

Curs 9

2014/2015

Dispozitive și circuite de microunde pentru radiocomunicații

Stabilitatea amplificatoarelor de microunde

Amplificatoare de microunde

Stabilitate

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

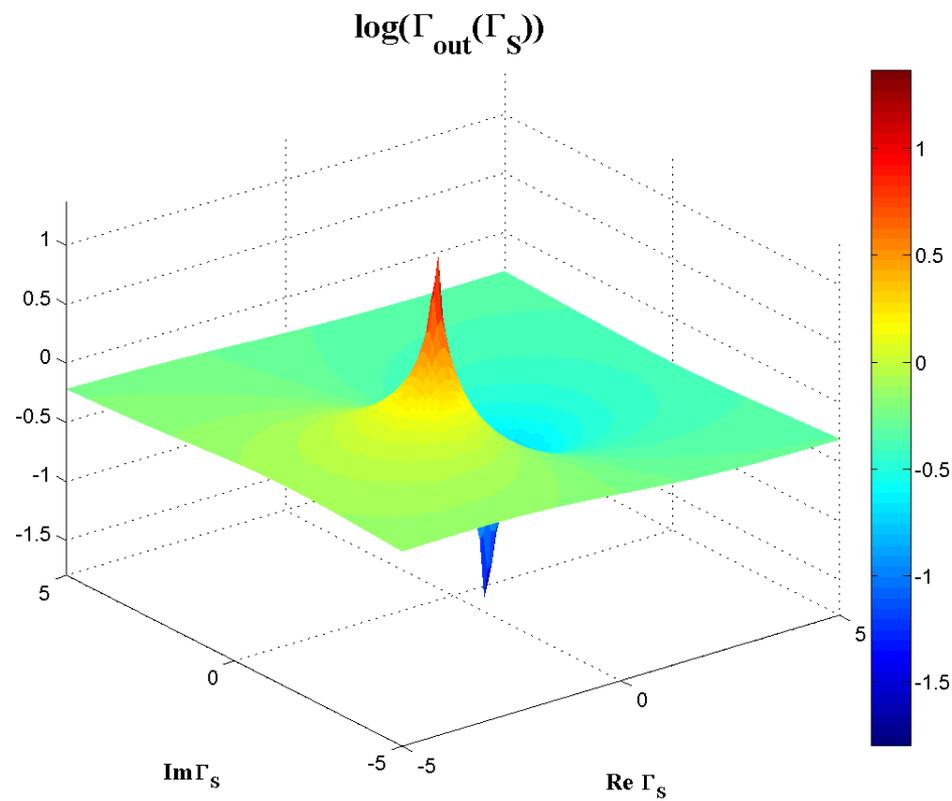
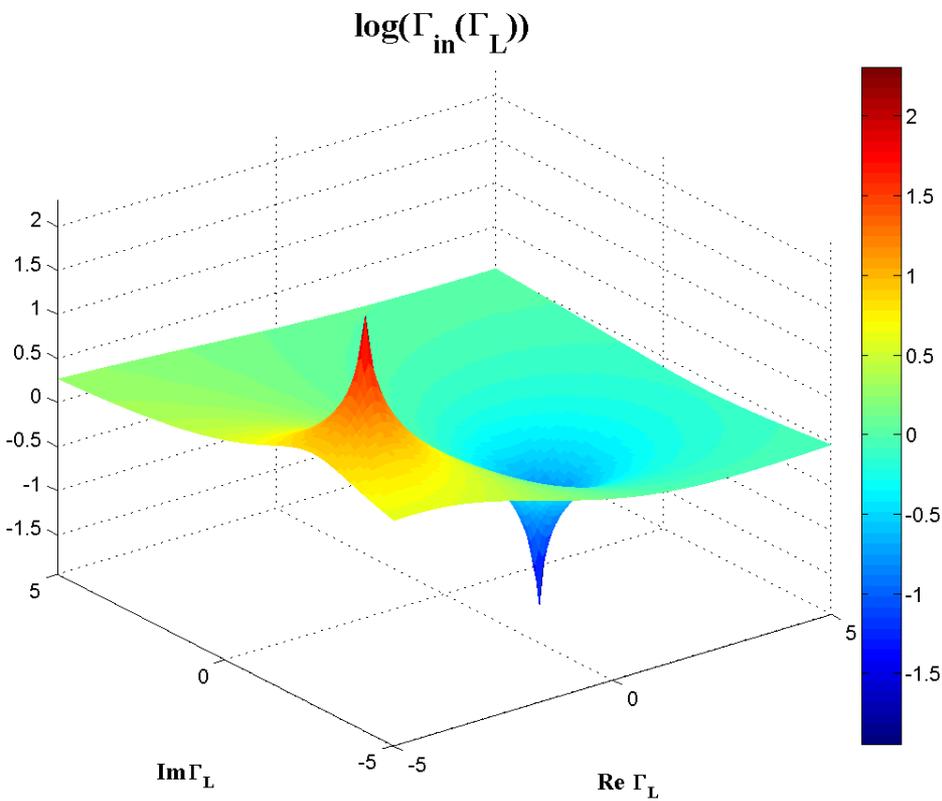
- Obținem condițiile ce trebuie îndeplinite de Γ_L pentru a obține stabilitatea

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

- Obținem condițiile ce trebuie îndeplinite de Γ_S pentru a obține stabilitatea

Reprezentare 3D $|\Gamma_{in}|, |\Gamma_{out}|$

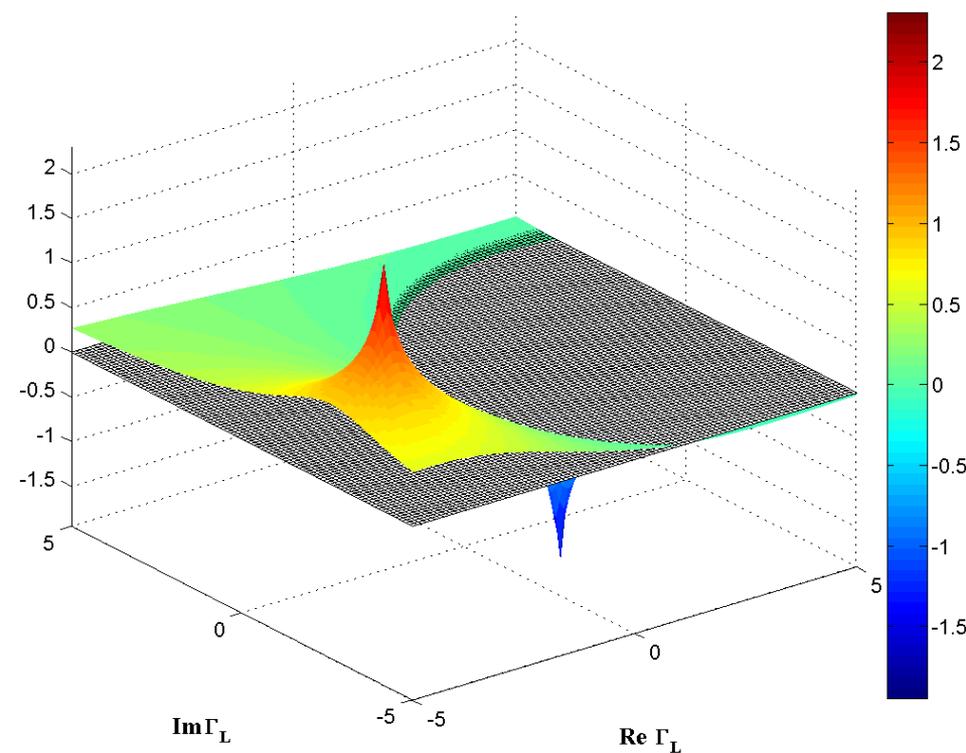
- $\log_{10}|\Gamma_{in}|, \log_{10}|\Gamma_{out}|$



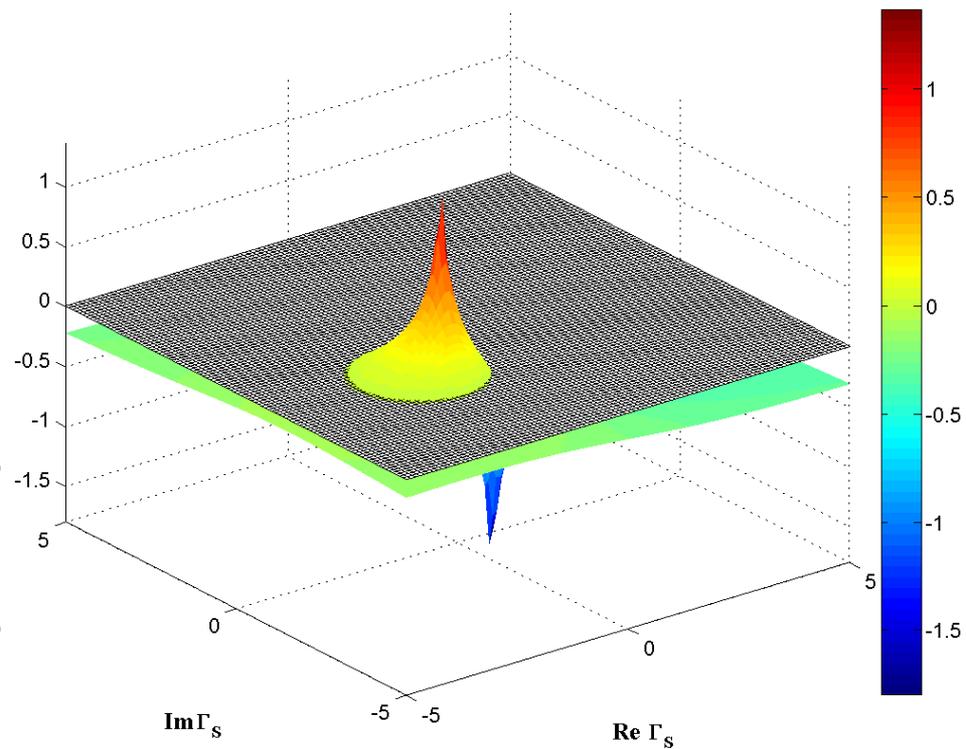
Reprezentare 3D $|\Gamma_{in}|$, $|\Gamma_{out}|$, $|\Gamma|=1$

- $|\Gamma| = 1 \rightarrow \log_{10}|\Gamma| = 0$, intersectia = cerc

$\log(\Gamma_{in}(\Gamma_L))$

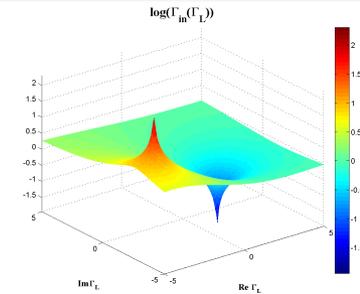


$\log(\Gamma_{out}(\Gamma_S))$

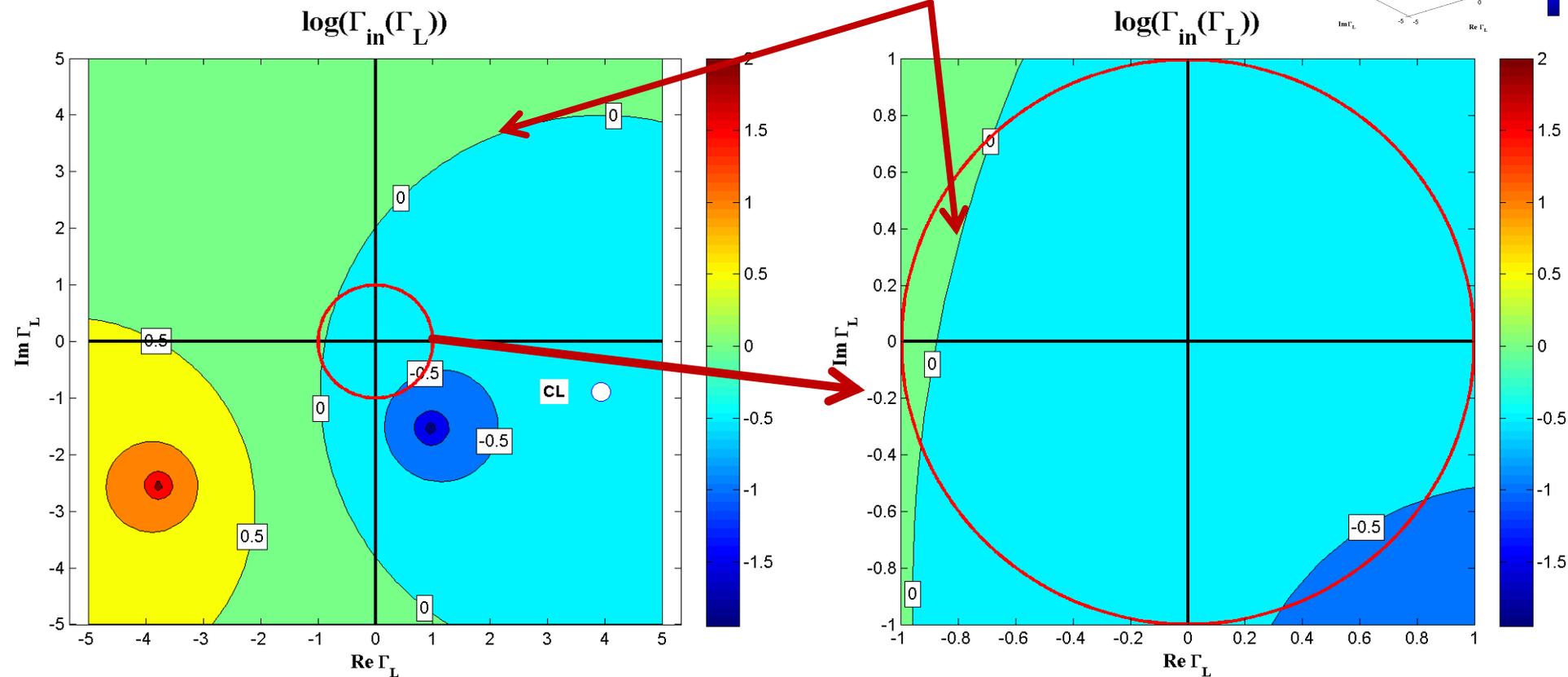


Reprezentare 3D $|\Gamma_{in}|$

- $\log_{10}|\Gamma_{in}| = 0, \Gamma_L, \text{CSOUT}$

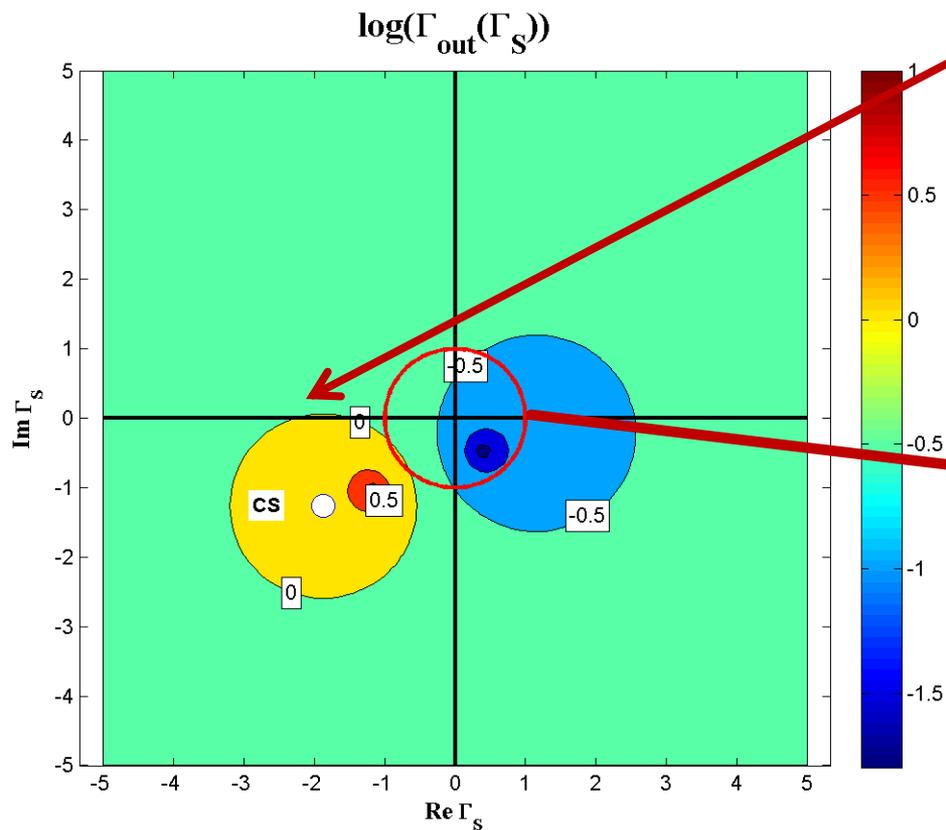
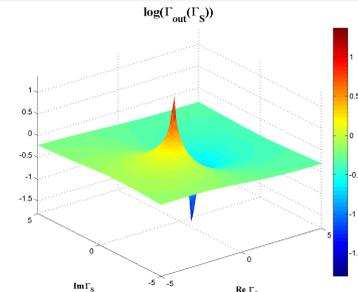


$$\log_{10}|\Gamma_{in}| = 0, \\ |\Gamma_{in}| = 1$$

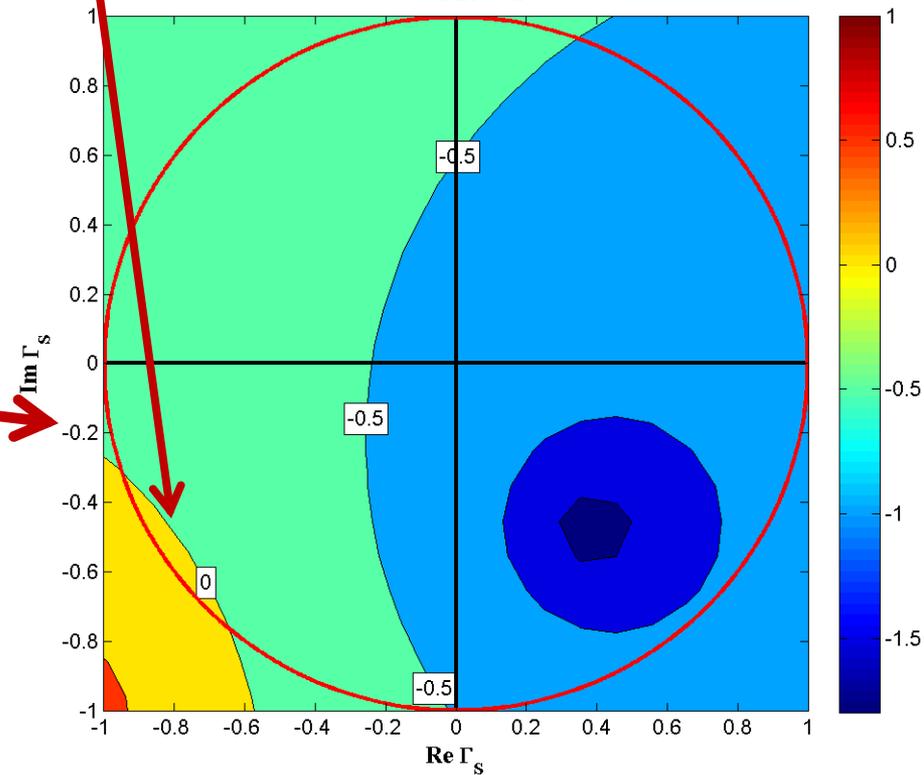


Reprezentare 3D $|\Gamma_{out}|$

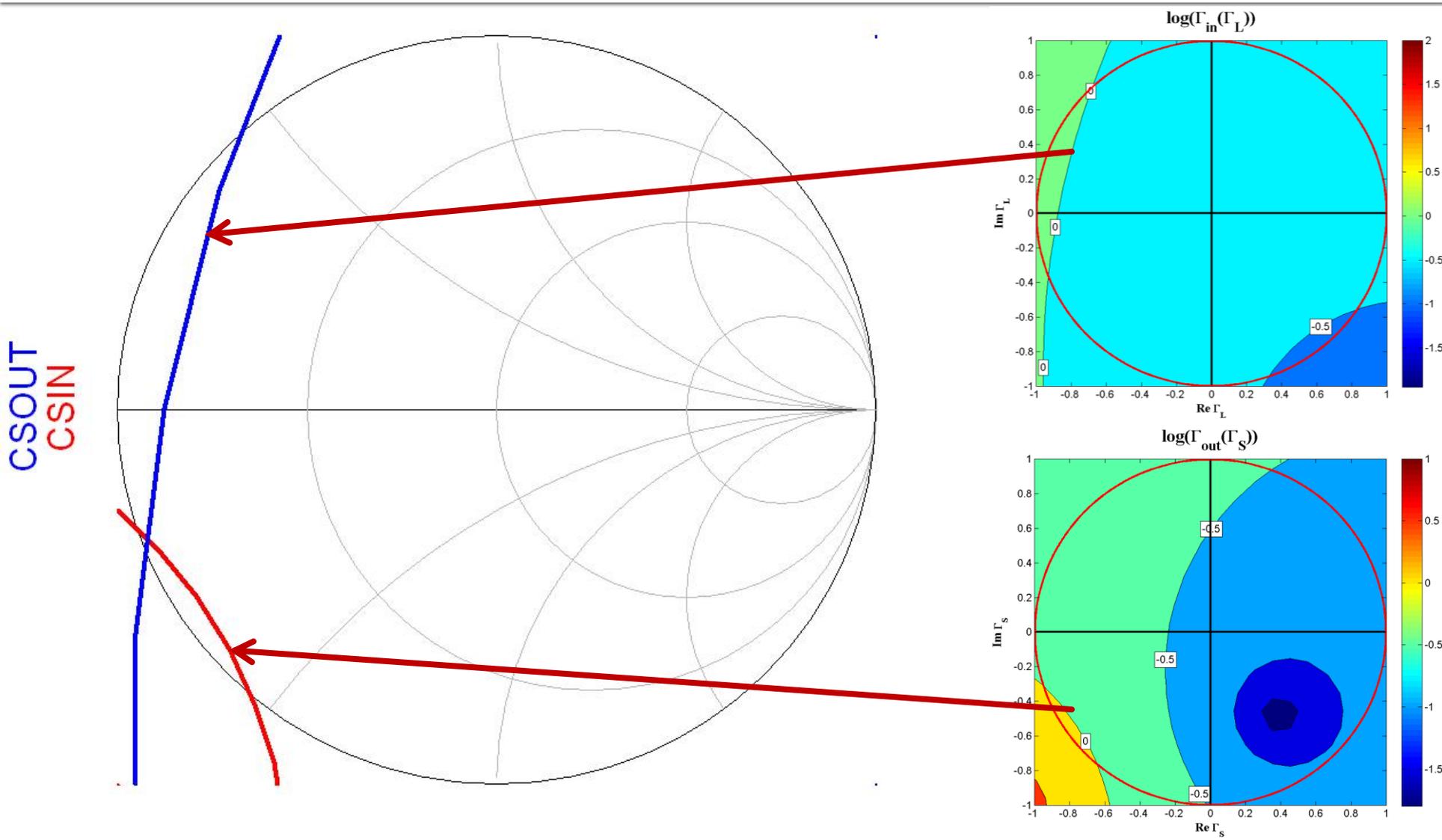
- $\log_{10}|\Gamma_{out}| = 0, \Gamma_S, \text{CSIN}$



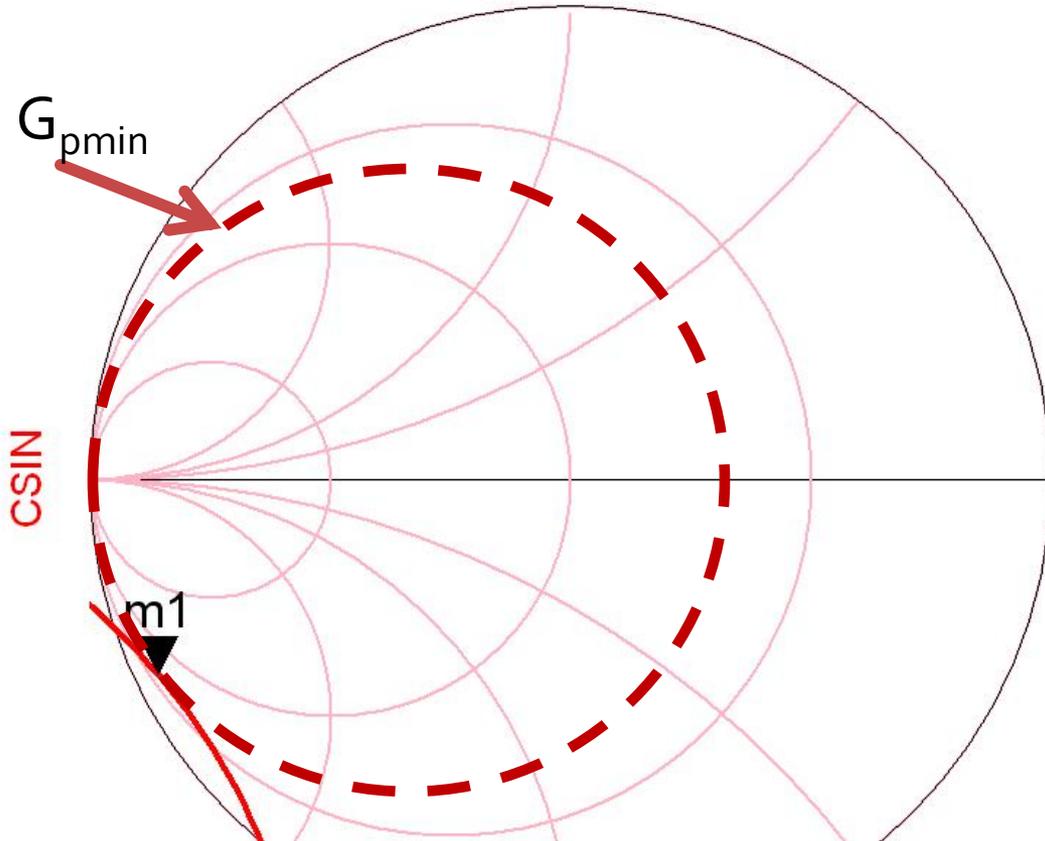
$\log_{10}|\Gamma_{out}| = 0,$
 $|\Gamma_{out}| = 1$



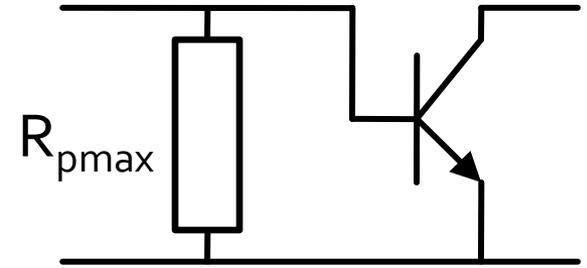
CSIN, CSOUT



Rezistentă paralel la intrare



m1
 indep(m1)=28
 CSIN=0.952 / -154.504
 freq=5.000000GHz
 impedance = Z0 * (0.026 - j0.226)

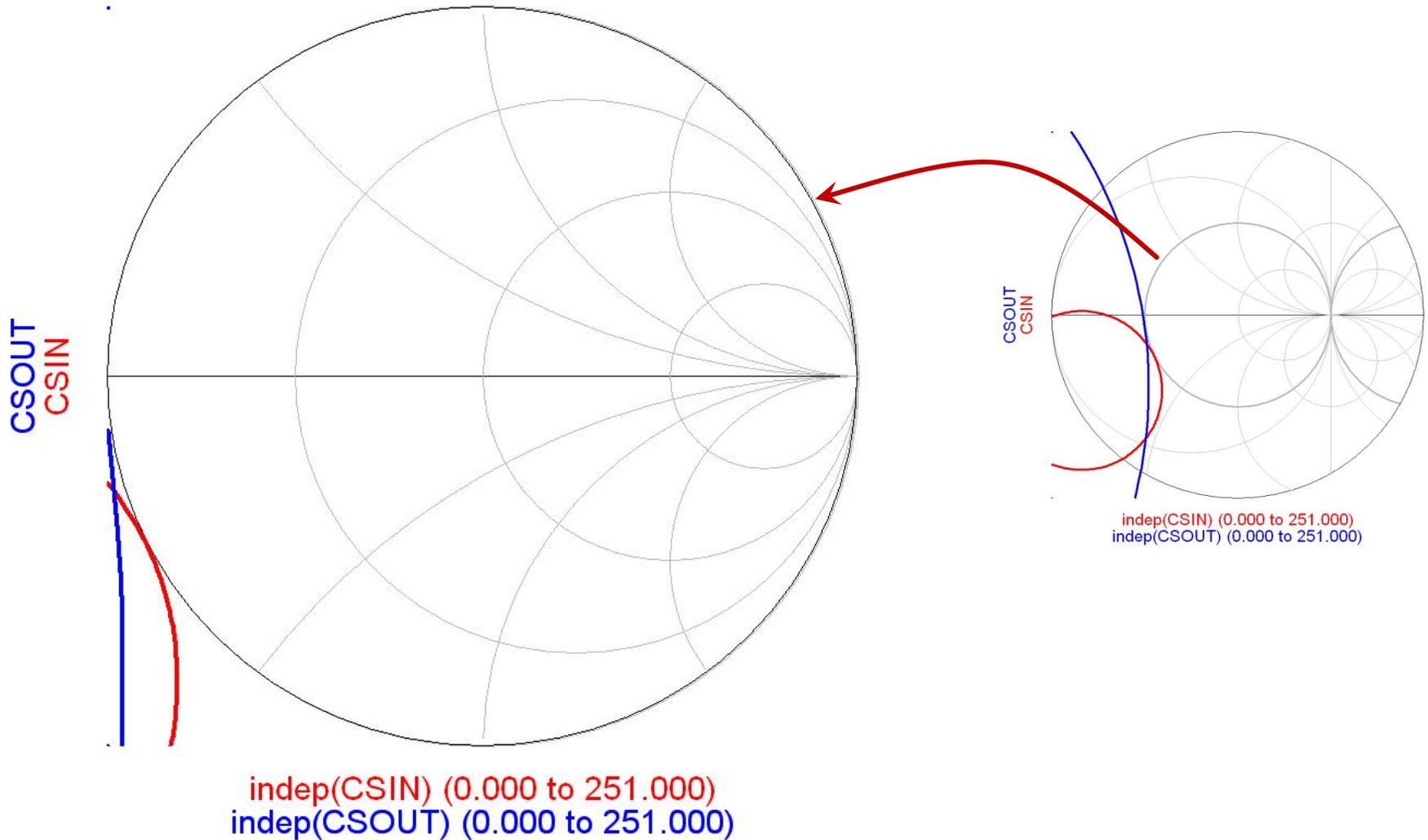


$$R_{p\max} = \frac{1}{G_{p\min}}$$

$$\frac{1}{0.026 - j \cdot 0.226} = 0.502 + j \cdot 4.367$$

$$R_{p\max} = \frac{50\Omega}{0.502} = 99.6\Omega$$

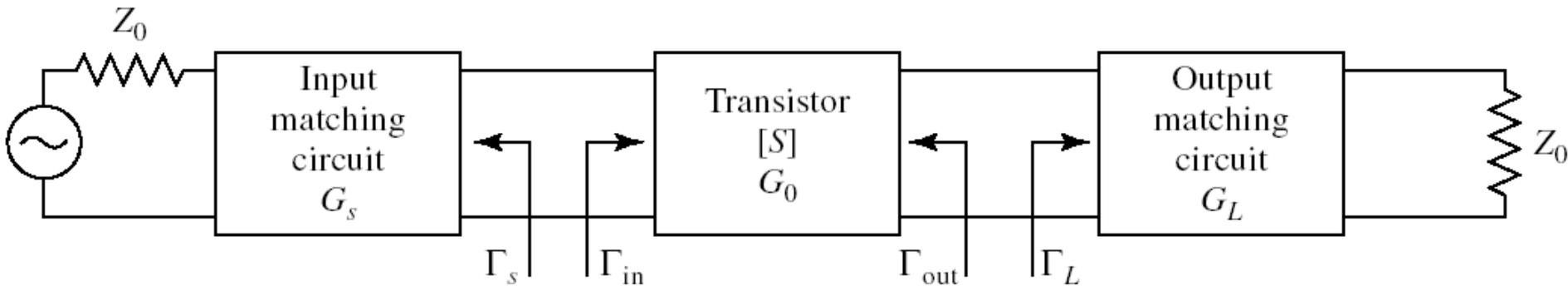
ADS, $R_p = 90^\circ\Omega$



Proiectare pentru castig maxim

Amplificatoare de microunde

Proiectare pentru castig maxim



- Castig maxim de putere se obtine cand

$$\Gamma_{in} = \Gamma_S^* \quad \Gamma_{out} = \Gamma_L^*$$

- Pentru retele de adaptare fara pierderi

$$G_{T \max} = \frac{|S_{21}|^2 \cdot (1 - |\Gamma_S|^2) \cdot (1 - |\Gamma_L|^2)}{|1 - \Gamma_S \cdot \Gamma_{in}|^2 \cdot |1 - S_{22} \cdot \Gamma_L|^2} \quad G_{T \max} = \frac{1}{1 - |\Gamma_S|^2} \cdot |S_{21}|^2 \cdot \frac{1 - |\Gamma_L|^2}{|1 - S_{22} \cdot \Gamma_L|^2}$$

- Pentru tranzistor bilateral ($S_{12} \neq 0$) Γ_{in} si Γ_{out} se influenteaza reciproc deci adaptarea trebuie sa fie simultana

Adaptare simultana

- Adaptarea simultana se poate realiza numai pentru amplificatoarele **neconditionat stabile** la frecventa de lucru, si solutia cu $|\Gamma| < 1$ se obtine cu semnul –

$$\Gamma_S = \frac{B_1 - \sqrt{B_1^2 - 4 \cdot |C_1|^2}}{2 \cdot C_1}$$

$$\begin{cases} B_1 = 1 + |S_{11}|^2 - |S_{22}|^2 - |\Delta|^2 \\ C_1 = S_{11} - \Delta \cdot S_{22}^* \end{cases}$$

$$\Gamma_L = \frac{B_2 - \sqrt{B_2^2 - 4 \cdot |C_2|^2}}{2 \cdot C_2}$$

$$\begin{cases} B_2 = 1 + |S_{22}|^2 - |S_{11}|^2 - |\Delta|^2 \\ C_2 = S_{22} - \Delta \cdot S_{11}^* \end{cases}$$

Adaptare simultana

- In conditiile adaptarii simultane se obtine castigul de transfer maxim pentru tranzistorul bilateral

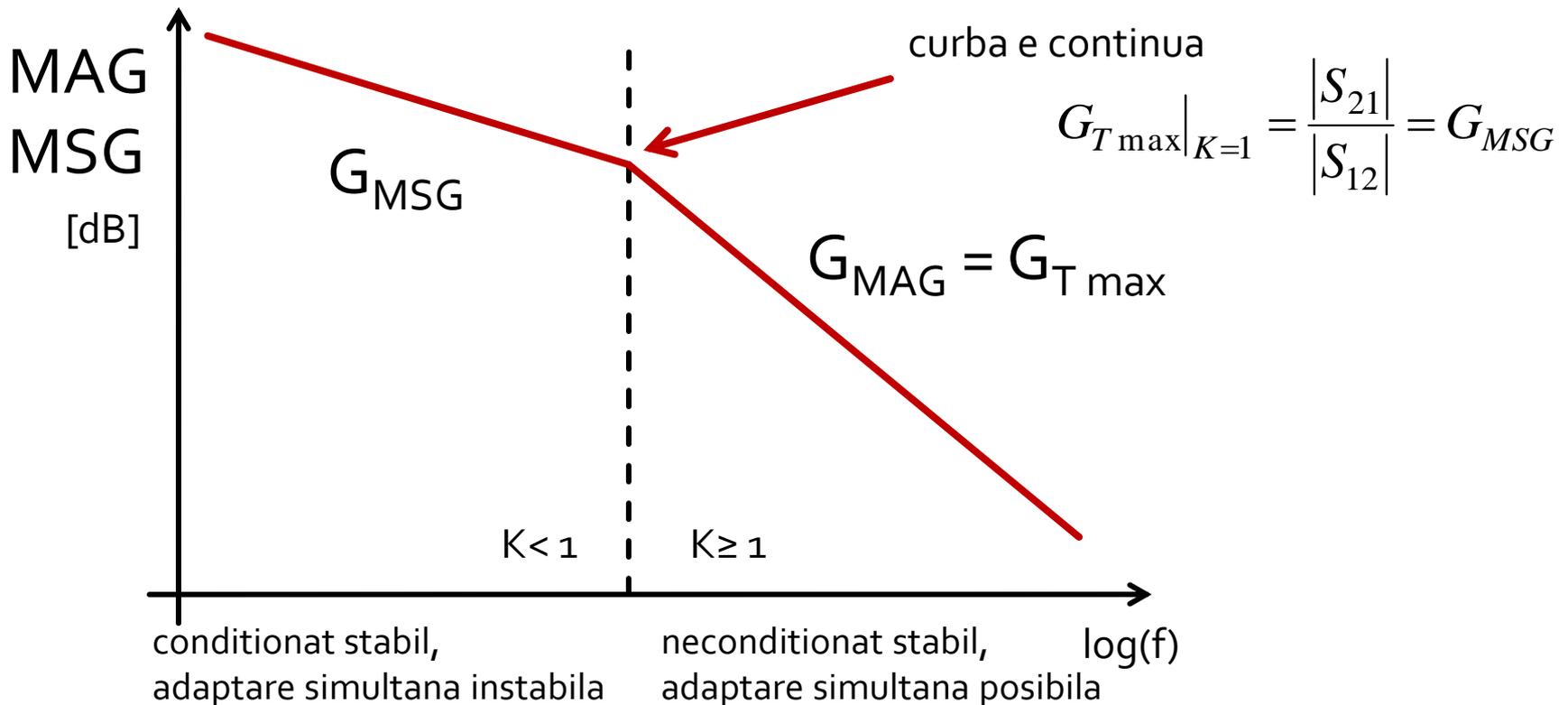
$$G_{T_{\max}} = \frac{|S_{21}|}{|S_{12}|} \cdot \left(K - \sqrt{K^2 - 1} \right)$$

- Daca dispozitivul nu este neconditionat stabil se poate folosi ca o indicatie a capacitatii de amplificare castigul maxim stabil (Maximum Stable Gain)

$$G_{MSG} = \frac{|S_{21}|}{|S_{12}|}$$

Maximum Available Gain

- Indicator in intregă gama de frecvență a capacității de a obține câștig



Adaptare simultana, tranzistor unilateral

- Daca amplificatorul/tranzistorul este **unilateral** ($S_{12} = 0$) adaptarea simultana e posibila si implica:

$$\begin{aligned}\Gamma_{in} &= S_{11} & \Gamma_{out} &= S_{22} \\ \Gamma_S &= S_{11}^* & \Gamma_L &= S_{22}^*\end{aligned}$$

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

$$\mu = \frac{1 - |S_{11}|^2}{|S_{22} - \Delta \cdot S_{11}^*| + |S_{12} \cdot S_{21}|} = \frac{1 - |S_{11}|^2}{|S_{22} - S_{22} \cdot S_{11} \cdot S_{11}^*|} = \frac{1 - |S_{11}|^2}{|1 - |S_{11}|^2| \cdot |S_{22}|} > 1$$

Exemplu

- ATF-34143 **at $V_{ds}=3V$ $I_d=20mA$.**
 - fara stabilizare $K = 0.886$, $MAG = 14.248dB$ @ 5GHz
 - nu poate fi folosit in aceasta polarizare
- ATF-34143 **at $V_{ds}=4V$ $I_d=40mA$**
 - fara stabilizare $K = 1.031$, $MAG = 12.9dB$ @ 5GHz
 - utilizam aceasta polarizare pentru a implementa un amplificator

Exemplu

- ATF-34143 at $V_{ds}=4V$ $I_d=40mA$.
- @5GHz
 - $S_{11} = 0.64 \angle 111^\circ$
 - $S_{12} = 0.117 \angle -27^\circ$
 - $S_{21} = 2.923 \angle -6^\circ$
 - $S_{22} = 0.21 \angle 111^\circ$

Calcol

■ Parametri S

- $S_{11} = -0.229 + 0.597 \cdot j$

- $S_{12} = 0.104 - 0.053 \cdot j$

- $S_{21} = 2.907 - 0.306 \cdot j$

- $S_{22} = -0.075 + 0.196 \cdot j$

$$K = 1.031$$

$$G_{T \max} = \frac{|S_{21}|}{|S_{12}|} \cdot \left(K - \sqrt{K^2 - 1} \right) = 19.497 = 12.9 \text{ dB}$$

$$G_{TU \max} = \frac{1}{1 - |S_{11}|^2} \cdot |S_{21}|^2 \cdot \frac{1}{1 - |S_{22}|^2} = 15.139 = 11.8 \text{ dB}$$

Calcul

$$\begin{cases} B_1 = 1 + |S_{11}|^2 - |S_{22}|^2 - |\Delta|^2 \\ C_1 = S_{11} - \Delta \cdot S_{22}^* \end{cases}$$

$$\begin{cases} B_1 = 1.207 \\ C_1 = -0.277 + j \cdot 0.529 \end{cases}$$

$$\Gamma_S = \frac{B_1 - \sqrt{B_1^2 - 4 \cdot |C_1|^2}}{2 \cdot C_1}$$

$$\Gamma_S = -0.403 - j \cdot 0.768$$

$$\Gamma_S = 0.867 \angle -117.7^\circ$$

$$|\Gamma_S| = 0.867 < 1$$

$$\begin{cases} B_2 = 1 + |S_{22}|^2 - |S_{11}|^2 - |\Delta|^2 \\ C_2 = S_{22} - \Delta \cdot S_{11}^* \end{cases}$$

$$\begin{cases} B_2 = 0.476 \\ C_2 = -0.222 - j \cdot 0.013 \end{cases}$$

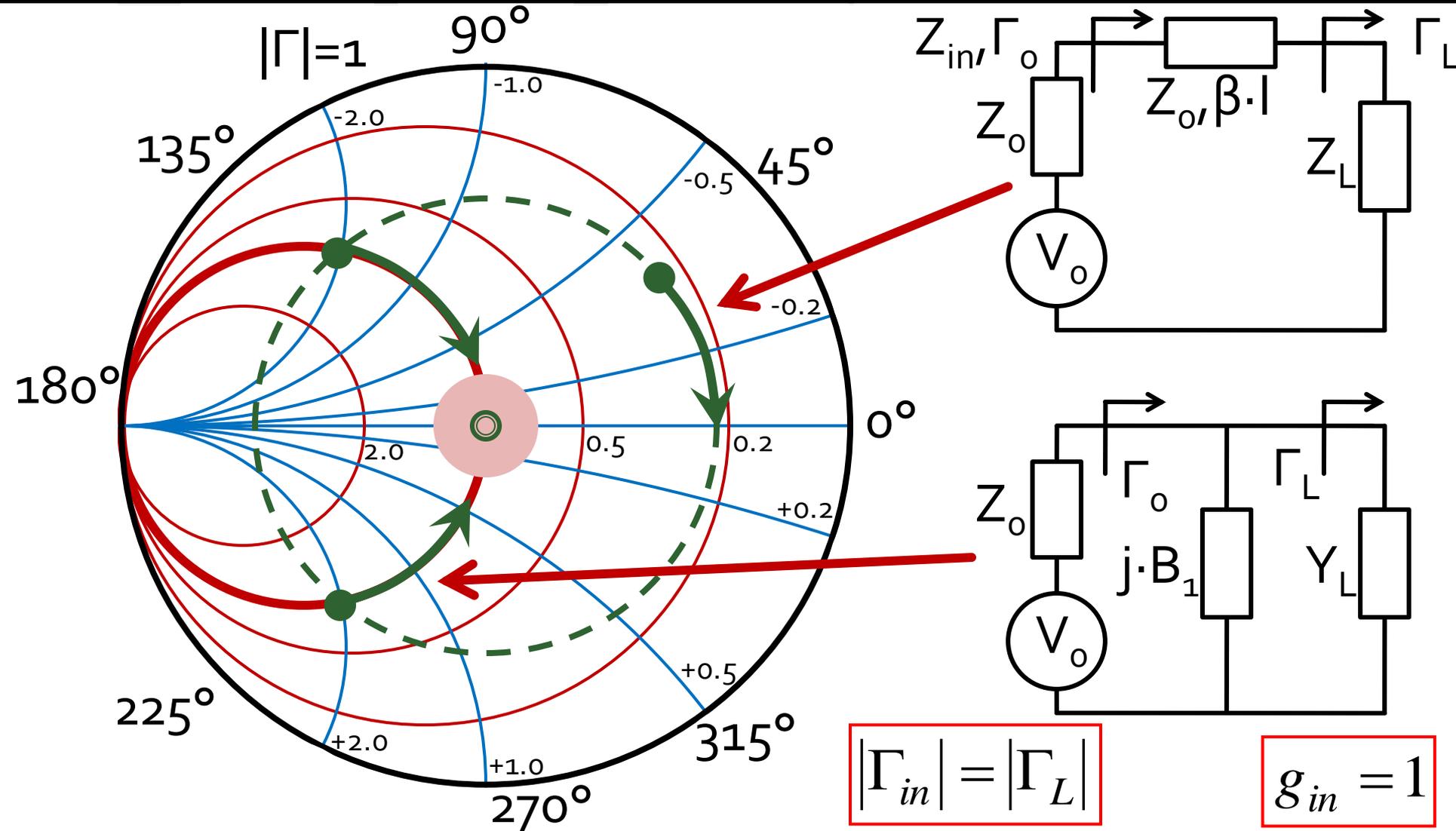
$$\Gamma_L = \frac{B_2 - \sqrt{B_2^2 - 4 \cdot |C_2|^2}}{2 \cdot C_2}$$

$$\Gamma_L = -0.685 + j \cdot 0.04$$

$$\Gamma_L = 0.686 \angle 176.7^\circ$$

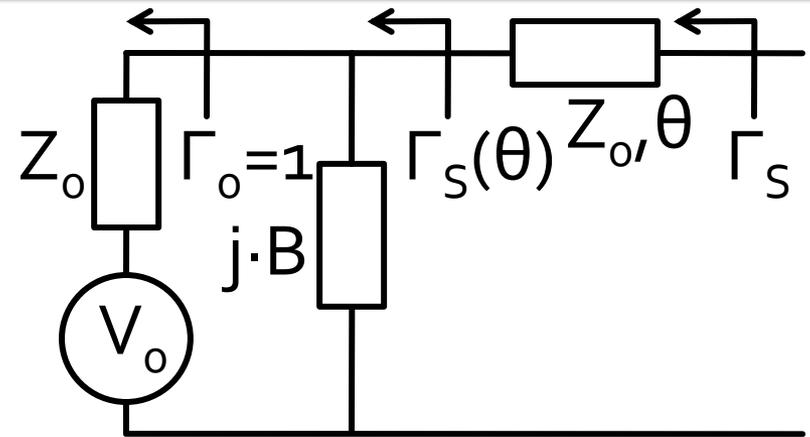
$$|\Gamma_L| = 0.686 < 1$$

Adaptare cu stub-uri, C6



Calcul analitic, coeficienti de reflexie

- linie serie
 - lungime electrica $E = \beta \cdot l = \theta$
 - muta coeficientul de reflexie pe cercul $g=1$
- stub paralel muta coeficientul de reflexie in centrul diagramei Smith



$$y_s = \frac{Y_s}{Y_0} = Y_s \cdot Z_0 = Y_s \cdot 50$$

$$y_s = \frac{1 - \Gamma_s}{1 + \Gamma_s} = 0.263 + j \cdot 1.622$$

$$\Gamma_s(\theta) = \Gamma_s \cdot e^{2j\theta}$$

$$y_s(\theta) = \frac{1 - \Gamma_s(\theta)}{1 + \Gamma_s(\theta)} = \frac{1 - \Gamma_s \cdot e^{2j\theta}}{1 + \Gamma_s \cdot e^{2j\theta}}$$

Calcul analitic, stub

- Dupa sectiunea de linie cu lungimea electrica θ

$$\operatorname{Re}[y_S(\theta)] = 1 \qquad \operatorname{Im}[y_S(\theta)] = B$$

$$\operatorname{Re}[y_S(\theta)] = \frac{1}{2} \cdot [y_S(\theta) + y_S^*(\theta)] \qquad \operatorname{Im}[y_S(\theta)] = \frac{1}{2j} \cdot [y_S(\theta) - y_S^*(\theta)]$$

$$\operatorname{Re}[y_S(\theta)] = \frac{1}{2} \cdot \left[\frac{1 - \Gamma_S \cdot e^{2j\theta}}{1 + \Gamma_S \cdot e^{2j\theta}} + \frac{1 - \Gamma_S^* \cdot e^{-2j\theta}}{1 + \Gamma_S^* \cdot e^{-2j\theta}} \right] \qquad \Gamma_S = |\Gamma_S| \cdot e^{j\varphi}$$

$$\operatorname{Re}[y_S(\theta)] = \frac{1}{2} \cdot \left[\frac{(1 - |\Gamma_S| \cdot e^{j(\varphi+2\theta)}) \cdot (1 + |\Gamma_S| \cdot e^{-j(\varphi+2\theta)}) + (1 - |\Gamma_S| \cdot e^{-j(\varphi+2\theta)}) \cdot (1 + |\Gamma_S| \cdot e^{j(\varphi+2\theta)})}{(1 + |\Gamma_S| \cdot e^{-j(\varphi+2\theta)}) \cdot (1 + |\Gamma_S| \cdot e^{j(\varphi+2\theta)})} \right]$$

$$\operatorname{Re}[y_S(\theta)] = \frac{1}{2} \cdot \left[\frac{2 - 2 \cdot |\Gamma_S|^2}{1 + |\Gamma_S|^2 + 2 \cdot |\Gamma_S| \cdot \cos(\varphi + 2\theta)} \right] \qquad \operatorname{Re}[y_S(\theta)] = 1$$

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

Calcul analitic, stub

- Ecuatia pentru calcularea θ

$$\operatorname{Re}[y_S(\theta)] = 1 \Rightarrow \cos(\varphi + 2\theta) = -|\Gamma_S|$$

$$\Gamma_S = |\Gamma_S| \cdot e^{j\varphi} \quad \Gamma_S = 0.867 \angle -117.7^\circ \quad |\Gamma_S| = 0.867; \quad \varphi = -117.7^\circ$$

- doua solutii posibile, normate la intervalul $0 \div 180^\circ$

$$\theta = \frac{1}{2} \cdot [\pm \cos^{-1}(-|\Gamma_S|) - \varphi + k \cdot 360^\circ] = \frac{1}{2} \cdot [\pm \cos^{-1}(-|\Gamma_S|) - \varphi] + k \cdot 180^\circ$$

$$\forall k \in \mathbb{N}$$

$$\cos(\varphi + 2\theta) = -0.867 \Rightarrow (\varphi + 2\theta) = \pm 150.1^\circ$$

$$(-117.7^\circ + 2\theta) = \begin{cases} +150.1^\circ \\ -150.1^\circ \end{cases}$$

$$\theta = \begin{cases} +133.9^\circ \\ -16.2^\circ + 180^\circ = +163.8^\circ \end{cases}$$

Calcul analitic, stub paralel

- Ecuația pentru calcularea stub-ului paralel

$$\operatorname{Re}[y_S(\theta)] = 1 \qquad \cos(\varphi + 2\theta) = -|\Gamma_S|$$

$$\operatorname{Im}[y_S(\theta)] = \frac{1}{2j} \cdot \left[\frac{1 - \Gamma_S \cdot e^{2j\theta}}{1 + \Gamma_S \cdot e^{2j\theta}} - \frac{1 - \Gamma_S^* \cdot e^{-2j\theta}}{1 + \Gamma_S^* \cdot e^{-2j\theta}} \right] \qquad \Gamma_S = |\Gamma_S| \cdot e^{j\varphi}$$

$$\operatorname{Im}[y_S(\theta)] = \frac{1}{2j} \cdot \left[\frac{(1 - |\Gamma_S| \cdot e^{j(\varphi+2\theta)}) \cdot (1 + |\Gamma_S| \cdot e^{-j(\varphi+2\theta)}) - (1 - |\Gamma_S| \cdot e^{-j(\varphi+2\theta)}) \cdot (1 + |\Gamma_S| \cdot e^{j(\varphi+2\theta)})}{(1 + |\Gamma_S| \cdot e^{-j(\varphi+2\theta)}) \cdot (1 + |\Gamma_S| \cdot e^{j(\varphi+2\theta)})} \right]$$

$$\operatorname{Im}[y_S(\theta)] = \frac{1}{2j} \cdot \left[\frac{2 \cdot |\Gamma_S| \cdot e^{-j(\varphi+2\theta)} - 2 \cdot |\Gamma_S| \cdot e^{+j(\varphi+2\theta)}}{1 + |\Gamma_S|^2 + 2 \cdot |\Gamma_S| \cdot \cos(\varphi + 2\theta)} \right] = \frac{-2 \cdot |\Gamma_S| \cdot \sin(\varphi + 2\theta)}{1 + |\Gamma_S|^2 + 2 \cdot |\Gamma_S| \cdot \cos(\varphi + 2\theta)}$$

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

Calcul analitic, stub paralel

- Ecuația pentru calcularea stub-ului paralel

$$\cos(\varphi + 2\theta) = -|\Gamma_S| \Rightarrow \sin(\varphi + 2\theta) = \pm \sqrt{1 - |\Gamma_S|^2}$$

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

- doua situatii

$$\varphi + 2\theta \in [0^\circ, 180^\circ] \Rightarrow \sin(\varphi + 2\theta) \geq 0$$

$$\sin(\varphi + 2\theta) = \sqrt{1 - |\Gamma_S|^2}$$

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

$$\varphi + 2\theta \in (-180^\circ, 0^\circ) \Rightarrow \sin(\varphi + 2\theta) < 0$$

$$\sin(\varphi + 2\theta) = -\sqrt{1 - |\Gamma_S|^2}$$

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

Calcul analitic, stub paralel

- Se prefera (pentru microstrip) stub in gol

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

- Susceptanta raportata introdusa pentru adaptare

$$b = \text{Im} \left[\frac{Y_{in,g}}{Y_0} \right] = \text{Im} \left[\frac{Z_0}{Z_{in,g}} \right] = \tan \beta \cdot l = \text{Im}[y_S(\theta)]$$

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

Calcul analitic

$$(\varphi + 2\theta) = \begin{cases} +150.1^\circ \\ -150.1^\circ \end{cases} \quad \theta = \begin{cases} 133.9^\circ \\ 163.8^\circ \end{cases} \quad \text{Im}[y_S(\theta)] = \begin{cases} -3.477 \\ +3.477 \end{cases} \quad \theta_{sp} = \begin{cases} -74^\circ + 180^\circ = 106^\circ \\ +74^\circ \end{cases}$$

- Se alege **una** din cele doua solutii posibile
- Similar pentru adaptarea la iesire

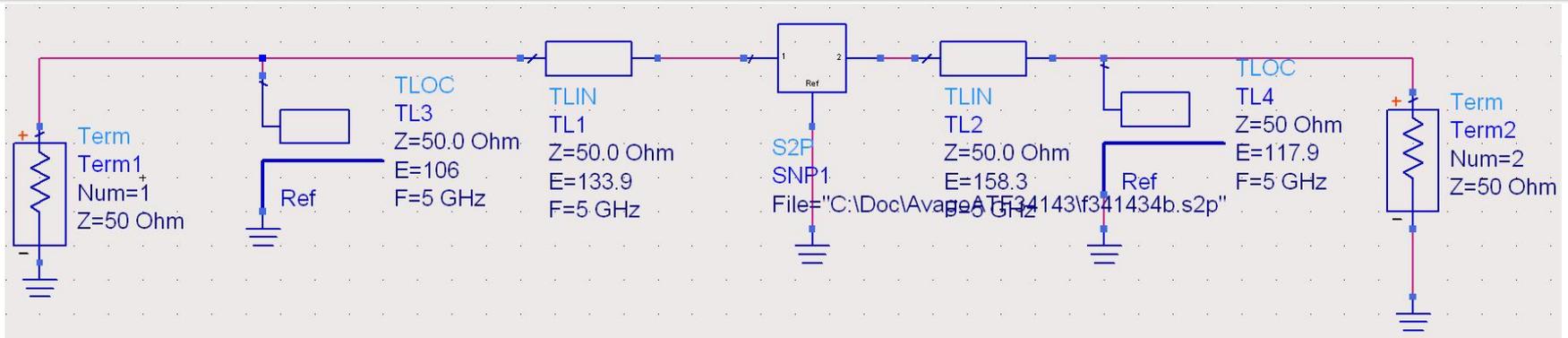
$$\Gamma_L = 0.686 \angle 176.7^\circ \quad \text{Re}[y_L(\theta)] = 1 \Rightarrow \quad \cos(\varphi + 2\theta) = -|\Gamma_L|$$

$$(176.7^\circ + 2\theta) = \begin{cases} +133.3^\circ \\ -133.3^\circ \end{cases} \quad \theta = \begin{cases} -21.7^\circ + 180^\circ = +158.3^\circ \\ -155^\circ + 180^\circ = +25^\circ \end{cases}$$

$$\text{Im}[y_L(\theta)] = \frac{-2 \cdot |\Gamma_L|}{\sqrt{1 - |\Gamma_L|^2}} = -1.885 \quad \theta_{sp} = \begin{cases} -62.1^\circ + 180^\circ = 117.9^\circ \\ +62.1^\circ \end{cases}$$

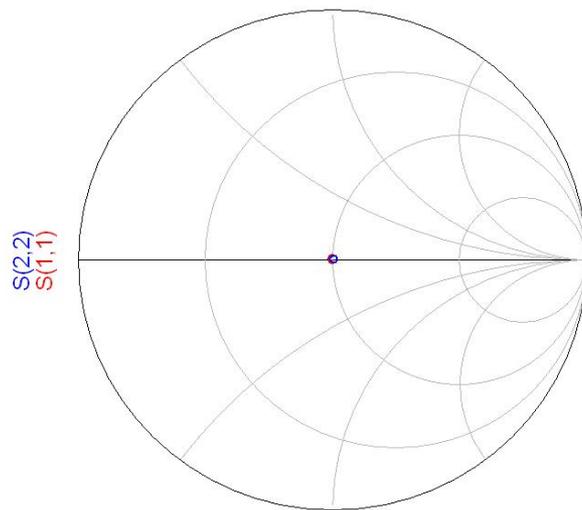
$$(\varphi + 2\theta) = \begin{cases} +133.3^\circ \\ -133.3^\circ \end{cases} \quad \theta = \begin{cases} 158.3^\circ \\ 25.0^\circ \end{cases} \quad \text{Im}[y_S(\theta)] = \begin{cases} -1.885 \\ +1.885 \end{cases} \quad \theta_{sp} = \begin{cases} 117.9^\circ \\ 62.1^\circ \end{cases}$$

ADS



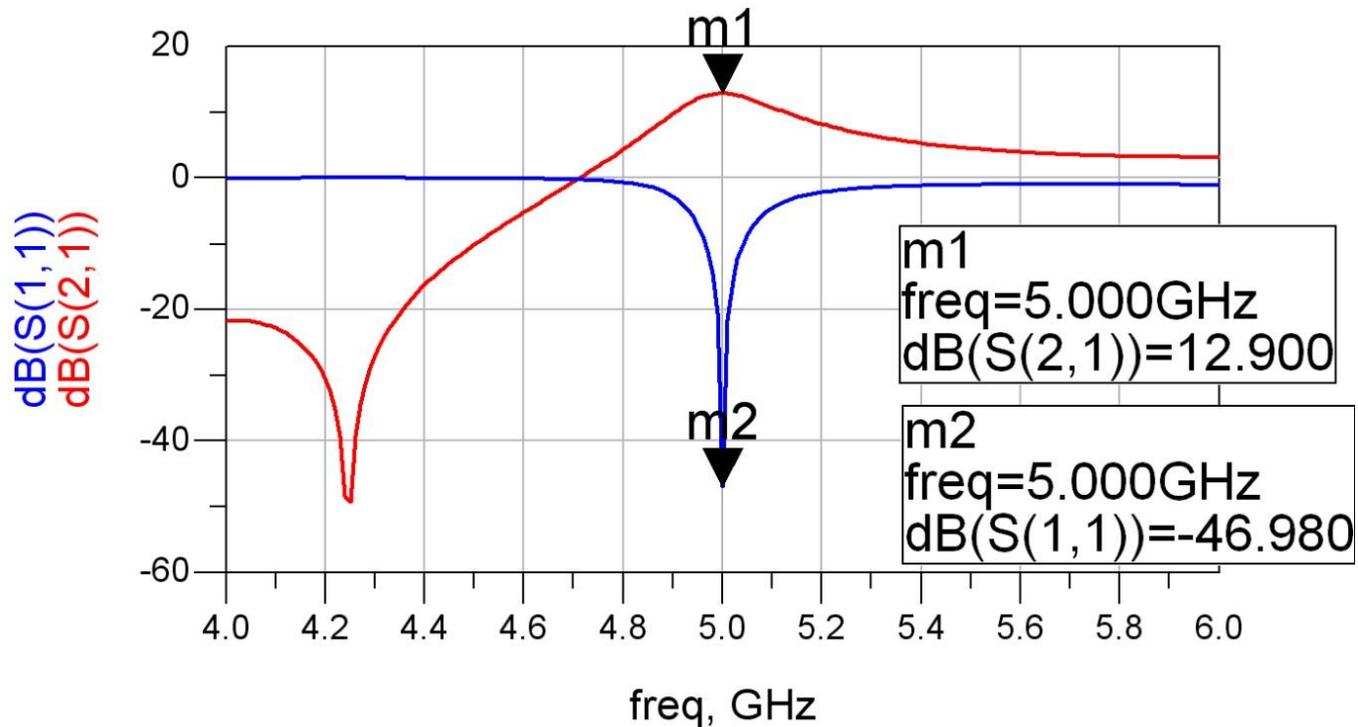
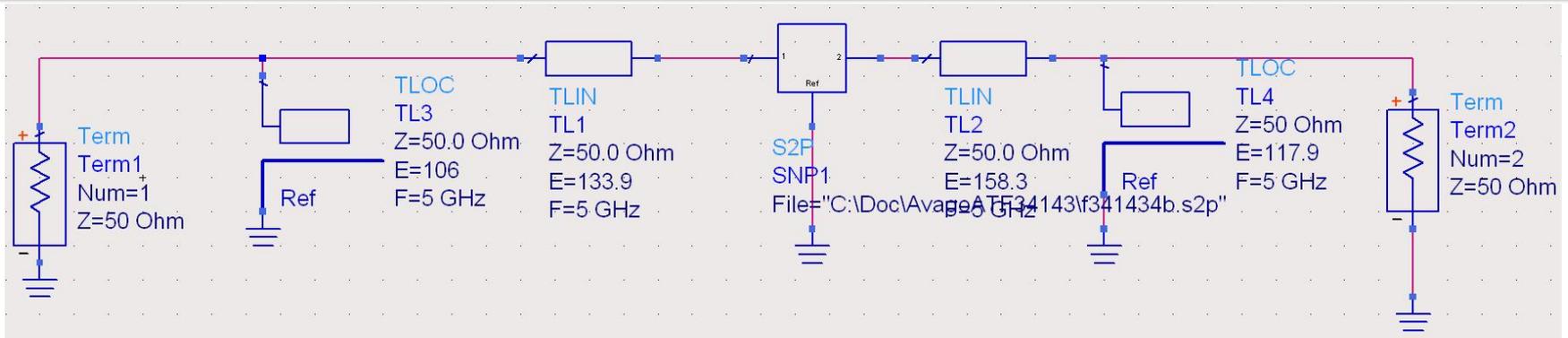
$$\text{Eqn GT} = 10 * \log(\text{mag}(S(2,1))^{**2})$$

freq	S(2,1)	GT	S(1,1)	S(2,2)
5.000GHz	4.415 / 157....	12.900	0.004 / 86.088	0.004 / 37.766



freq (5.000GHz to 5.000GHz)

ADS



Proiectare pentru castig impus

Amplificatoare de microunde

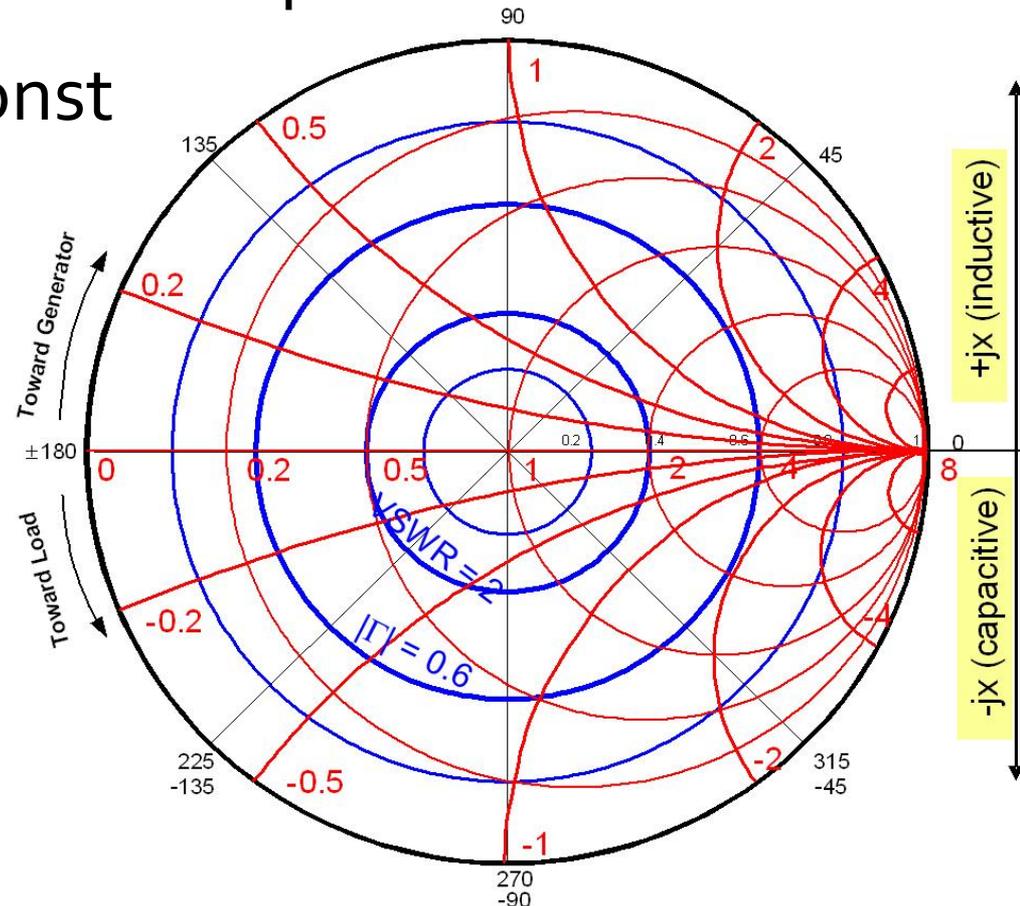
Proiectare pentru castig impus

- 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 ($L_3 + C_9$)
 - conditii de stabilitate mai bune
 - obtinerea unui VSWR mai mic
 - controlul performantelor la mai multe frecvente
 - banda de functionare a amplificatorului

VSWR

- Anumite aplicatii pot impune un raport intre tensiunile maxime/minime pe linii
- $VSWR = \text{const} \rightarrow \Gamma = \text{const}$

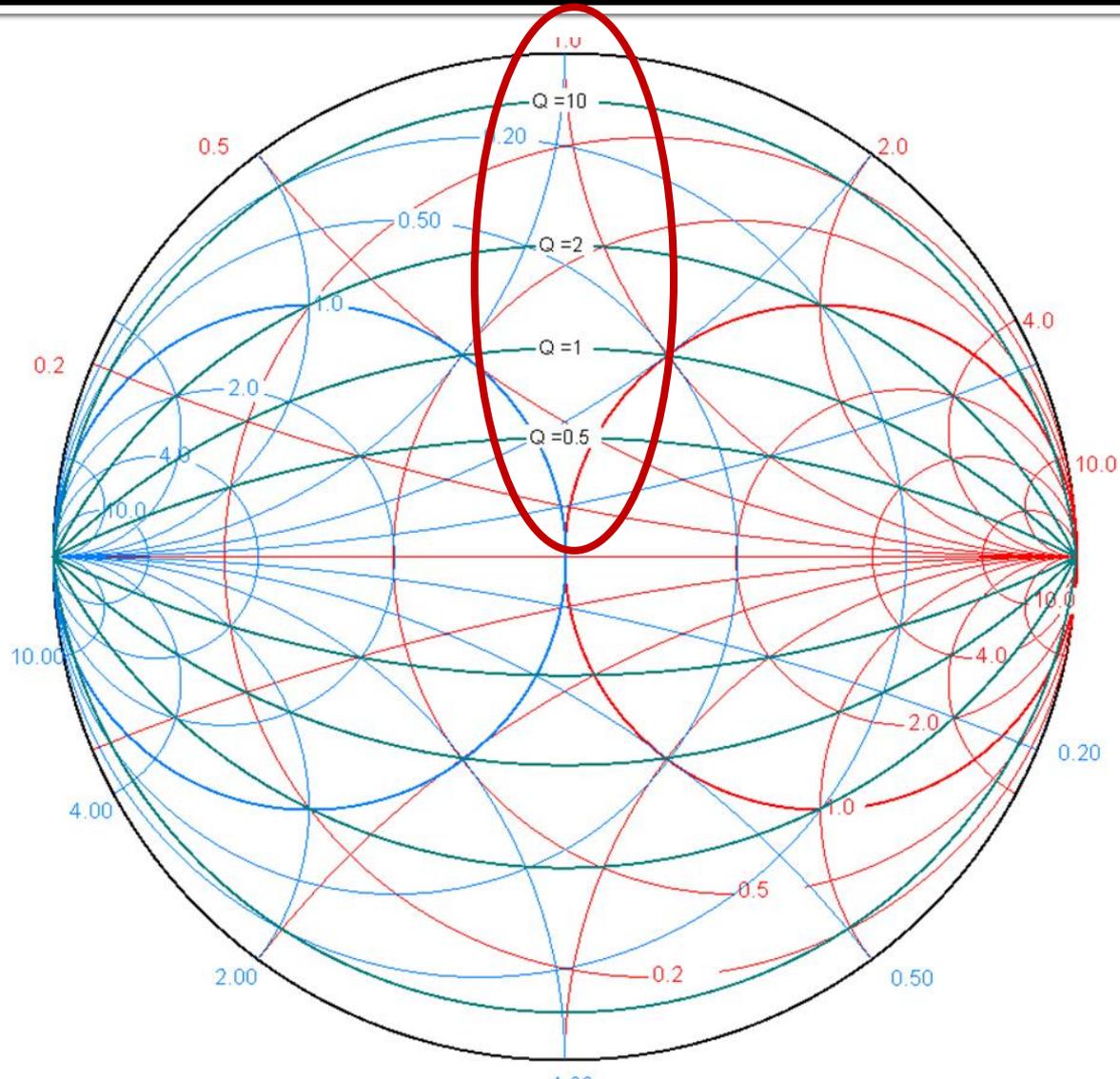
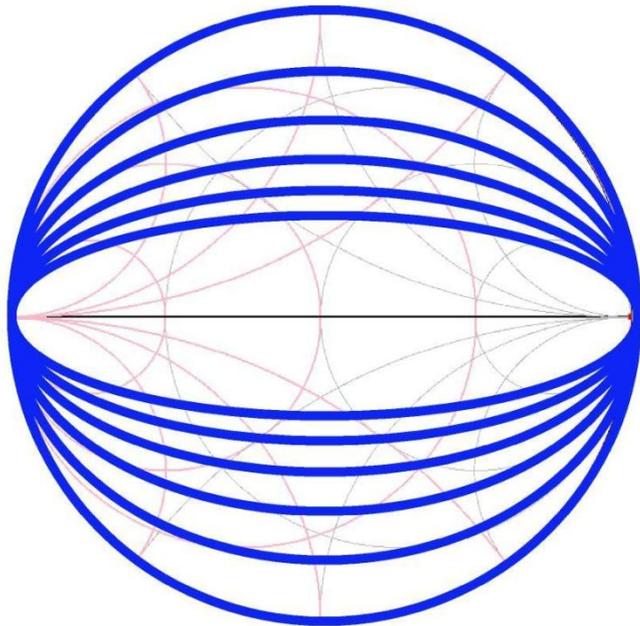
$$VSWR = \frac{V_{\max}}{V_{\min}} = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$



Cercuri de factor de calitate constant

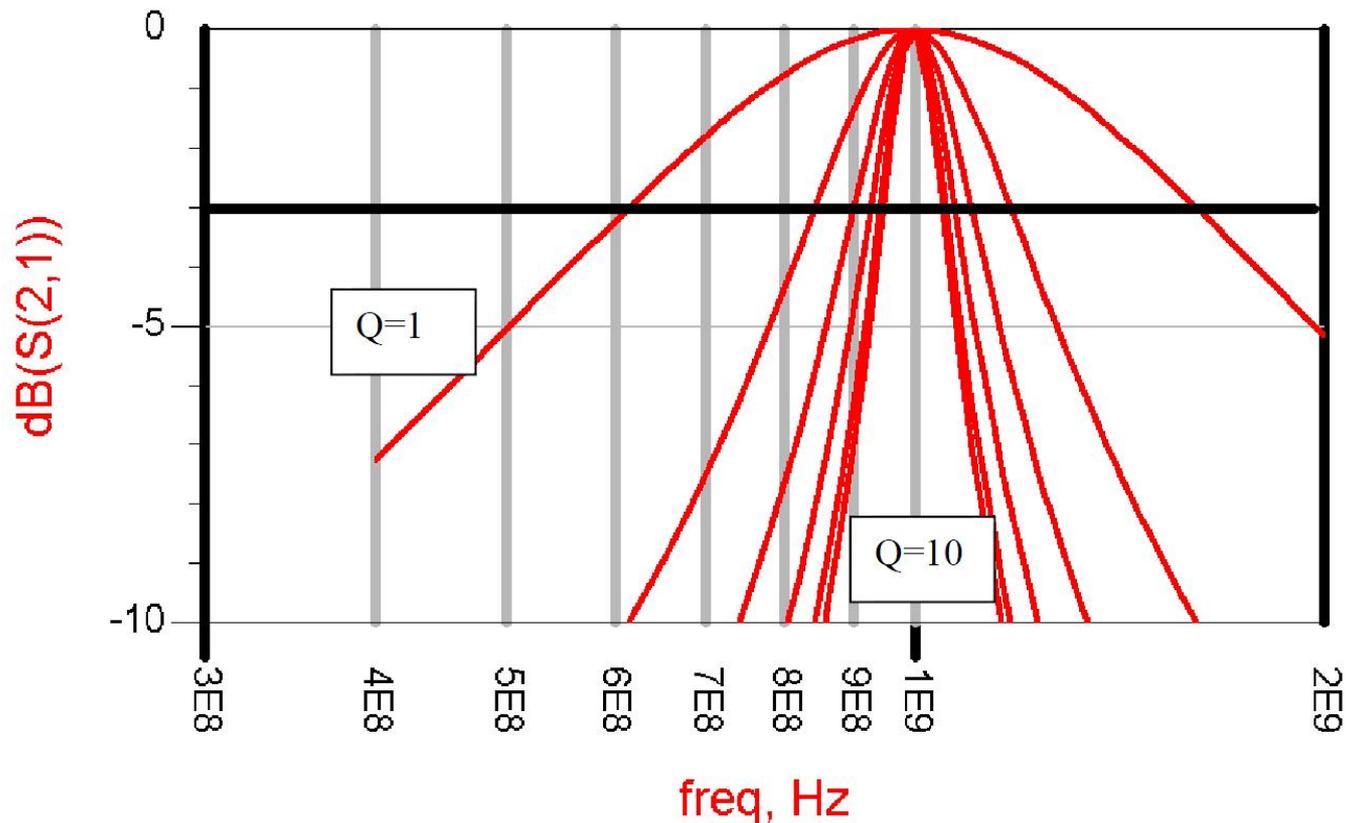
- Diagrama Smith

$$Q = \frac{X}{R} = \frac{G}{B} = \text{const}$$

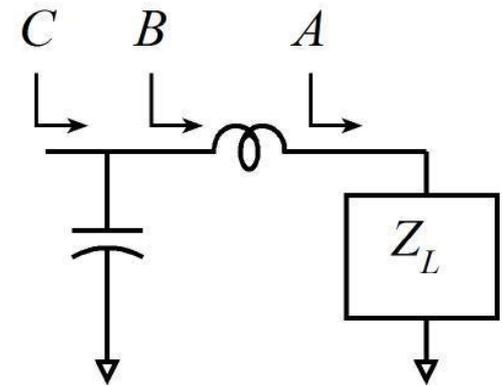
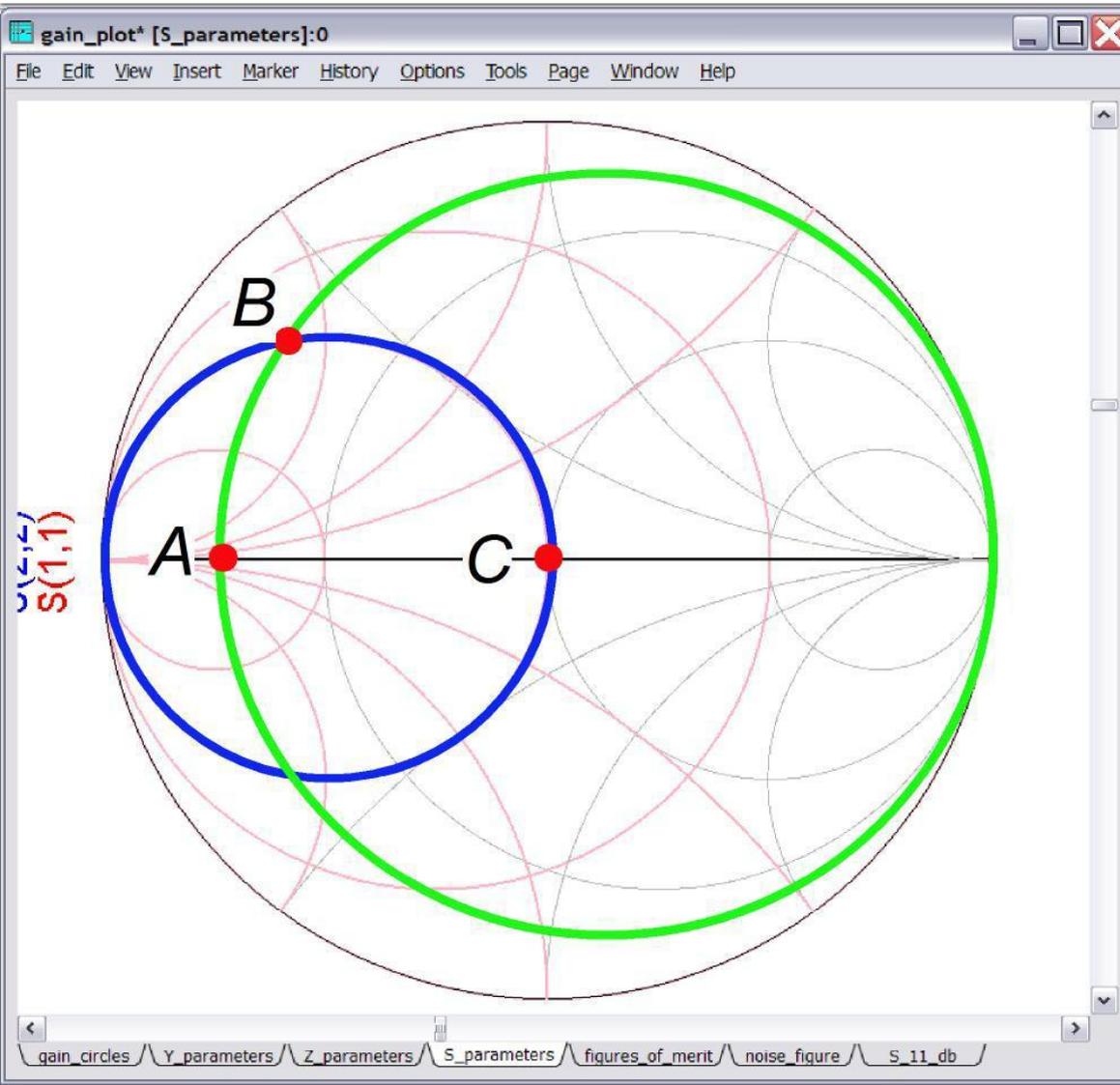


Factor de calitate - banda

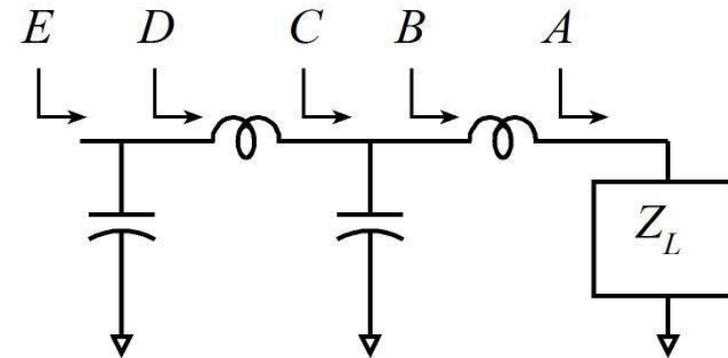
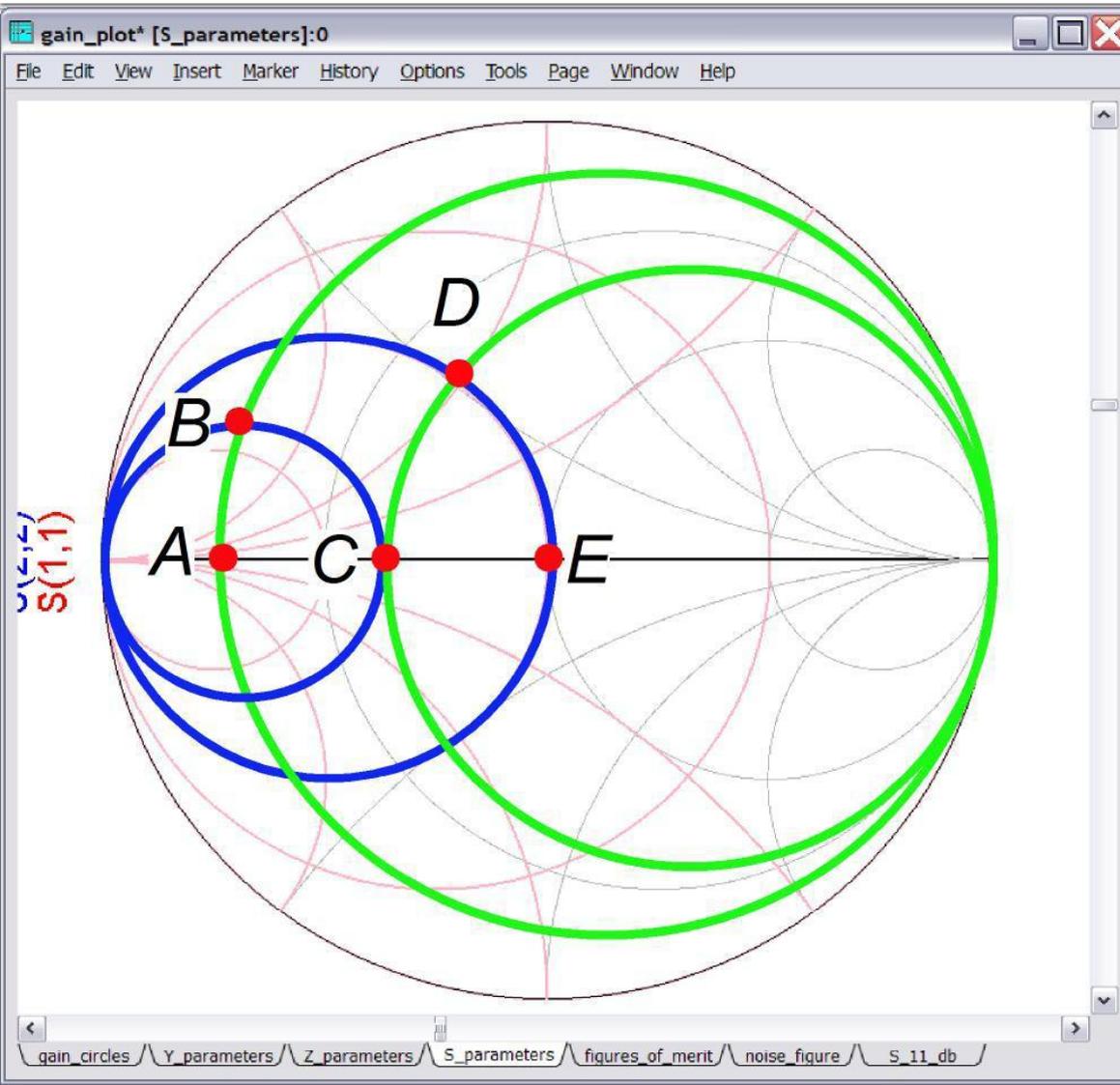
- Factor de calitate ridicat echivalent cu banda ingusta



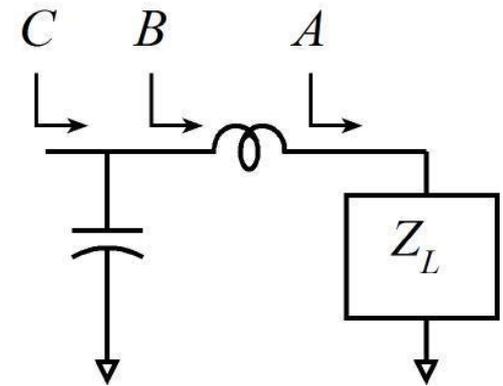
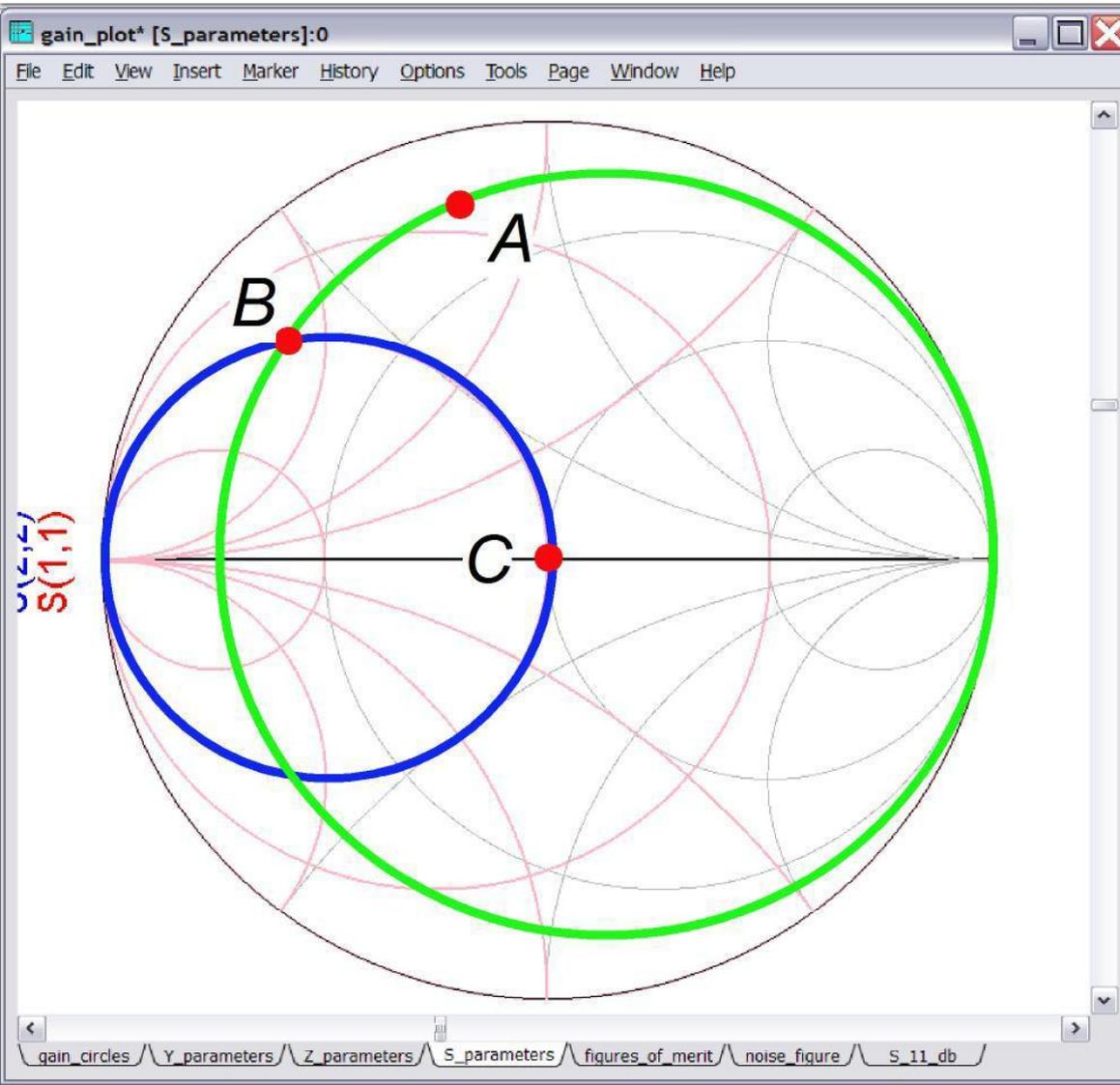
Adaptare - banda



Adaptare - banda

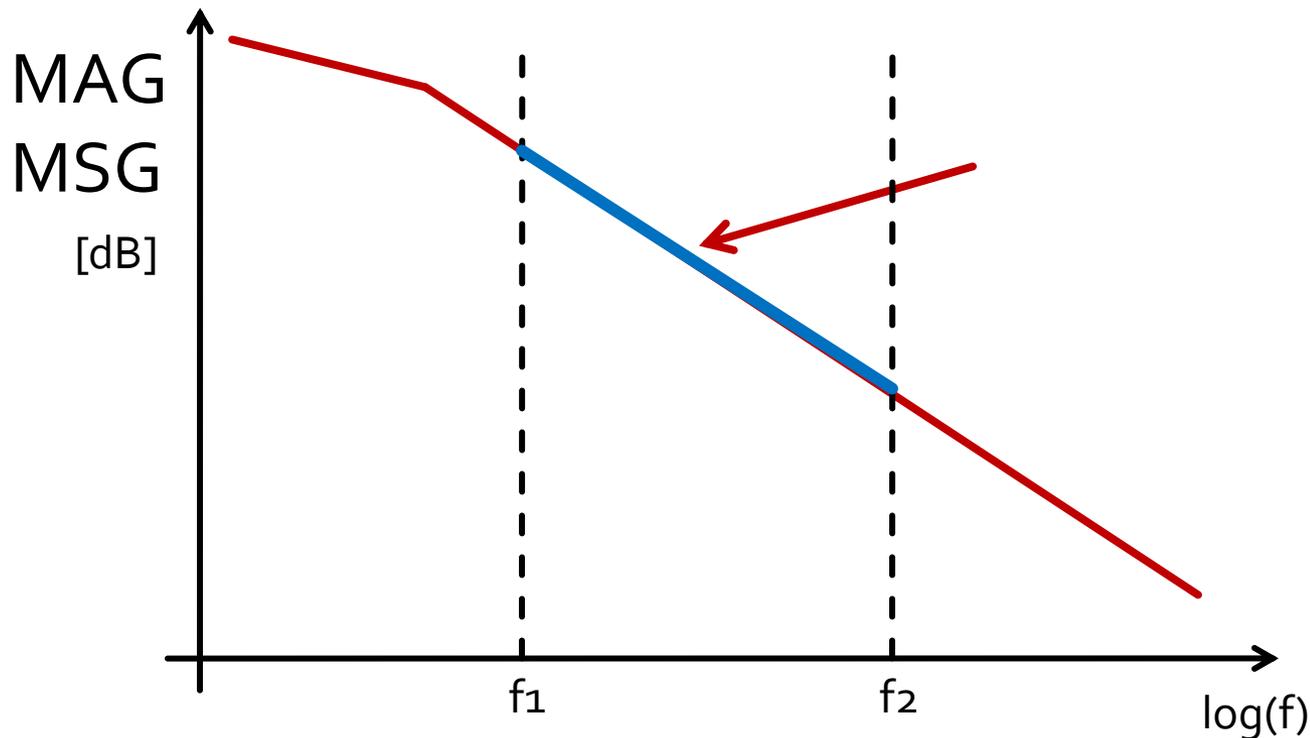


Adaptare - banda



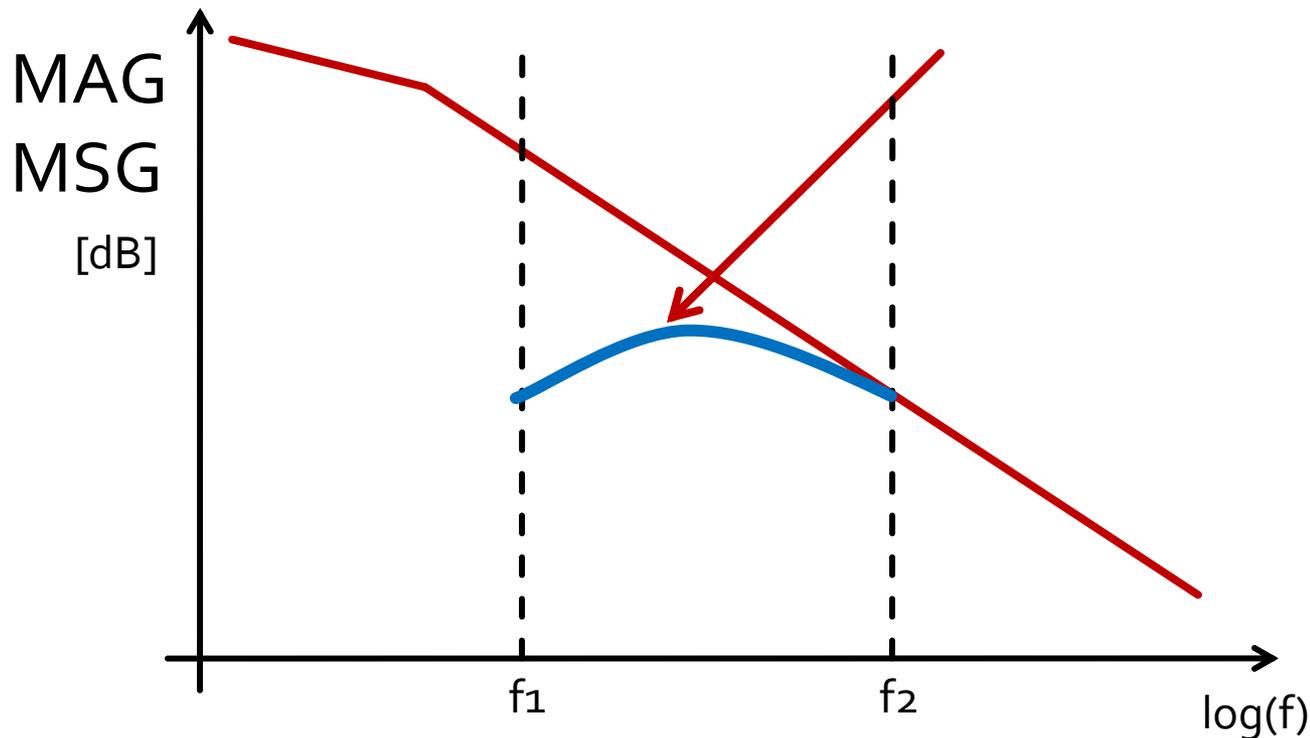
Amplificator de banda larga

- 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

- Se realizeaza cu asumarea unilaterala a amplificatorului

Permite tratarea separata a intrarii si iesirii

$$G_{TU} = |S_{21}|^2 \cdot \frac{1 - |\Gamma_S|^2}{|1 - S_{11} \cdot \Gamma_S|^2} \cdot \frac{1 - |\Gamma_L|^2}{|1 - S_{22} \cdot \Gamma_L|^2} \quad S_{12} \cong 0 \quad \Gamma_{in} = S_{11}$$

- Castig maxim

$$\Gamma_S = S_{11}^*$$

$$\Gamma_L = S_{22}^*$$

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

Factor de merit unilateral

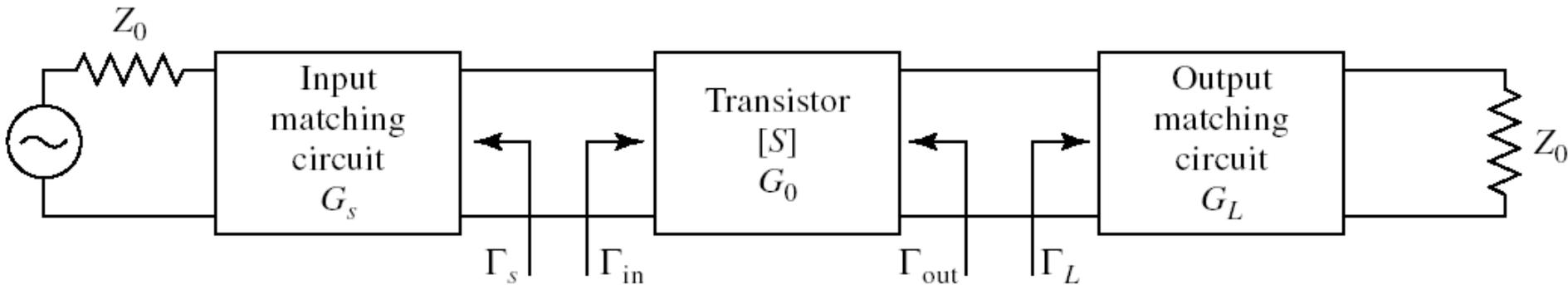
- Permite estimarea erorii induse de ipoteza tranzistorului unilateral

$$\frac{1}{(1+U)^2} < \frac{G_T}{G_{TU}} < \frac{1}{(1-U)^2} \quad U = \frac{|S_{12}| \cdot |S_{21}| \cdot |S_{11}| \cdot |S_{22}|}{(1-|S_{11}|^2) \cdot (1-|S_{22}|^2)}$$

- Se calculeaza U si abaterea maxima si minima a lui GTU fata de GT
 - aceasta abatere trebuie prevazuta in proiectare ca rezerva pentru castigul maxim

$$-20 \cdot \log(1+U) < G_T [dB] - G_{TU} [dB] < -20 \cdot \log(1-U)$$

Proiectare pentru castig impus



- Daca ipoteza tranzistorului unilateral este justificata:

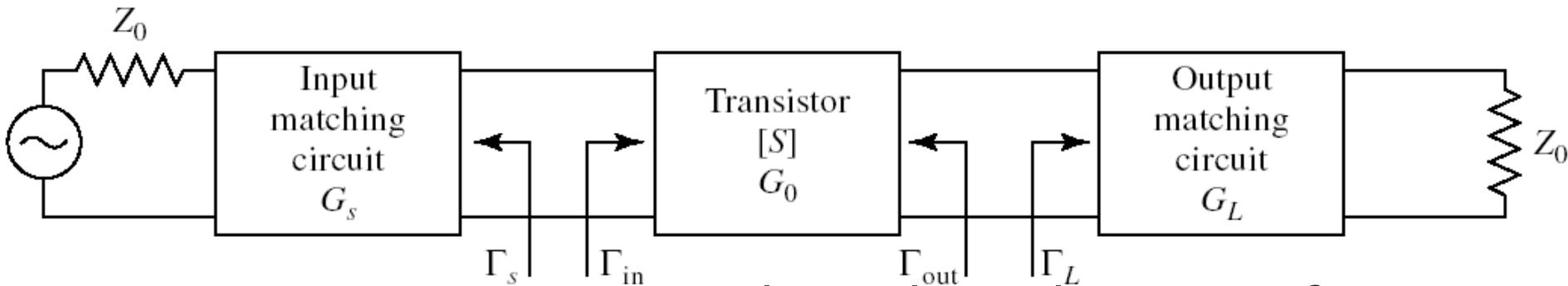
$$G_{TU} = |S_{21}|^2 \cdot \frac{1 - |\Gamma_S|^2}{|1 - S_{11} \cdot \Gamma_S|^2} \cdot \frac{1 - |\Gamma_L|^2}{|1 - S_{22} \cdot \Gamma_L|^2}$$

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

$$G_0 = |S_{21}|^2$$

$$G_L = \frac{1 - |\Gamma_L|^2}{|1 - S_{22} \cdot \Gamma_L|^2}$$

Proiectare pentru castig impus

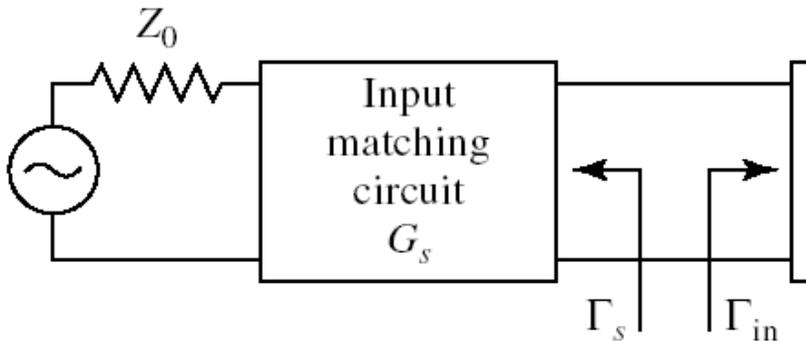


- Daca ipoteza tranzistorului unilateral este justificata:
 - castigul adaugat prin adaptare mai buna la intrare **nu** depinde de adaptarea la iesire
 - castigul adaugat prin adaptare mai buna la iesire **nu** depinde de adaptarea la intrare
- Adaptarile la intrare/iesire pot fi tratate independent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

$$G_T = G_S \cdot G_0 \cdot G_L$$

$$G_T [dB] = G_S [dB] + G_0 [dB] + G_L [dB]$$

Adaptarea la intrare



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

- Castig maxim pentru adaptare complex conjugata (putere) la intrare

$$\Gamma_S = S_{11}^* \Rightarrow G_{S \max} = \frac{1}{1 - |S_{11}|^2}$$

- Pentru oricare alta retea de adaptare

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

Exemplu

- ATF-34143 at $V_{ds}=3V$ $I_d=20mA$.
- @5GHz

- $S_{11} = 0.64 \angle 139^\circ$
- $S_{12} = 0.119 \angle -21^\circ$
- $S_{21} = 3.165 \angle 16^\circ$
- $S_{22} = 0.22 \angle 146^\circ$

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

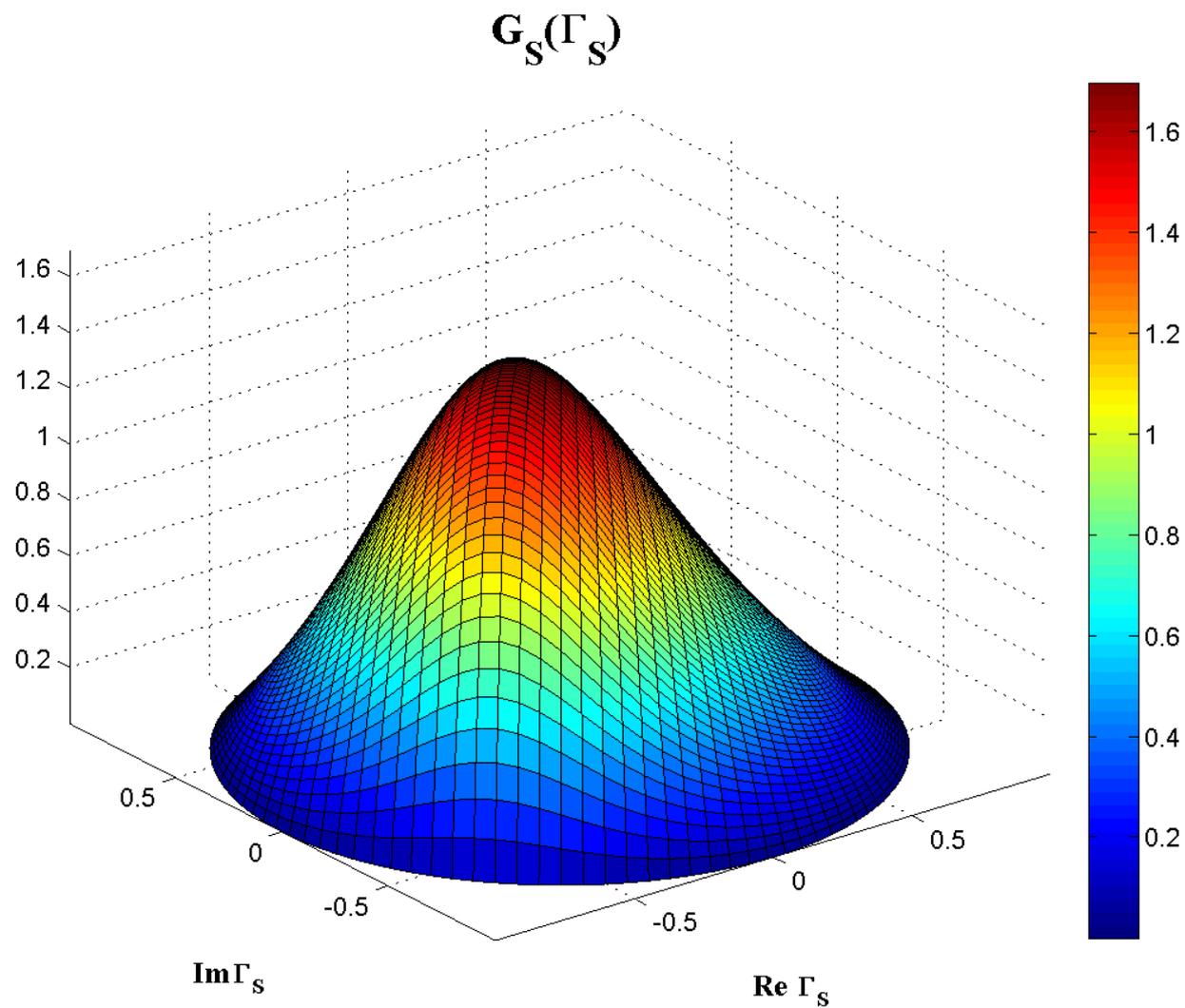
$$-0.783 \text{ dB} < G_T [\text{dB}] - G_{TU} [\text{dB}] < 0.861 \text{ dB}$$

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

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

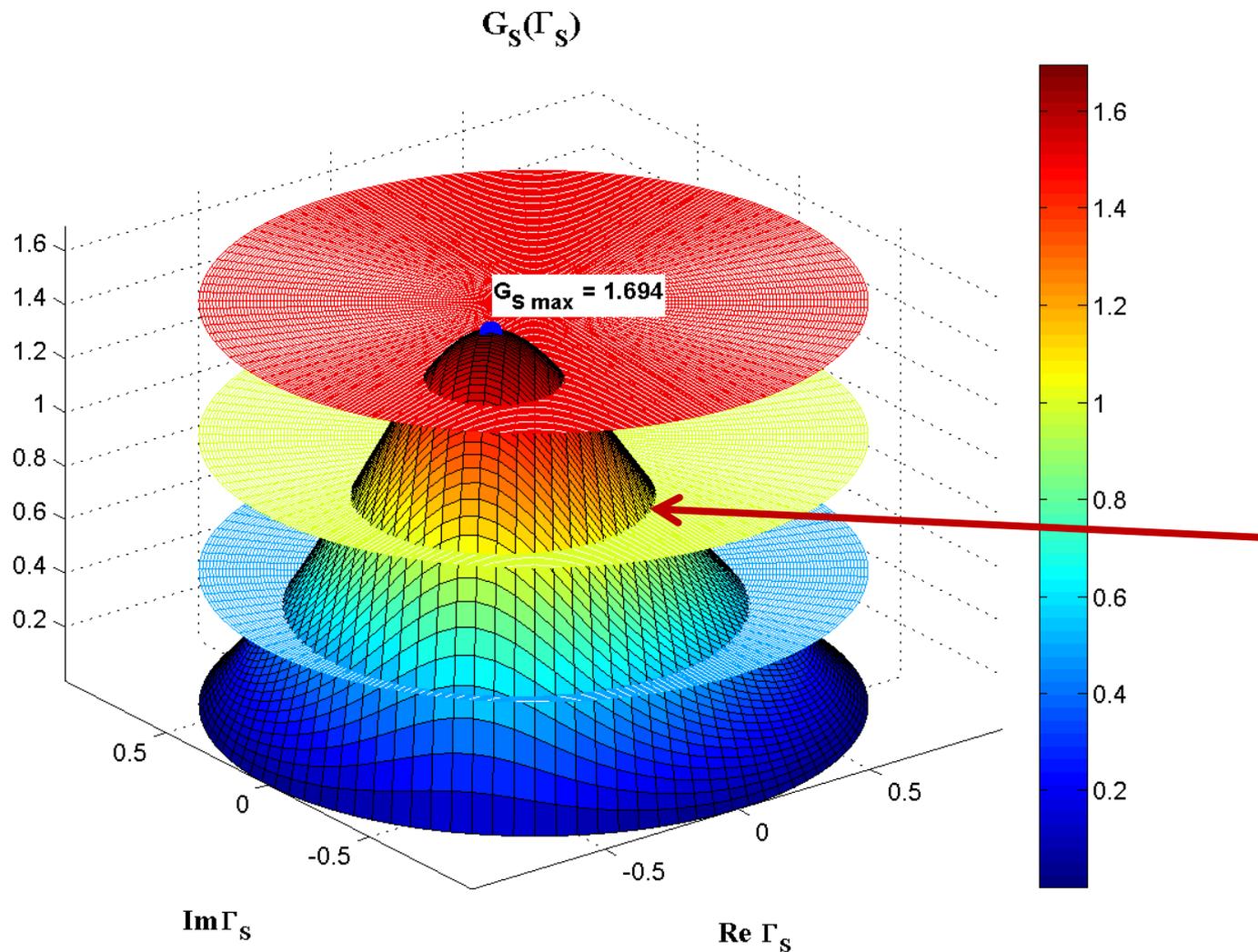
$$G_{S \text{ max}} = \frac{1}{1 - |S_{11}|^2} = 1.694 = 2.289 \text{ dB}$$

$G_S(\Gamma_S)$



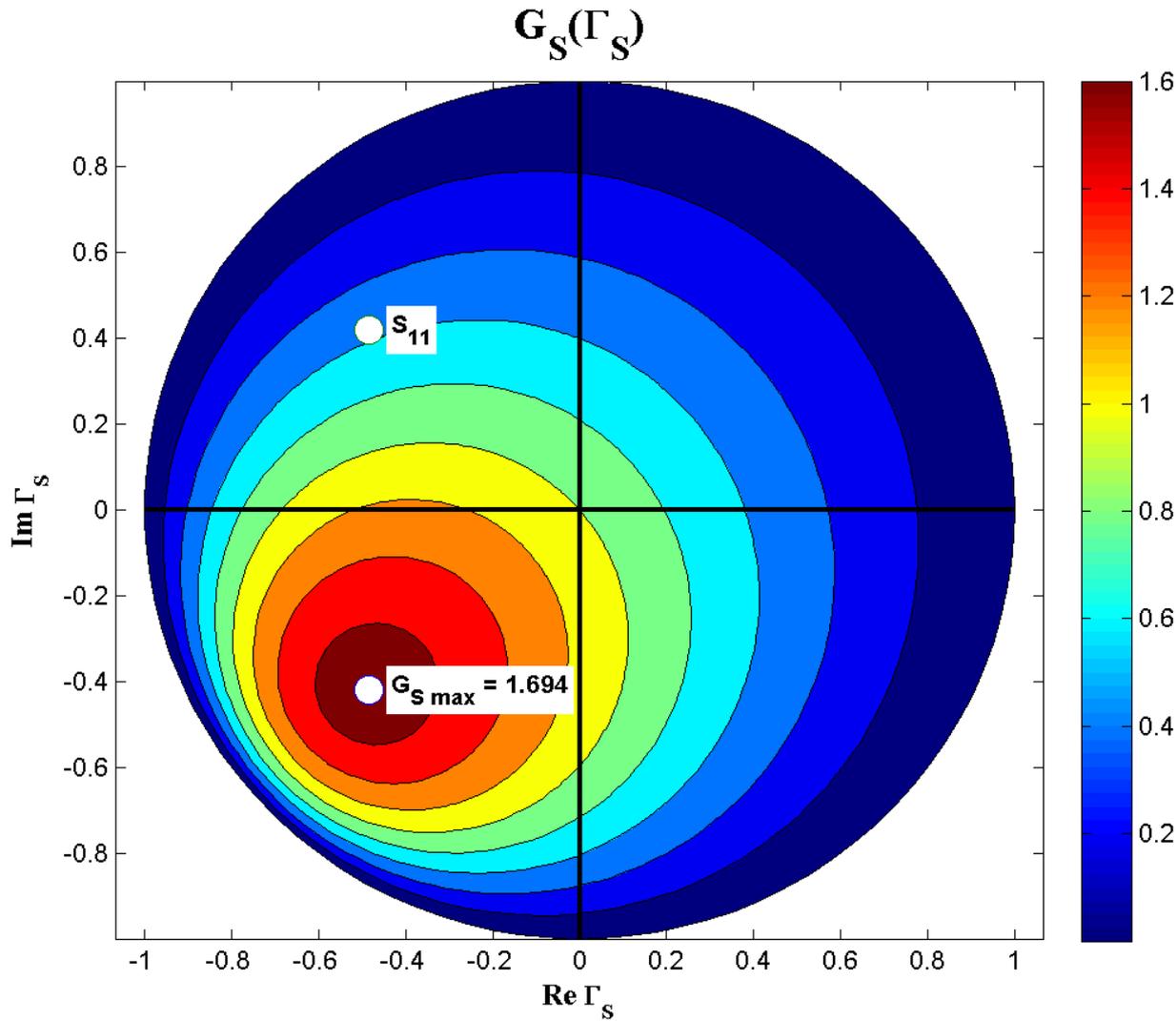
$$G_S = \frac{1 - |\Gamma_S|^2}{|1 - S_{11} \cdot \Gamma_S|^2}$$

$G_S(\Gamma_S)$, nivel constant



$G_S = 1.5$
 $G_S = 1.0$
 $G_S = 0.5$
Cercuri

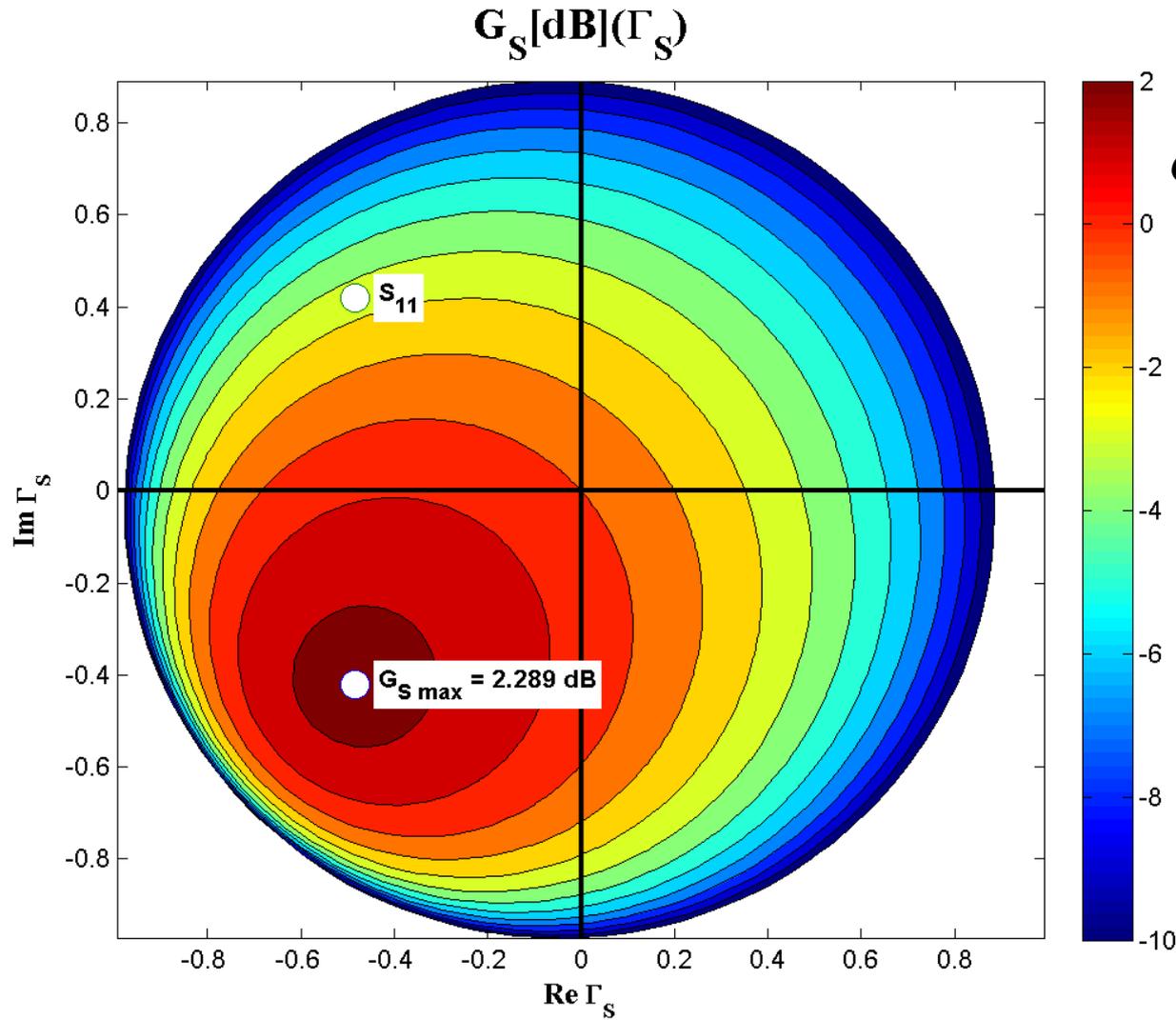
$G_S(\Gamma_S)$, diagrama de nivel



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

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

$G_S[dB](\Gamma_S)$, 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

- Castig normal (coordonate liniare)

$$g_S = \frac{G_S}{G_{S_{\max}}} = \frac{1 - |\Gamma_S|^2}{|1 - S_{11} \cdot \Gamma_S|^2} \cdot (1 - |S_{11}|^2) < 1$$

- Punctele de nivel constant, pentru un $g_S < 1$ fixat

$$\begin{aligned} g_S \cdot |1 - S_{11} \cdot \Gamma_S|^2 &= (1 - |\Gamma_S|^2) \cdot (1 - |S_{11}|^2) \\ (g_S \cdot |S_{11}|^2 + 1 - |S_{11}|^2) \cdot |\Gamma_S|^2 - g_S \cdot (S_{11} \cdot \Gamma_S + S_{11}^* \cdot \Gamma_S^*) &= 1 - |S_{11}|^2 - g_S \\ \Gamma_S \cdot \Gamma_S^* - \frac{g_S \cdot (S_{11} \cdot \Gamma_S + S_{11}^* \cdot \Gamma_S^*)}{1 - (1 - g_S) \cdot |S_{11}|^2} &= \frac{1 - |S_{11}|^2 - g_S}{1 - (1 - g_S) \cdot |S_{11}|^2} \Bigg/ + \frac{g_S^2 \cdot |S_{11}|^2}{[1 - (1 - g_S) \cdot |S_{11}|^2]^2} \end{aligned}$$

Cercuri de castig constant la intrare

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

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

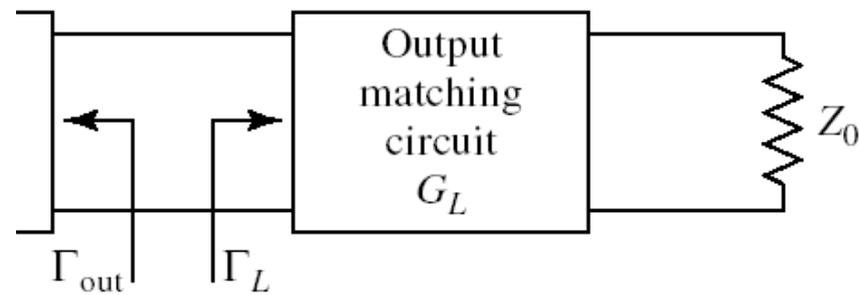
- Ecuatia unui cerc in planul complex in care reprezinta Γ_S
- **Interpretare:** Orice punct Γ_S care este reprezentat in planul complex se gaseste **pe** cercul desenat pentru $g_{\text{cerc}} = G_{\text{cerc}}/G_{S_{\text{max}}}$ va conduce la obtinerea castigului $G_S = G_{\text{cerc}}$
 - Orice punct **in exteriorul** acestui cerc va genera un castig $G_S < G_{\text{cerc}}$
 - Orice punct **in interiorul** acestui cerc va genera un castig $G_S > G_{\text{cerc}}$

Cercuri de castig constant la intrare

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

- Centrele cercurilor se gasesc pe segmentul care uneste $\Gamma_S = S_{11}^*$ cu centrul diagramei Smith
- Cercurile se traseaza (traditional, CAD) in **coordonate logaritmice** ([dB])
 - relatiile de calcul sunt in coordonate **liniare** !
- Cercul corespunzator lui $g_S = 0$ dB trece prin origine

Cercuri de castig constant la iesire



$$G_L = \frac{1 - |\Gamma_L|^2}{|1 - S_{22} \cdot \Gamma_L|^2}$$

- Castig maxim $\Gamma_L = S_{22}^* \Rightarrow G_{L\max} = \frac{1}{1 - |S_{22}|^2}$

$$g_L = \frac{G_L}{G_{L\max}} = \frac{1 - |\Gamma_L|^2}{|1 - S_{22} \cdot \Gamma_L|^2} \cdot (1 - |S_{22}|^2) < 1$$

- Calcul similar

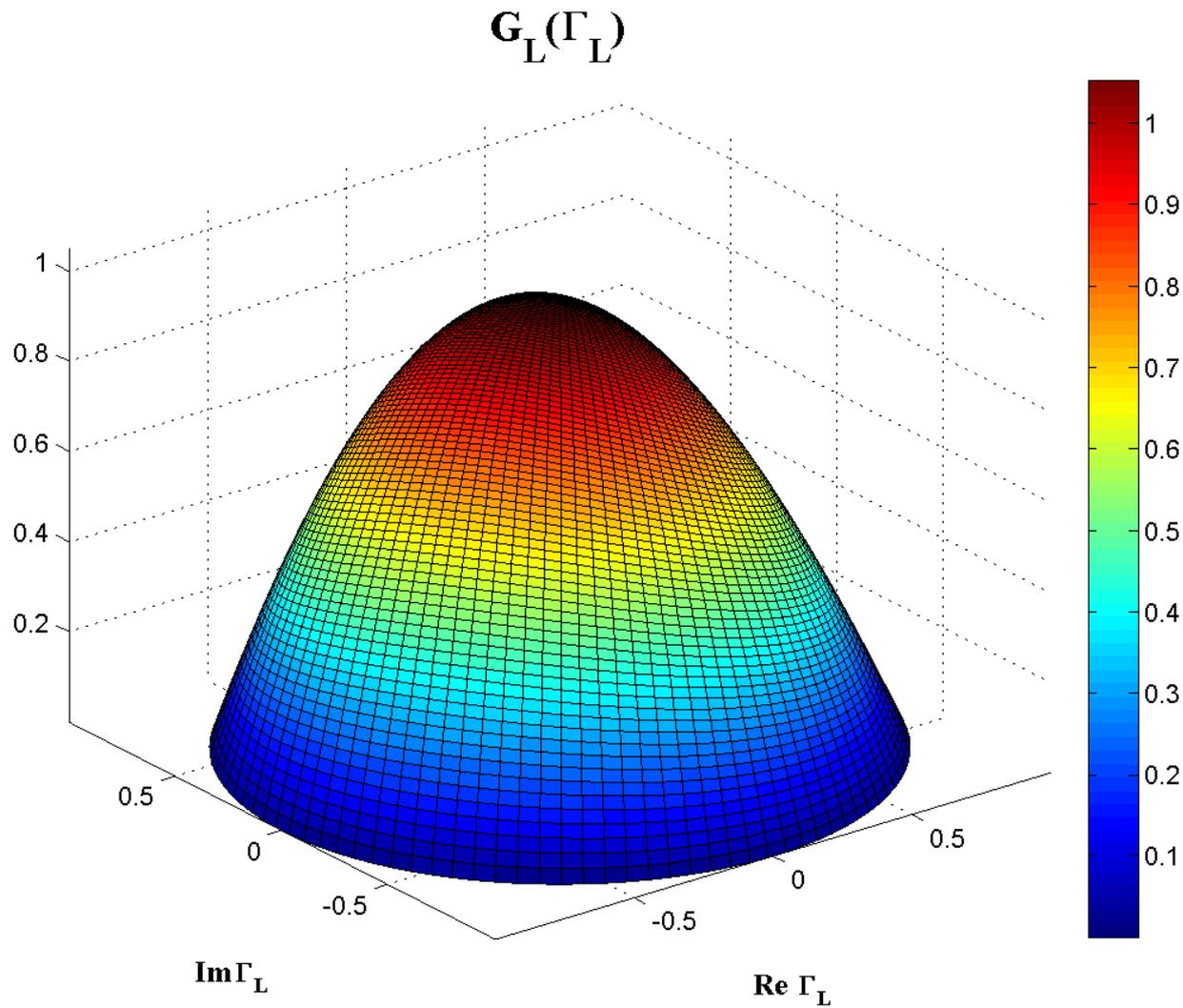
$$C_L = \frac{g_L \cdot S_{22}^*}{1 - (1 - g_L) \cdot |S_{22}|^2}$$

$$R_L = \frac{\sqrt{1 - g_L} \cdot (1 - |S_{22}|^2)}{1 - (1 - g_L) \cdot |S_{22}|^2}$$

- Exemplu

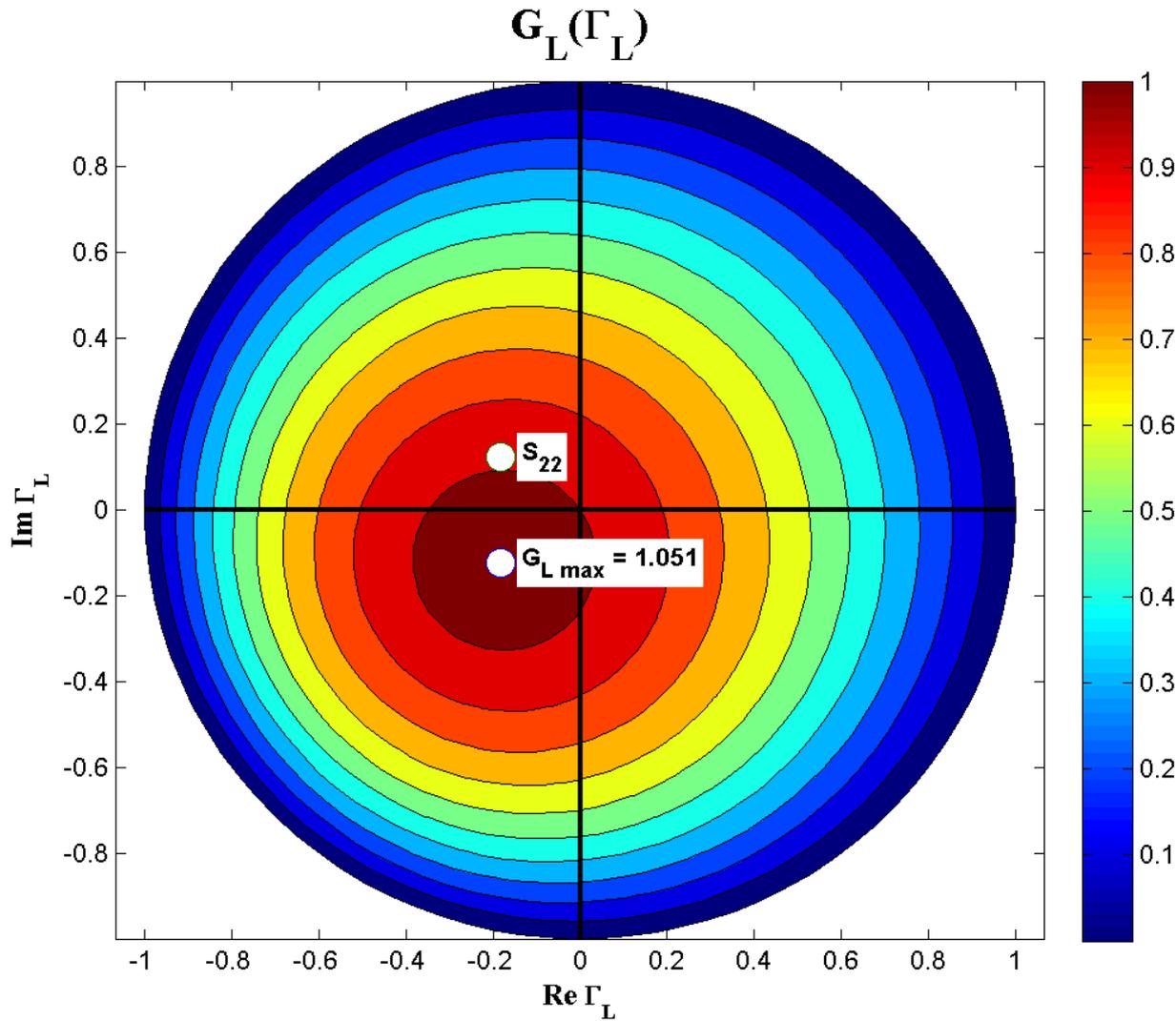
$$G_{L\max} = \frac{1}{1 - |S_{22}|^2} = 1.051 = 0.215 \text{ dB}$$

$G_L(\Gamma_L)$



$$G_L = \frac{1 - |\Gamma_L|^2}{|1 - S_{22} \cdot \Gamma_L|^2}$$

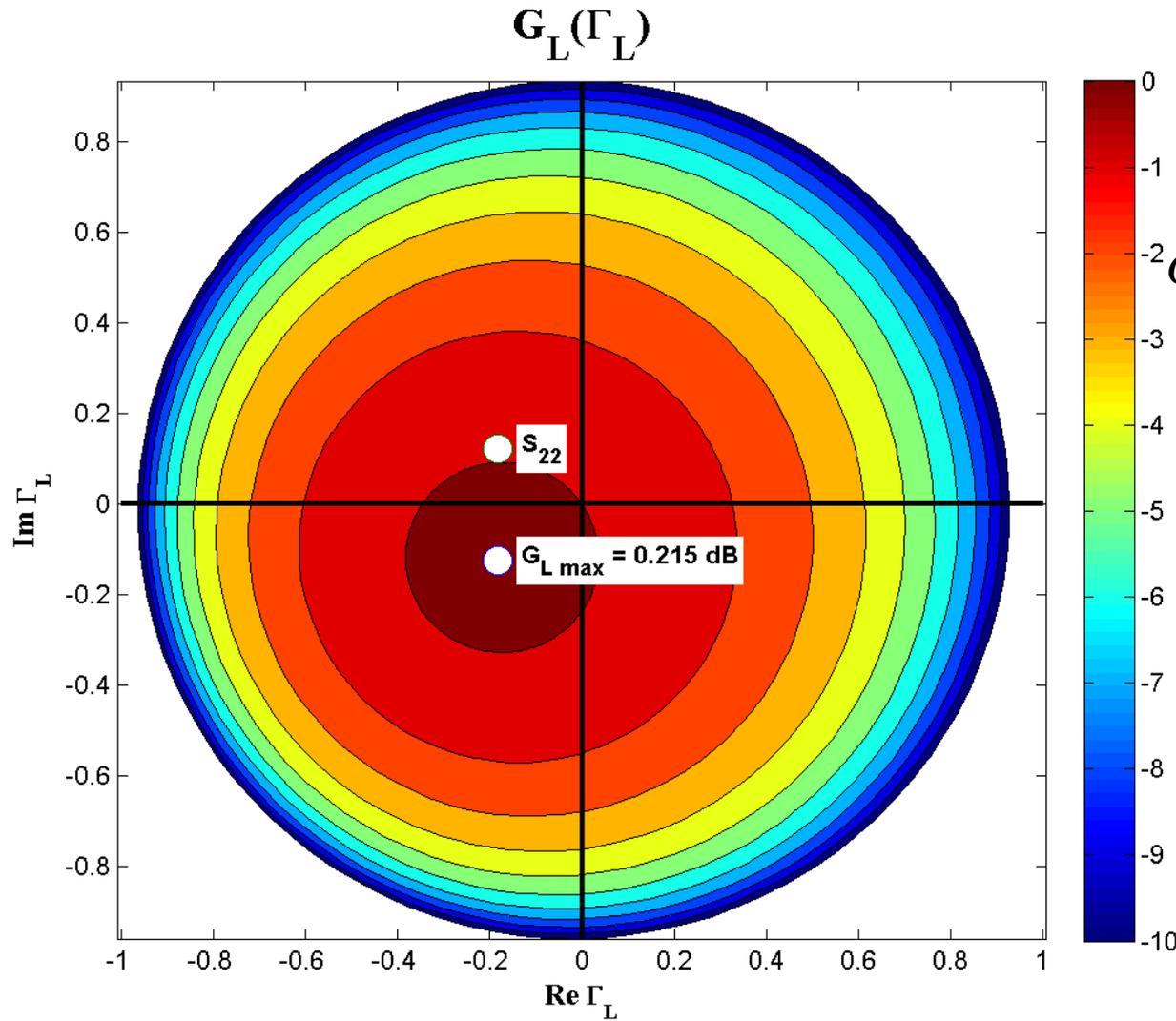
$G_L(\Gamma_L)$, diagrama de nivel



$$G_L = \frac{1 - |\Gamma_L|^2}{|1 - S_{22} \cdot \Gamma_L|^2}$$

$$G_{L\max} = G_L \Big|_{\Gamma_L = S_{22}^*}$$

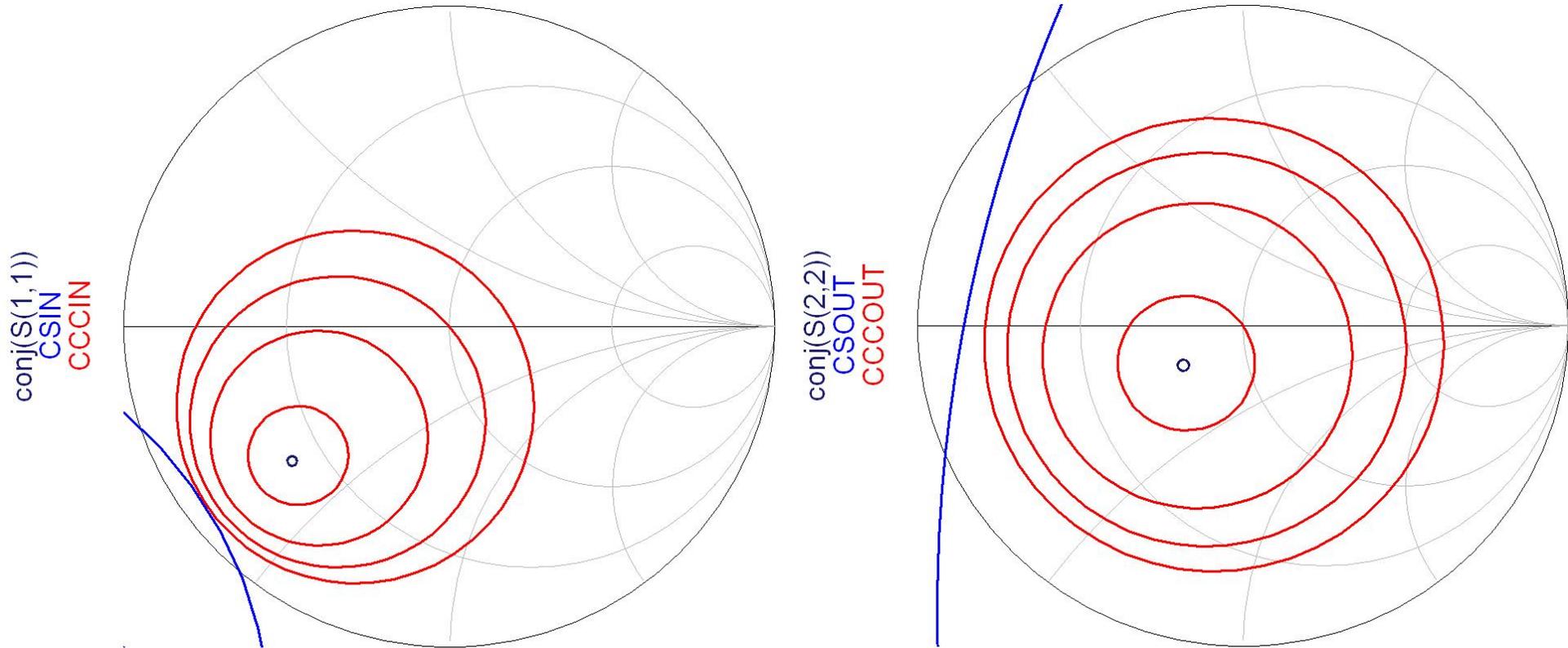
$G_L[\text{dB}](\Gamma_L)$, diagrama de nivel



$$G_L[\text{dB}] = 10 \cdot \log \left(\frac{1 - |\Gamma_L|^2}{|1 - S_{22} \cdot \Gamma_L|^2} \right)$$

$$G_{L \text{ max}} = G_L \Big|_{\Gamma_L = S_{22}^*}$$

ADS



- Cercurile se reprezinta pentru valorile cerute in dB
- Este utila calcularea $G_{S_{\max}}$ si $G_{L_{\max}}$ anterior

Proiectare pentru castig impus

- Se calculeaza G_o , $G_{S_{max}}$, $G_{L_{max}}$
- Pentru obtinerea castigului impus se **aleg** valorile suplimentare necesare (suplimentar la G_o)
 - se tine cont de abaterea caracterizata de factorul de merit U

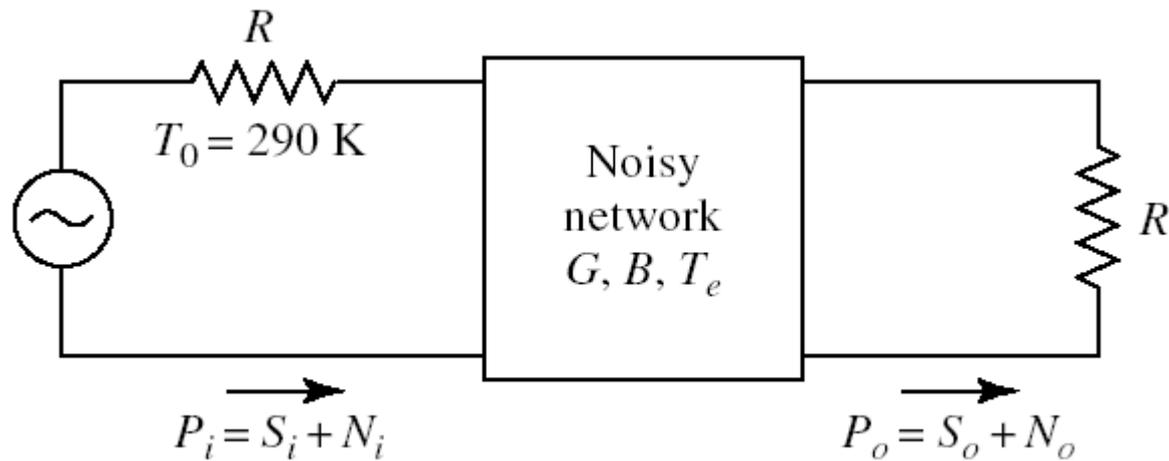
$$G_{dorit} [dB] = G_{S_dorit} [dB] + G_o [dB] + G_{L_dorit} [dB]$$

- Se reprezinta cercurile de castig pentru valorile alese G_{S_dorit} , G_{L_dorit}
- Se proiecteaza retelele de adaptare care muta coeficientul de reflexie **pe** sau **in interiorul** cercurilor dorite (in functie de aplicatie)

Proiectare pentru zgomot redus

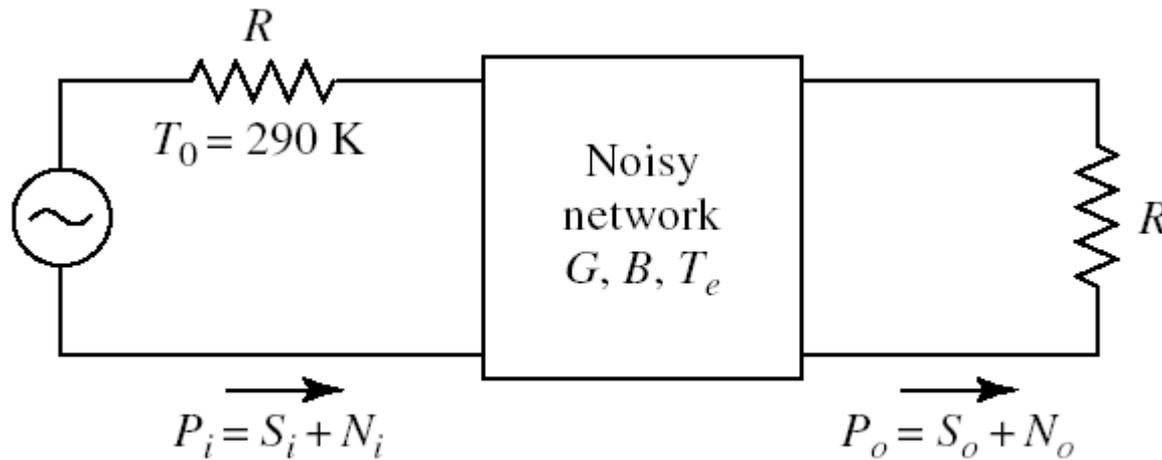
Amplificatoare de microunde

Factor de zgomot



- O componenta poate fi caracterizata dpdv al zgomotului prin:
 - putere de zgomot
 - temperatura echivalenta de zgomot T_N
 - factor de zgomot F

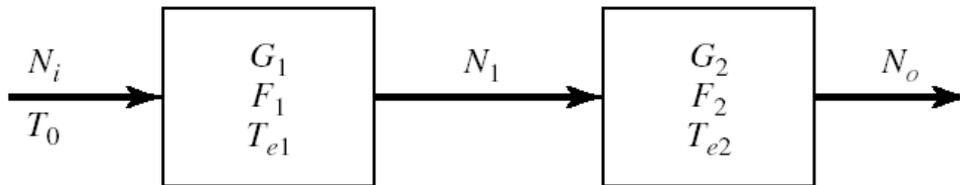
Factor de zgomot



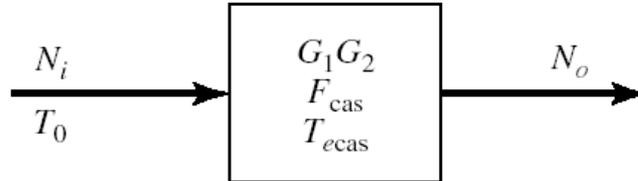
- Factorul de zgomot F caracterizeaza degradarea raportului semnal/zgomot intre intrarea si iesirea unei componente

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

Factor de zgomot al circuitelor cascade



(a)



(b)

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

■ Ecuatia Friis

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

Zgomotul unui amplificator

- Caracterizat de $F_{\min}, r_N = \frac{R_N}{Z_0}, \Gamma_{opt}$

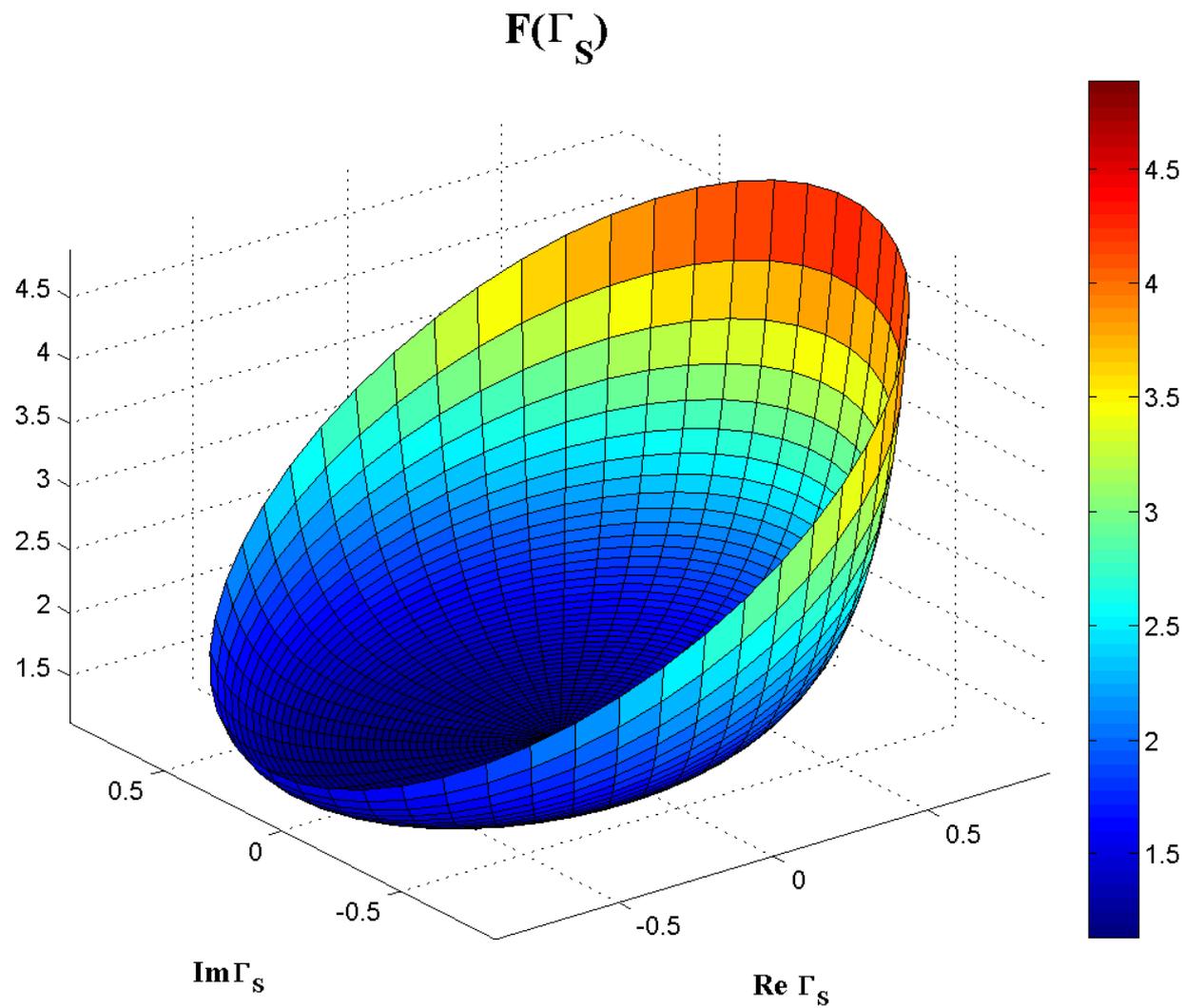
$$F = F_{\min} + \frac{R_N}{G_S} \cdot |Y_S - Y_{opt}|^2$$

$$F = F_{\min} + 4 \cdot r_n \cdot \frac{|\Gamma_S - \Gamma_{opt}|^2}{(1 - |\Gamma_S|^2) \cdot |1 + \Gamma_{opt}|^2}$$

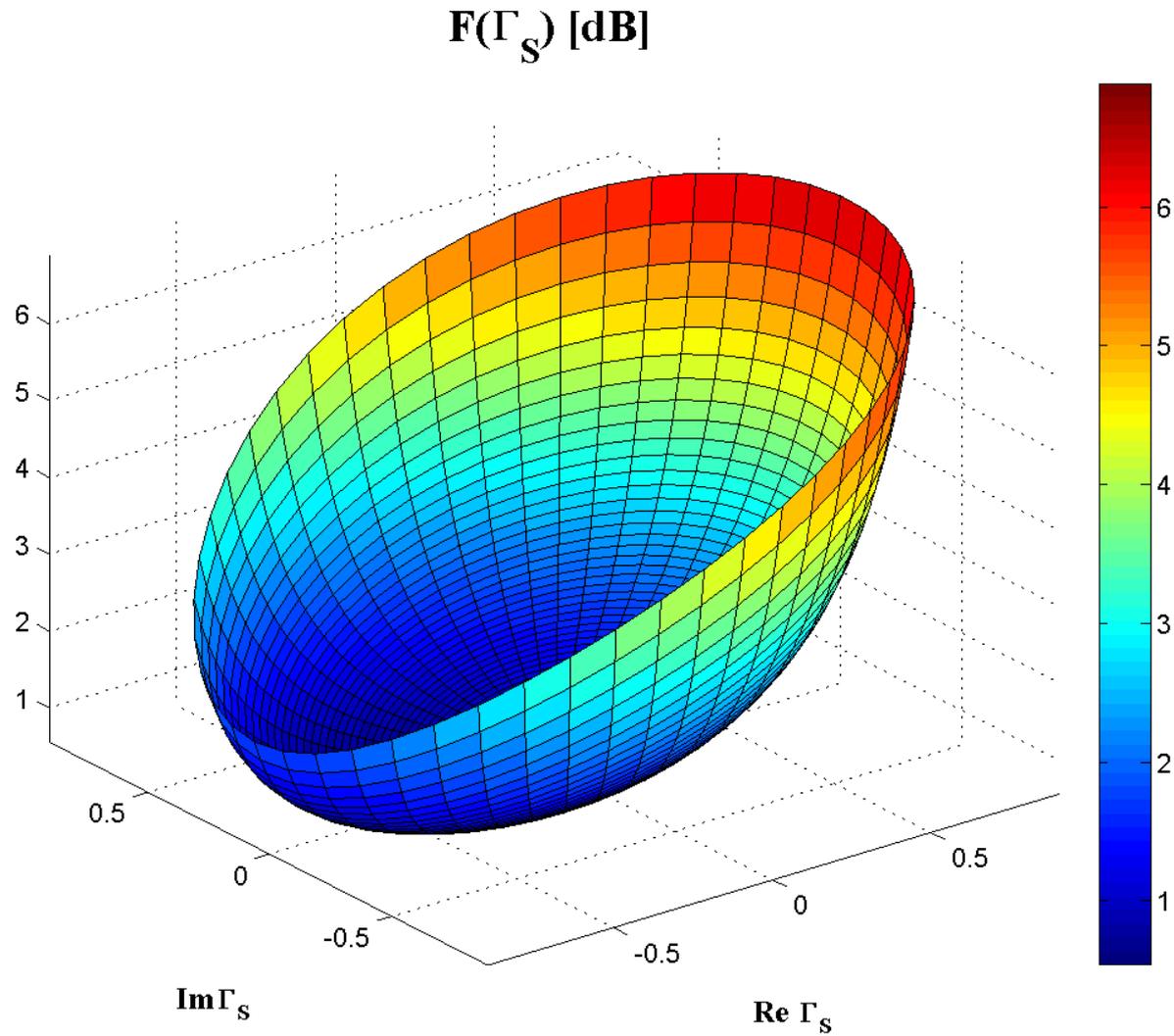
Exemplu

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- @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] !**)
 - $\Gamma_{opt} = 0.45 \angle 174^\circ$
 - $r_n = 0.03$

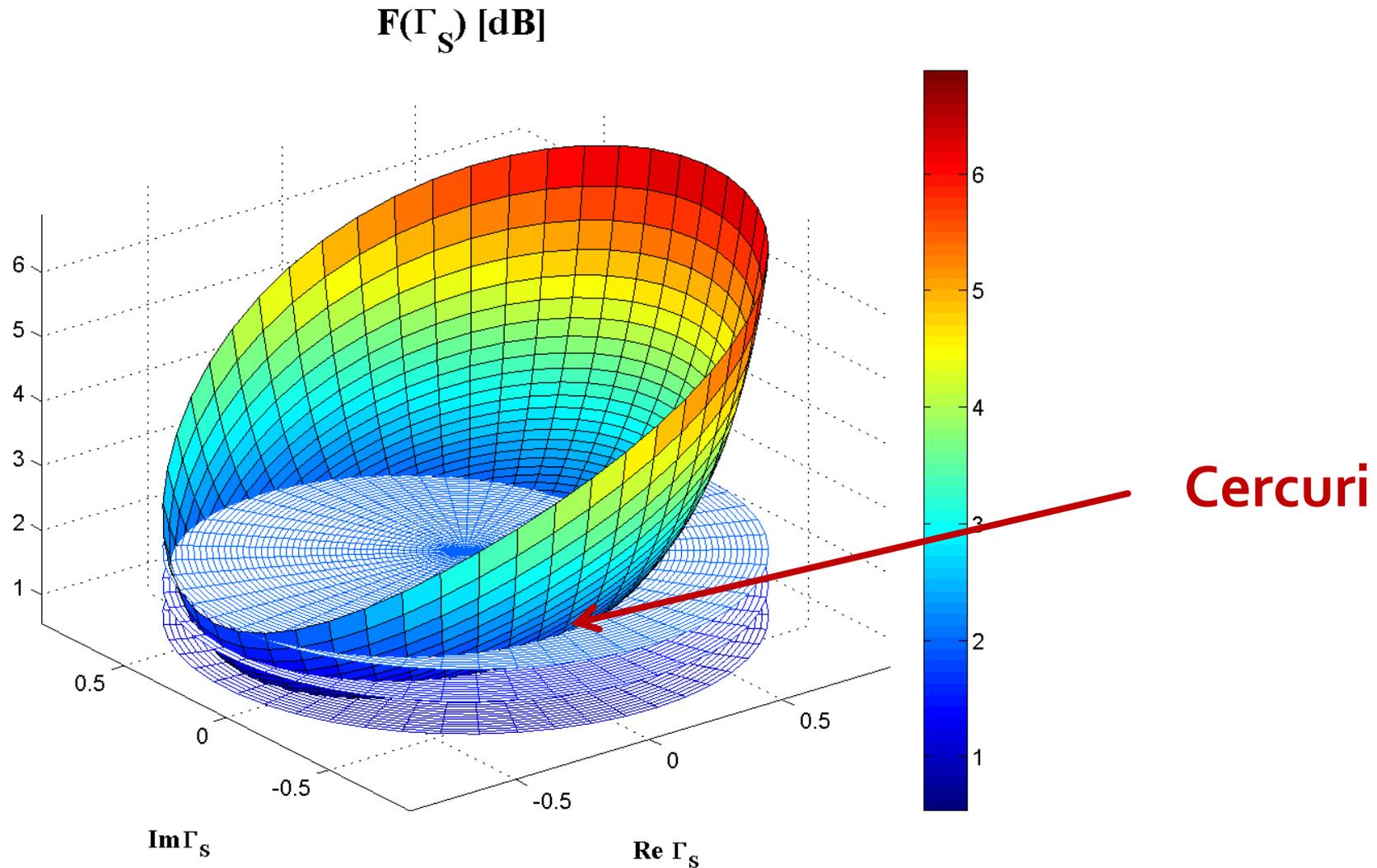
$F(\Gamma_S)$



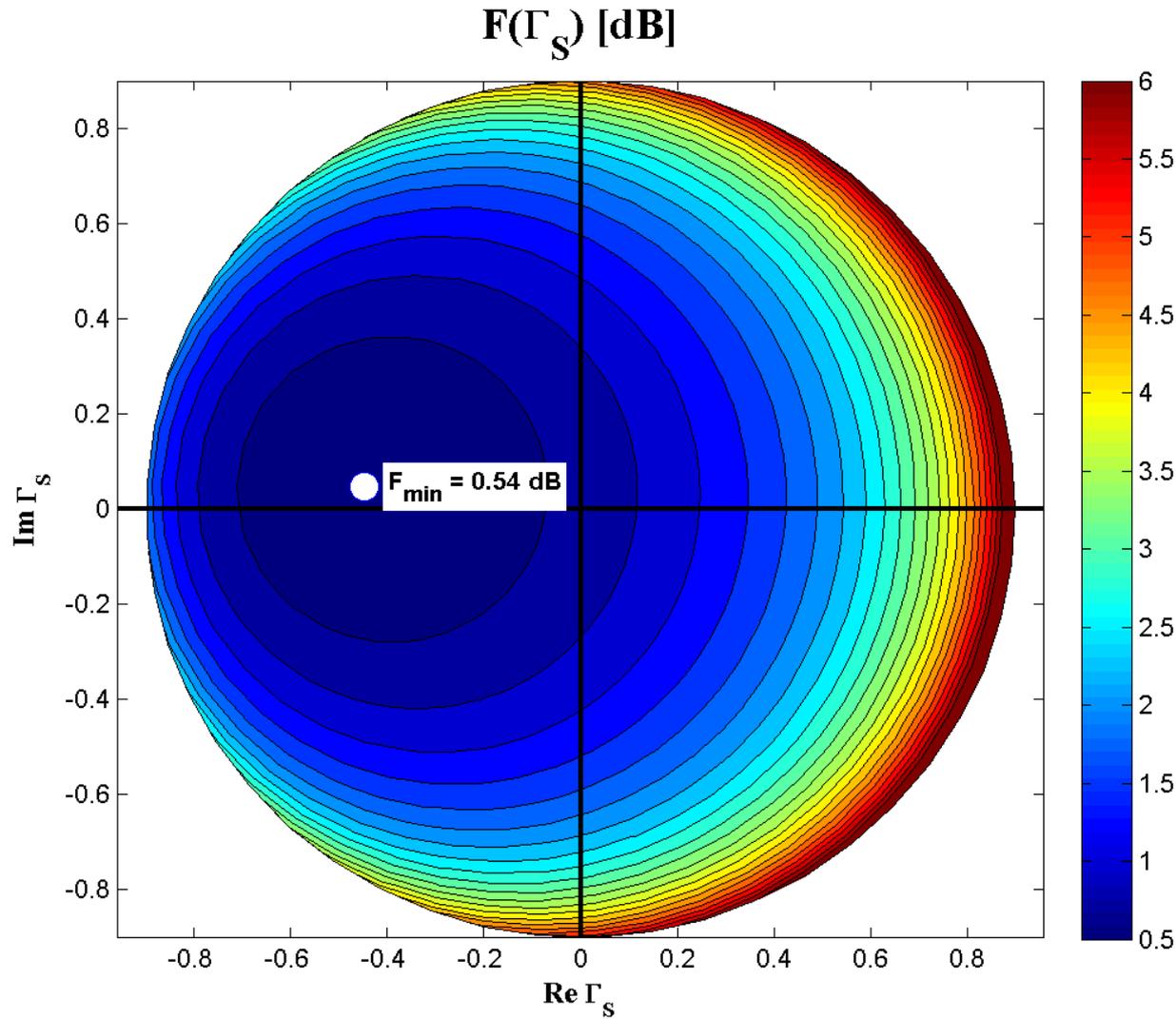
$F[\text{dB}](\Gamma_S)$



$F[\text{dB}](\Gamma_s)$, diagrama de nivel

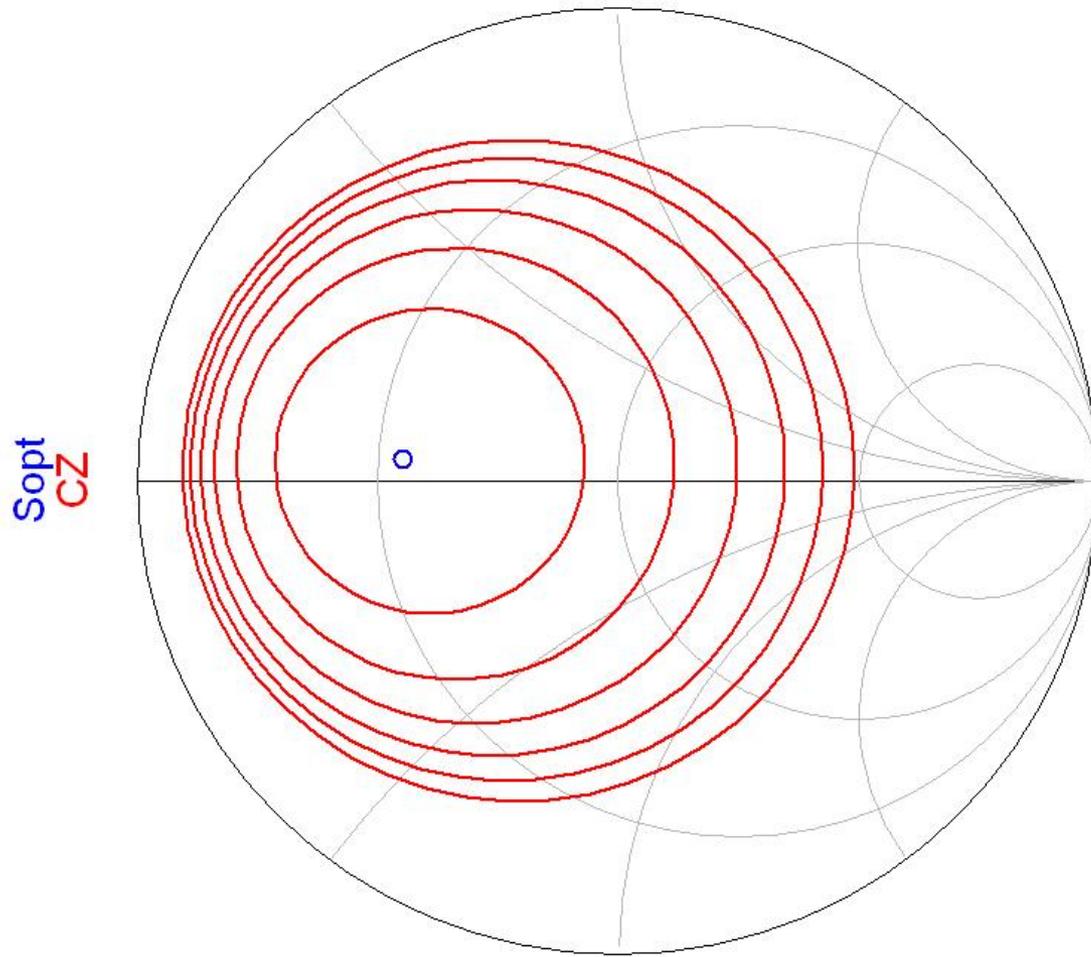


$G_S[\text{dB}](\Gamma_S)$, diagrama de nivel



$$\Gamma_{\text{opt}} = 0.45 \angle 174^\circ$$

ADS



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

Contact

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- rdamian@etti.tuiasi.ro