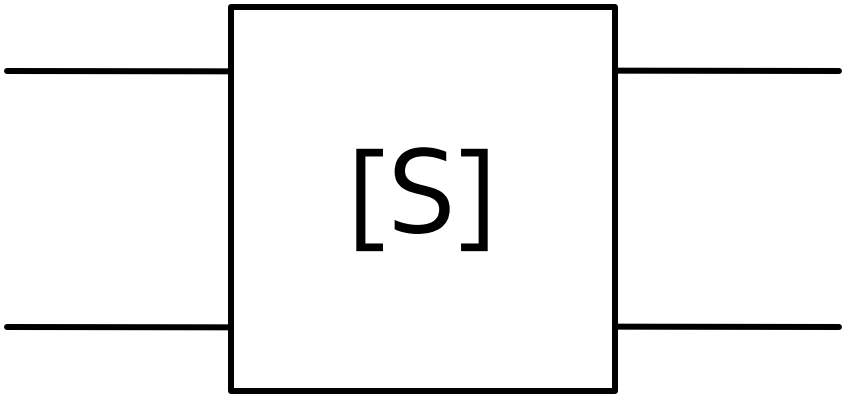
Laborator 4

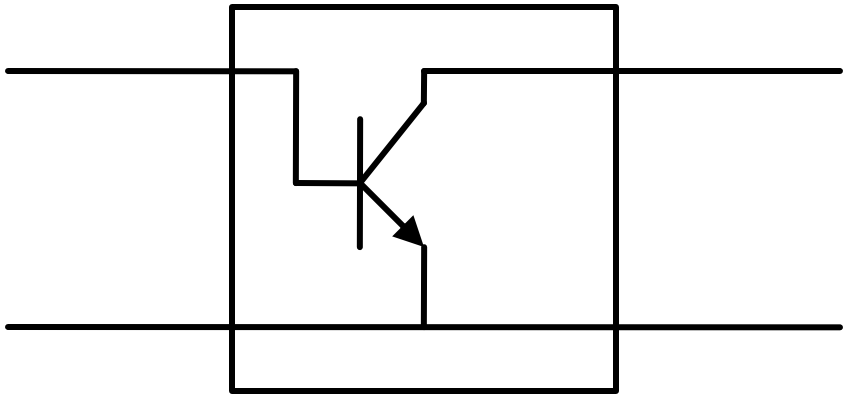
2020/2021

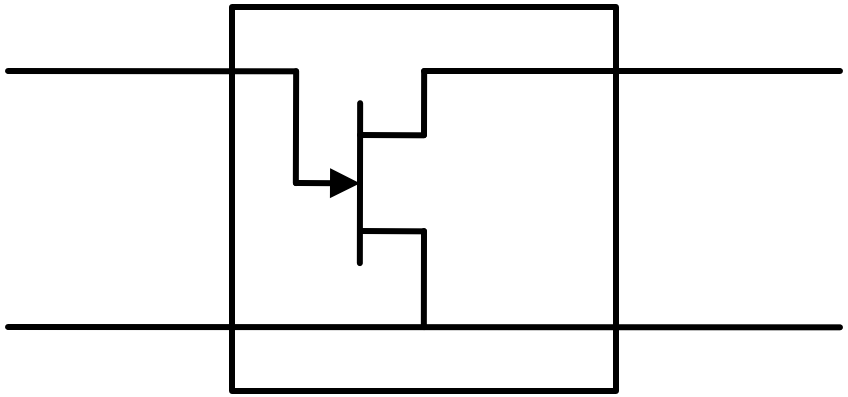
Dispozitive şi circuite de microunde pentru radiocomunicații

Scurta teorie

Parametri S

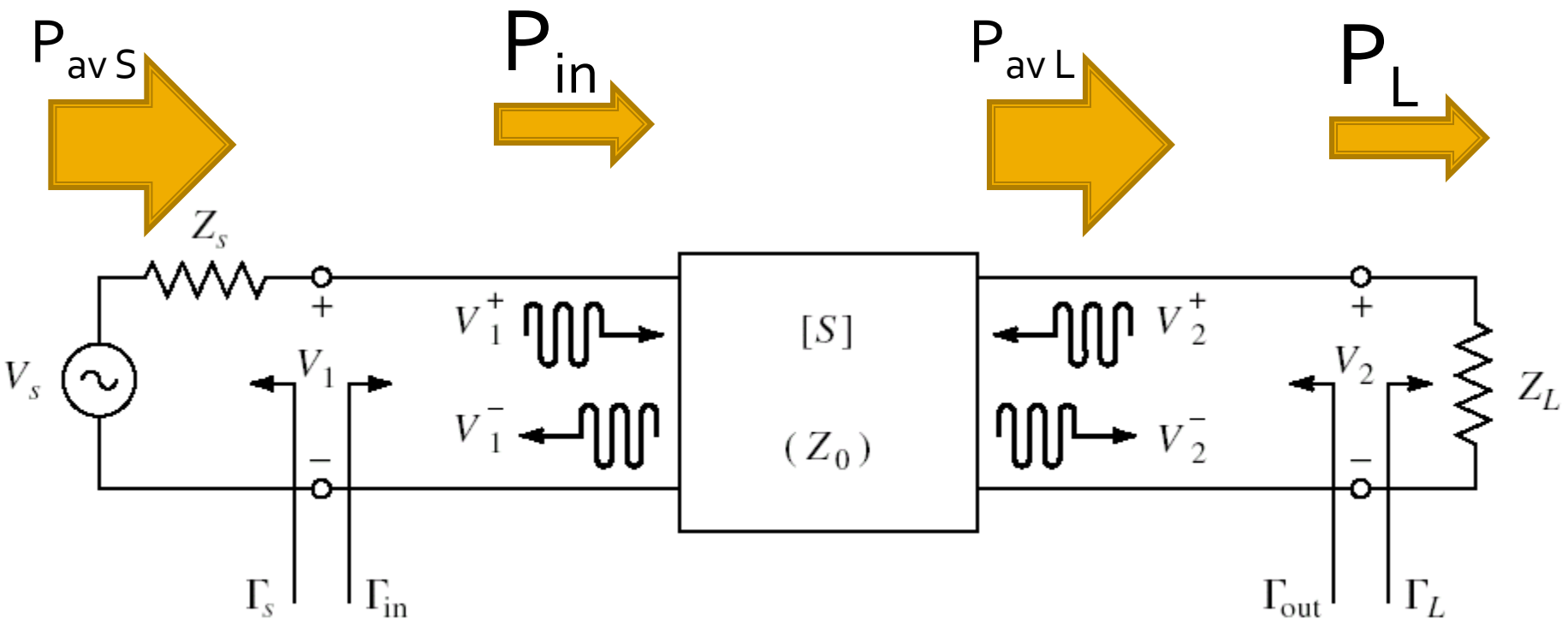




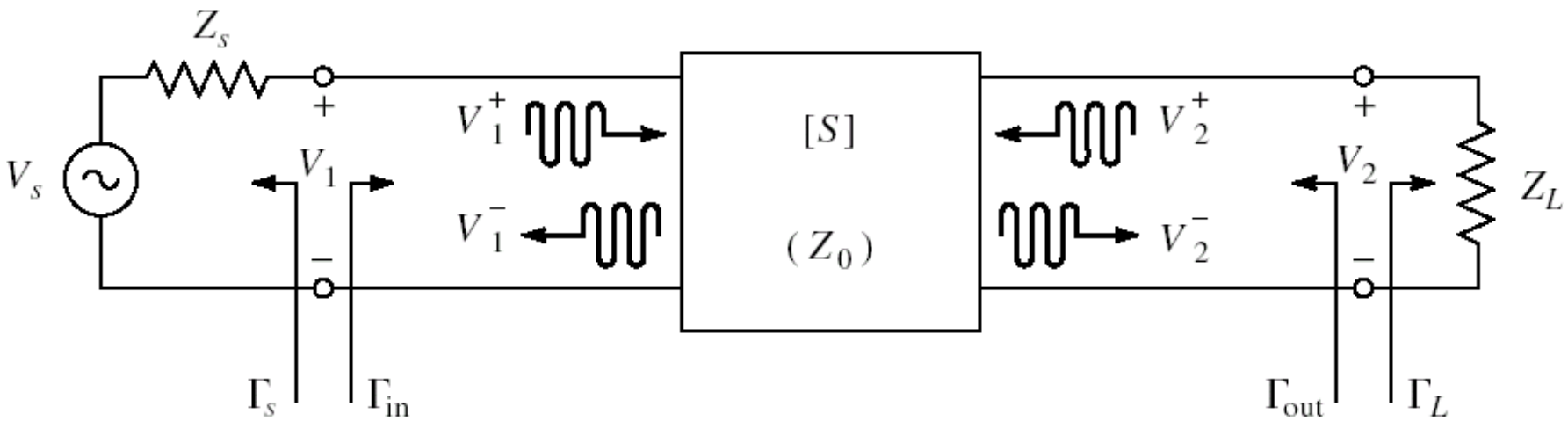


Puteri / Adaptare

- Doua porturi in care adaptarea influenteaza transferul de putere

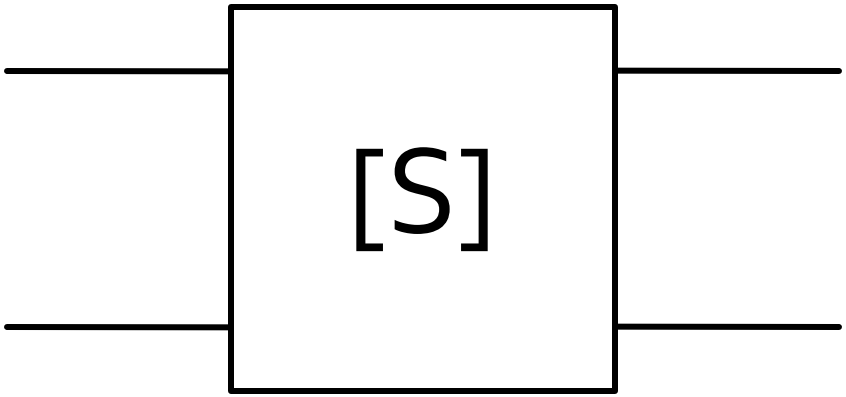


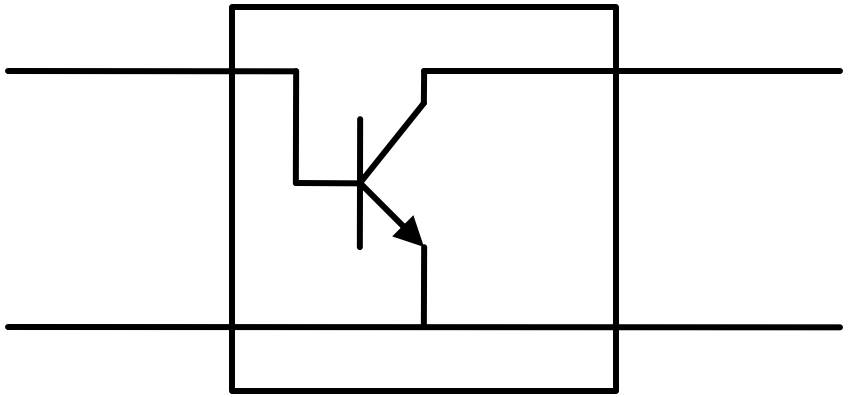
Cuadripol Amplificator (diport)

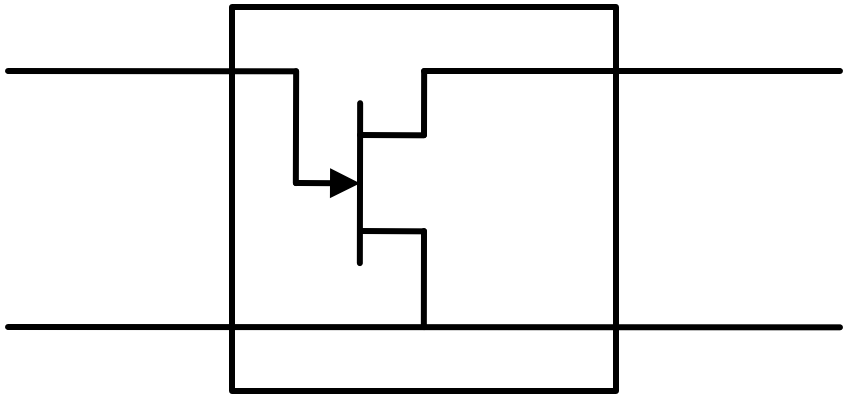


- Caracterizare cu parametri S
- Normalizati la Zo (implicit 50Ω)
- Cataloage: parametri S pentru anumite polarizari

Parametri S







Stabilitate

$$|\Gamma_{in}| < 1 \qquad \left| S_{11} + \frac{S_{12} \cdot S_{21} \cdot \Gamma_L}{1 - S_{22} \cdot \Gamma_L} \right| < 1$$

- Obtinem conditiile ce trebuie indeplinite de Γ_L pentru a obtine stabilitatea

$$|\Gamma_{out}| < 1 \qquad \left| S_{22} + \frac{S_{12} \cdot S_{21} \cdot \Gamma_S}{1 - S_{11} \cdot \Gamma_S} \right| < 1$$

- Obtinem conditiile ce trebuie indeplinite de Γ_S pentru a obtine stabilitatea

Cerc de stabilitate la iesire (CSOUT)

$$\left|\Gamma_L - \frac{\left(S_{22} - \Delta \cdot S_{11}^*\right)^*}{|S_{22}|^2 - |\Delta|^2}\right| = \left|\frac{S_{12} \cdot S_{21}}{|S_{22}|^2 - |\Delta|^2}\right| \qquad |\Gamma_L - C_L| = R_L$$

- Ecuatia unui cerc, care reprezinta locul geometric al punctelor Γ_L pentru **limita** de stabilitate
- Cercul se numeste **cerc de stabilitate la iesire** (Γ_L)

$$C_L = \frac{\left(S_{22} - \Delta \cdot S_{11}^*\right)^*}{|S_{22}|^2 - |\Delta|^2} \qquad R_L = \frac{|S_{12} \cdot S_{21}|}{\left||S_{22}|^2 - |\Delta|^2\right|}$$

Cerc de stabilitate la intrare (CSIN)

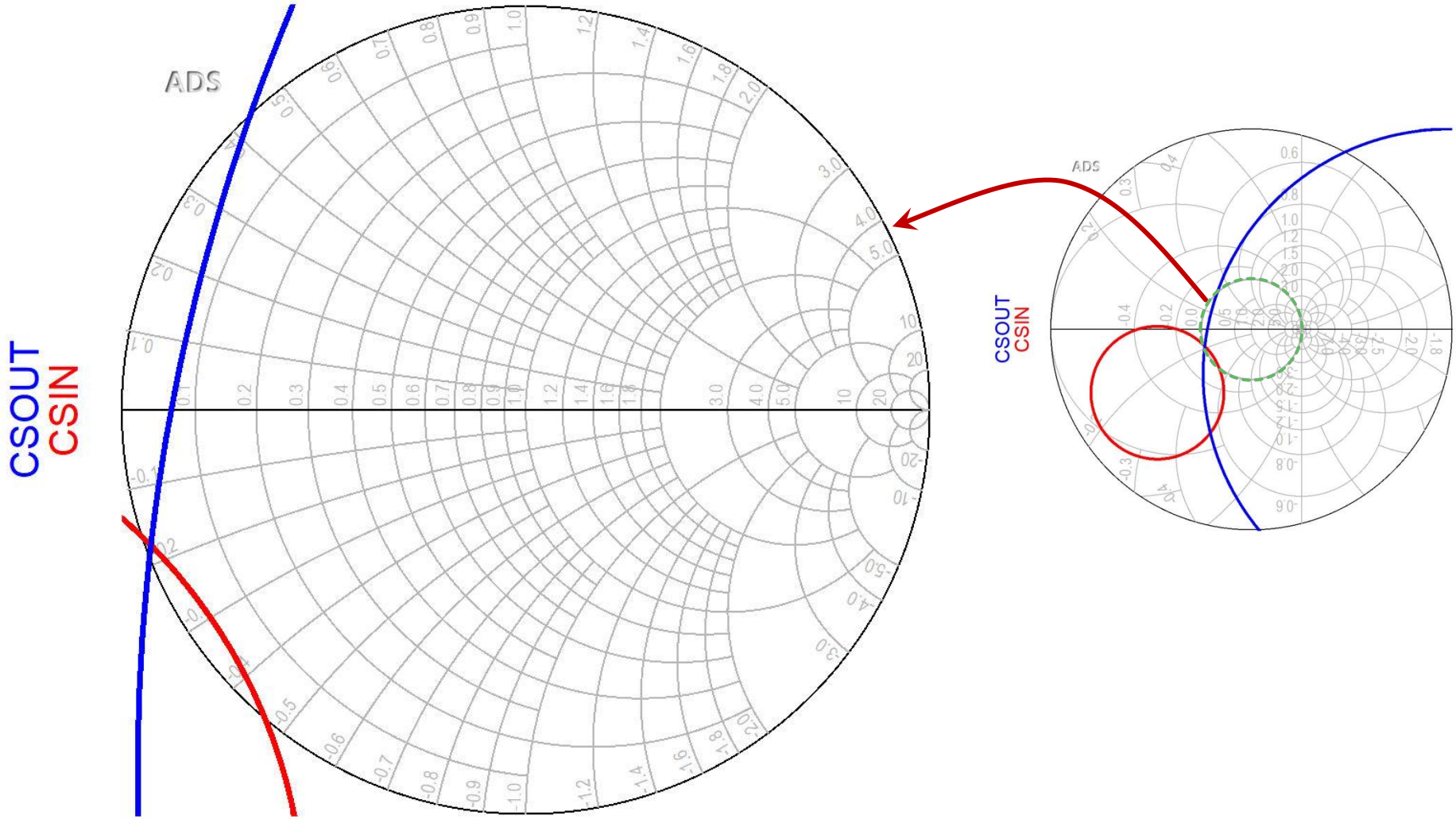
- Similar

$$|\Gamma_{out}| = 1 \qquad \left| S_{22} + \frac{S_{12} \cdot S_{21} \cdot \Gamma_S}{1 - S_{11} \cdot \Gamma_S} \right| = 1$$

- Ecuatia unui cerc, care reprezinta locul geometric al punctelor Γ_S pentru **limita** de stabilitate
- Cercul se numeste **cerc de stabilitate la intrare** (Γ_S)

$$C_S = \frac{\left(S_{11} - \Delta \cdot S_{22}^*\right)^*}{|S_{11}|^2 - |\Delta|^2} \qquad R_S = \frac{|S_{12} \cdot S_{21}|}{\left||S_{11}|^2 - |\Delta|^2\right|}$$

ADS

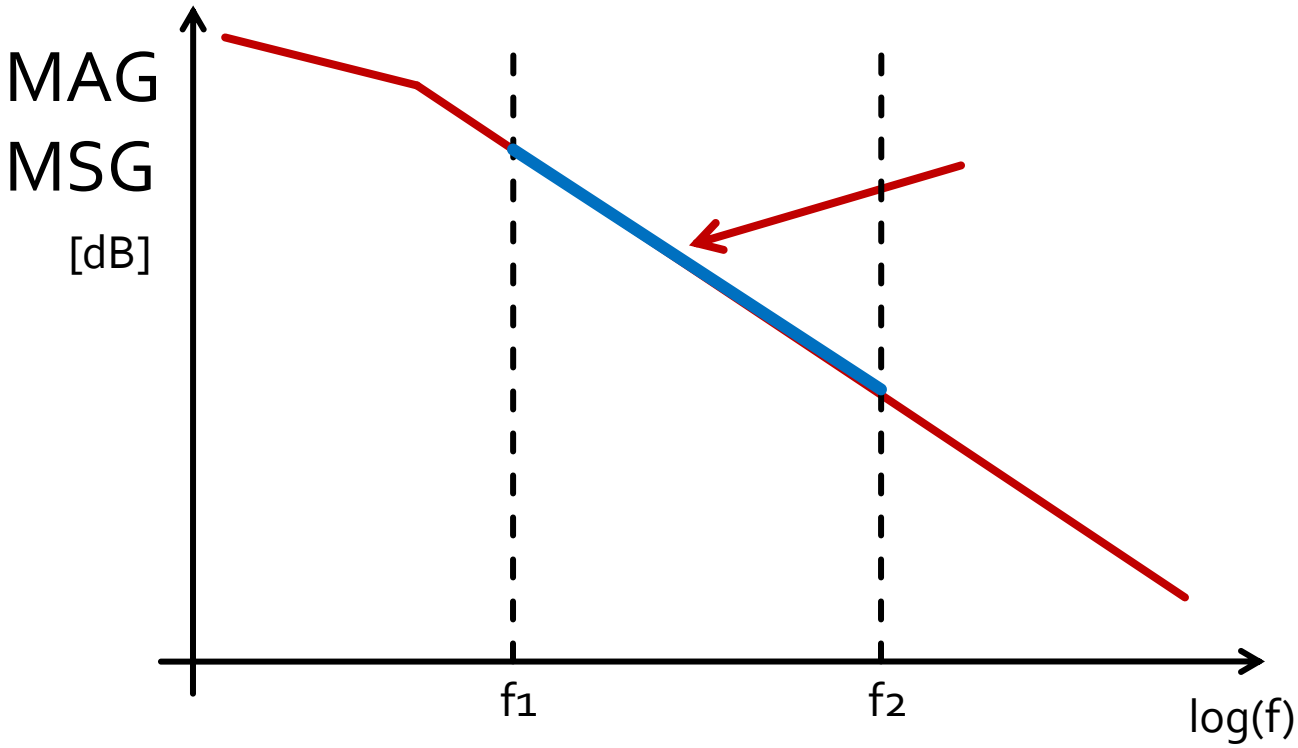


Proiectare pentru castig impus

- Deseori este necesara o alta abordare decat "forta bruta" si se prefera obtinerea unui **castig mai mic** decat cel maxim posibil pentru:
  - conditii de zgomot avantajoase (L3)
  - conditii de stabilitate mai bune
  - obtinerea unui VSWR mai mic
  - controlul performantelor la mai multe frecvente
  - banda de functionare a amplificatorului

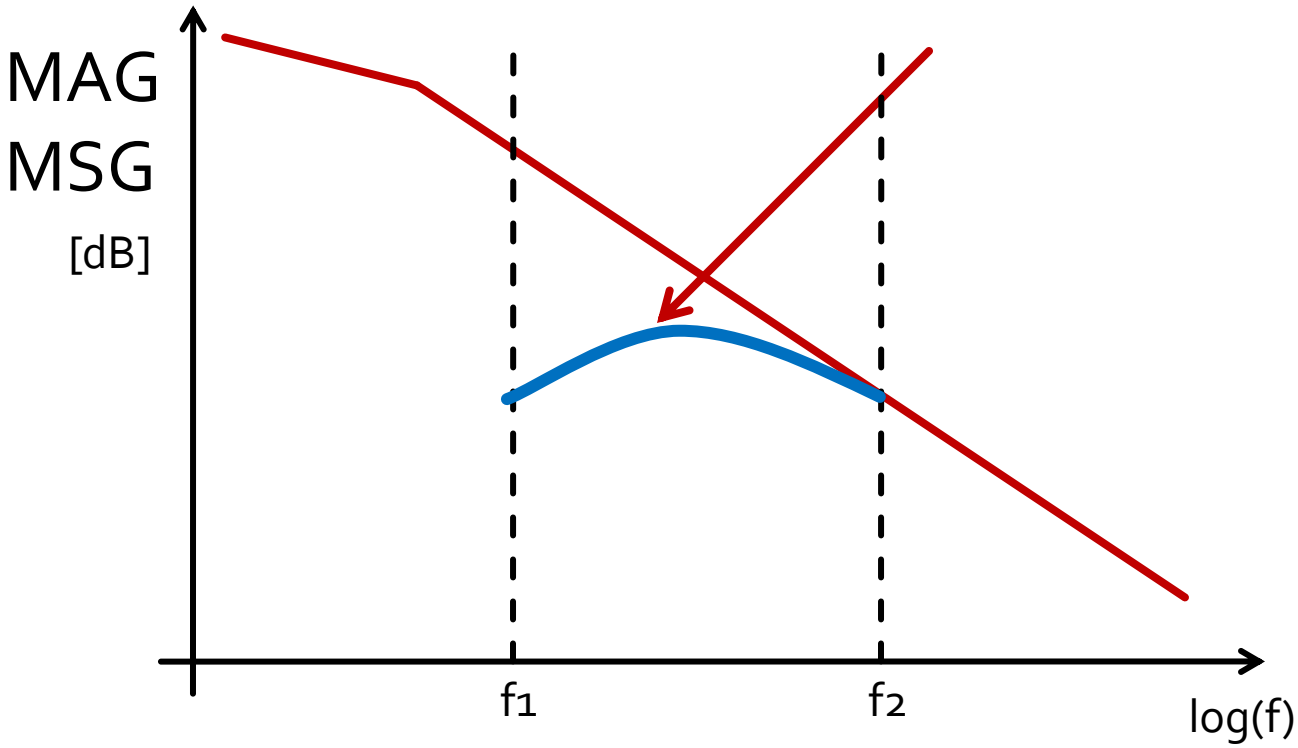
Amplificator de banda larga

- Adaptarea pentru castig maxim la doua frecvente genereaza o comportare dezechilibrata

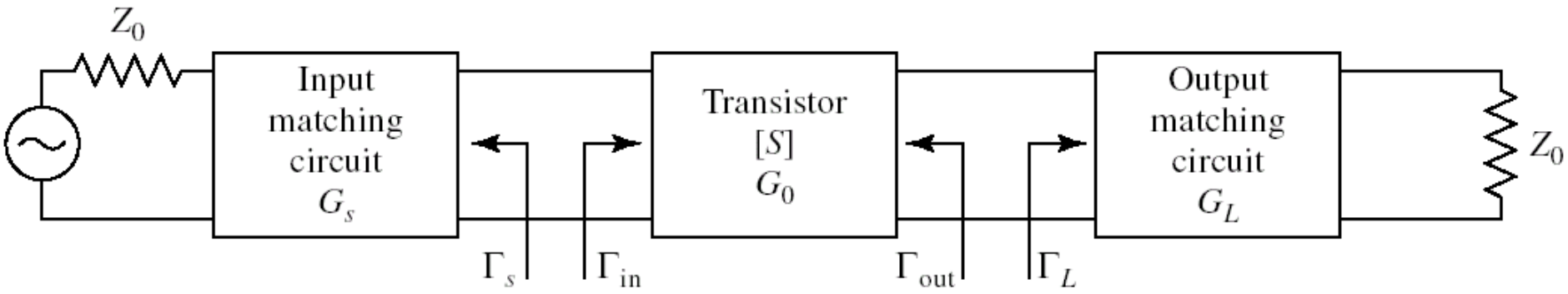


Amplificator de banda larga

- Adaptare pentru castig maxim la frecventa maxima
- Dezadaptare controlata la frecventa minima
  - eventual la mai multe frecvente din banda



Proiectare pentru castig impus

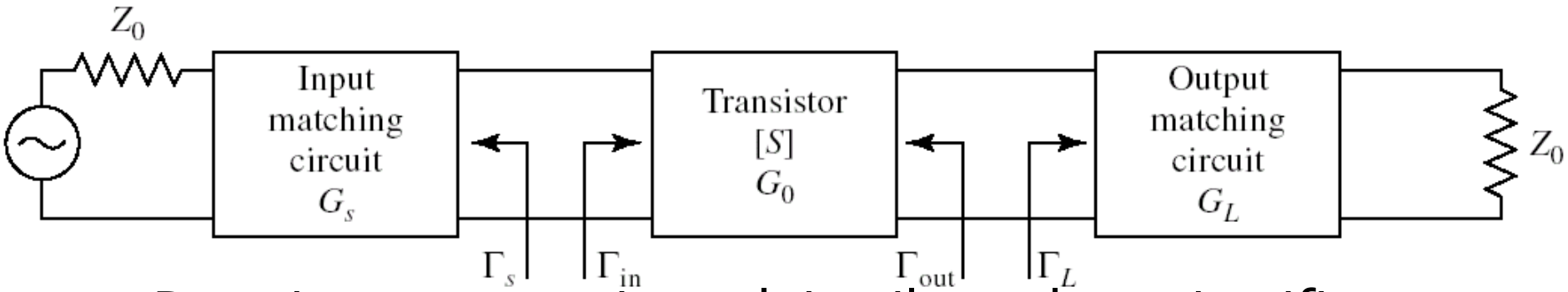


- Daca ipoteza tranzistorului unilateral este justificata:

$$G_{TU} = |S_{21}|^2 \cdot \frac{1-|\Gamma_S|^2}{|1-S_{11}\cdot\Gamma_S|^2} \cdot \frac{1-|\Gamma_L|^2}{|1-S_{22}\cdot\Gamma_L|^2}$$

$$G_S = \frac{1-|\Gamma_S|^2}{|1-S_{11}\cdot\Gamma_S|^2} \qquad G_0 = |S_{21}|^2 \qquad G_L = \frac{1-|\Gamma_L|^2}{|1-S_{22}\cdot\Gamma_L|^2}$$

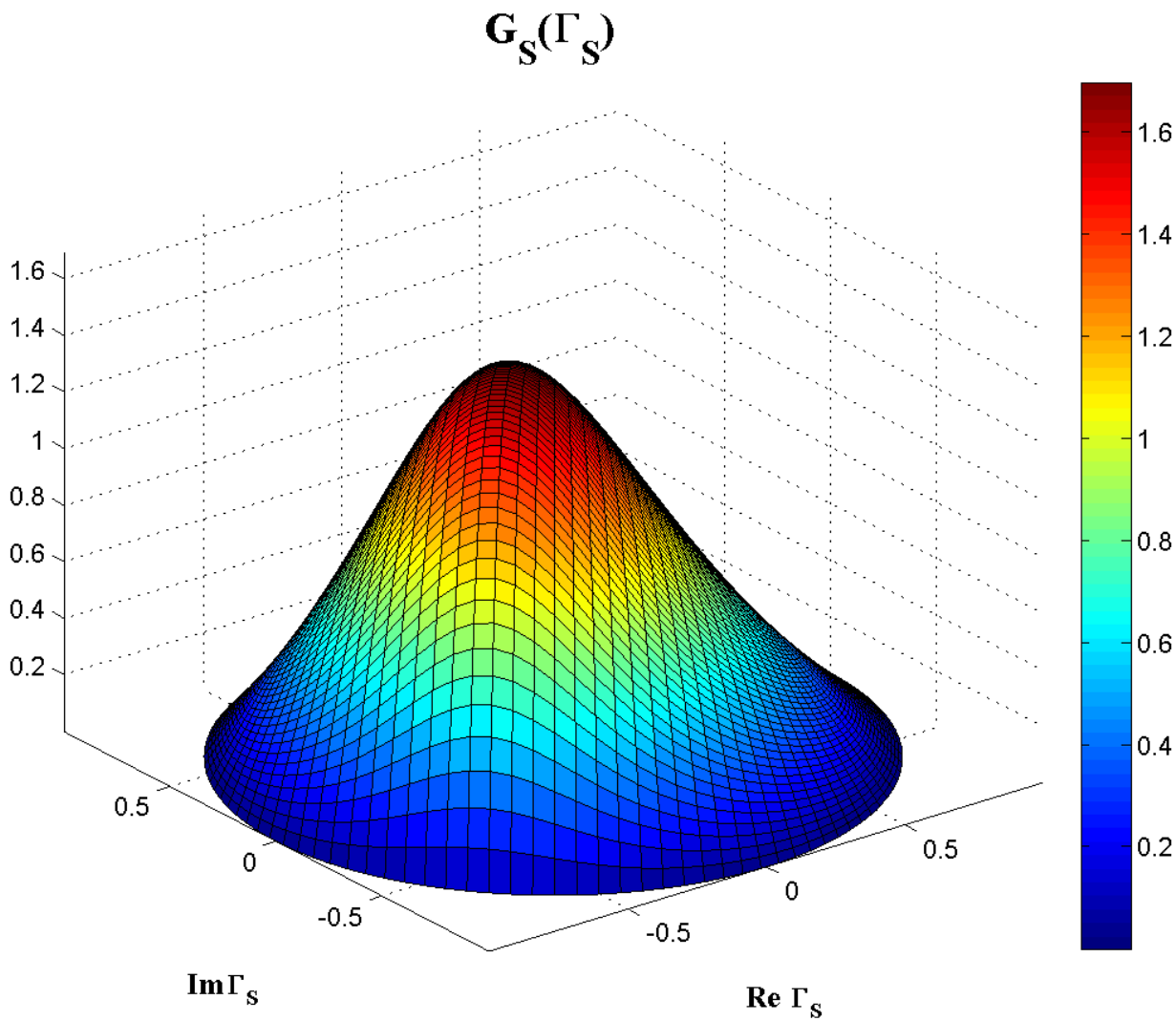
Proiectare pentru castig impus



- Daca ipoteza tranzistorului unilateral este justificata:
  - castigul adaugat prin adaptare mai buna la intrare **nu** depinde de adaptarea la iesire
  - castigul adaugat prin adaptare mai buna la iesire **nu** depinde de adaptarea la intrare
- Adaptarile la intrare/iesire pot fi tratate independent
  - Se pot impune cerinte diferite intrare/iesire
  - se tine cont de compunerea castigurilor generate

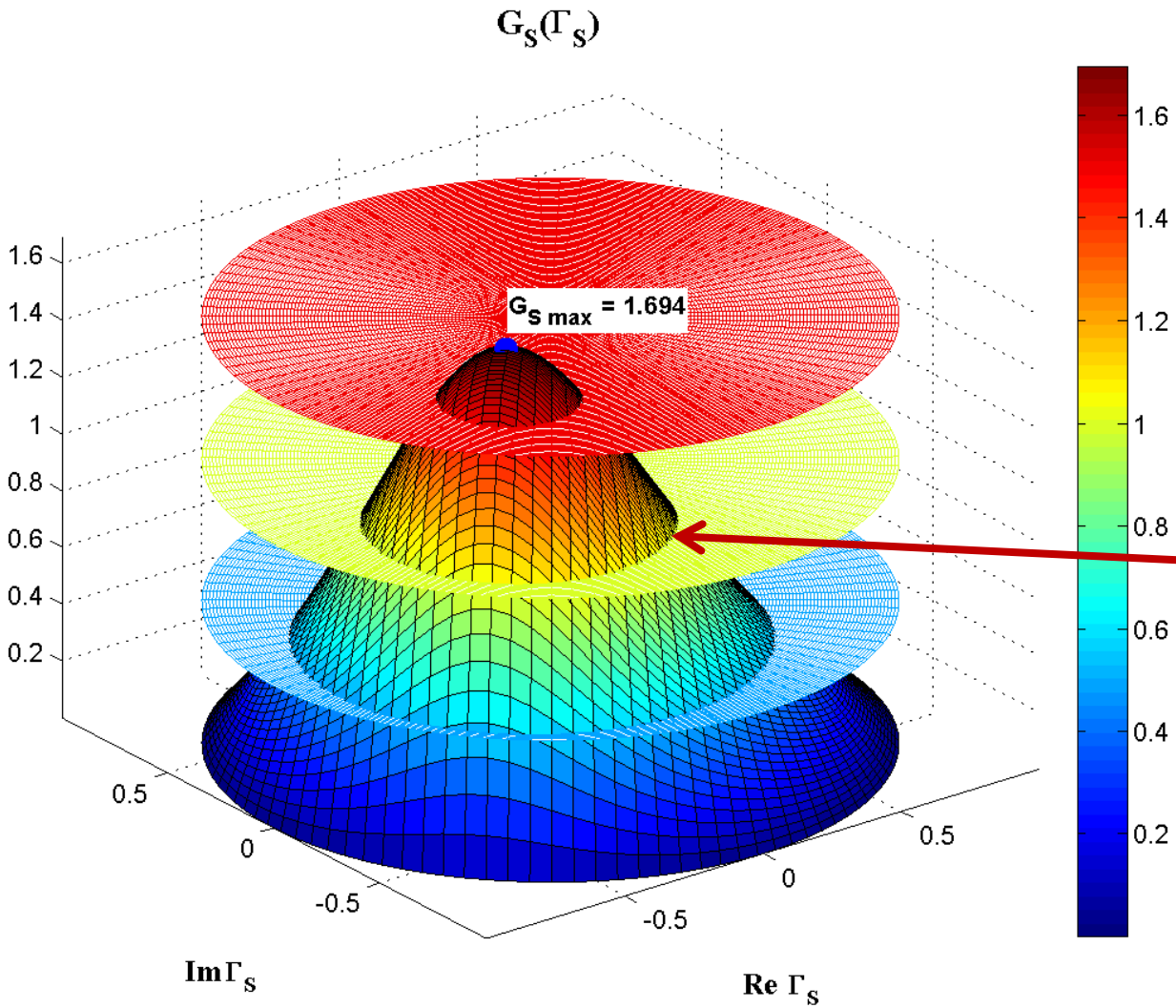
$$G_T = G_S \cdot G_0 \cdot G_L \qquad G_T[dB] = G_S[dB] + G_0[dB] + G_L[dB]$$

$G_S(\Gamma_S)$



$$G_S = \frac{1-|\Gamma_S|^2}{|1-S_{11}\cdot\Gamma_S|^2}$$

$G_S(\Gamma_S)$, nivel constant



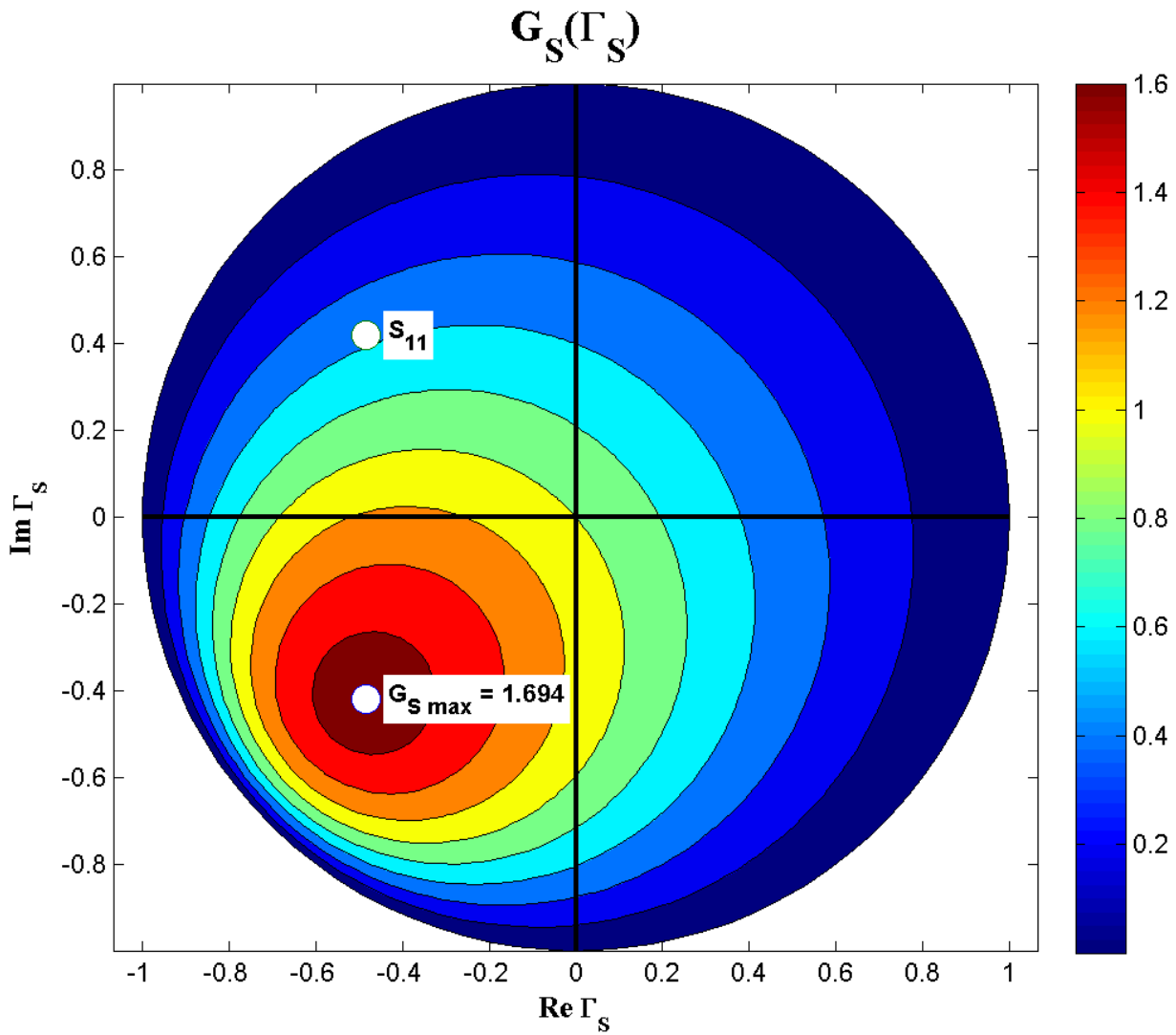
$G_S = 1.5$

$G_S = 1.0$

$G_S = 0.5$

Cercuri

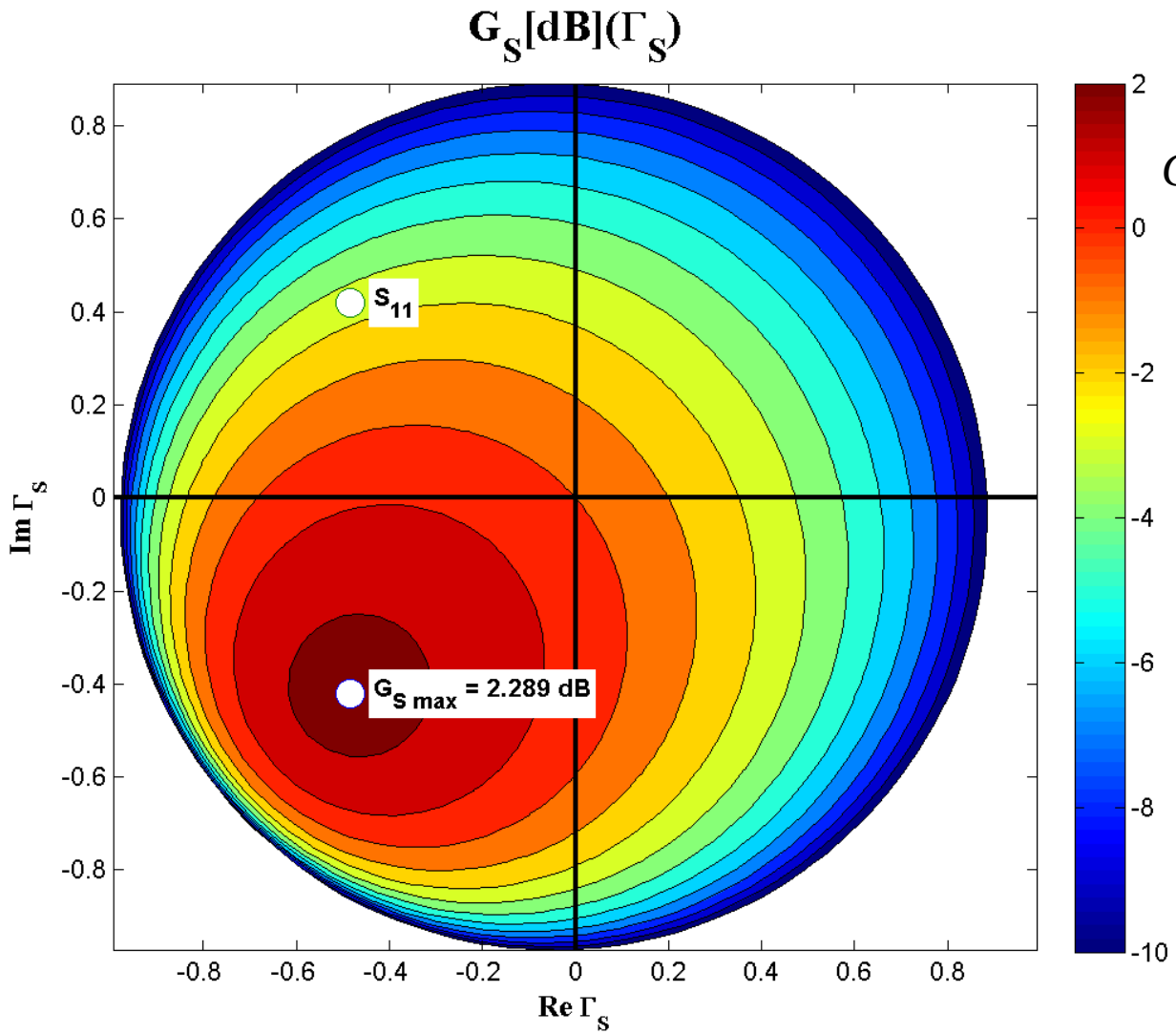
$G_S(\Gamma_S)$, diagrama de nivel



$$G_S = \frac{1-|\Gamma_S|^2}{|1-S_{11}\cdot\Gamma_S|^2}$$

$$G_{S\,\max} = G_S\big|_{\Gamma_S = S_{11}^*}$$

$G_S[dB](\Gamma_S)$, diagrama de nivel



$$G_S[dB] = 10 \cdot \log\left(\frac{1-|\Gamma_S|^2}{|1-S_{11}\cdot\Gamma_S|^2}\right)$$

$$G_{S\,\max} = G_S\big|_{\Gamma_S = S_{11}^*}$$

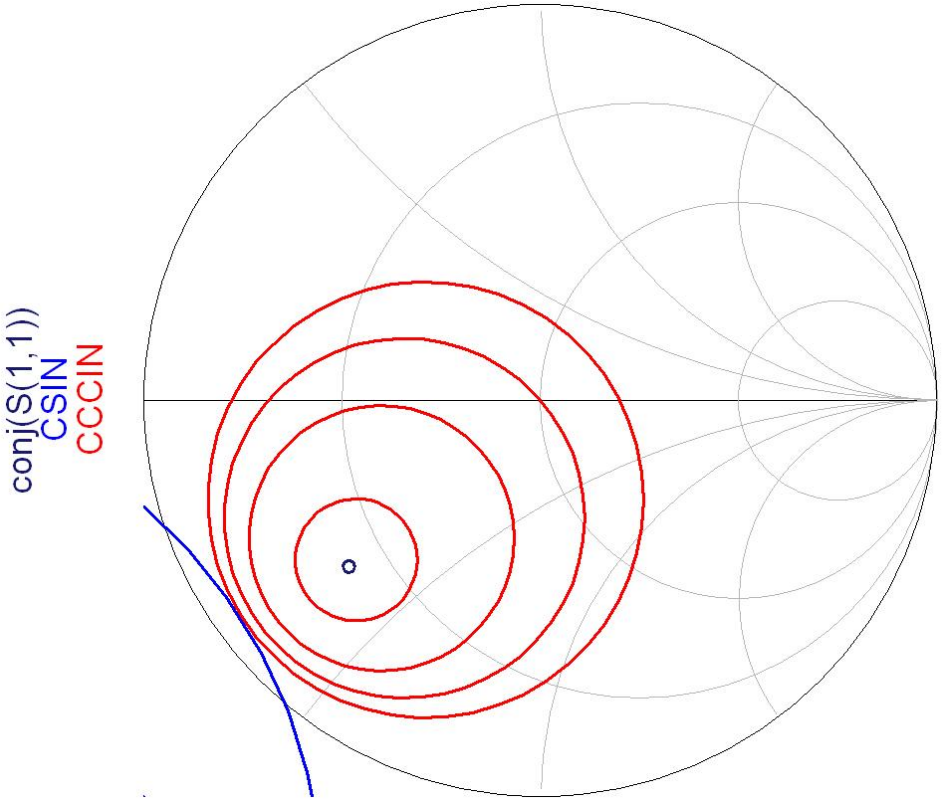
Cercuri de castig constant la intrare

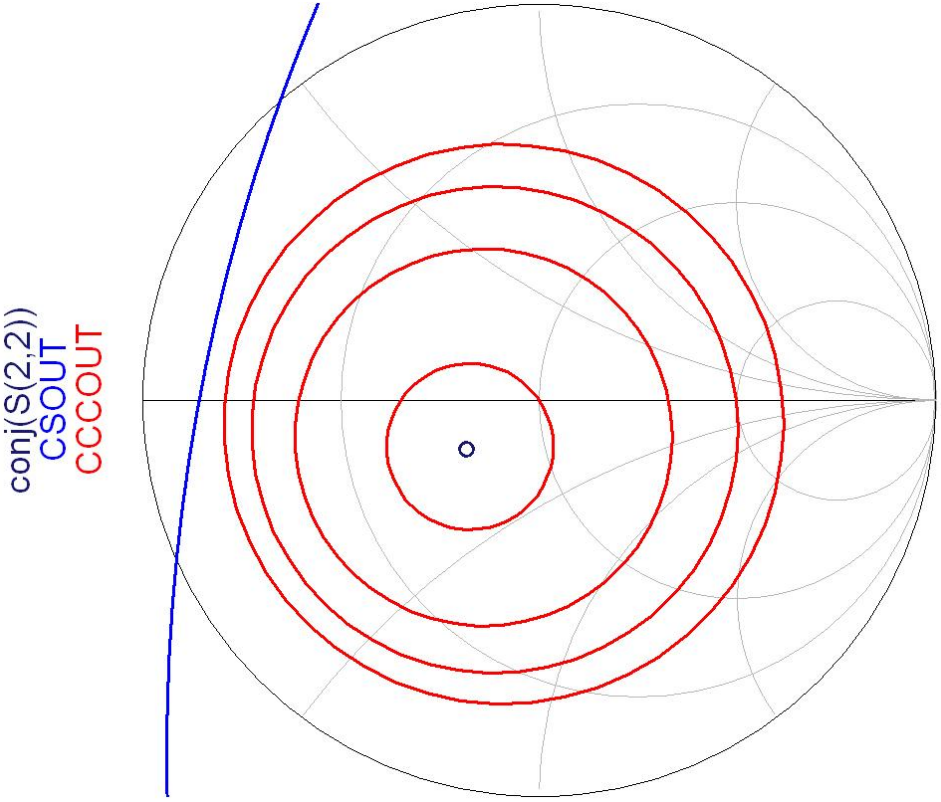
$$\left|\Gamma_S - \frac{g_S \cdot S_{11}^*}{1-(1-g_S)\cdot|S_{11}|^2}\right| = \frac{\sqrt{1-g_S}\cdot\left(1-|S_{11}|^2\right)}{1-(1-g_S)\cdot|S_{11}|^2} \qquad |\Gamma_S - C_S| = R_S$$

$$C_S = \frac{g_S \cdot S_{11}^*}{1-(1-g_S)\cdot|S_{11}|^2} \qquad R_S = \frac{\sqrt{1-g_S}\cdot\left(1-|S_{11}|^2\right)}{1-(1-g_S)\cdot|S_{11}|^2}$$

- Ecuatia unui cerc in planul complex in care reprezint Γ_S
- **Interpretare**: Orice punct Γ_S care reprezentat in planul complex se gaseste **pe** cercul desenat pentru $g_{cerc} = G_{cerc}/G_{Smax}$ va conduce la obtinerea castigului $G_S = G_{cerc}$
  - Orice punct **in exteriorul** acestui cerc va genera un castig $G_S < G_{cerc}$
  - Orice punct **in interiorul** acestui cerc va genera un castig $G_S > G_{cerc}$
- Discutie similara la iesire **CCCIN, CCCOUT**

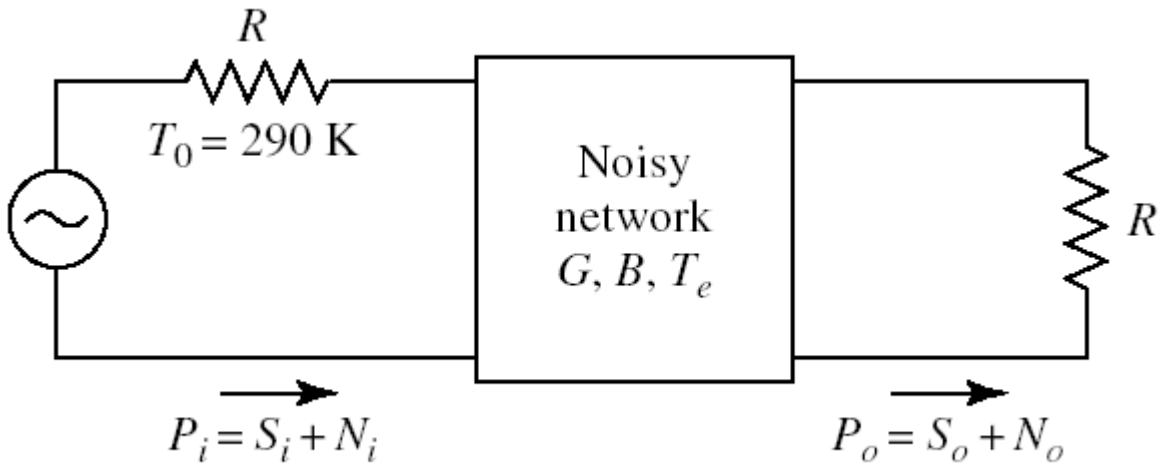
CCCIN, CCCOUT





- Cercurile se reprezinta pentru valorile cerute in dB
- Este utila calcularea G_{Smax} si G_{Lmax} anterior

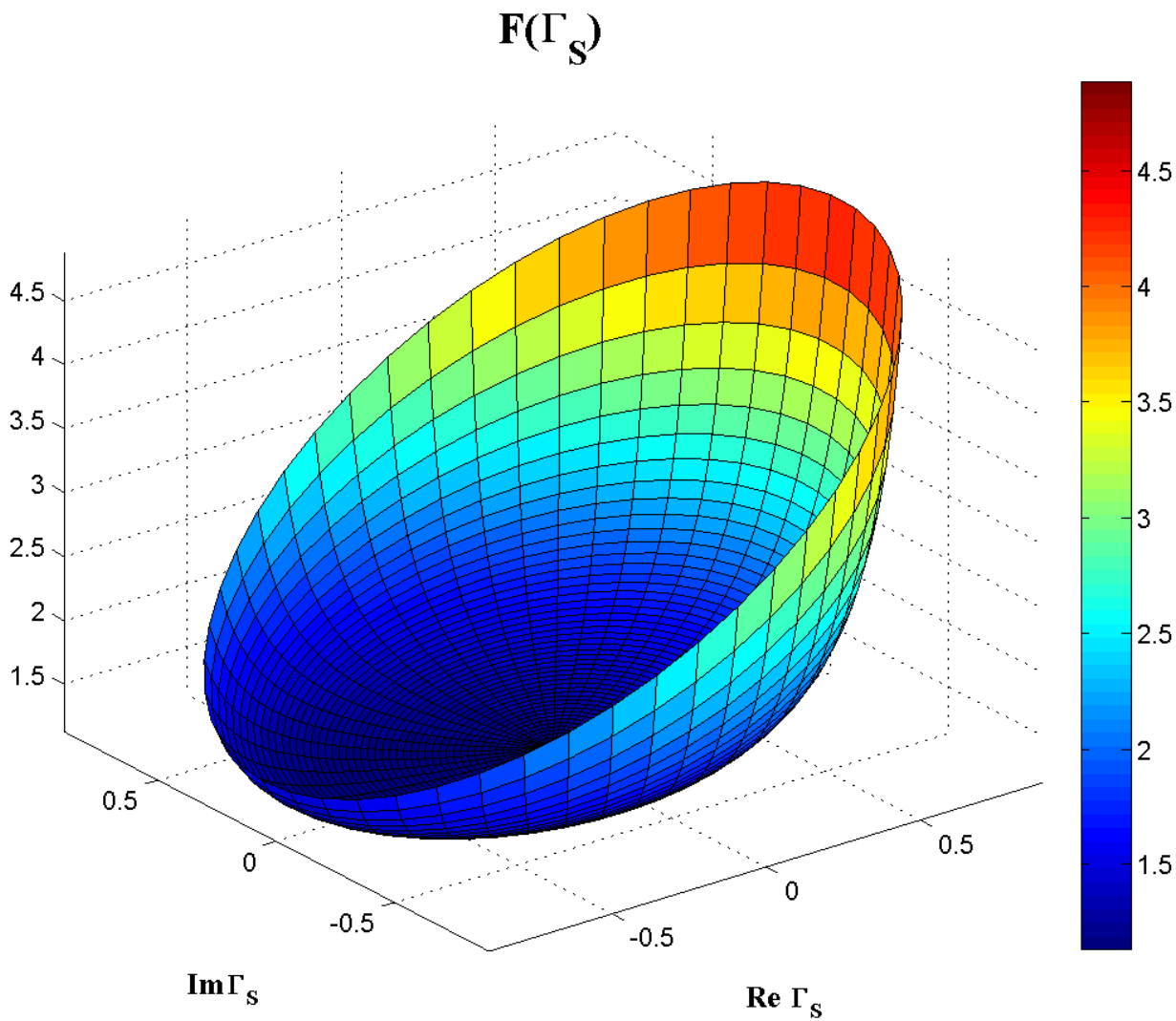
Factor de zgomot



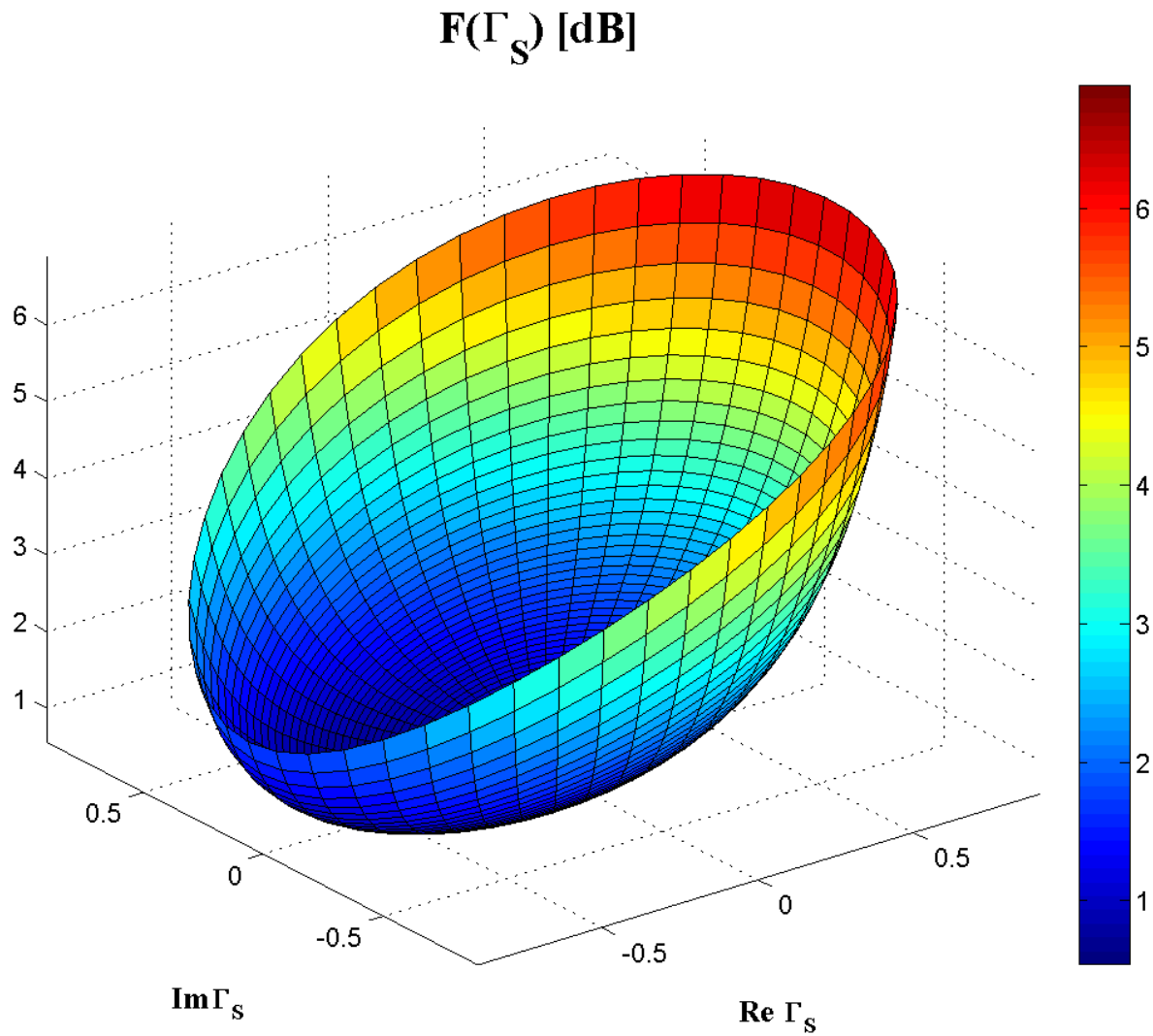
- Factorul de zgomot F caracterizeaza degradarea raportului semnal/zgomot intre intrarea si iesirea unei componente

$$F = \frac{S_i / N_i}{S_o / N_o}$$

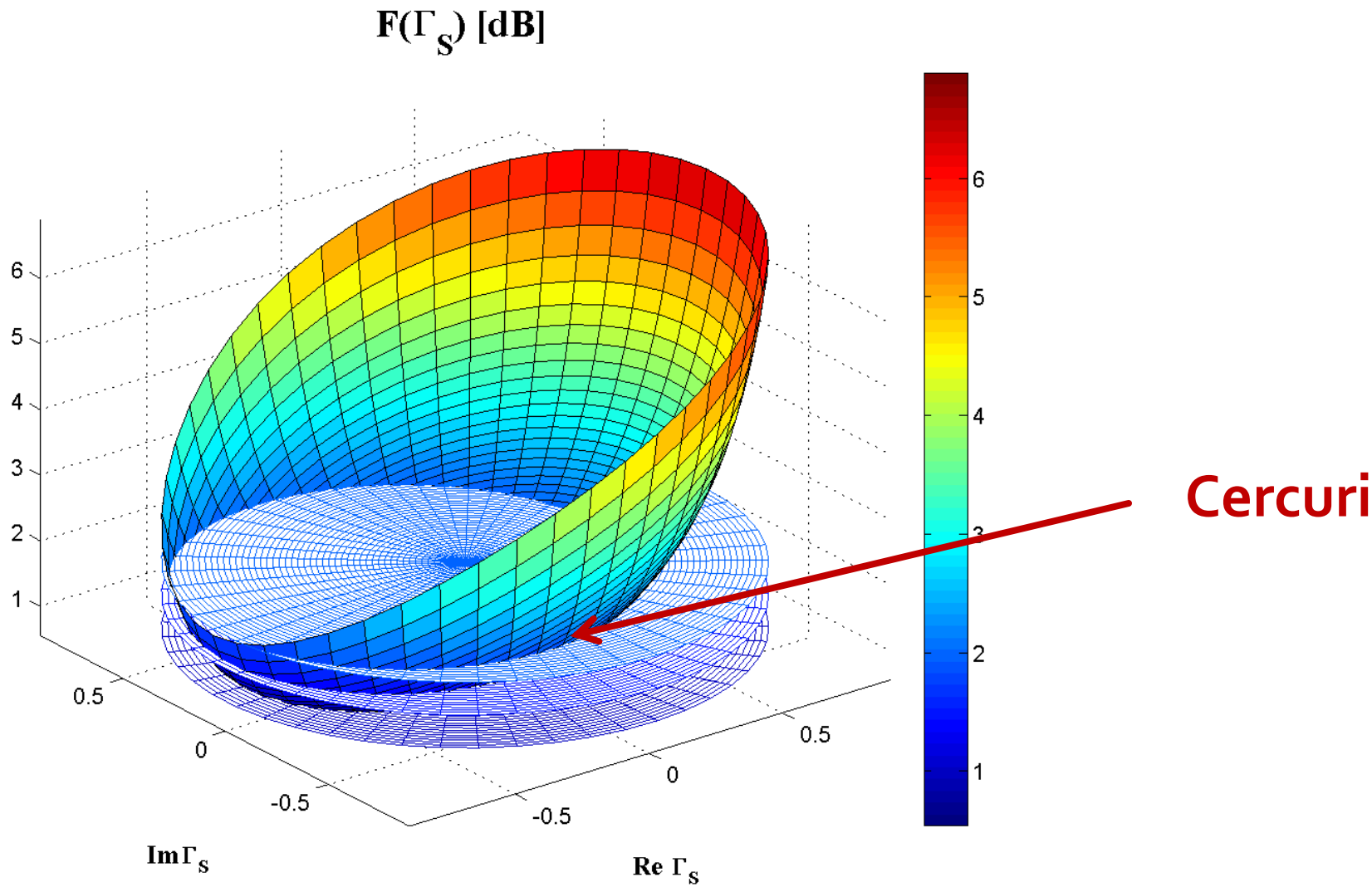
$F(\Gamma_S)$



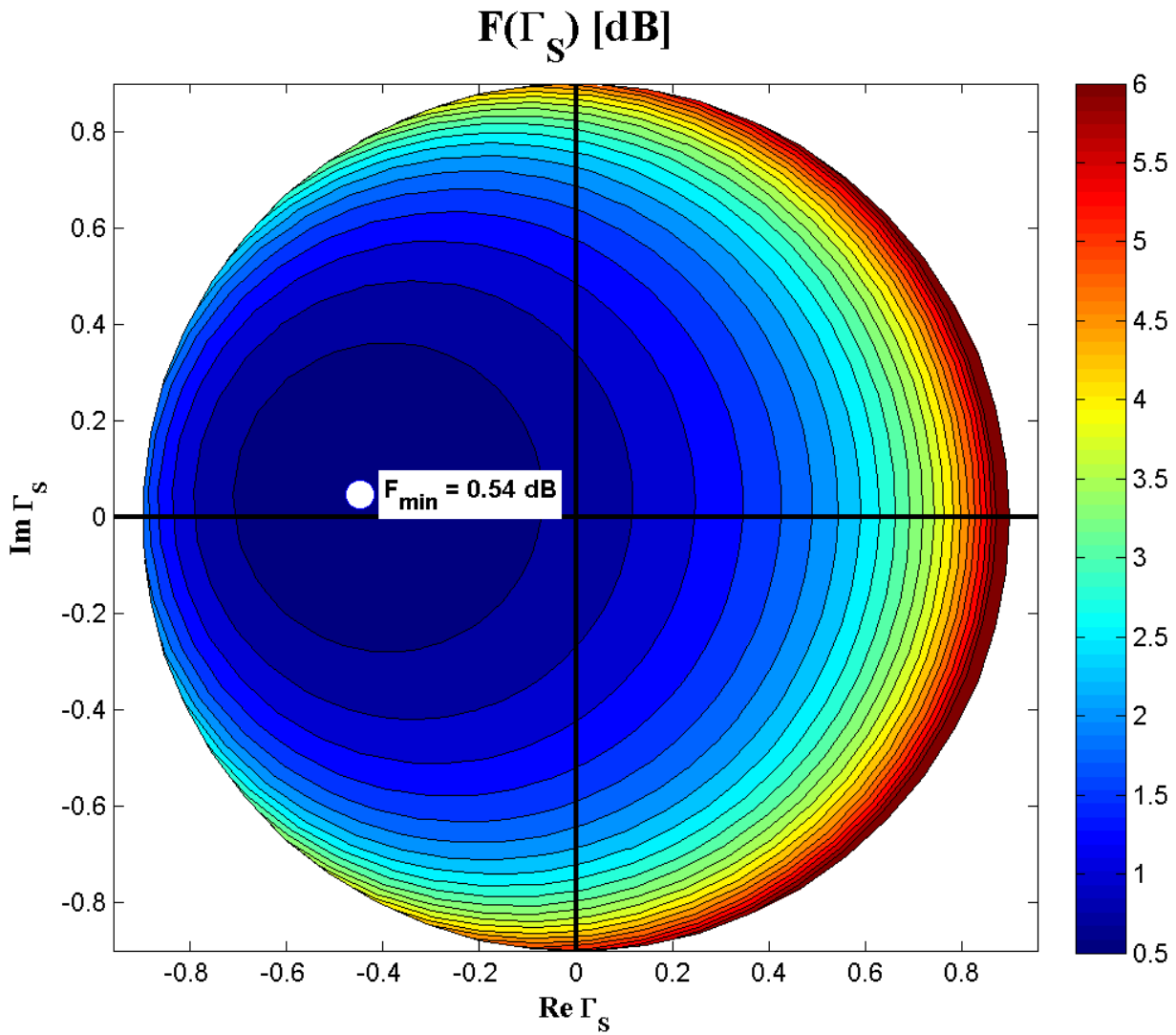
$F[dB](\Gamma_S)$



F[dB](Γ_S), diagrama de nivel

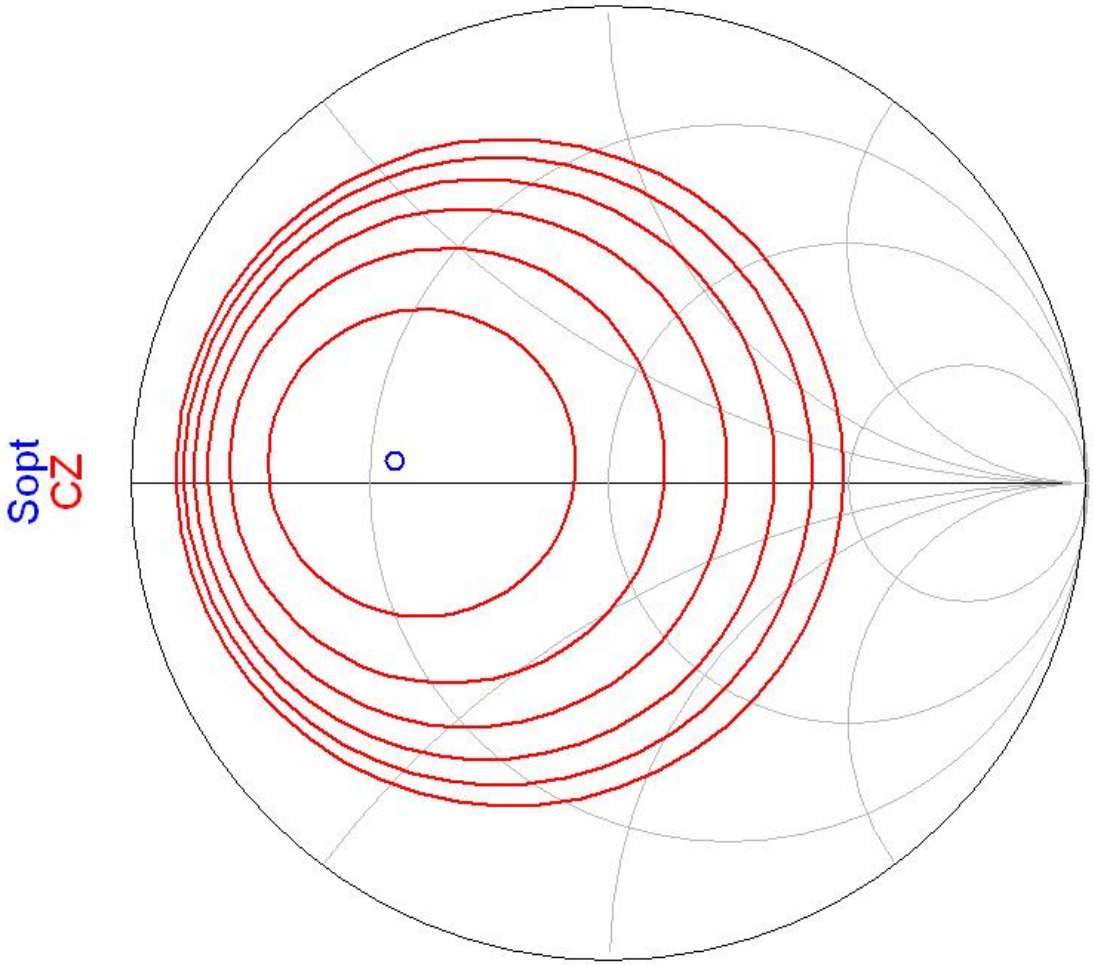


$G_S[dB](\Gamma_S)$, diagrama de nivel



$\Gamma opt = 0.45 \angle 174°$

CZ – numai la intrare !

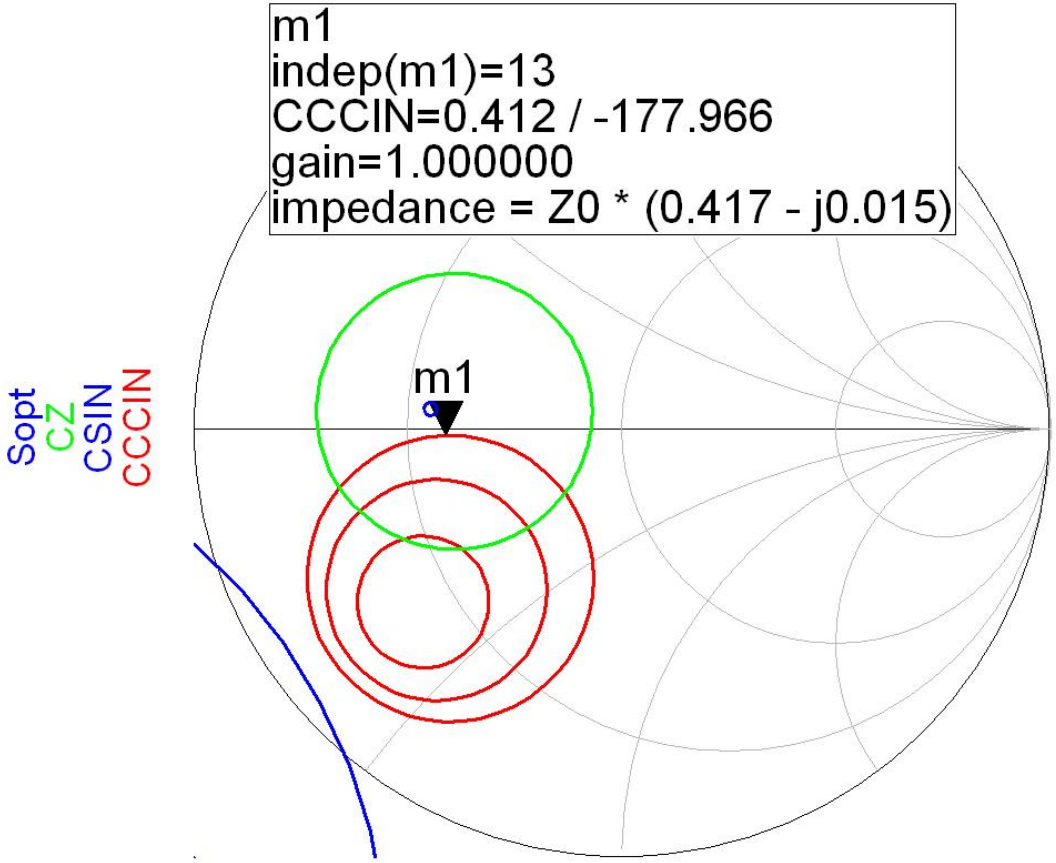


cir_pts (0.000 to 51.000)
freq (5.000GHz to 5.000GHz)

Exemplu, LNA @ 5 GHz

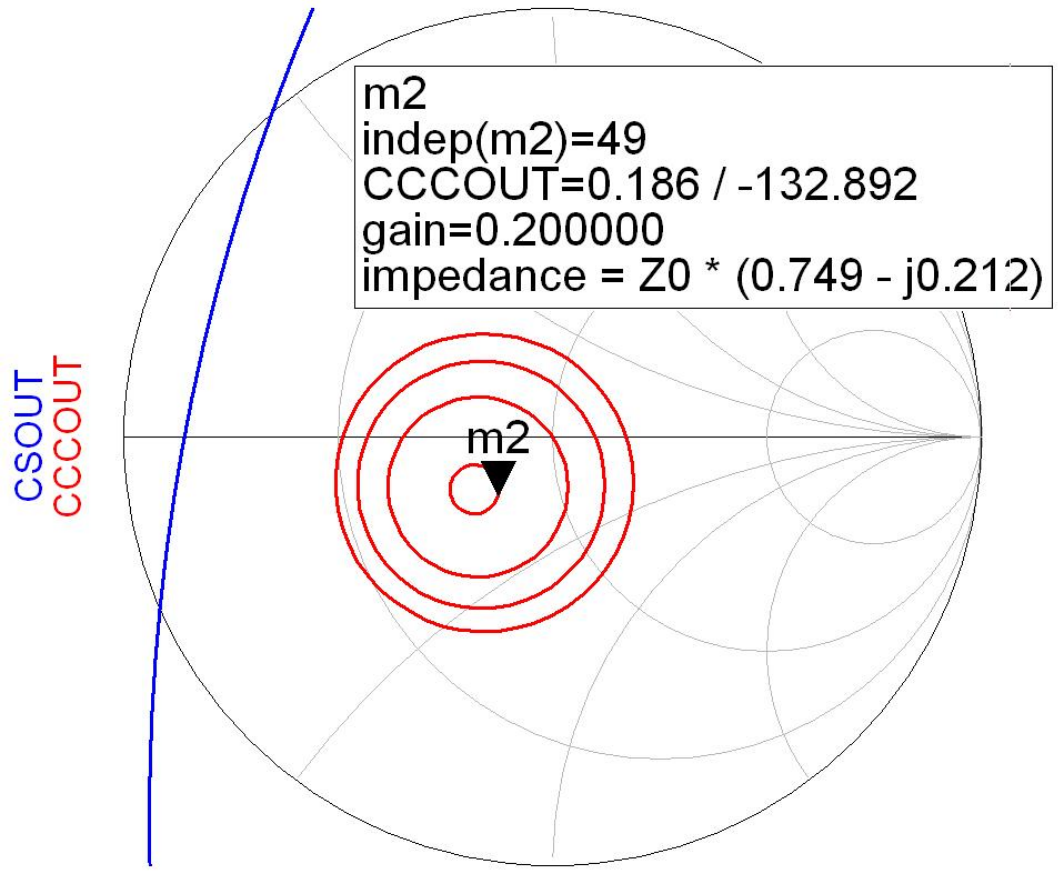
- Amplificator de zgomot redus
- La intrare e necesar un compromis intre
  - zgomot (cerc de zgomot constant ~~la intrare~~)
  - castig (cerc de castig constant la intrare)
  - stabilitate (cerc de stabilitate la intrare)
- La iesire zgomotul **nu intervine** (nu exista influenta). Compromis intre:
  - castig (cerc de castig constant la iesire)
  - stabilitate (cerc de stabilitate la iesire)

Adaptare la intrare



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

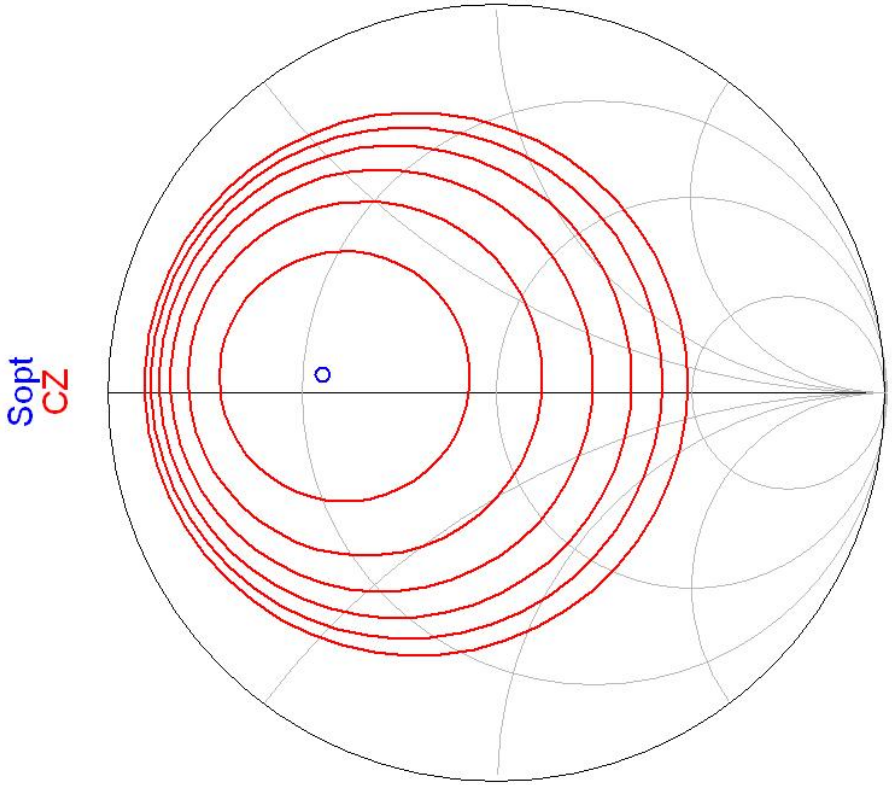
Adaptare la iesire

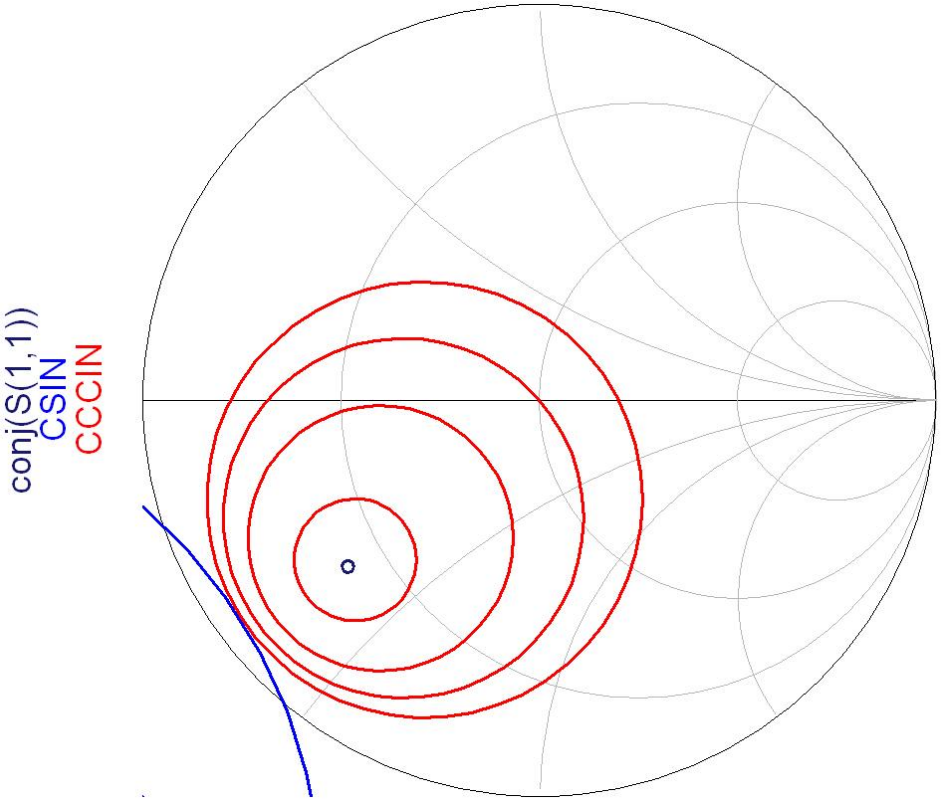


- CCCOUT: -0.4dB, -0.2dB, 0dB, +0.2dB
- Lipsa conditiilor privitoare la zgomot ofera posibilitatea obtinerii unui castig mai mare (spre maxim)

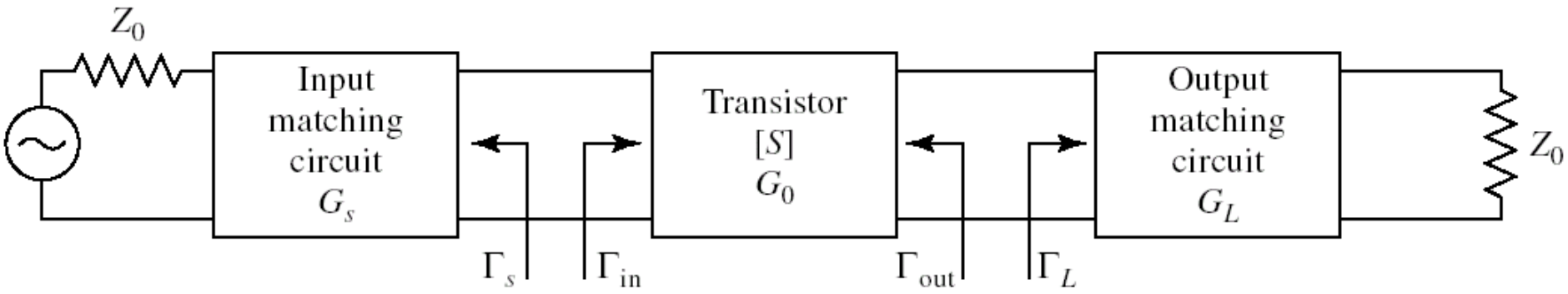
LNA

- De obicei un tranzistor potrivit pentru implementarea unui LNA la o anumita frecventa va avea cercurile de castig la intrare si cercurile de zgomot in aceeasi zona pentru Γ_S





Proiectare pentru castig impus



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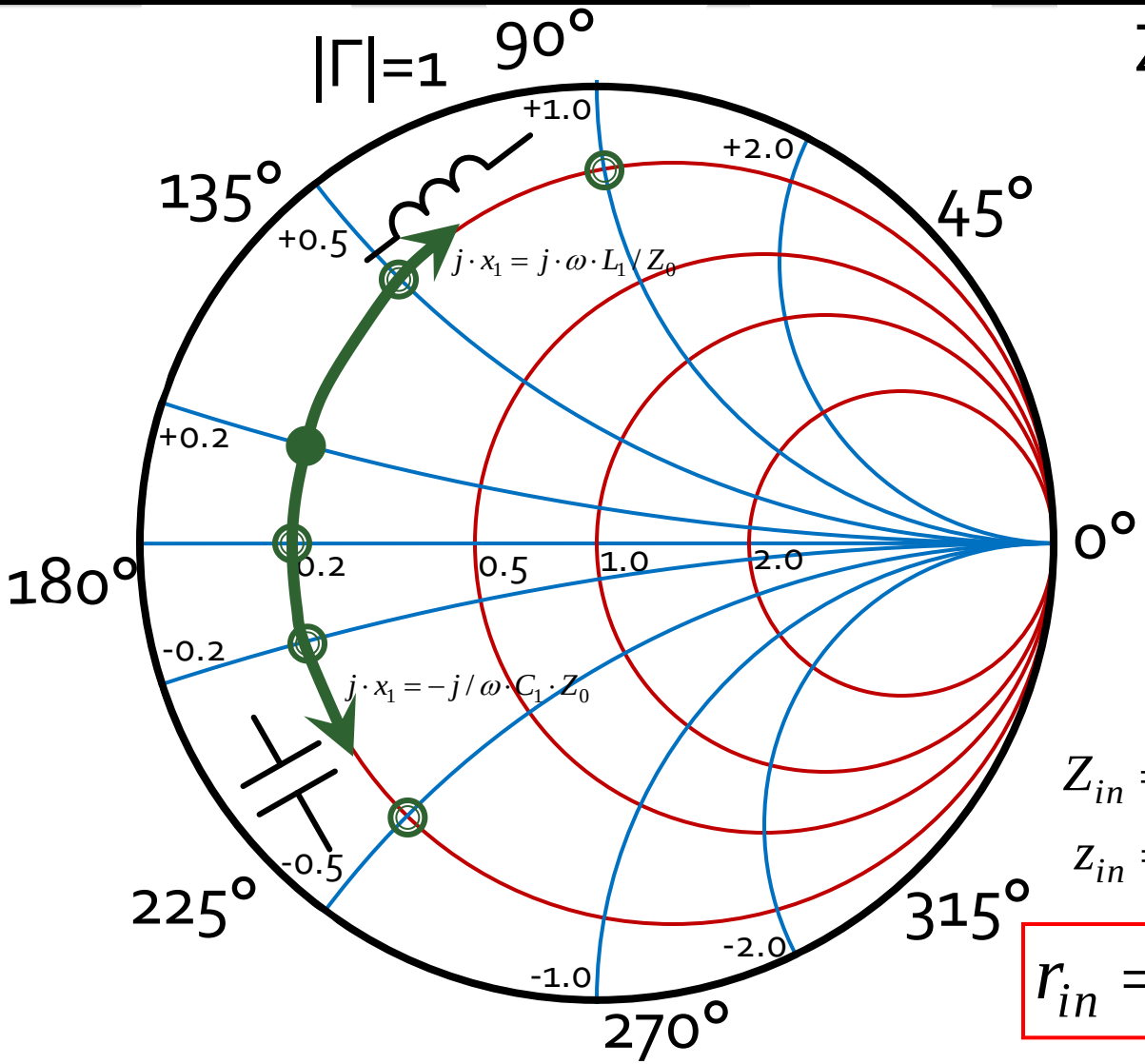
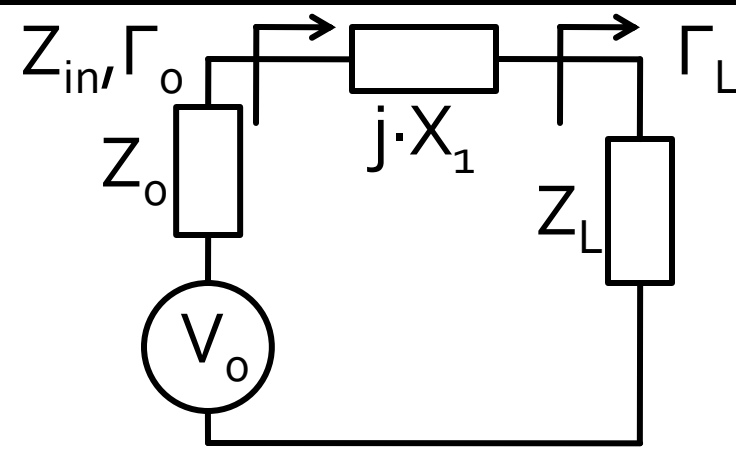
$$G_S = \frac{1-|\Gamma_S|^2}{|1-S_{11}\cdot\Gamma_S|^2} \qquad G_0 = |S_{21}|^2 \qquad G_L = \frac{1-|\Gamma_L|^2}{|1-S_{22}\cdot\Gamma_L|^2}$$

Diagrama Smith, coeficient de reflexie, reactanta in serie





$$Z_0 = 50\Omega$$

$$Z_L = R_L + j \cdot X_L = 10\Omega + j \cdot 10$$

$$z_L = r_L + j \cdot x_L = 0.2 + j \cdot 0.2$$

$$\Gamma_L = 0.678 \angle 156.5°$$

$$Z_{in} = Z_L + j \cdot X_1 = R_L + j \cdot (X_L + X_1$$

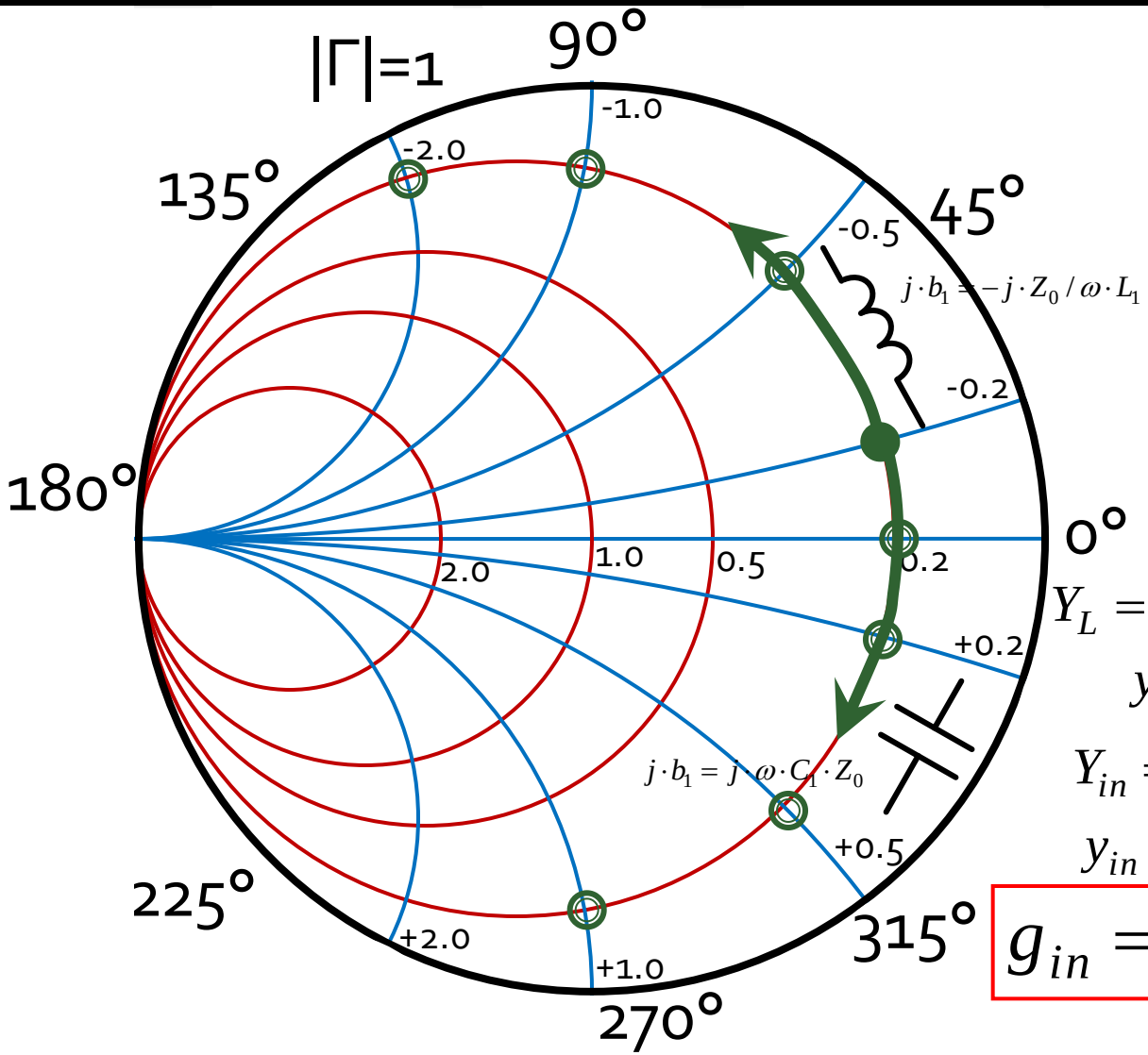
$$z_{in} = r_L + j \cdot (x_L + x_1)$$

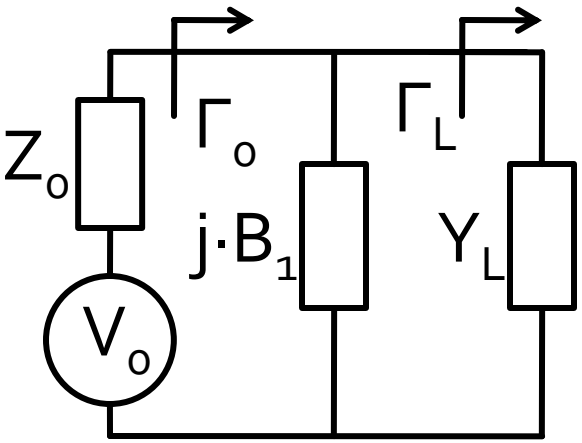
$$\boxed{r_{in} = r_L}$$

$$j \cdot x_1 = j \cdot \omega \cdot L_1 / Z_0 > 0$$

$$j \cdot x_1 = -j / \omega \cdot C_1 \cdot Z_0 < 0$$

Diagrama Smith, coeficient de reflexie, susceptanta in paralel





$$Z_0 = 50\Omega, Y_0 = 0.02\,S$$

$$\Gamma_L = 0.678\angle 23.5°$$

$$Y_L = G_L + j \cdot B_L = 0.004\,S + j \cdot 0.004$$

$$y_L = g_L + j \cdot b_L = 0.2 - j \cdot 0.2$$

$$Y_{in} = Y_L + j \cdot B_1 = G_L + j \cdot (B_L + B_1)$$

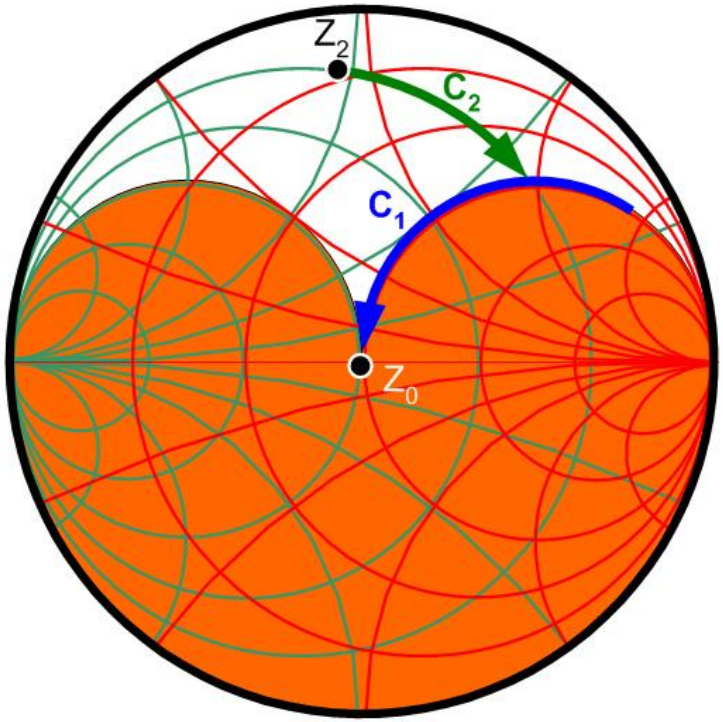
$$y_{in} = g_L + j \cdot (b_L + b_1)$$

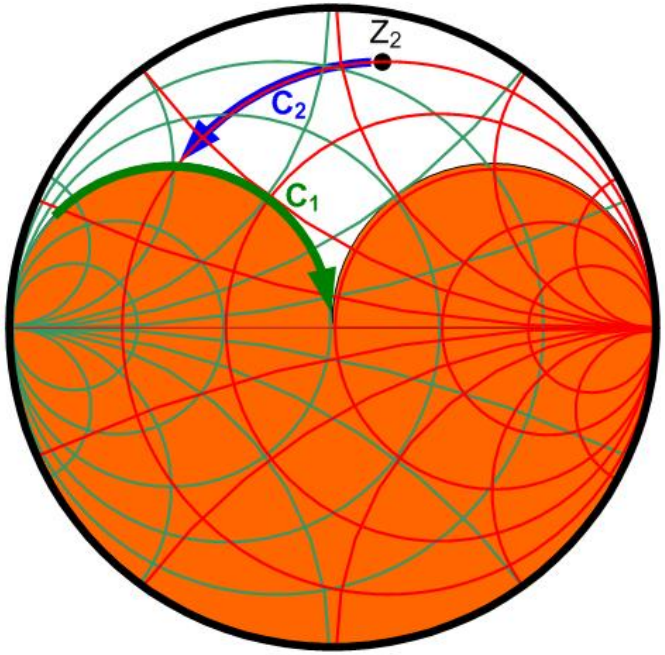
$$\boxed{g_{in} = g_L}$$

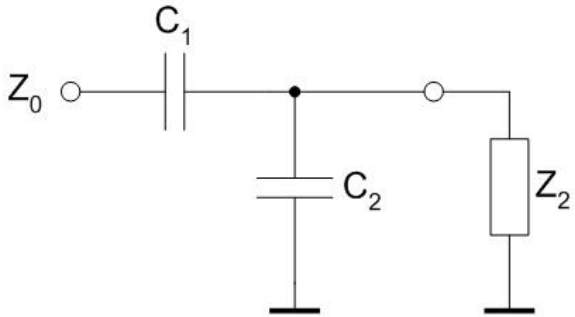
$$j \cdot b_1 = j \cdot \omega \cdot C_1 \cdot Z_0 > 0$$

$$j \cdot b_1 = -j \cdot Z_0 / \omega \cdot L_1 < 0$$

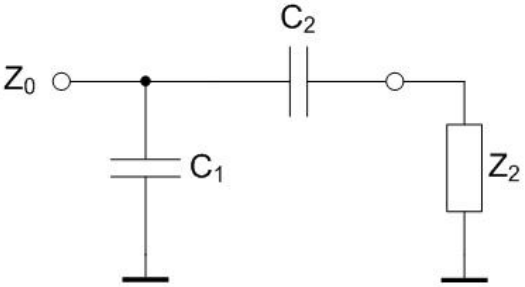
C serie, C paralel / C paralel, C serie



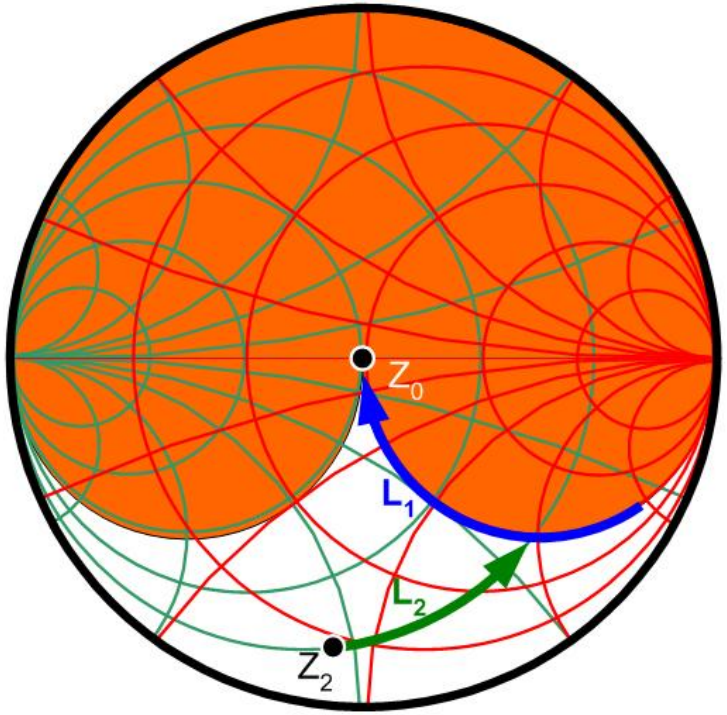


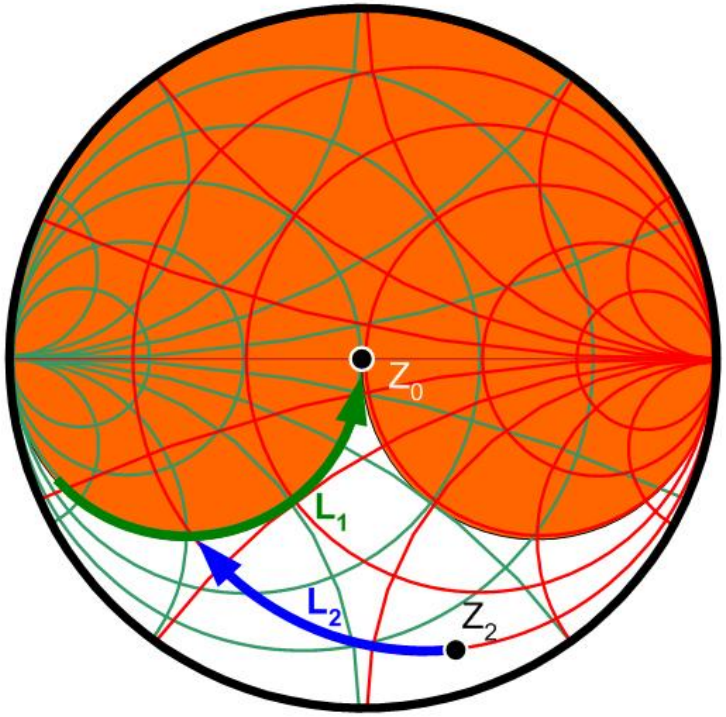


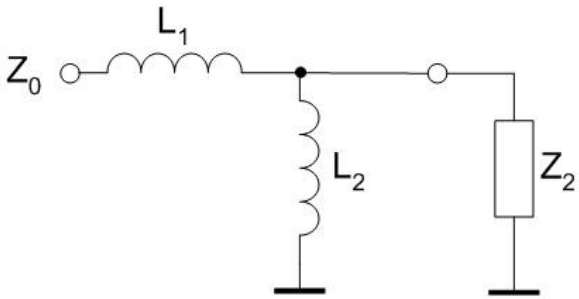
Zona interzisa cu schema curenta



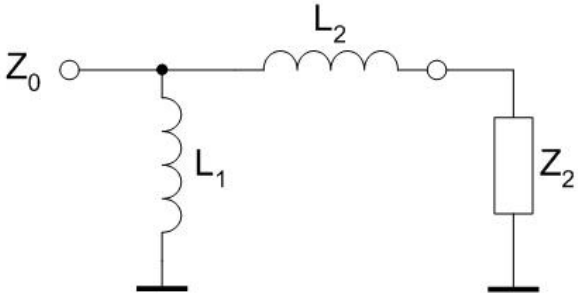
L serie, L paralel / L paralel, L serie



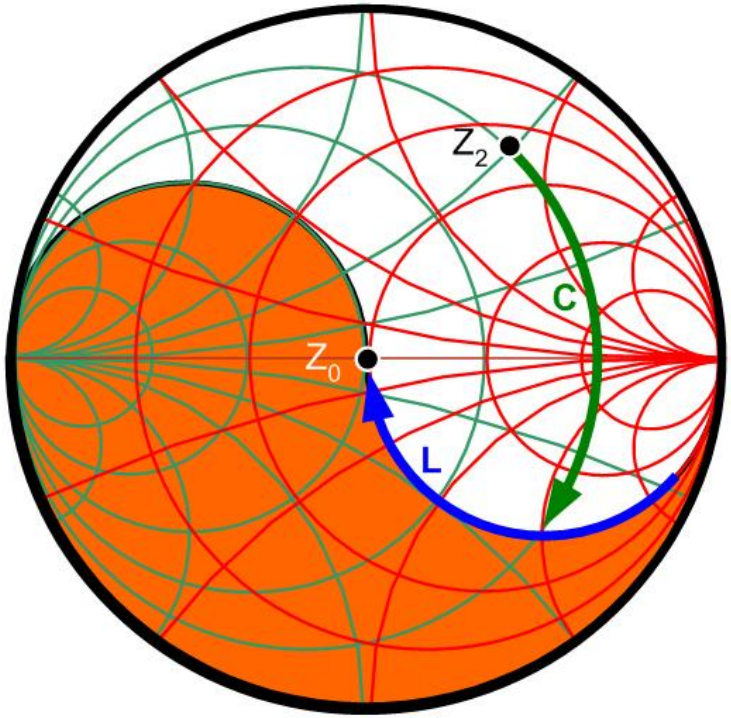


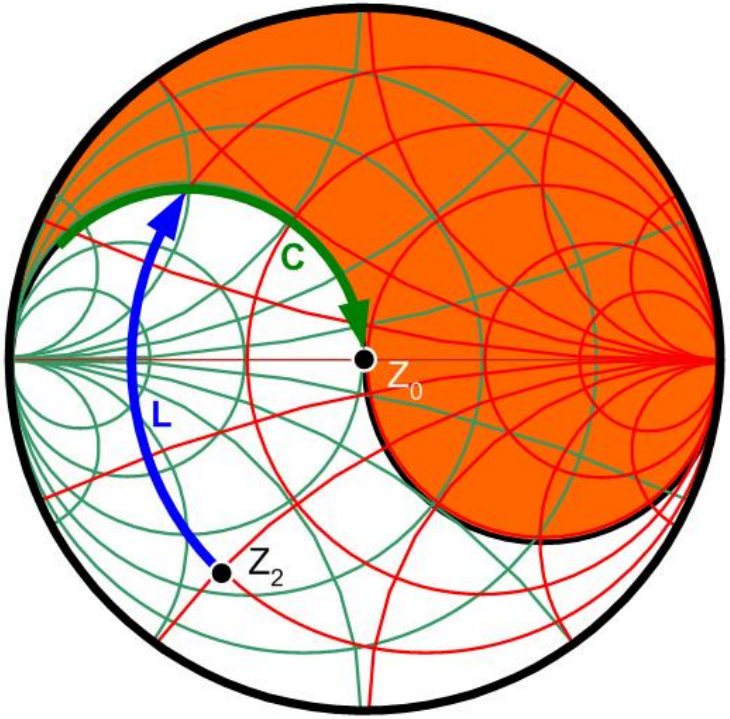


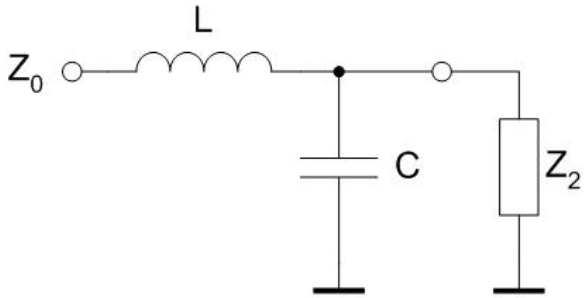
Zona interzisa cu schema curenta



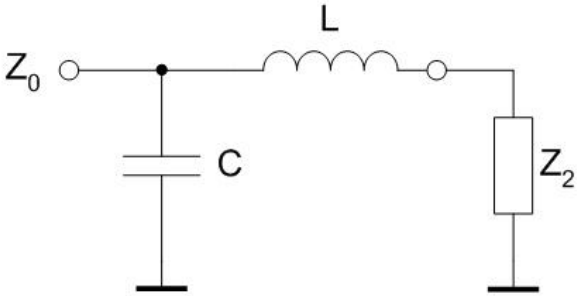
L serie, C paralel / C paralel, L serie



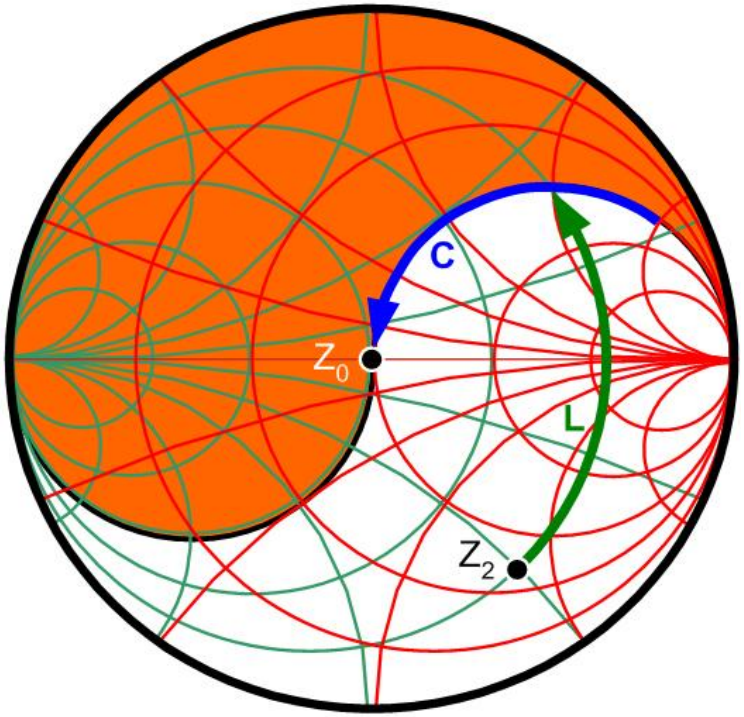


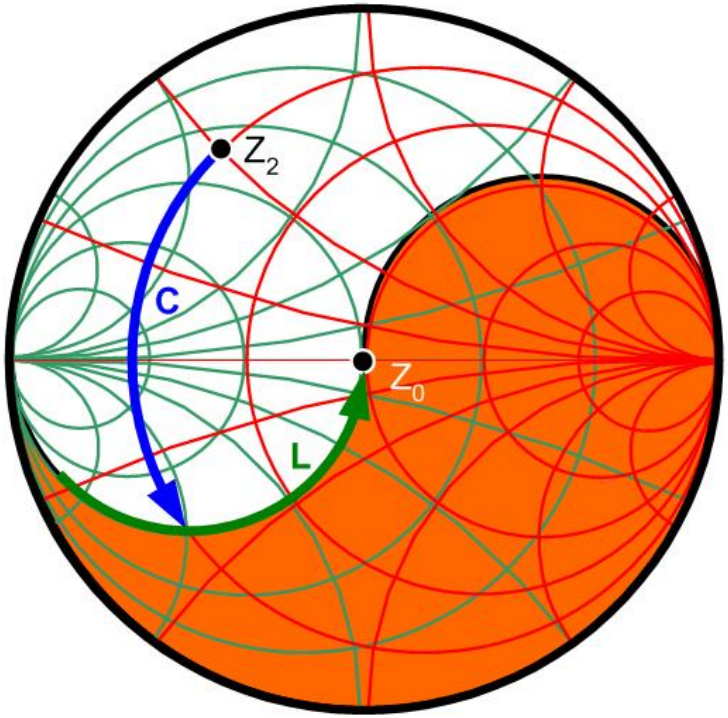


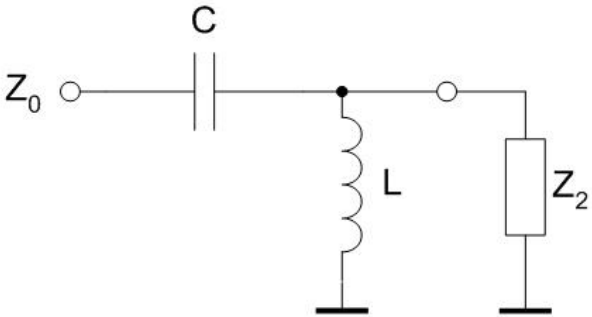
Zona interzisa cu schema curenta



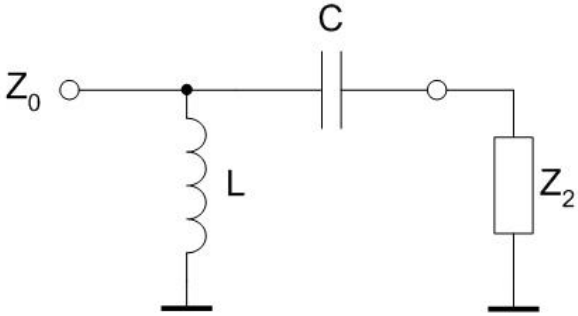
C serie, L paralel / L paralel, C serie



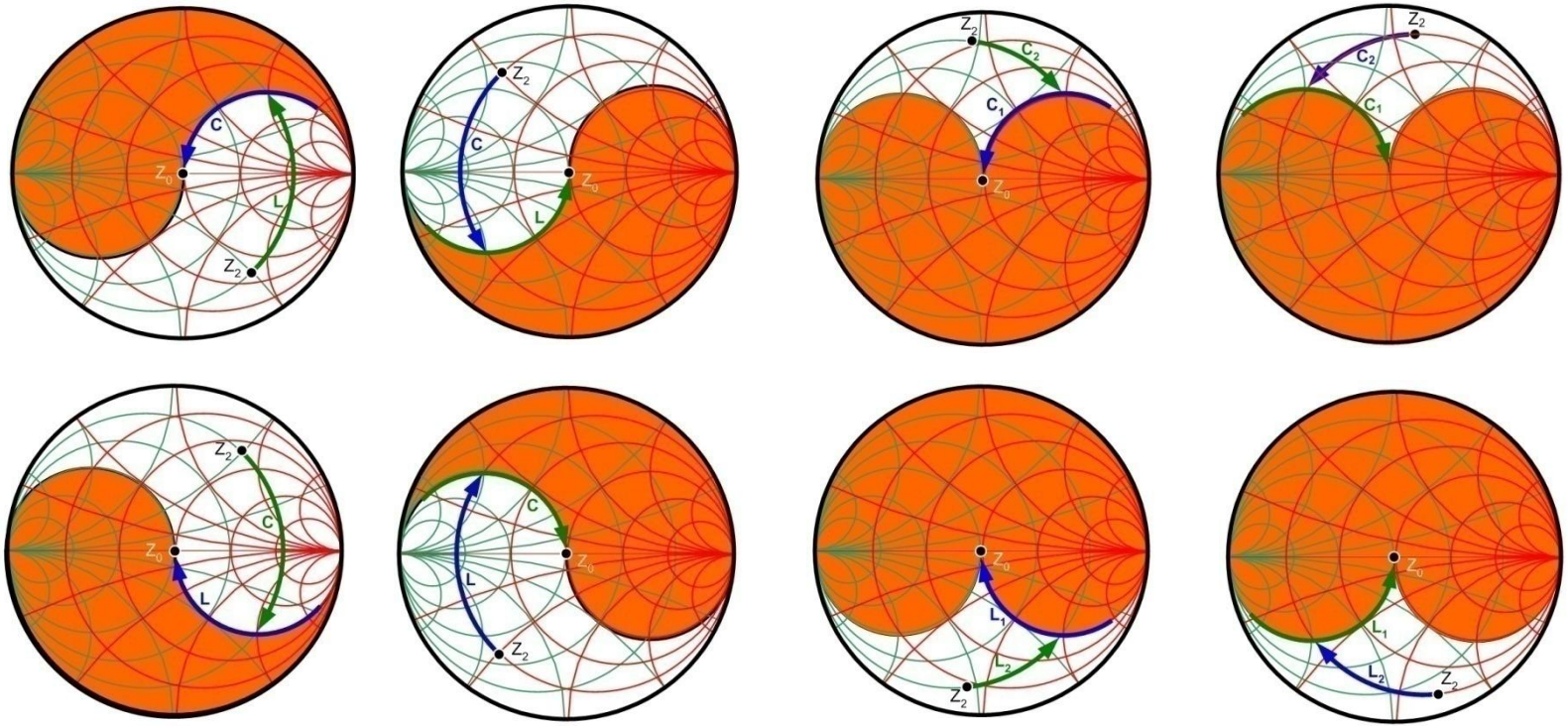




Zona interzisa cu schema curenta



Adaptare cu doua elemente reactive (retele in L)



Zona interzisa cu schema curenta

Adaptare cu doua elemente reactive (retele in L)

- Pentru orice Γ_L exista cel putin 2 retele in L de adaptare posibile (L+C)
- Pentru anumite zone de start de pe diagrama Smith exista 4 posibilitati (+2 retele C+C/L+L)
- Se alege reteaua care necesita componente de valori realizabile
- Prin adaugarea elementelor rezistive se pot suplimenta retelele posibile cu **pierdere de putere (nerecomandat)**

Partea a II-a

Mod de lucru

Pas 0

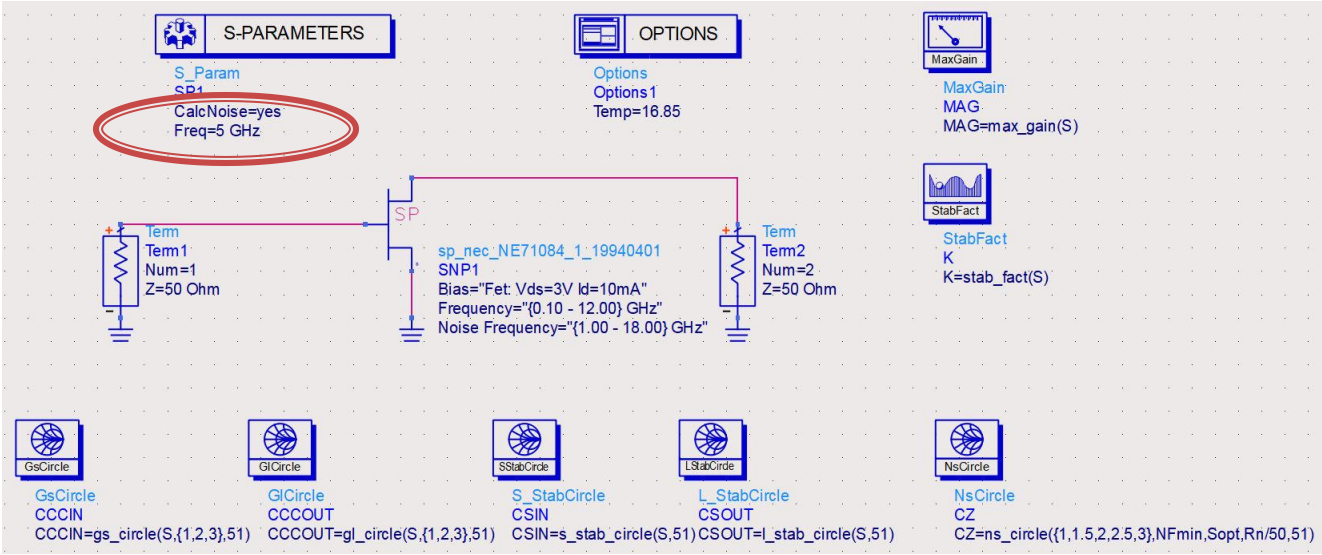
- Se scrie de mana de 100 de ori pe o foaie de hartie:
- **Promit solemn sa citesc SI textul si sa nu sar din poza in poza**
- ☺

Pas 1

- Se preia din interfata de examen de pe rf-opto tema personala
  - frecventa de lucru - **fo** [GHz]
  - factor de zgomot - **NF** [dB] (maxim, orice valoare mai mica e mai buna si de dorit cat mai mica posibil)
  - castig de putere – **G** [dB] (minim, orice valoare mai mare e mai buna si se accepta)

Pas 2

- se schimba frecventa de lucru in **schema 1** – **fo** si se realizeaza simularea



Pas 3

- se verifica valorile din tabel (din care unele obtinute din **ecuatii!**)

Eqn gamma_opt=Sopt Eqn G0=10*log(mag(S(2,1))**2)

Eqn GSmax=10*log(1/(1-mag(S(1,1))**2)) Eqn GLmax=10*log(1/(1-mag(S(2,2))**2))

freq	K	MAG	NFmin	Sopt	Rn	G0	GLmax	GSmax
5.000 GHz	0.533	15.293	0.700	0.960 / 106....	19.500	8.974	1.634	4.249

- se verifica ca tranzistorul poate indeplini tema (altfel se alege un alt tranzistor)
  - NFmin < **NF**
  - MAG > **G**

Pas 4

- se verifica valorile din tabel (din care unele obtinute din **ecuatii!**)

Eqn gamma_opt=Sopt Eqn G0=10*log(mag(S(2,1))**2)

Eqn GSmax=10*log(1/(1-mag(S(1,1))**2)) Eqn GLmax=10*log(1/(1-mag(S(2,2))**2))

freq	K	MAG	NFmin	Sopt	Rn	G0	GLmax	GSmax
5.000 GHz	0.533	15.296	0.700	0.660 / 106....	19.500	8.914	1.634	4.249

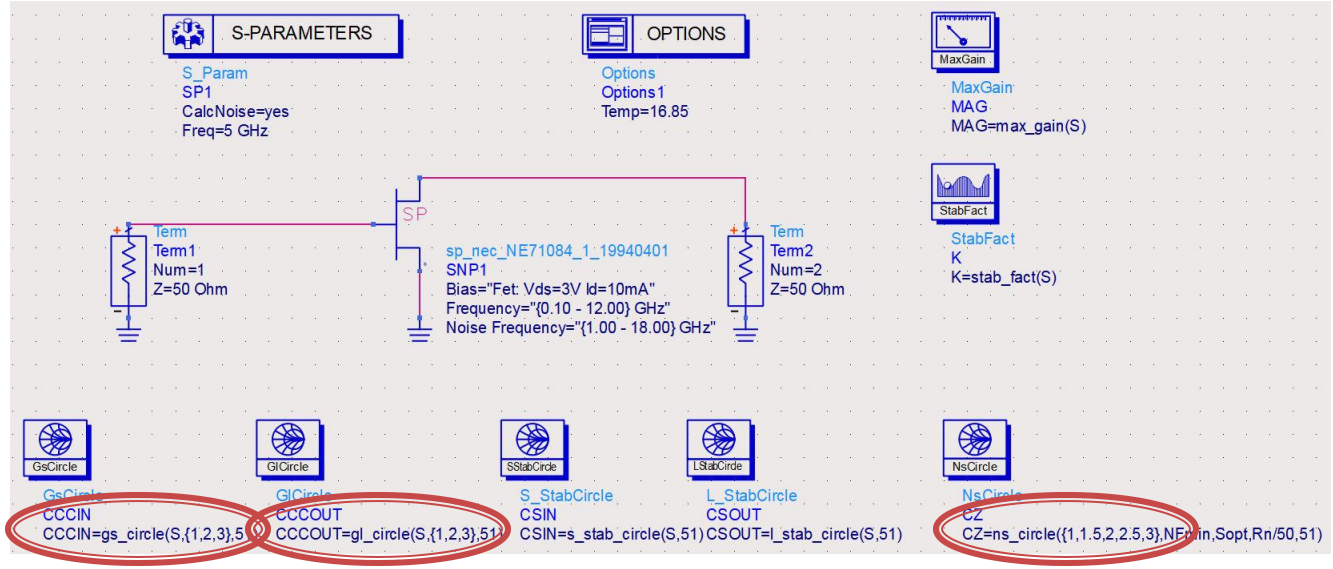
- Pentru obtinerea castigului impus se **aleg** valorile suplimentare necesare (suplimentar la G_o)

$$G_{dorit}[dB] = G_{S\_dor}[dB] + G_0[dB] + G_{L\_dor}[dB]$$

$$G_{dorit}[dB] > G_{tema} \quad G_{S\_dor}[dB] < GS\max \quad G_{L\_dor}[dB] < GL\max$$

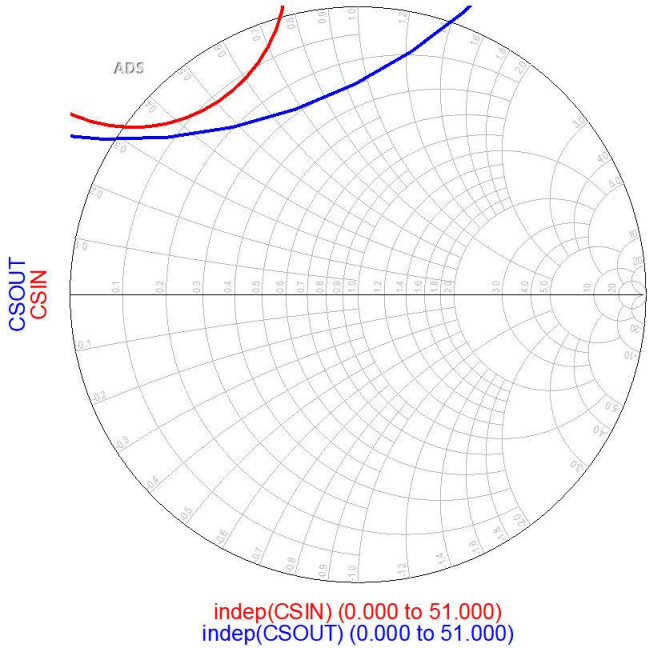
Pas 5

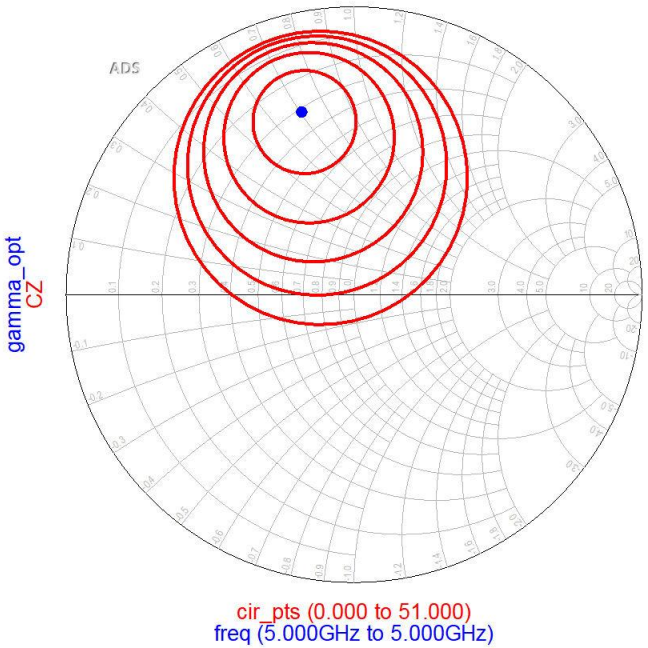
- in schema 1 se schimba valorile dorite pentru cercuri (in loc de {1,2,3} se pun valori in jur de GSdor, GLdor, NF) – toate valorile in dB



Pas 6

- se reprezinta **familii de cercuri** si se verifica ca sunt in pozitii potrivite



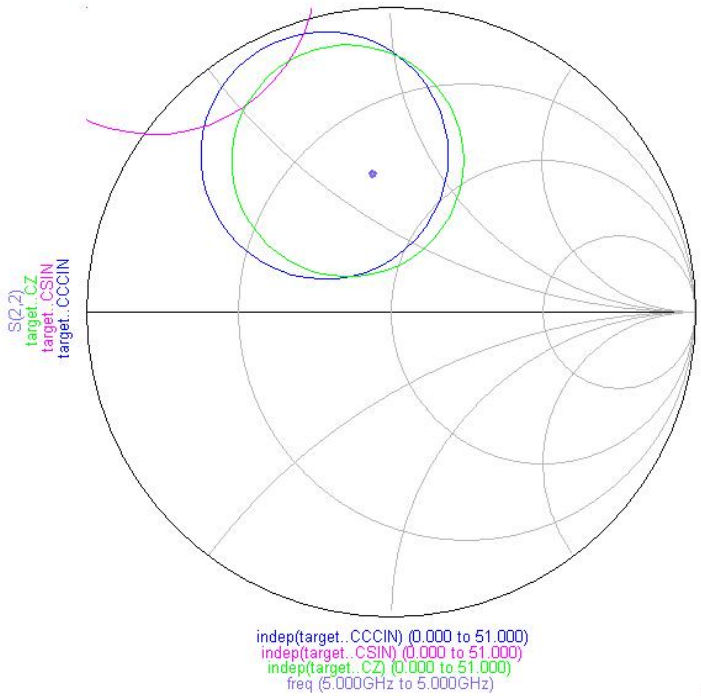


Pas 7

- se schimba frecventa de lucru in **schema 2 – fo** si se realizeaza simularea
- Analizand rezultatele din **schema 1** se alege cate **un singur cerc** tinta:
  - stabilitate (intrare/iesire)
  - castig (intrare GSdor/iesire GLdor)
  - zgomot (intrare NFdor)
- Afisarea cerurilor nu e necesara
  - cercurile vor fi utilizate efectiv in **schema 3**

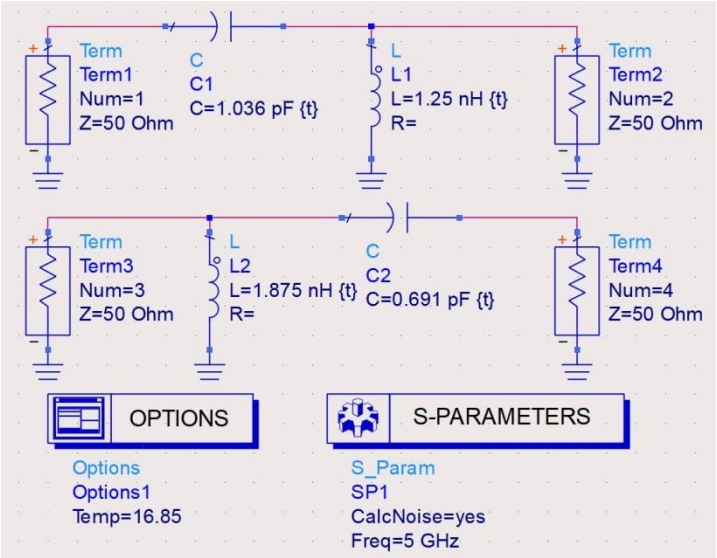
Pas 7

- Chiar daca nu sunt afisate, schema 2 **calculeaza** cercurile (pentru tranzistor)
  - 3 intrare (stabilitate/castig/zgomot)
  - 2 iesire (stabilitate/castig)
- E recomandabil sa se utilizeze rezerva
  - Gdor > **G**
  - NFdor < **NF**



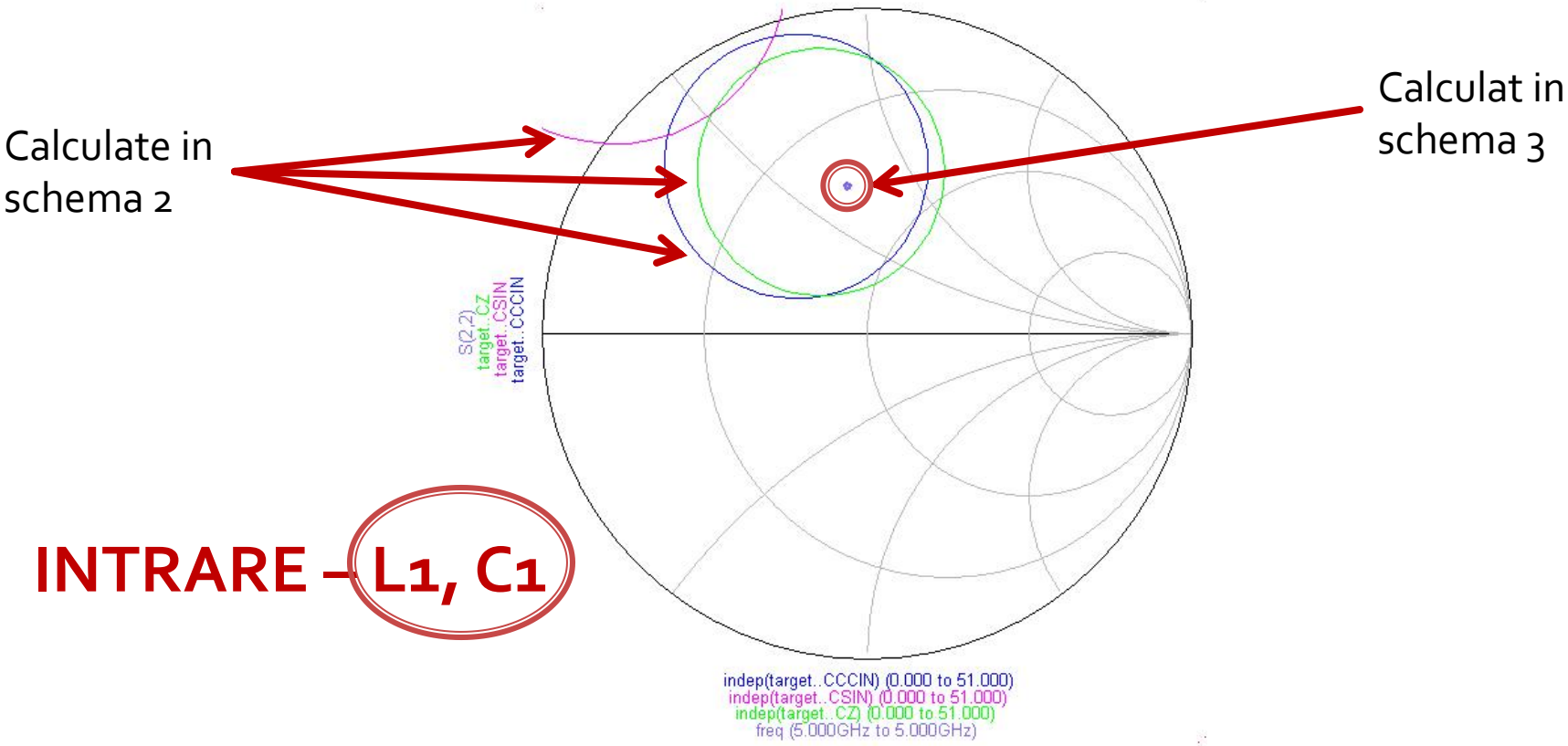
Pas 8

- se schimba frecventa de lucru in **schema 3 – fo** si se realizeaza simularea
- Se utilizeaza cercurile calculate in **schema 2** ca “tinta”/indicator



Pas 9

- Se **regleaza** (tune) elementele din retelele de adaptare pentru atingerea punctelor dorite

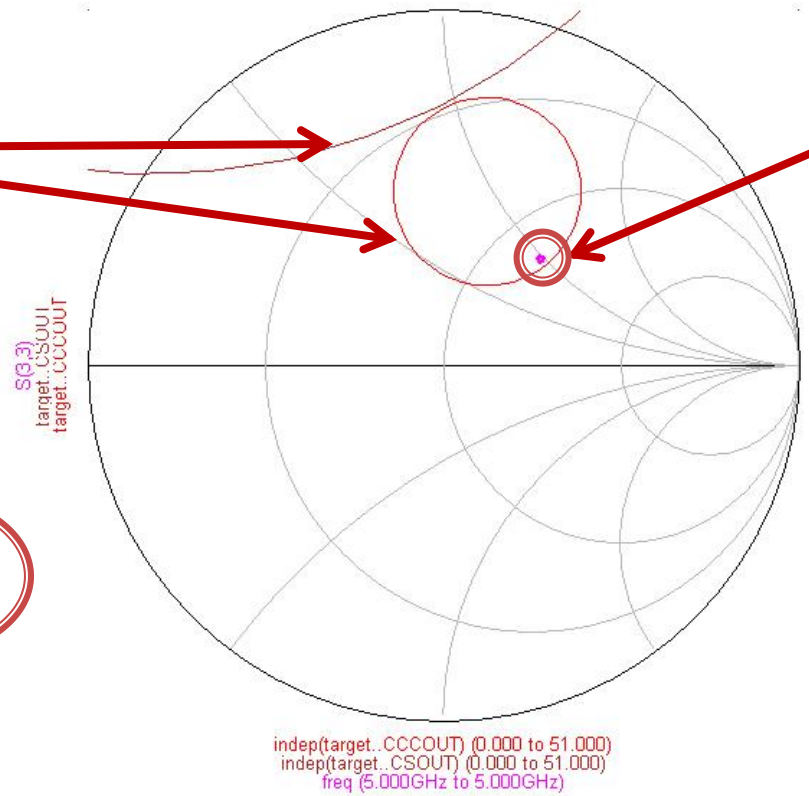


Pas 10

- Se **regleaza** (tune) elementele din retelele de adaptare pentru atingerea punctelor dorite

Calculate in schema 2

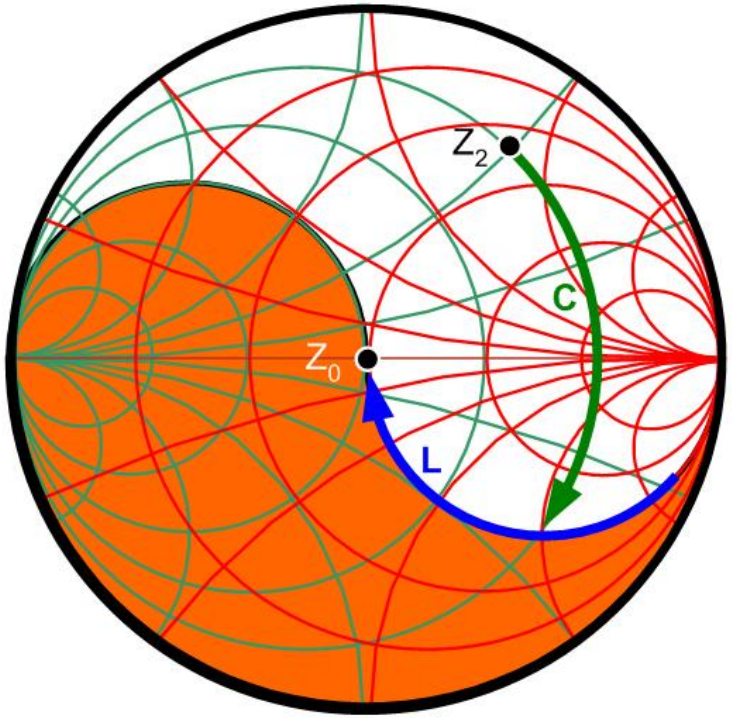
Calculat in schema 3

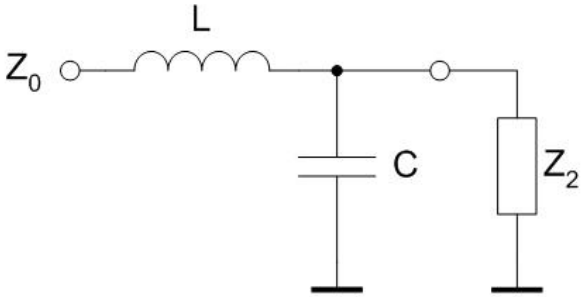


IESIRE – L2, C2

Pas 11

- Daca nu se reuseste deplasarea punctului in pozitia dorita – cel mai probabil pozitia dorita e in zona interzisa pentru schema utilizata
  - se schimba schema utilizata (LC/CL, serie/paralel etc)



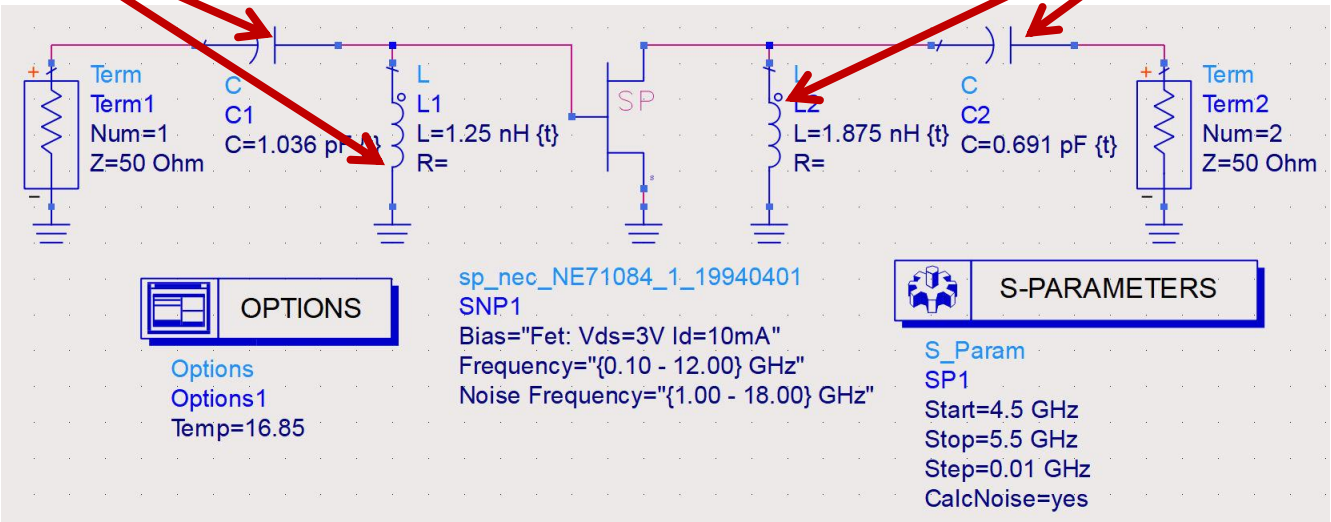


Pas 12

- Se introduc componentele gasite in **schema 3** ca retele de adaptare la intrare/iesire pentru tranzistor in **schema 4** (valori si schema!)
- Se schimba frecventele de lucru in **schema 4** – in jurul lui **fo** (**fo** in centrul intervalului)

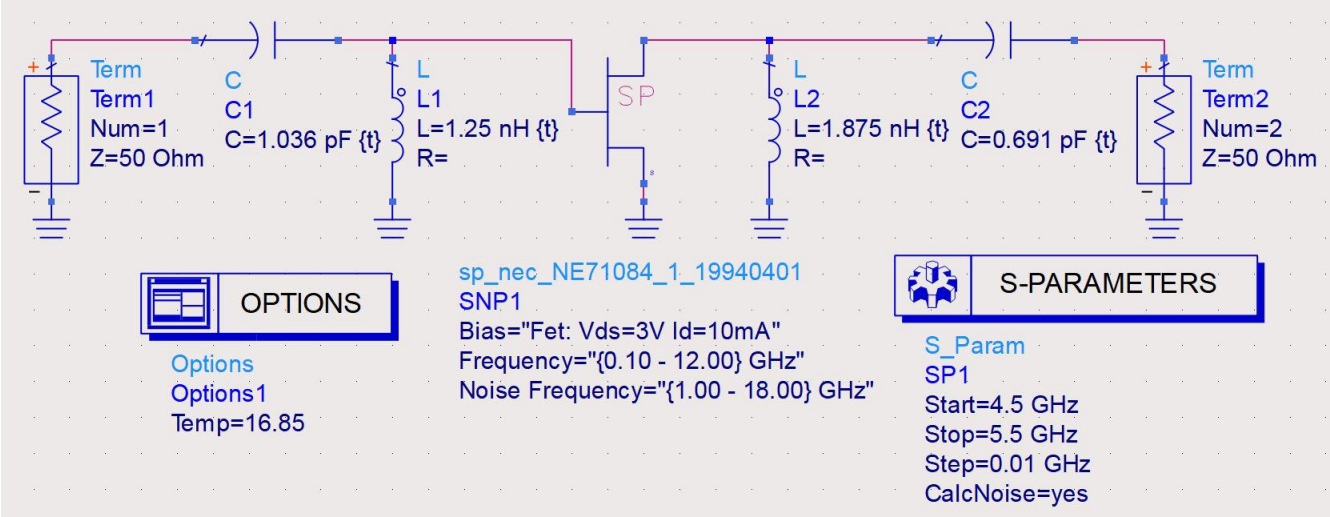
Determinate in schema 3

Determinate in schema 3



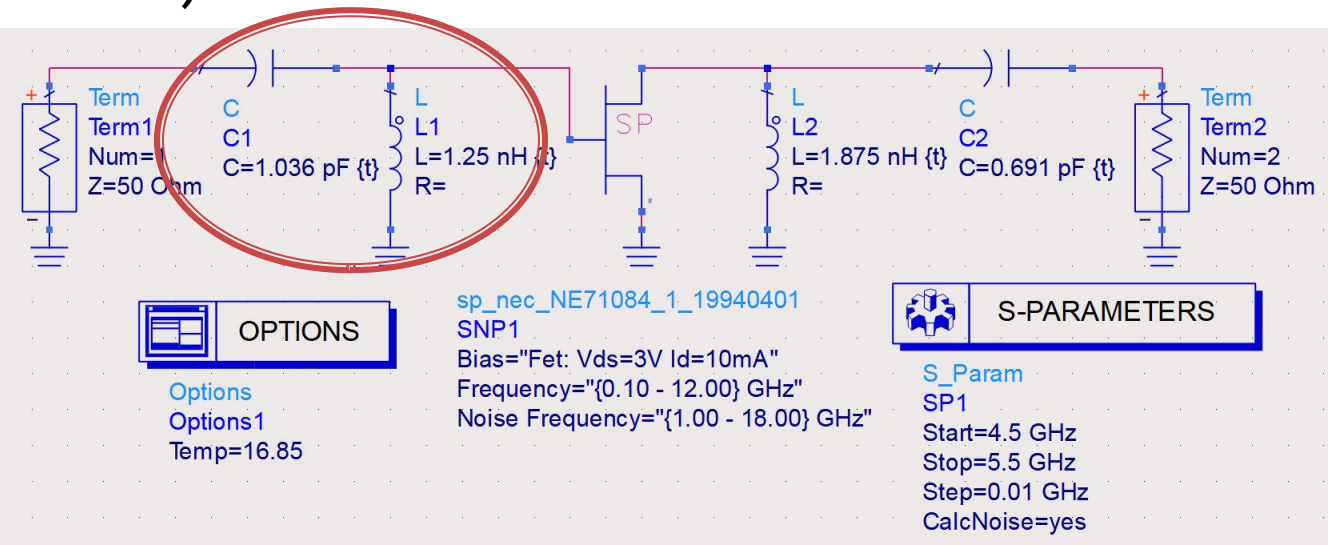
Pas 13

- Se **regleaza** elementele din retelele de adaptare pentru o caracteristica mai convenabila



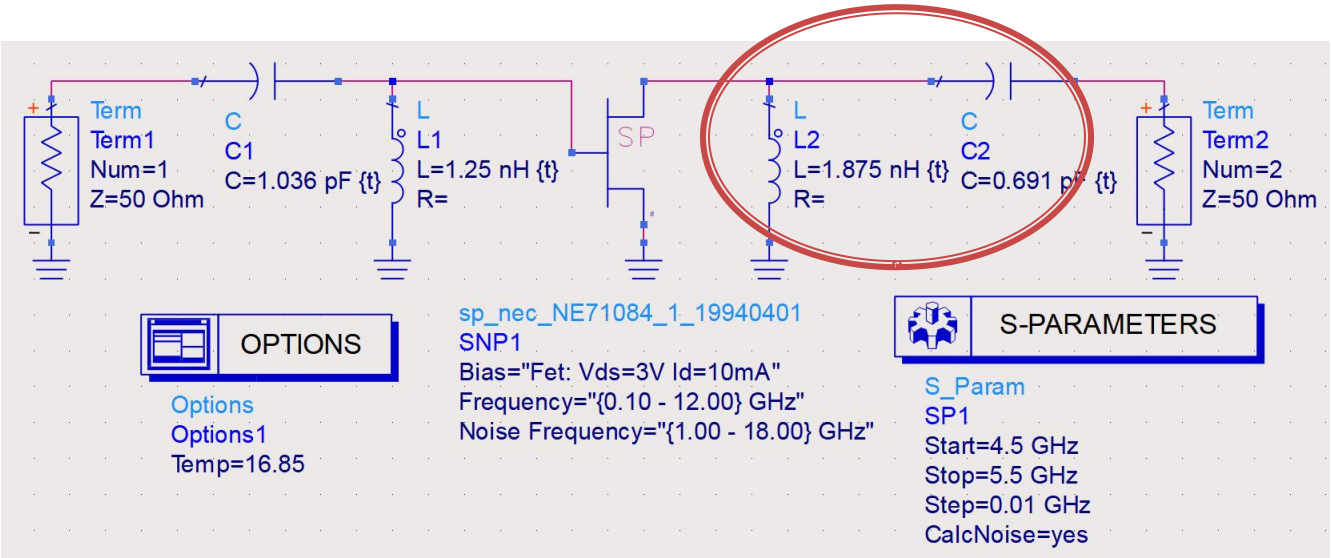
Schema finala

- componentele de la intrare influenteaza **si castigul si zgomotul**
  - se regleaza mai intai, separat, urmarindu-se indeplinirea conditiilor de zgomot cu acceptarea deteriorarii caracteristicii de castig (in anumite limite)



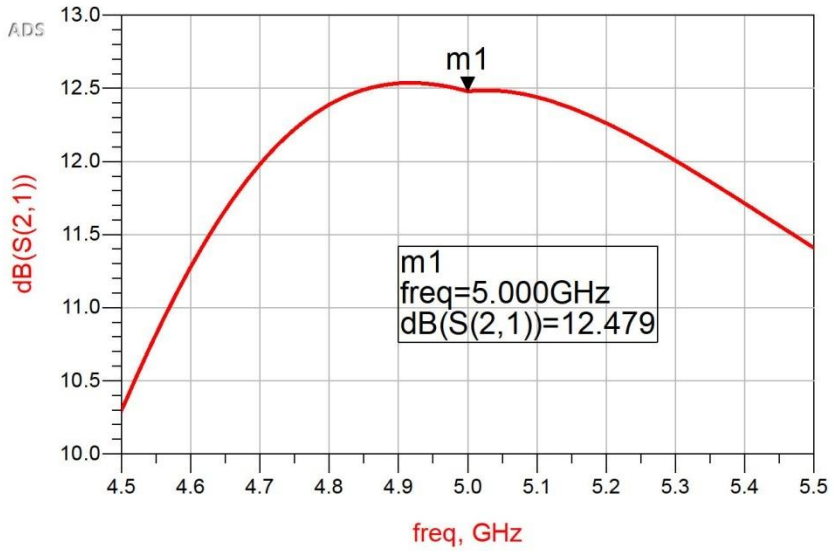
Schema finala

- componentele de la iesire influenteaza **numai castigul**
  - se regleaza separat urmarindu-se corectarea caracteristicii de castig (eventual deteriorata in urma optimizarii zgomotului)



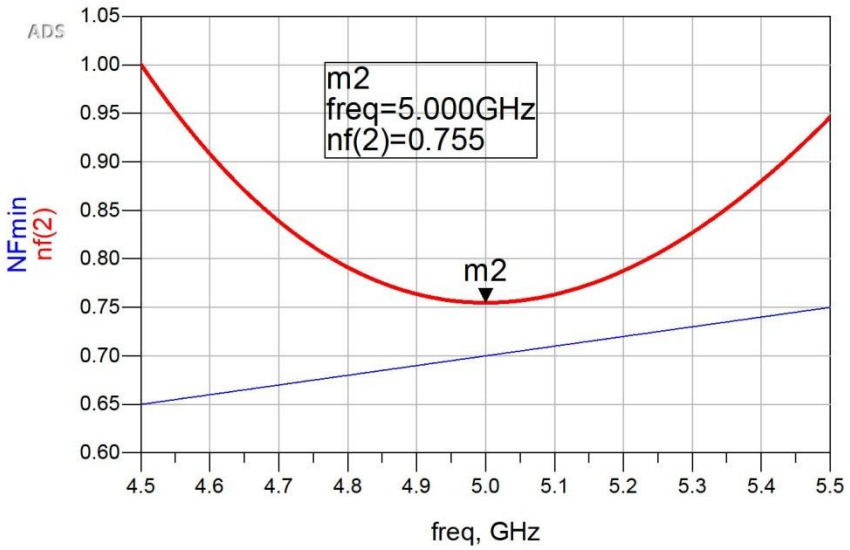
Schema finala

- Se obtine comportamentul schemei finale cu verificarea indeplinirii temei:
  - Castig (de putere) – mai mare ca cel din tema, cu rezerva (0.5, 1, 2 dB) dar nu se sacrifica zgomotul pentru a-l creste excesiv
  - Caracteristica trece banda centrata pe **fo** e de dorit (macar una din retelele de adaptare trebuie sa fie de tip FTS)



Schema finala

- Se obtine comportamentul schemei finale cu verificarea indeplinirii temei:
  - Factor de zgomot – cat mai mic posibil, cu cat e mai mic cu atat e mai bine



Contact

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