Curs 13
2025/2026

Dispozitive şi circuite de microunde pentru radiocomunicații

Disciplina 2025/2026

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

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

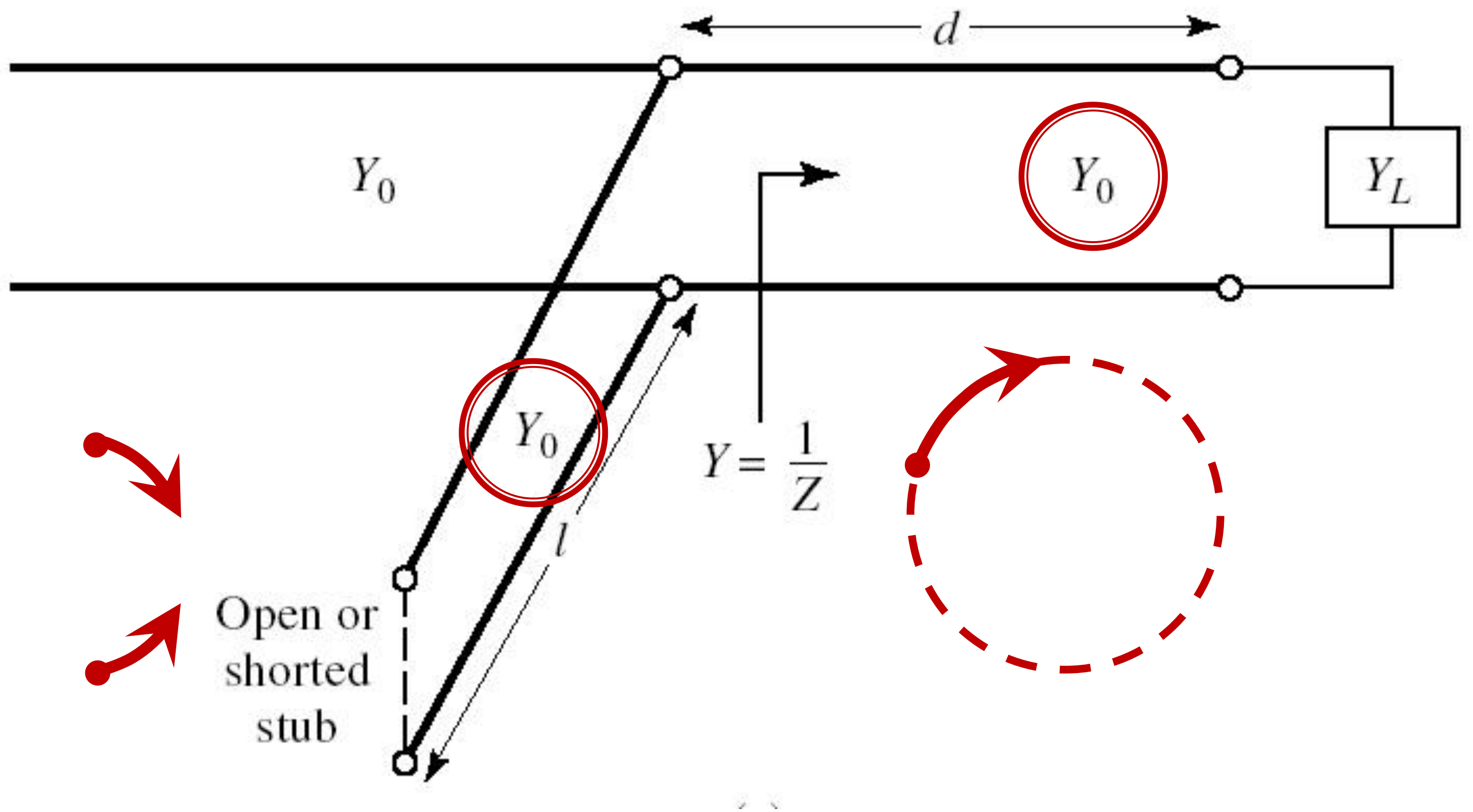
- Curs - **conf. Radu Damian**
  - Vineri 10-12/**Video (istoric)**, C1, corp C
  - E – **50%** din nota
  - **probleme** + (2p prez. curs) + (3 teste) + (bonus activitate)
    - primul test L1: ~01.10.2025 (t2 si t3 neanuntate la **curs**)
    - 3pz (C) ≈ +0.5p (**2p** max)
  - **toate materialele permise**

Adaptarea cu sectiuni de linii (stub)

Adaptarea de impedanța

Single stub tuning

- Shunt Stub (sectiune de linie in paralel)

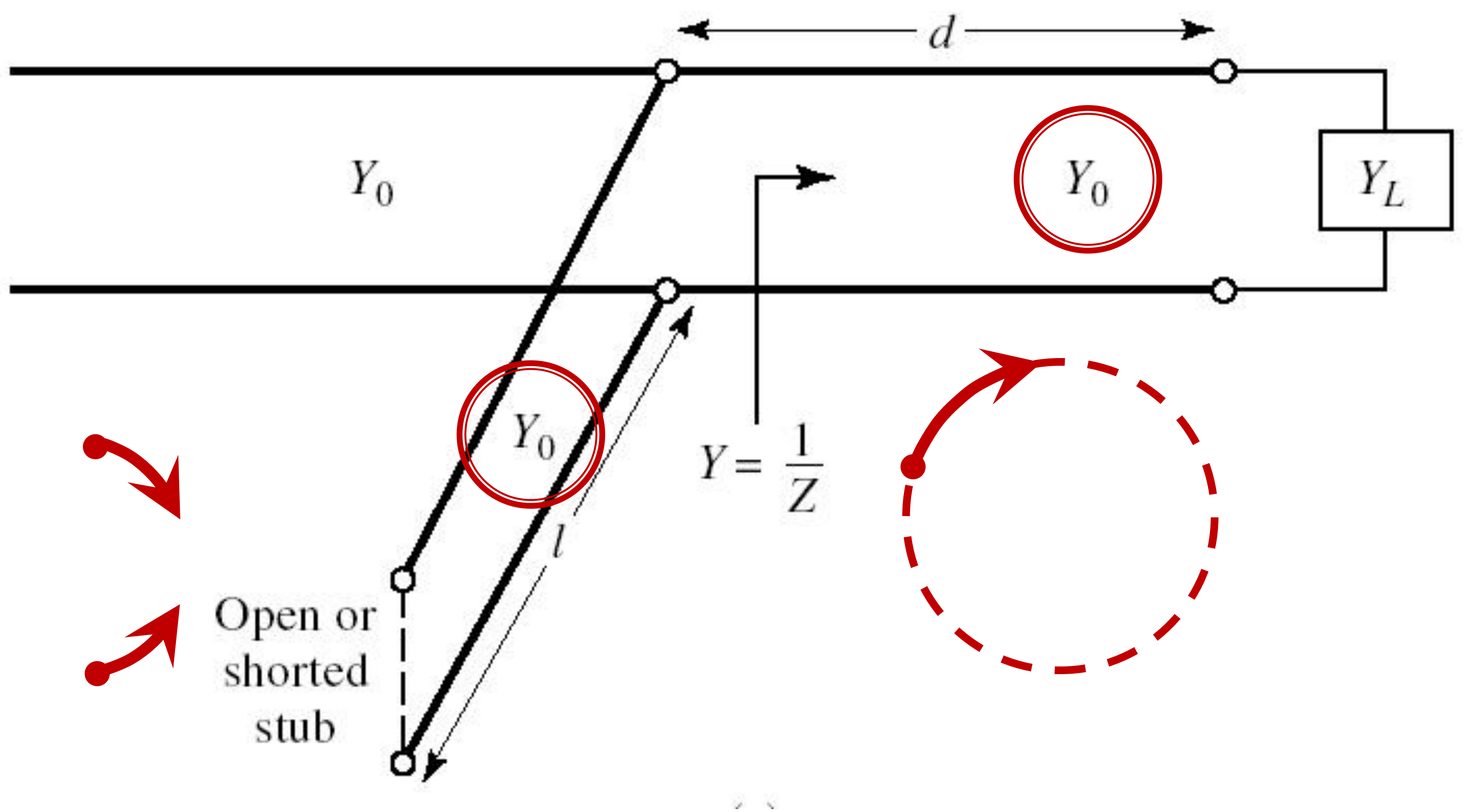


Solutii analitice

Examen / Proiect

Caz 1, Shunt Stub

- Shunt Stub (sectiune de linie in paralel)



Calcul analitic (calcul efectiv)

$$\boxed{\cos(\varphi + 2\theta) = -|\Gamma_S|} \qquad \boxed{\theta_{sp} = \beta \cdot l = \tan^{-1} \frac{\mp 2 \cdot |\Gamma_S|}{\sqrt{1 - |\Gamma_S|^2}}}$$

$$\Gamma_S = 0.593\angle 46.85°$$

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

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

    $$(46.85° + 2\theta) = +126.35° \qquad \theta = +39.7° \qquad \mathrm{Im}\, y_S = \frac{-2 \cdot |\Gamma_S|}{\sqrt{1 - |\Gamma_S|^2}} = -1.472$$

    $$\theta_{sp} = \tan^{-1}(\mathrm{Im}\, y_S) = -55.8° \underline{(+180°)} \rightarrow \theta_{sp} = 124.2°$$

  - **solutia "cu -"**

    $$(46.85° + 2\theta) = -126.35° \qquad \theta = -86.6° \underline{(+180°)} \rightarrow \theta = 93.4°$$

    $$\mathrm{Im}\, y_S = \frac{+2 \cdot |\Gamma_S|}{\sqrt{1 - |\Gamma_S|^2}} = +1.472 \qquad \theta_{sp} = \tan^{-1}(\mathrm{Im}\, y_S) = 55.8°$$

Calcul analitic (calcul efectiv)

$$(\varphi+2\theta)=\begin{cases}+126.35^\circ\\-126.35^\circ\end{cases}\quad \theta=\begin{cases}39.7^\circ\\93.4^\circ\end{cases}\quad \mathrm{Im}\left[y_S(\theta)\right]=\begin{cases}-1.472\\+1.472\end{cases}\quad \theta_{sp}=\begin{cases}-55.8^\circ+180^\circ=124.2^\circ\\+55.8^\circ\end{cases}$$

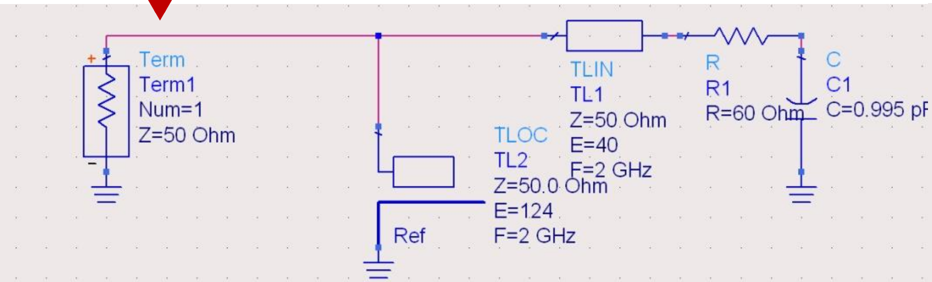
- Se alege **una** din cele doua solutii posibile
- **Semnul** (+/-) solutiei alese la **prima** ecuatie impune **semnul** solutiei utilizate la a **doua** ecuatie

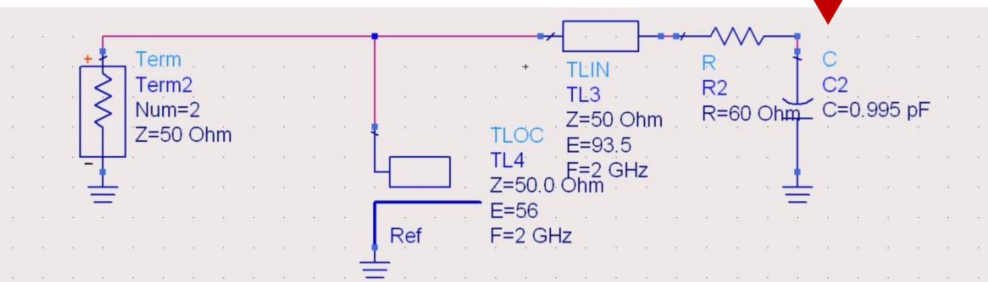
$$l_1=\frac{39.7^\circ}{360^\circ}\cdot\lambda=0.110\cdot\lambda$$

$$l_2=\frac{124.2^\circ}{360^\circ}\cdot\lambda=0.345\cdot\lambda$$

$$l_1=\frac{93.4^\circ}{360^\circ}\cdot\lambda=0.259\cdot\lambda$$

$$l_2=\frac{55.8^\circ}{360^\circ}\cdot\lambda=0.155\cdot\lambda$$





Filtre pentru microunde

Metoda pierderilor de insertie

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

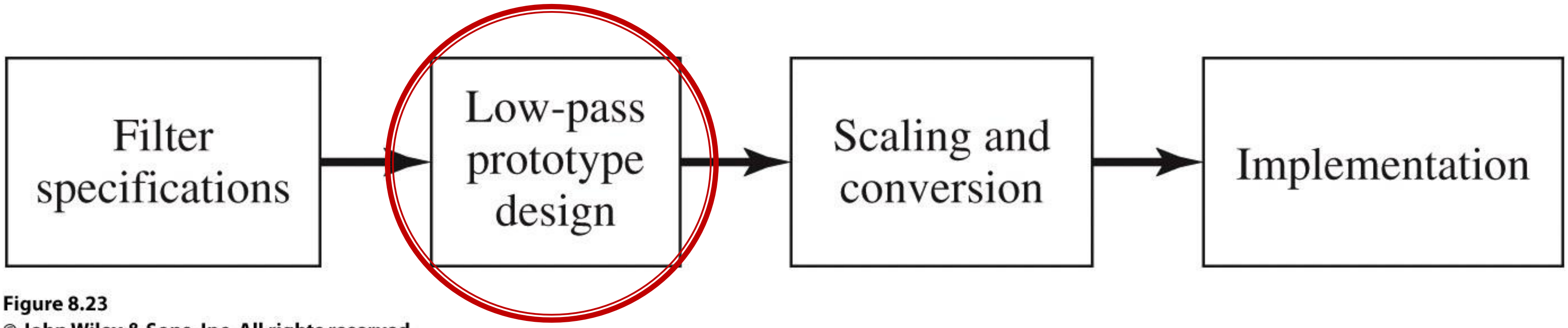


Figure 8.23

FTJ prototip Maxim plat/Echiriplu

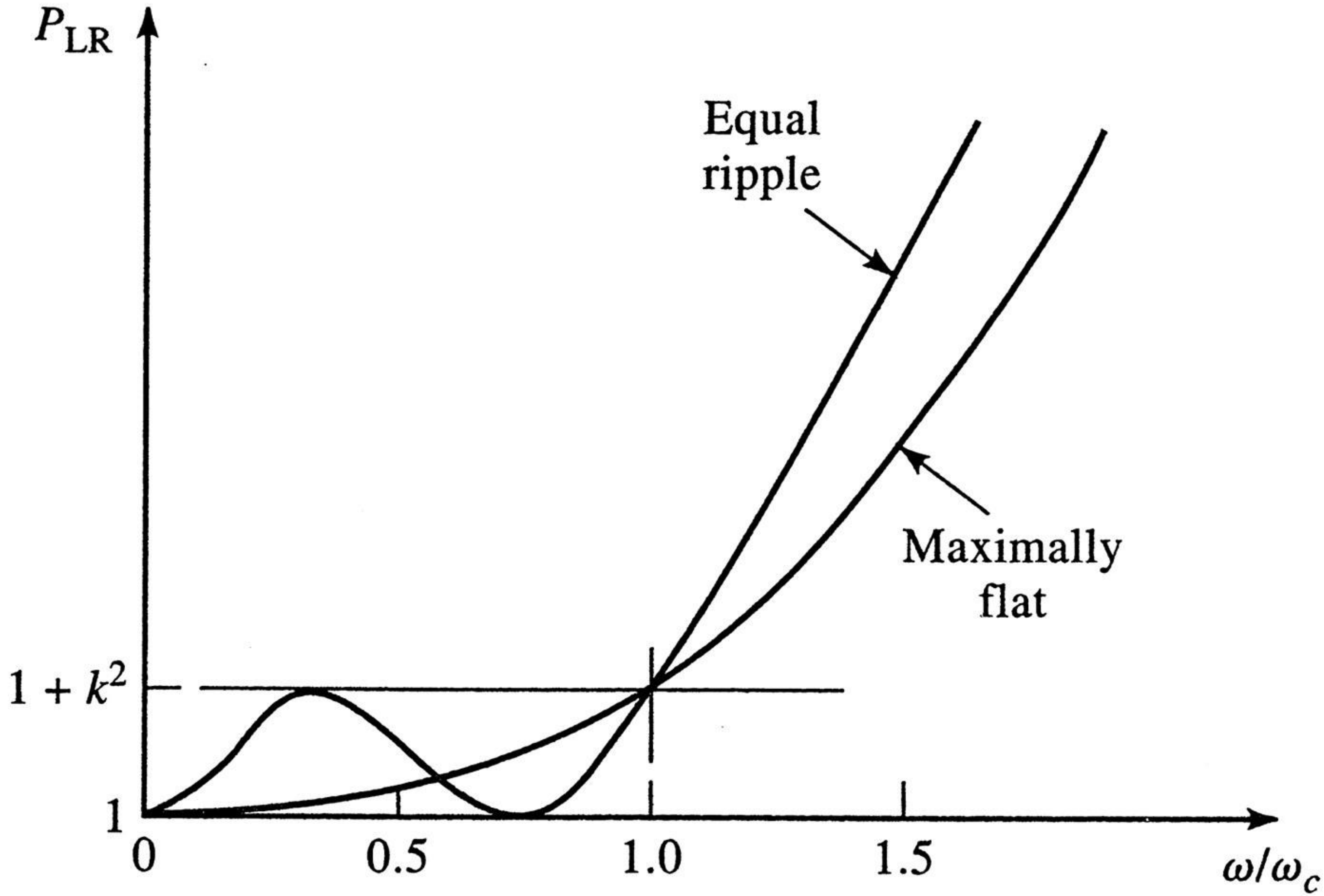


Figure 8.21

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.

Table 8.3

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.

Table 8.4

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

Scalare si conversie

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

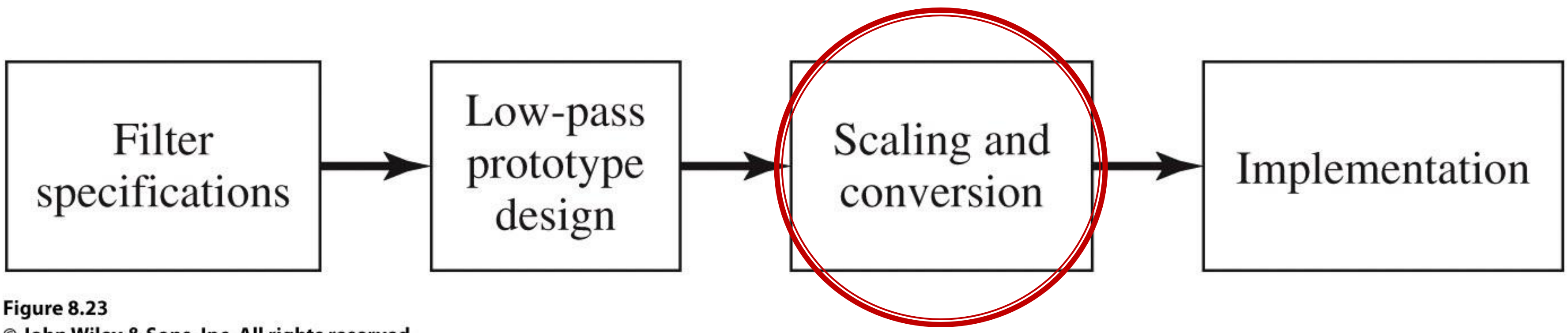


Figure 8.23

Transformari ale filtrului prototip

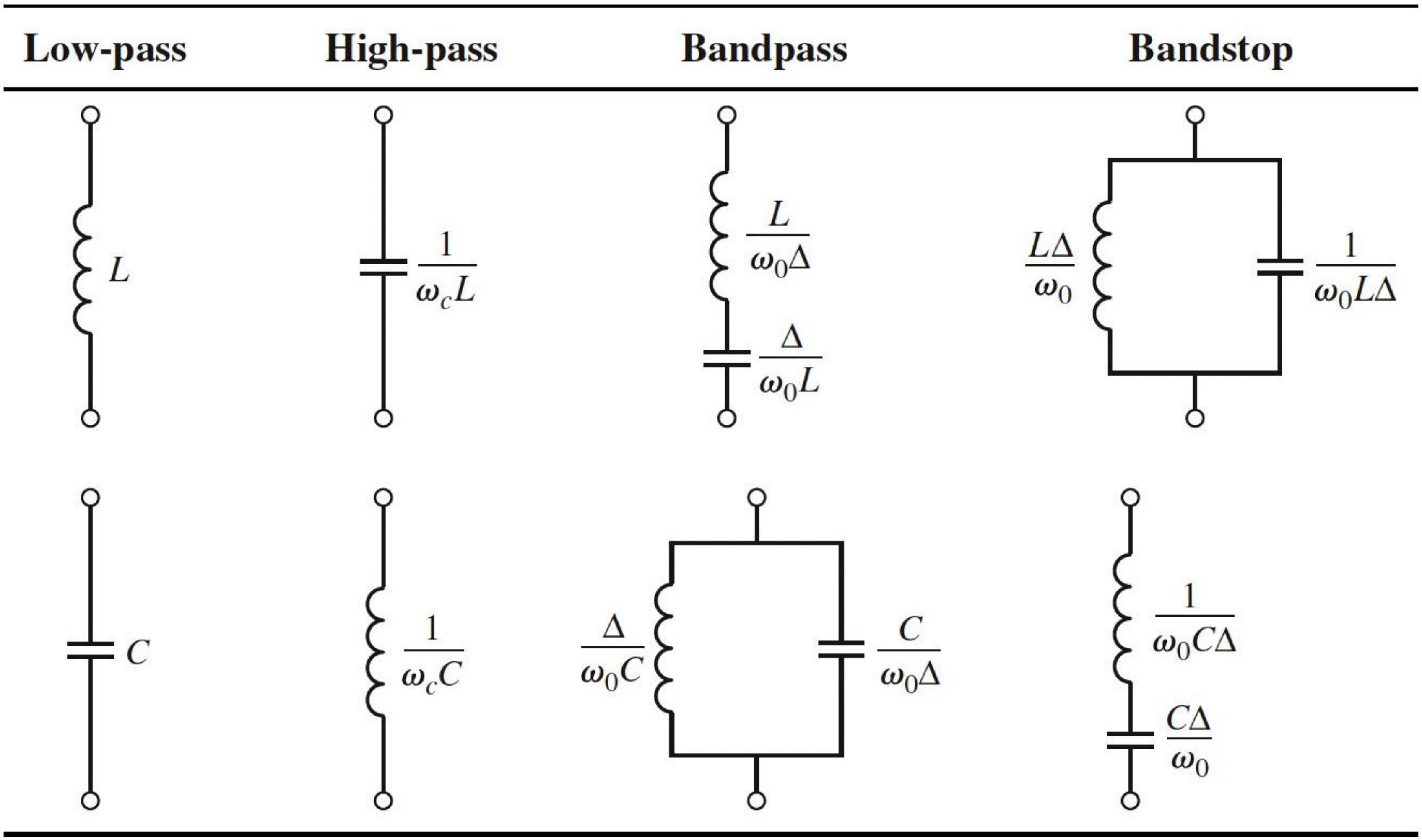


Table 8.6

Implementare filtre pentru microunde

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

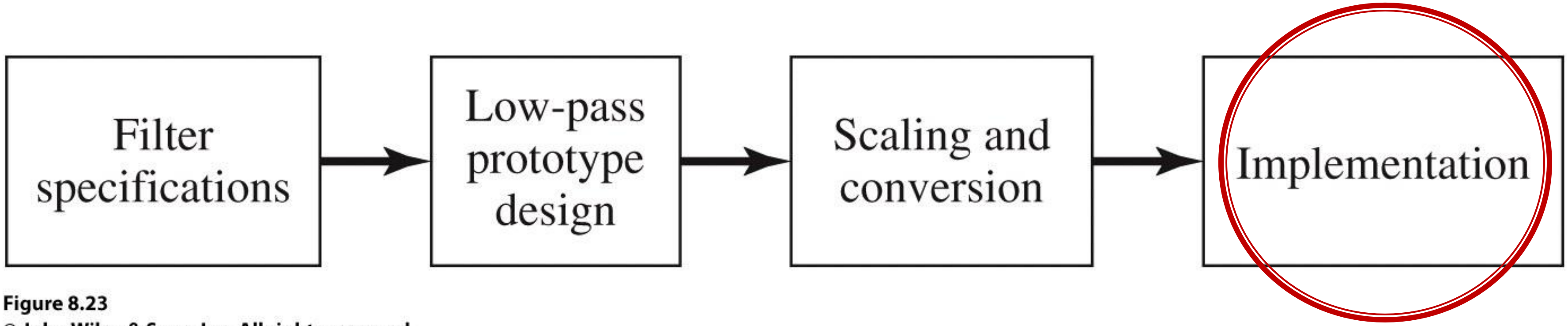
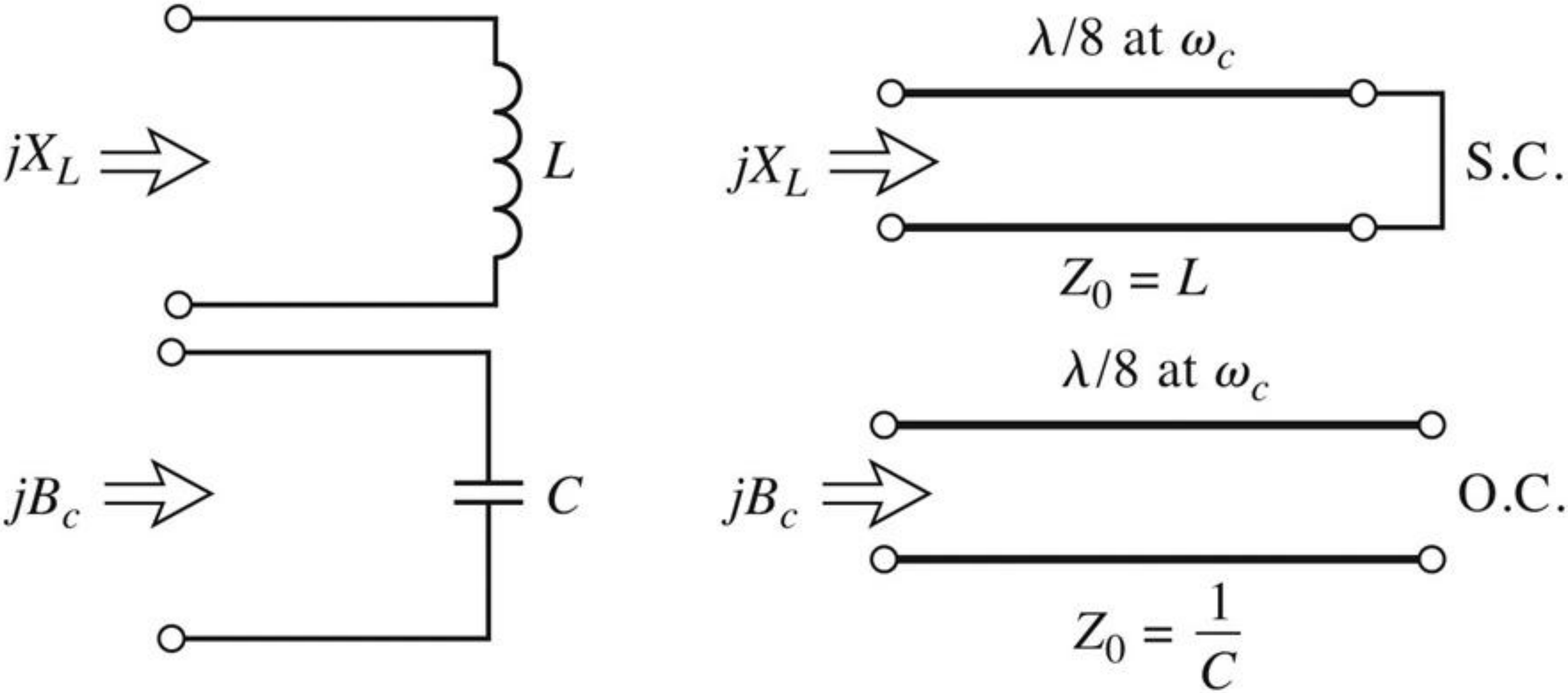


Figure 8.23

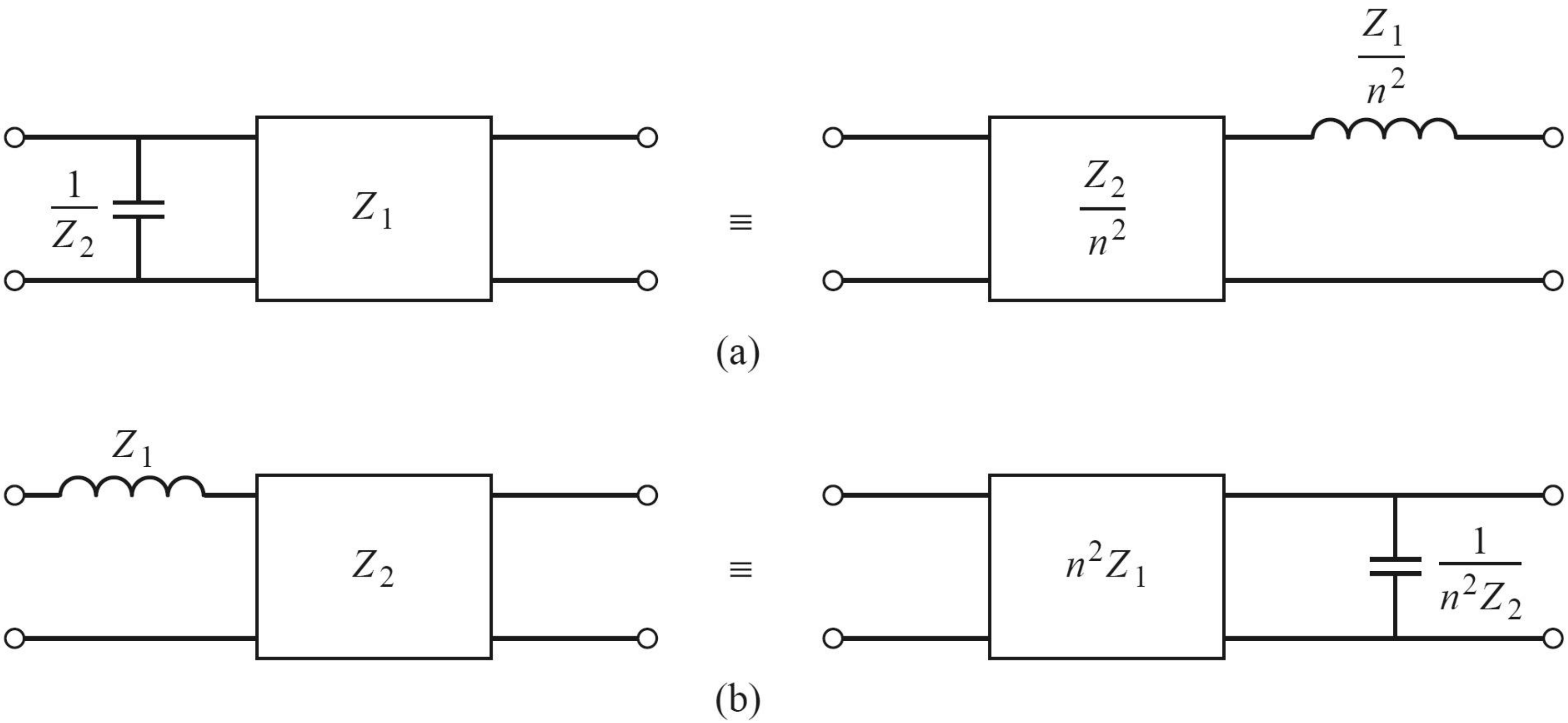
Transformarea Richards

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

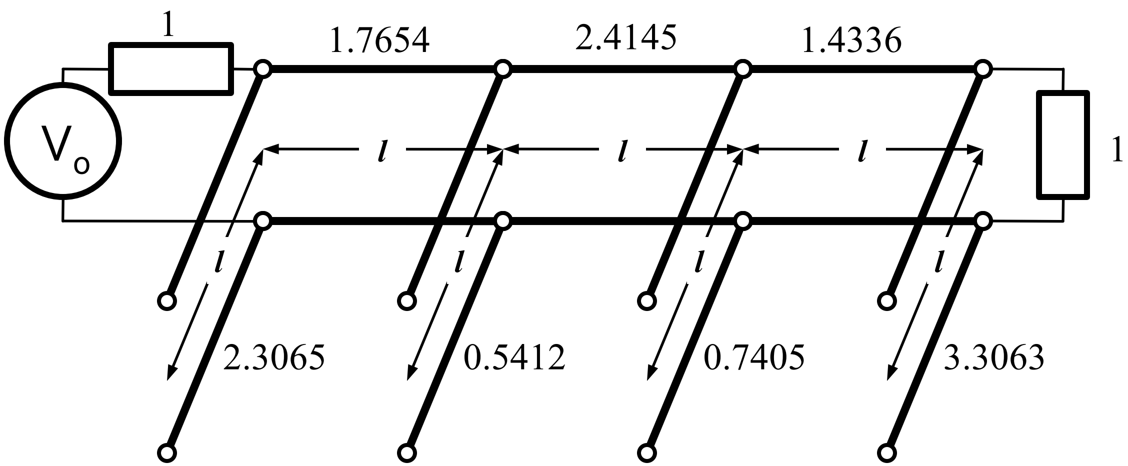


Identitatile Kuroda

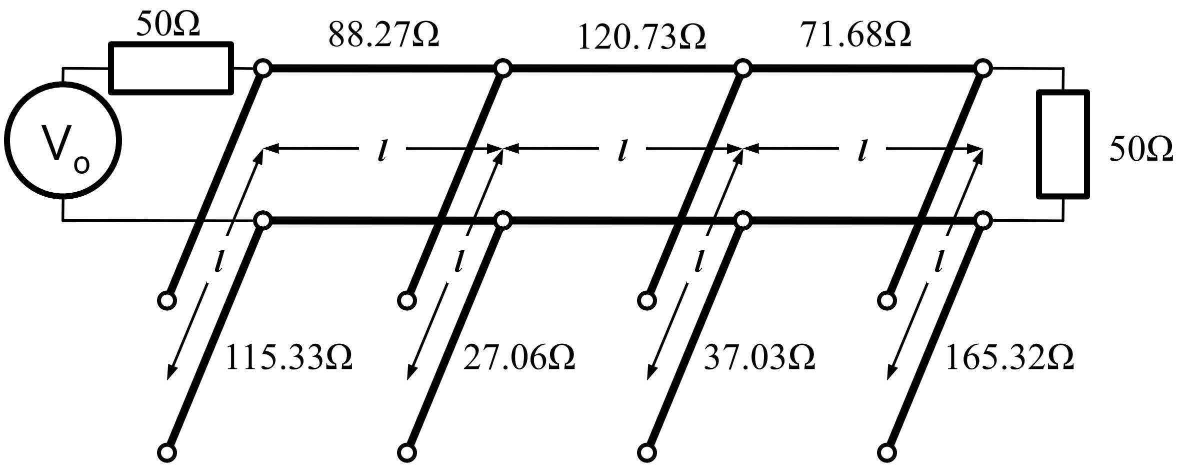
- 4 echivalente de circuit (a,b)



Exemplu



- Scalare la 50Ω



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**

$$Z_{in} = \frac{K^2}{Z_L} \qquad\qquad Y_{in} = \frac{J^2}{Y_L}$$

Impedance inverters   Admittance inverters

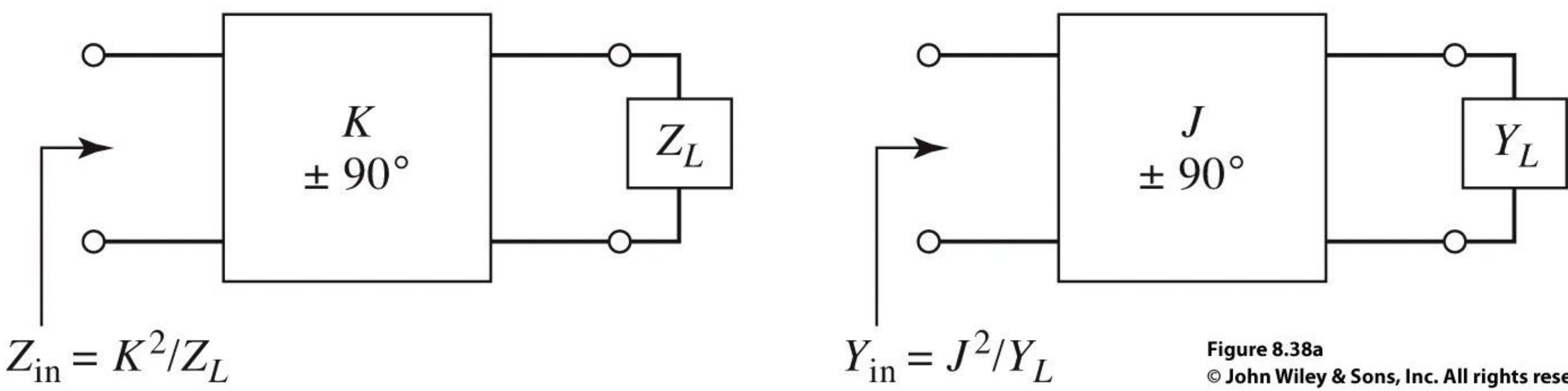
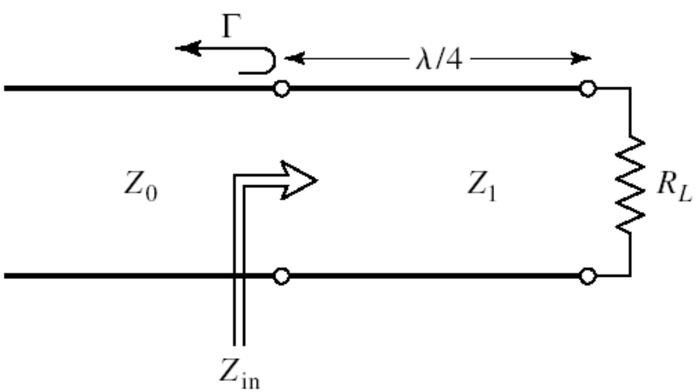


Figure 8.38a

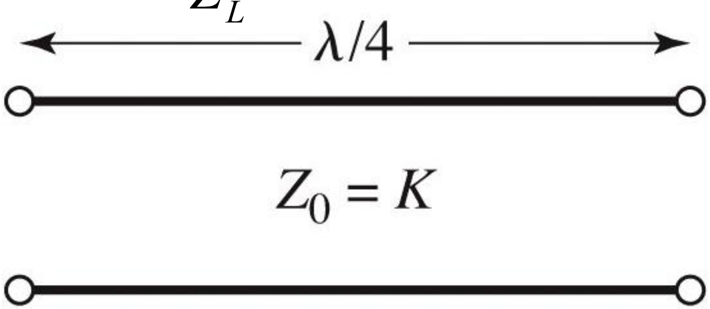
Inversoare de impedanta si admitanta

- Cel mai simplu exemplu de inversor de impedanta/admitanta este **transformatorul in sfert de lungime de unda** (C4)



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

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



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

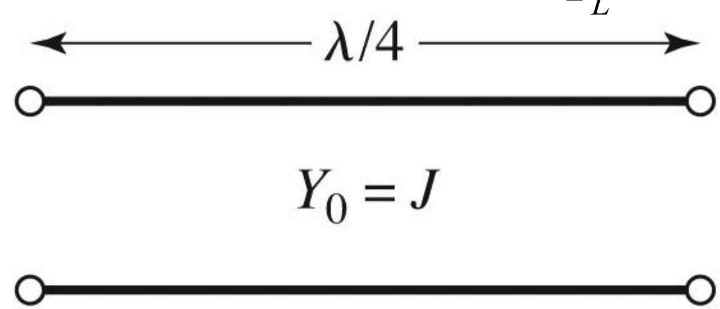
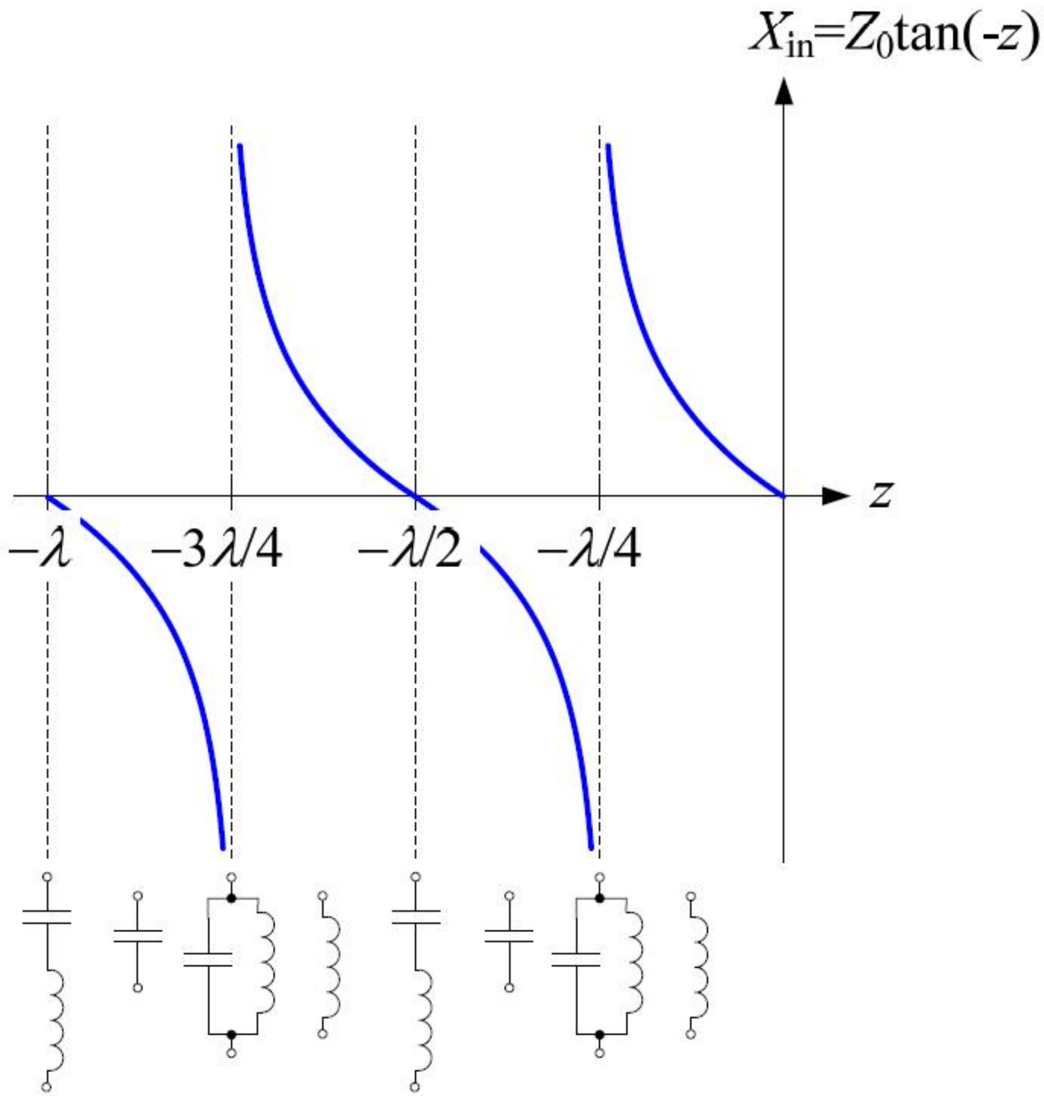


Figure 8.38b

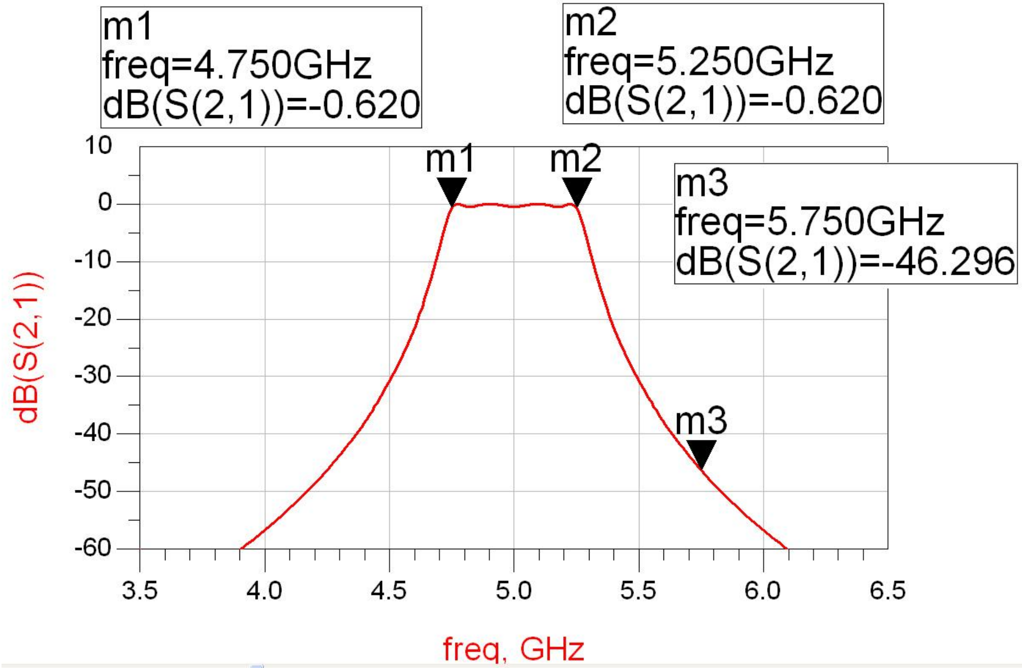
Linii ca rezonatoare

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



Etapa 9

- Se verifica cu atentie banda obtinuta, si valoarea riplului/atenuarii maxime in banda
  - banda corecta intervine **semnificativ** la nota de proiect
  - eventualele atenuari se vor scadea din castigul amplificatorului si se poate ajunge la neindeplinirea cerintelor de castig din tema



Continuare

Amplificatoare de banda larga

Amplificatoare de microunde

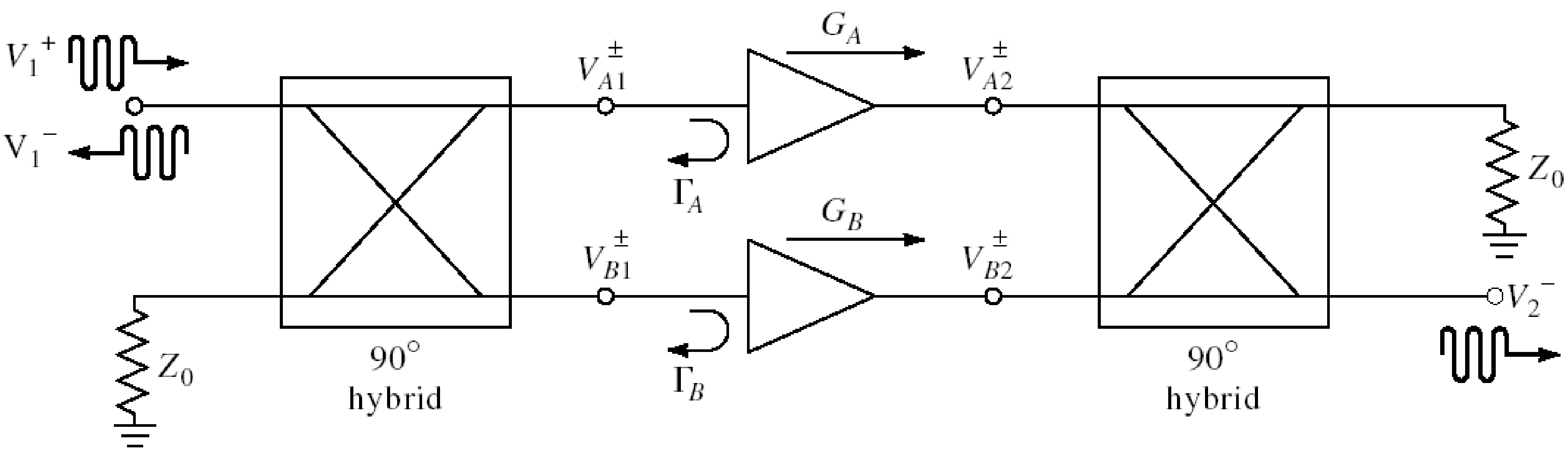
Cuprins

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

Amplificatoare de banda larga

- Se pot obtine prin un numar de tehnici de proiectare
  1. Retele de adaptare care sa compenseze scaderea castigului cu frecventa
  2. Retele de adaptare rezistive
  3. Reactie negativa
  4. Amplificatoare echilibrate
  5. Amplificatoare distribuite
  6. Amplificatoare diferentiale

Amplificatoare echilibrate



- 2 Amplificatoare (identice) cu doua cuploare hibride 3 dB / 90° la intrare si iesire

$$S_{21} = \frac{-j}{2}\cdot(G_A + G_B)$$

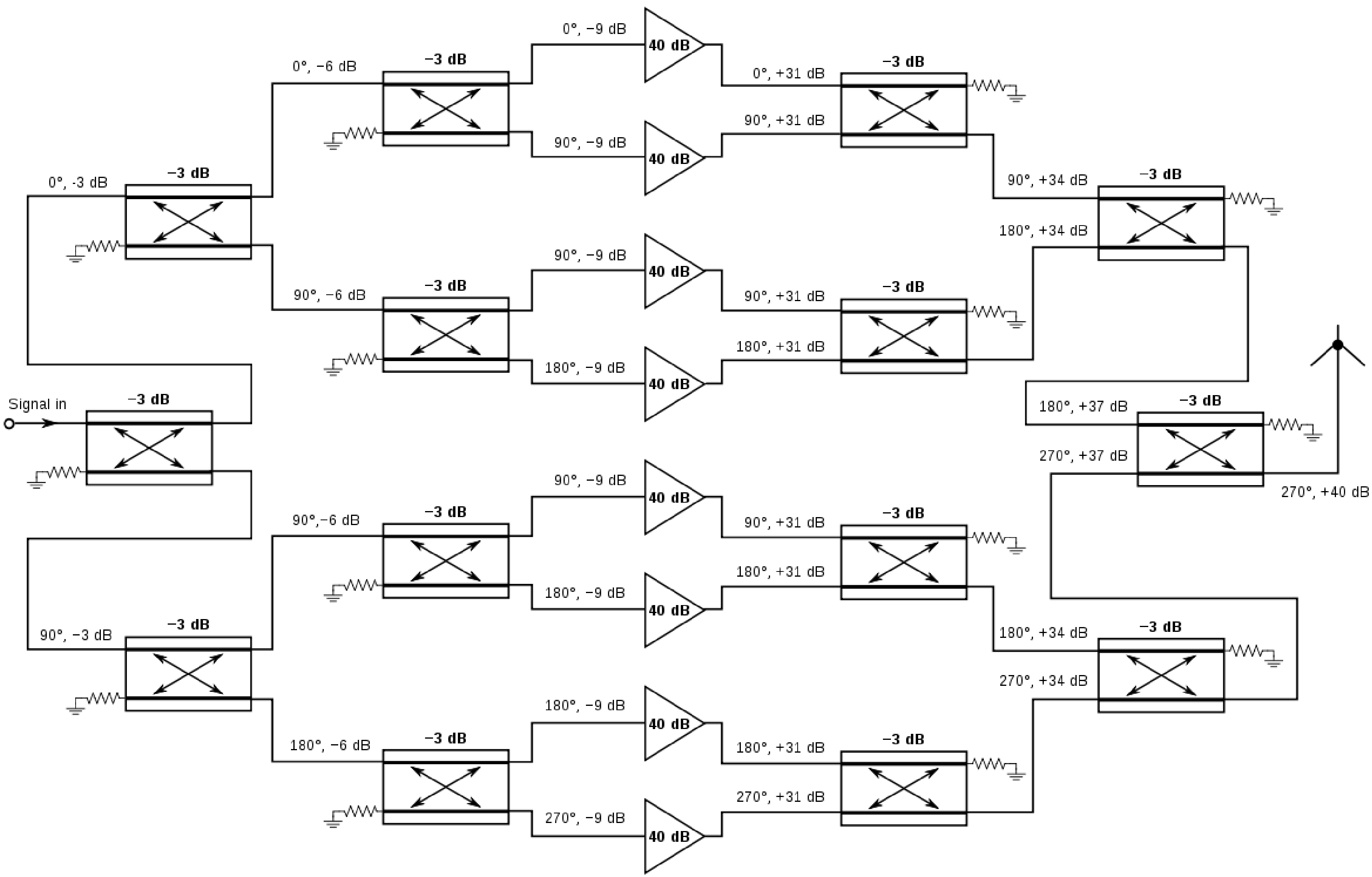
$$S_{11} = \frac{1}{2}\cdot(\Gamma_A - \Gamma_B)$$

$$F = \frac{1}{2}\cdot(F_A + F_B)$$

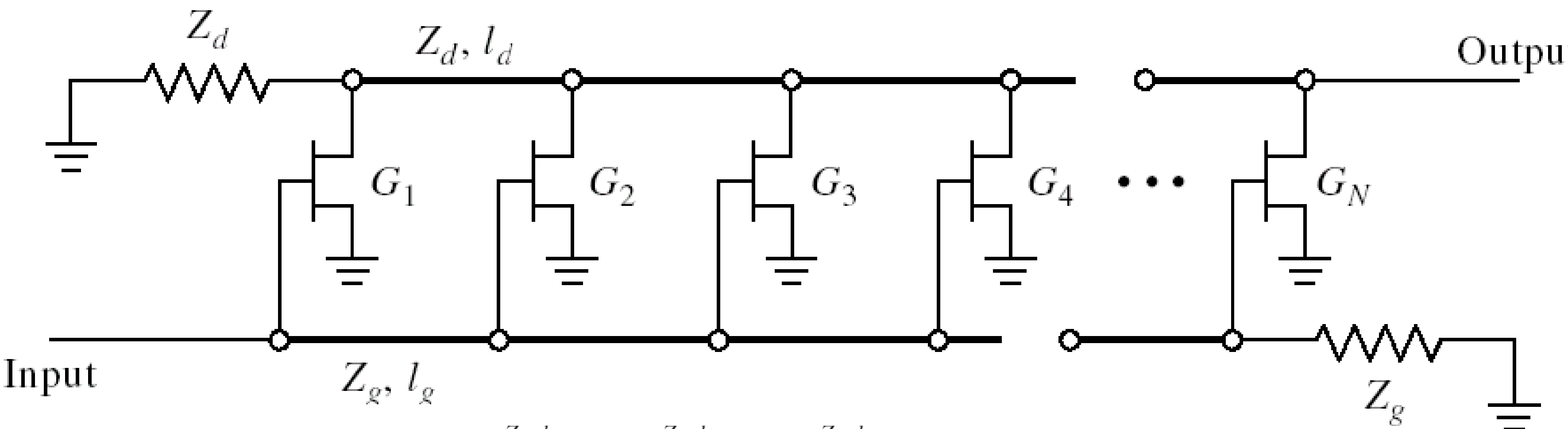
$$S_{21}\big|_{A=B} = -j\cdot G$$

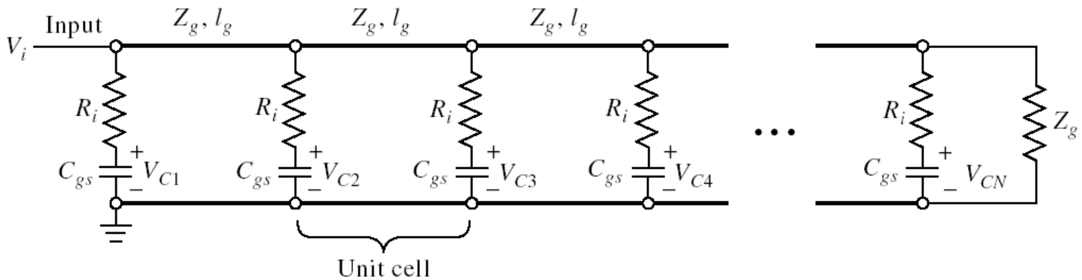
$$S_{11}\big|_{A=B} = 0$$

Amplificatoare echilibrate

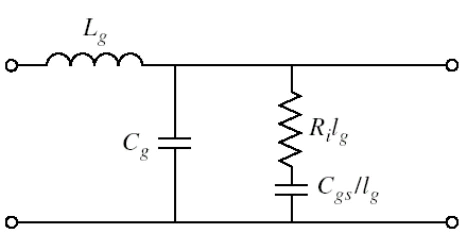


Amplificatoare distribuite





(a)



(b)

Amplificatoare distribuite

- Conditia de sincronizare
  - intarzierea pe liniile de intrare (grila) egala cu cea de pe liniile de iesire (drena)

$$\gamma_g = \alpha_g + j \cdot \beta_g \qquad \gamma_d = \alpha_d + j \cdot \beta_d \qquad \beta_g \cdot l_g = \beta_d \cdot l_d$$

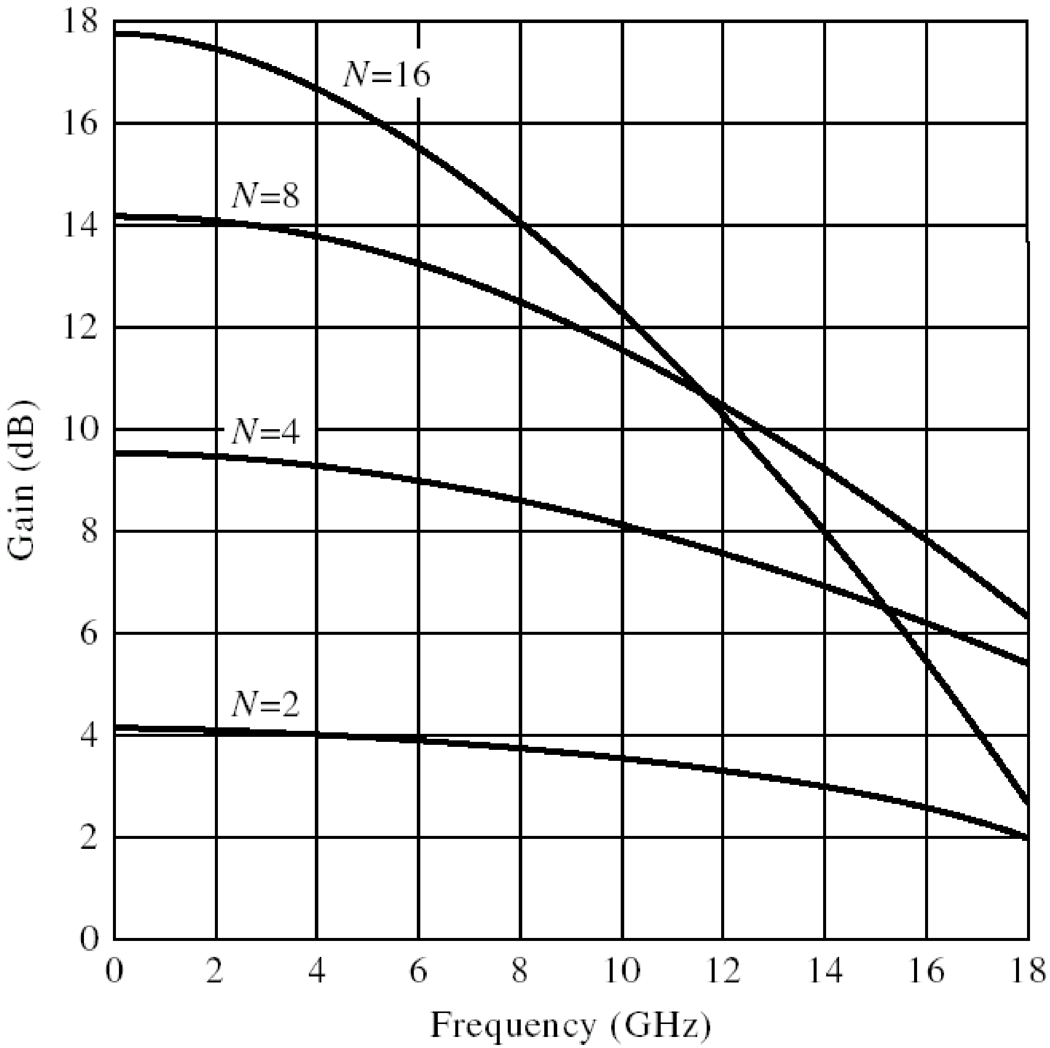
- Castigul de putere

$$G = \frac{g_m^2 \cdot Z_d \cdot Z_g}{4} \cdot \frac{\left(e^{-N \cdot \alpha_g \cdot l_g} - e^{-N \cdot \alpha_d \cdot l_d}\right)^2}{\left(e^{-\alpha_g \cdot l_g} - e^{-\alpha_d \cdot l_d}\right)^2}$$

- Castigul de putere fara pierderi

$$G = \frac{g_m^2 \cdot Z_d \cdot Z_g \cdot N^2}{4}$$

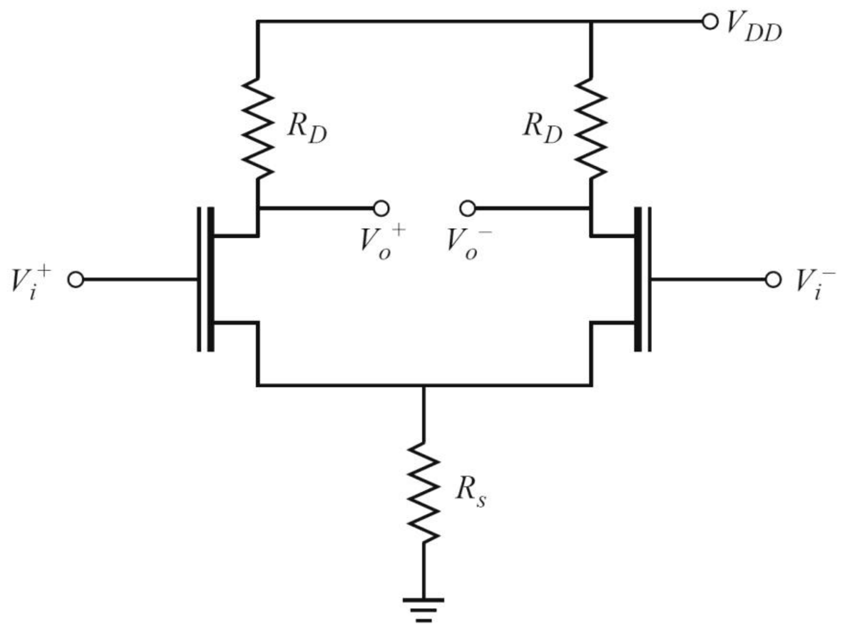
Amplificatoare distribuite



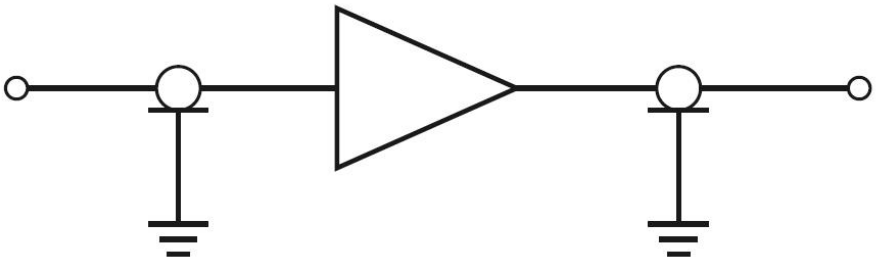
$$N_{opt} = \frac{\ln(\alpha_g \cdot l_g) - \ln(\alpha_d \cdot l_d)}{\alpha_g \cdot l_g - \alpha_d \cdot l_d}$$

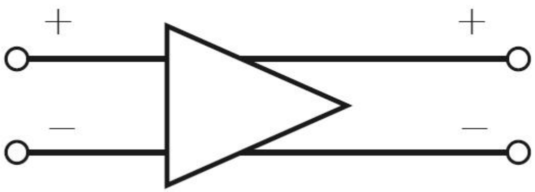
Amplificatoare diferentiale

- Capacitatile de intrare in cele doua tranzistoare in conexiune diferentiala apar conectate in serie
- Se dubleaza astfel frecventa unitara

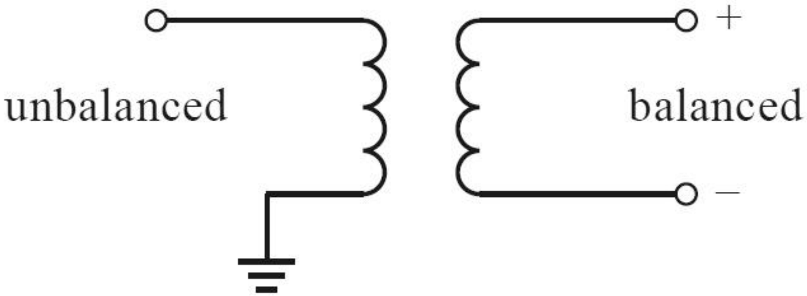


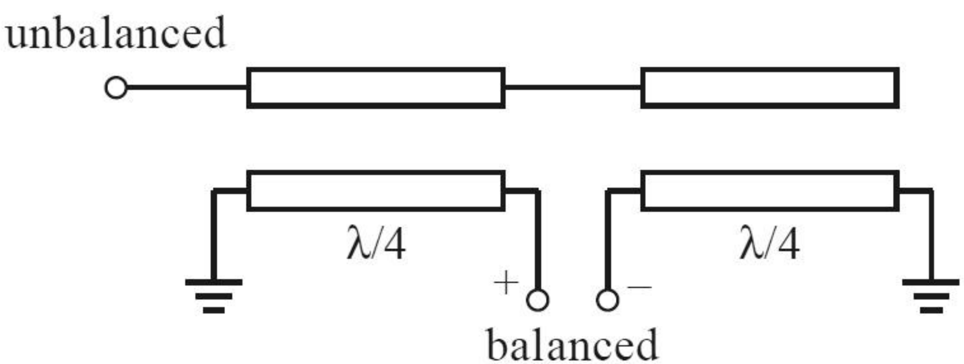
Amplificatoare diferentiale





- Se utilizeaza structuri de circuit care sa faca conversia de la dispozitivele unipolare la cele diferentiale
  - cuploare hibride 3dB / 180°
  - "balun" (balanced - unbalanced)





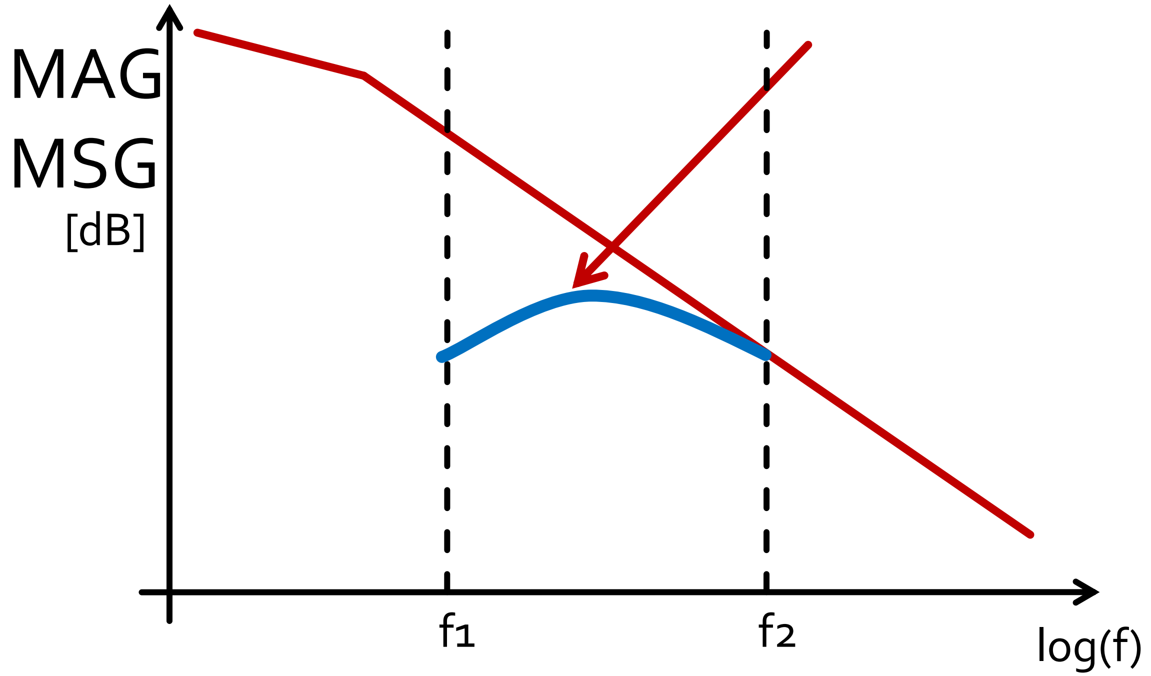
Amplificatoare de banda larga

- Se pot obtine prin un numar de tehnici de proiectare
  1. **Retele de adaptare care sa compenseze scaderea castigului cu frecventa**
  2. Retele de adaptare rezistive
  3. Reactie negativa
  4. Amplificatoare echilibrate
  5. Amplificatoare distribuite
  6. Amplificatoare diferentiale

Amplificatoare de banda larga

1. **Retele de adaptare care sa compenseze scaderea castigului cu frecventa**

- Metoda utilizata este de a repeta proiectarea la mai multe (macar 2) frecvente si impunerea unui castig egal la acestea

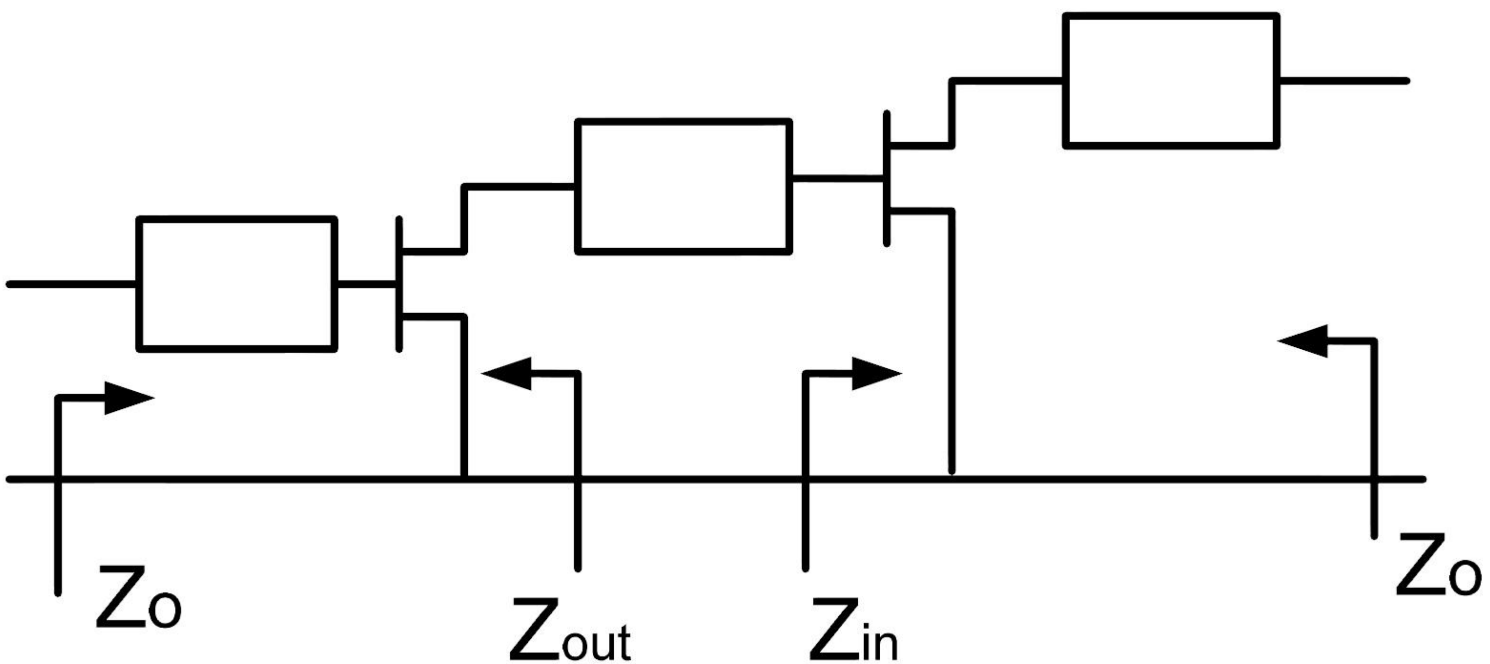


Amplificatoare in cascada

Amplificatoare de microunde

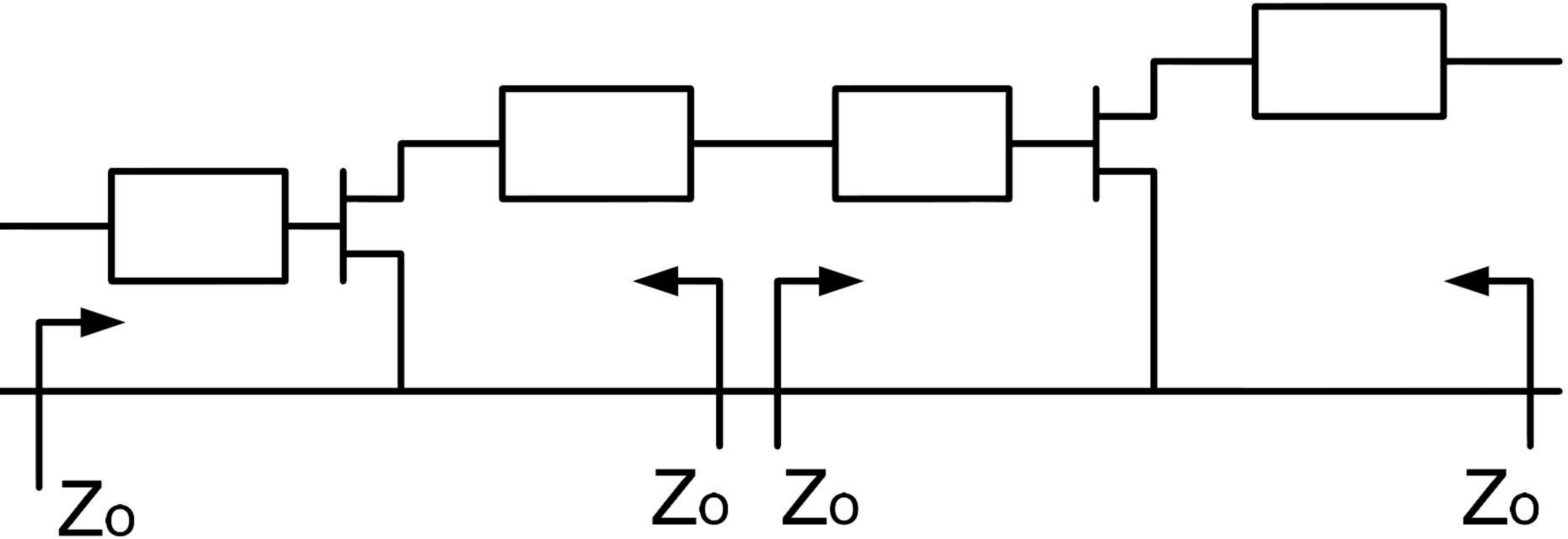
Amplificatoare in cascada

- Adaptarea inter-etaje se poate proiecta in doua moduri:
  - adaptarea unui etaj spre Γ necesar pentru celalalt



Amplificatoare in cascada

- Adaptarea inter-etaje se poate proiecta in doua moduri:
  - adaptarea fiecarui etaj spre un $\Gamma = 0$ intermediar

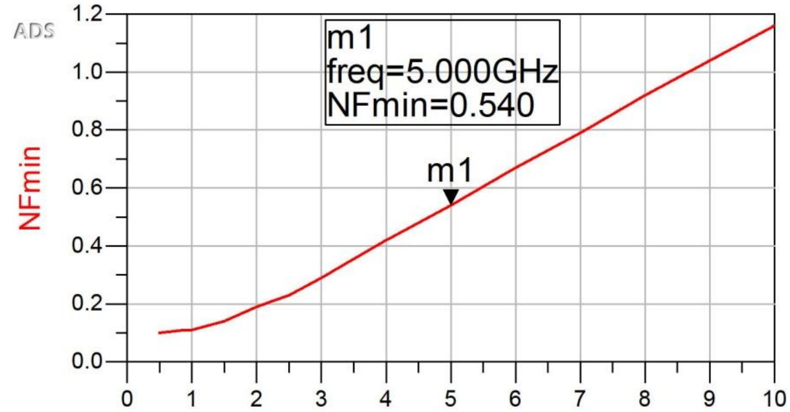


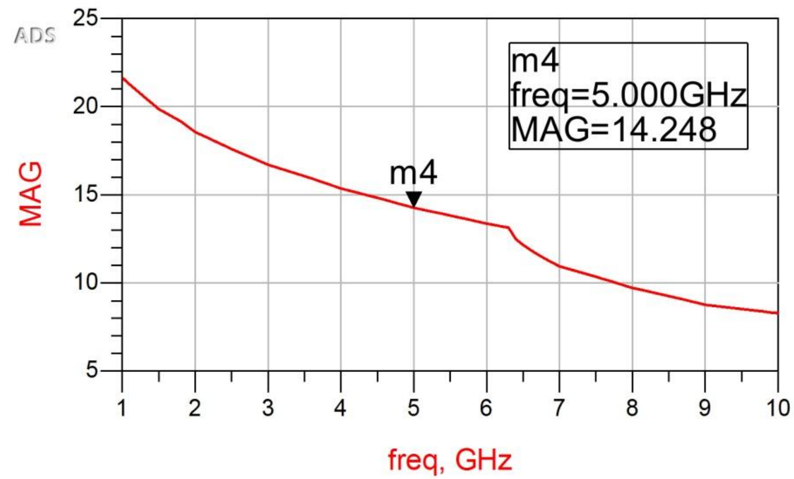
Exemplu LNA cascada

- Similar cu tema de la mini-proiect
- Amplificator LNA cu ATF-34143 avand caracteristicile:
  - G = 20dB
  - F = 1dB
  - @f = 5GHz

Exemplu

- ATF-34143 **at Vds=3V Id=20mA**.
- @5GHz
  - $S_{11} = 0.64 \angle 139°$
  - $S_{12} = 0.119 \angle -21°$
  - $S_{21} = 3.165 \angle 16°$
  - $S_{22} = 0.22 \angle 146°$
  - $F_{min} = 0.54$ (**tipic [dB] !**)
  - $\Gamma_{opt} = 0.45 \angle 174°$
  - $r_n = 0.03$





Exemplu, LNA @ 5 GHz

- ATF-34143 **at Vds=3V Id=20mA.**
- @5GHz
  - $S_{11} = 0.64\angle 139°$
  - $S_{12} = 0.119\angle -21°$
  - $S_{21} = 3.165\ \angle 16°$
  - $S_{22} = 0.22\ \angle 146°$
  - Fmin = 0.54 (**tipic [dB]**)
  - $\Gamma_{opt} = 0.45\ \angle 174°$
  - $r_n = 0.03$

```
!ATF-34143
!S-PARAMETERS at Vds=3V  Id=20mA.   LAST UPDATED 01-29-99

# ghz s ma r 50

2.0  0.75  -126  6.306  90  0.088  23  0.26  -120
2.5  0.72  -145  5.438  75  0.095  15  0.25  -140
3.0  0.69  -162  4.762  62  0.102  7  0.23  -156
4.0  0.65  166  3.806  38  0.111  -8  0.22  174
5.0  0.64  139  3.165  16  0.119  -21  0.22  146
6.0  0.65  114  2.706  -5  0.125  -35  0.23  118
7.0  0.66  89  2.326  -27  0.129  -49  0.25  91
8.0  0.69  67  2.017  -47  0.133  -62  0.29  67
9.0  0.72  48  1.758  -66  0.135  -75  0.34  46

!FREQ   Fopt    GAMMA OPT      RN/Zo
!GHZ     dB     MAG     ANG       -

2.0  0.19  0.71  66  0.09
2.5  0.23  0.65  83  0.07
3.0  0.29  0.59  102  0.06
4.0  0.42  0.51  138  0.03
5.0  0.54  0.45  174  0.03
6.0  0.67  0.42  -151  0.05
7.0  0.79  0.42  -118  0.10
8.0  0.92  0.45  -88  0.18
9.0  1.04  0.51  -63  0.30
10.0  1.16  0.61  -43  0.46
```

Amplificatoare in cascada

- Daca e necesar un castig mai mare decat cel care poate fi oferit de un singur tranzistor
  - necesar 20dB
  - MAG @5GHz = 14.248 dB < 20dB
- Se utilizeaza formula lui Friis pentru a imparti necesarul de:
  - castig
  - zgomot
- pe cele doua etaje individuale

Formula lui Friis (zgomot)

$$F_{cas} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 \cdot G_2} + \frac{F_4 - 1}{G_1 \cdot G_2 \cdot G_3} + \cdots$$

- Formula lui Friis, efecte:
  - e esential ca primul etaj de amplificare sa fie **nezgomotos**, chiar cu sacrificarea in parte a castigului
  - urmatoarele etaje pot fi optimizate pentru **castig**
- Formula lui Friis trebuie utilizata in **coordonate liniare**
- **Avago/Broadcom AppCAD**
  - AppCAD Free Design Assistant Tool for Microsoft Windows → Google

Formula lui Friis (zgomot)

$$G_{cas} = G_1 \cdot G_2 \qquad F_{cas} = F_1 + \frac{1}{G_1}\left(F_2 - 1\right)$$

- Formula lui Friis
  - primul etaj factor de zgomot mai mic, probabil insotit de un castig mai mic
  - al doilea etaj castig mare, probabil insotit de un factor de zgomot mai mare
- Este esential sa se pastreze o rezerva
  - $G = G_{tema} + \Delta G$
  - $F = F_{tema} - \Delta F$
- Tema se interpreteaza
  - $G > G_{tema}$, mai bine, fara a fi nevoie sa se sacrifice alti parametri pentru castiguri mult mai mari
  - $F < F_{tema}$, mai bine, cu cat mai mic cu atat mai bine, e util sa se incerce obtinerea unui **zgomot cat mai mic**, **cu indeplinirea** celorlalte conditii

Formula lui Friis (zgomot)

- Formula lui Friis
  - primul etaj factor de zgomot mai mic, probabil insotit de un castig mai mic
  - al doilea etaj castig mare, probabil insotit de un factor de zgomot mai mare
- Impartire pe cele doua etaje (Estimat)
  - intrare: F1 = 0.7 dB, G1 = 9 dB
  - iesire: F2 = 1.2 dB, G2 = 13 dB
- Transformare **in coordonate liniare !**

$$F_1 = 10^{\frac{F_1[dB]}{10}} = 10^{0.07} = 1.175 \qquad G_1 = 10^{\frac{G_1[dB]}{10}} = 10^{0.9} = 7.943$$

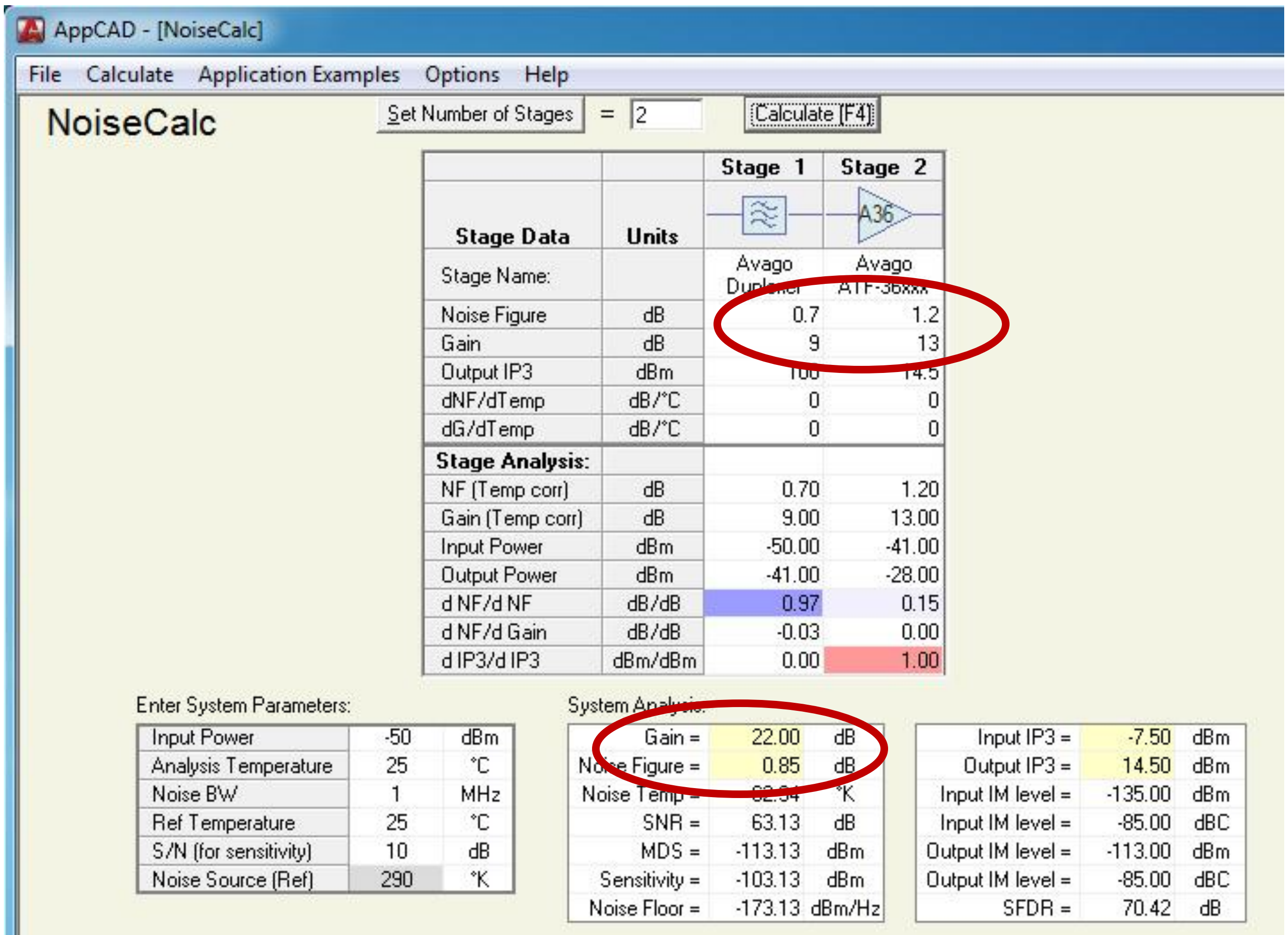
$$F_2 = 10^{\frac{F_2[dB]}{10}} = 10^{0.12} = 1.318 \qquad G_2 = 10^{\frac{G_2[dB]}{10}} = 10^{1.3} = 19.953$$

$$F_{cas} = F_1 + \frac{1}{G_1}(F_2 - 1) = 1.215 \qquad G_{cas} = G_1 \cdot G_2 = 158.49$$

$$F_{cas} = 10 \cdot \log(1.215) = 0.846\,dB \qquad G_{cas} = 10 \cdot \log(158.49) = 22\,dB$$

Formula lui Friis (zgomot)

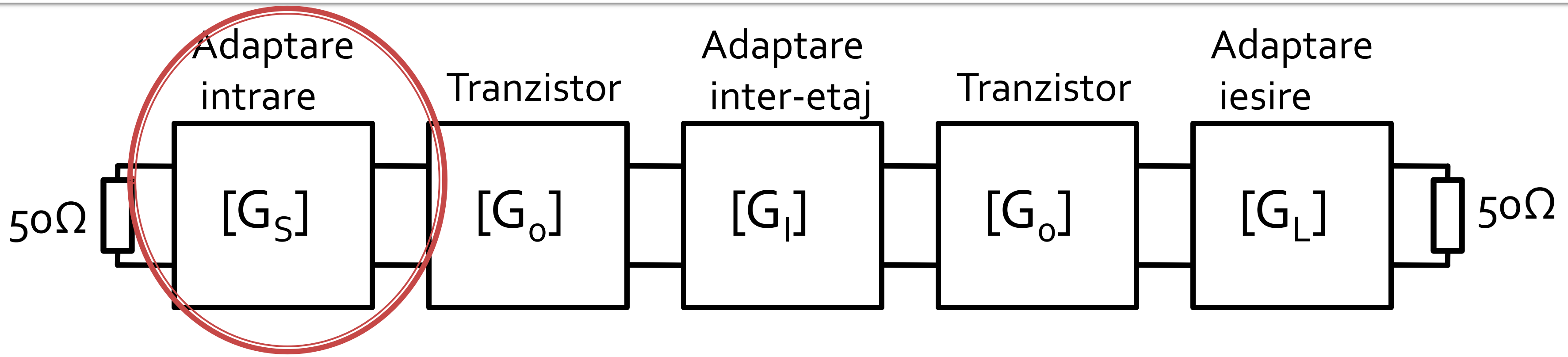
- Avago/Broadcom AppCAD



Proiectare etaje cascadate

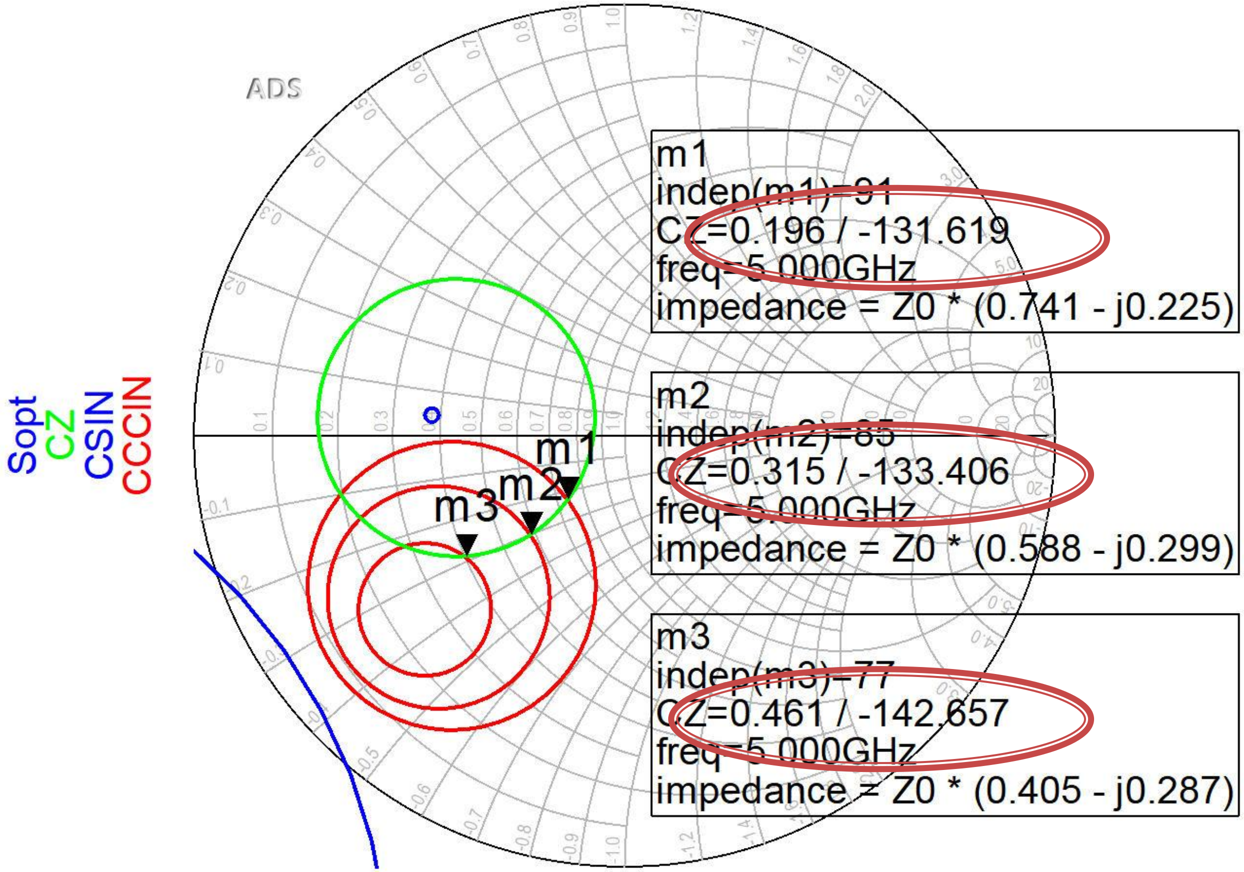
- Impartire pe cele doua etaje (Estimat)
  - intrare: $F_1 = 0.7$ dB, $G_1 = 9$ dB
  - iesire: $F_2 = 1.2$ dB, $G_2 = 13$ dB
  - total: $F = 0.85$ dB, $G = 22$ dB
- Indeplineste conditiile din tema (cu rezerva corespunzatoare)
- Se poate refolosi o parte din calculul amplificatorului cu un singur etaj (C11)
  - adaptarea la intrare anterioara este potrivita la intrarea amplificatorului multietaj – zgomot f. mic, castig onorabil
  - adaptare la iesire este conceputa pentru castig maxim
  - intrarea si iesirea erau proiectate pentru 50Ω la intrare si iesire (similar cu situatia curenta)

Adaptare la intrare



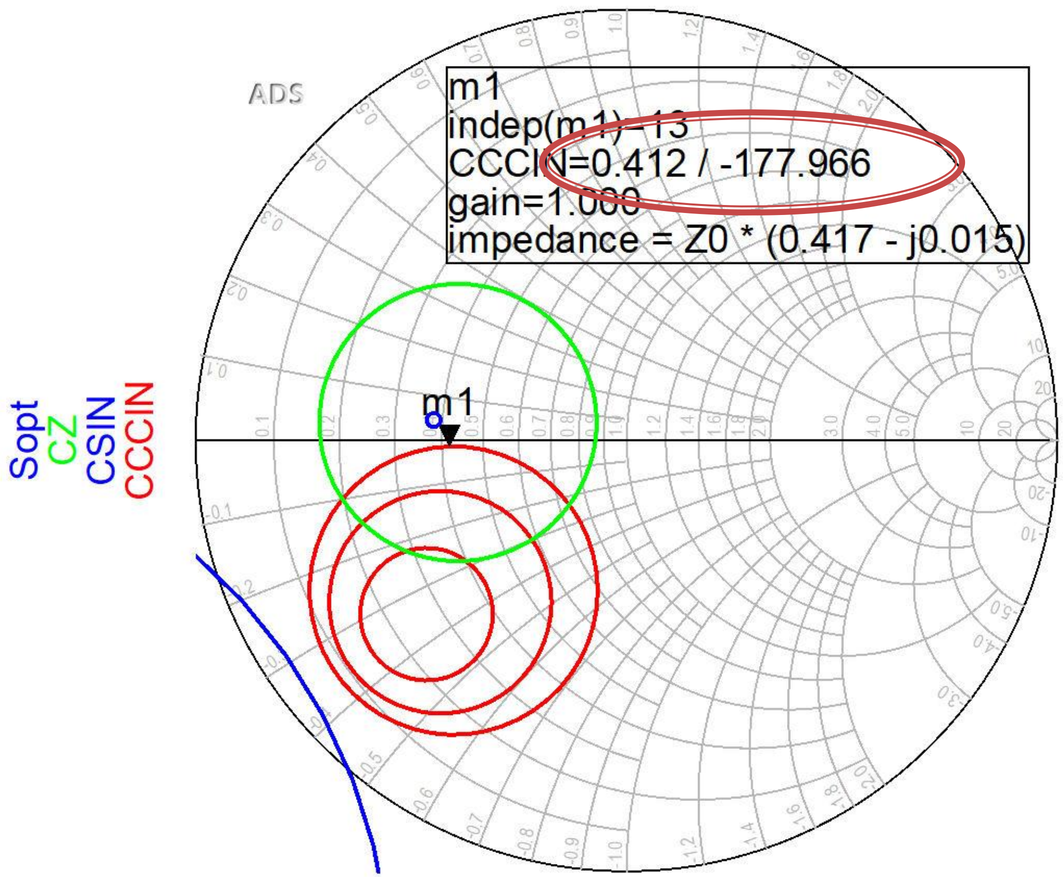
- Se acorda importanta in special comportarii la **zgomot** (mic/minim)
- Se mai tine cont de
  - Castig (sacrificat, dar nu foarte mult)
  - Banda dorita (prin factorul de calitate Q)
  - Stabilitate

Adaptare la intrare



- Pentru reteaua de adaptare la intrare
  - CZ: 0.75dB
  - CCCIN: 1dB, 1.5dB, 2 dB
- Aleg (Q mic → banda larga) pozitia m1

Adaptare la intrarea etajului 1 (S1)



- Daca se sacrifica 1.2dB castig la intrare pentru conditii convenabile F,Q (Gs = 1 dB)
- Se prefera obtinerea unui **zgomot mai mic**

Adaptare la intrarea etajului 1 (S1)

- **G_{S1}**: Pozitia m1 de pe grafic, **1dB**

$$\Gamma_S = 0.412\angle -178^\circ \qquad |\Gamma_S| = 0.412; \quad \varphi = -178^\circ$$

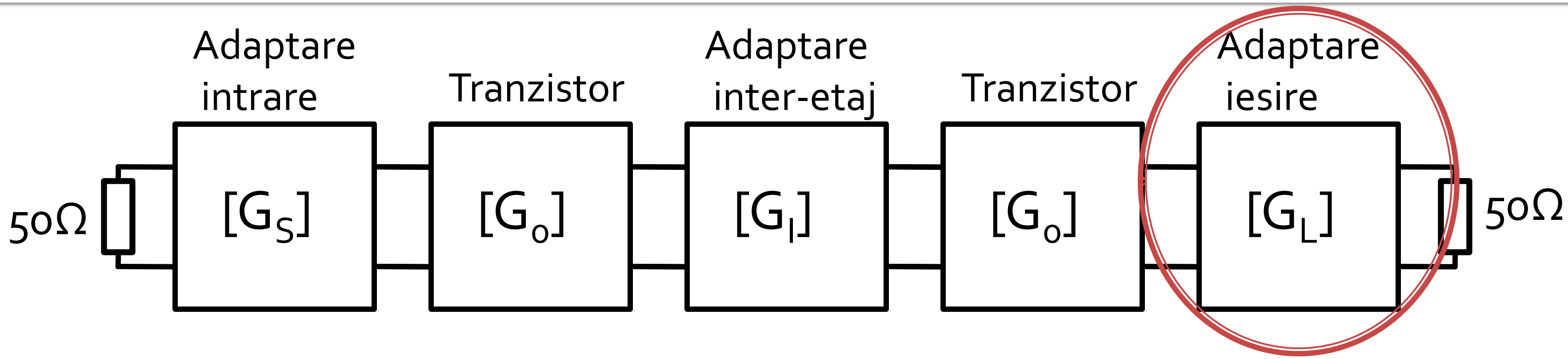
$$\cos(\varphi + 2\theta) = -|\Gamma_S| \qquad \mathrm{Im}[y_S(\theta)] = \frac{\mp 2\cdot|\Gamma_S|}{\sqrt{1-|\Gamma_S|^2}}$$

$$\cos(\varphi + 2\theta) = -0.412 \Rightarrow \qquad (\varphi + 2\theta) = \pm 114.33^\circ$$

$$\theta_{sp} = \tan^{-1}(\mathrm{Im}[y_S(\theta)]) = \tan^{-1}\left(\frac{\mp 2\cdot|\Gamma_S|}{\sqrt{1-|\Gamma_S|^2}}\right)$$

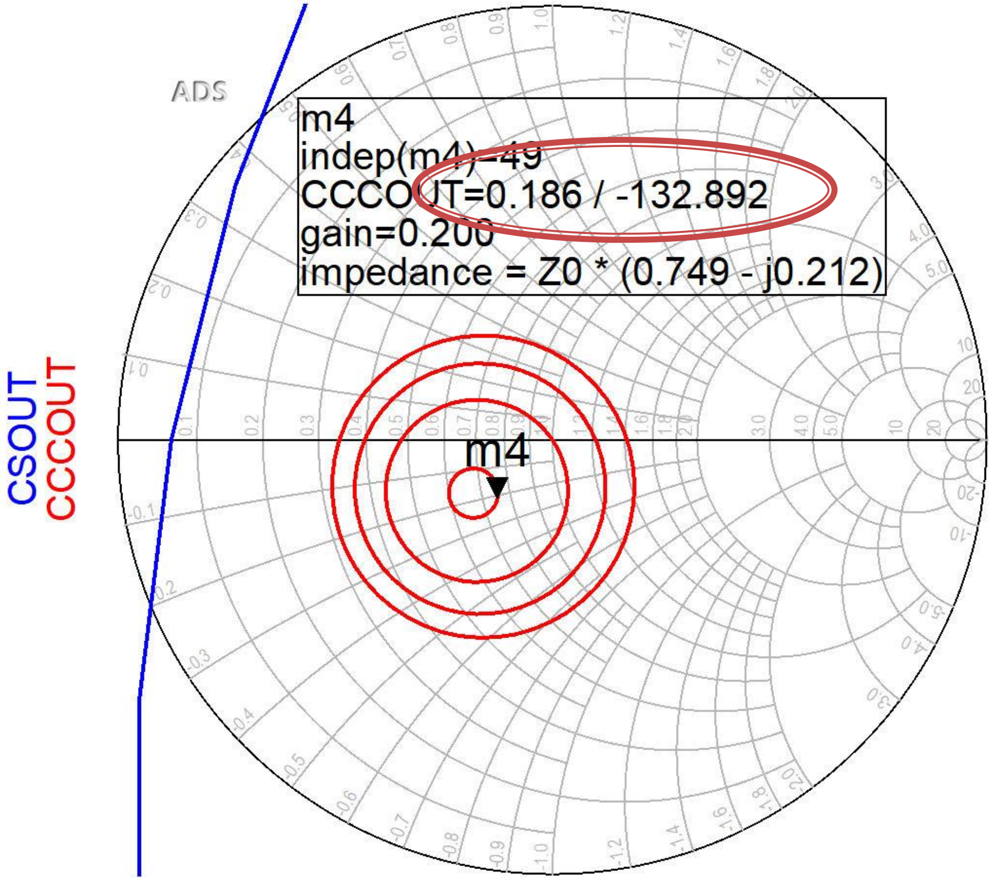
$$(\varphi + 2\theta) = \begin{cases} +114.33^\circ \\ -114.33^\circ \end{cases} \quad \theta = \begin{cases} 146.2^\circ \\ 31.8^\circ \end{cases} \quad \mathrm{Im}[y_S(\theta)] = \begin{cases} -0.904 \\ +0.904 \end{cases} \quad \theta_{sp} = \begin{cases} 137.9^\circ \\ 42.1^\circ \end{cases}$$

Adaptare la iesire



- Se acorda importanta in special **castigului** (mare/maxim)
- Se mai tine cont de
  - Banda dorita (prin factorul de calitate Q)
  - Stabilitate
  - Zgomotul **nu** intervine, nu este afectat

Adaptare la iesirea etajului 2 (L2)



- CCCOUT: -0.4dB, -0.2dB, 0dB, +0.2dB
- Lipsa conditiilor privitoare la zgomot ofera posibilitatea obtinerii unui castig mai mare (spre maxim)

Adaptare la iesirea etajului 2 (L2)

- G_{L_2}: Pozitia m4 de pe grafic, **0.2dB**

$$\Gamma_L = 0.186\angle -132.9^\circ \qquad |\Gamma_L| = 0.186; \quad \varphi = -132.9^\circ$$

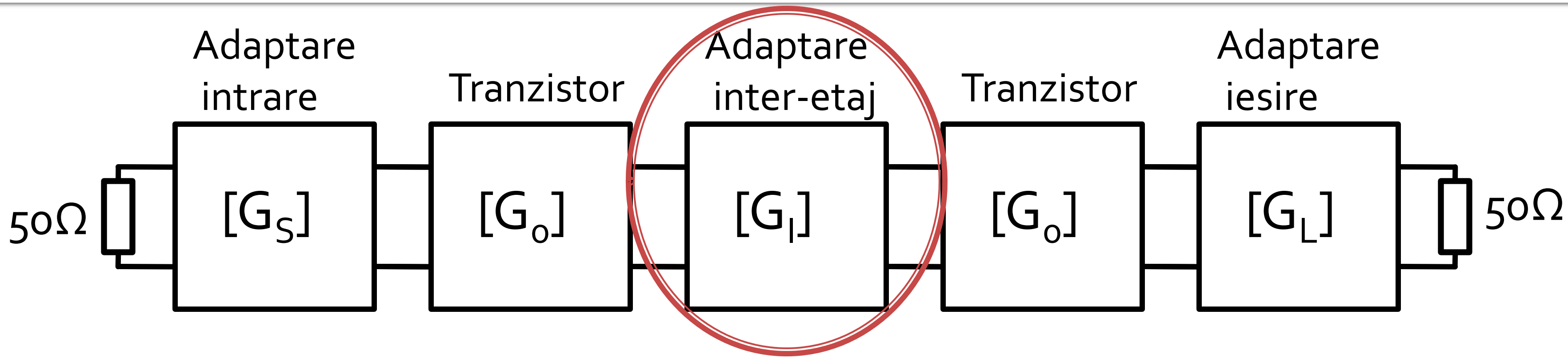
$$\cos(\varphi + 2\theta) = -|\Gamma_L| \qquad \mathrm{Im}[y_L(\theta)] = \frac{-2\cdot|\Gamma_L|}{\sqrt{1-|\Gamma_L|^2}} = -0.379$$

$$\cos(\varphi + 2\theta) = -0.186 \Rightarrow \quad (\varphi + 2\theta) = \pm 100.72^\circ$$

$$\theta_{sp} = \tan^{-1}(\mathrm{Im}[y_L(\theta)]) = \tan^{-1}\left(\frac{\mp 2\cdot|\Gamma_L|}{\sqrt{1-|\Gamma_L|^2}}\right)$$

$$(\varphi + 2\theta) = \begin{cases} +100.72^\circ \\ -100.72^\circ \end{cases} \quad \theta = \begin{cases} 116.8^\circ \\ 16.1^\circ \end{cases} \quad \mathrm{Im}[y_L(\theta)] = \begin{cases} -0.379 \\ +0.379 \end{cases} \quad \theta_{sp} = \begin{cases} 159.3^\circ \\ 20.7^\circ \end{cases}$$

Adaptare inter etaj



- Se acorda importanta **castigului** (mare) dar si zgomotului
- Se mai tine cont de
  - Banda dorita (prin factorul de calitate Q)
  - Stabilitate
  - Prin afectarea factorului de zgomot al celui de-al doilea etaj (acceptat mai mare cu Friis), zgomotul trebuie considerat dar cu conditii mai putin restrictive

Proiectare etaje cascadate

- Castig

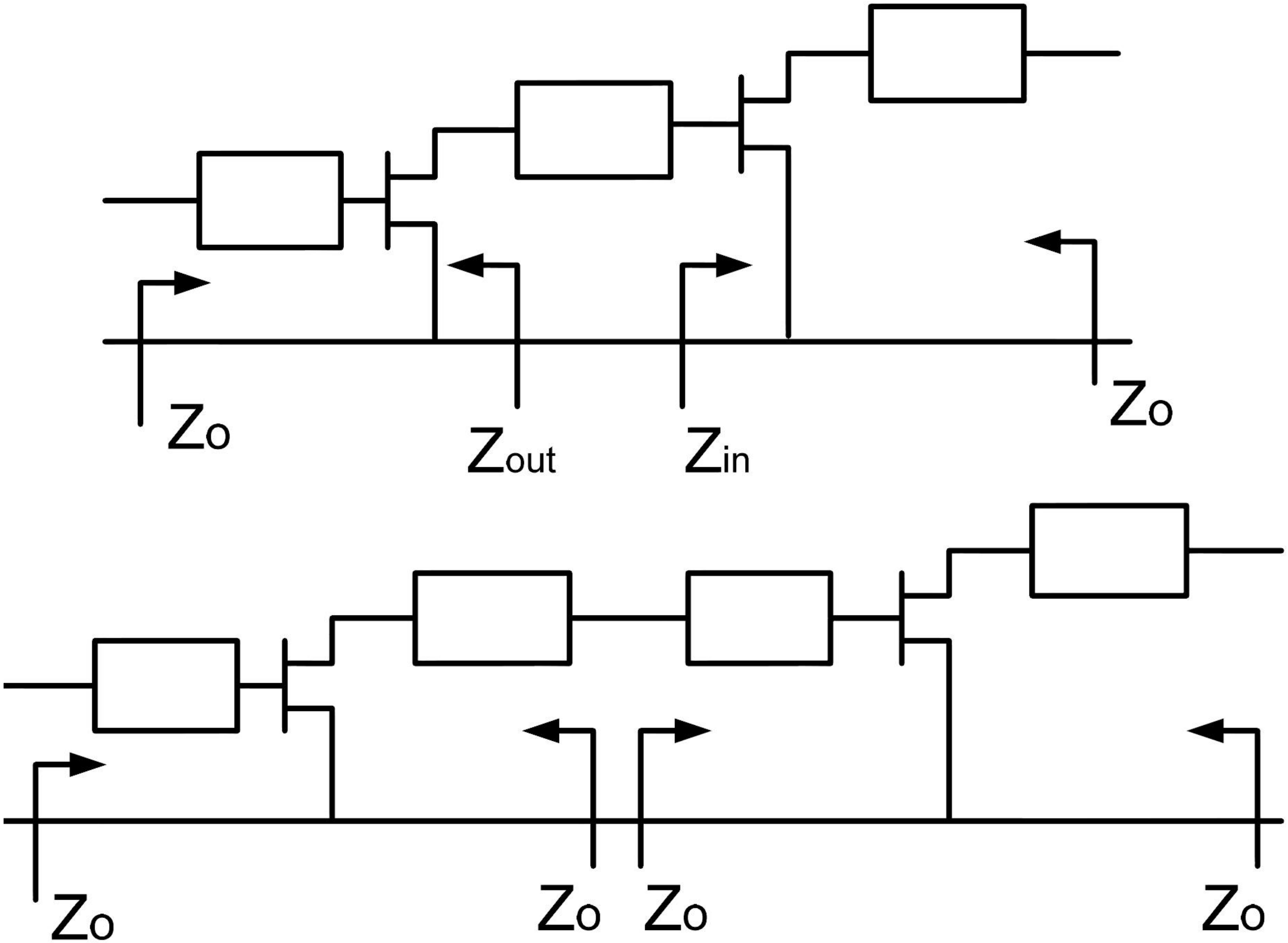
$$G_T[dB] = G_{S1}[dB] + G_0[dB] + G_I[dB] + G_0[dB] + G_{L2}[dB]$$

$$G_T[dB] = 1\ dB + 10\ dB + G_I[dB] + 10\ dB + 0.2\ dB$$

$$G_T[dB] = 21.2\ dB + G_I[dB]$$

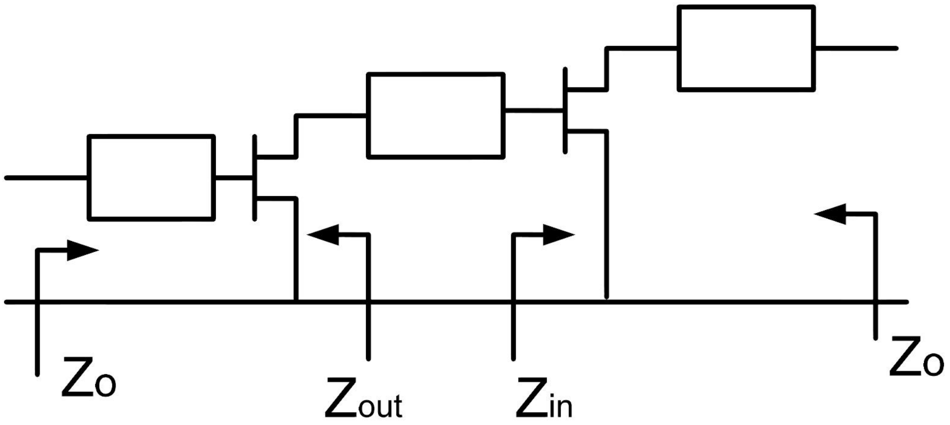
- Prin proiectarea inter-etaje trebuie obtinut un castig de minim 0.8dB prin adaptare mai buna a primului etaj la iesire si a celui de-al doilea la intrare

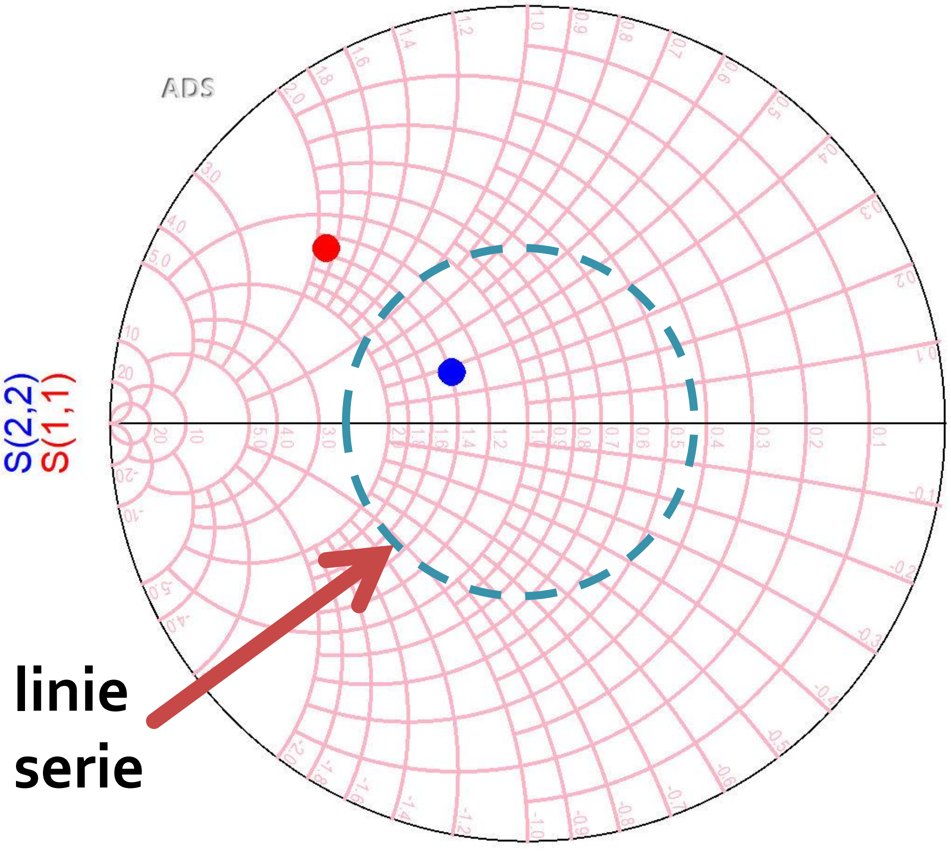
Adaptare inter-etaje 1/2



Adaptare inter-etaje 1

- O singura linie de transmisie pastreaza modulul coeficientului de reflexie



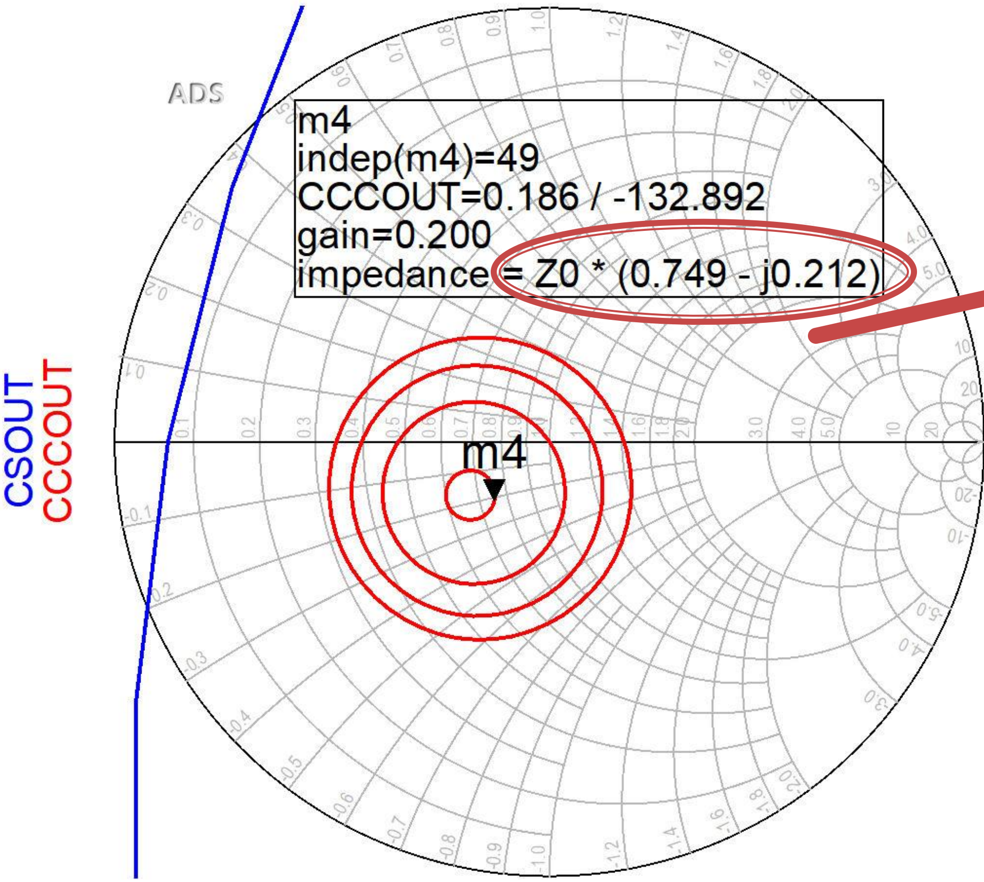


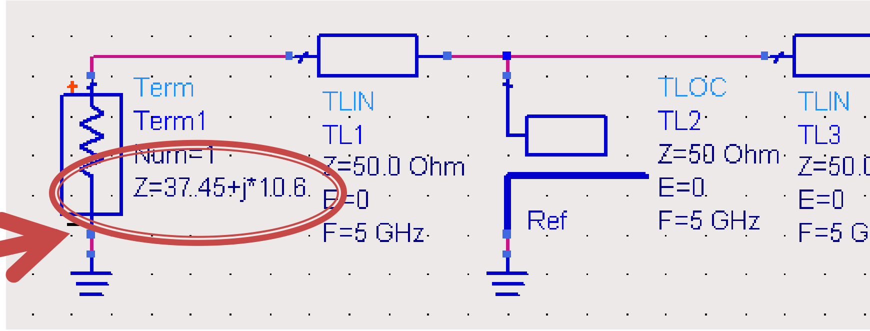
Adaptare inter-etaje 1

- Se poate face in doua moduri:
  - plecand de la iesirea primului etaj (coeficient de reflexie $S22^*$) spre cercurile (desenate pentru etajul al doilea) de:
    - stabilitate
    - castig
    - zgomot
  - plecand de la intrarea celui de-al doilea etaj (coeficient de reflexie $S11^*$) spre cercurile (desenate pentru primul etaj) de:
    - stabilitate
    - castig
- Prima varianta are avantajul de a controla zgomotul introdus de al doilea etaj

Adaptare inter etaj

- Punct de pornire – complex conjugat





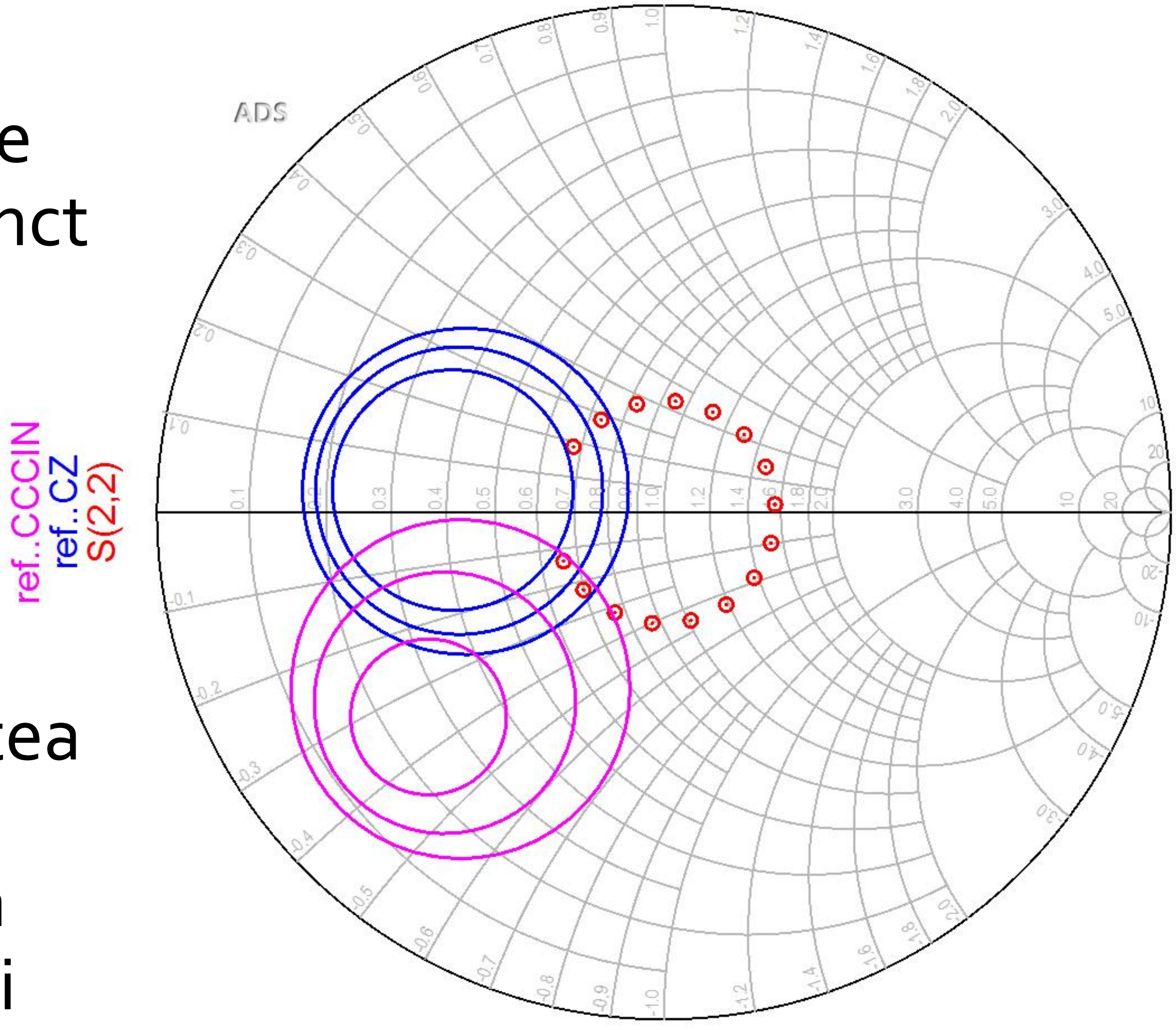
$$Z = 50\Omega \cdot (0.749 - j \cdot 0.212)$$

$$Z = 37.45\Omega - j \cdot 10.6\Omega$$

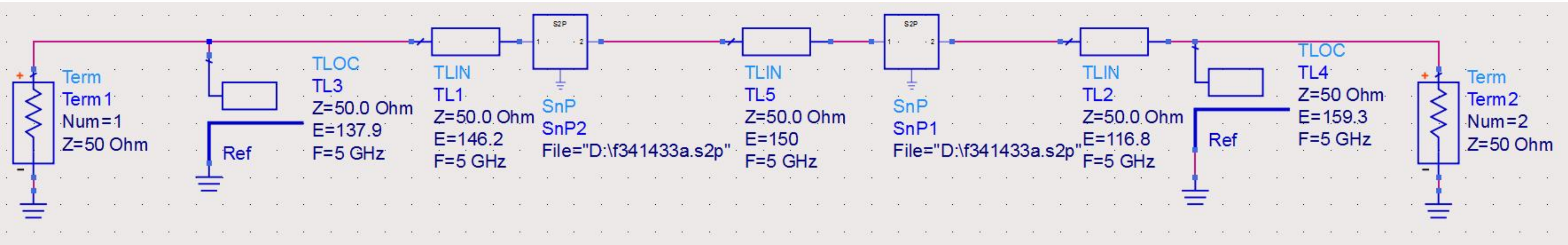
$$Z^* = 37.45\Omega + j \cdot 10.6\Omega$$

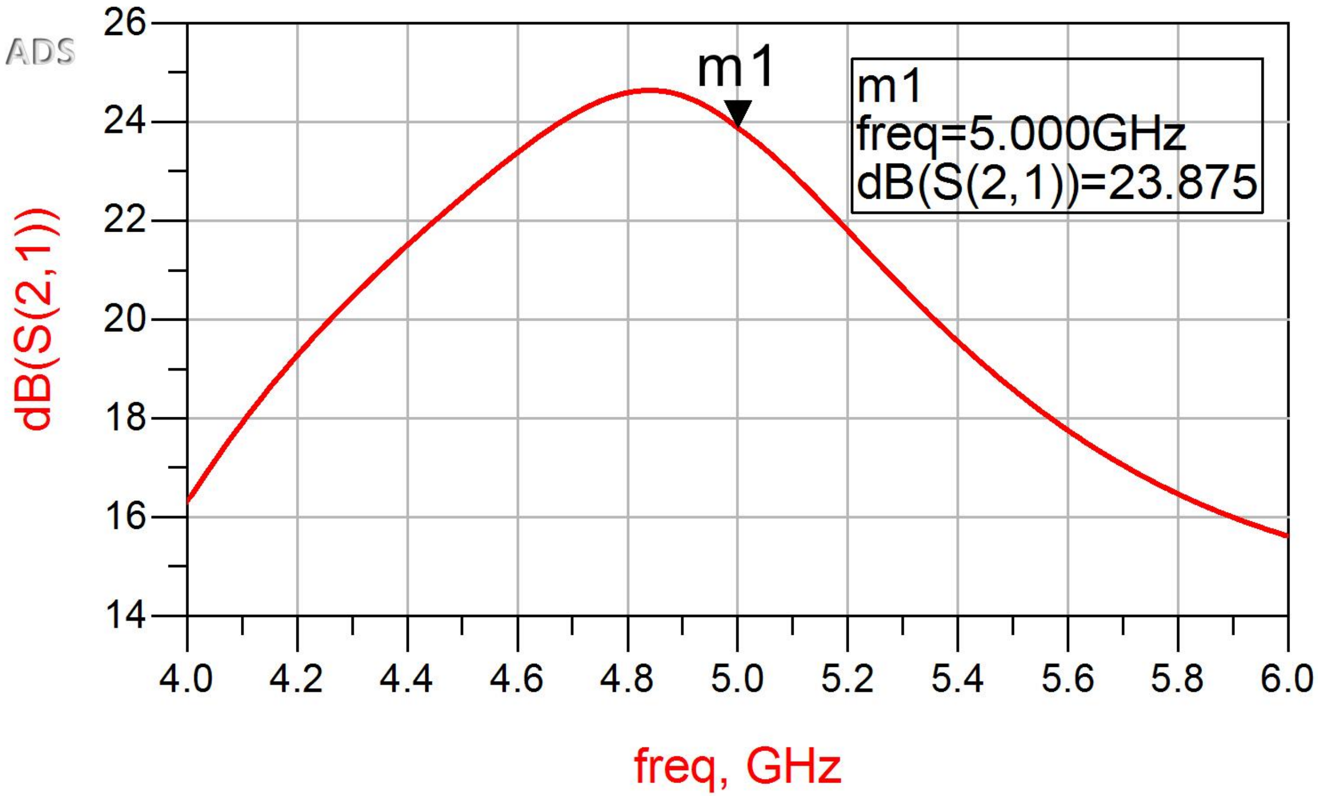
Adaptare inter-etaje 1

- O **singura** linie de transmisie permite atingerea unui punct care nu poate fi optimizat
  - $G_{L1} = 0.2dB$
  - $G_{S2} = 1\ dB$
  - $F_2 = 0.7\ dB$
- Elimina posibilitatea de reglaj pentru controlul in banda larga a amplificarii

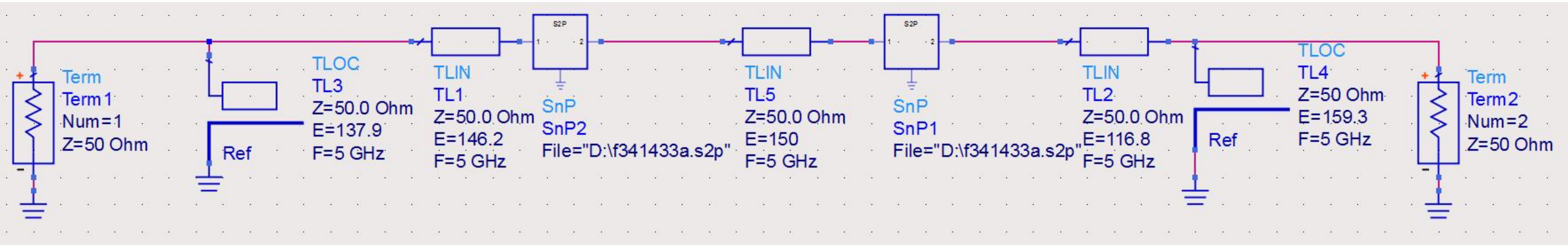


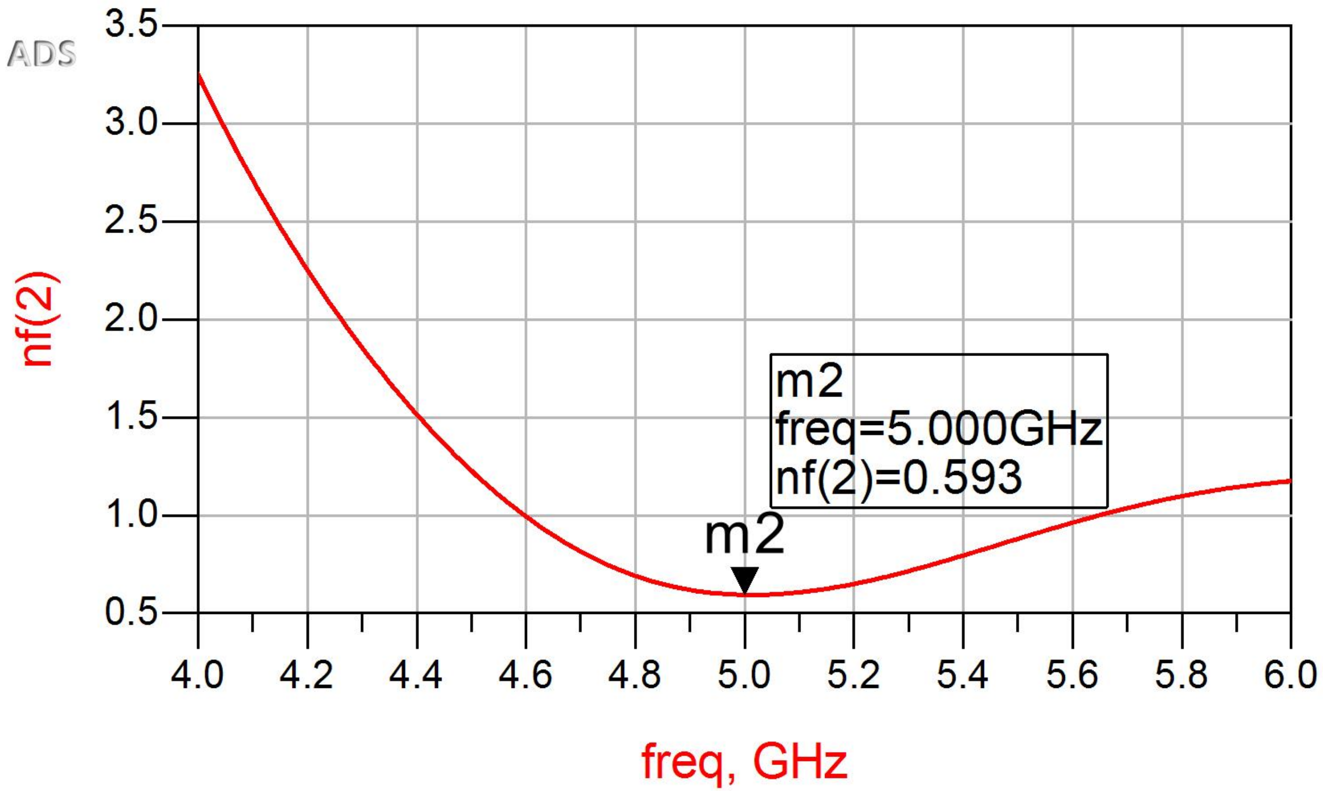
ADS


Term
Term1
Num=1
Z=50 Ohm
Ref
TLOC
TL3
Z=50.0 Ohm
E=137.9
F=5 GHz
TLIN
TL1
Z=50.0 Ohm
E=146.2
F=5 GHz
SnP
SnP2
File="D:\f341433a.s2p"
TLIN
TL5
Z=50.0 Ohm
E=150
F=5 GHz
SnP
SnP1
File="D:\f341433a.s2p"
TLIN
TL2
Z=50.0 Ohm
E=116.8
F=5 GHz
Ref
TLOC
TL4
Z=50 Ohm
E=159.3
F=5 GHz
Term
Term2
Num=2
Z=50 Ohm


m1
m1
freq=5.000GHz
dB(S(2,1))=23.875
dB(S(2,1))
freq, GHz
26
24
22
20
18
16
14
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0

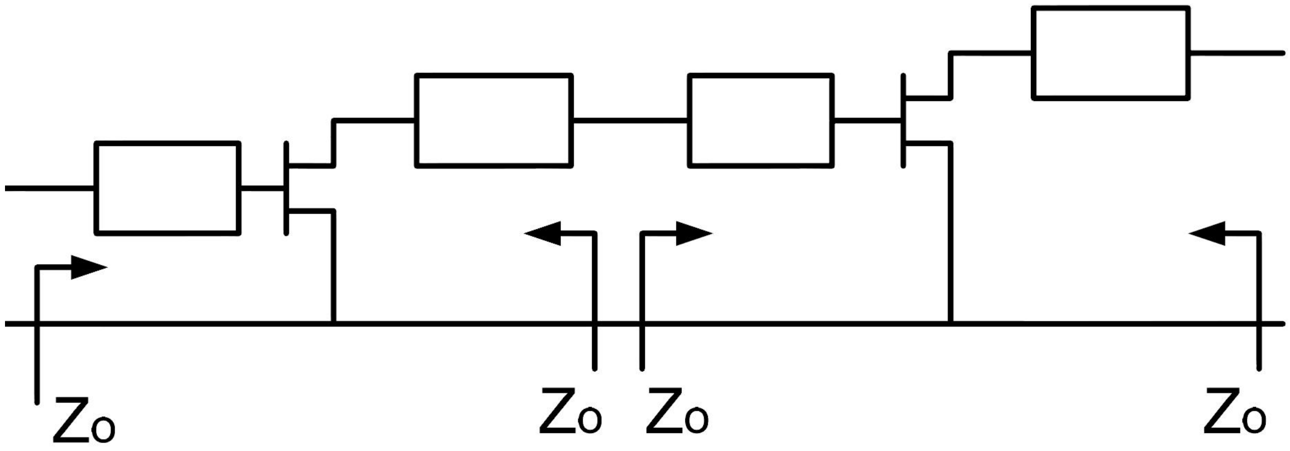
ADS


Term
Term1
Num=1
Z=50 Ohm
Ref
TLOC
TL3
Z=50.0 Ohm
E=137.9
F=5 GHz
TLIN
TL1
Z=50.0 Ohm
E=146.2
F=5 GHz
SnP
SnP2
File="D:\f341433a.s2p"
TLIN
TL5
Z=50.0 Ohm
E=150
F=5 GHz
SnP
SnP1
File="D:\f341433a.s2p"
TLIN
TL2
Z=50.0 Ohm
E=116.8
F=5 GHz
Ref
TLOC
TL4
Z=50 Ohm
E=159.3
F=5 GHz
Term
Term2
Num=2
Z=50 Ohm

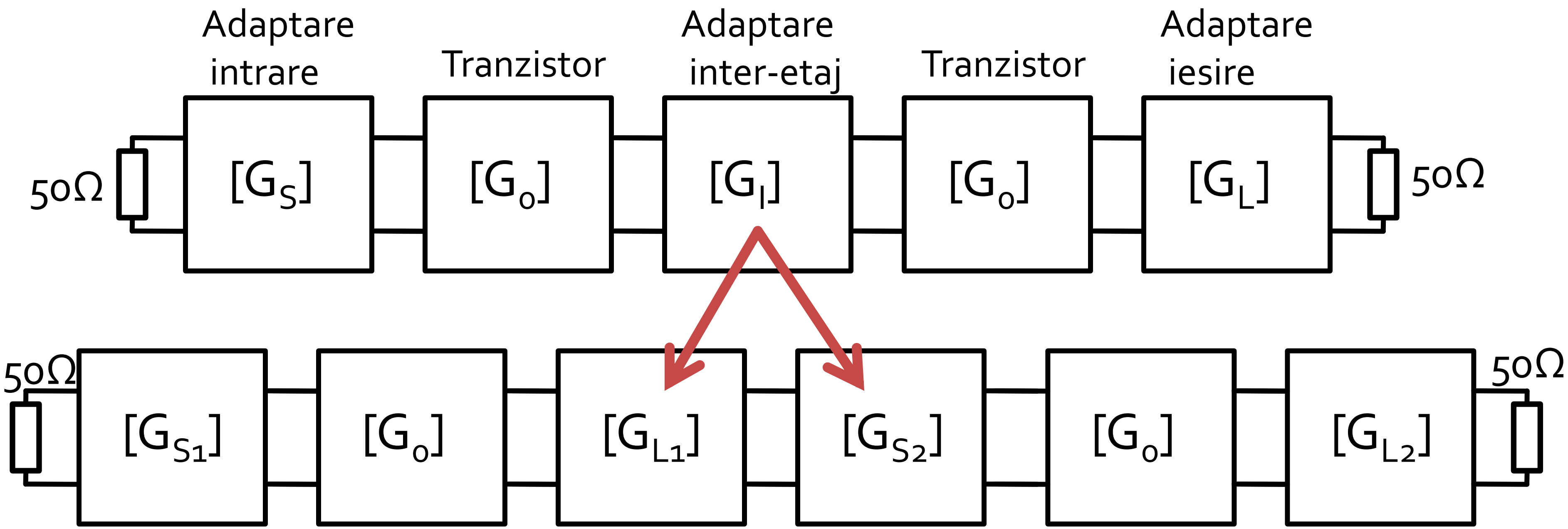

ADS
nf(2)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
m2
freq=5.000GHz
nf(2)=0.593
m2
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0
freq, GHz

Adaptare inter-etaje 2

- Utilizarea mai multor linii de transmisie pentru adaptarea la un punct intermediar cu coeficient de reflexie Γ=0 permite controlul in detaliu al punctului final



Proiectare etaje cascadate



- Calcul castig
  - Adaptarea inter-etaje poate aduce un supliment de castig la ambele etaje de amplificare
  - Proiectarea pentru etajele de intrare si iesire e recomandabil sa se faca pe schema mai simpla cu un singur tranzistor

Proiectare etaje cascadate

- Castig

$$G_T[dB] = G_{S1}[dB] + G_0[dB] + G_{L1}[dB] + G_{S2}[dB] + G_0[dB] + G_{L2}[dB]$$

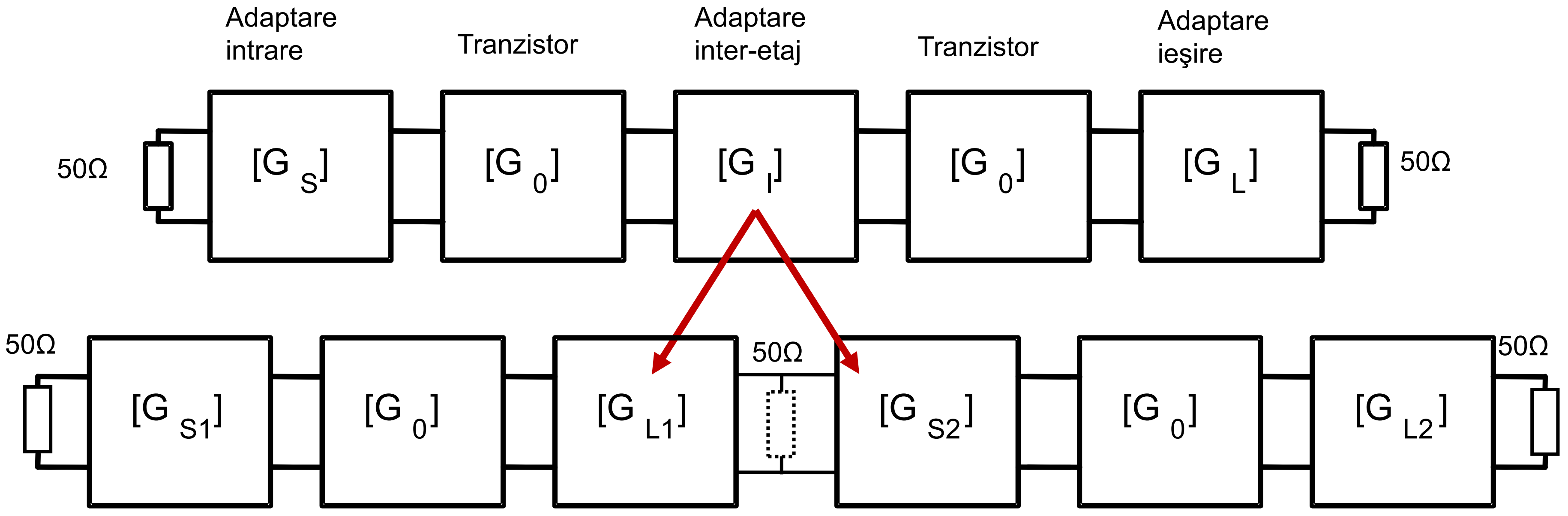
$$G_T[dB] = 1\ dB + 10\ dB + G_{L1}[dB] + G_{S2}[dB] + 10\ dB + 0.2\ dB$$

$$G_T[dB] = 21.2\ dB + G_{L1}[dB] + G_{S2}[dB]$$

- Prin proiectarea inter-etaje trebuie obtinut un castig de minim 0.8dB prin adaptare mai buna a primului etaj la iesire si a celui de-al doilea la intrare

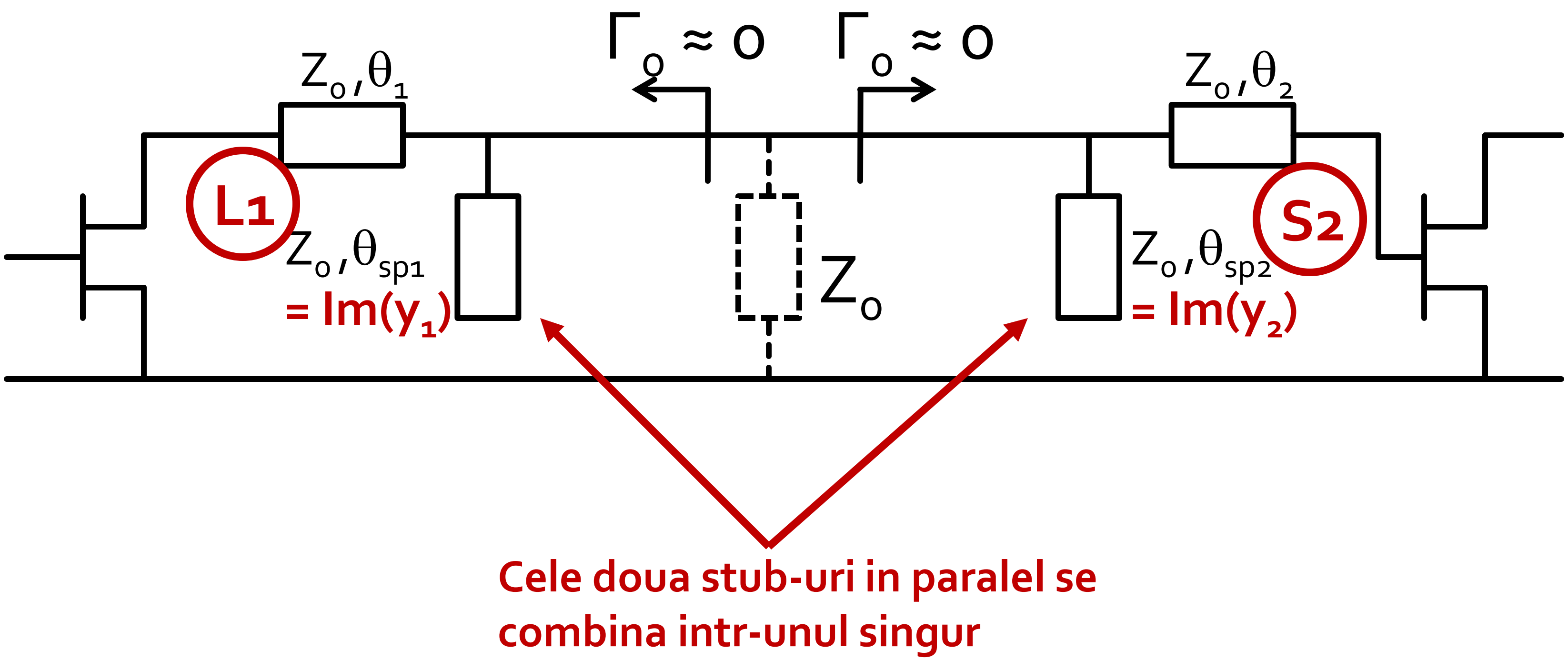
Adaptare inter-etaje 2

- Utilizarea mai multor linii de transmisie pentru adaptarea la un punct intermediar cu coeficient de reflexie Γ=0 permite controlul in detaliu al punctului final



Adaptare inter-etaje 2

- Unul din etaje **creaza** prin reteaua sa de adaptare un coeficient de reflexie Γ=0 la care apoi se adapteaza celalalt etaj



Adaptare inter-etaje 2

- Cele doua stub-uri in paralel se combina intr-unul singur

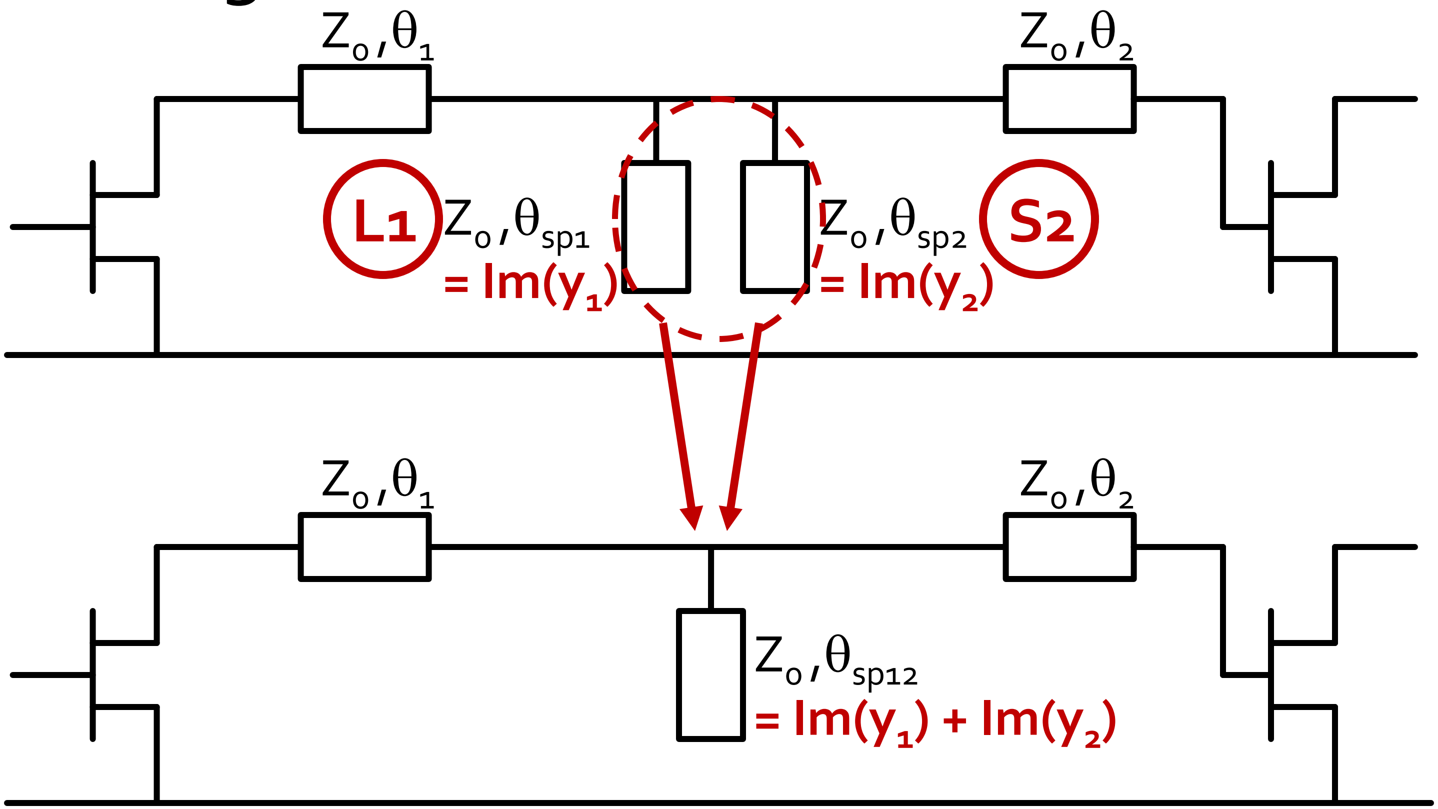
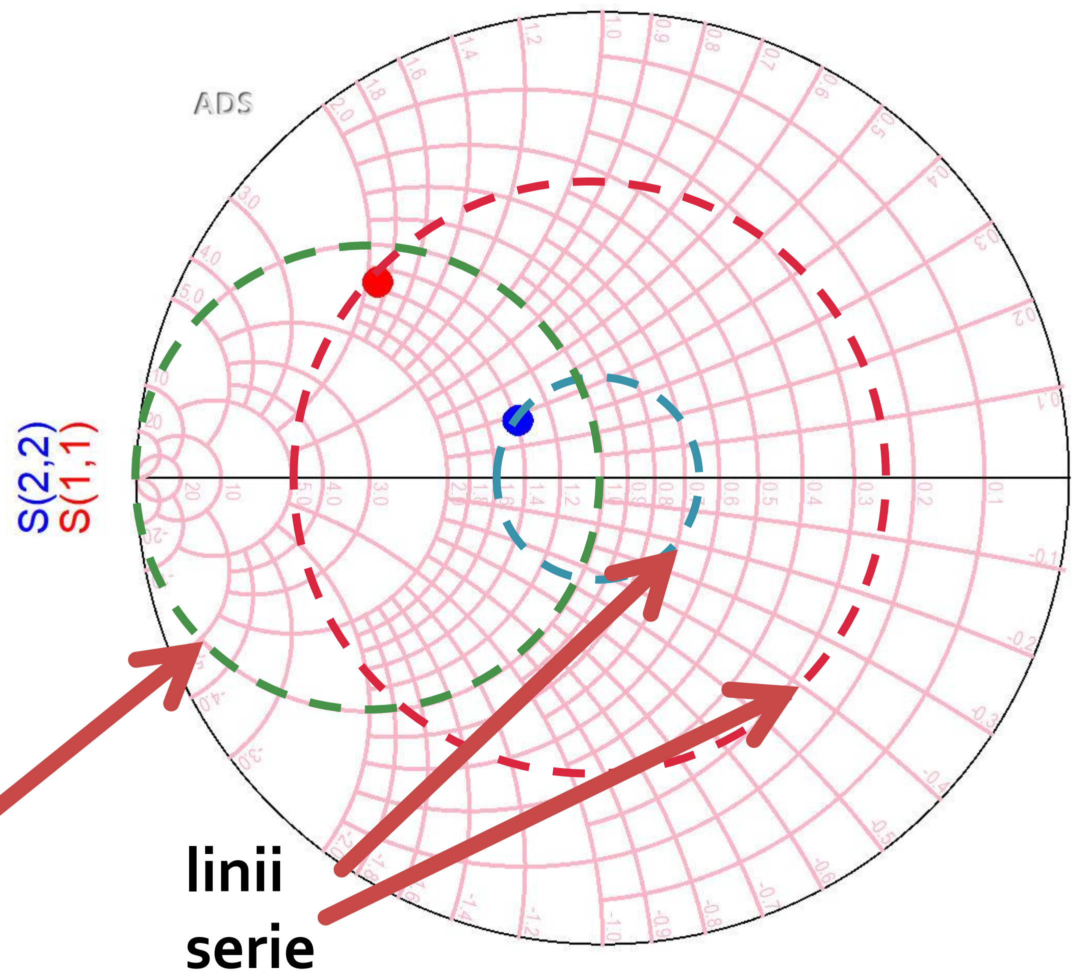


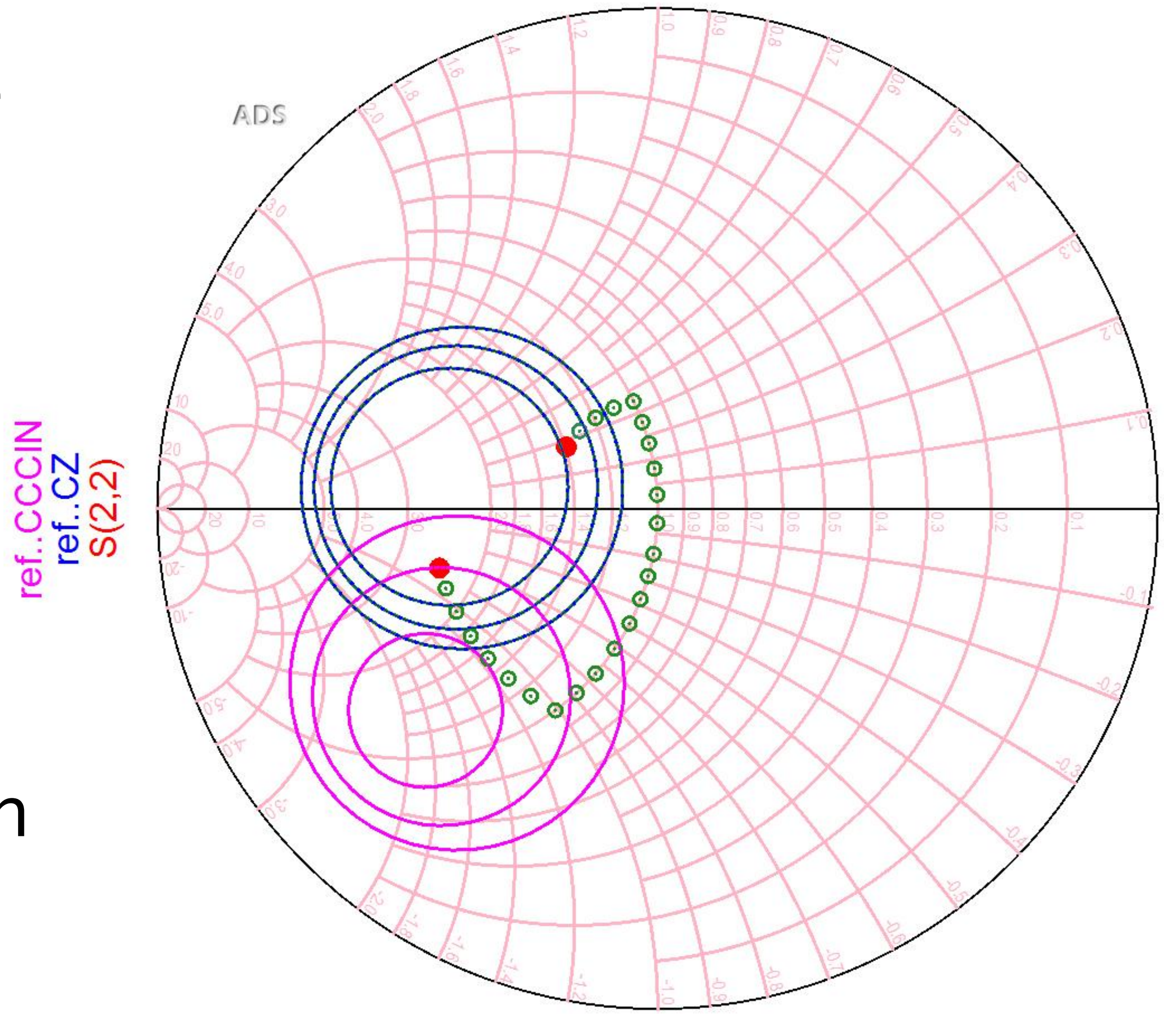
Diagrama Smith

- linie serie → pe cercul cu centrul in originea DS
- stub paralel → pe cercul g=1



Adaptare inter-etaje 2

- Pentru fiecare etaj utilizam o linie serie si un stub paralel
  - Linia serie muta coeficientul de reflexie pe cercul unitate g=1
  - Stub-ul paralel muta punctul in centrul diagramei (adaptare la Zo)
- Cele doua stub-uri in paralel se combina intr-unul singur



Adaptare la iesirea etajului 1 (L1)

- G_{L1} (putem folosi tot punctul de la iesirea L2)

$$\Gamma_L = 0.186\angle -132.9^\circ \qquad |\Gamma_L| = 0.186; \quad \varphi = -132.9^\circ$$

$$\cos(\varphi + 2\theta) = -|\Gamma_L| \qquad \mathrm{Im}[y_L(\theta)] = \frac{-2\cdot|\Gamma_L|}{\sqrt{1-|\Gamma_L|^2}} = -0.379$$

$$\cos(\varphi + 2\theta) = -0.186 \Rightarrow \quad (\varphi + 2\theta) = \pm 100.72^\circ$$

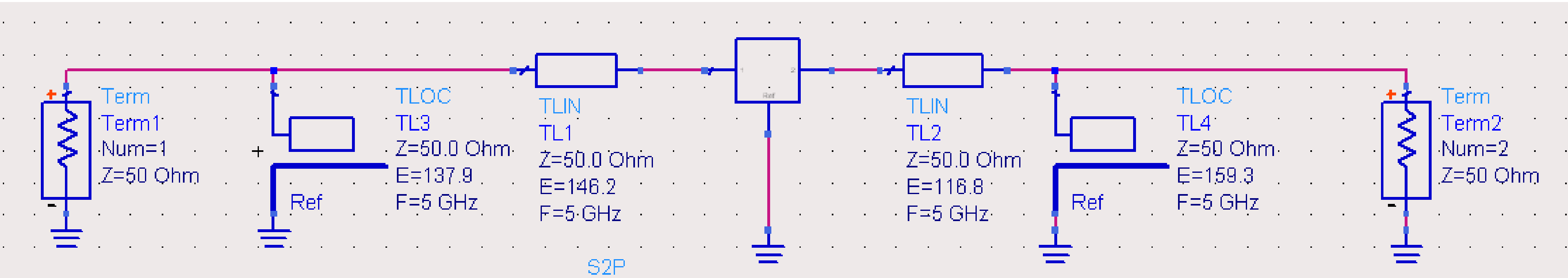
- nu e obligatoriu sa se calculeze θ_{sp} deoarece **nu** va fi necesar
  - decat daca doresc simularea/verificarea amplificatorului 1 separat (**recomandat**)

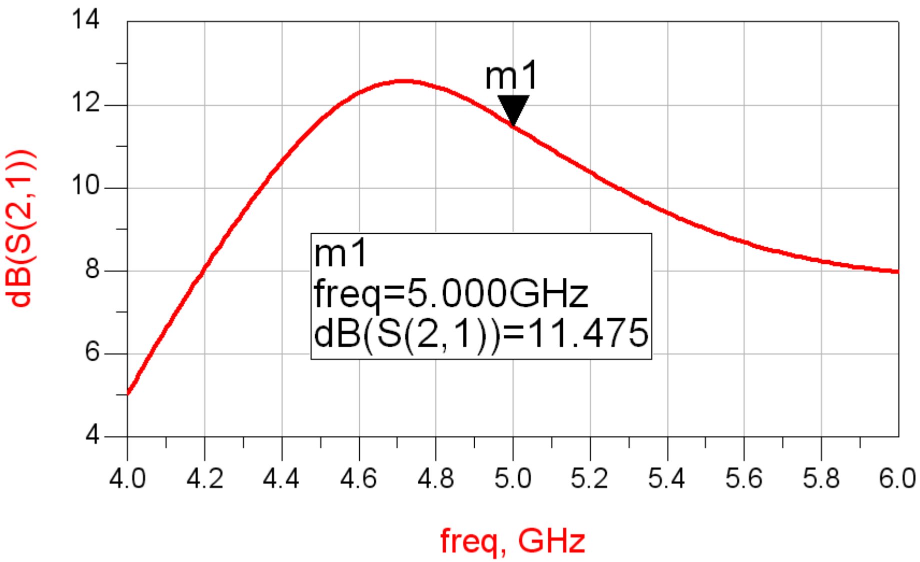
$$(\varphi + 2\theta) = \begin{cases} +100.72^\circ \\ -100.72^\circ \end{cases} \quad \theta = \begin{cases} 116.8^\circ \\ 16.1^\circ \end{cases} \quad \mathrm{Im}[y_L(\theta)] = \begin{cases} -0.379 \\ +0.379 \end{cases}$$

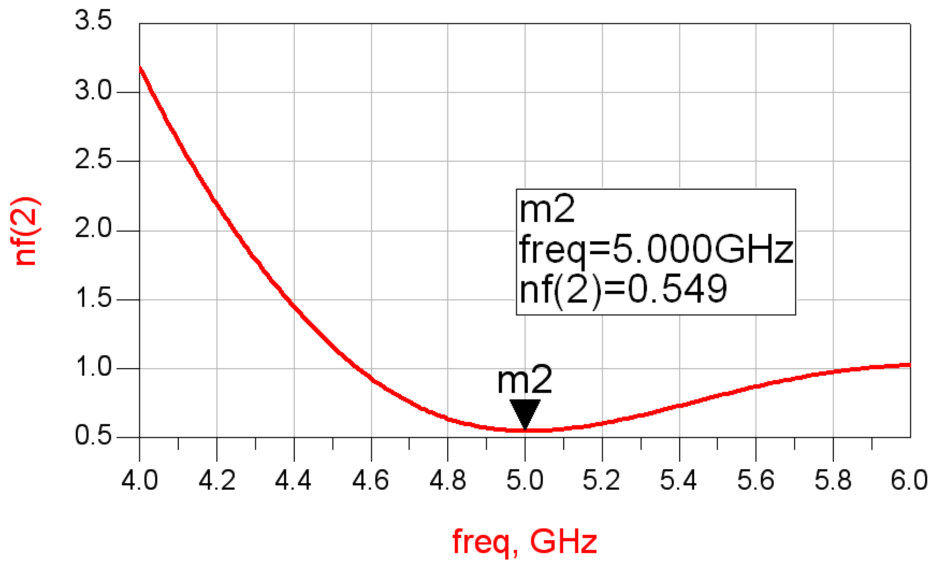
Adaptare la iesirea etajului 1 (L1)

Ecuaţie	**Soluţia L1A**	**Soluţia L1B**
$\Phi+2\theta$	$+100.72°$	$-100.72°$
θ	$116.8°$	$16.1°$
$Im[y(\theta)]$	-0.379	$+0.379$

Verificare etaj 1

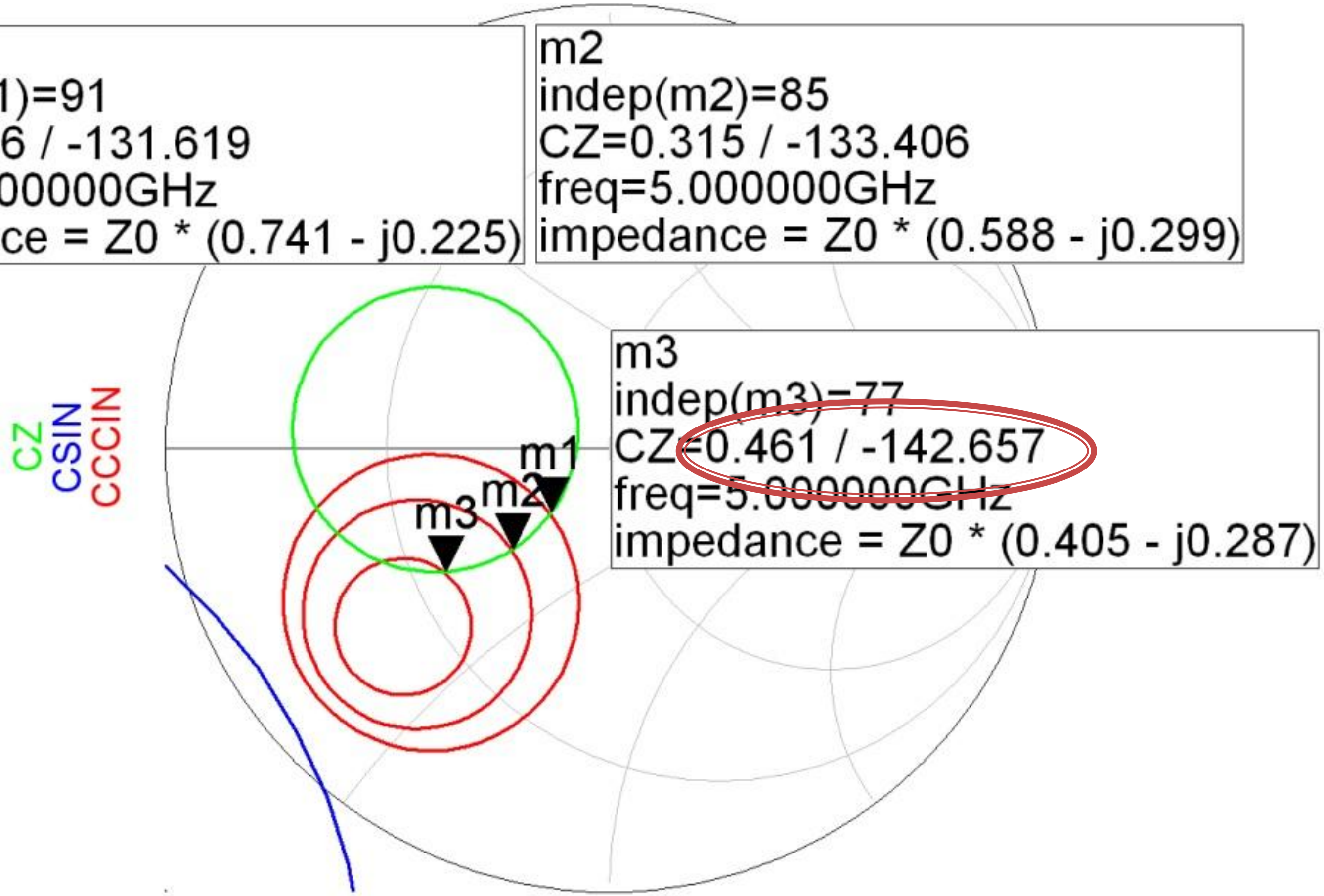






Adaptare la intrarea etajului 2 (S2)

- G_{S_2} (plecare din Γ_{S_2} ales spre origine – m3 – castig 2dB)



Adaptare la intrarea etajului 2 (S2)

- G_{S_2} (plecare din m3 spre origine)

$$\Gamma_{S2} = 0.461\angle -142.66^\circ \qquad |\Gamma_{S2}| = 0.461; \quad \varphi = -142.66^\circ$$

$$\cos(\varphi + 2\theta) = -|\Gamma_{S2}| \qquad \mathrm{Im}[y_{S2}(\theta)] = \frac{\mp 2 \cdot |\Gamma_{S2}|}{\sqrt{1 - |\Gamma_{S2}|^2}}$$

$$\cos(\varphi + 2\theta) = -0.461 \Rightarrow \qquad (\varphi + 2\theta) = \pm 117.45^\circ$$

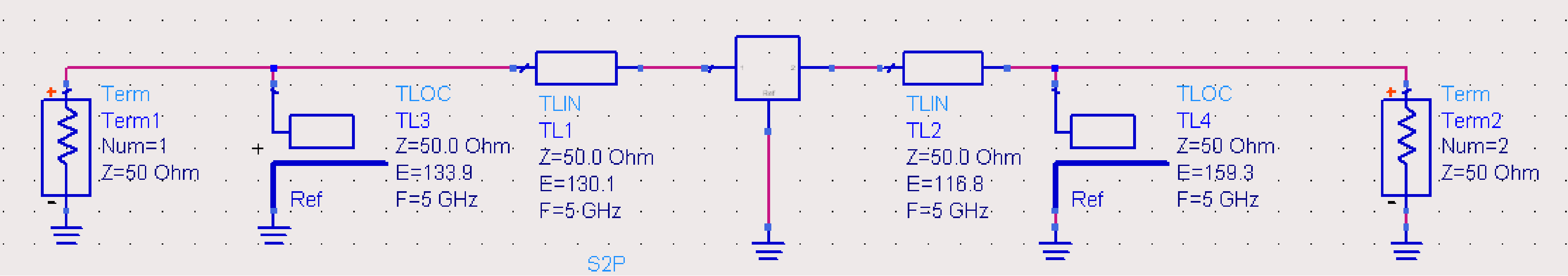
- nu e obligatoriu sa se calculeze θ_{sp} deoarece **nu** va fi necesar
  - decat daca doresc simularea/verificarea amplificatorului 2 separat (**recomandat**)

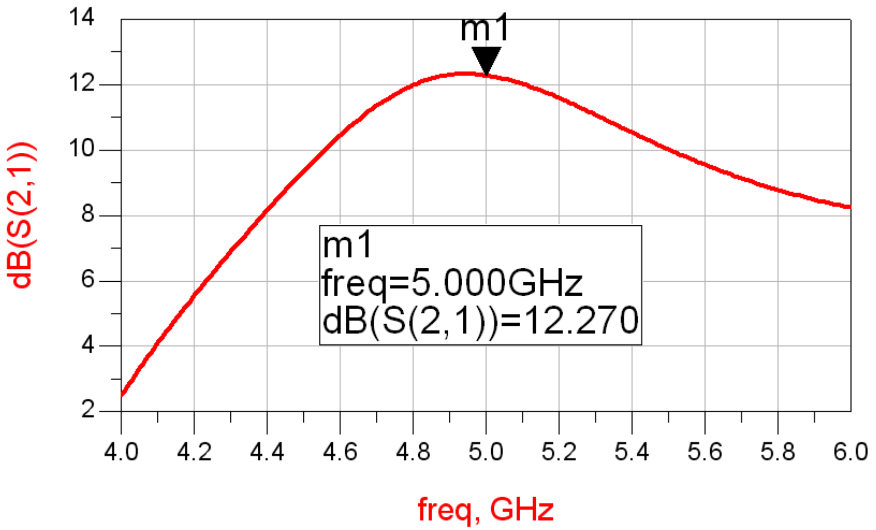
$$(\varphi + 2\theta) = \begin{cases} +117.45^\circ \\ -117.45^\circ \end{cases} \quad \theta = \begin{cases} 130.1^\circ \\ 12.6^\circ \end{cases} \quad \mathrm{Im}[y_{S2}(\theta)] = \begin{cases} -1.039 \\ +1.039 \end{cases}$$

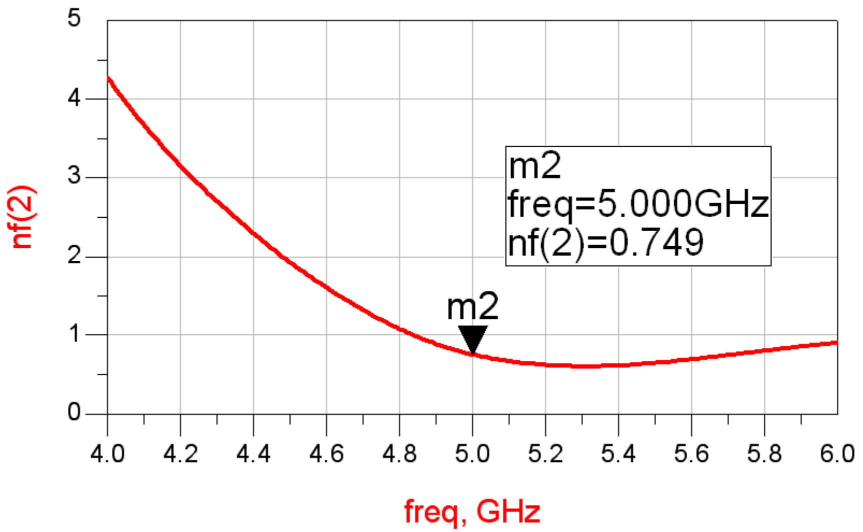
Adaptare la intrarea etajului 2 (S2)

Ecuaţie	Soluţia S2A	Soluţia S2B
$\Phi+2\theta$	$+117.45°$	$-117.45°$
θ	$130.1°$	$12.6°$
$\mathrm{Im}[y(\theta)]$	-1.039	$+1.039$

Verificare etaj 2

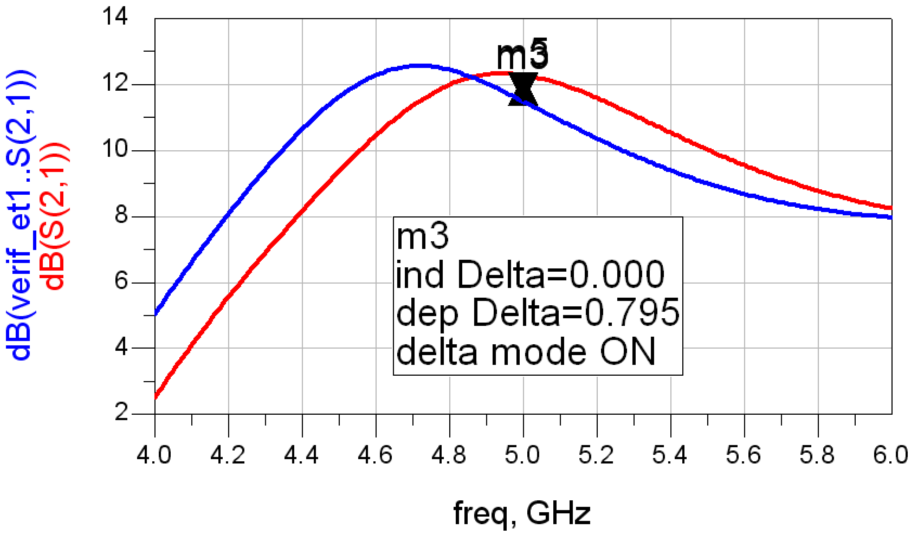


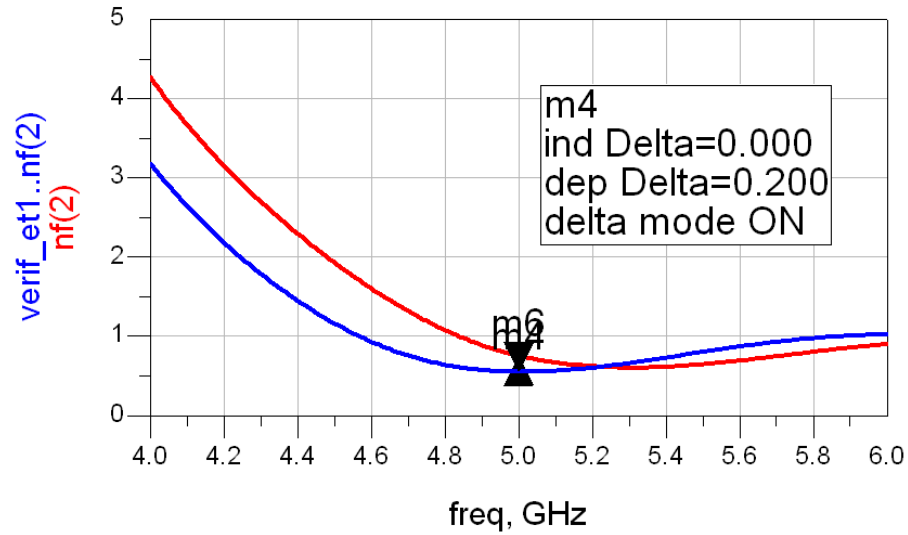




Etaj 1/2

- Conform concluziilor obtinute din formula Friis al doilea etaj obtine castig mai mare deoarece se accepta un zgomot mai mare





Combinarea celor 2 stub-uri paralel

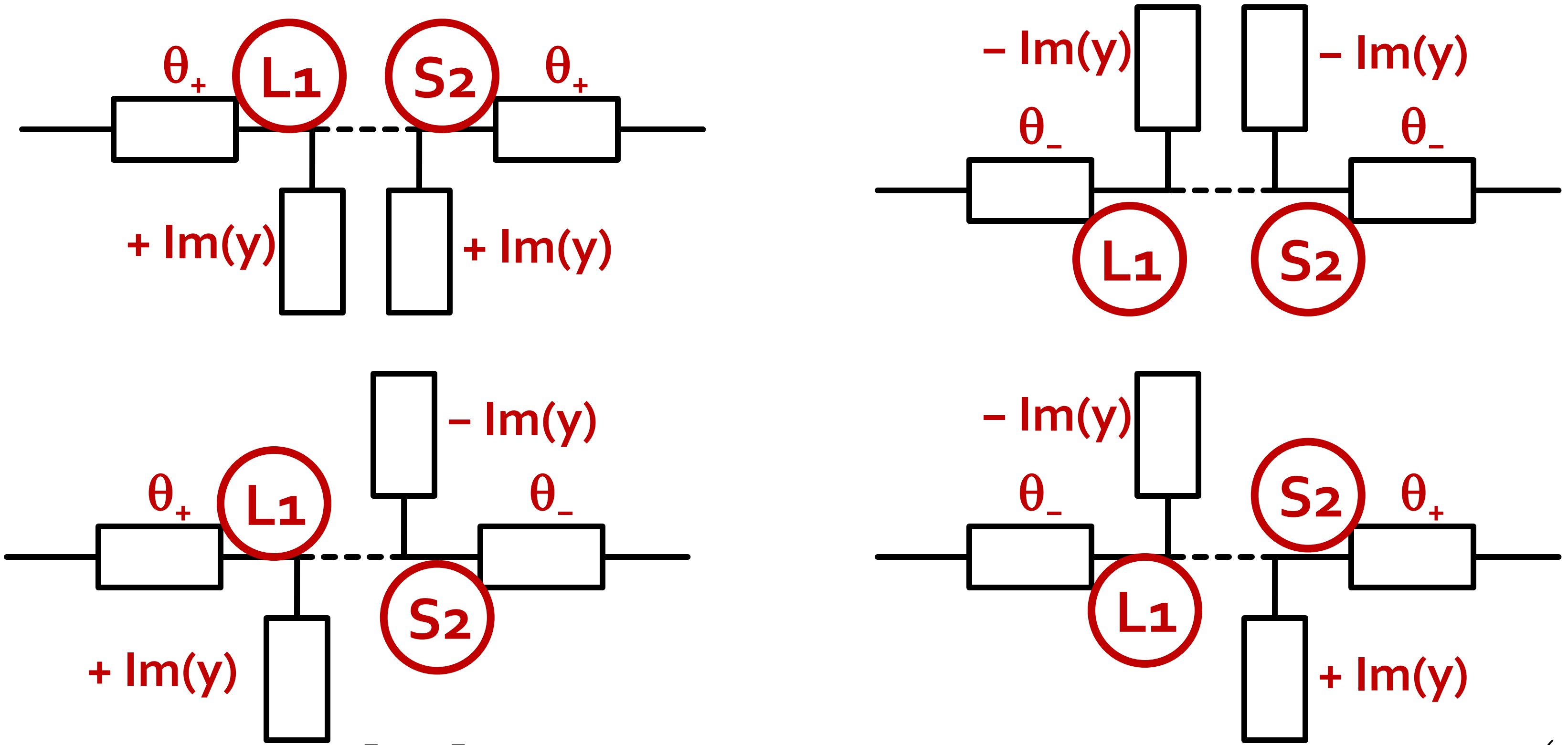
- **Cele doua stub-uri in paralel se combina intr-unul singur**
- Exista **4 combinatii posibile** in functie de cum se combina lungimile electrice alese pentru cele doua linii serie
  - pentru fiecare lungime electrica aleasa (θ) se foloseste obligatoriu Im[y(θ)] corespunzator
- Ex:

$$\theta_{L1} = 116.8^\circ \qquad \theta_{S2} = 130.1^\circ \qquad \mathrm{Im}[y_{sp}] = \mathrm{Im}[y_{L1}(\theta)] + \mathrm{Im}[y_{S2}(\theta)] = -1.418$$

$$\theta_{sp} = \tan^{-1}(\mathrm{Im}[y_{sp}]) \qquad \theta_{sp} = 125.2^\circ$$

Combinarea celor 2 stub-uri paralel

- 4 combinatii posibile
  - **admitantele** sunt in paralel si se **aduna**, nu lungimile electrice



$$\mathrm{Im}\left[y_{sp}\right] = \mathrm{Im}\left[y_{L1}(\theta)\right] + \mathrm{Im}\left[y_{S2}(\theta)\right] \qquad \theta_{sp} = \tan^{-1}\left(\mathrm{Im}\left[y_{sp}\right]\right)$$

Combinarea celor 2 stub-uri paralel

		Soluţia S2A	Soluţia S2B
		θ =130.1° Im[y(θ)] = -1.039	θ =12.6° Im[y(θ)] = +1.039
Soluţia L1A	θ = 116.8° Im[y(θ)] = -0.379	θ_{L1} =116.8° Im[y(θ)] = -1.418 θ_p =125.2° θ_{S2} =130.1°	θ_{L1} =116.8° Im[y(θ)] = +0.66 θ_p =33.4° θ_{S2} =12.6°
Soluţia L1B	θ =16.1° Im[y(θ)] = +0.379	θ_{L1} =16.1° Im[y(θ)] = -0.66 θ_p =146.6° θ_{S2} =130.1°	θ_{L1} =16.1° Im[y(θ)] = 1.418 θ_p =54.8° θ_{S2} =12.6°

Diagrama Smith

- linie serie → pe cercul cu centrul in originea DS
- stub paralel → pe cercul g=1

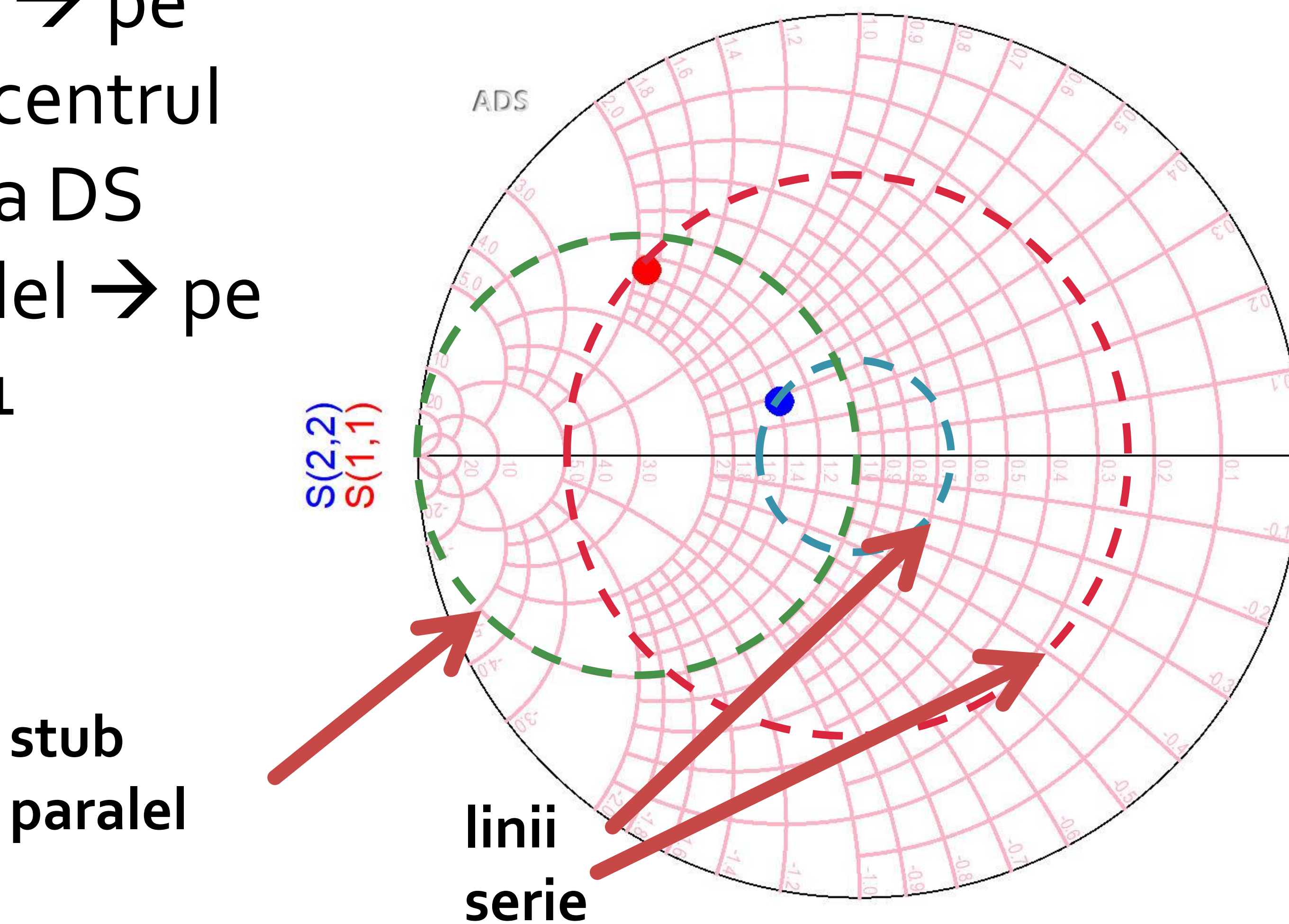


Diagrama Smith 1

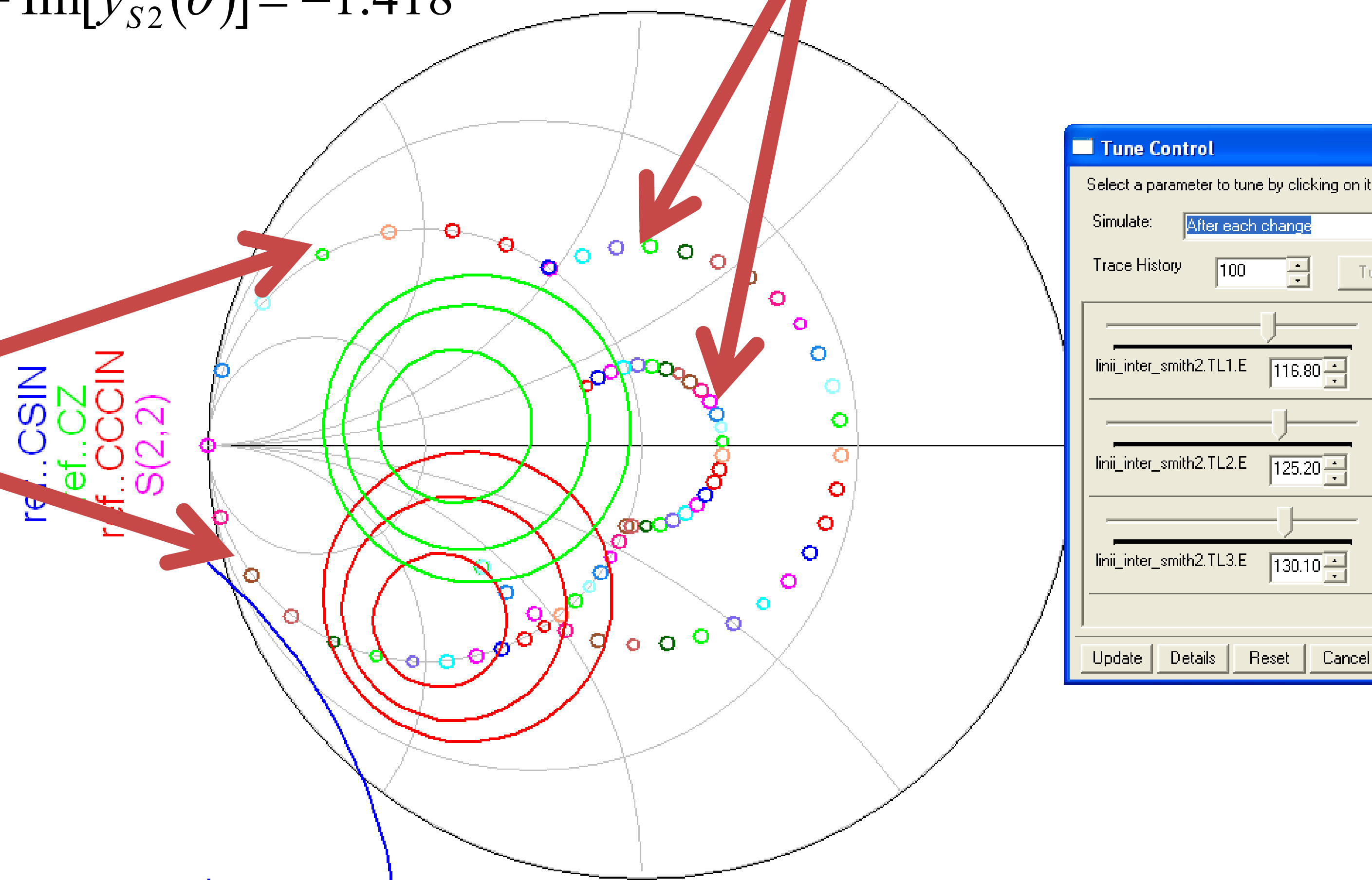
$$\theta_{L1} = 116.8^\circ \qquad \theta_{S2} = 130.1^\circ$$

$$\mathrm{Im}\left[y_{sp}\right] = \mathrm{Im}\left[y_{L1}(\theta)\right] + \mathrm{Im}\left[y_{S2}(\theta)\right] = -1.418$$

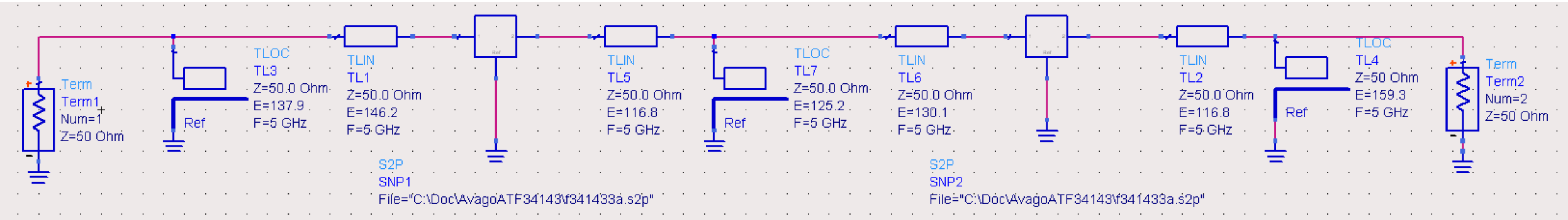
$$\theta_{sp} = 125.2^\circ$$

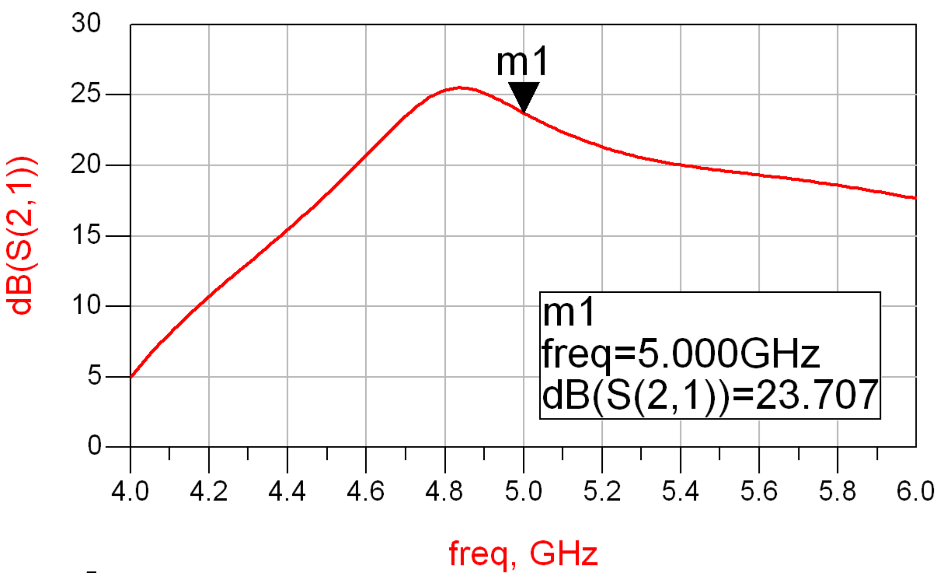
stub "combinat"

linii serie



ADS 1


Term
Term1
Num=1
Z=50 Ohm
Ref
TLOC
TL3
Z=50.0 Ohm
E=137.9
F=5 GHz
TLIN
TL1
Z=50.0 Ohm
E=146.2
F=5 GHz
S2P
SNP1
File="C:\Doc\AvagoATF34143\f341433a.s2p"
TLIN
TL5
Z=50.0 Ohm
E=116.8
F=5 GHz
Ref
TLOC
TL7
Z=50.0 Ohm
E=125.2
F=5 GHz
TLIN
TL6
Z=50.0 Ohm
E=130.1
F=5 GHz
S2P
SNP2
File="C:\Doc\AvagoATF34143\f341433a.s2p"
TLIN
TL2
Z=50.0 Ohm
E=116.8
F=5 GHz
Ref
TLOC
TL4
Z=50 Ohm
E=159.3
F=5 GHz
Term
Term2
Num=2
Z=50 Ohm


dB(S(2,1))
30
25
20
15
10
5
0
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0
m1
m1
freq=5.000GHz
dB(S(2,1))=23.707
freq, GHz

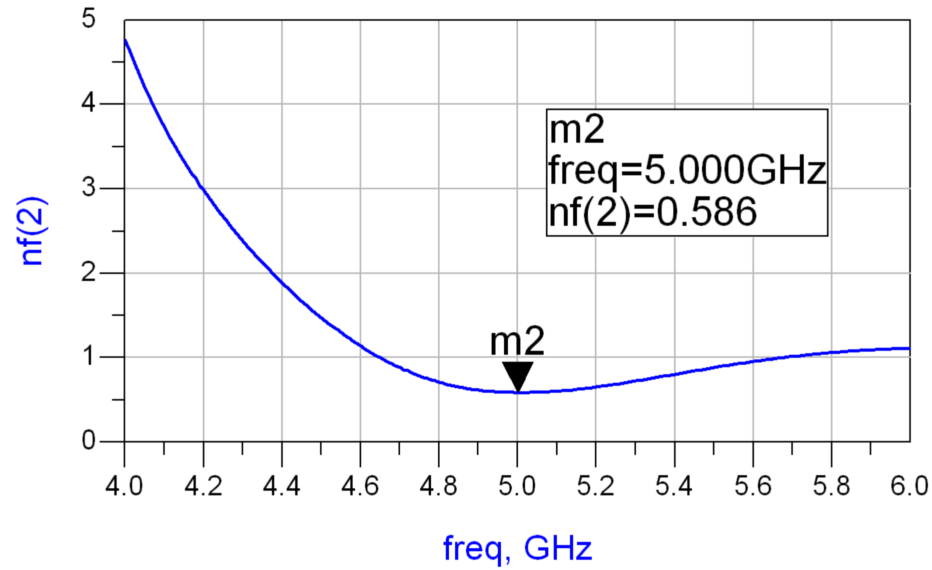

nf(2)
5
4
3
2
1
0
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0
m2
freq=5.000GHz
nf(2)=0.586
m2
freq, GHz

Diagrama Smith 2

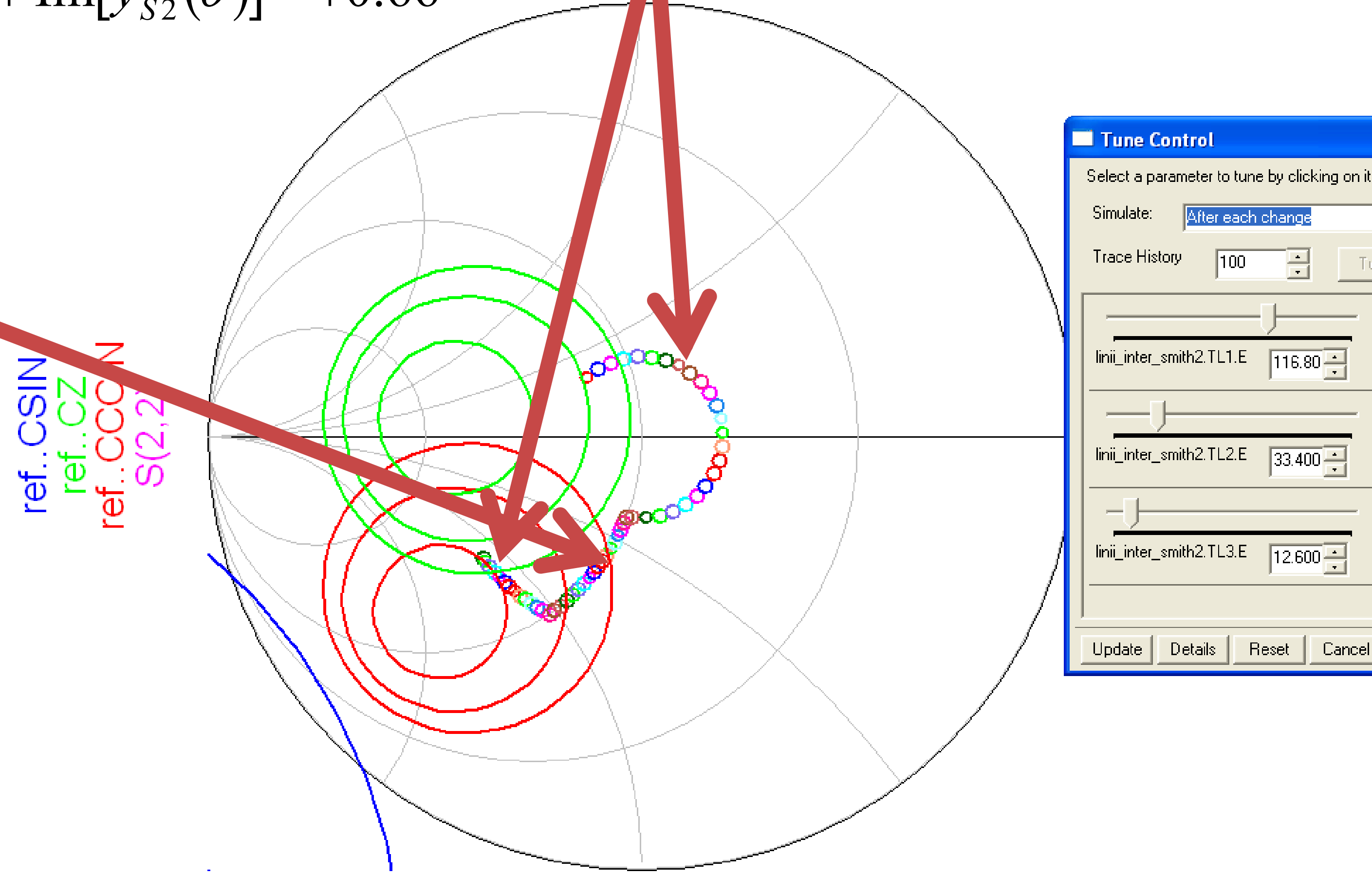
$$\theta_{L1} = 116.8° \qquad \theta_{S2} = 12.6°$$

$$\mathrm{Im}[y_{sp}] = \mathrm{Im}[y_{L1}(\theta)] + \mathrm{Im}[y_{S2}(\theta)] = +0.66$$

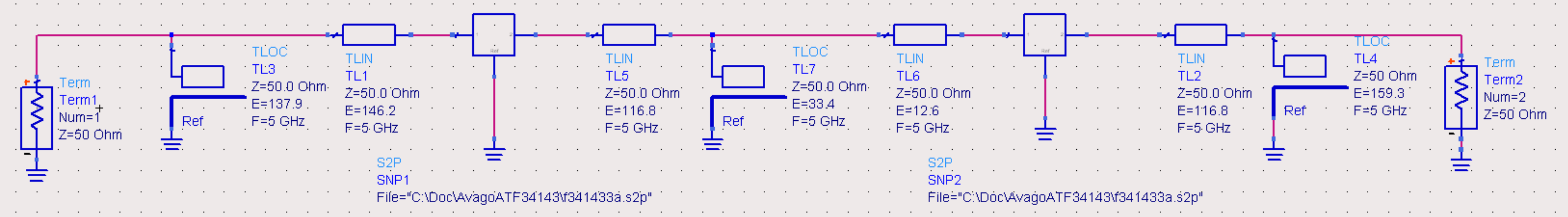
$$\theta_{sp} = 33.4°$$

linii serie

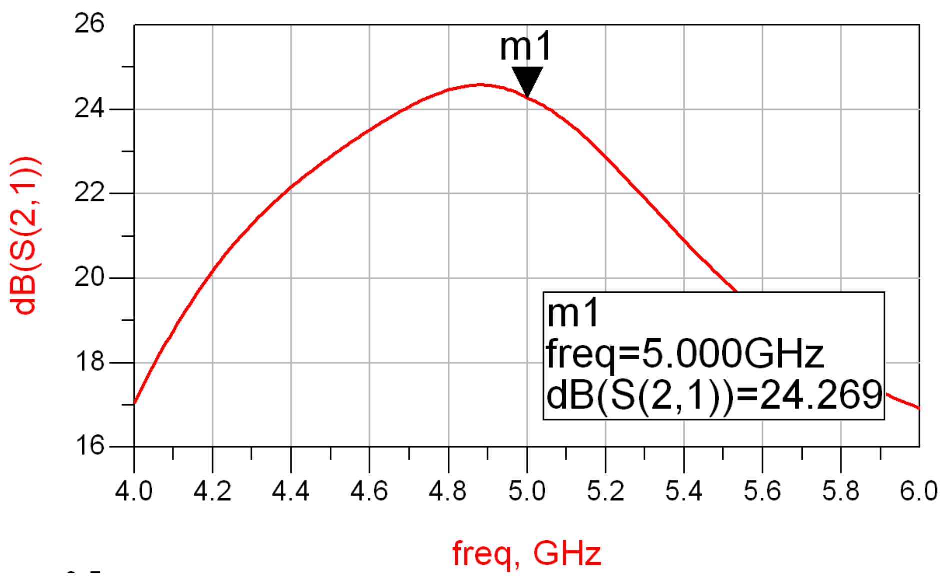
stub "combinat"



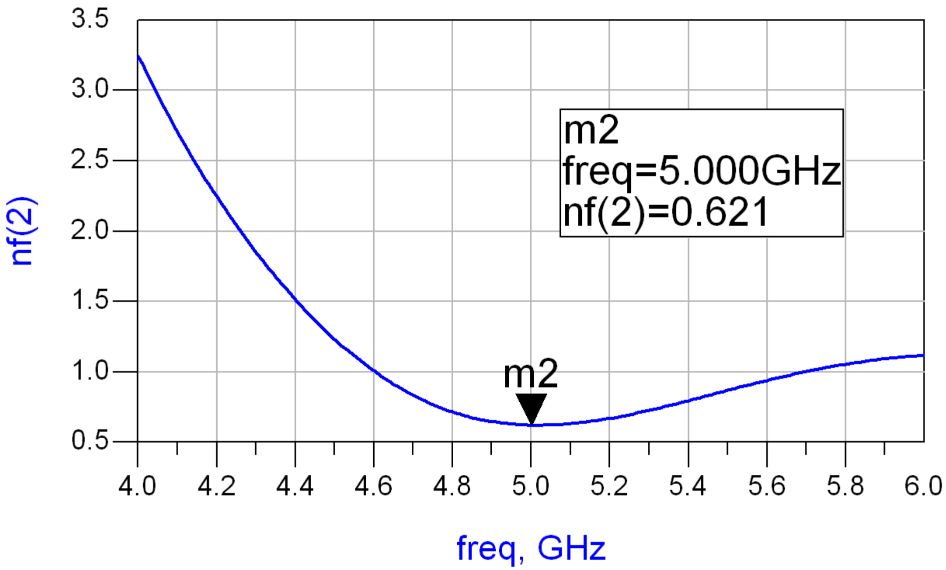
ADS 2



Term
Term1
Num=1
Z=50 Ohm
Ref
TLOC
TL3
Z=50.0 Ohm
E=137.9
F=5 GHz
TLIN
TL1
Z=50.0 Ohm
E=146.2
F=5 GHz
S2P
SNP1
File="C:\Doc\AvagoATF34143\f341433a.s2p"
TLIN
TL5
Z=50.0 Ohm
E=116.8
F=5 GHz
Ref
TLOC
TL7
Z=50.0 Ohm
E=33.4
F=5 GHz
TLIN
TL6
Z=50.0 Ohm
E=12.6
F=5 GHz
S2P
SNP2
File="C:\Doc\AvagoATF34143\f341433a.s2p"
TLIN
TL2
Z=50.0 Ohm
E=116.8
F=5 GHz
Ref
TLOC
TL4
Z=50 Ohm
E=159.3
F=5 GHz
Term
Term2
Num=2
Z=50 Ohm



m1
m1
freq=5.000GHz
dB(S(2,1))=24.269
dB(S(2,1))
freq, GHz
26
24
22
20
18
16
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0



m2
freq=5.000GHz
nf(2)=0.621
m2
nf(2)
freq, GHz
3.5
3.0
2.5
2.0
1.5
1.0
0.5
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0

Diagrama Smith 3

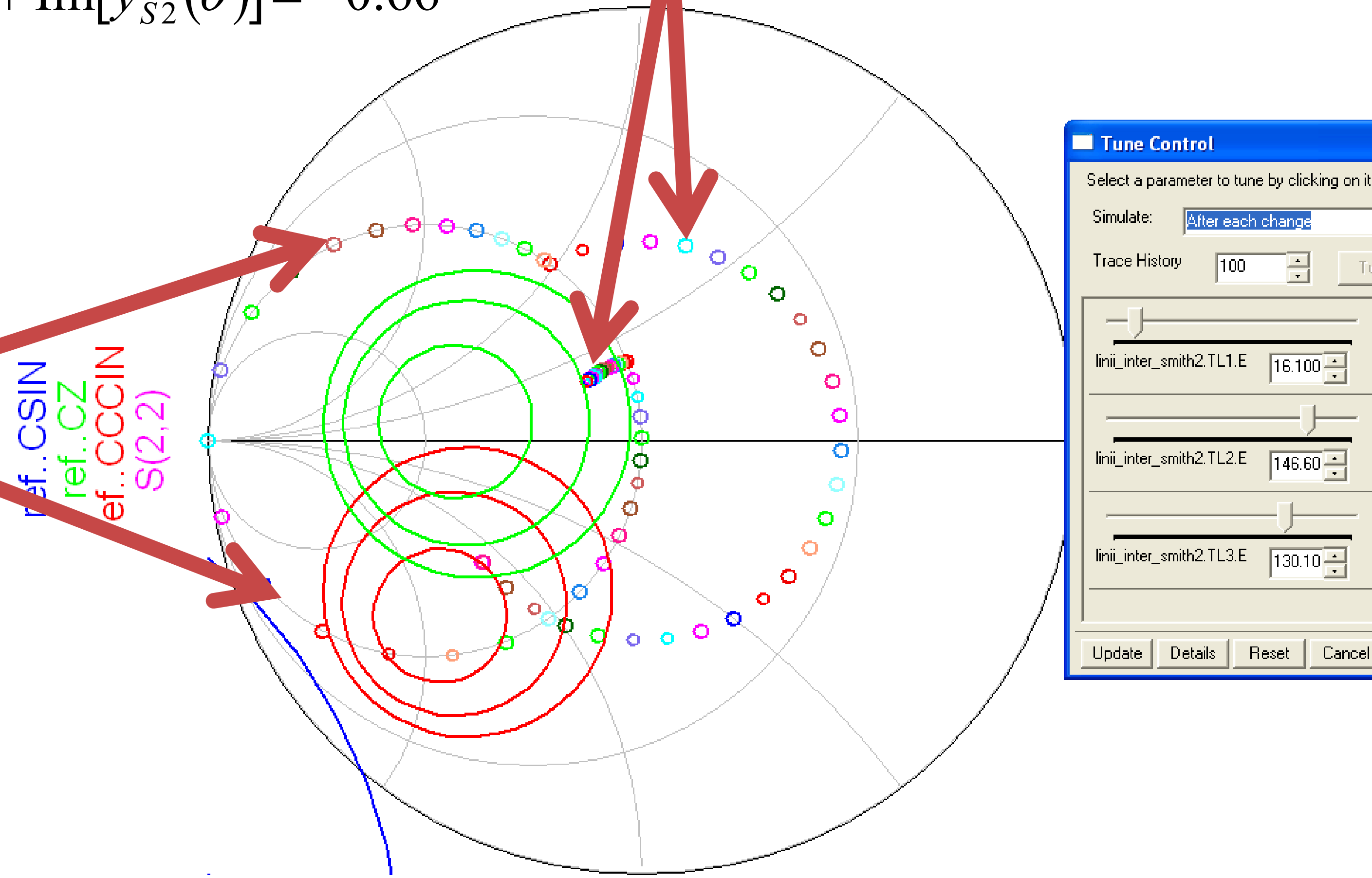
$\theta_{L1} = 16.1°$ $\theta_{S2} = 130.1°$

$$\mathrm{Im}\left[y_{sp}\right] = \mathrm{Im}\left[y_{L1}(\theta)\right] + \mathrm{Im}\left[y_{S2}(\theta)\right] = -0.66$$

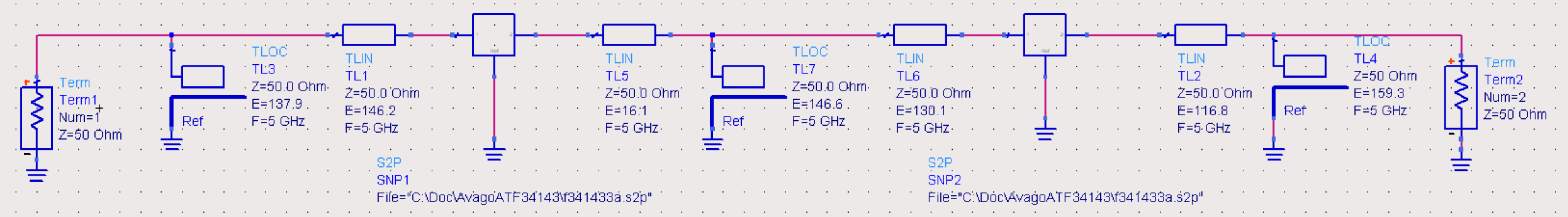
$\theta_{sp} = 146.6°$

linii serie

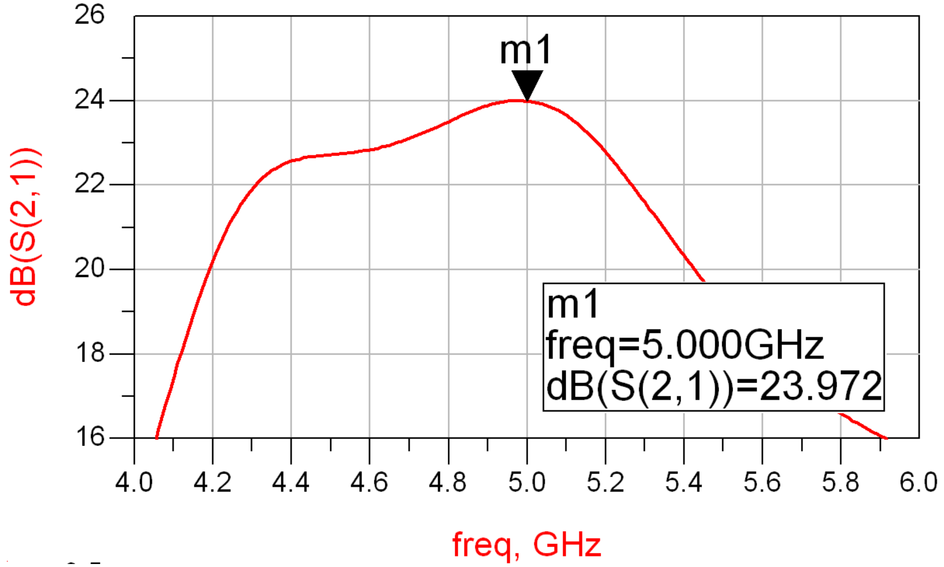
stub "combinat"



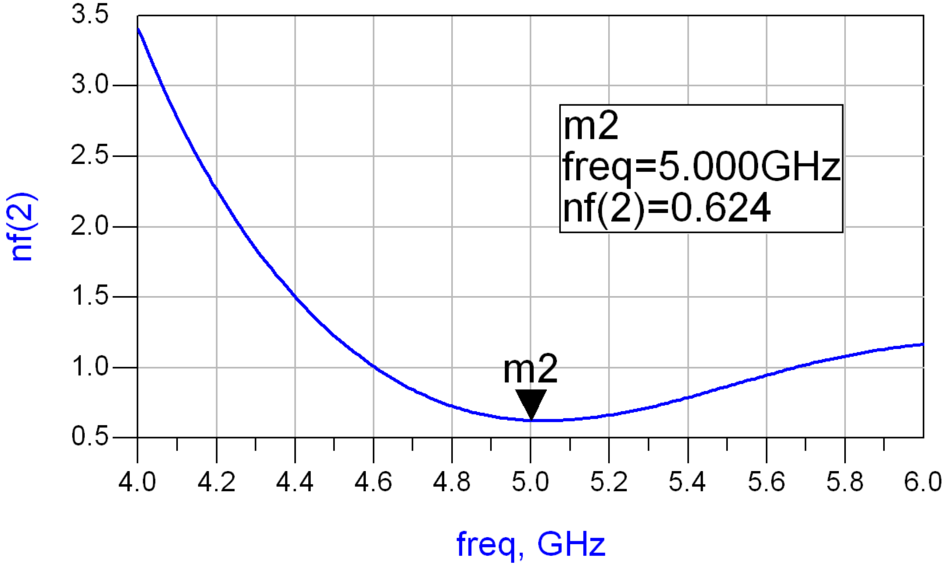
ADS 3



Term
Term1
Num=1
Z=50 Ohm
Ref
TLOC
TL3
Z=50.0 Ohm
E=137.9
F=5 GHz
TLIN
TL1
Z=50.0 Ohm
E=146.2
F=5 GHz
S2P
SNP1
File="C:\Doc\AvagoATF34143\f341433a.s2p"
TLIN
TL5
Z=50.0 Ohm
E=16.1
F=5 GHz
Ref
TLOC
TL7
Z=50.0 Ohm
E=146.6
F=5 GHz
TLIN
TL6
Z=50.0 Ohm
E=130.1
F=5 GHz
S2P
SNP2
File="C:\Doc\AvagoATF34143\f341433a.s2p"
TLIN
TL2
Z=50.0 Ohm
E=116.8
F=5 GHz
Ref
TLOC
TL4
Z=50 Ohm
E=159.3
F=5 GHz
Term
Term2
Num=2
Z=50 Ohm



m1
freq=5.000GHz
dB(S(2,1))=23.972
dB(S(2,1))
freq, GHz



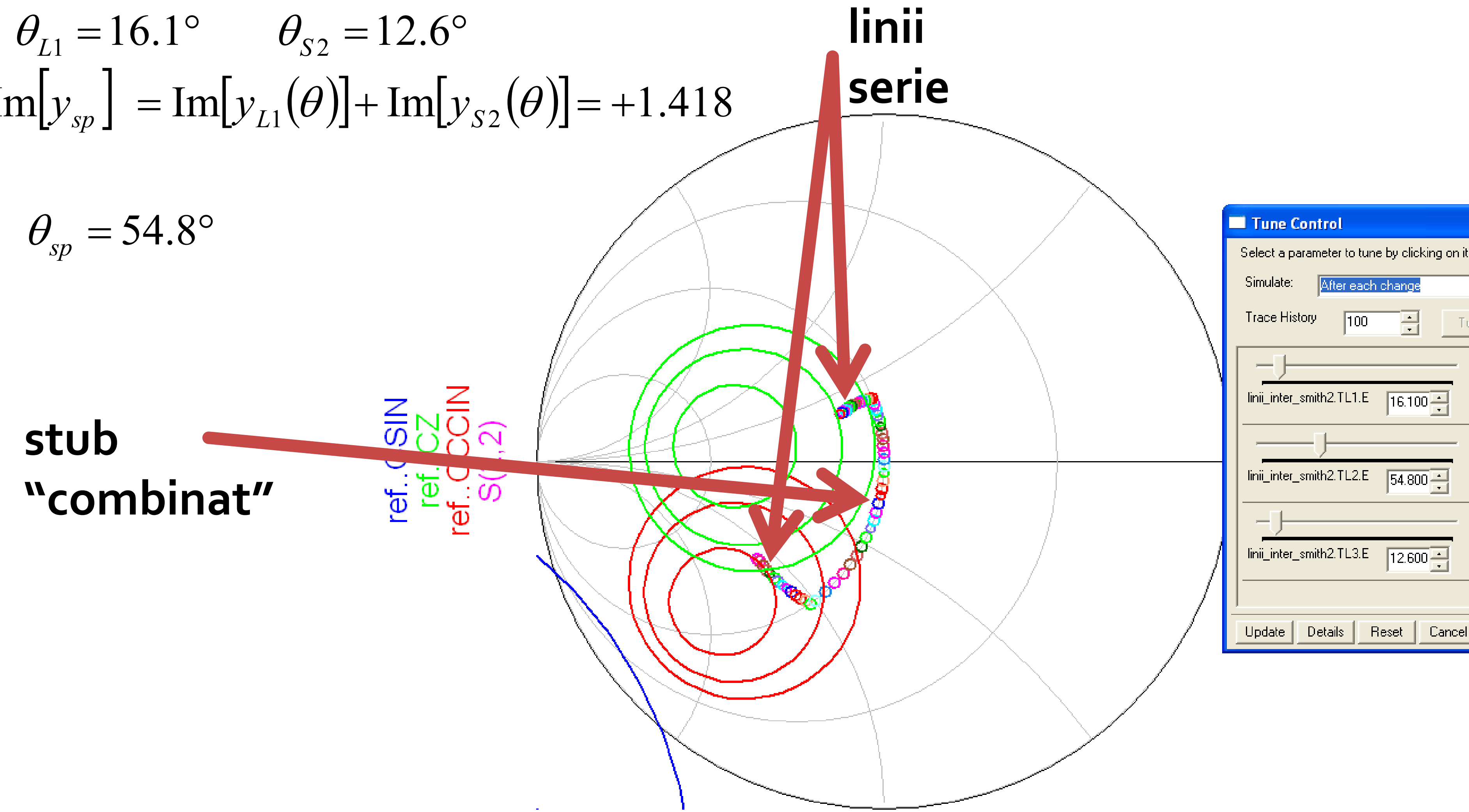
m2
freq=5.000GHz
nf(2)=0.624
nf(2)
freq, GHz

Diagrama Smith 4

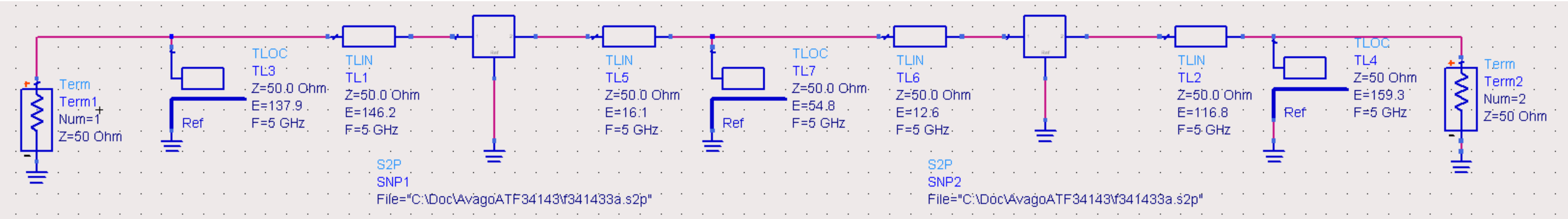
$$\theta_{L1} = 16.1° \qquad \theta_{S2} = 12.6°$$

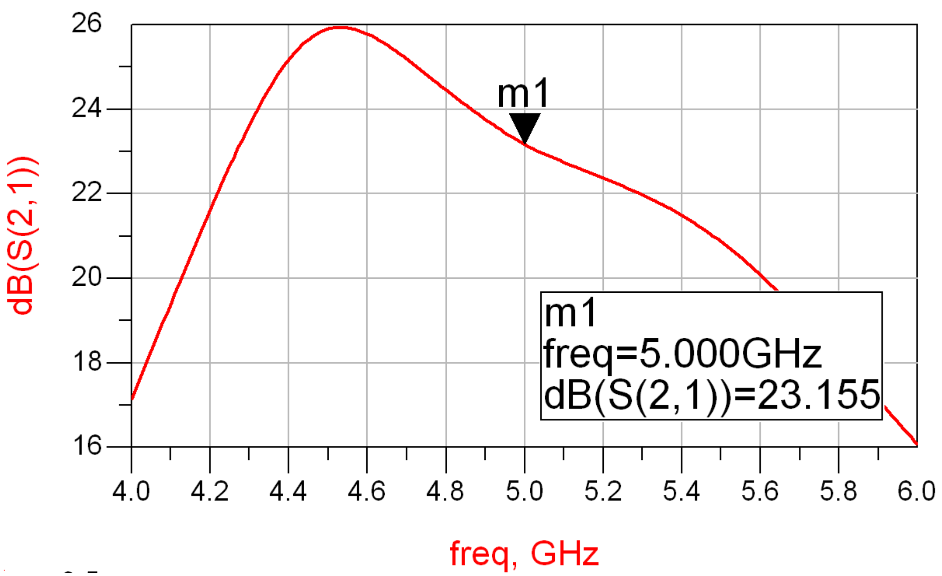
$$\mathrm{Im}[y_{sp}] = \mathrm{Im}[y_{L1}(\theta)] + \mathrm{Im}[y_{S2}(\theta)] = +1.418$$

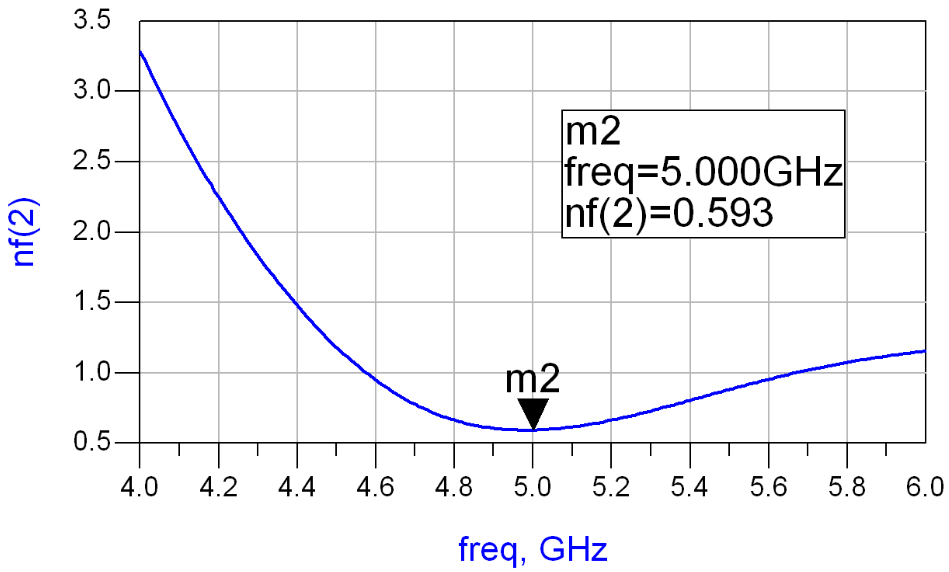
$$\theta_{sp} = 54.8°$$



ADS 4


Term
Term1
Num=1
Z=50 Ohm
TLOC
TL3
Z=50.0 Ohm
E=137.9
F=5 GHz
Ref
TLIN
TL1
Z=50.0 Ohm
E=146.2
F=5 GHz
S2P
SNP1
File="C:\Doc\AvagoATF34143\f341433a.s2p"
TLIN
TL5
Z=50.0 Ohm
E=16.1
F=5 GHz
TLOC
TL7
Z=50.0 Ohm
E=54.8
F=5 GHz
Ref
TLIN
TL6
Z=50.0 Ohm
E=12.6
F=5 GHz
S2P
SNP2
File="C:\Doc\AvagoATF34143\f341433a.s2p"
TLIN
TL2
Z=50.0 Ohm
E=116.8
F=5 GHz
TLOC
TL4
Z=50 Ohm
E=159.3
F=5 GHz
Ref
Term
Term2
Num=2
Z=50 Ohm


m1
m1
freq=5.000GHz
dB(S(2,1))=23.155
dB(S(2,1))
freq, GHz
26
24
22
20
18
16
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0


m2
freq=5.000GHz
nf(2)=0.593
m2
nf(2)
freq, GHz
3.5
3.0
2.5
2.0
1.5
1.0
0.5
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0

Adaptare inter-etaje

- Toate variantele obtinute indeplinesc conditiile de castig si zgomot
- Se alege una convenabila in functie de:
  - dimensiunile fizice ale liniilor $l = \frac{\theta}{360^\circ} \cdot \lambda$
  - comportare in frecventa
  - stabilitate
  - performanta (zgomot/castig)
  - reflexie intrare iesire
  - etc.

Supliment Mini Proiect

Alegere tranzistor

- Ghid de selectie

Alegere tranzistor

- Ghid de selectie
  - Low noise / LNA
  - Frecventa de lucru

Ultra-low-noise SiGe:C transistors up to 12 GHz

Product name	SP No	OPN	Electrical characteristics								Package
			V_{CEO} (max) [V]	I_C (max) [mA]	NF_{min} (typ) [dB]	G_{max} (typ) [dB]	OIP3 [dBm]	OP1dB [dBm]	f_T (typ) [GHz]	P_{tot} (max) [mW]	
BFP640ESD	SP000785482	BFP640ESDH6327XTSA1	4.1	50.0	0.65	25.0	27.0	12.0	46.0	200.0	SOT343
BFP640FESD	SP000890034	BFP640FESDH6327XTSA1	4.1	50.0	0.55	26.5	26.0	11.5	46.0	200.0	TSFP-4-1
BFP620	SP000745302	BFP620H7764XTSA1	2.3	80.0	0.7	21.5	25.5	14.5	65.0	185.0	SOT343
BFP620F	SP000745304	BFP620FH7764XTSA1	2.3	80.0	0.7	21.0	25.0	14.0	65.0	185.0	TSFP-4-1
BFP640	SP000745306	BFP640H6327XTSA1	4.0	50.0	0.65	24.0	26.5	13.0	40.0	200.0	SOT343
BFP640F	SP000750404	BFP640FH6327XTSA1	4.0	50.0	0.65	23.0	27.5	13.5	40.0	200.0	TSFP-4-1

Alegere tranzistor

- Selectare candidat
  - Ex: BFP620F

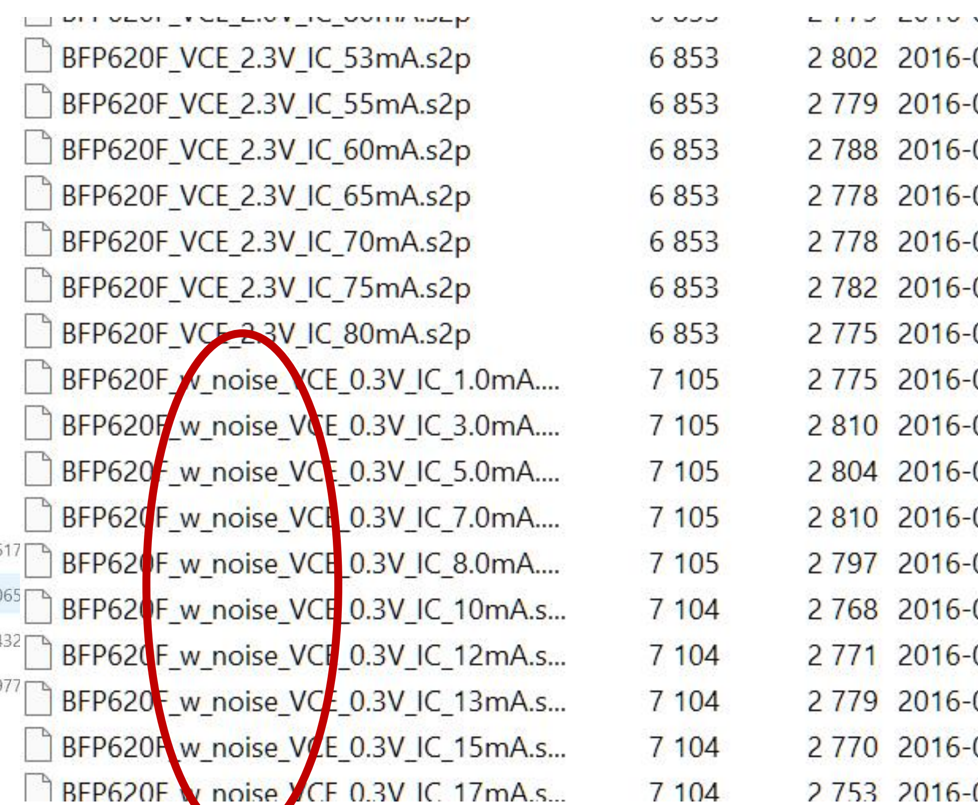
Ultra-low-noise SiGe:C transistors up to 12 GHz

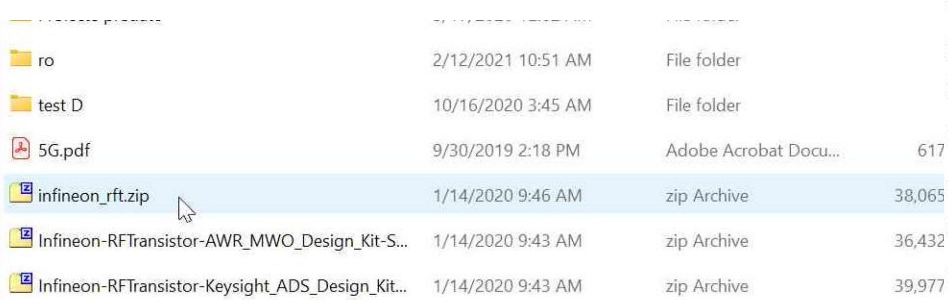
Product name	SP No	OPN	Electrical characteristics								Package
			V_{CEO} (max) [V]	I_C (max) [mA]	NF_{min} (typ) [dB]	G_{max} (typ) [dB]	OIP3 [dBm]	OP1dB [dBm]	f_T (typ) [GHz]	P_{tot} (max) [mW]	
BFP640ESD	SP000785482	BFP640ESDH6327XTSA1	4.1	50.0	0.65	25.0	27.0	12.0	46.0	200.0	SOT343
BFP640FESD	SP000890034	BFP640FESDH6327XTSA1	4.1	50.0	0.55	26.5	26.0	11.5	46.0	200.0	TSFP-4-1
BFP620	SP000745302	BFP620H7764XTSA1	2.3	80.0	0.7	21.5	25.5	14.5	65.0	185.0	SOT343
BFP620F	SP000745304	BFP620FH7764XTSA1	2.3	80.0	0.7	21.0	25.0	14.0	65.0	185.0	TSFP-4-1
BFP640	SP000745306	BFP640H6327XTSA1	4.0	50.0	0.65	24.0	26.5	13.0	40.0	200.0	SOT343
BFP640F	SP000750404	BFP640FH6327XTSA1	4.0	50.0	0.65	23.0	27.5	13.5	40.0	200.0	TSFP-4-1

- Cautare model
  - verificare zip rf-opto
  - Google BFP620F s2p

Alegere transistor, model

- zip: 8064 fisiere
- BFP620F: 281 fisiere
  - diverse polarizari
  - necesar w_noise **!!**
    - **with noise**





Alegere transistor, catalog

- Cautare Google BFP620F datasheet
- Preferabil de pe site-ul oficial (daca mai exista)

BFP620F

Low profile high gain silicon NPN RF bipolar transistor

Order now | Technical documents | Simulation | Support

Product description

The BFP620F is a RF bipolar transistor based on SiGe:C technology that is part of Infineon's established sixth generation transistor family. Its high gain and low noise characteristics make the device suitable for frequencies as high as 6 GHz. It remains cost competitive without compromising on ease of use.

Alegere transistor, catalog

- Parametrii variaza cu frecventa si polarizarea

Table 6 **AC characteristics, V_{CE} = 1.5 V, f = 1.8 GHz**

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Power gain		–		–	dB	
• Maximum power gain	G_{ms}		21			I_C = 50 mA
• Transducer gain	$\|S_{21}\|^2$		19.5			
Noise figure						
• Minimum noise figure	NF_{min}		0.7			I_C = 5 mA
Linearity					dBm	
• 3rd order intercept point at output	OIP_3		25			I_C = 50 mA, V_{CE} = 2 V,
• 1 dB gain compression point at output	OP_{1dB}		14			$Z_S = Z_L$ = 50 Ω

Table 7 **AC characteristics, V_{CE} = 1.5 V, f = 6 GHz**

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Power gain		–		–	dB	
• Maximum power gain	G_{ma}		10			I_C = 50 mA
• Transducer gain	$\|S_{21}\|^2$		9.5			
Noise figure						
• Minimum noise figure	NF_{min}		1.3			I_C = 5 mA

Alegere transistor, catalog

- Grafice cu variatia in frecventa
  - NF (f)

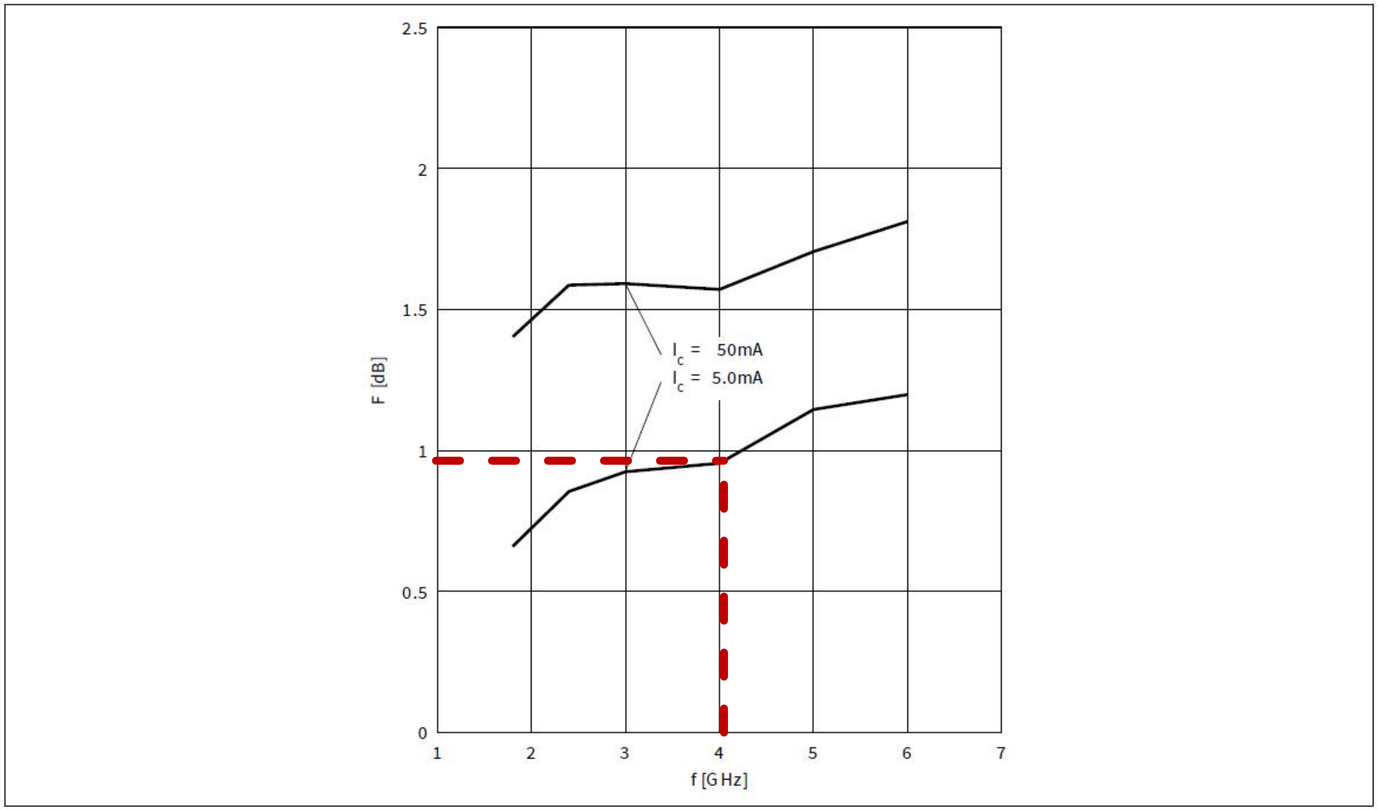


Figure 12 **Noise figure NF_{min} = f(f), $Z_S = Z_{S,opt}$, V_{CE} = 1.5 V, I_C = 5 / 50 mA**

Alegere transistor, catalog

- Grafice cu variatia in frecventa
  - G (f)

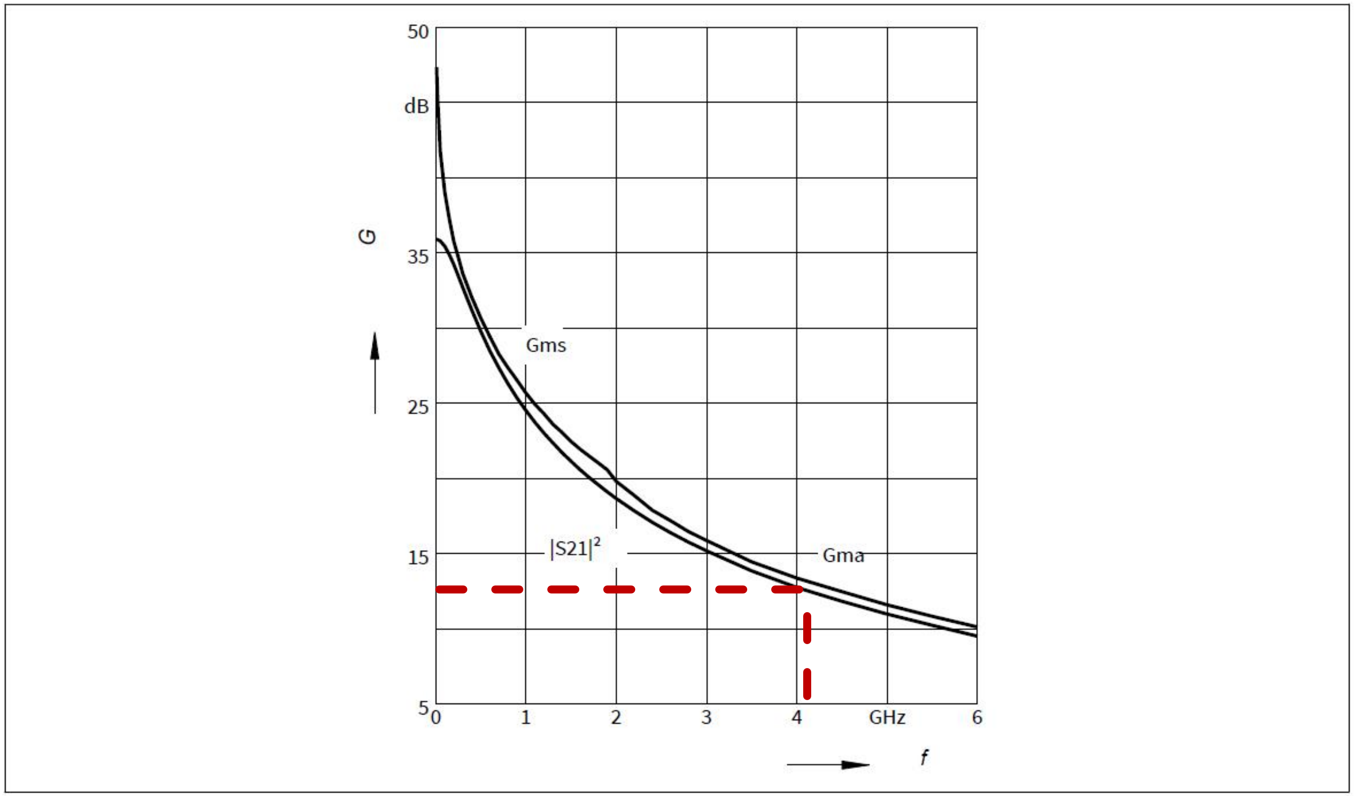


Figure 8 **Gain G_{ma}, G_{ms}, $|S_{21}|^2 = f(f)$, $V_{CE} = 1.5$ V, $I_C = 50$ mA**

Alegere transistor, catalog

- Grafice care ghideaza in alegerea polarizarii
  - NF (I_C)

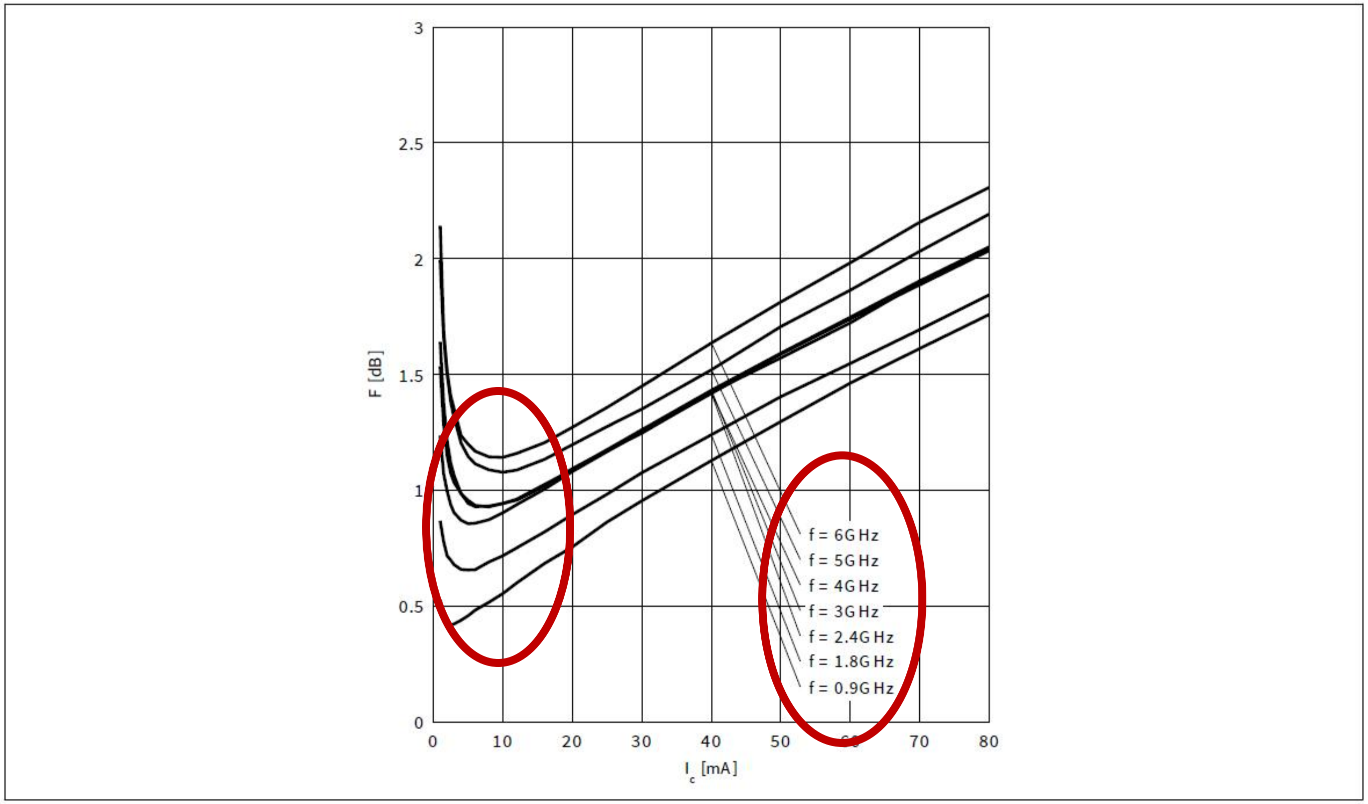


Figure 13 **Noise figure $NF_{min} = f(I_C)$, $Z_S = Z_{S,opt}$, $V_{CE} = 1.5$ V, f = parameter in GHz**

Alegere transistor, catalog

- Grafice care ghideaza in alegerea polarizarii
  - G (I_C)

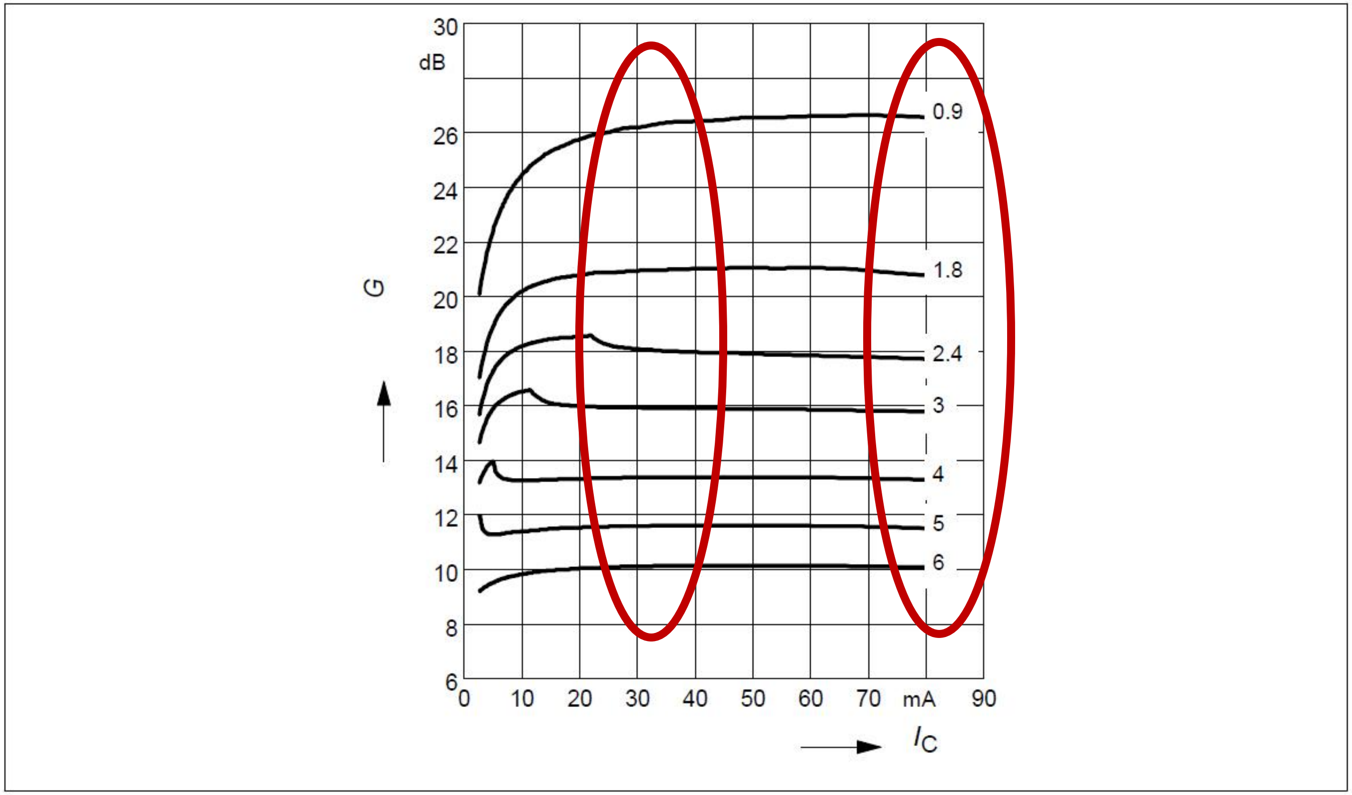


Figure 9 **Maximum power gain G_{max} = f(I_C), V_{CE} = 1.5 V, f = parameter in GHz**

Alegere transistor, catalog

- Grafice care ghideaza in alegerea polarizarii
  - G (V_{CE})

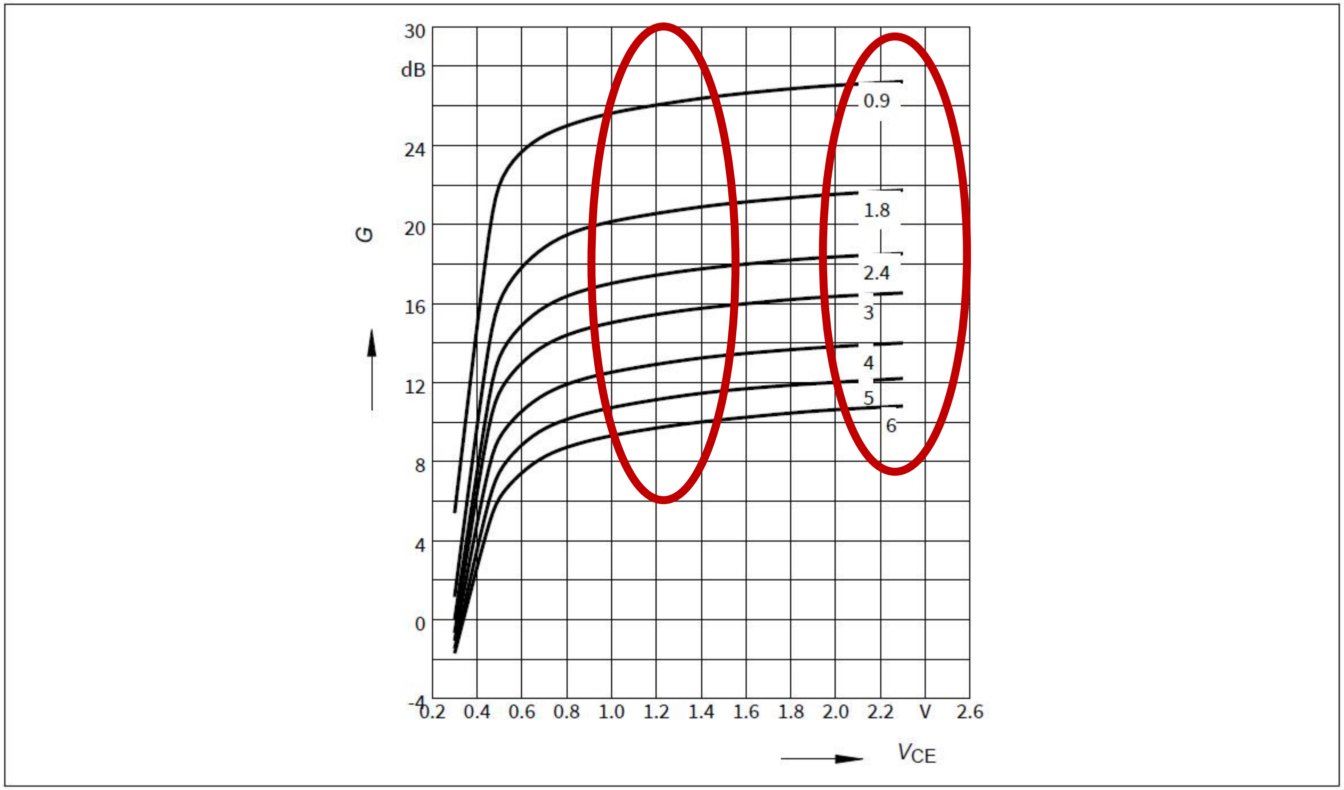


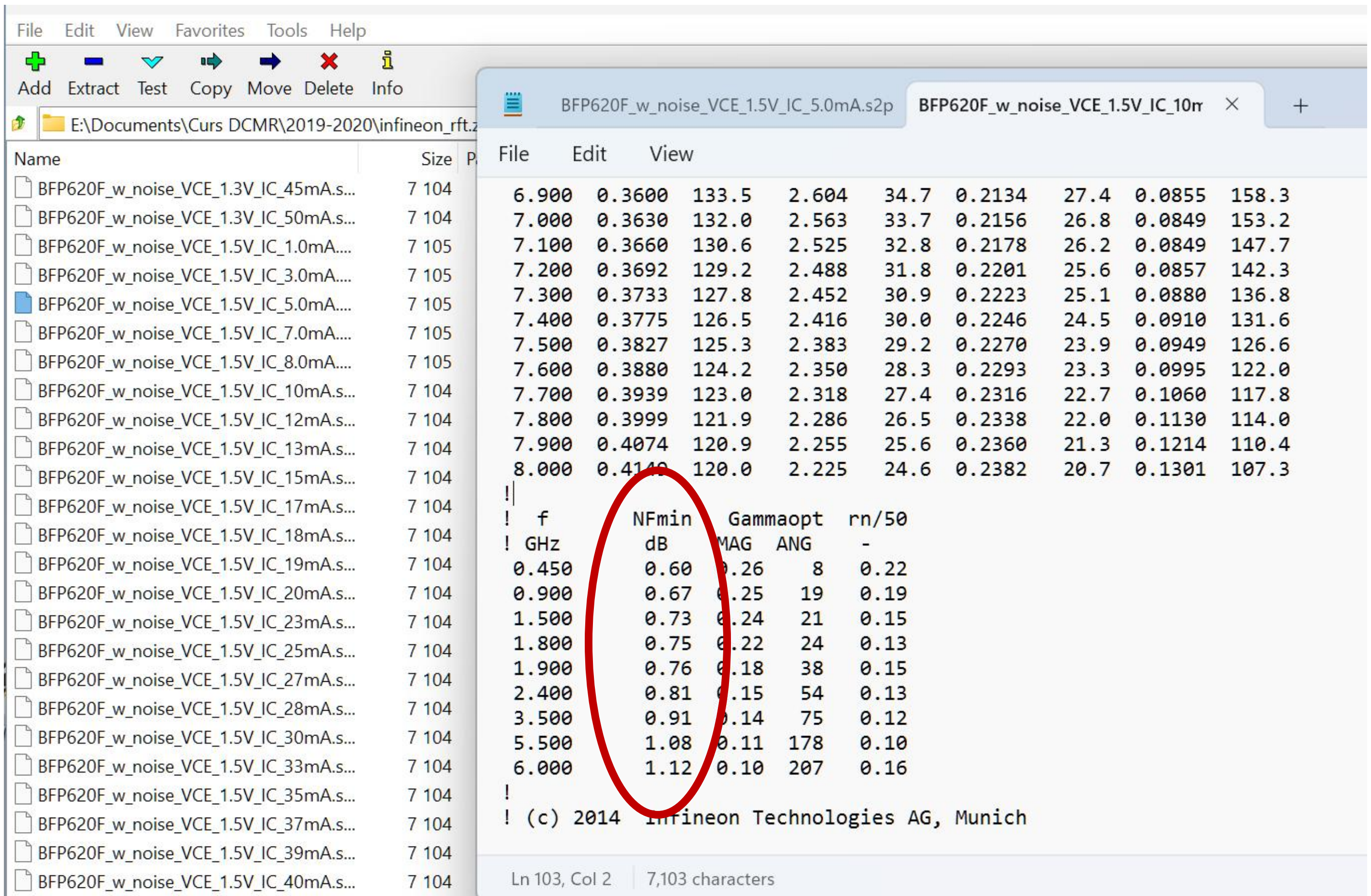
Figure 10 **Maximum power gain G_{max} = f(V_{CE}), I_C = 50 mA, f = parameter in GHz**

Alegere transistor, catalog

- De obicei:
  - polarizarile cu valori reduse (ex. BFP620F: 1.5V V_{CE}, 5÷ 10mA I_C) ofera zgomot mai mic, iar polarizarile cu valori ridicate V_{CE}, I_C ofera castig mai mare

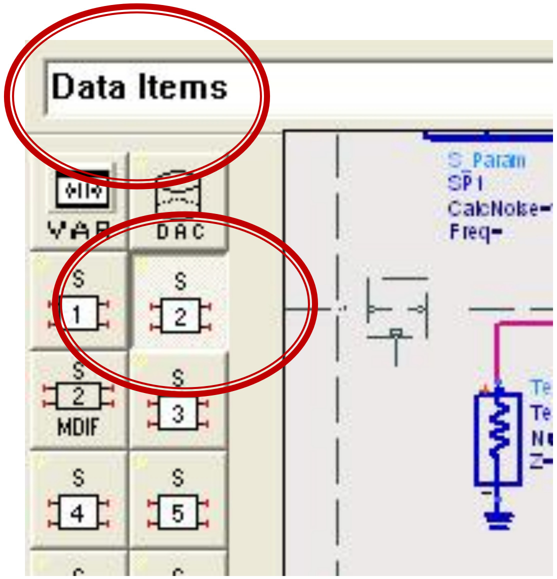
Alegere transistor, catalog

- Fisierele s2p sunt text si pot fi direct vizualizate



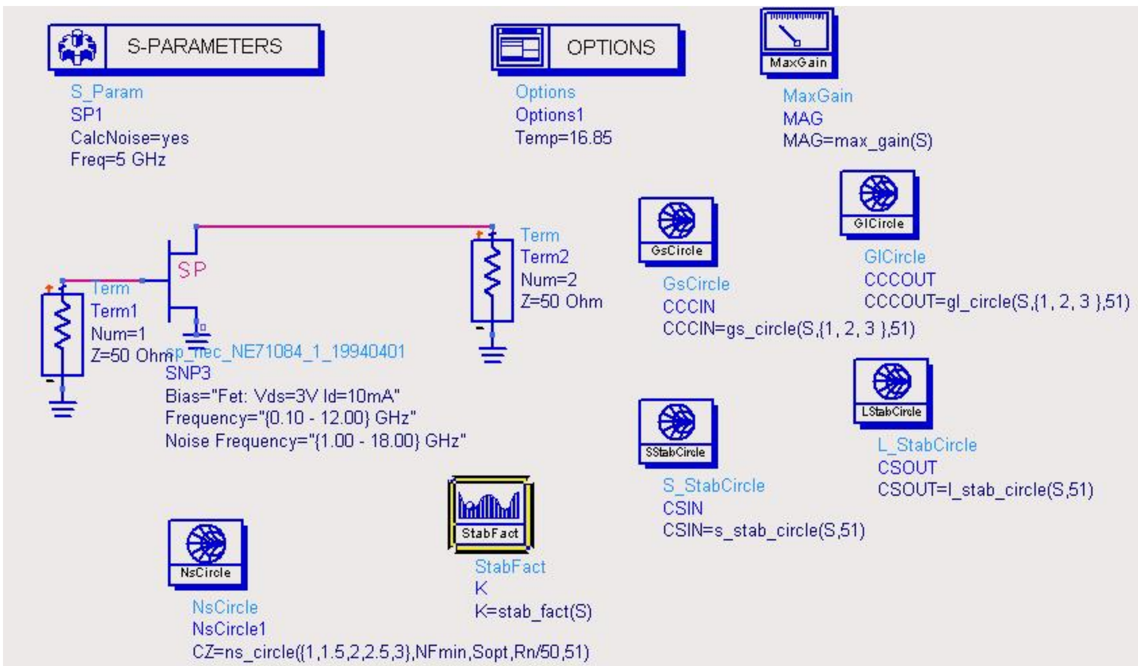
Alegere transistor, ADS

- Tranzistoare se introduc cu componente tip diport
  - se bazeaza pe un fisier s2p pe care il incarca de pe disc
  - paleta Data Items > diport (2)



Alegere transistor, ADS

- schema 1/lab 3-4
- se introduce un fisier cu parametri S si se verifica rapid prin simulare (**repetata**)

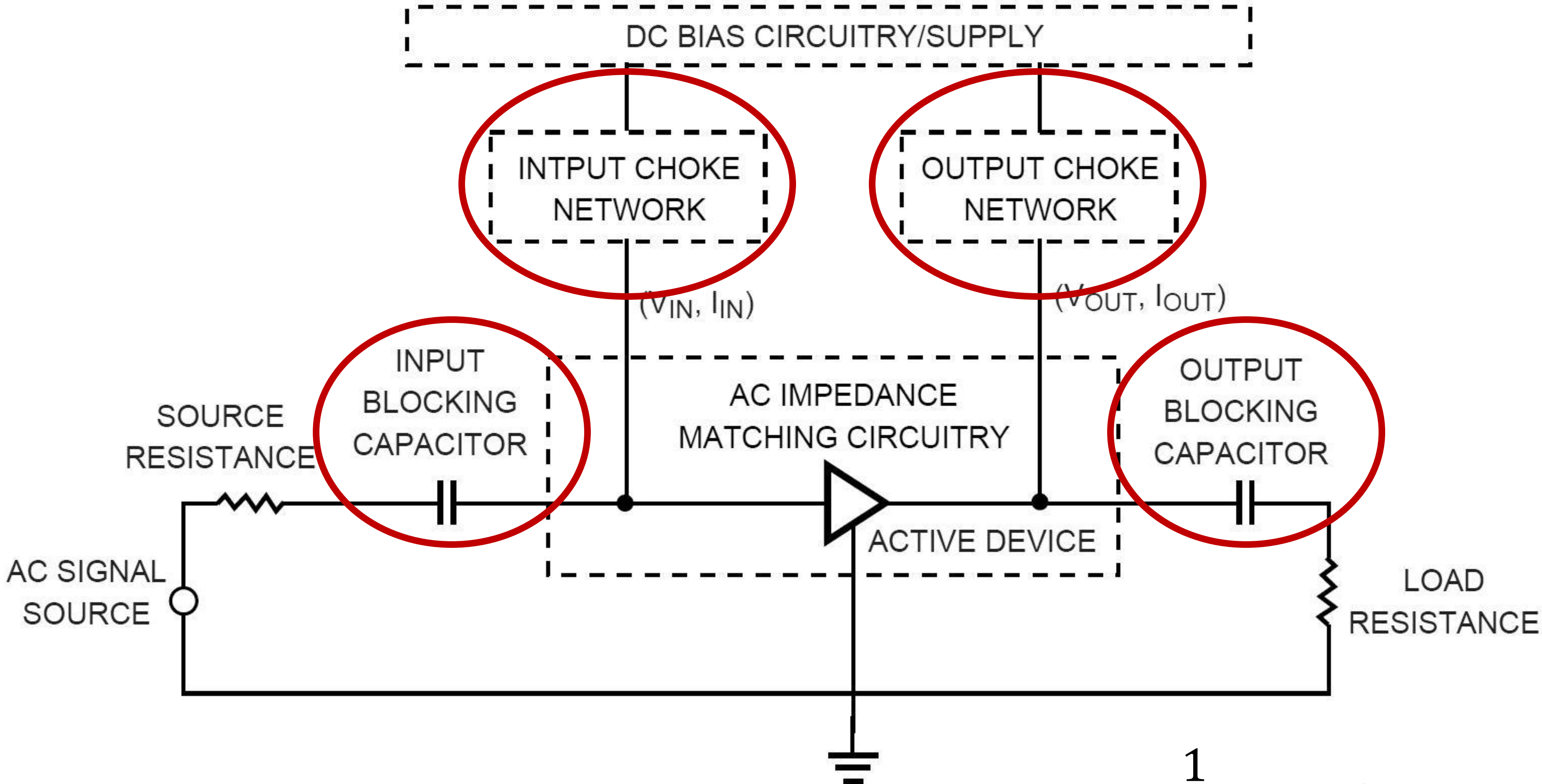


freq	K	MAG	NFmin	Sopt	Rn	G0	GLmax	GSmax
5.000 GHz	0.5[illegible]3	15.29[illegible]	0.700	0.[illegible]60 / 106....	19.500	8.974	1.634	4.249

Polarizare

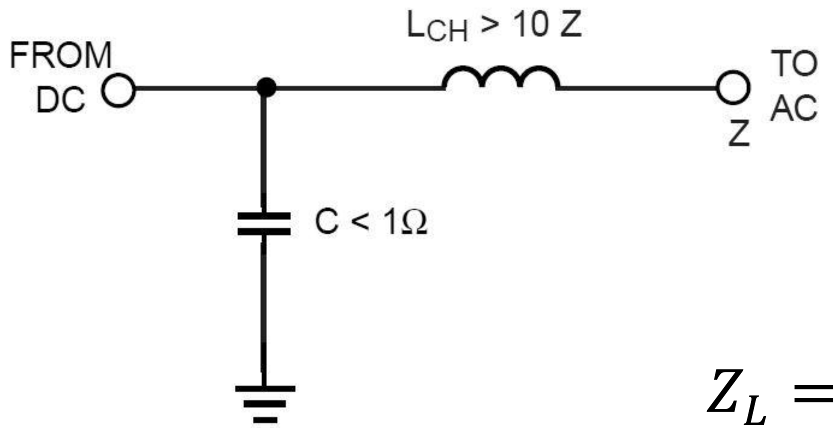
- https://rf-opto.etti.tuiasi.ro
- note de aplicatii importante Agilent
  - decuplarea circuit de semnal/circuit de polarizare
  - detalii de implementare a circuitelor de polarizare pentru tranzistoarele cu microunde
- Appcad contine instrumente pentru calculul schemelor de polarizare

Polarizare



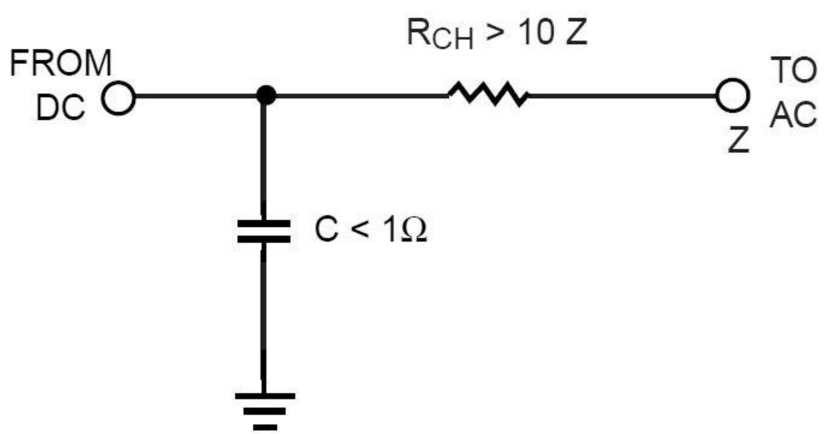
$$Z_C = \frac{1}{j \cdot \omega \cdot C} \ll 50\Omega$$

Polarizare, soc tipic



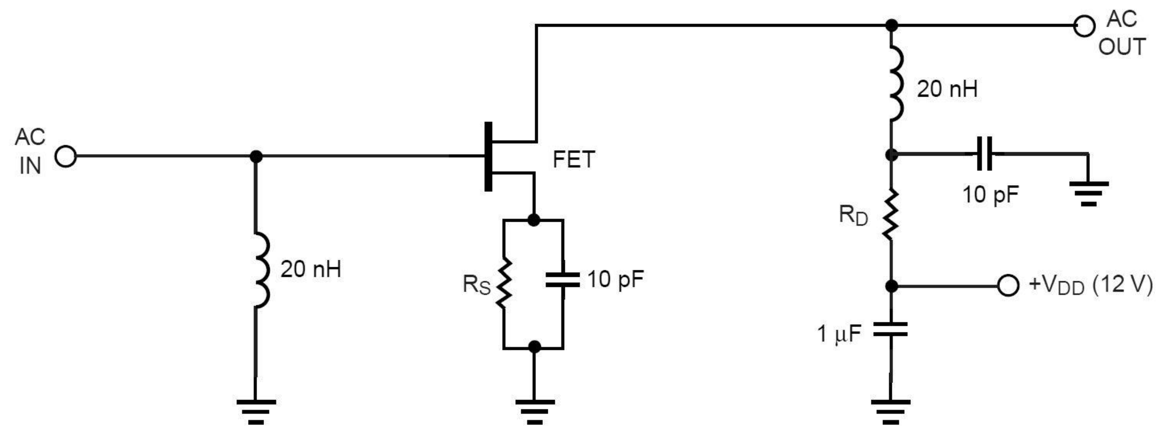
CURRENT CONTROLLED

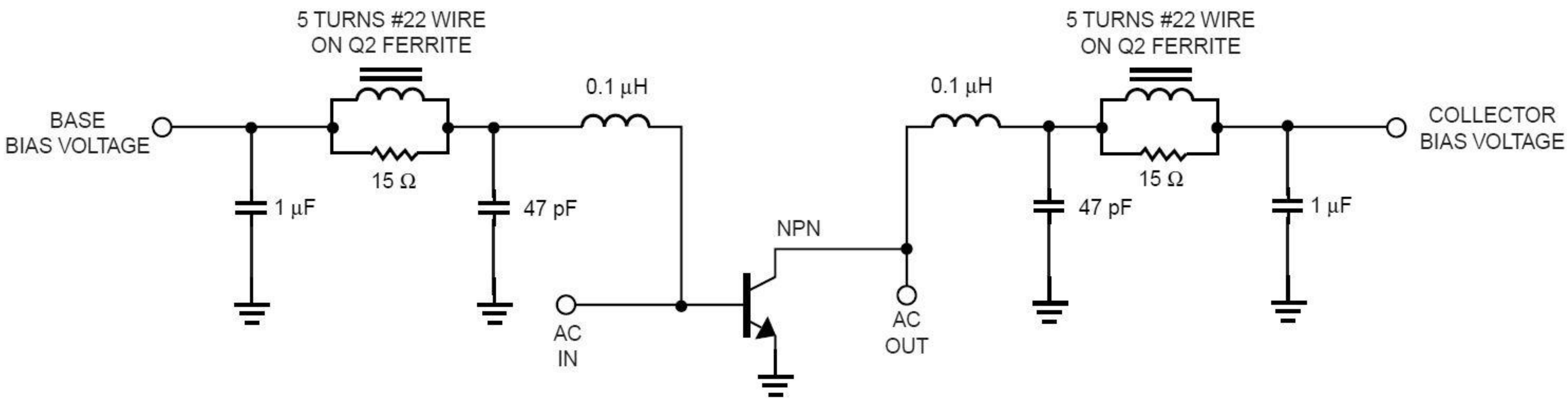
$$Z_L = j \cdot \omega \cdot L \gg 50\Omega$$



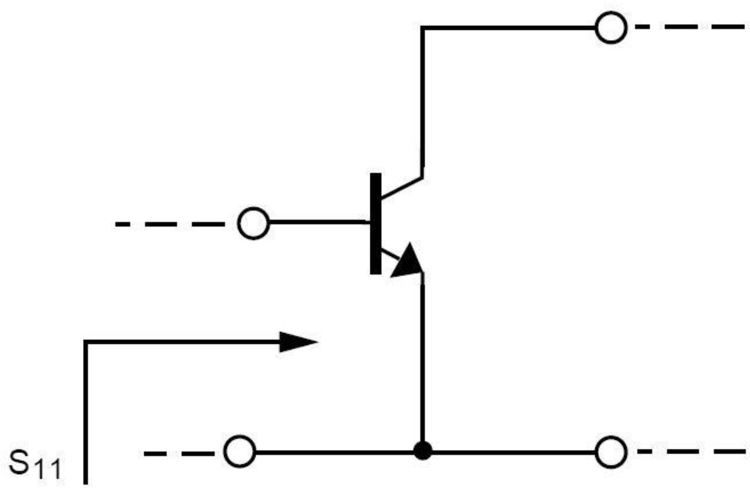
VOLTAGE CONTROLLED
(FET GATE)

Polarizare, scheme/valori tipice



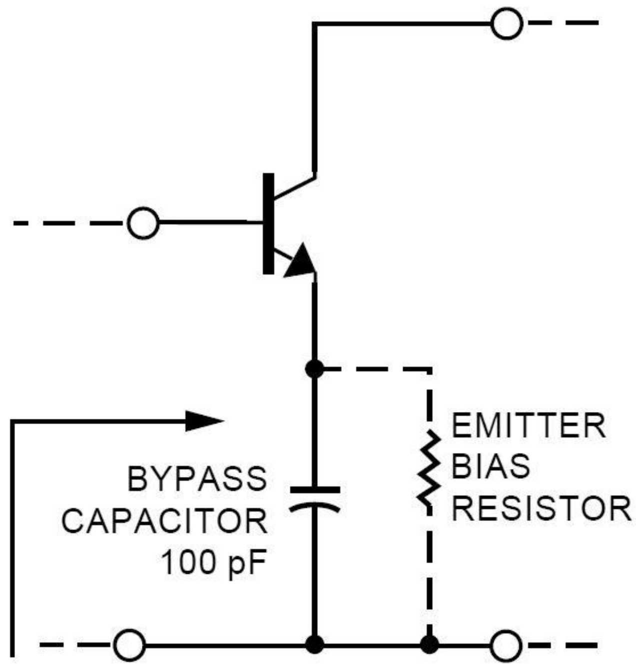


Polarizare, problema elementelor conectate in E/S



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

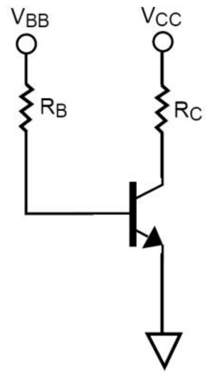
S_{11} (AT 0.1 GHz) = $0.901 \angle -14.9^\circ$



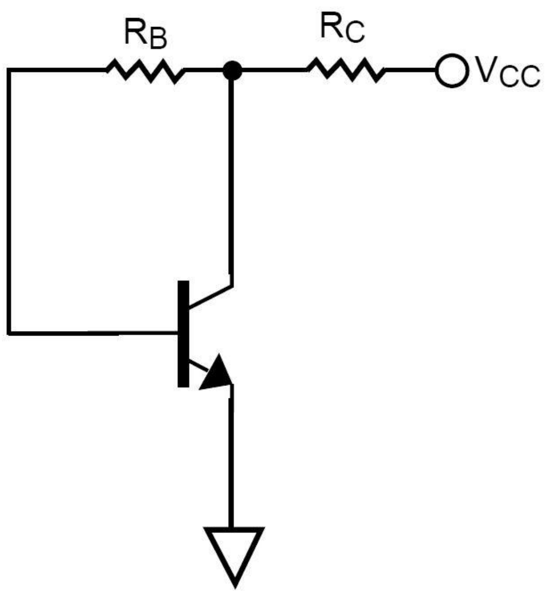
S'_{11} (AT 4 GHz) = $0.52 \angle 154^\circ$ UNCHANGED AT 4 GHz

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

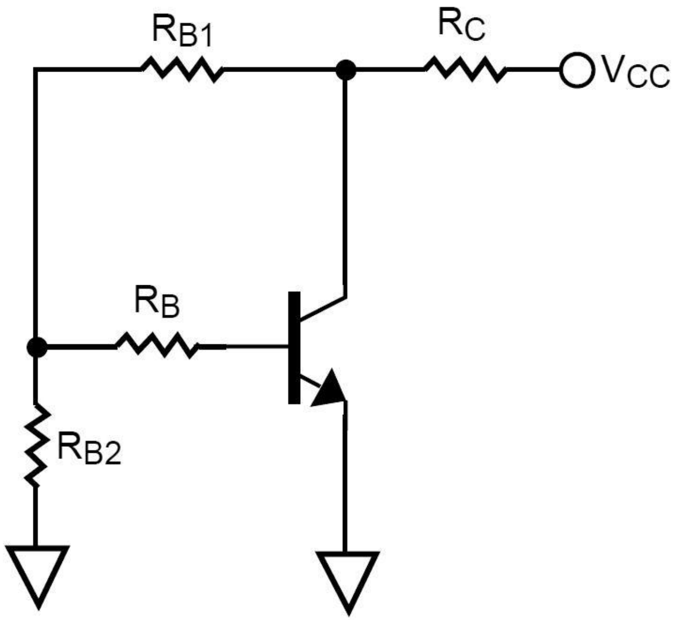
Polarizare TB scheme de polarizare



NON-STABILIZED



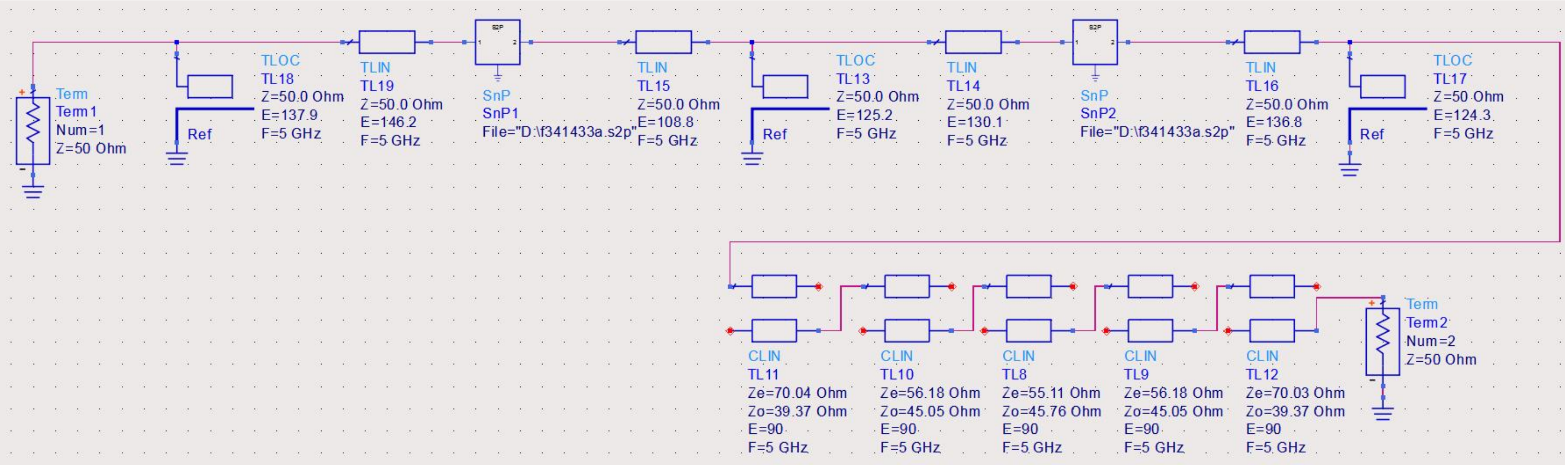
VOLTAGE FEEDBACK



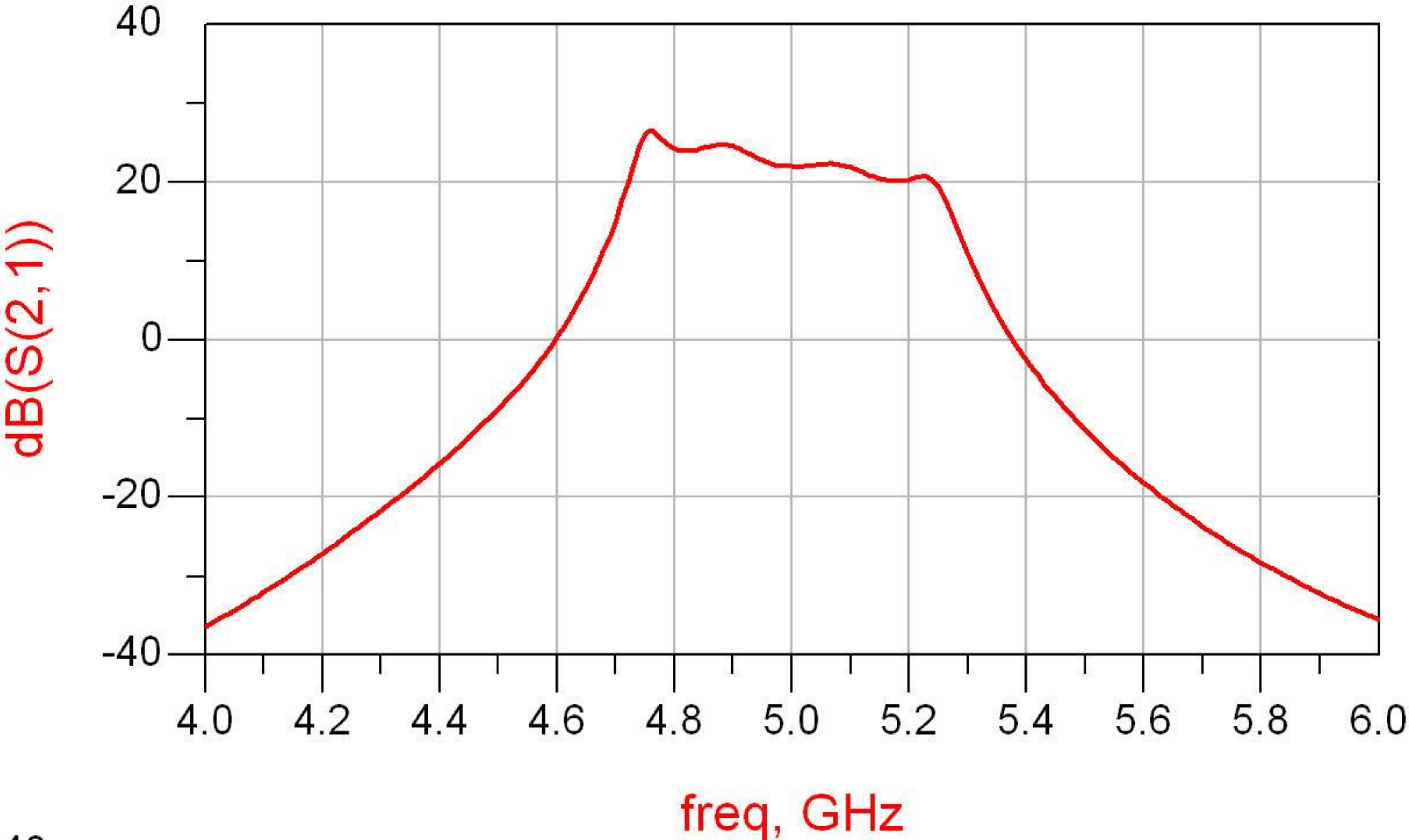
VOLTAGE FEEDBACK AND CONSTANT
BASE CURRENT SOURCE

Exemplu proiect

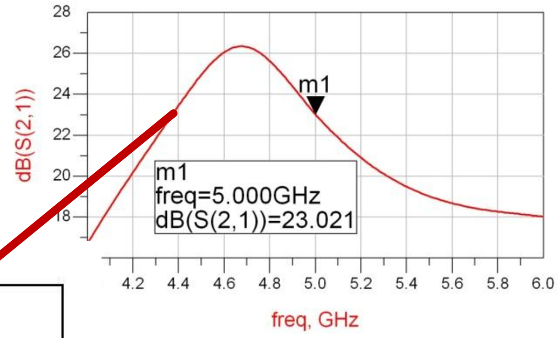
- Unirea celor doua scheme
  - C11 – amplificator
  - C12 – filtru

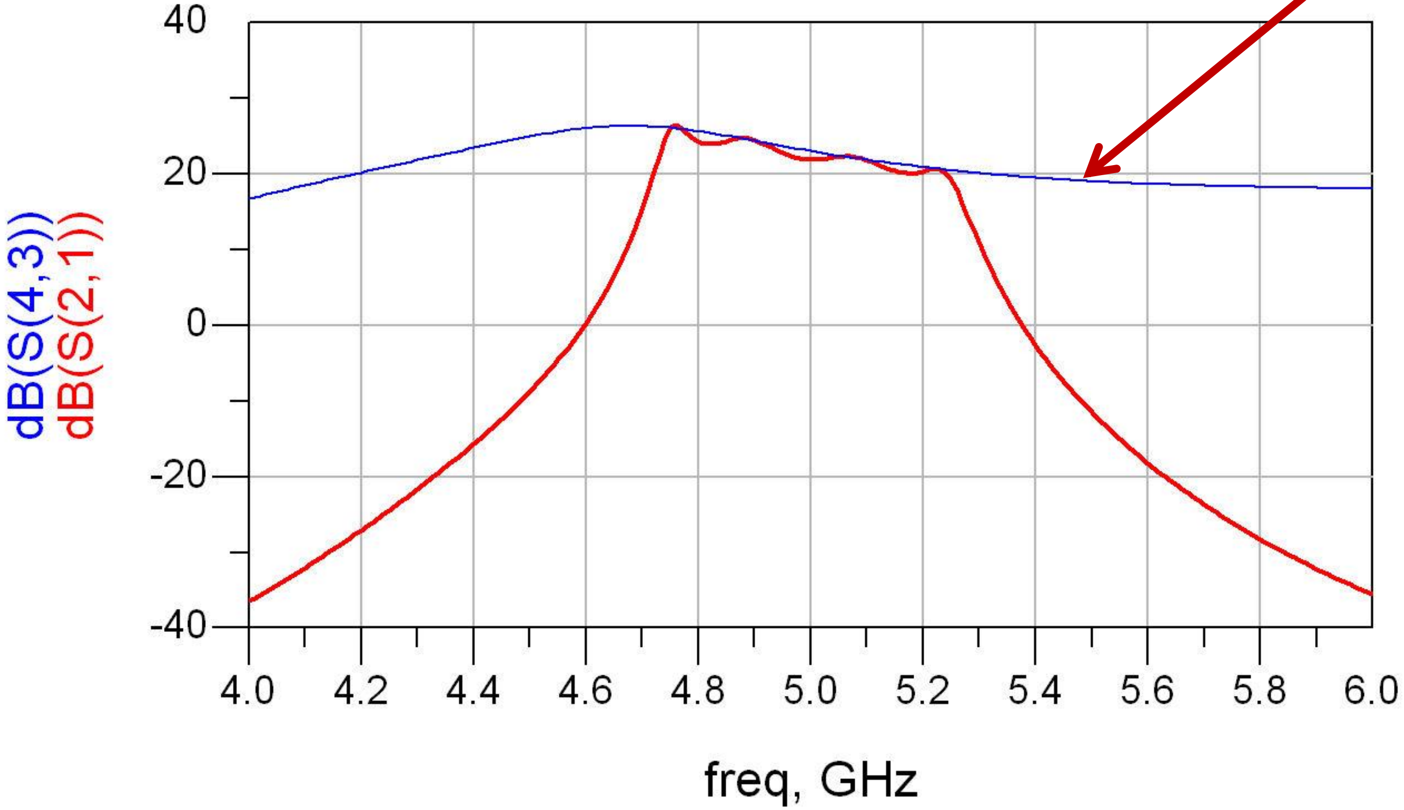


Rezultat (dezechilibrat)

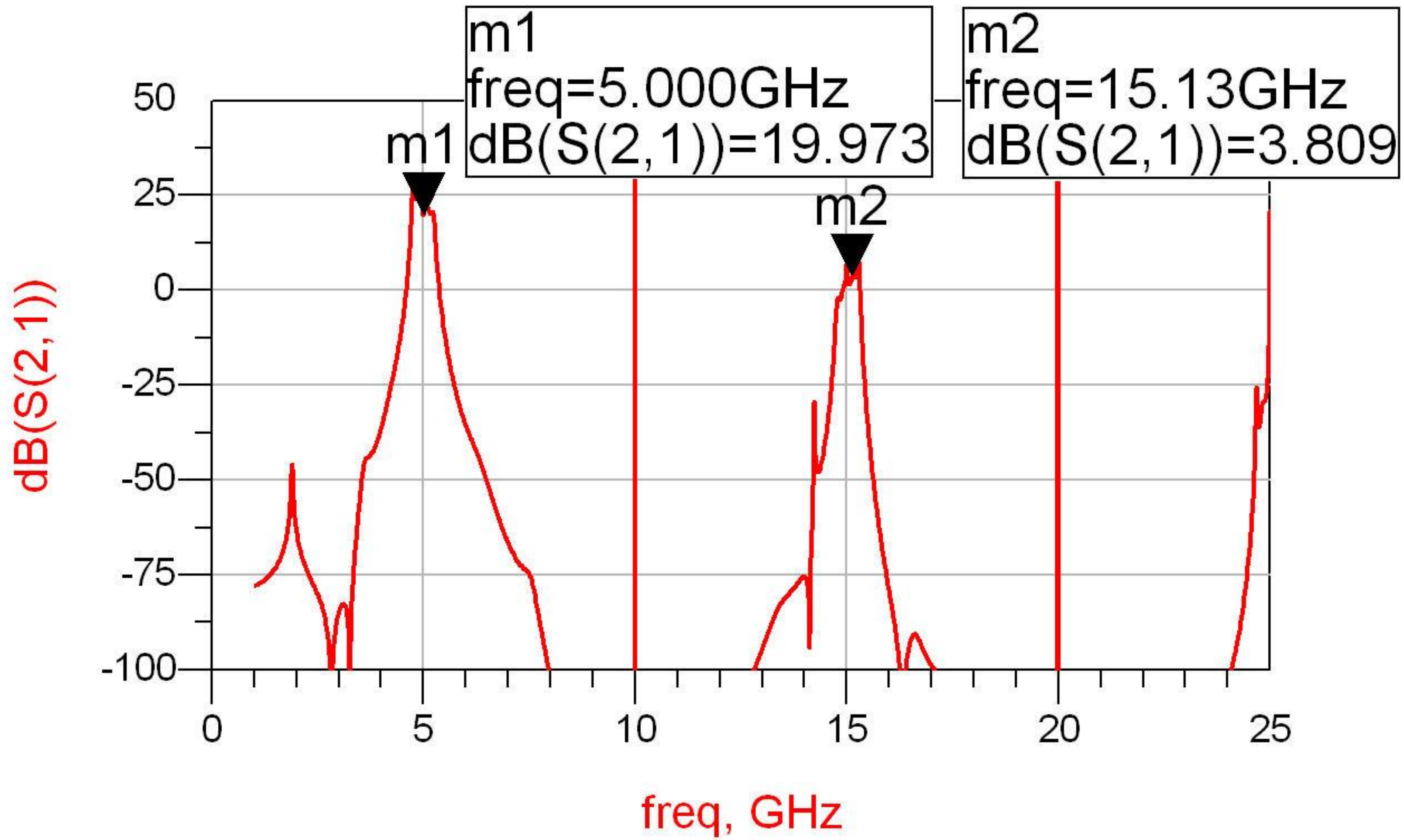


Rezultat (dezechilibrat)



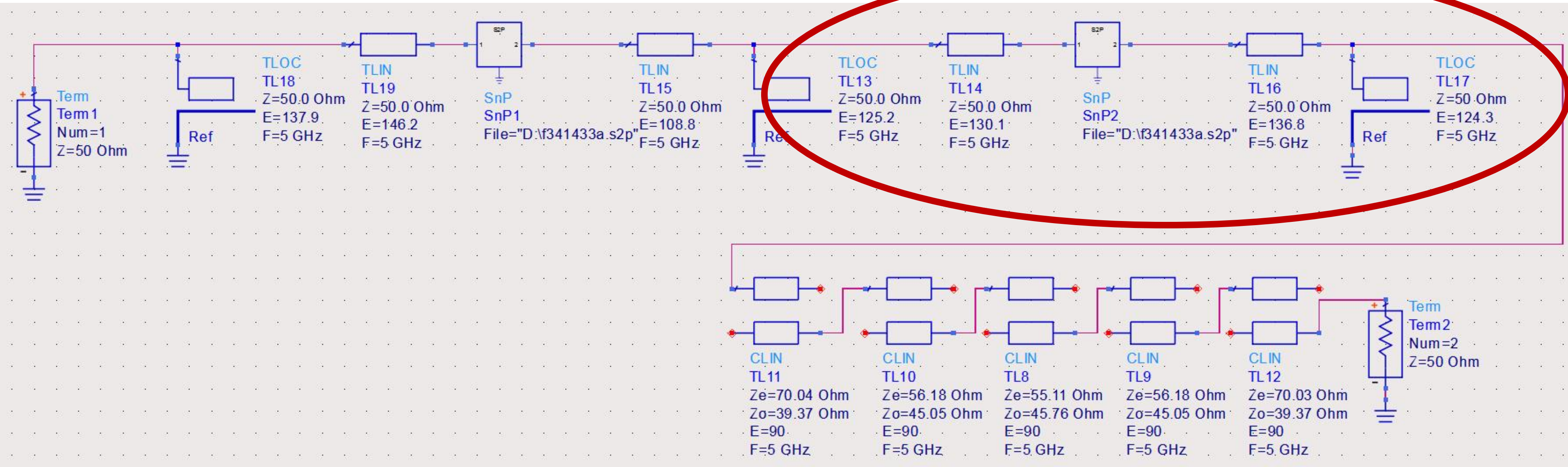


Rezultat (periodic in frecventa)

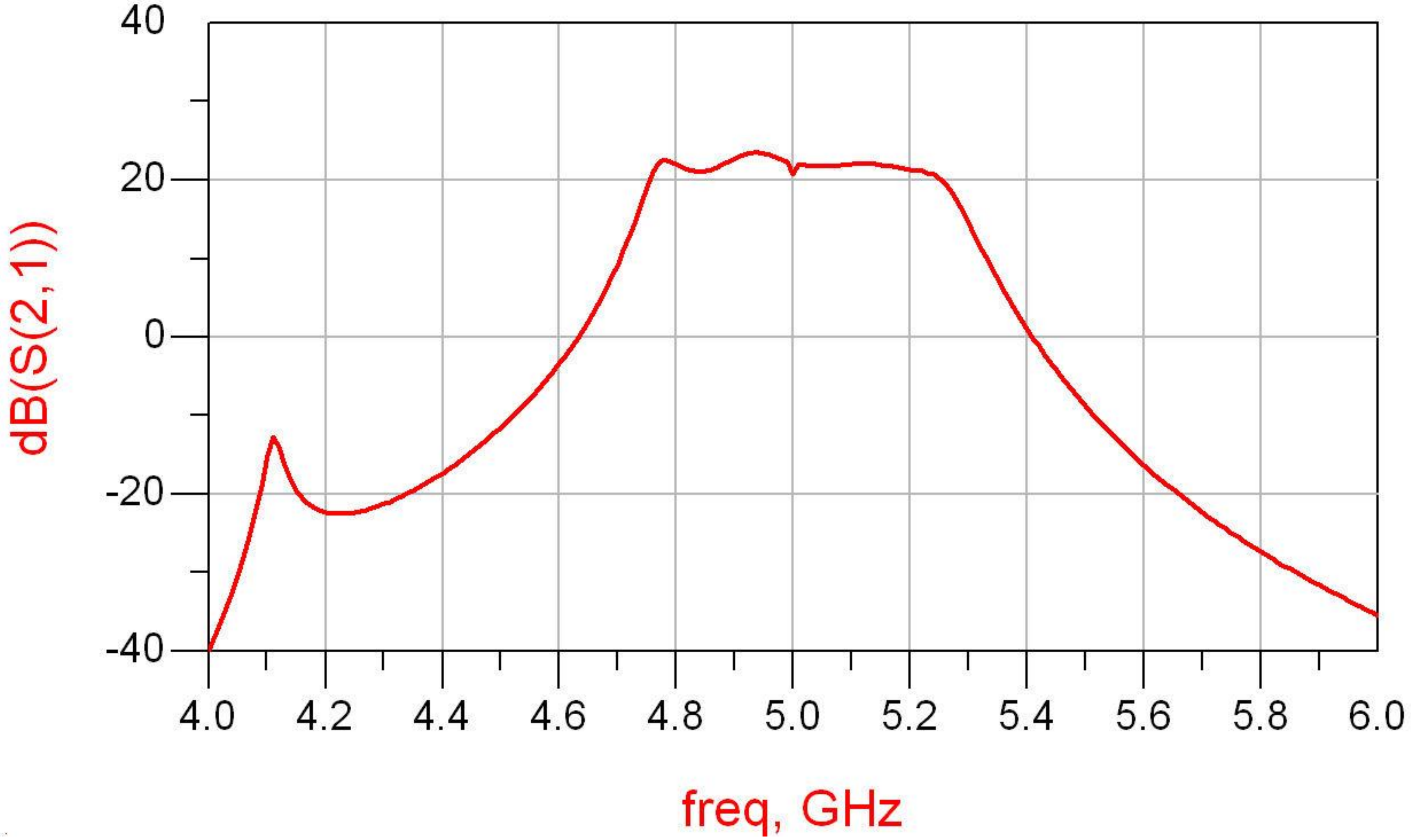


Reglaj -> echilibrare

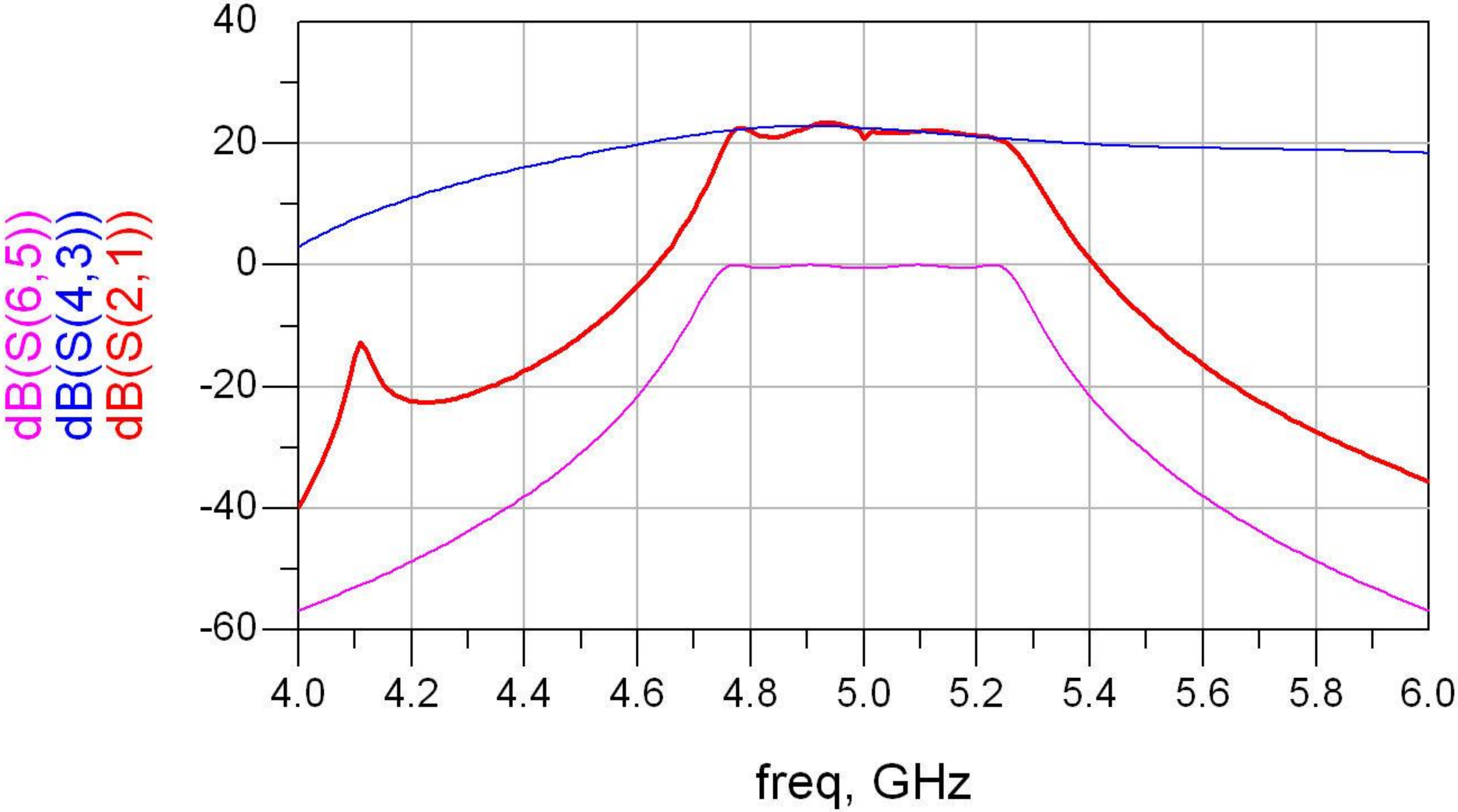
- scopul: echilibrarea caracteristicii amplificatorului (maxim la frecventa centrala)
  - se prefera reglarea lungimii liniilor de la iesirea amplificatorului
    - micsorarea afectarii zgomotului



Reglaj -> echilibrare, efect



Amplificator, Filtru, Total



Implementare cu linii microstrip

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

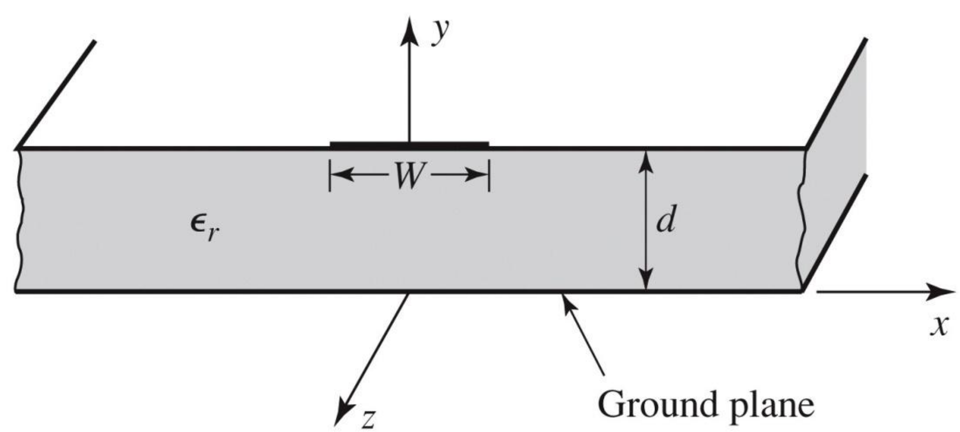


Figure 3.25a

Implementare cu linii microstrip

- Linie quasi TEM

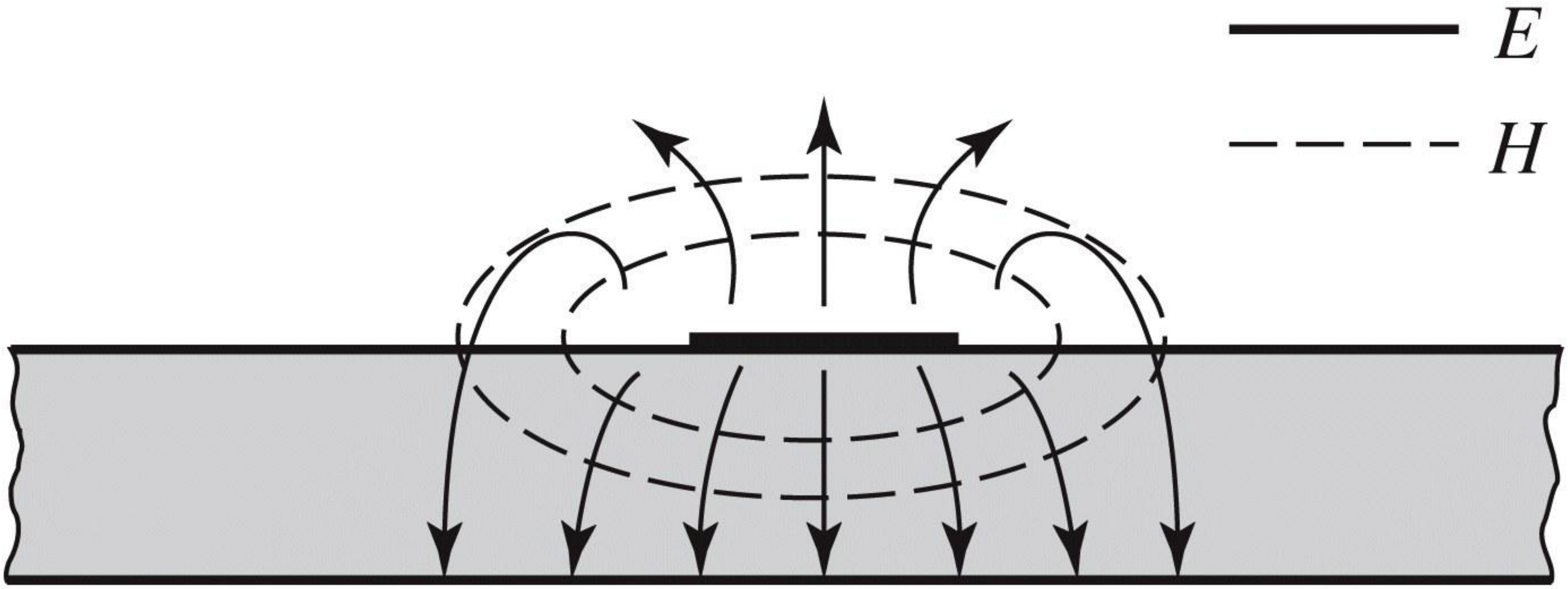
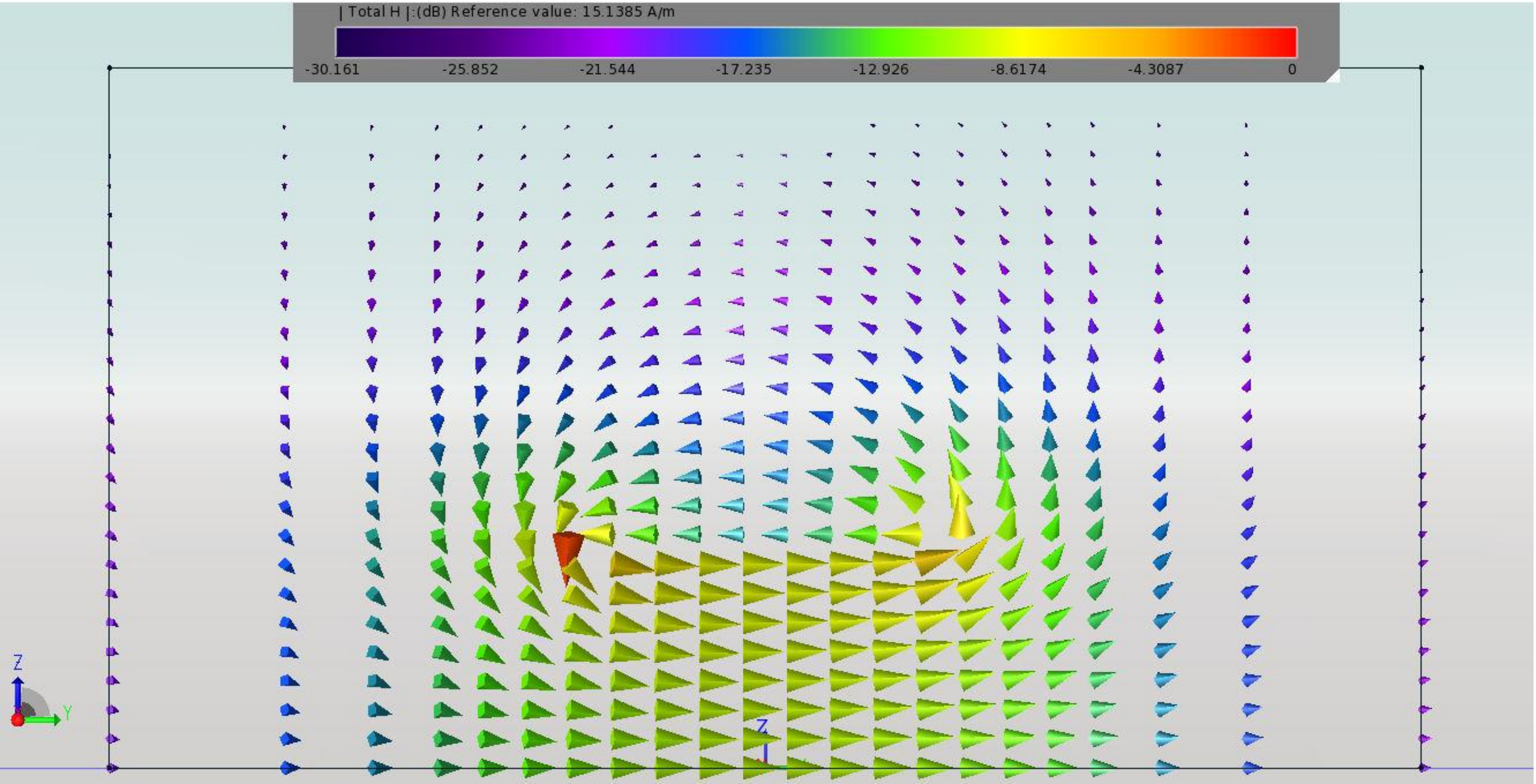


Figure 3.25b

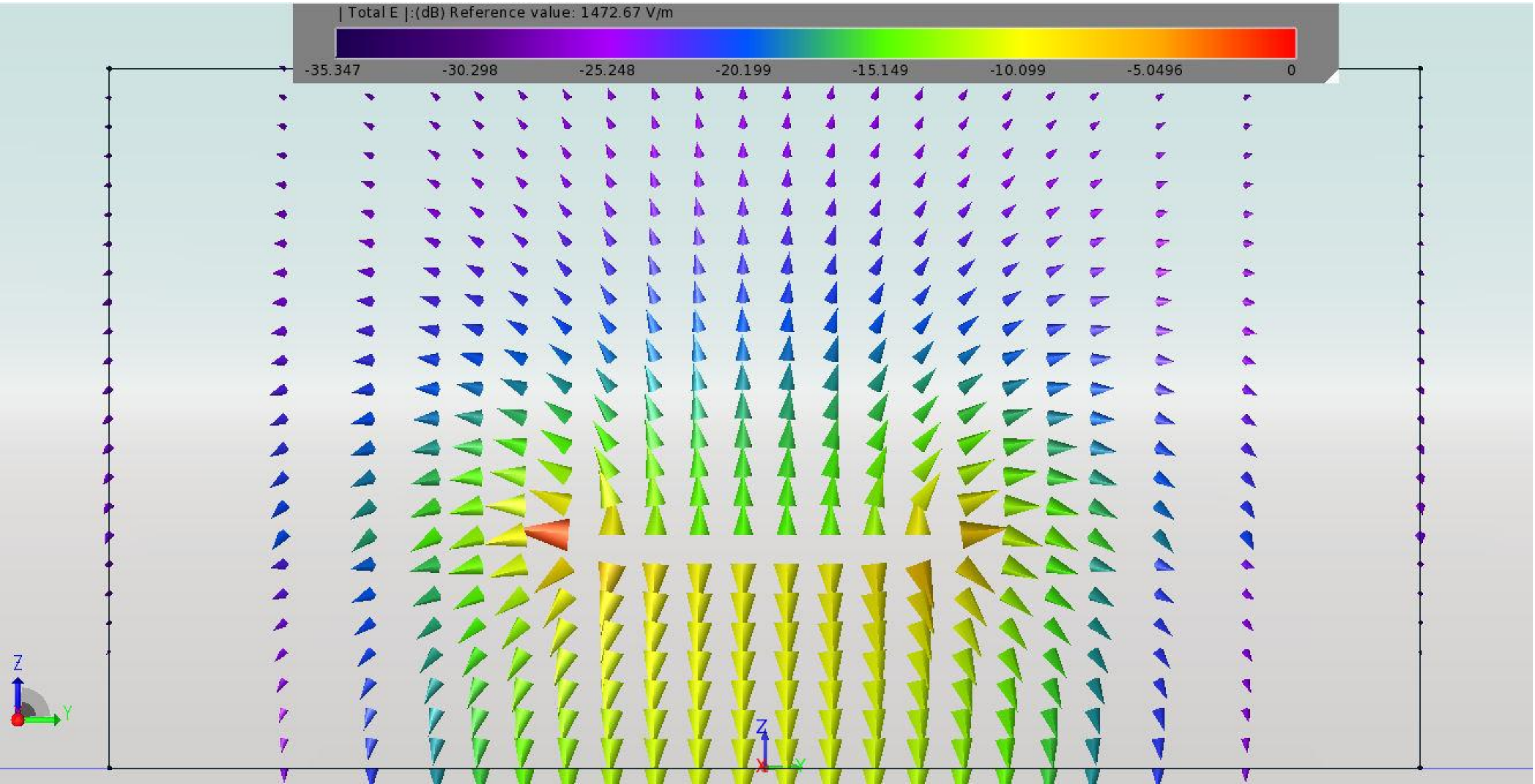
Implementare cu linii microstrip

- Linie quasi TEM, EmPro



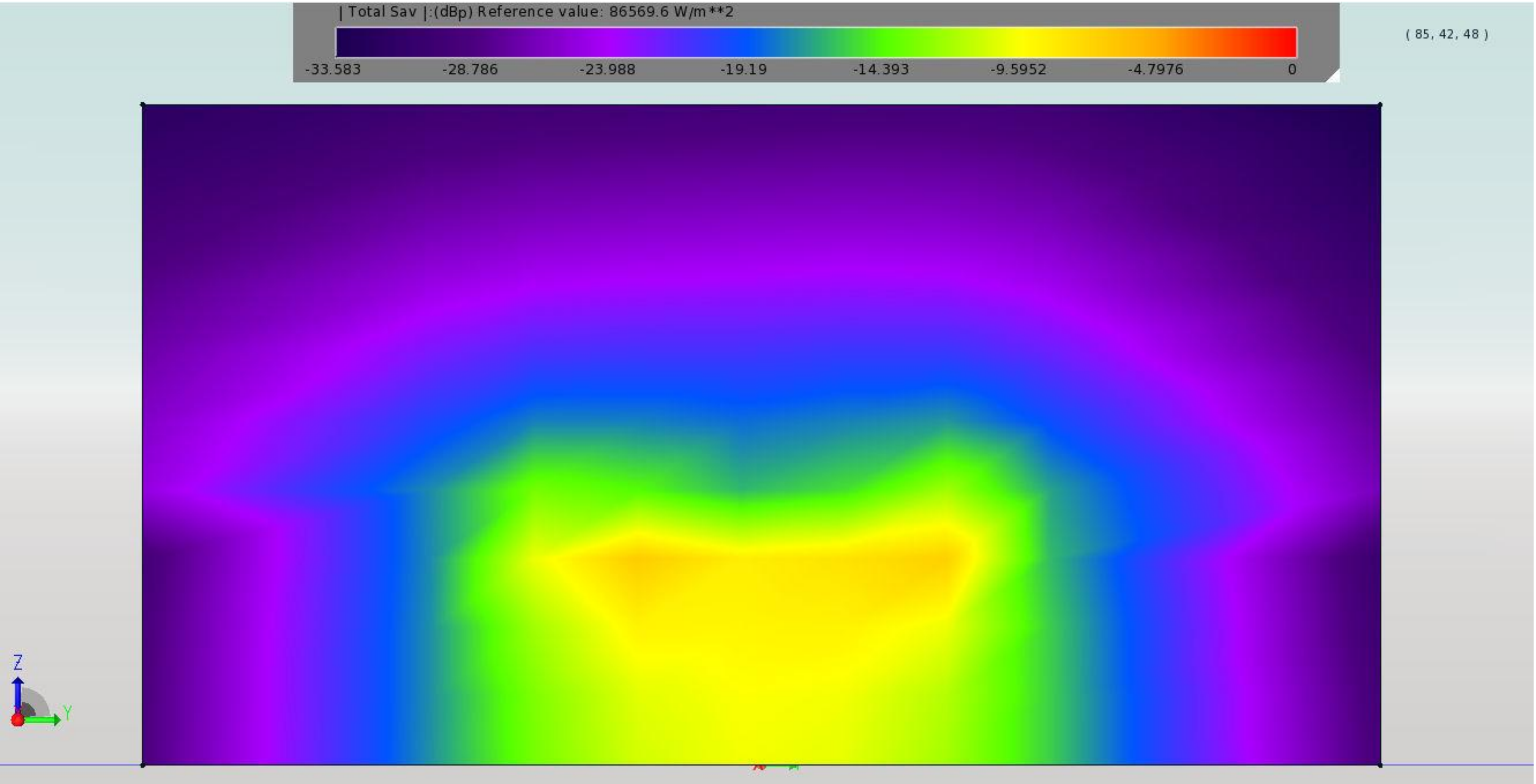
Implementare cu linii microstrip

- Linie quasi TEM, EmPro



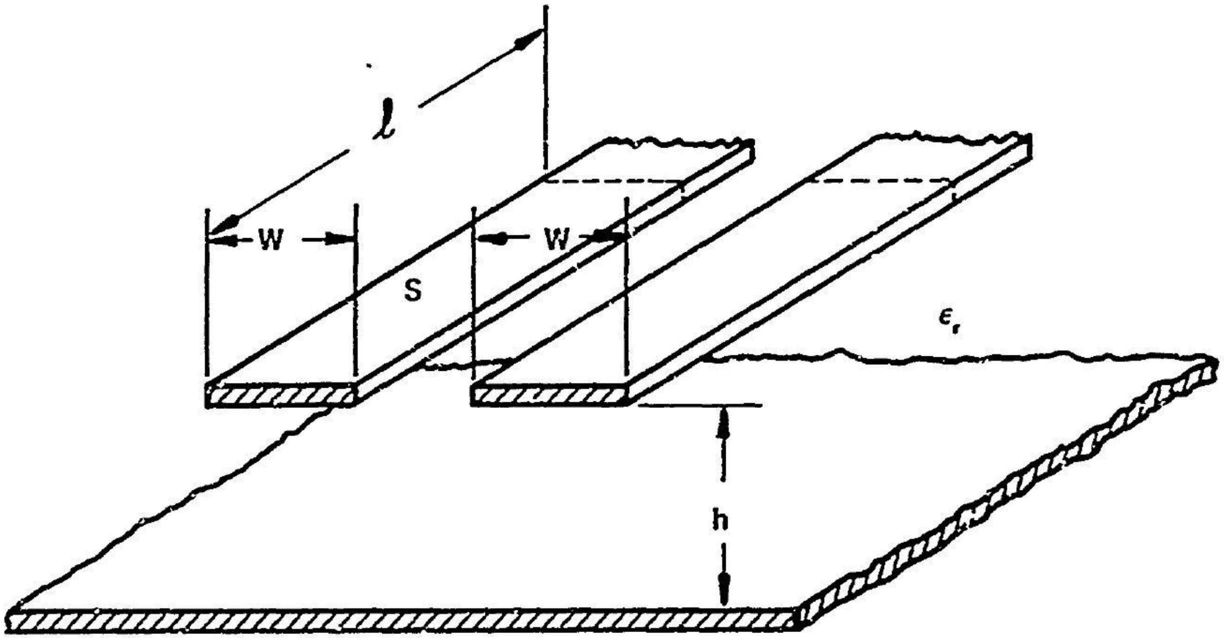
Implementare cu linii microstrip

- Linie quasi TEM, EmPro



Implementare cu linii microstrip

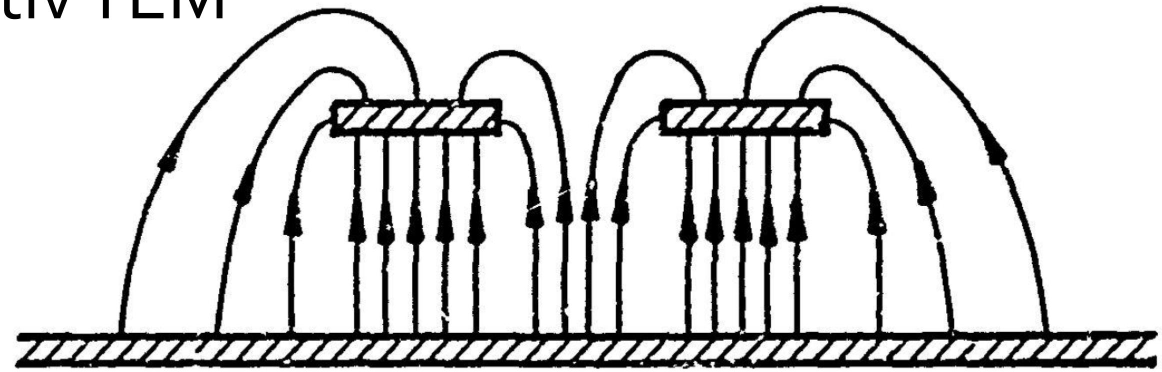
- ~ Aproximativ TEM



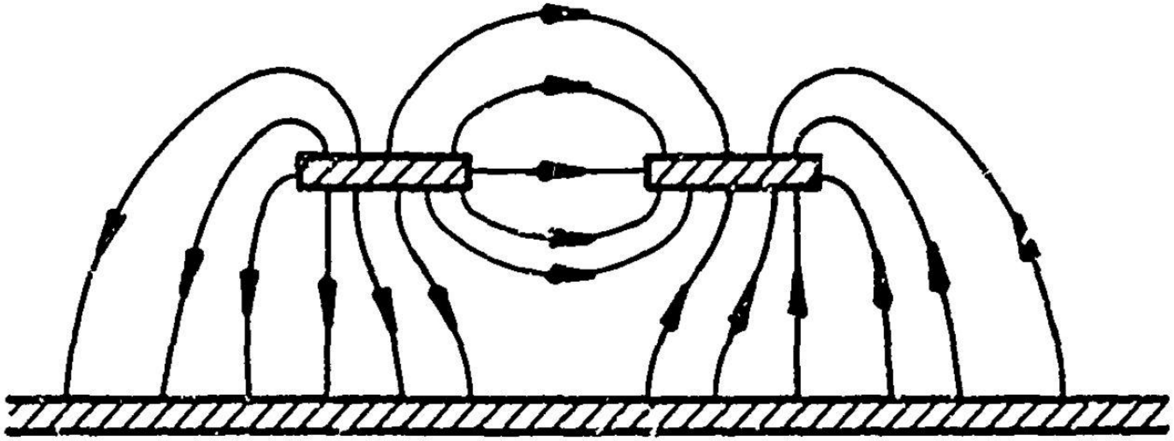
a) COUPLED STRIP GEOMETRY

Implementare cu linii microstrip

- ~ Aproximativ TEM



b) EVEN MODE ELECTRIC FIELD PATTERN (SCHEMATIC)



c) ODD MODE ELECTRIC FIELD PATTERN (SCHEMATIC)

Implementare cu linii microstrip

- Se echivaleaza linia cu o linie cu dielectric omogen echivalent

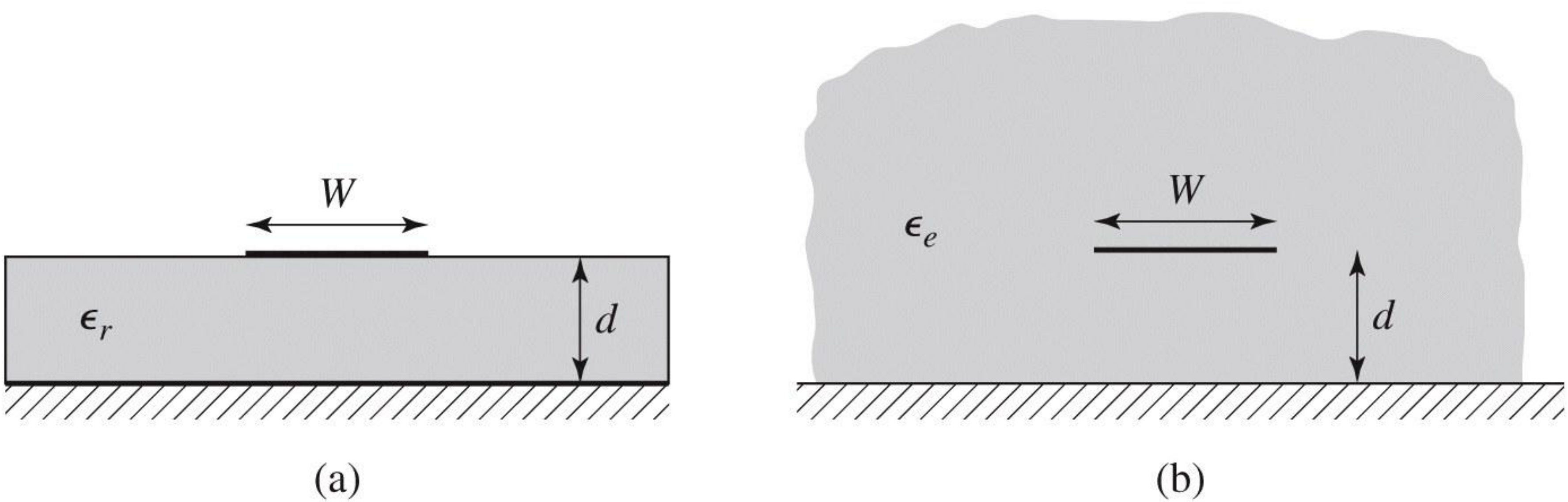


Figure 3.26

Calcul

- Calcul empiric

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

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

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

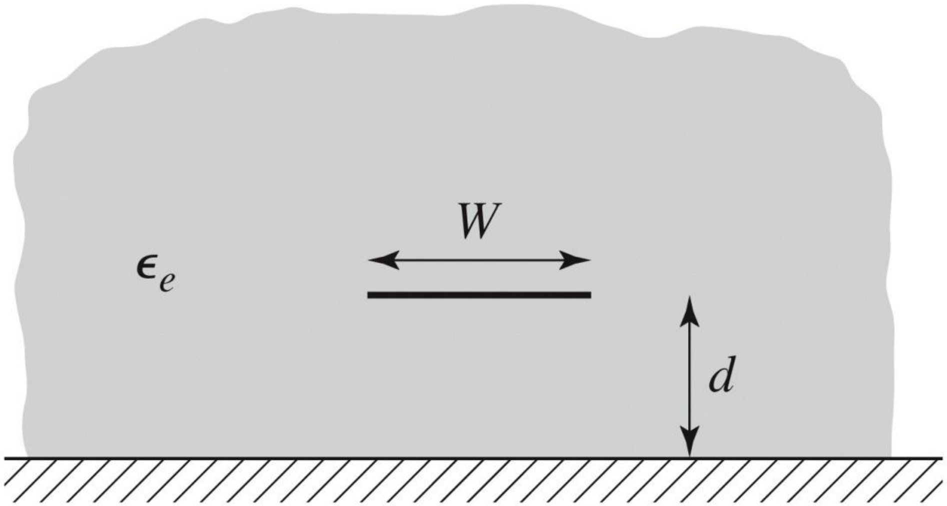


Figure 3.26b

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

Calcul

- Calcul empiric

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

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

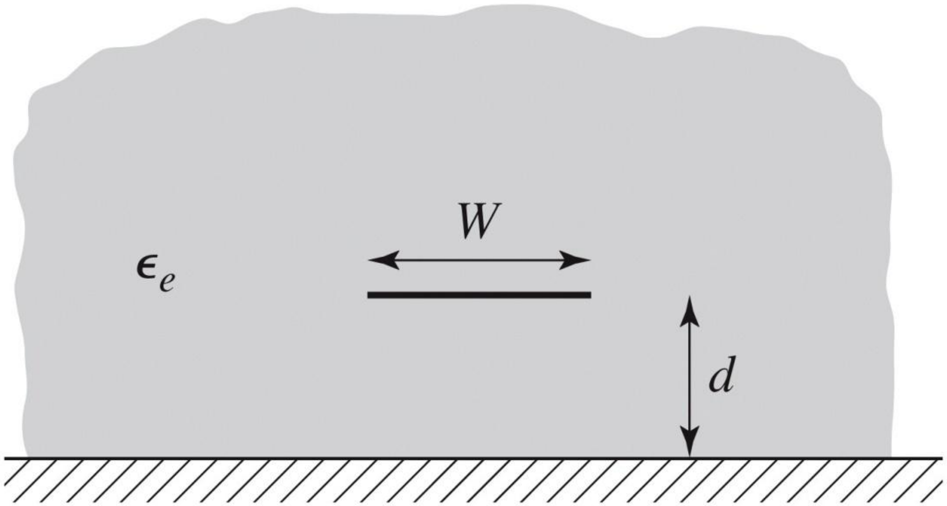
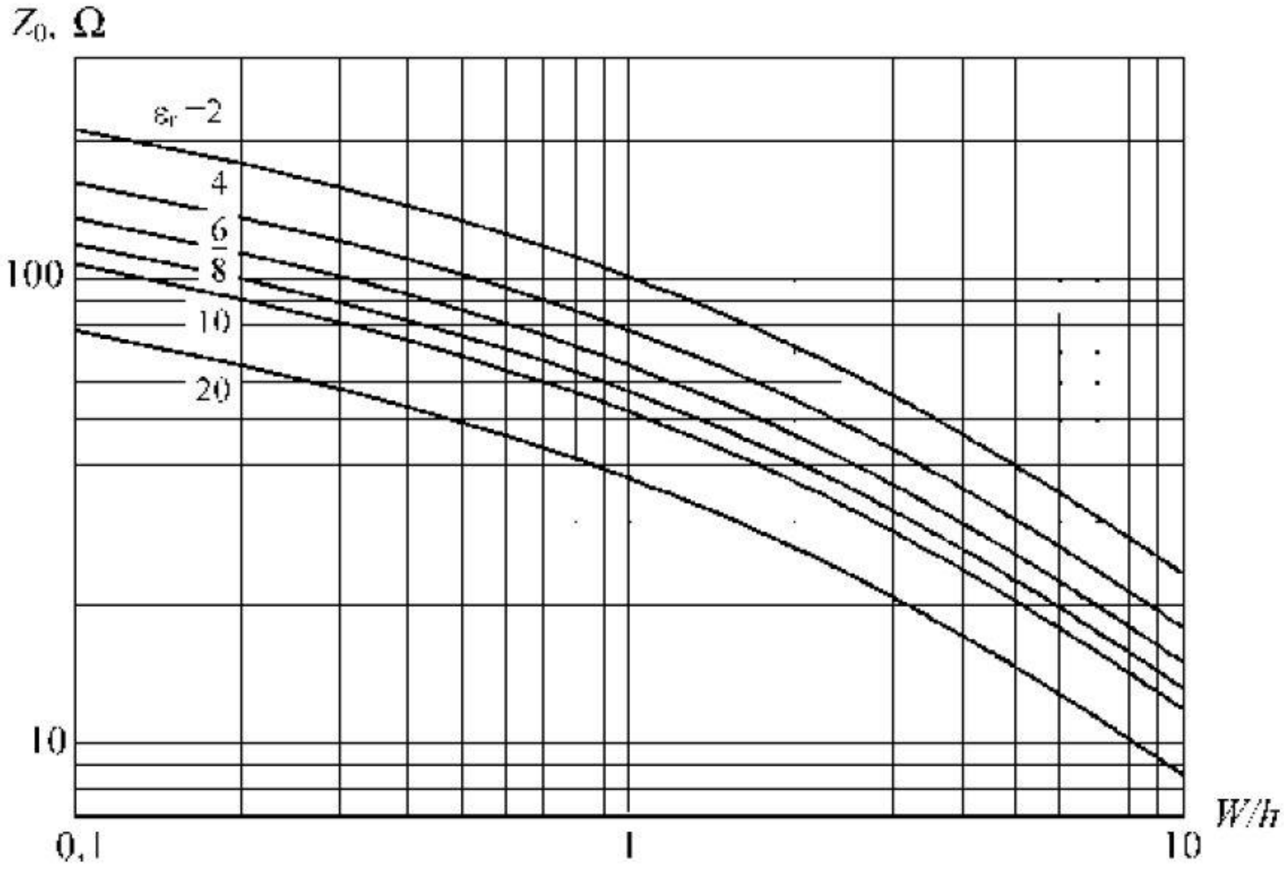


Figure 3.26b

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

Impedanta caracteristica

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



$$k_0 = \frac{2\pi f}{c}$$

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

Microstrip standardizare

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

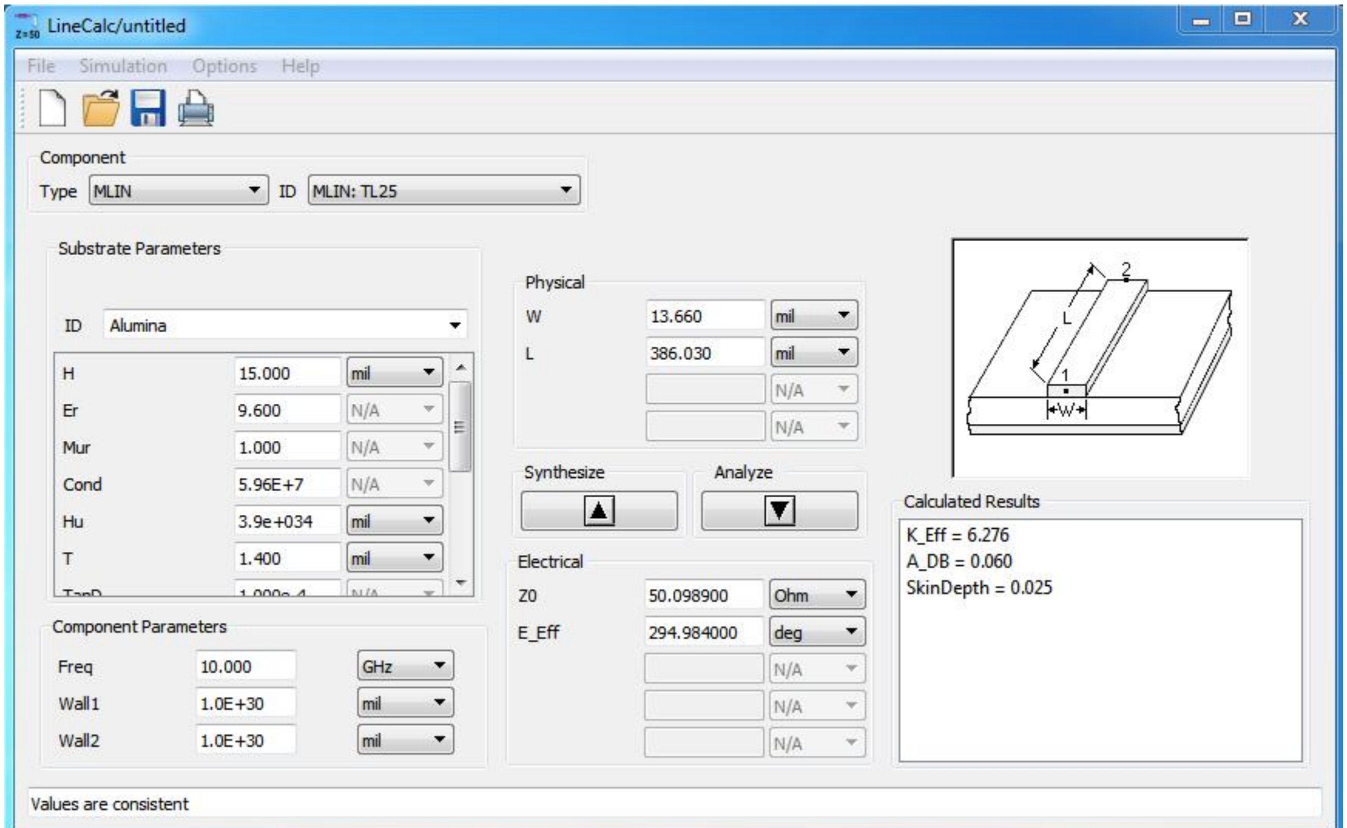
Standard Thickness
RO4003C: 0.008" (0.203mm), 0.012 (0.305mm), 0.016" (0.406mm), 0.020" (0.508mm) 0.032" (0.813mm), 0.060" (1.524mm) **RO4350B**: *0.004" (0.101mm), 0.0066" (0.168mm) 0.010" (0.254mm), 0.0133 (0.338mm), 0.0166 (0.422mm), 0.020" (0.508mm) 0.030" (0.762mm), 0.060" (1.524mm)

Microstrip, materiale substrat

	Constanta dielectrică relativă	Factorul de pierderi dielectrice	Conductivi-tate 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 quarț	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	-	-	-

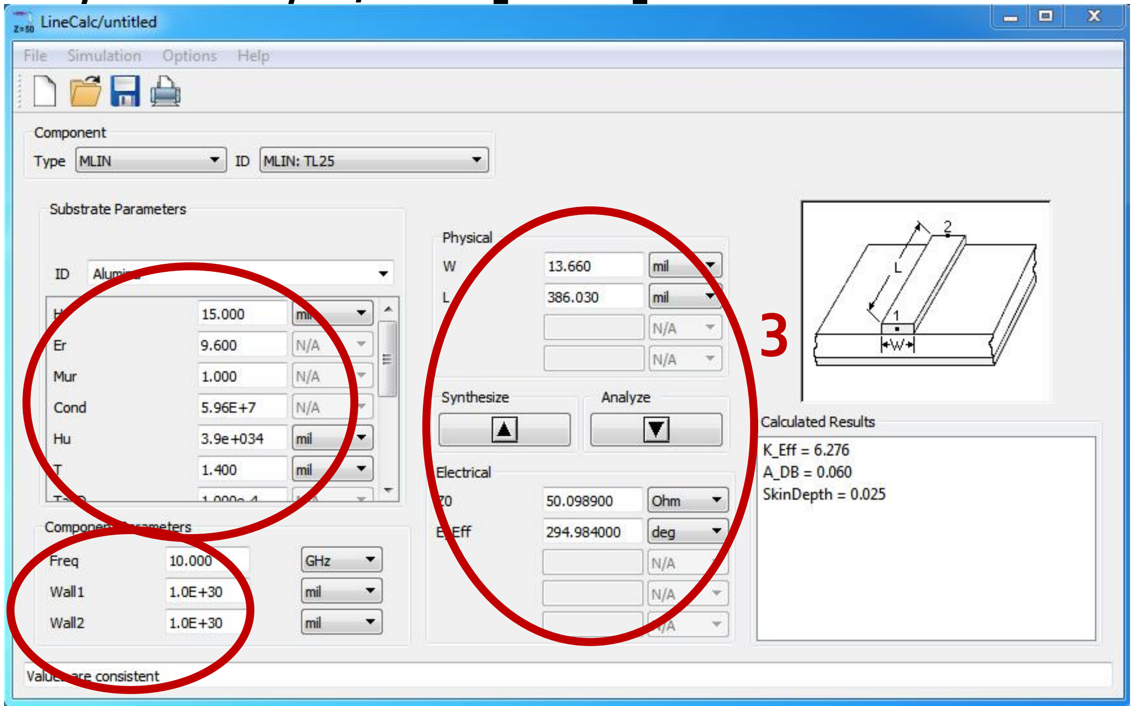
ADS linecalc

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



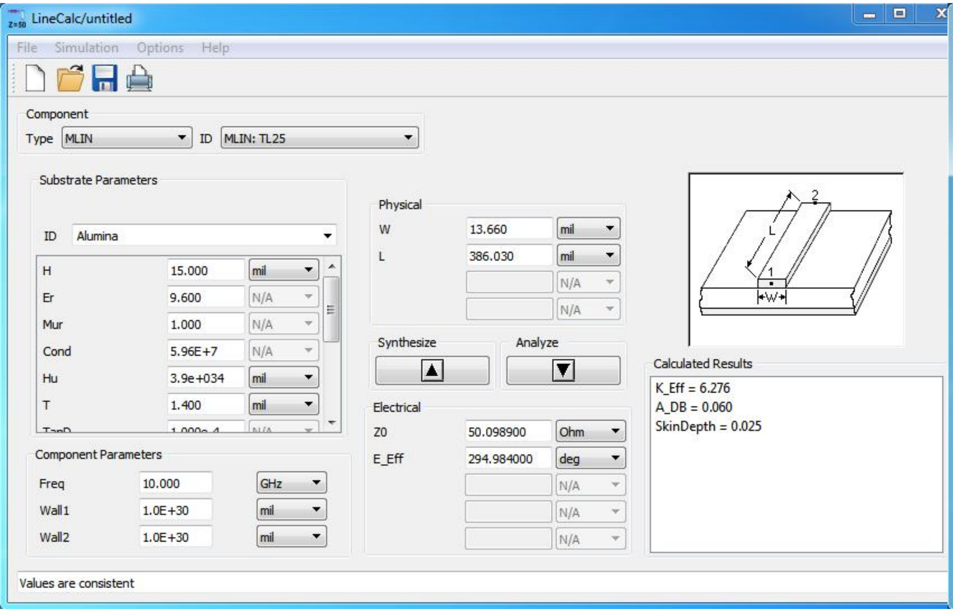
ADS linecalc

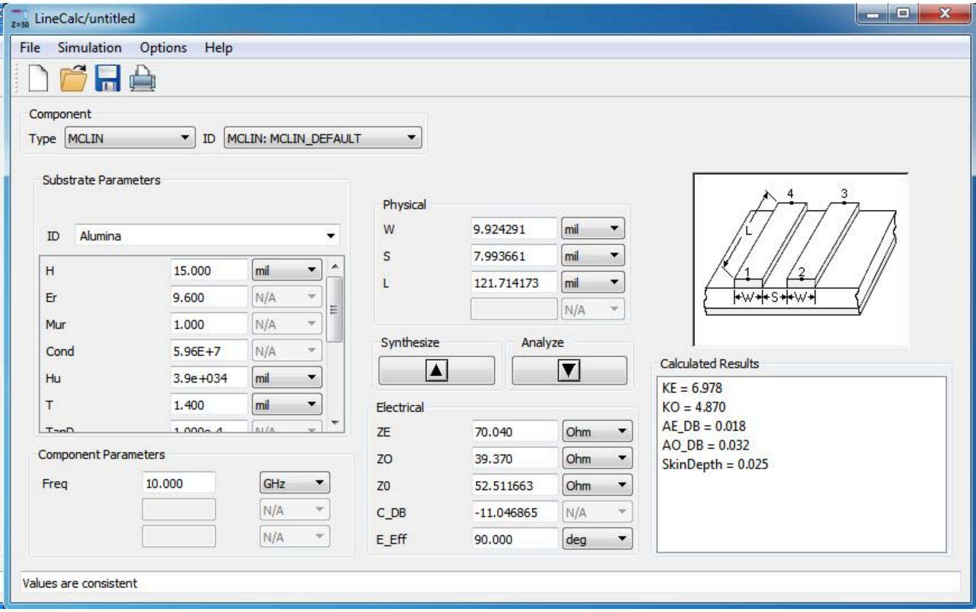
- 1. Definire (receptie din schema) substrat
- 2. Introducere frecventa
- 3. Introducere date de intrare
  - Analiza: W,L → Zo,E sau Ze,Zo,E / la f [GHz]
  - Sinteza: Zo,E → W,L / la f [GHz]



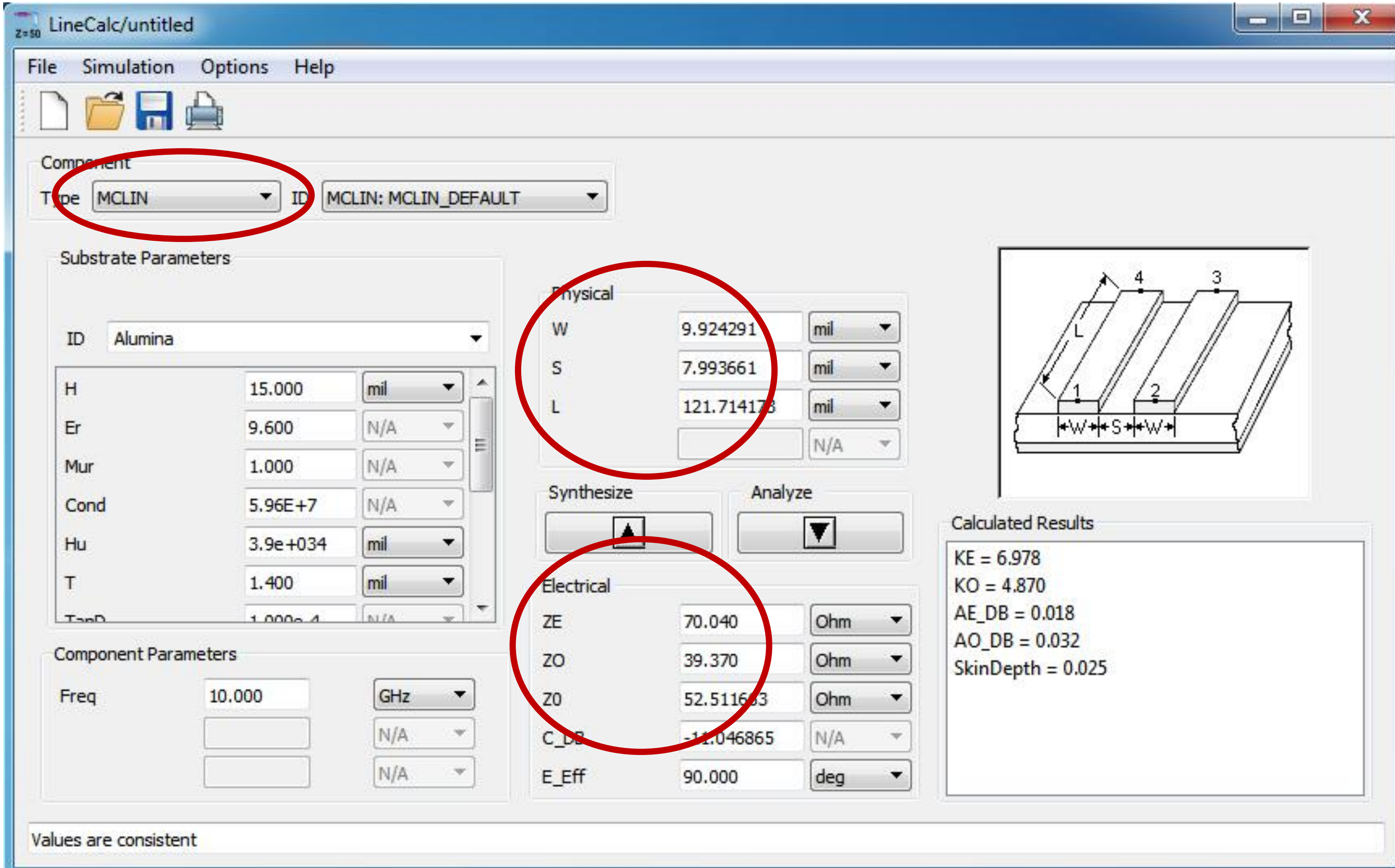
ADS linecalc

- Se poate utiliza pentru:
  - linii microstrip MLIN: W,L ⇔ Zo,E
  - linii cuplate microstrip MCLIN: W,L ⇔ Ze,Zo,E





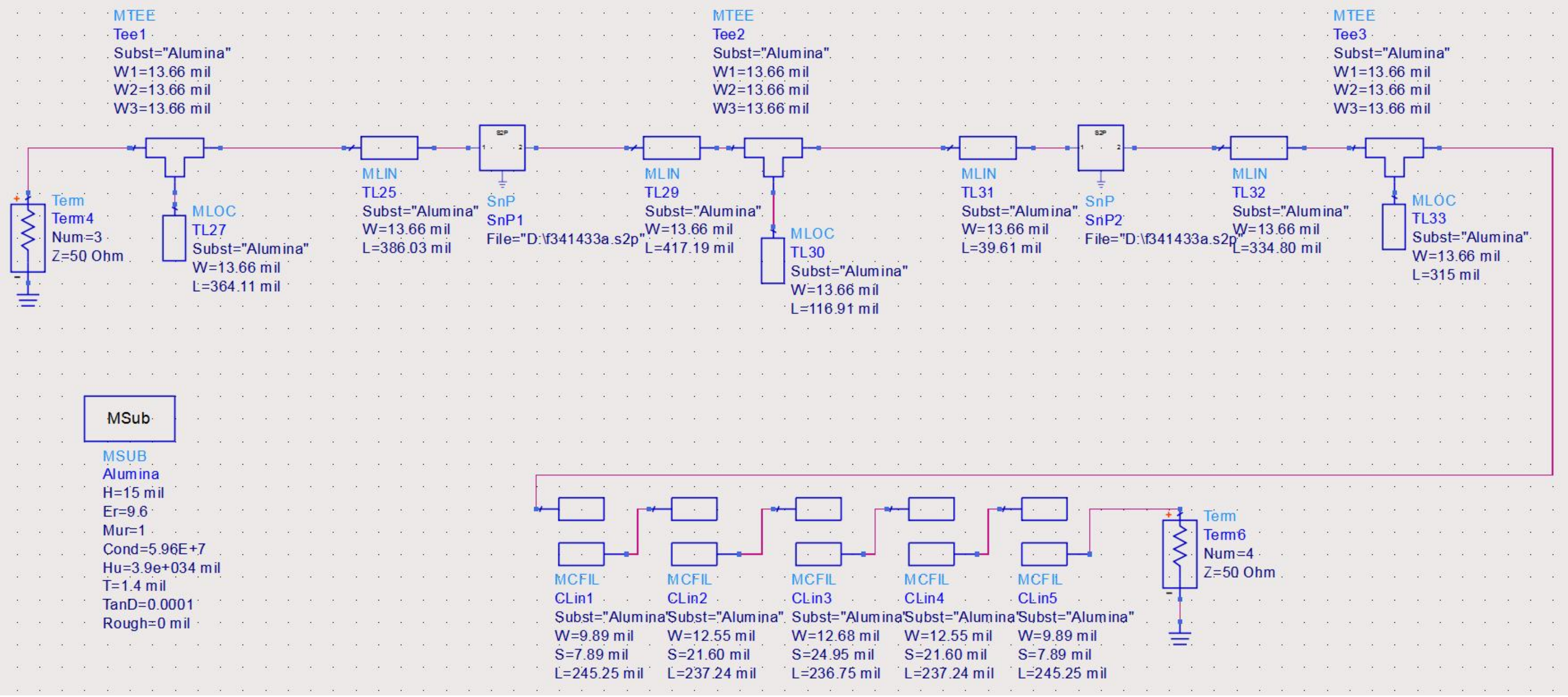
ADS linecalc



Linii de transmisie

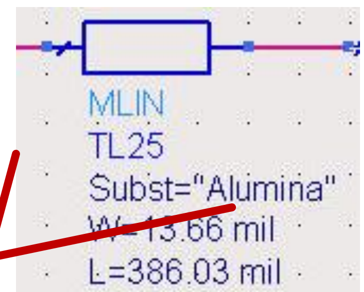
- **https://rf-opto.etti.tuiasi.ro**
- linii de transmisie Rogers
  - relatii dependente de
    - t, inaltimea metalizarilor
    - f, frecventa
  - relatii pentru
    - microstrip
    - strip
    - linii cuplate

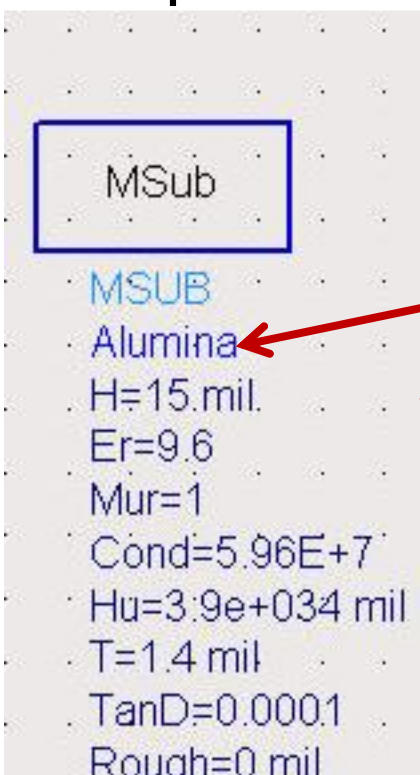
Implementare cu linii microstrip

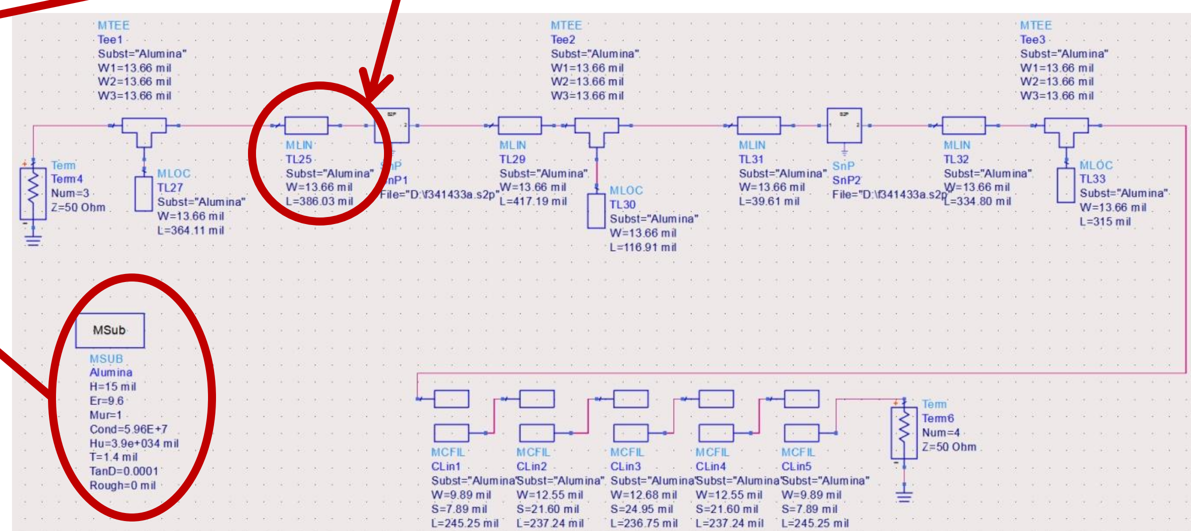


Implementare cu linii microstrip

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





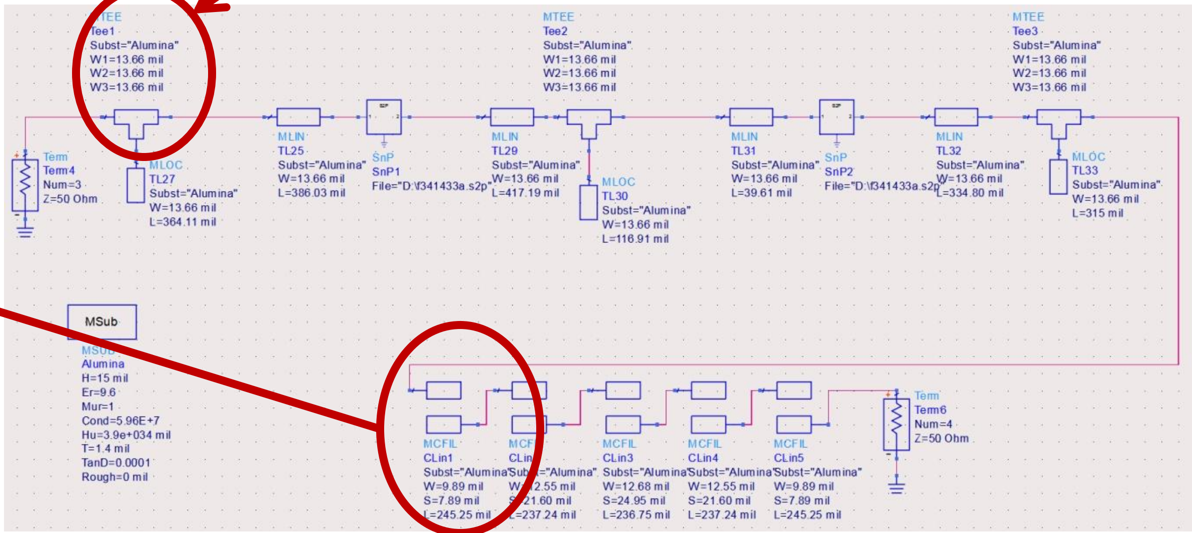


Implementare cu linii microstrip

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

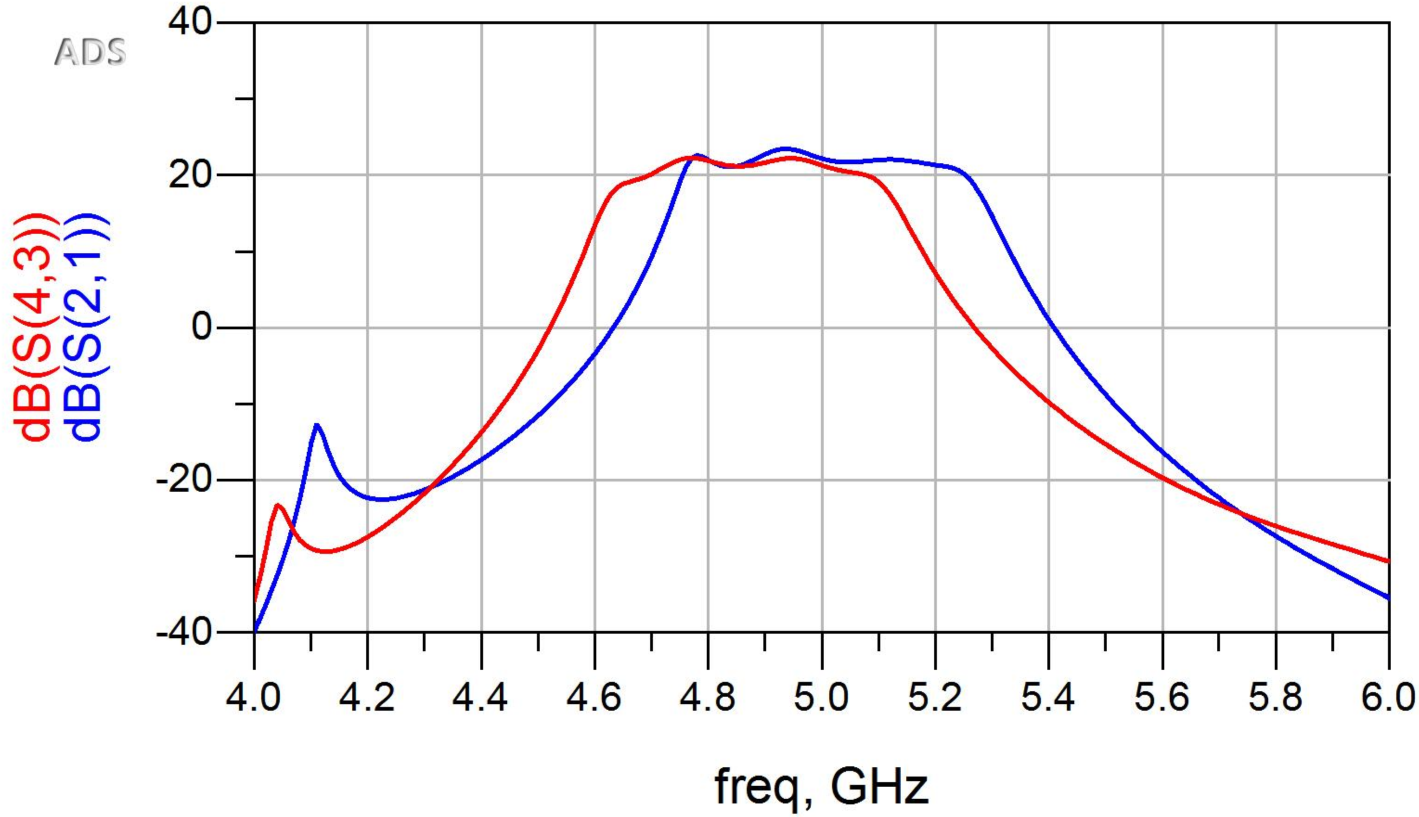
Implementare cu linii microstrip

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



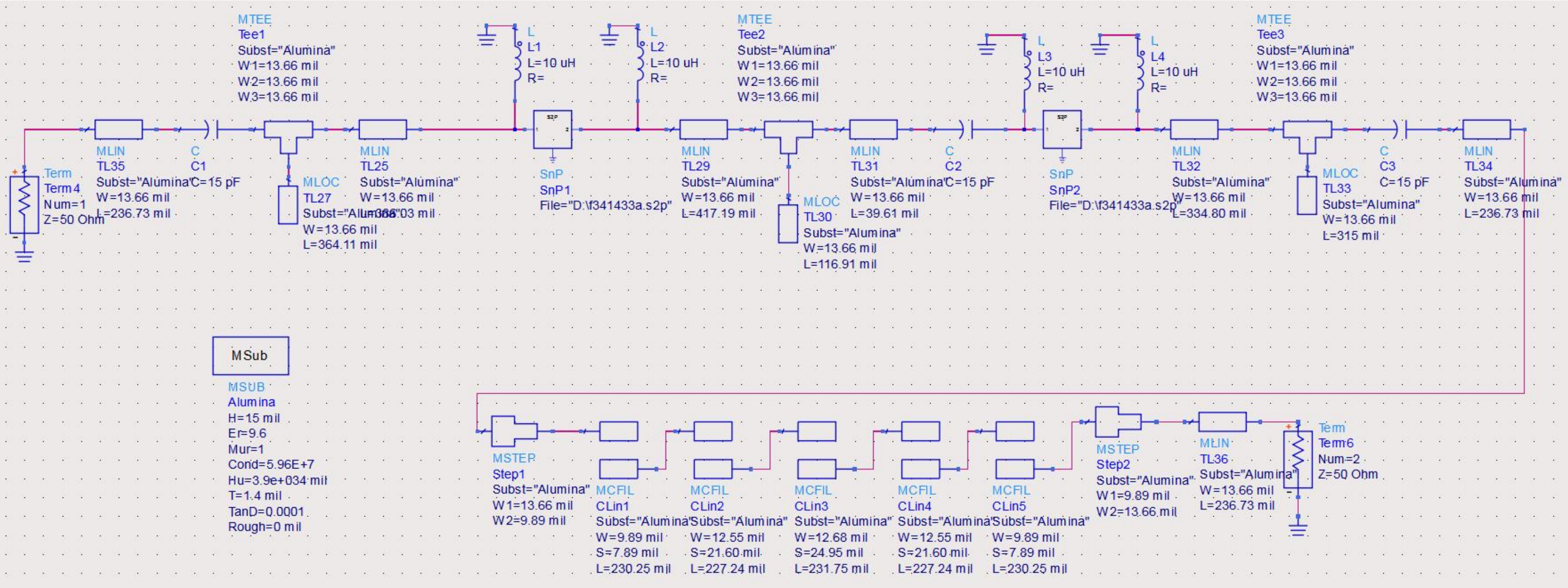
Implementare cu linii microstrip Rezultat

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

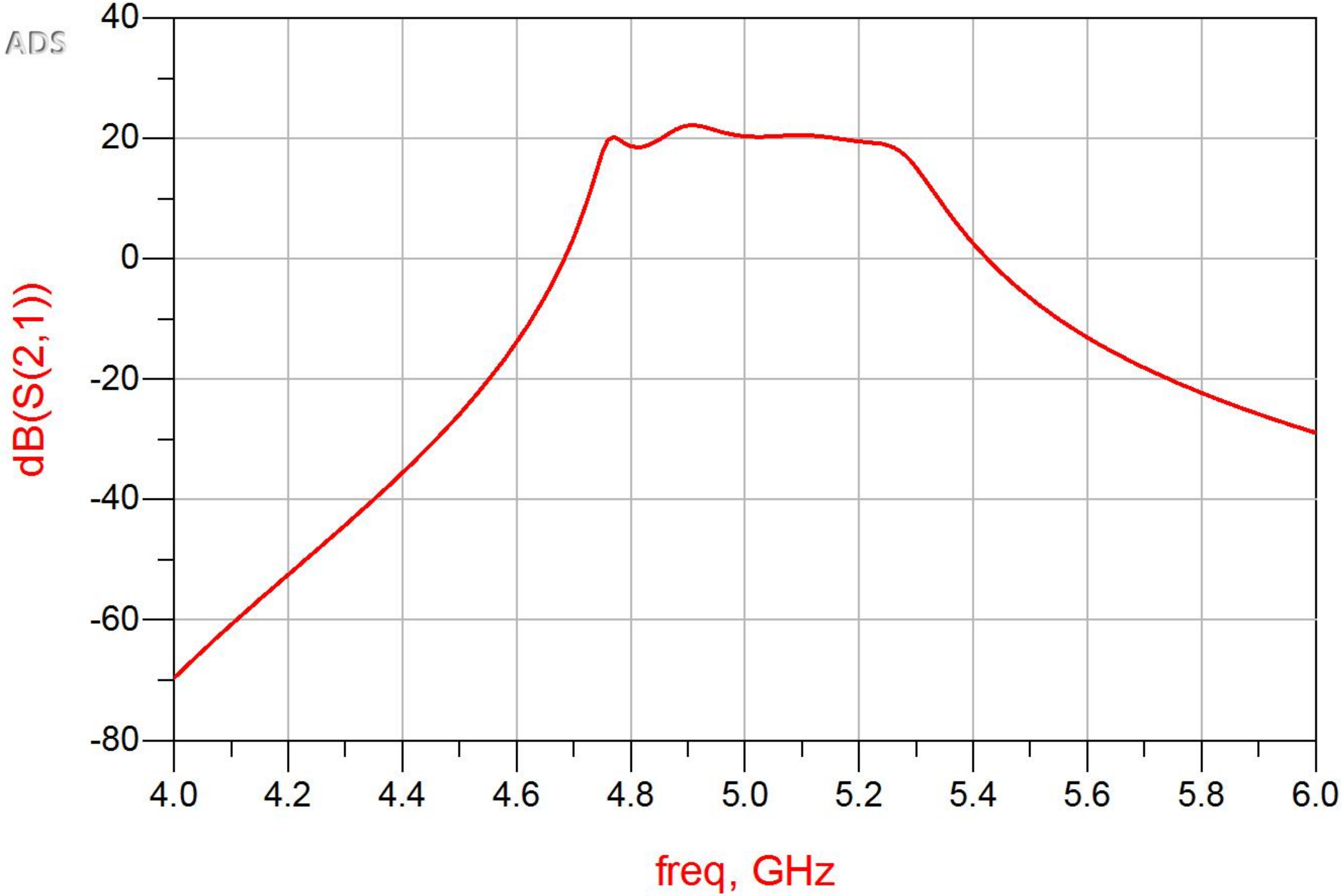


Introducere elemente de polarizare

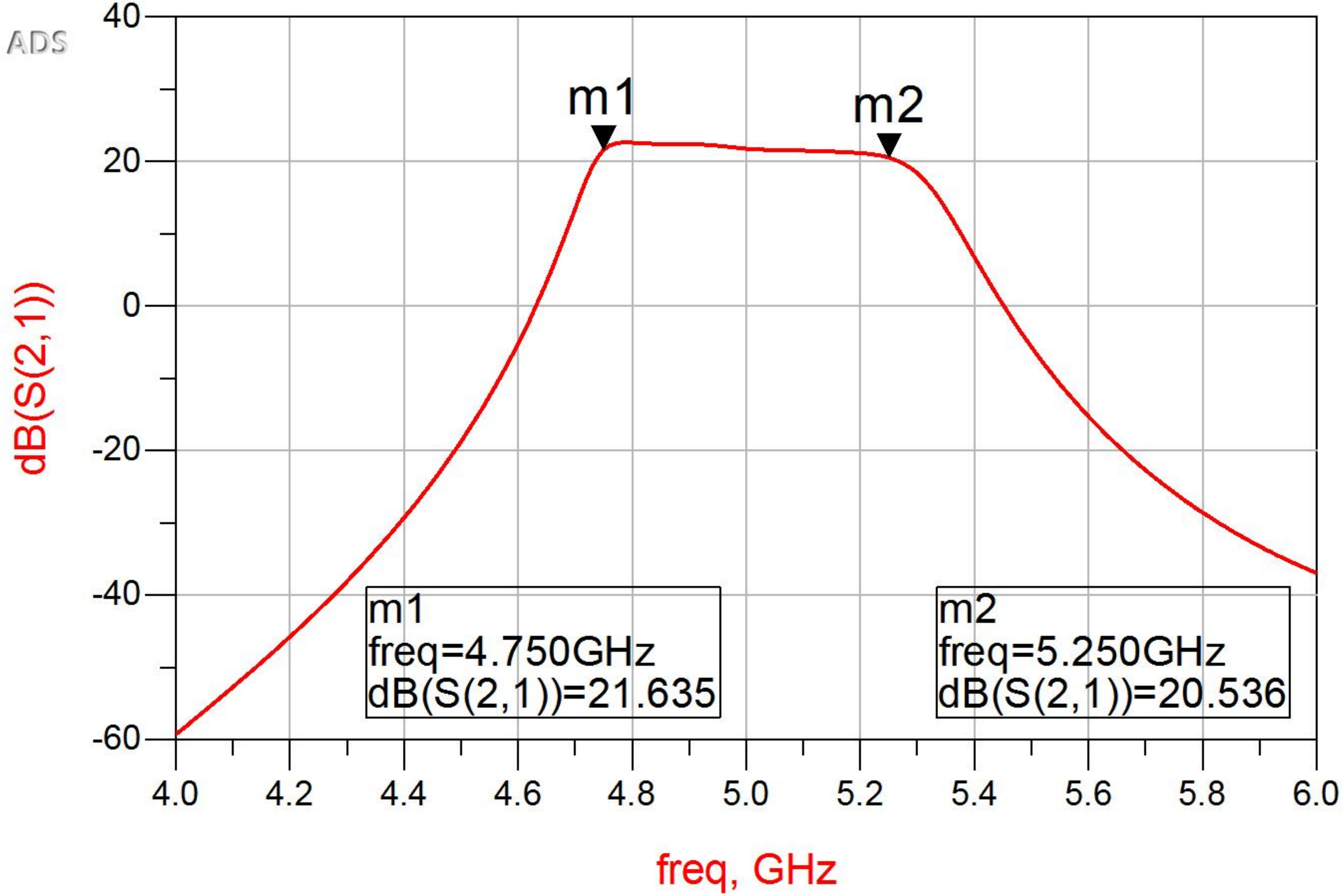
- Reglaj de lungimi la elementele filtrului pentru reglarea frecventelor in jurul fo = 5GHz
- Introducere L (soc RF) si C (decuplare)



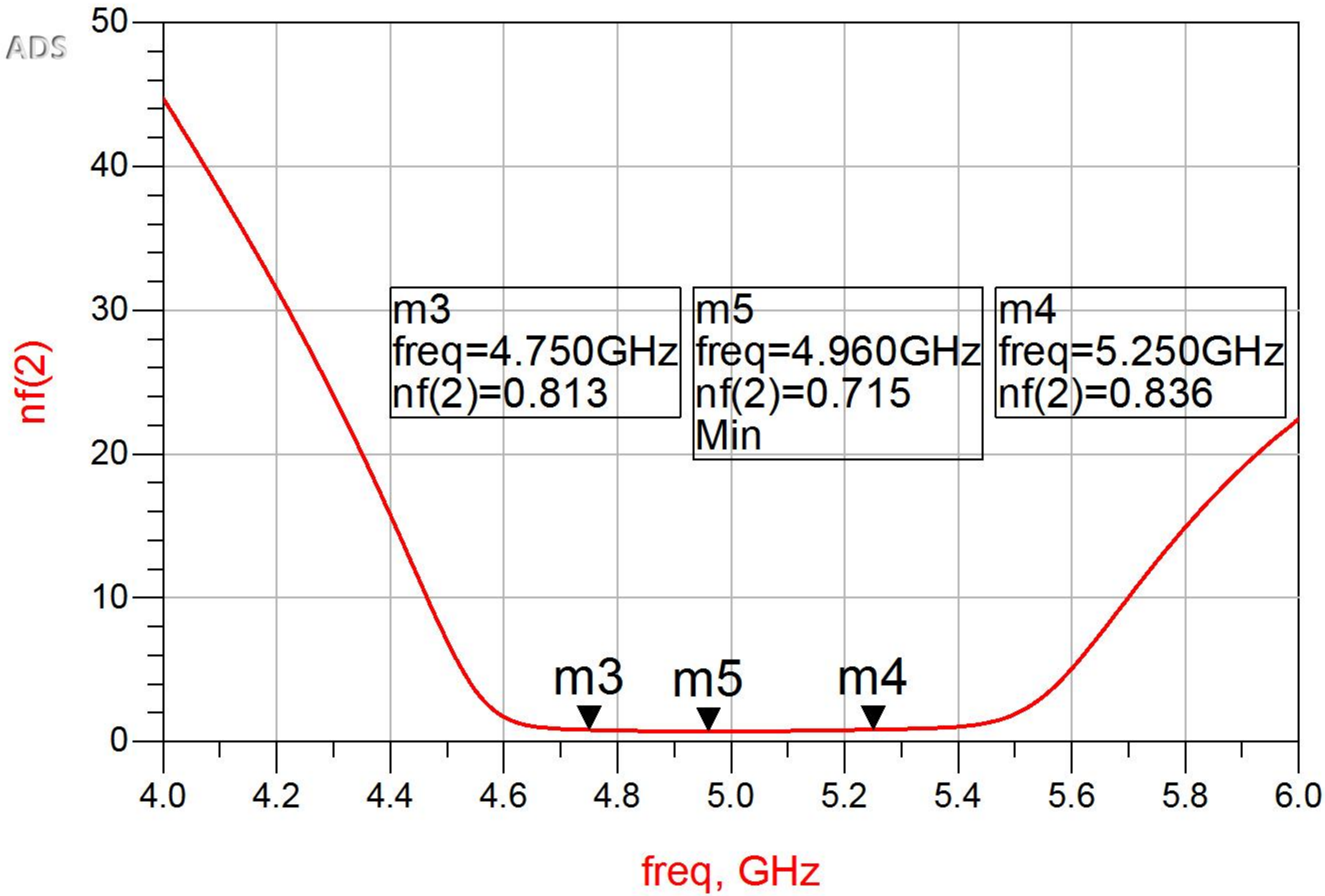
Castig -> Reglaj/Optimizare



Rezultat final (Castig)

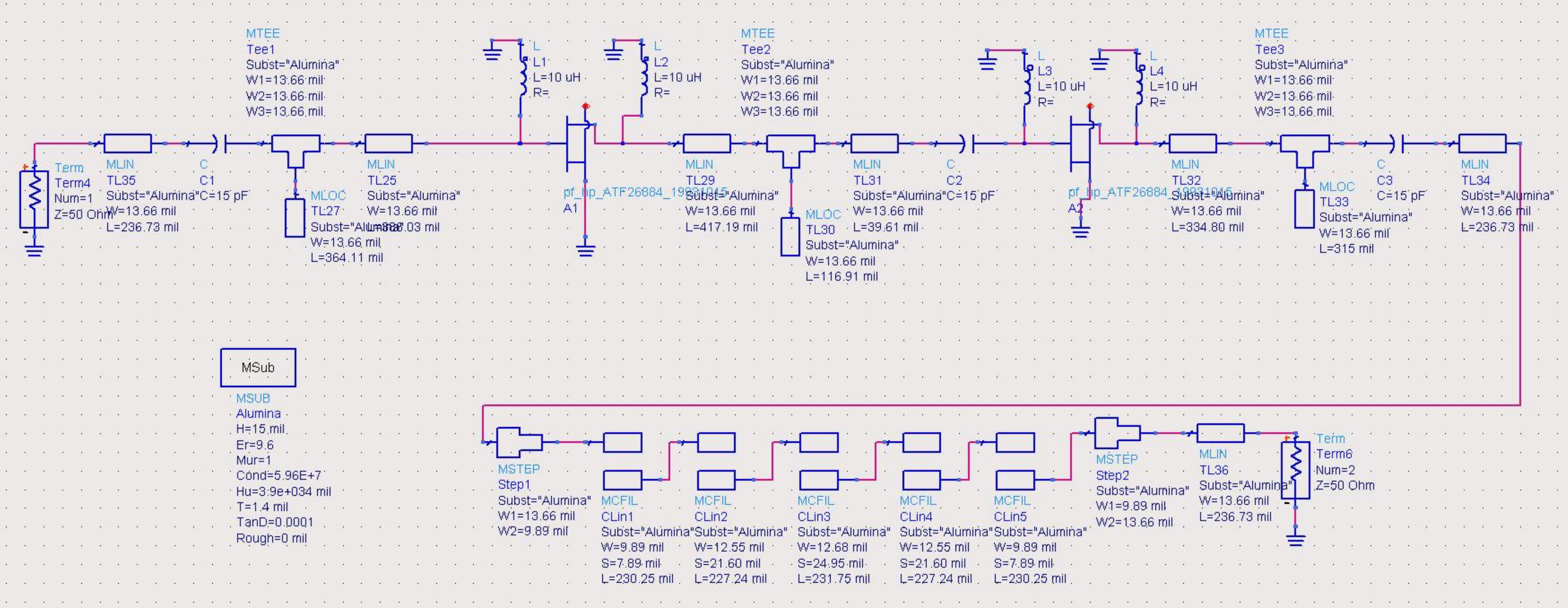


Rezultat final (Zgomot)

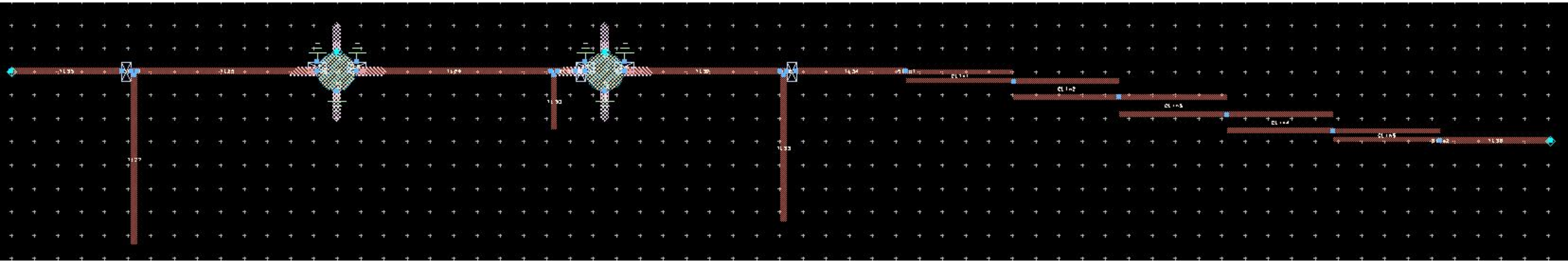


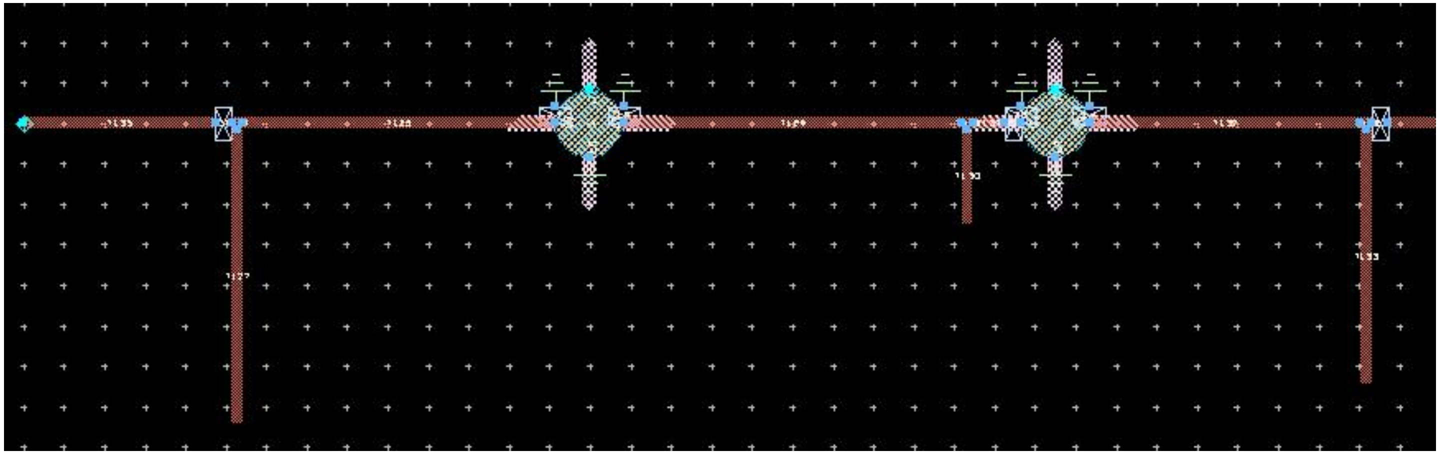
Layout (Exemplu)

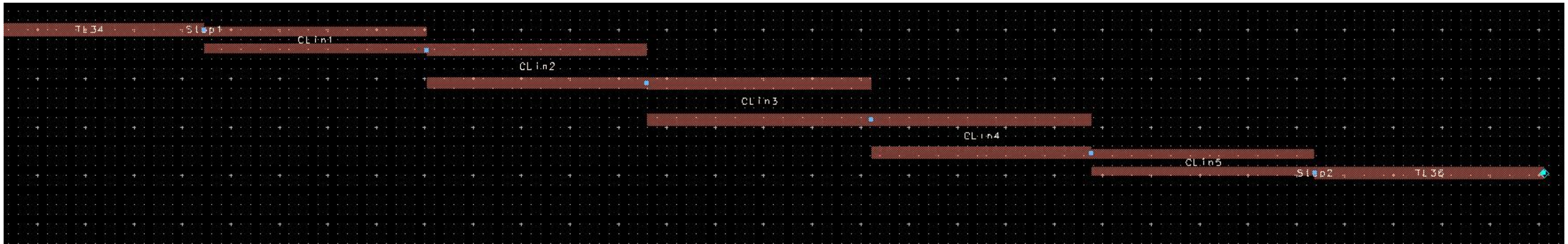
- Inlocuirea (fictiva) a tranzistoarelor si elementelor concentrate (LC) cu elemente pentru care ADS are informatii despre capsule



Layout (Exemplu)







Contact

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