- scurtcircuit ($Z_L = 0$) $Z_{in,sc} = j \cdot Z_0 \cdot \tan \beta \cdot l$

- Se obtine comportare:

- capacitiva $Z_{in,g} = j \cdot X_C = \frac{1}{j \cdot B_C}$

- inductiva $Z_{in,sc} = j \cdot X_L$

$$Z_0 \leftrightarrow \frac{1}{C} \quad \tan \beta \cdot l \leftrightarrow \omega$$

$$Z_0 \leftrightarrow L \quad \tan \beta \cdot l \leftrightarrow \omega$$

Transformarea Richards

- Schimbare de variabila

$$\Omega = \tan \beta \cdot l = \tan \left(\frac{\omega \cdot l}{v_p} \right)$$

- Cu aceasta schimbare de variabila definim
 - reactanta unei inductante

$$j \cdot X_L = j \cdot \Omega \cdot L = j \cdot L \cdot \tan \beta \cdot l$$

- susceptanta unei capacitati

$$j \cdot B_C = j \cdot \Omega \cdot C = j \cdot C \cdot \tan \beta \cdot l$$

- Filtrul echivalent in Ω are frecventa de taiere la:

$$\Omega = 1 = \tan \beta \cdot l \rightarrow \beta \cdot l = \frac{\pi}{4} \rightarrow l = \frac{\lambda}{8}$$

Transformarea Richards

- Alegand sectiunile de linie in gol sau scurtcircuit sa fie $\lambda/8$ la frecventa de taiere dorita (ω_c) si impedantele caracteristice corespunzatoare (L/C) vom obtine foarte precis la frecvente in jurul lui ω_c o comportare similara cu a filtrului prototip
 - La frecvente departate de ω_c comportarea filtrului nu va mai fi identica cu a prototipului (in situatii specifice trebuie **verificata** o comportare potrivita cu tipul de filtru dorit)
 - Scalarea in frecventa se simplifica: alegerea lungimii fizice pentru indeplinirea lungimii electrice $\lambda/8$ la frecventa dorita
- Toate sectiunile de linii vor avea lungimi electrice egale ($\lambda/8$) si lungimi fizice comparabile, deci liniile se numesc linii **comensurabile**

Transformarea Richards

- la frecventa $\omega = 2 \cdot \omega_c$ lungimile liniilor sunt $\lambda/4$
$$l = \frac{\lambda}{4} \Rightarrow \beta \cdot l = \frac{\pi}{2} \Rightarrow \tan \beta \cdot l \rightarrow \infty$$
- apare un pol suplimentar de atenuare la $2 \cdot \omega_c$ (FTJ)
 - inductantele (de obicei in serie) $Z_{in,sc} = j \cdot Z_0 \cdot \tan \beta \cdot l \rightarrow \infty$
 - capacitatile (de obicei in paralel) $Z_{in,g} = -j \cdot Z_0 \cdot \cot \beta \cdot l \rightarrow 0$

Transformarea Richards

- periodicitatea functiei tangenta genereaza periodicitatea raspunsului in frecventa al circuitelor cu linii
 - raspunsul filtrului se repeta la fiecare $4 \cdot \omega_c$

$$\tan(\alpha + \pi) = \tan \alpha$$

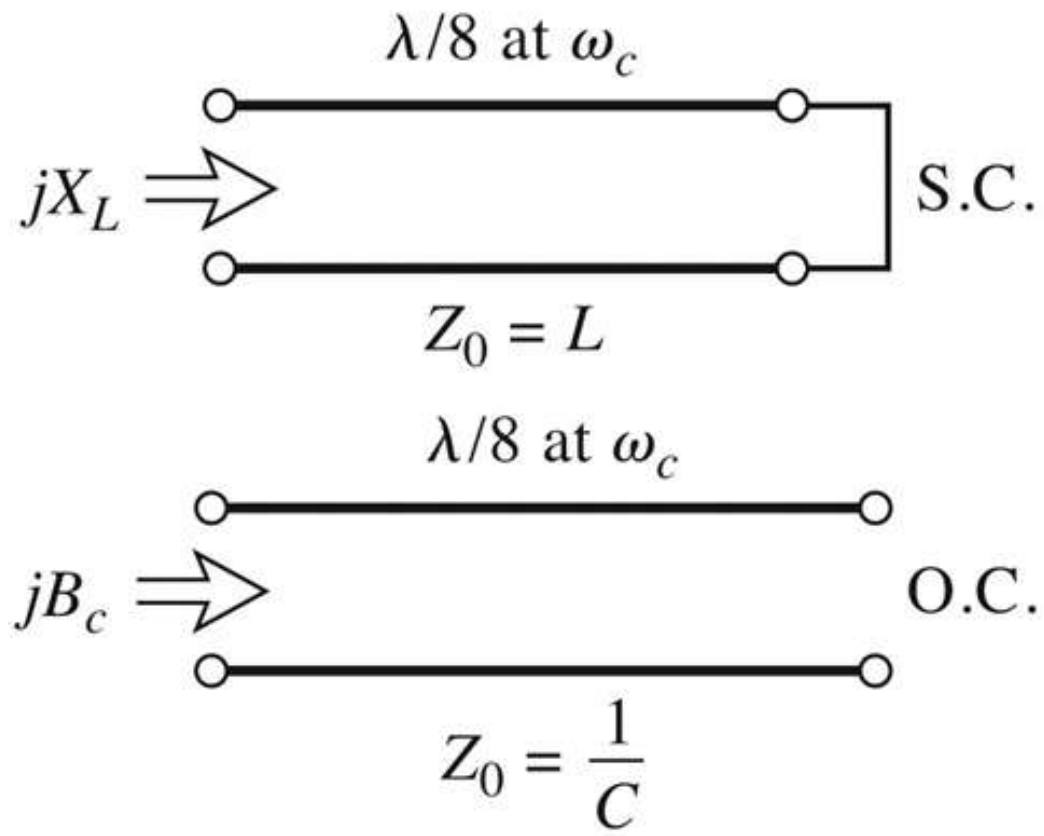
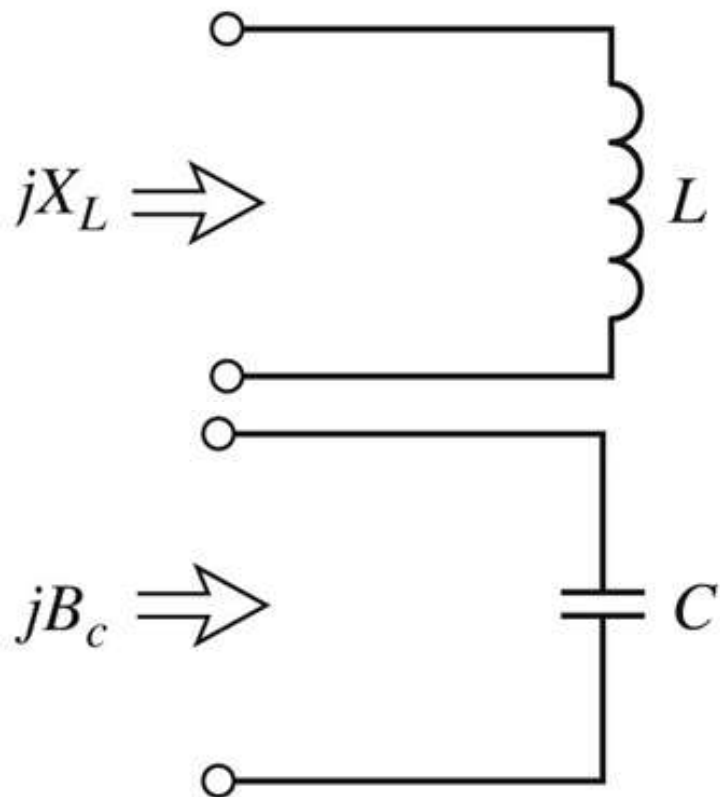
$$\beta \cdot l \Big|_{\omega=\omega_c} = \frac{\pi}{4} \Rightarrow \frac{\omega_c \cdot l}{v_p} = \frac{\pi}{4} \Rightarrow \pi = \frac{(4 \cdot \omega_c) \cdot l}{v_p}$$

$$Z_{in}(\omega) = Z_{in}(\omega + 4 \cdot \omega_c) \Rightarrow P_{LR}(\omega) = P_{LR}(\omega + 4 \cdot \omega_c)$$

$$P_{LR}(4 \cdot \omega_c) = P_{LR}(0) \quad P_{LR}(3 \cdot \omega_c) = P_{LR}(-\omega_c) \quad P_{LR}(5 \cdot \omega_c) = P_{LR}(\omega_c)$$

Transformarea Richards

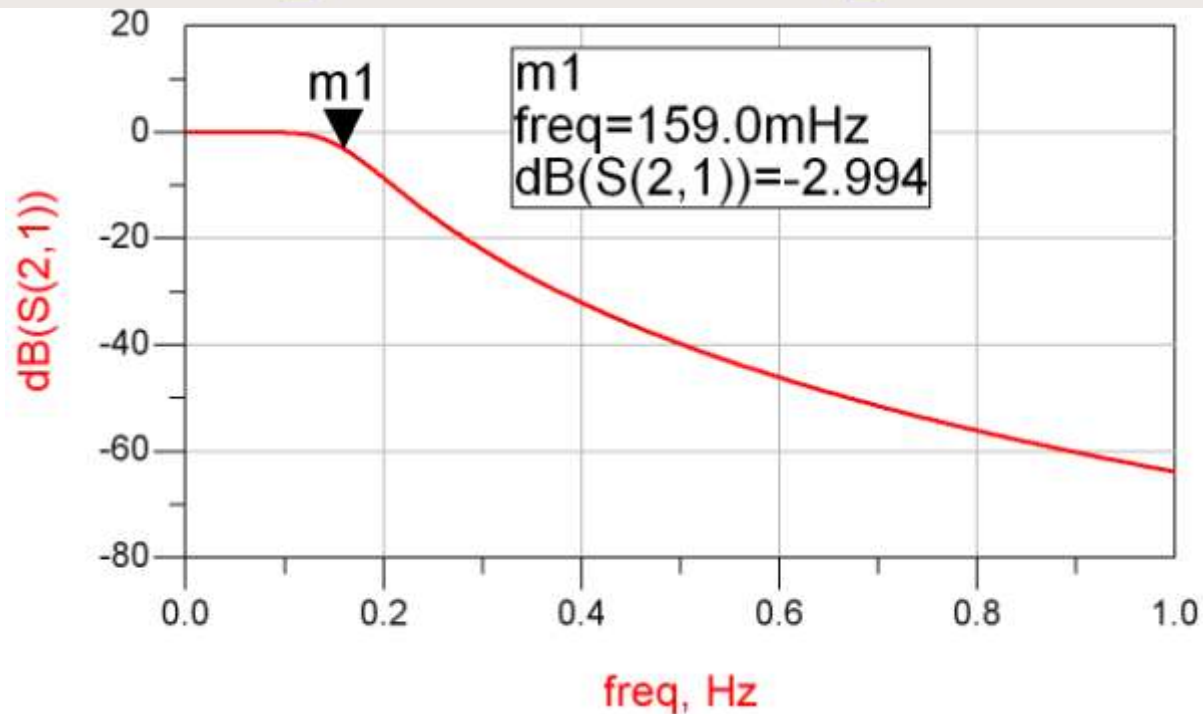
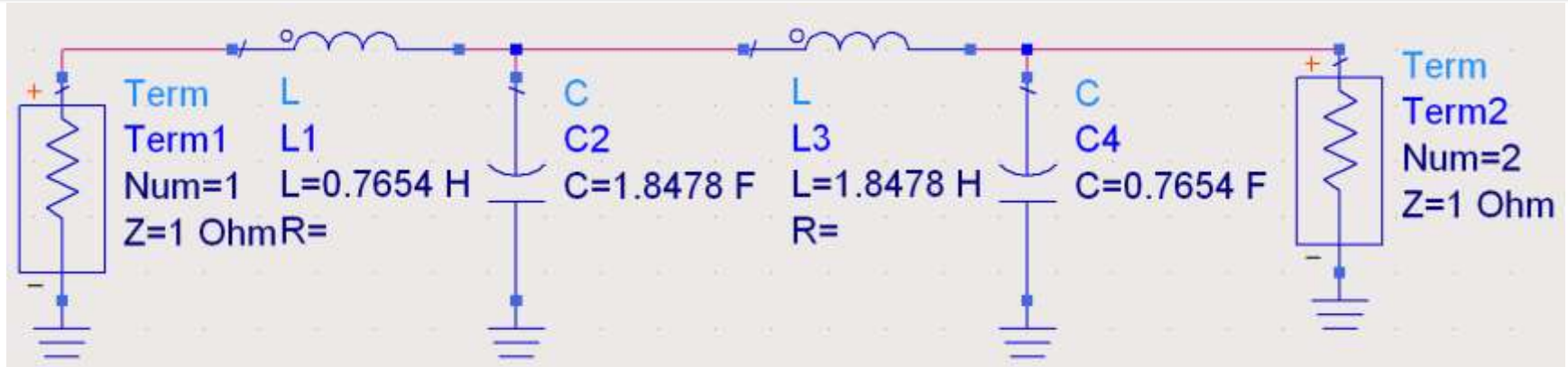
- permite obtinerea cu sectiuni de linii a inductantelor si capacitatilor **dupa** scalarea prototipului pentru functia corespunzatoare (FTJ/FTS/FTB /FOB)



Exemplu

- Filtru trece jos de ordinul 4, cu frecventa de taiere de 4 GHz, de tip maxim plat (care sa functioneze pe 50Ω 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)

Prototip FTJ



Elemente concentrare

$$\omega_c = 2 \cdot \pi \cdot 4 \text{GHz} = 2.5133 \cdot 10^{10} \text{rad/s}$$

$$g_1 = 0.7654 = L_1,$$

$$g_2 = 1.8478 = C_2,$$

$$g_3 = 1.8478 = L_3,$$

$$g_4 = 0.7654 = C_4,$$

$$g_5 = 1 = RL$$

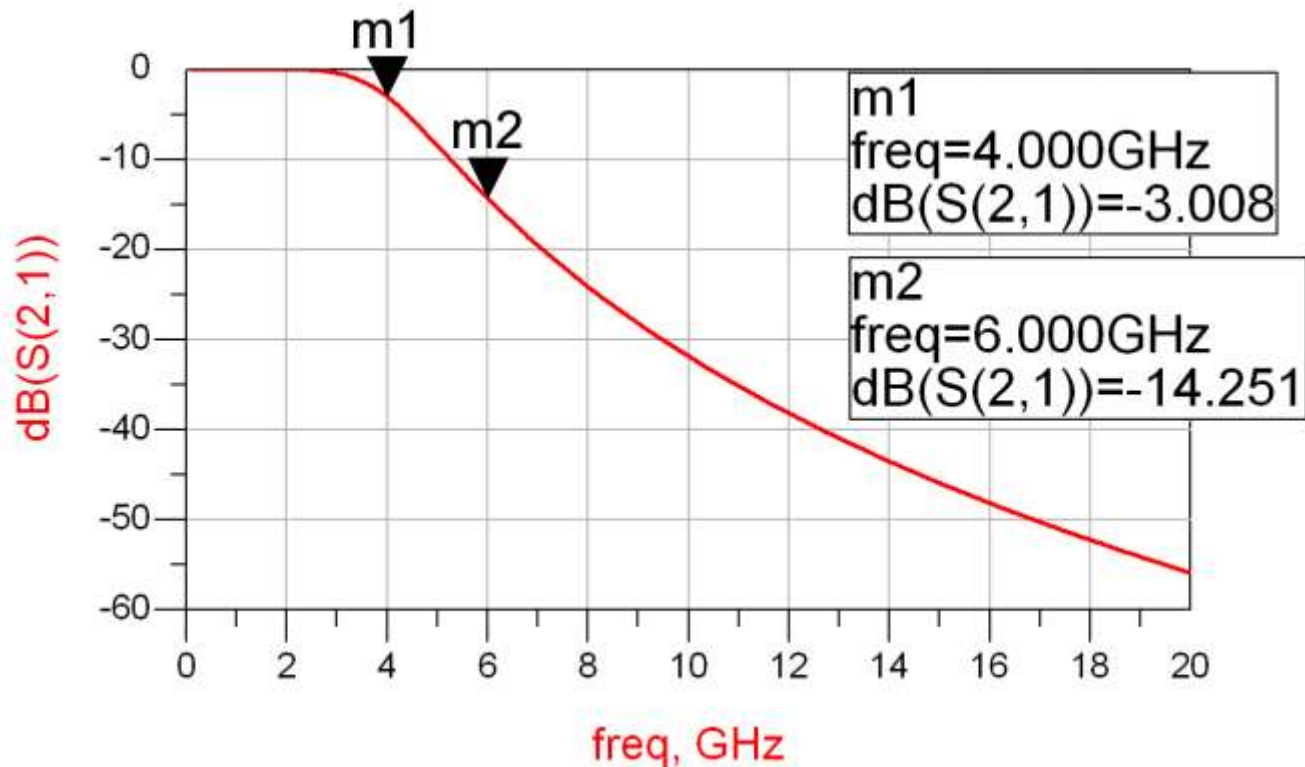
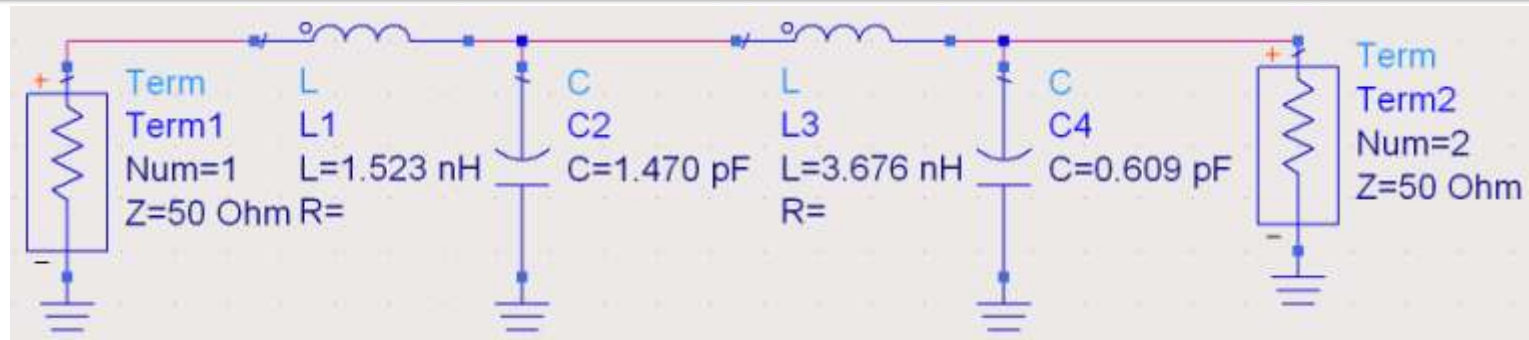
$$L'_1 = \frac{R_0 \cdot L_1}{\omega_c} = 1.523 \text{ nH}$$

$$C'_2 = \frac{C_2}{R_0 \cdot \omega_c} = 1.470 \text{ pF}$$

$$L'_3 = \frac{R_0 \cdot L_3}{\omega_c} = 3.676 \text{ nH}$$

$$C'_4 = \frac{C_4}{R_0 \cdot \omega_c} = 0.609 \text{ pF}$$

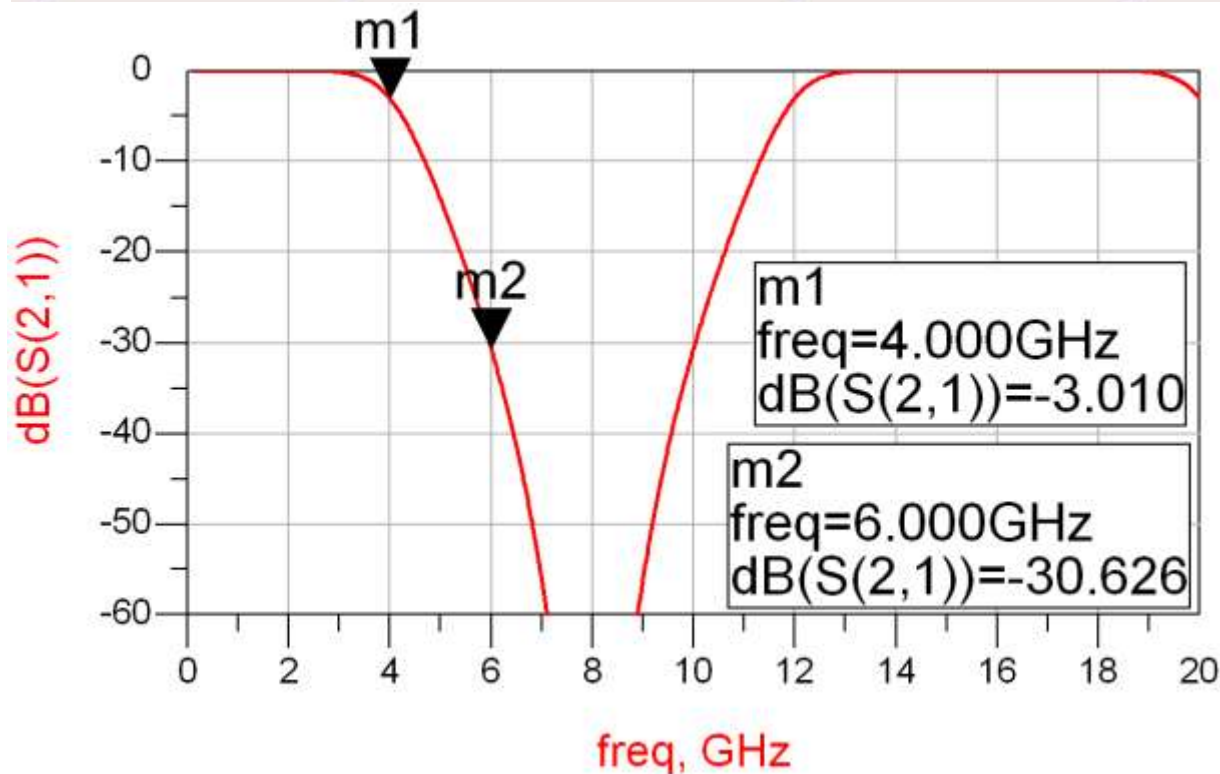
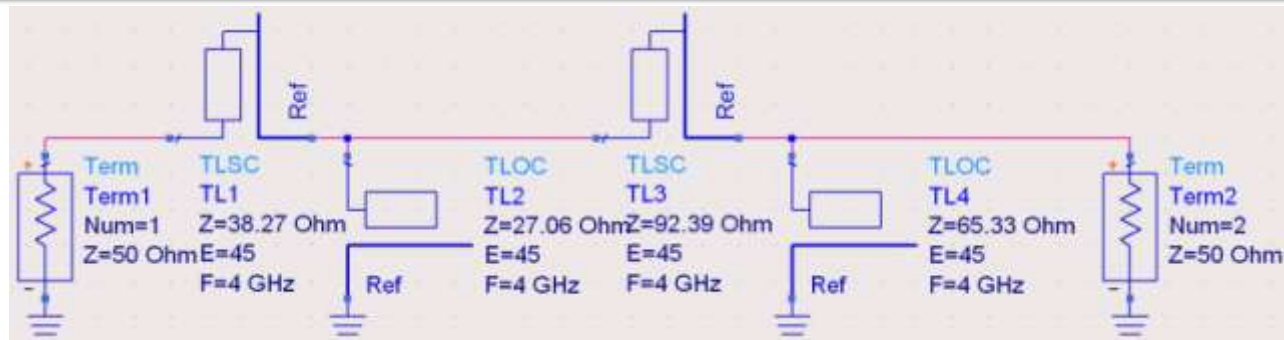
Elemente concentrate – ADS



Transformarea Richards

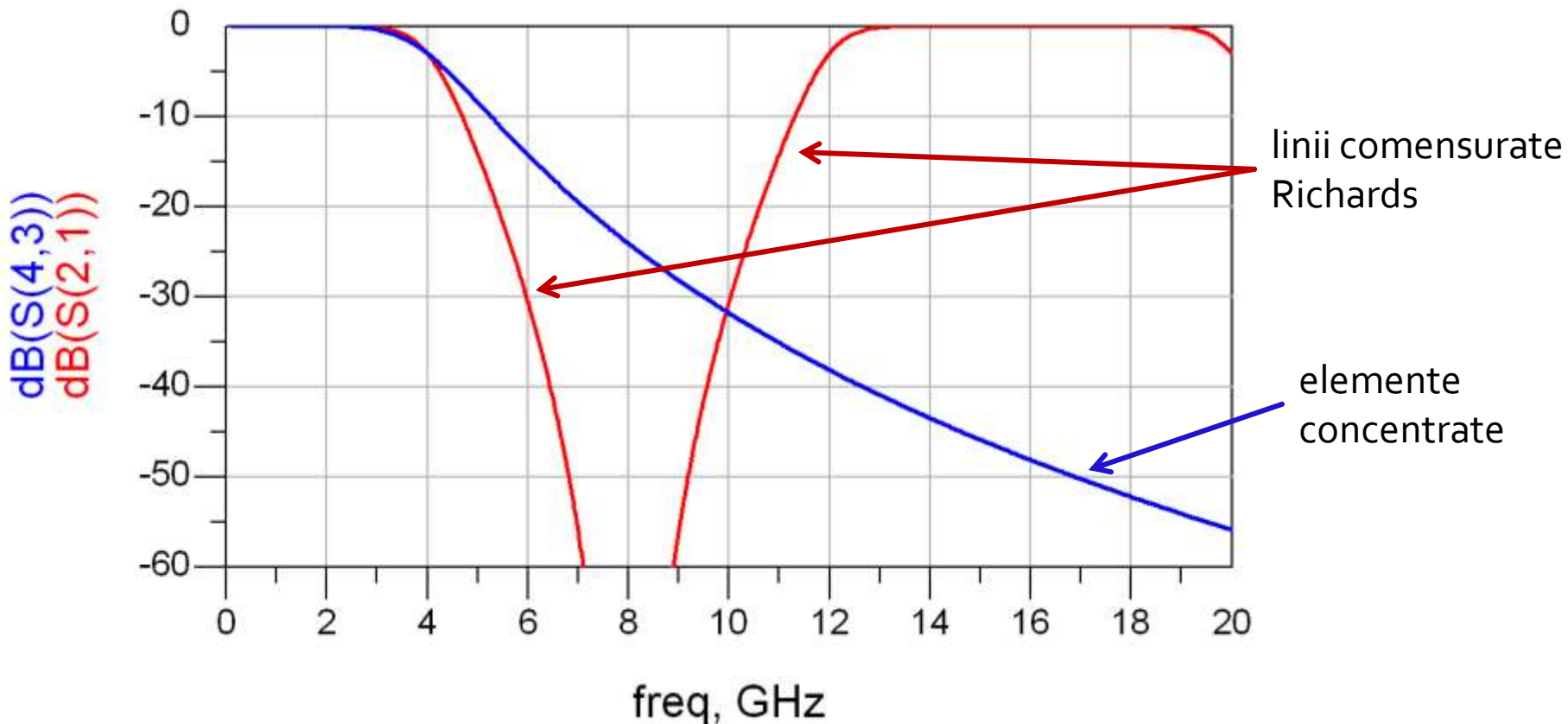
- Parametrii filtrului prototip:
 - $g_1 = 0.7654 = L_1$
 - $g_2 = 1.8478 = C_2$
 - $g_3 = 1.8478 = L_3$
 - $g_4 = 0.7654 = C_4$
- Impedantele raportate ale liniilor
 - $z_1 = 0.7654 = \text{serie / scurt circuit}$
 - $z_2 = 1 / 1.8478 = 0.5412 = \text{paralel / gol}$
 - $z_3 = 1.8478 = \text{serie / scurt circuit}$
 - $z_4 = 1 / 0.7654 = 1.3065 = \text{paralel / gol}$
- Scalarea in impedanta presupune inmultirea cu $Z_0 = 50\Omega$
- Toate liniile au lungimea $\lambda/8$ (lungime electrica 45°) la 4GHz

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



Filtru prototip echiriplu

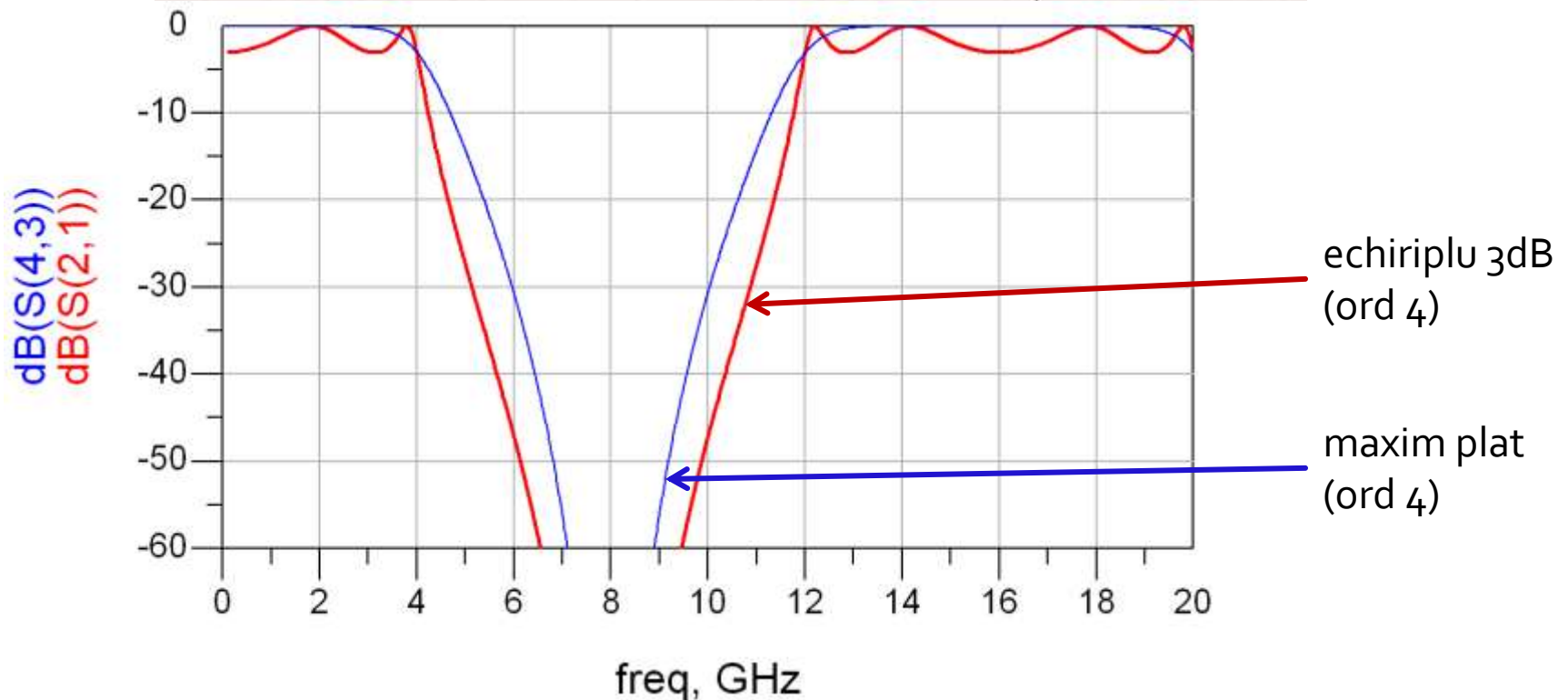
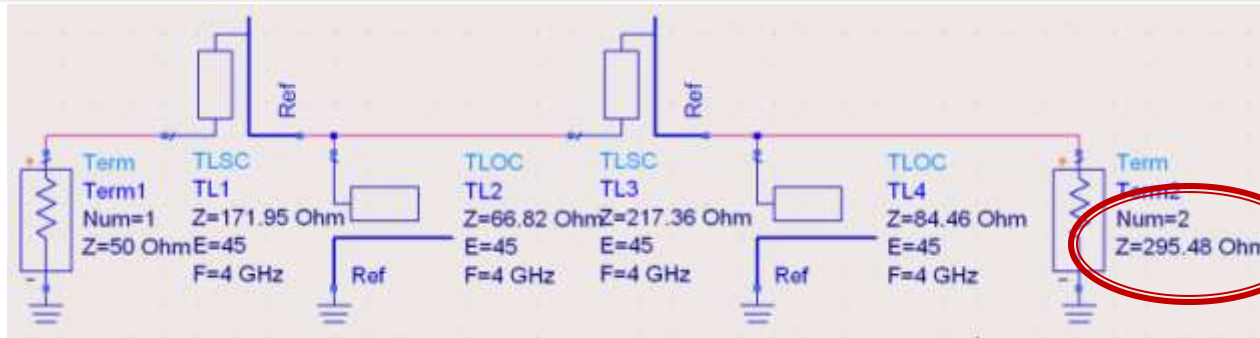
- Pentru ordin par al filtrului ($N = 2, 4, 6, 8 \dots$) filtrele echiriplu **trebuie** sa fie inchise pe o impedanta de terminatie diferita de cea standard
- Daca aplicatia nu suporta aceasta comportare, e necesara introducerea unei adaptari de impedanta suplimentare (transformator in sfert de lungime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

$$g_{N+1} \neq 1 \rightarrow R \neq R_0 \quad (50\Omega)$$

Observatie: ordin par/echiriplu

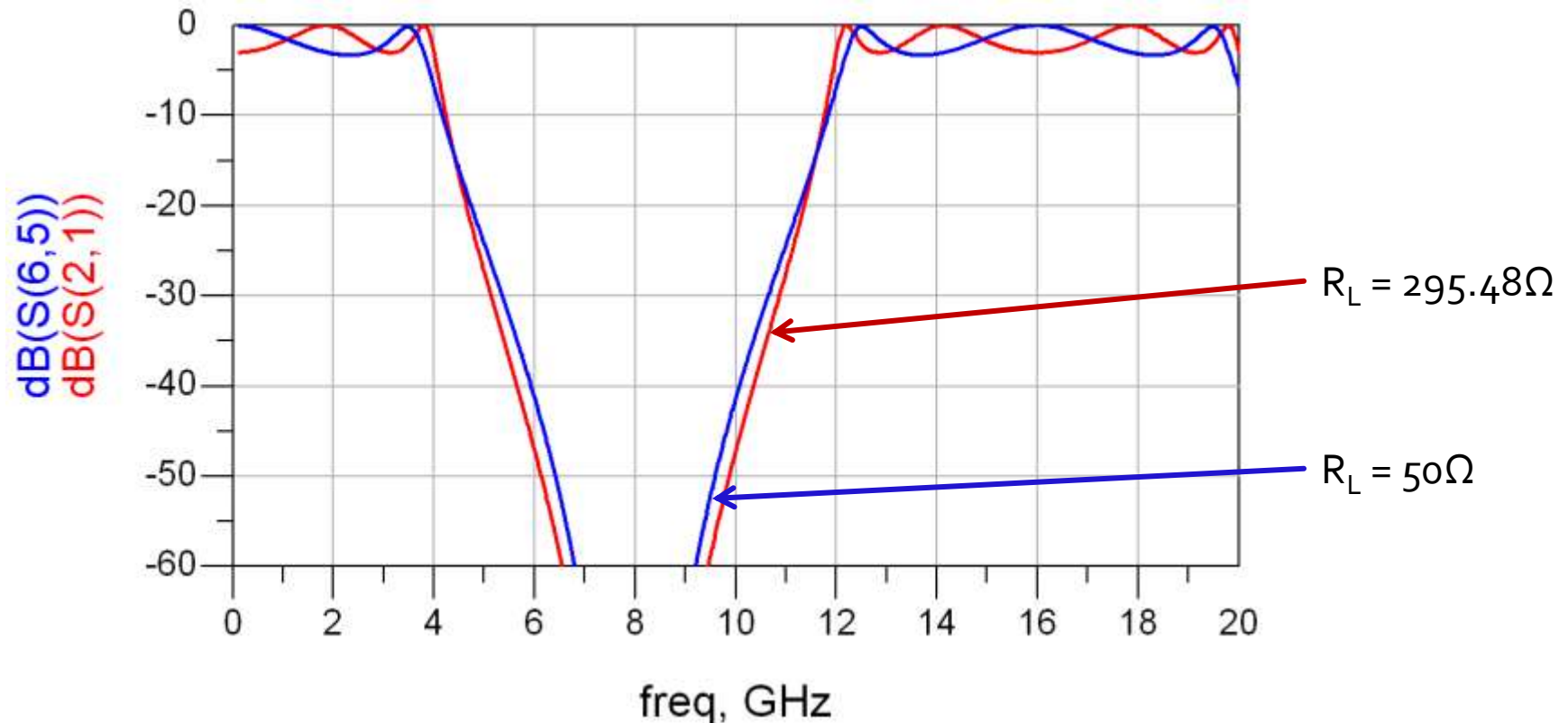
- Acelasi filtru, echiriplu 3dB
- Tabel echiriplu 3dB sau relatii de calcul:
 - $g_1 = 3.4389 = L_1$
 - $g_2 = 0.7483 = C_2$
 - $g_3 = 4.3471 = L_3$
 - $g_4 = 0.5920 = C_4$
 - $g_5 = 5.8095 = R_L$
- Impedantele liniilor
 - $Z_1 = 3.4389 \cdot 50\Omega = 171.945\Omega$ serie / scurt circuit
 - $Z_2 = 50\Omega / 0.7483 = 66.818\Omega$ = paralel / gol
 - $Z_3 = 4.3471 \cdot 50\Omega = 217.355\Omega$ serie / scurt circuit
 - $Z_4 = 50\Omega / 0.5920 = 84.459\Omega$ = paralel / gol
 - $R_L = 5.8095 \cdot 50\Omega = 295.475\Omega$ = sarcina

Ordin par/echiriplu – ADS



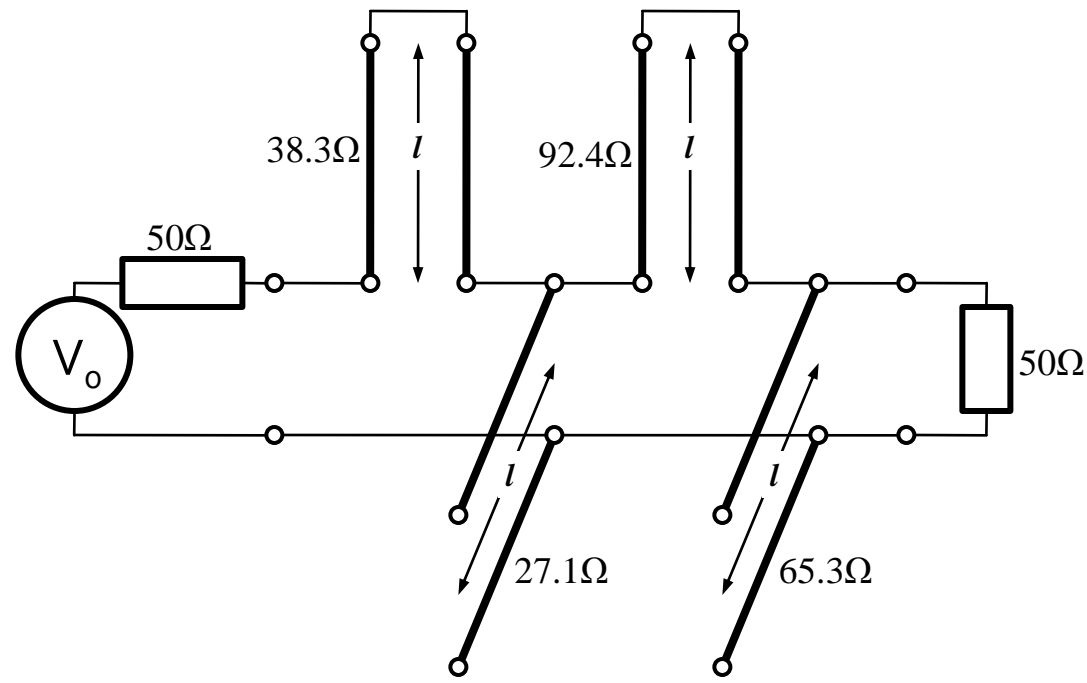
Observatie: ordin par/echiriplu

- Filtrele echiriplu au nevoie de adaptare la iesire spre 50Ω pentru a functiona precis.
Exemplu:



Identitatile Kuroda

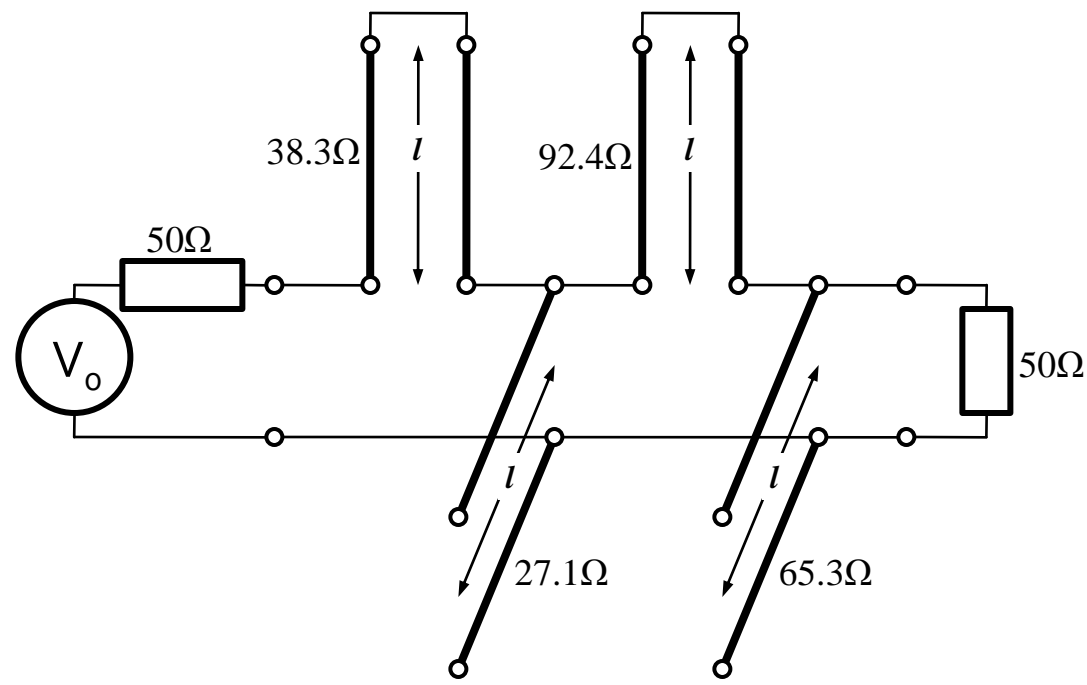
- Filtre implementate cu transformarea Richards au anumite dezavantaje in ceea ce priveste implementarea practica
- Identitatile/Transformarile Kuroda pot fi utilizate pentru a elimina o parte din aceste dezavantaje
- Se utilizeaza sectiuni de linie suplimentare pentru a obtine sisteme mai simplu de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



Identitatile Kuroda

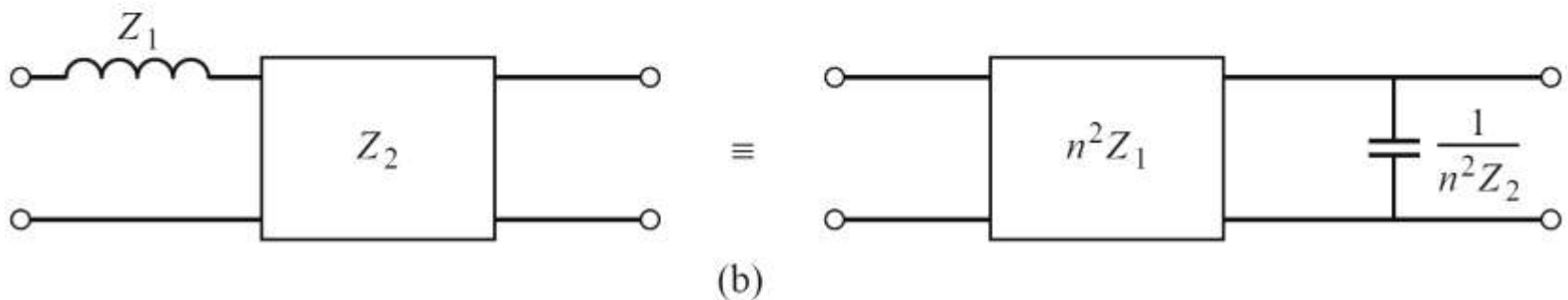
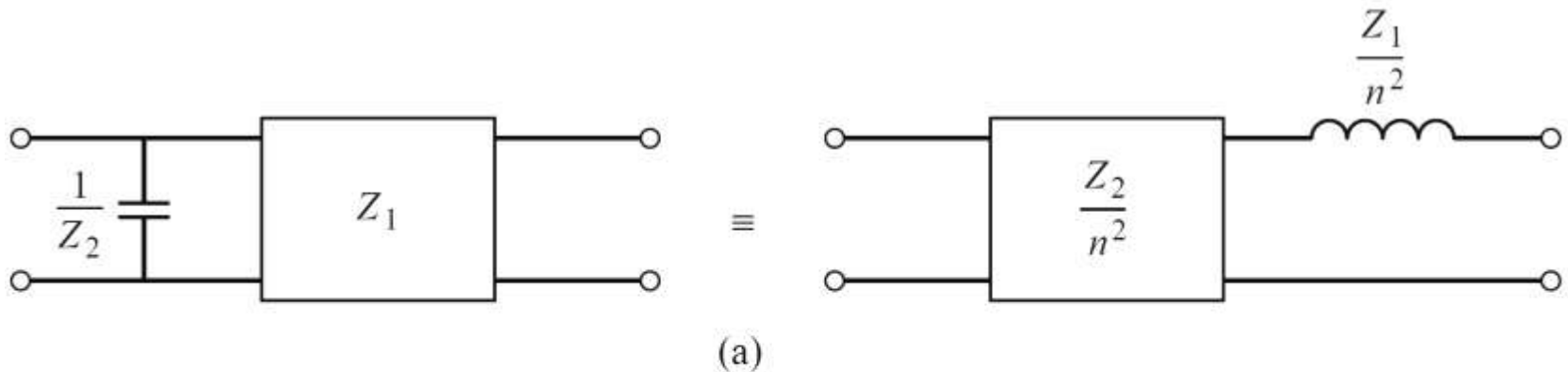
- Identitatile Kuroda pot fi utilizate pentru a realiza urmatoarele operatii:

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



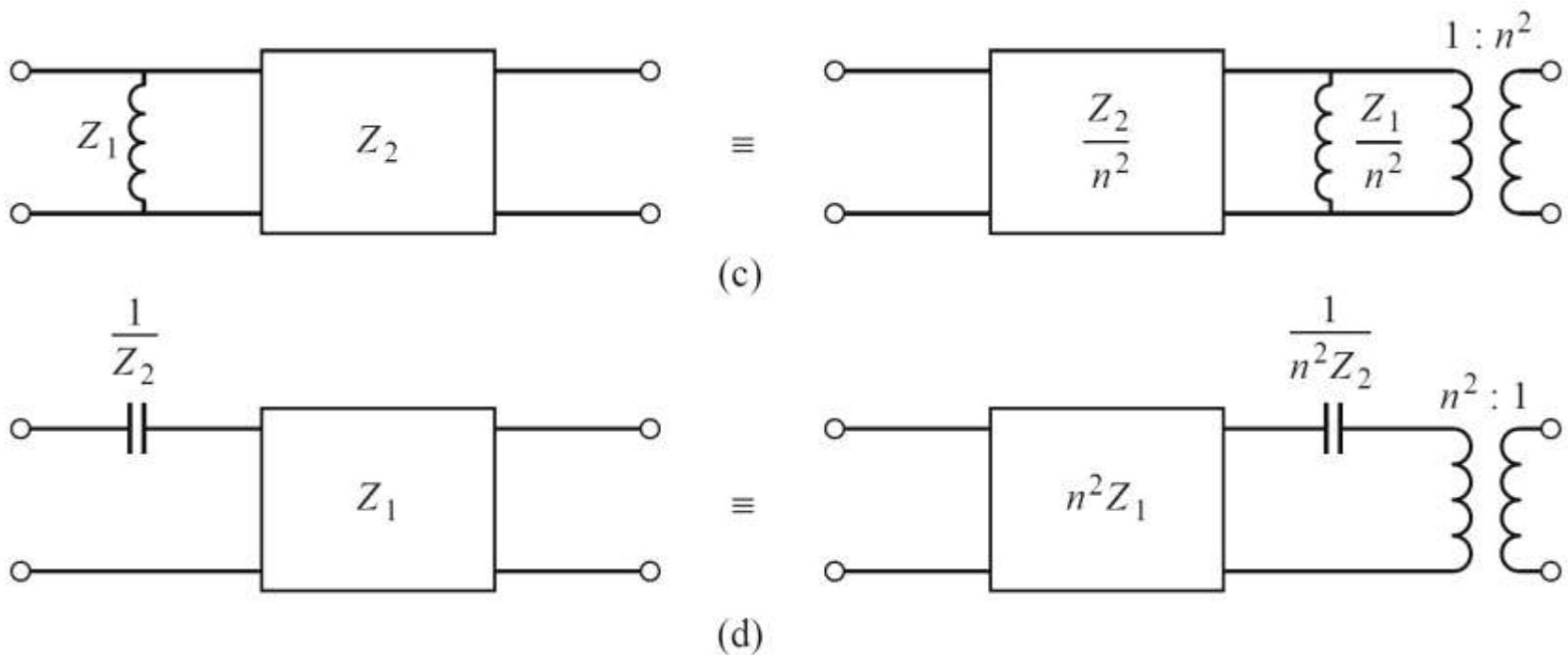
Identitățile Kuroda

- 4 echivalente de circuit



Identitățile Kuroda

- 4 echivalente de circuit



Identitatile Kuroda

- In toate echivalentele de scheme Kuroda:
 - n:
$$n^2 = 1 + \frac{Z_2}{Z_1}$$
 - inductantele si capacitatile reprezinta stub-uri scurtcircuitate sau in gol (obtinute prin transformarea Richards, de lungime $\lambda/8$)
 - blocurile reprezinta elemente unitare (linii de transmisie de impedanta caracteristica indicata si lungime $\lambda/8$)

Prima Identitate Kuroda

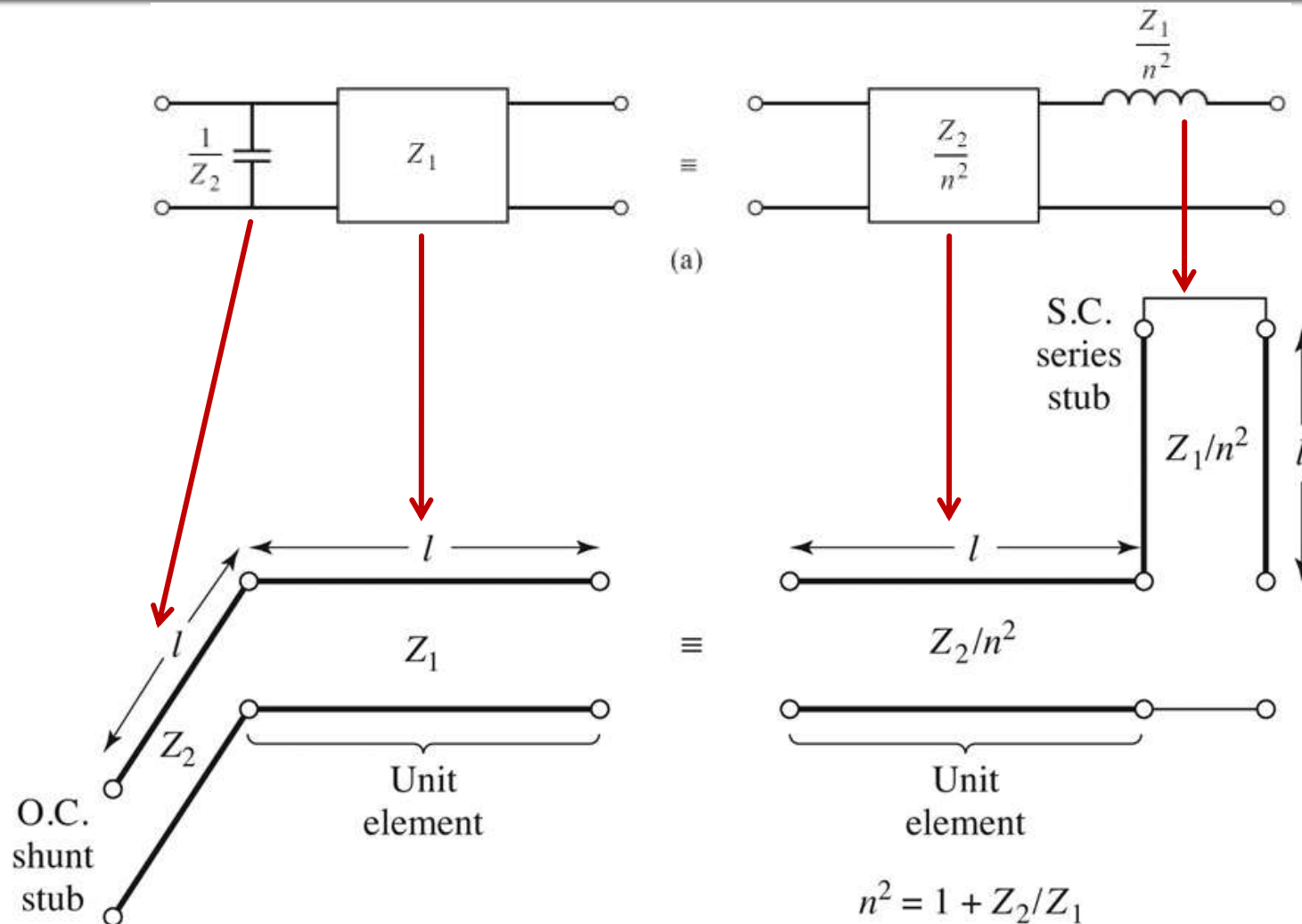
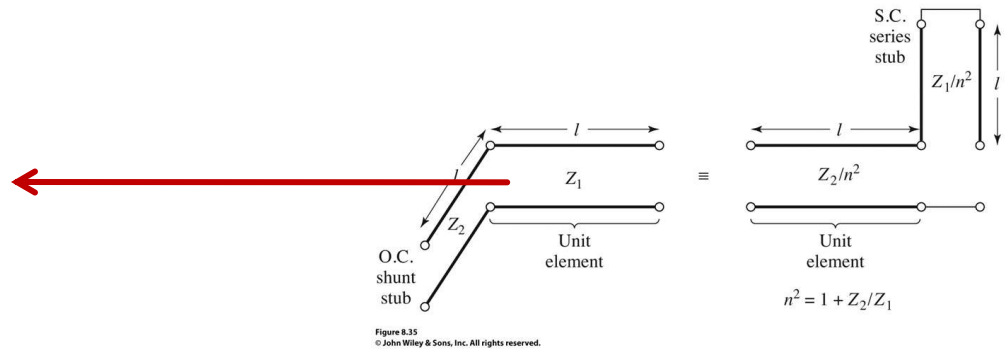
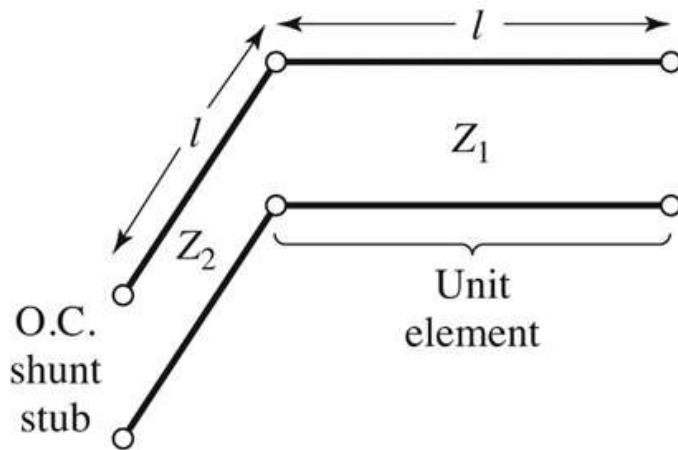
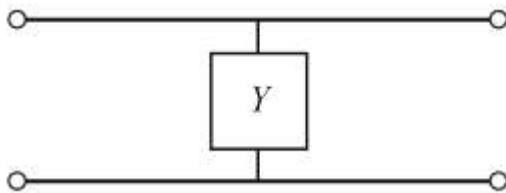


Figure 8.35
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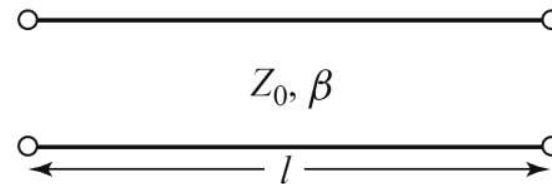
Prima Identitate Kuroda – Demonstratie



■ Matrici ABCD, C₄



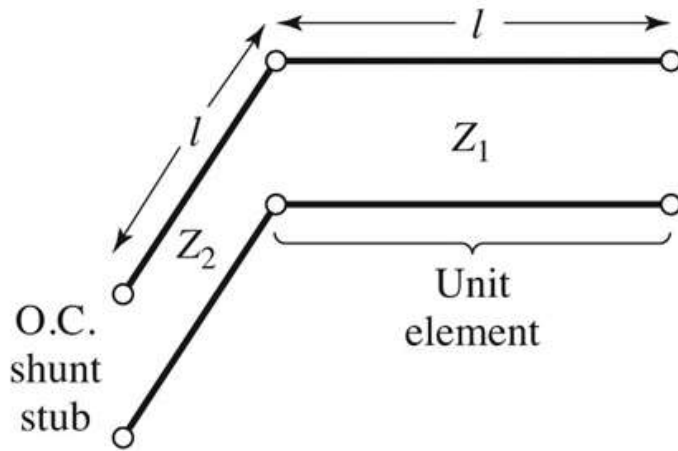
+



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

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

Prima Identitate Kuroda – Demonstratie



$$\Omega = \tan \beta \cdot l$$

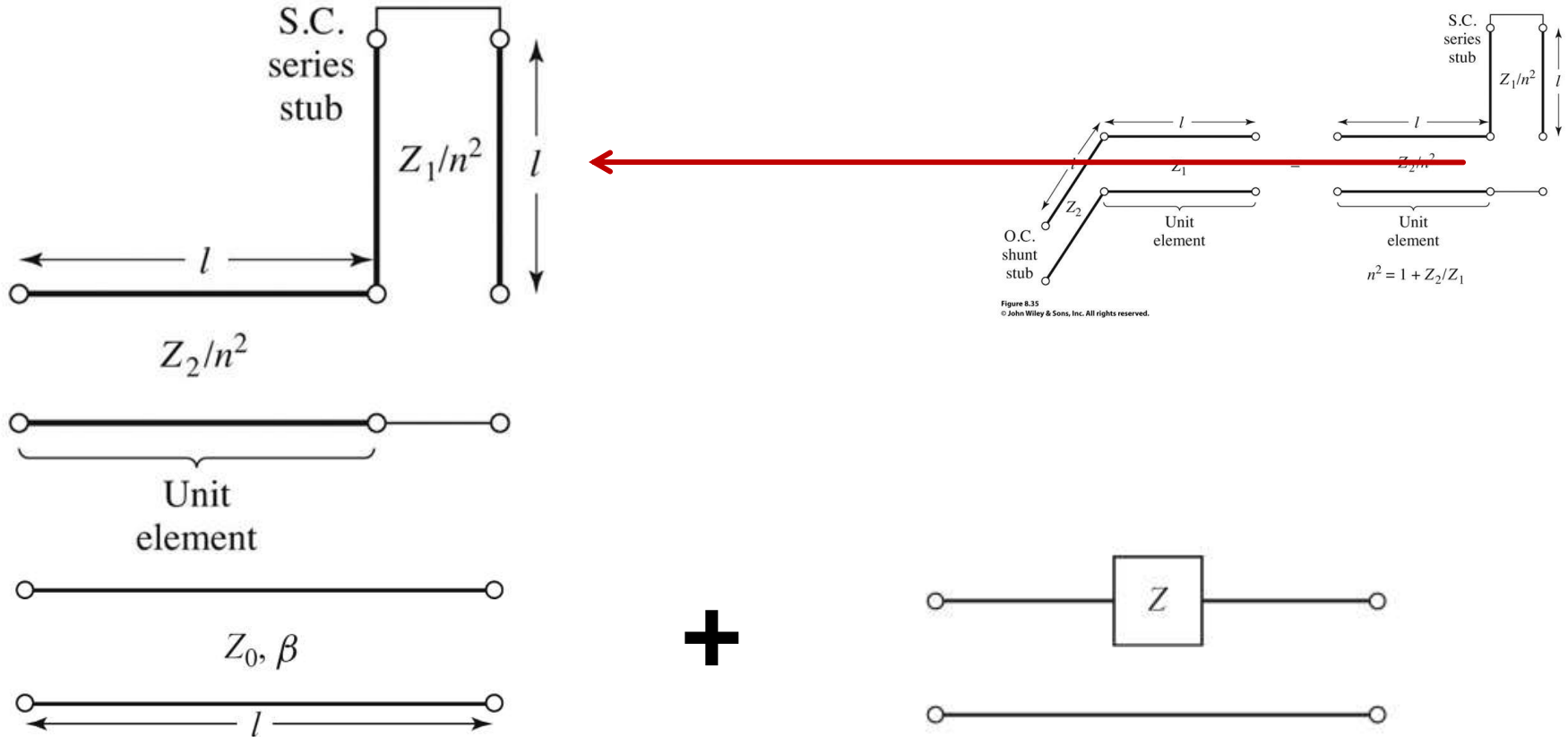
$$\cos \beta \cdot l = \frac{1}{\sqrt{1 + \Omega^2}} \quad \sin \beta \cdot l = \frac{\Omega}{\sqrt{1 + \Omega^2}}$$

$$Z_{in,g} = -j \cdot Z_2 \cdot \cot \beta \cdot l = -j \cdot \frac{Z_2}{\Omega}$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ \frac{j \cdot \Omega}{Z_2} & 1 \end{bmatrix} \cdot \begin{bmatrix} \frac{1}{\sqrt{1 + \Omega^2}} & j \cdot Z_1 \cdot \frac{\Omega}{\sqrt{1 + \Omega^2}} \\ j \cdot \frac{1}{Z_1} \cdot \frac{\Omega}{\sqrt{1 + \Omega^2}} & \frac{1}{\sqrt{1 + \Omega^2}} \end{bmatrix}$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \frac{1}{\sqrt{1 + \Omega^2}} \cdot \begin{bmatrix} 1 & 0 \\ \frac{j \cdot \Omega}{Z_2} & 1 \end{bmatrix} \cdot \begin{bmatrix} 1 & j \cdot \Omega \cdot Z_1 \\ \frac{j \cdot \Omega}{Z_1} & 1 \end{bmatrix} = \frac{1}{\sqrt{1 + \Omega^2}} \cdot \begin{bmatrix} 1 & j \cdot \Omega \cdot Z_1 \\ j \cdot \Omega \cdot \left(\frac{1}{Z_1} + \frac{1}{Z_2} \right) & 1 - \Omega^2 \cdot \frac{Z_1}{Z_2} \end{bmatrix}$$

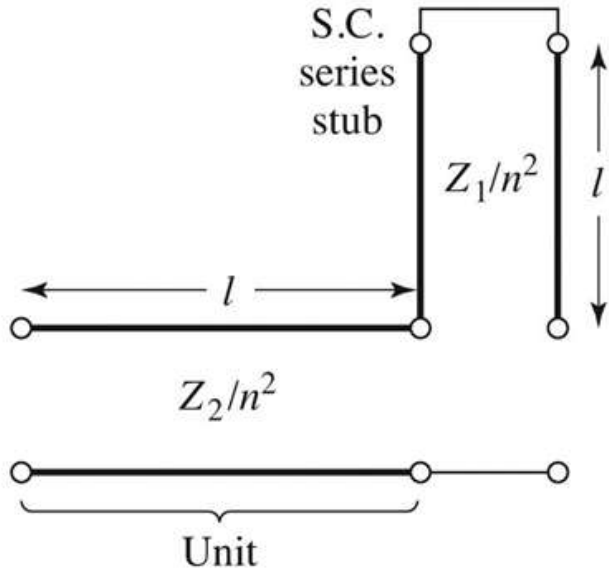
Prima Identitate Kuroda – Demonstratie



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

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

Prima Identitate Kuroda – Demonstratie



$$\Omega = \tan \beta \cdot l$$

$$\cos \beta \cdot l = \frac{1}{\sqrt{1 + \Omega^2}} \quad \sin \beta \cdot l = \frac{\Omega}{\sqrt{1 + \Omega^2}}$$

$$Z_{in,sc} = j \cdot \left(\frac{Z_1}{n^2} \right) \cdot \tan \beta \cdot l = \frac{j \cdot \Omega \cdot Z_1}{n^2}$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & j \cdot \frac{Z_2}{n^2} \cdot \frac{\Omega}{\sqrt{1 + \Omega^2}} \\ j \cdot \frac{n^2}{Z_2} \cdot \frac{\Omega}{\sqrt{1 + \Omega^2}} & 1 \end{bmatrix} \cdot \begin{bmatrix} 1 & \frac{j \cdot \Omega \cdot Z_1}{n^2} \\ 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \frac{1}{\sqrt{1 + \Omega^2}} \cdot \begin{bmatrix} 1 & j \cdot \Omega \cdot \frac{Z_2}{n^2} \\ \frac{j \cdot \Omega \cdot n^2}{Z_2} & 1 \end{bmatrix} \cdot \begin{bmatrix} 1 & j \cdot \Omega \cdot \frac{Z_1}{n^2} \\ 0 & 1 \end{bmatrix} = \frac{1}{\sqrt{1 + \Omega^2}} \cdot \begin{bmatrix} 1 & j \cdot \frac{\Omega}{n^2} \cdot (Z_1 + Z_2) \\ \frac{j \cdot \Omega \cdot n^2}{Z_2} & 1 - \Omega^2 \cdot \frac{Z_1}{Z_2} \end{bmatrix}$$

Prima Identitate Kuroda – Demonstratie

- Prima schema

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \frac{1}{\sqrt{1+\Omega^2}} \cdot \begin{bmatrix} 1 & j \cdot \Omega \cdot Z_1 \\ j \cdot \Omega \cdot \left(\frac{1}{Z_1} + \frac{1}{Z_2} \right) & 1 - \Omega^2 \cdot \frac{Z_1}{Z_2} \end{bmatrix}$$

- A doua schema

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \frac{1}{\sqrt{1+\Omega^2}} \cdot \begin{bmatrix} 1 & j \cdot \frac{\Omega}{n^2} \cdot (Z_1 + Z_2) \\ \frac{j \cdot \Omega \cdot n^2}{Z_2} & 1 - \Omega^2 \cdot \frac{Z_1}{Z_2} \end{bmatrix}$$

- Rezultatele sunt identice daca alegem

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

- Similar se pot demonstra si celelalte trei identitati

(Acelasi) Exemplu

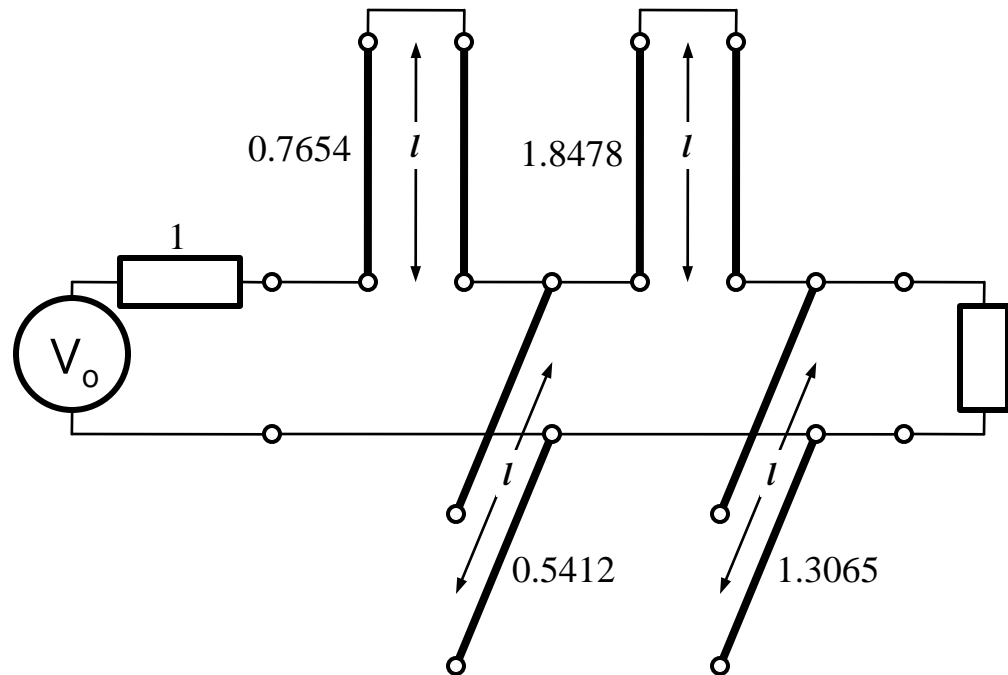
- Filtru trece jos de ordinul 4, cu frecventa de taiere de 4 GHz, de tip maxim plat (care sa functioneze pe 50Ω la intrare si iesire)
- Tabel maxim plat sau relatii de calcul:
 - $g_1 = 0.7654 = L_1$
 - $g_2 = 1.8478 = C_2$
 - $g_3 = 1.8478 = L_3$
 - $g_4 = 0.7654 = C_4$
 - $g_5 = 1$ (**nu** are nevoie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

Exemplu

■ Se aplica transformarea Richards

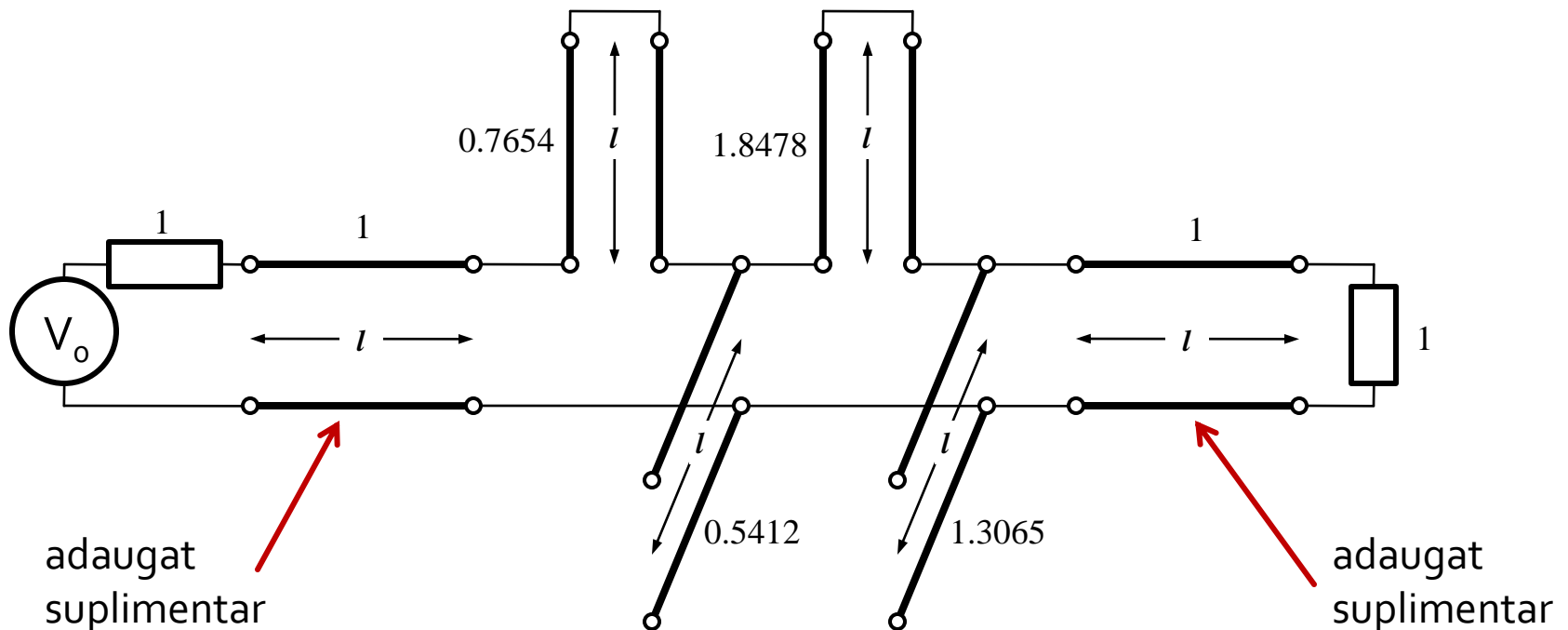
■ Probleme:

- 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 50Ω



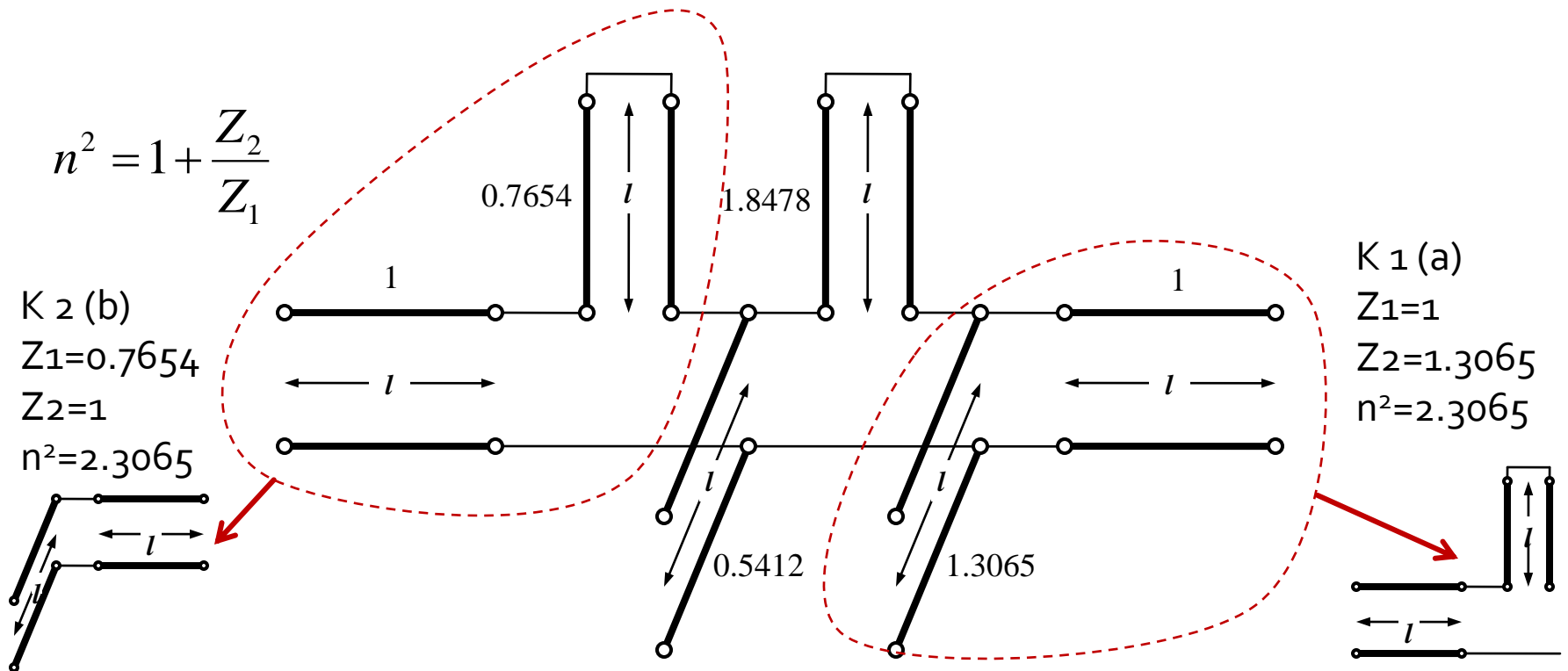
Exemplu

- 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

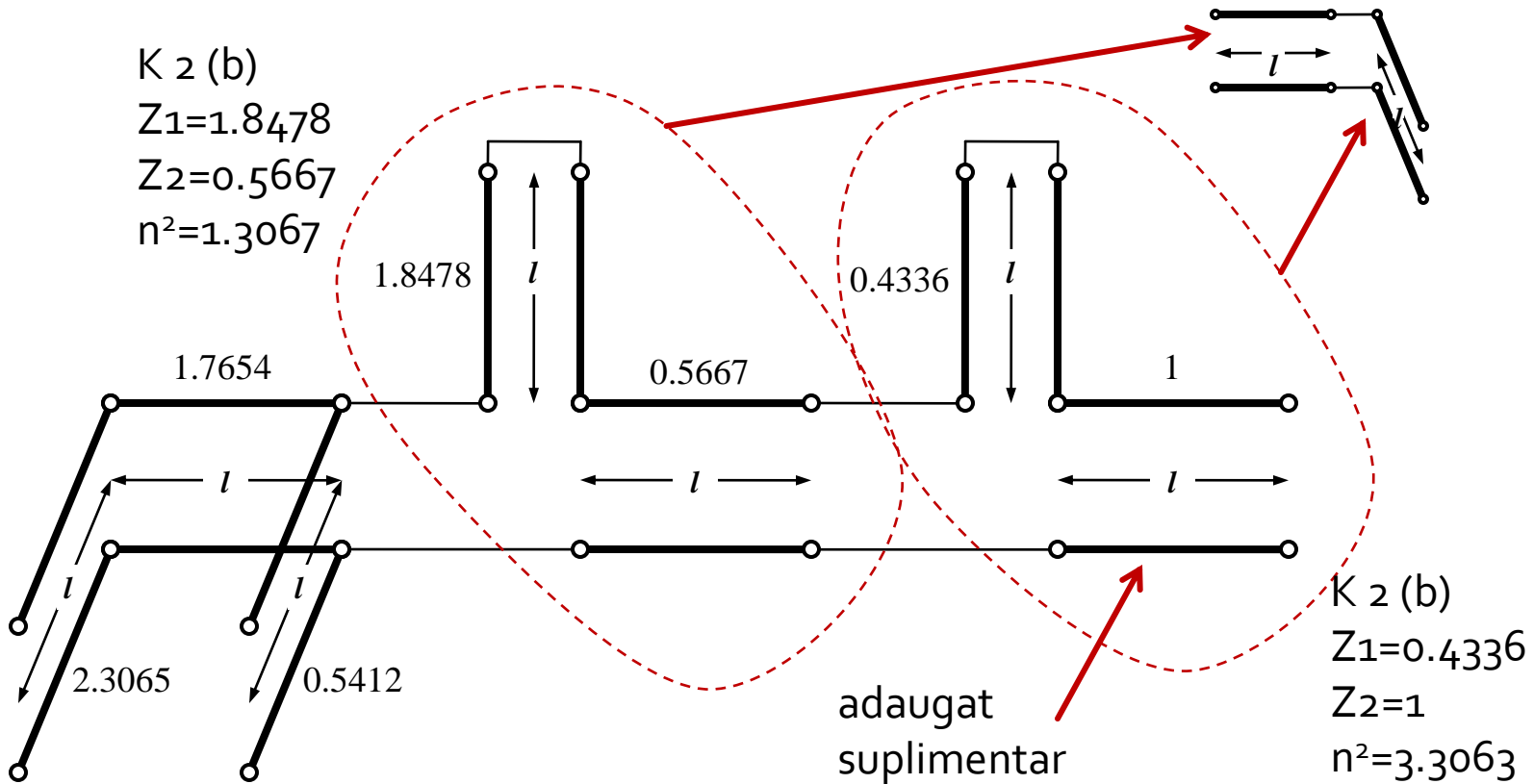
- Se aplica :
 - Kuroda 2 (L,Z cunoscut \rightarrow C,Z) in partea stanga
 - Kuroda 1 (C,Z cunoscut \rightarrow L,Z) in partea dreapta



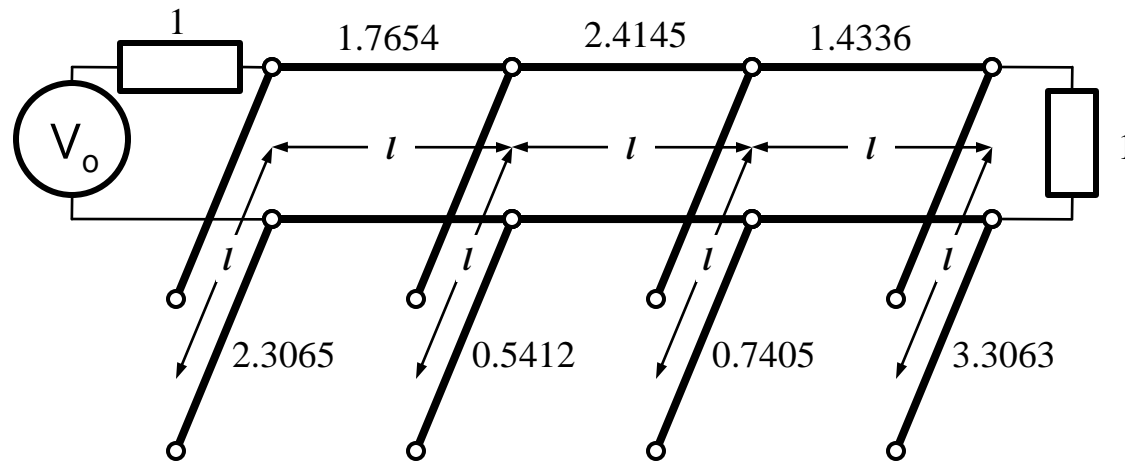
Exemplu

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

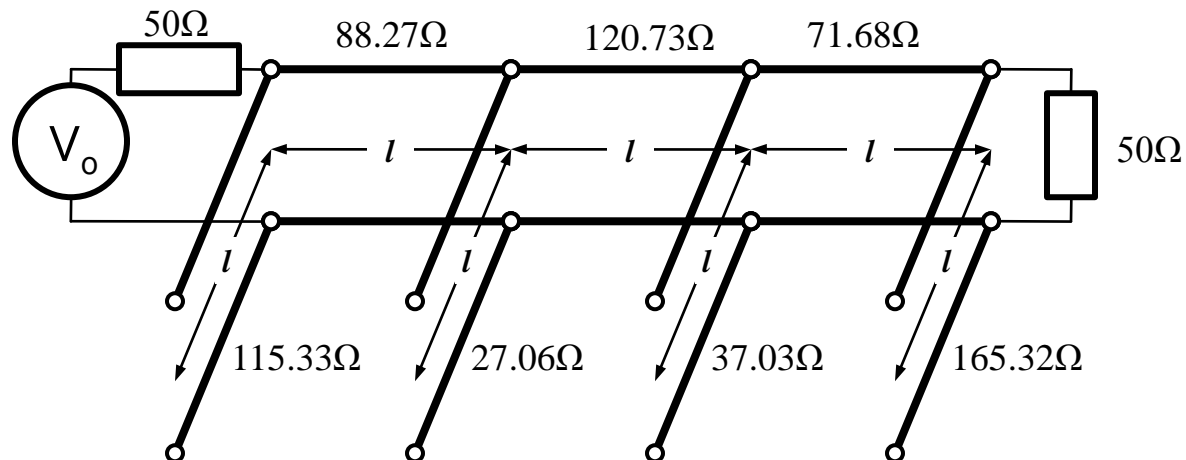
$$n^2 = 1 + \frac{Z_2}{Z_1}$$



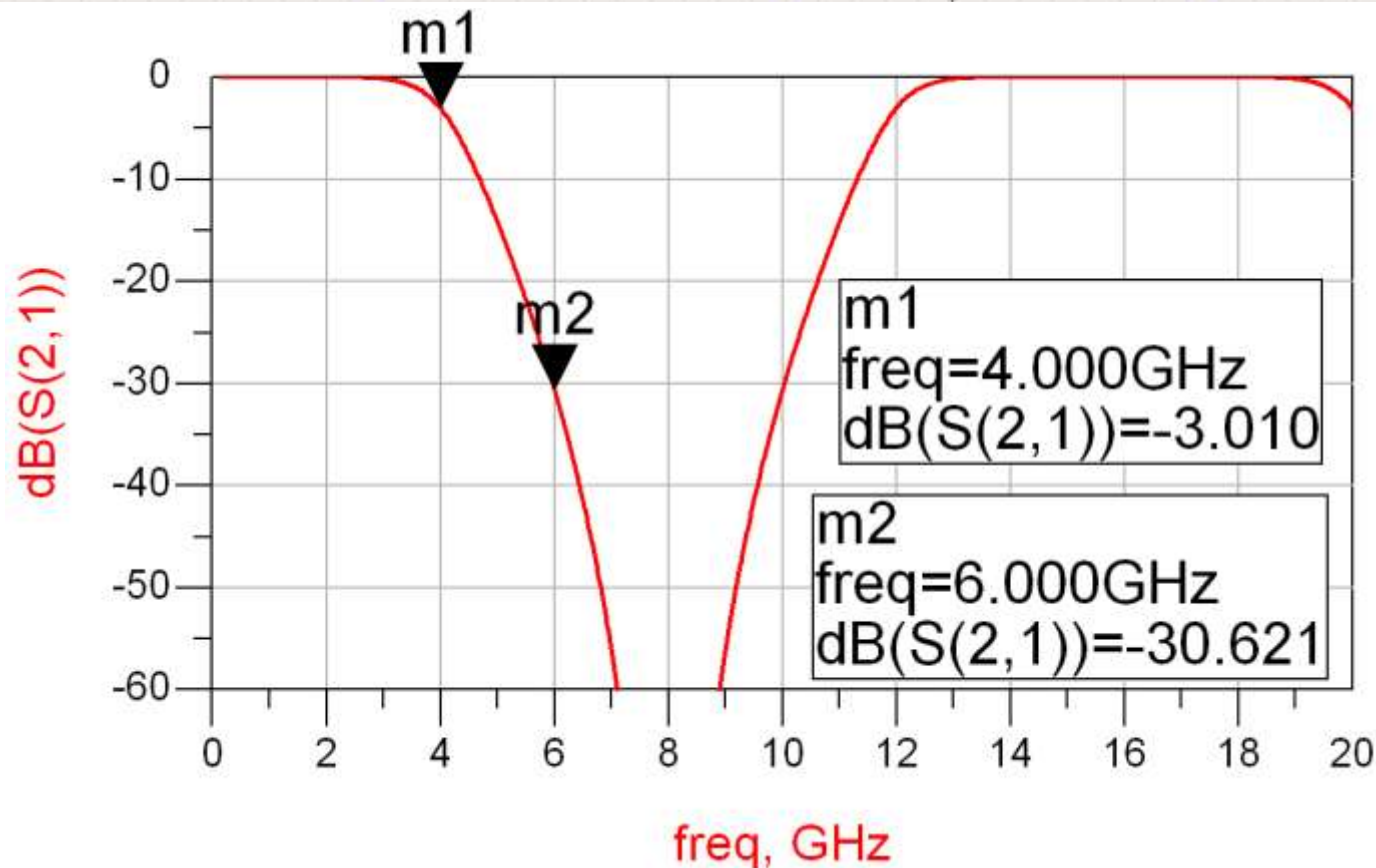
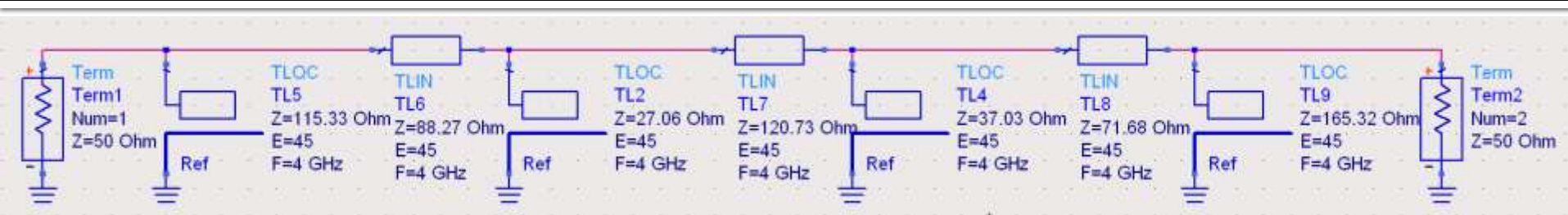
Exemplu



- Scalare la 50Ω



Identitatile Kuroda – ADS



Example

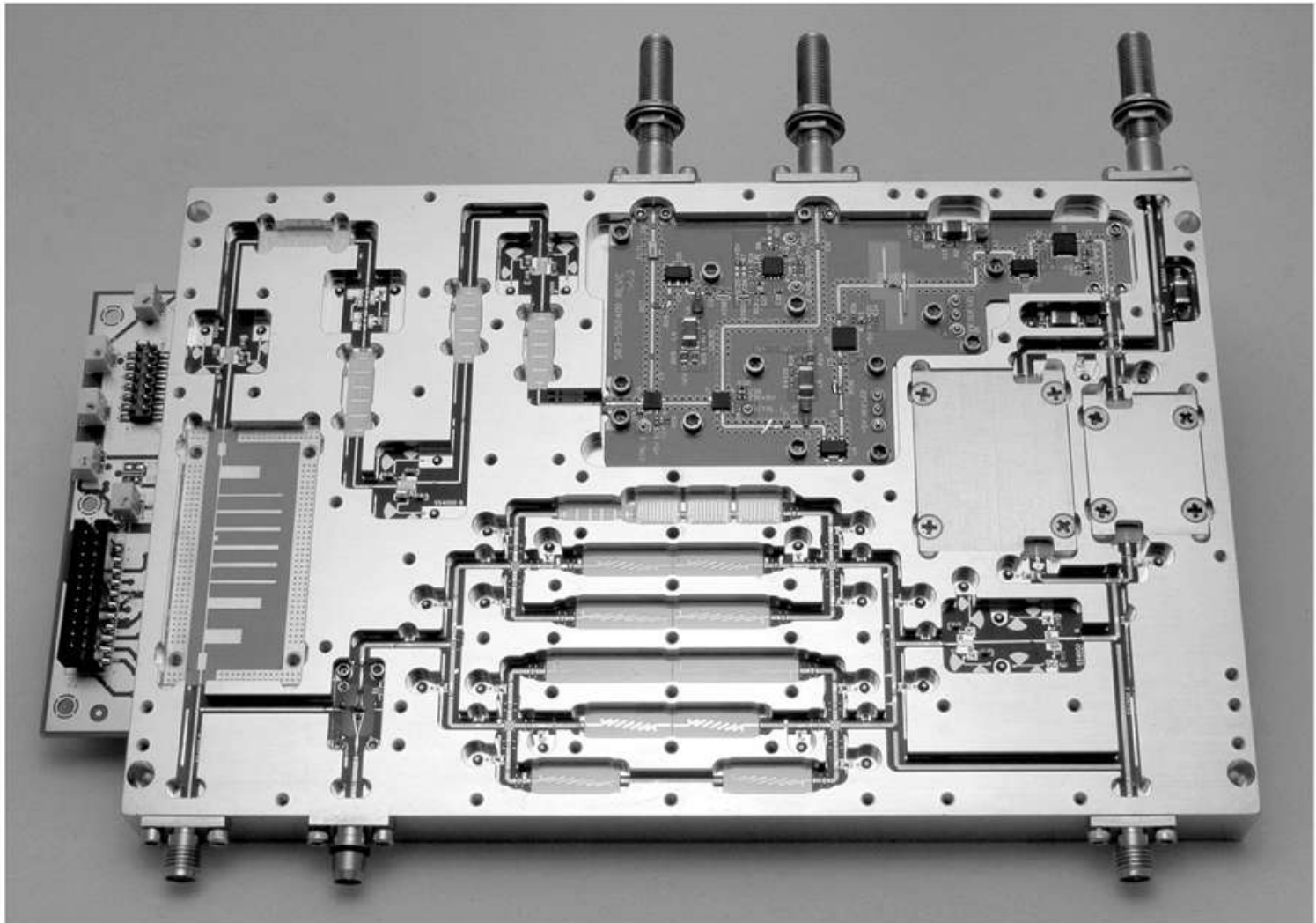


Figure 8.55
Courtesy of LNX Corporation, Salem, N.H.

Example

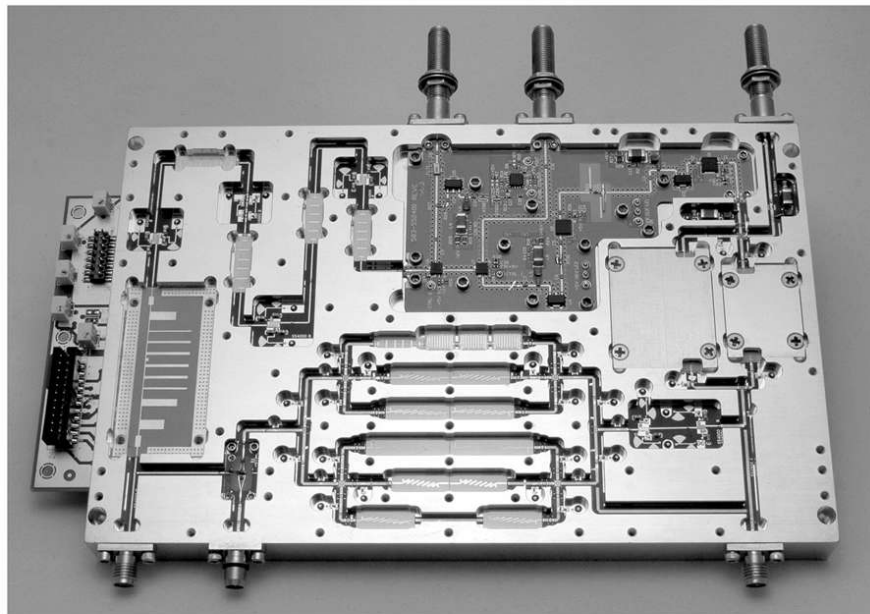
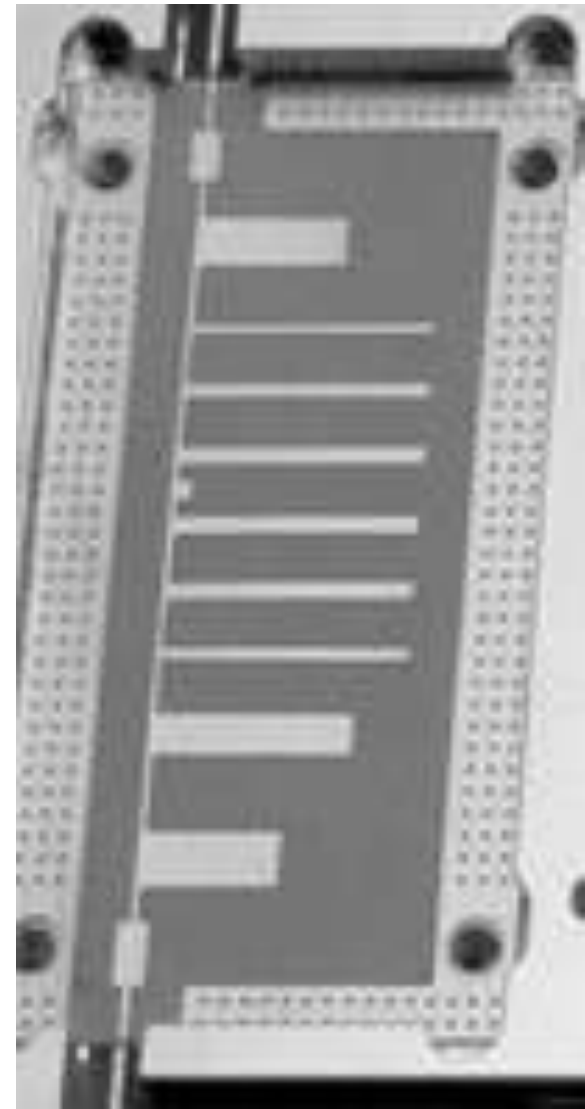
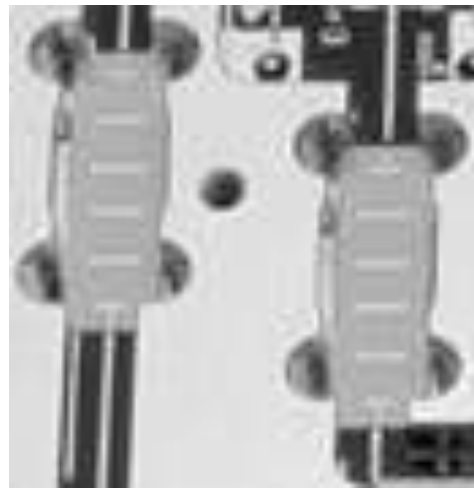
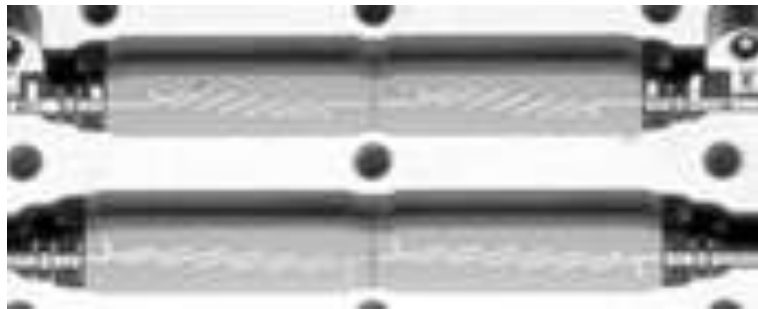


Figure 8.55
Courtesy of LNX Corporation, Salem, N.H.



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

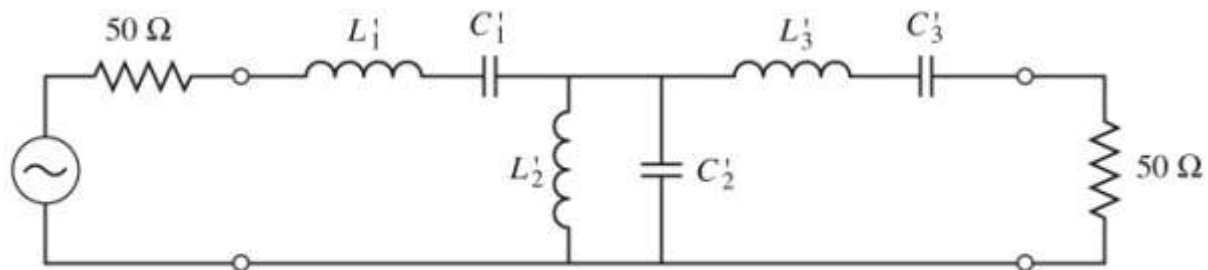


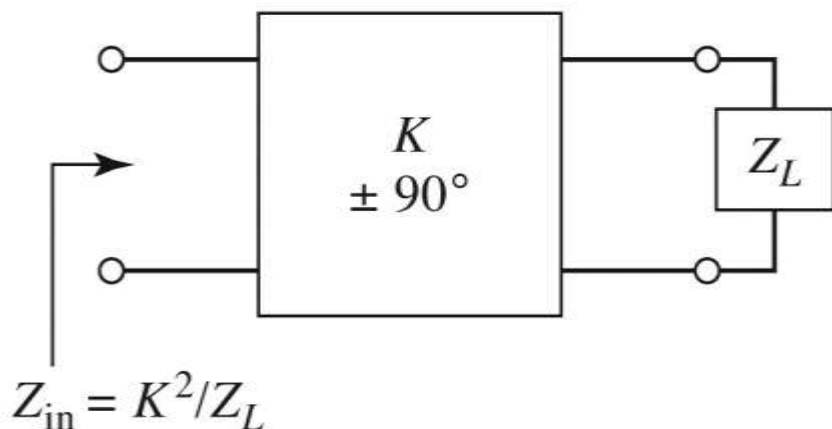
Figure 8.32
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Inversoare de impedanta si admitanta

- 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

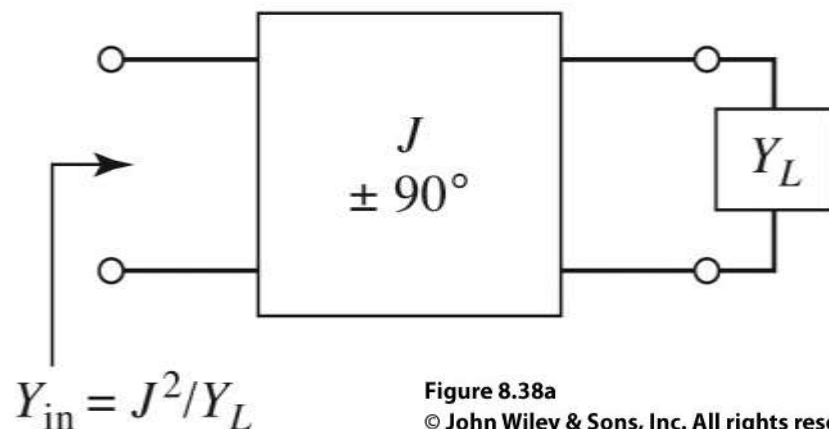


Figure 8.38a

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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)

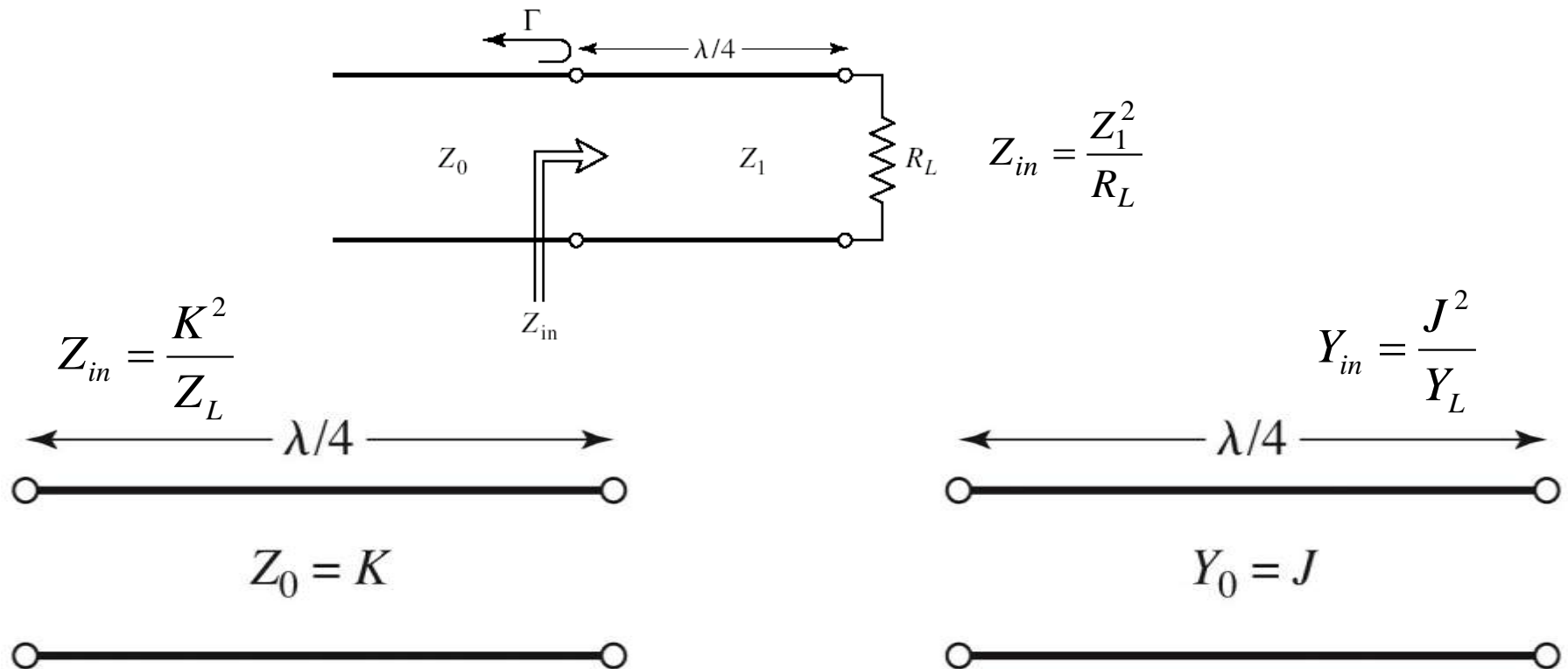
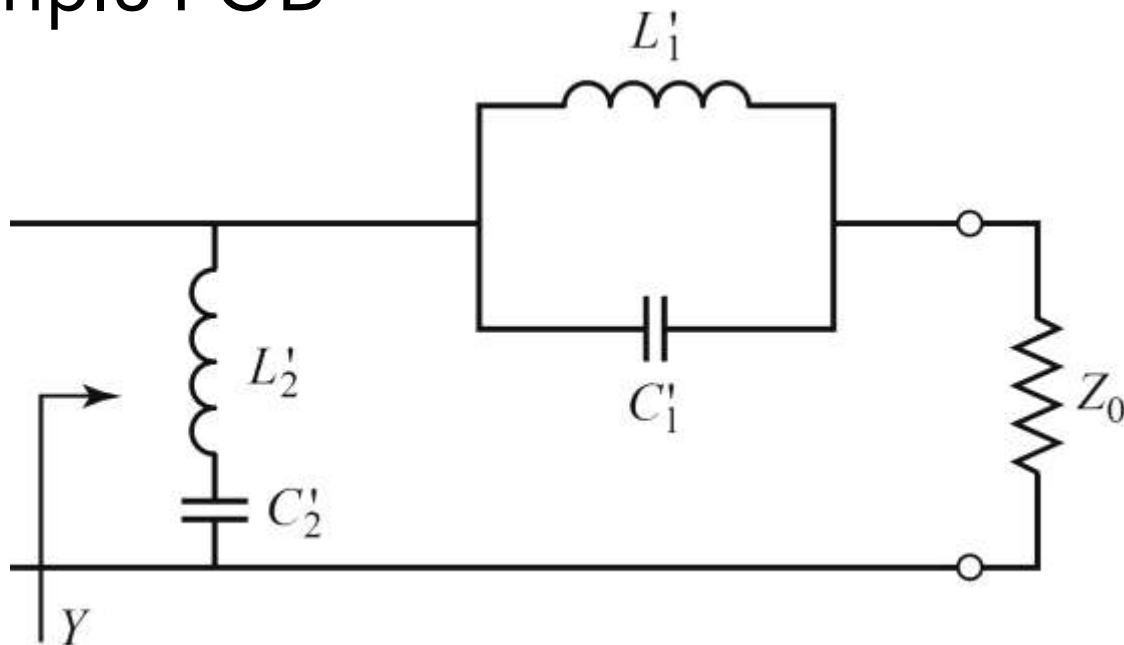


Figure 8.38b

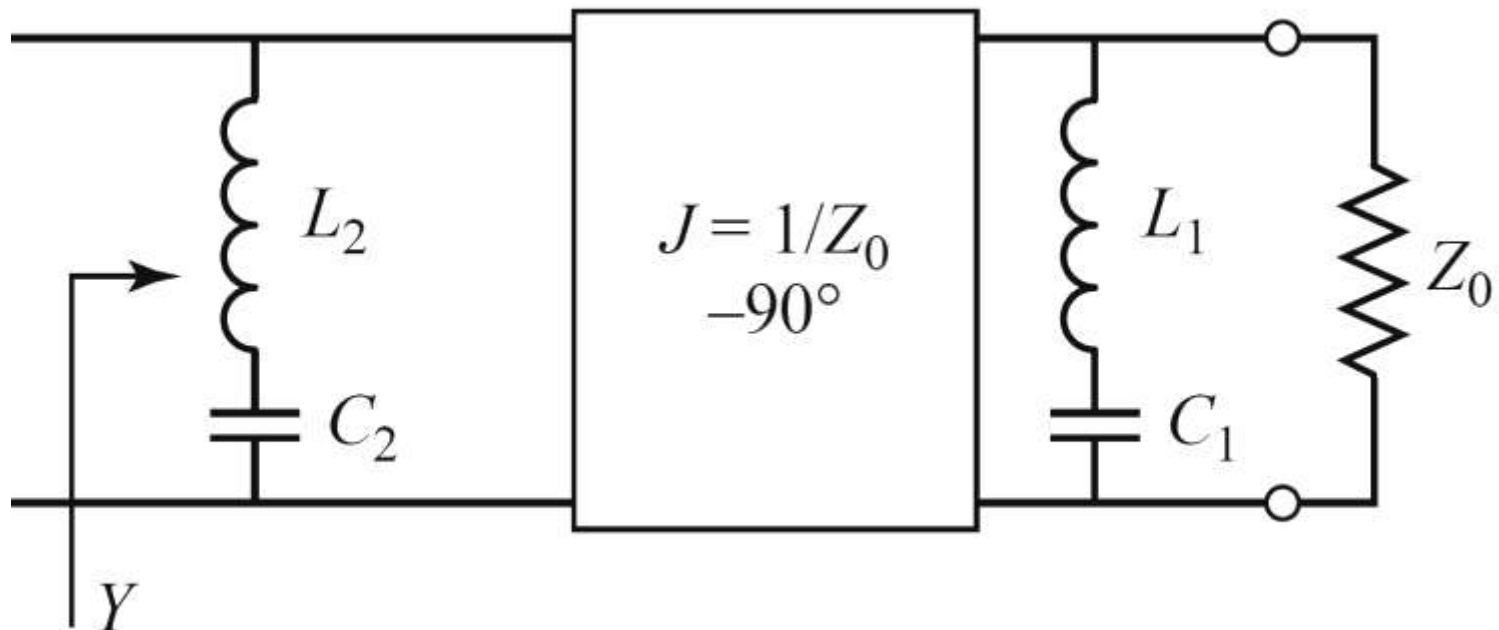
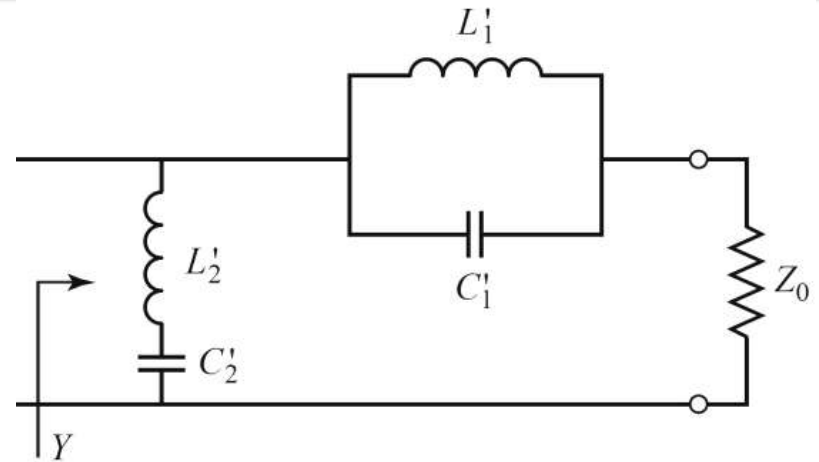
Inversoare de impedanta si admitanta

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



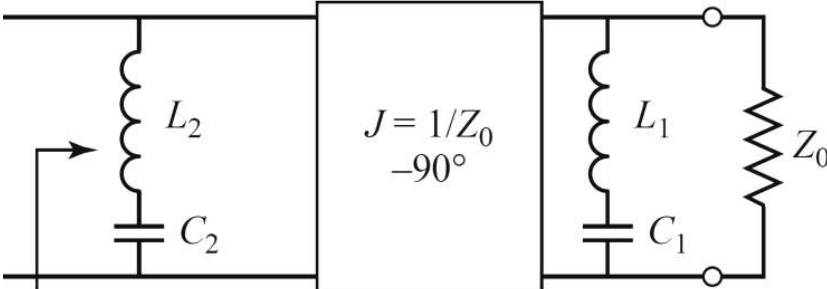
Inversoare de impedanta si admitanta

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



Inversoare de impedanta si admitanta

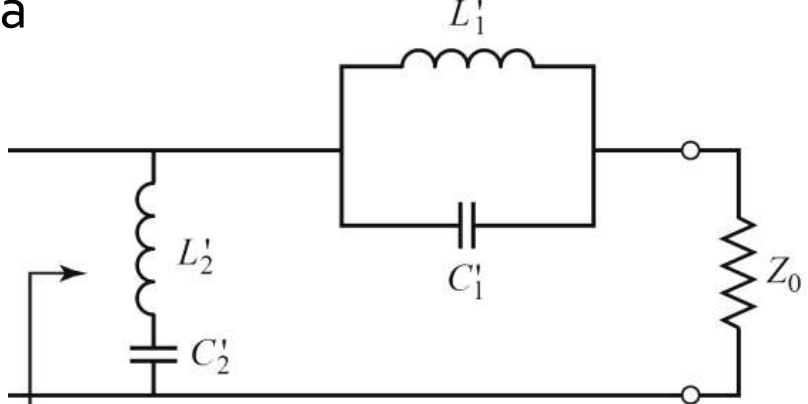
- Echivalenta celor doua scheme se demonstreaza prin obtinerea aceleiasi admitante de intrare
- Echivalenta completa se obtine prin incadrarea grupului simulat intre doua invertoare de admitanta



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

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

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

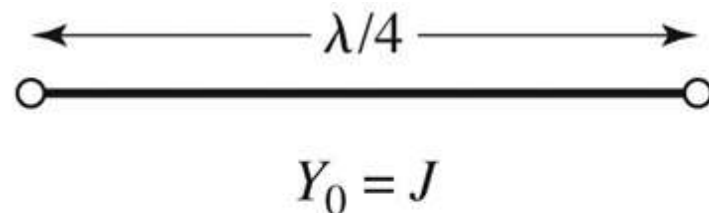
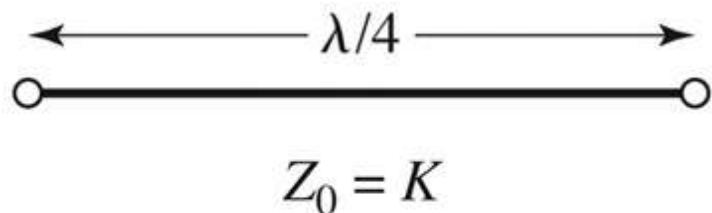


$$Y' = \frac{1}{j \cdot \omega \cdot L'_2 + \frac{1}{j \cdot \omega \cdot C'_2}} + \left(\frac{1}{j \cdot \omega \cdot C'_1 + \frac{1}{j \cdot \omega \cdot L'_1}} + Z_0 \right)^{-1}$$

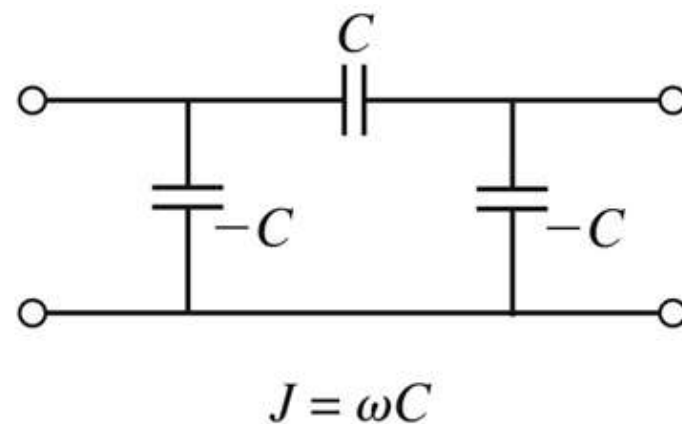
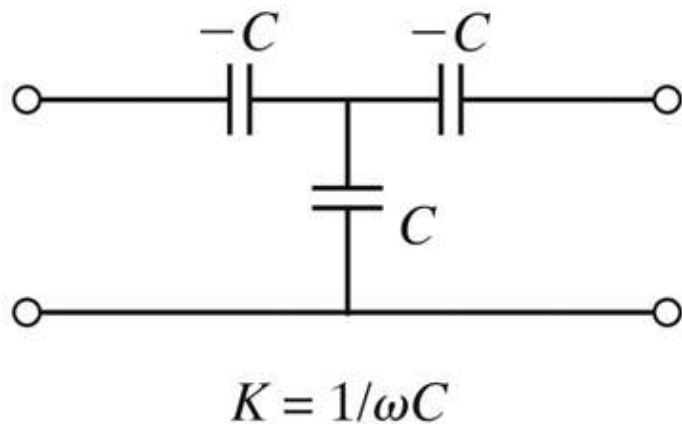
- Rezultat similar se obtine si pentru filtrul trece banda
- Un grup **LC serie** introdus in serie se poate inlocui cu un grup **LC paralel** introdus in paralel incadrat de doua invertoare de admitanta

Realizari practice de inversoare de impedanta/admitanta

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

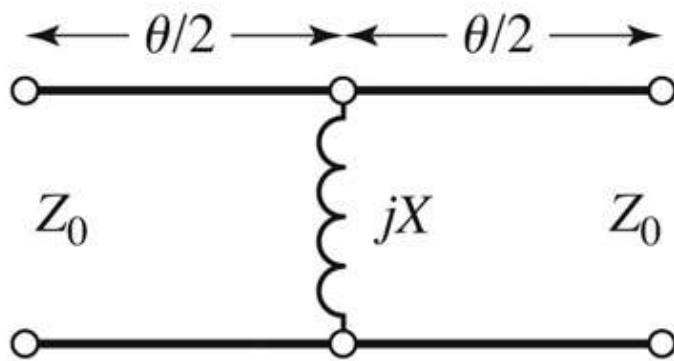


- Realizare cu elemente concentrate

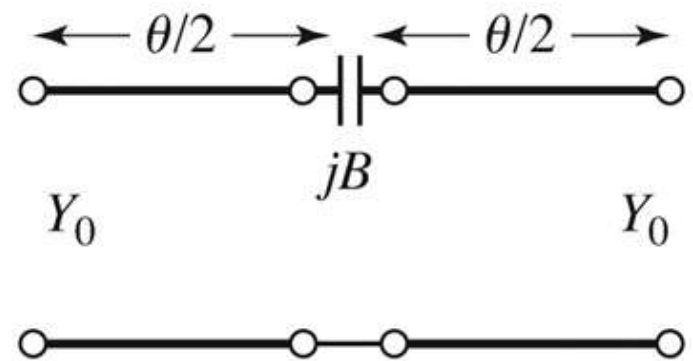


Realizari practice de inversoare de impedanta/admitanta

■ Realizare cu linii



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



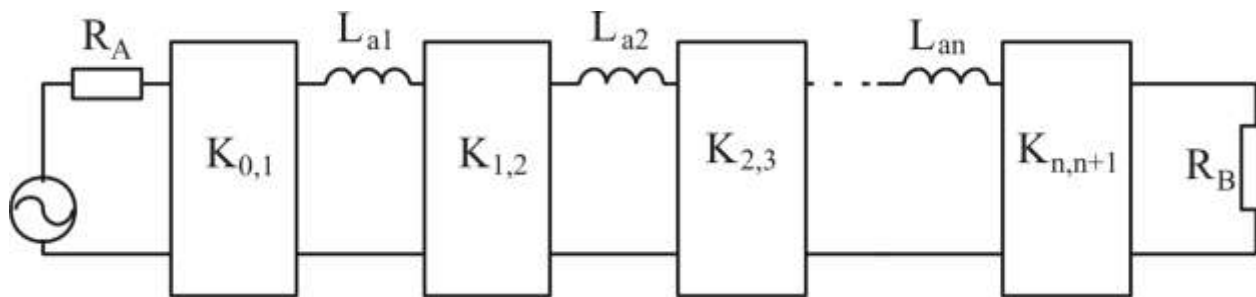
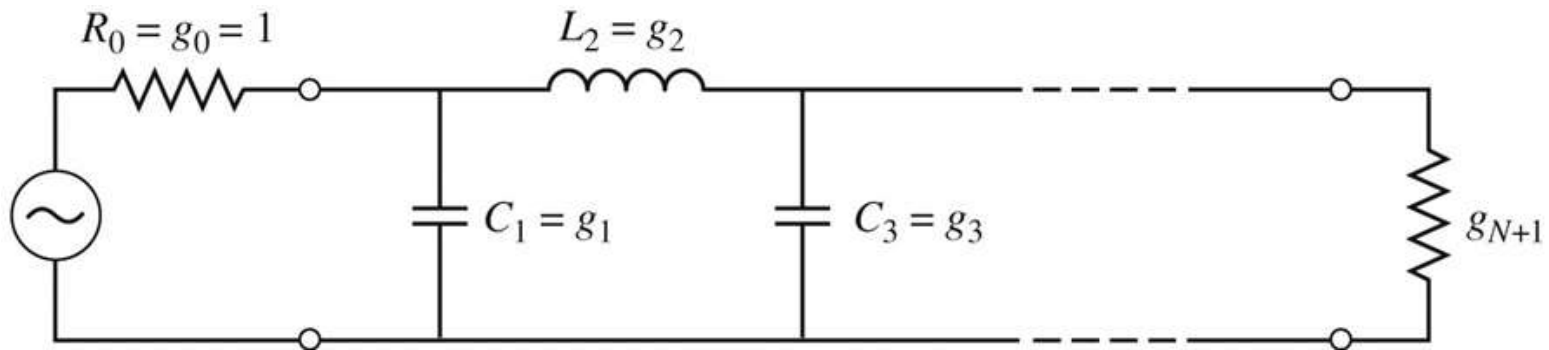
$$J = Y_0 \cdot \tan \left| \frac{\theta}{2} \right|$$
$$B = \frac{J}{1 - \left(\frac{J}{Y_0} \right)^2}$$
$$\theta = -\tan^{-1} \frac{2 \cdot B}{Y_0}$$

Red arrows point from the two diagrams to the equation:

$$\theta < 0$$

Filtre prototip cu inversoare

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



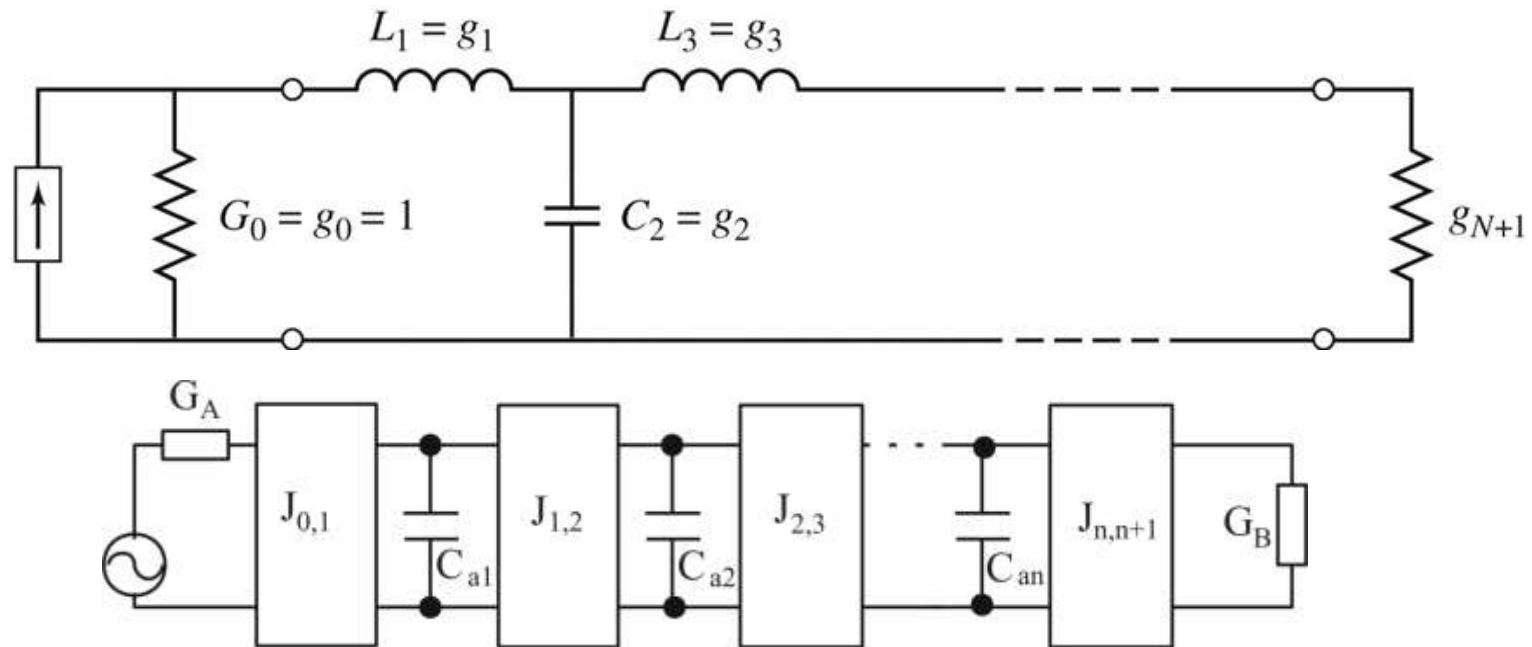
$$K_{0,1} = \sqrt{\frac{R_A \cdot L_{a,1}}{g_0 \cdot g_1}}$$

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

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

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

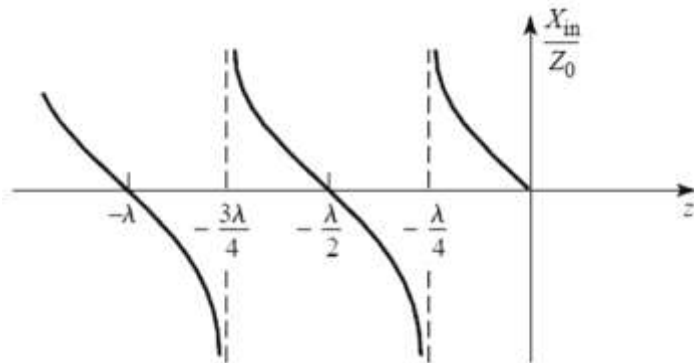
- Pentru filtrele prototip cu inversoare exista $2 \cdot N + 1$ parametri si $N + 1$ ecuatii care asigura echivalenta raspunsului deci N parametri pot fi alesi din considerente oarecare
 - se pot alege valorile reactantelor, urmand ca parametrii inversoarelor sa rezulte din calcul
 - se pot alege convenabil 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 ω_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

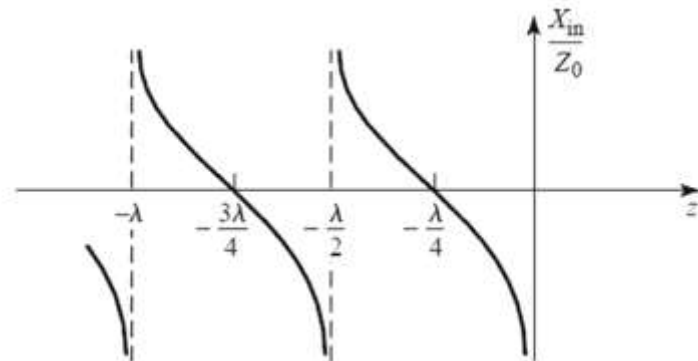
- Impedanta de intrare intr-o linie (stub) scurtcircuitata sau lasata in gol la capat manifesta comportament rezonant care poate fi utilizat pentru implementarea rezonatoarelor

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

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

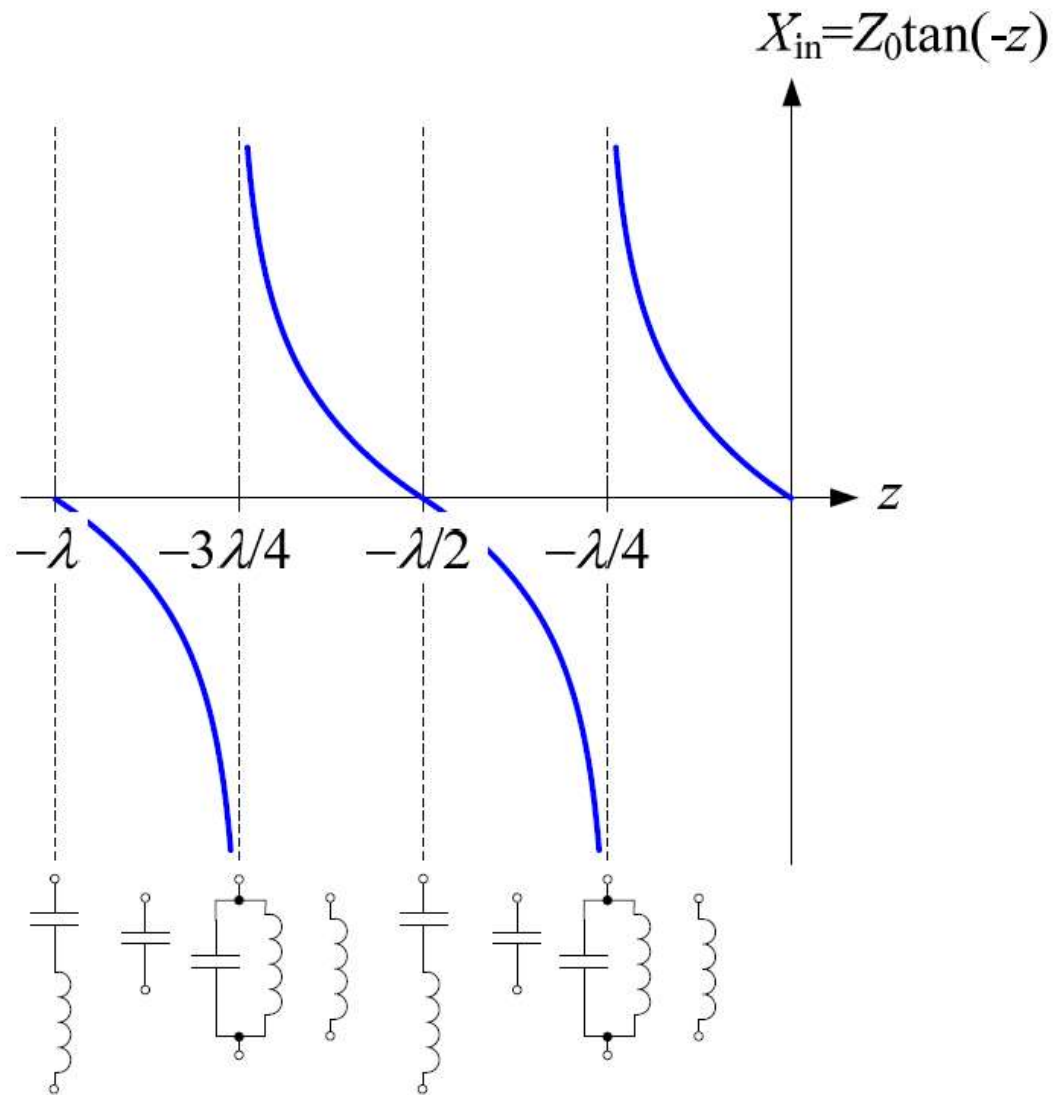


$$Z_{in,g} = -j \cdot Z_0 \cdot \cot \beta \cdot l$$



Linii ca rezonatoare

- Linie in scurtcircuit
- Pentru frecventa (ω_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 $l = \lambda/4$

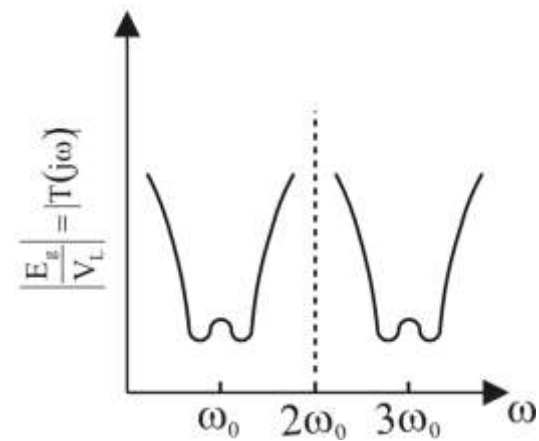
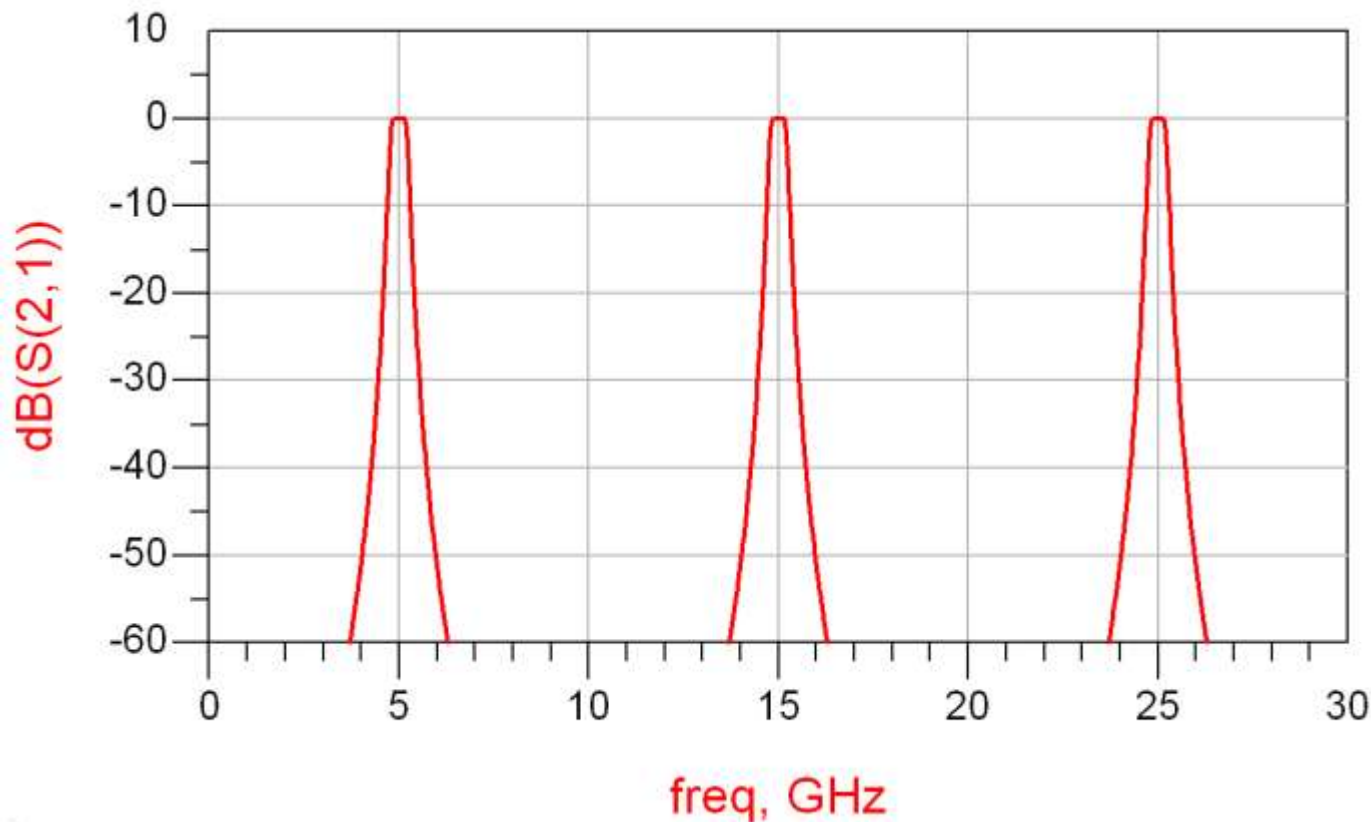
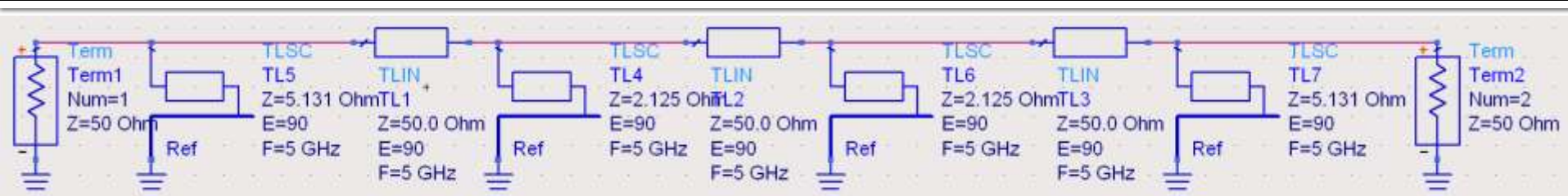
$$Z_{0n} \approx \frac{4 \cdot Z_0}{\pi \cdot g_n \cdot \Delta}$$

Exemplu

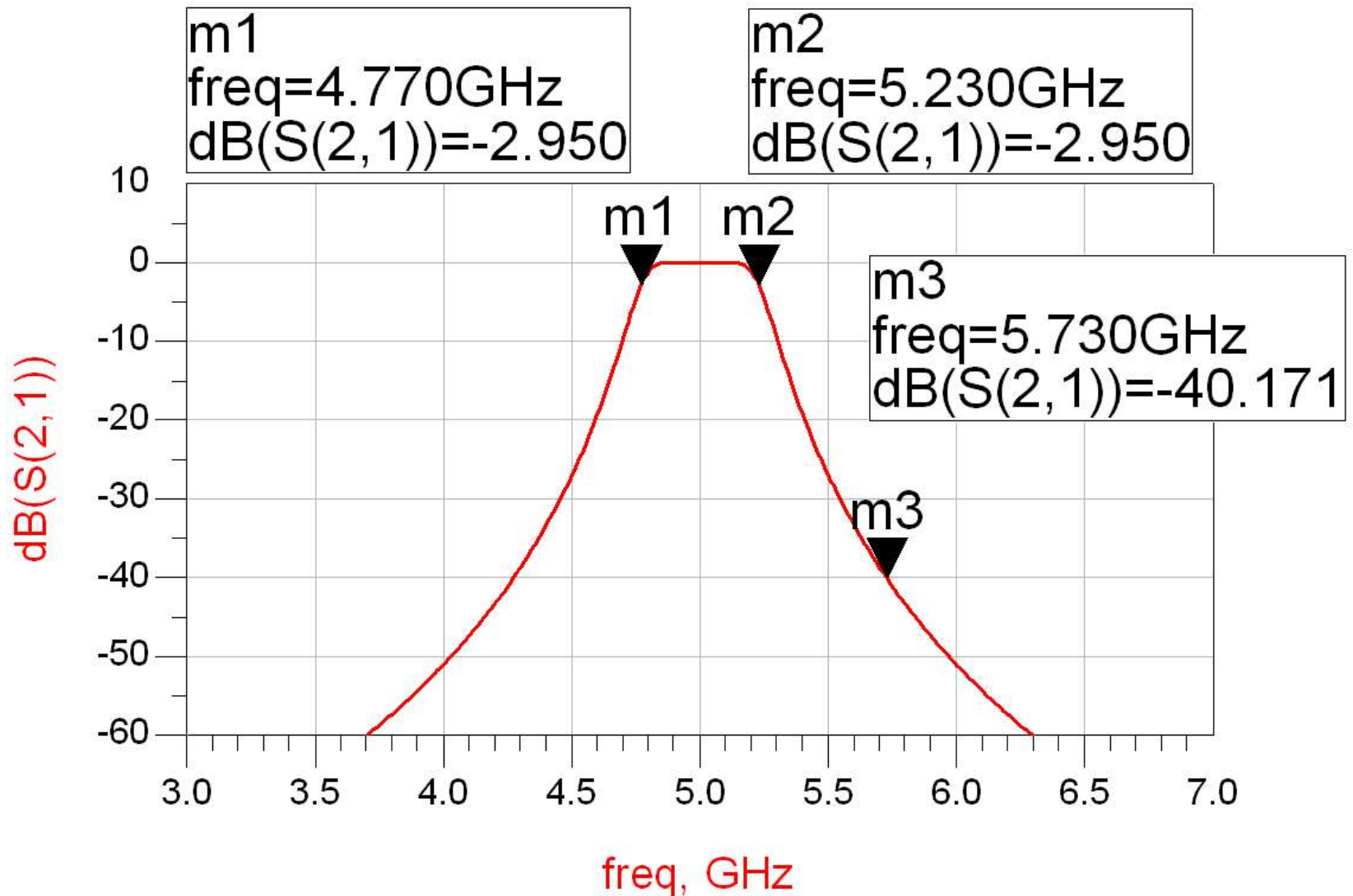
- Similar cu o tema de proiect
- Continuarea amplificatorului C9
- Filtru trece banda de ordinul 4, $f_0 = 5\text{GHz}$, banda 10 %
- Tabel maxim plat sau relatii de calcul:

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

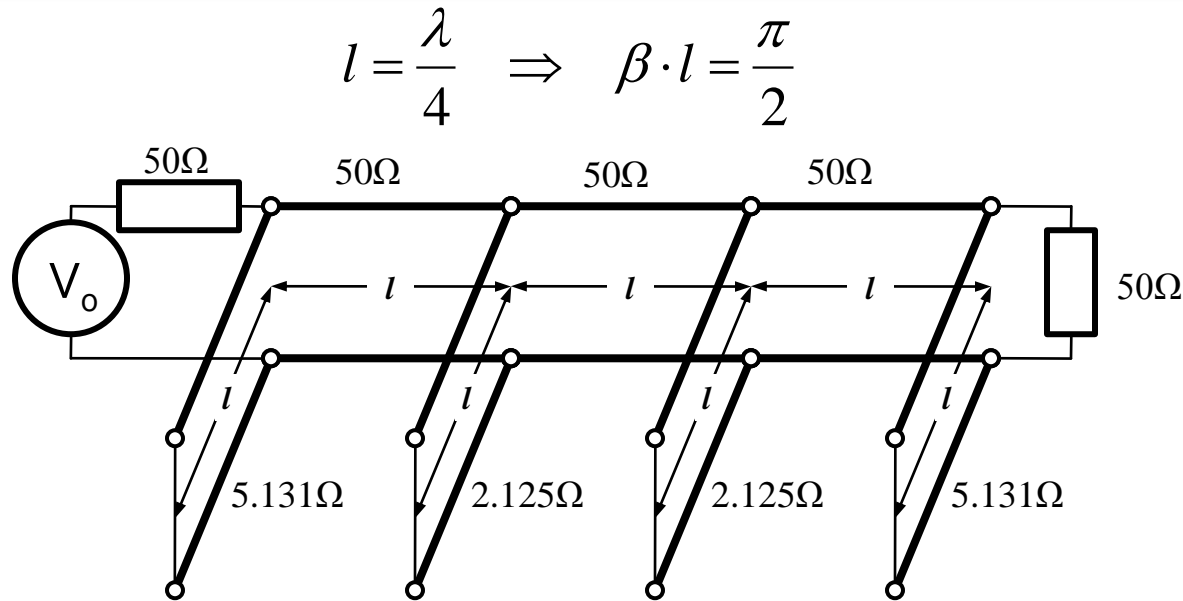
ADS – FTB



ADS – FTB



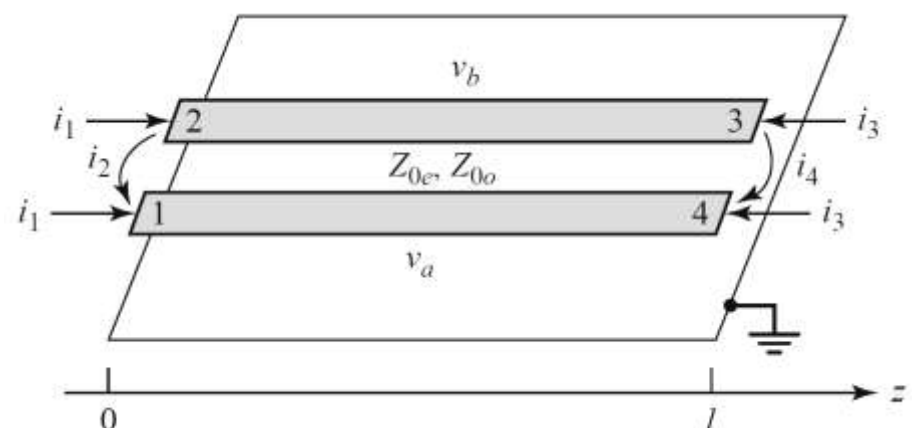
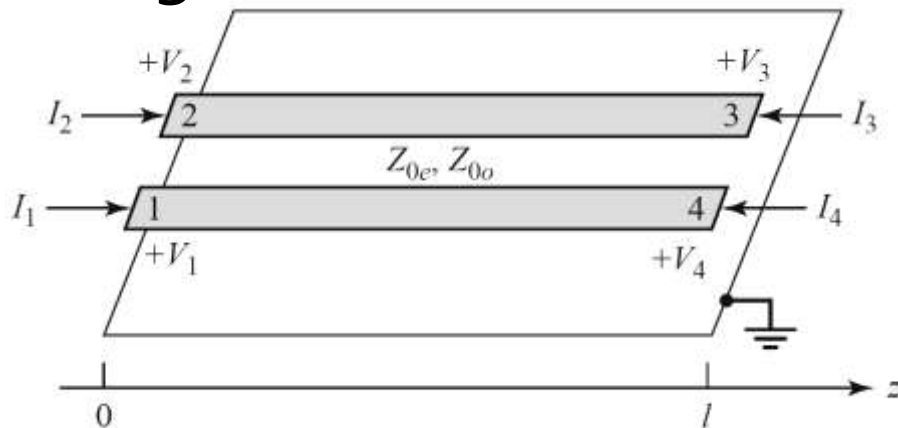
Exemplu



- 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

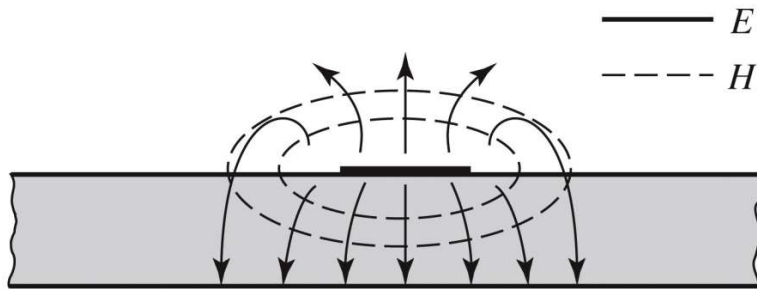
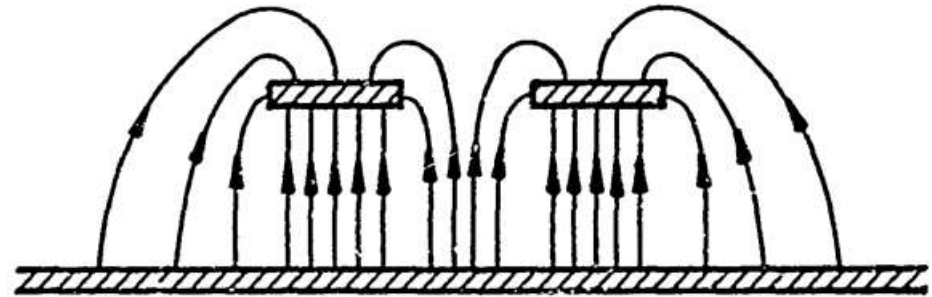
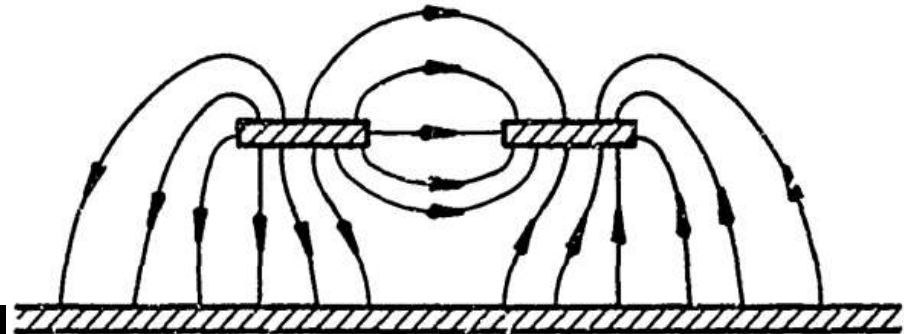


Figure 3.25b
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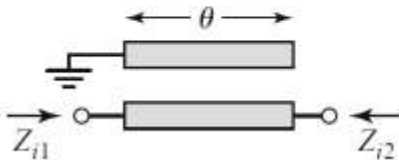
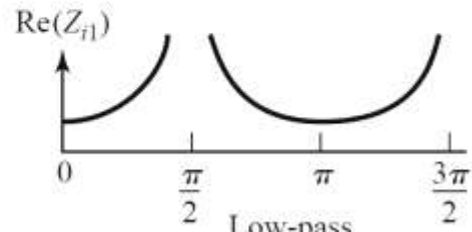
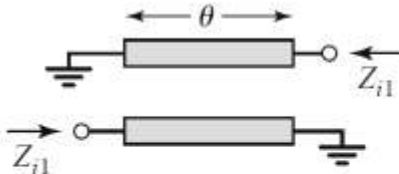
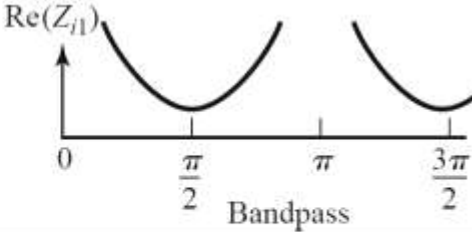
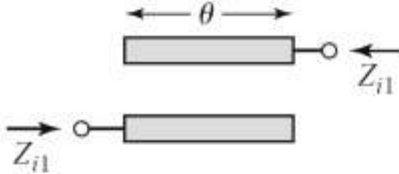
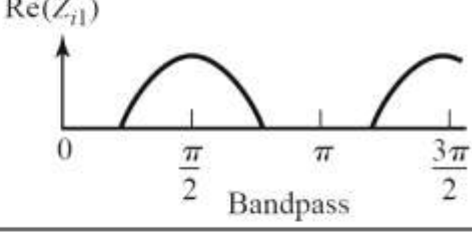
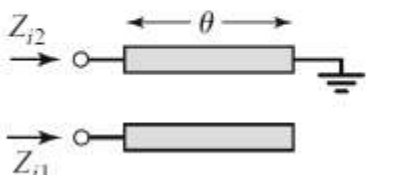
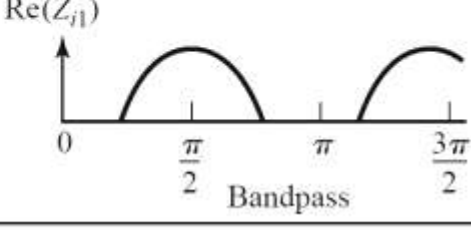
b) EVEN MODE ELECTRIC FIELD PATTERN (SCHEMATIC)



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 $\theta = \pi/2$ ($l = \lambda/4$)

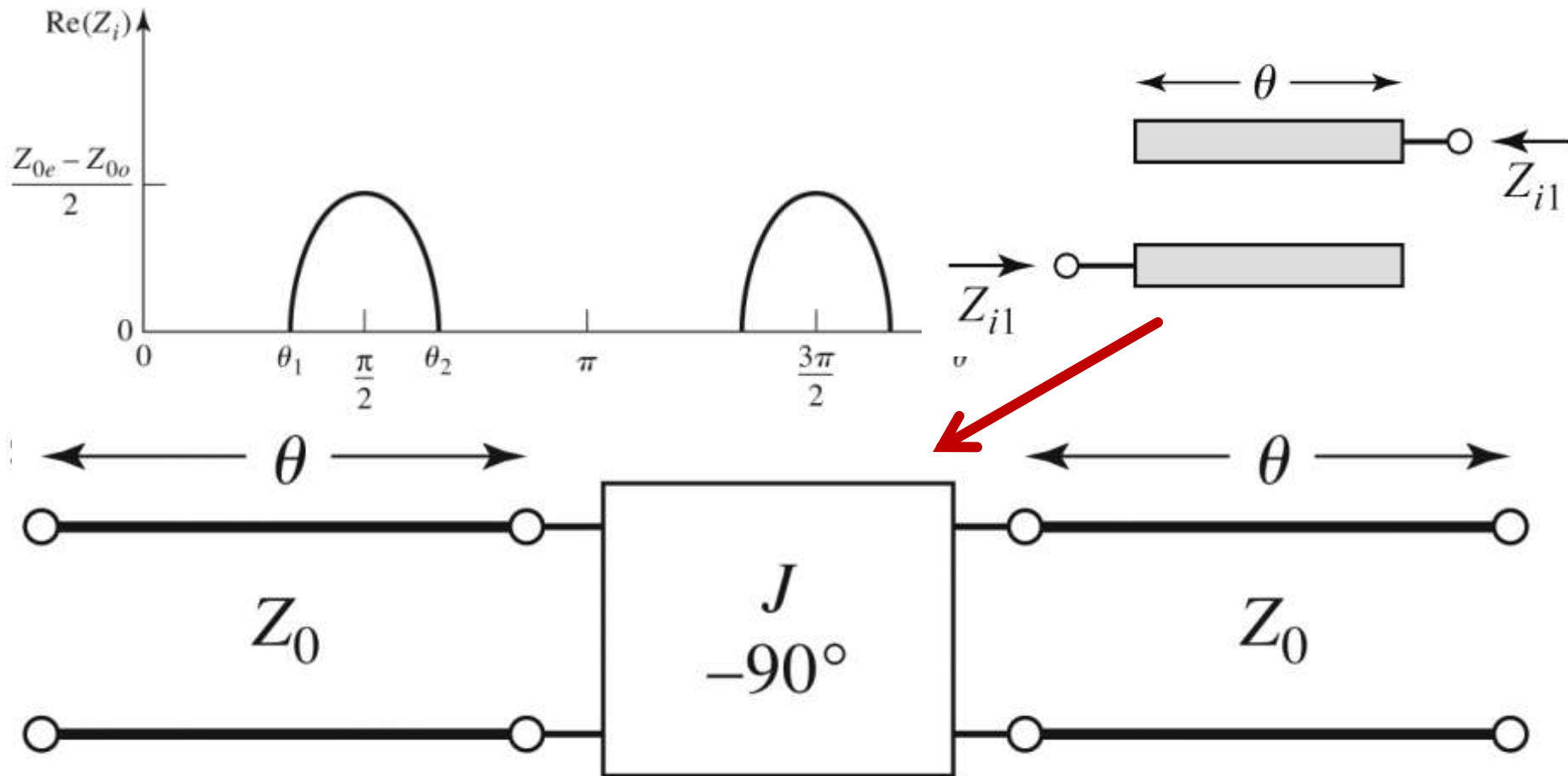
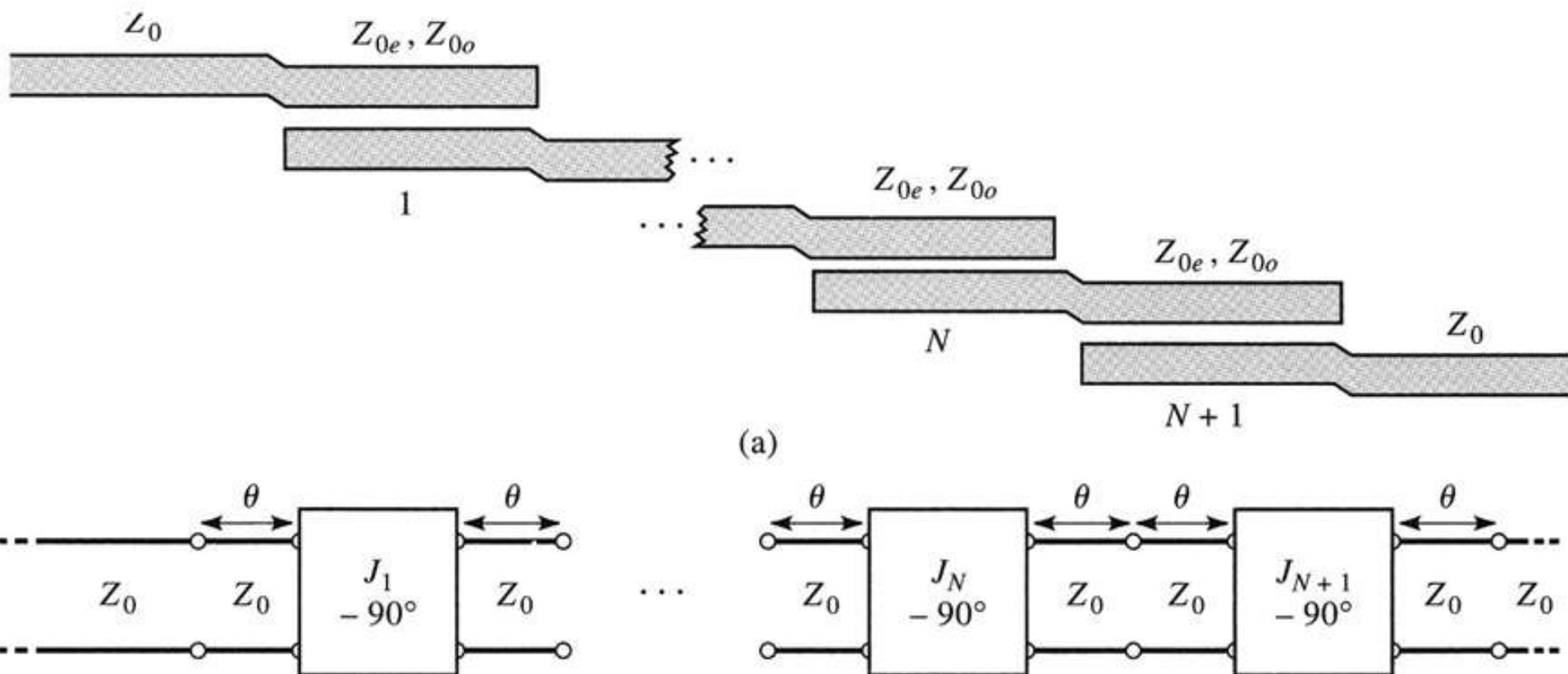


Figure 8.44

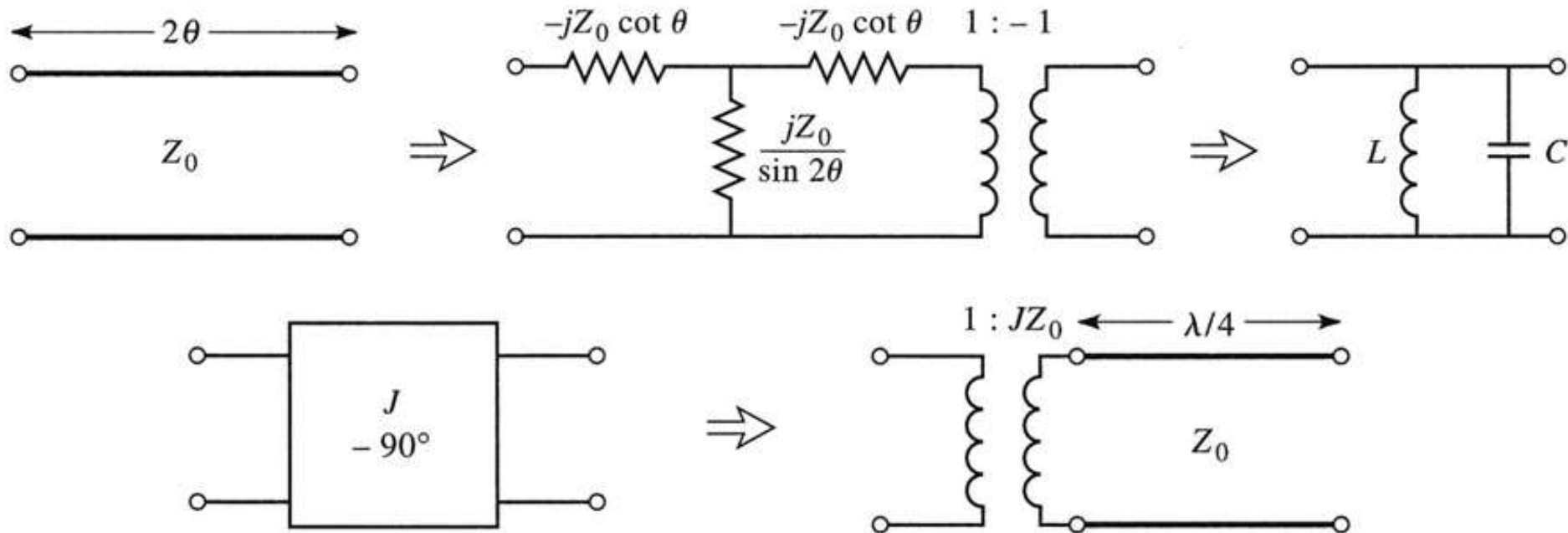
Filtre cu linii cuplate

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



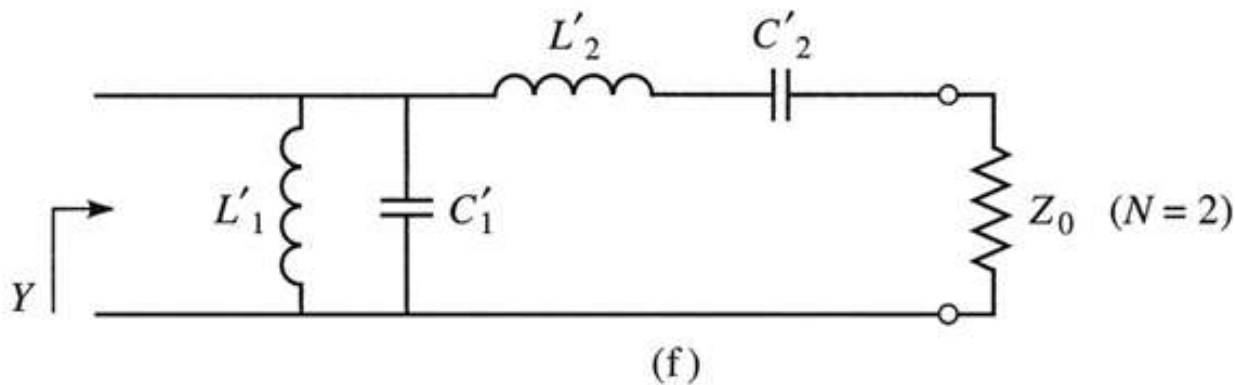
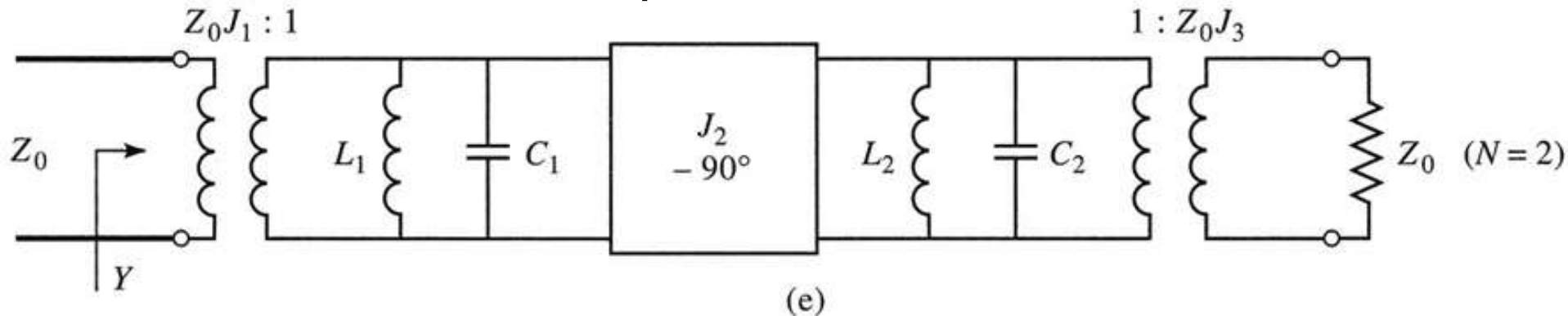
Filtre cu linii cuplate

- 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 $l = \lambda/4$)

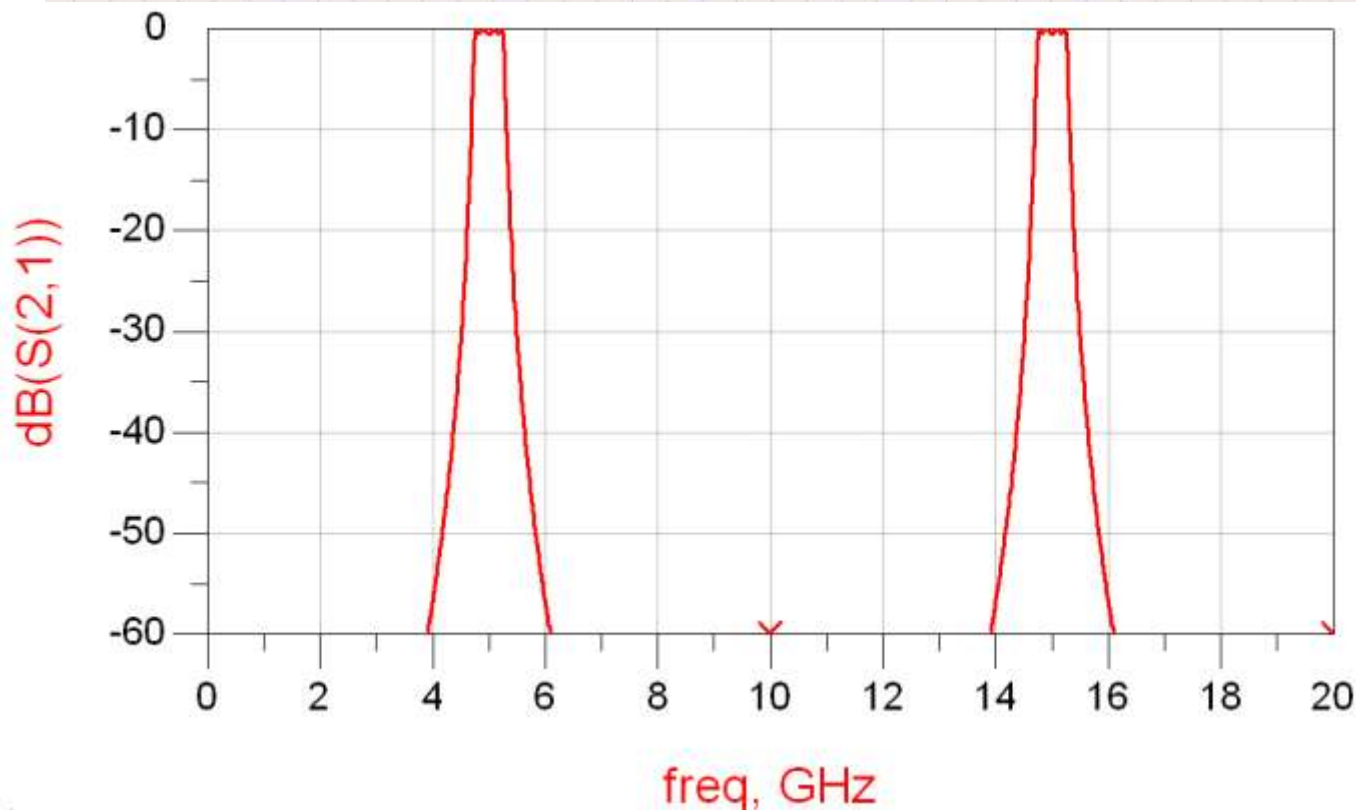
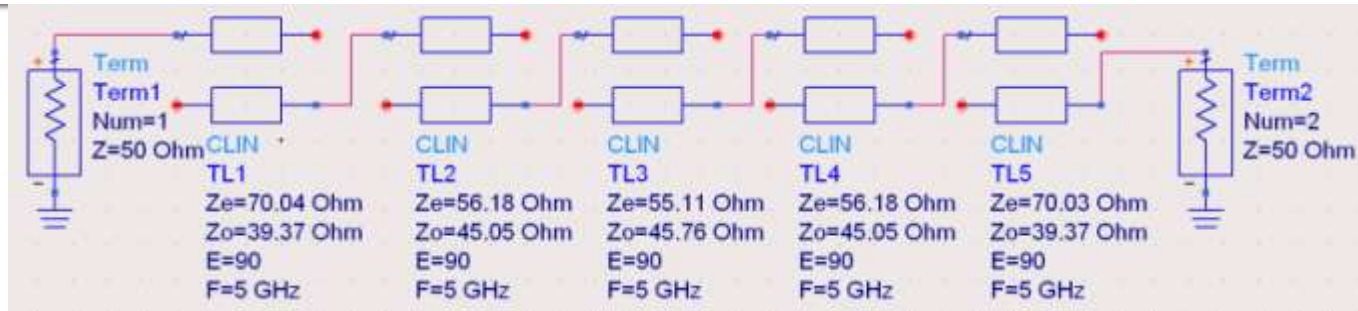
$$\begin{aligned} Z_{0e,n} &= Z_0 \cdot \left[1 + J_n \cdot Z_0 + (J_n \cdot Z_0)^2 \right] \\ Z_{0o,n} &= Z_0 \cdot \left[1 - J_n \cdot Z_0 + (J_n \cdot Z_0)^2 \right] \end{aligned} \quad n = \overline{1, N+1}$$

Exemplu

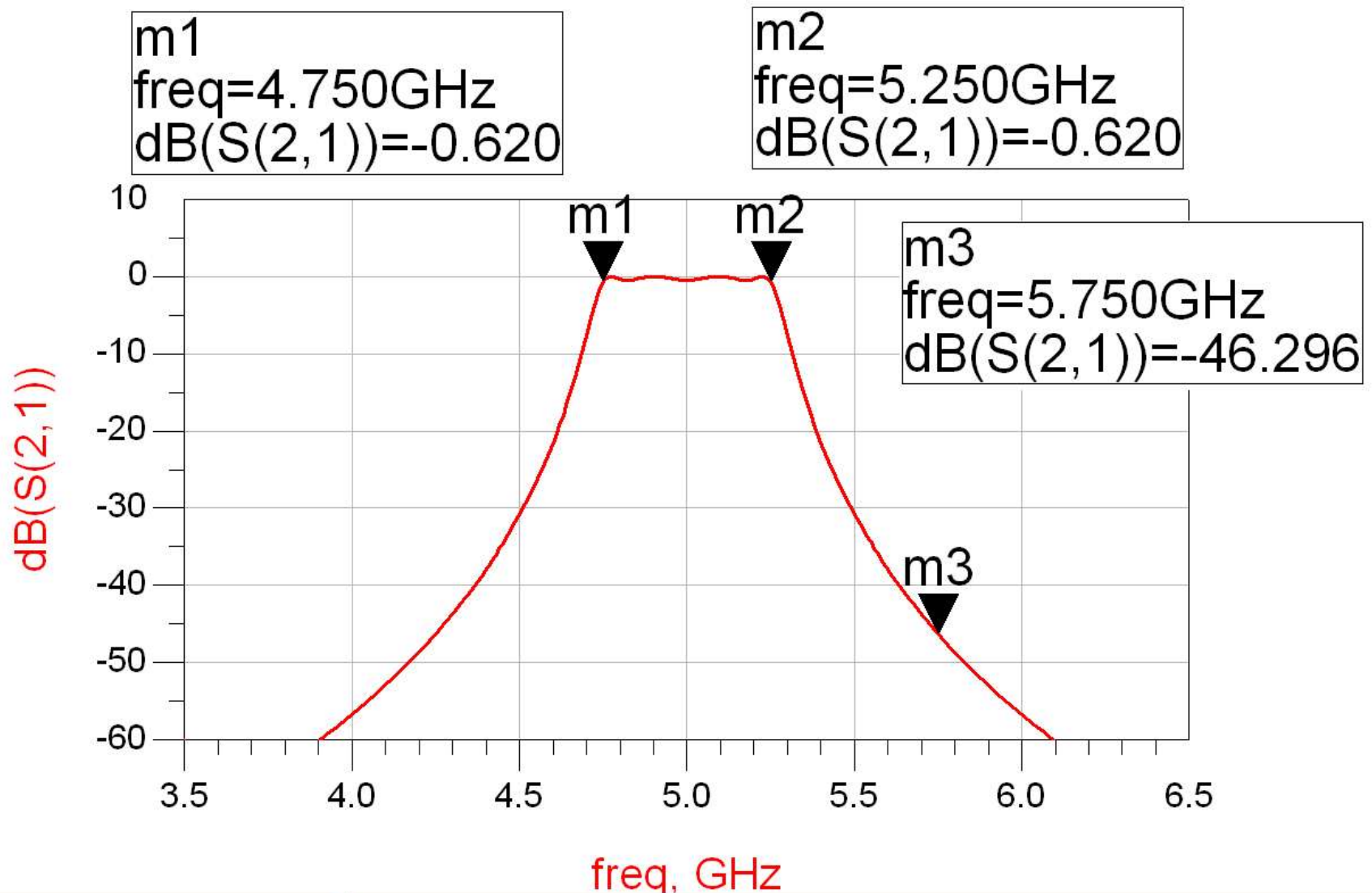
- Similar cu o tema de proiect
- Continuarea amplificatorului C₁₁
- Filtru trece banda de ordinul 4, $f_0 = 5\text{GHz}$, banda 10 %
- Tabel echiriplu 0.5dB sau relatii de calcul:

n	g	ZoJn	Zoe	Zoo
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

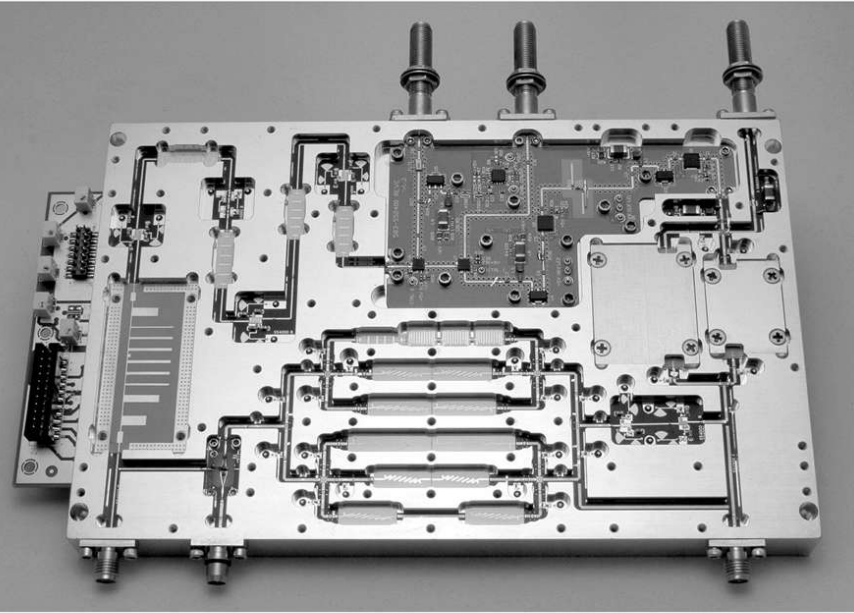
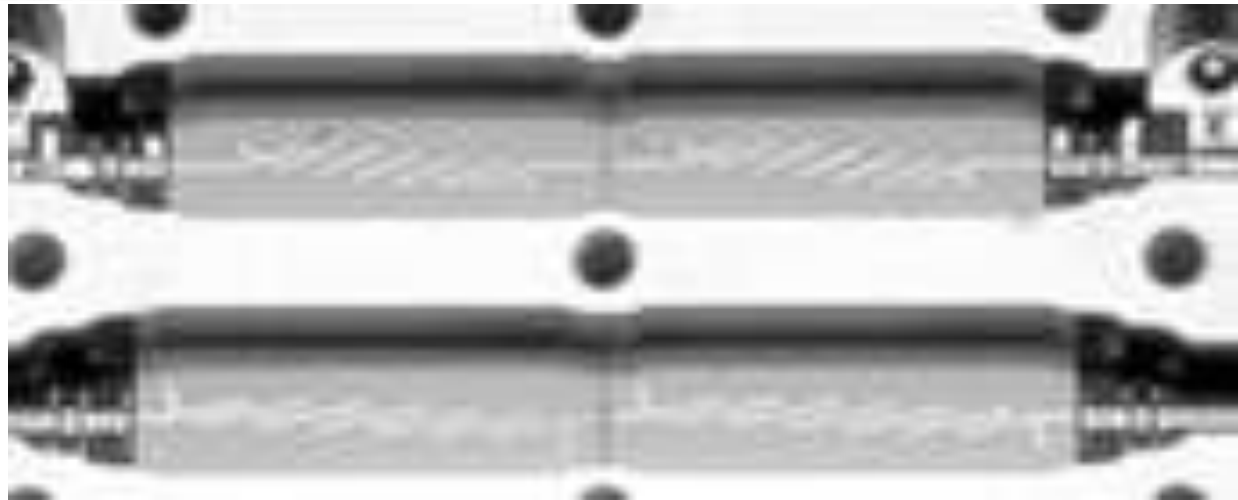
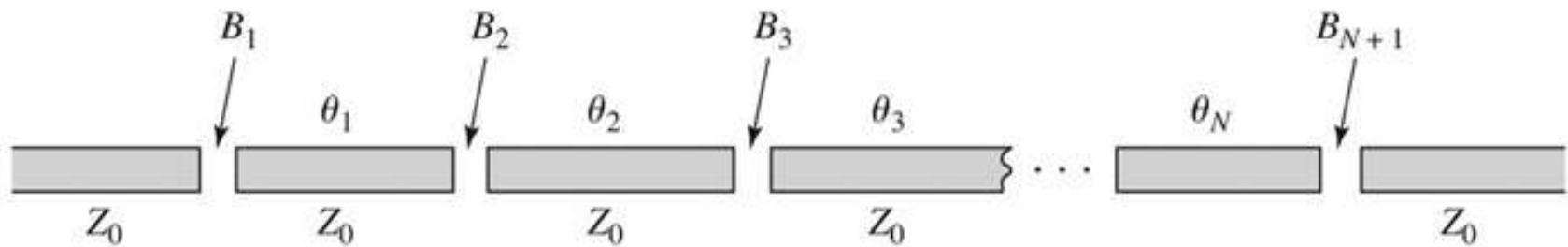


Figure 8.55
Courtesy of LNX Corporation, Salem, N.H.

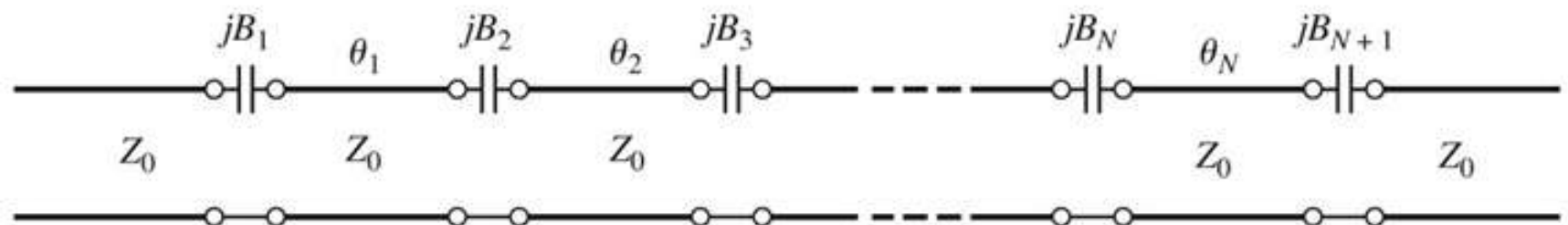


Filtru cu rezonatoare serie cuplate capacitiv

- 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 $\phi = \pi$, $l = \lambda/2$)

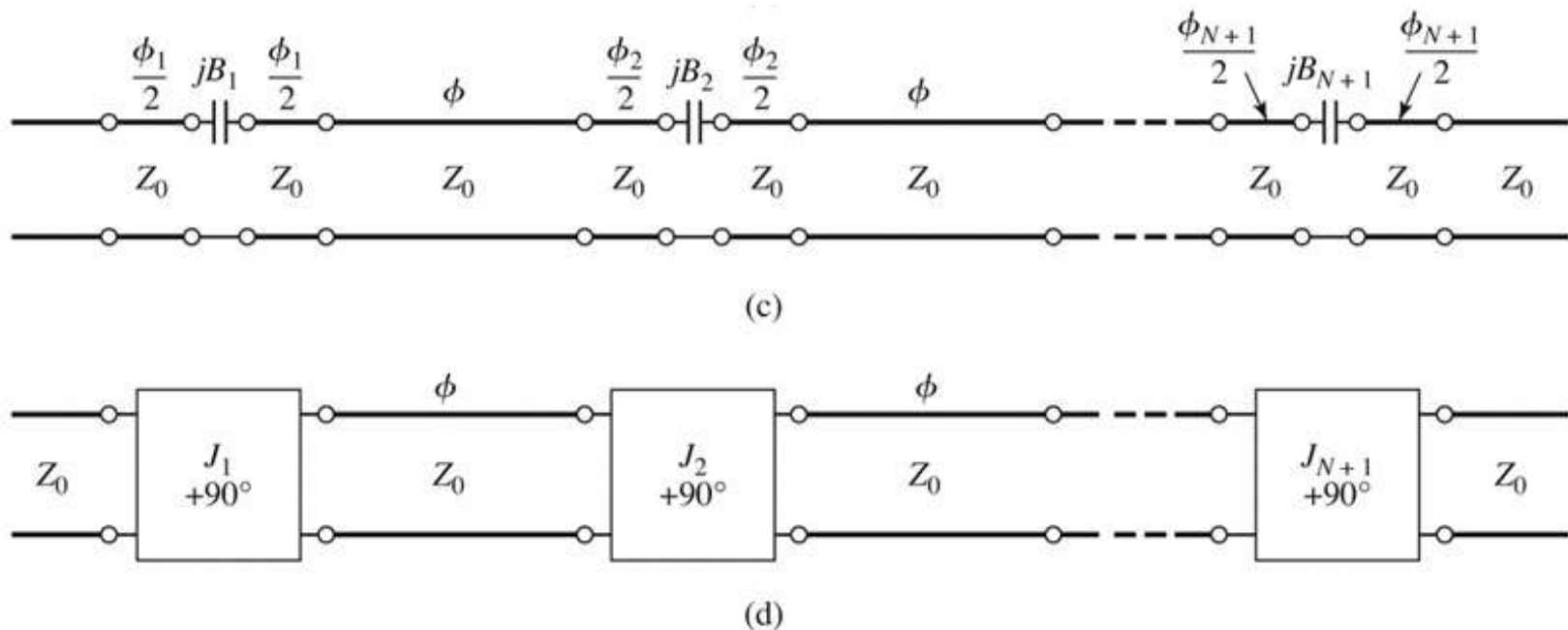


Figure 8.50

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

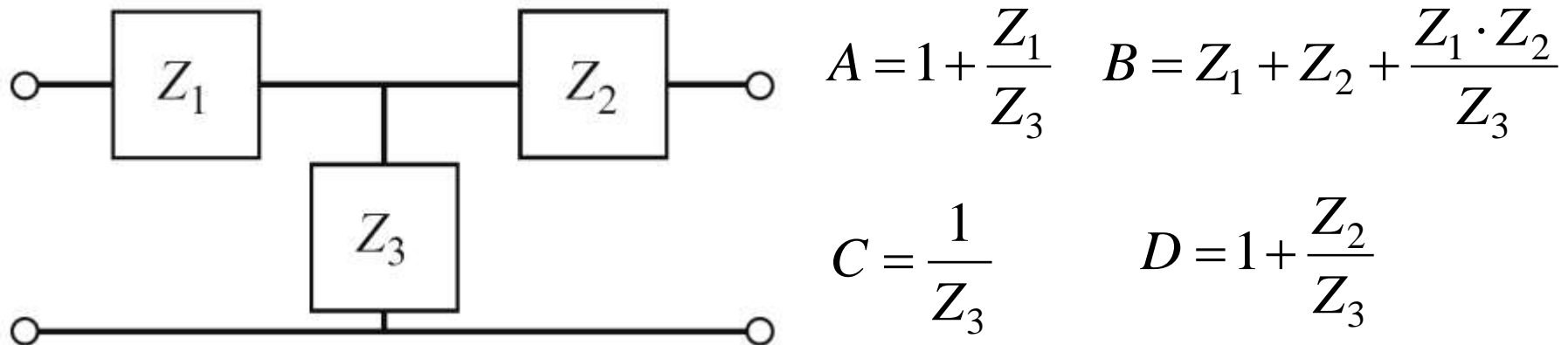
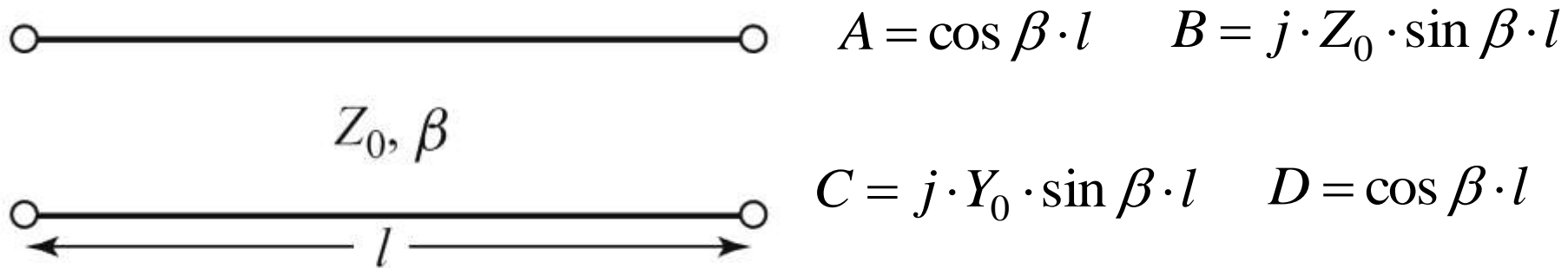
$$\phi_n = -\tan^{-1}(2 \cdot Z_0 \cdot B_n), n = \overline{1, N+1} \quad \phi_n < 0, n = \overline{1, N+1}$$

- 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

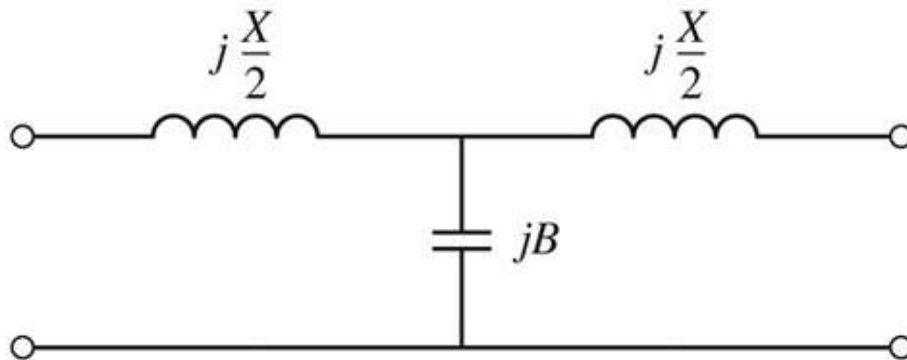
$$Z_3 = \frac{1}{j \cdot Y_0 \cdot \sin \beta \cdot l}$$

- 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

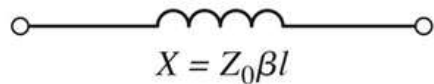


$$\frac{X}{2} = Z_0 \cdot \tan \frac{\beta \cdot l}{2}$$

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

Circuite echivalente pentru sectiuni scurte de linii

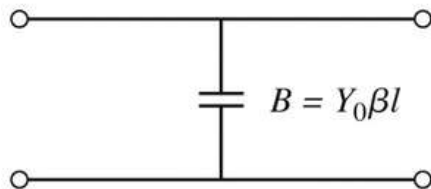
- In functie de valoarea impedantei caracteristice
 - impedanta ridicata $Z_0 \gg$



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



- 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

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

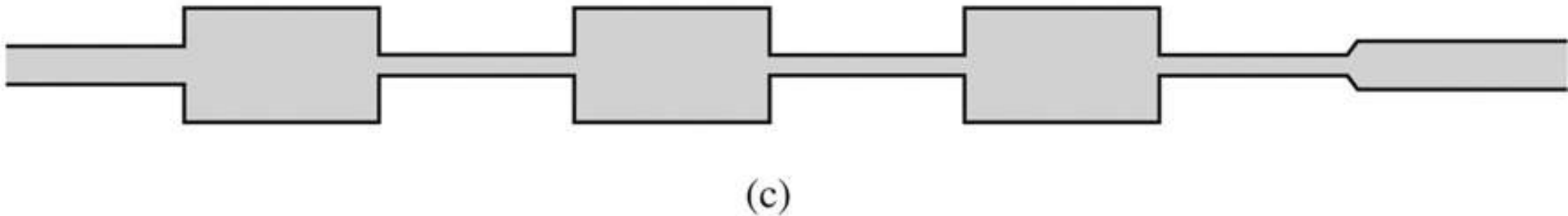
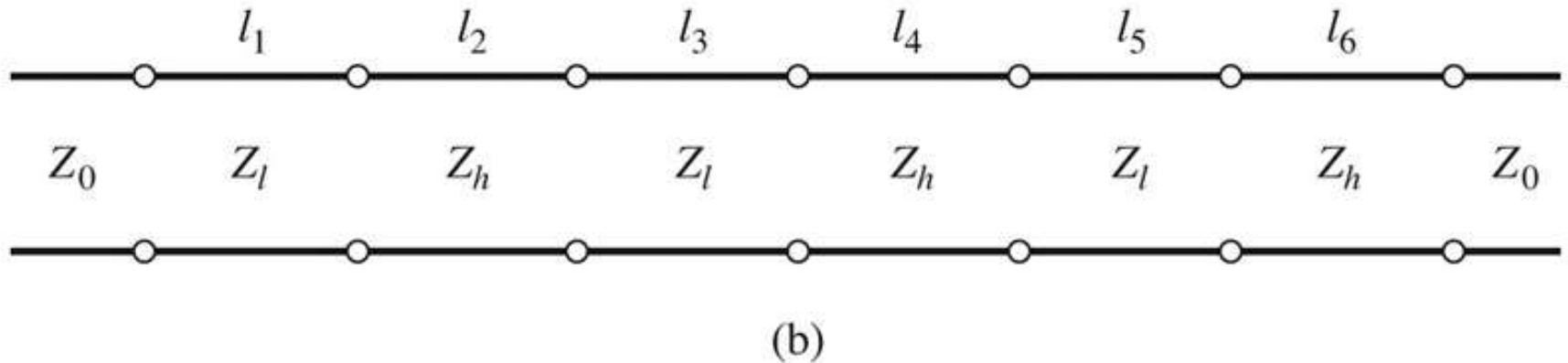
- linii cu impedanta caracteristica mica pentru a implementa o capacitate

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

- 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

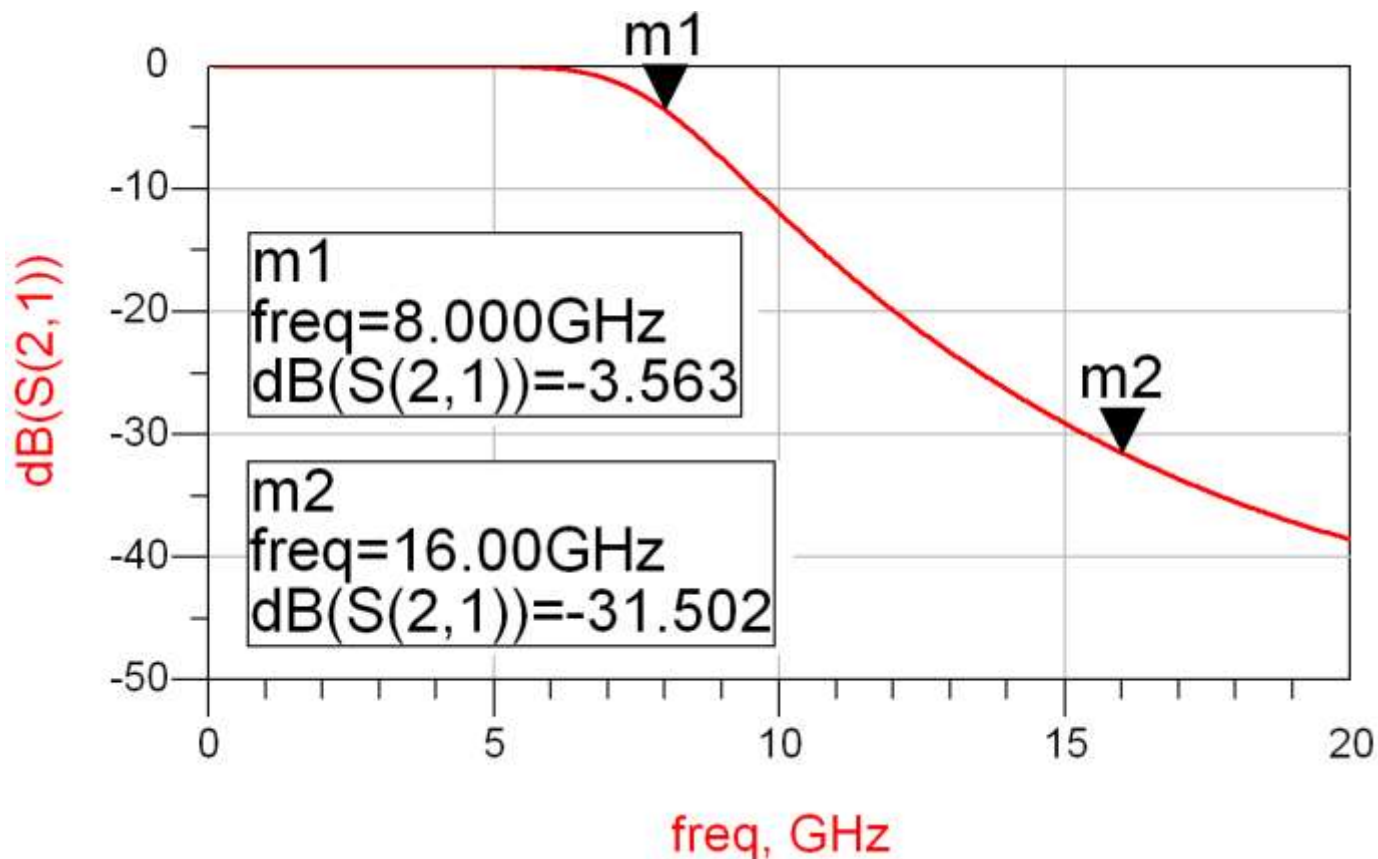


Exemplu

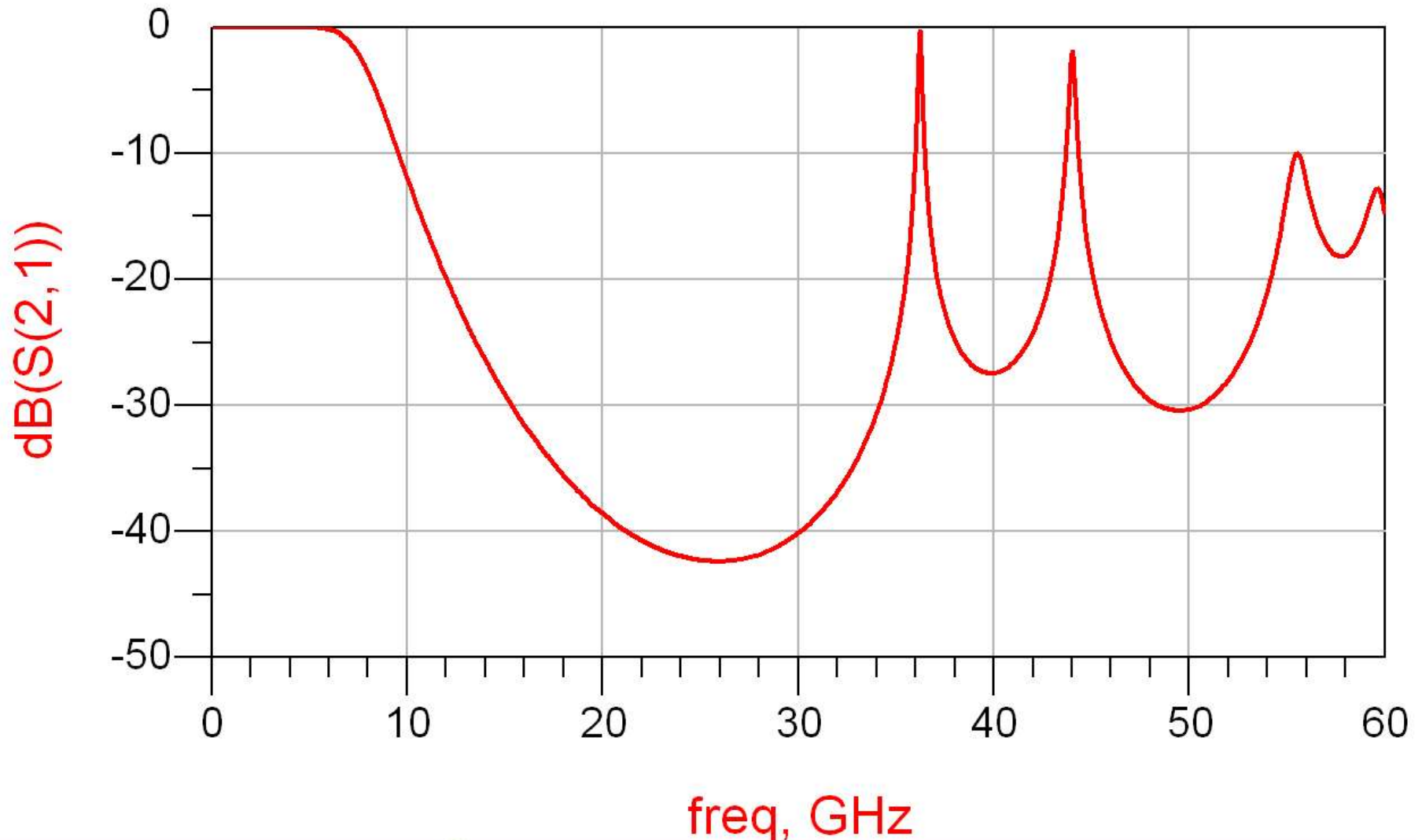
- FTJ cu frecventa de taiere 8GHz, de ordinul 6. Impedanta maxima realizabila este 150Ω iar cea minima 15Ω .

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

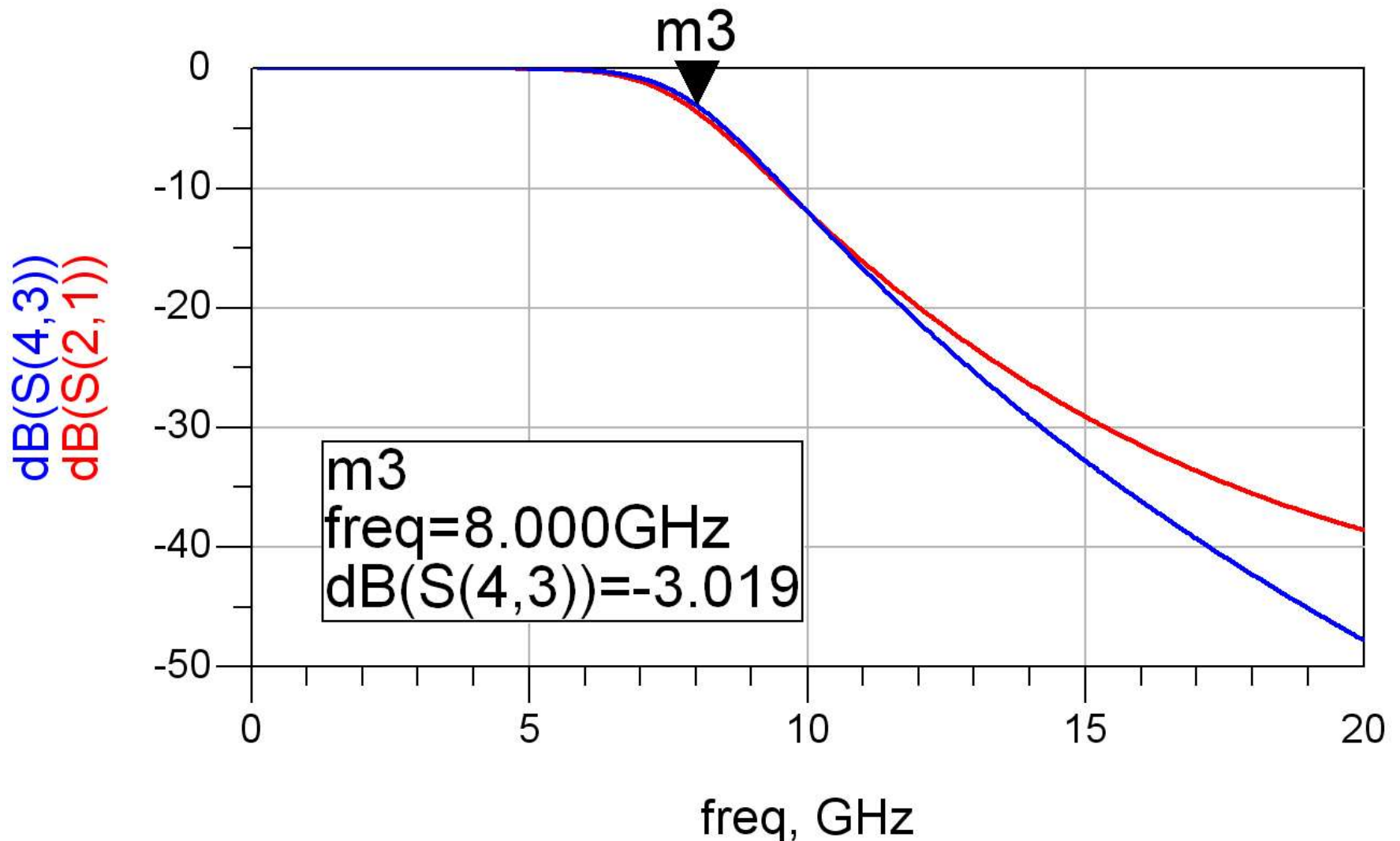
ADS – FTJ stepped impedance



ADS – FTJ stepped impedance



ADS – FTJ comparatie cu elemente concentrate



Example

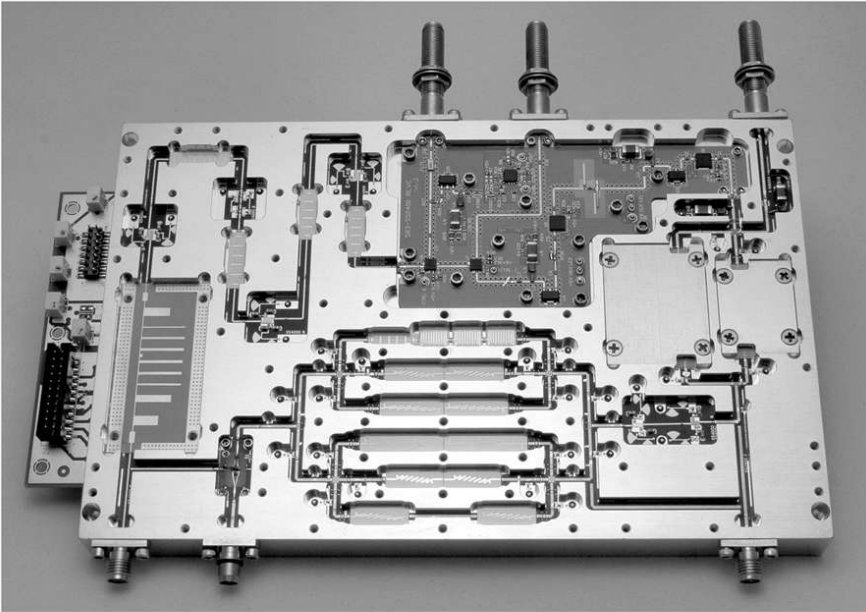
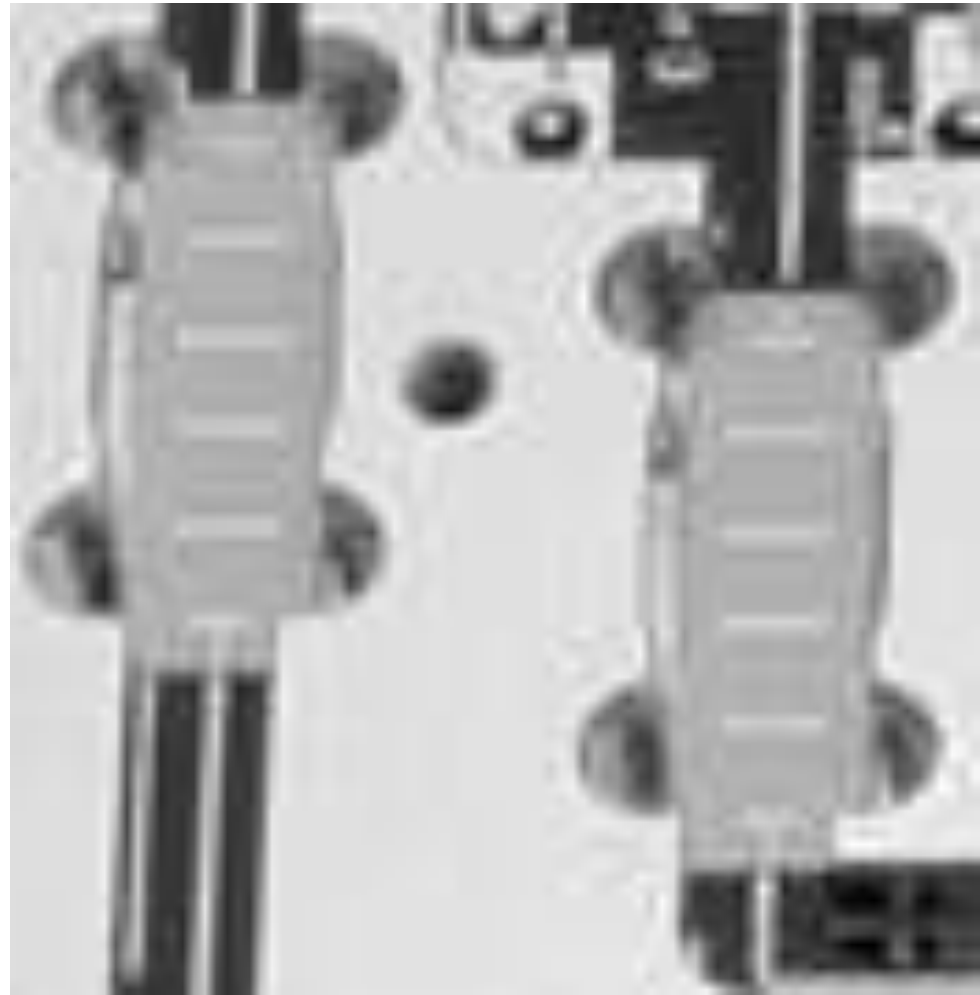


Figure 8.55
Courtesy of LNX Corporation, Salem, N.H.



Supliment Mini Proiect

Implementare cu linii microstrip

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

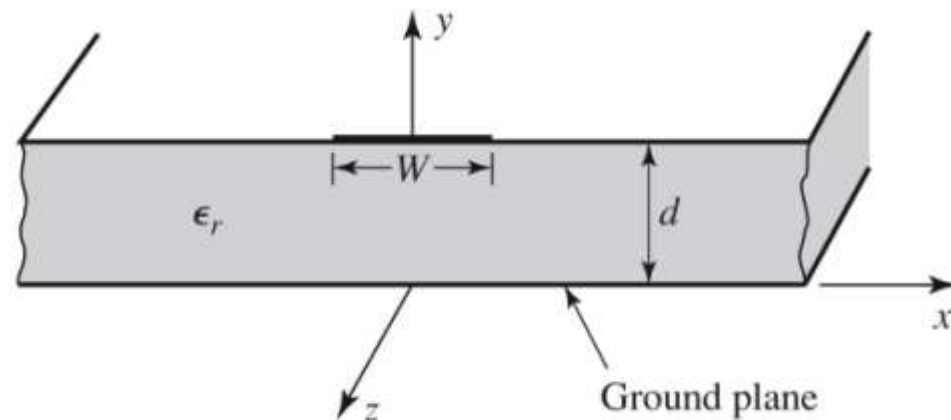


Figure 3.25a
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Implementare cu linii microstrip

- Linie quasi TEM

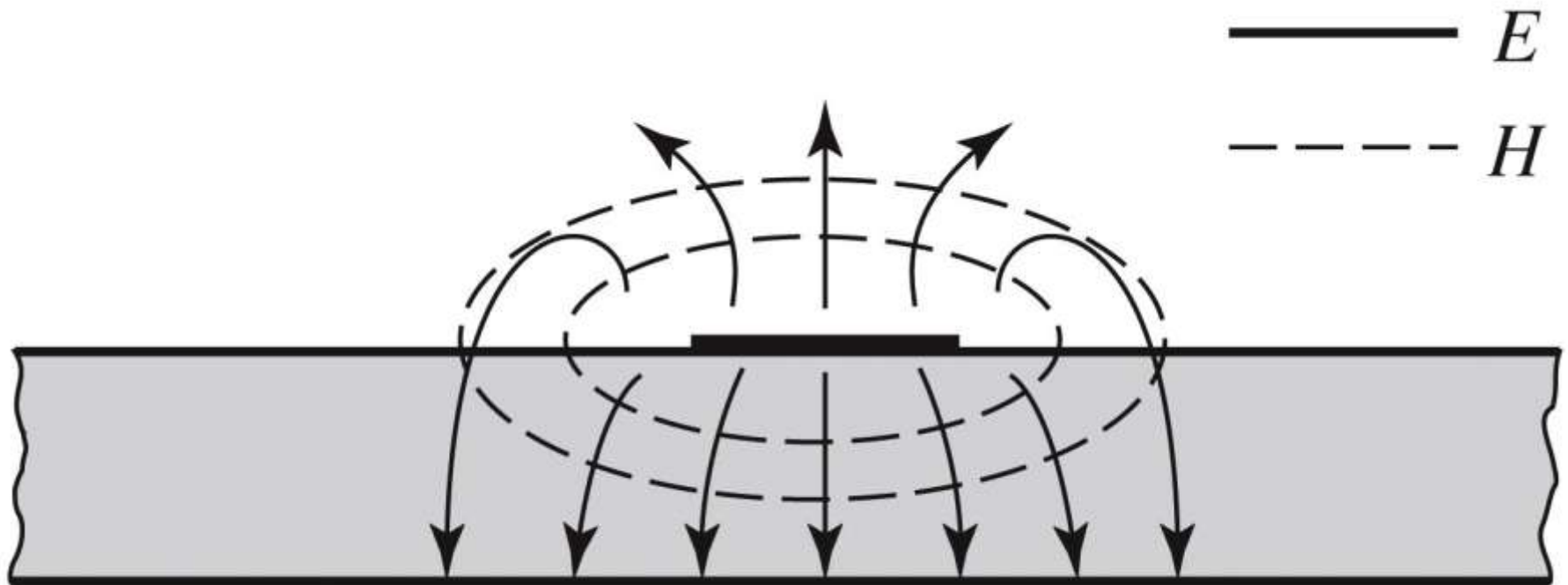


Figure 3.25b

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Implementare cu linii microstrip

- Se echivaleaza linia cu o linie cu dielectric omogen echivalent

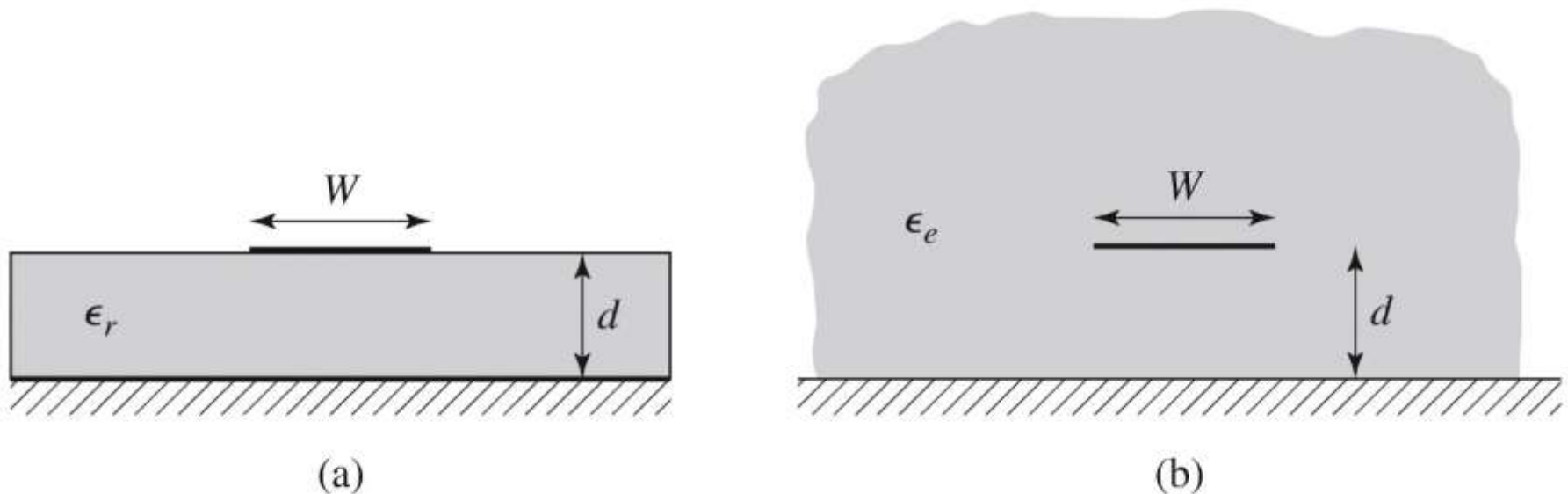
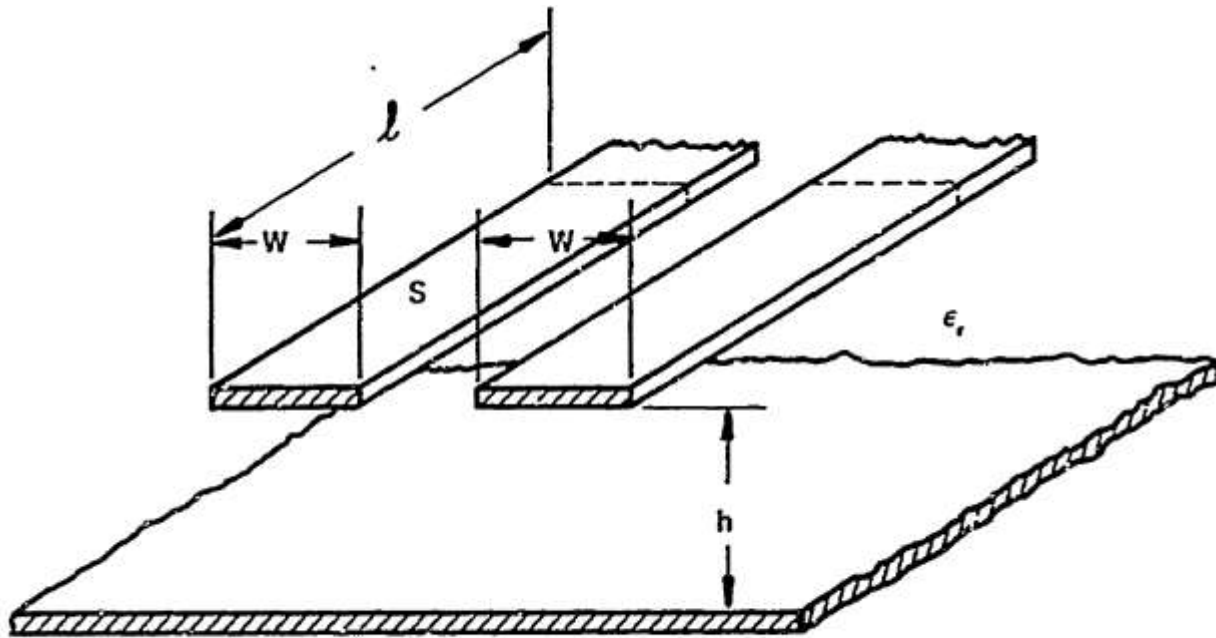


Figure 3.26
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Implementare cu linii microstrip

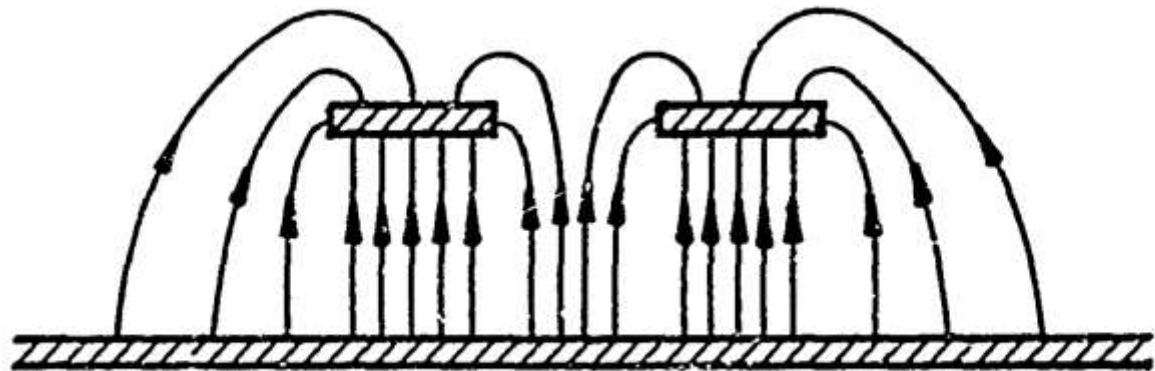
- ~ Aproximativ TEM



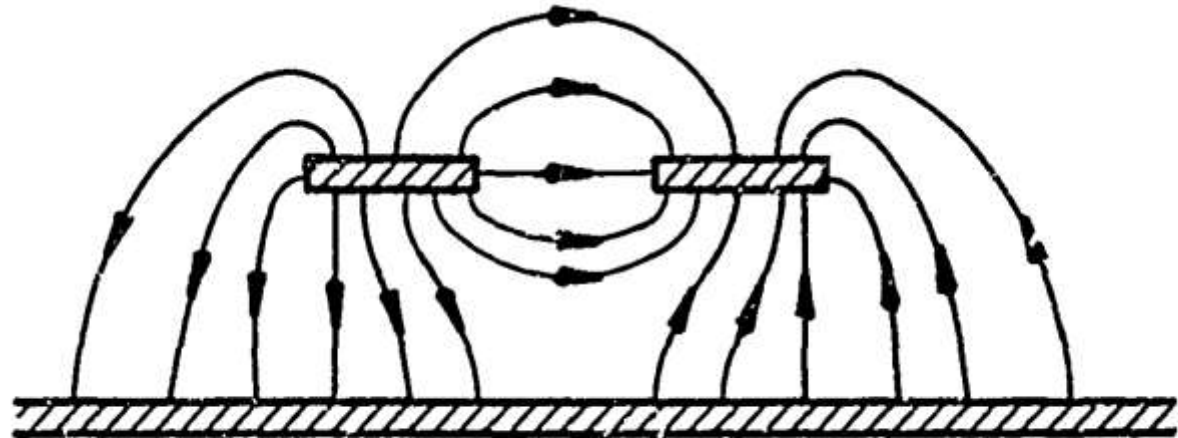
a) COUPLED STRIP GEOMETRY

Implementare cu linii microstrip

- ~ Aproximativ TEM



b) EVEN MODE ELECTRIC FIELD PATTERN (SCHEMATIC)



c) ODD MODE ELECTRIC FIELD PATTERN (SCHEMATIC)

Calcul

■ Calcul empiric

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

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

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

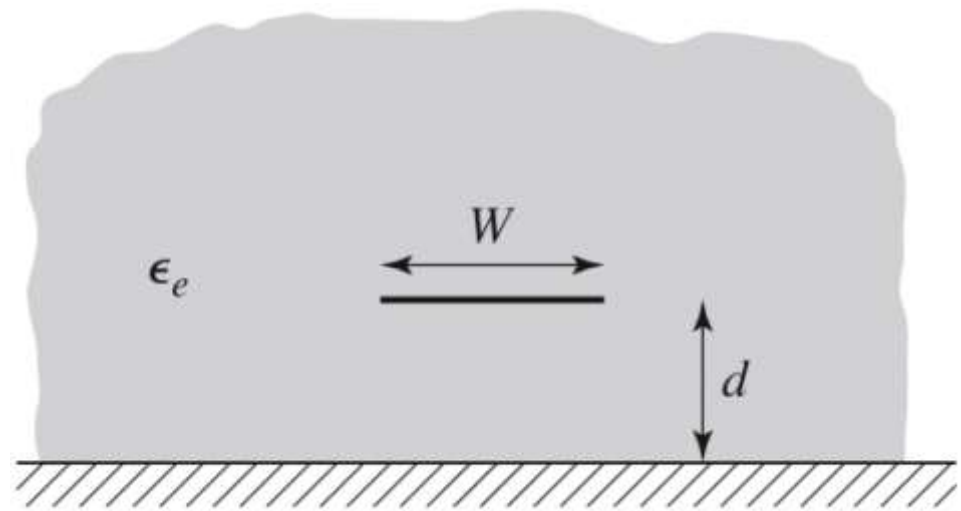


Figure 2.26b
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$$Z_0 = \begin{cases} \frac{60}{\sqrt{\epsilon_e}} \ln \left(\frac{8d}{W} + \frac{W}{4d} \right) & \text{for } W/d \leq 1 \\ \frac{120\pi}{\sqrt{\epsilon_e} [W/d + 1.393 + 0.667 \ln (W/d + 1.444)]} & \text{for } W/d \geq 1. \end{cases}$$

Calcul

■ Calcul empiric

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

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

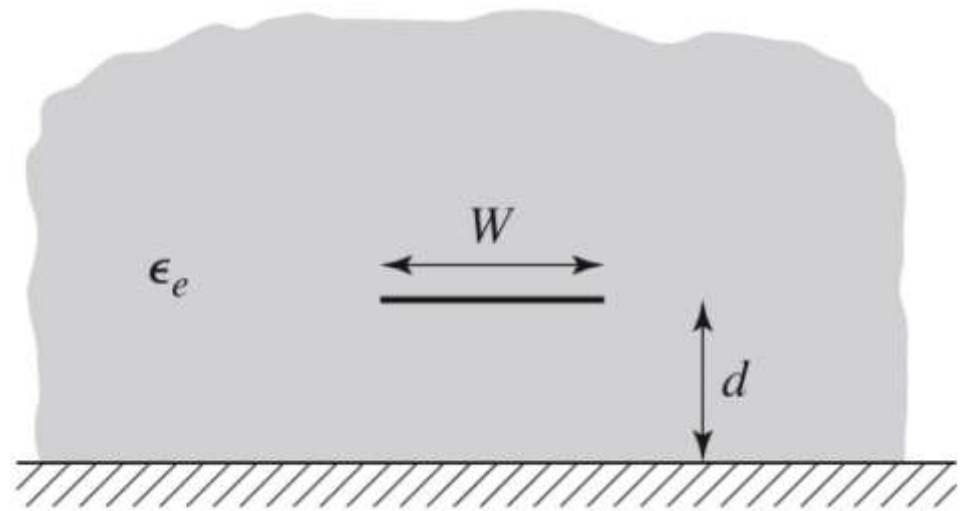
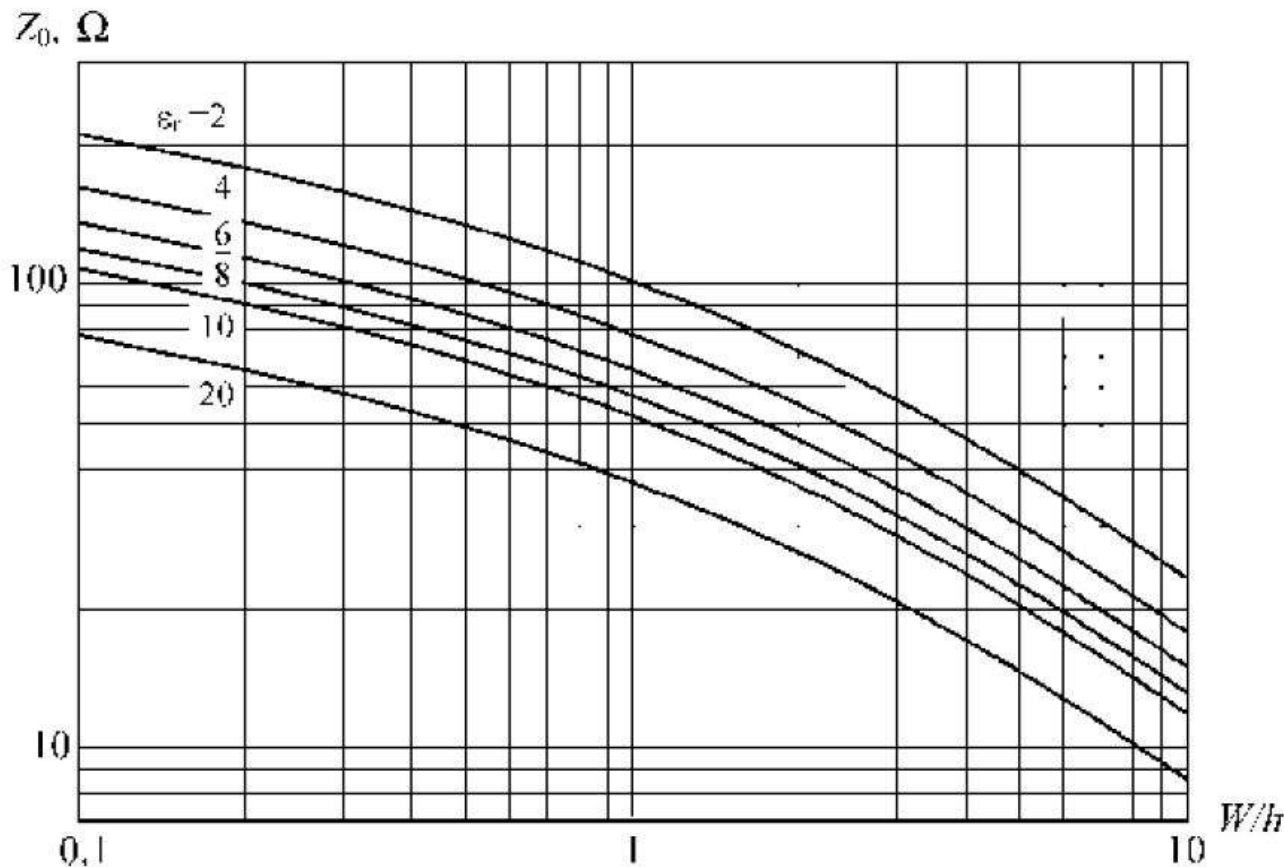


Figure 2.26b
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$$\frac{W}{d} = \begin{cases} \frac{8e^A}{e^{2A} - 2} & \text{for } W/d < 2 \\ \frac{2}{\pi} \left[B - 1 - \ln(2B - 1) + \frac{\epsilon_r - 1}{2\epsilon_r} \left\{ \ln(B - 1) + 0.39 - \frac{0.61}{\epsilon_r} \right\} \right] & \text{for } W/d > 2, \end{cases}$$

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/ft²)
 - 10z=28.35g și 1ft=30.48cm

Greutatea cuprului depus		Grosimea stratului	
oz/ft ²	g/ft ²	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

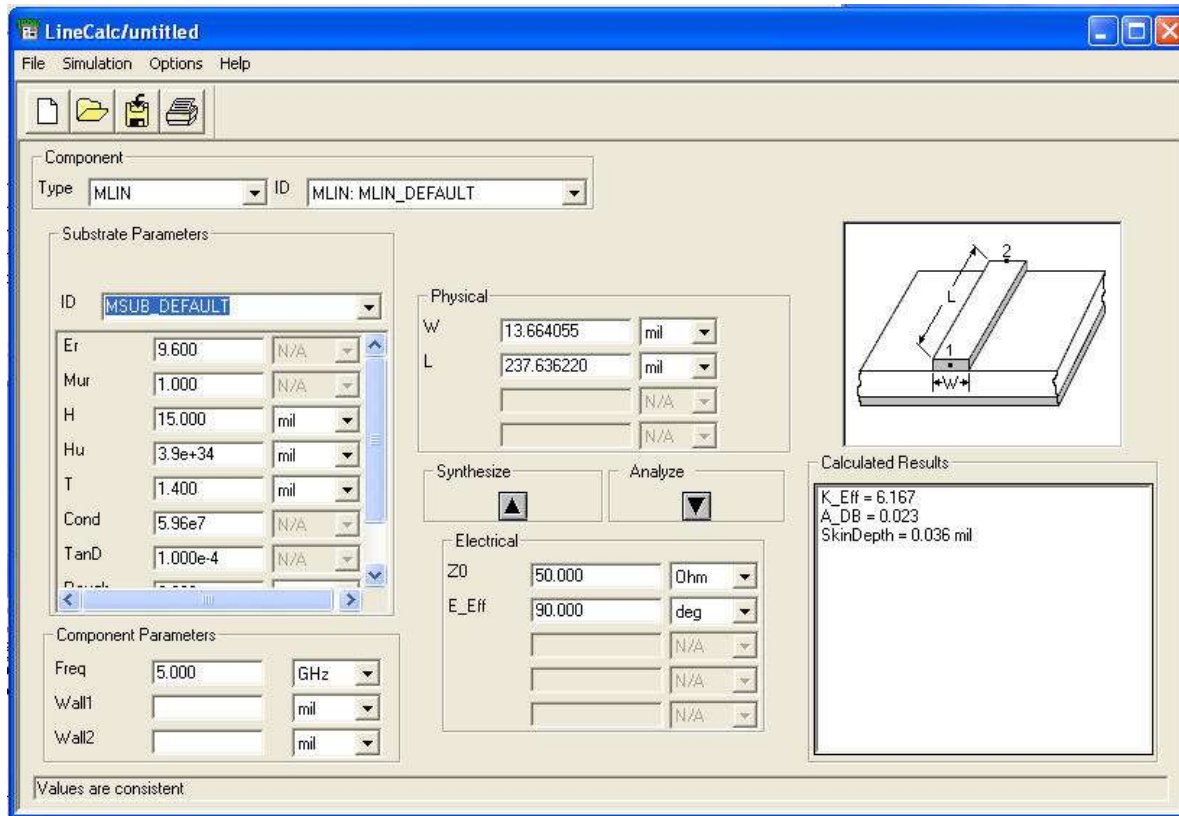
Standard Thickness
RO4003C: 0.008" (0.203mm), 0.012 (0.305mm), 0.016" (0.406mm), 0.020" (0.508mm) 0.032" (0.813mm), 0.060" (1.524mm)
RO4350B: *0.004" (0.101mm), 0.0066" (0.168mm) 0.010" (0.254mm), 0.0133 (0.338mm), 0.0166 (0.422mm), 0.020" (0.508mm) 0.030" (0.762mm), 0.060" (1.524mm)

Microstrip, materiale substrat

	Constanta dielectrică relativă	Factorul de pierderi dielectrice	Conductivitate termică	Coeficient liniar de expansiune	Coeficient de temperatură a lui ϵ_r
Material	-	-	W/cm/K	ppm/K	ppm/K
Al_2O_3 (99.5%)	9.8	0.0001	0.37	6.3	+136
Al_2O_3 (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_2	85	0.004	0.05	7.5	-575
Tetratitanat de Ba (BaTi_4O_9)	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	-	-	-

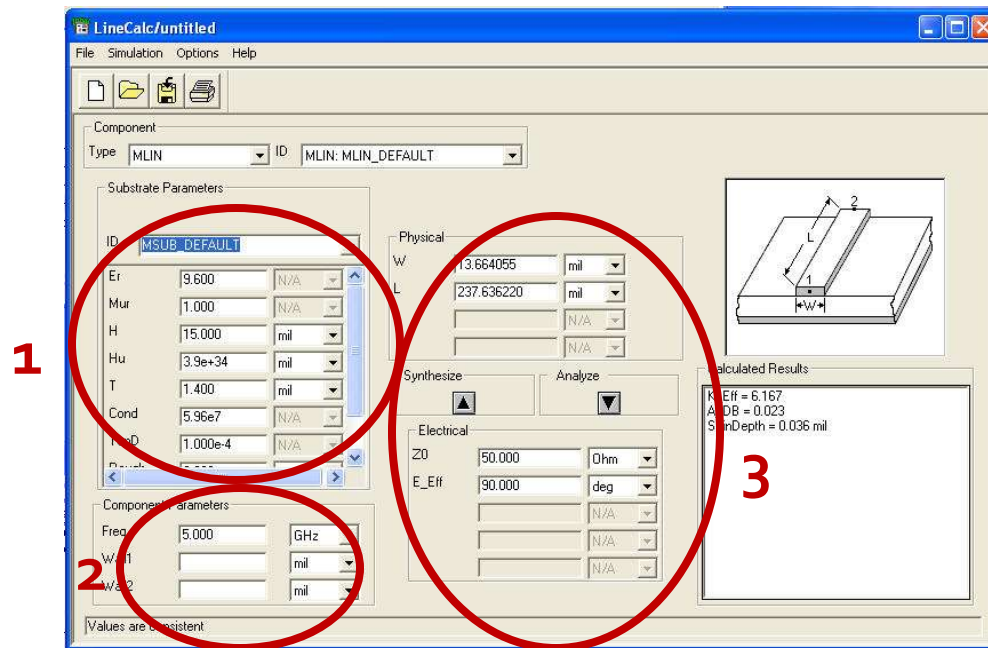
ADS linecalc

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



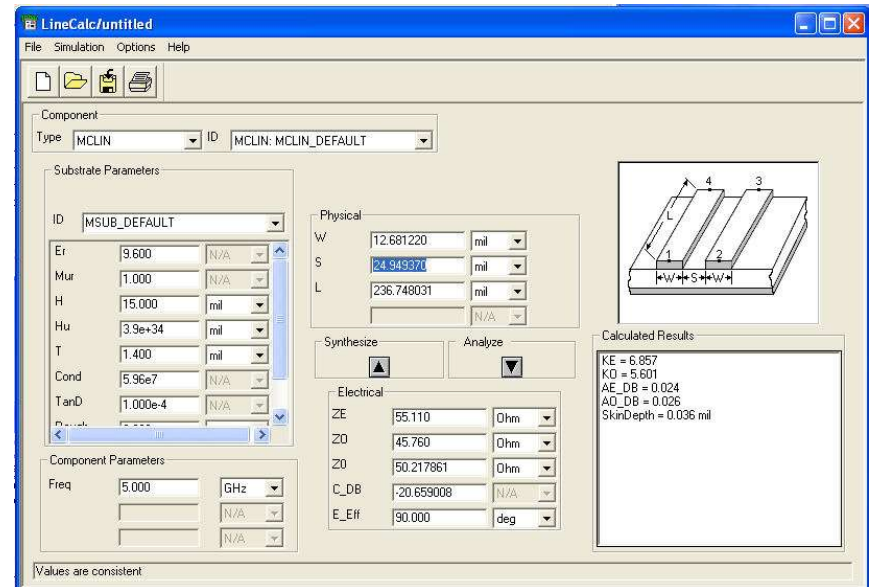
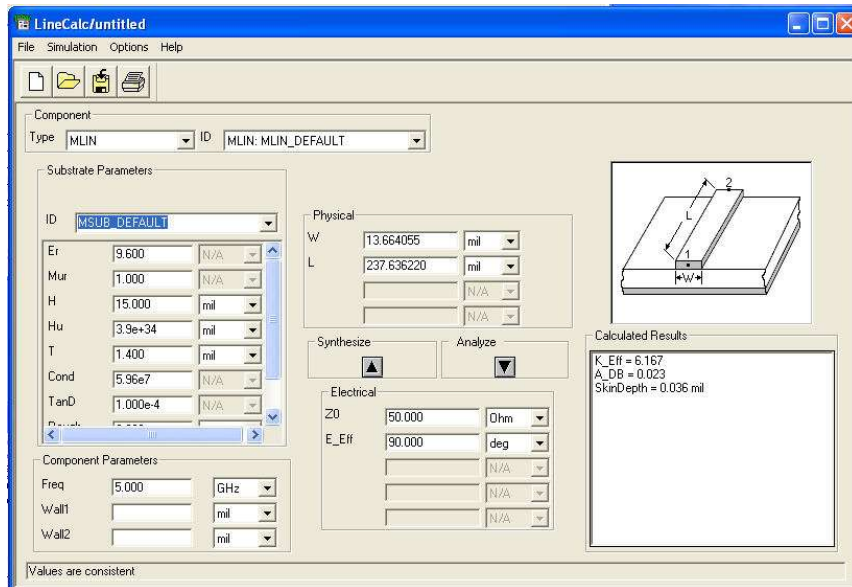
ADS linecalc

- 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: MSUB_DEFAULT

Er	9.600	N/A
Mur	1.000	N/A
H	15.000	mil
Hu	3.9e+34	mil
T	1.400	mil
Cond	5.96e7	N/A
TanD	1.000e-4	N/A

Physical

W	12.681220	mil
S	24.949370	mil
L	236.748031	mil

Synthesize Analyze

Electrical

ZE	55.110	Ohm
ZO	45.760	Ohm
Z0	50.217861	Ohm
C_DB	-20.659008	N/A
E_Eff	90.000	deg

Diagram: A 3D perspective view of a microstrip line on a substrate. The diagram shows the width of the strip (W), the spacing between strips (S), and the length of the strip (L). The strips are numbered 1, 2, 3, and 4.

Calculated Results

KE = 6.857
KO = 5.601
AE_DB = 0.024
AD_DB = 0.026
SkinDepth = 0.036 mil

Values are consistent

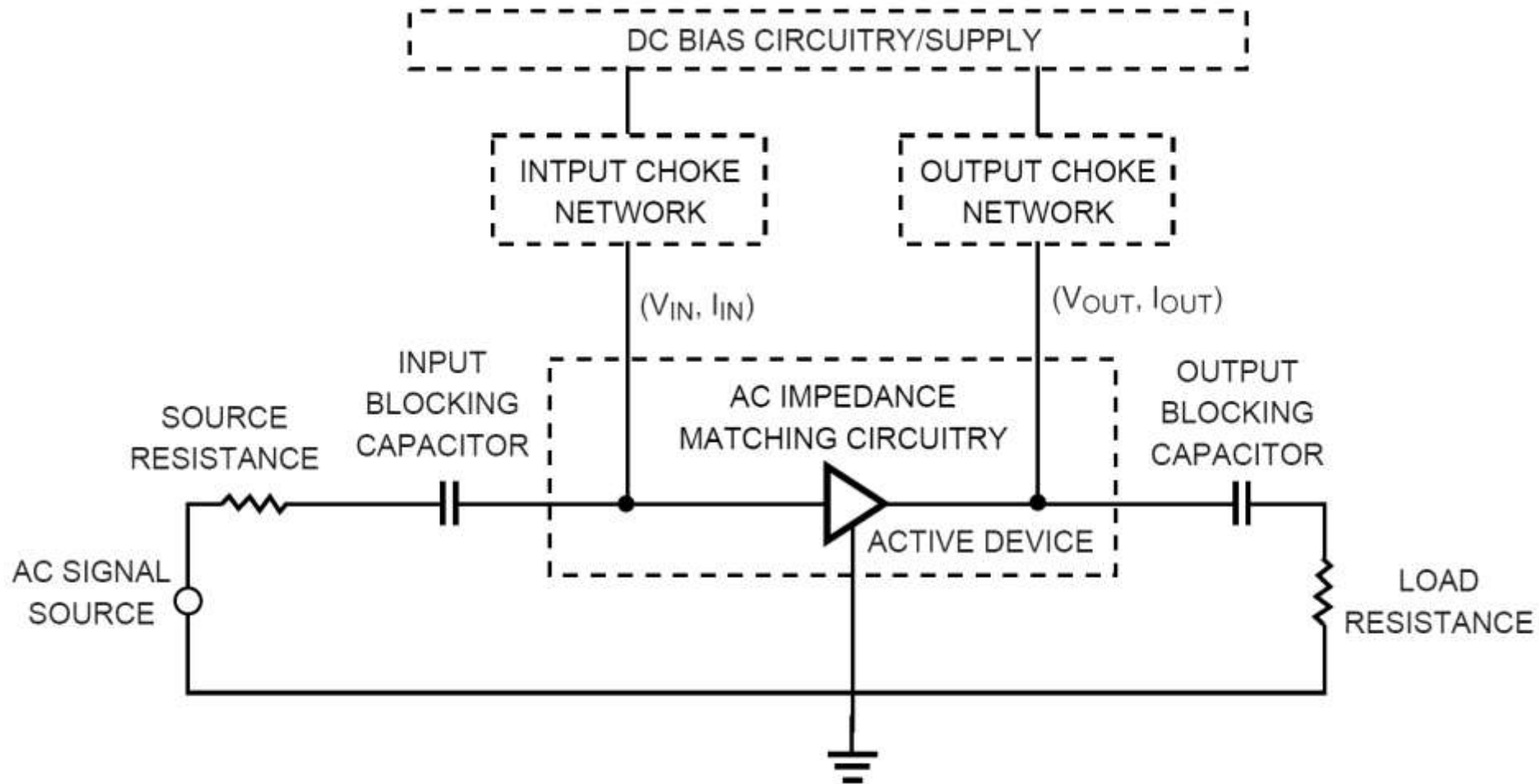
Linii de transmisie

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

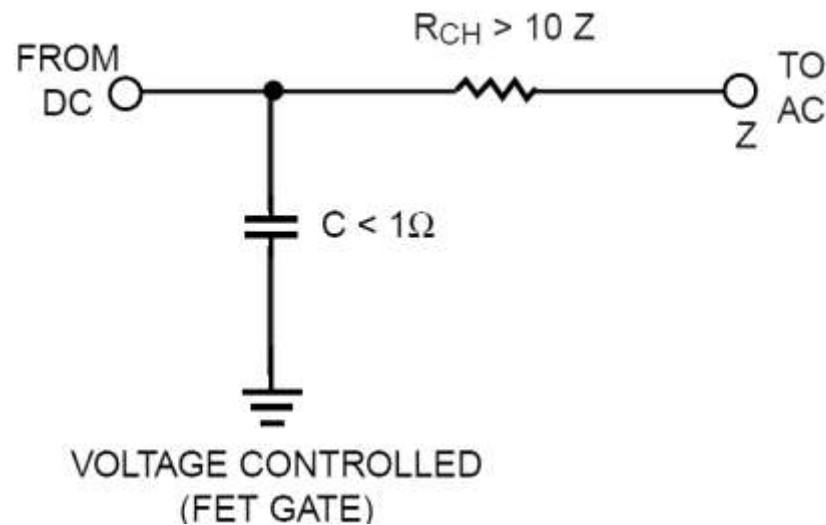
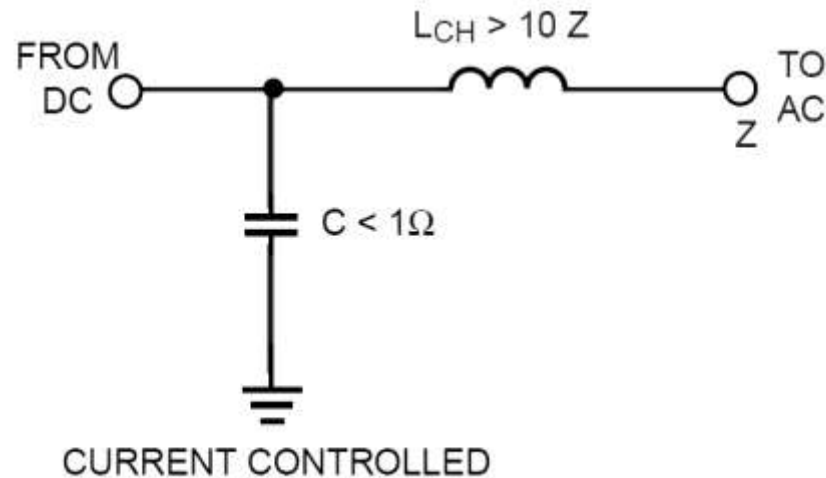
Polarizare

- <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

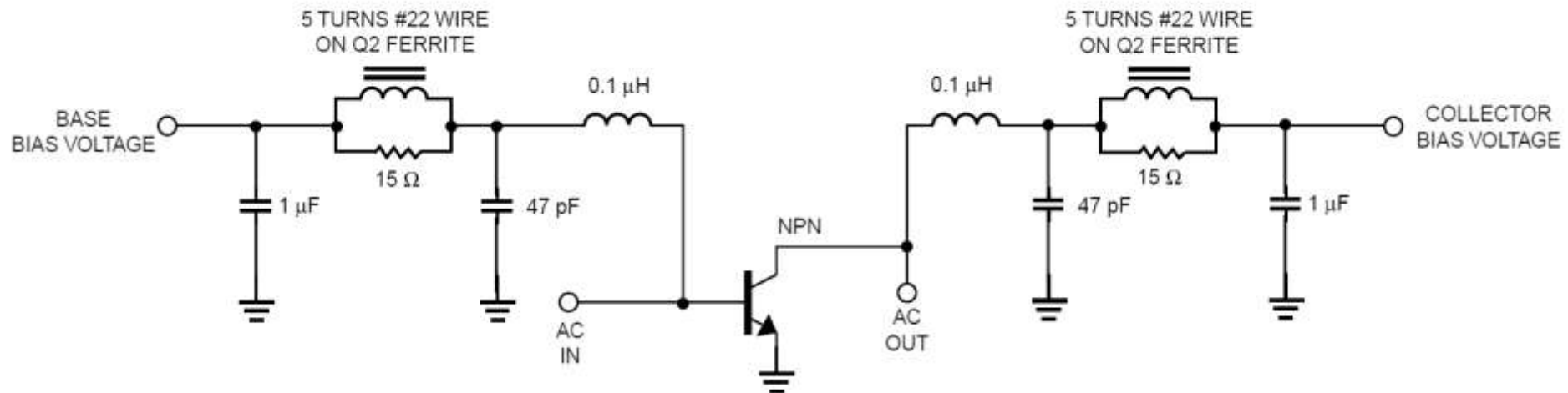
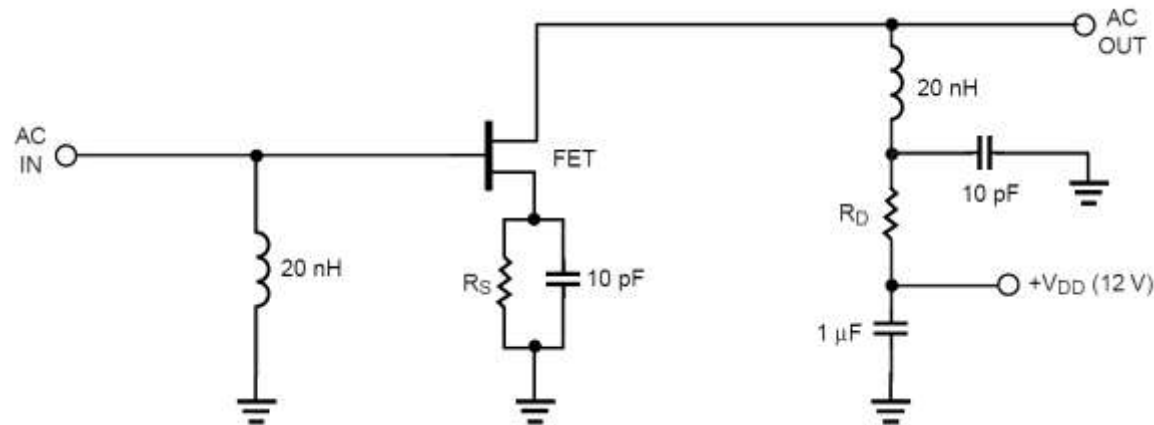
Polarizare



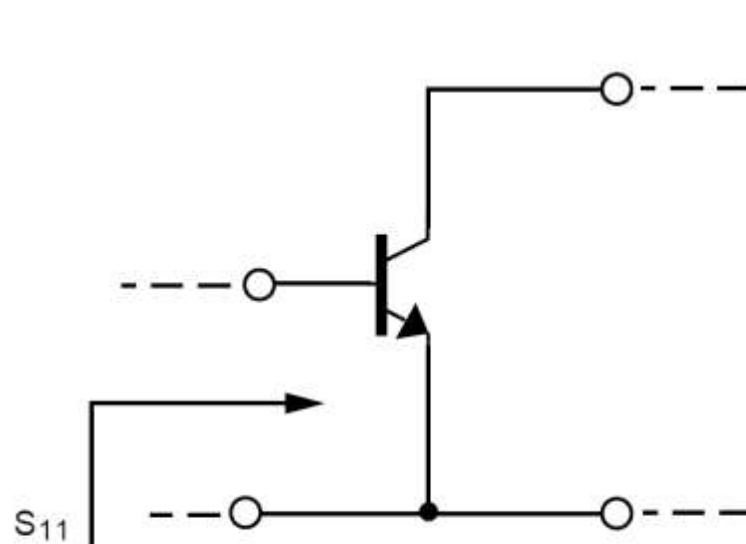
Polarizare, soc tipic



Polarizare, scheme/valori tipice

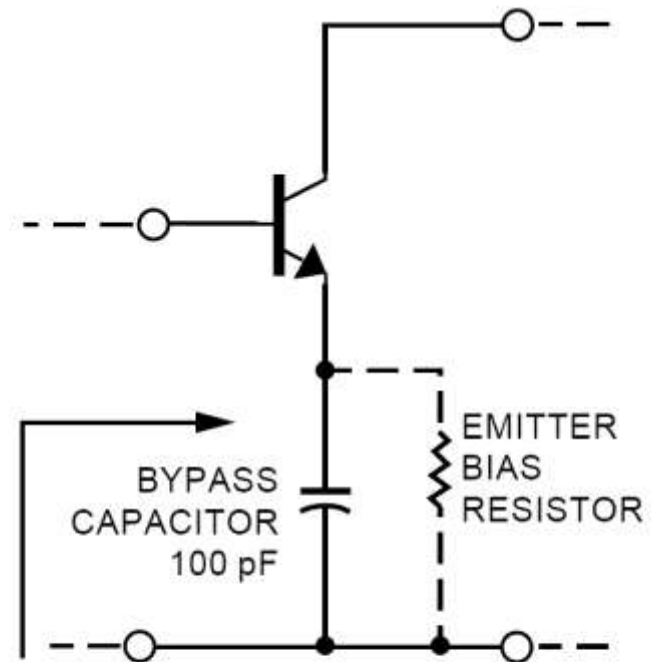


Polarizare, problema elementelor conectate in E/S



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

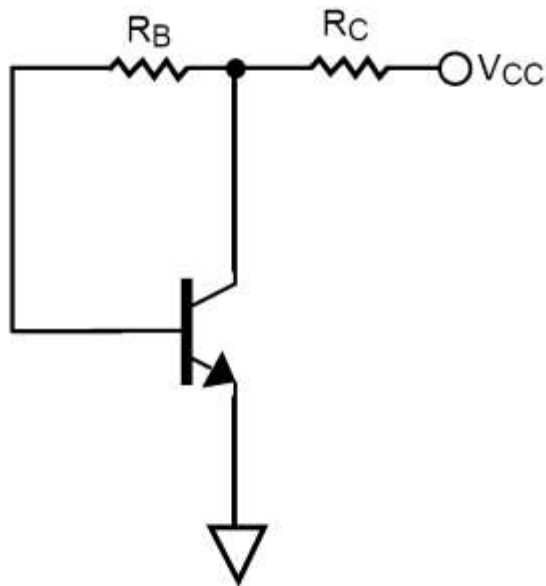
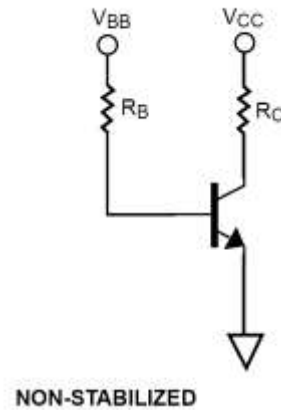
$$S_{11} \text{ (AT 0.1 GHz)} = 0.901 \angle -14.9^\circ$$



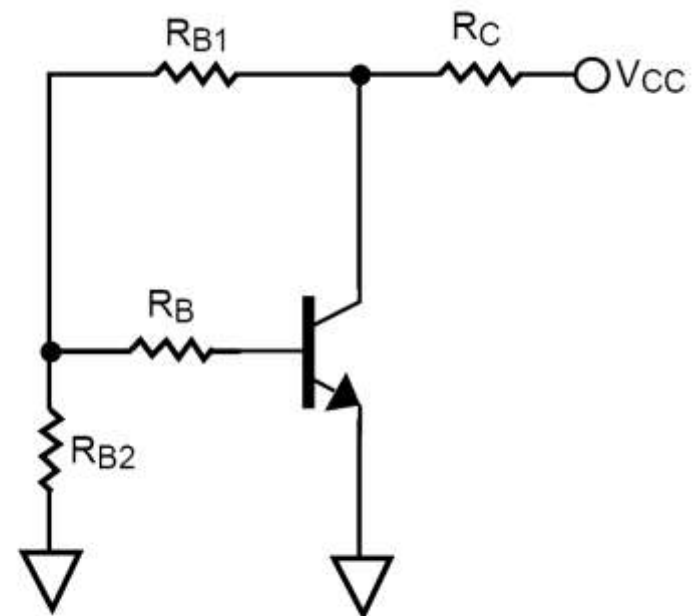
$$S'_{11} \text{ (AT 4 GHz)} = 0.52 \angle 154^\circ \text{ UNCHANGED AT 4 GHz}$$

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

Polarizare TB scheme de polarizare



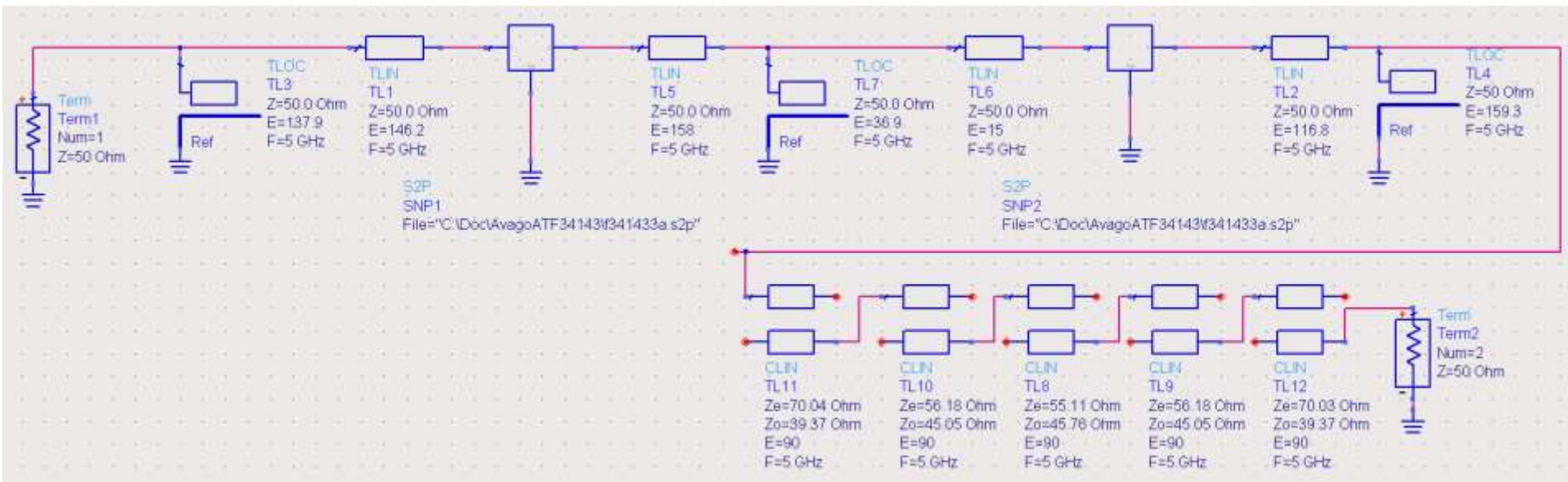
VOLTAGE FEEDBACK



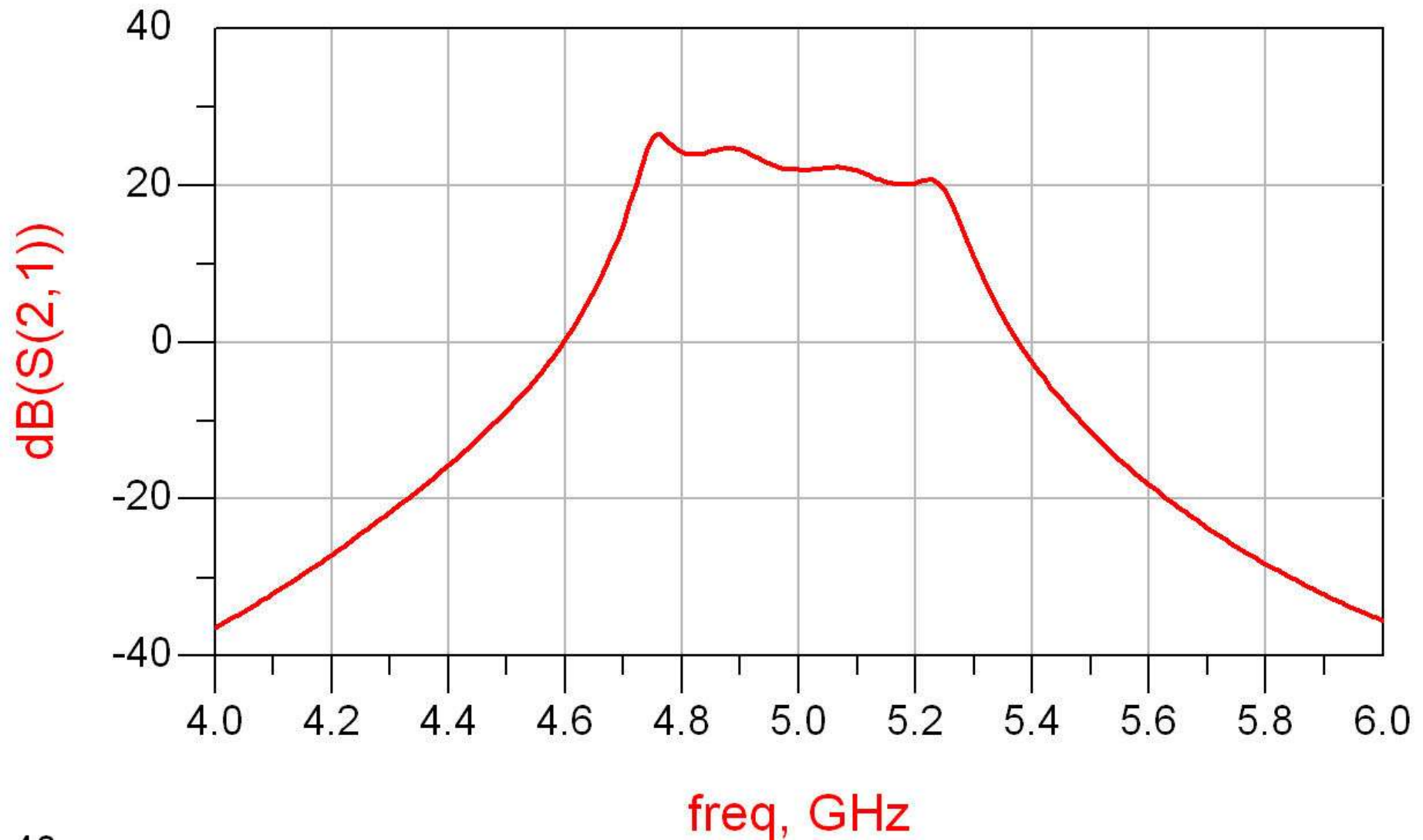
VOLTAGE FEEDBACK AND CONSTANT
BASE CURRENT SOURCE

Exemplu proiect

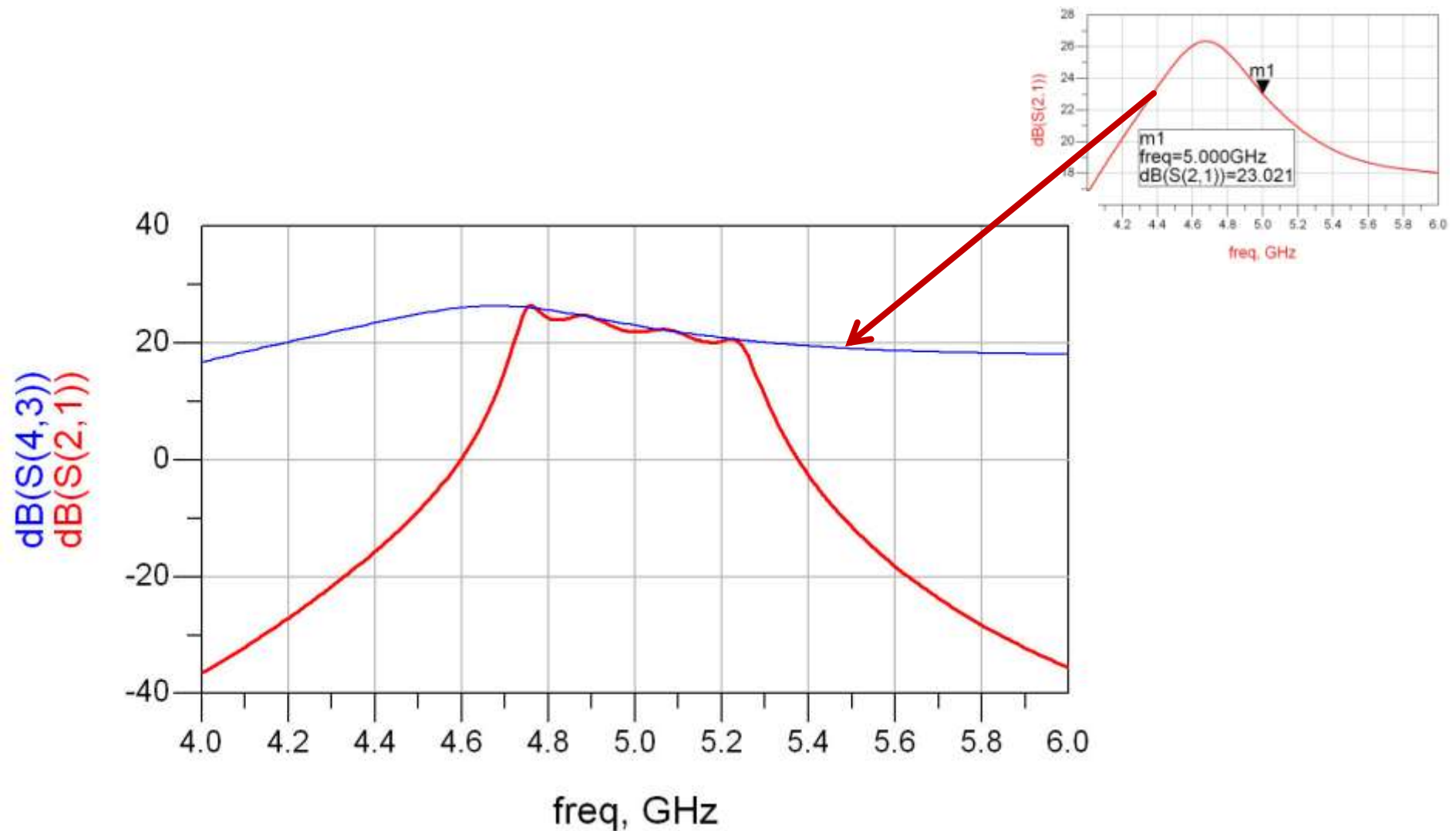
- Unirea celor doua scheme
 - C11 – amplificator (var 4/S36-37)
 - ~~C13~~ – filtre



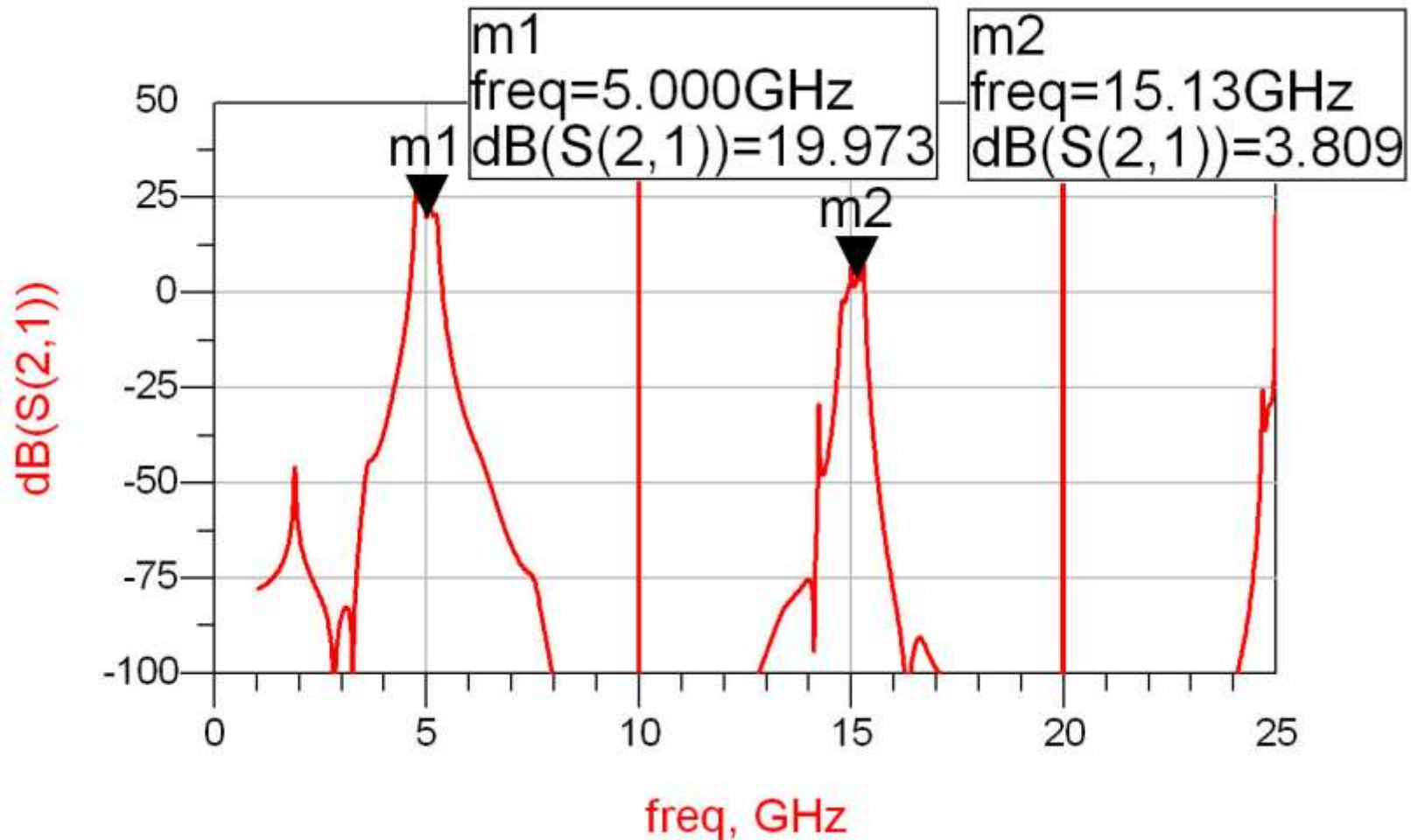
Rezultat (dezechilibrat)



Rezultat (dezechilibrat)

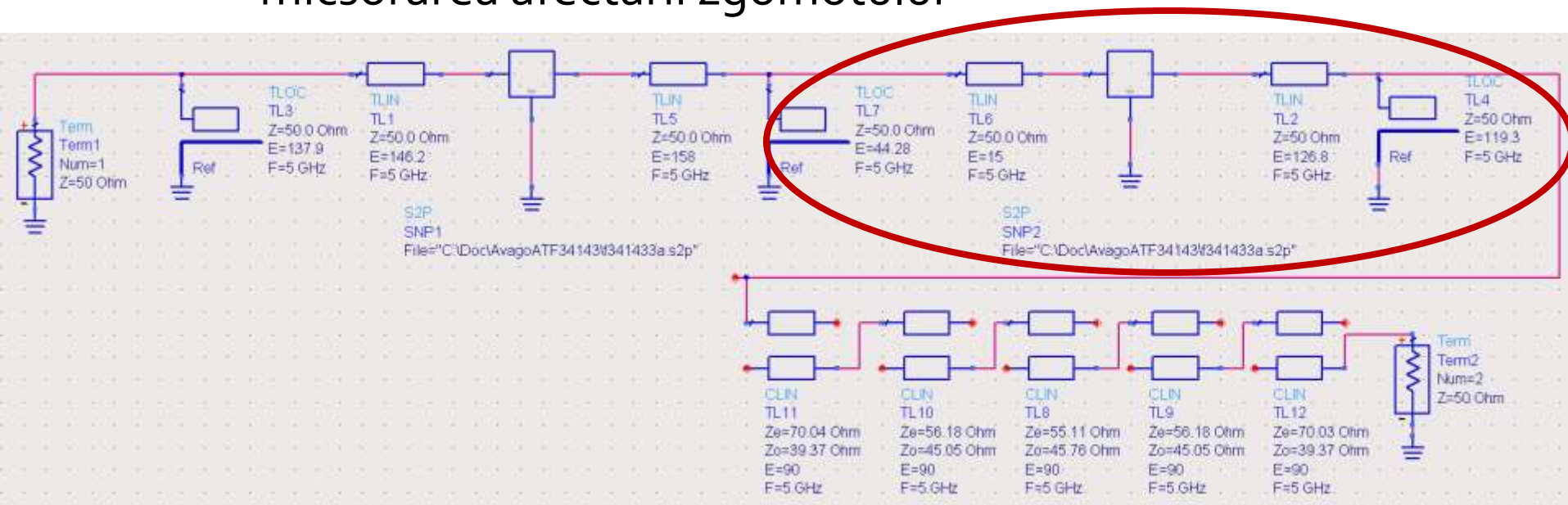


Rezultat (periodic in frecventa)

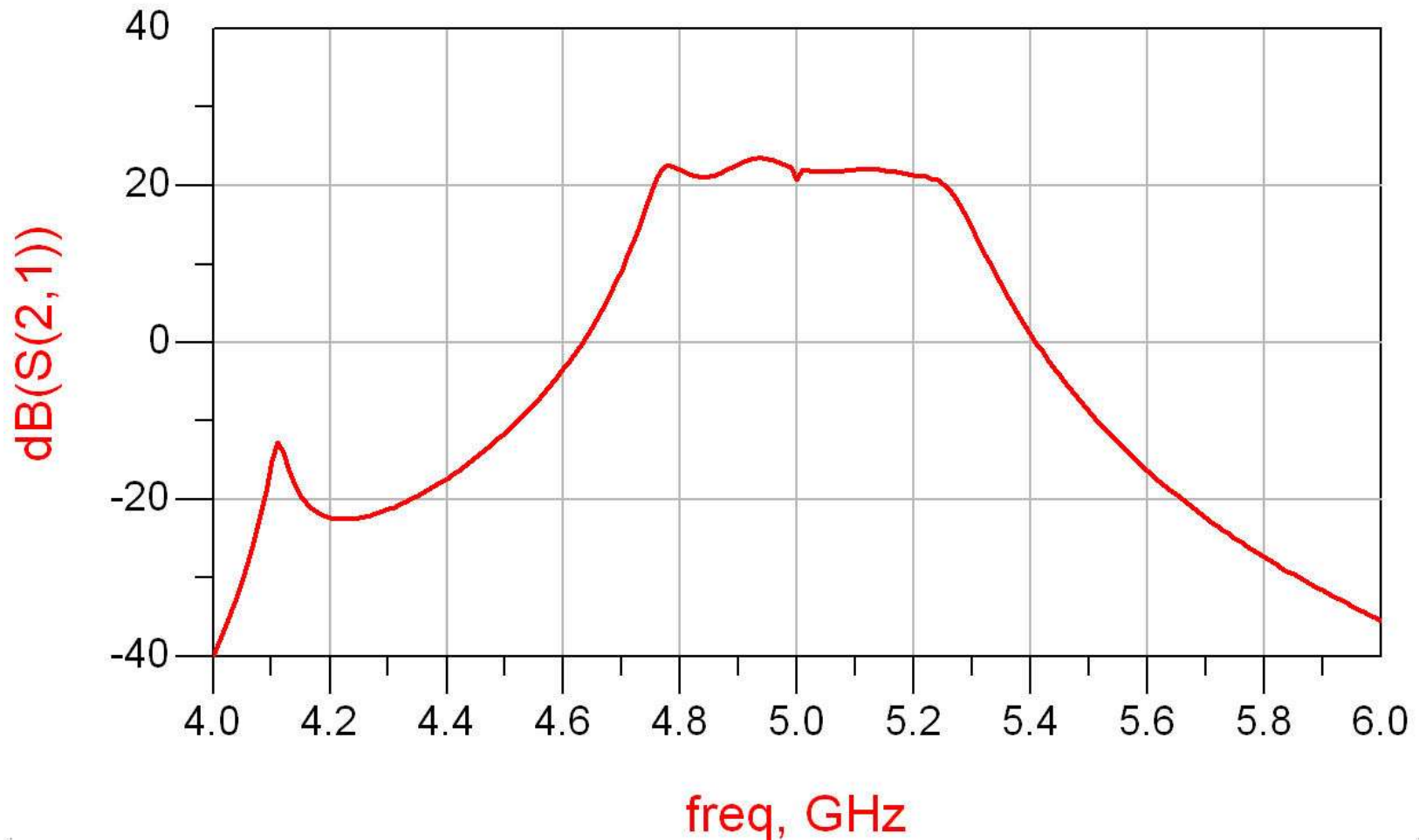


Reglaj -> echilibrare

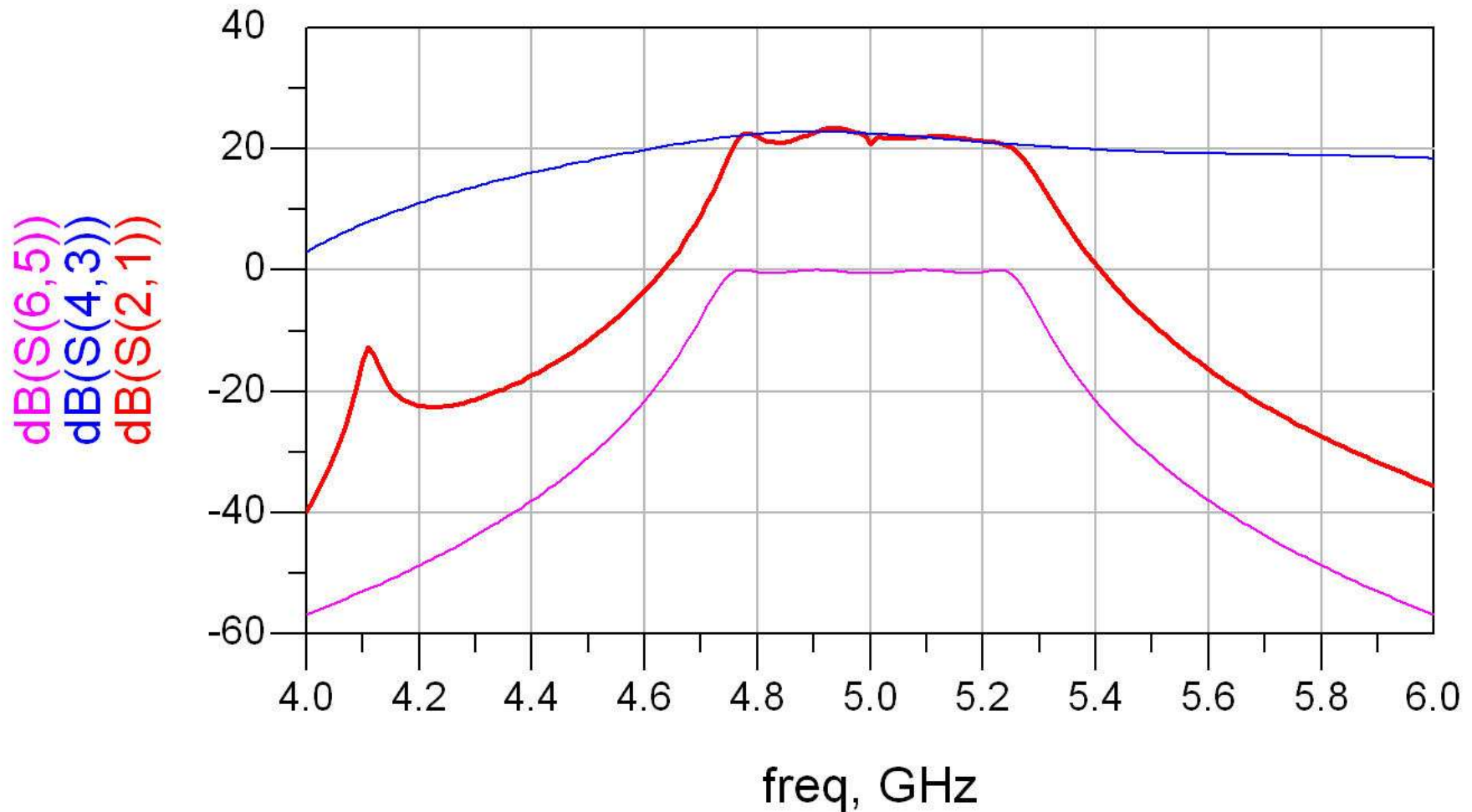
- scopul: echilibrarea caracteristicii amplificatorului (maxim la frecventa centrala)
 - se prefera reglarea lungimii liniilor de la iesirea amplificatorului
 - micsorarea afectarii zgomotului



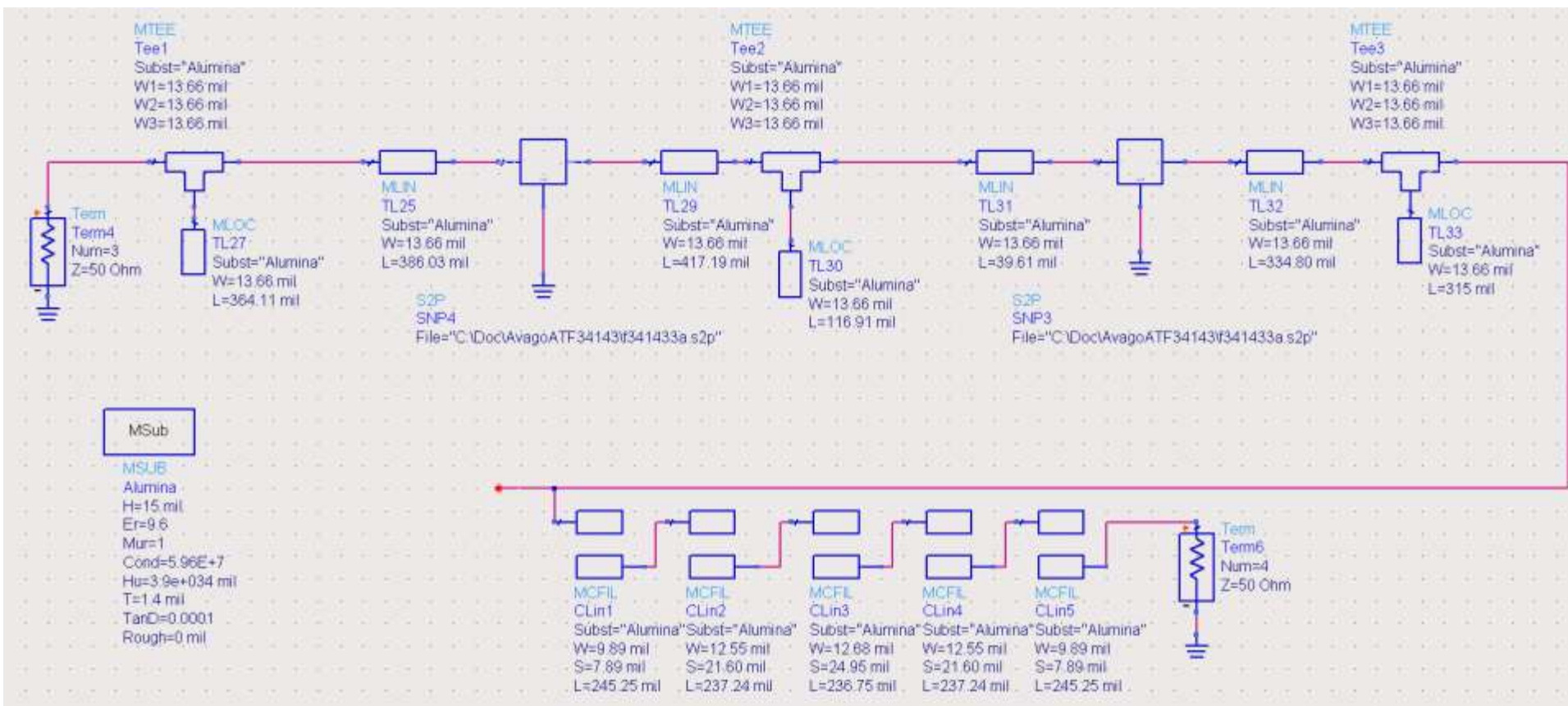
Reglaj -> echilibrare, efect



Amplificator, Filtru, Total

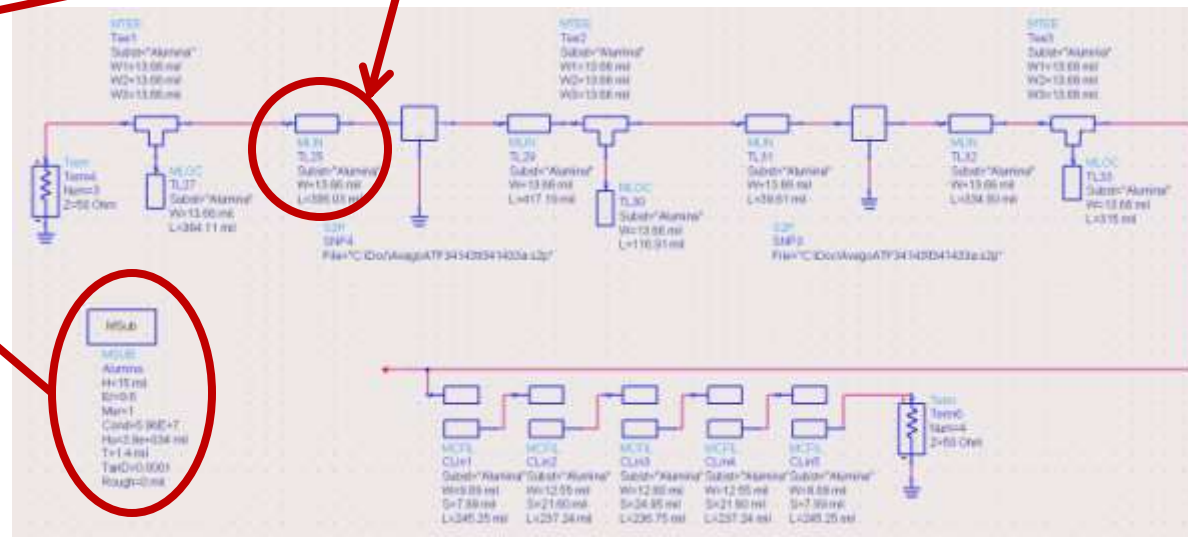
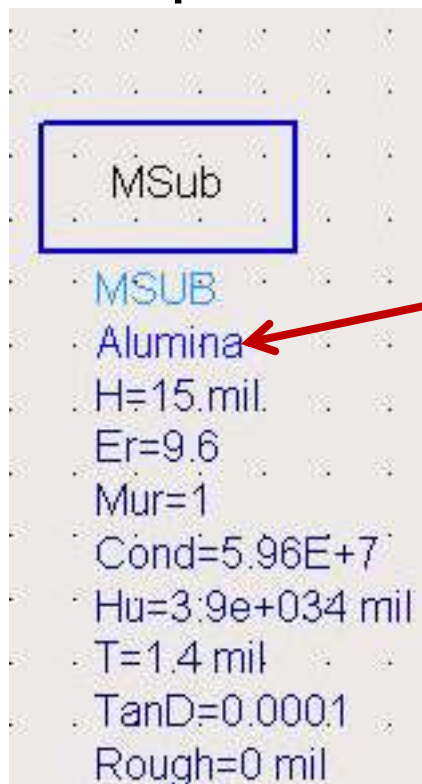


Implementare cu linii microstrip



Implementare cu linii microstrip

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

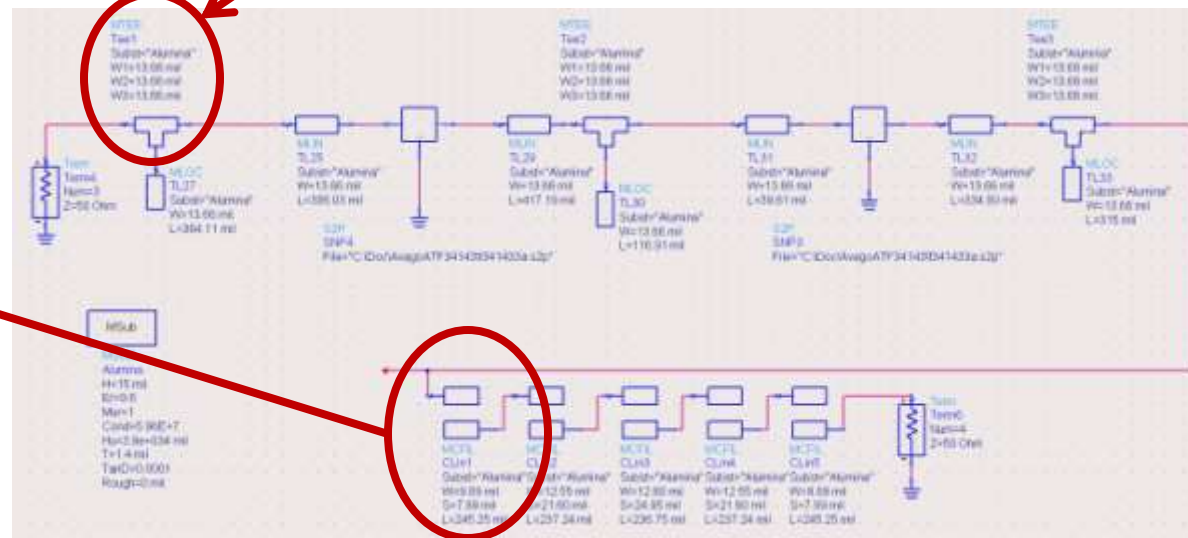
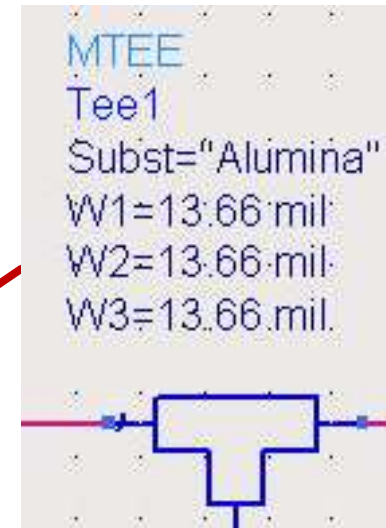


Implementare cu linii microstrip

- 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

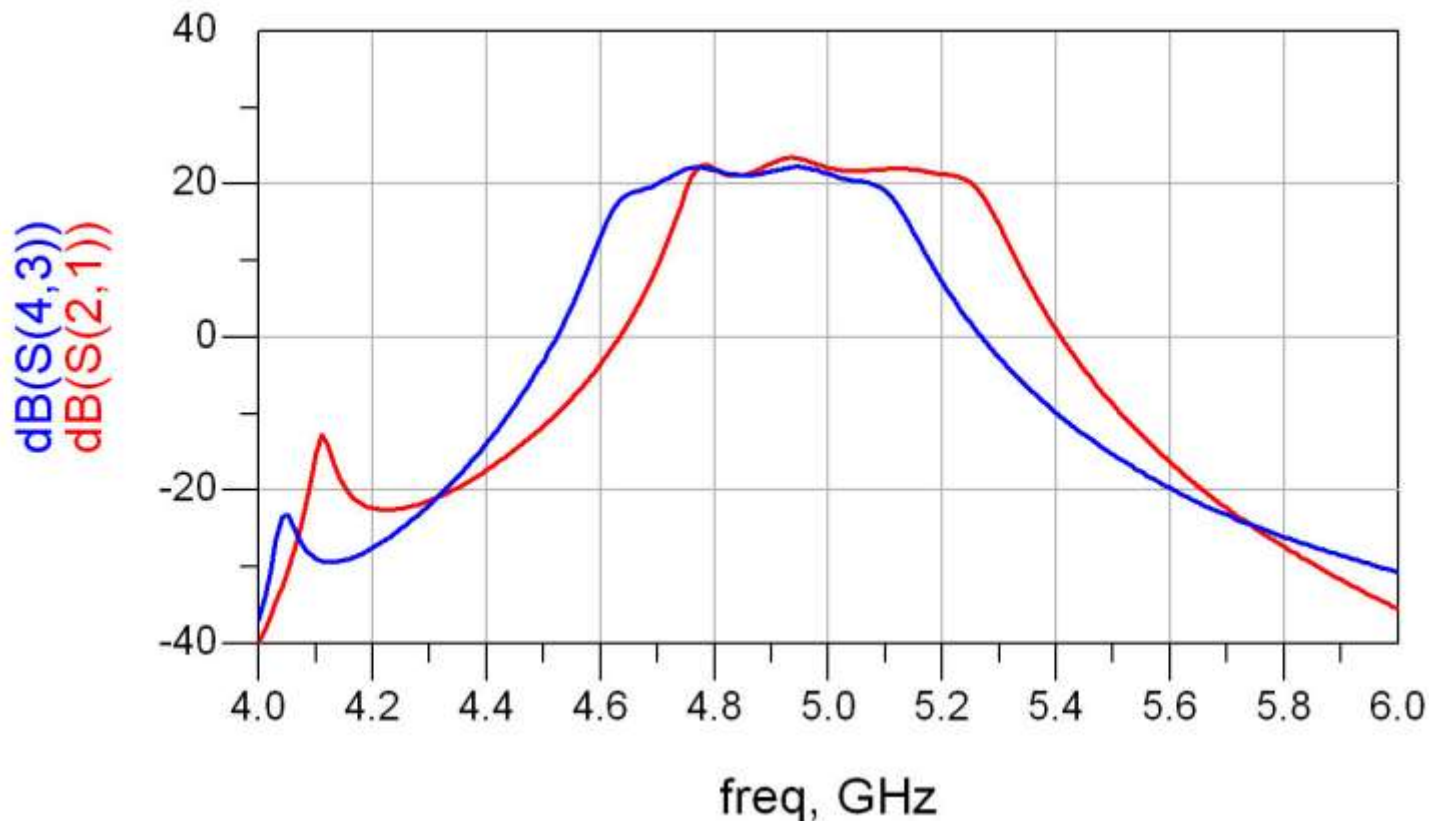
- E necesara atentie la completarea parametrilor pentru MTEE si MCFIL prin verificarea in schema a latimii liniilor conectate la fiecare terminal



Implementare cu linii microstrip

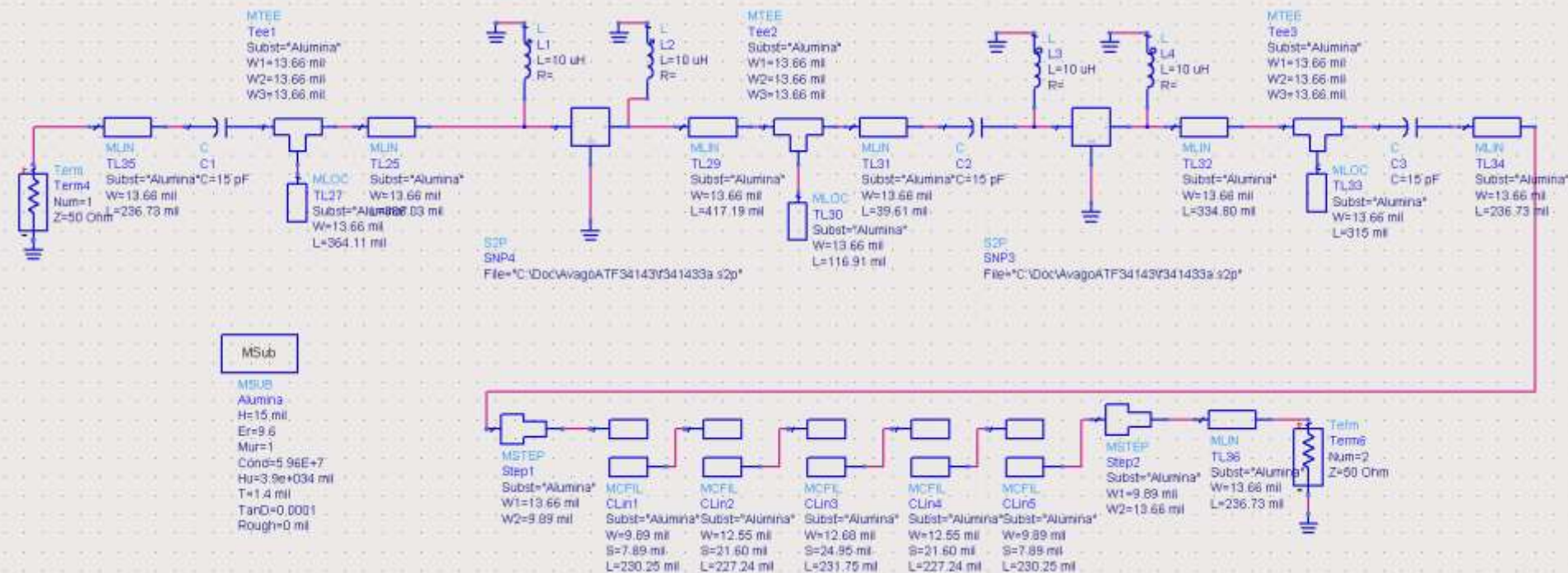
Rezultat

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

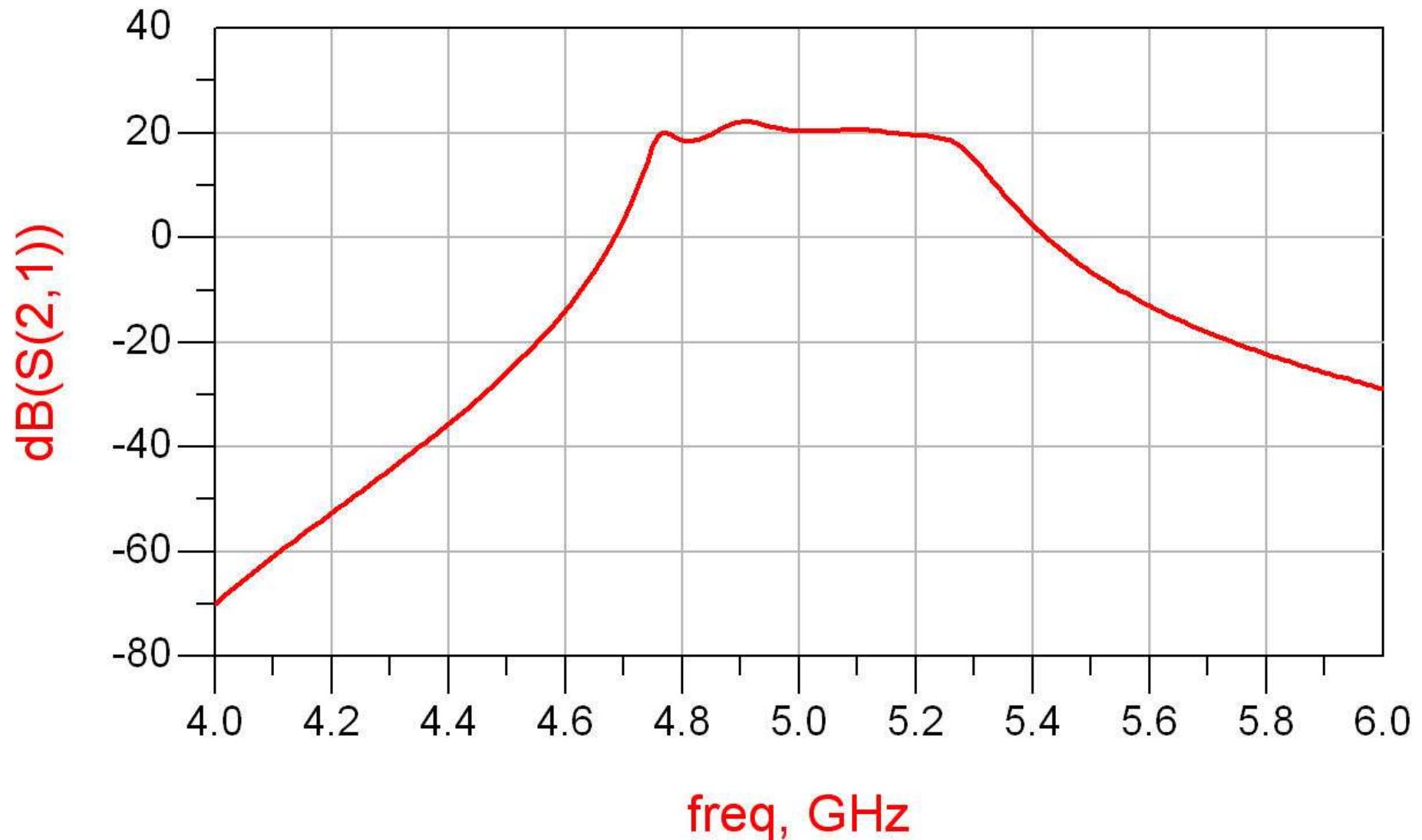


Introdúcere elemente de polarizare

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

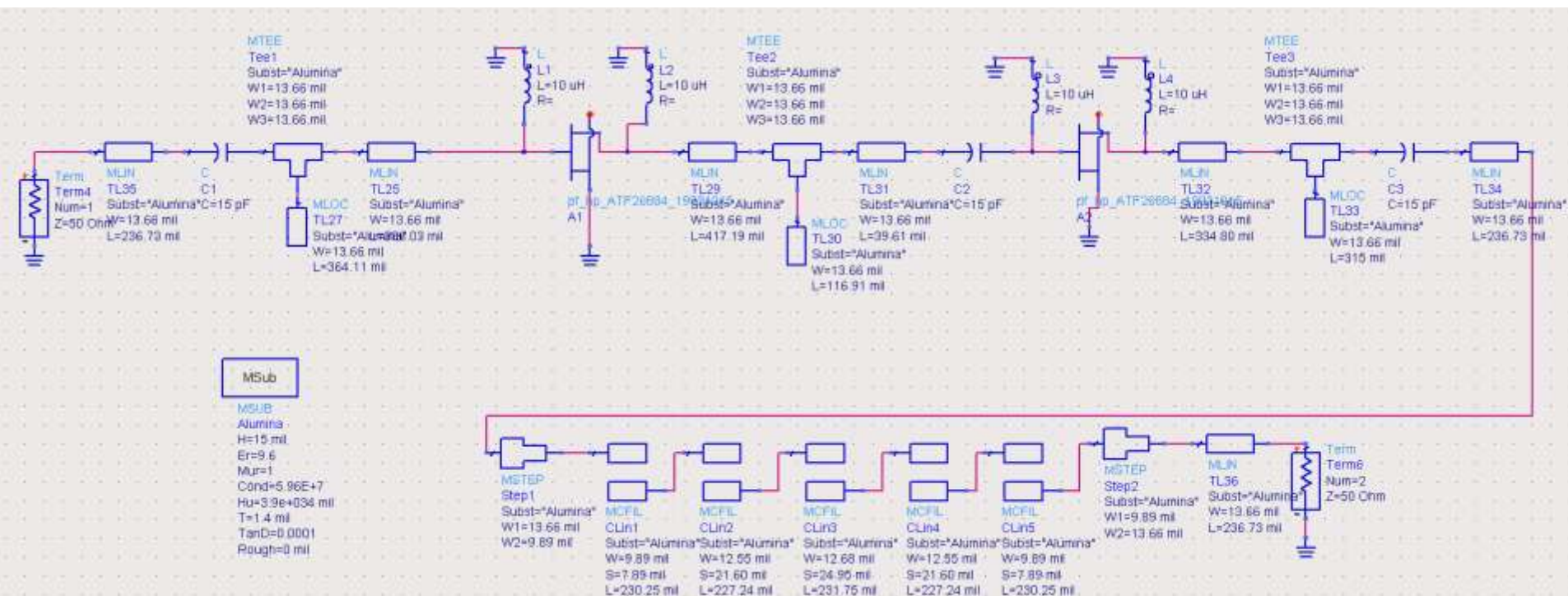


Rezultat final (Castig)

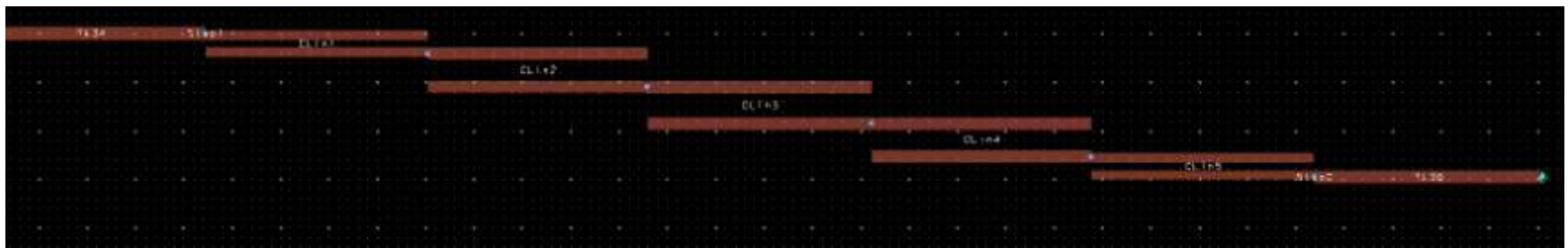
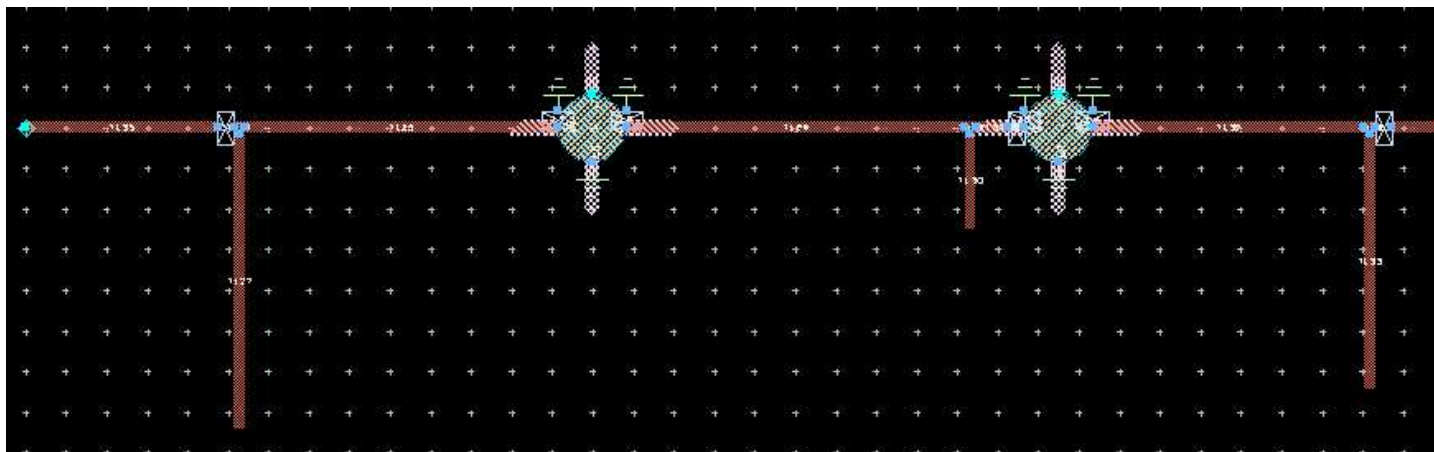
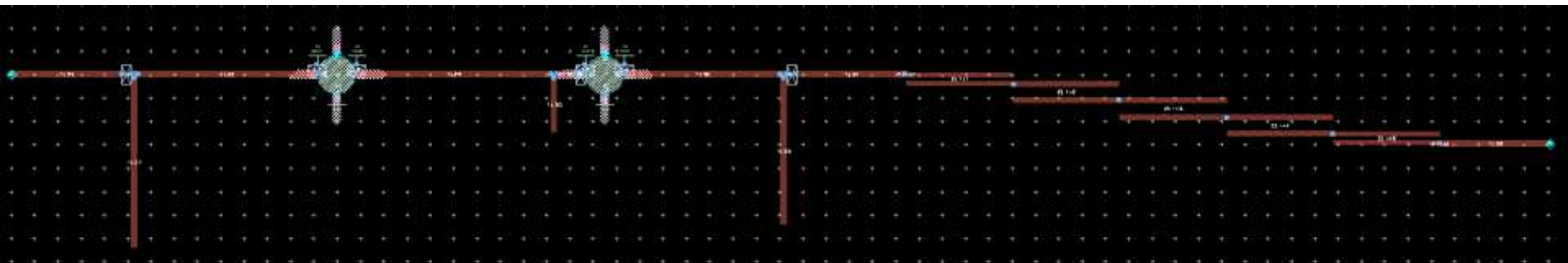


Layout (Exemplu)

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



Layout (Exemplu)



Contact

- Laboratorul de microunde si optoelectronica
- <http://rf-opto.etti.tuiasi.ro>
- rdamian@etti.tuiasi.ro