

Curs 9
2018/2019

Dispozitive și circuite de microunde pentru radiocomunicații

Disciplina 2018/2019

- 2C/1L, DCMR (CDM)
- Minim 7 prezente (curs+laborator)
- Curs - conf. Radu Damian
 - Vineri 11-13, P7
 - E – 50% din nota
 - probleme + (2p prez. curs) + (3 **teste**) + (bonus activitate)
 - 3pz=+0.5p
 - toate materialele permise
- Laborator – conf. Radu Damian
 - Joi 8-14 impar II.13
 - L – 25% din nota
 - P – 25% din nota

Documentatie

■ <http://rf-opto.etti.tuiasi.ro>

Laboratorul de Microunde si Optică

Not secure | rf-opto.etti.tuiasi.ro/microwave_cd.php?chg_lang=1

RF-OPTO

Universitatea Tehnică "Gheorghe Asachi" din Iași

English | Romana

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Microunde Comunicatii Optice Optoelectronica Internet Antene Practica Retele Soft didactic

Dispozitive si circuite de microunde pentru radiocomunicatii

Disciplina: DCMR (2017-2018)

Coordinator Disciplina: conf. dr. Radu-Florin Damian

Cod: DOS412T

Tip Disciplina: DOS; Disciplina Optionala, Disciplina de Specialitate

Credite: 4

An de Studiu: 4, Sem. 7

Activitati

Curs: Cadru Didactic: conf. dr. Radu-Florin Damian, 2 Ore/Saptamana, Sectie Specializare, Orar:

Laborator: Cadru Didactic: conf. dr. Radu-Florin Damian, 1 Ore/Saptamana, Grupa, Orar:

Evaluare

Tip: Examen

A: 50%, (Examen/Colocviu)

B: 25%, (Activitate Seminar/Laborator/Proiect)

D: 25%, (Teme de casa/Lucrari de specialitate)

Note

[Rezultate totale](#)

Prezenta

[Curs](#)

[Laborator](#)

Liste

[Bonus-uri acumulate \(final\)](#)

[Studenti care nu pot intra in examen](#)

Examen: Reprezentare logaritmică

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Examen

- Operatii cu numere complexe!
- $z = a + j \cdot b ; j^2 = -1$

Adaptarea de impedanță

Adaptare dpdv al puterii

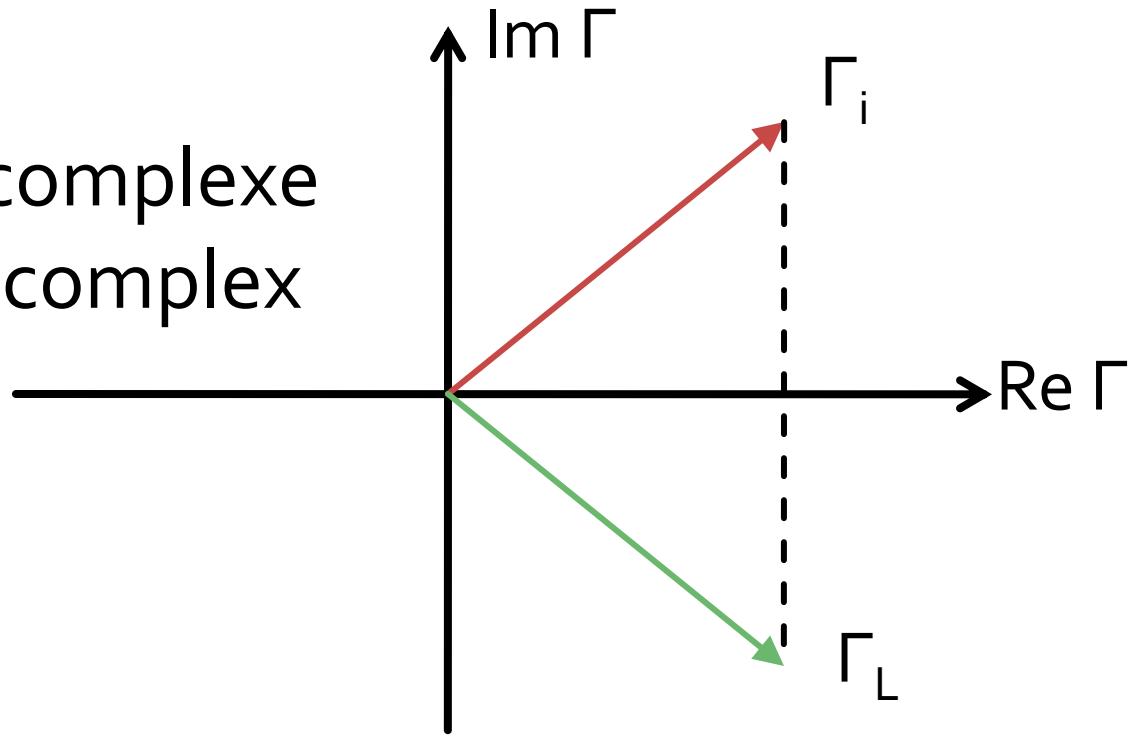
$$Z_L = Z_i^*$$

Daca se alege un Z_0 real

$$\Gamma = \frac{Z - Z_0}{Z + Z_0}$$

$$\Gamma_L = \Gamma_i^*$$

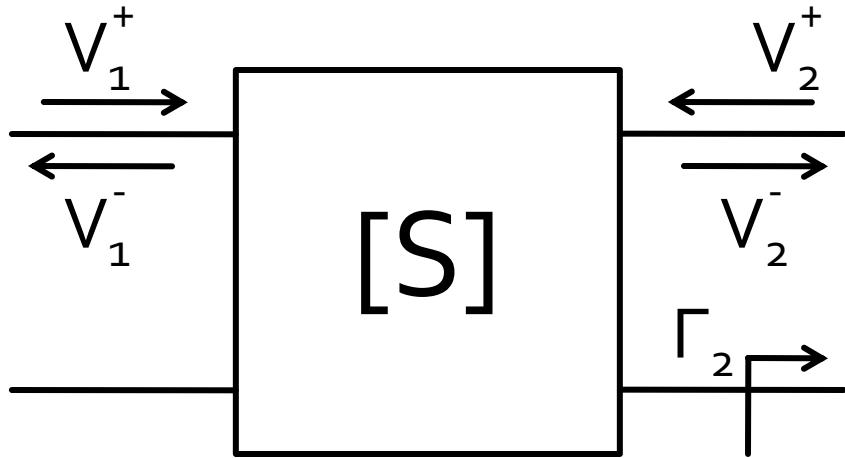
- numere complexe
- in planul complex



**Analiza la nivel de rețea a
circuitelor de microunde**

Matricea S (repartitie)

- Scattering parameters



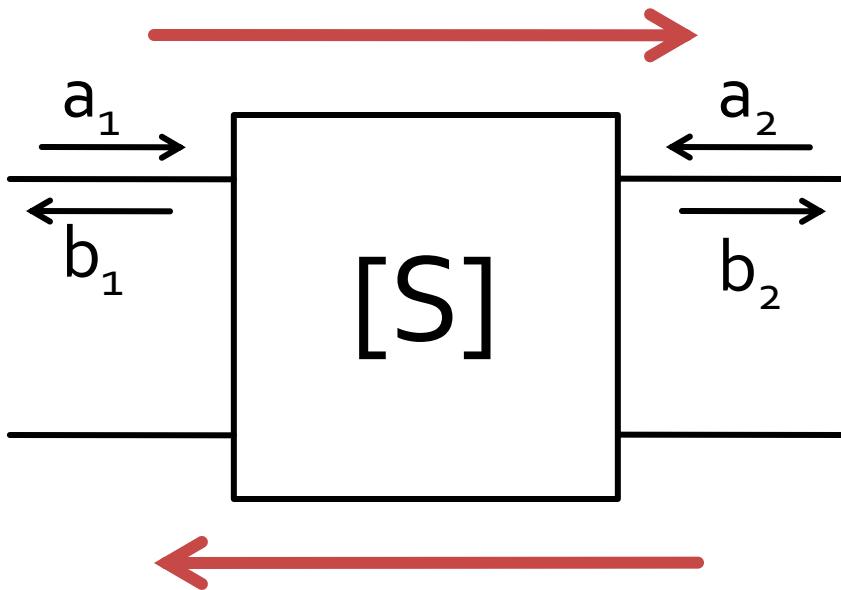
$$\begin{bmatrix} V_1^- \\ V_2^- \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} V_1^+ \\ V_2^+ \end{bmatrix}$$

$$S_{11} = \frac{V_1^-}{V_1^+} \Big|_{V_1^+=0} \quad S_{21} = \frac{V_2^-}{V_1^+} \Big|_{V_2^+=0}$$

- $V_2^+ = 0$ are semnificatia: la portul 2 este conectata impedanta care realizeaza conditia de adaptare (complex conjugat)

$$\Gamma_2 = 0 \rightarrow V_2^+ = 0$$

Matricea S (repartitie)



$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

$$|S_{21}|^2 = \frac{\text{Putere sarcina } Z_0}{\text{Putere sursa } Z_0}$$

- a,b
 - informatia despre putere **SI** faza
- S_{ij}
 - influenta circuitului asupra puterii semnalului incluzand informatiile relativ la faza

Adaptarea de impedanță

Diagrama Smith

Diagrama Smith

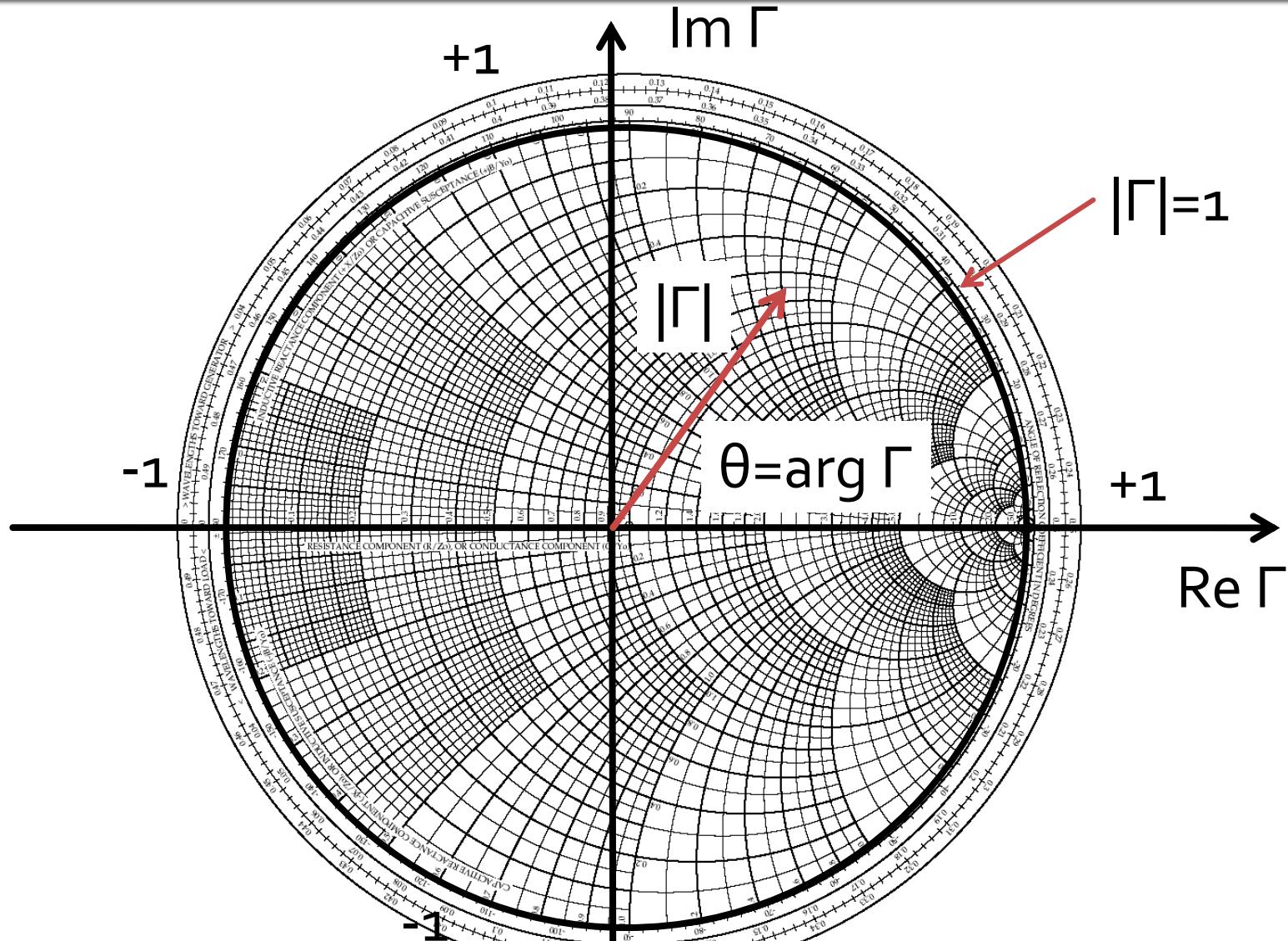
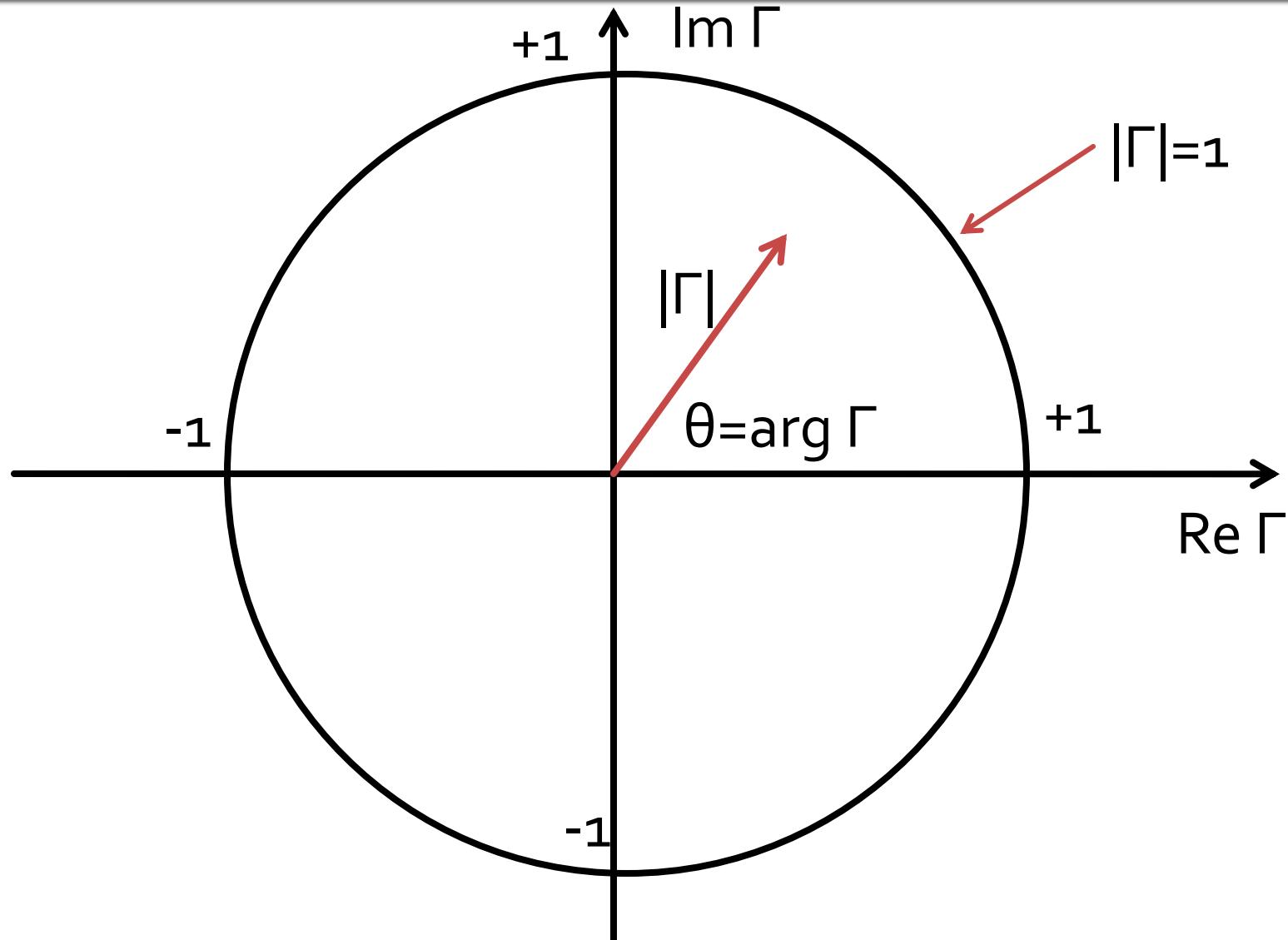


Diagrama Smith

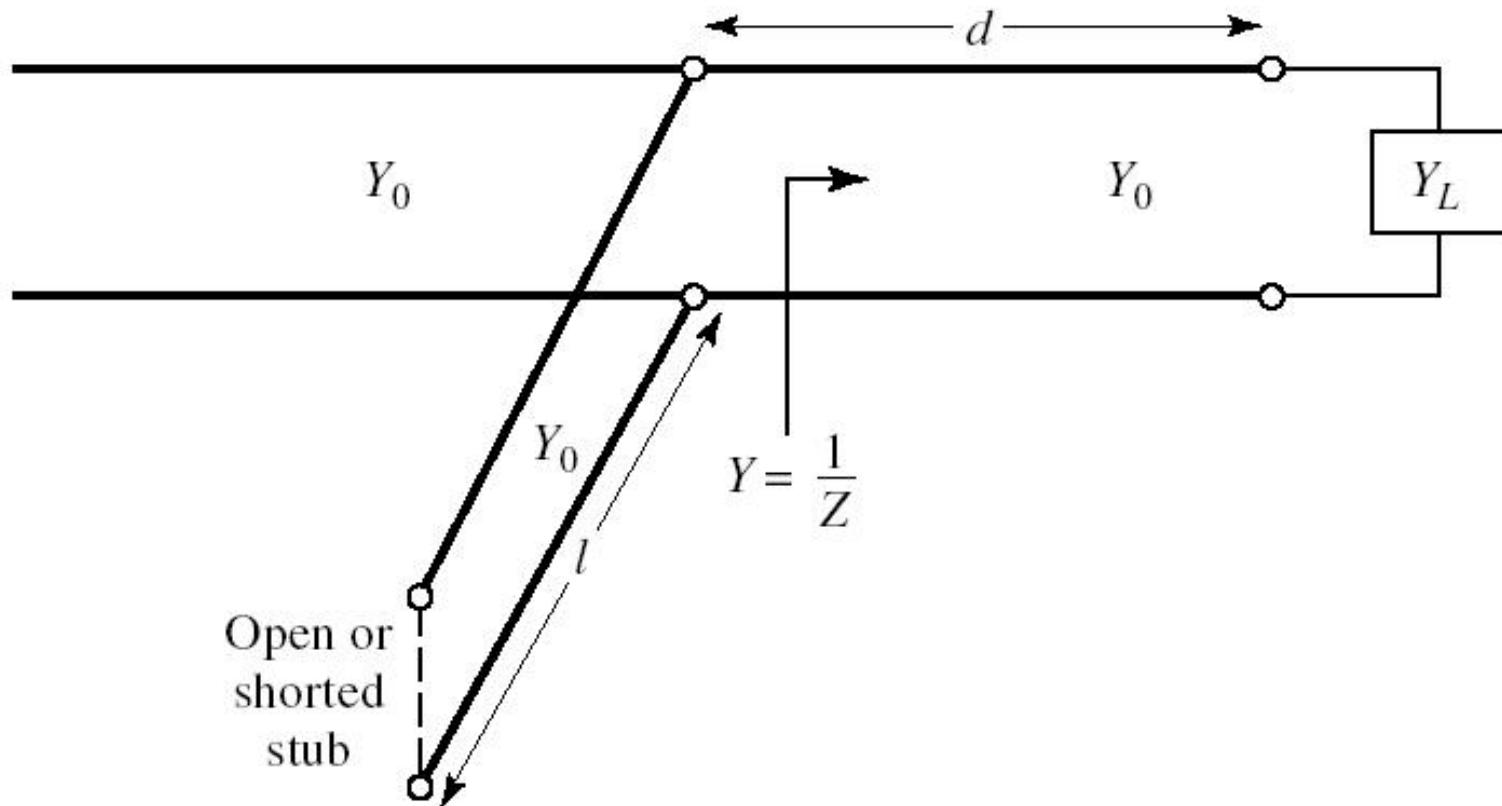


Adaptarea cu sectiuni de linii (stub)

Adaptarea de impedanță

Single stub tuning

- Shunt Stub (secțiune de linie în paralel)



Single stub tuning

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

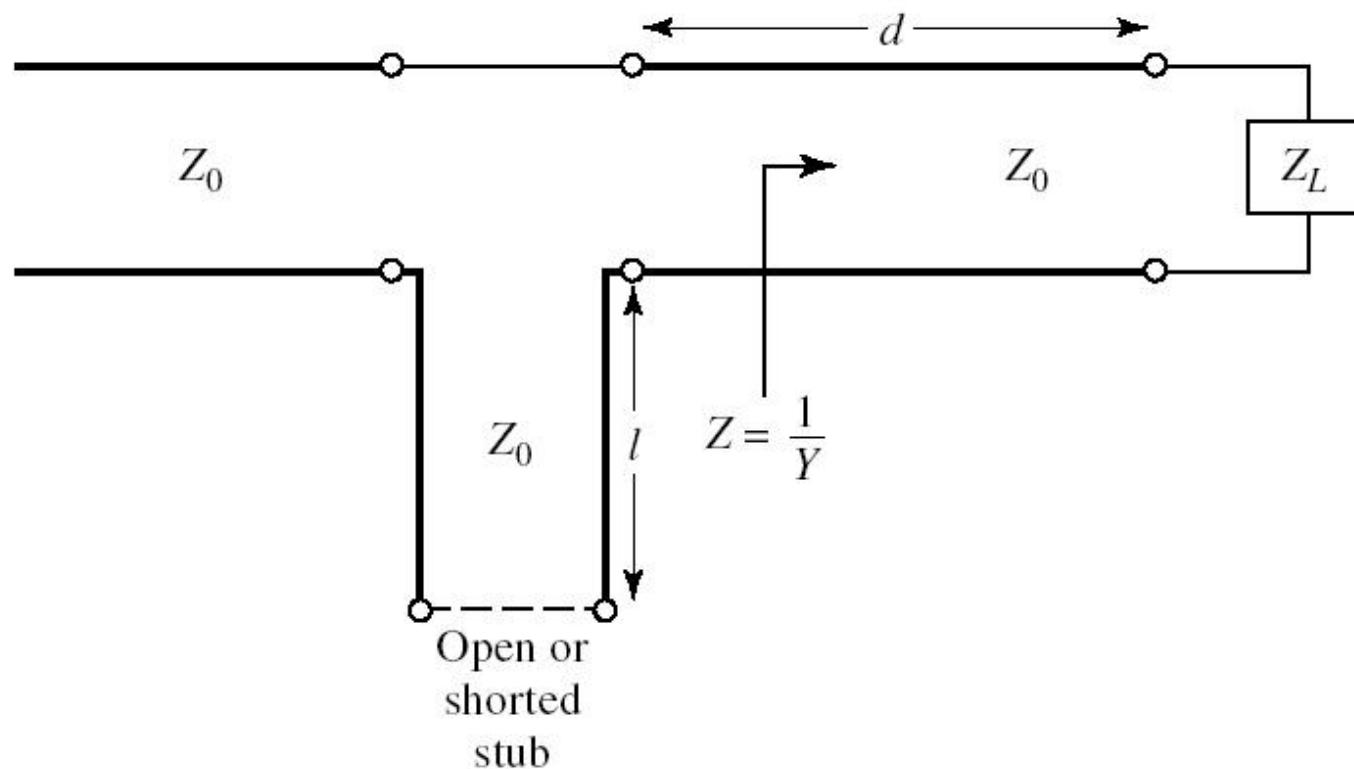
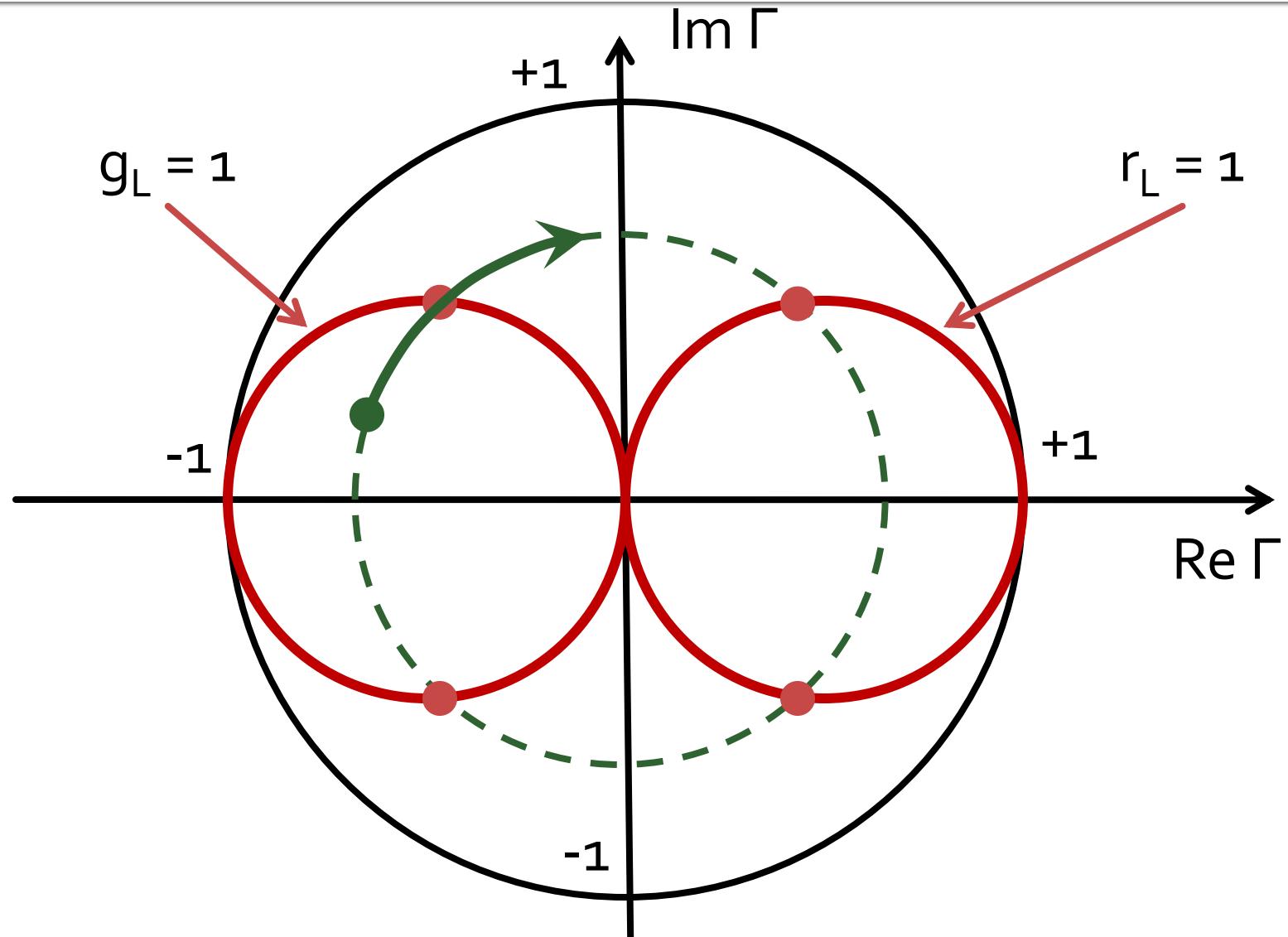
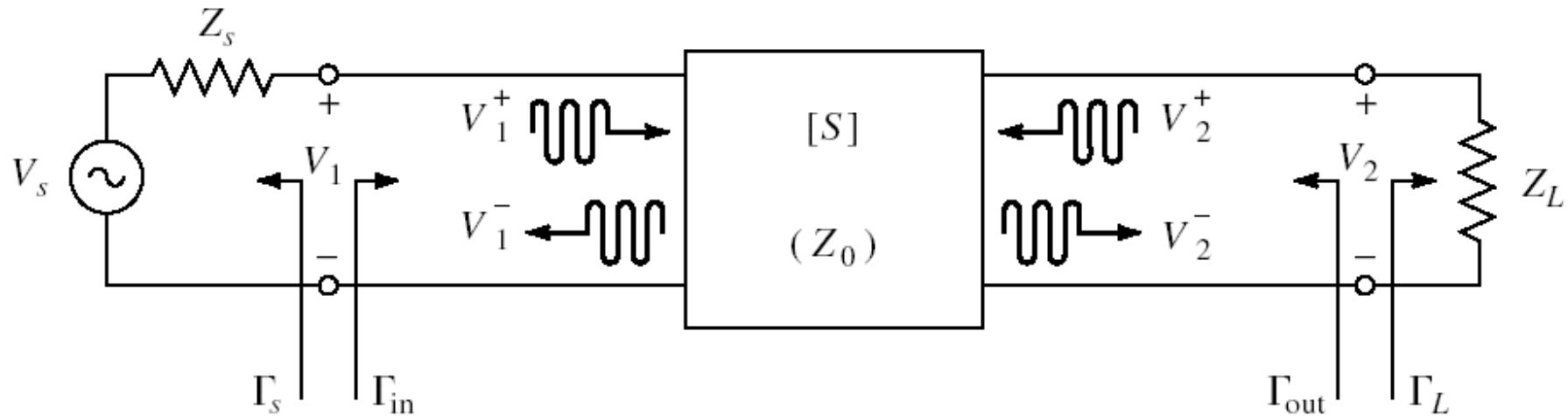


Diagrama Smith, $r=1$ si $g=1$



Amplificatoare de microunde

Cuadripol Amplificator (diport)



- Caracterizare cu parametri S
- Normalizati la Z_0 (implicit 50Ω)
- Catalogage: parametri S pentru anumite polarizari

Catalogage

NE46100

VCE = 5 V, Ic = 50 mA

FREQUENCY (MHz)	S ₁₁		S ₂₁		S ₁₂		S ₂₂		K	MAG ² (dB)
	MAG	ANG	MAG	ANG	MAG	ANG	MAG	ANG		
100	0.778	-137	26.776	114	0.028	30	0.555	-102	0.16	29.8
200	0.815	-159	14.407	100	0.035	29	0.434	-135	0.36	26.2
500	0.826	-177	5.855	84	0.040	38	0.400	-162	0.75	21.7
800	0.827	176	3.682	76	0.052	43	0.402	-169	0.91	18.5
1000	0.826	173	2.963	71	0.058	47	0.405	-172	1.02	16.3
1200	0.825	170	2.441	66	0.064	47	0.412	-174	1.08	14.0
1400	0.820	167	2.111	61	0.069	47	0.413	-176	1.17	12.4
1600	0.828	165	1.863	57	0.078	54	0.426	-177	1.15	11.4
1800	0.827	162	1.671	53	0.087	50	0.432	-178	1.14	10.6
2000	0.828	159	1.484	49	0.093	50	0.431	-180	1.17	9.5
2500	0.822	153	1.218	39	0.11	48	0.462	177	1.18	7.8
3000	0.818	148	1.010	30	0.135	46	0.490	174	1.16	6.3
3500	0.824	142	0.876	21	0.147	44	0.507	170	1.16	5.3
4000	0.812	137	0.762	13	0.168	38	0.535	167	1.14	4.3

VCE = 5 V, Ic = 100 mA

100	0.778	-144	27.669	111	0.027	35	0.523	-114	0.27	30.2
200	0.820	-164	14.559	97	0.029	29	0.445	-144	0.42	27.0
500	0.832	-179	5.885	84	0.035	38	0.435	-166	0.81	22.2
800	0.833	175	3.691	76	0.048	45	0.435	-173	0.95	18.8
1000	0.831	172	2.980	71	0.056	51	0.437	-176	1.05	16.0
1200	0.836	169	2.464	67	0.061	52	0.432	-178	1.11	14.0
1400	0.829	166	2.121	61	0.072	53	0.447	-180	1.12	12.6
1600	0.831	164	1.867	58	0.080	54	0.445	179	1.14	11.4

S₂P - Touchstone

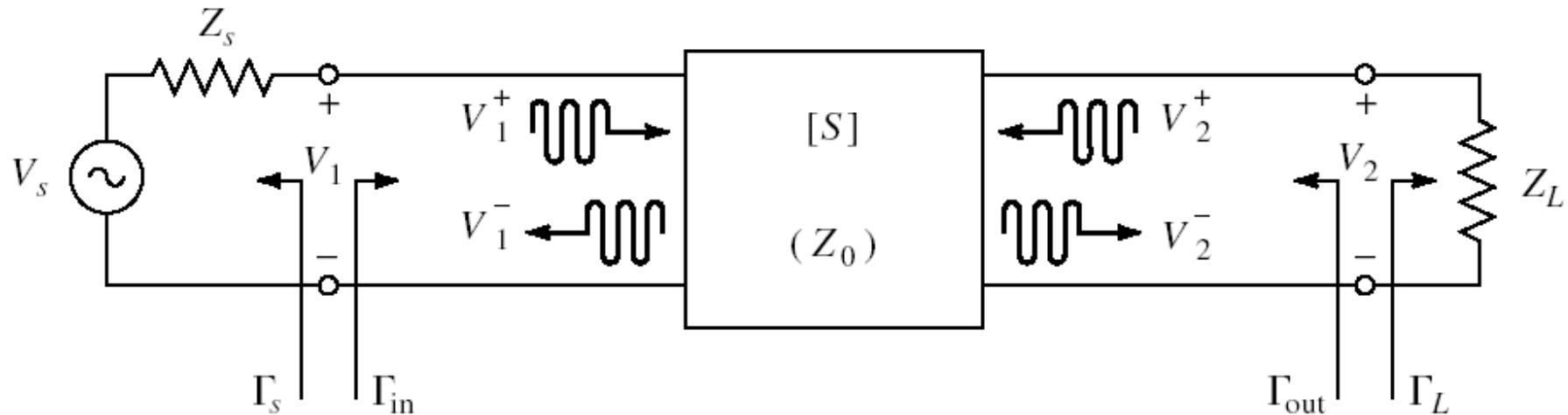
- Fisiere format Touchstone (*.s2p)

```
! SIEMENS Small Signal Semiconductors
! VDS = 3.5 V  ID = 15 mA
# GHz S MA R 50
! f    S11      S21      S12      S22
! GHz  MAG  ANG  MAG  ANG  MAG  ANG  MAG  ANG
1.000 0.9800 -18.0  2.230 157.0  0.0240  74.0  0.6900 -15.0
2.000 0.9500 -39.0  2.220 136.0  0.0450  57.0  0.6600 -30.0
3.000 0.8900 -64.0  2.210 110.0  0.0680  40.0  0.6100 -45.0
4.000 0.8200 -89.0  2.230  86.0  0.0850  23.0  0.5600 -62.0
5.000 0.7400 -115.0 2.190  61.0  0.0990  7.0   0.4900 -80.0
6.000 0.6500 -142.0 2.110  36.0  0.1070 -10.0  0.4100 -98.0
!
! f    Fmin  Gammaopt rn/50
! GHz  dB   MAG  ANG  -
2.000 1.00 0.72 27 0.84
4.000 1.40 0.64 61 0.58
```

Stabilitate

Amplificatoare de microunde

Cuadripol Amplifier



- marimi care intereseaza:
 - **stabilitate**
 - castig de putere
 - zgomot (uneori – semnal mic)
 - liniaritate (uneori – semnal mare)

Stabilitate

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

■ Limite de stabilitate/instabilitate

$$|\Gamma_{in}| = 1 \quad \log_{10} |\Gamma_{in}| = 0 \quad \left| S_{11} + \frac{S_{12} \cdot S_{21} \cdot \Gamma_L}{1 - S_{22} \cdot \Gamma_L} \right| = 1$$

$$|S_{11} \cdot (1 - S_{22} \cdot \Gamma_L) + S_{12} \cdot S_{21} \cdot \Gamma_L| = |1 - S_{22} \cdot \Gamma_L|$$

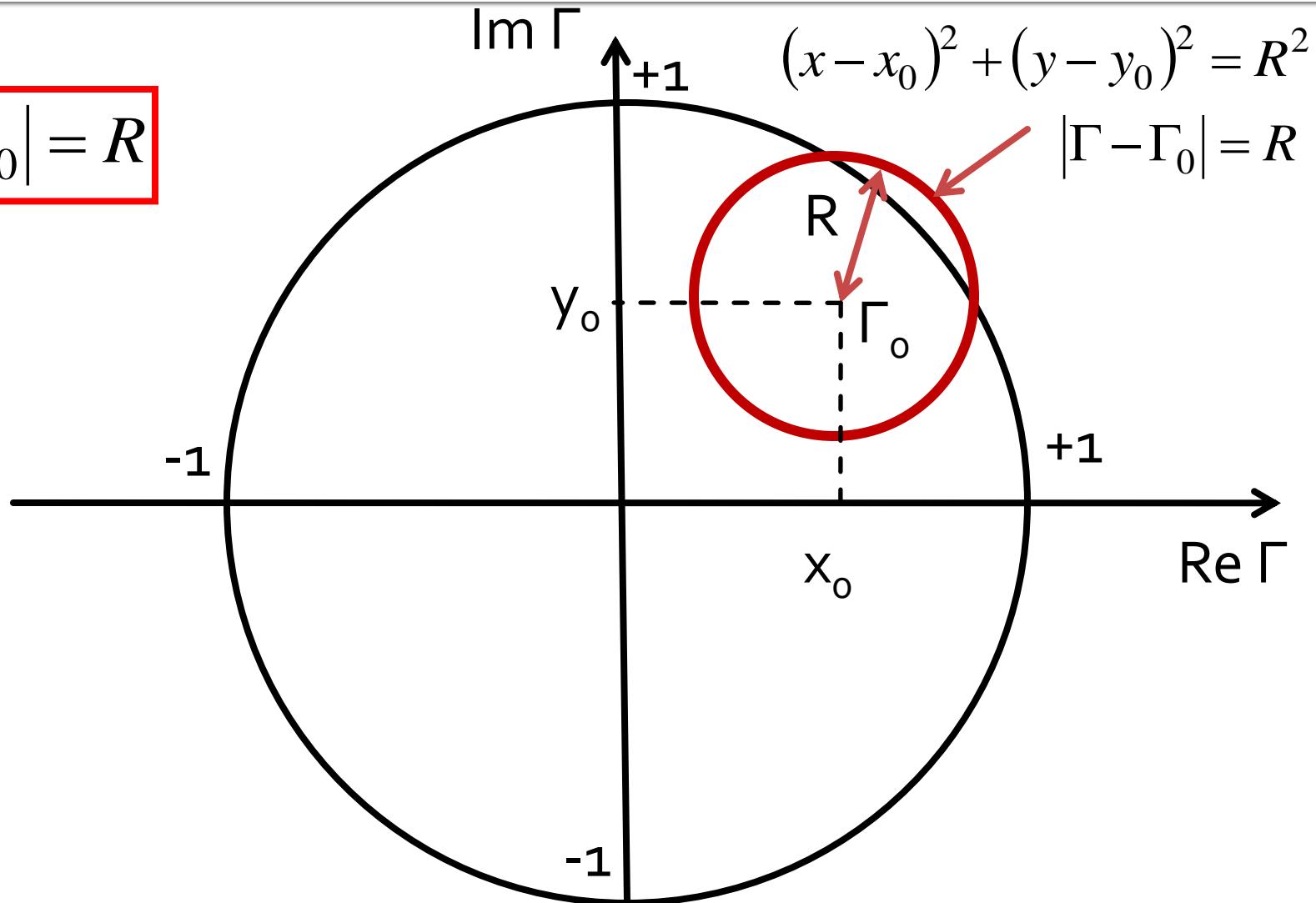
■ Determinantul matricii S $\Delta = S_{11} \cdot S_{22} - S_{12} \cdot S_{21}$

$$|S_{11} - \Delta \cdot \Gamma_L| = |1 - S_{22} \cdot \Gamma_L|$$

$$|S_{11} - \Delta \cdot \Gamma_L|^2 = |1 - S_{22} \cdot \Gamma_L|^2$$

Stabilitate

$$|\Gamma - \Gamma_0| = R$$



Cerc de stabilitate la ieșire (CSOUT)

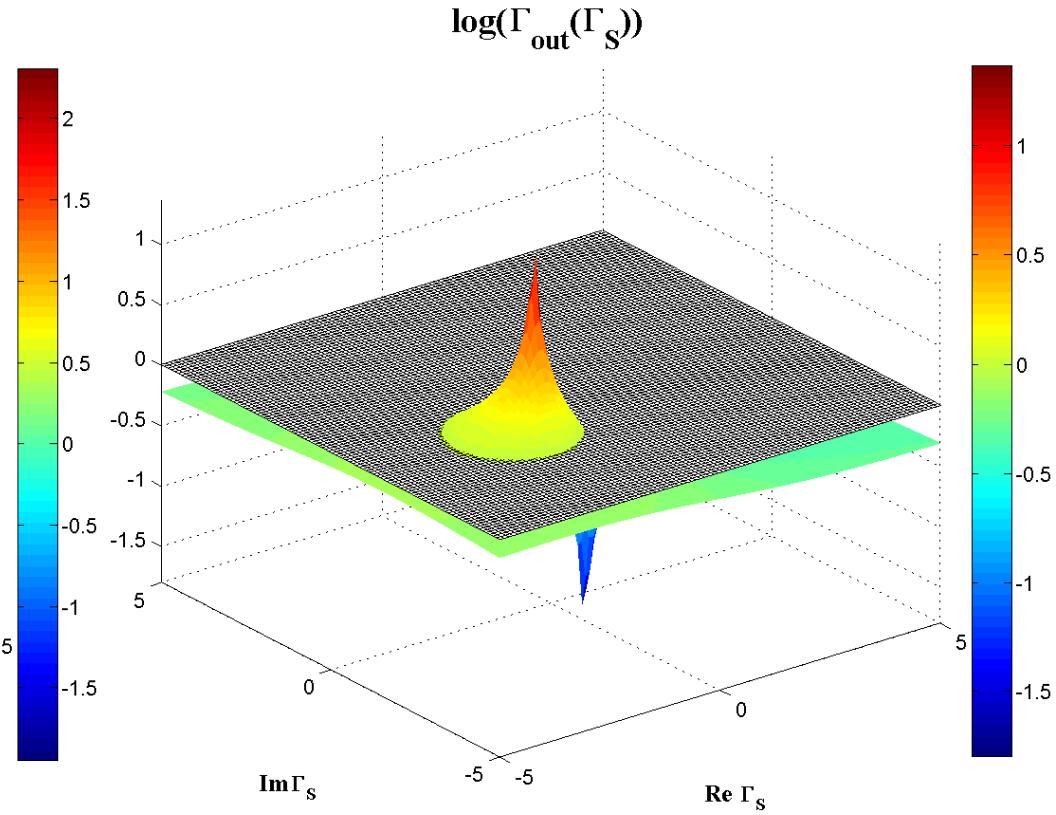
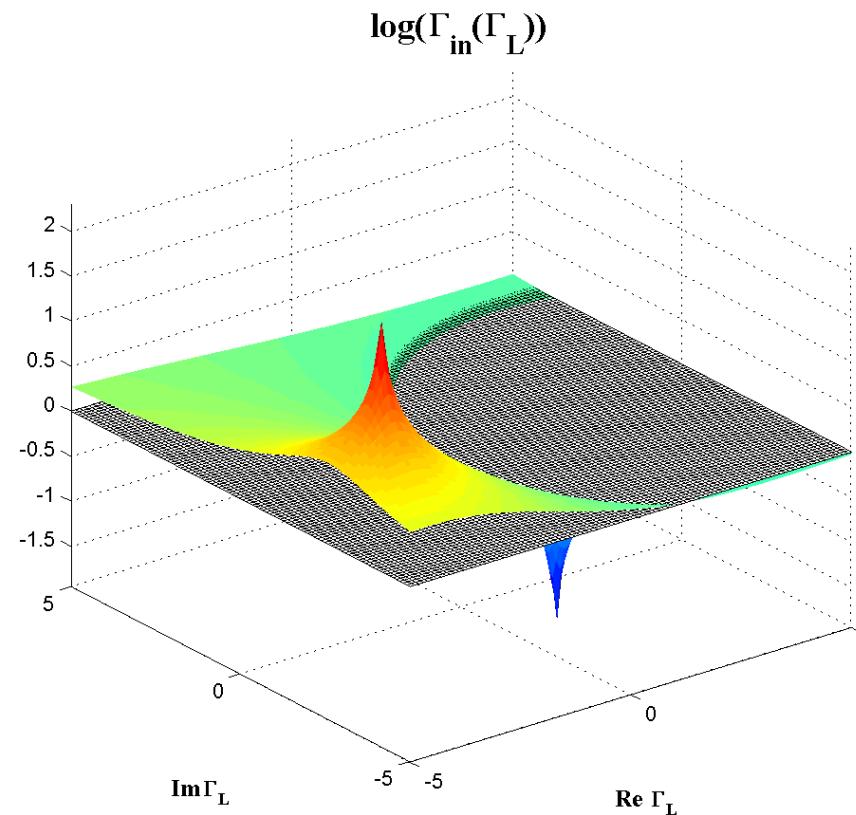
$$\left| \Gamma_L - \frac{(S_{22} - \Delta \cdot S_{11}^*)^*}{|S_{22}|^2 - |\Delta|^2} \right| = \left| \frac{S_{12} \cdot S_{21}}{|S_{22}|^2 - |\Delta|^2} \right| \quad |\Gamma_L - C_L| = R_L$$

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

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

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

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



Conditia Rollet

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

- Diportul este **neconditionat stabil** daca:
 - Sunt indeplinite simultan conditiile
 - $K > 1$
 - $|\Delta| < 1$
 - Sunt valabile si conditiile implice
 - $|S_{11}| < 1$
 - $|S_{22}| < 1$

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

Criteriul μ

- Conditia Rollet depinde de doi parametri, K si Δ , si nu poate fi utilizata pentru compararea stabilitatii a doua scheme

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

- Diportul este **neconditionat stabil** daca:
 - $\mu > 1$
- Sunt valabile si conditiile implicite
 - $|S_{11}| < 1$
 - $|S_{22}| < 1$
- In plus se poate spune ca daca μ creste se obtine stabilitate mai buna
 - μ este distanta de la centrul diagramei Smith la cercul de stabilitate la iesire

Criteriul μ'

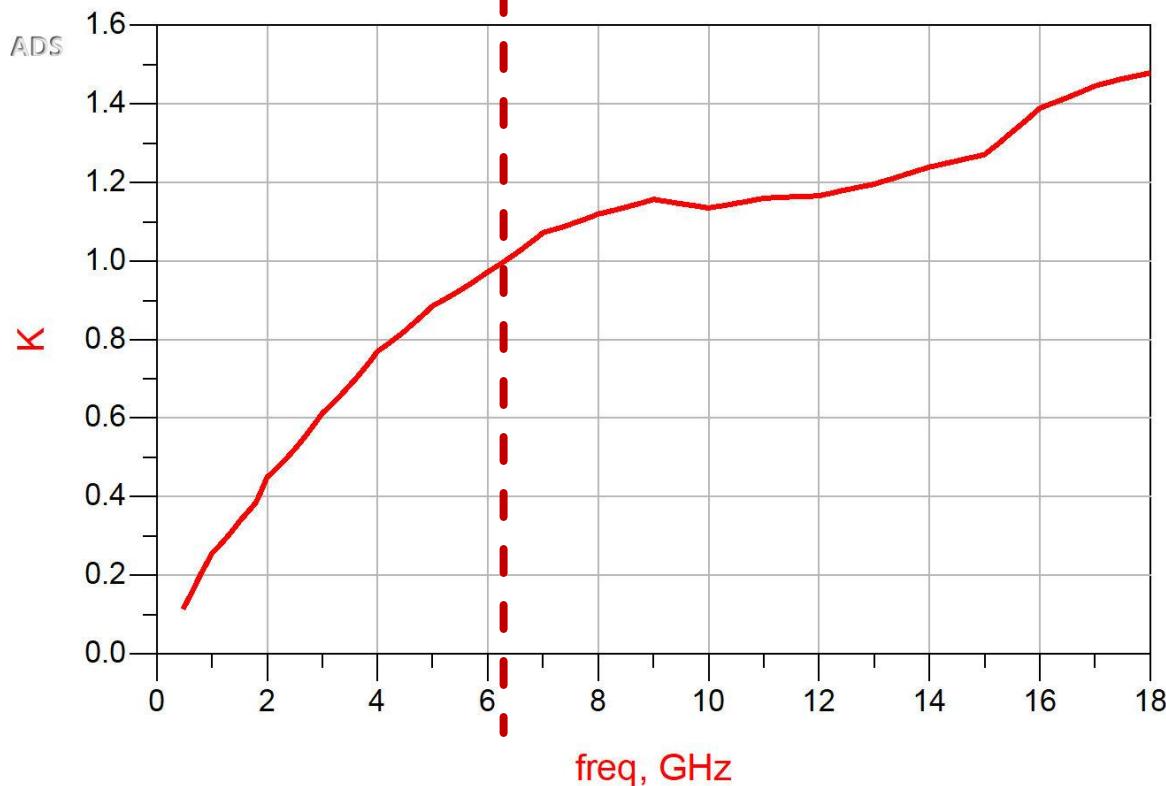
- Parametru dual pentru μ , determinat relativ la cercul de stabilitate la intrare

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

- Diportul este **neconditionat stabil** daca:
 - $\mu' > 1$
- Sunt valabile si conditiile implice
 - $|S_{11}| < 1$
 - $|S_{22}| < 1$
- In plus se poate spune ca daca μ' creste se obtine stabilitate mai buna
 - μ' este distanta de la centrul diagramei Smith la cercul de stabilitate la intrare

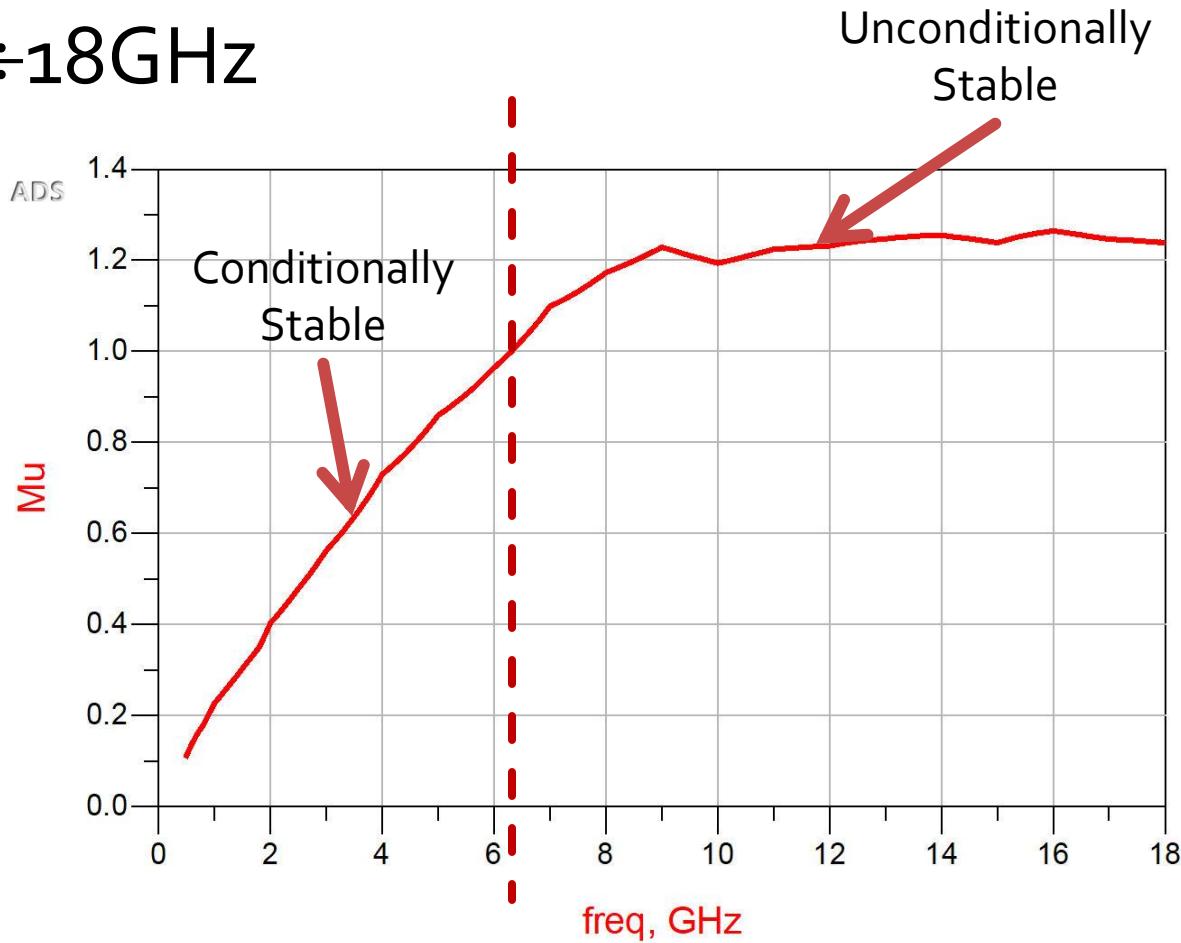
Conditia Rollet

- ATF-34143 at $V_{ds}=3V$ $I_d=20mA$.
- @ $0.5 \div 18GHz$



Criteriul μ

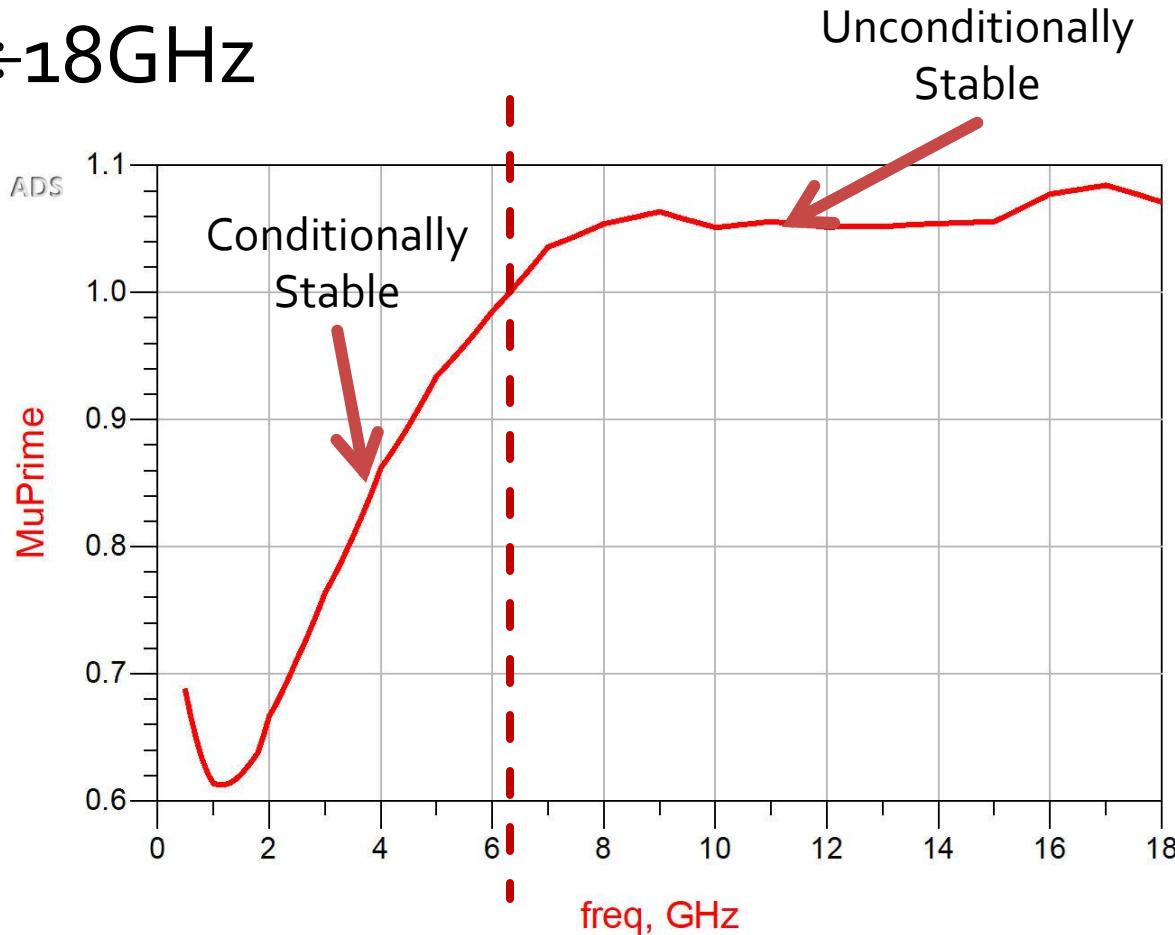
- ATF-34143 at $V_{ds}=3V$ $I_d=20mA$.
- @ $0.5 \div 18GHz$



Criteriul μ'

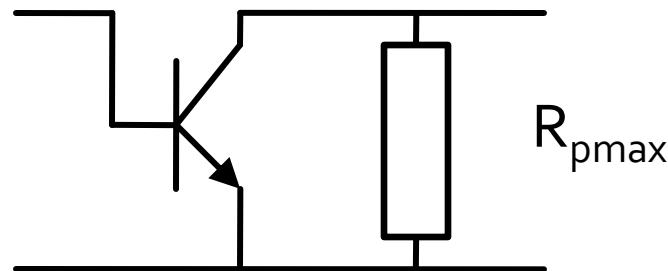
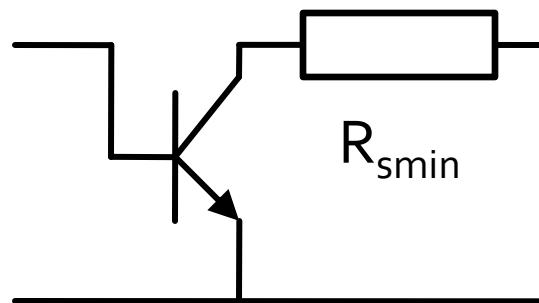
- ATF-34143 at $V_{ds}=3V$ $I_d=20mA$.

- @ $0.5 \div 18GHz$

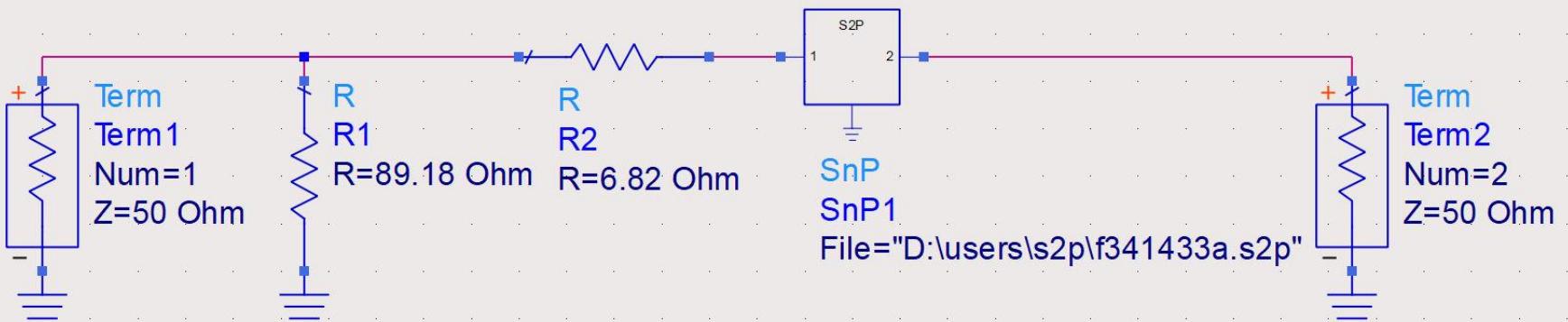


Rezistenta serie/paralel la iesire

- Procedura se poate aplica similar la iesire (plecand de la CSOUT)
- Din exemplele anterioare, incarcarea rezistiva la intrare are efect pozitiv si asupra stabilitatii la iesire si viceversa (incarcare la iesire efect asupra stabilitatii la intrare)



Stabilizarea unui diport



S-PARAMETERS

S_Param

SP1

Start=0.5 GHz

Stop=10.0 GHz

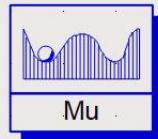
Step=0.1 GHz



MaxGain

MAG

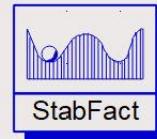
MAG=max_gain(S)



Mu

Mu1

Mu=mu(S)

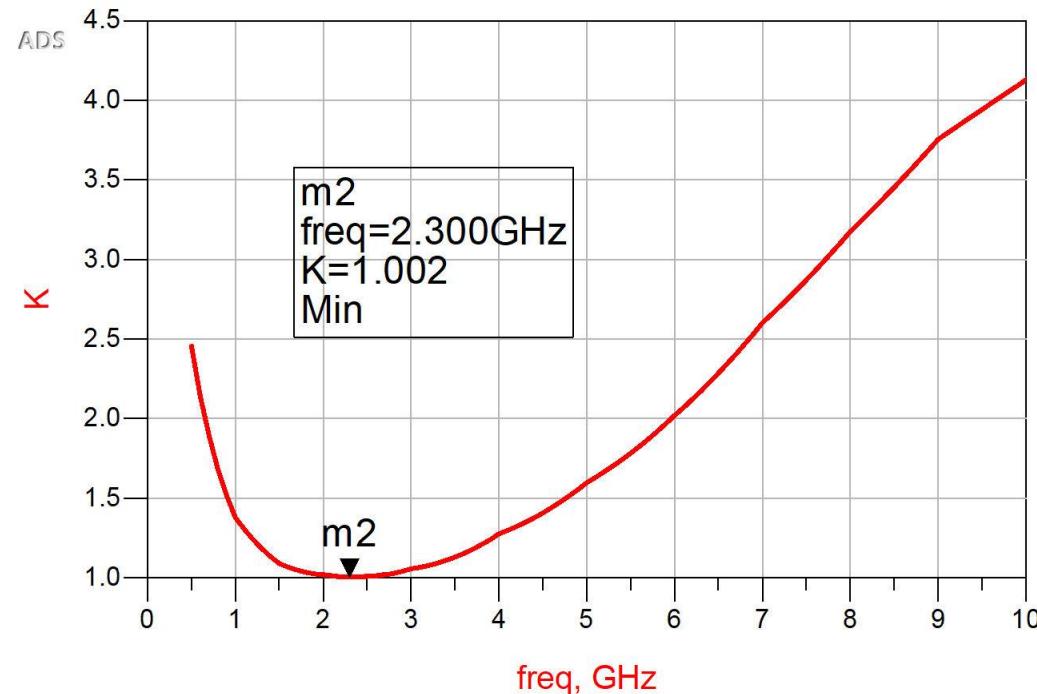
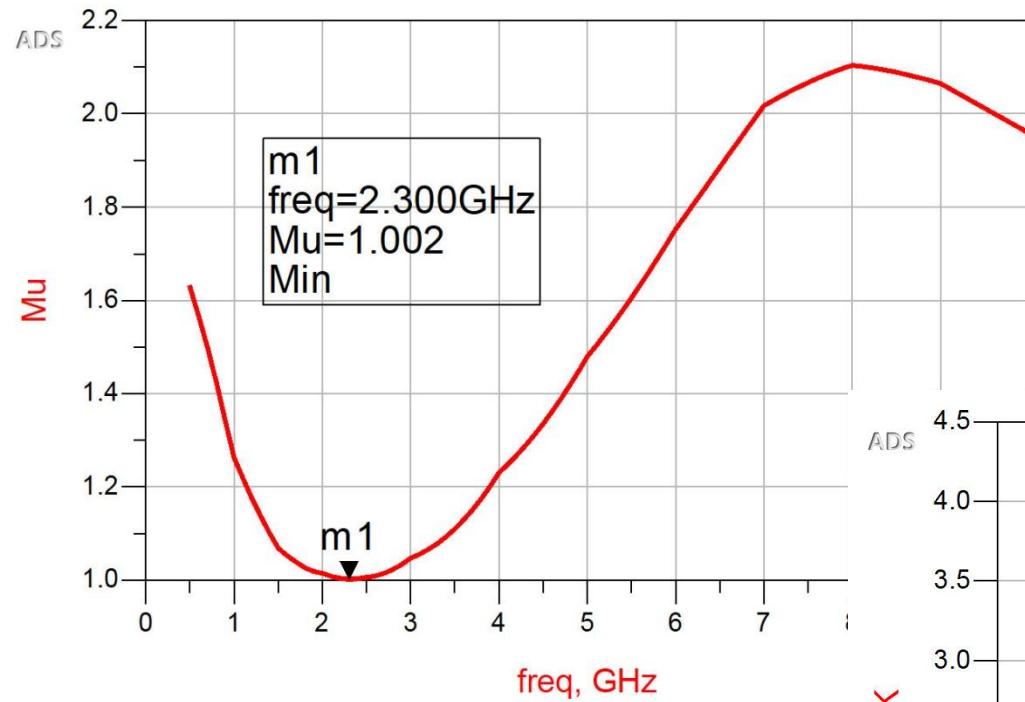


StabFact

K

K=stab_fact(S)

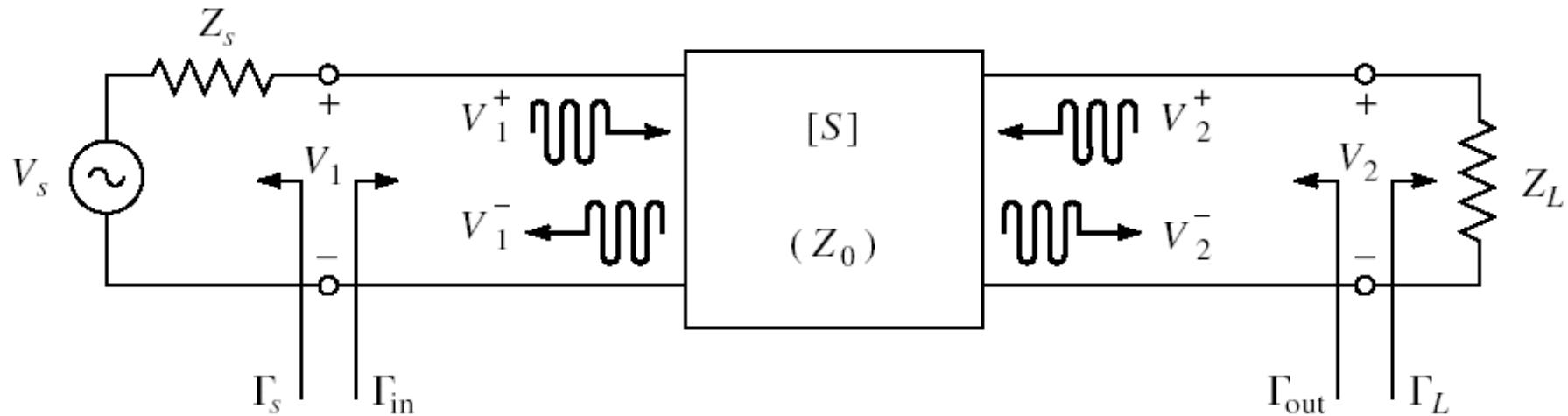
Stabilizarea unui dipoz



Castigul amplificatoarelor de microunde

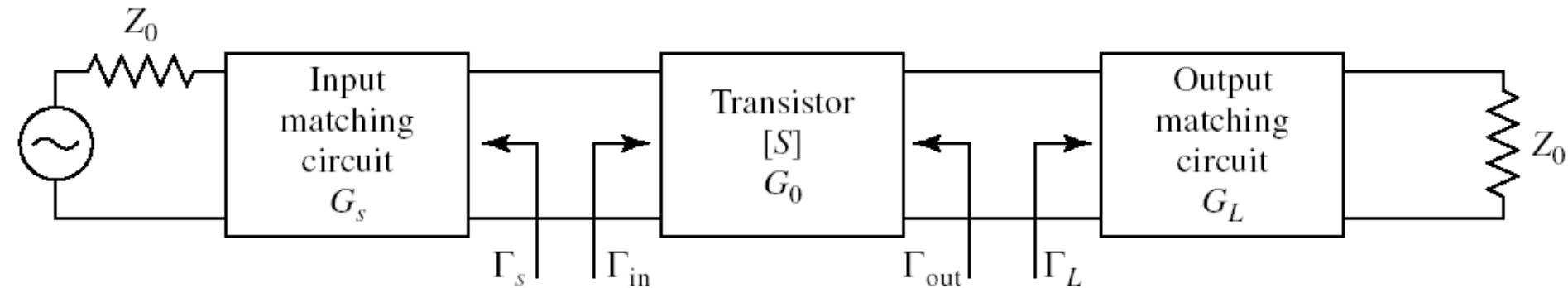
Amplificatoare de microunde

Cuadripol Amplifier



- marimi care intereseaza:
 - stabilitate
 - **castig de putere**
 - zgomot (uneori – semnal mic)
 - liniaritate (uneori – semnal mare)

Proiectare pentru castig maxim



- Castig maxim de putere se obtine cand

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

- Pentru retelele de adaptare fara pierderi

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

$$G_{T\max} = \frac{1}{1 - |\Gamma_s|^2} \cdot |S_{21}|^2 \cdot \frac{1 - |\Gamma_L|^2}{|1 - S_{22} \cdot \Gamma_L|^2}$$

- 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 “-”

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

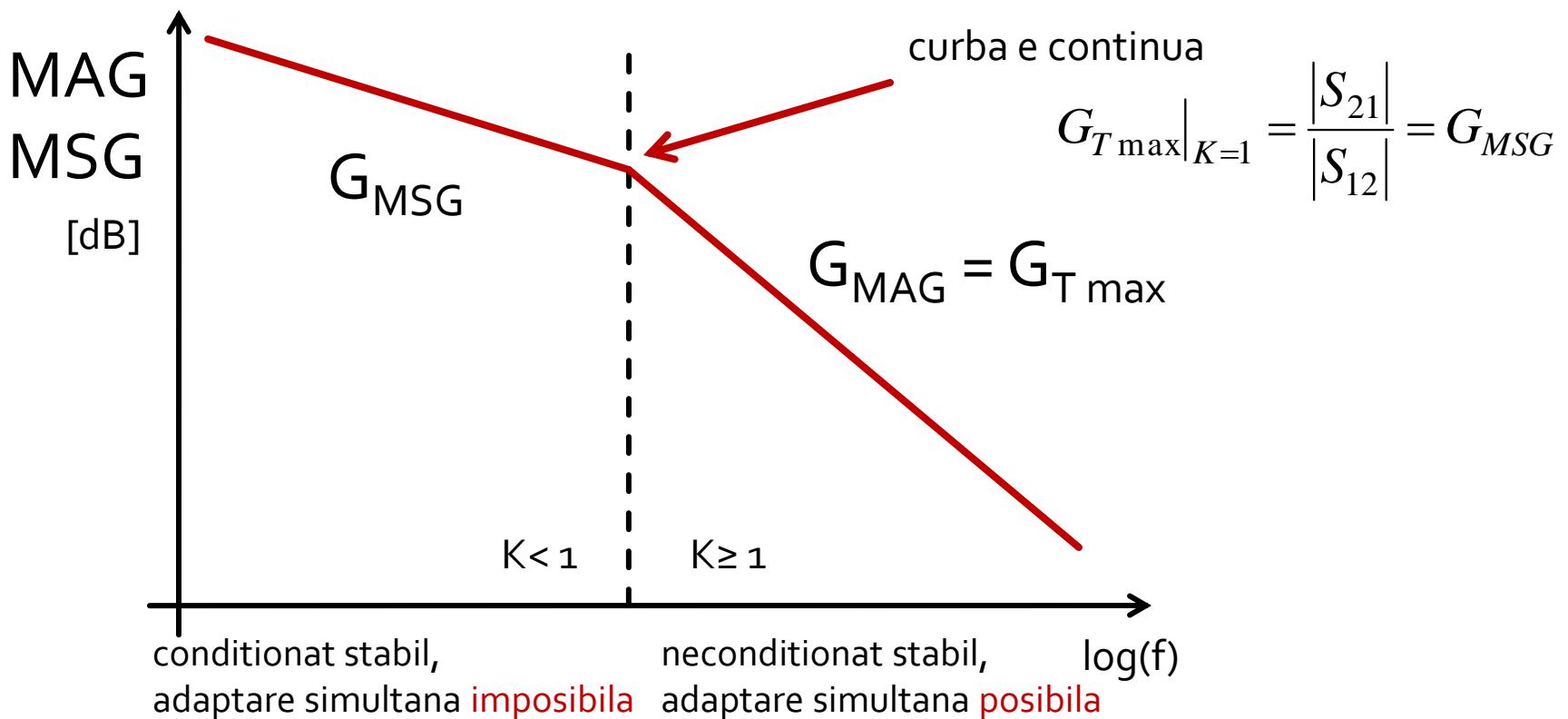
$$\begin{cases} B_1 = 1 + |S_{11}|^2 - |S_{22}|^2 - |\Delta|^2 \\ C_1 = S_{11} - \Delta \cdot S_{22}^* \end{cases}$$

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

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

Maximum Available Gain

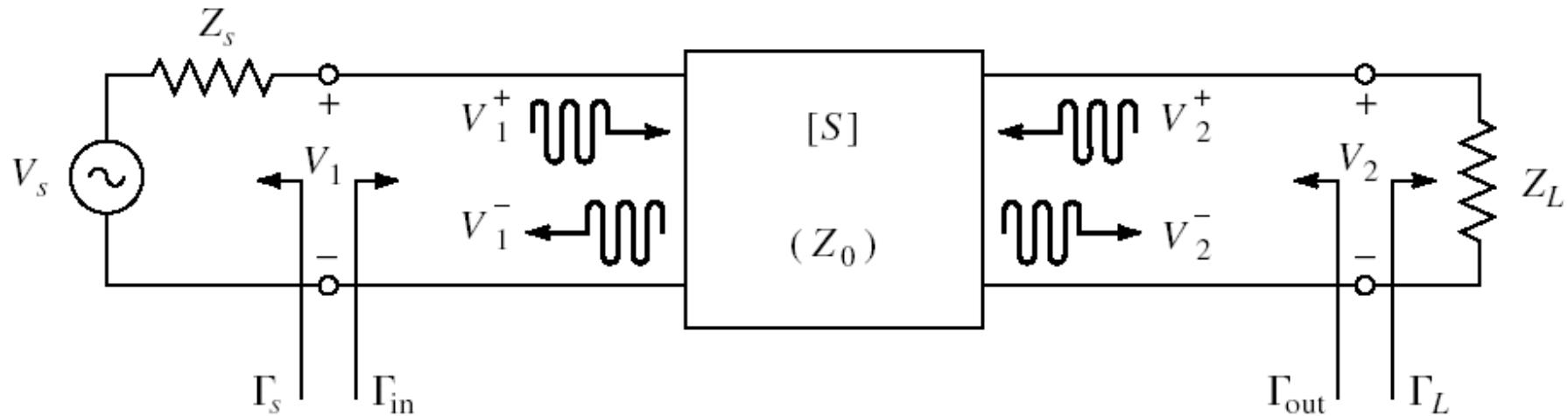
- Indicator in intreaga gama de frecventa a capacitatii de a obtine castig



Proiectare pentru castig impus

Amplificatoare de microunde

Cuadripol Amplifier



- marimi care intereseaza:
 - stabilitate
 - **castig de putere**
 - zgomot (uneori – semnal mic)
 - liniaritate (uneori – semnal mare)

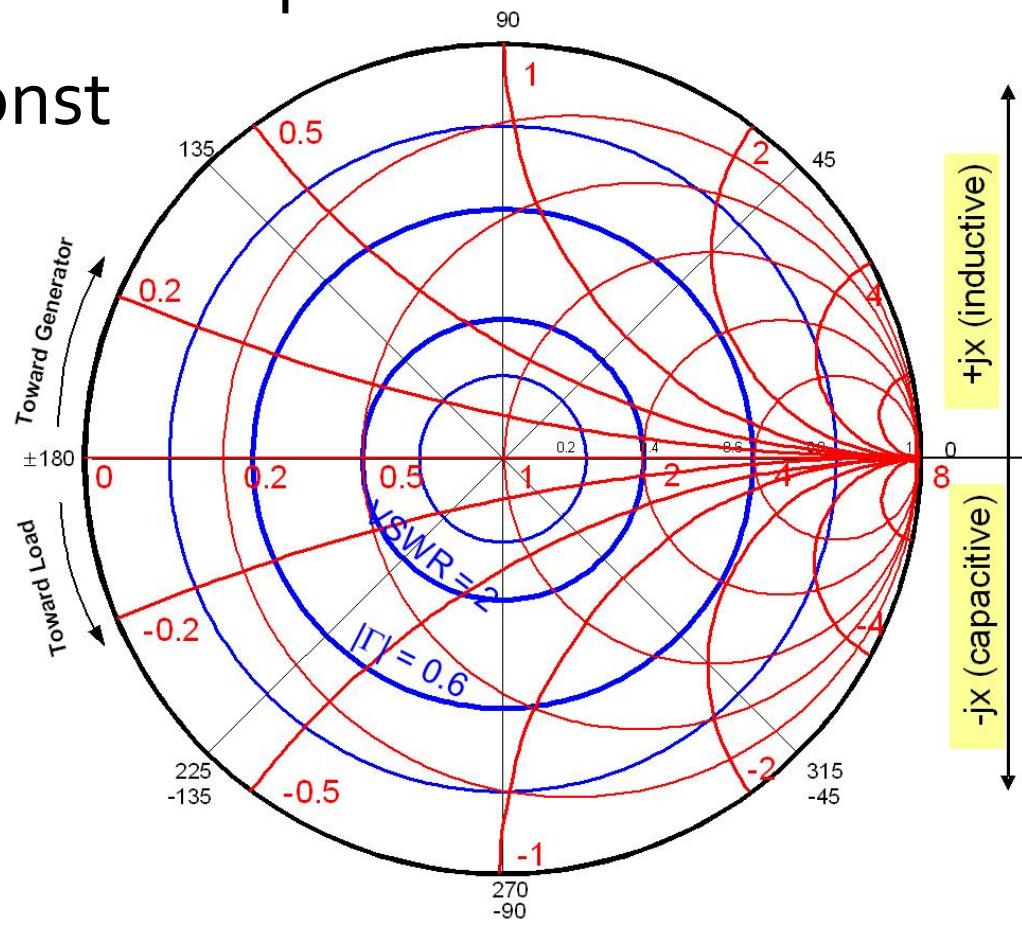
Proiectare pentru castig impus

- 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
- $VSWR = \text{const} \rightarrow \Gamma = \text{const}$

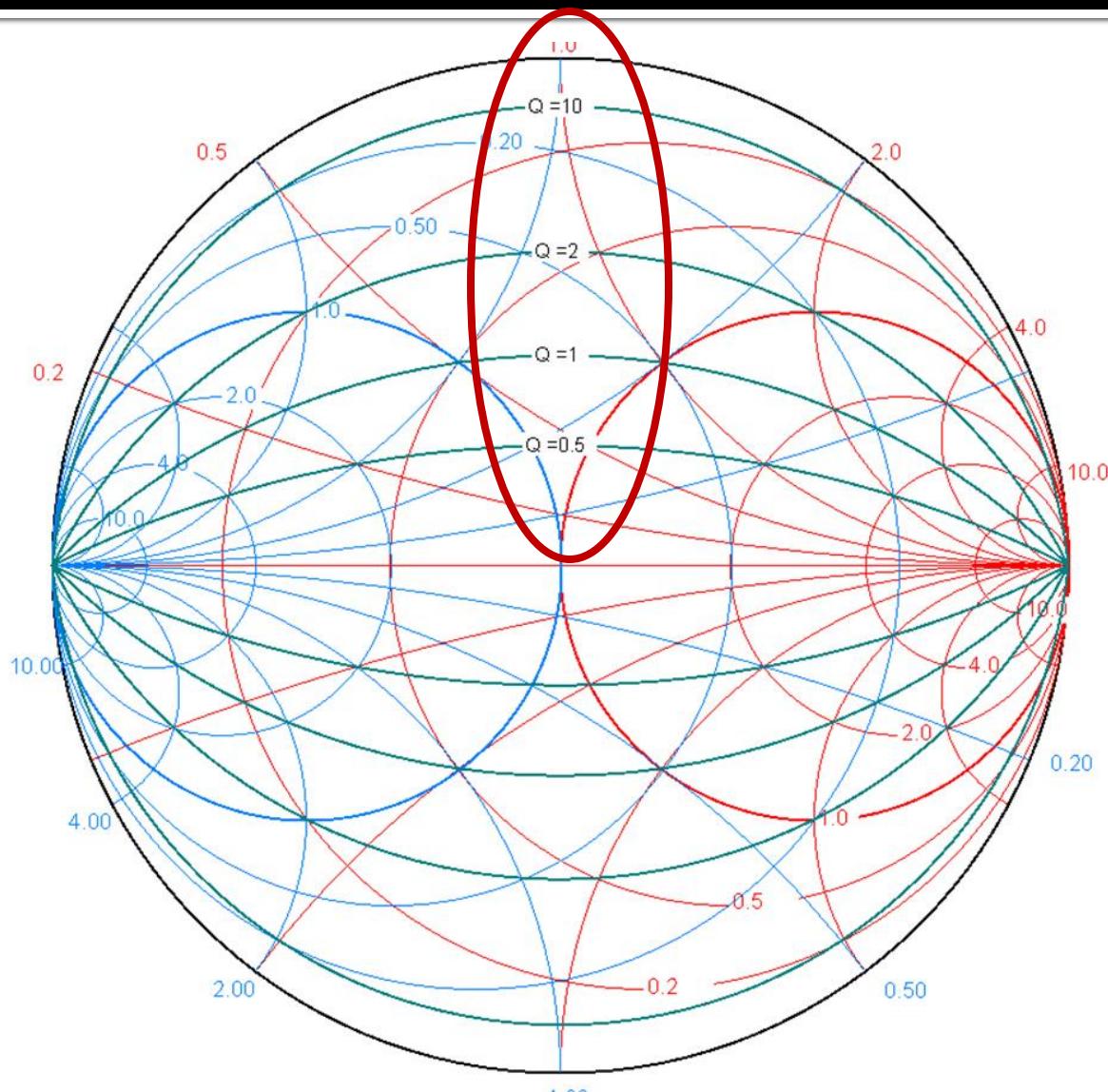
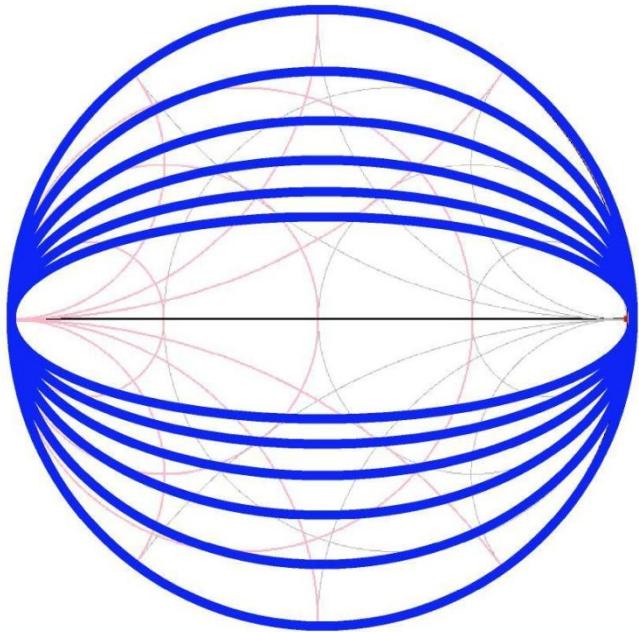
$$VSWR = \frac{V_{\max}}{V_{\min}} = \frac{1+|\Gamma|}{1-|\Gamma|}$$



Cercuri de factor de calitate constant

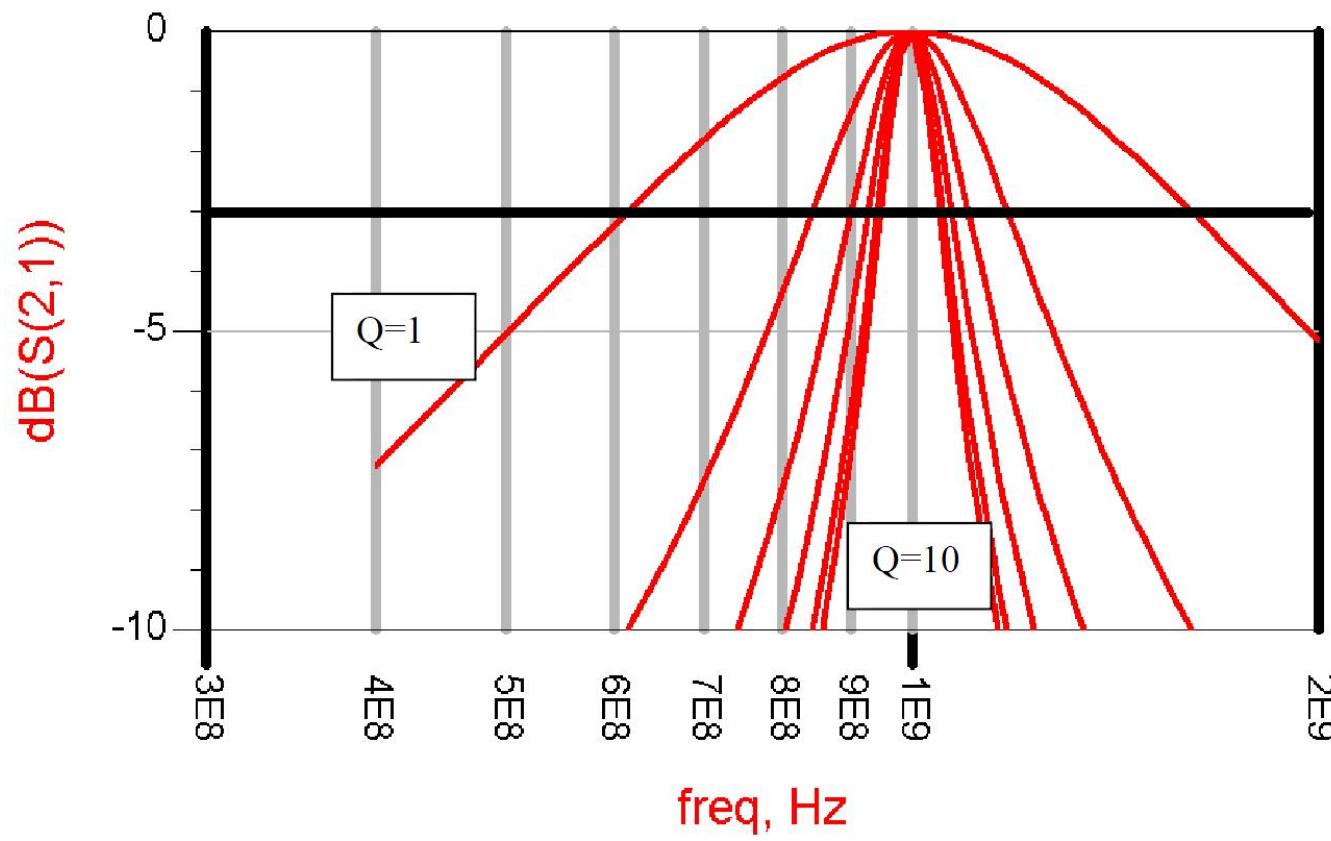
- Diagrama Smith

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



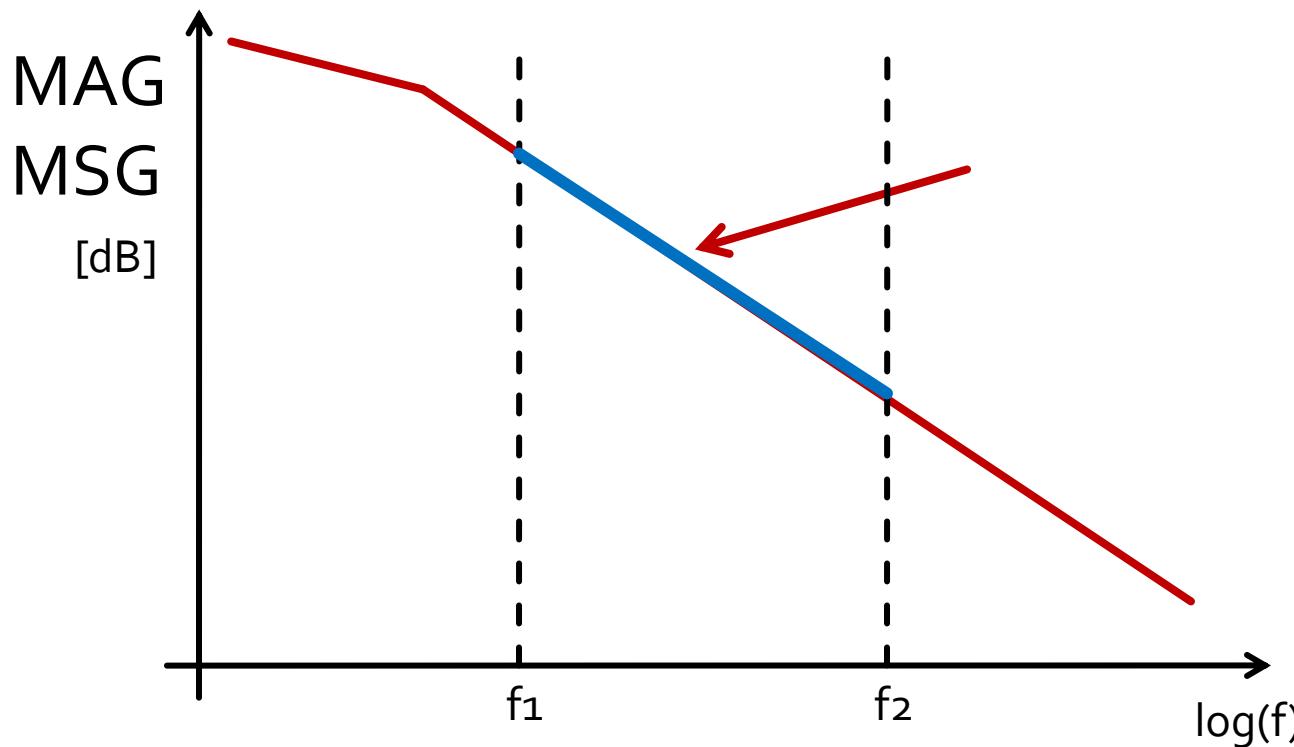
Factor de calitate - banda

- Factor de calitate ridicat echivalent cu banda ingusta



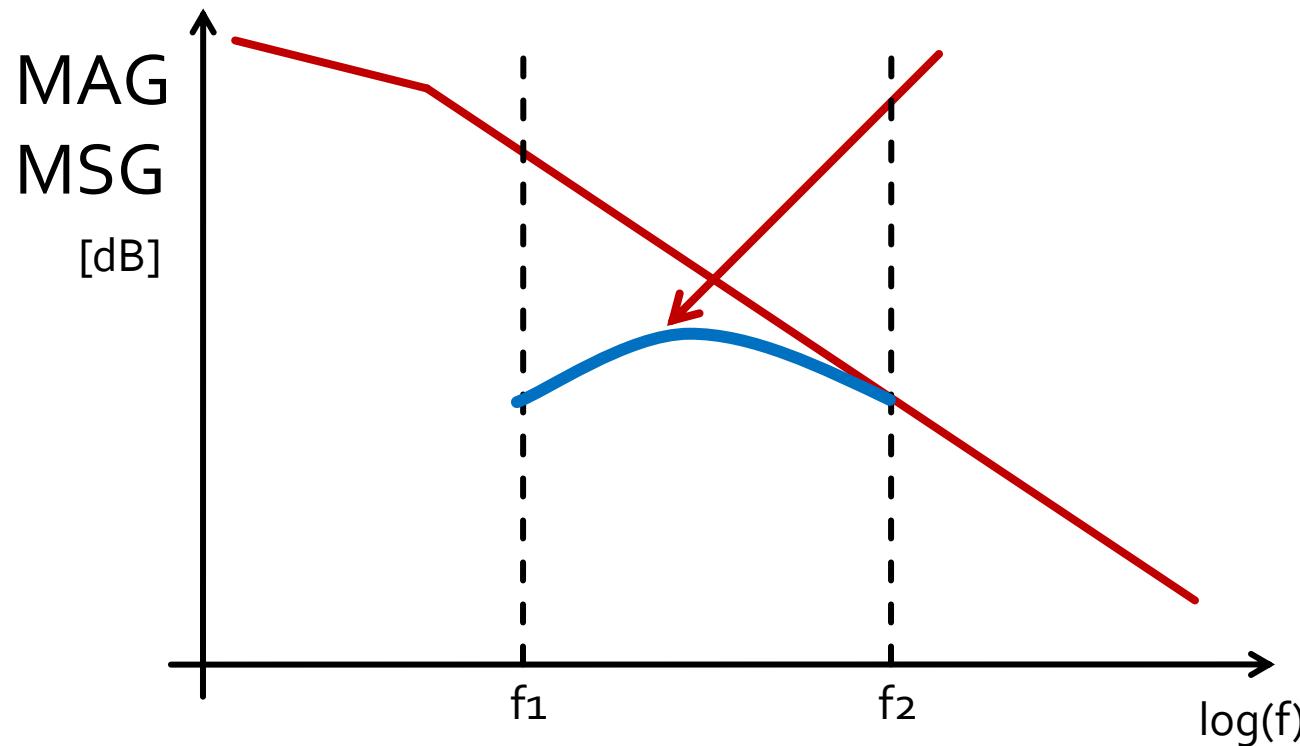
Amplificator de banda largă

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



Amplificator de banda largă

- 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 unilaterală a amplificatorului



Permite tratarea separata
a intrarii si iesirii

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

- 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

$$\frac{1}{(1+U)^2} < \frac{G_T}{G_{TU}} < \frac{1}{(1-U)^2}$$

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

- Se calculeaza U si abaterea maxima si minima a lui G_{TU} fata de G_T
 - aceasta abatere trebuie prevazuta in proiectare ca rezerva pentru castigul maxim

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

Exemplu

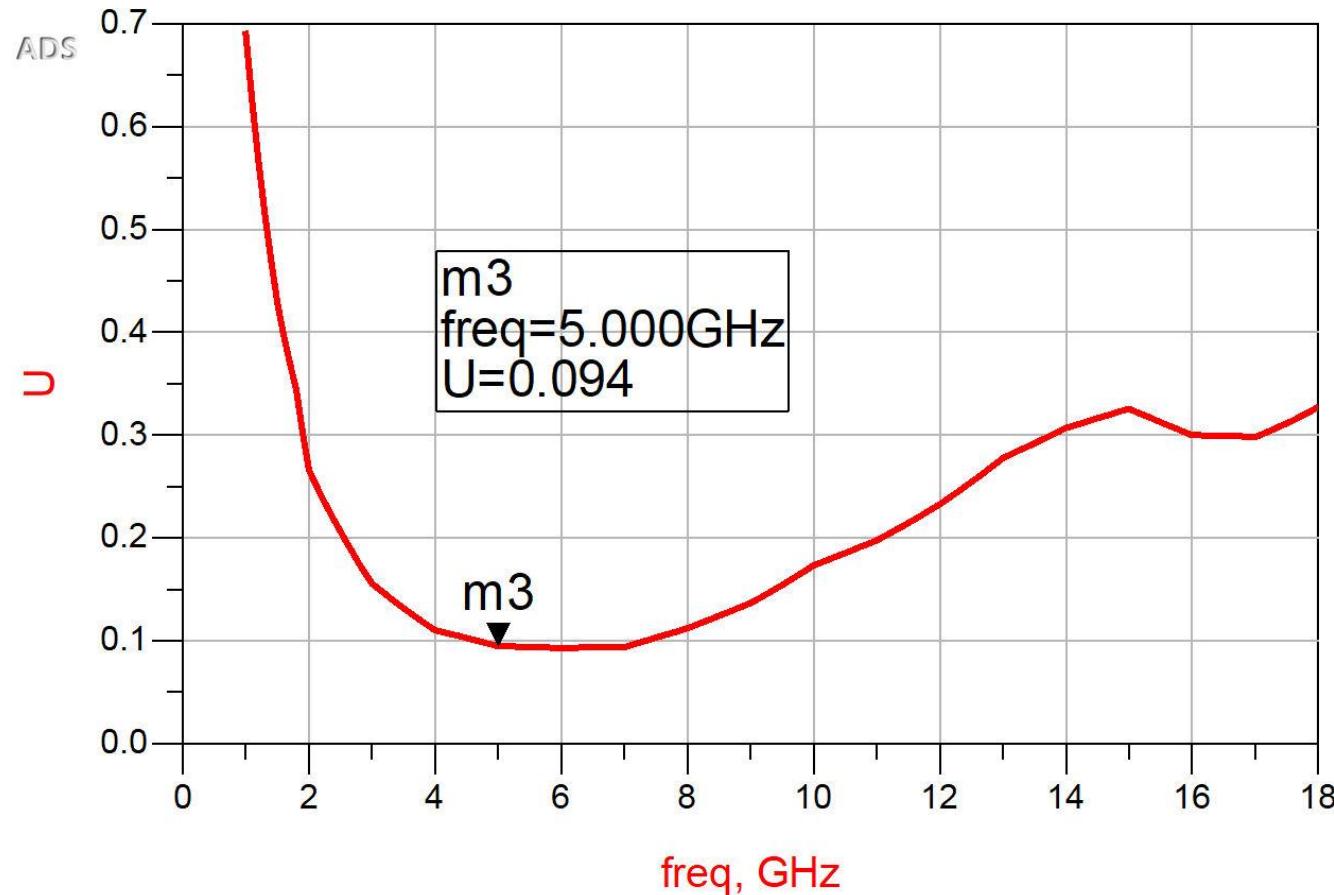
- ATF-34143 at $V_{ds}=3V$ $I_d=20mA$.
- @5GHz
 - $S_{11} = 0.64 \angle 139^\circ$
 - $S_{12} = 0.119 \angle -21^\circ$
 - $S_{21} = 3.165 \angle 16^\circ$
 - $S_{22} = 0.22 \angle 146^\circ$

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

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

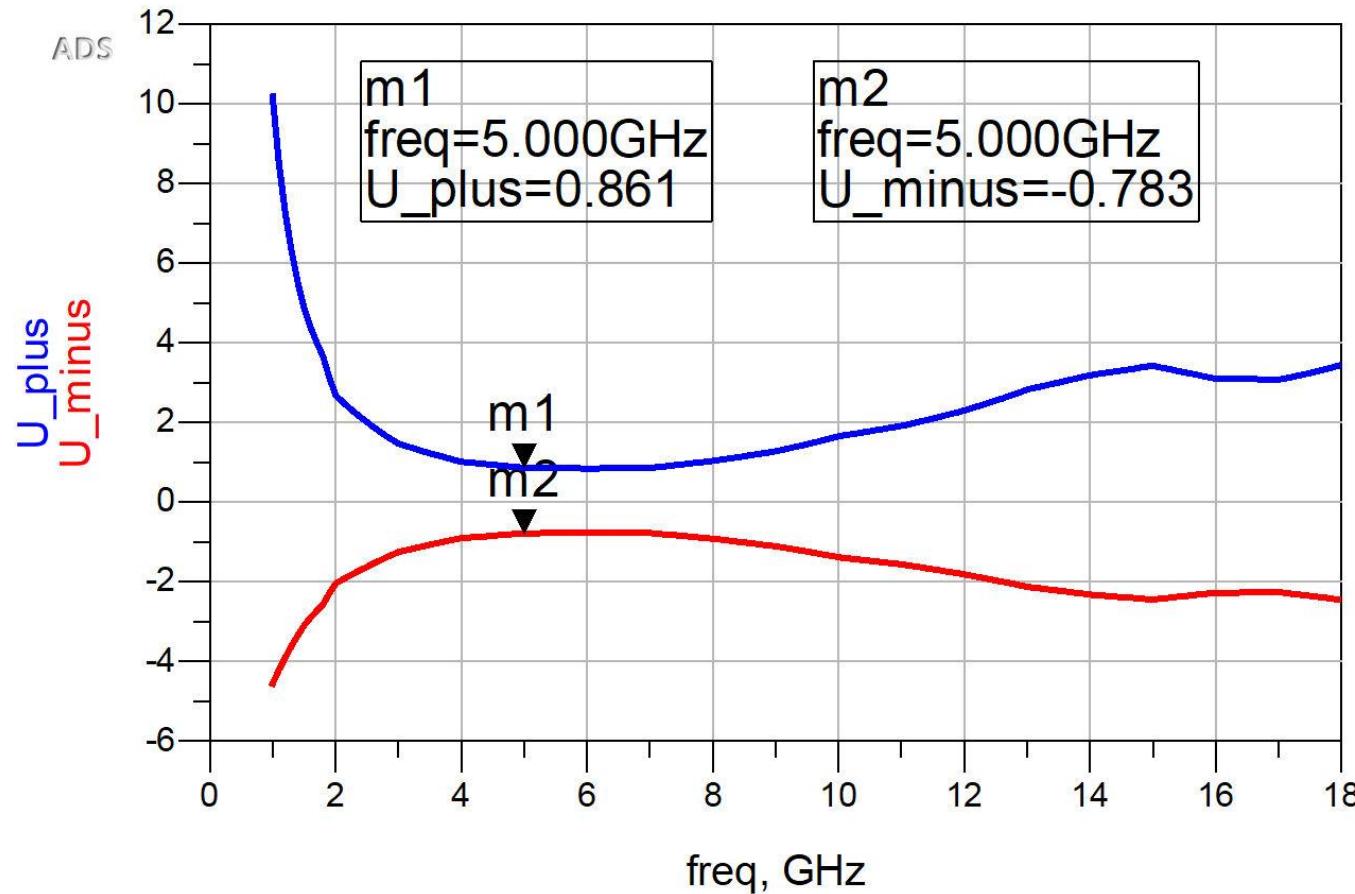
Exemplu

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

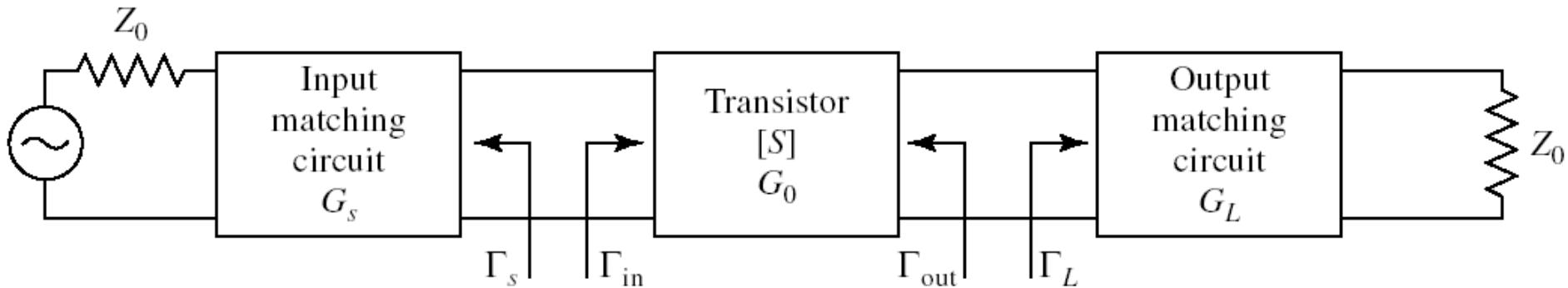


Exemplu

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



Proiectare pentru castig impus



- Daca ipoteza tranzistorului unilateral este justificata:

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

$$G_s = \frac{1 - |\Gamma_s|^2}{|1 - S_{11} \cdot \Gamma_s|^2}$$

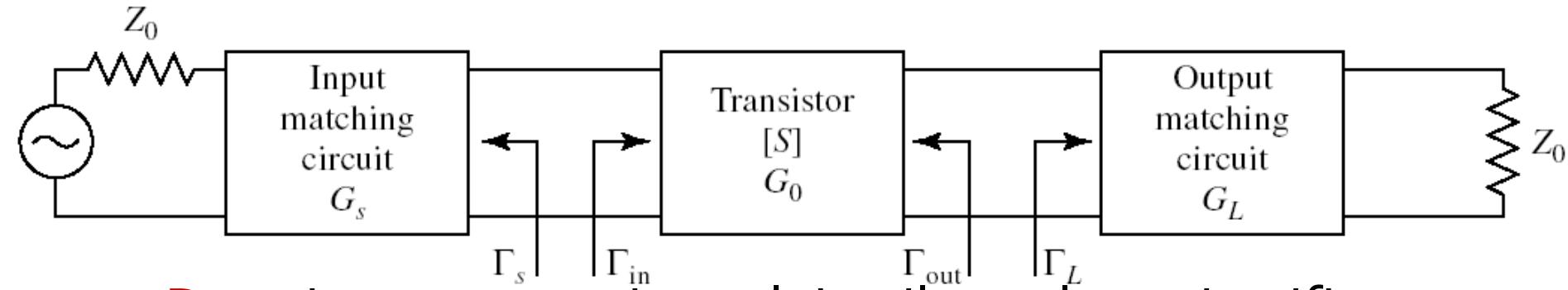
$$G_s = G_s(\Gamma_s)$$

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

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

$$G_L = G_L(\Gamma_L)$$

Proiectare pentru castig impus

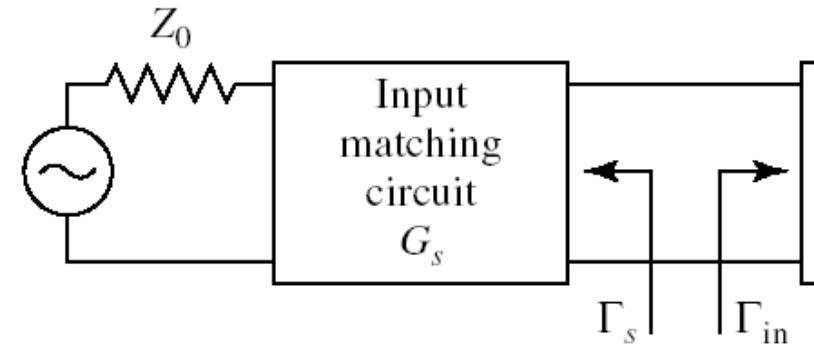


- **Daca** ipoteza tranzistorului unilateral este justificata:
 - castigul adaugat prin adaptare mai buna la intrare **nu** depinde de adaptarea la iesire $G_s = G_s(\Gamma_s)$
 - castigul adaugat prin adaptare mai buna la iesire **nu** depinde de adaptarea la intrare $G_L = G_L(\Gamma_L)$
- Adaptarile 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

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

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

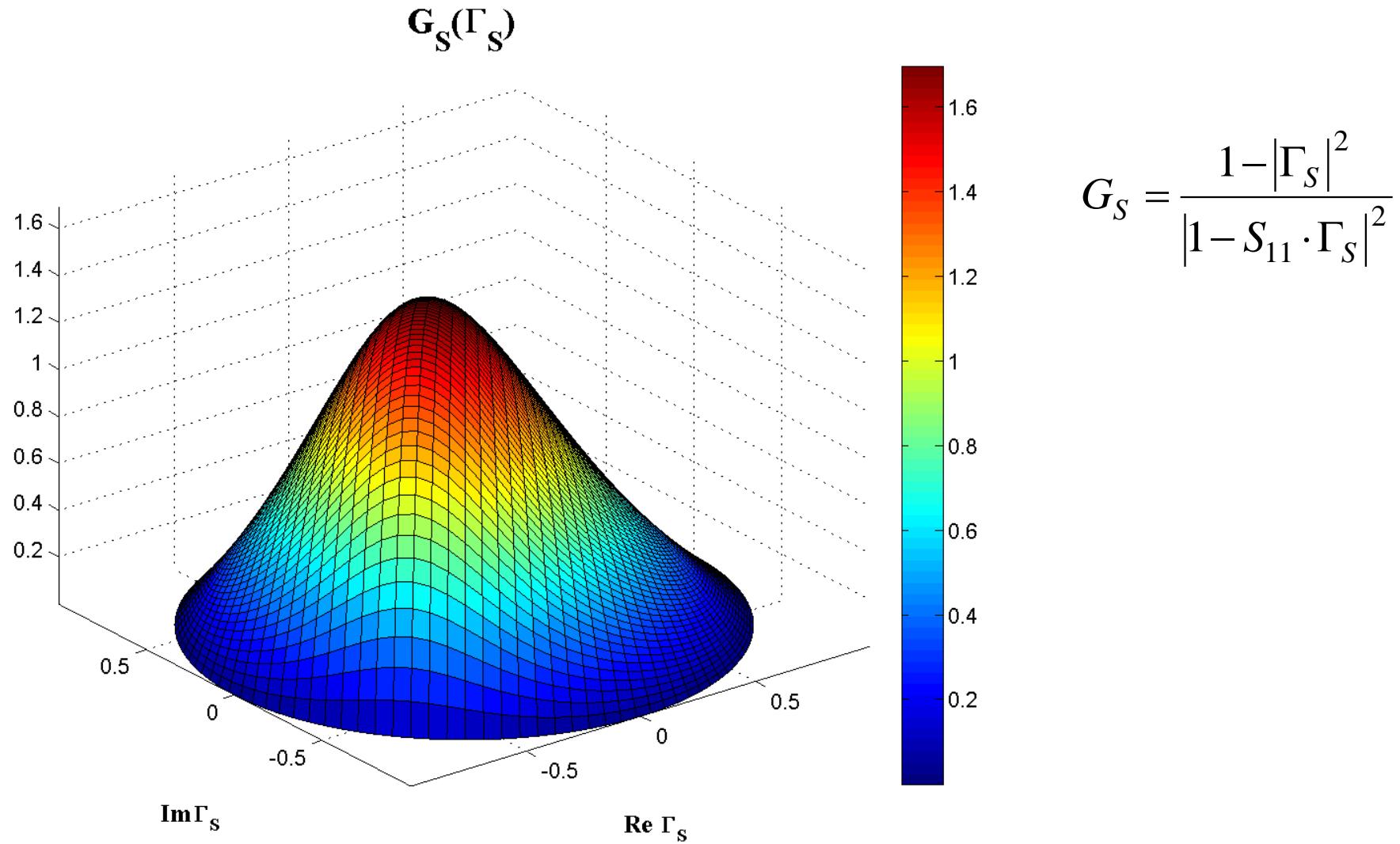
$$-0.783 \text{ dB} < G_T[\text{dB}] - G_{TU}[\text{dB}] < 0.861 \text{ dB}$$

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

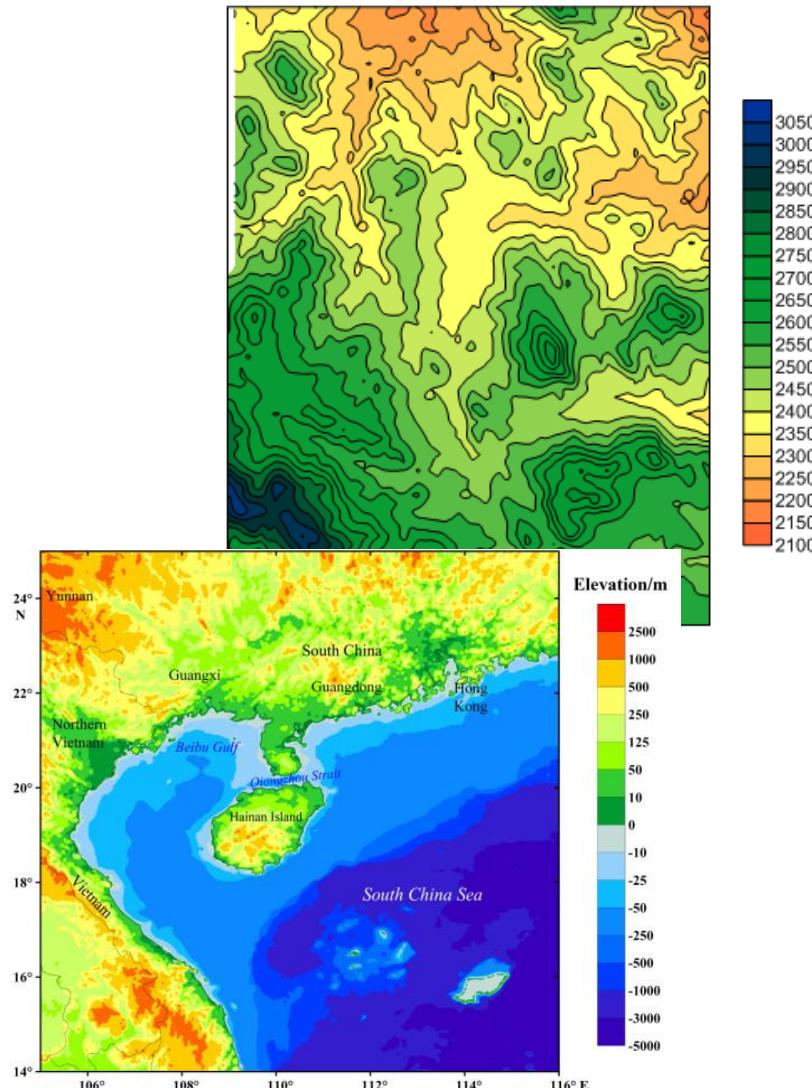
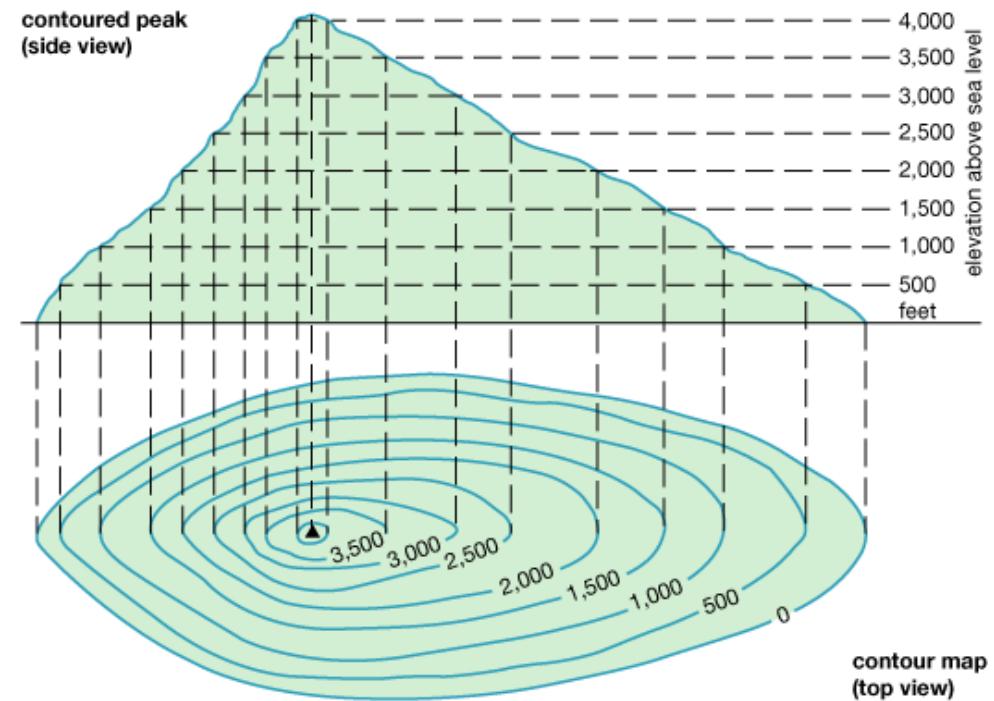
$$G_{TU \max}[\text{dB}] = 12.511 \text{ dB}$$

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

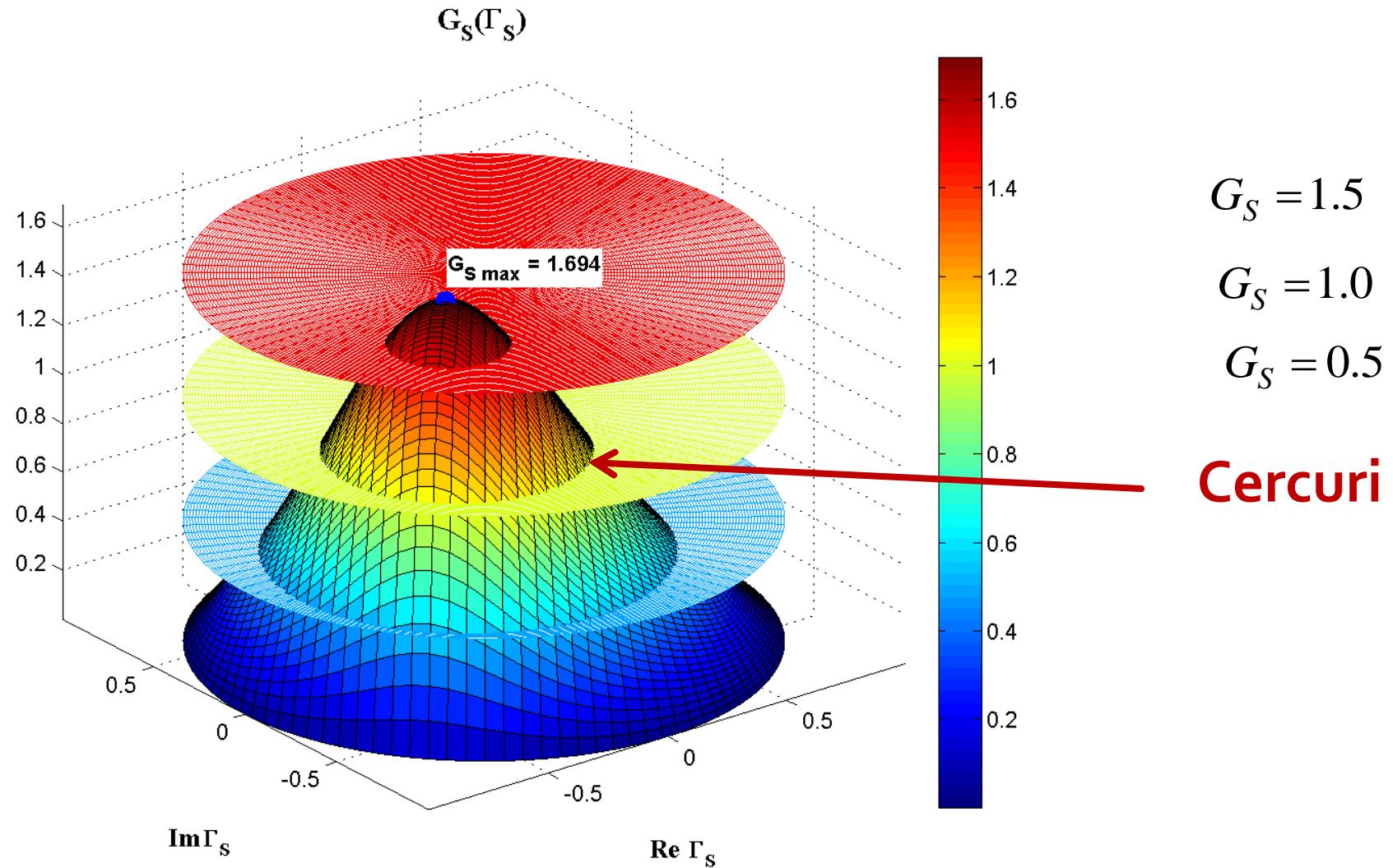
$\mathbf{G}_S(\Gamma_S)$



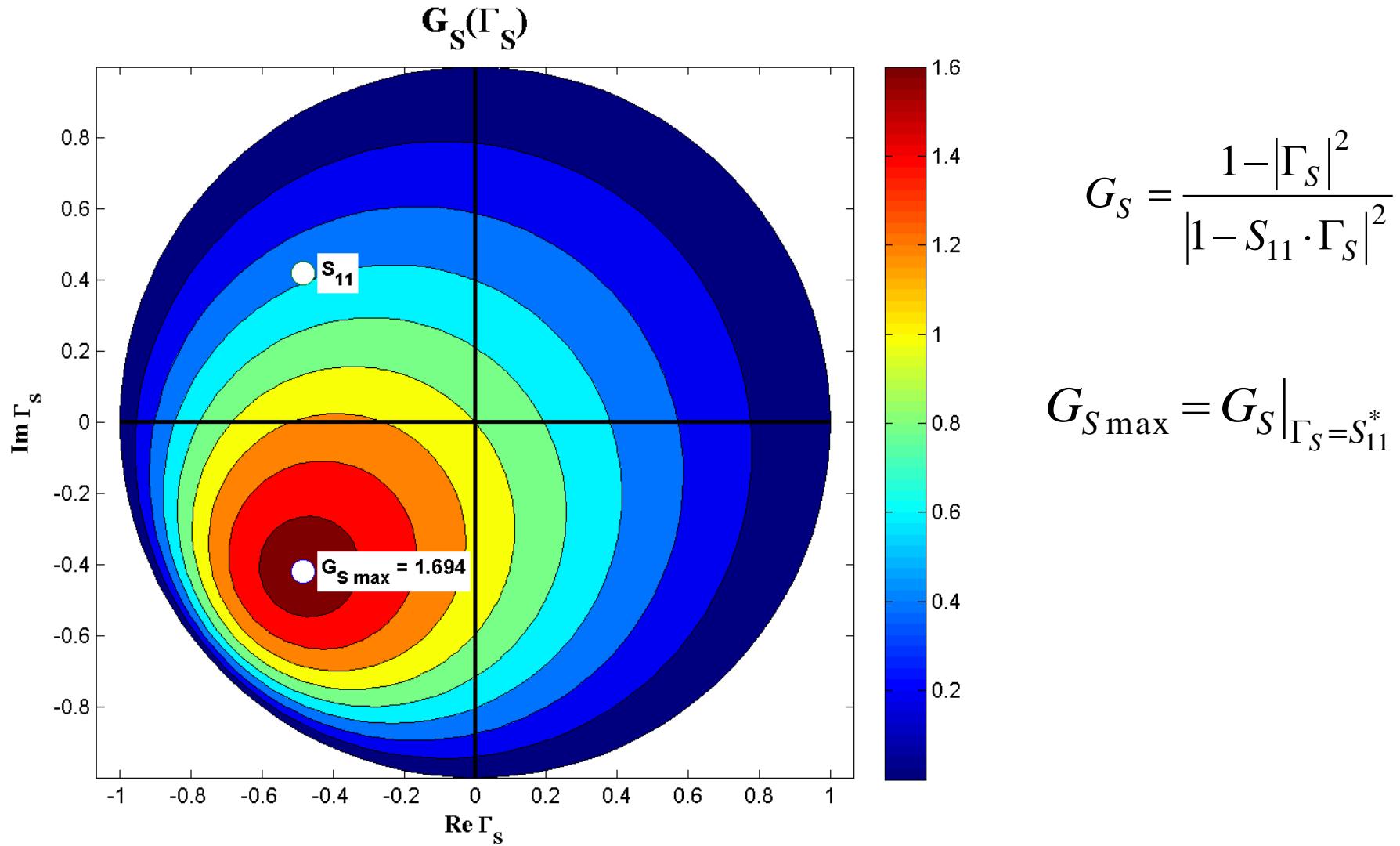
Contour map/lines



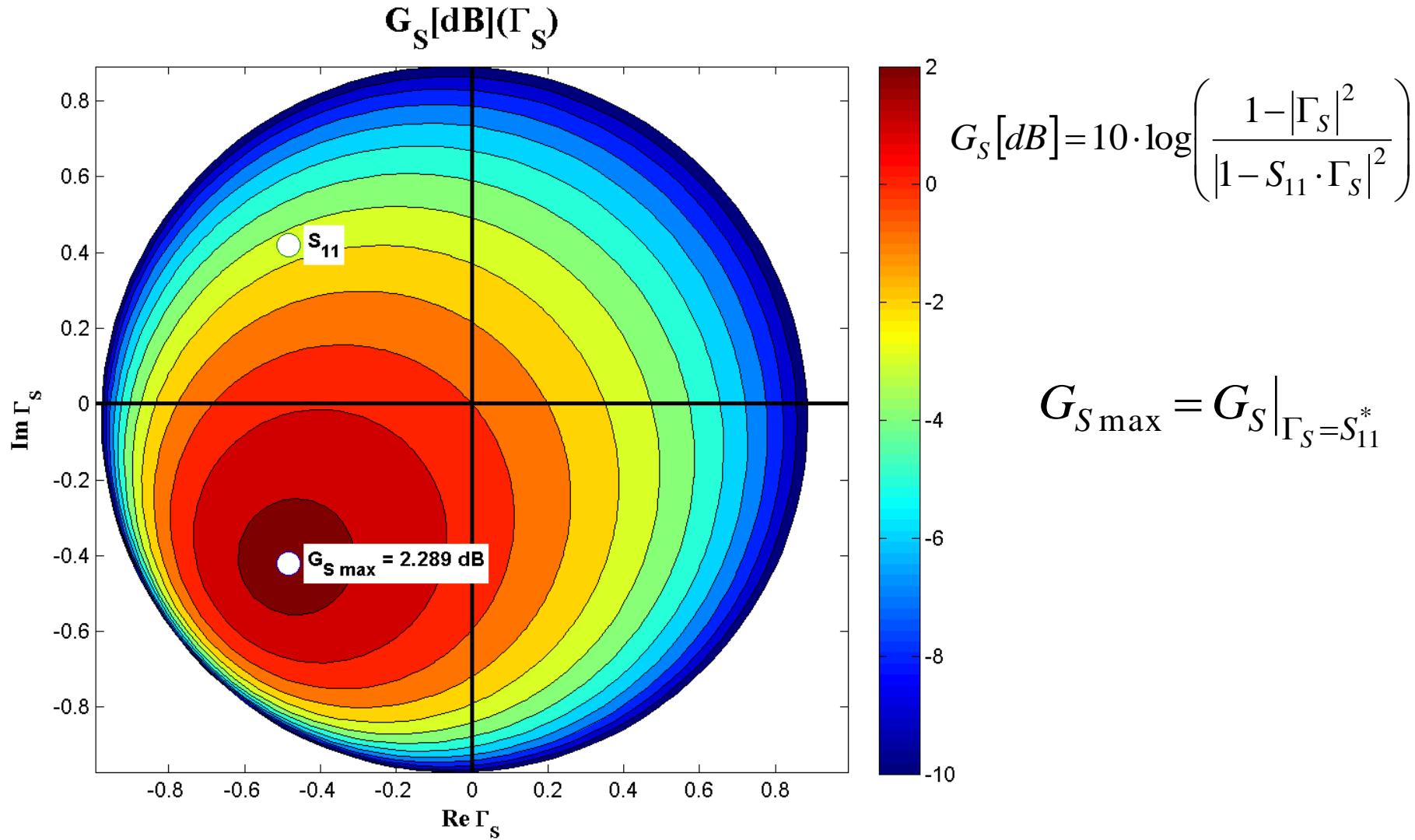
$G_S(\Gamma_S)$, nivel constant



$G_S(\Gamma_S)$, diagrama de nível



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



Cercuri de castig constant la intrare

- Castig normat (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

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

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 reprezint Γ_S
- **Interpretare:** Orice punct Γ_S care reprezentat in planul complex se gaseste **pe** cercul desenat pentru $g_{\text{cerc}} = G_{\text{cerc}}/G_{S\max}$ 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 $G_S > G_{\text{cerc}}$

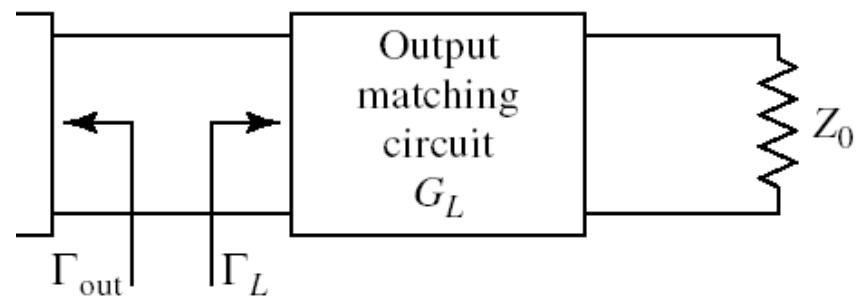
Cercuri de castig constant la intrare

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

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

- Centrele cercurilor se gasesc pe segmentul care unește $\Gamma_S = S_{11}^*$ 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

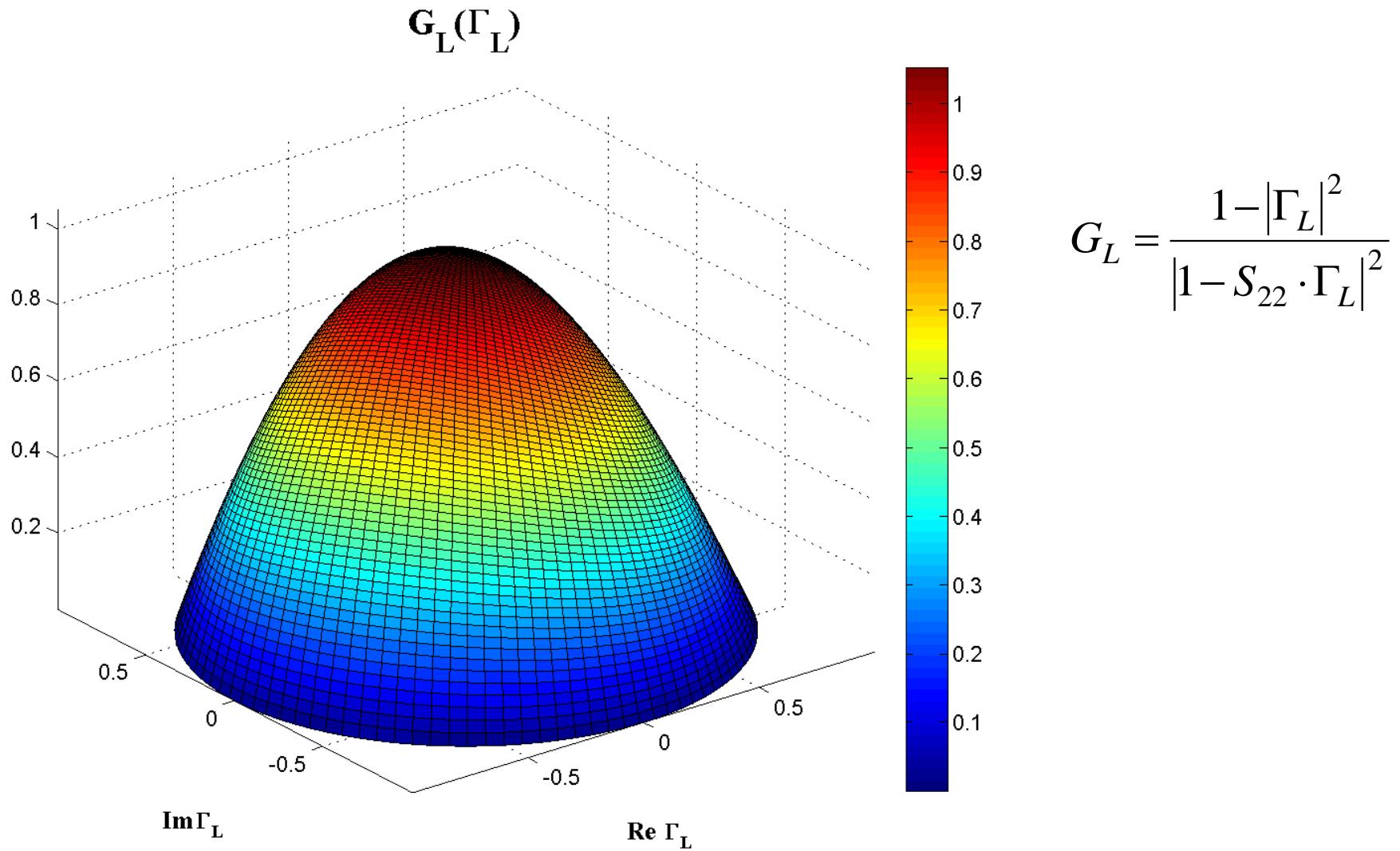
$$C_L = \frac{g_L \cdot S_{22}^*}{1 - (1 - g_L) \cdot |S_{22}|^2}$$

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

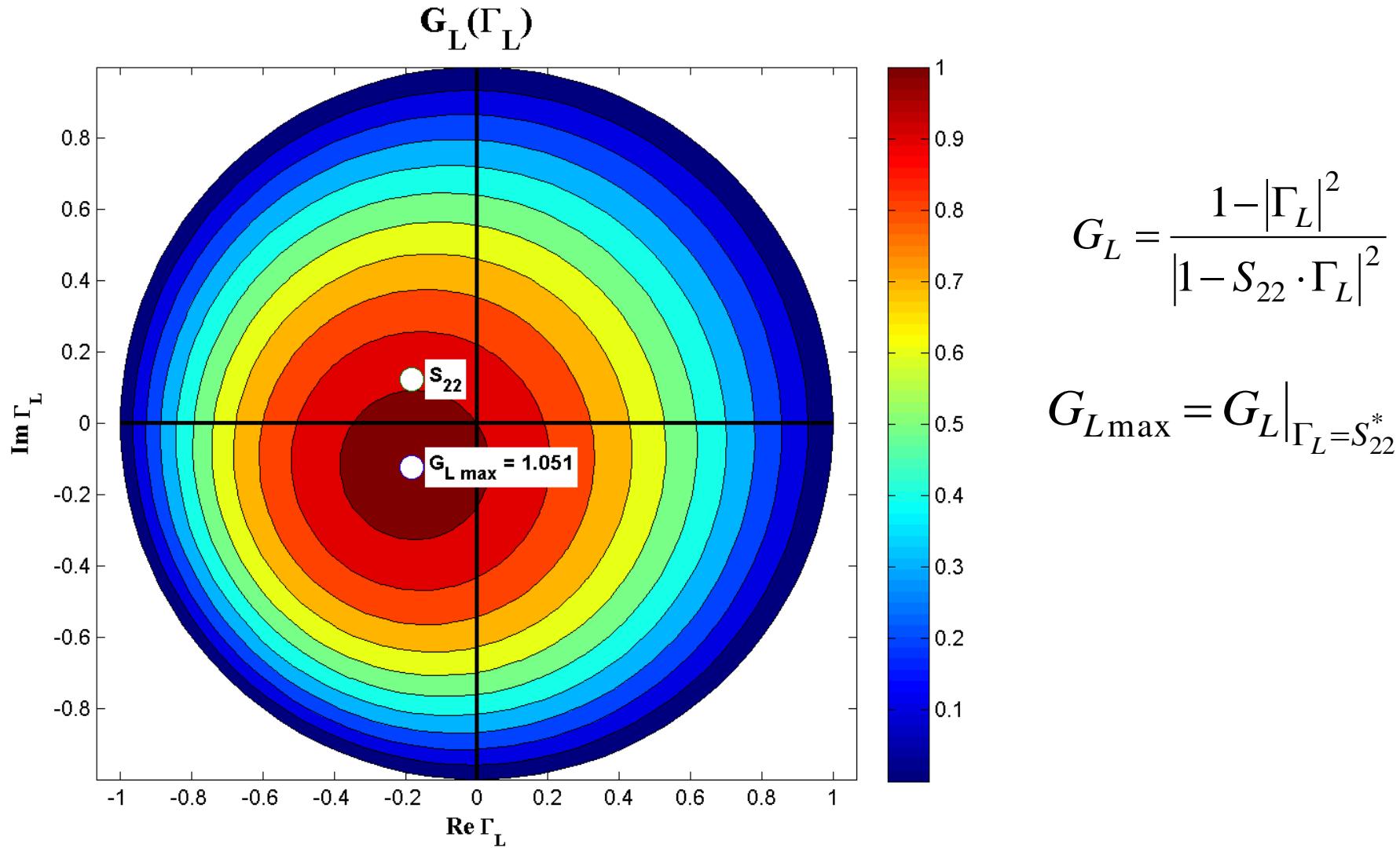
- Exemplu

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

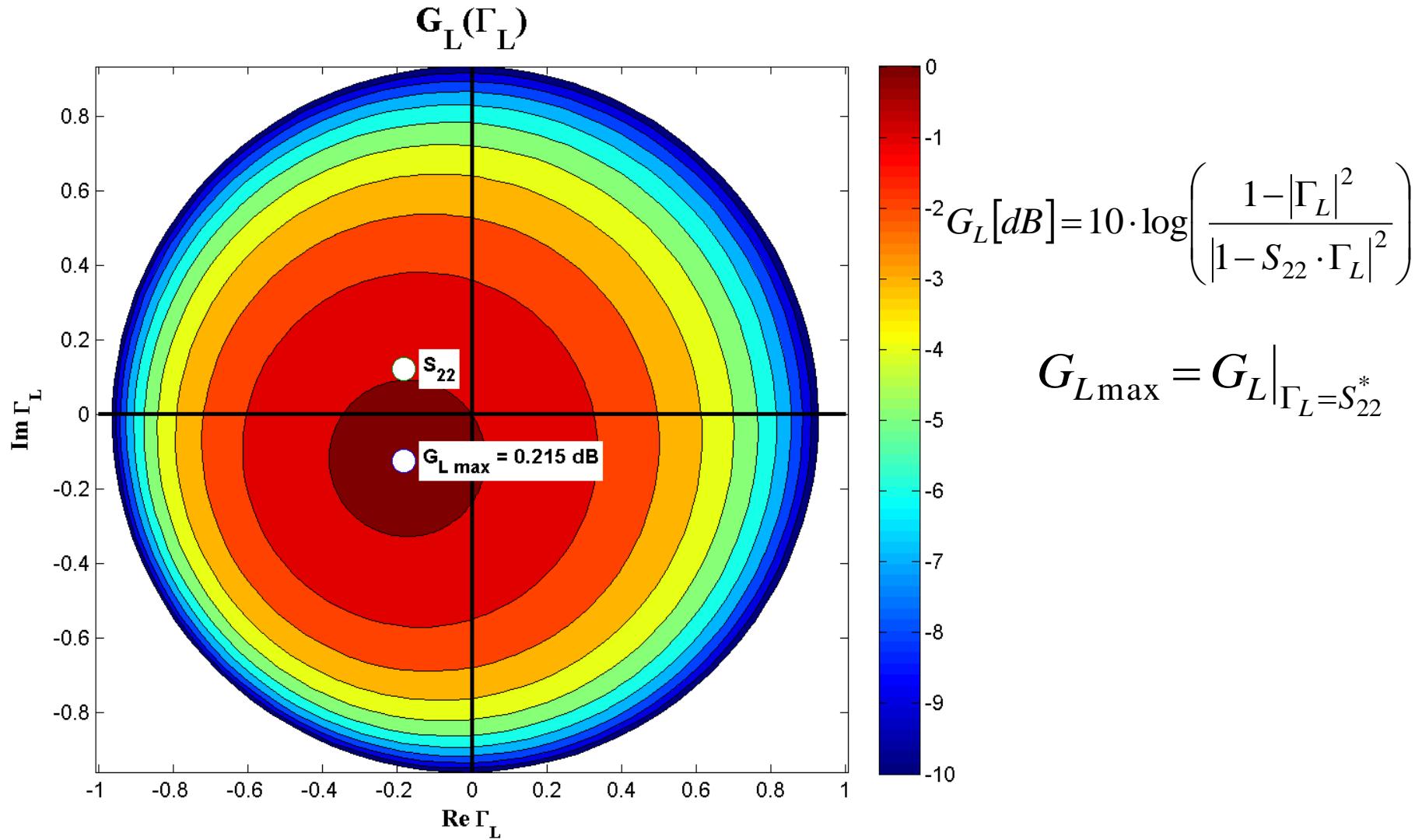
$\mathbf{G}_L(\Gamma_L)$



$G_L(\Gamma_L)$, diagrama de nível

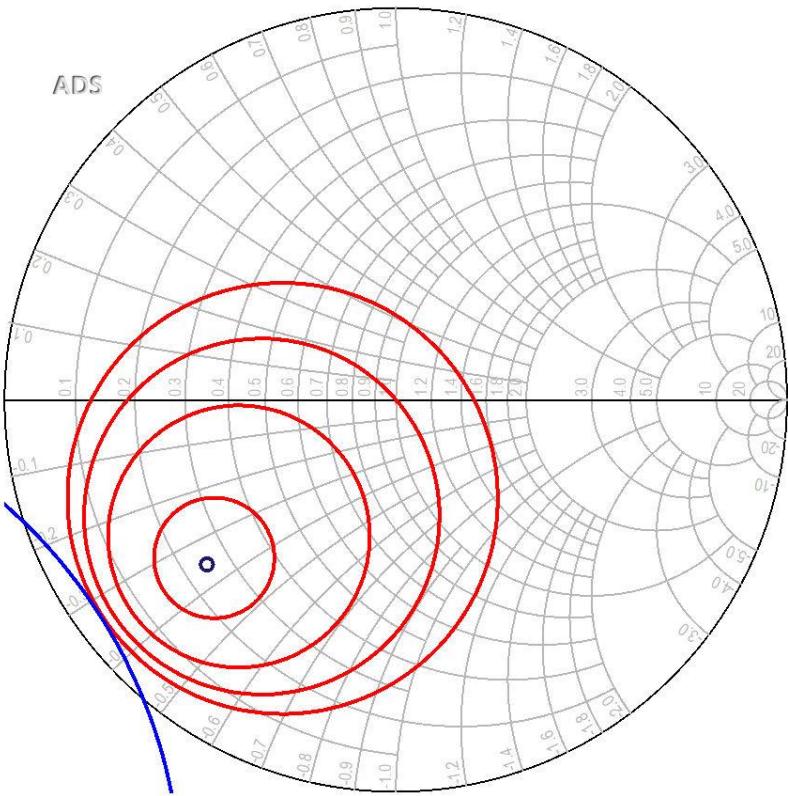


$G_L[\text{dB}](\Gamma_L)$, diagrama de nível

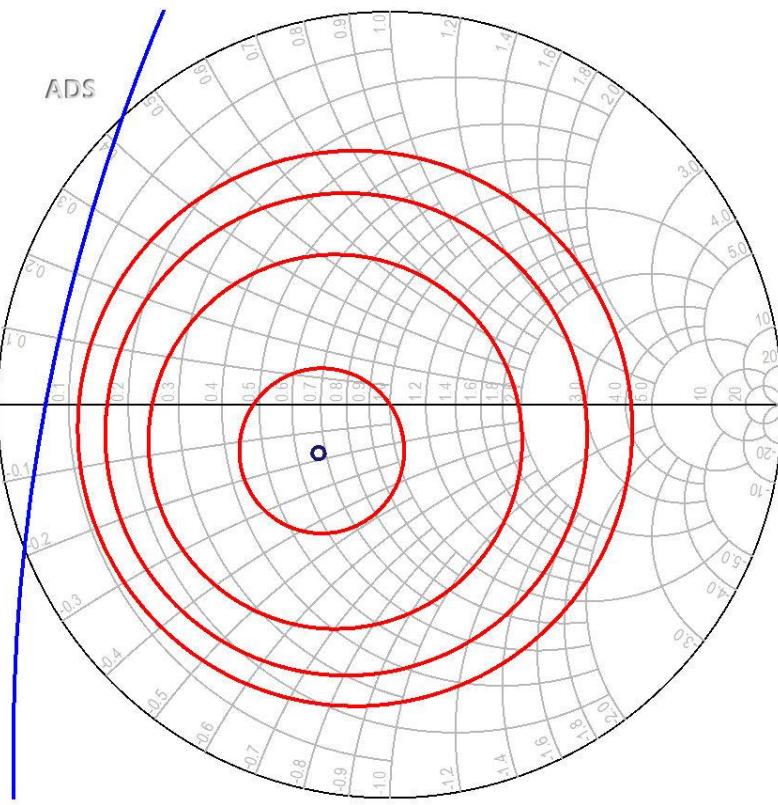


ADS

conj(S(1,1))
CSIN
CCCIN



conj(S(2,2))
CSOUT
CCCOUT



- Cerculile 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

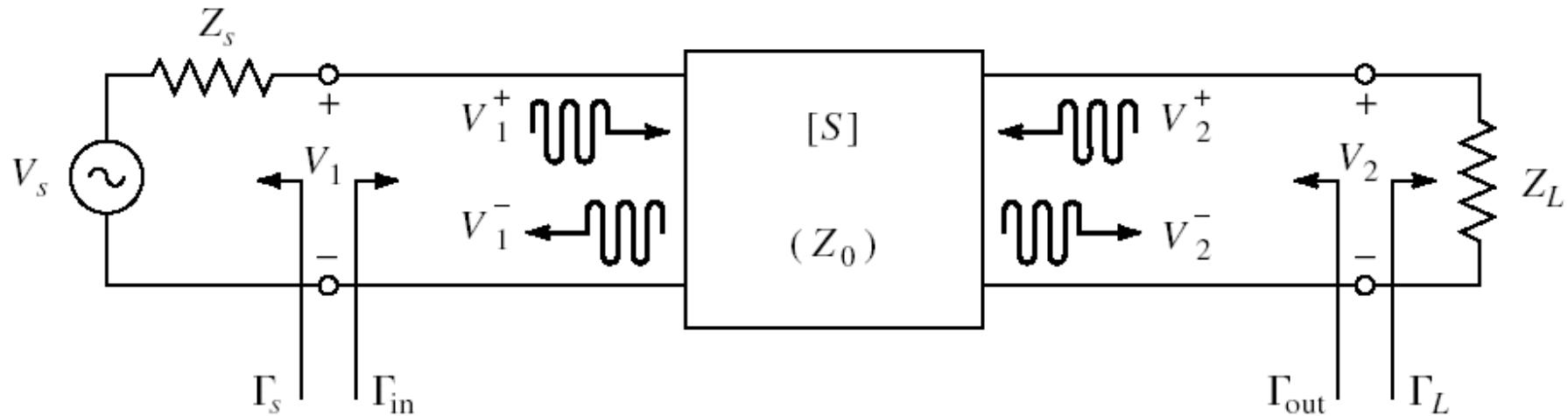
$$G_{dorit} [dB] = G_{S_dor} [dB] + G_0 [dB] + G_{L_dor} [dB]$$

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

Proiectare pentru zgomot redus

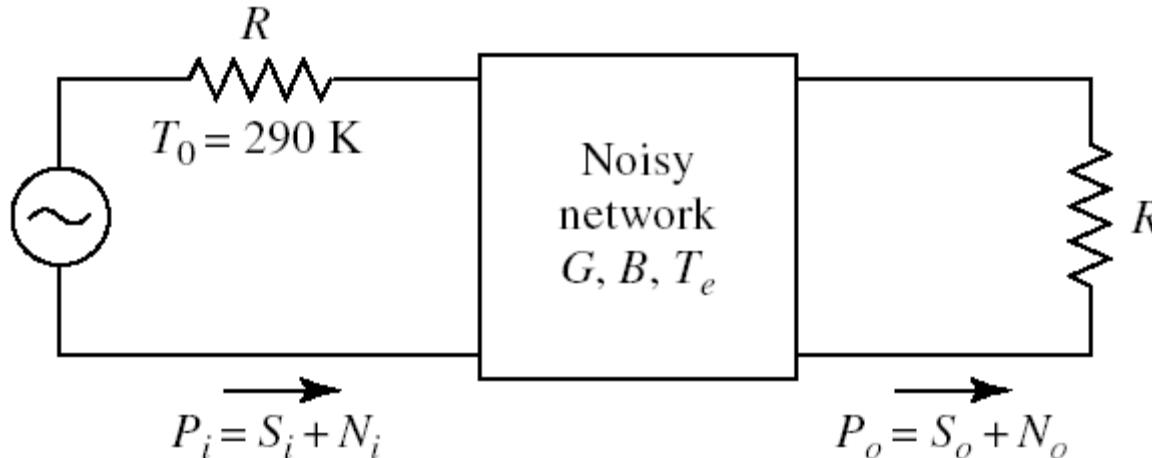
Amplificatoare de microunde

Cuadripol Amplifier



- marimi care intereseaza:
 - stabilitate
 - castig de putere
 - **zgomot (uneori – semnal mic)**
 - liniaritate (uneori – semnal mare)

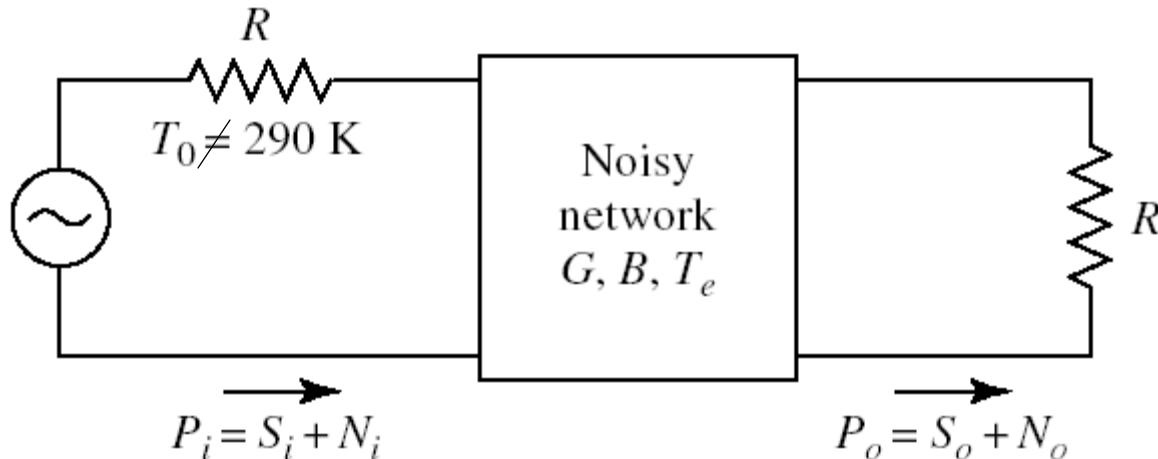
Factor de zgomot



- Factorul de zgomot F caracterizeaza degradarea raportului semnal/zgomot intre intrarea si iesirea unei componente, cand la intrare se aplica o putere de zgomot de referinta ($T_0 = 290\text{K}$)

$$F = \left. \frac{S_i/N_i}{S_o/N_o} \right|_{T_0=290K}$$

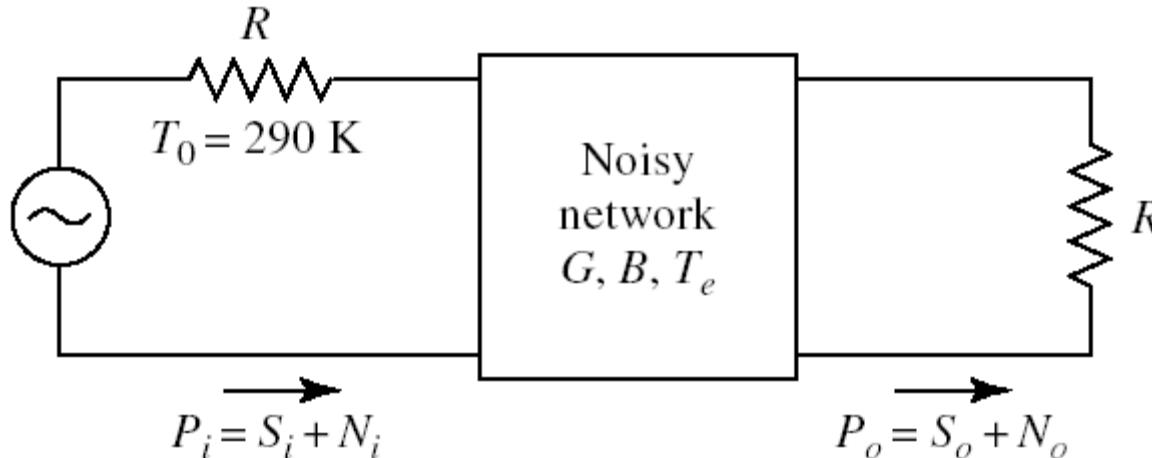
Factor de zgomot



- Factorul de zgomot F **nu** caracterizeaza direct degradarea raportului semnal/zgomot intre intrarea si iesirea unei componente, cand la intrare se aplica o putere de zgomot diferita de cea de referinta

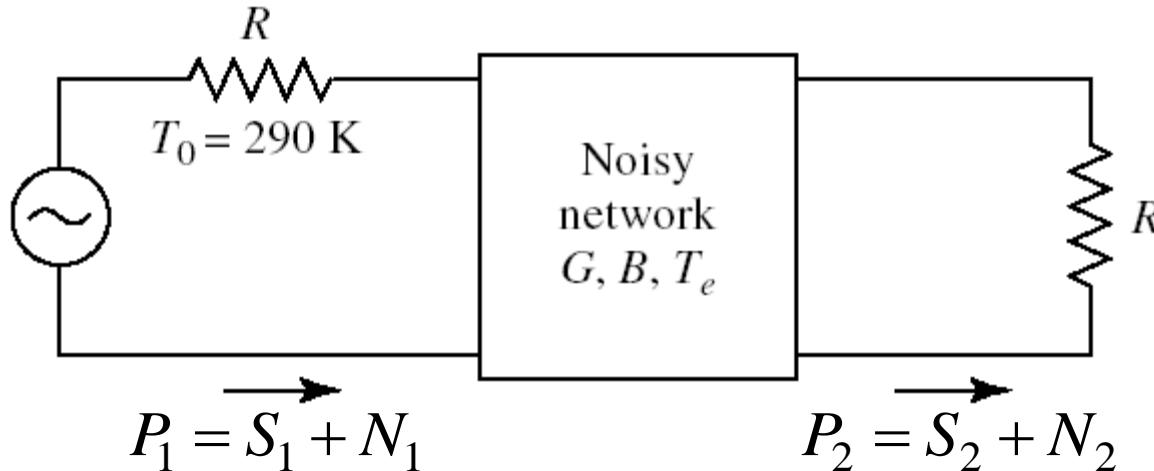
$$F \neq \left. \frac{S_i/N_i}{S_o/N_o} \right|_{T_0 \neq 290K}$$

Factor de zgomot



- În general, puterea de zgomot la ieșire se obtine cu două componente:
 - o putere datorată zgomotului de intrare amplificat cu castigul G (depinde de puterea de zgomot de la intrare)
 - o putere de zgomot generată intern de dispozitiv (care **nu** depinde de puterea de zgomot de la intrare)

Factor de zgomot



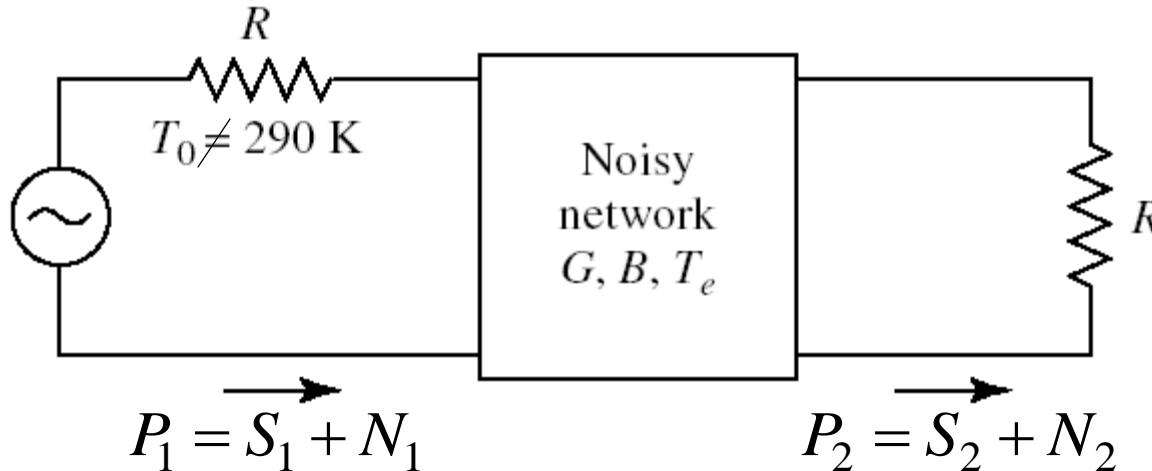
- Estimarea puterii de zgomot adaugate se poate face plecand de la definitia factorului de zgomot:

$$F = \left. \frac{S_1/N_1}{S_2/N_2} \right|_{T_0=290K, N_1=N_0}$$

$$N_2 = F \cdot N_0 \cdot \frac{S_2}{S_1} = F \cdot N_0 \cdot G$$

$$N_2 = N_0 \cdot G + (F - 1) \cdot N_0 \cdot G$$

Factor de zgomot

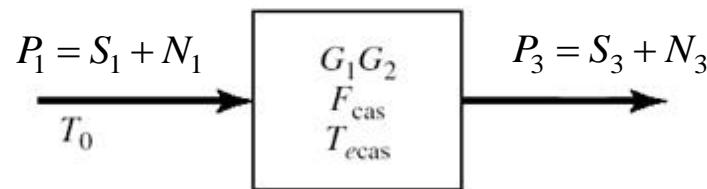
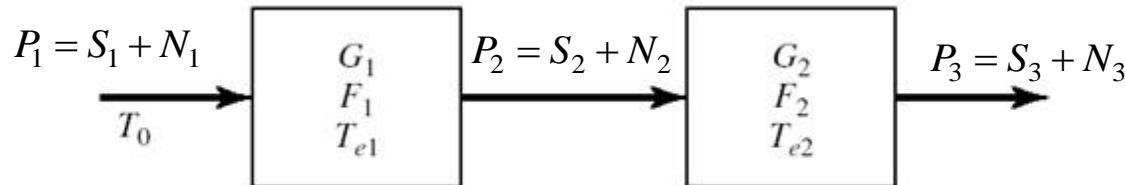


- Se identifica cele două termeni:
 - zgomotul de intrare amplificat
 - zgomotul adăugat intern
- Pentru o situație în care la intrare nu am zgomotul de referință ($N_1 \neq N_0$)

$$N_2 = N_0 \cdot G + (F - 1) \cdot N_0 \cdot G$$

\uparrow \uparrow

Factor de zgomot al circuitelor cascade



$$N_2 = N_1 \cdot G_1 + (F_1 - 1) \cdot N_0 \cdot G_1$$

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

$$N_3 = N_2 \cdot G_2 + (F_2 - 1) \cdot N_0 \cdot G_2$$

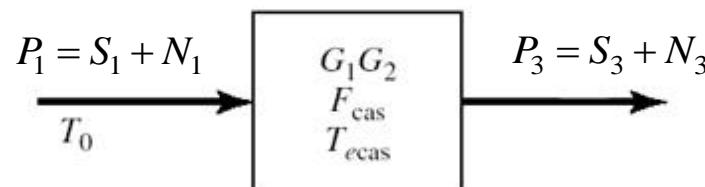
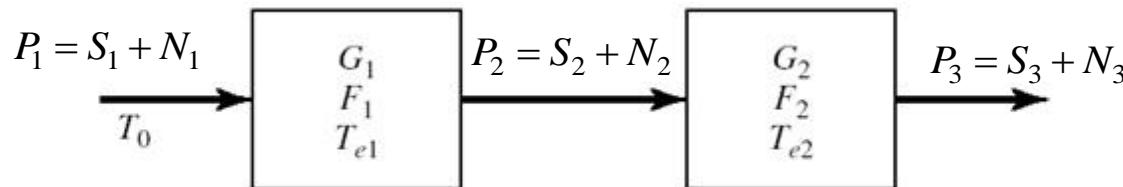
$$N_3 = N_1 \cdot G_{cas} + (F_{cas} - 1) \cdot N_0 \cdot G_{cas}$$



$$N_3 = [N_1 \cdot G_1 + (F_1 - 1) \cdot N_0 \cdot G_1] \cdot G_2 + (F_2 - 1) \cdot N_0 \cdot G_2$$

$$N_3 = N_1 \cdot G_1 \cdot G_2 + (F_1 - 1) \cdot N_0 \cdot G_1 \cdot G_2 + (F_2 - 1) \cdot N_0 \cdot G_2$$

Factor de zgomot al circuitelor cascade



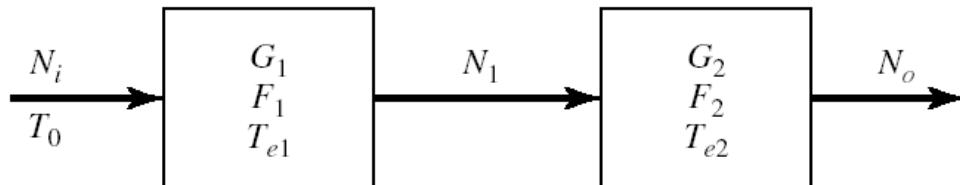
$$N_3 = N_1 \cdot G_1 \cdot G_2 + (F_1 - 1) \cdot N_0 \cdot G_1 \cdot G_2 + (F_2 - 1) \cdot N_0 \cdot G_2$$

$$G_{cas} = G_1 \cdot G_2 \quad N_3 = N_1 \cdot G_{cas} + (F_{cas} - 1) \cdot N_0 \cdot G_{cas}$$

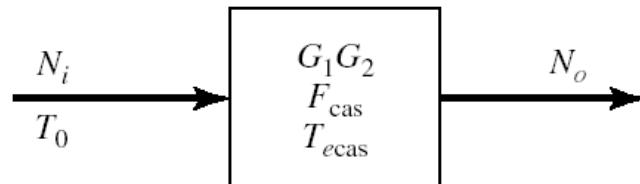
$$(F_1 - 1) \cdot N_0 \cdot G_1 \cdot G_2 + (F_2 - 1) \cdot N_0 \cdot G_2 = (F_{cas} - 1) \cdot N_0 \cdot G_1 \cdot G_2$$

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

Factor de zgomot al circuitelor cascade



(a)



(b)

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

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

- Ecuatia Friis (!coordonate liniare)

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

Formula lui Friis (zgomot)

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

- Formula lui Friis 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)

Formula lui Friis (zgomot)

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

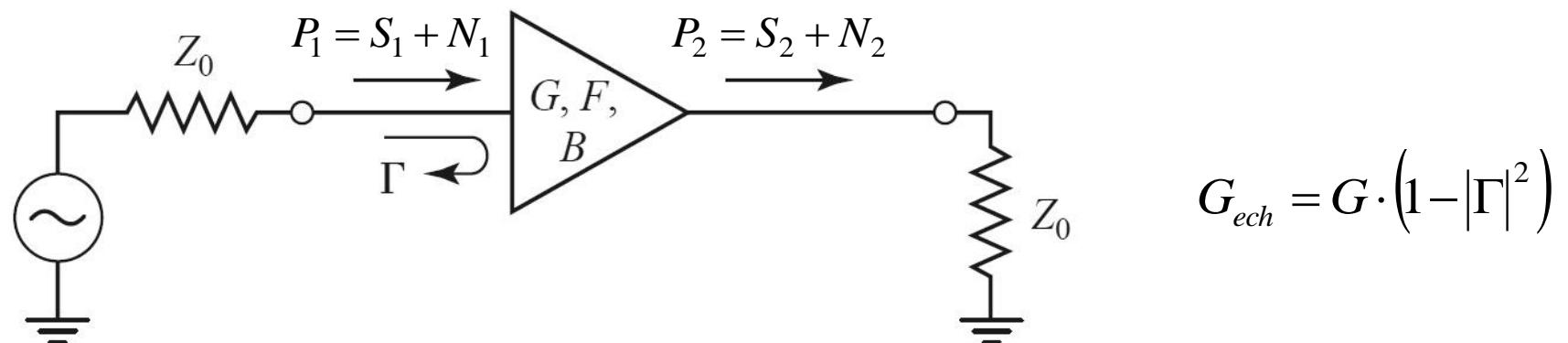
- Formula lui Friis, efecte:
 - in amplificatoare multietaj:
 - e esential ca primul etaj de amplificare sa fie nezgomotos, chiar cu sacrificarea in parte a castigului
 - urmatoarele etaje pot fi optimizate pentru castig
 - pentru un singur amplificator:
 - la intrare e important sa introducem elemente nezgomotoase (reactive, linii fara pierderi)
 - circuitul de adaptare la iesire are o influenta mai mica (zgomotul este generat intr-un punct in care semnalul este deja amplificat de tranzistor)

$$V_{n(ef)} = \sqrt{4kTBR}$$

$$P_n = kTB$$

Zgomotul amplificatoarelor dezadaptate

- Un amplificator dezadaptat la intrare ($\Gamma \neq 0$)



$$N_2 = N_1 \cdot G \cdot (1 - |\Gamma|^2) + (F - 1) \cdot N_0 \cdot G = N_1 \cdot G \cdot (1 - |\Gamma|^2) + \frac{F - 1}{1 - |\Gamma|^2} \cdot N_0 \cdot G \cdot (1 - |\Gamma|^2)$$

$$N_2 = N_1 \cdot G_{ech} + (F_{ech} - 1) \cdot N_0 \cdot G_{ech}$$

$$F_{ech} = 1 + \frac{F - 1}{1 - |\Gamma|^2} \geq F$$

- Obtinerea unui zgomot redus **necesa**tă o buna adaptare de impedanta

Exemplu

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

- @5GHz

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

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

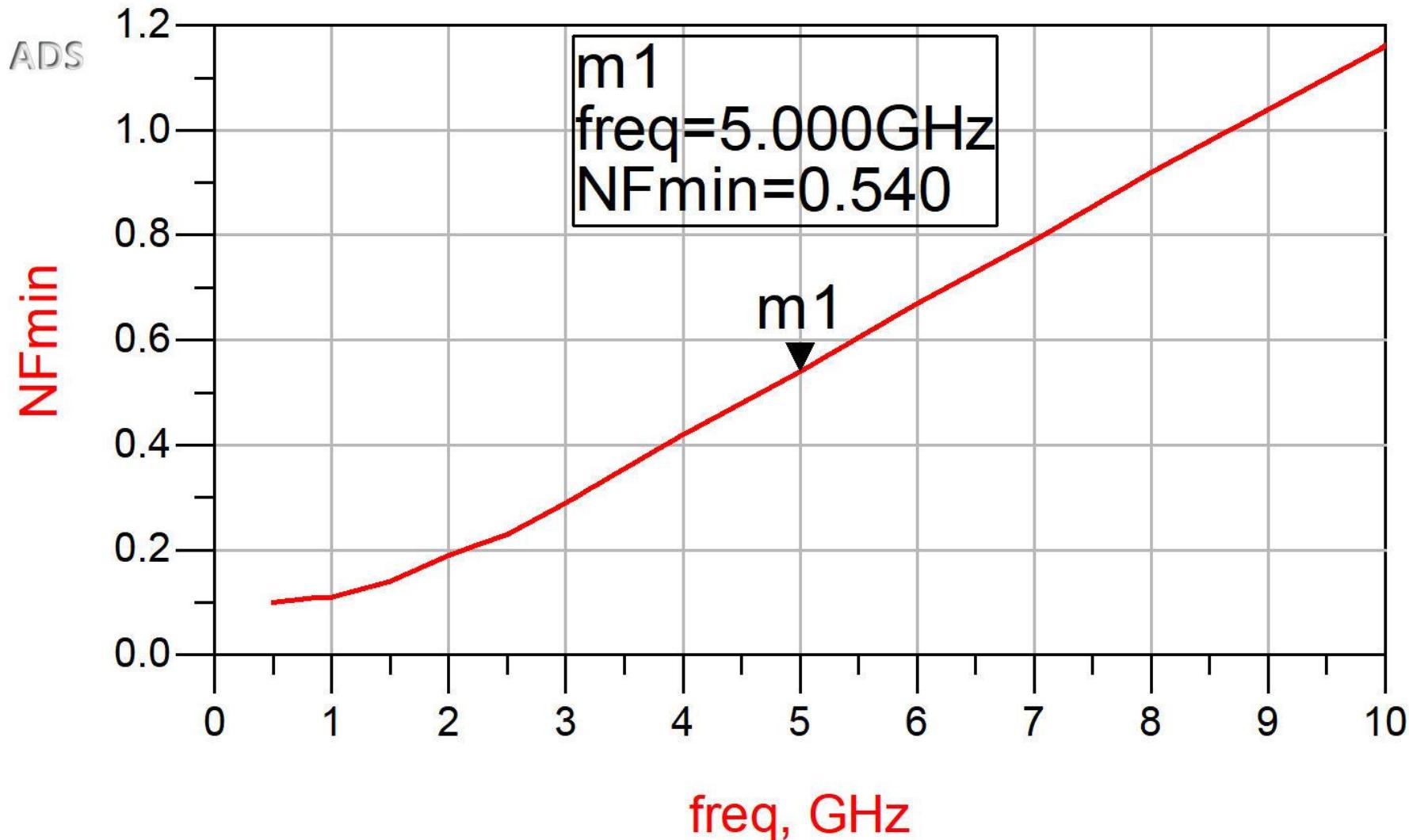
```
# ghz s ma r 50
```

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

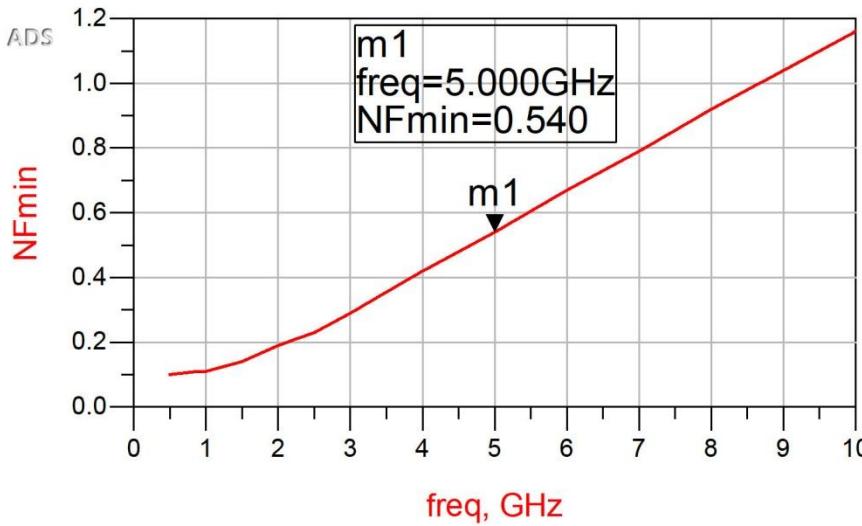
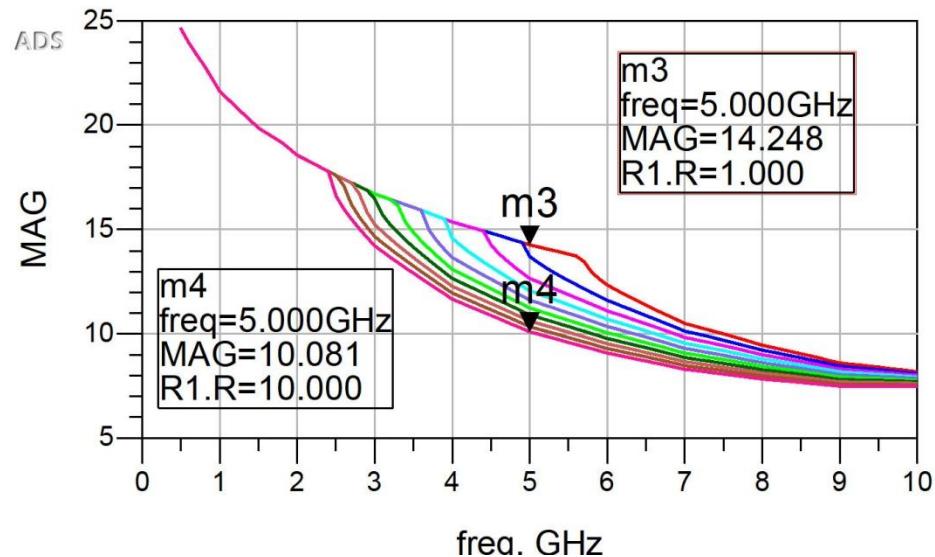
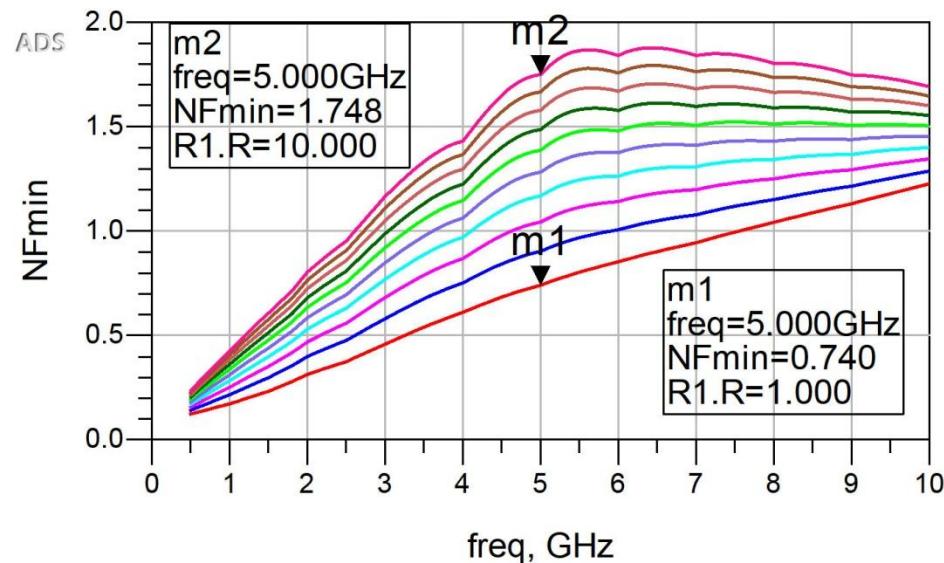
```
!FREQ Fopt GAMMA OPT RN/Zo
!GHZ dB MAG ANG -
```

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

Exemplu

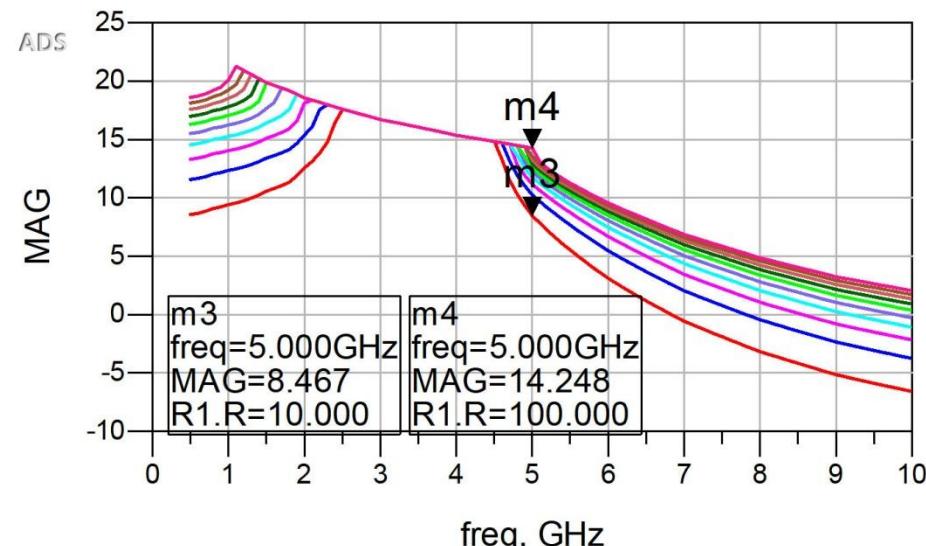
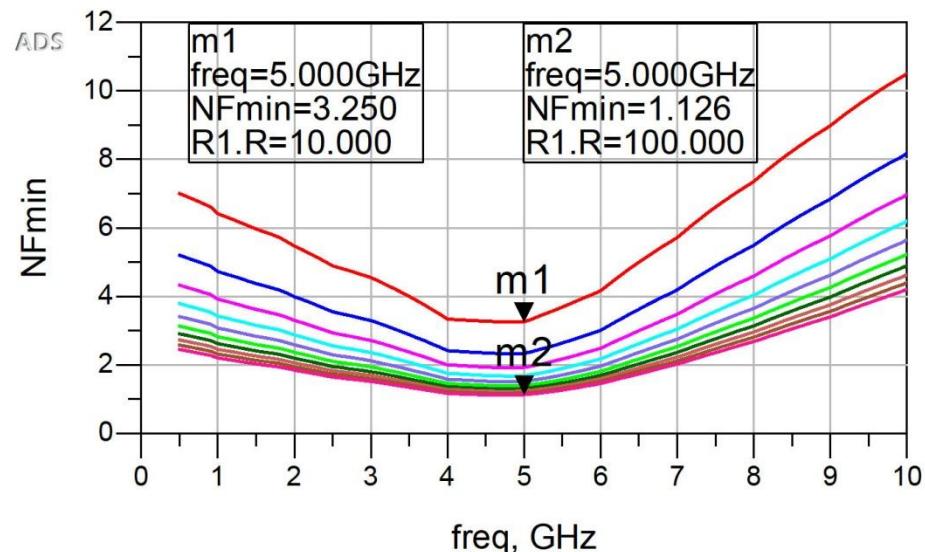


Stabilizare R serie la intrare

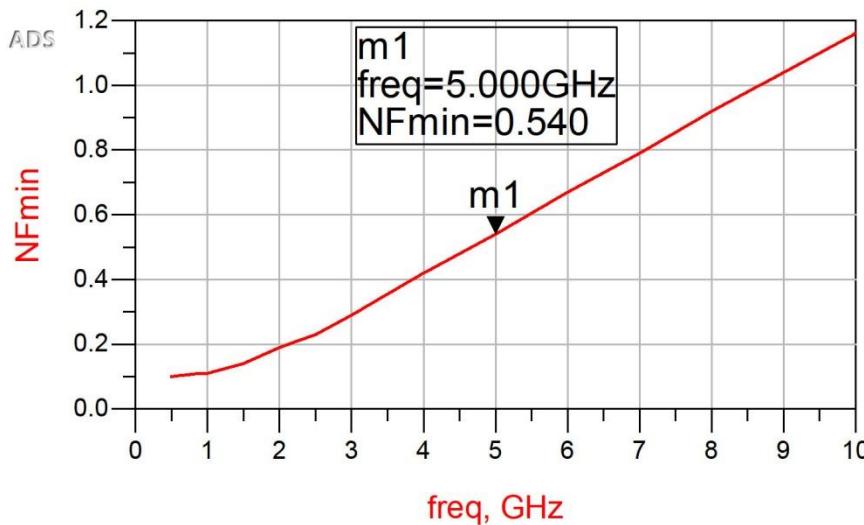


$$R_{SS} = 1 \div 10 \Omega$$

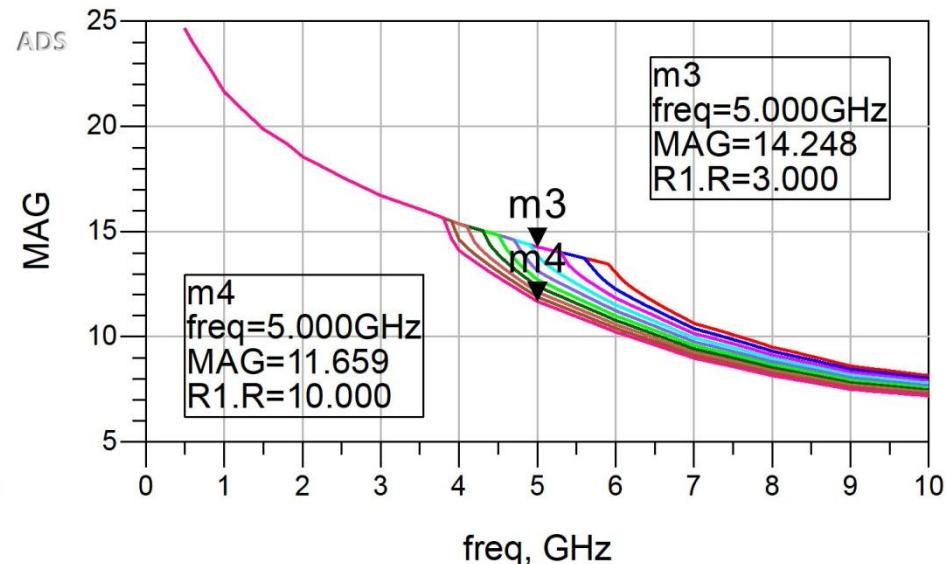
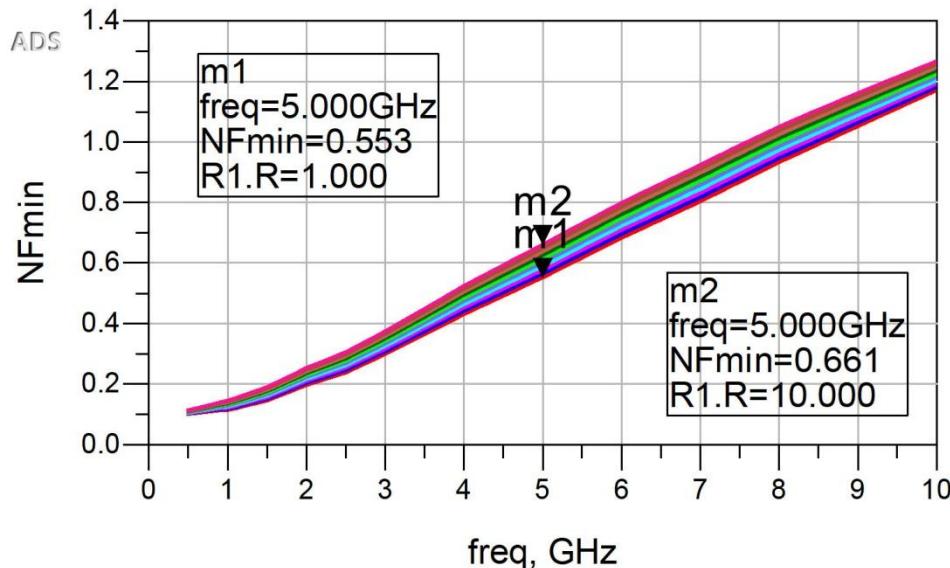
Stabilizare R paralel la intrare



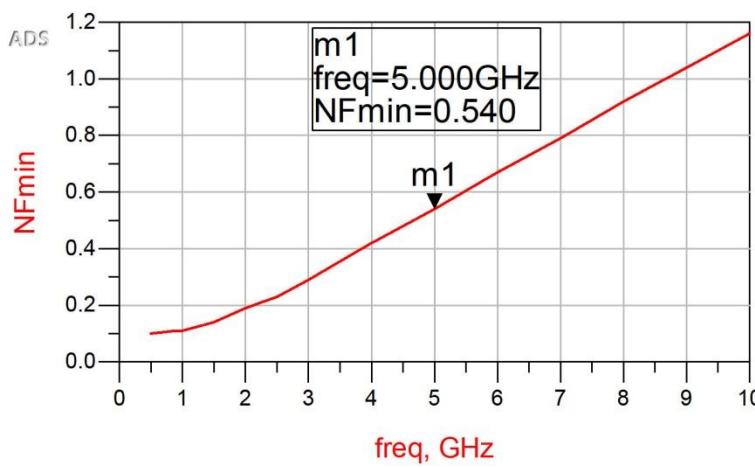
$$R_{PS} = 10 \div 100 \Omega$$



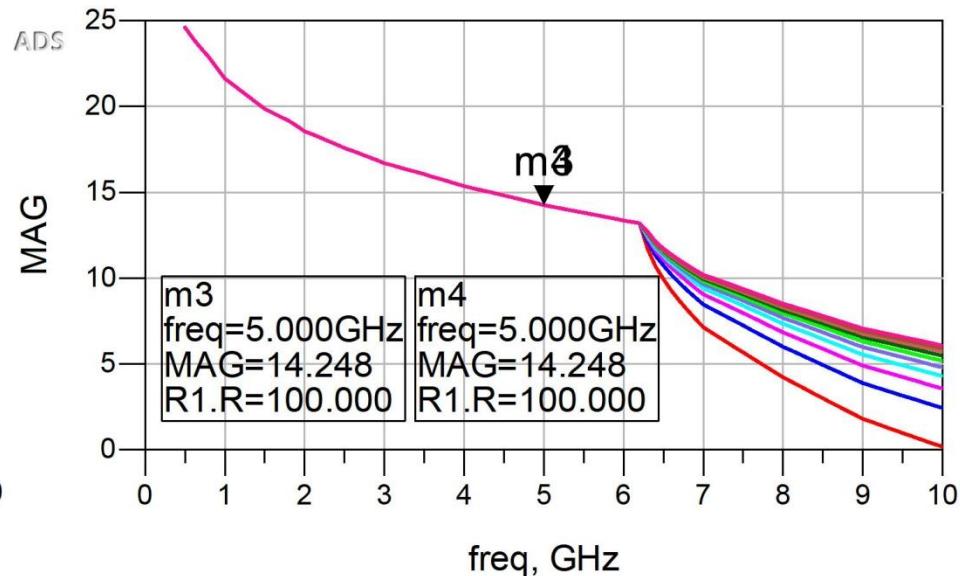
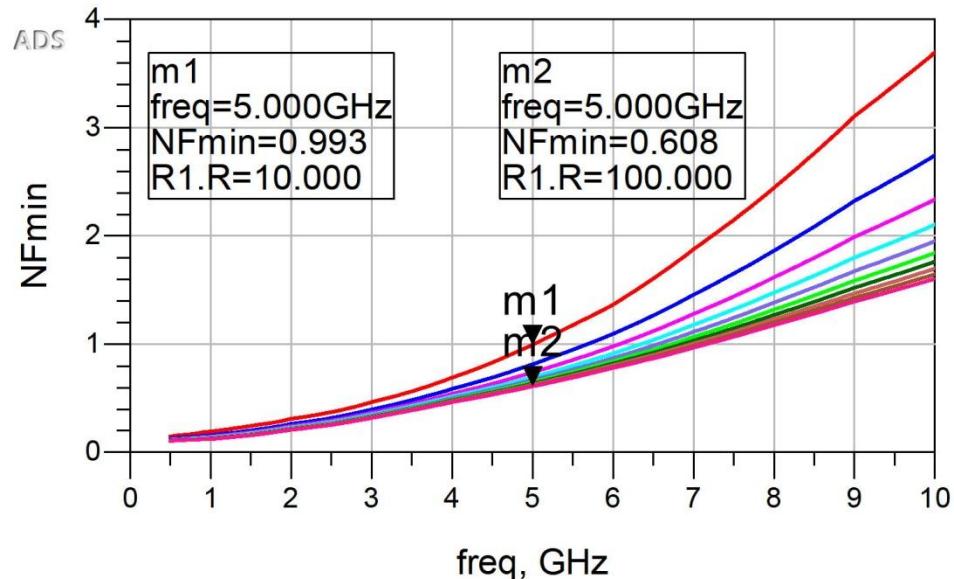
Stabilizare R serie la ieșire



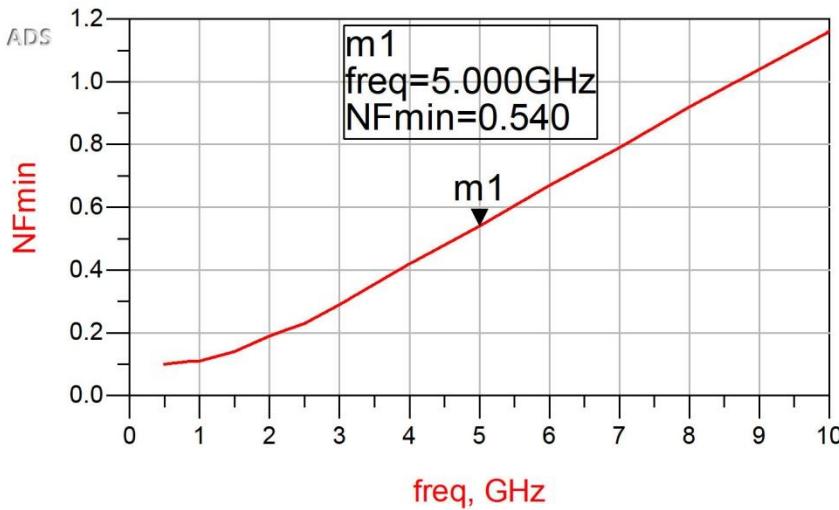
$$R_{SL} = 1 \div 10 \Omega$$



Stabilizare R paralel la ieșire



$$R_{PL} = 10 \div 100 \Omega$$



Zgomotul unui amplificator

- Caracterizat de 3 parametri (2 reali + 1 complex):

$$F_{\min}, r_n = \frac{R_N}{Z_0}, \Gamma_{opt}$$

$$F = F_{\min} + \frac{R_N}{G_S} \cdot |Y_S - Y_{opt}|^2 \quad Y_S = \frac{1}{Z_0} \cdot \frac{1 - \Gamma_S}{1 + \Gamma_S} \quad Y_{opt} = \frac{1}{Z_0} \cdot \frac{1 - \Gamma_{opt}}{1 + \Gamma_{opt}}$$

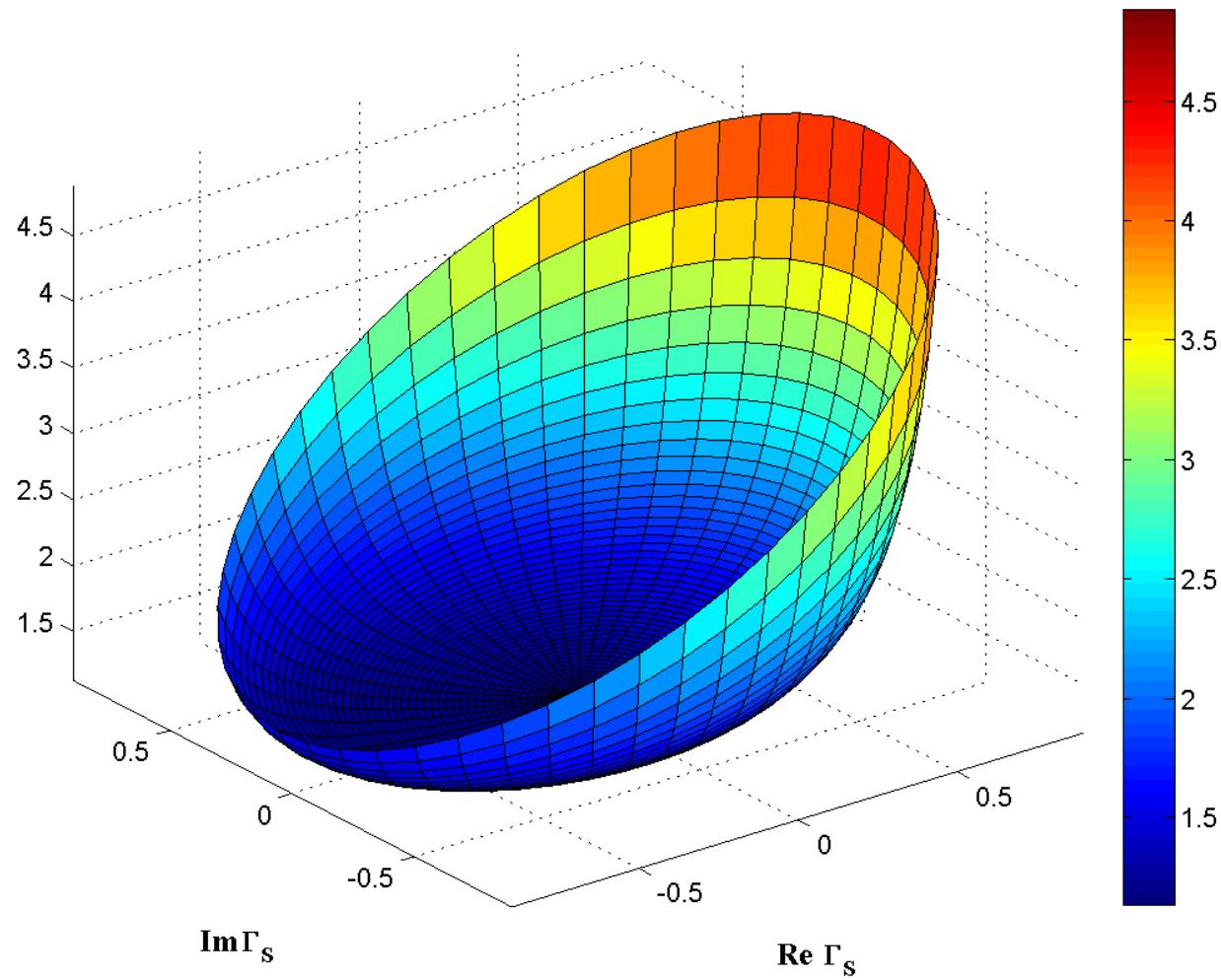
$$F = F_{\min} + 4 \cdot r_n \cdot \frac{|\Gamma_S - \Gamma_{opt}|^2}{(1 - |\Gamma_S|^2) \cdot |1 + \Gamma_{opt}|^2}$$

- Γ_{opt} reprezinta coeficientul optim de reflexie la intrare

$$\Gamma_S = \Gamma_{opt} \Rightarrow F = F_{\min}$$

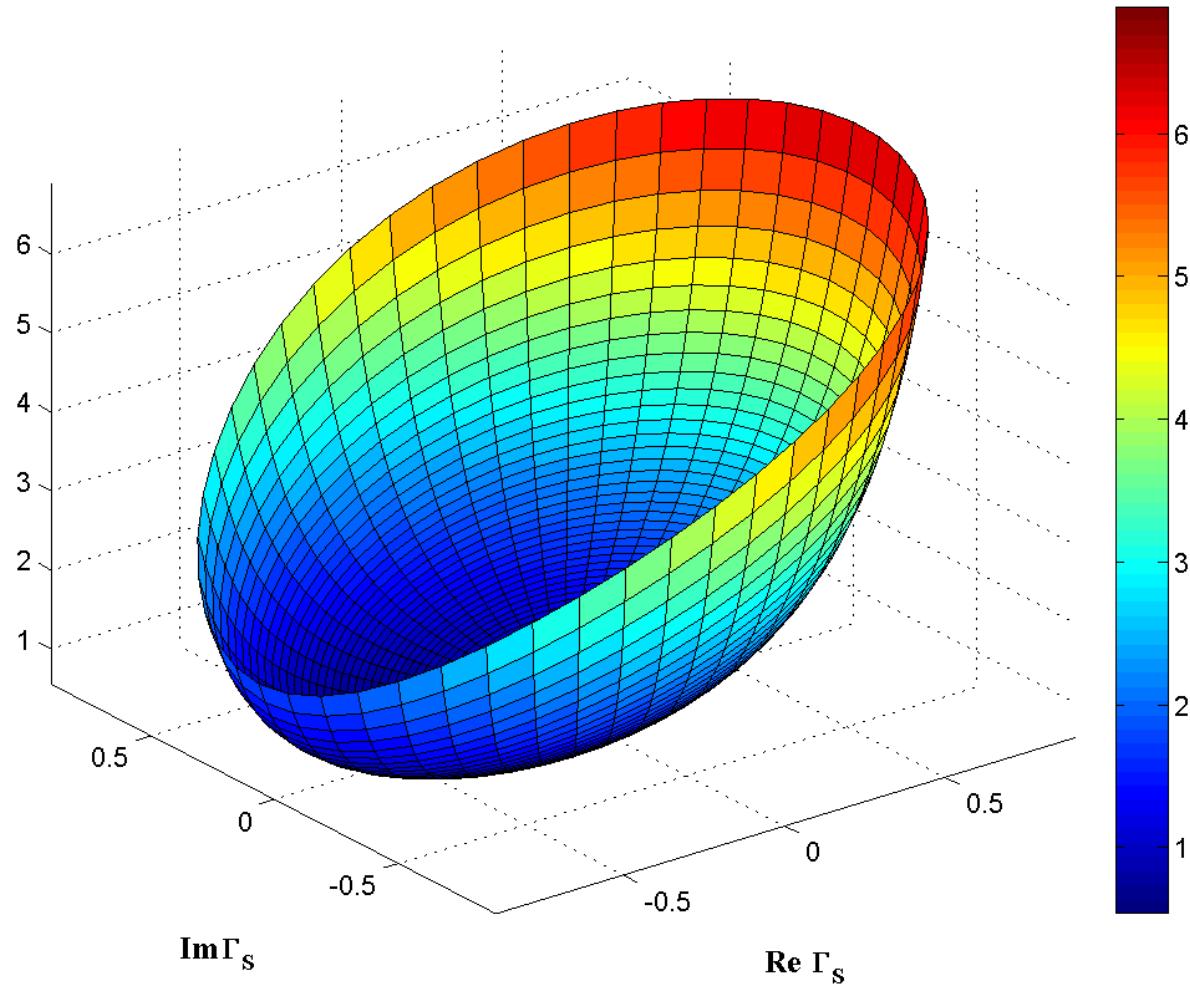
$F(\Gamma_s)$

$F(\Gamma_s)$

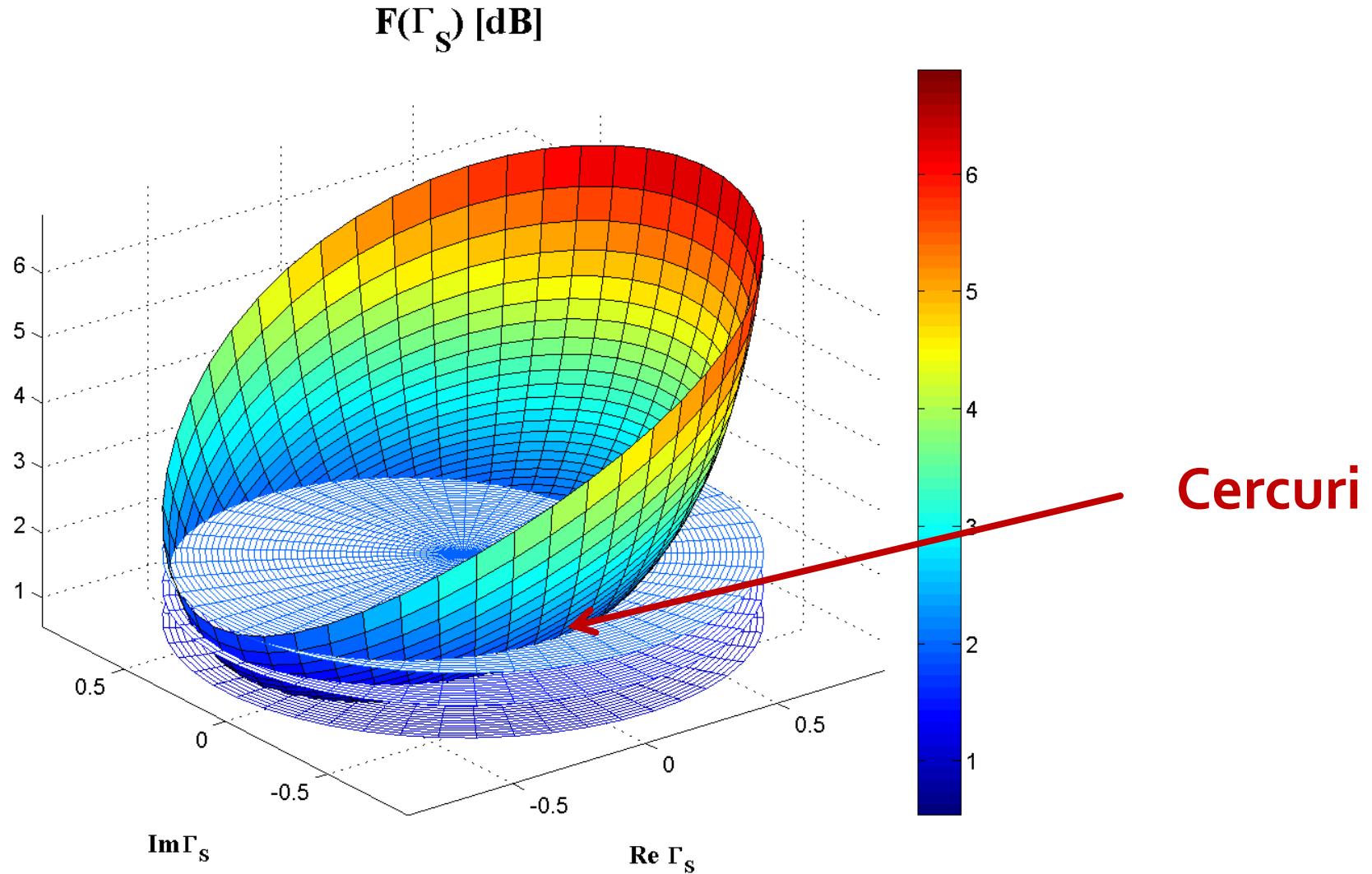


$F[dB](\Gamma_S)$

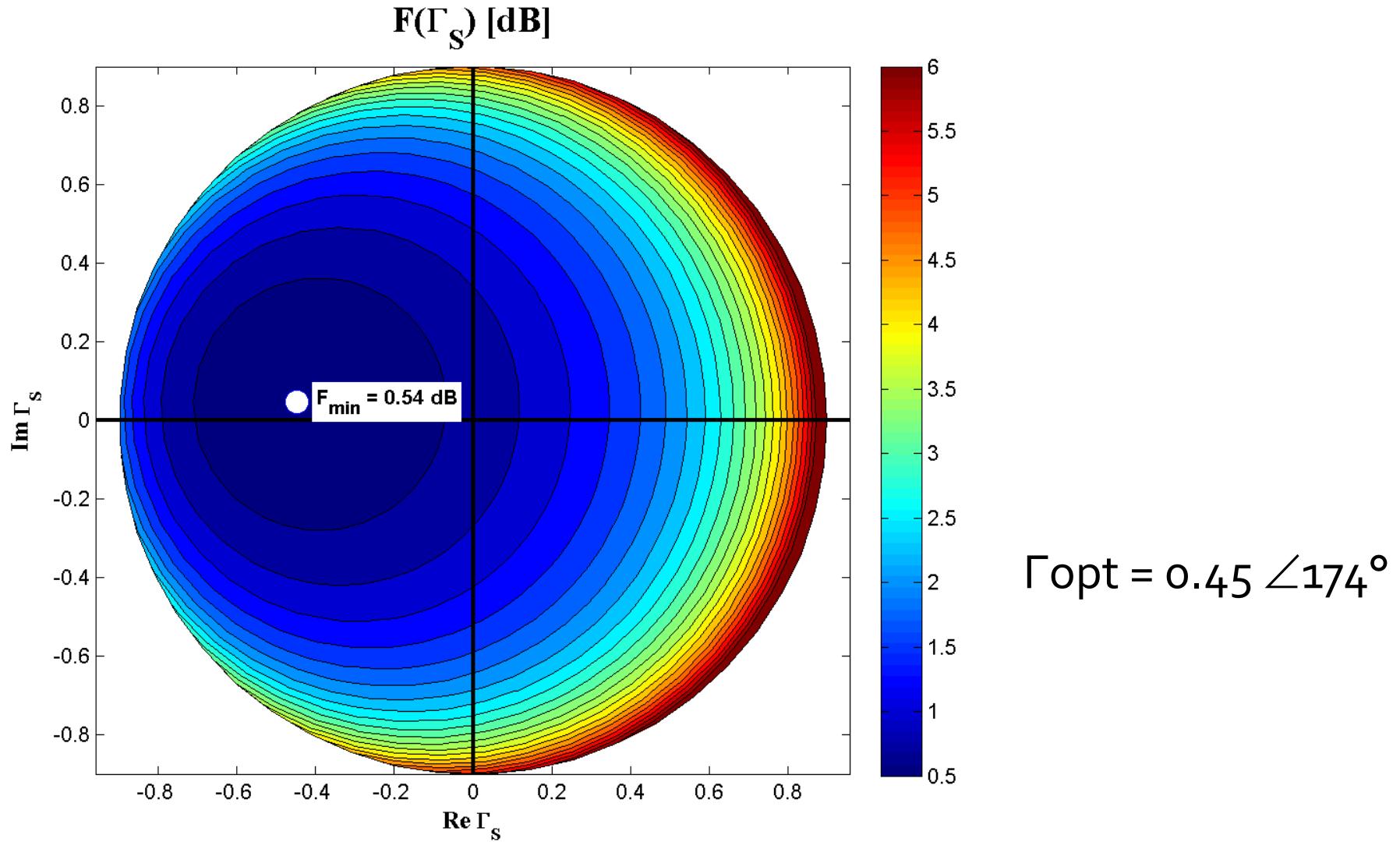
$F(\Gamma_S) [dB]$



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



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



Cercuri de zgromot constant

- Se noteaza cu N (parametru de zgromot)
 - N constant pentru F constant

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

$$(\Gamma_S - \Gamma_{opt}) \cdot (\Gamma_S^* - \Gamma_{opt}^*) = N \cdot (1 - |\Gamma_S|^2)$$

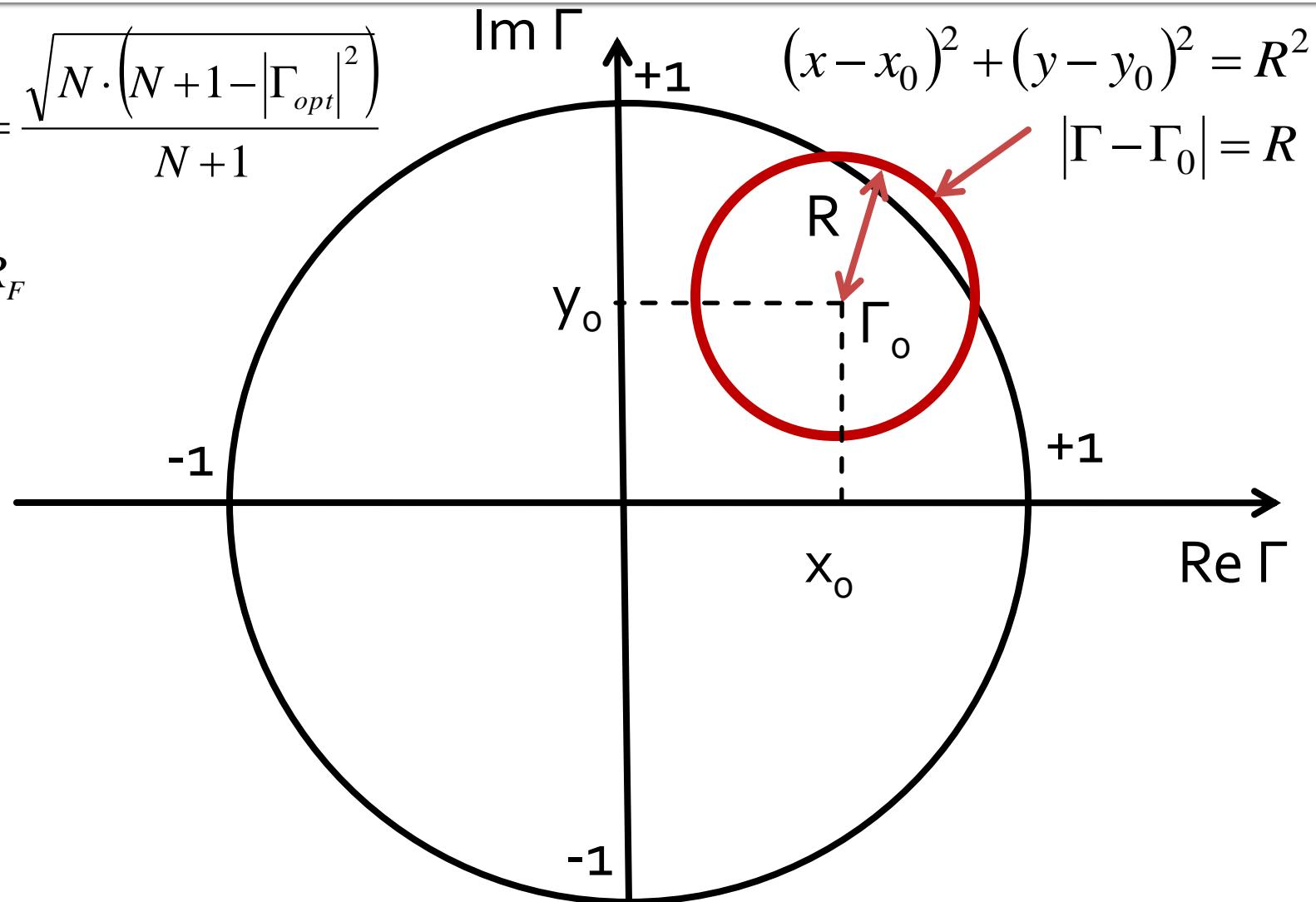
$$\Gamma_S \cdot \Gamma_S^* + N \cdot |\Gamma_S|^2 - (\Gamma_S \cdot \Gamma_{opt}^* - \Gamma_S^* \cdot \Gamma_{opt}) + \Gamma_{opt} \cdot \Gamma_{opt}^* = N$$

$$\Gamma_S \cdot \Gamma_S^* - \frac{\Gamma_S \cdot \Gamma_{opt}^* - \Gamma_S^* \cdot \Gamma_{opt}}{N+1} + \Gamma_{opt} \cdot \Gamma_{opt}^* = \frac{N - |\Gamma_{opt}|^2}{N+1} \quad \left. + \frac{|\Gamma_{opt}|^2}{(N+1)^2} \right.$$

Zgomot

$$\left| \Gamma_s - \frac{\Gamma_{opt}}{N+1} \right| = \frac{\sqrt{N \cdot (N+1 - |\Gamma_{opt}|^2)}}{N+1}$$

$$|\Gamma_s - C_F| = R_F$$



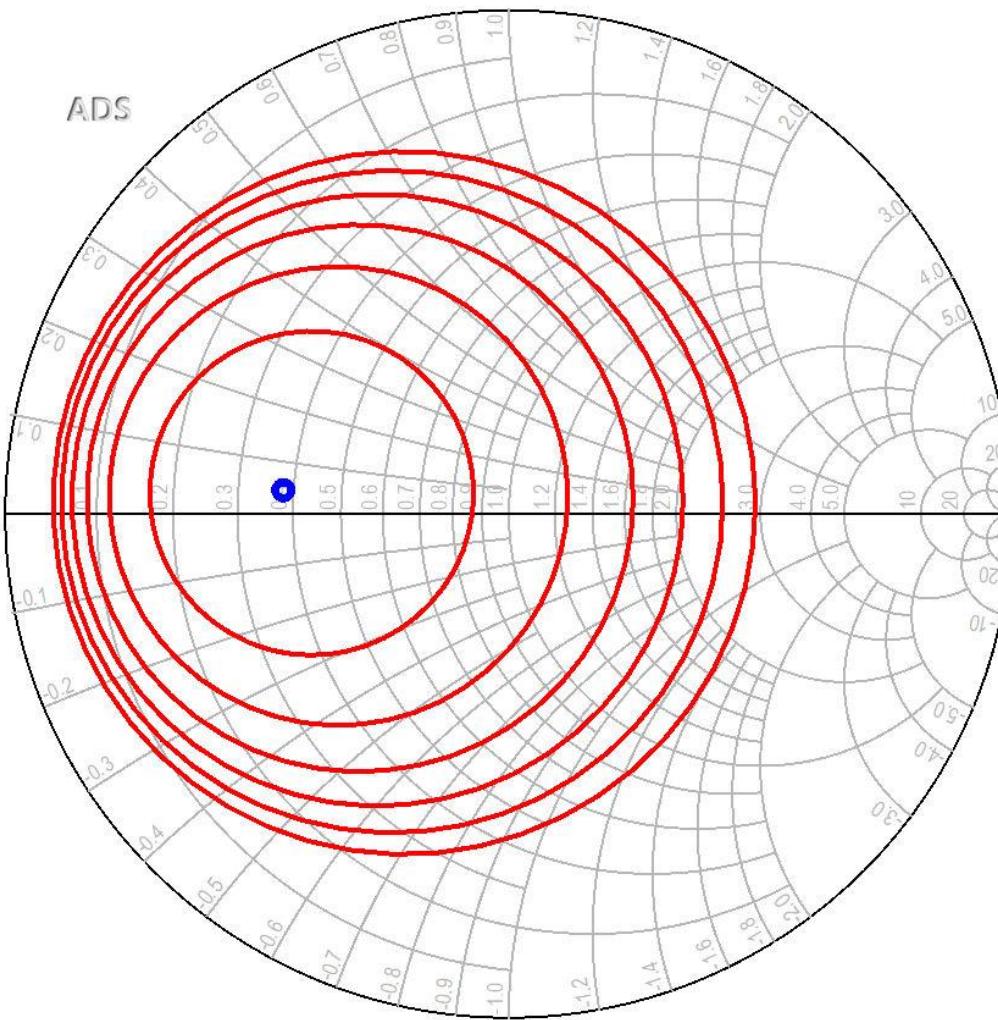
Cercuri de zgomot constant

$$\left| \Gamma_S - \frac{\Gamma_{opt}}{N+1} \right| = \frac{\sqrt{N \cdot (N+1 - |\Gamma_{opt}|^2)}}{N+1}$$
$$|\Gamma_S - C_F| = R_F$$
$$C_F = \frac{\Gamma_{opt}}{N+1}$$
$$R_F = \frac{\sqrt{N \cdot (N+1 - |\Gamma_{opt}|^2)}}{N+1}$$

- Locul geometric al punctelor caracterizate de factor de zgomot constant este un cerc
- **Interpretare:** Orice punct Γ_S care reprezentat in planul complex se gaseste **pe** cercul desenat pentru F_{cerc} va conduce la obtinerea factorului de zgomot $F = F_{cerc}$
 - Orice punct **in exteriorul** acestui cerc va genera un factor de zgomot $F > F_{cerc}$
 - Orice punct **in interiorul** acestui cerc va genera un factor de zgomot $F < F_{cerc}$

ADS

S_{opt}
CZ

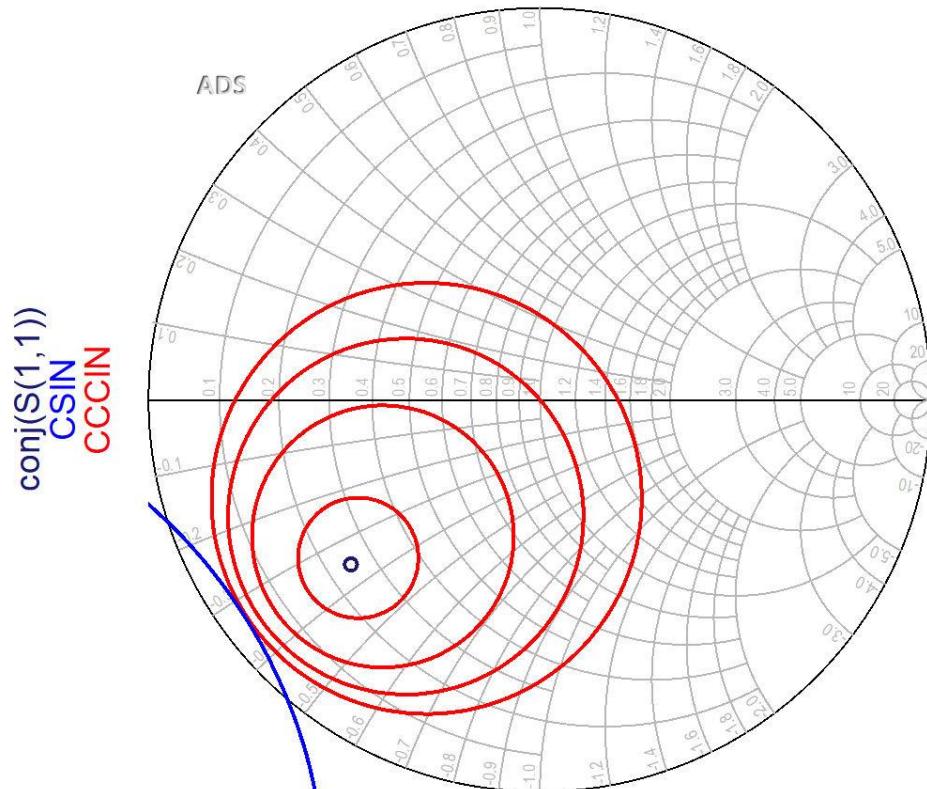
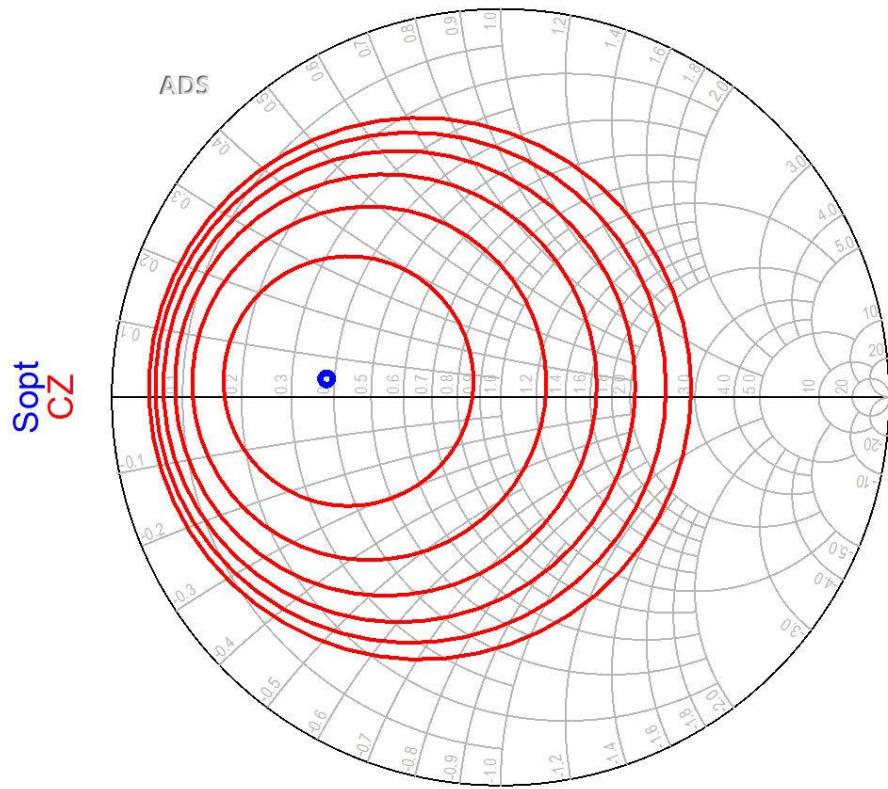


Cercuri de zgromot constant

- Se observa ca zgromotul generat de tranzistor depinde numai de modul in care se realizeaza adaptarea la intrare
- Se poate obtine un minim (F_{\min} care este parametru de catalog pentru tranzistor)
- Daca se urmareste realizarea unui amplificator de zgromot redus (**LNA**) o metoda uzuala este:
 - adaptarea la intrare a tranzistorului din considerente de zgromot
 - adaptarea la iesire utilizata pentru compensarea castigului (daca sunt elemente cu pierderi adaptarea la iesire poate adauga zgromot propriu, dar nu se influenteaza in nici un fel zgromotul generat de tranzistor)

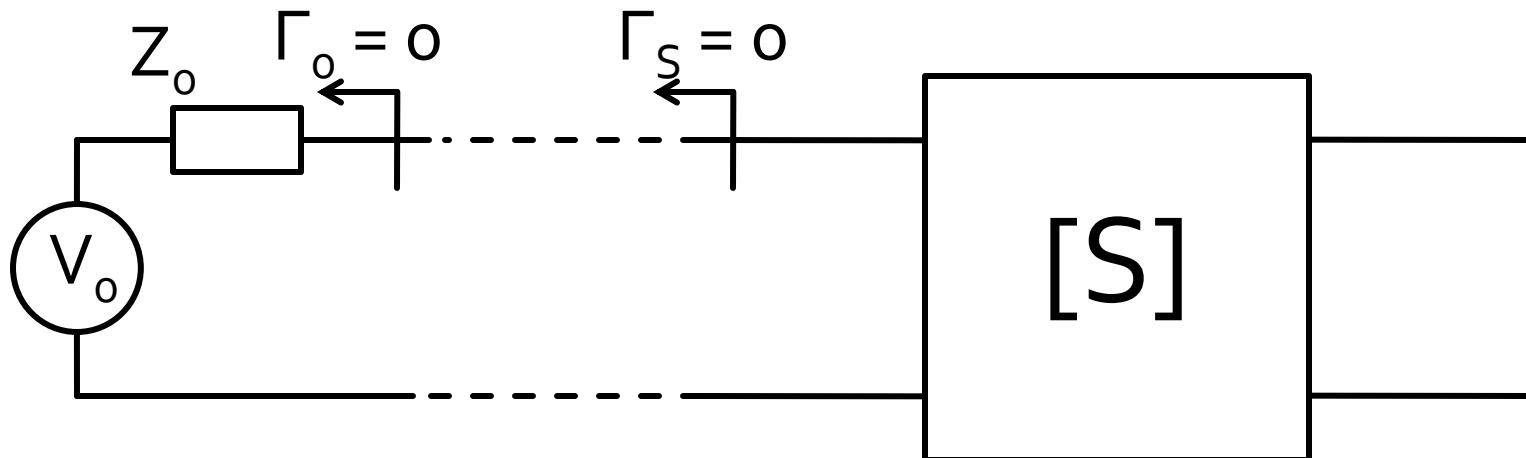
LNA – Low Noise Amplifier

- 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



Adaptare – 1

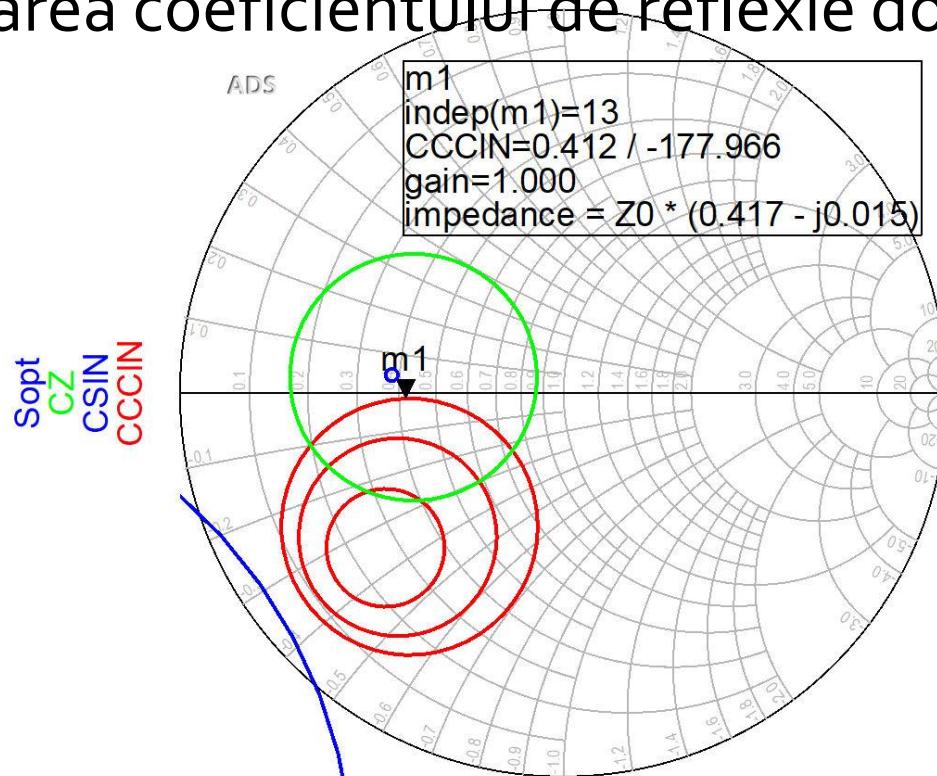
- Conectarea amplificatorului (tranzistorului) direct la sursa de semnal oferă un coeficient de reflexie la intrarea tranzistorului egal cu **0** (complex, $\Gamma_o = 0 + 0 \cdot j$)
 - de cele mai multe ori acest coeficient de reflexie nu oferă condiții optime de castig si/sau zgomot



Adaptare – 2

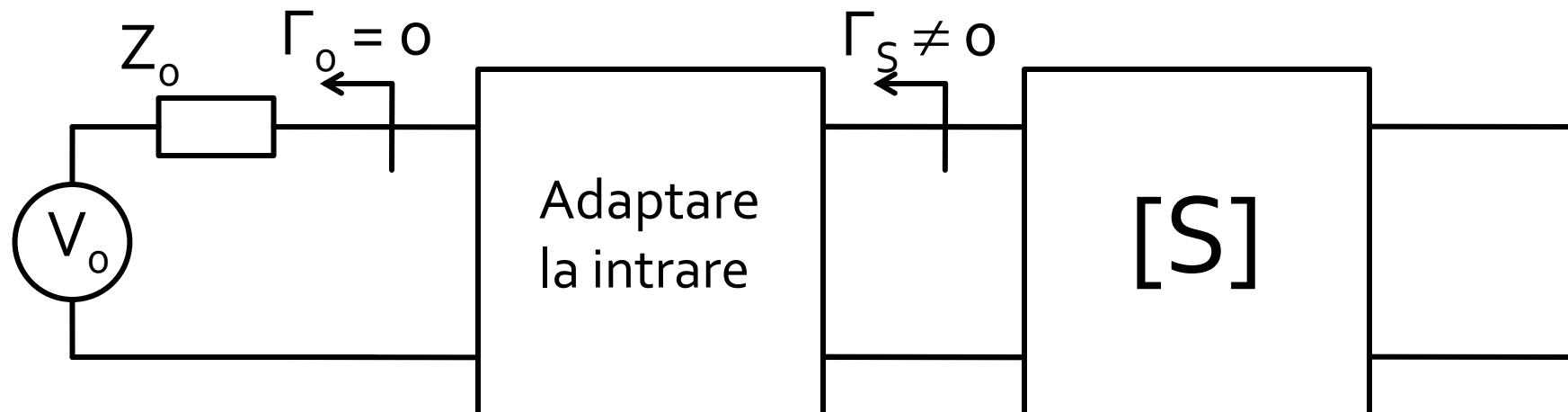
- Se deseneaza pe diagrama Smith cercurile de stabilitate/castig/zgomot, in functie de aplicatia
- Se alege punctul cu o pozitionare dorita relativ la aceste cercuri (de asemenea dependent de aplicatie)
- Se determina valoarea coeficientului de reflexie dorit la intrare Γ_S

$$\Gamma_S = 0.412 \angle -177.966^\circ$$



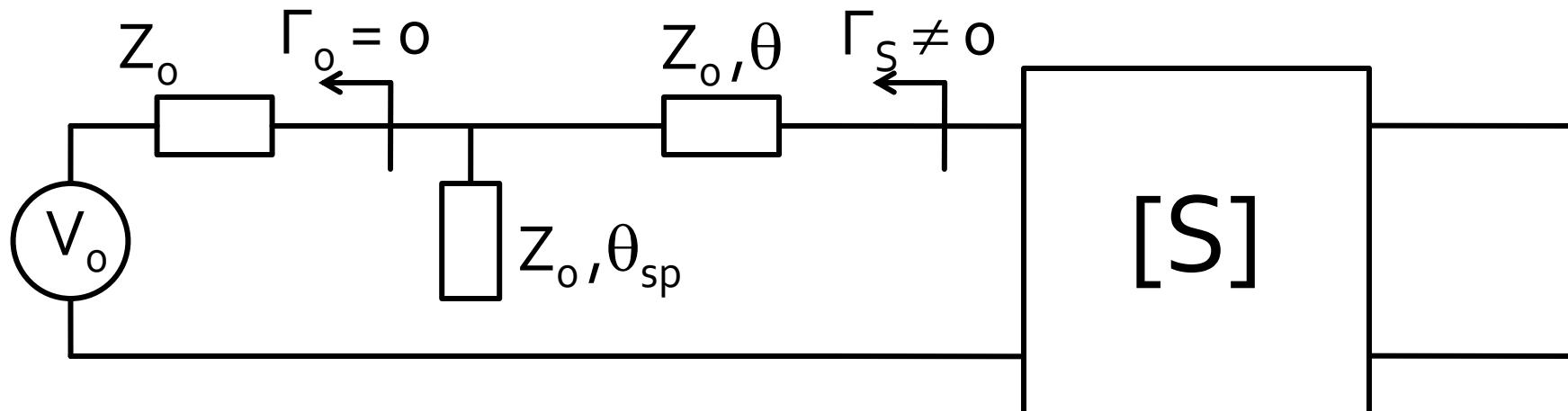
Adaptare – 3

- Se interpune reteaua de adaptare la intrare care permite obtinerea lui Γ_S determinat anterior



Adaptare – 4

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

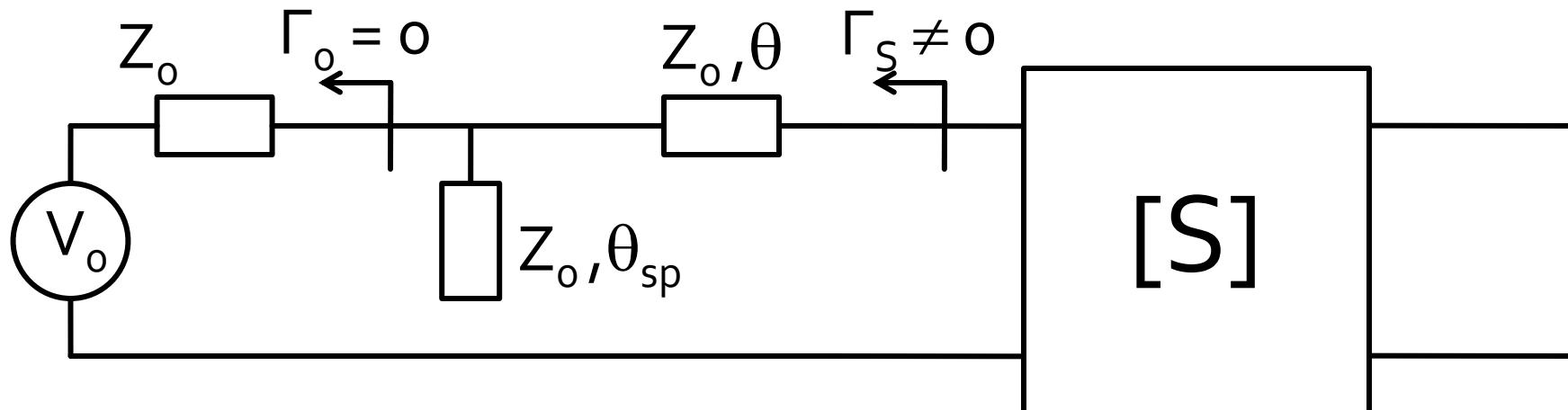


Adaptare – 5

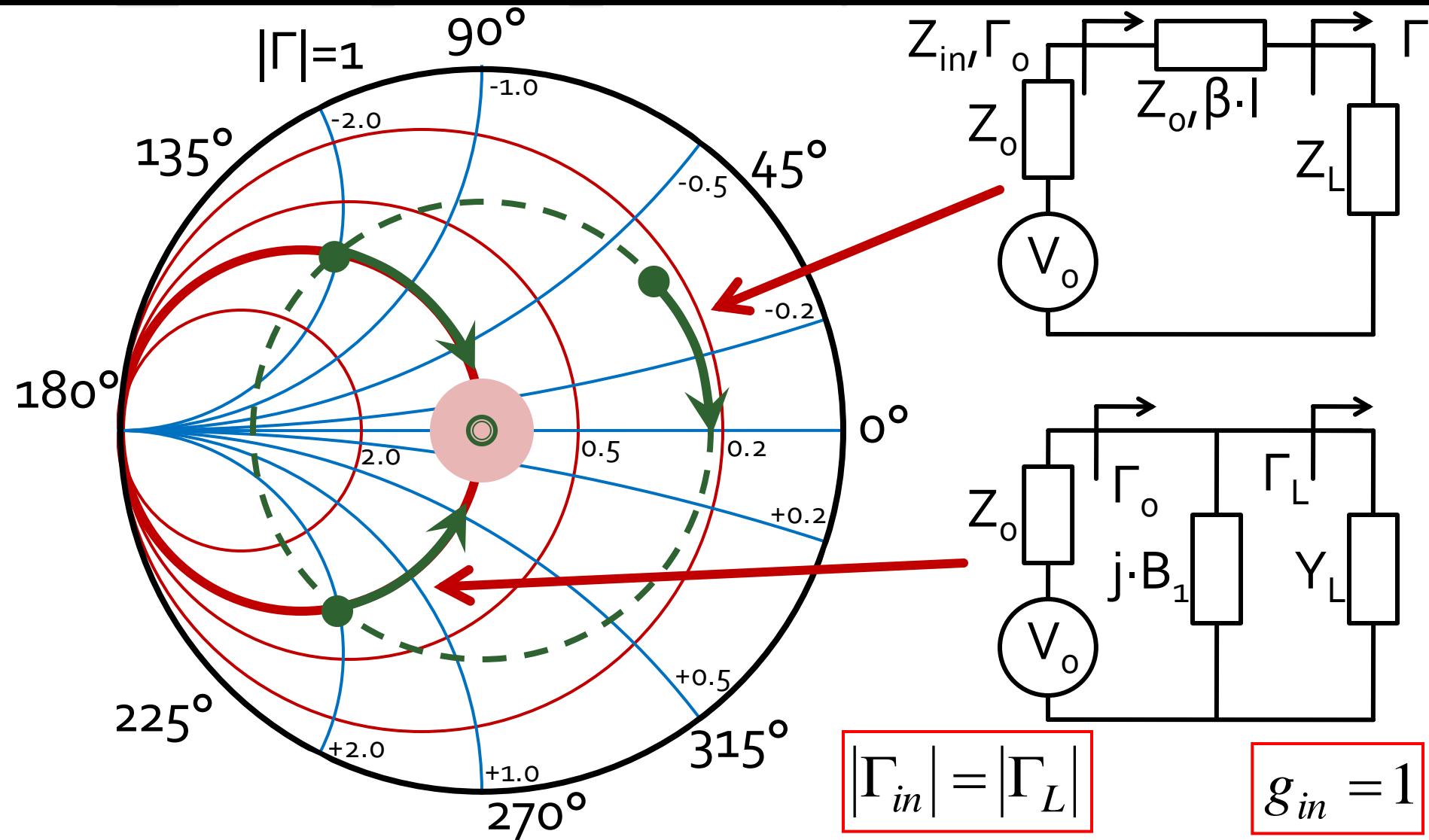
- Relatiile de calcul depind numai de Γ_s (modul si faza)

$$\cos(\varphi_s + 2\theta) = -|\Gamma_s| \quad \tan \theta_{sp} = \frac{\mp 2 \cdot |\Gamma_s|}{\sqrt{1 - |\Gamma_s|^2}}$$

- Prima ecuatie are doua solutii, semnul solutiei alese impune semnul utilizat in a doua ecuatie



Adaptare cu stub-uri, C6-7



Exemplu, LNA @ 5 GHz

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

- @5GHz

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

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

```
# ghz s ma r 50
```

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

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

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

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)

Exemplu, LNA @ 5 GHz

$$U = \frac{|S_{12}| \cdot |S_{21}| \cdot |S_{11}| \cdot |S_{22}|}{(1 - |S_{11}|^2) \cdot (1 - |S_{22}|^2)} = 0.094 \quad -0.783 \text{ dB} < G_T[\text{dB}] - G_{TU}[\text{dB}] < 0.861 \text{ dB}$$

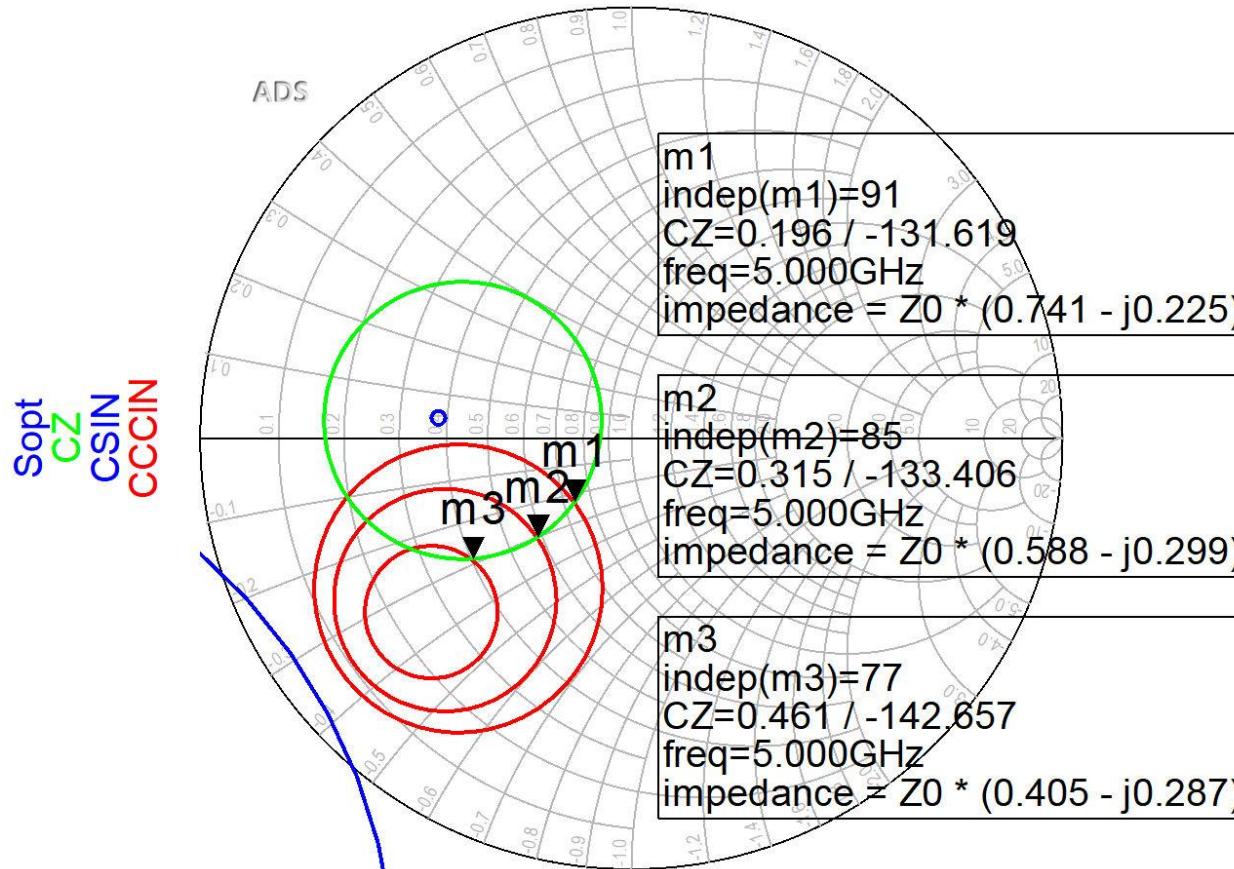
$$G_{TU\max} = \frac{1}{1 - |S_{11}|^2} \cdot |S_{21}|^2 \cdot \frac{1}{1 - |S_{22}|^2} = 17.83 \quad G_{TU\max}[\text{dB}] = 12.511 \text{ dB}$$

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

$$G_{S\max} = \frac{1}{1 - |S_{11}|^2} = 1.694 = 2.289 \text{ dB} \quad G_{L\max} = \frac{1}{1 - |S_{22}|^2} = 1.051 = 0.215 \text{ dB}$$

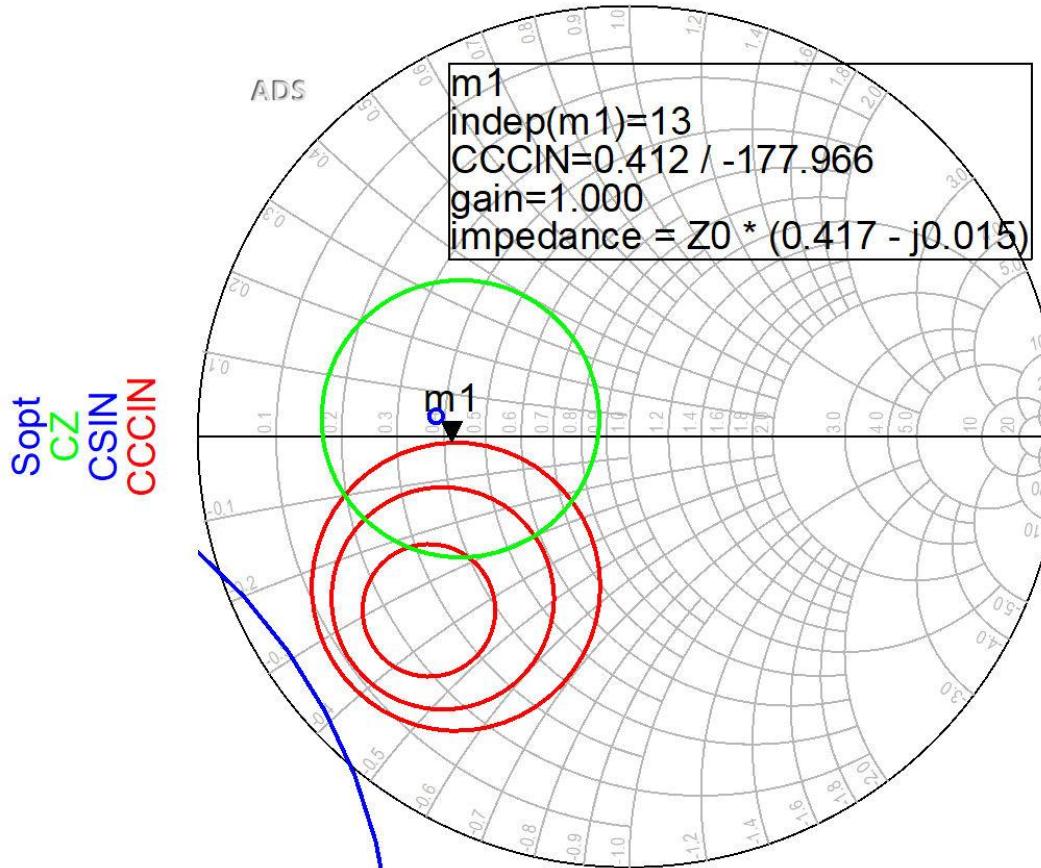
- În cazul particular prezent $G_{L\max} = 0.21 \text{ dB}$, amplificatorul ar putea functiona cu ieșirea conectată direct la o sarcină de 50Ω
- Absenta retelei de adaptare la ieșire nu conduce la o pierdere importantă de câștig, dar elimină posibilitatea ca prin reglaj să se compenseze compromisul câștig/zgomot introdus la intrare

Adaptare la intrare



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

Adaptare la intrare



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

Adaptare la intrare

■ Pozitia m1 de pe grafic

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

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

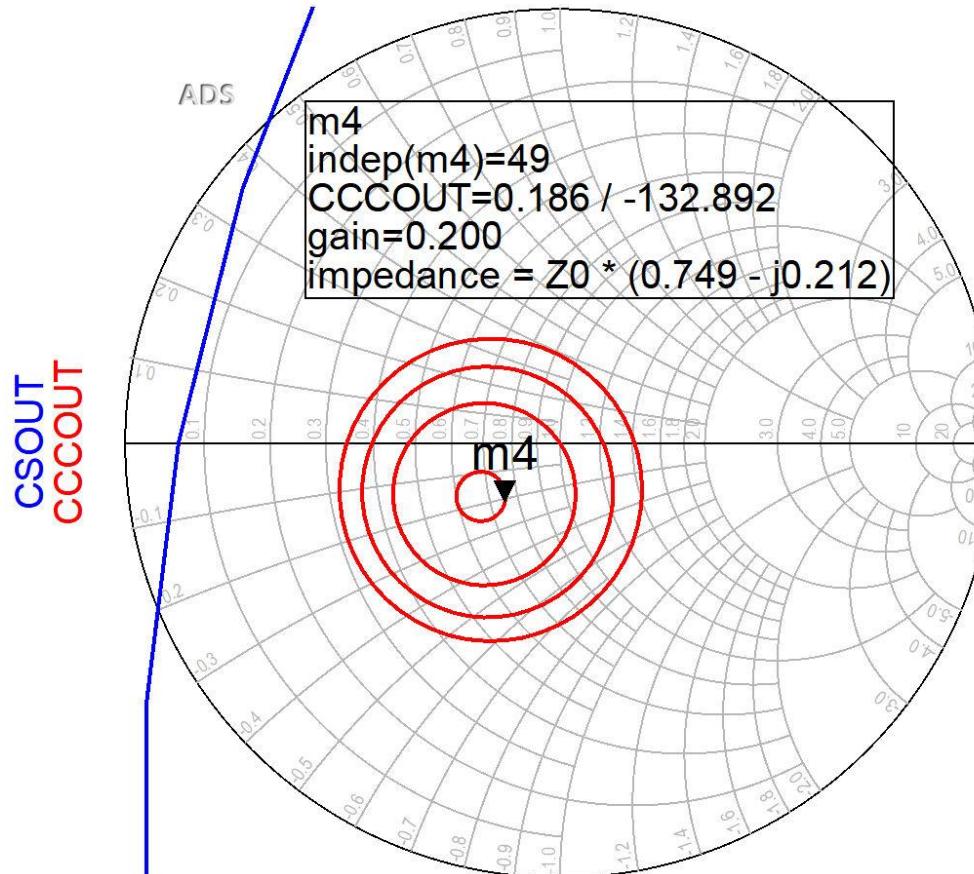
$$\cos(\varphi + 2\theta) = -|\Gamma_S|$$

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

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

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

Adaptare la ieșire



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

Adaptare la iesire

■ Pozitia m₄ de pe grafic

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

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

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

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

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

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

LNA

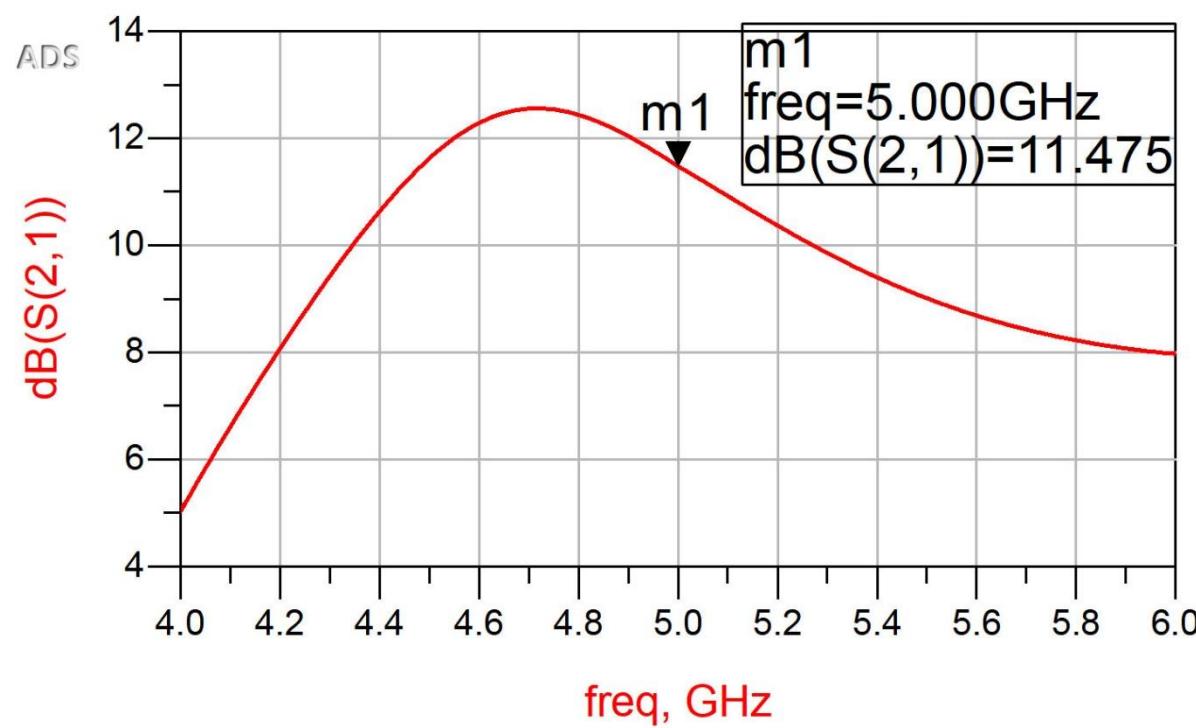
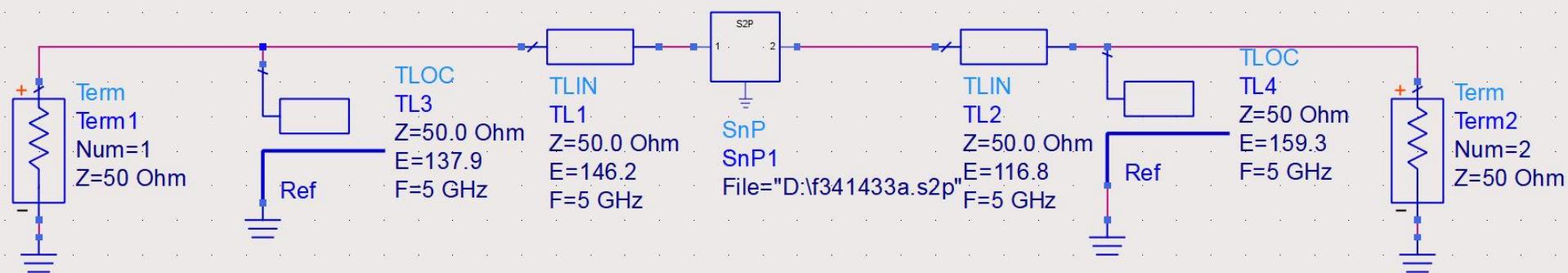
- Se estimeaza obtinerea unui castig (in ipoteza unilaterală, ± 0.9 dB)

$$G_T[\text{dB}] = G_S[\text{dB}] + G_0[\text{dB}] + G_L[\text{dB}]$$

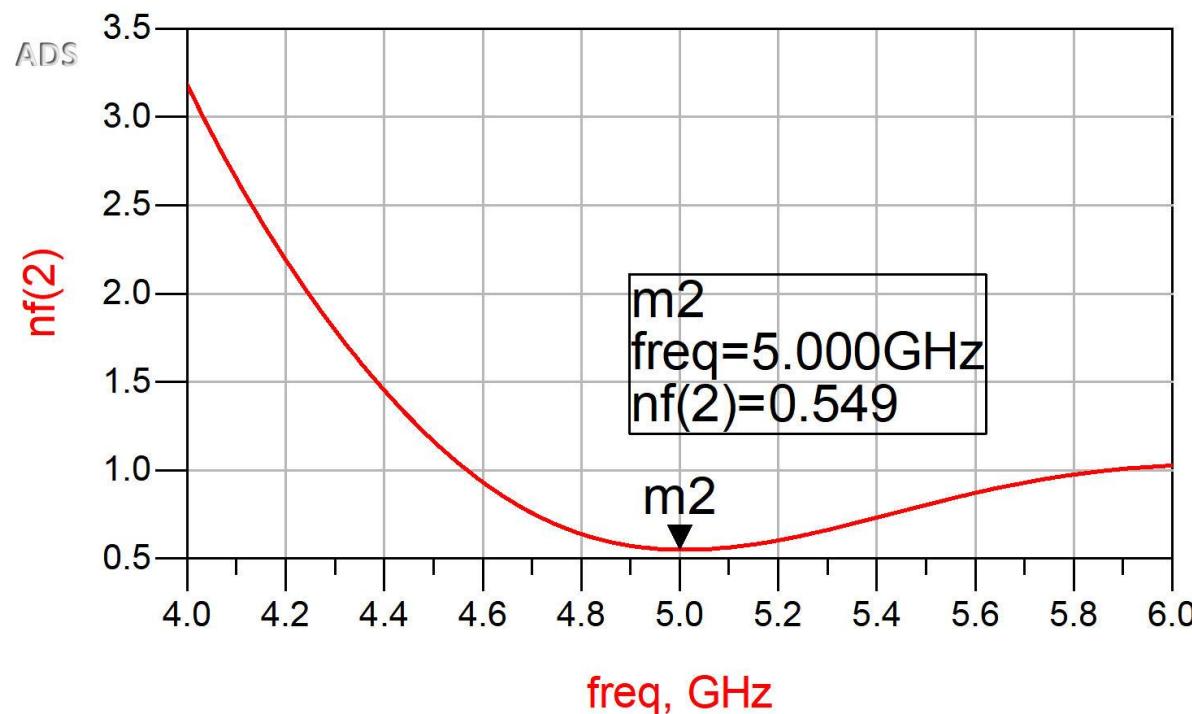
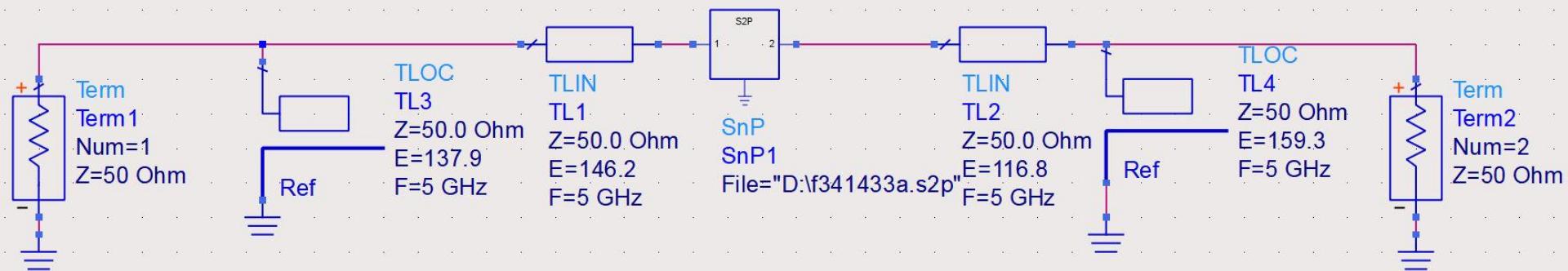
$$G_T[\text{dB}] = 1 \text{ dB} + 10 \text{ dB} + 0.2 \text{ dB} = 11.2 \text{ dB}$$

- Se estimeaza obtinerea unui factor de zgomot sub 0.75 dB (destul de apropiat de minim ~ 0.6 dB)

ADS



ADS



Contact

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- rdamian@etti.tuiasi.ro