

Curs 12

2023/2024

Dispozitive și circuite de microunde pentru radiocomunicații

Disciplina 2023/2024

- 2C/1L (+1), **DCMR (CDM)**
- Minim 7 prezente (curs+laborator)
- Curs - **conf. Radu Damian**
 - Miercuri 08(:**15**)-17, ~~Online~~/**Video (istoric)**, P5
 - E – **50%** din nota
 - **probleme** + (2p prez. curs) + (3 teste) + (bonus activitate)
 - primul test L1: 04.10.2023 (t2 si t3 neanuntate la **curs**)
 - 3pz (C) ≈ +0.5p (**2p** max)
 - **toate materialele permise**

Disciplina 2023/2024

- 2C/1L, **DCMR (CDM)**
- Laborator – **conf. Radu Damian**
 - Miercuri/Joi/Vineri, par/impar, **II.13**
 - L – **25%** din nota
 - ADS, 4 sedinte aplicatii
 - prezenta + **rezultate personale!**
 - P – **25%** din nota
 - ADS, 3 sedinte aplicatii (-1? 21-22.12.2022)
 - tema personala

Cuprins

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

Bibliografie

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

Examen: Reprezentare logaritmică

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$-20 \text{ dBm} = 1 \mu\text{W}$$

$$-30 \text{ dBm} = 1 \text{ nW}$$

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

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

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

Adaptarea de impedanță

Diagrama Smith

Cuprins

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

Diagrama Smith

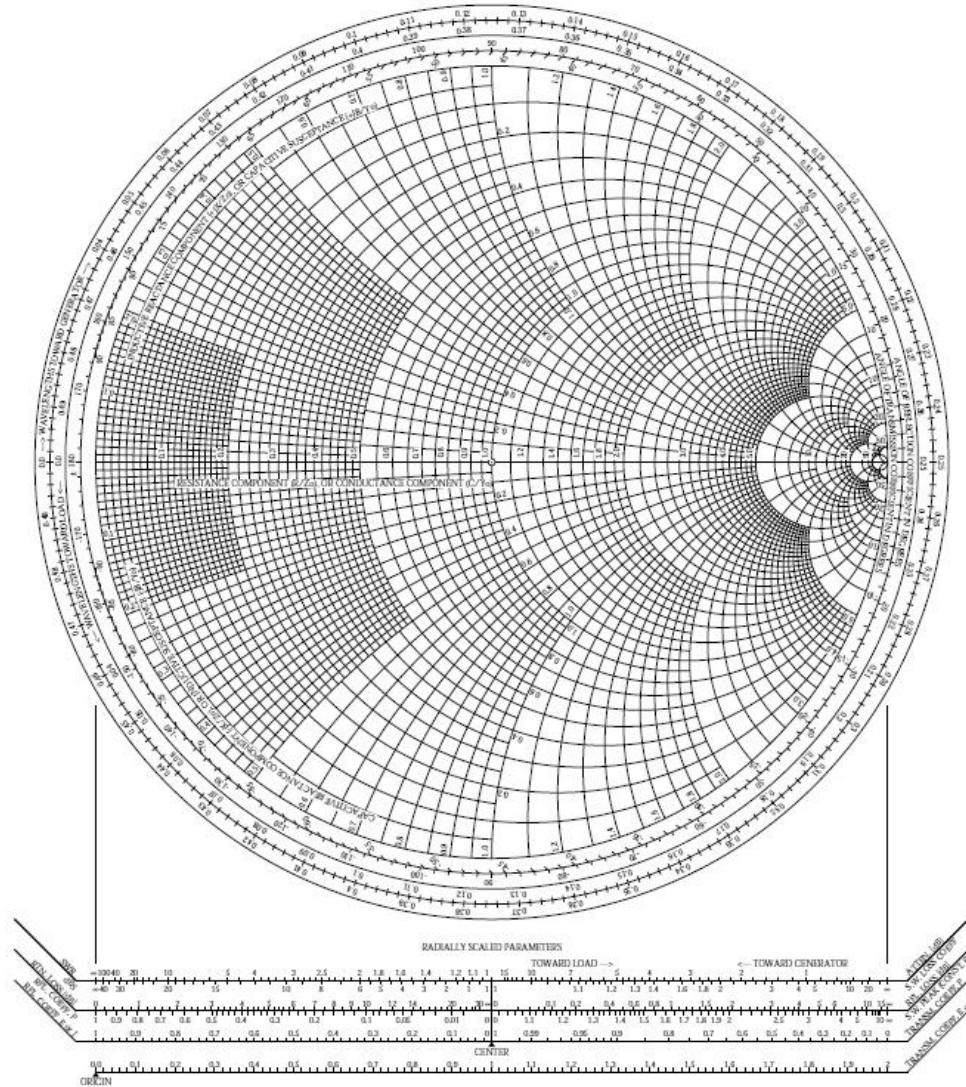


Diagrama Smith

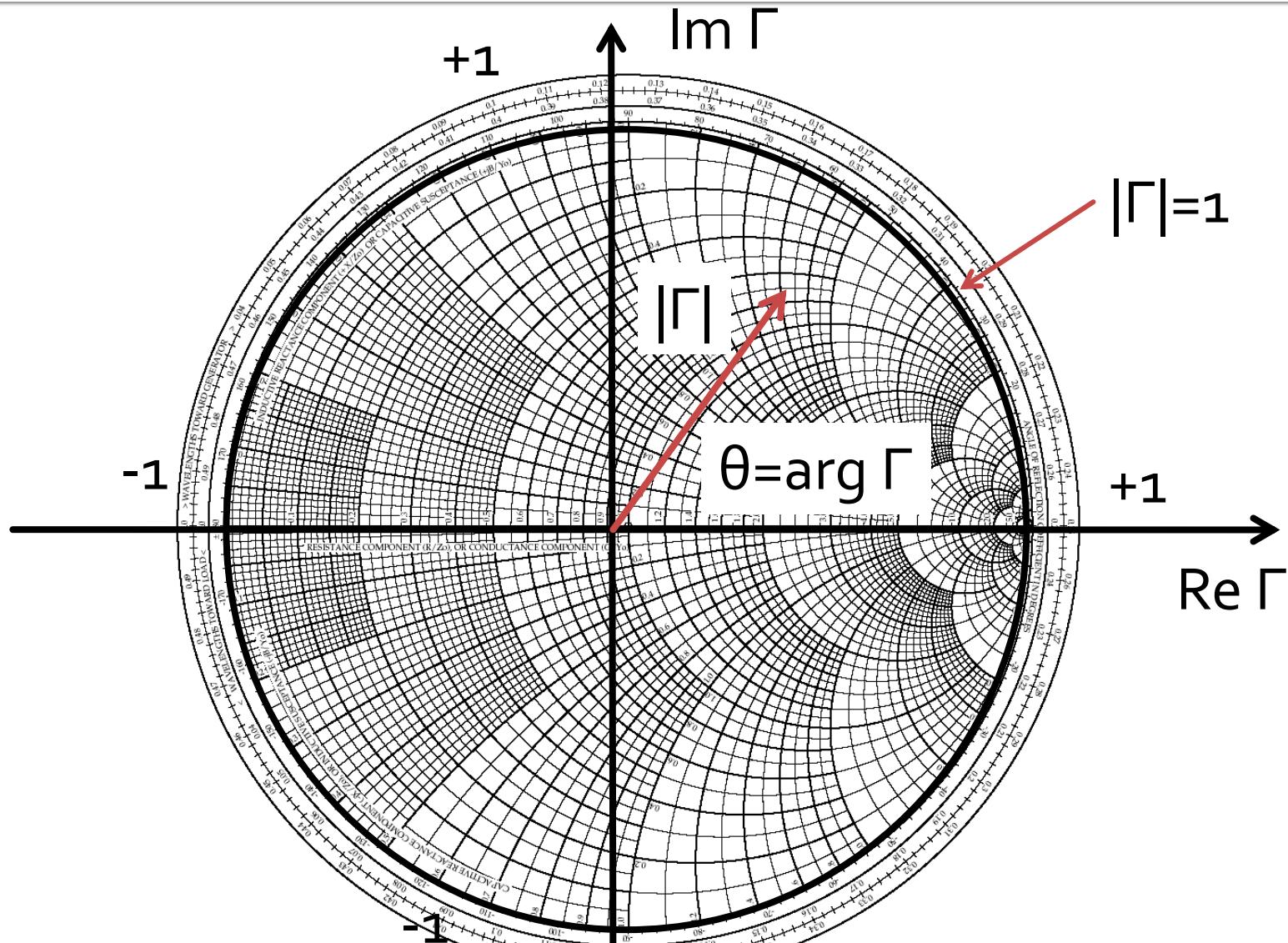
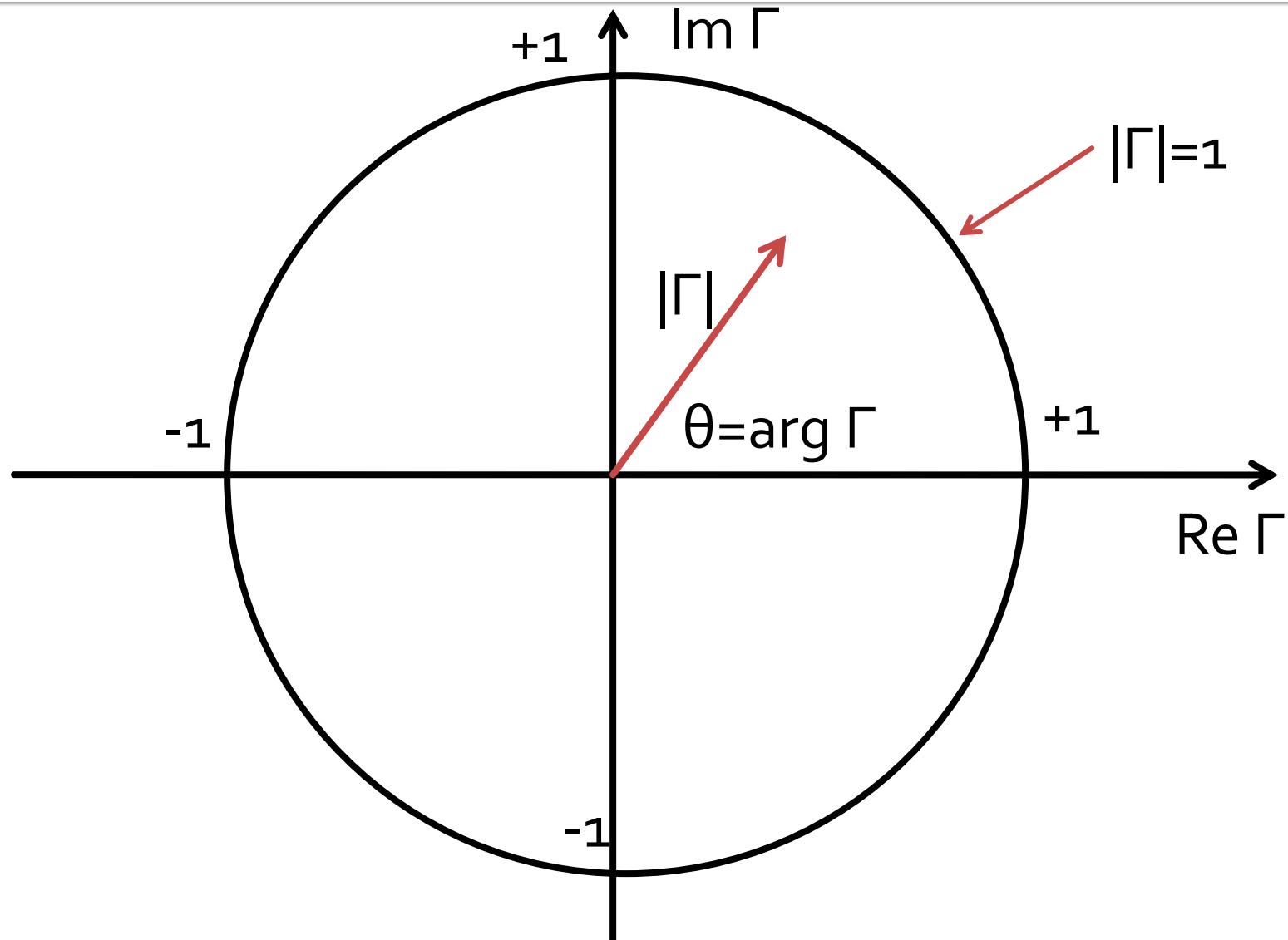


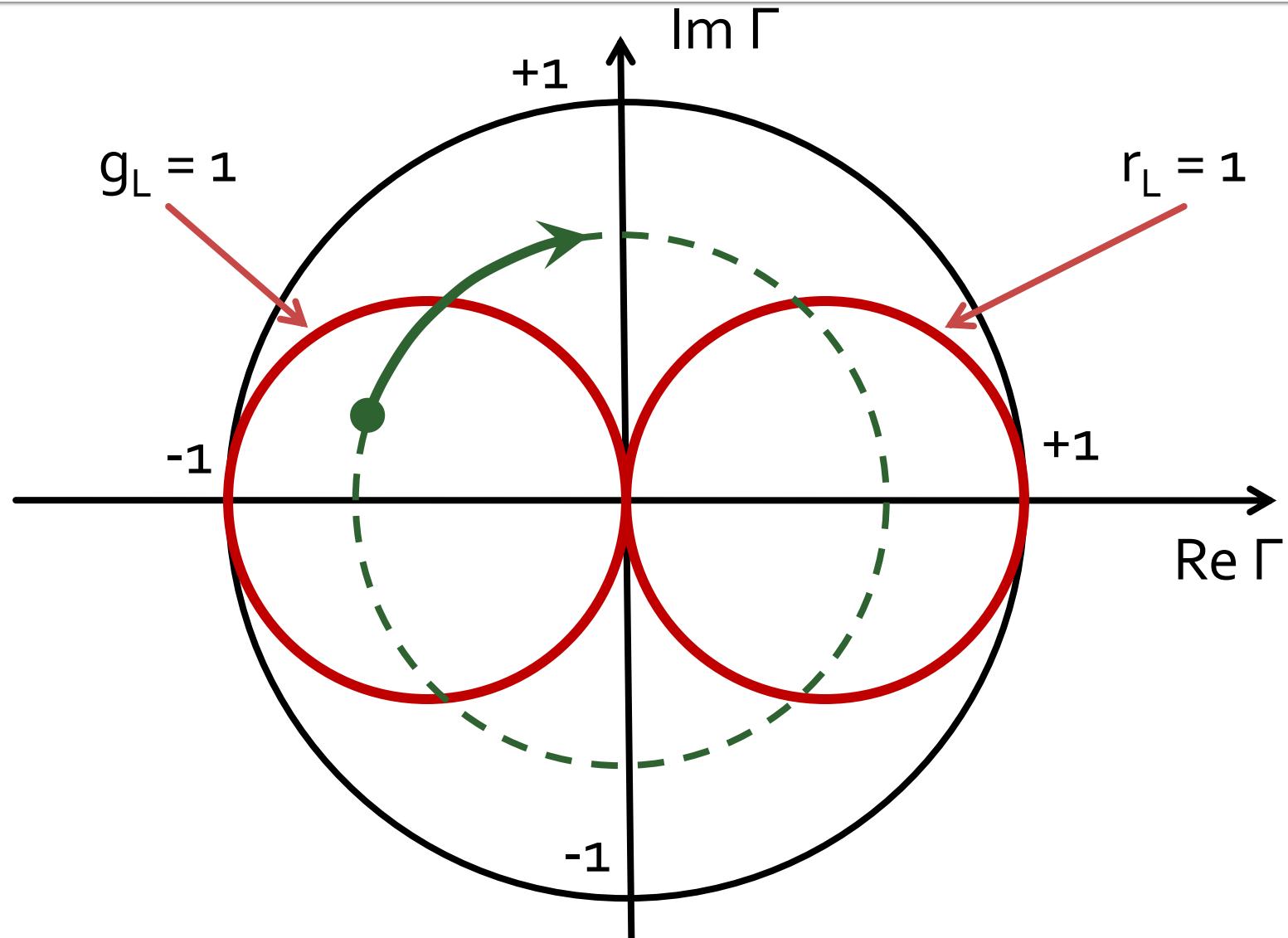
Diagrama Smith



Adaptarea cu sectiuni de linii (stub)

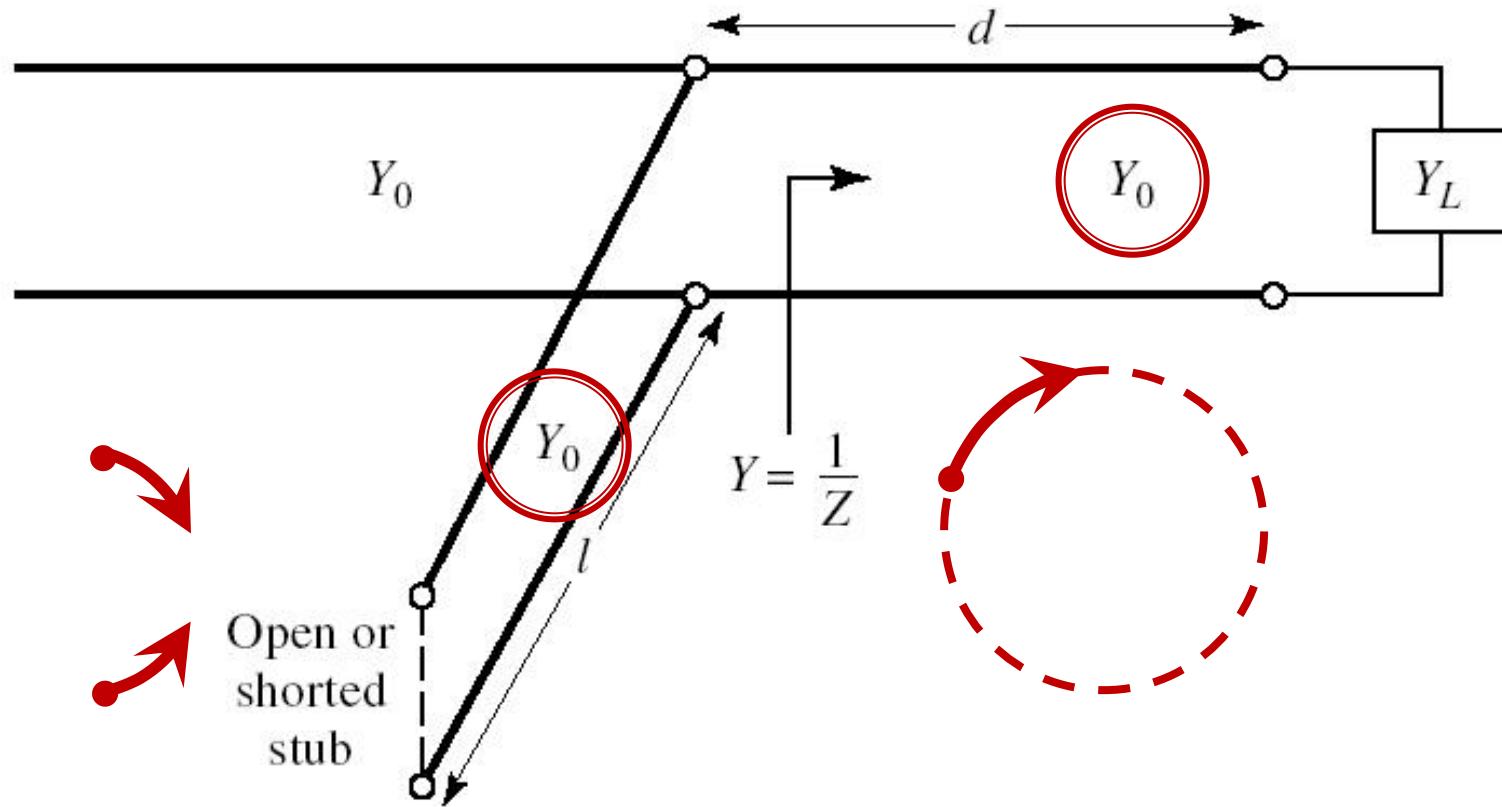
Adaptarea de impedanță

Diagrama Smith, $r=1$ si $g=1$



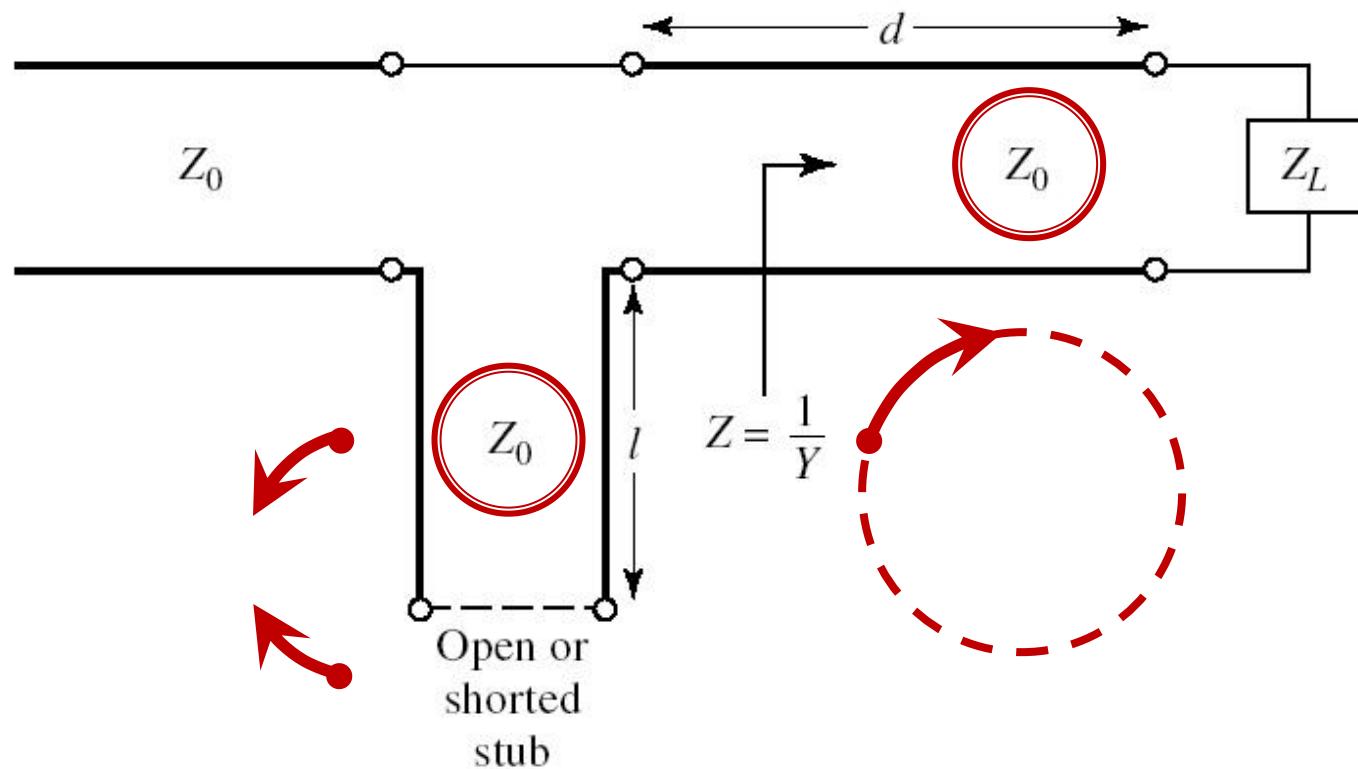
Single stub tuning

- Shunt Stub (secțiune de linie în paralel)



Single stub tuning

- Series Stub (secțiune de linie în serie)
- tehnologic mai dificil de realizat la liniile monofilare (microstrip)

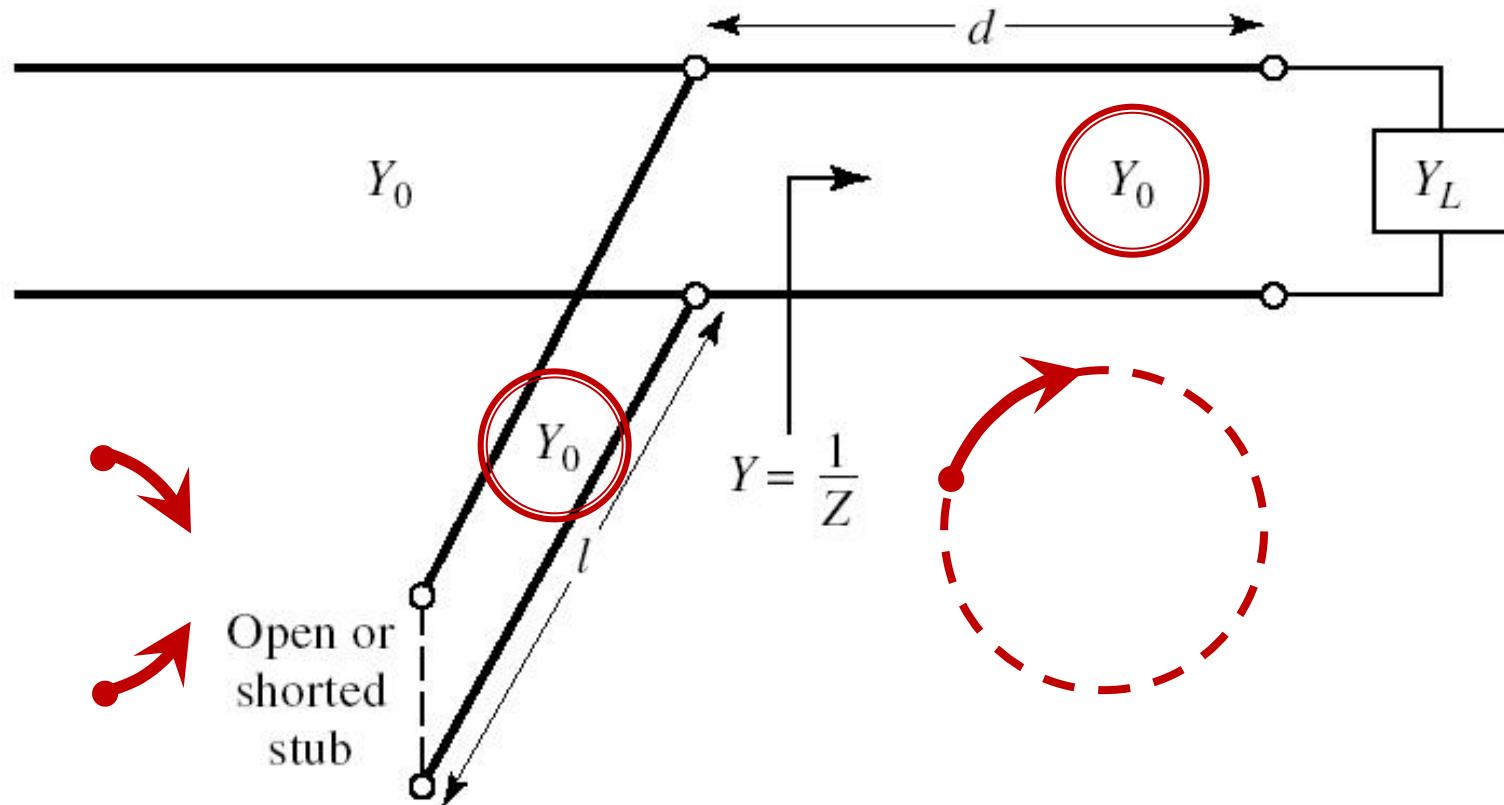


Solutii analitice

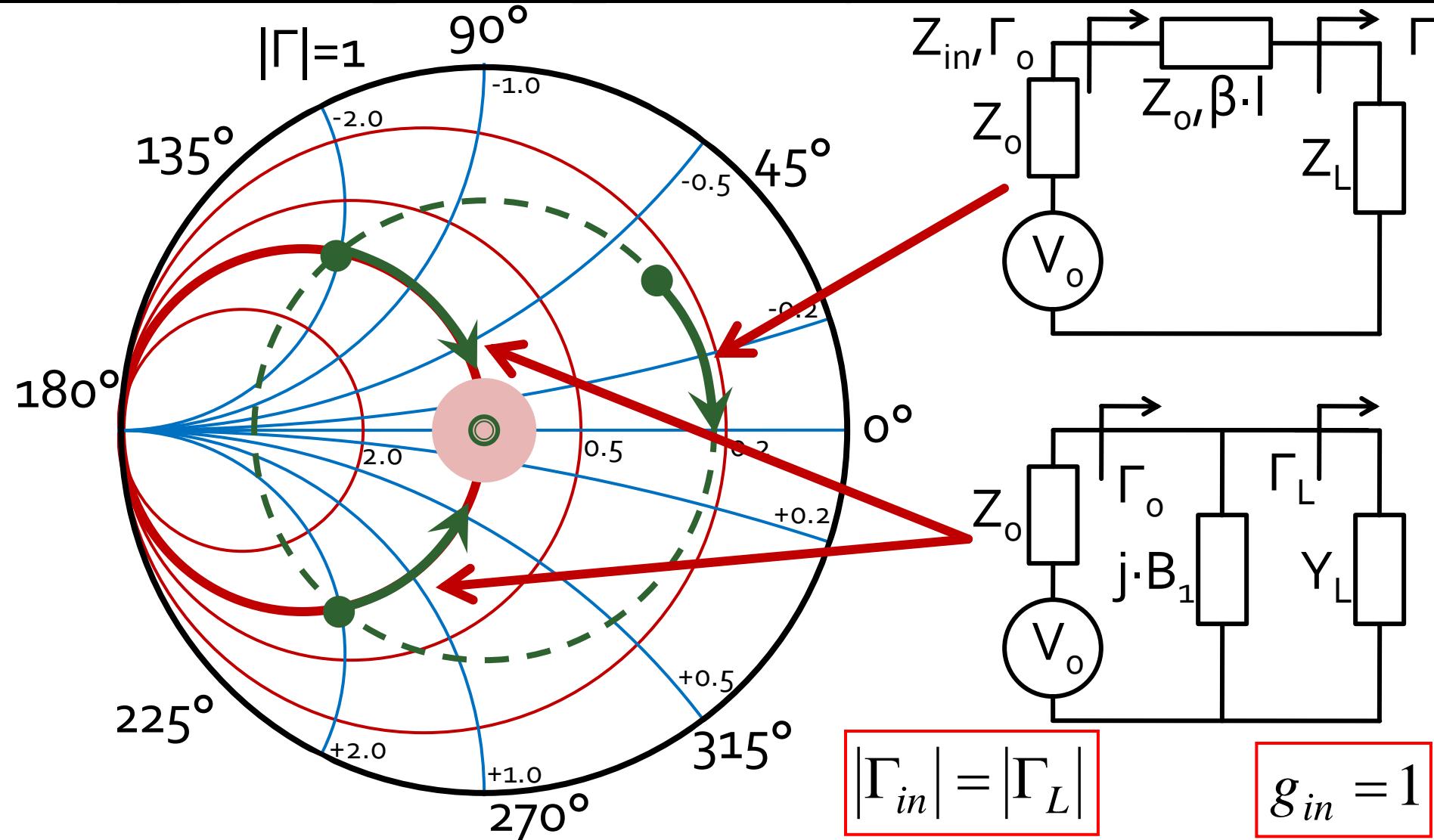
Examen / Proiect

Caz 1, Shunt Stub

- Shunt Stub (secțiune de linie în paralel)



Adaptare, linie serie + susceptanta in paralel



Calcul analitic (calcul efectiv)

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

$$|\Gamma_s| = 0.593 \angle 46.85^\circ$$

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

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

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

- **solutia "cu +"** 

$$(46.85^\circ + 2\theta) = +126.35^\circ \quad \theta = +39.7^\circ \quad \text{Im } y_s = \frac{-2 \cdot |\Gamma_s|}{\sqrt{1 - |\Gamma_s|^2}} = -1.472$$
$$\theta_{sp} = \tan^{-1}(\text{Im } y_s) = -55.8^\circ \underline{(+180^\circ)} \rightarrow \theta_{sp} = 124.2^\circ$$

- **solutia "cu -"** 

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

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

Calcul analitic (calcul efectiv)

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

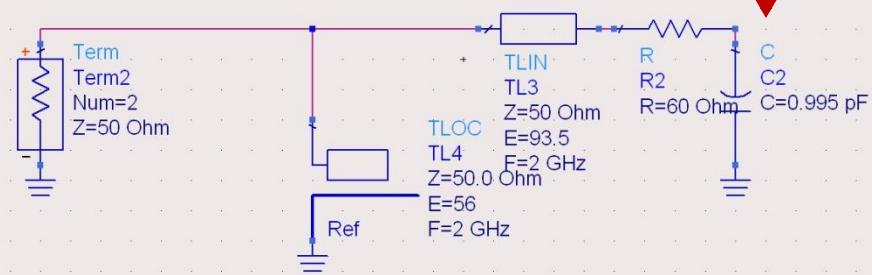
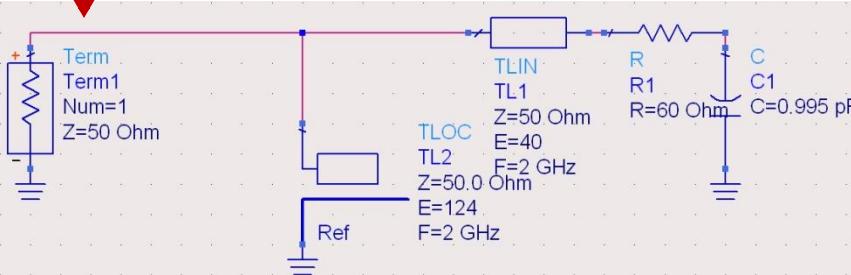
- Se alege **una** din cele doua solutii posibile
- **Semnul (+/-)** solutiei alese la **prima** ecuatie impune **semnul** solutiei utilizate la a **doua** ecuatie

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

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

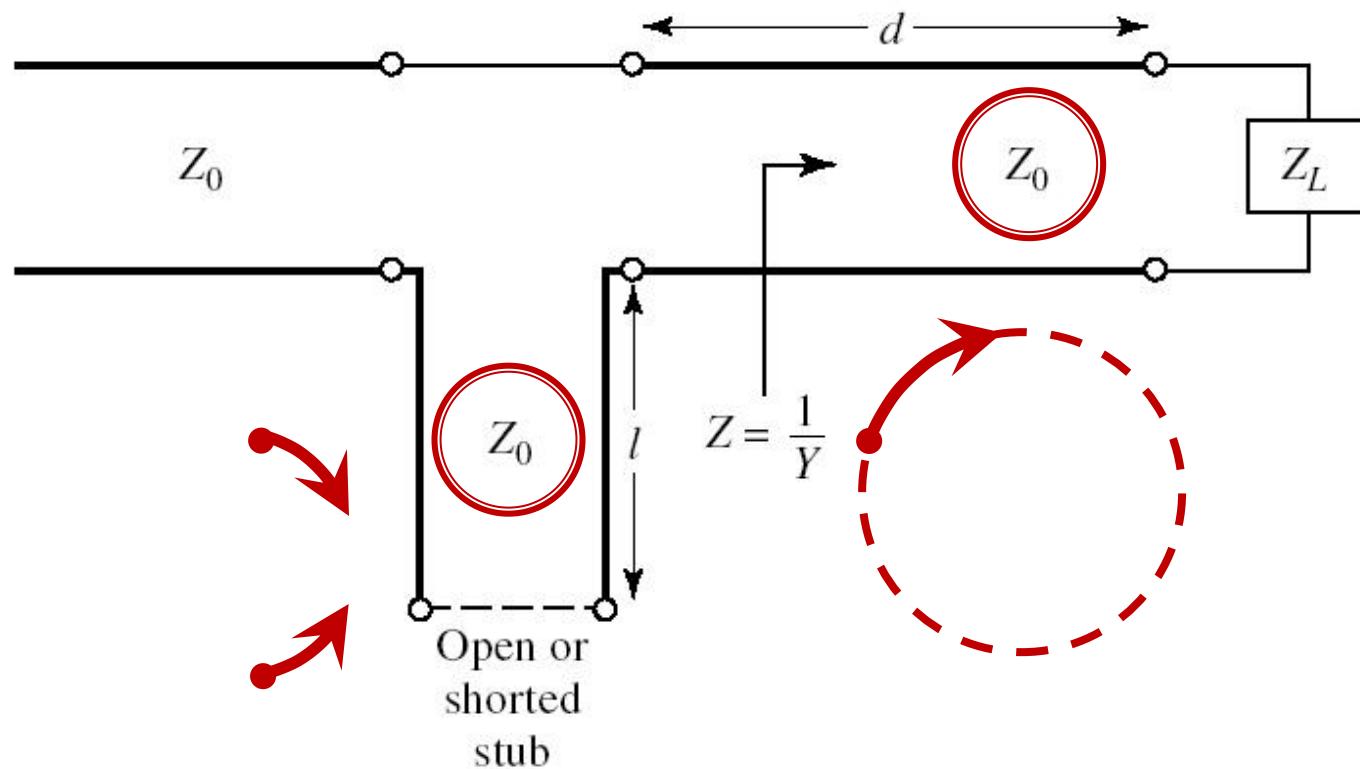
$$l_1 = \frac{93.4^\circ}{360^\circ} \cdot \lambda = 0.259 \cdot \lambda$$

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

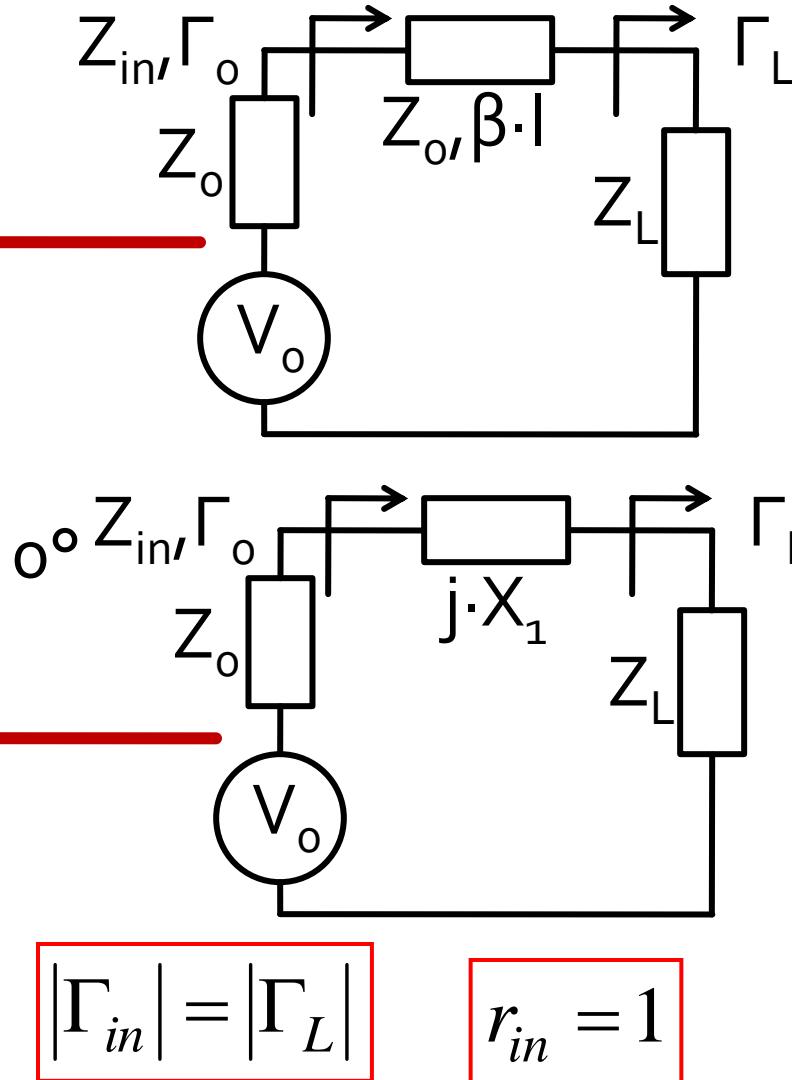
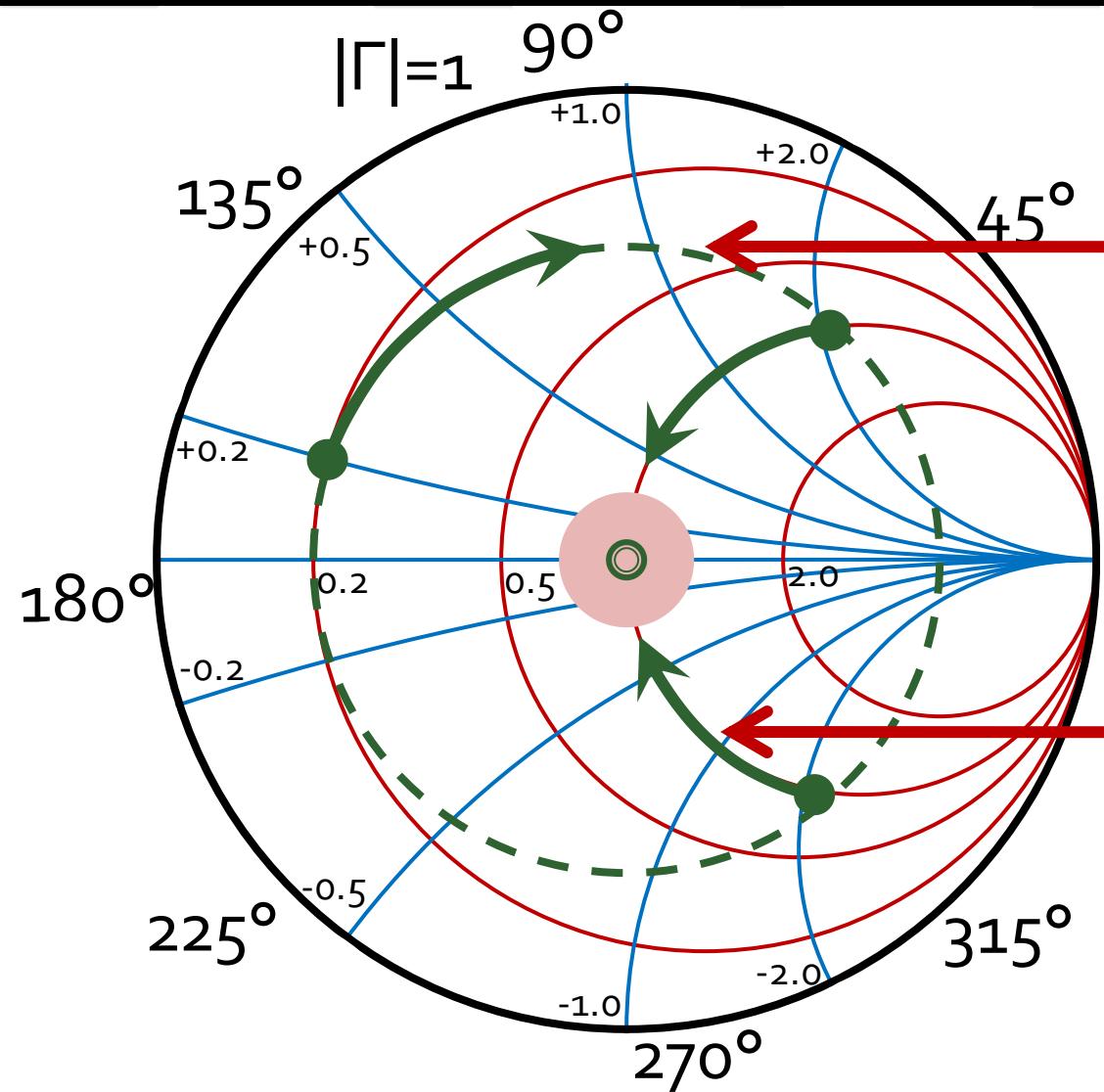


Caz 2, Series Stub

- Series Stub (secțiune de linie în serie)
- tehnologic mai dificil de realizat la liniile monofilare (microstrip)



Adaptare, linie serie + reactanta in serie



Calcul analitic (calcul efectiv)

$$\cos(\varphi + 2\theta) = |\Gamma_s|$$

$$\theta_{ss} = \beta \cdot l = \cot^{-1} \frac{\mp 2 \cdot |\Gamma_s|}{\sqrt{1 - |\Gamma_s|^2}}$$

$$|\Gamma_s| = 0.555 \angle -29.92^\circ$$

$$|\Gamma_s| = 0.555; \quad \varphi = -29.92^\circ \quad \cos(\varphi + 2\theta) = 0.555 \Rightarrow (\varphi + 2\theta) = \pm 56.28^\circ$$

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

- **solutia "cu +"**

$$(-29.92^\circ + 2\theta) = +56.28^\circ \quad \theta = 43.1^\circ \quad \text{Im } z_s = \frac{+2 \cdot |\Gamma_s|}{\sqrt{1 - |\Gamma_s|^2}} = +1.335$$

$$\theta_{ss} = -\cot^{-1}(\text{Im } z_s) = -36.8^\circ \underline{(+180^\circ)} \rightarrow \theta_{ss} = 143.2^\circ$$

- **solutia "cu -"**

$$(-29.92^\circ + 2\theta) = -56.28^\circ \quad \theta = -13.2^\circ \underline{(+180^\circ)} \rightarrow \theta = 166.8^\circ$$

$$\text{Im } z_s = \frac{-2 \cdot |\Gamma_s|}{\sqrt{1 - |\Gamma_s|^2}} = -1.335$$

$$\theta_{ss} = -\cot^{-1}(\text{Im } z_s) = 36.8^\circ$$

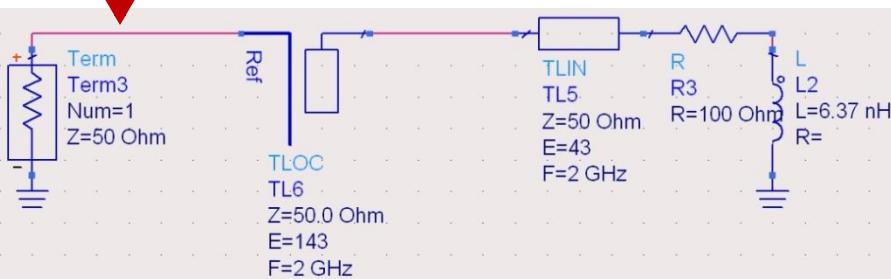
Calcul analitic (calcul efectiv)

$$(\varphi + 2\theta) = \begin{cases} +56.28^\circ \\ -56.28^\circ \end{cases} \quad \theta = \begin{cases} 43.1^\circ \\ 166.8^\circ \end{cases} \quad \text{Im}[z_s(\theta)] = \begin{cases} +1.335 \\ -1.335 \end{cases} \quad \theta_{ss} = \begin{cases} -36.8^\circ + 180^\circ = 143.2^\circ \\ +36.8^\circ \end{cases}$$

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

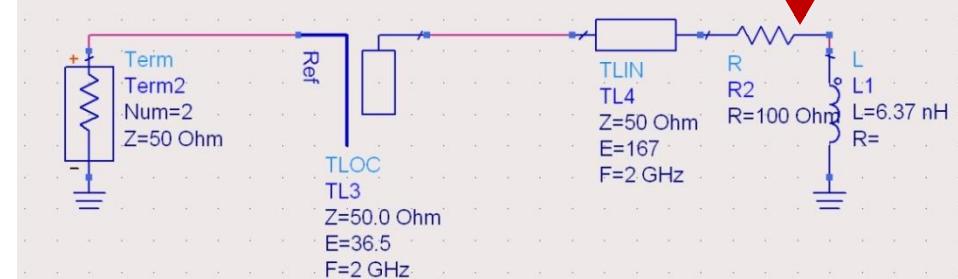
$$l_1 = \frac{43.1^\circ}{360^\circ} \cdot \lambda = 0.120 \cdot \lambda$$

$$l_2 = \frac{143.2^\circ}{360^\circ} \cdot \lambda = 0.398 \cdot \lambda$$



$$l_1 = \frac{166.8^\circ}{360^\circ} \cdot \lambda = 0.463 \cdot \lambda$$

$$l_2 = \frac{36.8^\circ}{360^\circ} \cdot \lambda = 0.102 \cdot \lambda$$



Stub, observatii

- adunarea si scadere de **180°** ($\lambda/2$) nu schimba rezultatul (rotatie completa in jurul diagramei)

$$E = \beta \cdot l = \pi = 180^\circ \quad l = k \cdot \frac{\lambda}{2}, \forall k \in \mathbf{N}$$

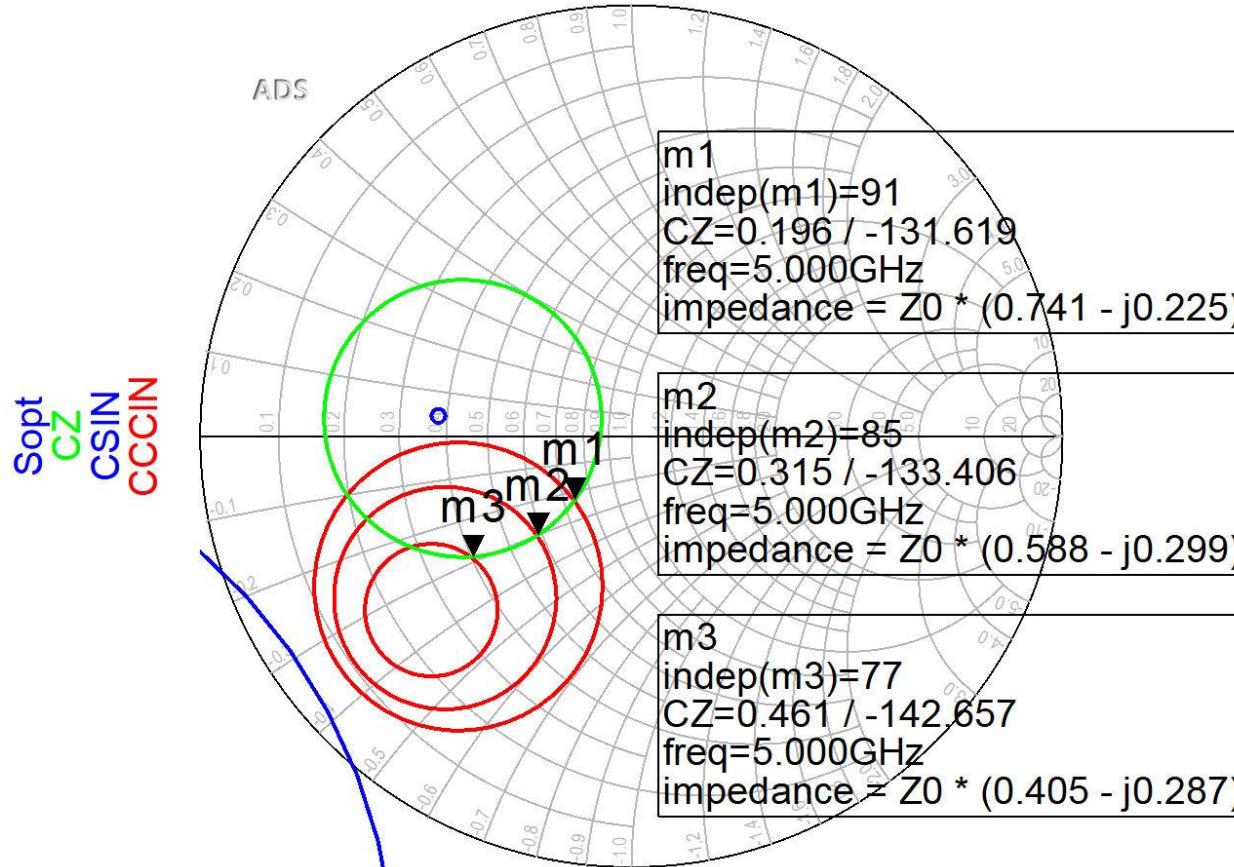
- pentru linii de “lungime” / “lungime electrica” **negative** se adauga $\lambda/2$ / 180° pentru a avea valoare pozitiva (realizabila fizic)
- o adaugare sau scadere de **90°** ($\lambda/4$) transforma impedanta stub-ului:

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

- pentru stub se poate adauga/scadea 90° ($\lambda/4$) simultan cu schimbare **gol** \Leftrightarrow **scurtcircuit**

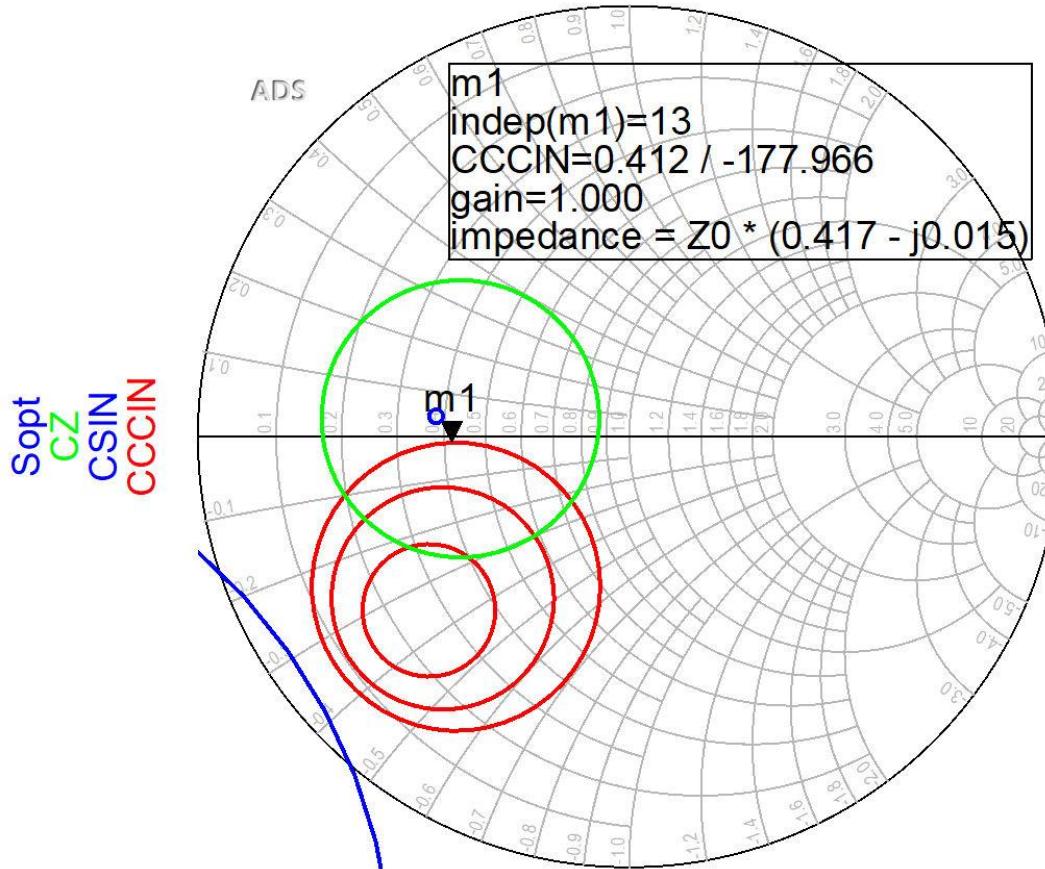
Amplificatoare de microunde

Adaptare la intrare



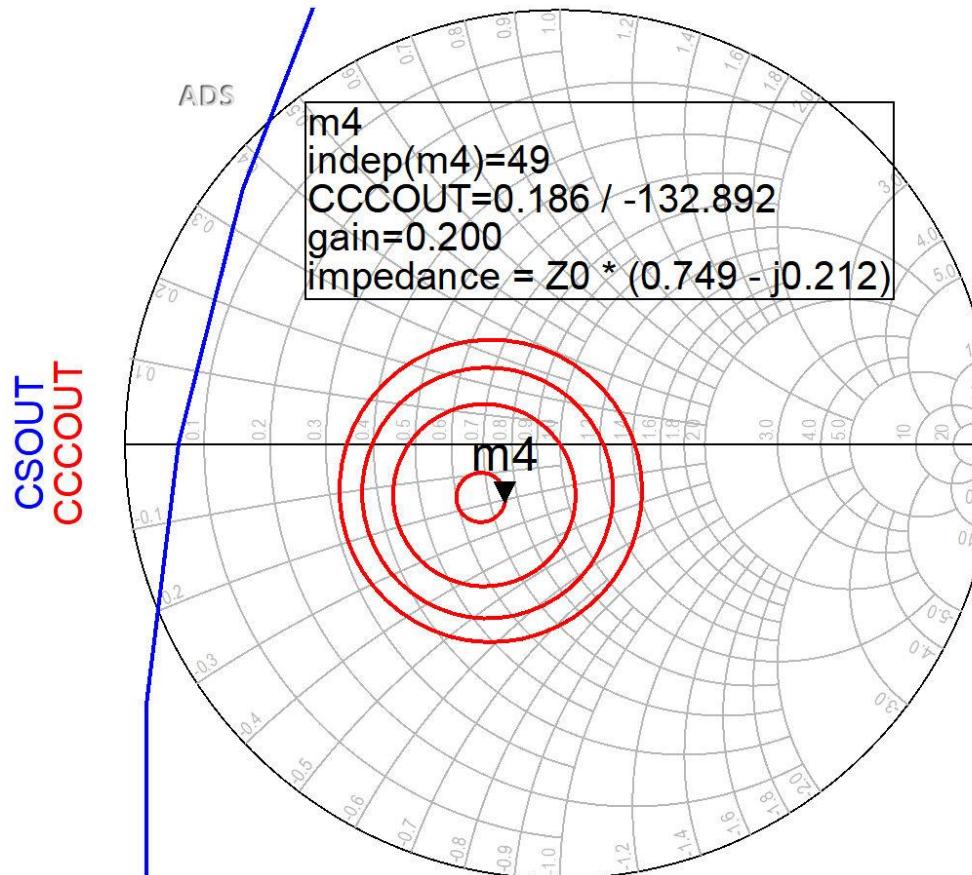
- Pentru reteaua de adaptare la intrare
 - CZ: 0.75dB
 - CCCIN: 1dB, 1.5dB, 2 dB
- Aleg (Q mic → banda largă) pozitia m1

Adaptare la intrare



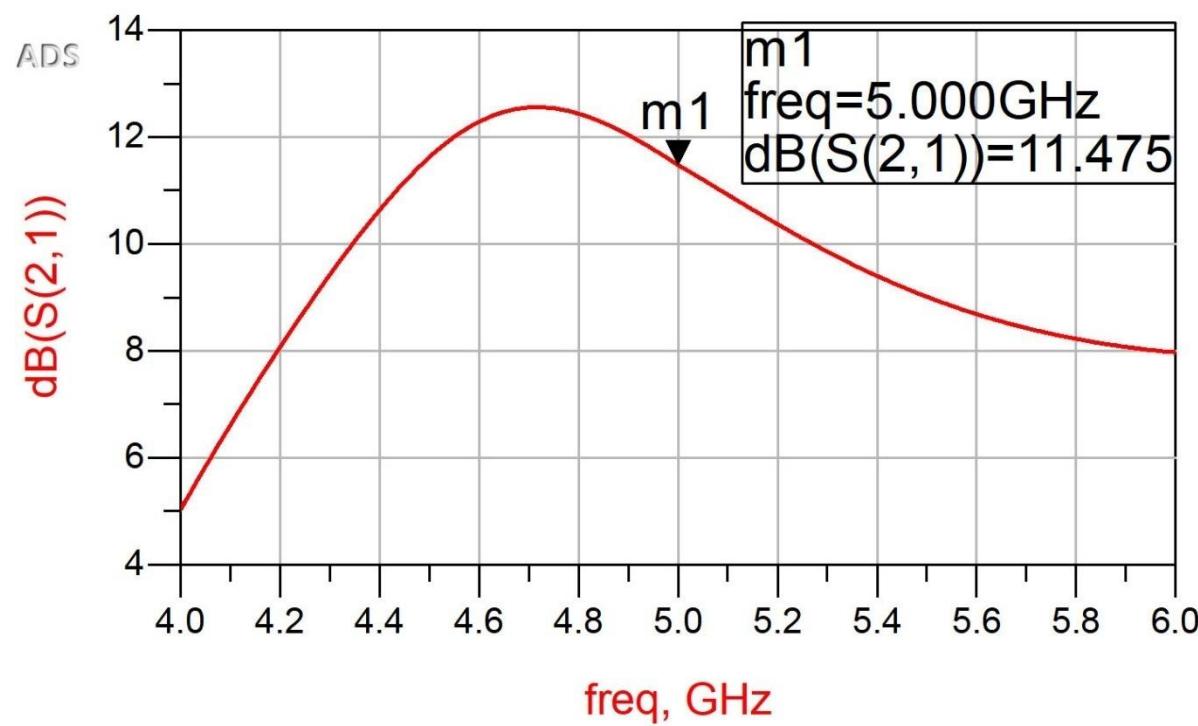
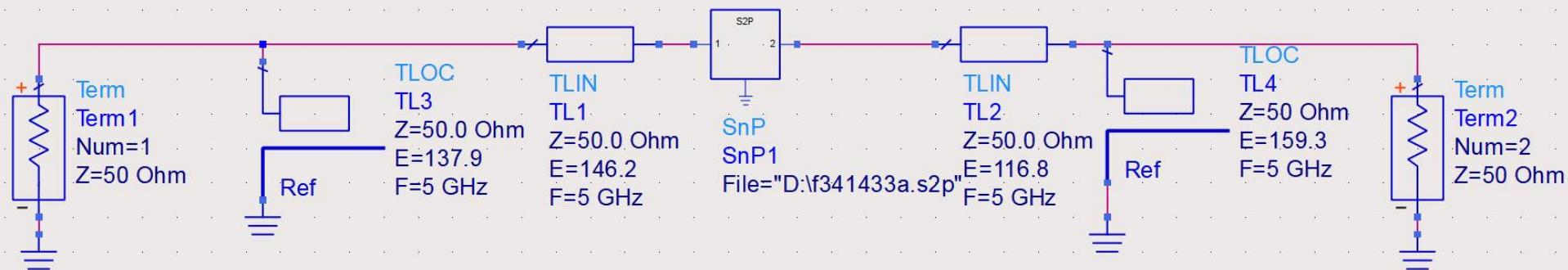
- Daca se sacrifică 1.2dB castig la intrare pentru conditii convenabile F,Q (Gs = 1 dB)
- Se prefera obtinerea unui zgomot mai mic

Adaptare la ieșire

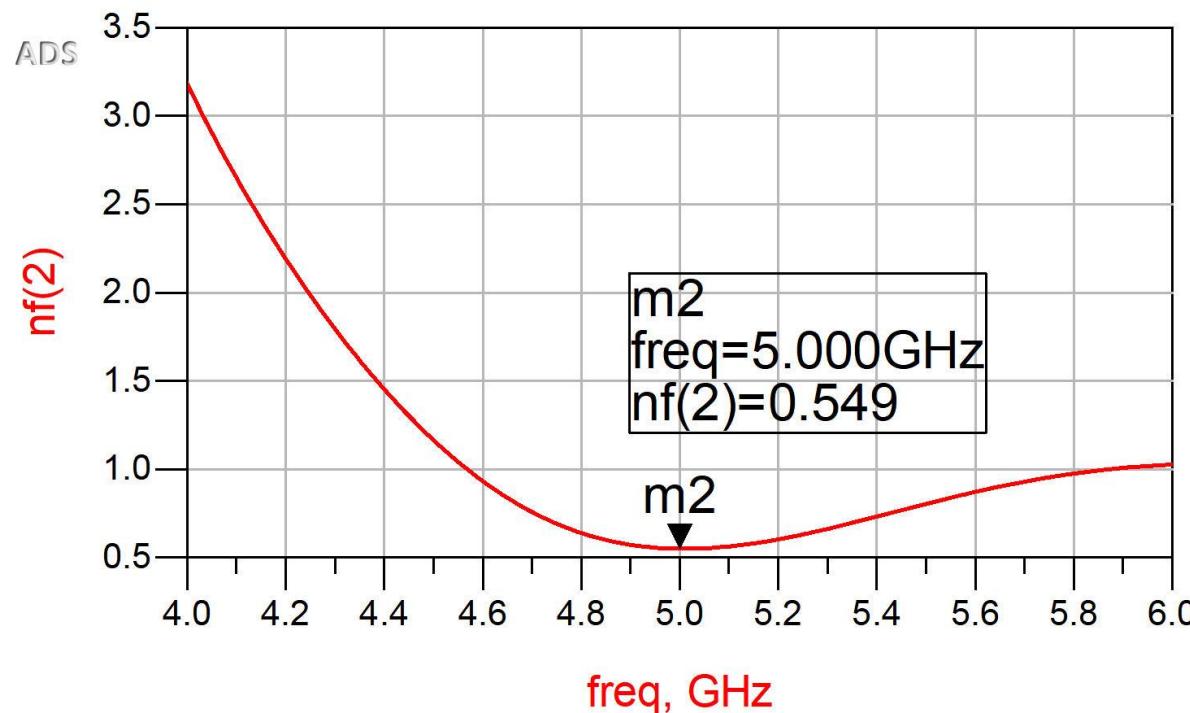
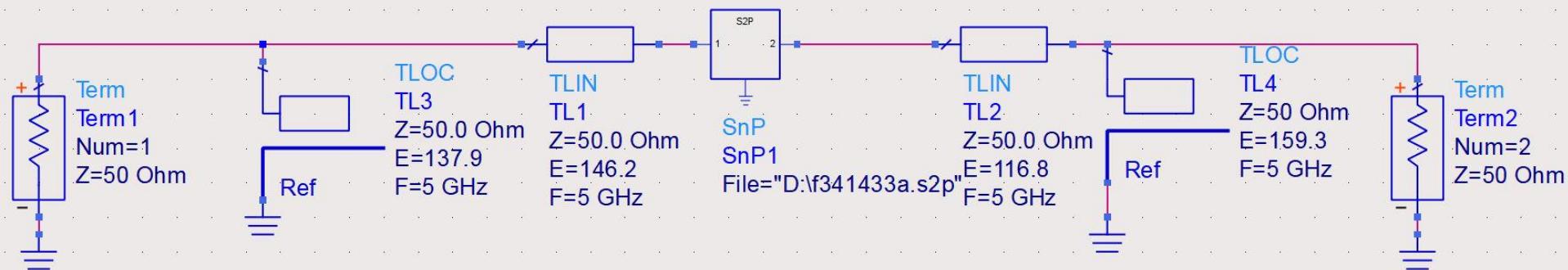


- CCCOUT: -0.4dB, -0.2dB, 0dB, +0.2dB
- Lipsa conditiilor privitoare la zgomot ofera posibilitatea obtinerii unui castig mai mare (spre maxim)

ADS



ADS



Adaptare – 4

- Varianta cea mai simplă de implementare, și pentru care există relații analitice de calcul constă în introducerea (în ordine, de la tranzistor spre sursă Z_0):
 - o secțiune de linie serie, cu impedanța caracteristică Z_0 și lungime electrică θ
 - un **stub paralel**, lasat în gol la capăt, realizat dintr-o linie cu impedanța caracteristică Z_0 și lungime electrică θ_{sp}

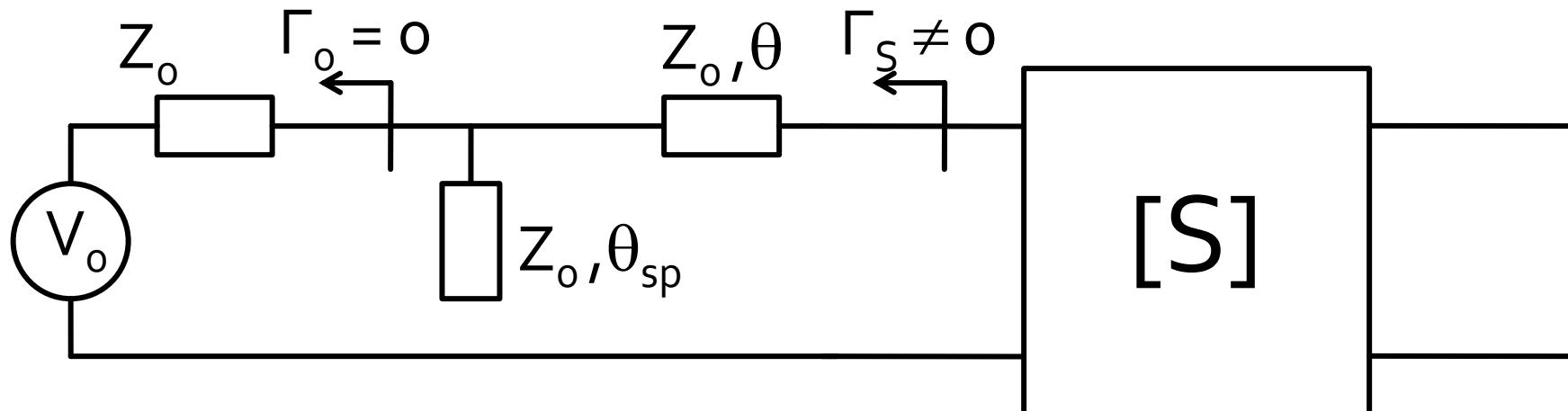


Diagrama Smith, $r=1$ si $g=1$

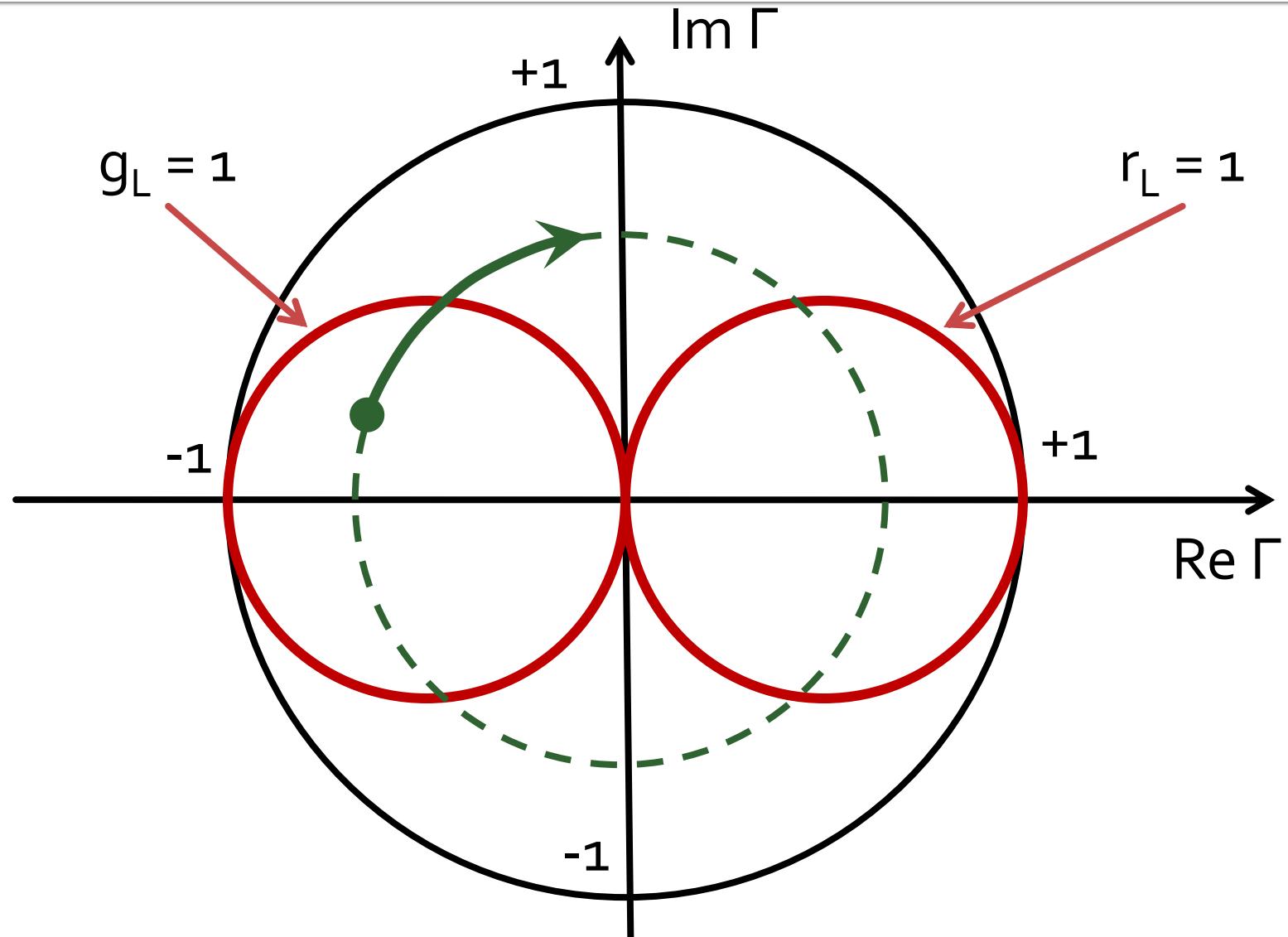
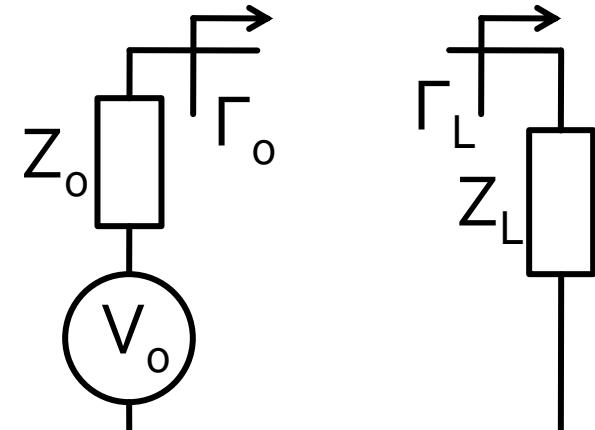
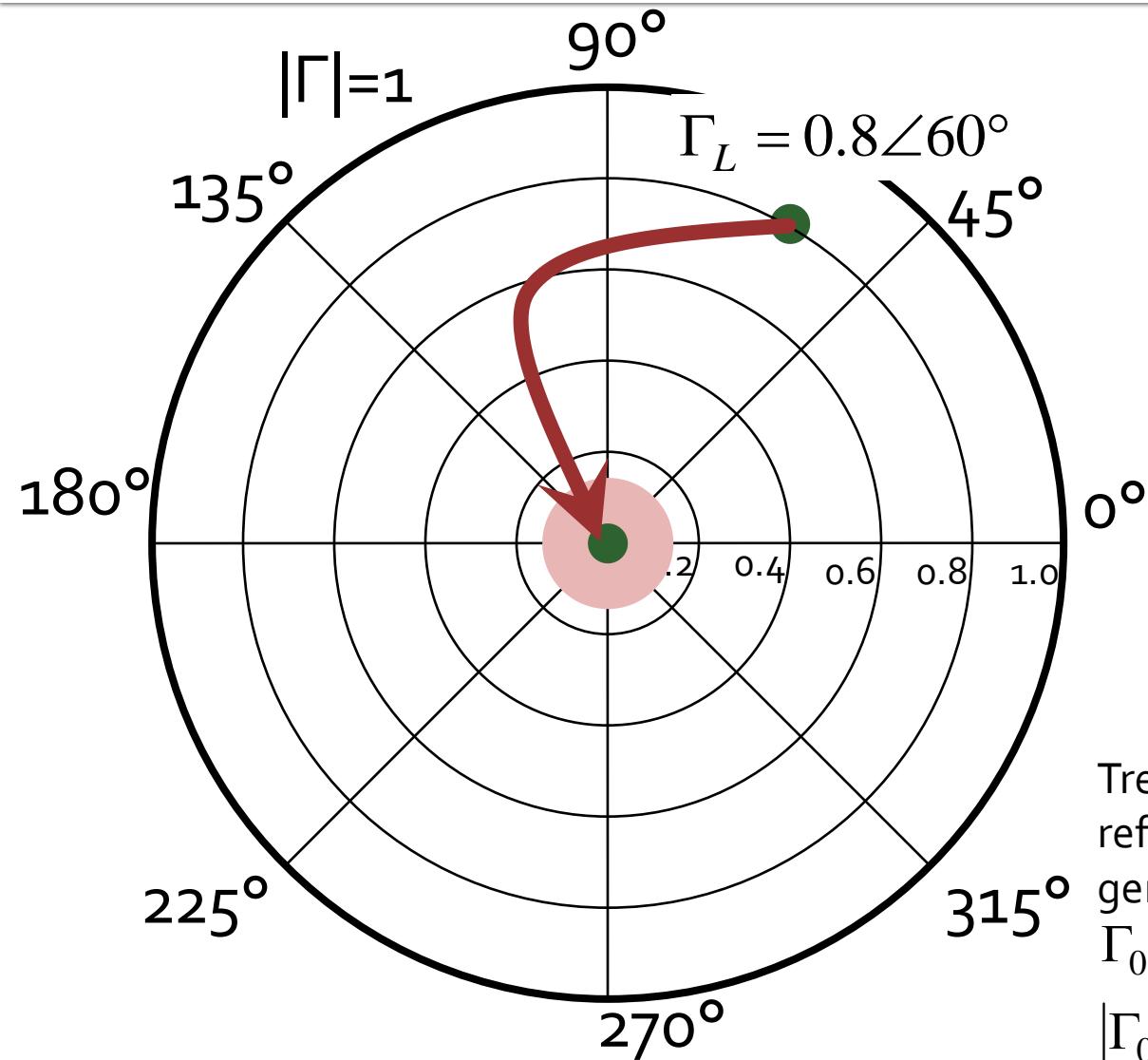


Diagrama Smith, adaptare, $Z_L \neq Z_o$

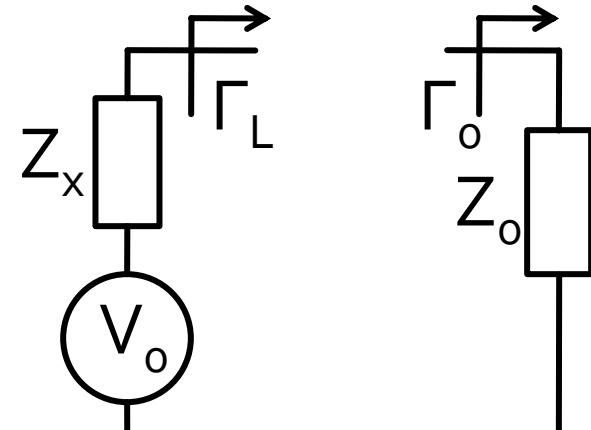
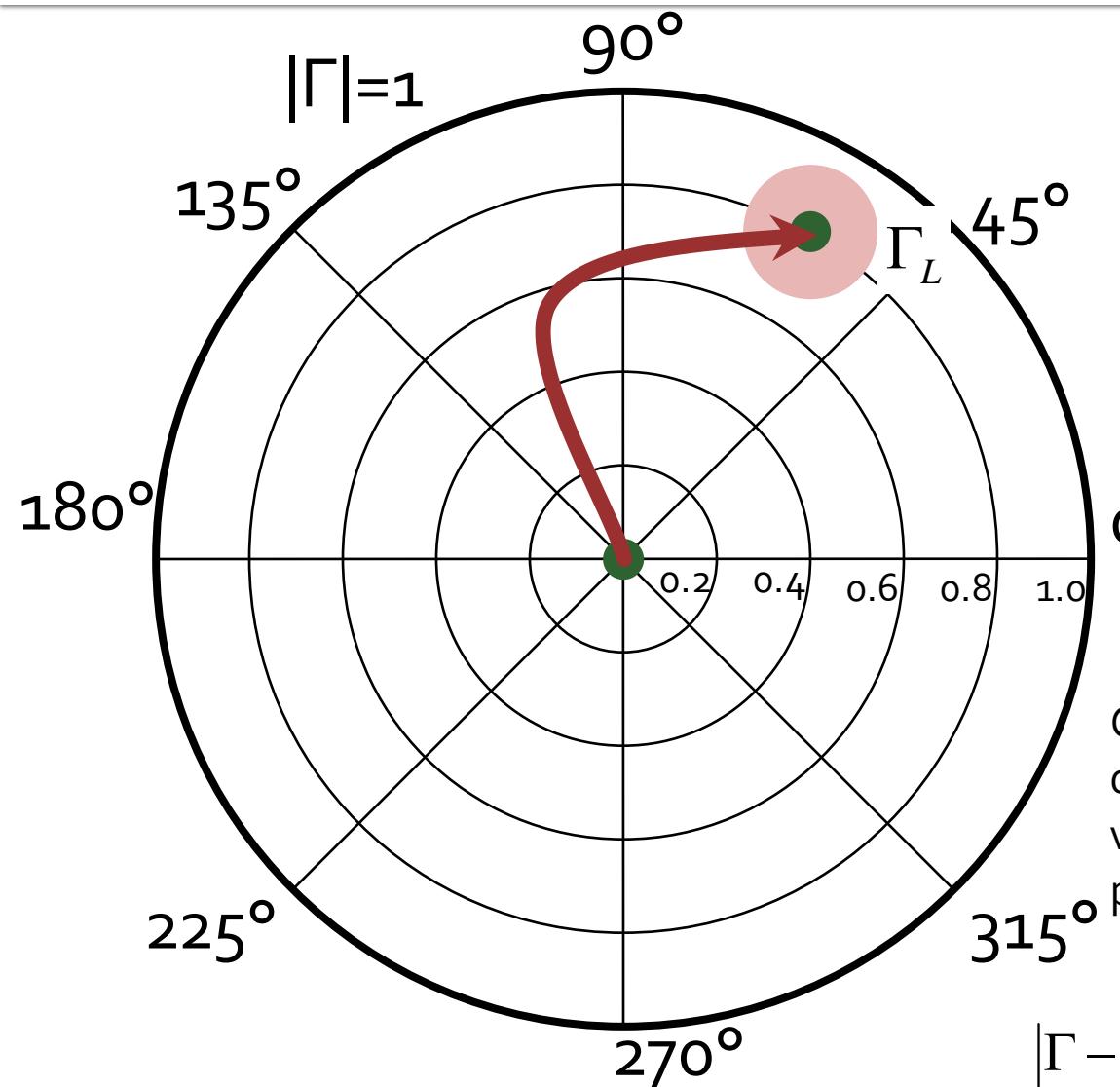


Adaptare Z_L la Z_o . Se raporteaza Z_L la Z_o
 $Z_L = 21.429\Omega + j \cdot 82.479\Omega$
 $z_L = 0.429 + j \cdot 1.65$
 $\Gamma_L = 0.8\angle 60^\circ$

Trebuie sa deplasez coeficientul de reflexie in zona in care pentru generator cu Z_o am:
 $\Gamma_0 = 0$ adaptare perfecta

$|\Gamma_0| \leq \Gamma_m$ adaptare "suficienta"

Diagrama Smith, adaptare, $Z_L = Z_o$



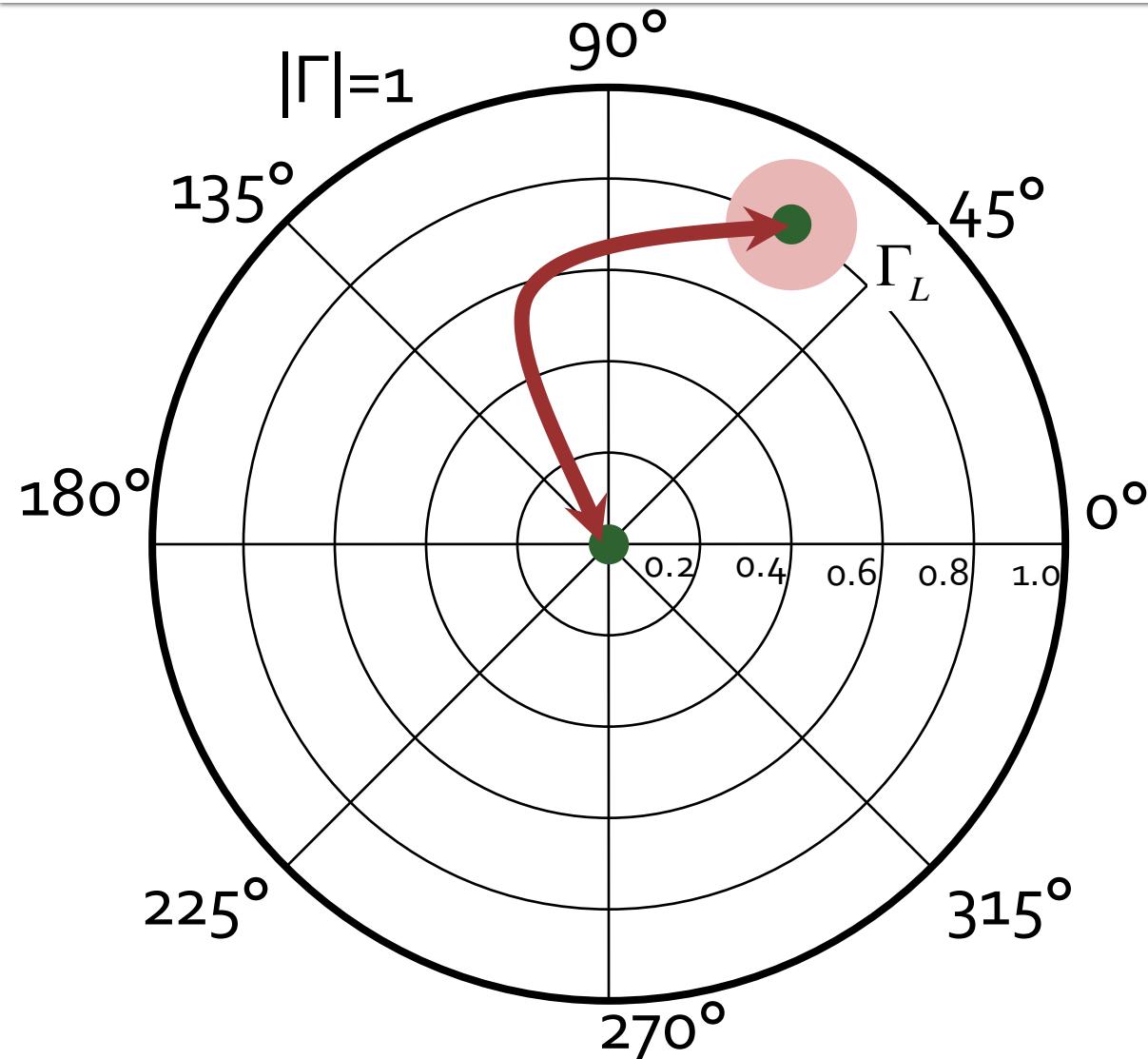
Sursa (de ex. tranzistorul) cu Z_x are nevoie de un anumit coeficient de reflexie Γ_L pentru a functiona corect

Circuitul de adaptare trebuie sa deplaseze coeficientul de reflexie vazut spre sarcina in zona in care pentru sarcina Z_o ($\Gamma_o=0$) am:

$\Gamma = \Gamma_L$ adaptare perfecta

$|\Gamma - \Gamma_L| \leq \Gamma_m$ adaptare "suficientă"

Diagrama Smith, adaptare, $Z_L = Z_o$



- Circuitele de adaptare care mută
 - Γ_L în Γ_o
 - Γ_o în Γ_L
- sunt **identice** ca realizare. Difera doar prin **ordinea** în care se introduc elementele în circuitul de adaptare
- Ca urmare se pot folosi în proiectarea circuitelor de adaptare aceleasi:
 - **metode**
 - **relatii**

Amplificatoare de banda largă

Amplificatoare de microunde

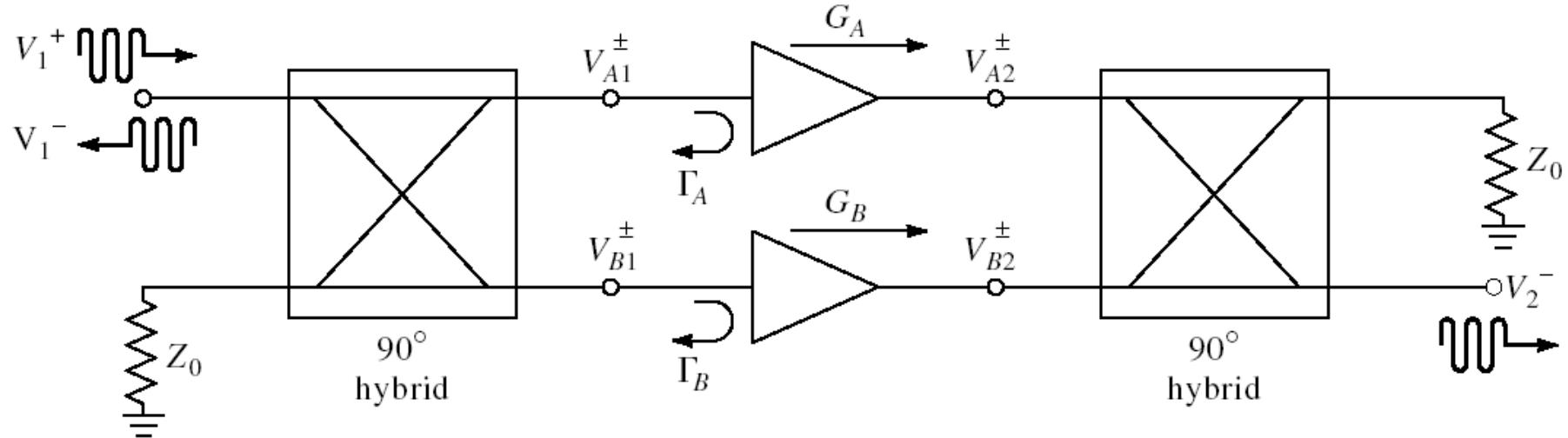
Cuprins

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

Amplificatoare de banda largă

- Se pot obține prin un număr de tehnici de proiectare
 1. Retele de adaptare care să compenseze scaderea castigului cu frecvența
 2. Retele de adaptare rezistive
 3. Reactie negativa
 4. Amplificatoare echilibratе
 5. Amplificatoare distribuite
 6. Amplificatoare diferențiale

Amplificatoare echilibrate



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

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

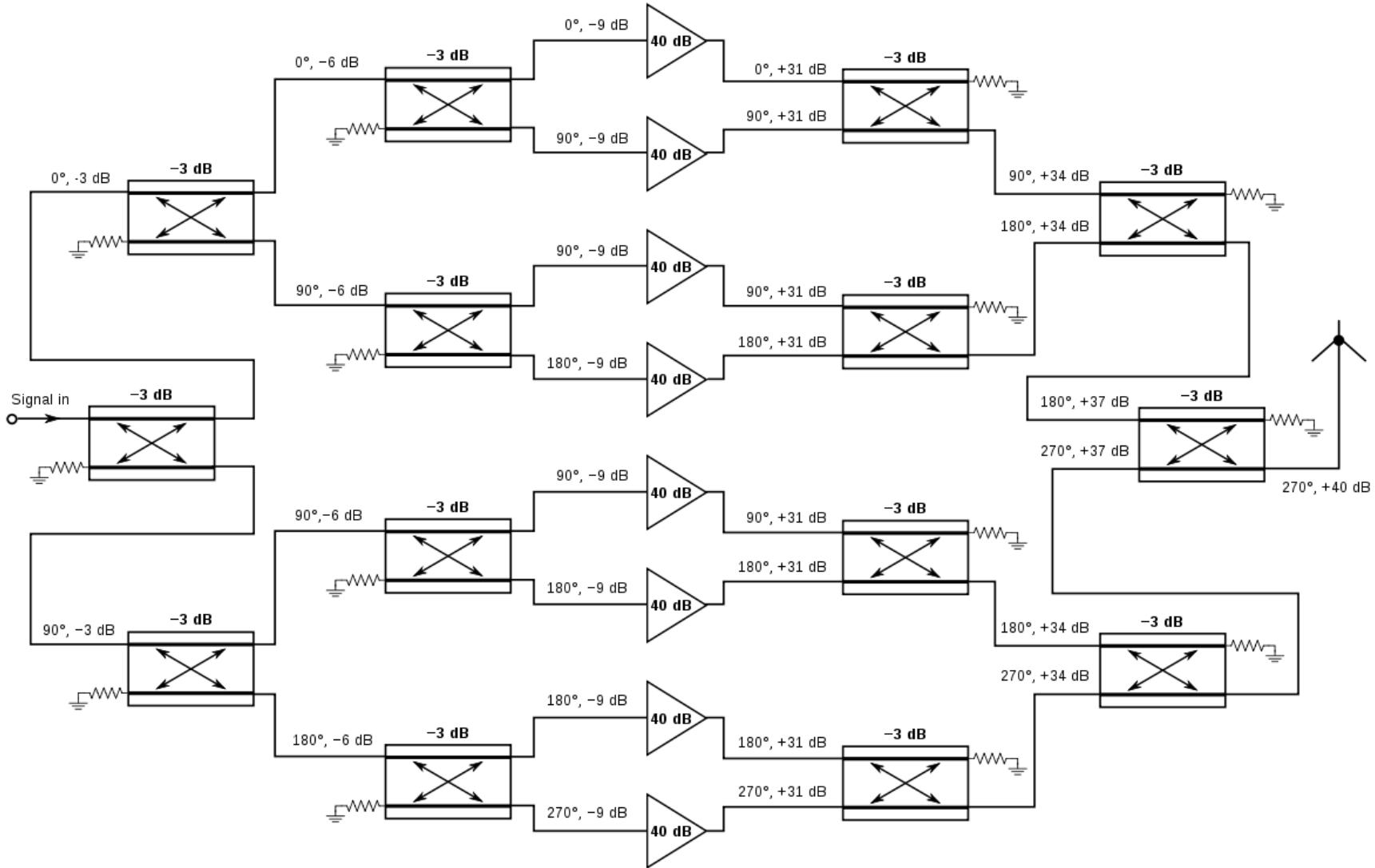
$$S_{11} = \frac{1}{2} \cdot (\Gamma_A - \Gamma_B)$$

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

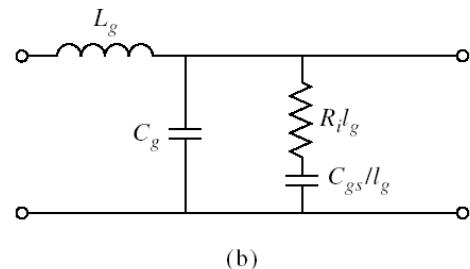
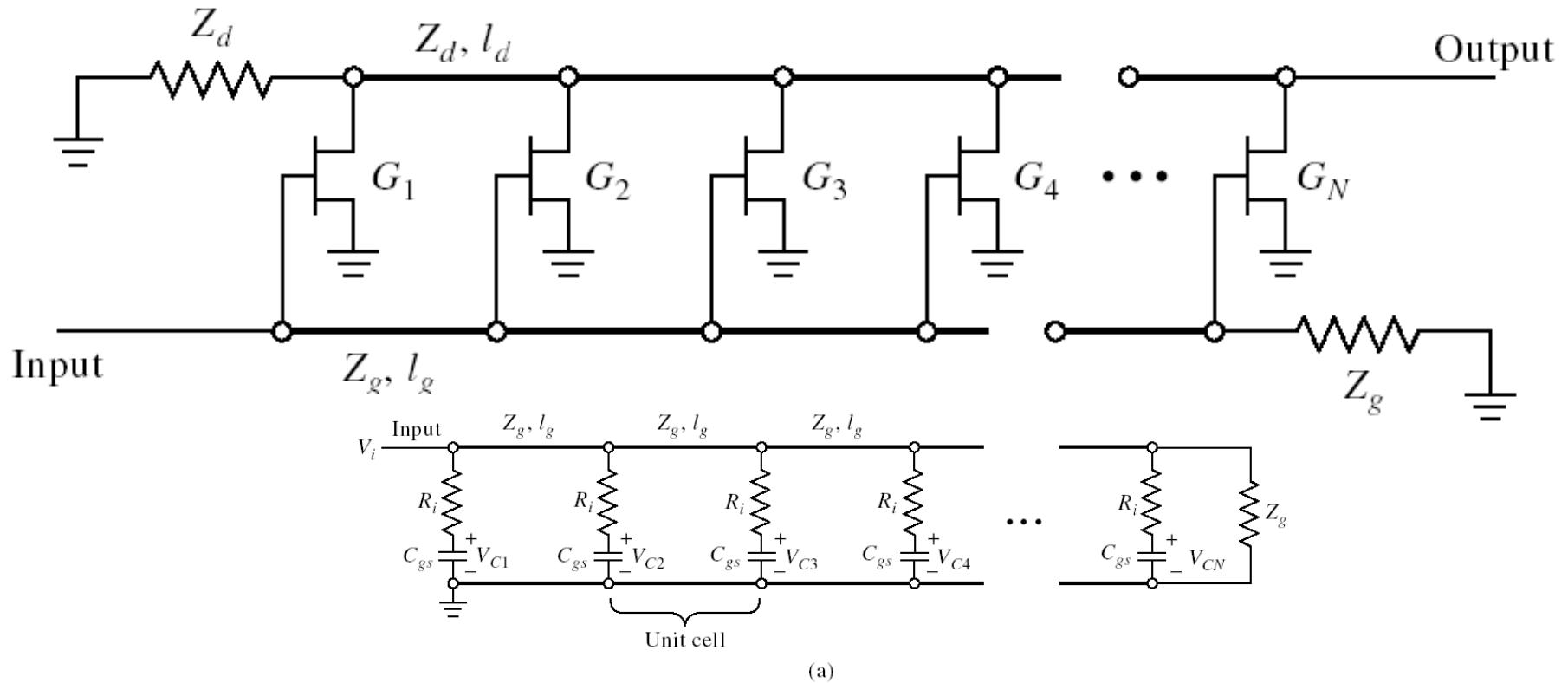
$$S_{21}|_{A=B} = -j \cdot G$$

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

Amplificatoare echilibrate



Amplificatoare distribuite



Amplificatoare distribuite

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

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

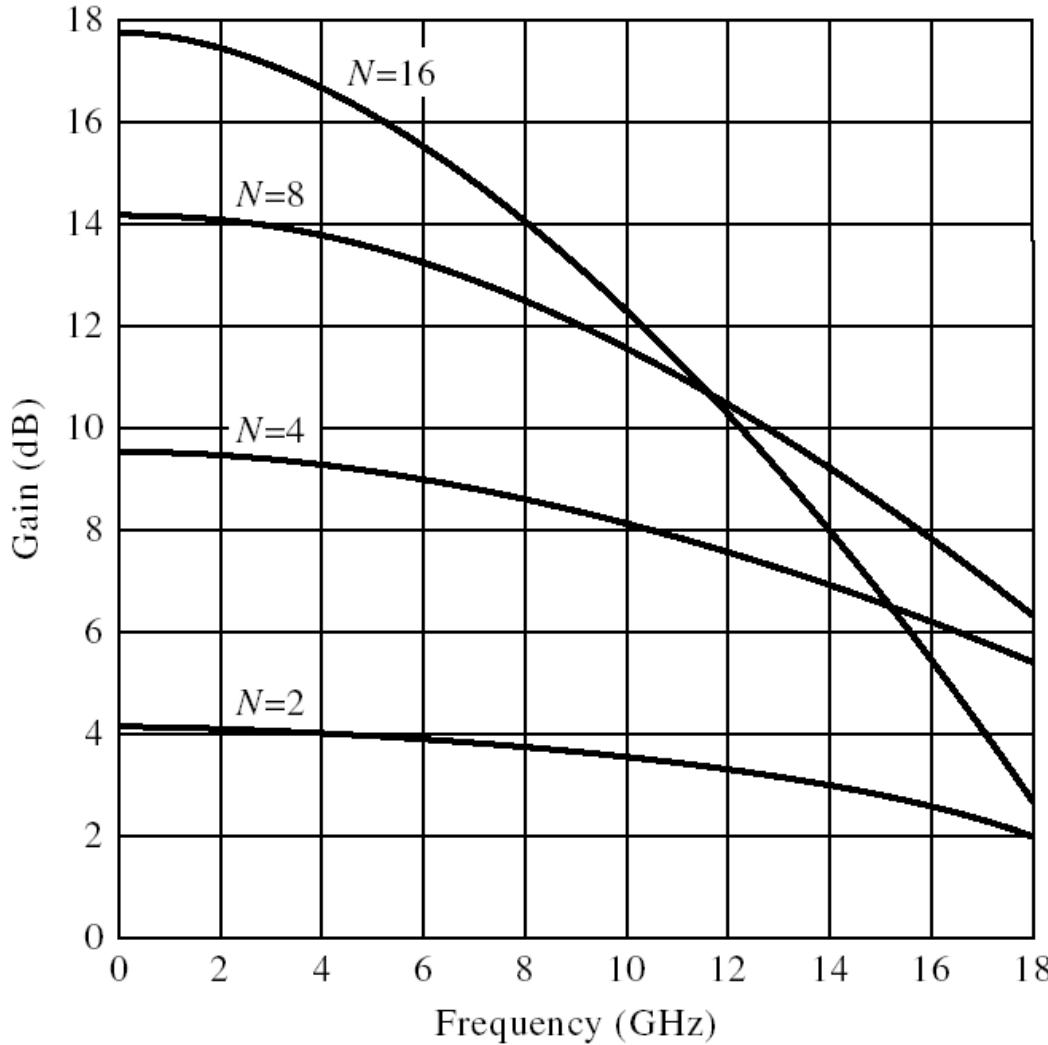
- Castigul de putere

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

- Castigul de putere fara pierderi

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

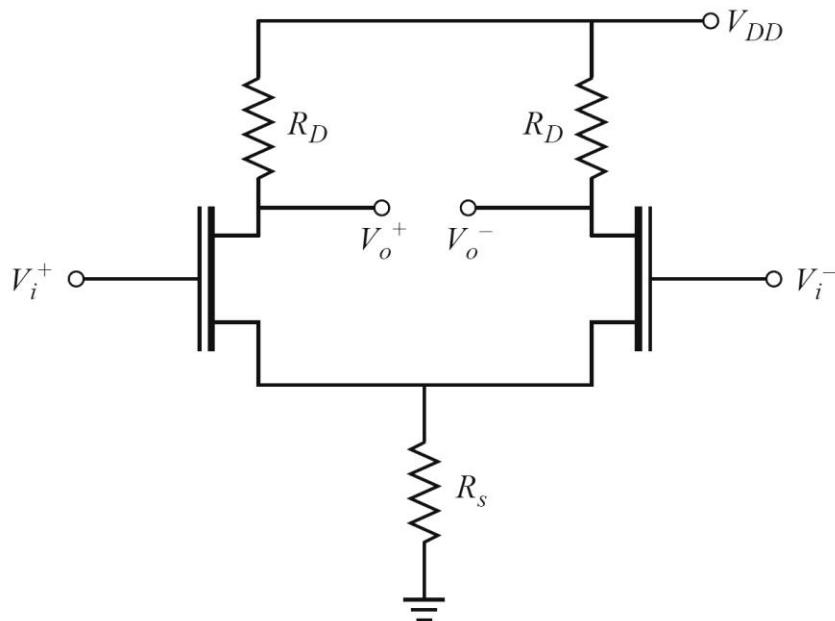
Amplificatoare distribuite



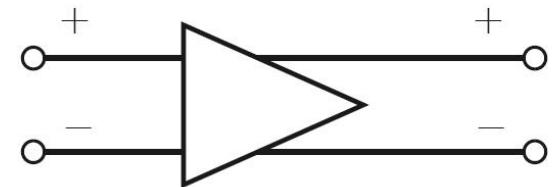
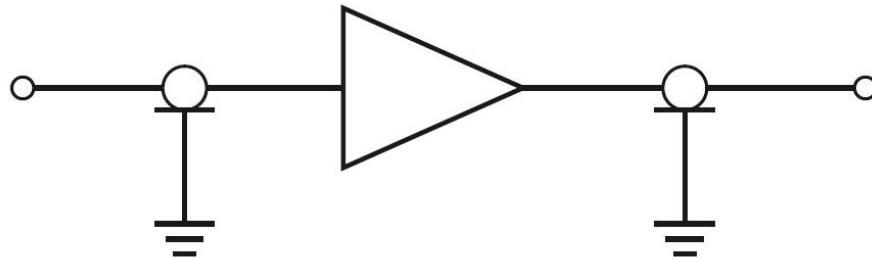
$$N_{opt} = \frac{\ln(\alpha_g \cdot l_g) - \ln(\alpha_d \cdot l_d)}{\alpha_g \cdot l_g - \alpha_d \cdot l_d}$$

Amplificatoare diferențiale

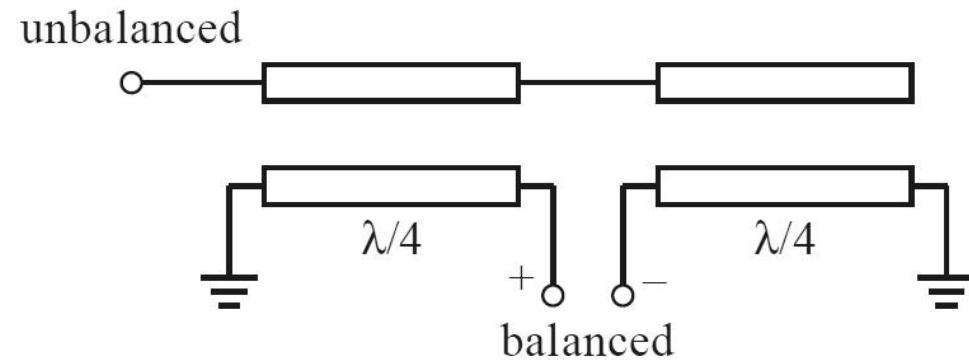
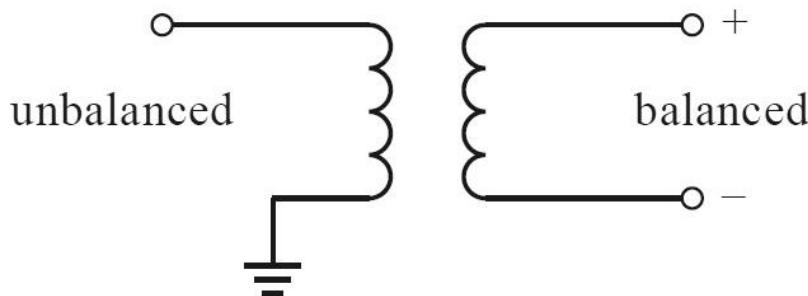
- Capacitatile de intrare în cele două tranzistoare în conexiune diferențială apar conectate în serie
- Se dublează astfel frecvența unitată



Amplificatoare diferențiale



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

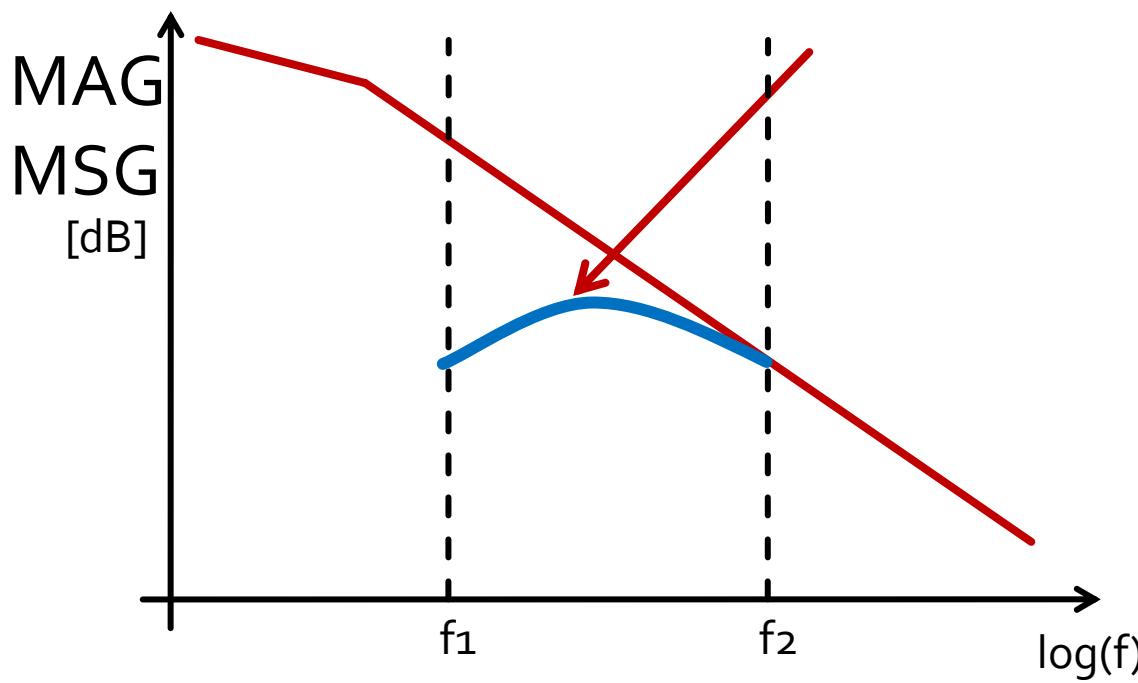


Amplificatoare de banda largă

- Se pot obține prin un număr de tehnici de proiectare
 1. **Retele de adaptare care să compenseze scaderea castigului cu frecventa**
 2. Retele de adaptare rezistive
 3. Reactie negativa
 4. Amplificatoare echilibratе
 5. Amplificatoare distribuite
 6. Amplificatoare diferențiale

Amplificatoare de banda largă

1. **Retele de adaptare care să 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

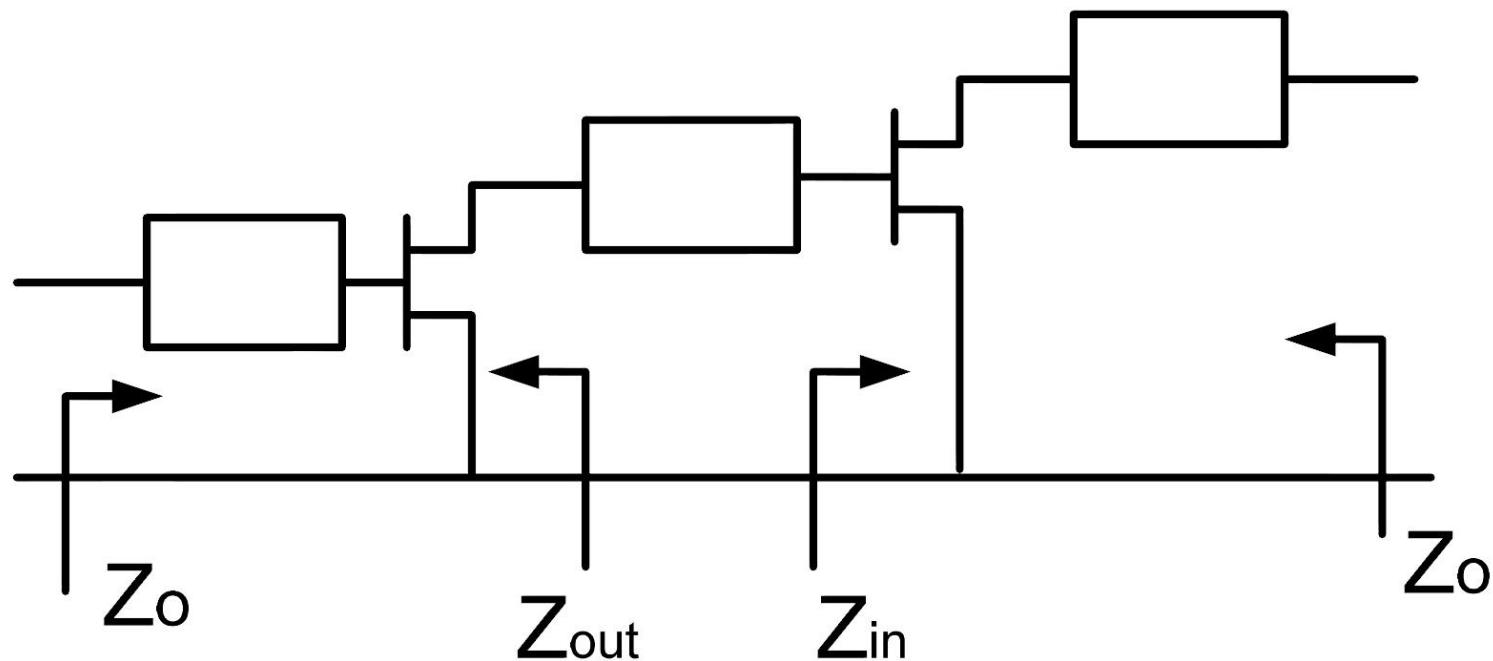


Amplificatoare in cascada

Amplificatoare de microunde

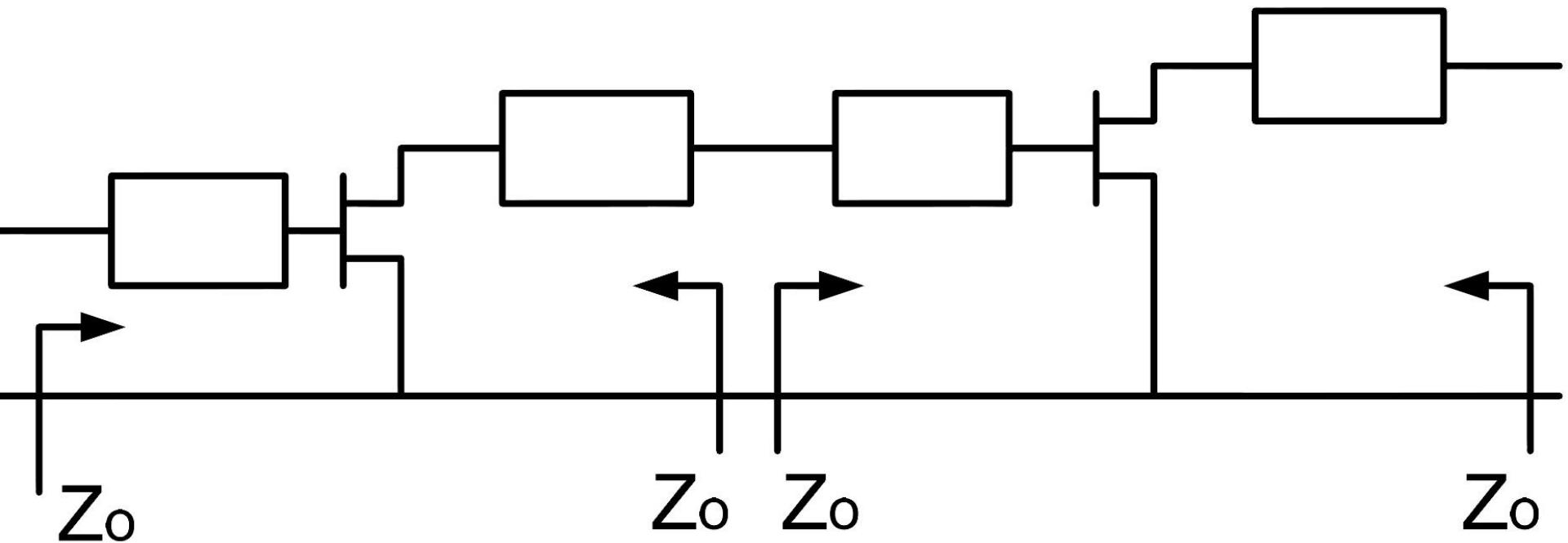
Amplificatoare in cascada

- Adaptarea inter-etaje se poate projecța în două moduri:
 - adaptarea unui etaj spre Γ necesar pentru celălalt



Amplificatoare in cascada

- Adaptarea inter-etaje se poate projecța în două moduri:
 - adaptarea fiecarui etaj spre un $\Gamma = \omega$ intermediar

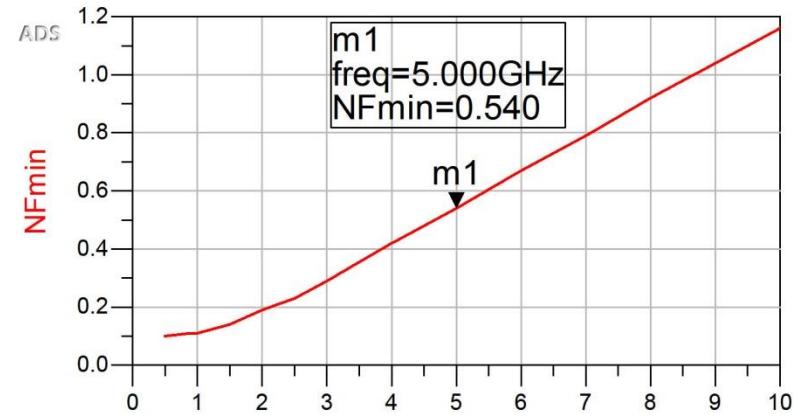


Exemplu LNA cascada

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

Exemplu

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



Exemplu, LNA @ 5 GHz

- ATF-34143 at $V_{ds}=3V$ $I_d=20mA$.

- @5GHz

- $S_{11} = 0.64 \angle 139^\circ$
- $S_{12} = 0.119 \angle -21^\circ$
- $S_{21} = 3.165 \angle 16^\circ$
- $S_{22} = 0.22 \angle 146^\circ$
- $F_{min} = 0.54$ (**tipic [dB]**)
- $\Gamma_{opt} = 0.45 \angle 174^\circ$
- $r_n = 0.03$

```
!ATF-34143
IS-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)

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

- 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)

$$G_{cas} = G_1 \cdot G_2$$

$$F_{cas} = F_1 + \frac{1}{G_1} (F_2 - 1)$$

- 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: $F_1 = 0.7 \text{ dB}$, $G_1 = 9 \text{ dB}$
 - iesire: $F_2 = 1.2 \text{ dB}$, $G_2 = 13 \text{ dB}$
- Transformare **in coordinate liniare !**

$$F_1 = 10^{\frac{F_1[\text{dB}]}{10}} = 10^{0.07} = 1.175$$

$$F_2 = 10^{\frac{F_2[\text{dB}]}{10}} = 10^{0.12} = 1.318$$

$$F_{cas} = F_1 + \frac{1}{G_1} (F_2 - 1) = 1.215$$

$$F_{cas} = 10 \cdot \log(1.215) = 0.846 \text{ dB}$$

$$G_1 = 10^{\frac{G_1[\text{dB}]}{10}} = 10^{0.9} = 7.943$$

$$G_2 = 10^{\frac{G_2[\text{dB}]}{10}} = 10^{1.3} = 19.953$$

$$G_{cas} = G_1 \cdot G_2 = 158.49$$

$$G_{cas} = 10 \cdot \log(158.49) = 22 \text{ dB}$$

Formula lui Friis (zgomot)

■ Avago/Broadcom AppCAD

AppCAD - [NoiseCalc]

File Calculate Application Examples Options Help

NoiseCalc Set Number of Stages = 2 Calculate [F4]

Stage Data	Units	Stage 1	Stage 2
		Avago Duplexer	Avago ATF-30xxA
Stage Name:			
Noise Figure	dB	0.7	1.2
Gain	dB	9	13
Output IP3	dBm	-100	-14.5
dNF/dTemp	dB/°C	0	0
dG/dTemp	dB/°C	0	0
Stage Analysis:			
NF (Temp corr)	dB	0.70	1.20
Gain (Temp corr)	dB	9.00	13.00
Input Power	dBm	-50.00	-41.00
Output Power	dBm	-41.00	-28.00
d NF/d NF	dB/dB	0.97	0.15
d NF/d Gain	dB/dB	-0.03	0.00
d IP3/d IP3	dBm/dBm	0.00	1.00

Enter System Parameters:

Input Power	-50	dBm
Analysis Temperature	25	°C
Noise BW	1	MHz
Ref Temperature	25	°C
S/N (for sensitivity)	10	dB
Noise Source (Ref)	290	°K

System Analysis:

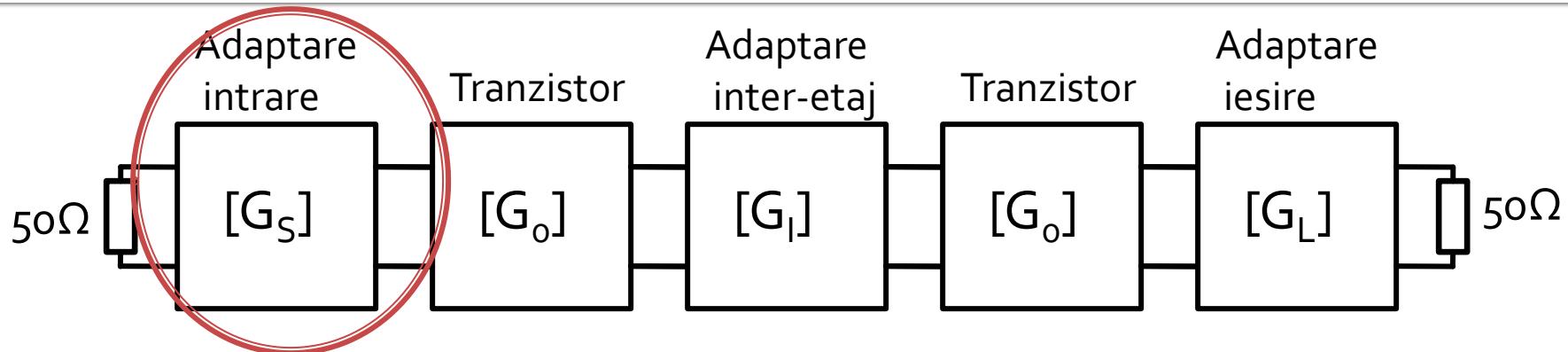
Gain =	22.00	dB
Noise Figure =	0.85	dB
Noise Temp =	52.34	°K
SNR =	63.13	dB
MDS =	-113.13	dBm
Sensitivity =	-103.13	dBm
Noise Floor =	-173.13	dBm/Hz

Input IP3 =	-7.50	dBm
Output IP3 =	14.50	dBm
Input IM level =	-135.00	dBm
Input IM level =	-85.00	dBc
Output IM level =	-113.00	dBm
Output IM level =	-85.00	dBc
SFDR =	70.42	dB

Proiectare etaje cascade

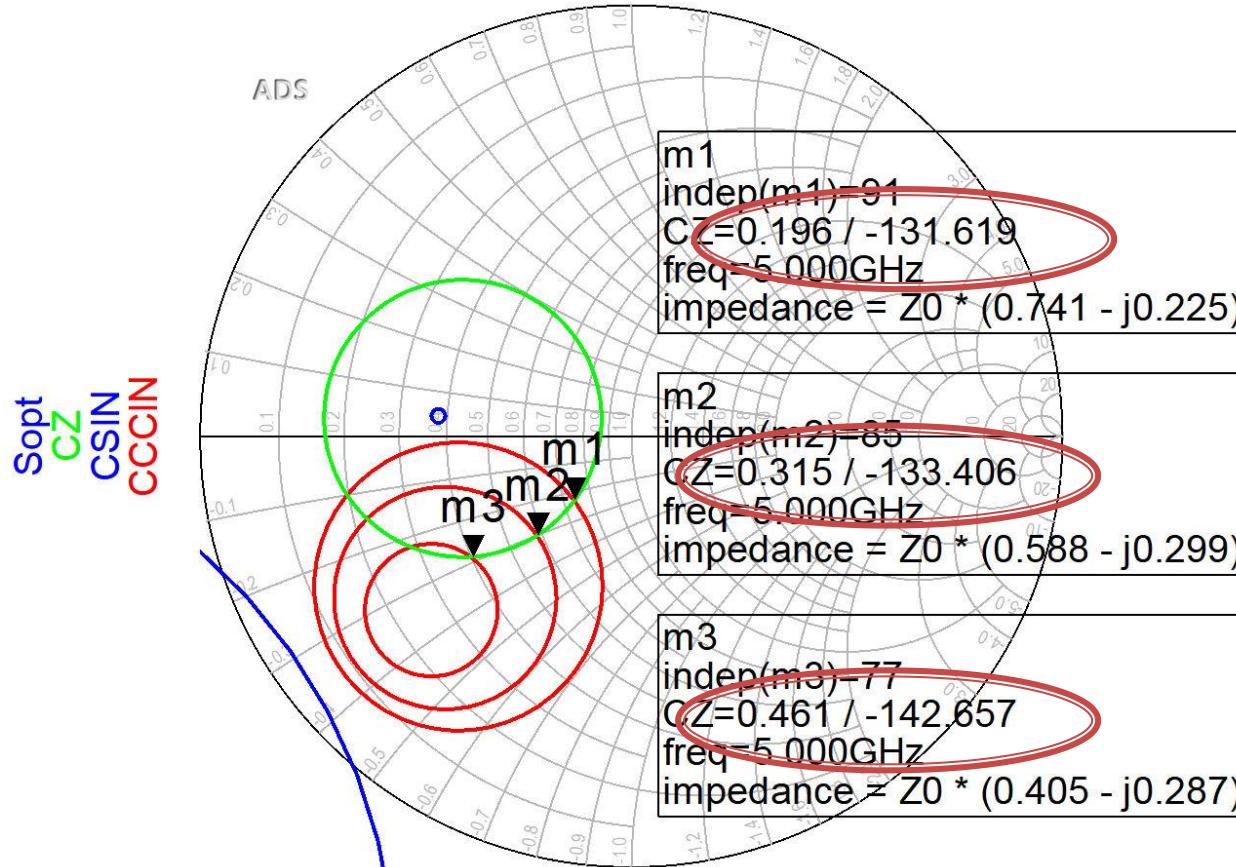
- Impartire pe cele doua etaje (Estimat)
 - intrare: $F_1 = 0.7 \text{ dB}$, $G_1 = 9 \text{ dB}$
 - iesire: $F_2 = 1.2 \text{ dB}$, $G_2 = 13 \text{ dB}$
 - total: $F = 0.85 \text{ dB}$, $G = 22 \text{ dB}$
- Indeplineste conditiile din tema (cu rezerva corespunzatoare)
- Se poate folosi o parte din calculul amplificatorului cu un singur etaj (C_{11})
 - adaptarea la intrare anteroara 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



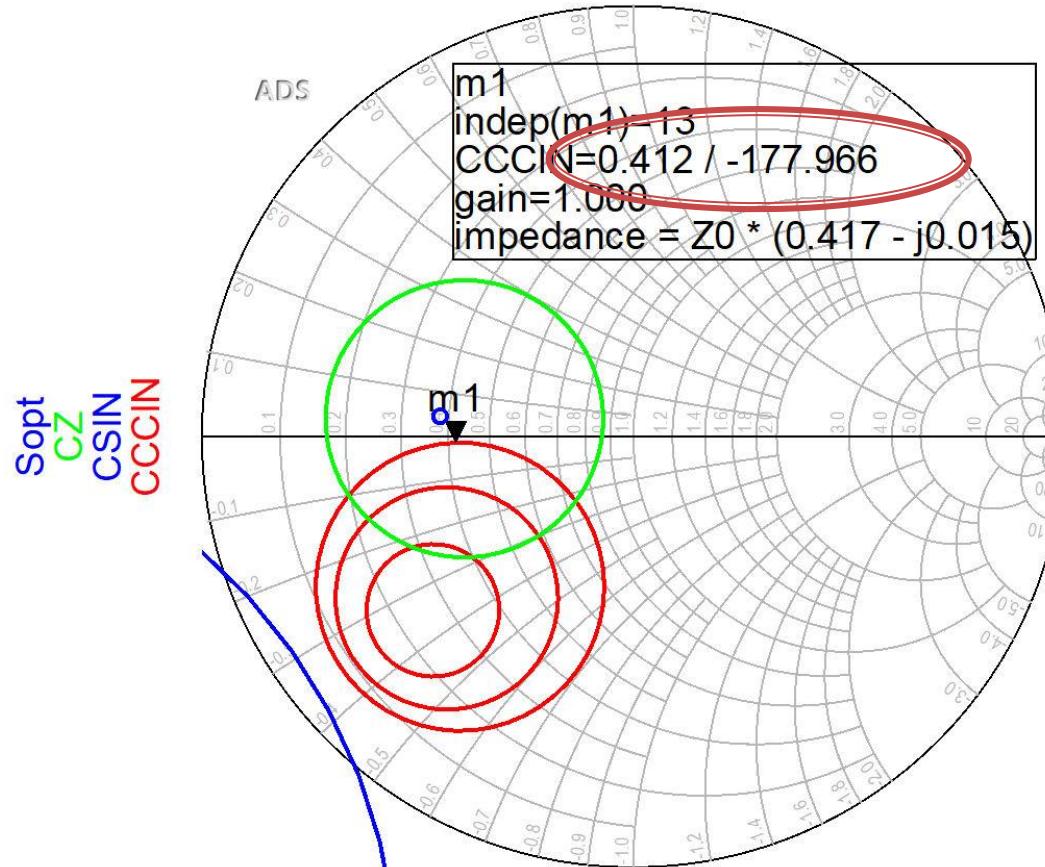
- Se acorda importanta in special comportarii la **zgomot** (mic/minim)
- Se mai tine cont de
 - Castig (sacrificat, dar nu foarte mult)
 - Banda dorita (prin factorul de calitate Q)
 - Stabilitate

Adaptare la intrare



- Pentru reteaua de adaptare la intrare
 - CZ: 0.75dB
 - CCCIN: 1dB, 1.5dB, 2 dB
- Aleg (Q mic → banda largă) pozitia m_1

Adaptare la intrarea etajului 1 (S1)



- Daca se sacrifică 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)

- $\mathbf{G}_{\mathbf{S1}}$: Pozitia m1 de pe grafic, **1dB**

$$\Gamma_S = 0.412 \angle -178^\circ$$

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

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

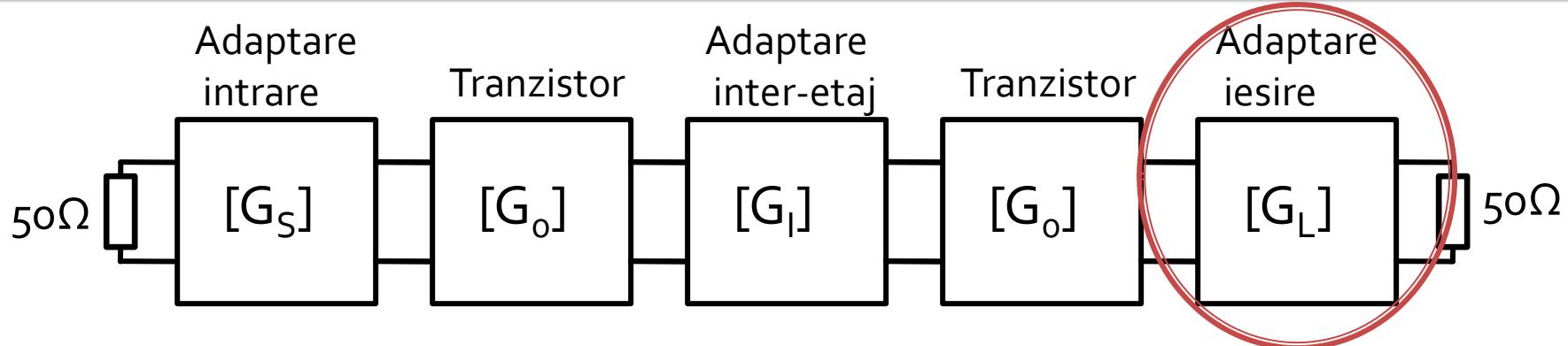
$$\text{Im}[y_S(\theta)] = \frac{\mp 2 \cdot |\Gamma_S|}{\sqrt{1 - |\Gamma_S|^2}}$$

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

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

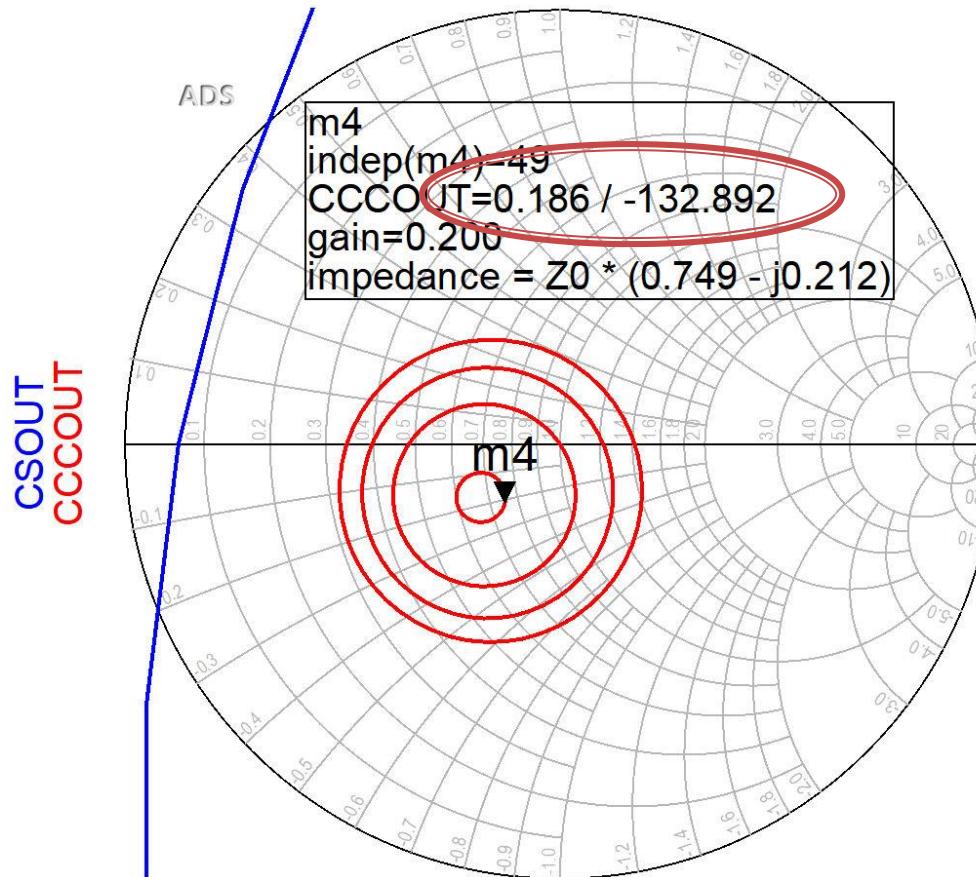
$$(\varphi + 2\theta) = \begin{cases} +114.33^\circ \\ -114.33^\circ \end{cases} \quad \theta = \begin{cases} 146.2^\circ \\ 31.8^\circ \end{cases} \quad \text{Im}[y_S(\theta)] = \begin{cases} -0.904 \\ +0.904 \end{cases} \quad \theta_{sp} = \begin{cases} 137.9^\circ \\ 42.1^\circ \end{cases}$$

Adaptare la ieșire



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

Adaptare la ieșirea 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 ieșirea etajului 2 (L2)

- G_{L2} : Poziția m4 de pe grafic, **0.2dB**

$$\Gamma_L = 0.186 \angle -132.9^\circ$$

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

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

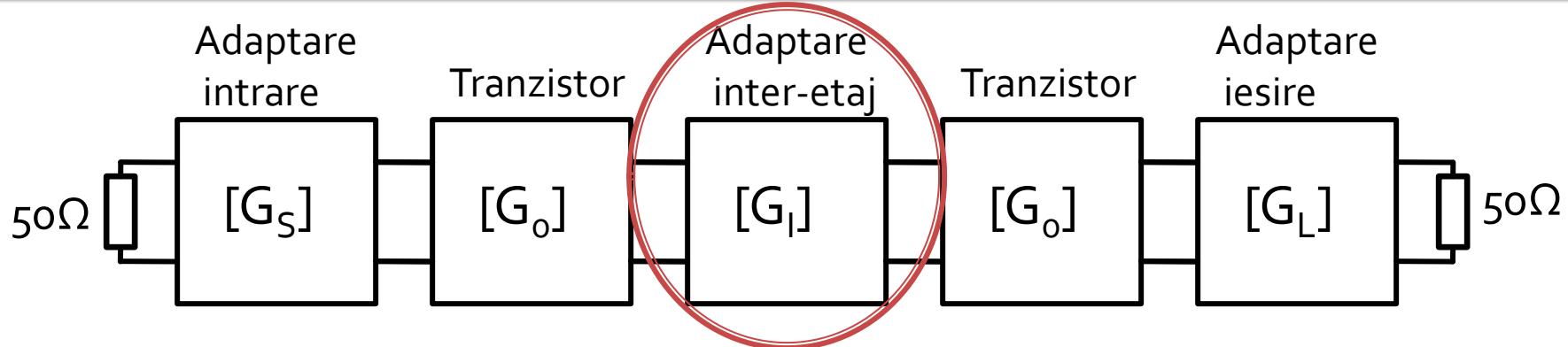
$$\text{Im}[y_L(\theta)] = \frac{-2 \cdot |\Gamma_L|}{\sqrt{1 - |\Gamma_L|^2}} = -0.379$$

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

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

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

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 cascade

■ Castig

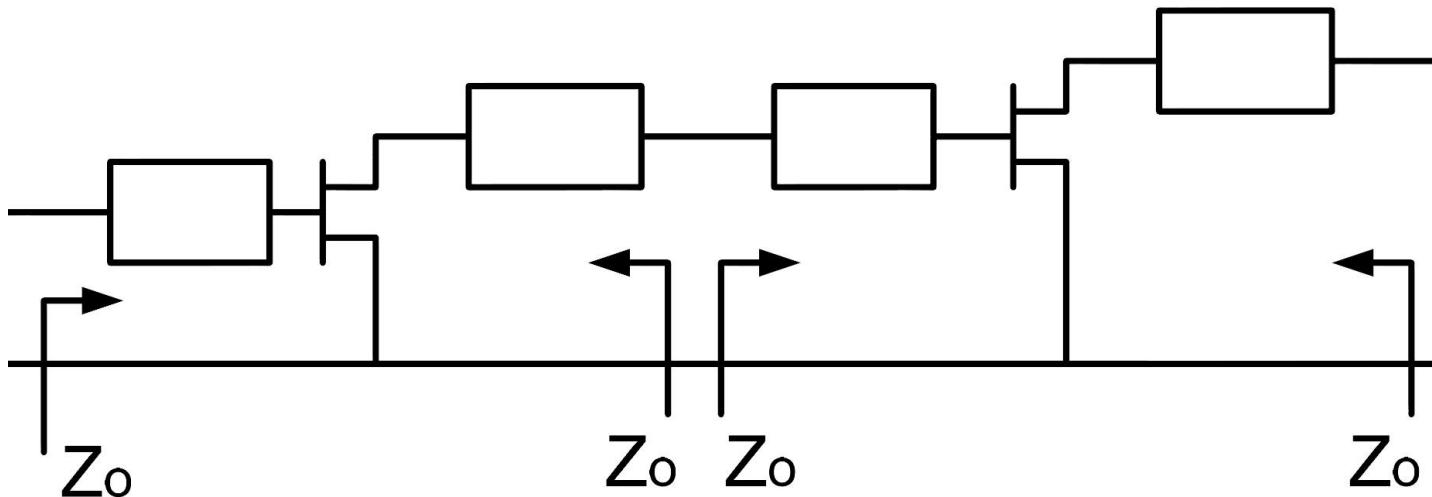
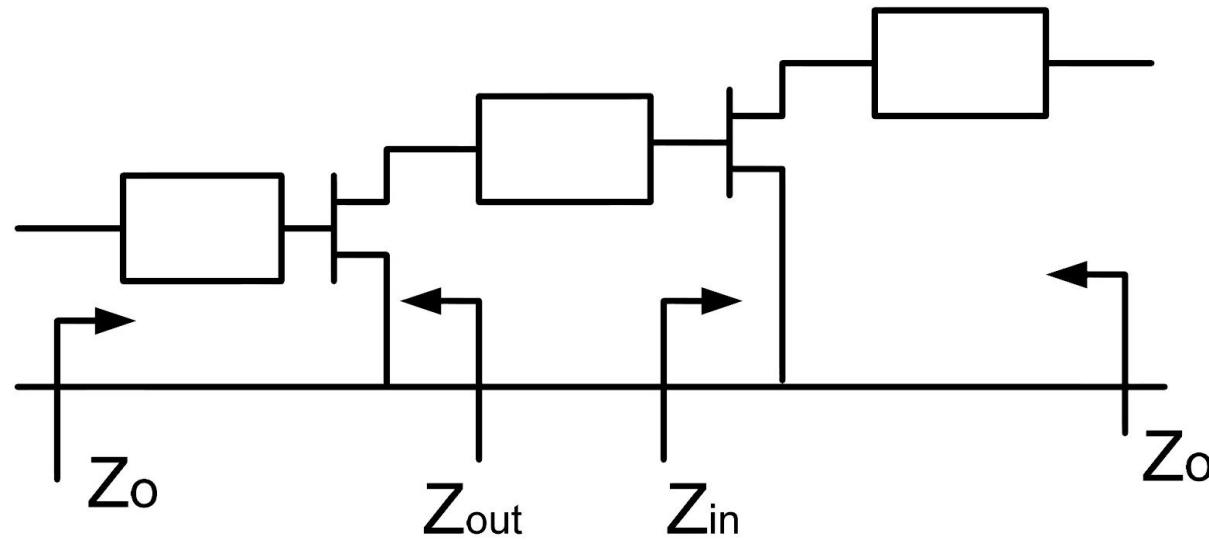
$$G_T[dB] = G_{S1}[dB] + G_0[dB] + G_I[dB] + G_0[dB] + G_{L2}[dB]$$

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

$$G_T[dB] = 21.2 \text{ dB} + G_I[dB]$$

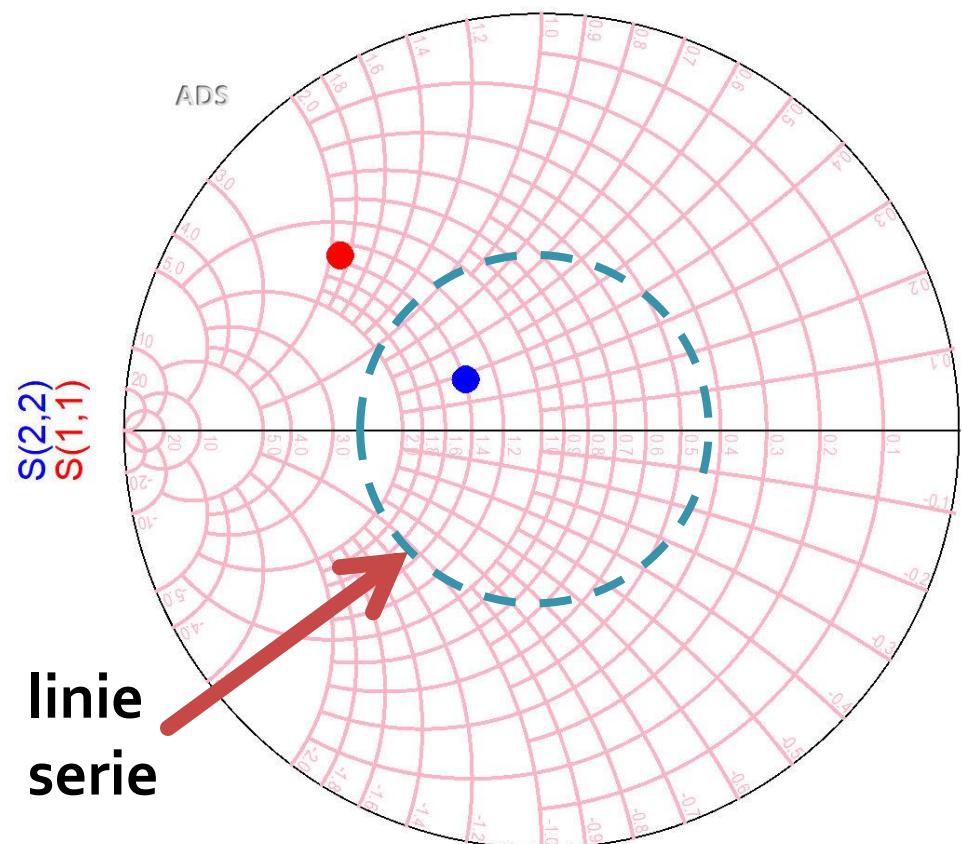
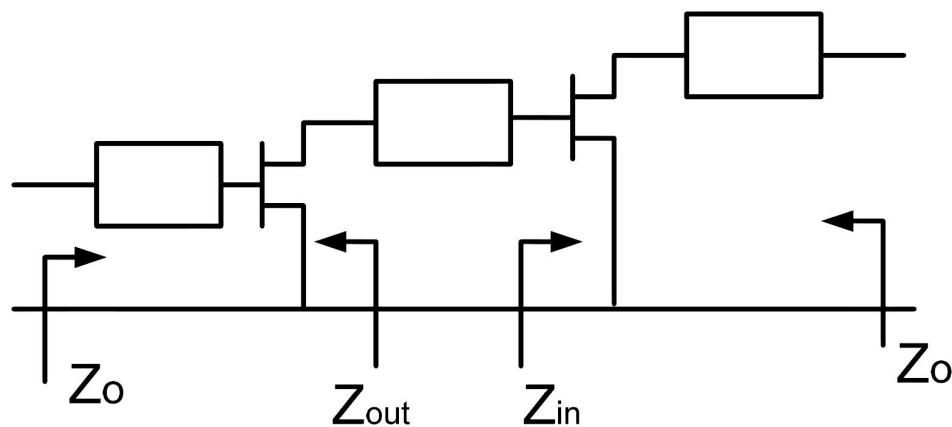
- Prin proiectarea inter-etaje trebuie obtinut un castig de minim 0.8dB prin adaptare mai buna a primului etaj la iesire si a celui de-al doilea la intrare

Adaptare inter-etaje 1/2



Adaptare inter-etaje 1

- O singura linie de transmisie pastreaza modulul coeficientului de reflexie

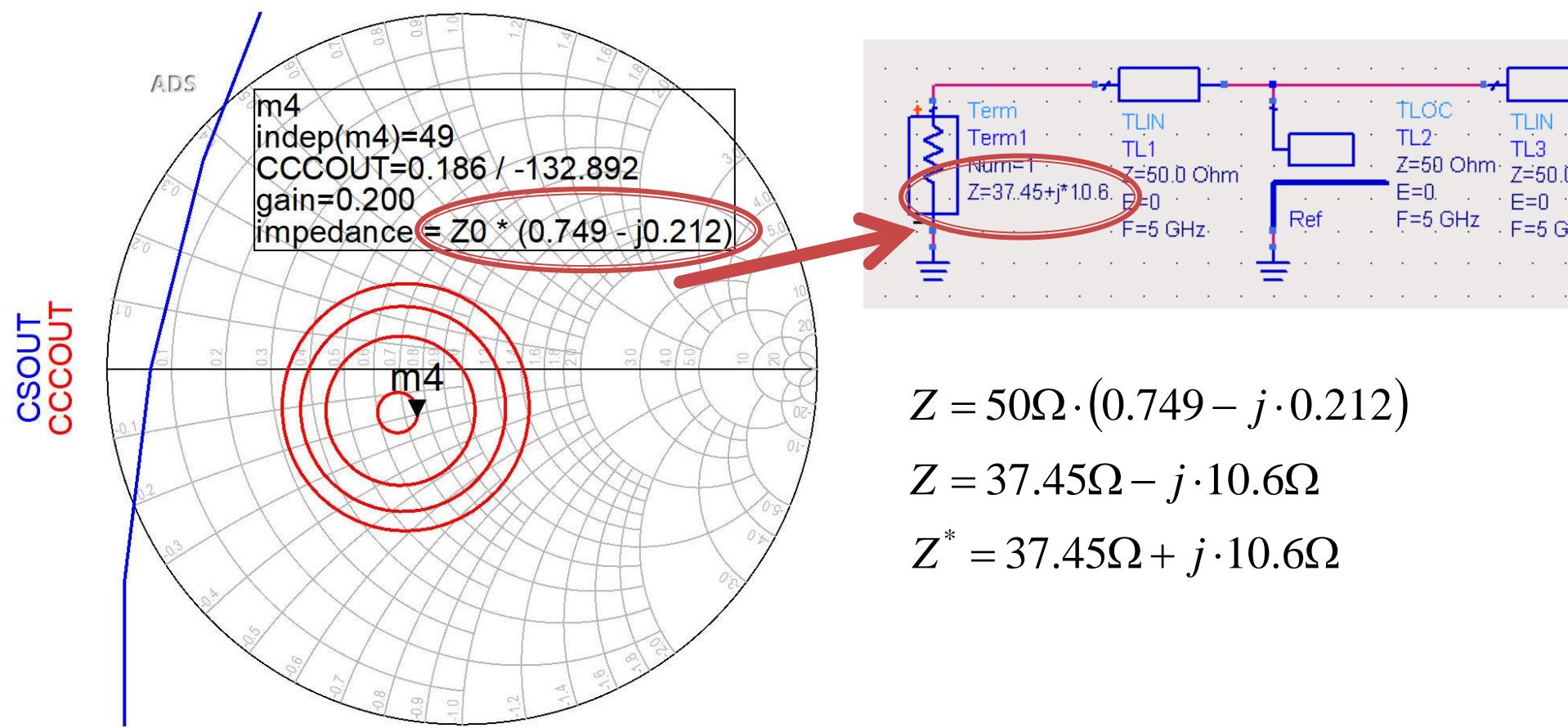


Adaptare inter-etaje 1

- Se poate face in doua moduri:
 - plecand de la iesirea primului etaj (coeficient de reflexie S_{22}^*) spre cercurile (desenate pentru etajul al doilea) de:
 - stabilitate
 - castig
 - zgomot
 - plecand de la intrarea celui de-al doilea etaj (coeficient de reflexie S_{11}^*) 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

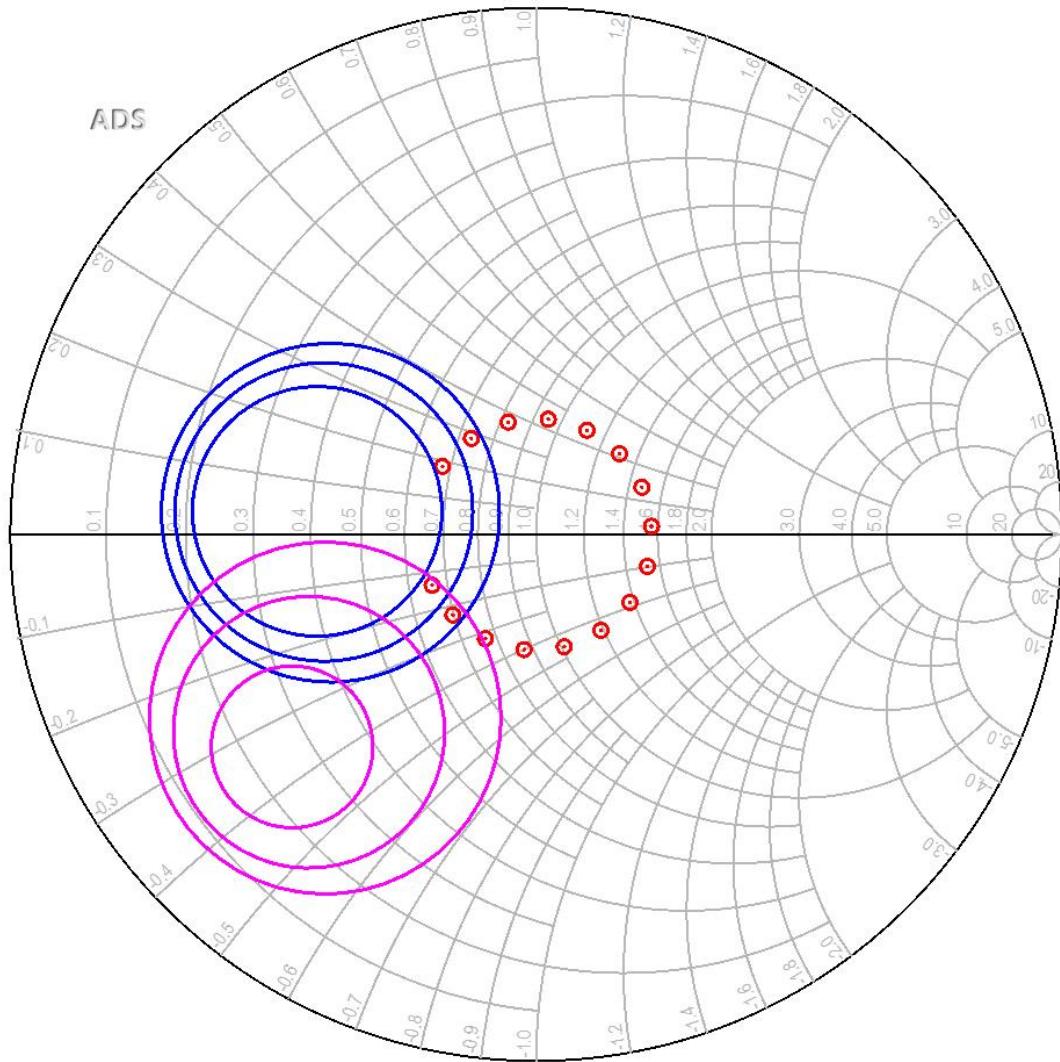
- Punct de pornire – complex conjugat



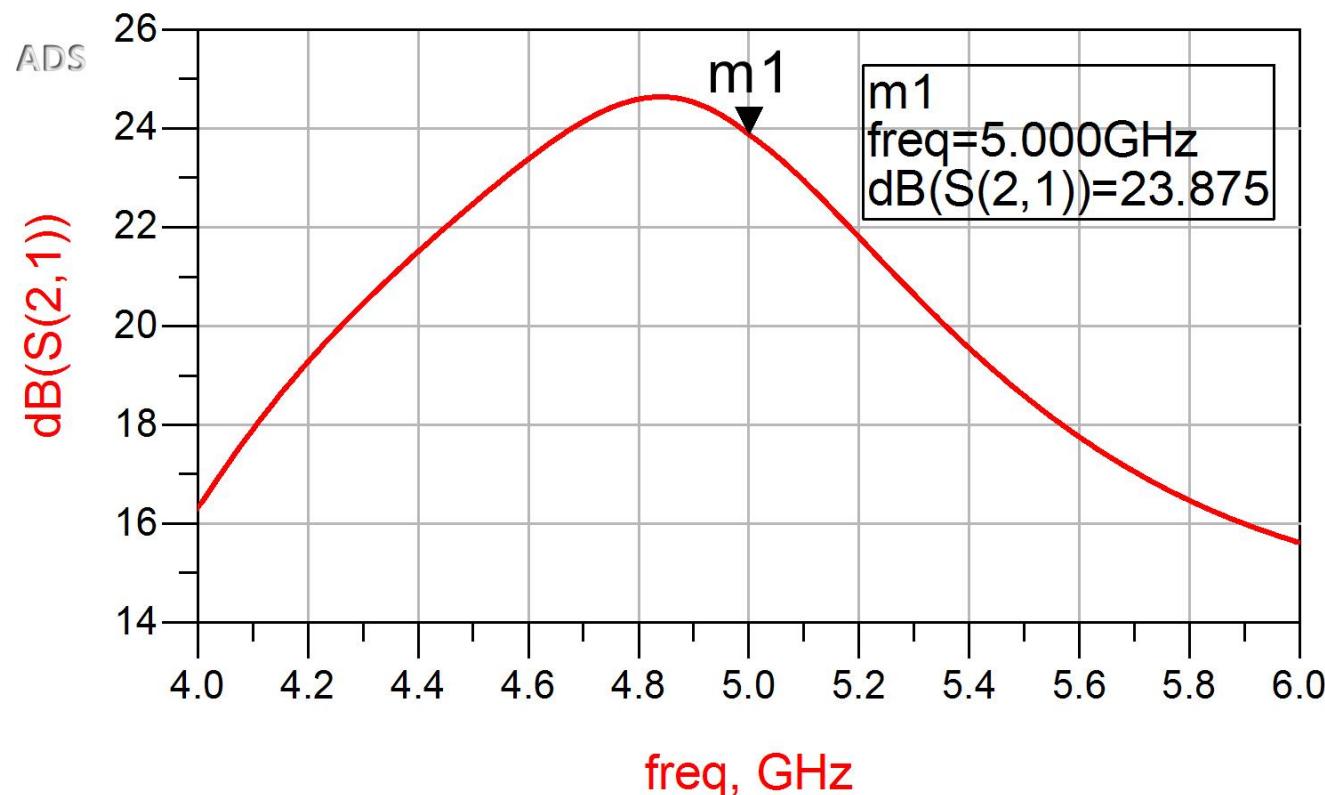
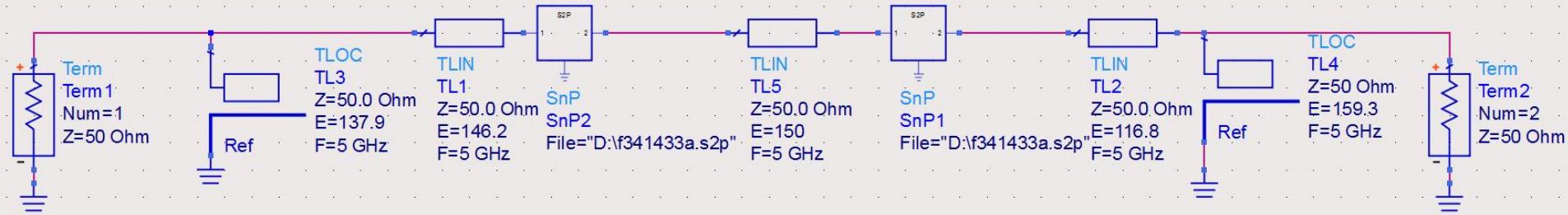
Adaptare inter-etaje 1

- O **singura** linie de transmisie permite atingerea unui punct care nu poate fi optimizat
 - $G_{L_1} = 0.2 \text{ dB}$
 - $G_{S_2} = 1 \text{ dB}$
 - $F_2 = 0.7 \text{ dB}$
- Elimina posibilitatea de reglaj pentru controlul în banda largă a amplificării

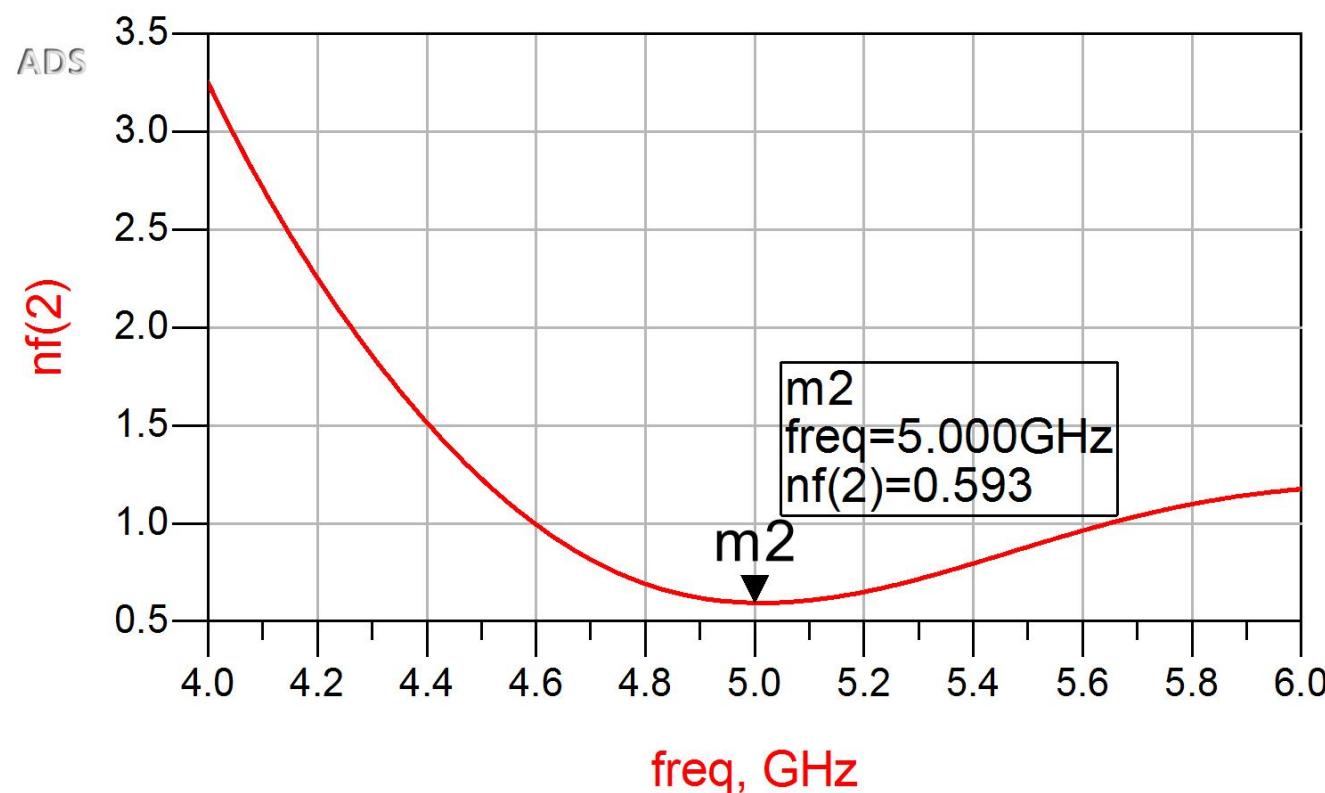
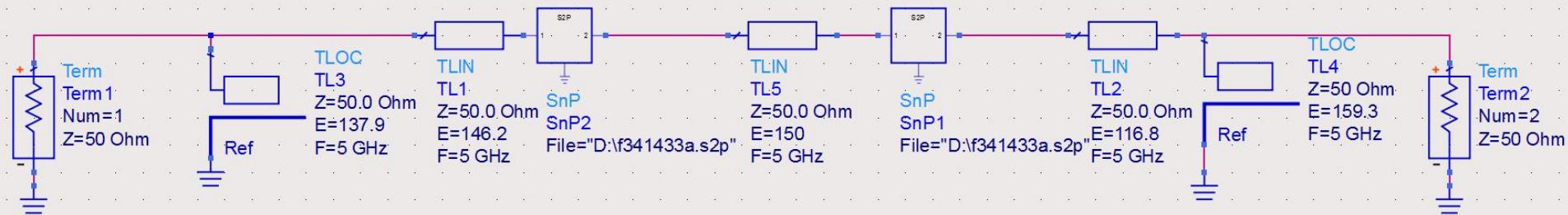
ref. CCCIN
ref. CZ
 $S(2,2)$



ADS

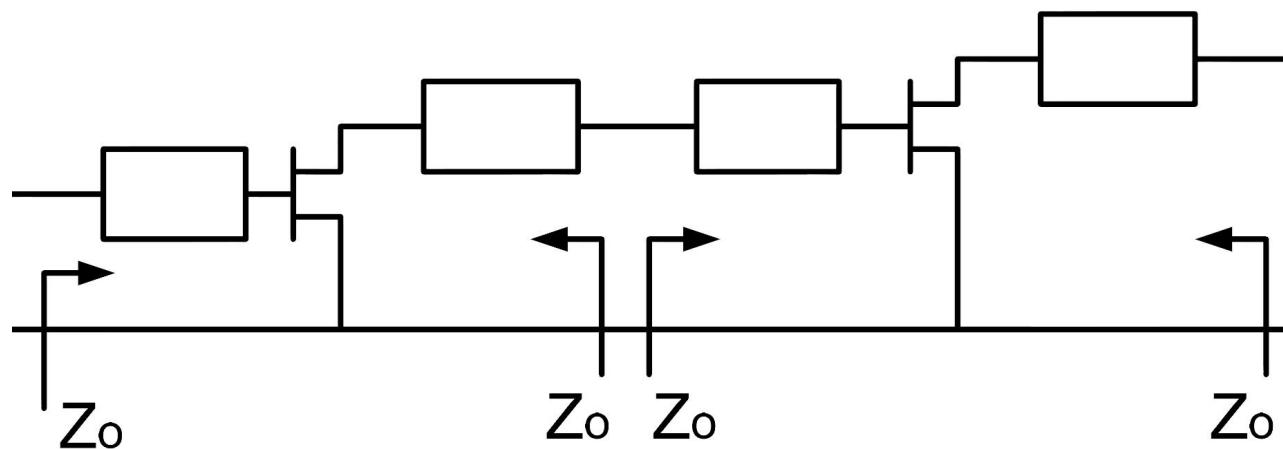


ADS

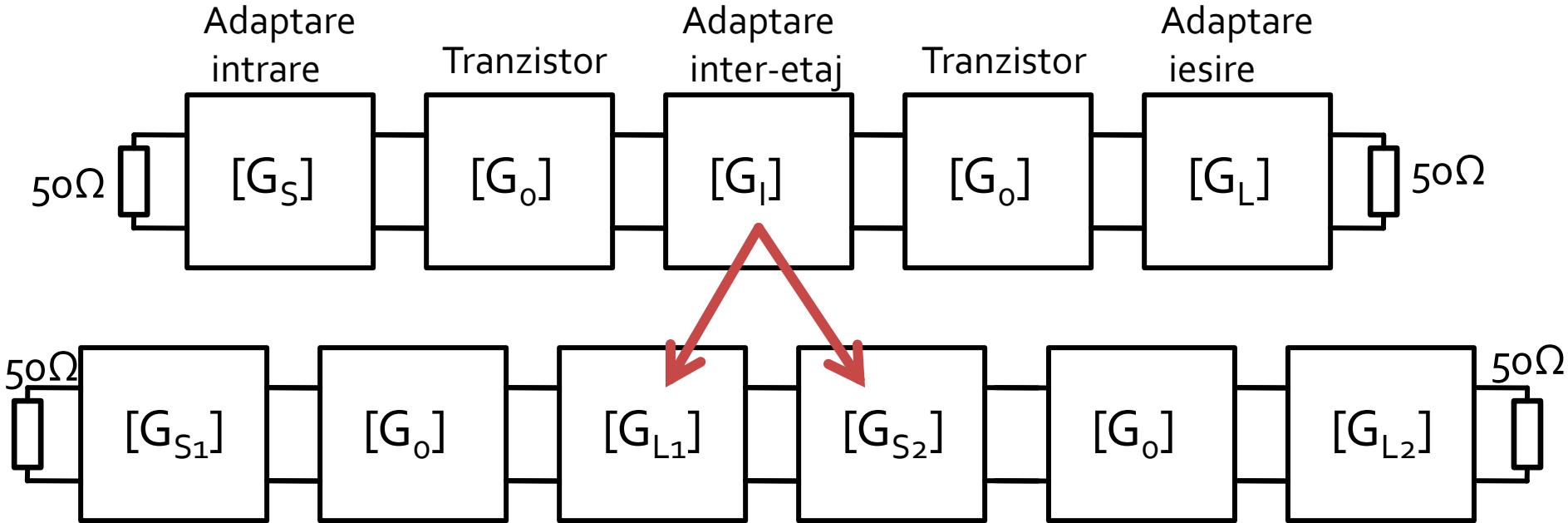


Adaptare inter-etaje 2

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



Proiectare etaje cascade



■ 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 cascade

■ Castig

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

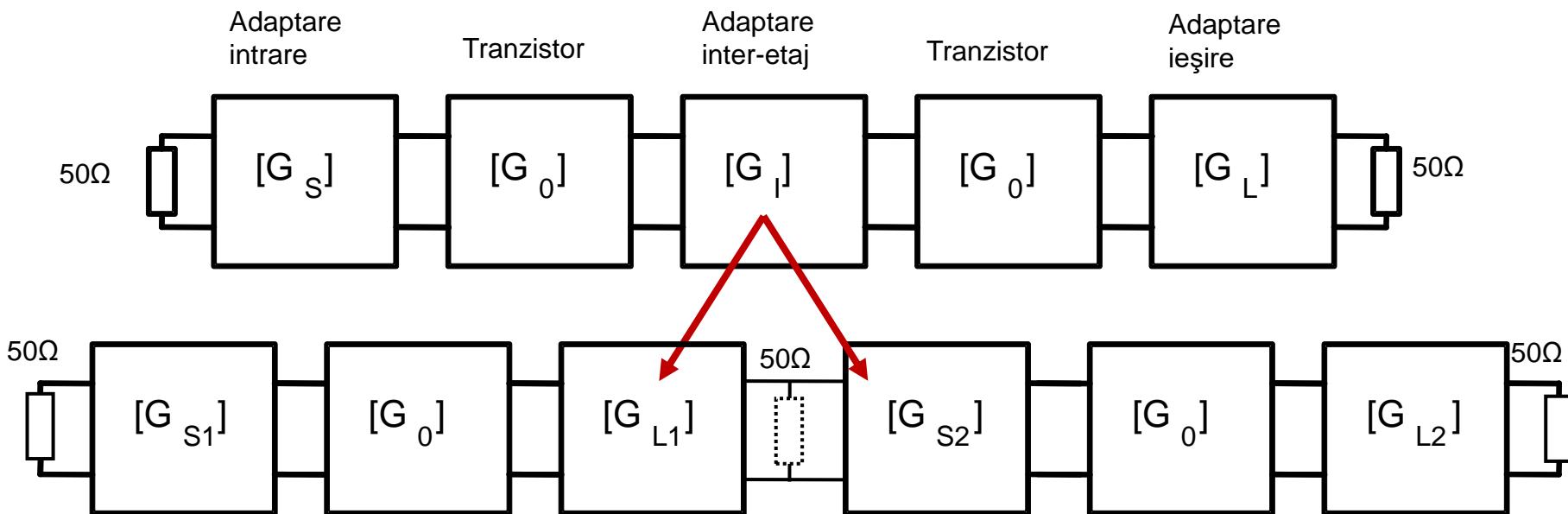
$$G_T[dB] = 1 \text{ dB} + 10 \text{ dB} + G_{L1}[dB] + G_{S2}[dB] + 10 \text{ dB} + 0.2 \text{ dB}$$

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

- 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

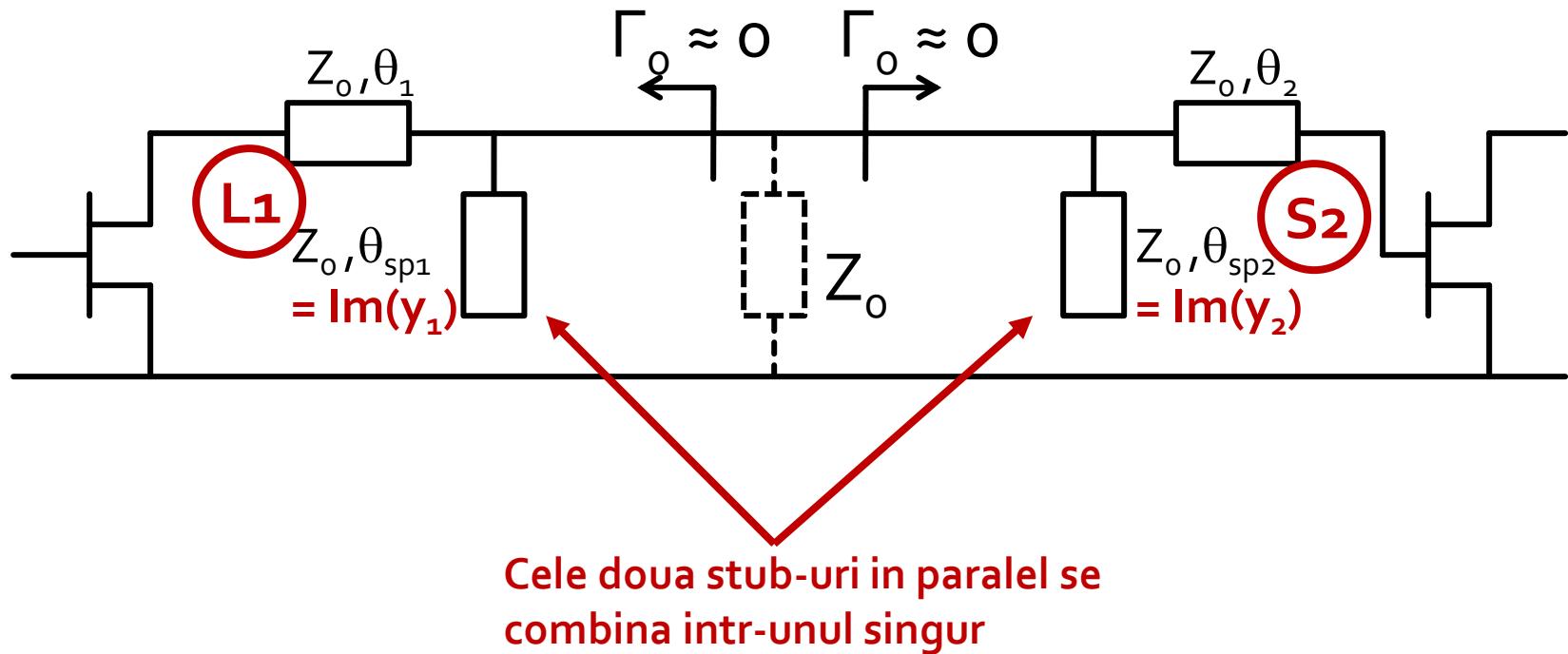
Adaptare inter-etaje 2

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



Adaptare inter-etaje 2

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



Adaptare inter-etaje 2

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

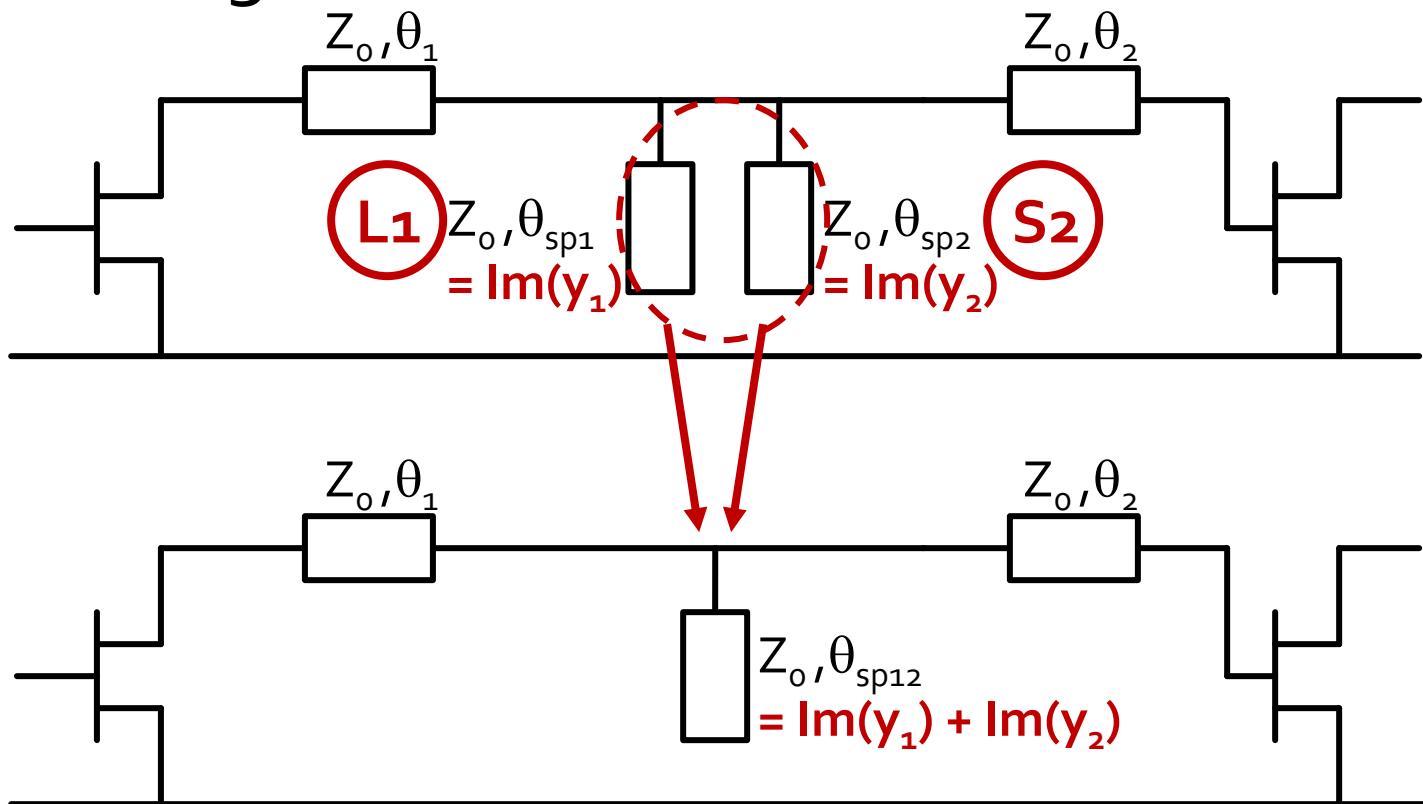
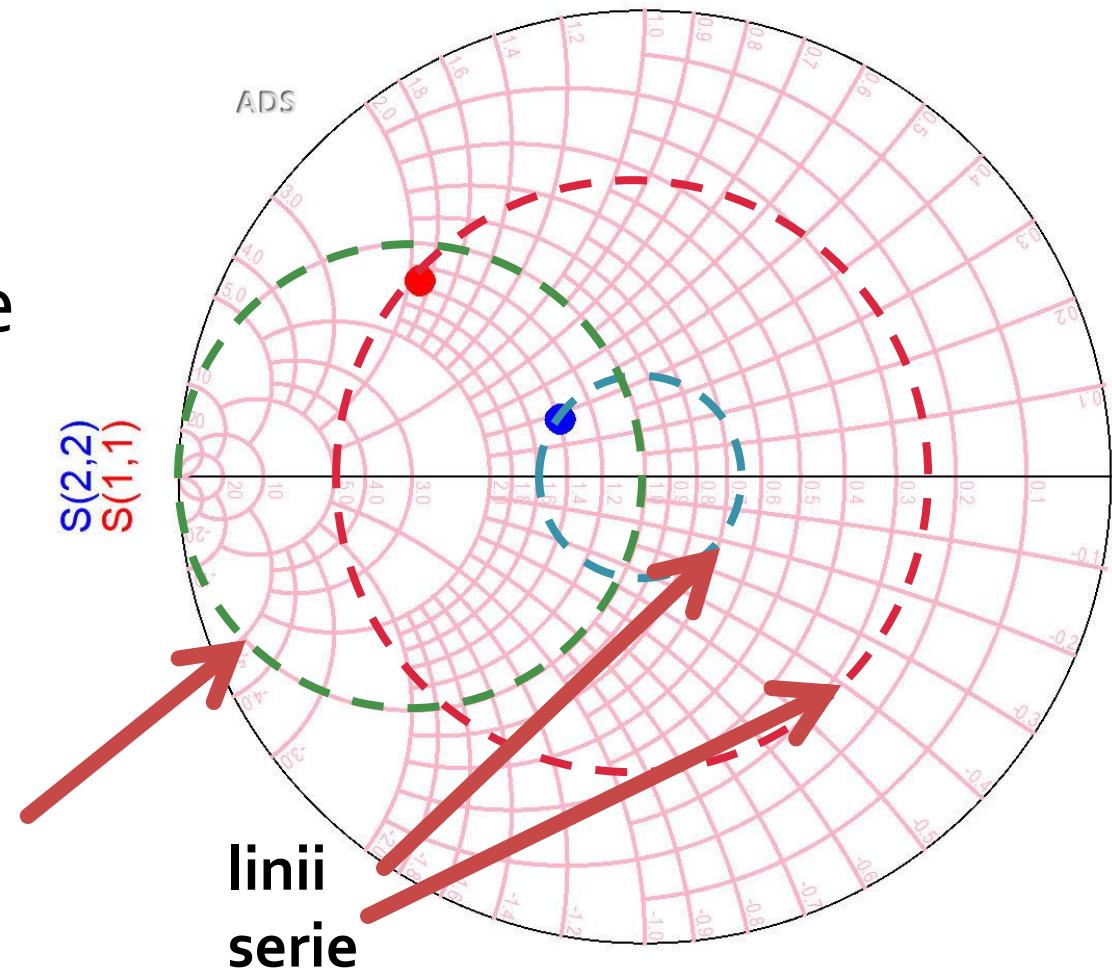


Diagrama Smith

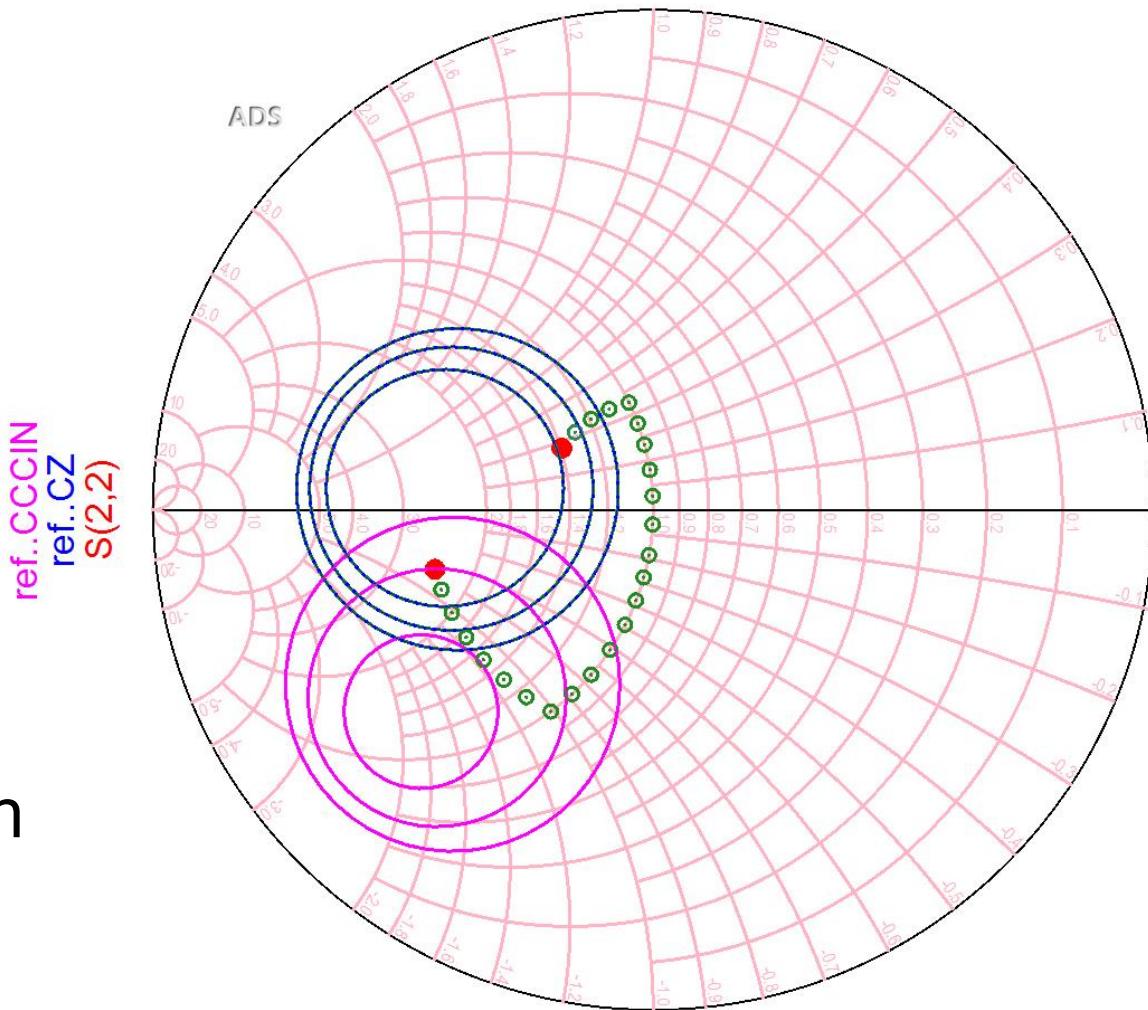
- linie serie → pe cercul cu centrul în originea DS
- stub paralel → pe cercul $g=1$

stub
paralel



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 Z_0)
- Cele doua stub-uri in paralel se combina intr-unul singur



Adaptare la iesirea etajului 1 (L1)

- G_{L_1} (putem folosi tot punctul de la iesirea L2)

$$\Gamma_L = 0.186 \angle -132.9^\circ$$

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

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

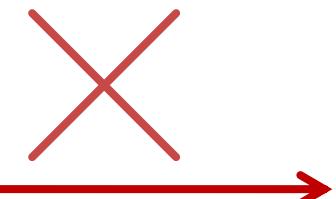
$$\text{Im}[y_L(\theta)] = \frac{-2 \cdot |\Gamma_L|}{\sqrt{1 - |\Gamma_L|^2}} = -0.379$$

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

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

$$(\varphi + 2\theta) = \begin{cases} +100.72^\circ \\ -100.72^\circ \end{cases} \quad \theta = \begin{cases} 116.8^\circ \\ 16.1^\circ \end{cases}$$

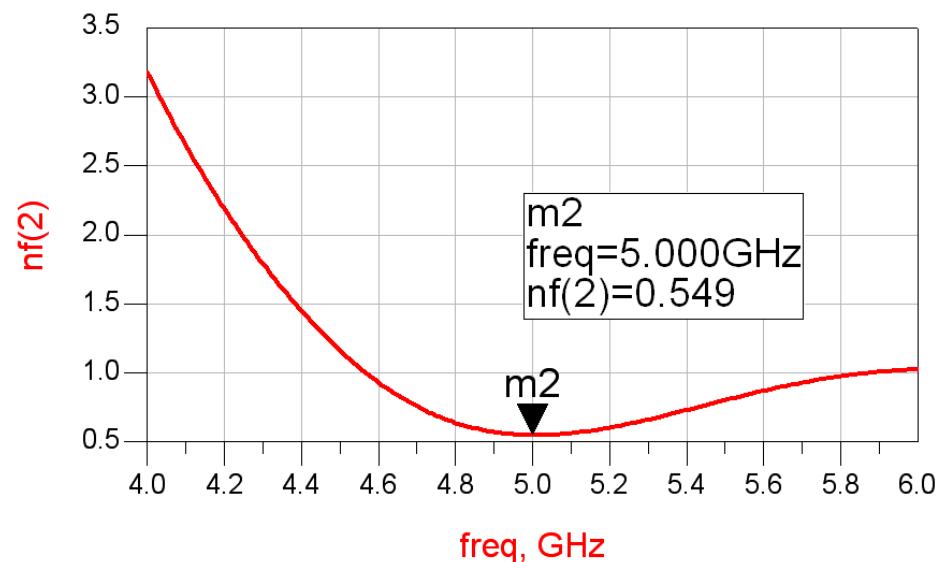
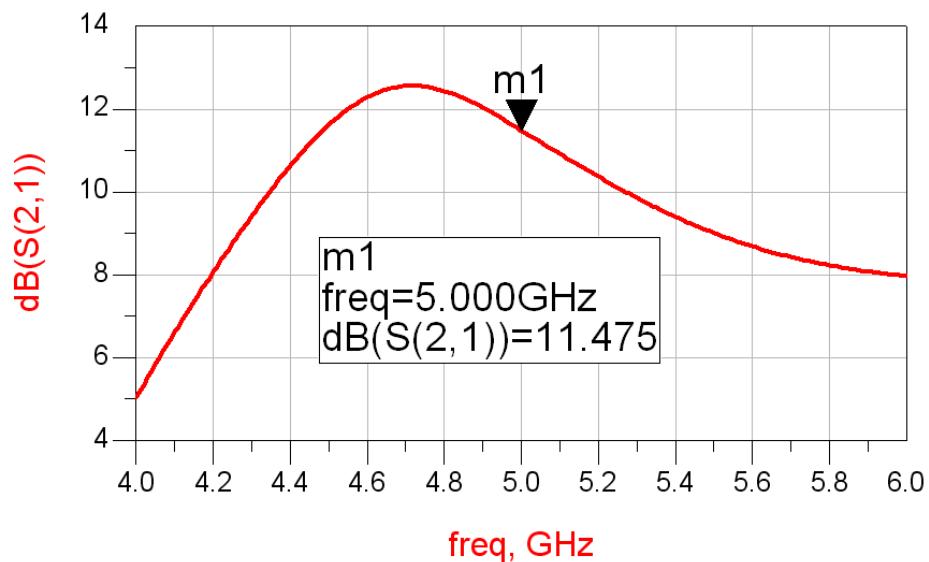
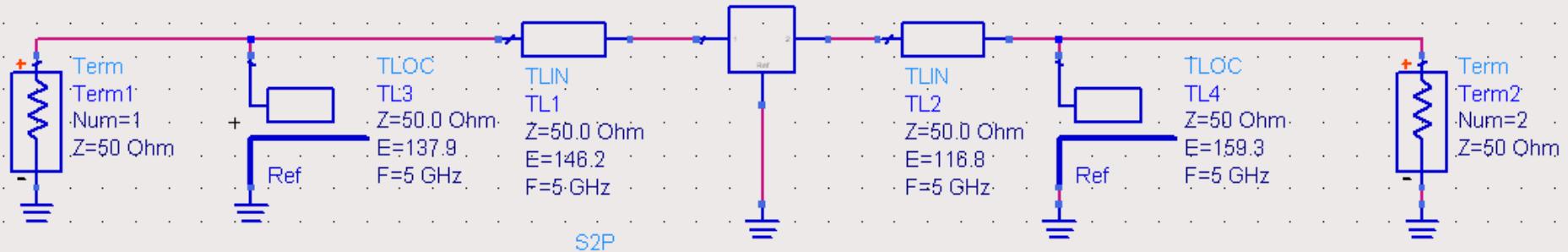
$$\text{Im}[y_L(\theta)] = \begin{cases} -0.379 \\ +0.379 \end{cases}$$



Adaptare la ieșirea etajului 1 (L1)

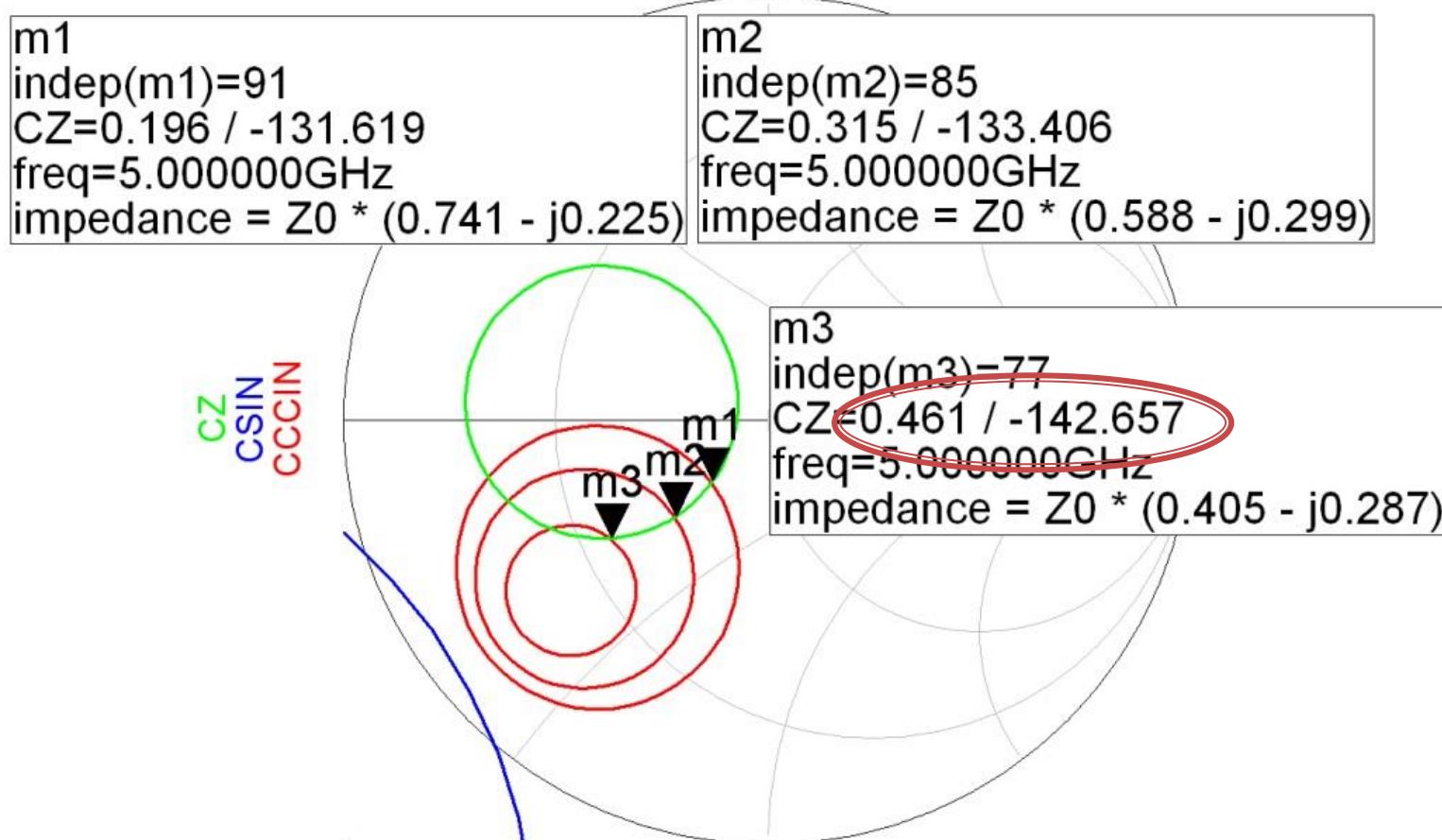
Ecuație	Soluția L1A	Soluția L1B
$\Phi + 2\theta$	+100.72°	-100.72°
θ	116.8°	16.1°
$\text{Im}[y(\theta)]$	-0.379	+0.379

Verificare etaj 1



Adaptare la intrarea etajului 2 (S_2)

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



Adaptare la intrarea etajului 2 (S_2)

- G_{S_2} (plecare din m_3 spre origine)

$$\Gamma_{S_2} = 0.461 \angle -142.66^\circ$$

$$|\Gamma_{S_2}| = 0.461; \quad \varphi = -142.66^\circ$$

$$\cos(\varphi + 2\theta) = -|\Gamma_{S_2}|$$

$$\text{Im}[y_{S_2}(\theta)] = \frac{\mp 2 \cdot |\Gamma_{S_2}|}{\sqrt{1 - |\Gamma_{S_2}|^2}}$$

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

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

$$(\varphi + 2\theta) = \begin{cases} +117.45^\circ \\ -117.45^\circ \end{cases} \quad \theta = \begin{cases} 130.1^\circ \\ 12.6^\circ \end{cases}$$

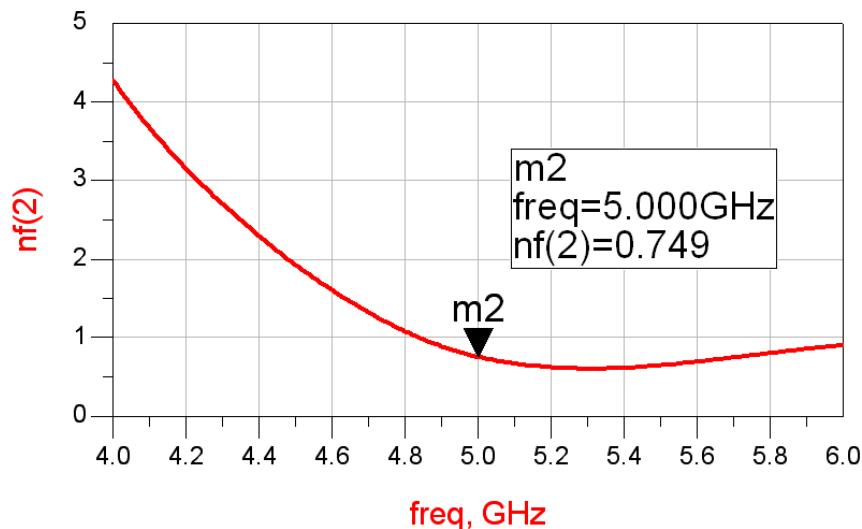
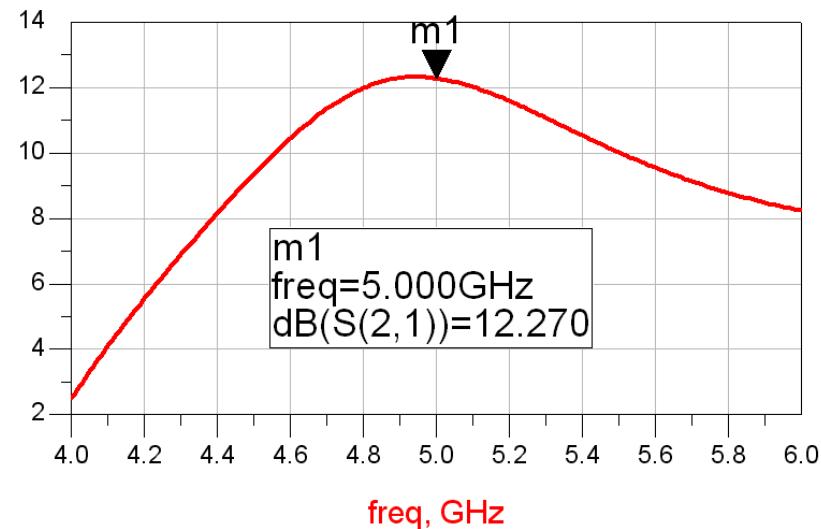
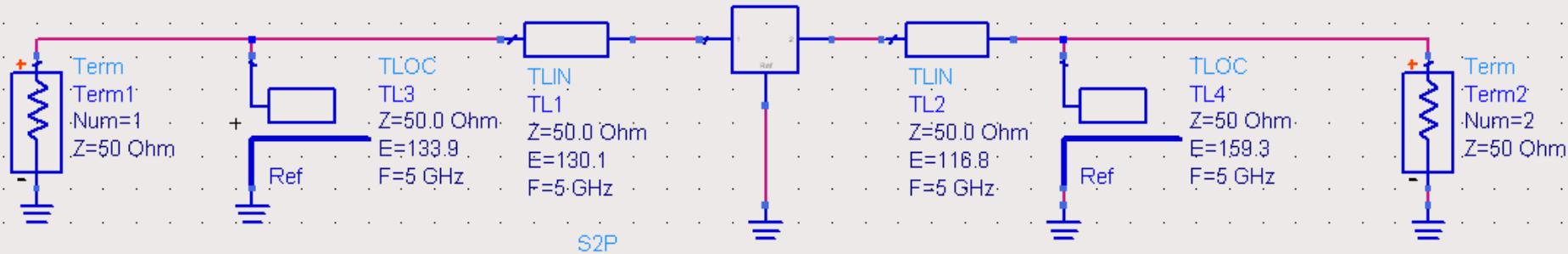
$$\text{Im}[y_{S_2}(\theta)] = \begin{cases} -1.039 \\ +1.039 \end{cases}$$



Adaptare la intrarea etajului 2 (S₂)

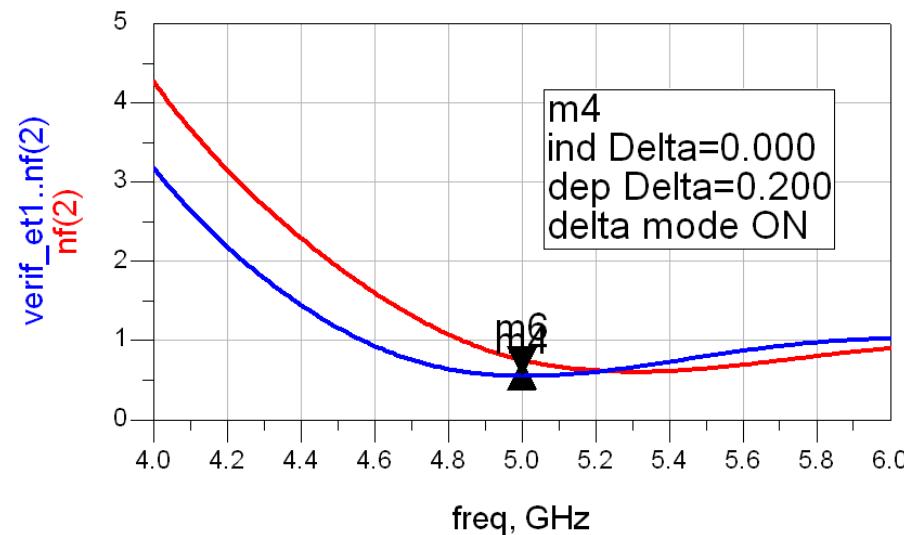
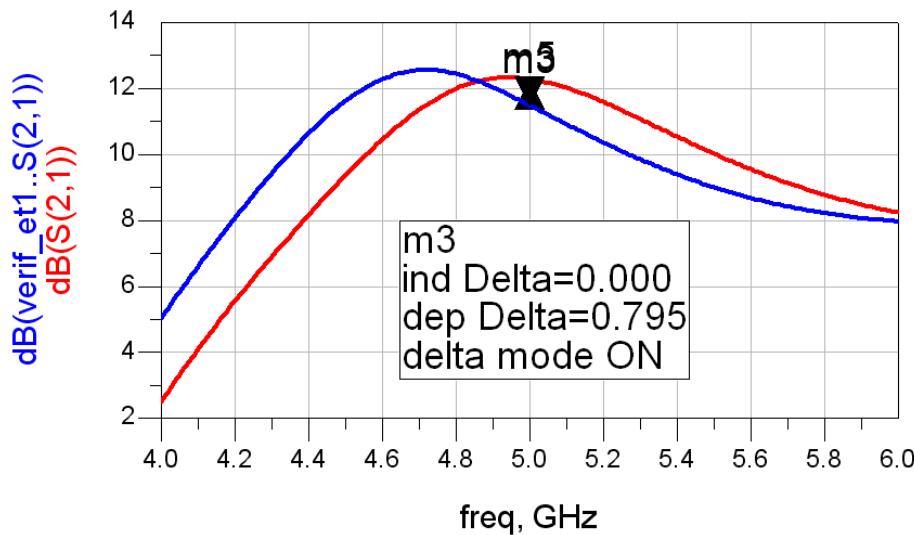
Ecuație	Soluția S _{2A}	Soluția S _{2B}
$\Phi + 2\theta$	+117.45°	-117.45°
θ	130.1°	12.6°
$\text{Im}[y(\theta)]$	-1.039	+1.039

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



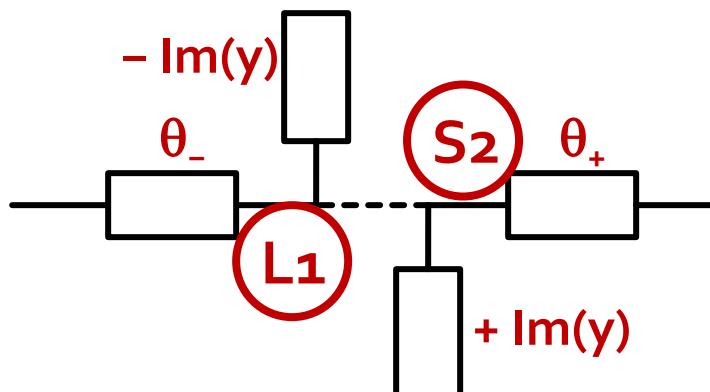
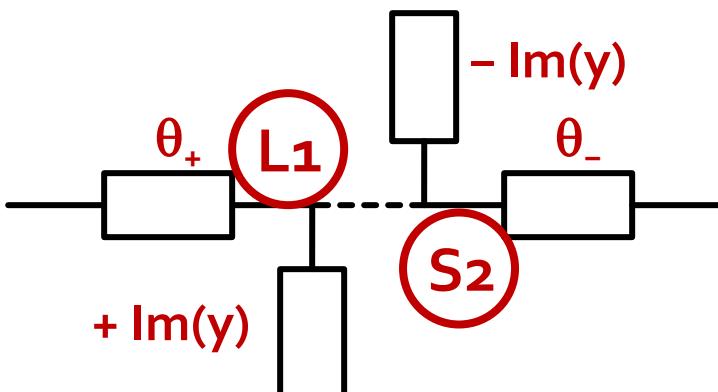
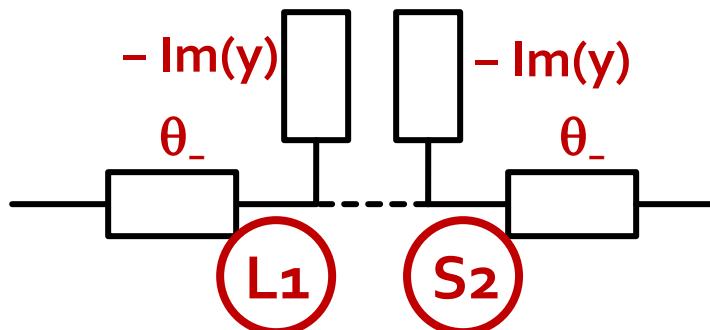
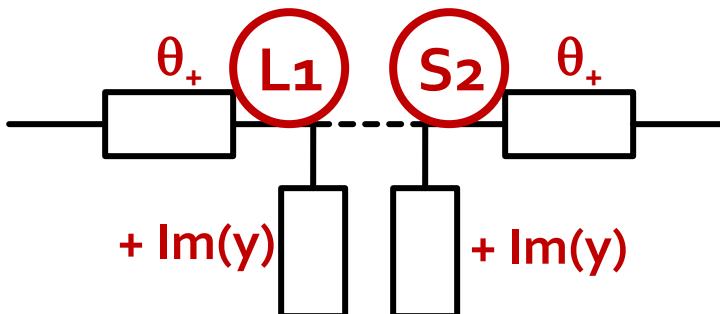
Combinarea celor 2 stub-uri paralel

- Cele doua stub-uri in paralel se combină intr-unul singur
- Există **4 combinatii posibile** în funcție de cum se combină lungimile electrice alese pentru cele două linii serie
 - pentru fiecare lungime electrică aleasă (θ) se folosește obligatoriu $\text{Im}[y(\theta)]$ corespunzător
- Ex:

$$\theta_{L1} = 116.8^\circ \quad \theta_{S2} = 130.1^\circ \quad \text{Im}[y_{sp}] = \text{Im}[y_{L1}(\theta)] + \text{Im}[y_{S2}(\theta)] = -1.418$$
$$\theta_{sp} = \tan^{-1}(\text{Im}[y_{sp}]) \quad \theta_{sp} = 125.2^\circ$$

Combinarea celor 2 stub-uri paralel

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



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

$$\theta_{sp} = \tan^{-1}(\text{Im}[y_{sp}])$$

Combinarea celor 2 stub-uri paralel

	Soluția S2A	Soluția S2B	
Soluția L1A	$\theta = 116.8^\circ$ $\text{Im}[y(\theta)] = -0.379$	$\theta_{L1} = 116.8^\circ$ $\text{Im}[y(\theta)] = -1.418$ $\theta_p = 125.2^\circ$ $\theta_{S2} = 130.1^\circ$	$\theta = 12.6^\circ$ $\text{Im}[y(\theta)] = +1.039$
Soluția L1B	$\theta = 16.1^\circ$ $\text{Im}[y(\theta)] = +0.379$	$\theta_{L1} = 16.1^\circ$ $\text{Im}[y(\theta)] = -0.66$ $\theta_p = 146.6^\circ$ $\theta_{S2} = 130.1^\circ$	$\theta_{L1} = 16.1^\circ$ $\text{Im}[y(\theta)] = 1.418$ $\theta_p = 54.8^\circ$ $\theta_{S2} = 12.6^\circ$

Diagrama Smith

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

stub
paralel

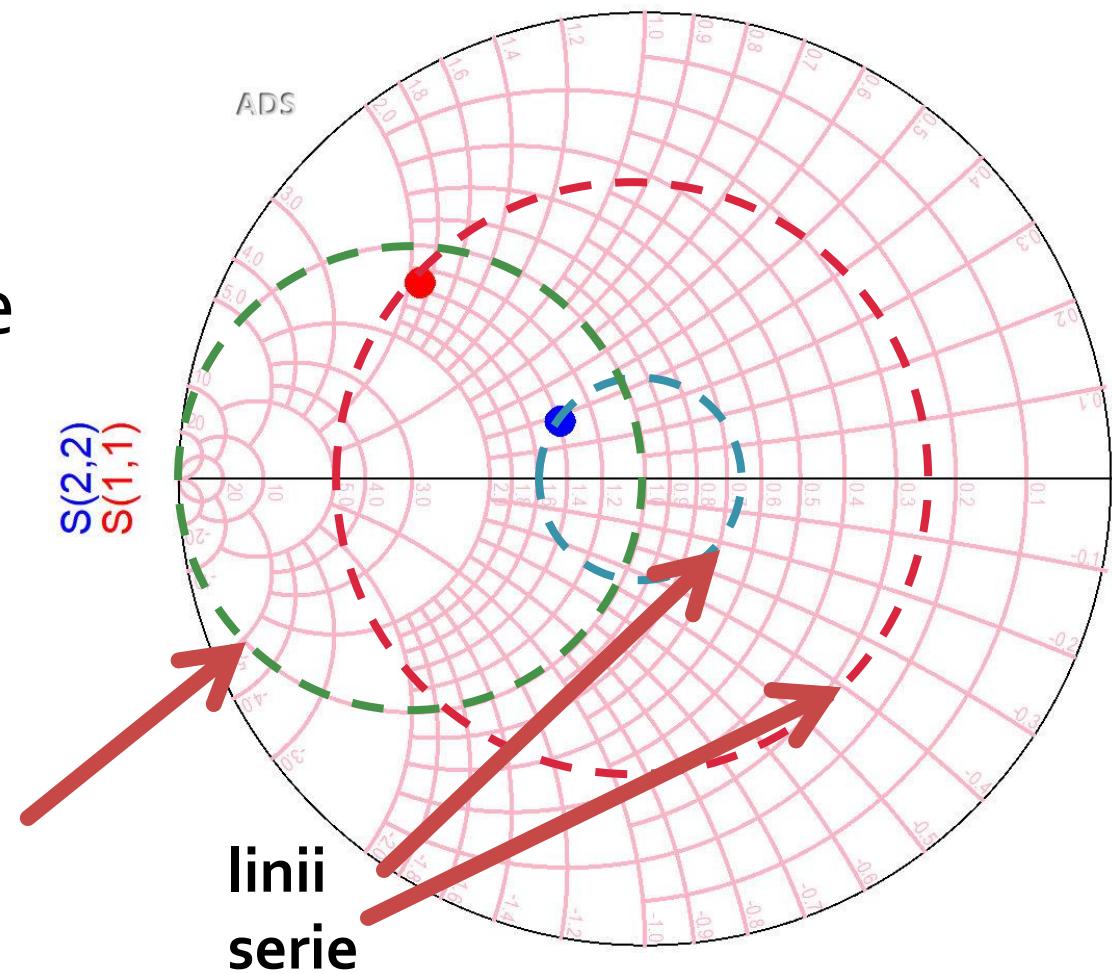


Diagrama Smith 1

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

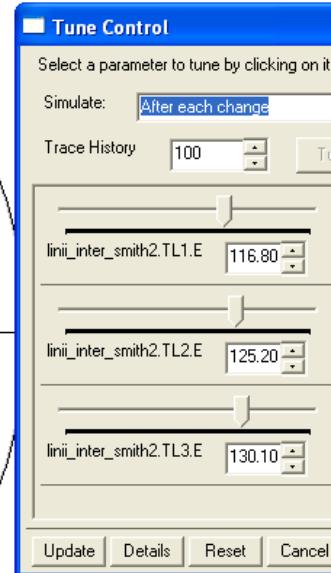
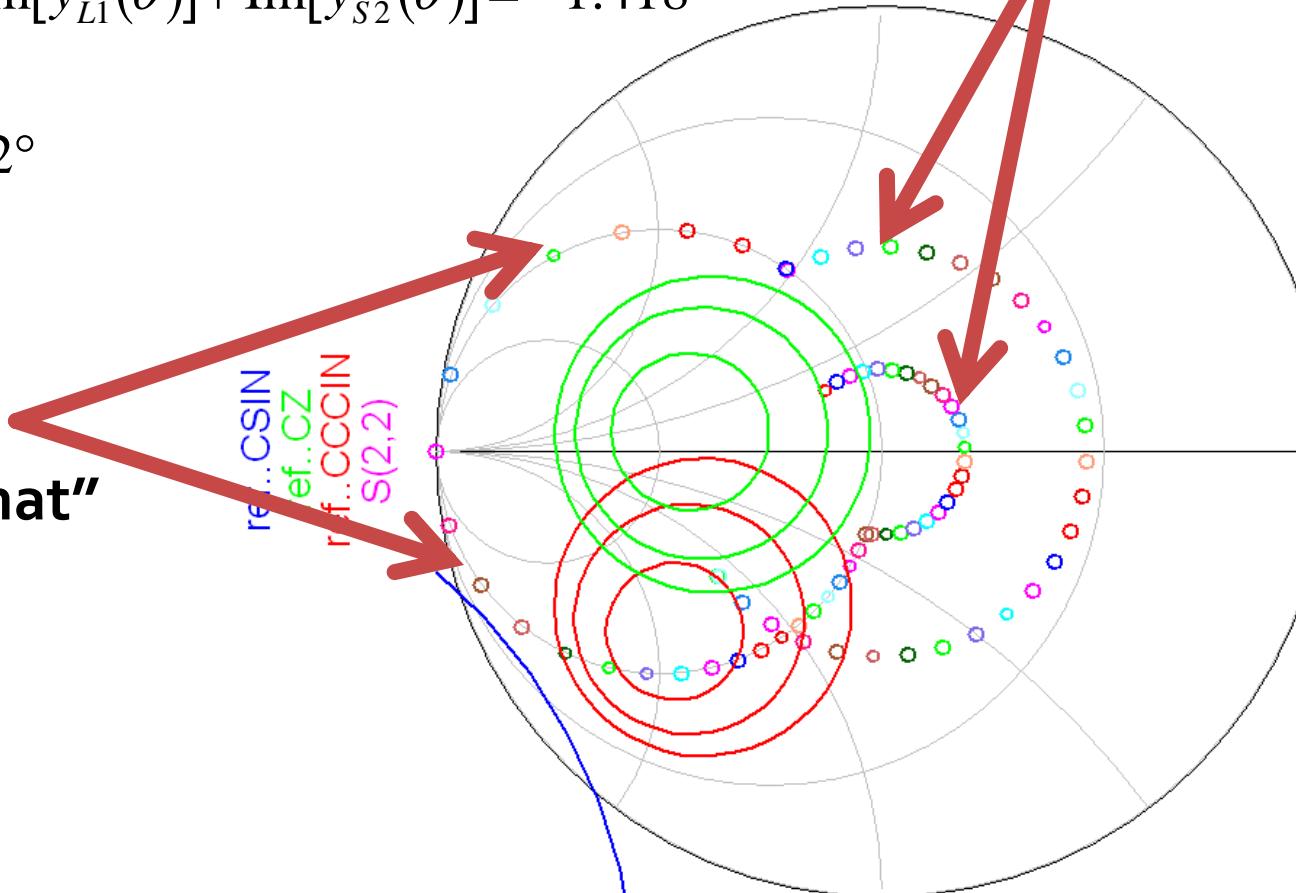
$$\text{Im}[y_{sp}] = \text{Im}[y_{L1}(\theta)] + \text{Im}[y_{S2}(\theta)] = -1.418$$

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

stub
“combinat”

ref..CSIN
ref..CZ
ref..CCCIN
ref..S(2,2)

linii
serie



ADS 1

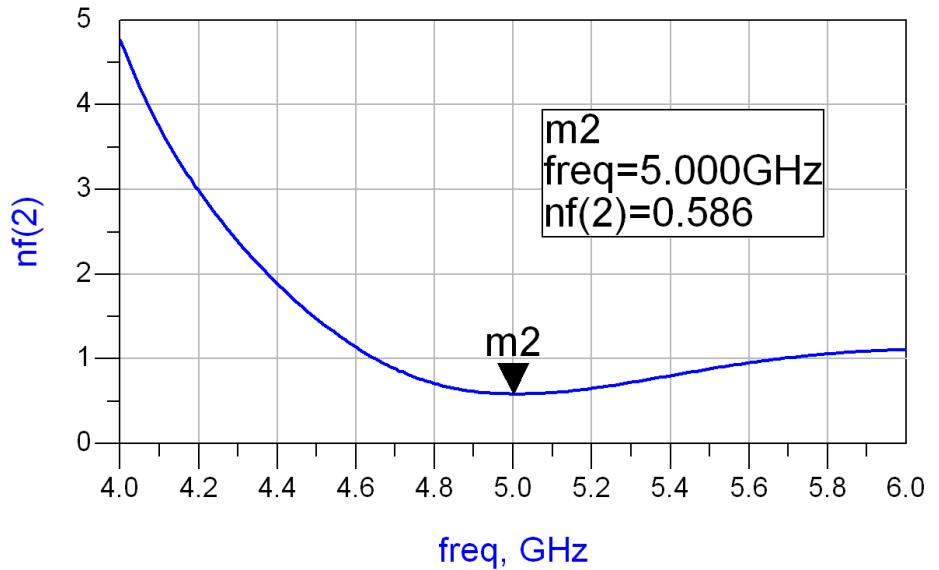
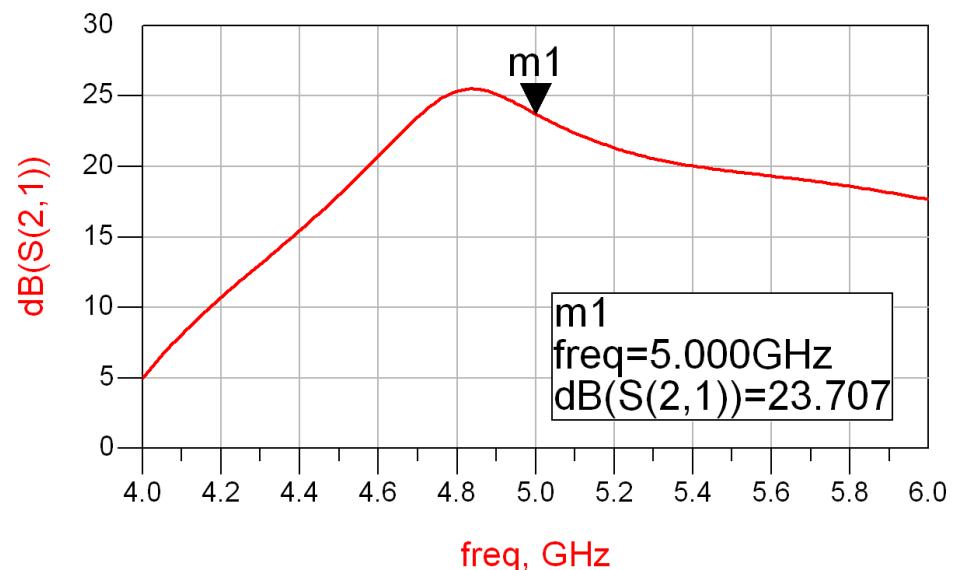
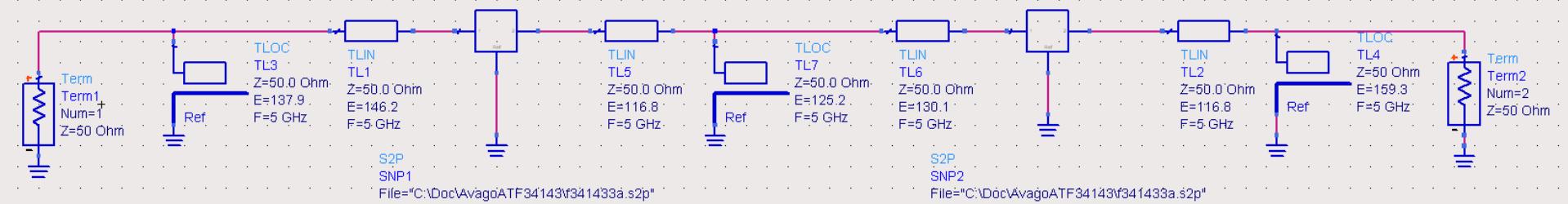


Diagramma Smith 2

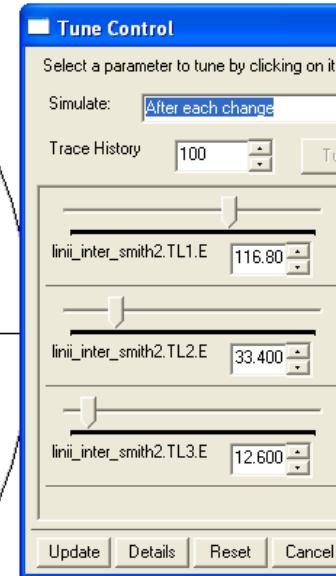
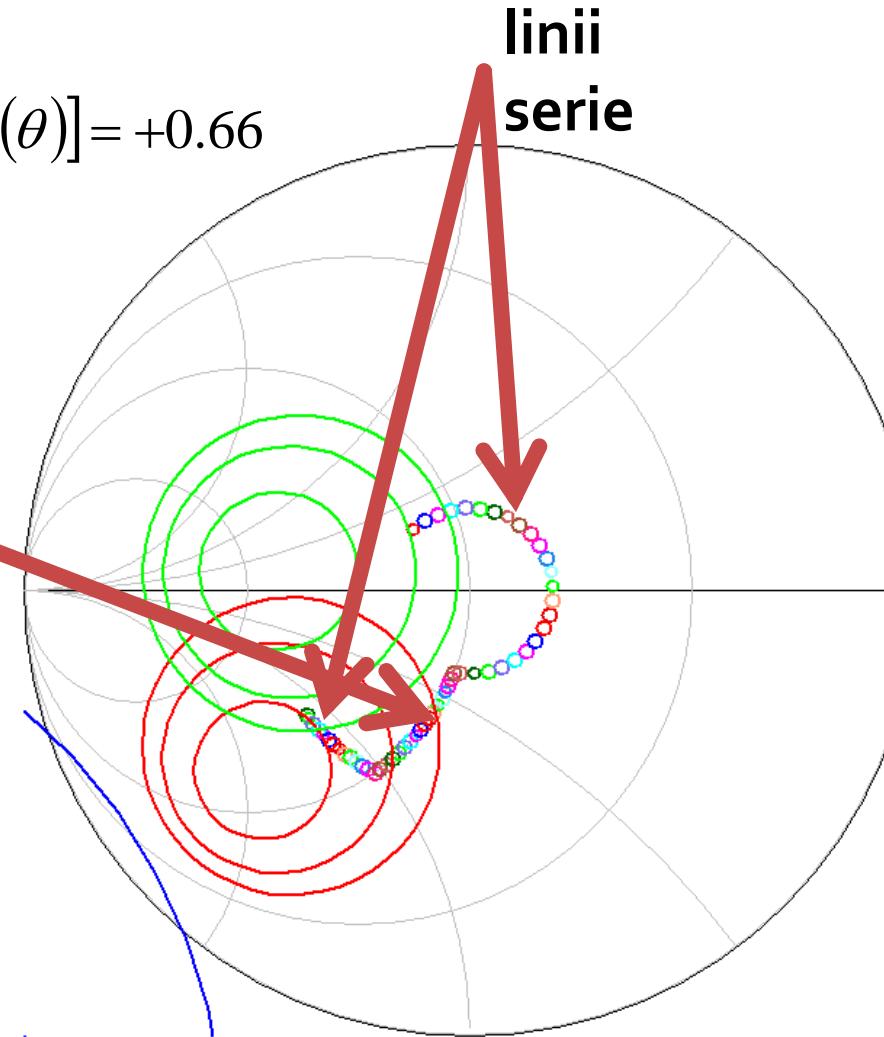
$$\theta_{L1} = 116.8^\circ \quad \theta_{S2} = 12.6^\circ$$

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

$$\theta_{sp} = 33.4^\circ$$

stub
“combinat”

ref..CSIN
ref..CZ
ref..CCCN
S(2,2)



ADS 2

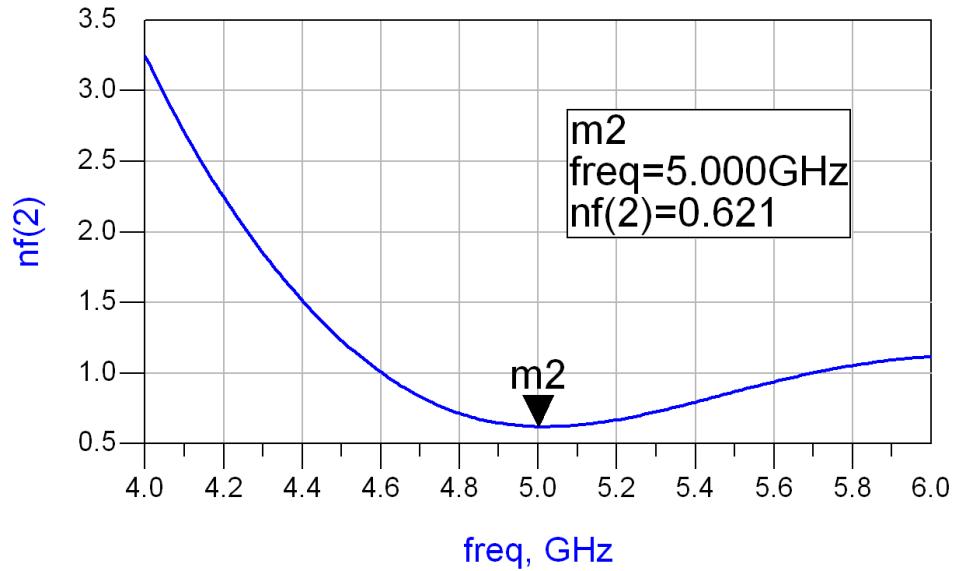
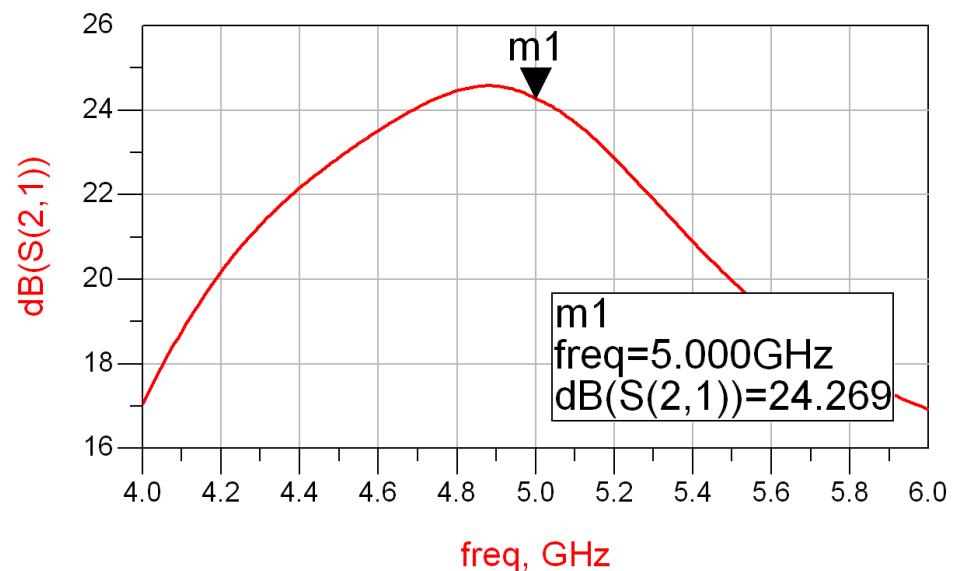
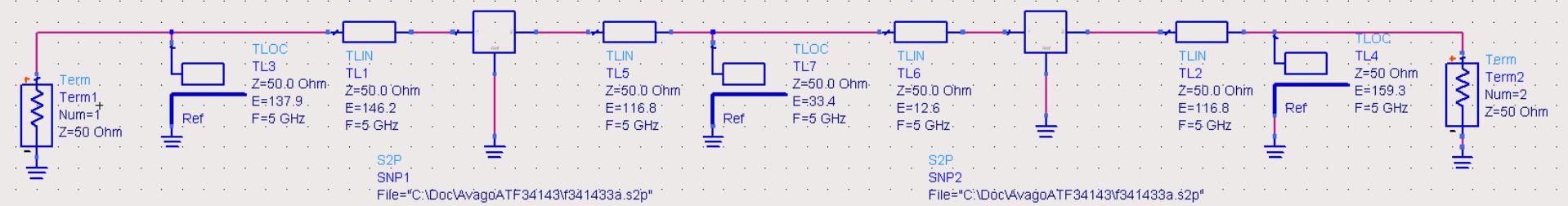


Diagrama Smith 3

$$\theta_{L1} = 16.1^\circ \quad \theta_{S2} = 130.1^\circ$$

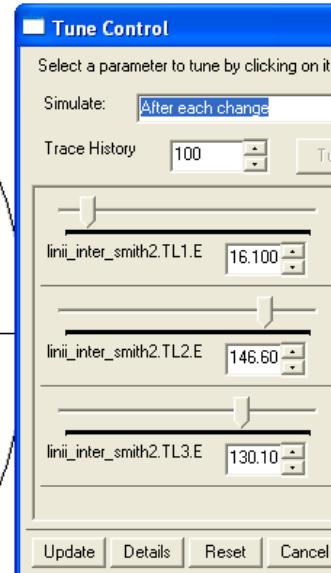
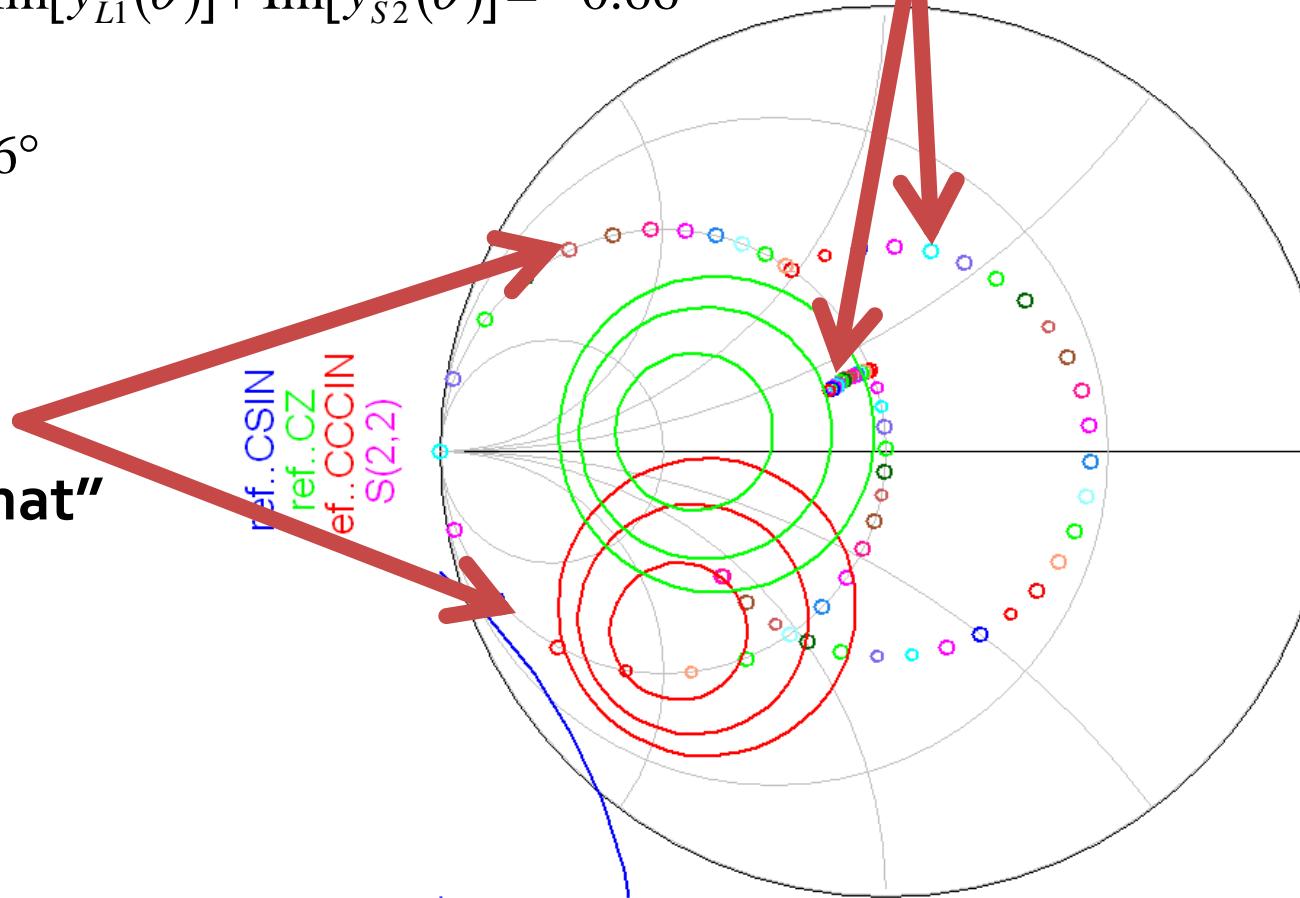
$$\text{Im}[y_{sp}] = \text{Im}[y_{L1}(\theta)] + \text{Im}[y_{S2}(\theta)] = -0.66$$

$$\theta_{sp} = 146.6^\circ$$

stub
“combinat”

ref..CSIN
ref..CZ
ref..CCCIN
 $S(2,2)$

linii
serie



ADS 3

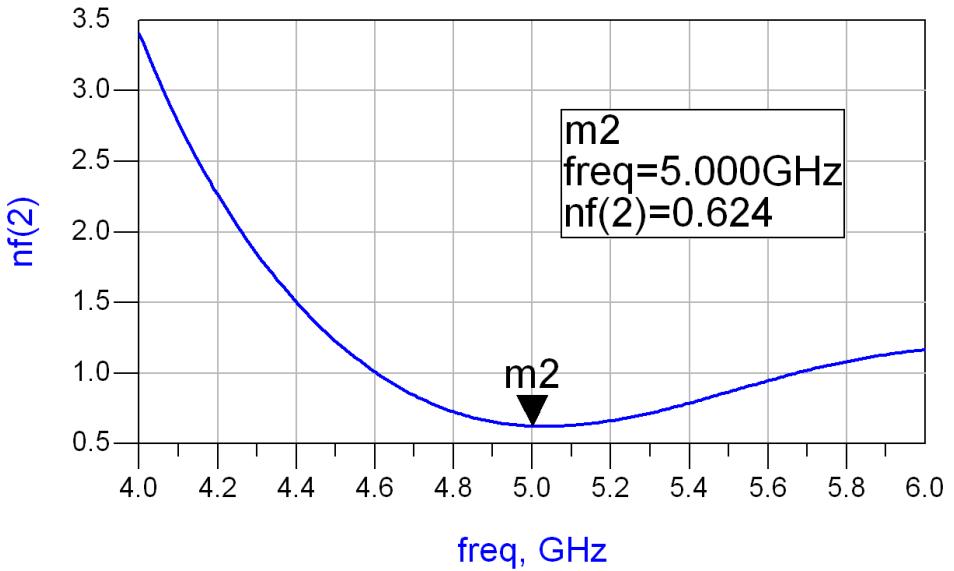
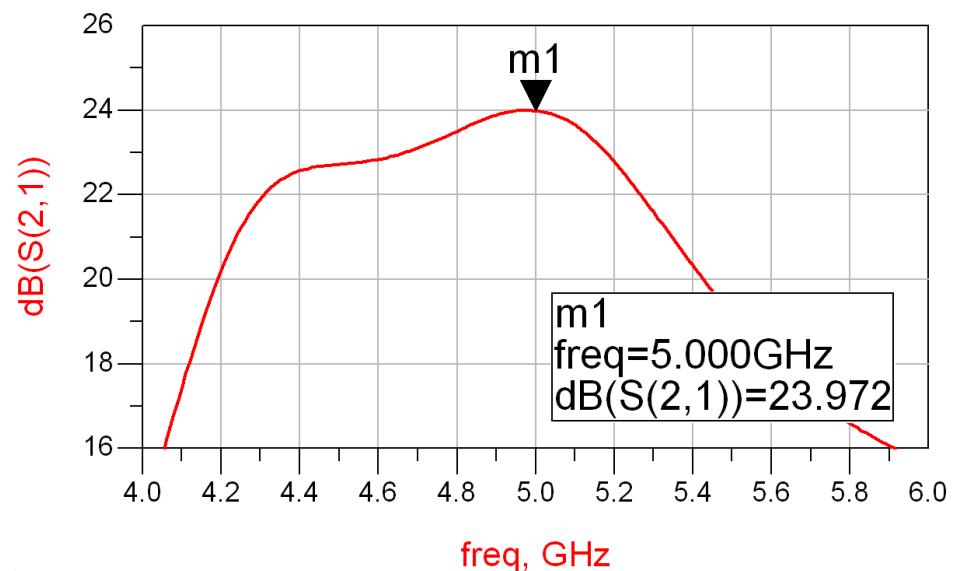
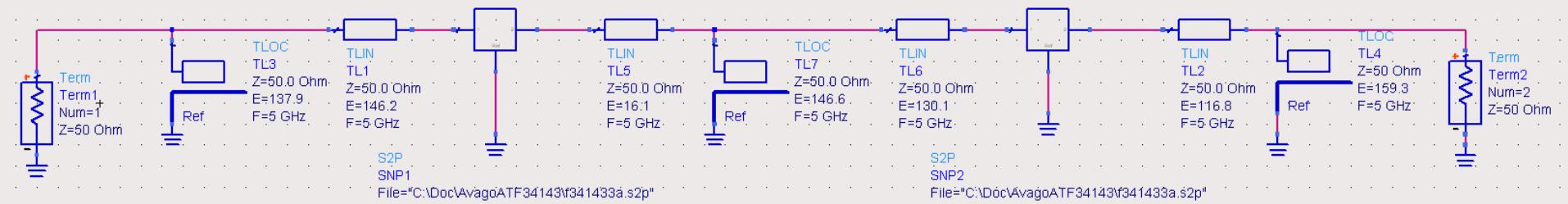


Diagramma Smith 4

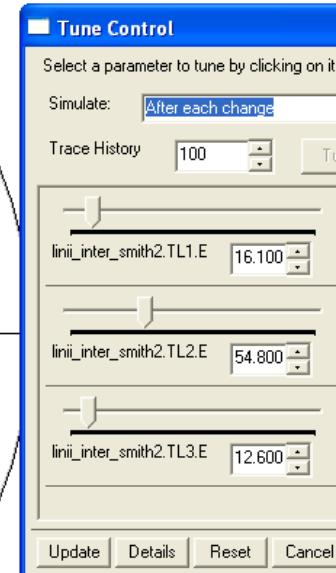
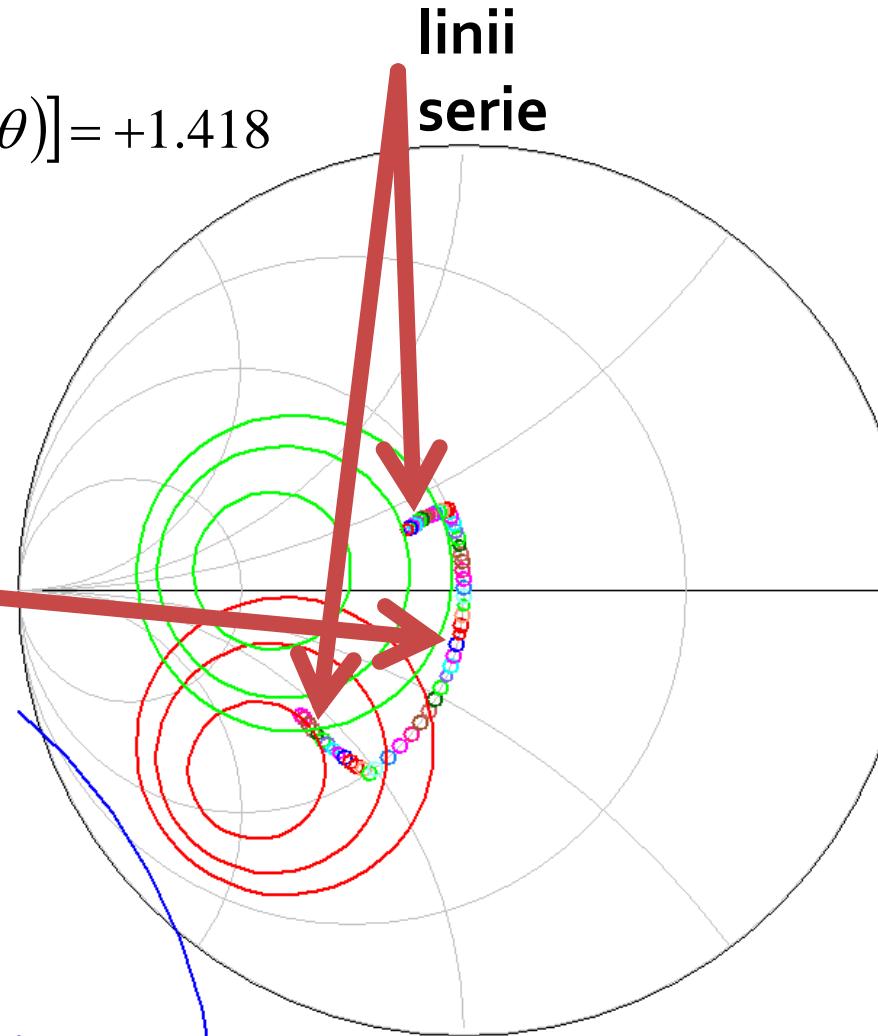
$$\theta_{L1} = 16.1^\circ \quad \theta_{S2} = 12.6^\circ$$

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

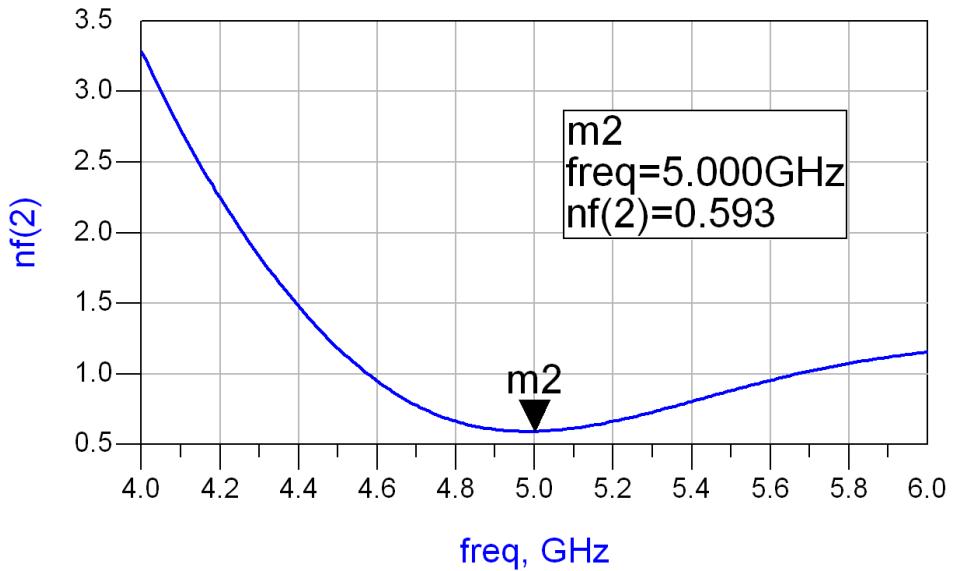
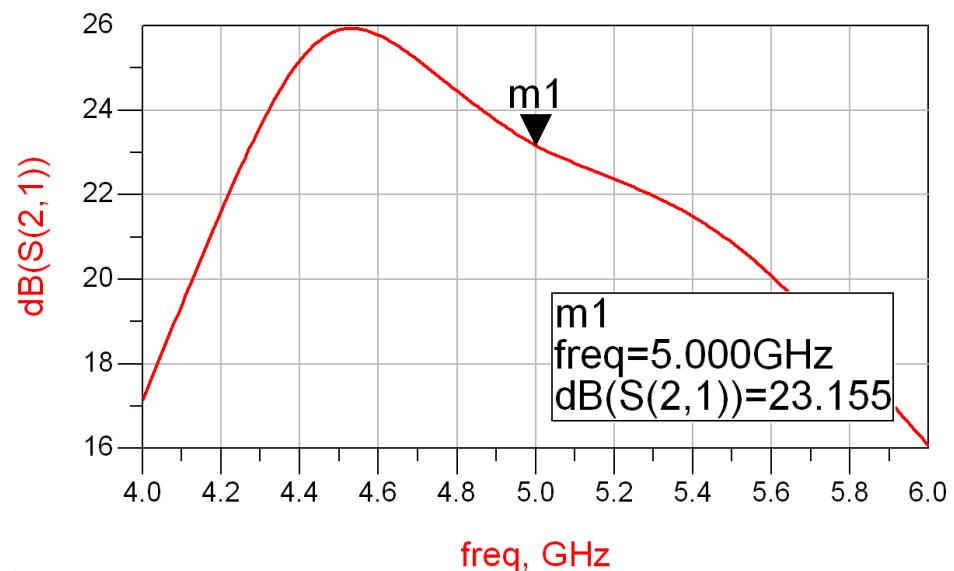
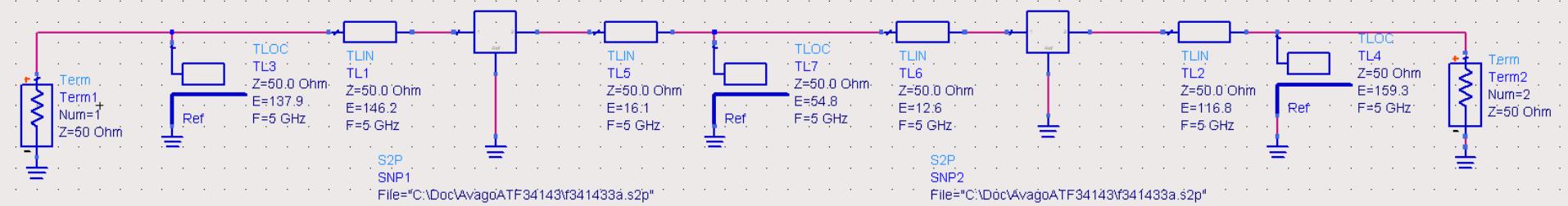
$$\theta_{sp} = 54.8^\circ$$

stub
“combinat”

ref. O SIN
ref. CZ
ref. OCCIN
ref. S(1,2)



ADS 4



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.

Contact

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