Curs 11

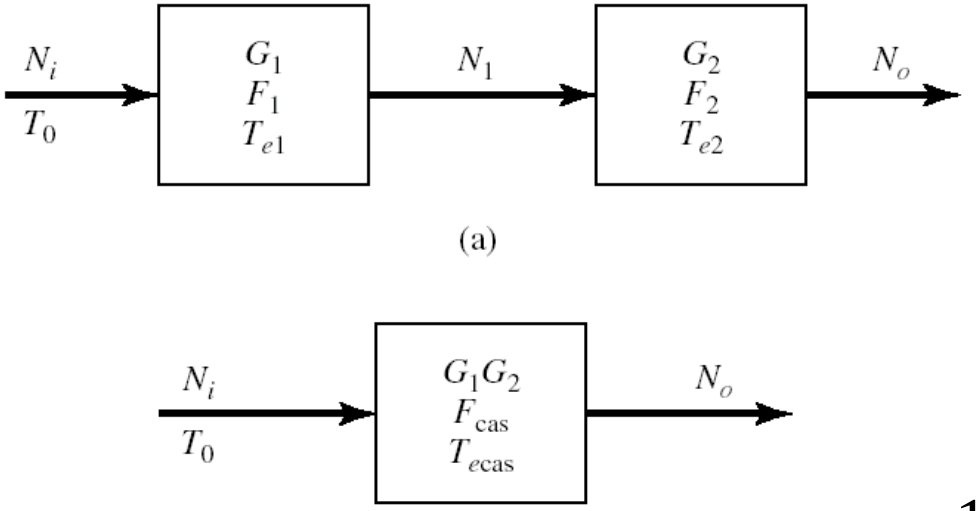
2015/2016

Dispozitive şi circuite de microunde pentru radiocomunicații

Proiectare pentru zgomot redus

Amplificatoare de microunde

Factor de zgomot al circutelor cascadate



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

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

- Ecuatia Friis (**!coordonate liniare**)

$$G_{cas} = G_1 \cdot G_2 \cdot G_3 \cdot G_4 \cdots$$

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

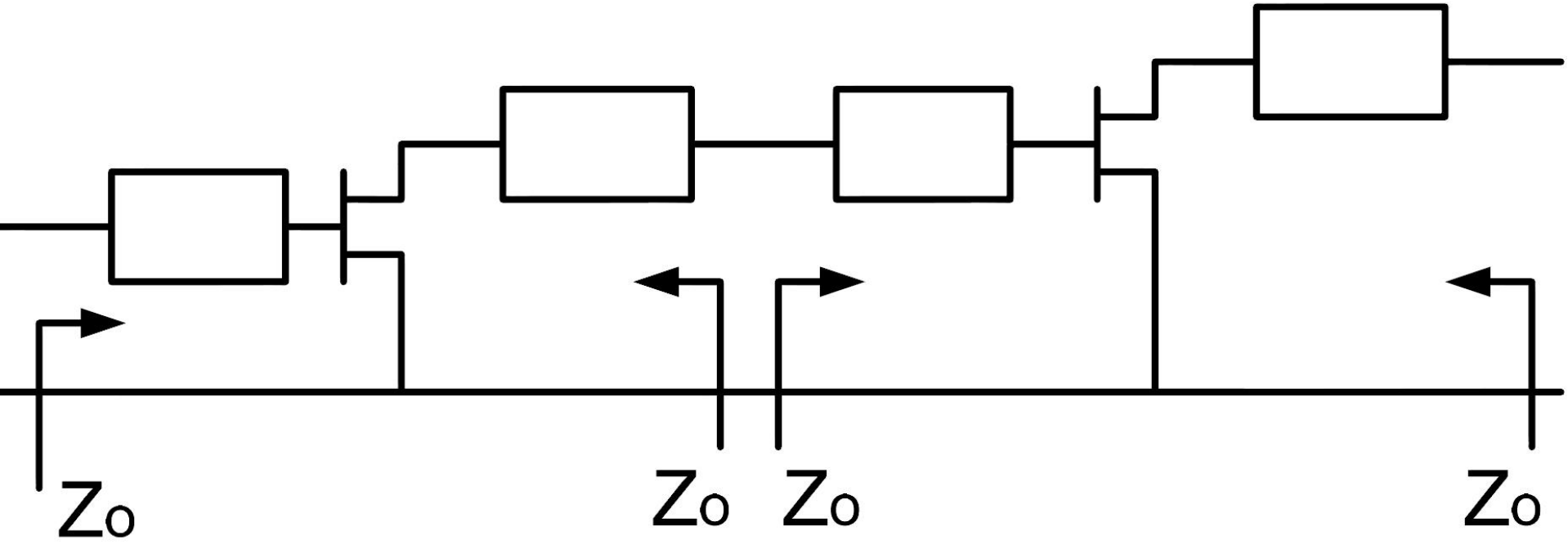
Formula lui Friis (zgomot)

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

- Formula lui Friis arata ca
  - zgomotul unor circuite in cascada este in mare parte determinat de circuitul de la intrare
  - zgomotul introdus de celelalte circuite este redus
    - -1
    - impartire la G (de obicei supraunitar)

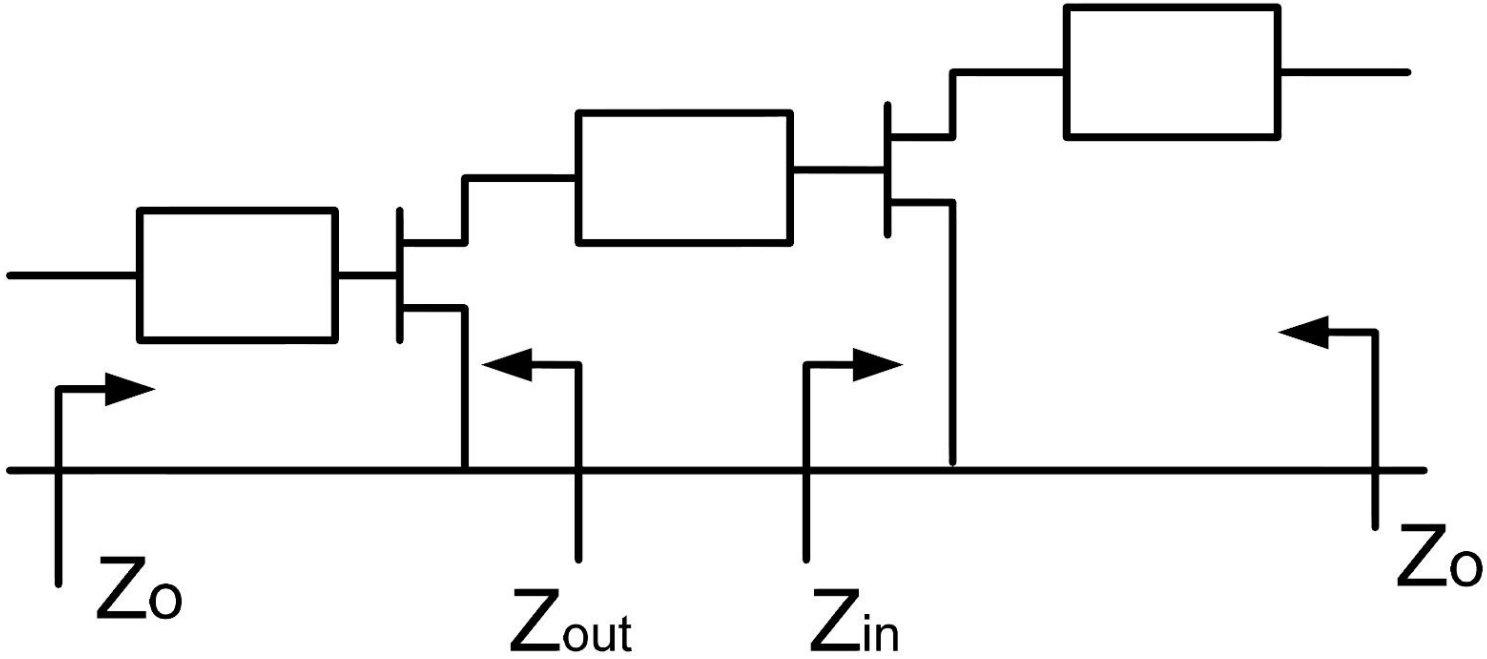
Amplificatoare in cascada

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



Amplificatoare in cascada

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

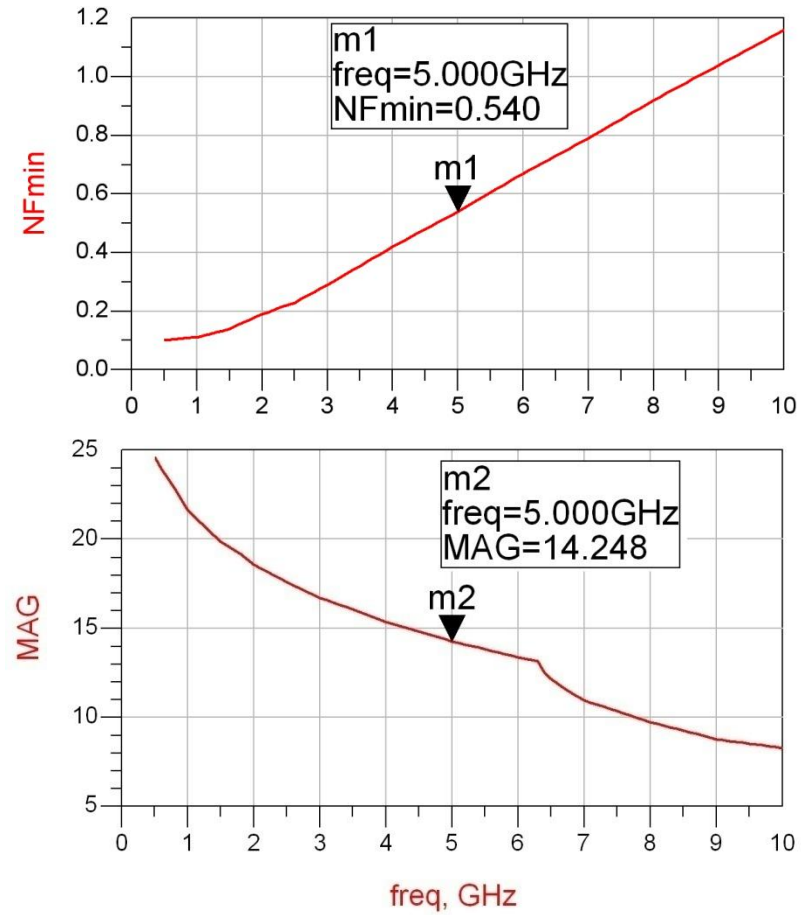


Exemplu LNA cascada

- 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
  - S11 = 0.64∠139°
  - S12 = 0.119∠-21°
  - S21 = 3.165 ∠16°
  - S22 = 0.22 ∠146°
  - Fmin = 0.54 (**tipic [dB] !**)
  - Γ_{opt} = 0.45 ∠174°
  - r_n = 0.03



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 AppCAD**
  - AppCAD Free Design Assistant Tool for Microsoft Windows

Formula lui Friis (zgomot)

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

- 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: F1 = 0.7 dB, G1 = 9 dB
  - iesire: F2 = 1.2 dB, G2 = 13 dB
- Transformare **in coordonate liniare !**

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

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

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

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

Proiectare etaje cascadate

- Impartire pe cele doua etaje (Estimat)
  - intrare: F1 = 0.7 dB, G1 = 9 dB
  - iesire: F2 = 1.2 dB, G2 = 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 (C10)
  - 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)

Exemplu C10, LNA @ 5 GHz

$$U = \frac{|S_{12}| \cdot |S_{21}| \cdot |S_{11}| \cdot |S_{22}|}{\left(1-|S_{11}|^2\right) \cdot \left(1-|S_{22}|^2\right)} = 0.094$$

$$-0.783\,dB < G_T[dB] - G_{TU}[dB] < 0.861\,dB$$

$$G_{TU\,\max} = \frac{1}{1-|S_{11}|^2} \cdot |S_{21}|^2 \cdot \frac{1}{1-|S_{22}|^2} = 17.83$$

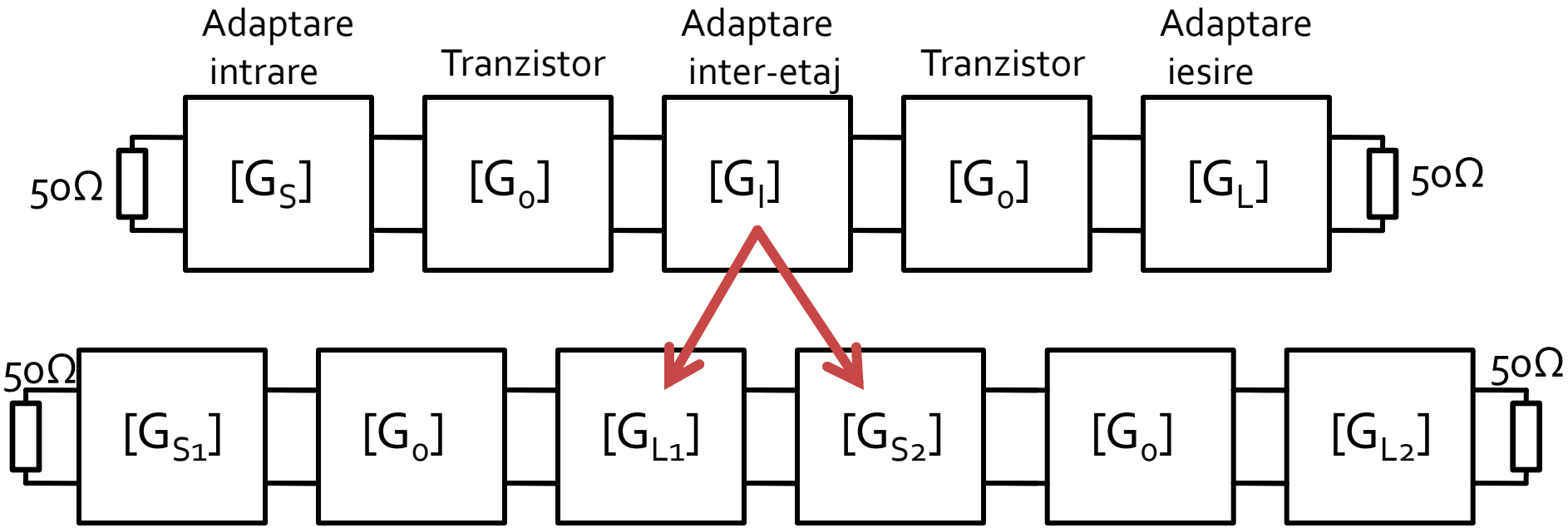
$$G_{TU\,\max}[dB] = 12.511\,dB$$

$$G_{S\,\max} = \frac{1}{1-|S_{11}|^2} = 1.694 = 2.289\,dB$$

$$G_0 = |S_{21}|^2 = 10.017 = 10.007\,dB$$

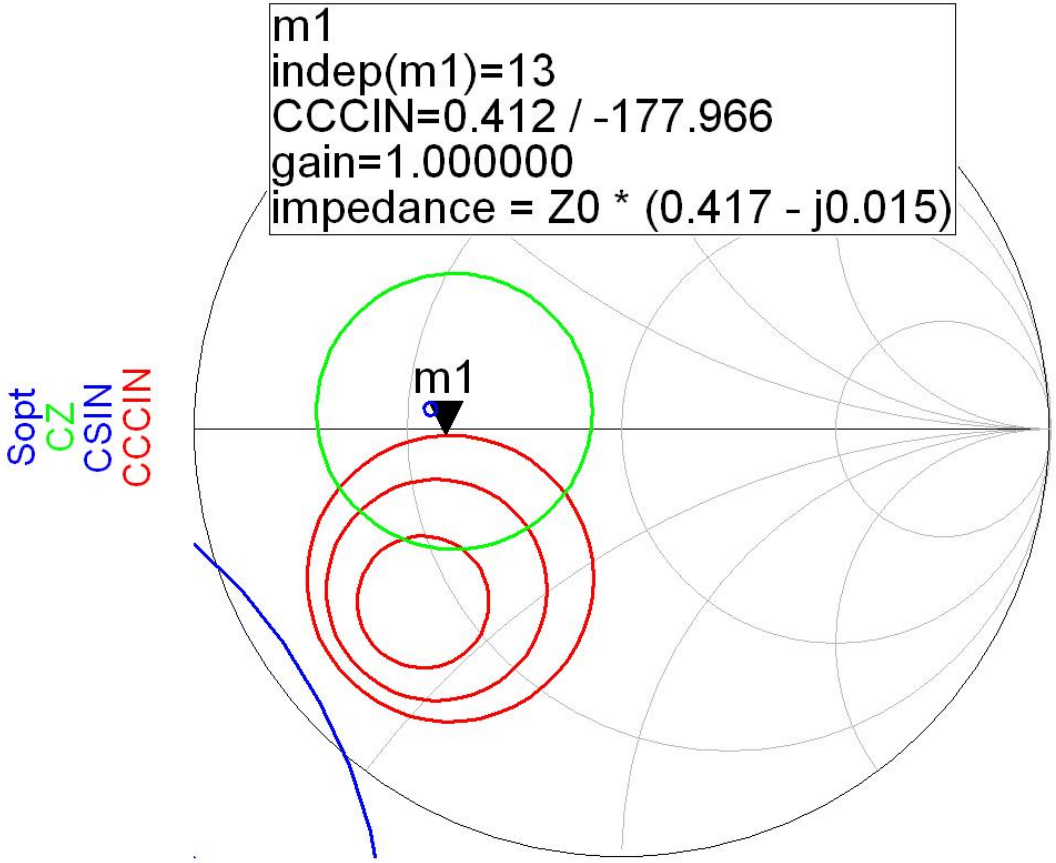
$$G_{L\,\max} = \frac{1}{1-|S_{22}|^2} = 1.051 = 0.215\,dB$$

Proiectare etaje cascadate



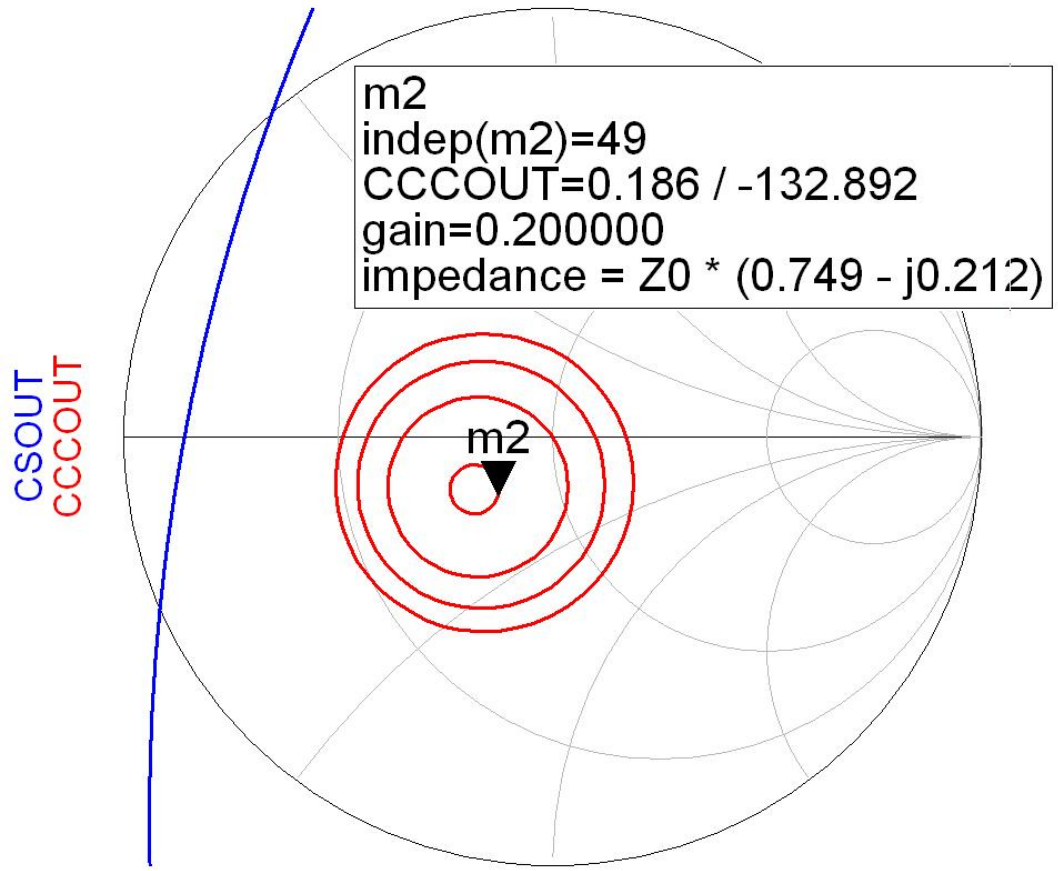
- Calcul castig
  - adaptarea inter-etaje poate aduce un supliment de castig la ambele etaje de amplificare
  - Proiectarea pentru etajele de intrare si iesire e recomandabil sa se faca pe schema mai simpla cu un singur tranzistor

Adaptare la intrare, C10



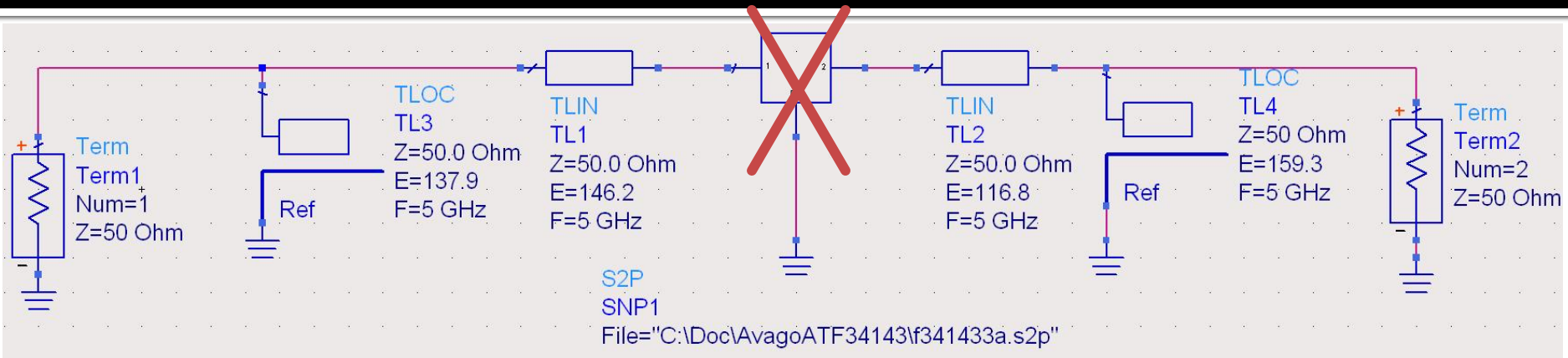
- G_{S1} = 1 dB
- F_1 = 0.55 dB

Adaptare la iesire, C10



- G_{L2} = 0.2 dB

Realizare cu linii, intrare si iesire



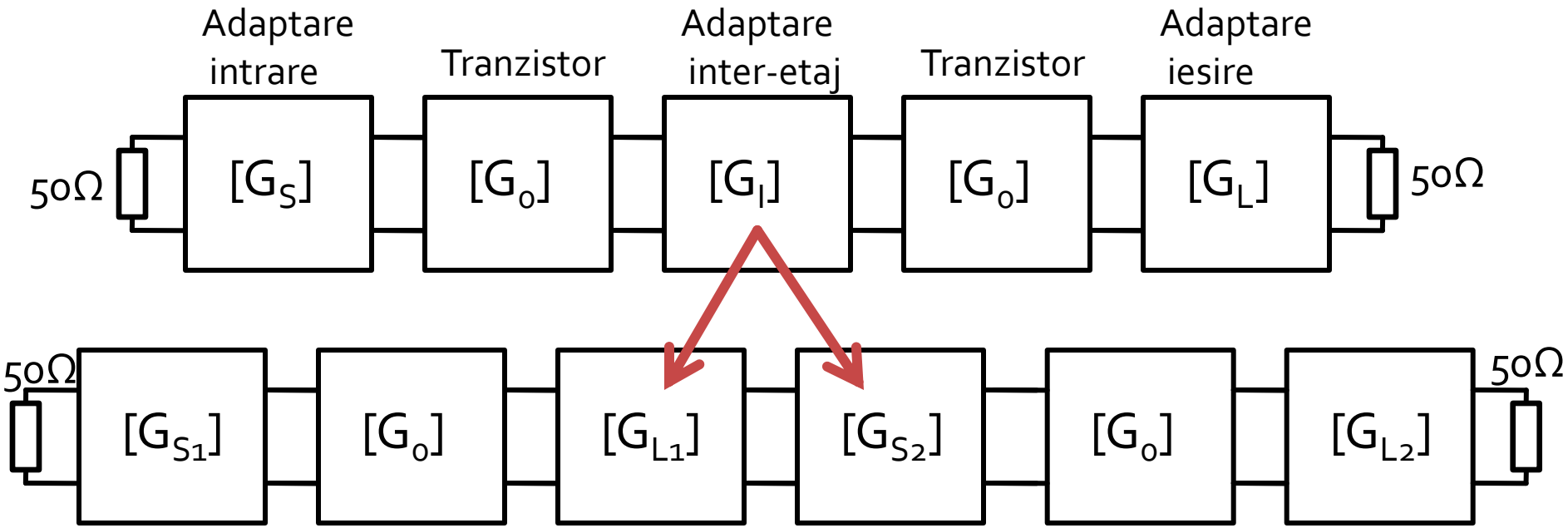
$$\cos(\varphi+2\theta)=-|\Gamma_S| \qquad \mathrm{Im}[y_S(\theta)]=\frac{\mp 2\cdot|\Gamma_S|}{\sqrt{1-|\Gamma_S|^2}}$$

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

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

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

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

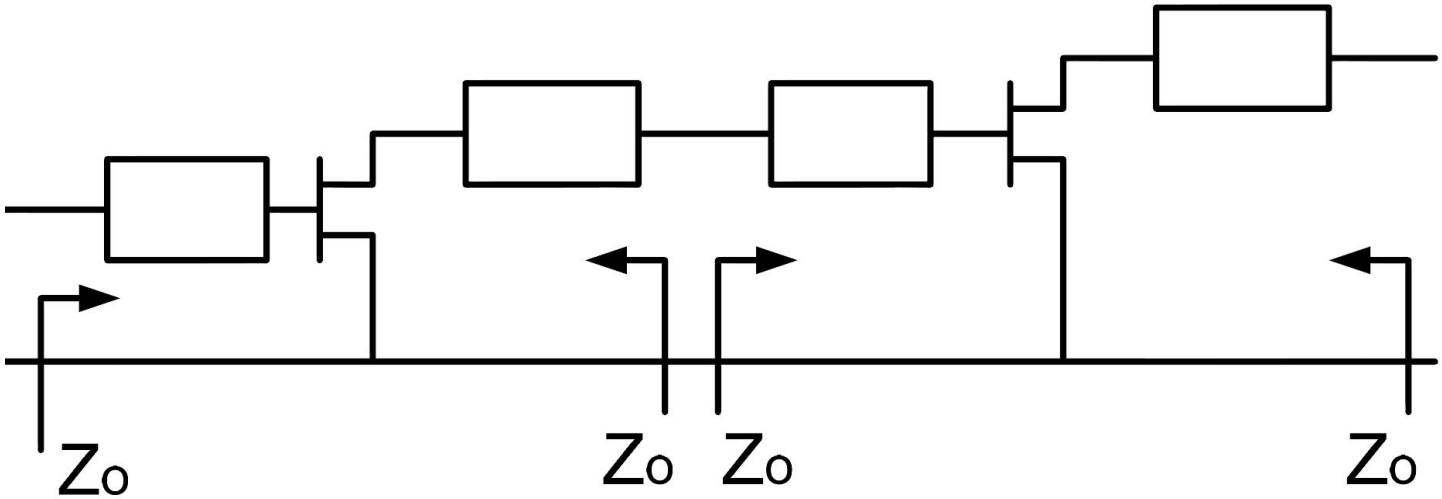
$$G_T[dB] = G_{S1}[dB] + G_0[dB] + G_{L1}[dB] + G_{S2}[dB] + G_0[dB] + G_{L2}[dB]$$

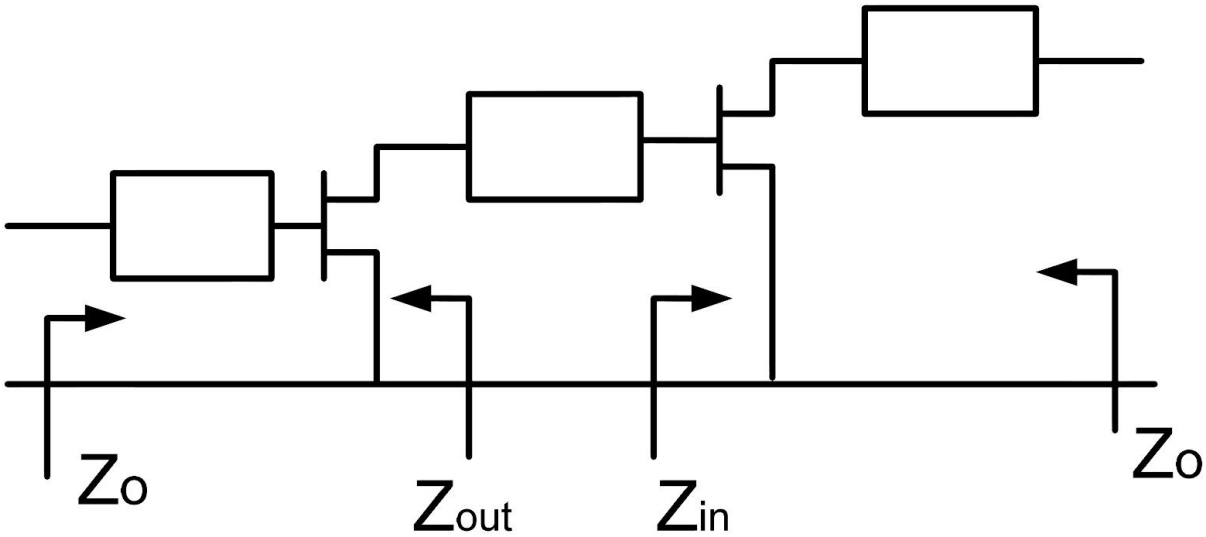
$$G_T[dB] = 1\,dB + 10\,dB + G_{L1}[dB] + G_{S2}[dB] + 10\,dB + 0.2\,dB$$

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

- Prin proiectarea interetaje trebuie obtinut un castig de minim o.8dB prin adaptare mai buna a primului etaj la iesire si a celui de-al doilea la intrare

Adaptare inter-etaje



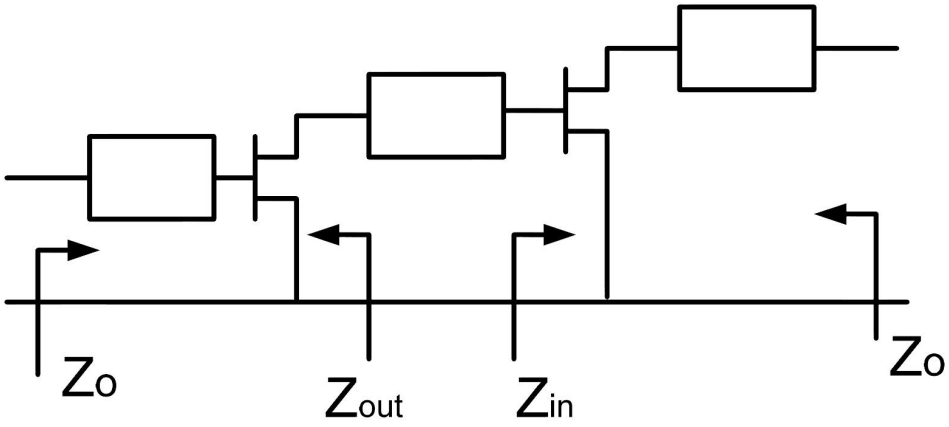


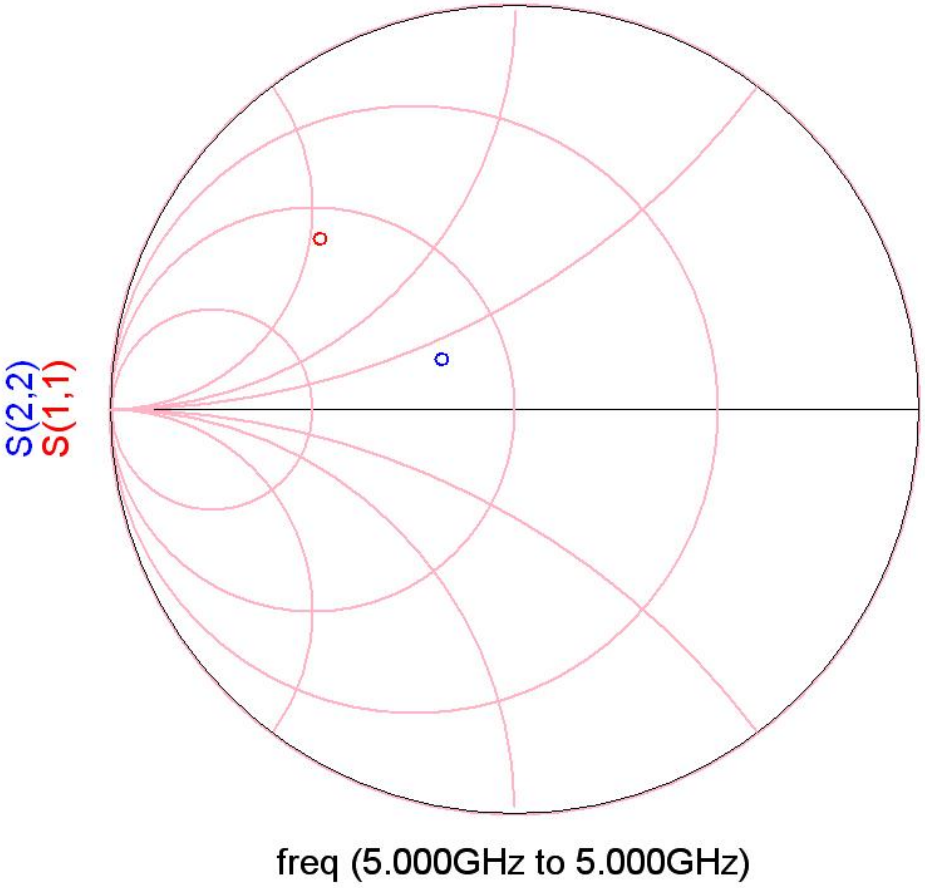
Adaptare inter-etaje

- 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-etaje

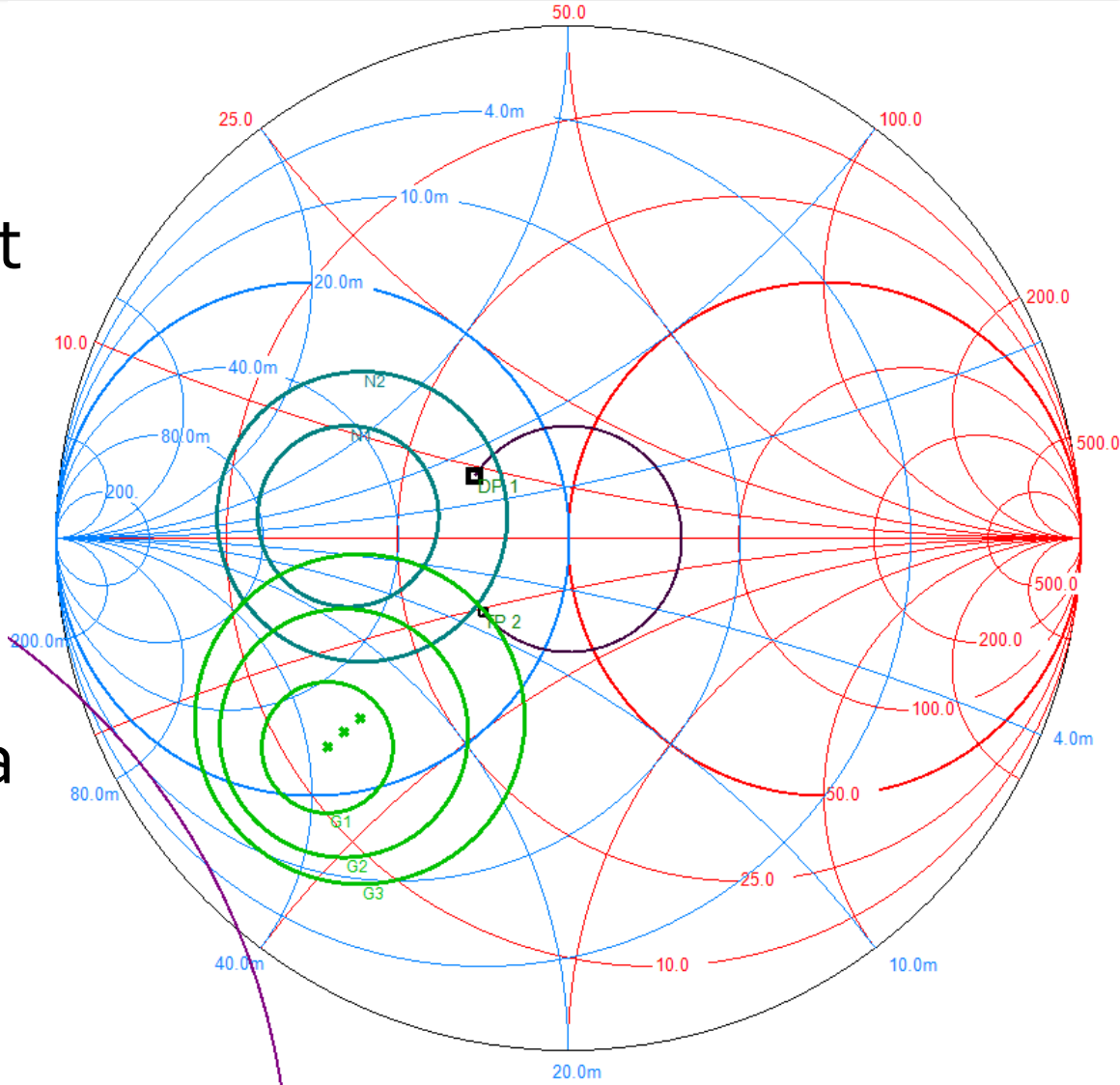
- O singura linie de transmisie pastreaza modulul coeficientului de reflexie





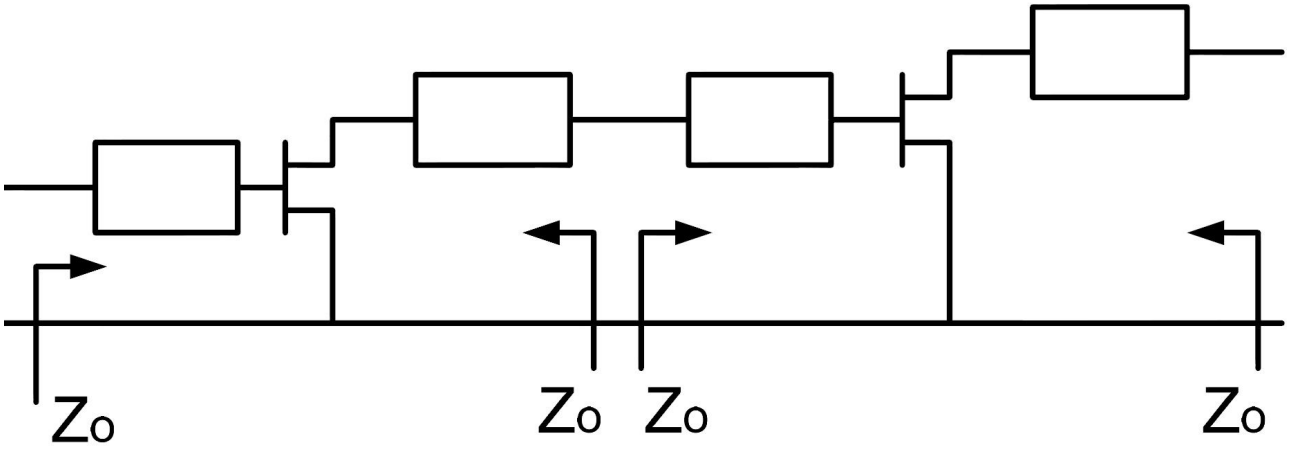
Adaptare inter-etaje

- 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



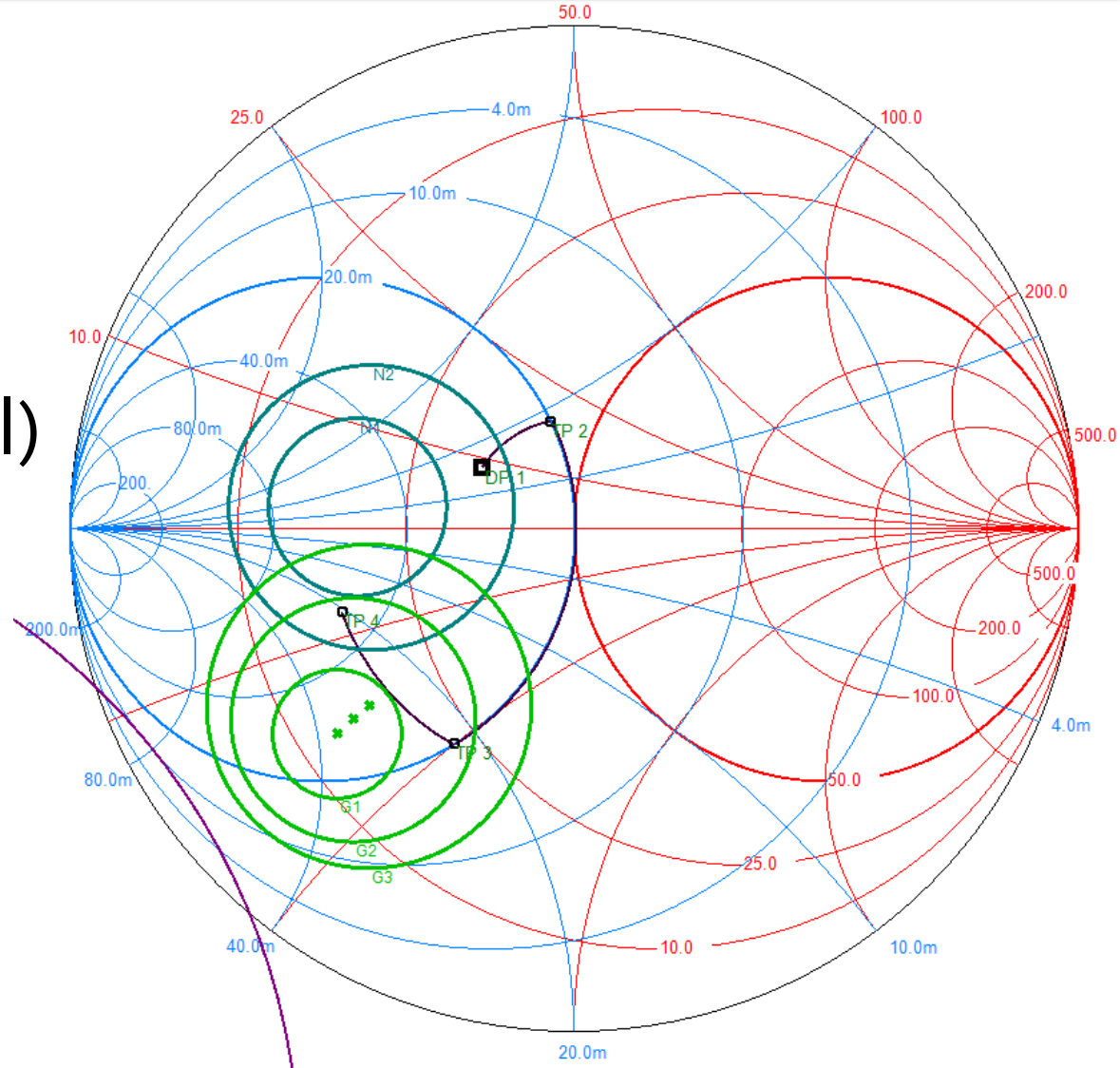
Adaptare inter-etaje

- 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

- Prima linie muta coeficientul de reflexie pe cercul unitate
- A doua (stub in gol) trece prin centrul diagramei (adaptare la Zo)
  - G_{L1} = 0.2dB
  - G_{S2} = 1.5 dB
  - F_2 = 0.6 dB



Calcul analitic

- G_{L1} (plecare din S22 spre origine)

$$S_{22} = 0.22\angle 146^\circ \qquad |S_{22}| = 0.22; \quad \varphi = 146^\circ$$

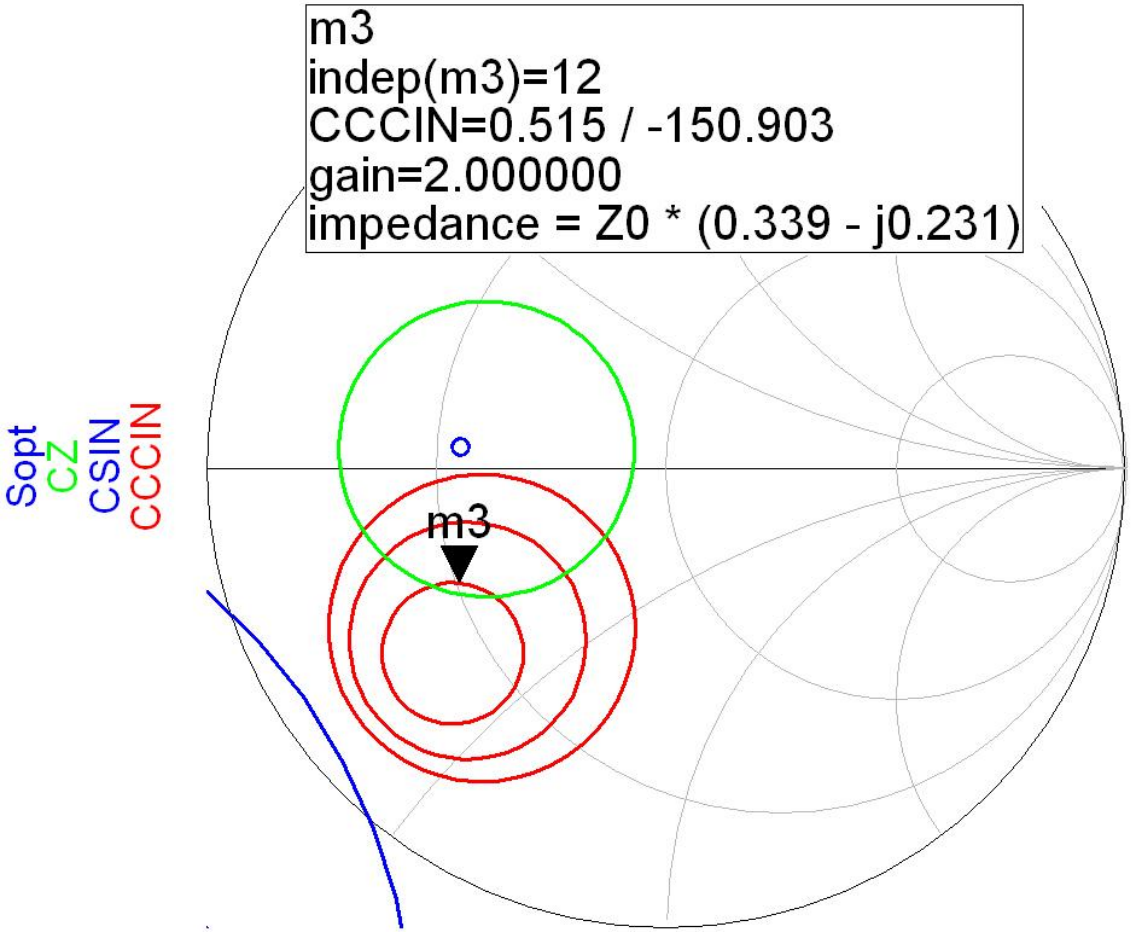
$$\cos(\varphi + 2\theta) = -|S_{22}| \qquad \mathrm{Im}[y_{L1}(\theta)] = \frac{\mp 2 \cdot |S_{22}|}{\sqrt{1 - |S_{22}|^2}}$$

$$\cos(\varphi + 2\theta) = -0.22 \Rightarrow \qquad (\varphi + 2\theta) = \pm 102.71^\circ$$

$$(\varphi + 2\theta) = \begin{cases} +102.71^\circ \\ -102.71^\circ \end{cases} \quad \theta = \begin{cases} 158.4^\circ \\ 55.6^\circ \end{cases} \quad \mathrm{Im}[y_{L1}(\theta)] = \begin{cases} -0.451 \\ +0.451 \end{cases} \quad \theta_{sp} = \begin{cases} 155.7^\circ \\ 24.3^\circ \end{cases}$$

Calcul analitic

- G_{S2} (plecare din Γ_{S2} ales spre origine – castig 2dB)



Calcul analitic

- G_{S2} (plecare din 2 spre origine)

$$\Gamma_{S2} = 0.515\angle -150.9^\circ \qquad |\Gamma_{S2}| = 0.515; \quad \varphi = -150.9^\circ$$

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

$$\cos(\varphi + 2\theta) = -0.515 \Rightarrow \qquad (\varphi + 2\theta) = \pm 121^\circ$$

$$(\varphi + 2\theta) = \begin{cases} +121^\circ \\ -121^\circ \end{cases} \quad \theta = \begin{cases} 135.9^\circ \\ 15^\circ \end{cases} \quad \mathrm{Im}[y_{S2}(\theta)] = \begin{cases} -1.202 \\ +1.202 \end{cases} \quad \theta_{sp} = \begin{cases} 129.8^\circ \\ 50.2^\circ \end{cases}$$

Calcul analitic

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

$$\theta_{L1} = 158.4^\circ \qquad \theta_{S2} = 135.9^\circ \qquad \mathrm{Im}\left[y_{sp}\right] = \mathrm{Im}\left[y_{L1}(\theta)\right] + \mathrm{Im}\left[y_{S2}(\theta)\right] = -1.653$$

$$\theta_{sp} = \tan^{-1}\left(\mathrm{Im}\left[y_{sp}\right]\right) \qquad \theta_{sp} = 121.2^\circ$$

Diagrama Smith

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

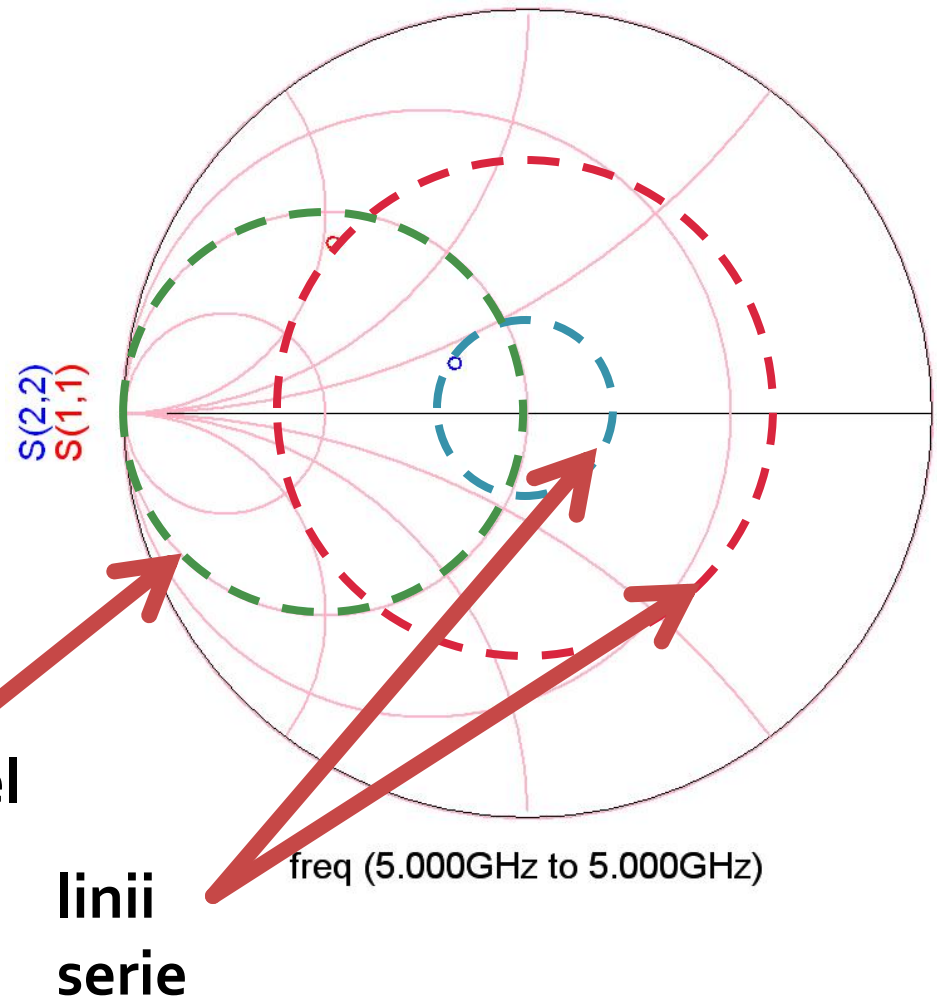


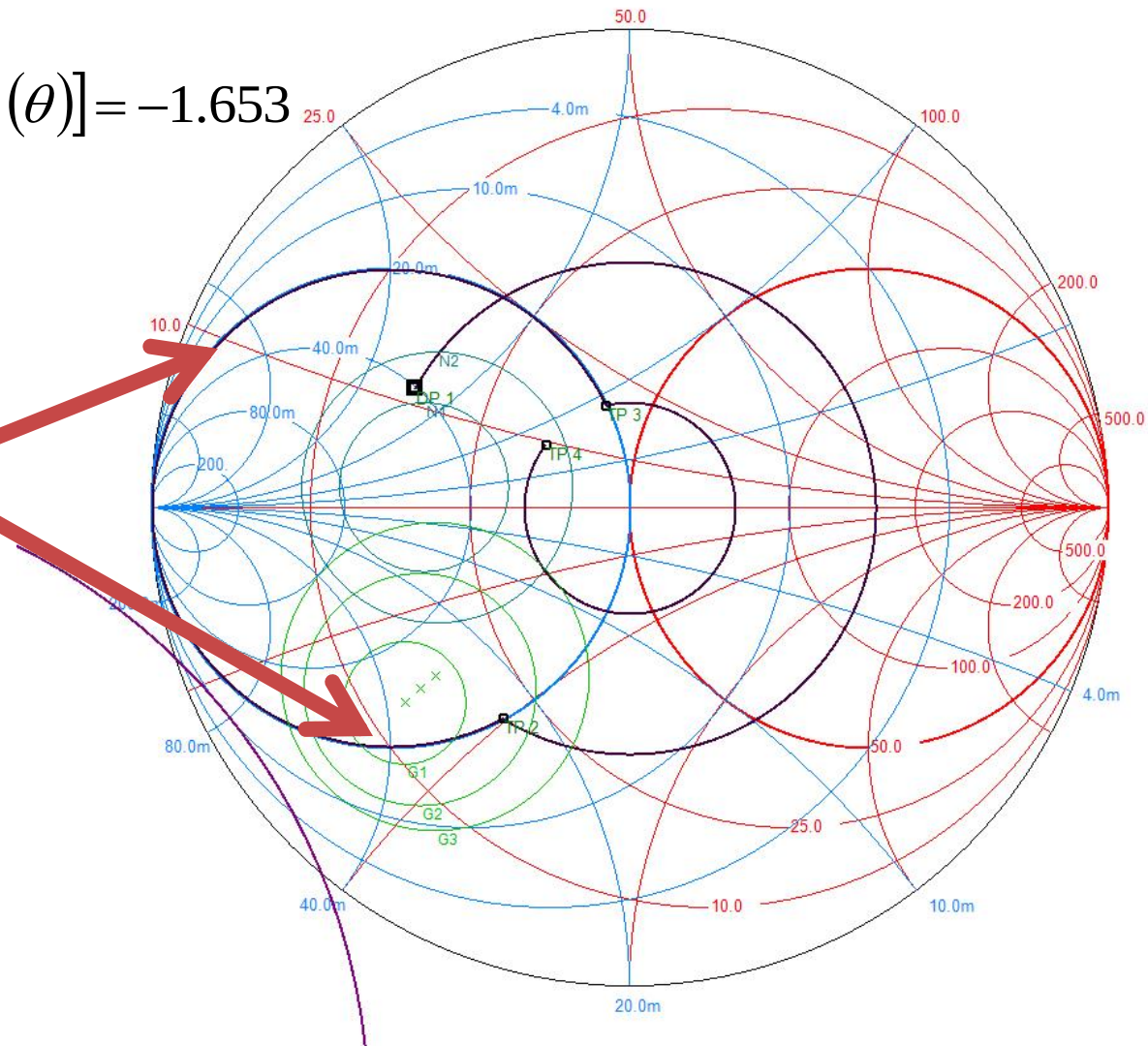
Diagrama Smith 1

$$\theta_{L1} = 158.4° \qquad \theta_{S2} = 135.9°$$

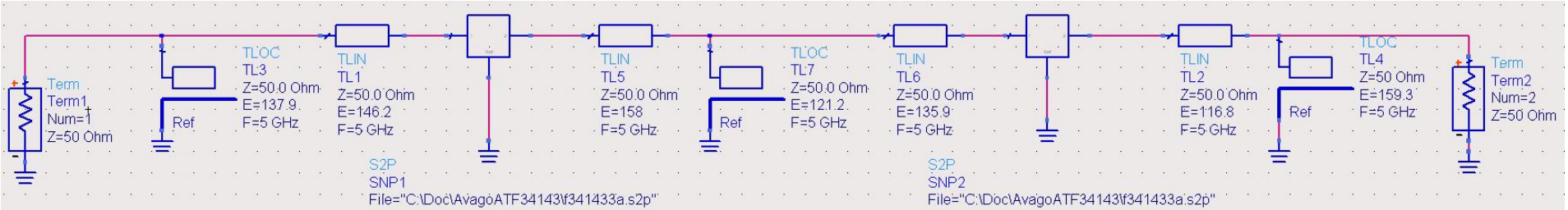
$$\mathrm{Im}\left[y_{sp}\right] = \mathrm{Im}\left[y_{L1}(\theta)\right] + \mathrm{Im}\left[y_{S2}(\theta)\right] = -1.653$$

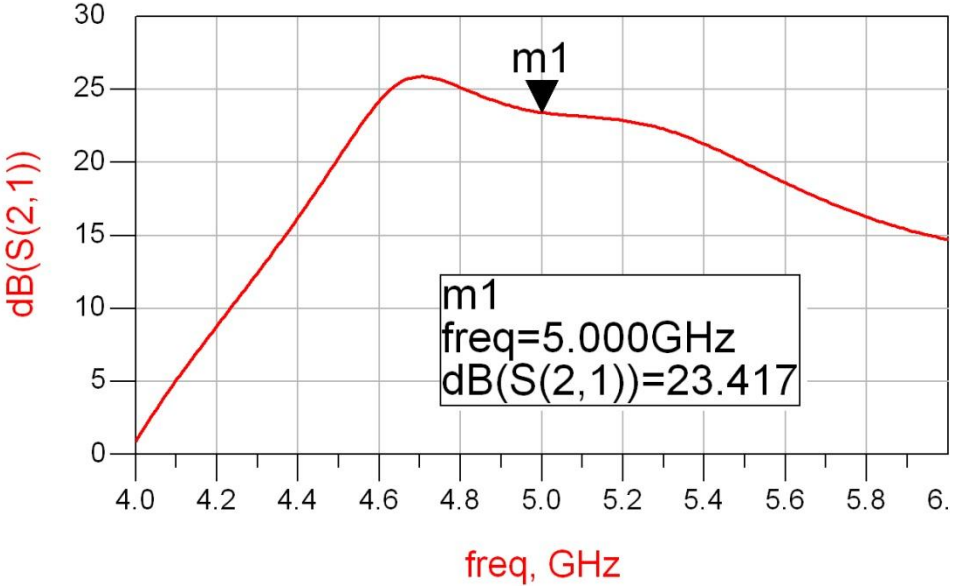
$$\theta_{sp} = 121.2°$$

stub "combinat"



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=158
F=5 GHz
Ref
TLOC
TL7
Z=50.0 Ohm
E=121.2
F=5 GHz
TLIN
TL6
Z=50.0 Ohm
E=135.9
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))=23.417
dB(S(2,1))
freq, GHz
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.

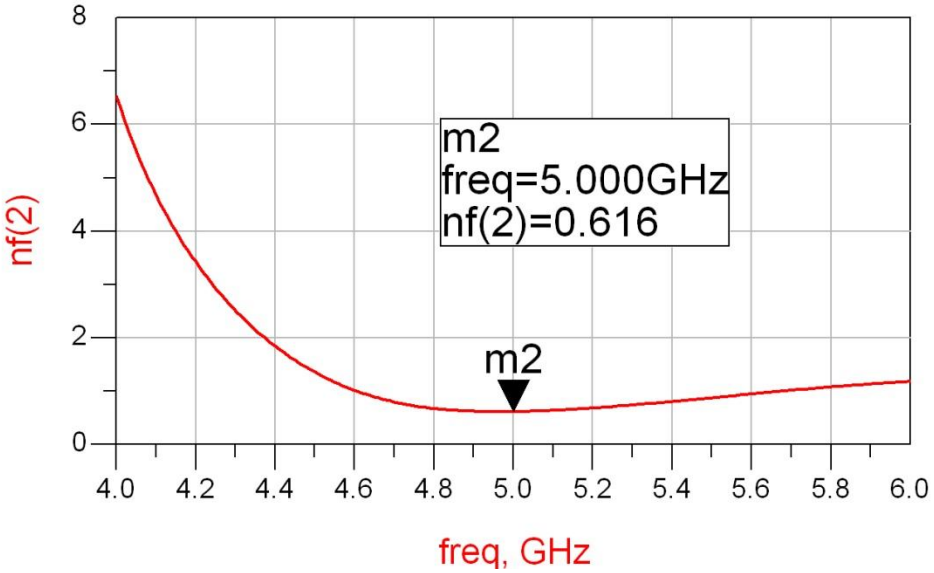

m2
freq=5.000GHz
nf(2)=0.616
m2
nf(2)
freq, GHz
8
6
4
2
0
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0

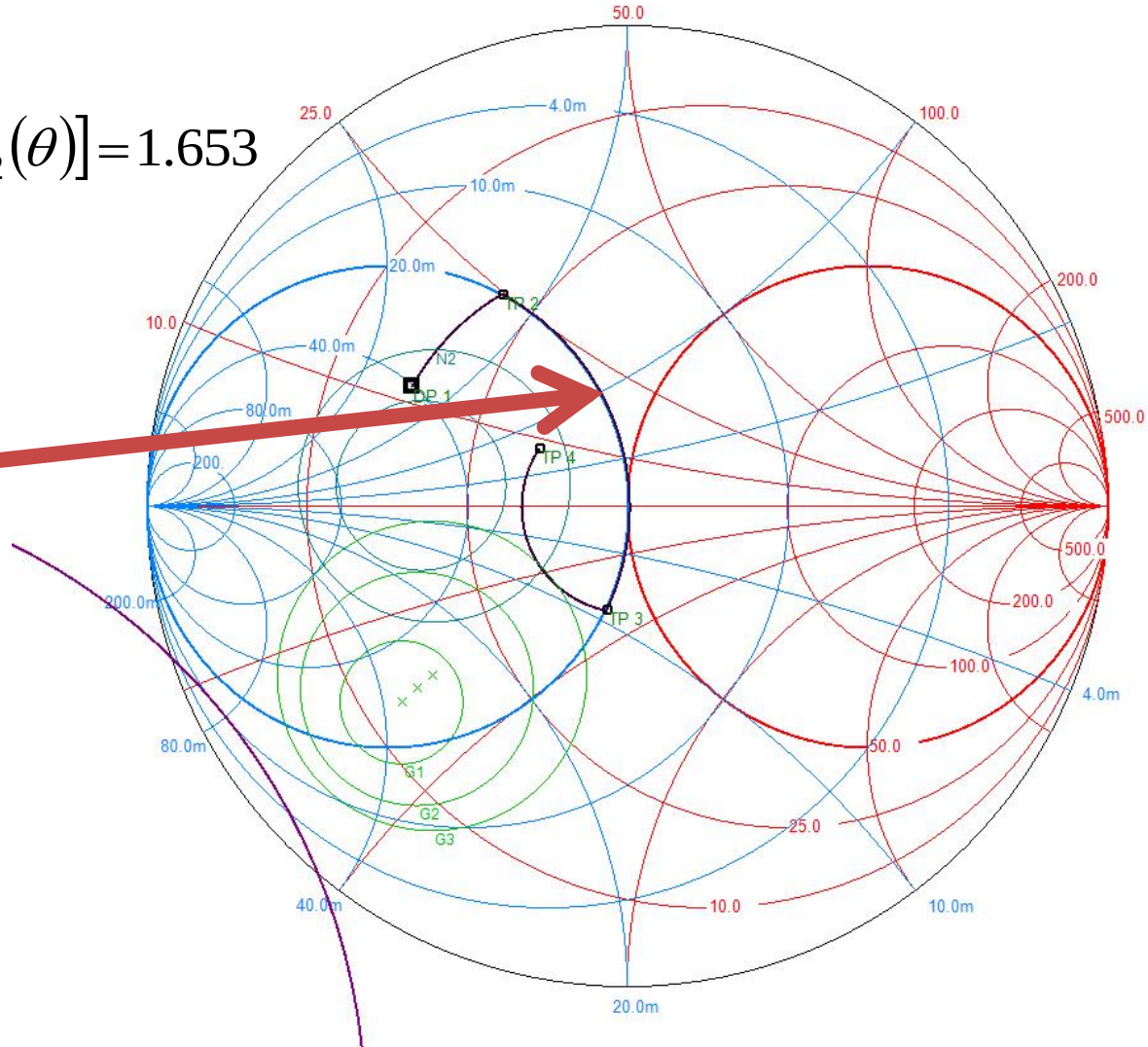
Diagrama Smith 2

$$\theta_{L1} = 55.6° \qquad \theta_{S2} = 15°$$

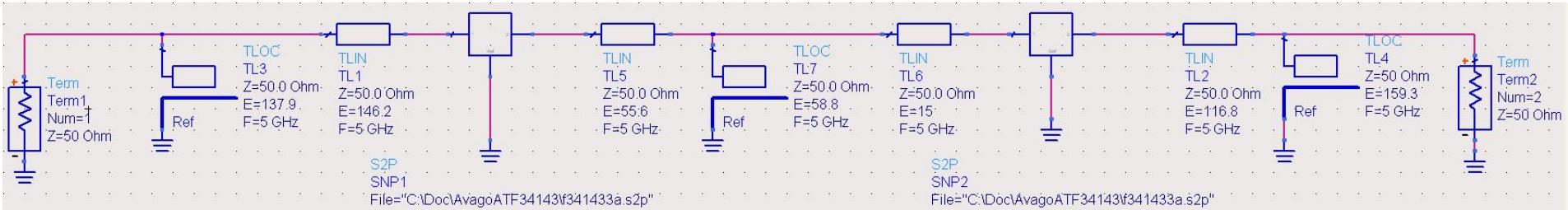
$$\mathrm{Im}\left[y_{sp}\right] = \mathrm{Im}\left[y_{L1}(\theta)\right] + \mathrm{Im}\left[y_{S2}(\theta)\right] = 1.653$$

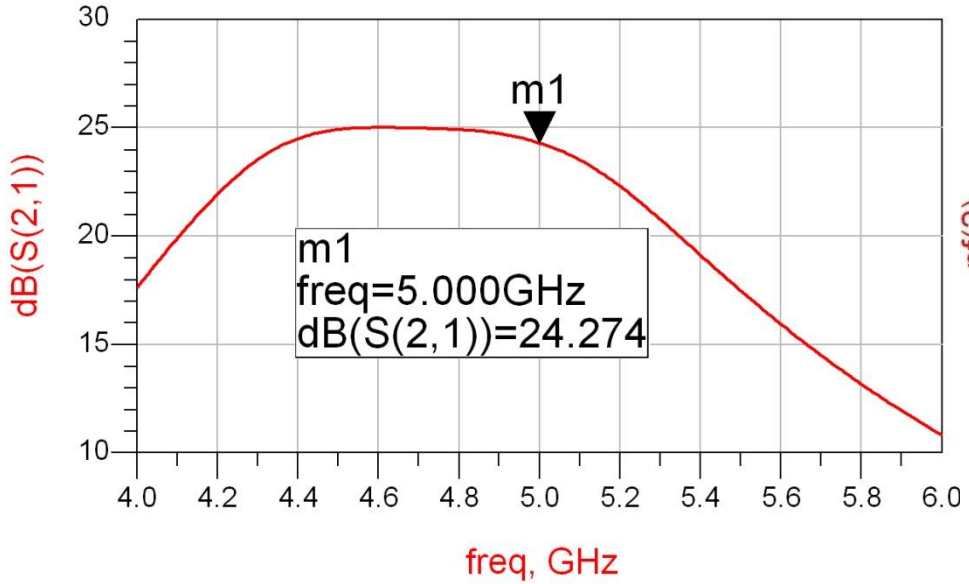
$$\theta_{sp} = 58.8°$$

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=55.6
F=5 GHz
Ref
TLOC
TL7
Z=50.0 Ohm
E=58.8
F=5 GHz
TLIN
TL6
Z=50.0 Ohm
E=15
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))
freq, GHz
m1
m1
freq=5.000GHz
dB(S(2,1))=24.274
30
25
20
15
10
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0

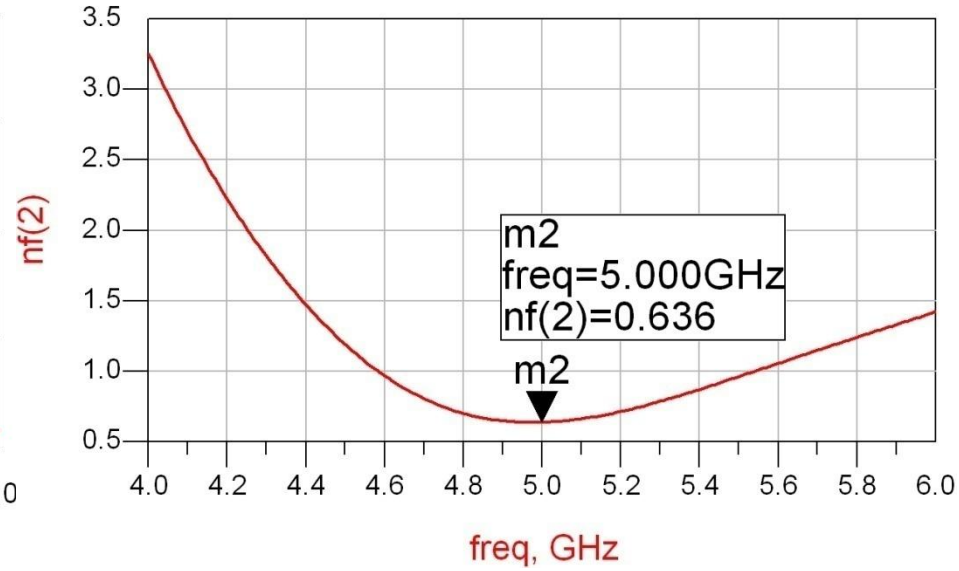

nf(2)
freq, GHz
m2
m2
freq=5.000GHz
nf(2)=0.636
3.5
3.0
2.5
2.0
1.5
1.0
0.5
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0

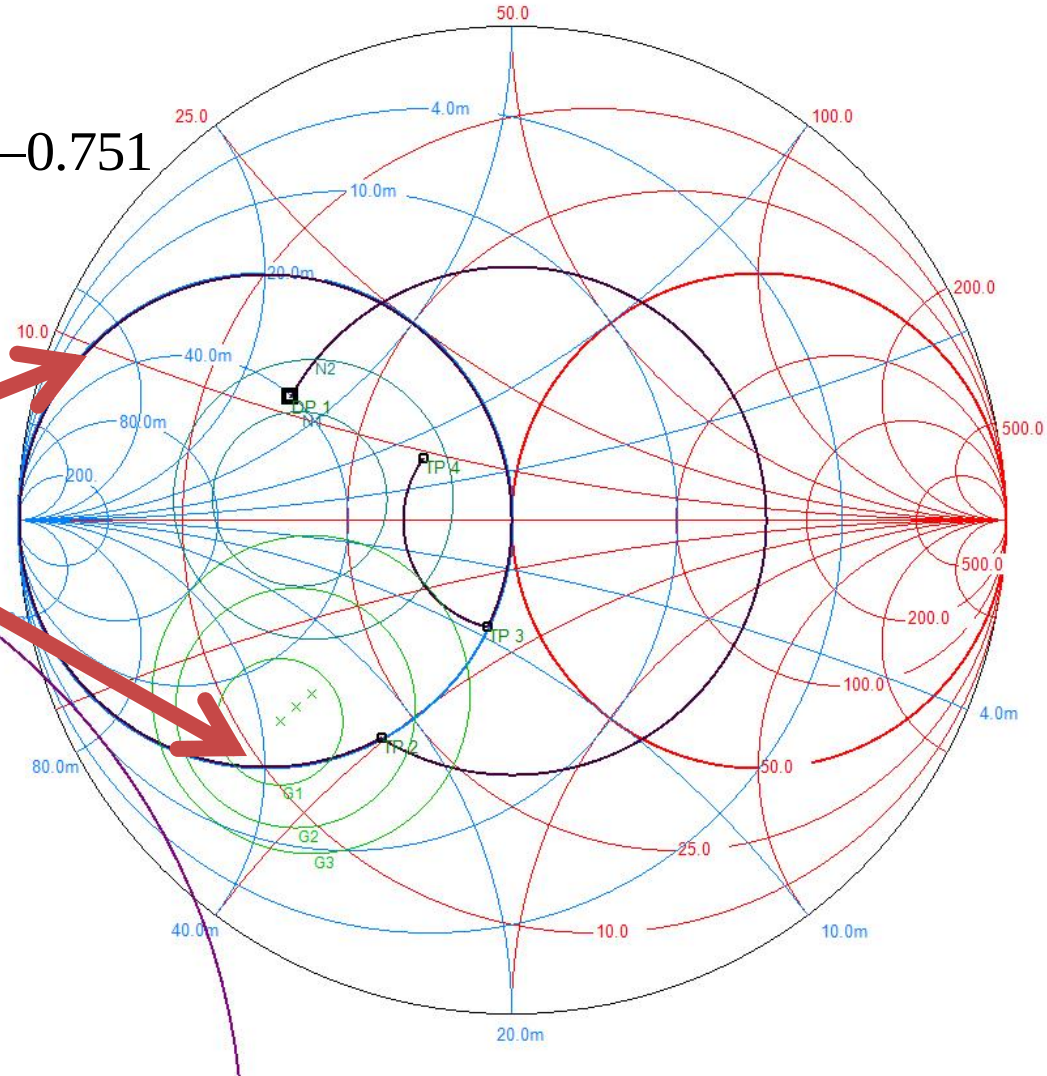
Diagrama Smith 3

$$\theta_{L1} = 55.6° \qquad \theta_{S2} = 135.9°$$

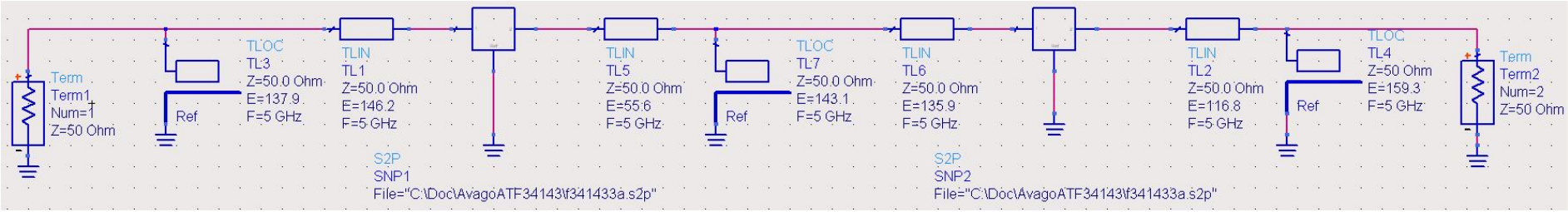
$$\mathrm{Im}\left[y_{sp}\right] = \mathrm{Im}\left[y_{L1}(\theta)\right] + \mathrm{Im}\left[y_{S2}(\theta)\right] = -0.751$$

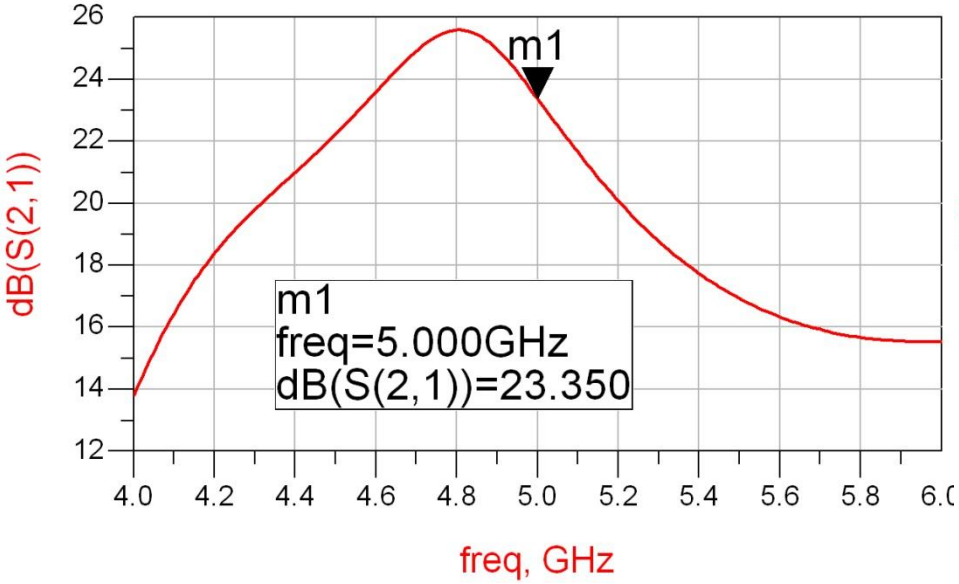
$$\theta_{sp} = 143.1°$$

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=55.6
F=5 GHz
Ref
TLOC
TL7
Z=50.0 Ohm
E=143.1
F=5 GHz
TLIN
TL6
Z=50.0 Ohm
E=135.9
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))=23.350
dB(S(2,1))
freq, GHz
26
24
22
20
18
16
14
12
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8

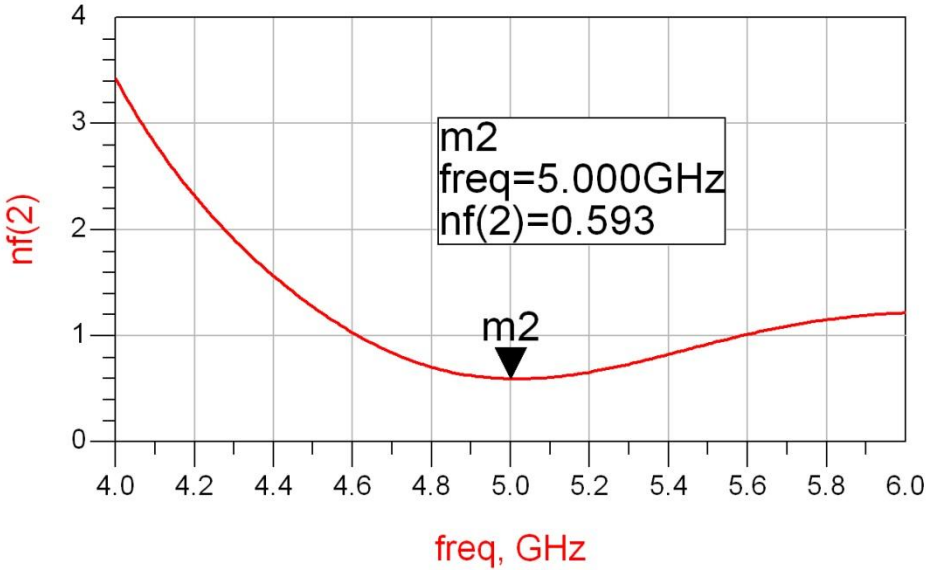

m2
m2
freq=5.000GHz
nf(2)=0.593
nf(2)
freq, GHz
4
3
2
1
0
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0

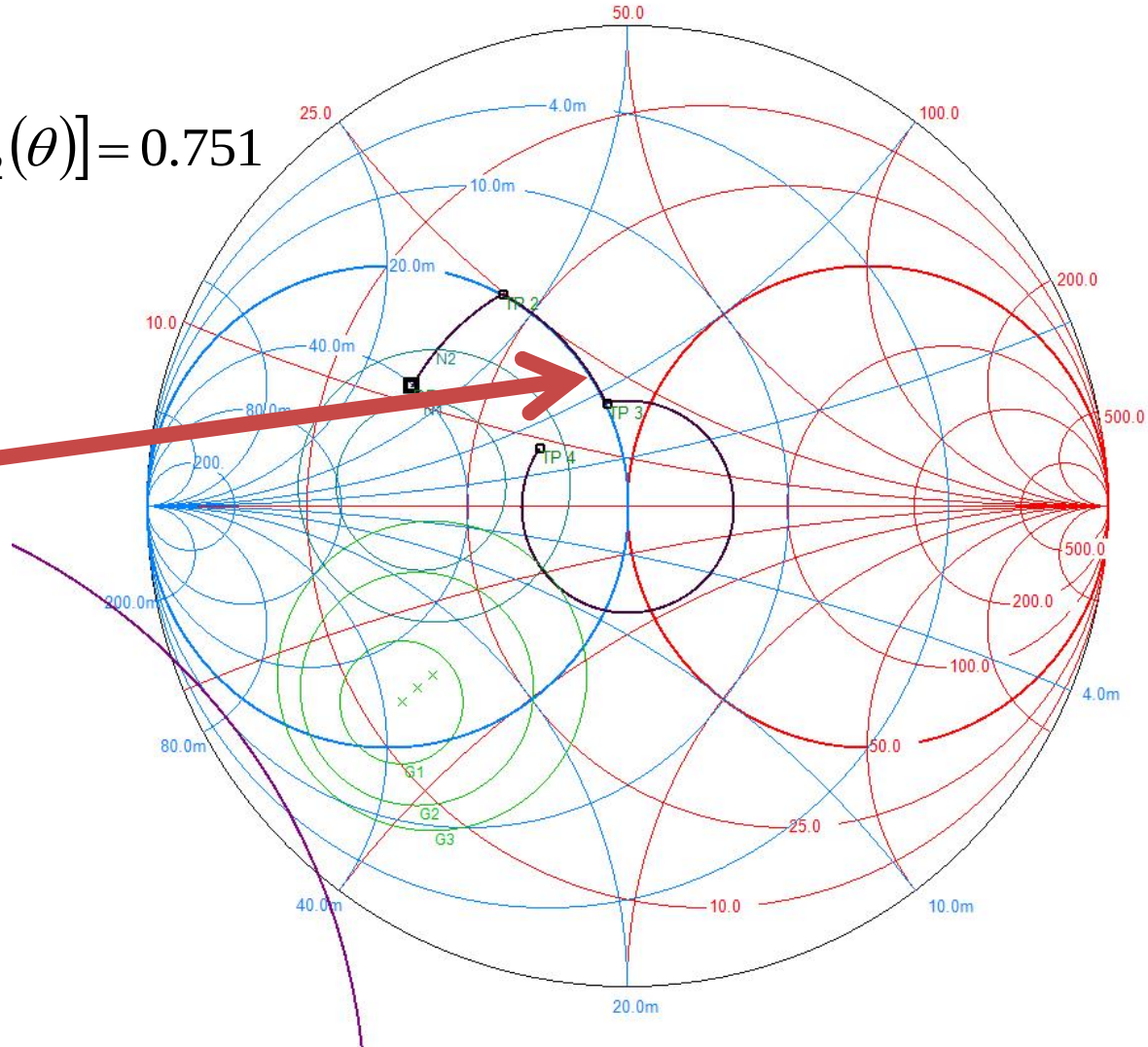
Diagrama Smith 4

$$\theta_{L1} = 158.4° \qquad \theta_{S2} = 15°$$

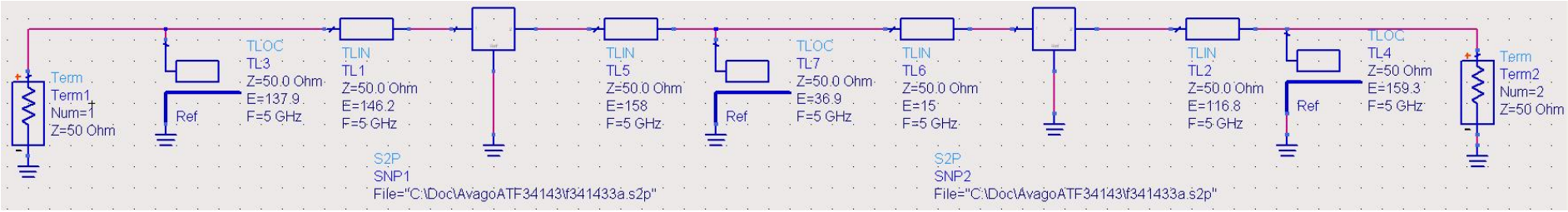
$$\mathrm{Im}\left[y_{sp}\right] = \mathrm{Im}\left[y_{L1}(\theta)\right] + \mathrm{Im}\left[y_{S2}(\theta)\right] = 0.751$$

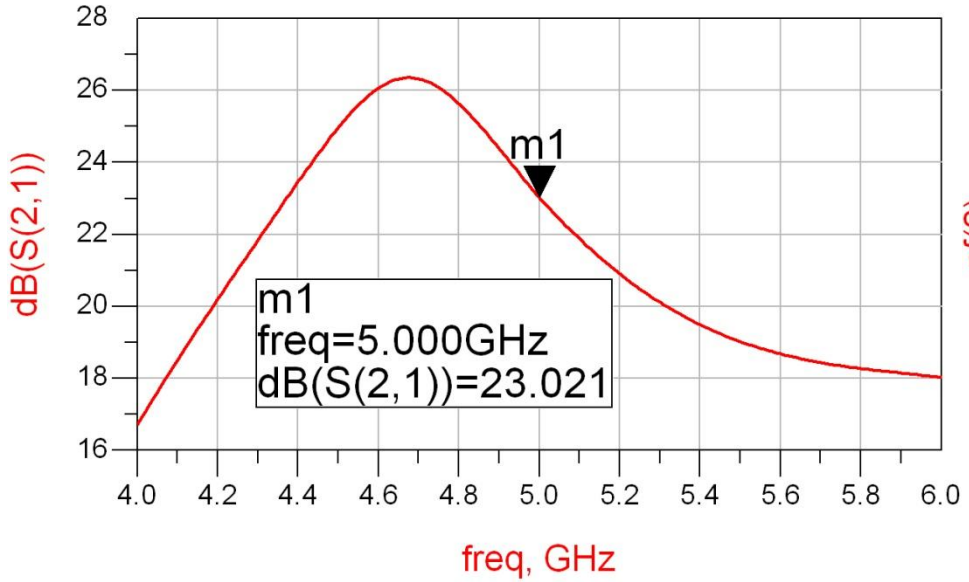
$$\theta_{sp} = 36.9°$$

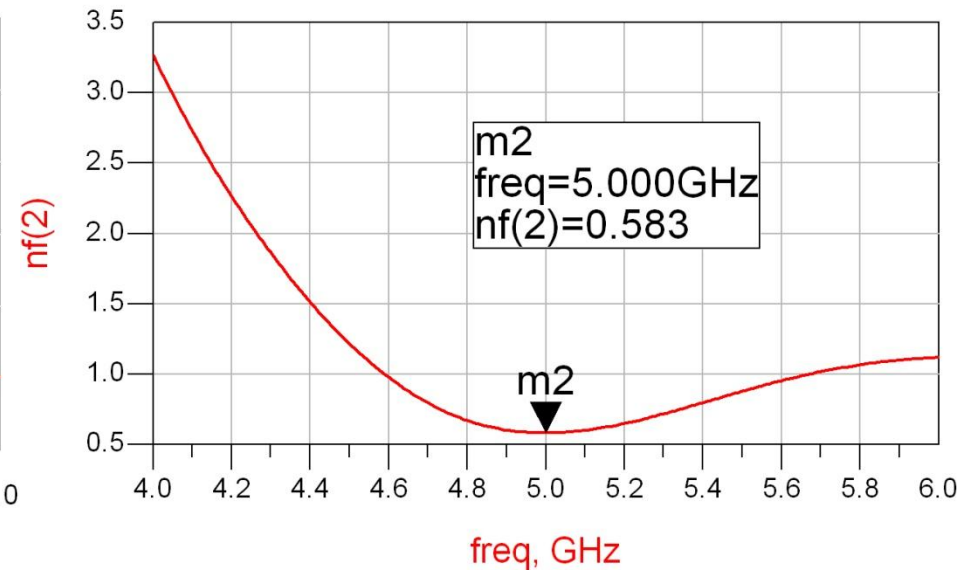
stub "combinat"



ADS 4


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=158
F=5 GHz
Ref
TLOC
TL7
Z=50.0 Ohm
E=36.9
F=5 GHz
TLIN
TL6
Z=50.0 Ohm
E=15
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))
28
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
freq, GHz
m1
m1
freq=5.000GHz
dB(S(2,1))=23.021


nf(2)
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
freq, GHz
m2
m2
freq=5.000GHz
nf(2)=0.583

Adaptare inter-etaje

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

Amplificatoare de banda larga

Amplificatoare de microunde

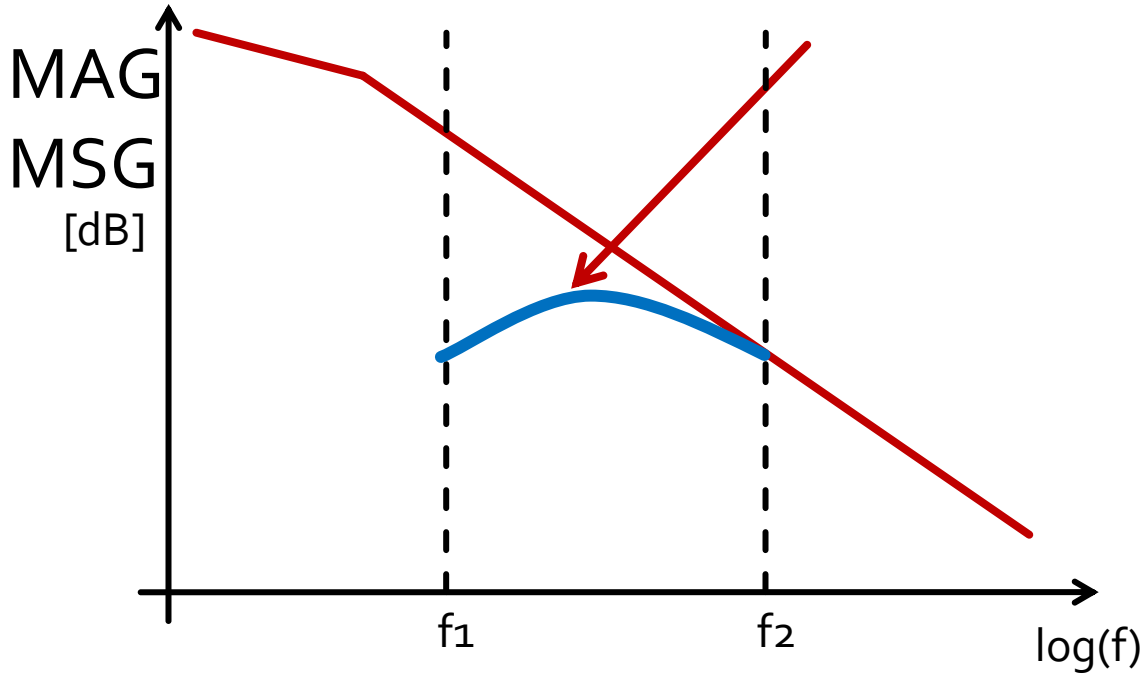
Amplificatoare de banda larga

- 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 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



Supliment Mini Proiect

Implementare cu linii microstrip

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

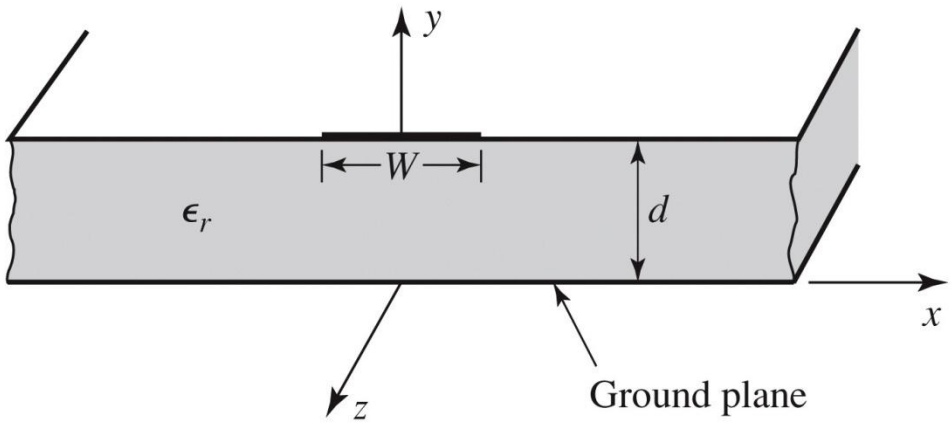


Figure 3.25a

Implementare cu linii microstrip

- Linie quasi TEM

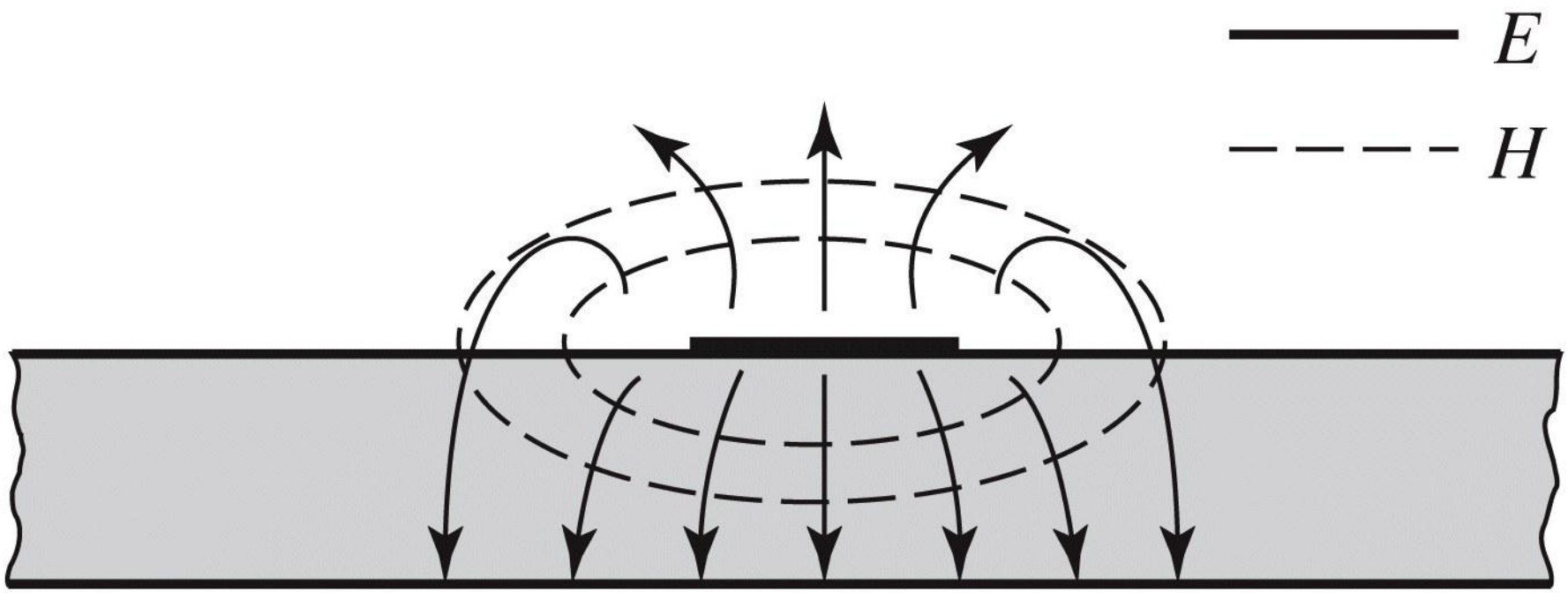


Figure 3.25b

Implementare cu linii microstrip

- Se echivaleaza linia cu o linie cu dielectric omogen echivalent

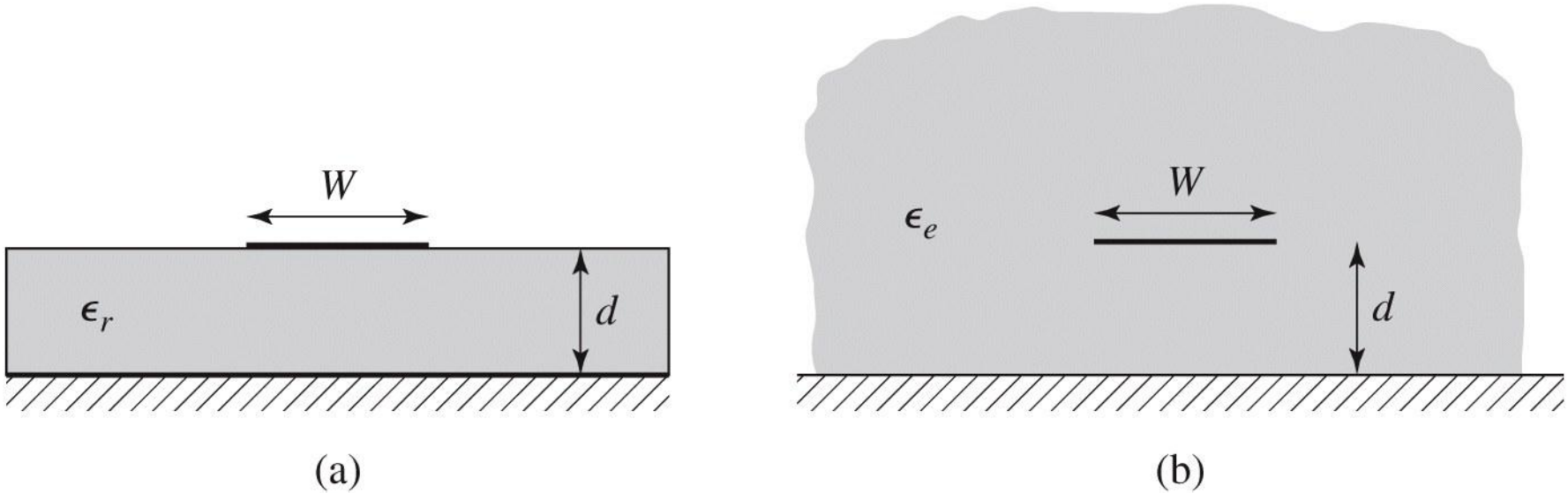
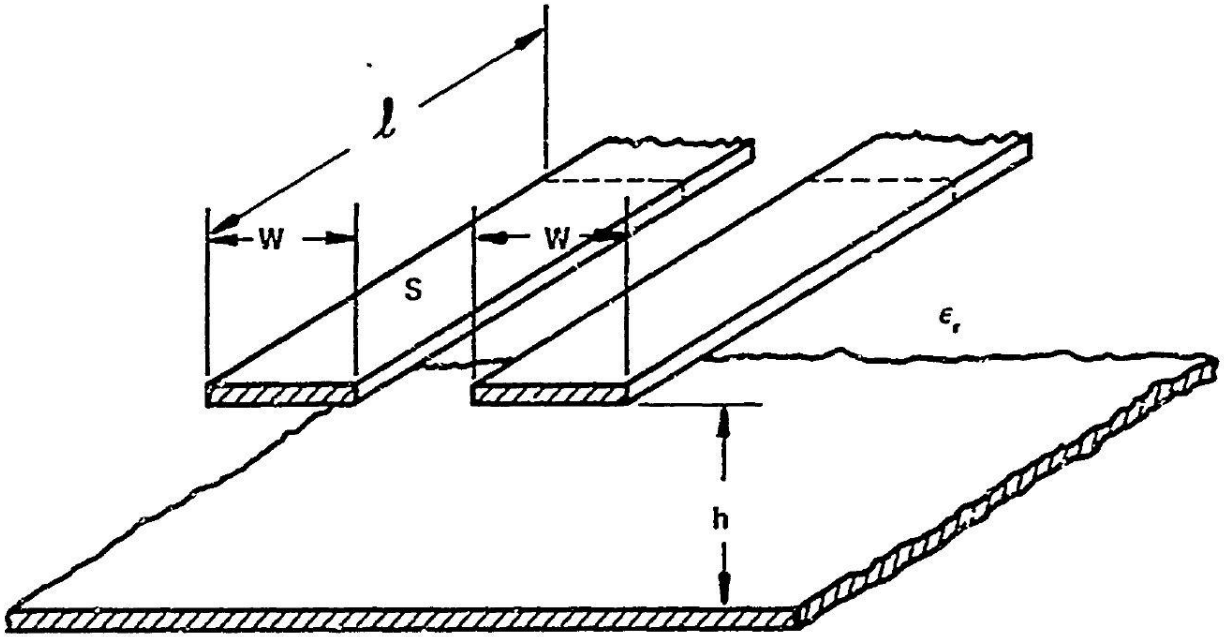


Figure 3.26

Implementare cu linii microstrip

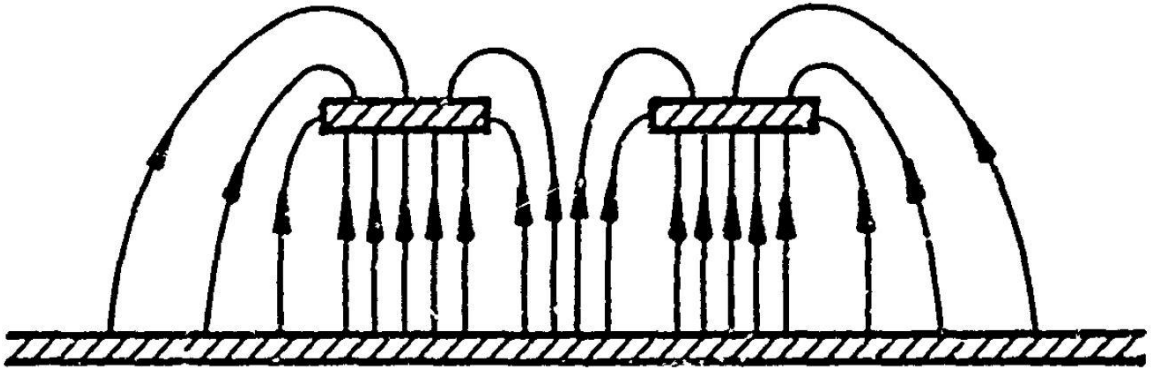
- ~ Aproximativ TEM



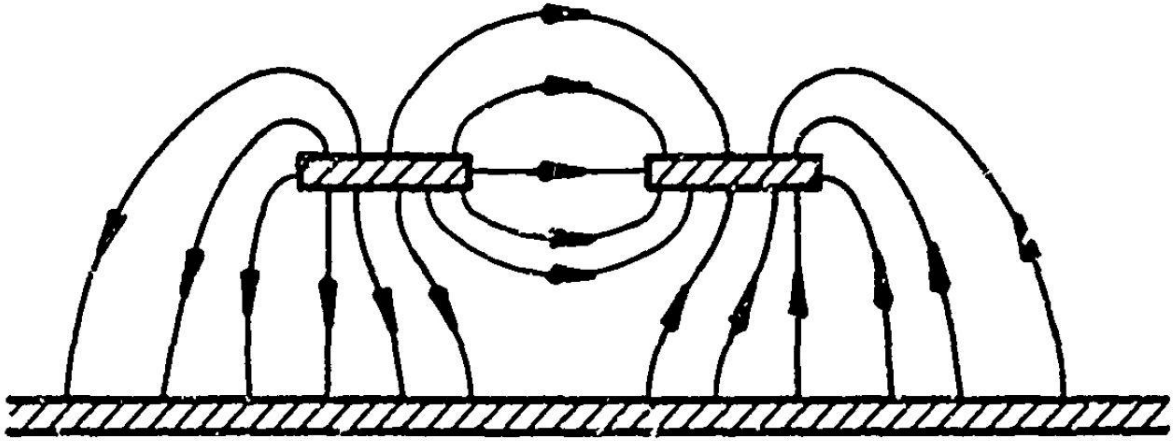
a) COUPLED STRIP GEOMETRY

Implementare cu linii microstrip

- ~ Aproximativ TEM



b) EVEN MODE ELECTRIC FIELD PATTERN (SCHEMATIC)



c) ODD MODE ELECTRIC FIELD PATTERN (SCHEMATIC)

Calcul

- Calcul empiric

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

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

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

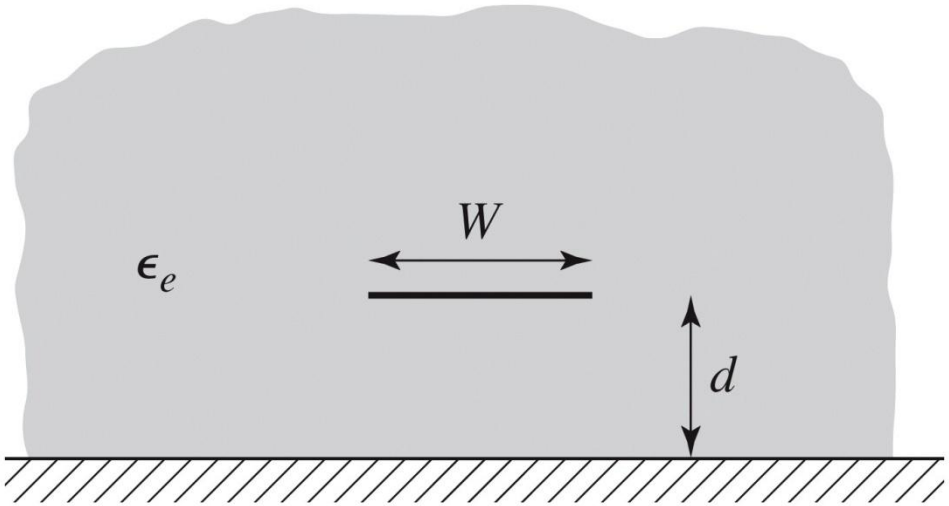


Figure 3.26b

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

Calcul

- Calcul empiric

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

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

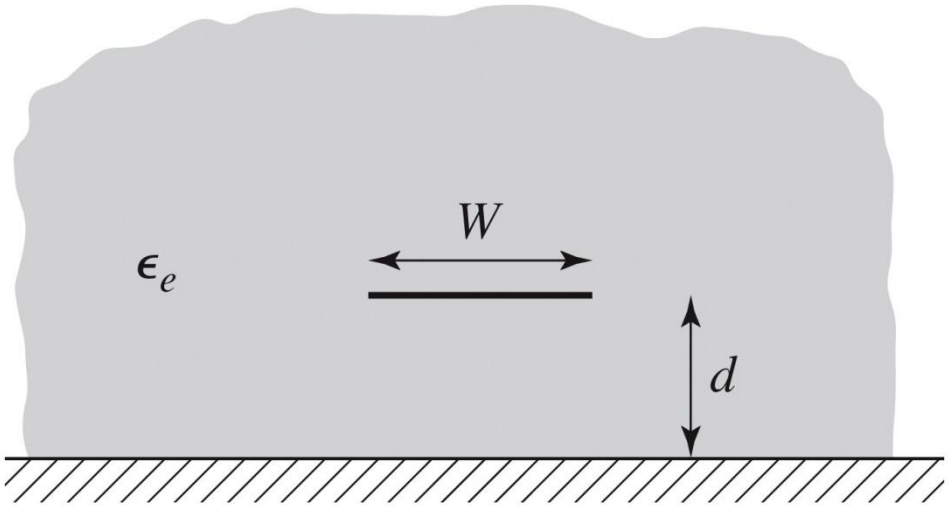
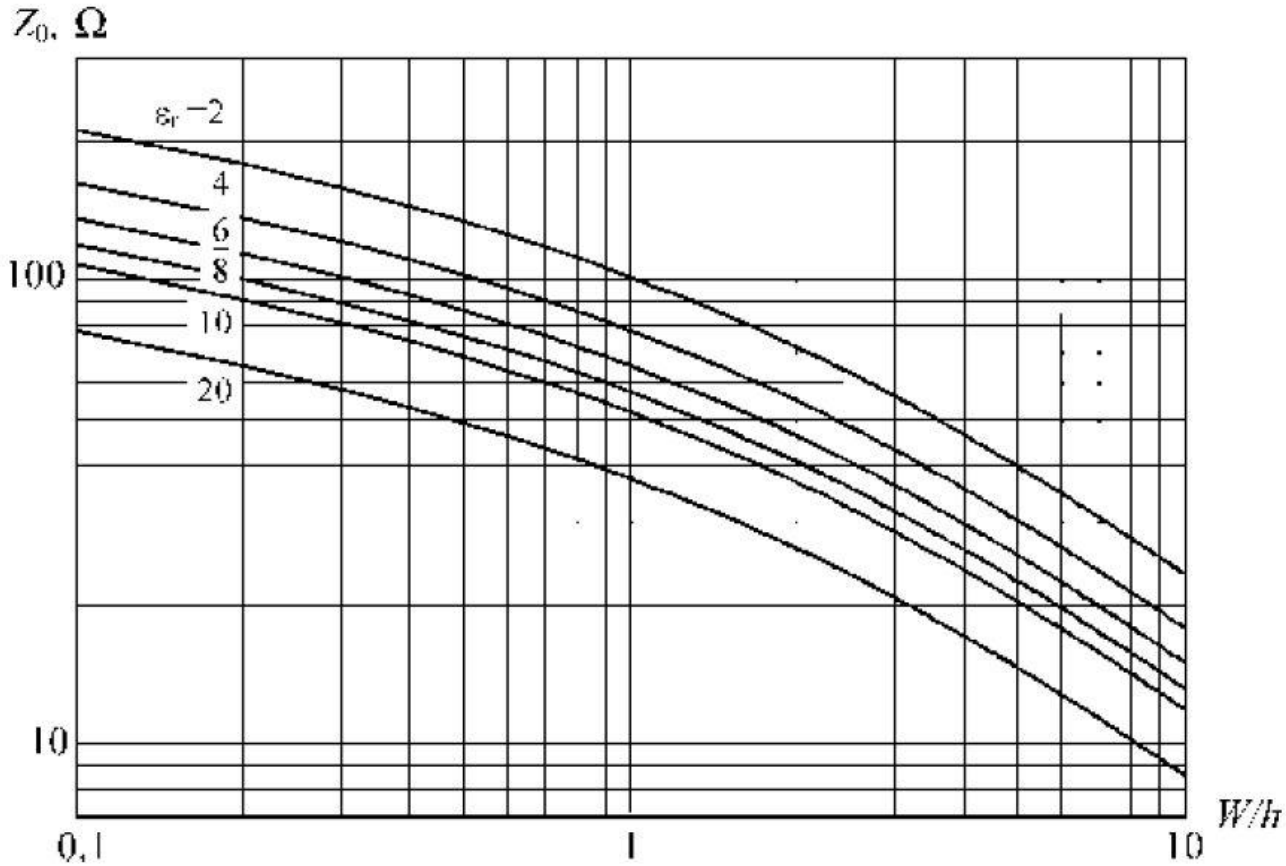


Figure 3.26b

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

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

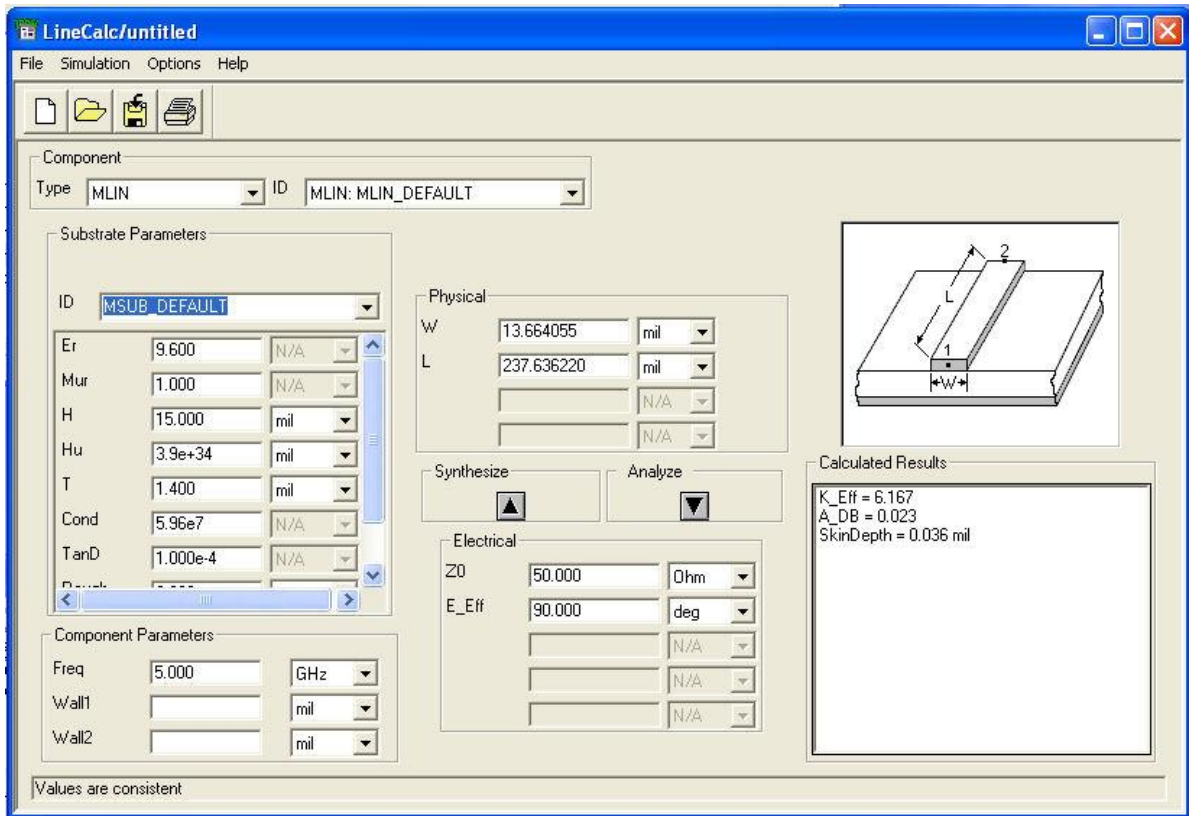
Standard Thickness
RO4003C: 0.008" (0.203mm), 0.012 (0.305mm), 0.016" (0.406mm), 0.020" (0.508mm) 0.032" (0.813mm), 0.060" (1.524mm) **RO4350B**: *0.004" (0.101mm), 0.0066" (0.168mm) 0.010" (0.254mm), 0.0133 (0.338mm), 0.0166 (0.422mm), 0.020" (0.508mm) 0.030" (0.762mm), 0.060" (1.524mm)

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	-	-	-

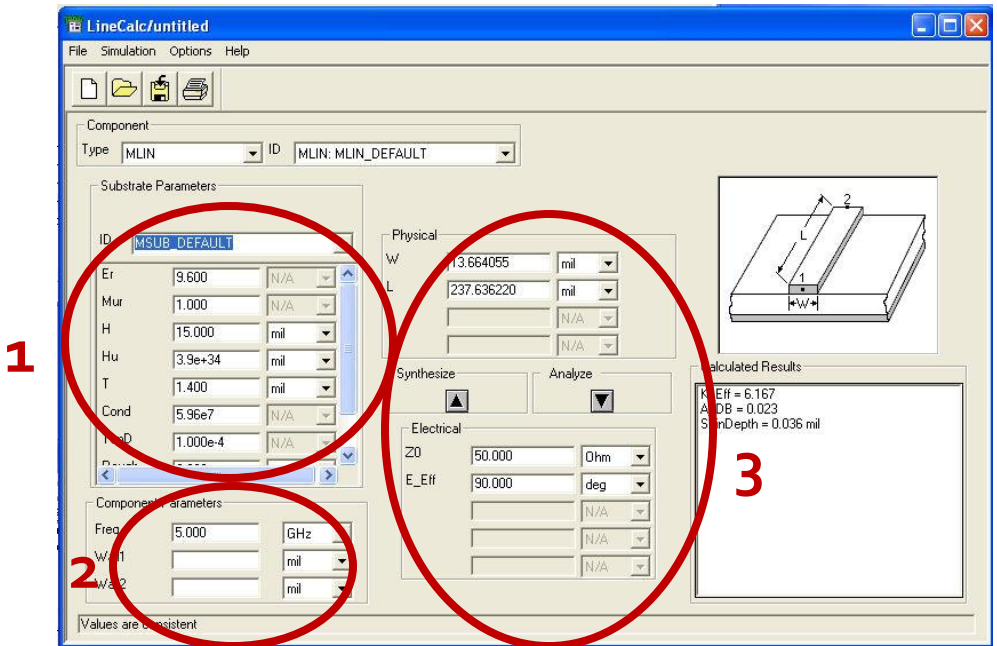
ADS linecalc

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



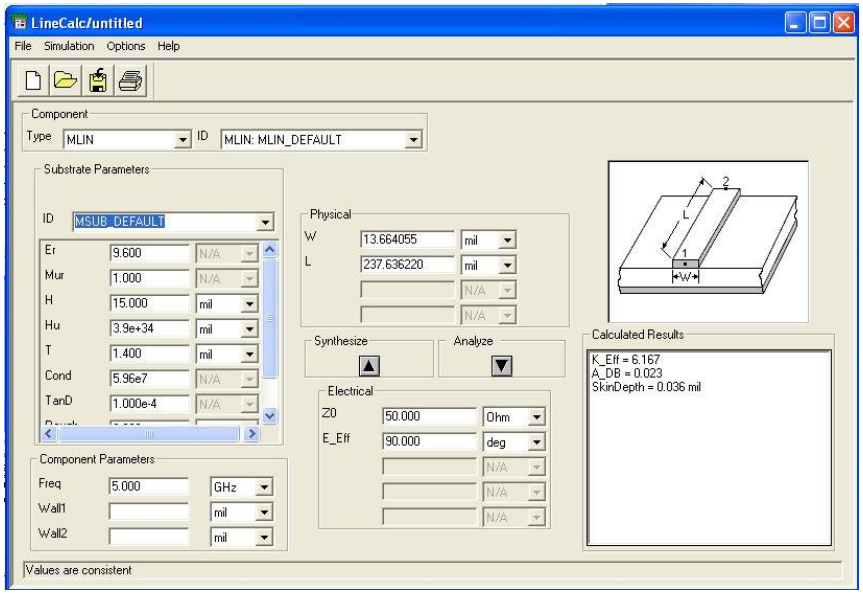
ADS linecalc

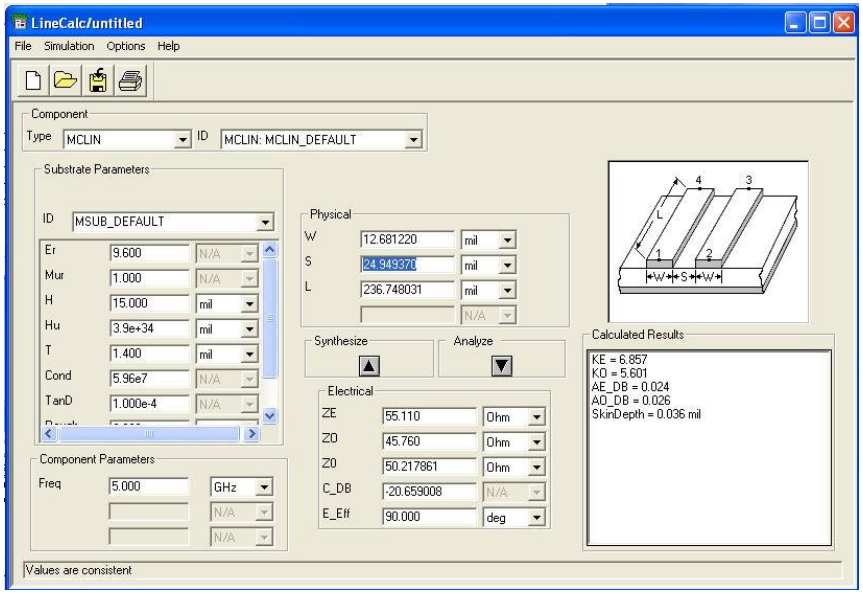
- 1. Definire (receptie din schema) substrat
- 2. Introducere frecventa
- 3. Introducere date de intrare
  - Analiza: W,L → Zo,E sau Ze,Zo,E / la f [GHz]
  - Sinteza: Zo,E → W,L / la f [GHz]



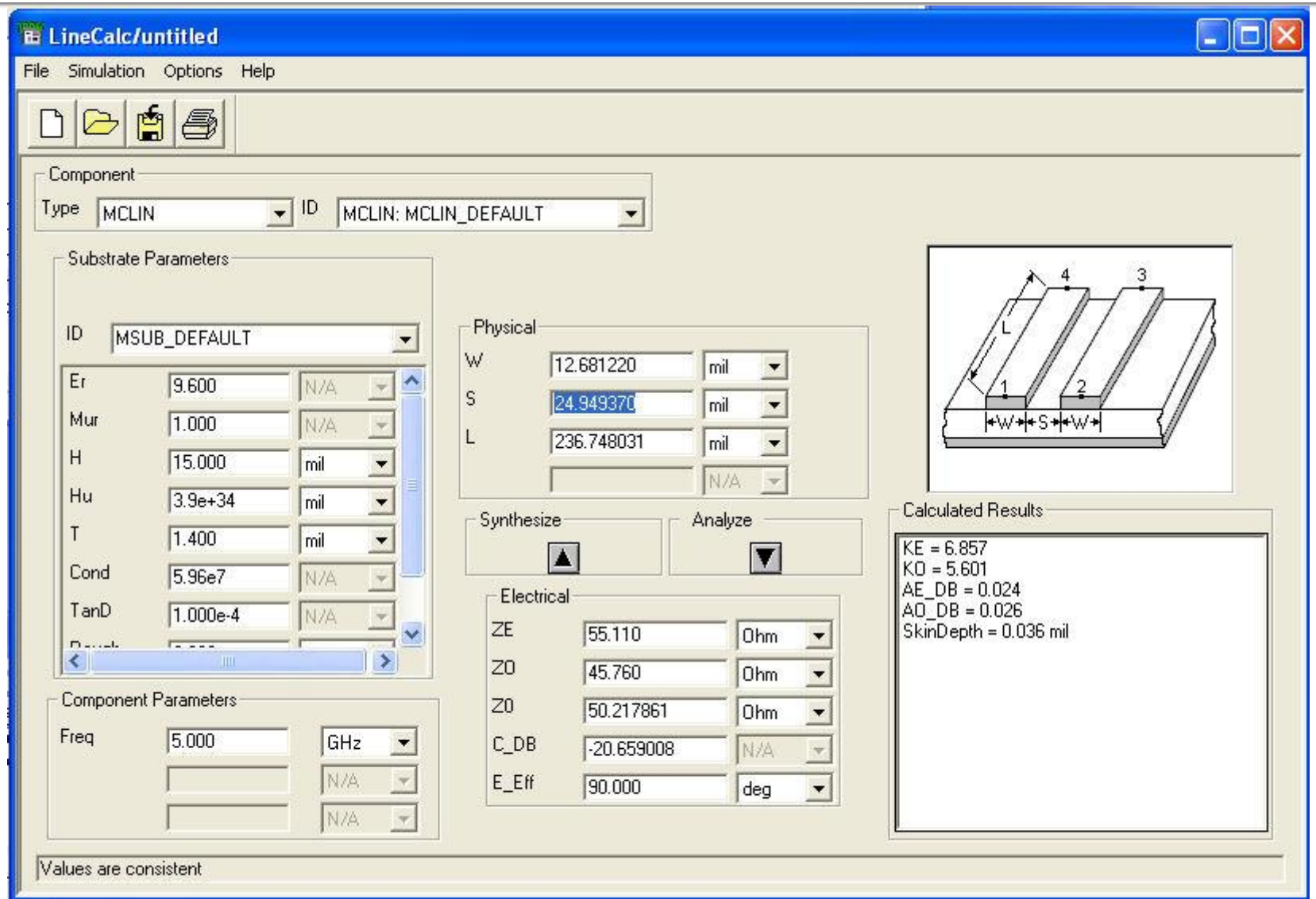
ADS linecalc

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





ADS linecalc



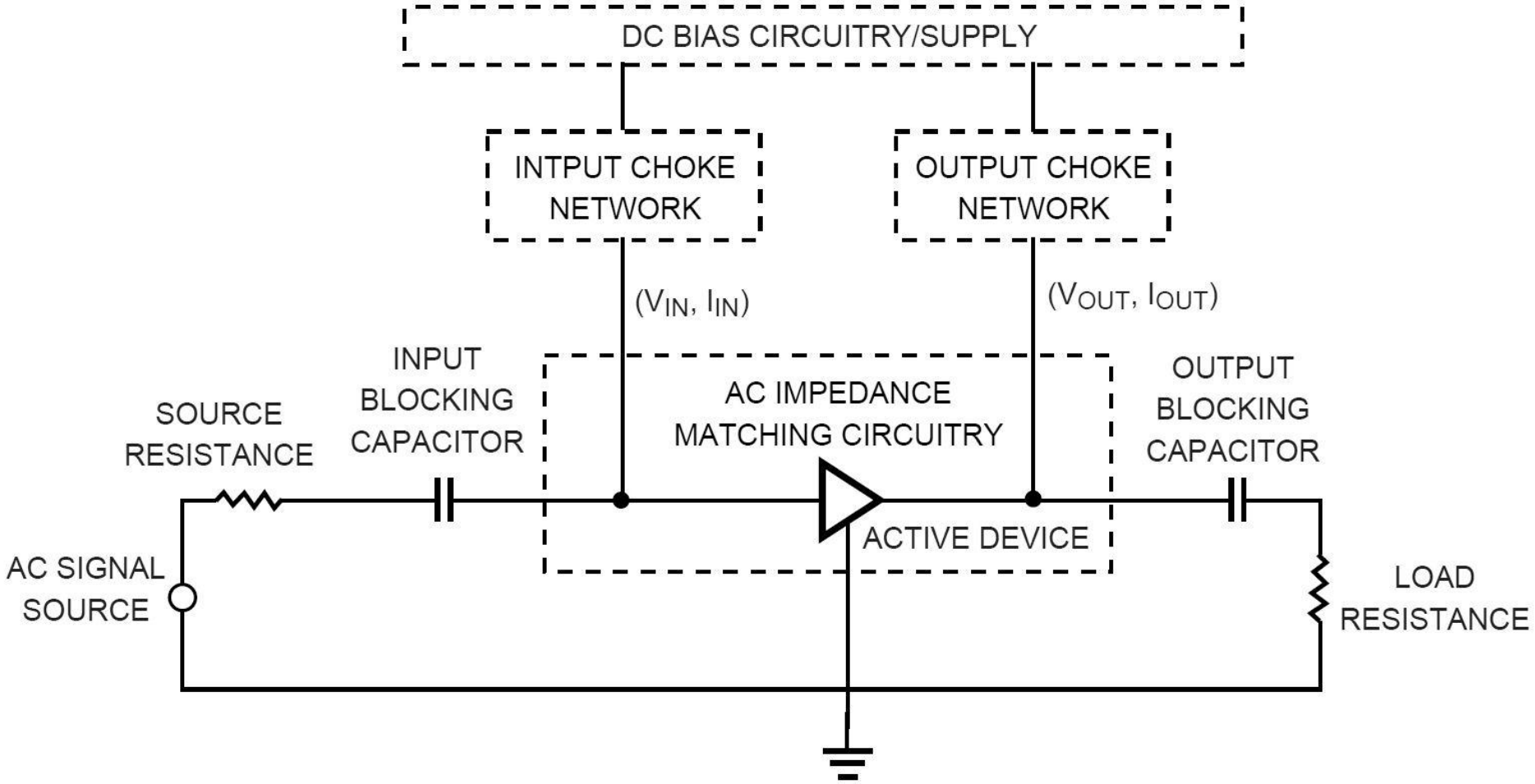
Linii de transmisie

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

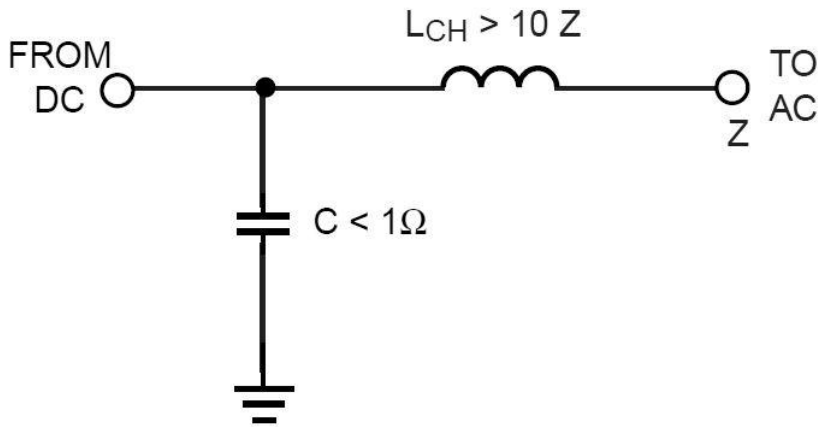
Polarizare

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

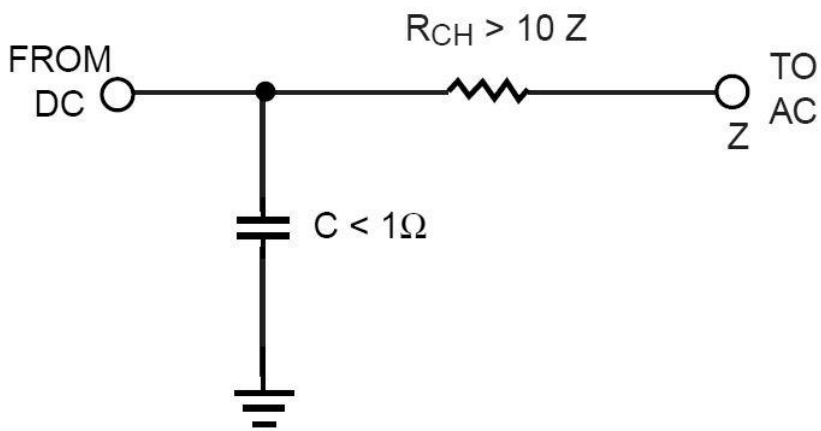
Polarizare


DC BIAS CIRCUITRY/SUPPLY
INTPUT CHOKE NETWORK
OUTPUT CHOKE NETWORK
(VIN, IIN)
(VOUT, IOUT)
INPUT BLOCKING CAPACITOR
AC IMPEDANCE MATCHING CIRCUITRY
OUTPUT BLOCKING CAPACITOR
SOURCE RESISTANCE
ACTIVE DEVICE
AC SIGNAL SOURCE
LOAD RESISTANCE

Polarizare, soc tipic

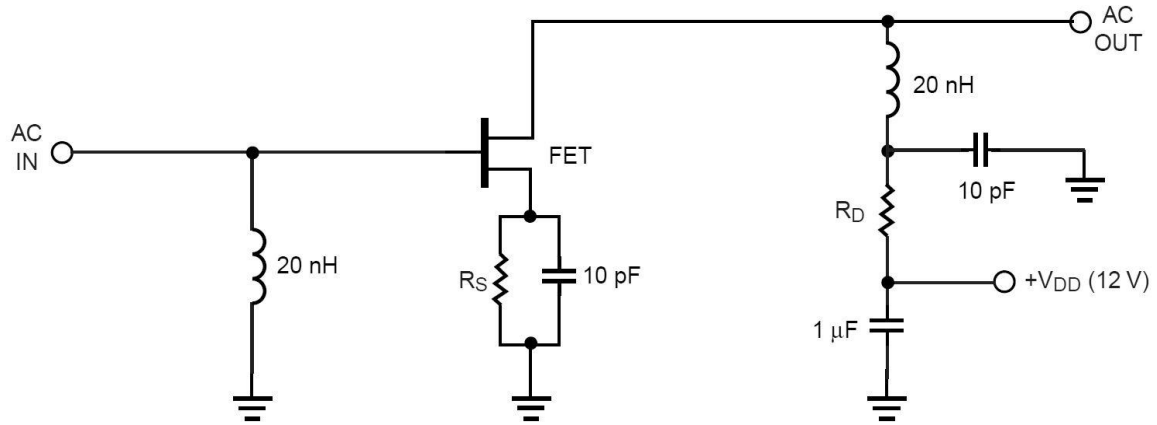


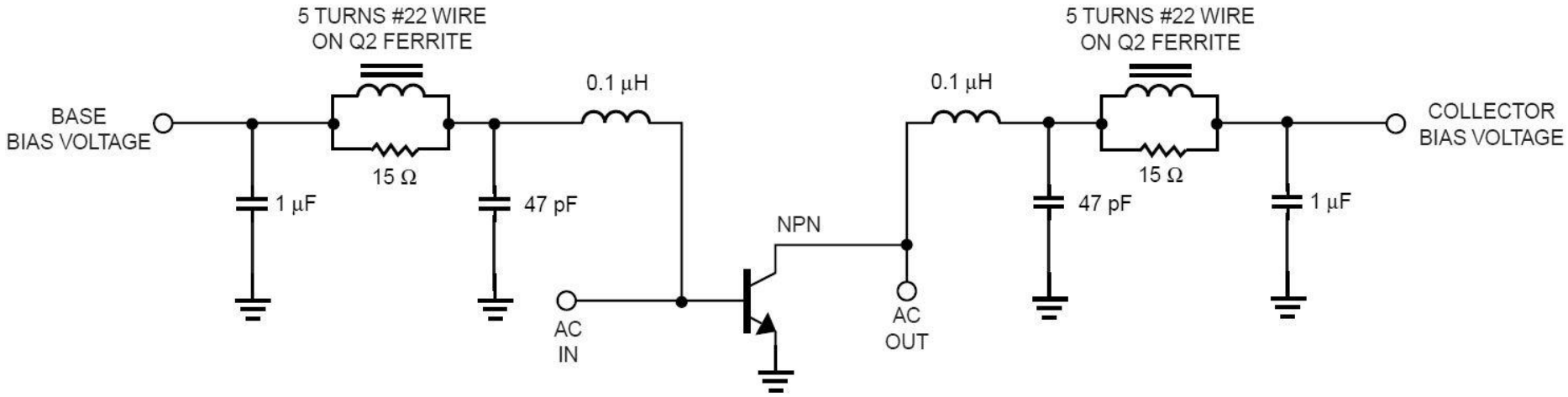
CURRENT CONTROLLED



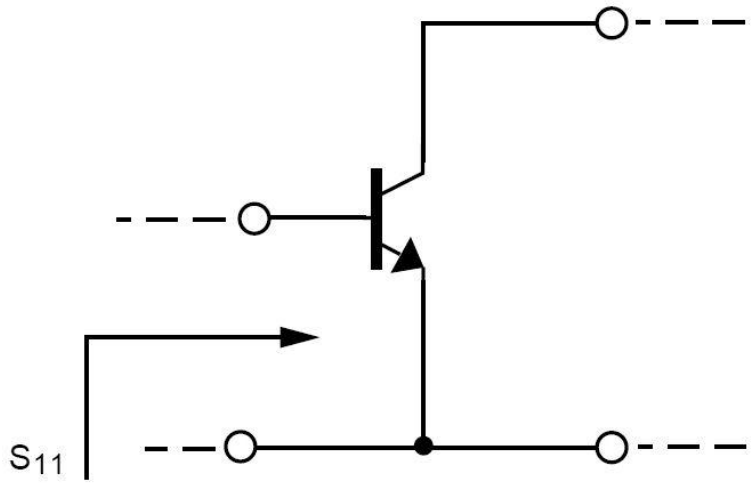
VOLTAGE CONTROLLED
(FET GATE)

Polarizare, scheme/valori tipice



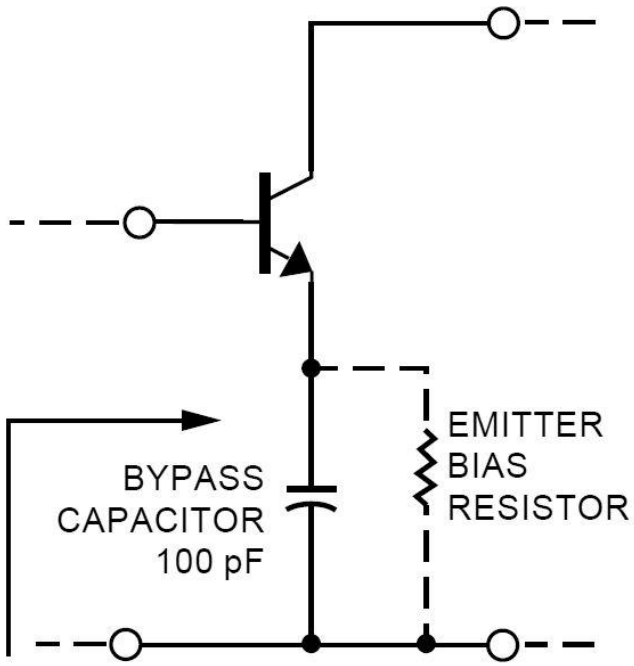


Polarizare, problema elementelor conectate in E/S



S_{11} (AT 4 GHz) = 0.52 ∠ 154°

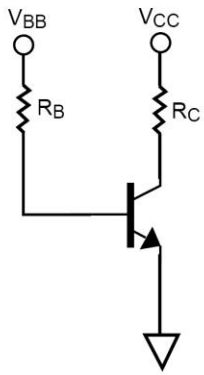
S_{11} (AT 0.1 GHz) = 0.901 ∠ –14.9°



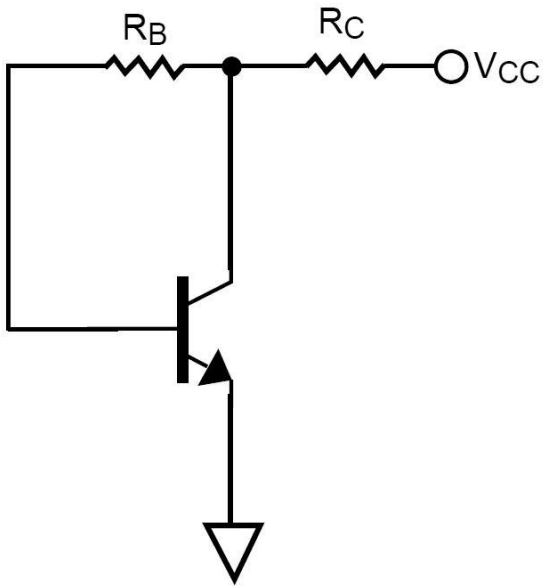
S'_{11} (AT 4 GHz) = 0.52 ∠ 154° UNCHANGED AT 4 GHz

S'_{11} (AT 0.1 GHz) = 1.066 ∠ -8.5° $|S_{11}|>1$ AT 0.1GHz

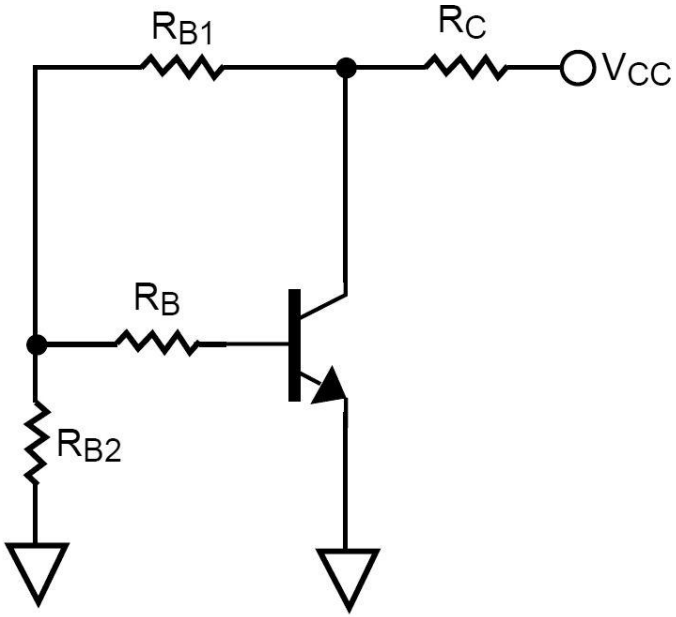
Polarizare TB scheme de polarizare



NON-STABILIZED



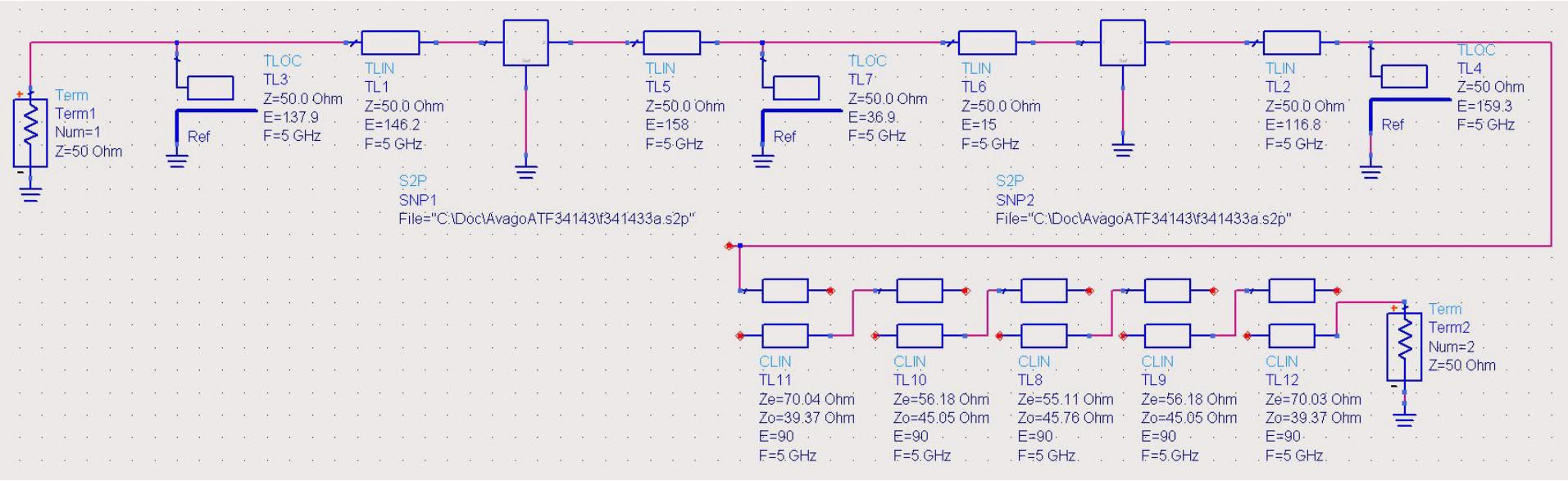
VOLTAGE FEEDBACK



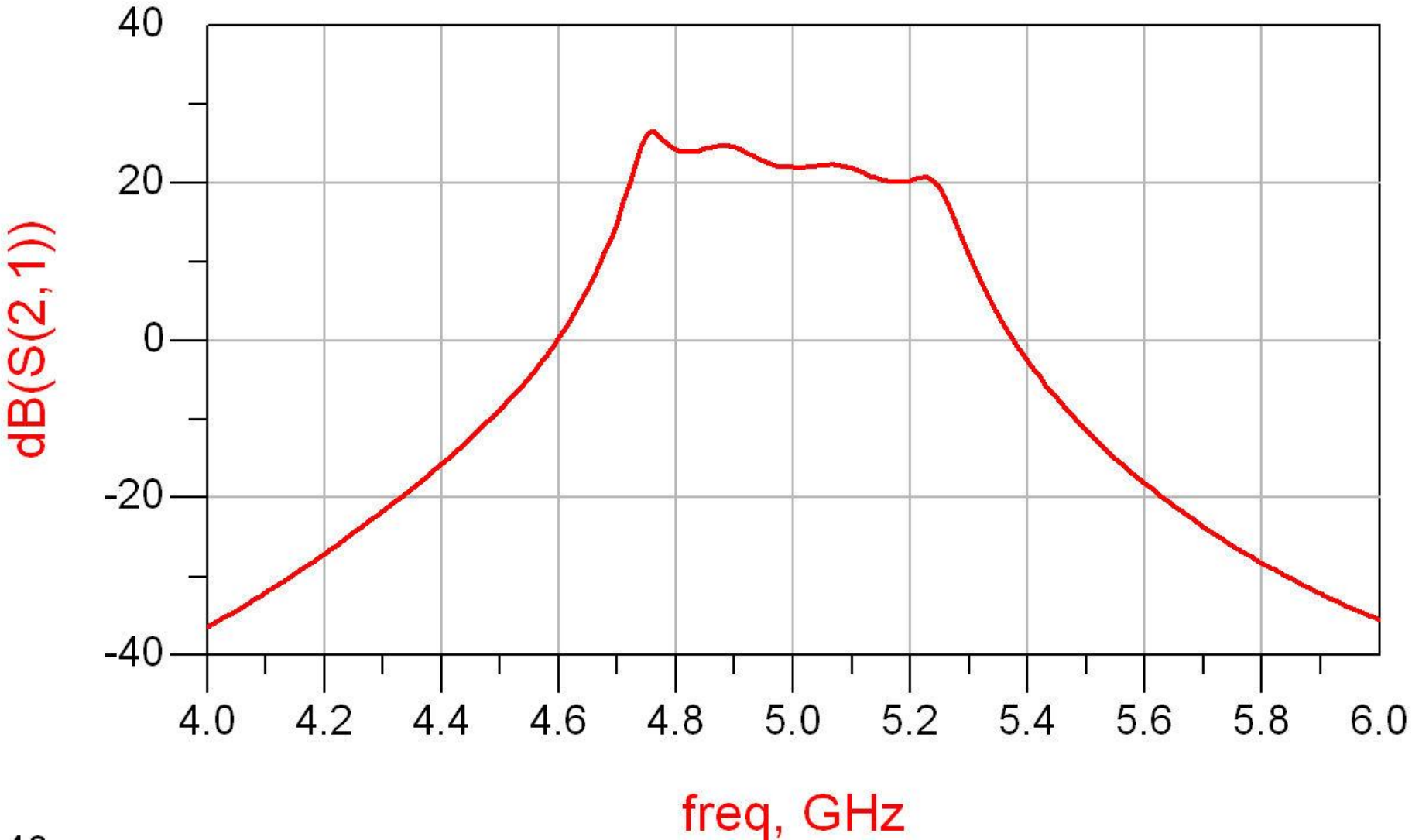
VOLTAGE FEEDBACK AND CONSTANT BASE CURRENT SOURCE

Exemplu proiect

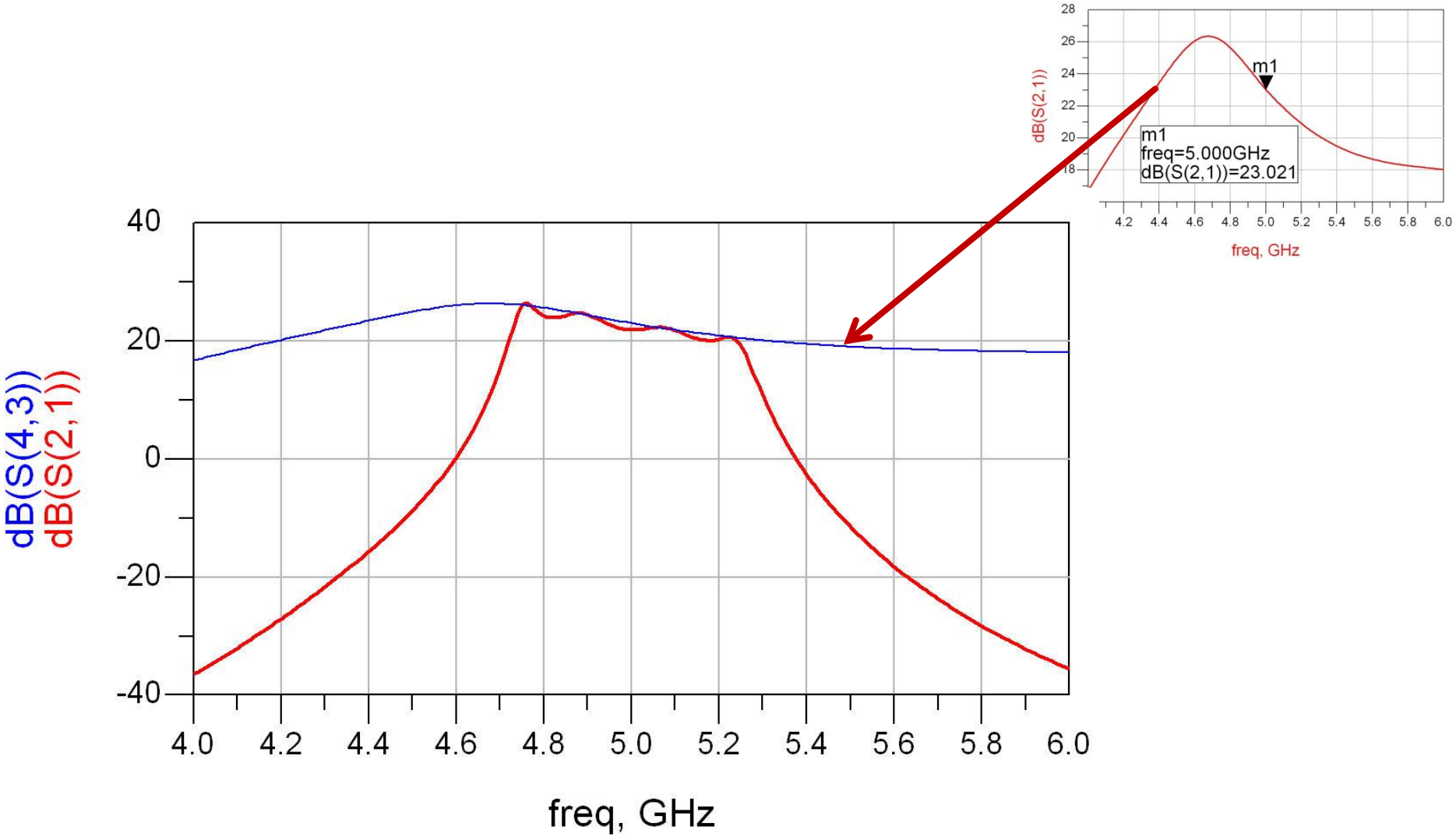
- Unirea celor doua scheme
  - C11 – amplificator (var 4/S36-37)
  - ~~C13 – filtre~~



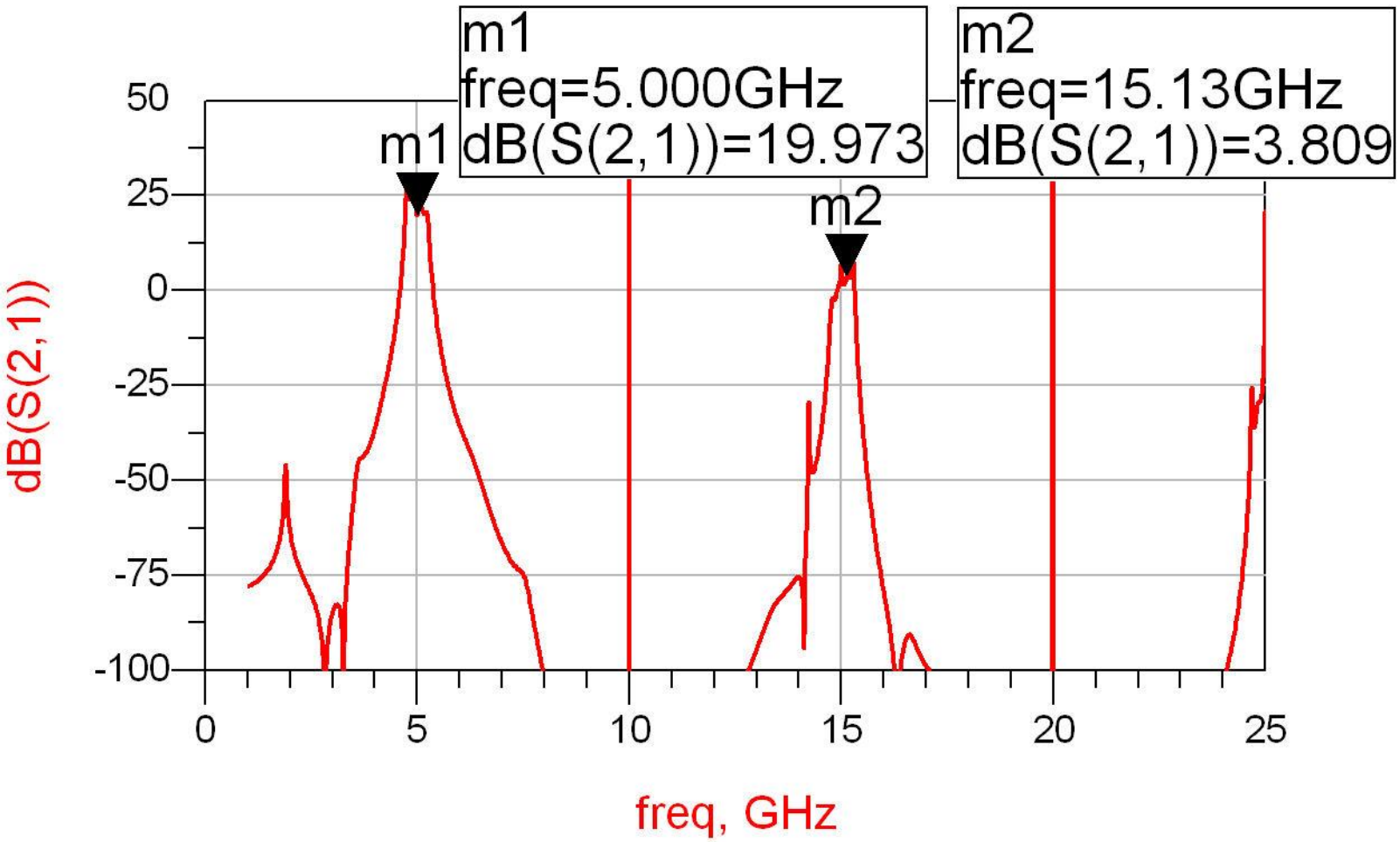
Rezultat (dezechilibrat)



Rezultat (dezechilibrat)

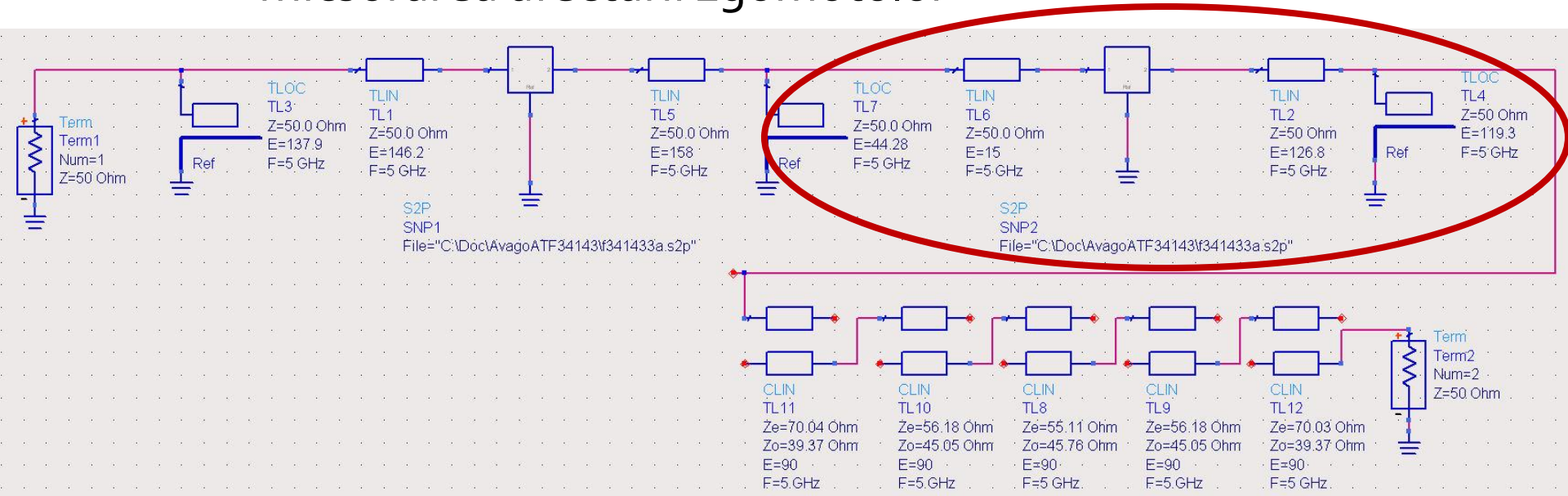


Rezultat (periodic in frecventa)

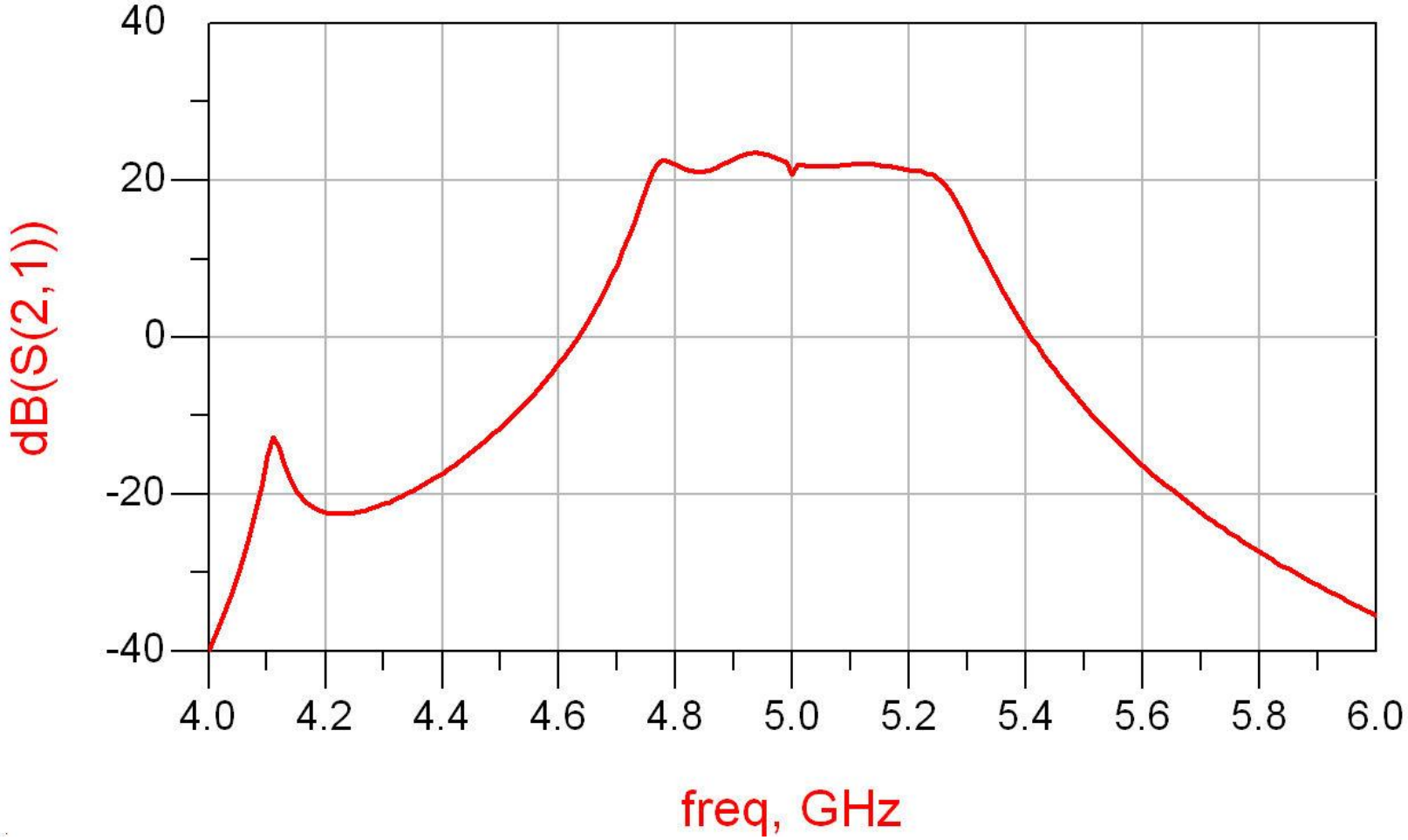


Reglaj -> echilibrare

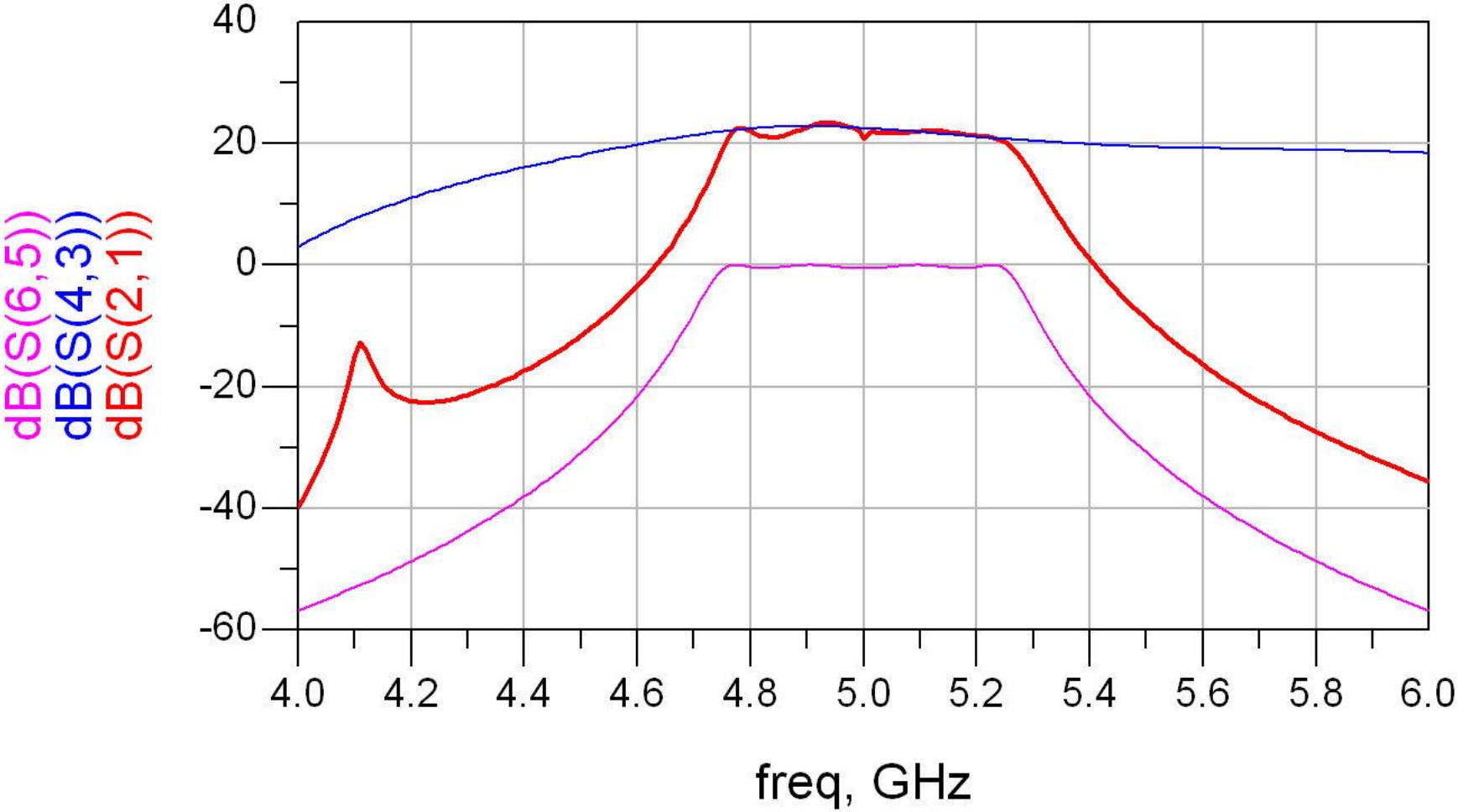
- scopul: echilibrarea caracteristicii amplificatorului (maxim la frecventa centrala)
  - se prefera reglarea lungimii liniilor de la iesirea amplificatorului
    - micsorarea afectarii zgomotului



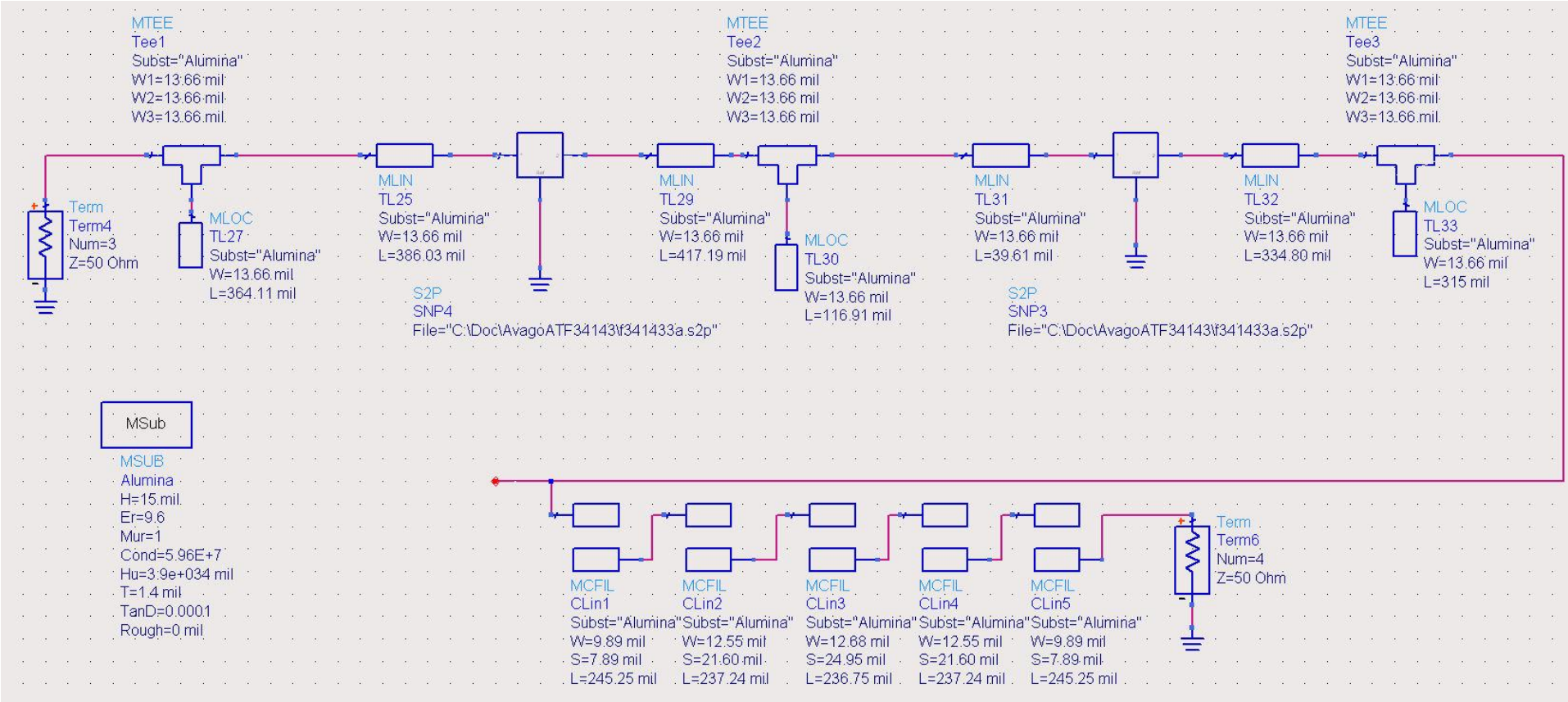
Reglaj -> echilibrare, efect



Amplificator, Filtru, Total

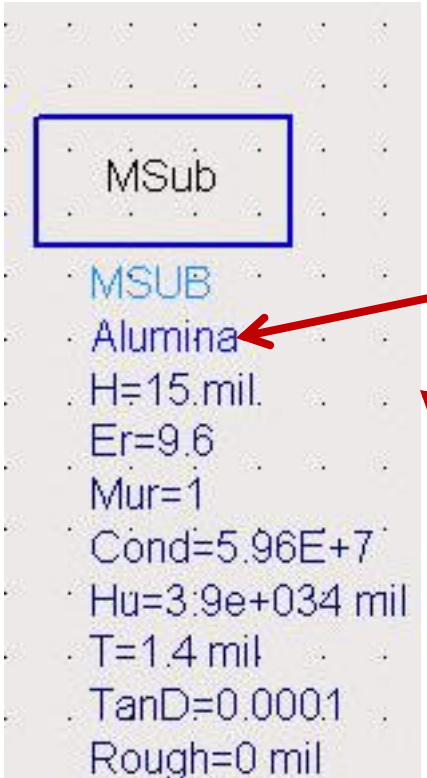


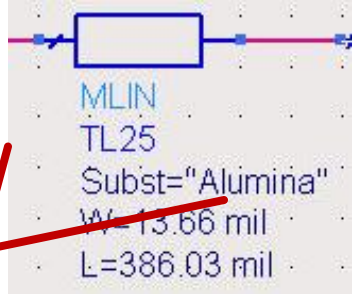
Implementare cu linii microstrip

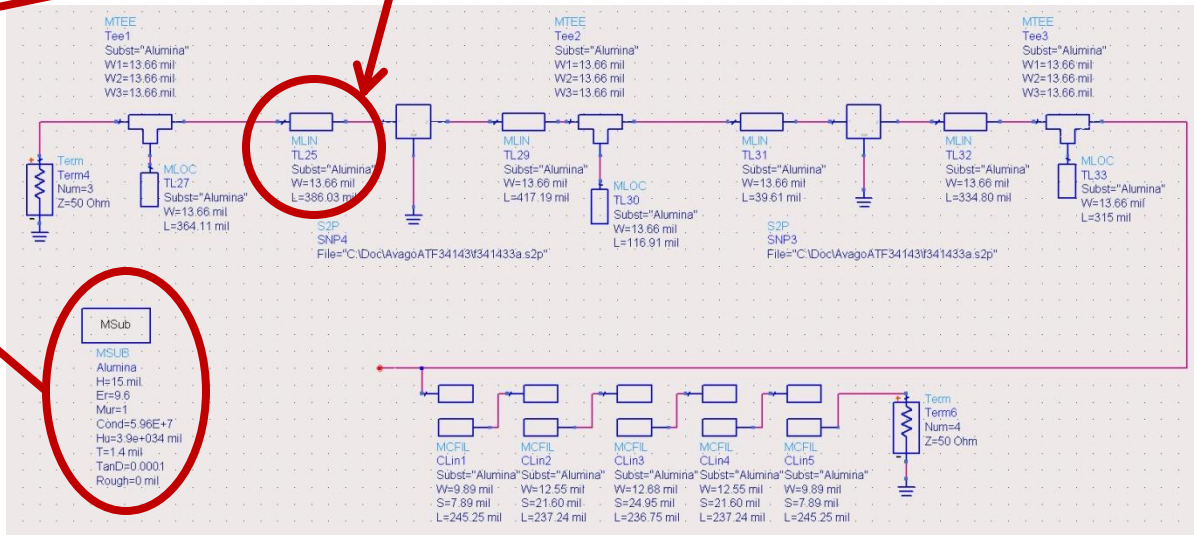


Implementare cu linii microstrip

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





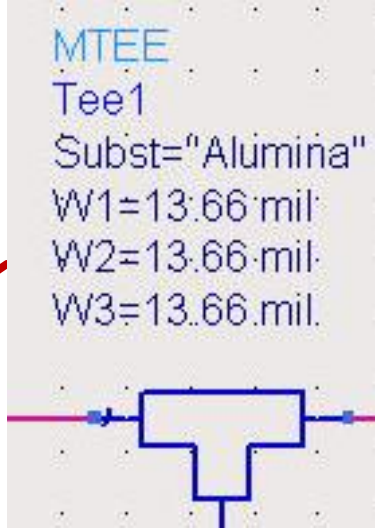


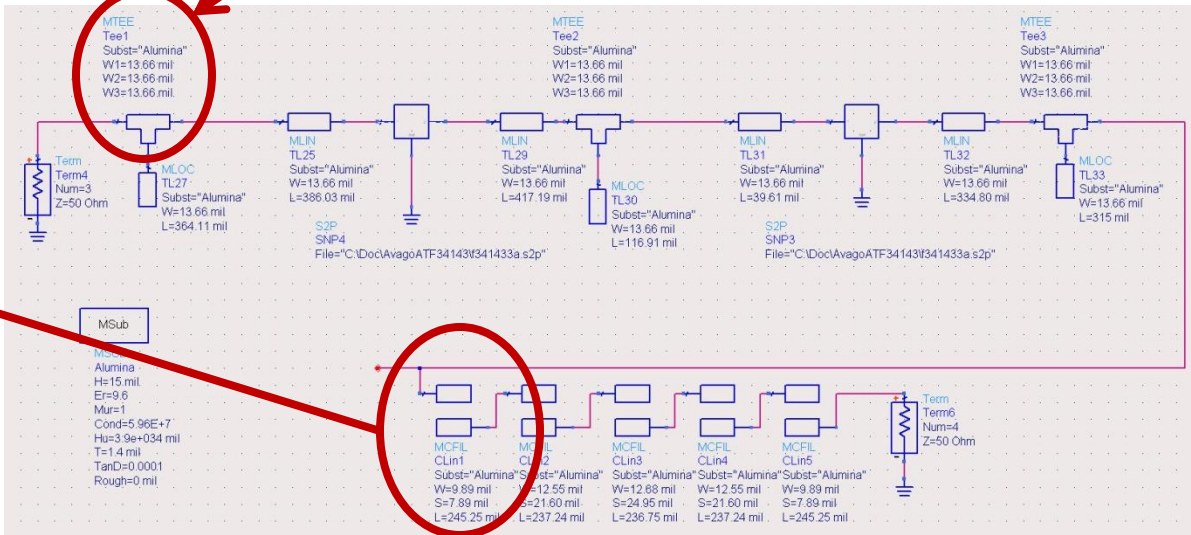
Implementare cu linii microstrip

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

Implementare cu linii microstrip

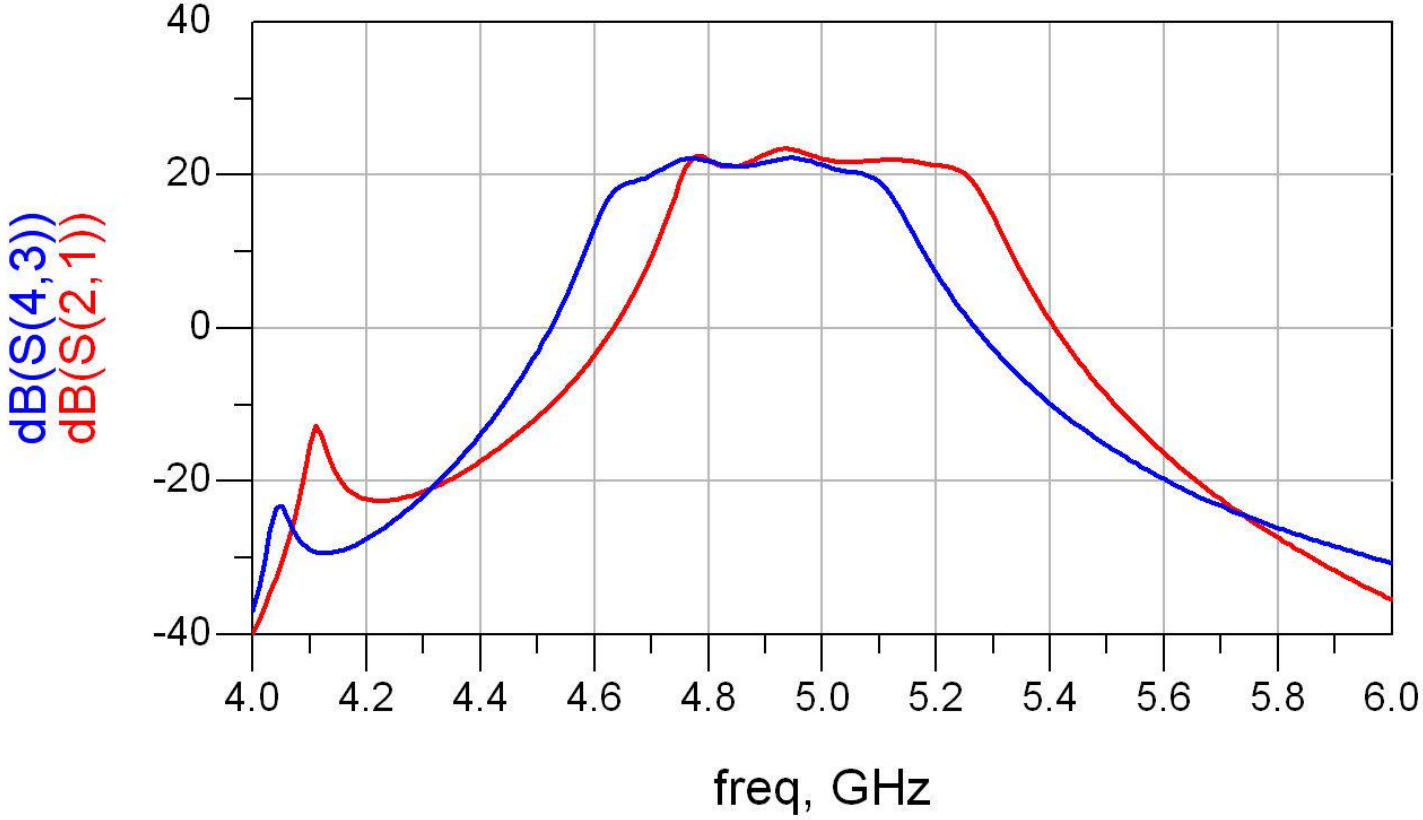
- E necesara atentie la completarea parametrilor pentru MTEE si MCFIL prin verificarea in schema a latimii liniilor conectate la fiecare terminal





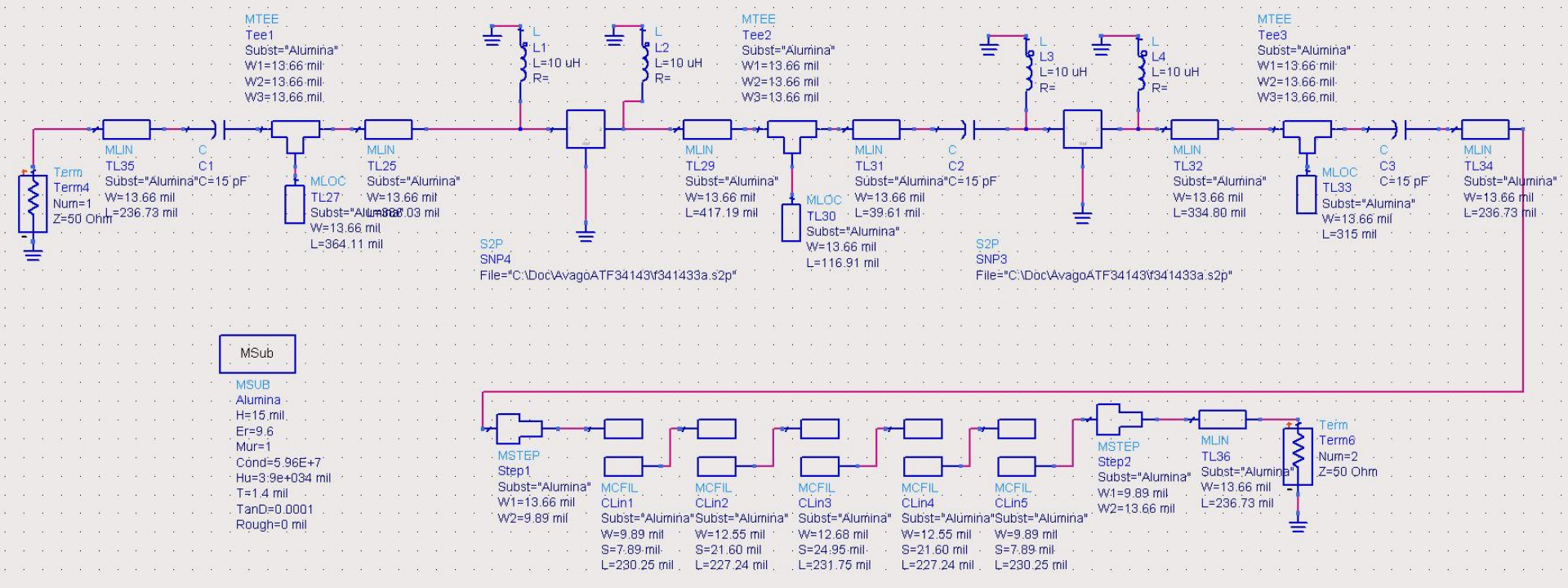
Implementare cu linii microstrip
Rezultat

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

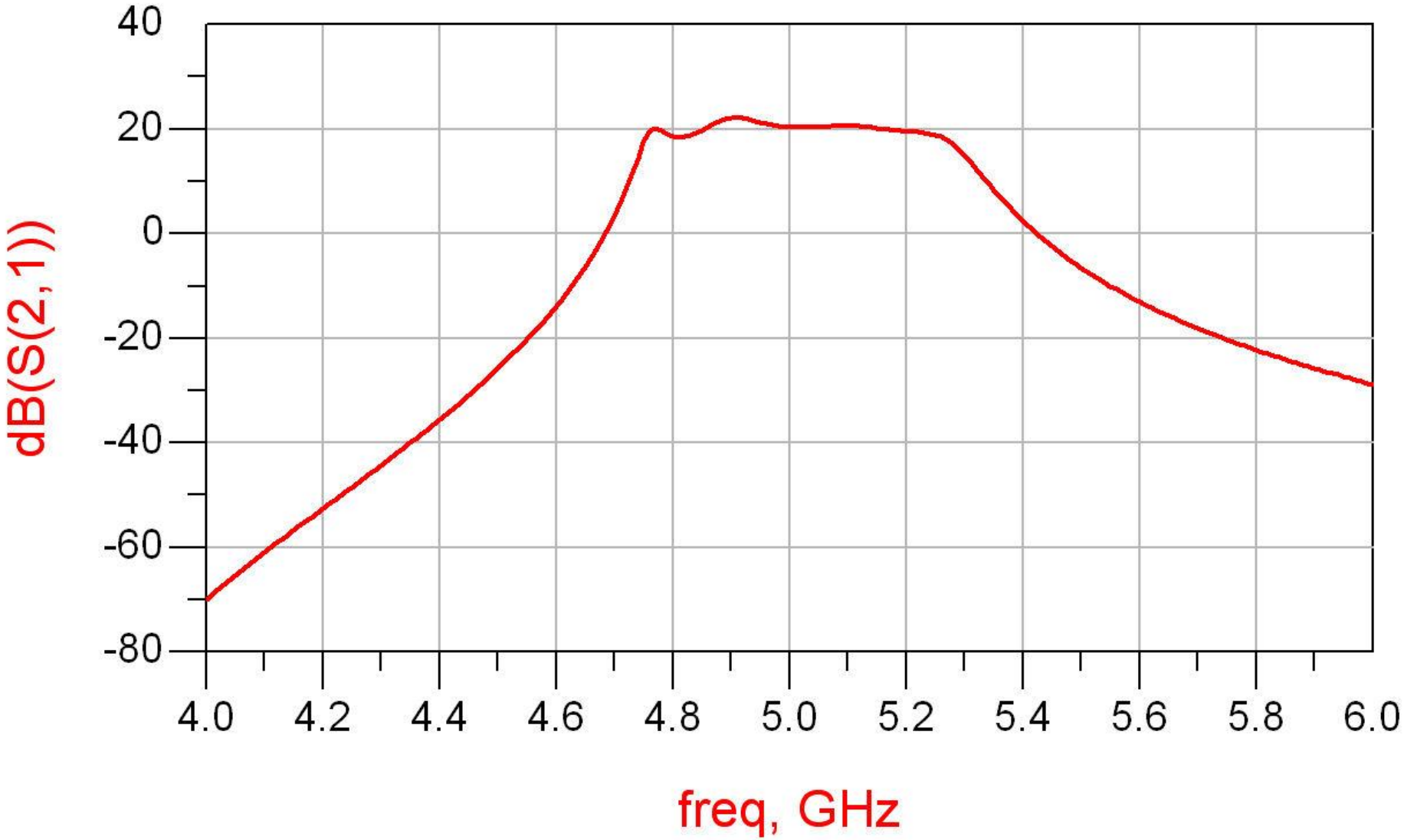


Introducere elemente de polarizare

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

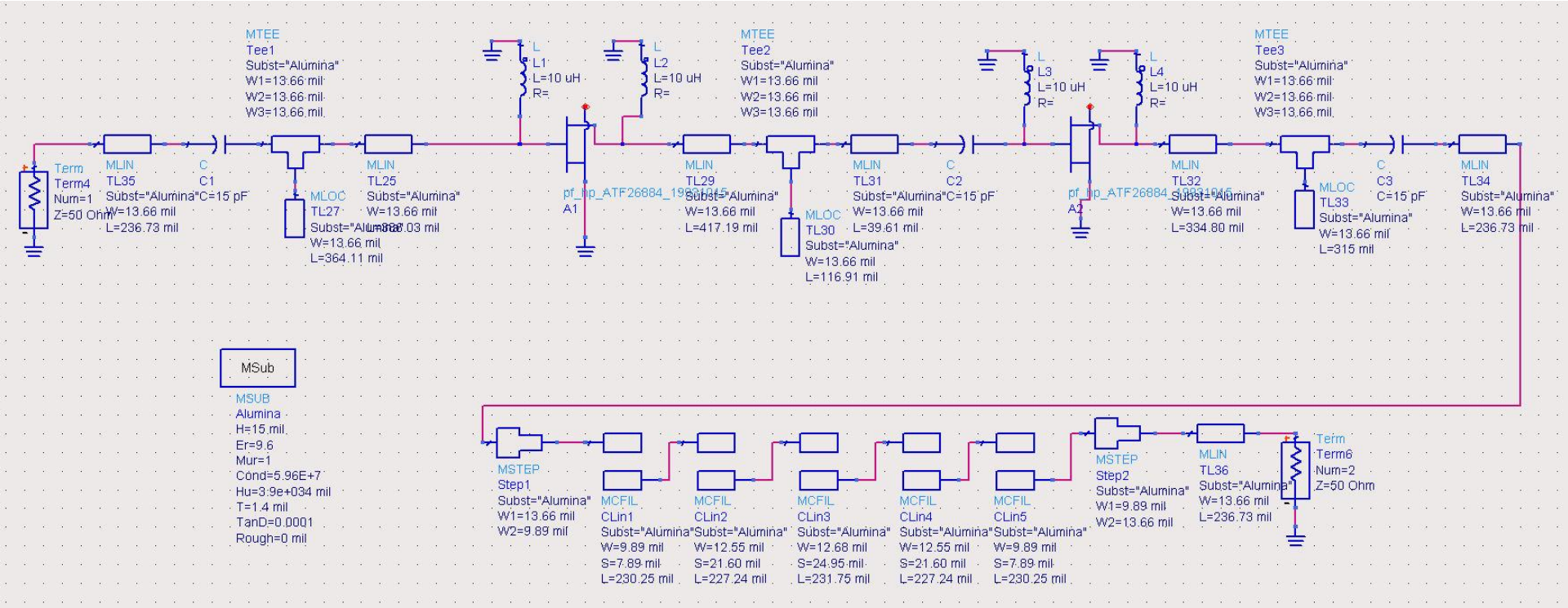


Rezultat final (Castig)

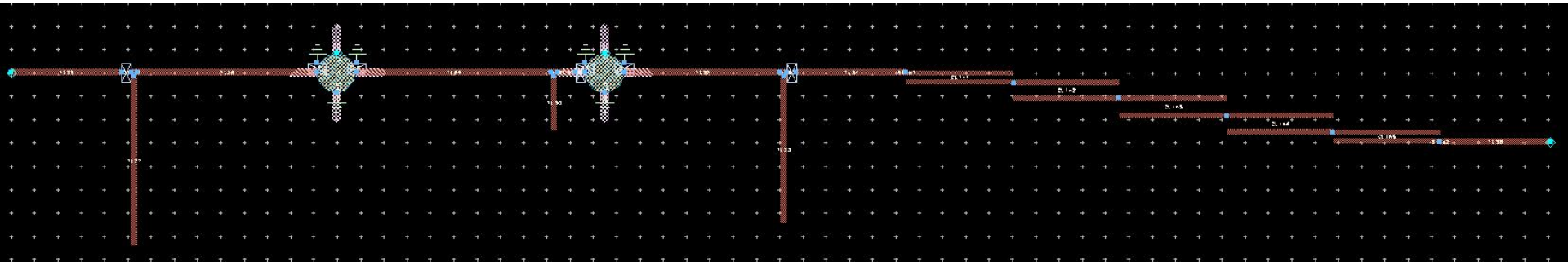


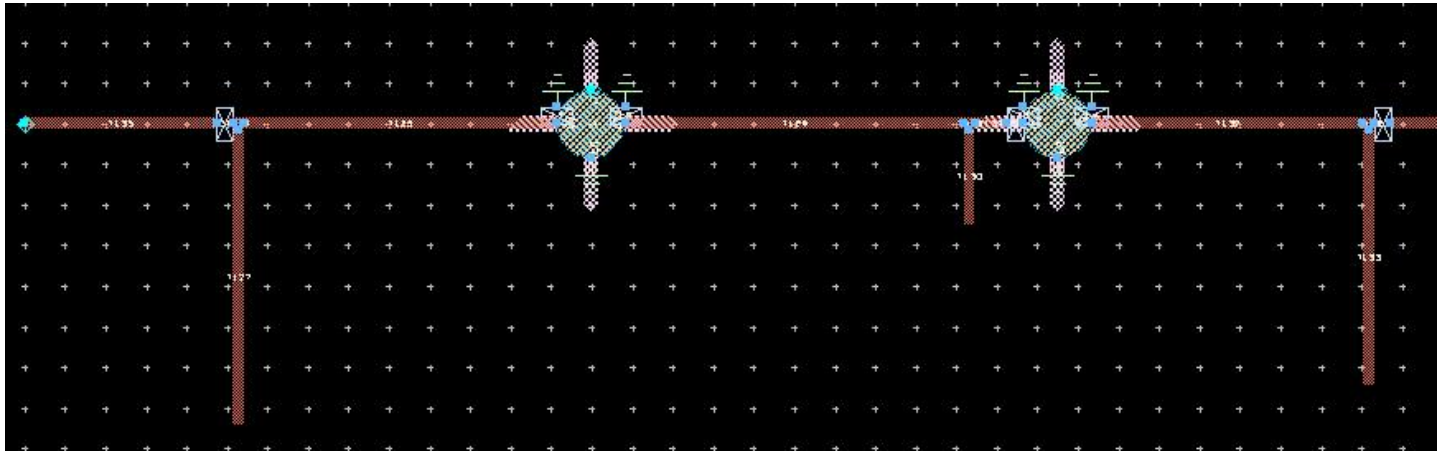
Layout (Exemplu)

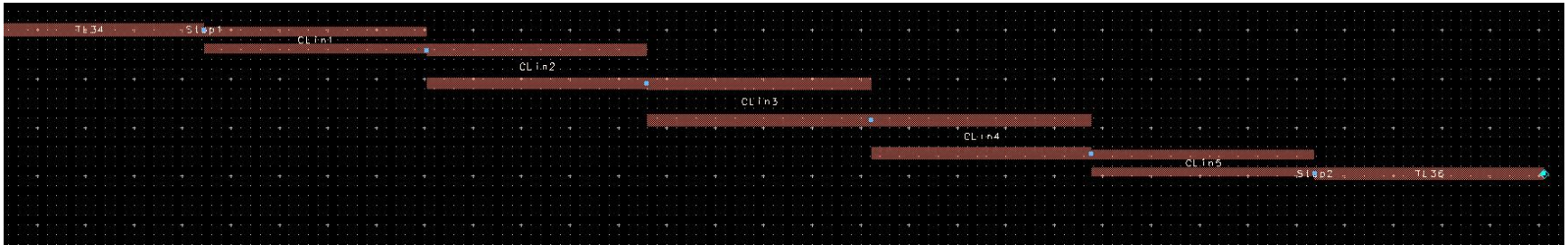
- Inlocuirea (fictiva) a tranzistoarelor si elementelor concentrate (LC) cu elemente pentru care ADS are informatii despre capsule



Layout (Exemplu)







Contact

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