

**Curs 8**

2021/2022

# **Dispozitive și circuite de microunde pentru radiocomunicații**

# Disciplina 2021/2022

- 2C/1L, DCMR (CDM)
- Minim 7 prezente (curs+laborator)
- Curs - **conf. Radu Damian**
  - Marti 8-10, Online/**Video**, Microsoft Teams
  - E – **50%** din nota
  - probleme + (2p prez. curs) + (3 teste) + (bonus activitate)
    - primul test C2: 12.10.2020 (t2 si t3 neanuntate)
    - 3pz (C) ≈ +0.5p (**2p** max)
  - toate materialele permise

# Online

- acces la **examene** necesita **parola** primita prin email

English | Romana |

Start Didactic Master Colectiv Cercetare **Studenti**

Note Lista Studenti Examene Fotografii

## POPESCU GOPO ION

Fotografia nu exista

Date:

Grupa	5700 (2019/2020)
Specializarea	Inginerie electronica si telecomunicatii
Marca	7000021

Acceseaza ca acest student | [Vere acces la licente](#)

Note obtinute

Inca nu a fost notat.

Start Didactic Master Colectiv C

Note **Lista Studenti** Examene Fotografii

### Identificare

Introduceti numele si adresa de email utilizata la inscriere

Nume  
POPESCU GOPO

E-mail/Parola

Introduceti codul afisat mai jos

4db4457

Trimite

# Cuprins

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

# Bibliografie

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

# Examen: Reprezentare logaritmică

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

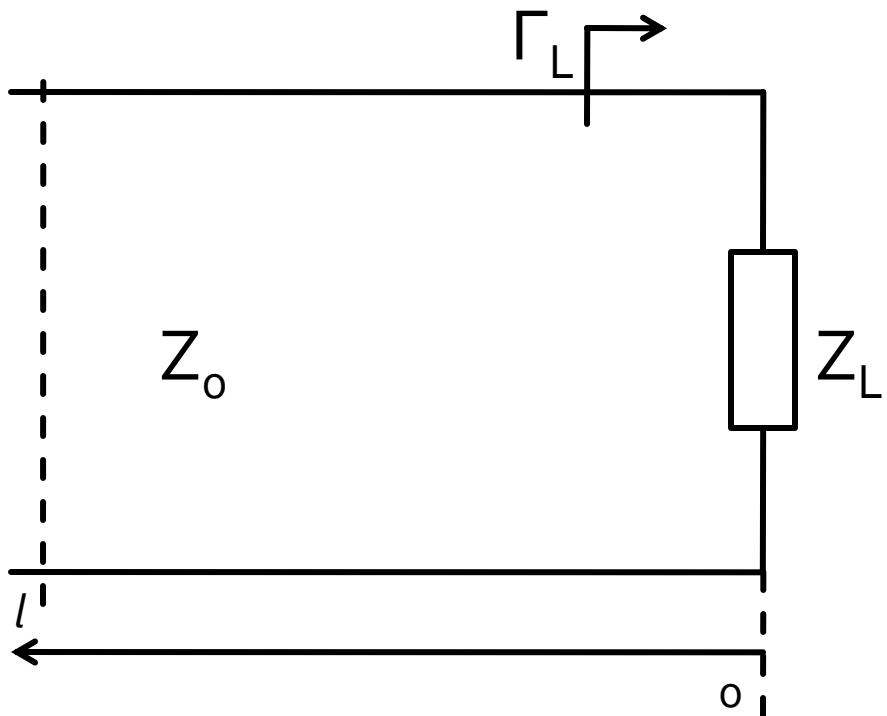
# Examen: numere complexe

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

# Cuprins

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

# Linie fara pierderi



$$V(z) = V_0^+ e^{-j\beta z} + V_0^- e^{j\beta z}$$

$$I(z) = \frac{V_0^+}{Z_0} e^{-j\beta z} - \frac{V_0^-}{Z_0} e^{j\beta z}$$

$$Z_L = \frac{V(0)}{I(0)} \quad Z_L = \frac{V_0^+ + V_0^-}{V_0^+ - V_0^-} \cdot Z_0$$

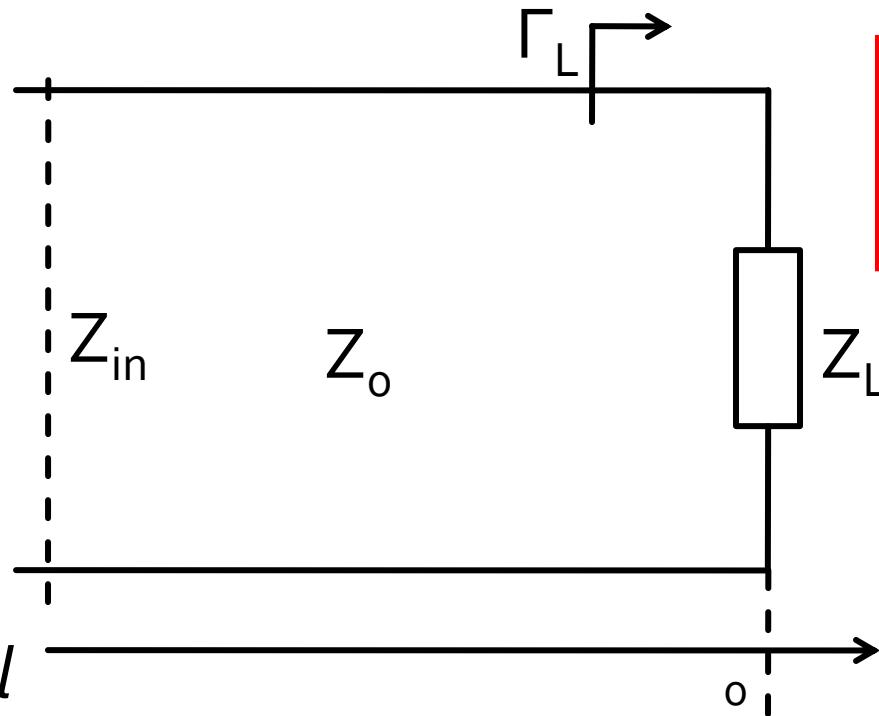
- coeficient de reflexie in tensiune

$$\Gamma = \frac{V_0^-}{V_0^+} = \frac{Z_L - Z_0}{Z_L + Z_0}$$

- $Z_0$  real

# Linie fara pierderi

- impedanta la intrarea liniei de impedanta caracteristica  $Z_0$ , de lungime  $l$ , terminata cu impedanta  $Z_L$



$$Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan \beta \cdot l}{Z_0 + j \cdot Z_L \cdot \tan \beta \cdot l}$$

# Cuprins

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

# Adaptare dpdv al puterii

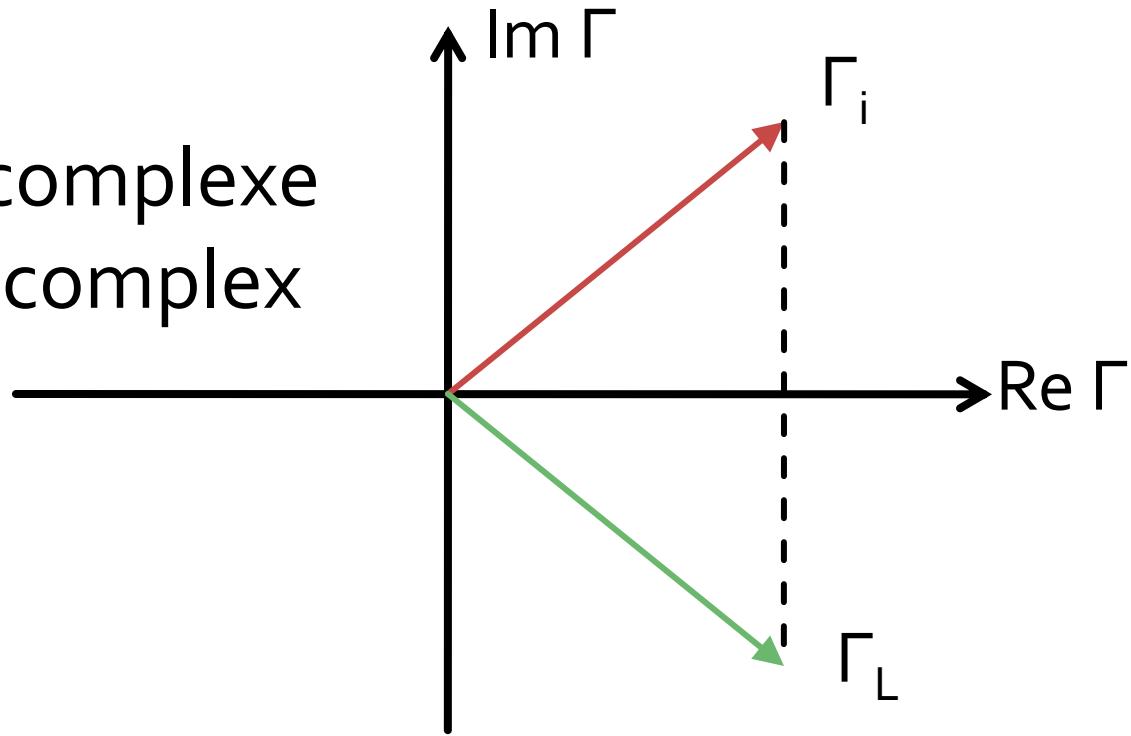
$$Z_L = Z_i^*$$

Daca se alege un  $Z_0$  real

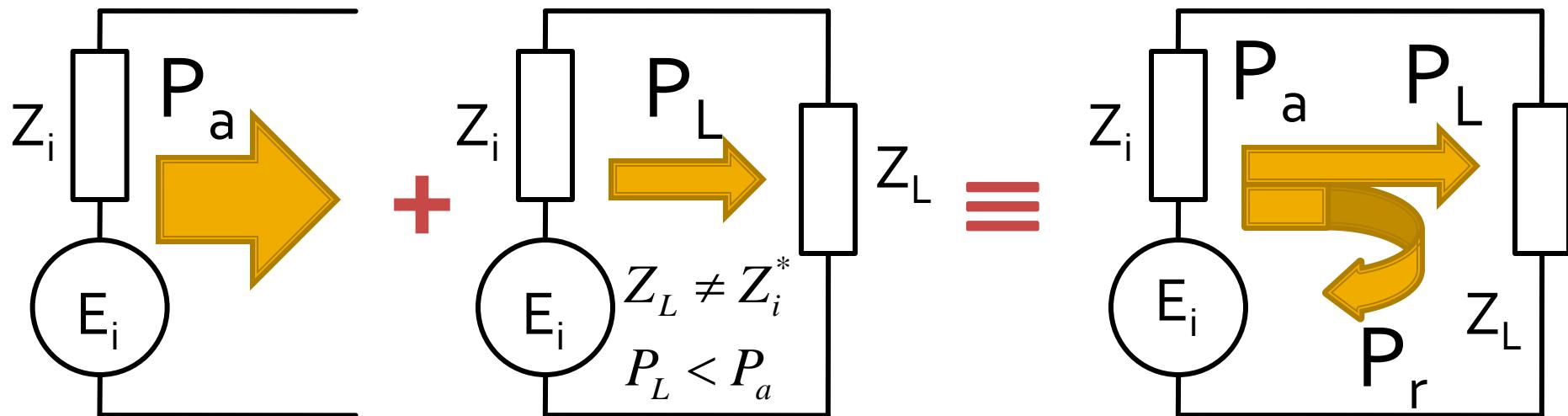
$$\Gamma = \frac{Z - Z_0}{Z + Z_0}$$

$$\Gamma_L = \Gamma_i^*$$

- numere complexe
- in planul complex

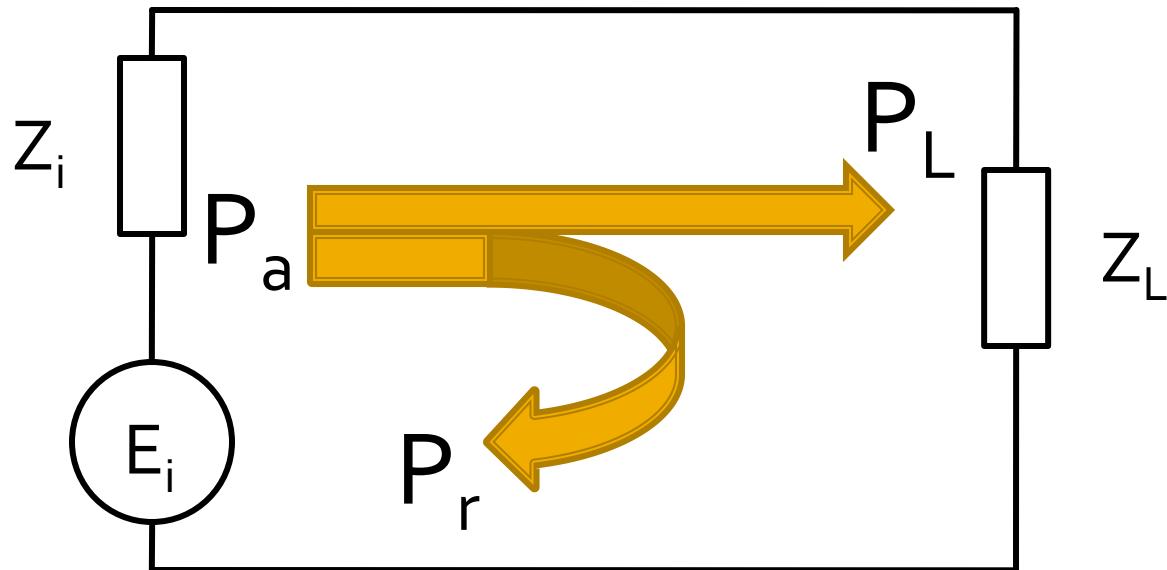


# Reflexie de putere / Model



- Generatorul are posibilitatea de a oferi o anumita putere maxima de semnal  $P_a$
- Pentru o sarcina oarecare, acesteia i se ofera o putere de semnal mai mica  $P_L < P_a$
- Se intampla **“ca si cum”** (model) o parte din putere se reflecta  $P_r = P_a - P_L$
- Puterea este o marime **scalara!**

# Reflexie de putere / Model



$$P_a = \frac{|E_i|^2}{4R_i}$$

$$P_L = \frac{R_L \cdot |E_i|^2}{(R_i + R_L)^2 + (X_i + X_L)^2}$$

$$P_r = P_a - P_L = \frac{|E_i|^2}{4R_i} - \frac{R_L \cdot |E_i|^2}{(R_i + R_L)^2 + (X_i + X_L)^2} = \frac{|E_i|^2}{4R_i} \cdot \left[ 1 - \frac{4R_L \cdot R_i}{(R_i + R_L)^2 + (X_i + X_L)^2} \right]$$

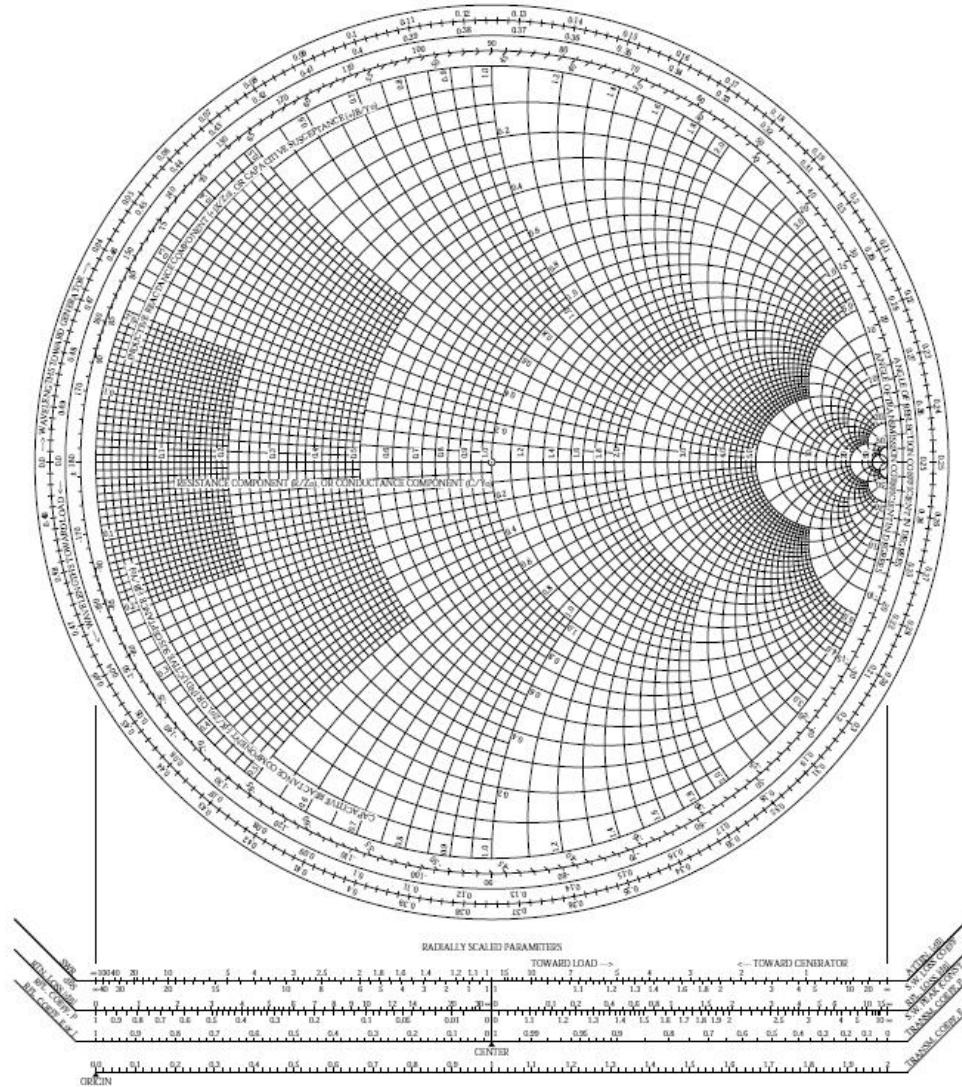
$$P_r = \frac{|E_i|^2}{4R_i} \cdot \left[ \frac{(R_i - R_L)^2 + (X_i + X_L)^2}{(R_i + R_L)^2 + (X_i + X_L)^2} \right] = P_a \cdot |\Gamma|^2$$

- $|\Gamma|^2$  este un coeficient de reflexie in putere

Adaptarea de impedanță

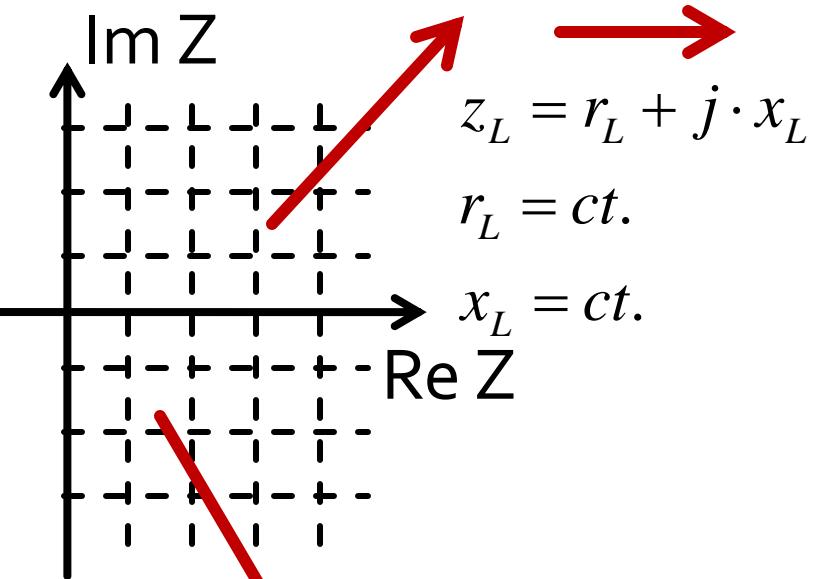
# Diagrama Smith

# Diagrama Smith

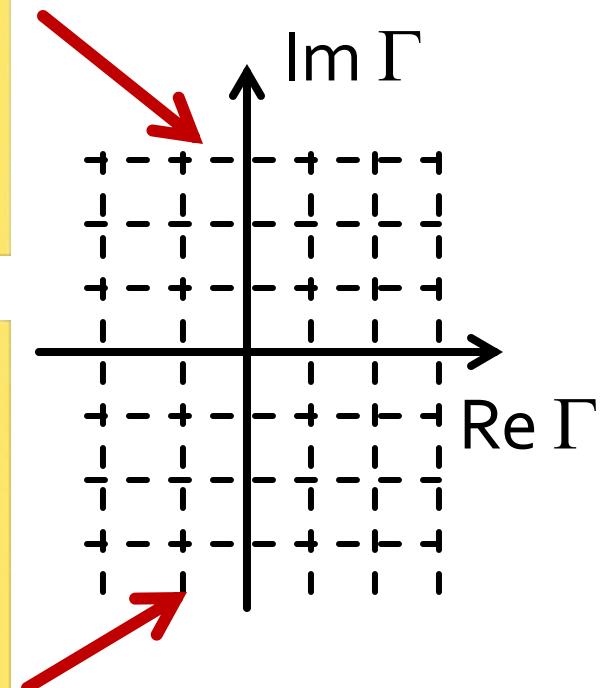
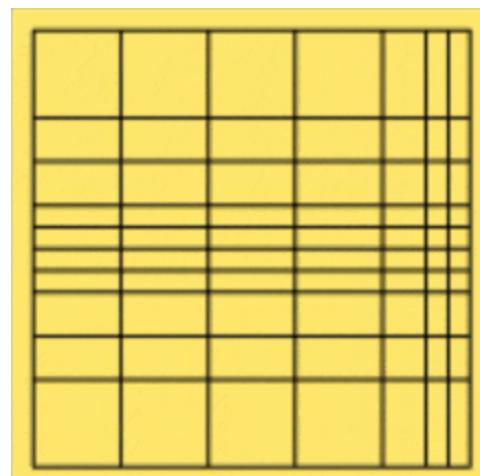
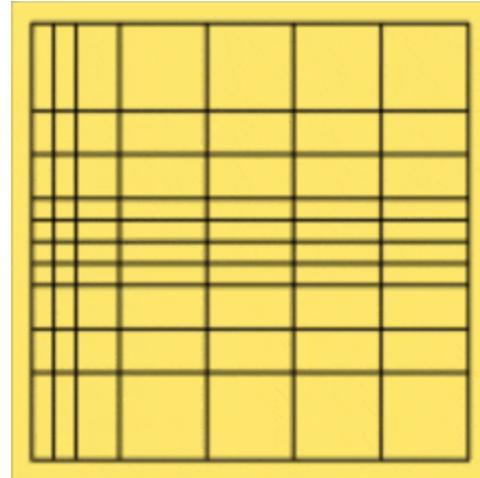


# Diagrama Smith

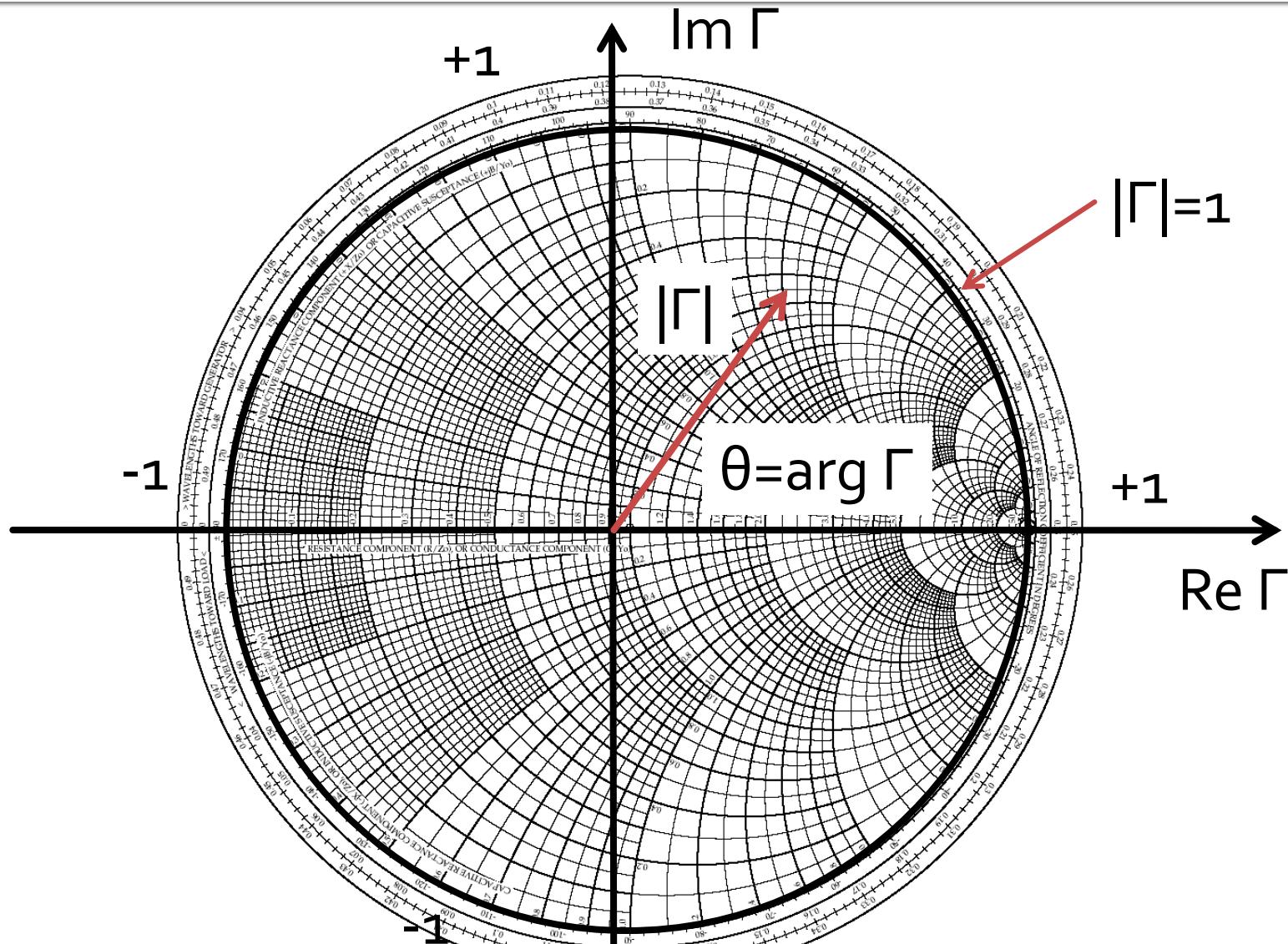
$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{z_L - 1}{z_L + 1}$$



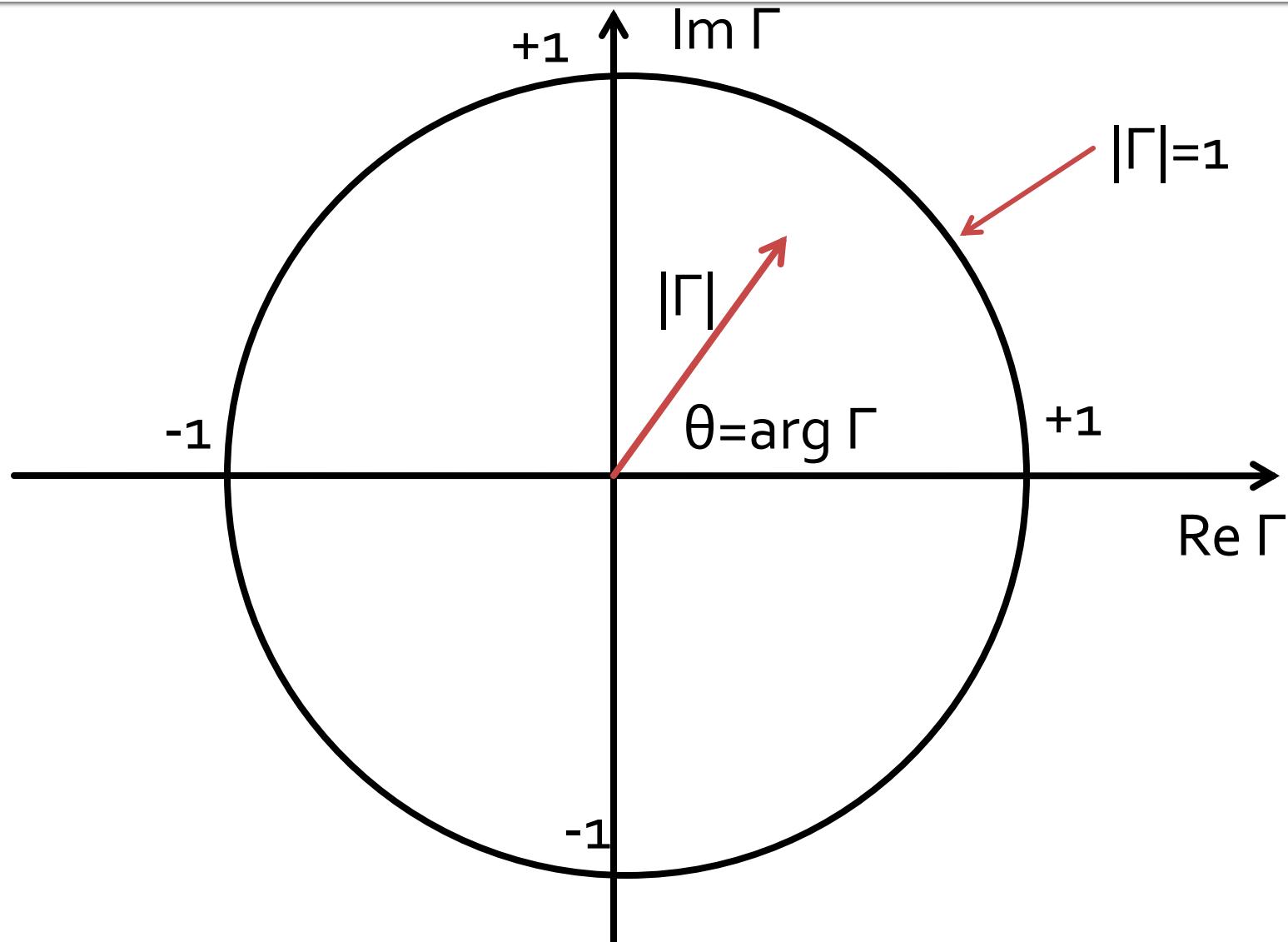
$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{Y_0 - Y_L}{Y_0 + Y_L} = \frac{1 - y_L}{1 + y_L}$$



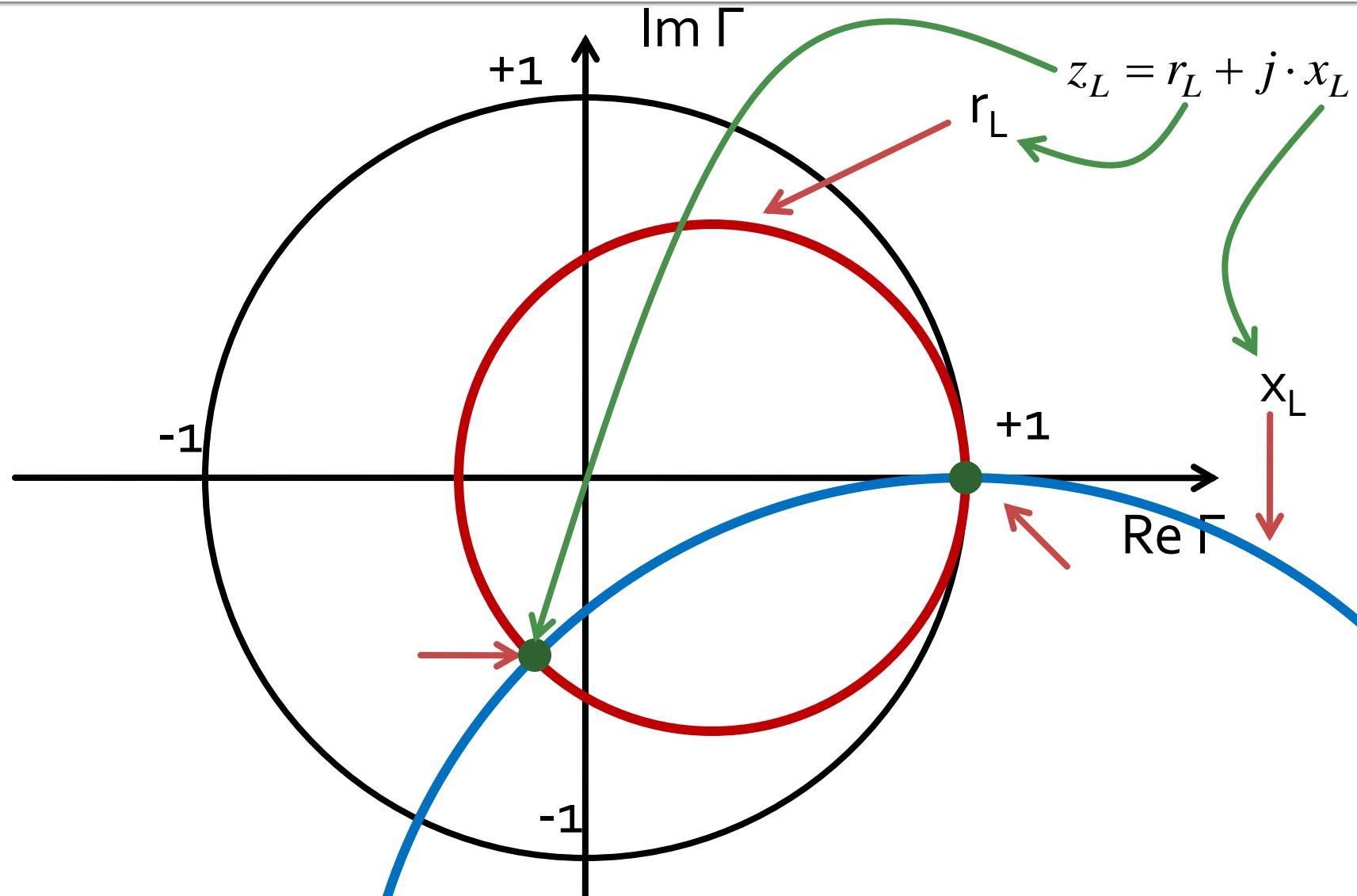
# Diagrama Smith



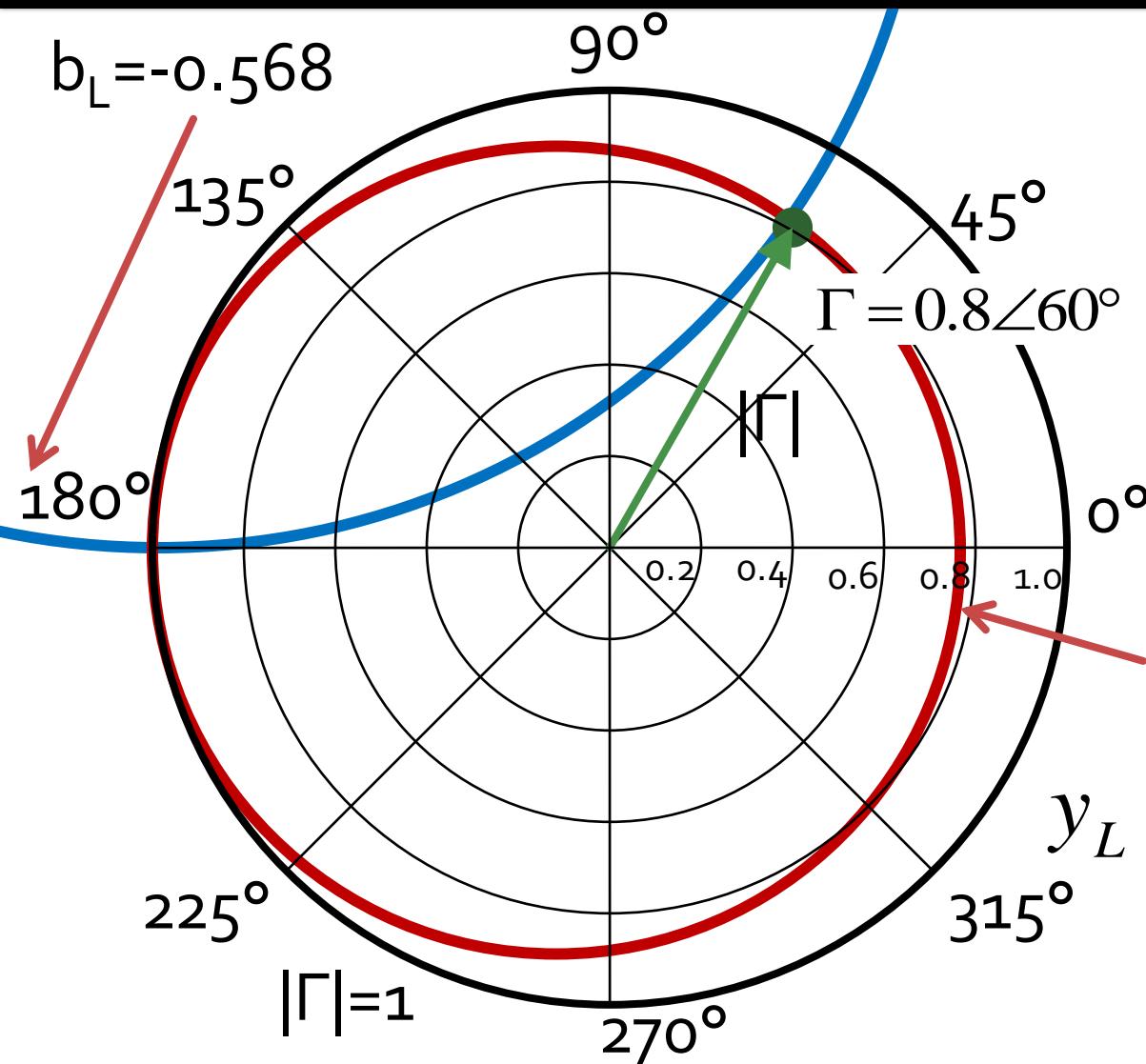
# Diagrama Smith



# Diagrama Smith, impedanta



# Diagrama Smith, coeficient de reflexie $\Leftrightarrow$ admitanta



$$\Gamma = 0.8∠60^\circ$$

$$Z_L = 21.429 \Omega + j \cdot 82.479 \Omega$$

$$z_L = 0.429 + j \cdot 1.65$$

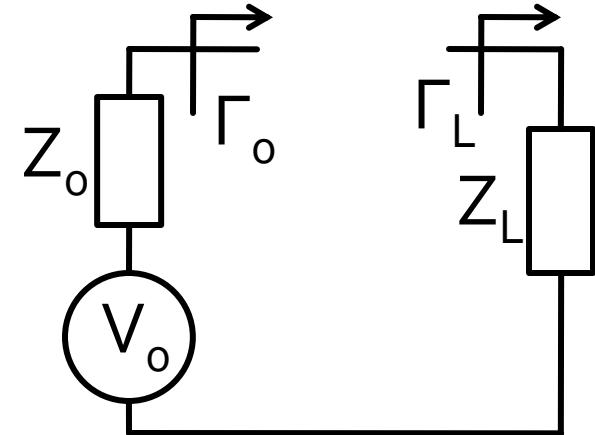
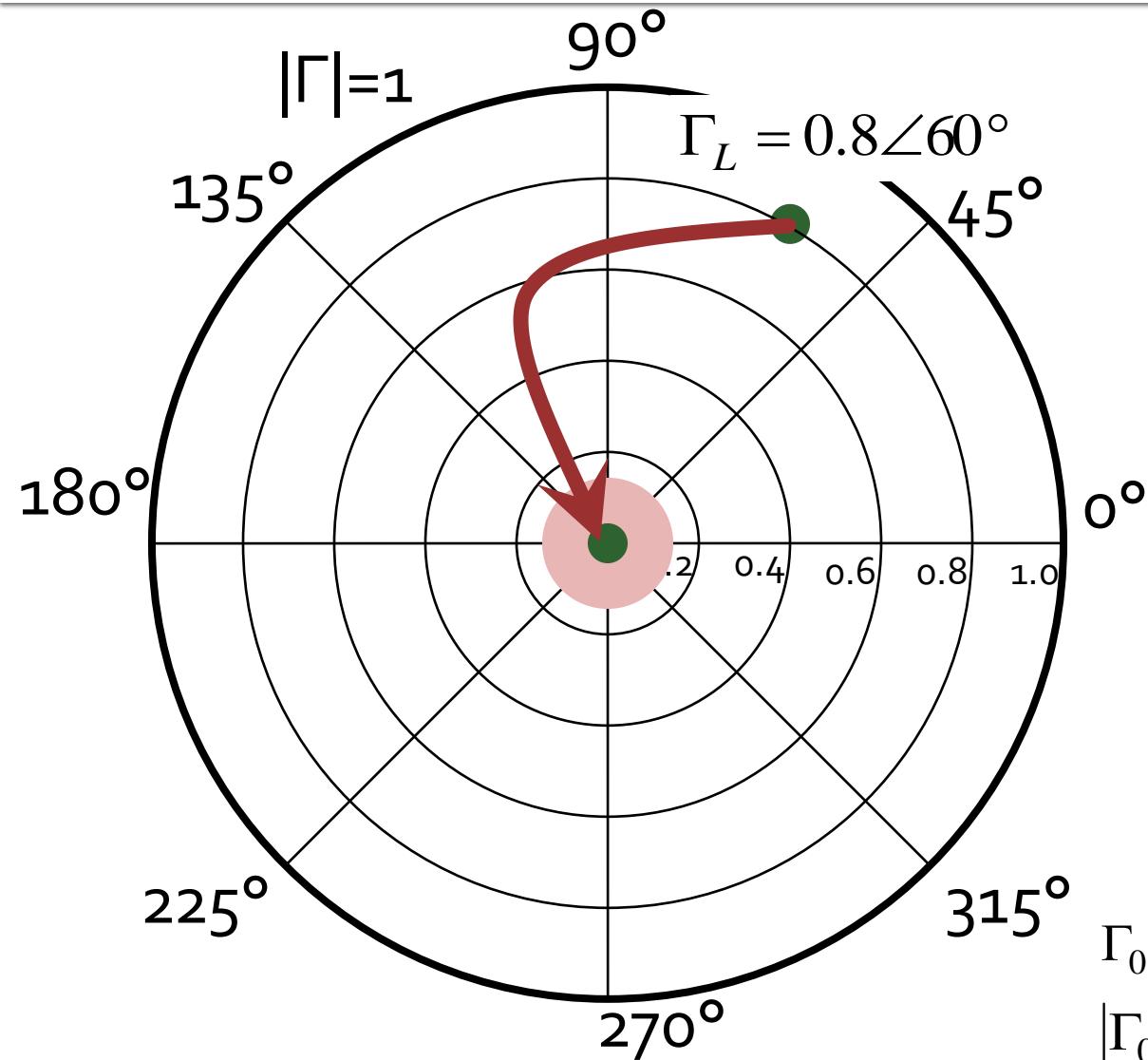
$$y_L = \frac{1}{z_L} = 0.148 - j \cdot 0.568$$

$$g_L = 0.148$$

$$y_L = 0.148 - j \cdot 0.568$$

(oricare  $Z_0$ )

# Adaptare de impedanță

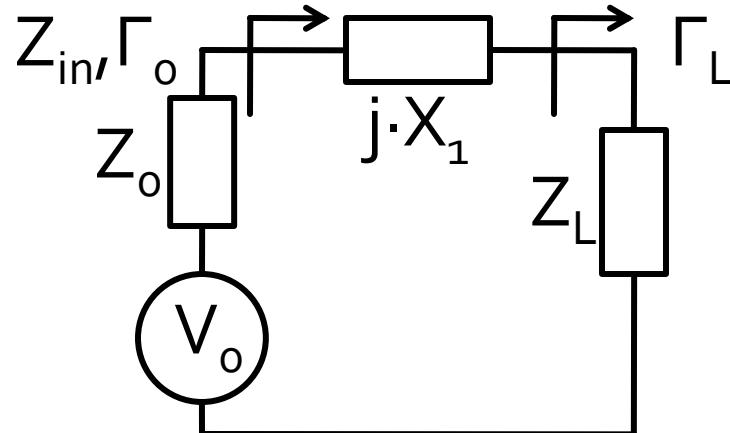
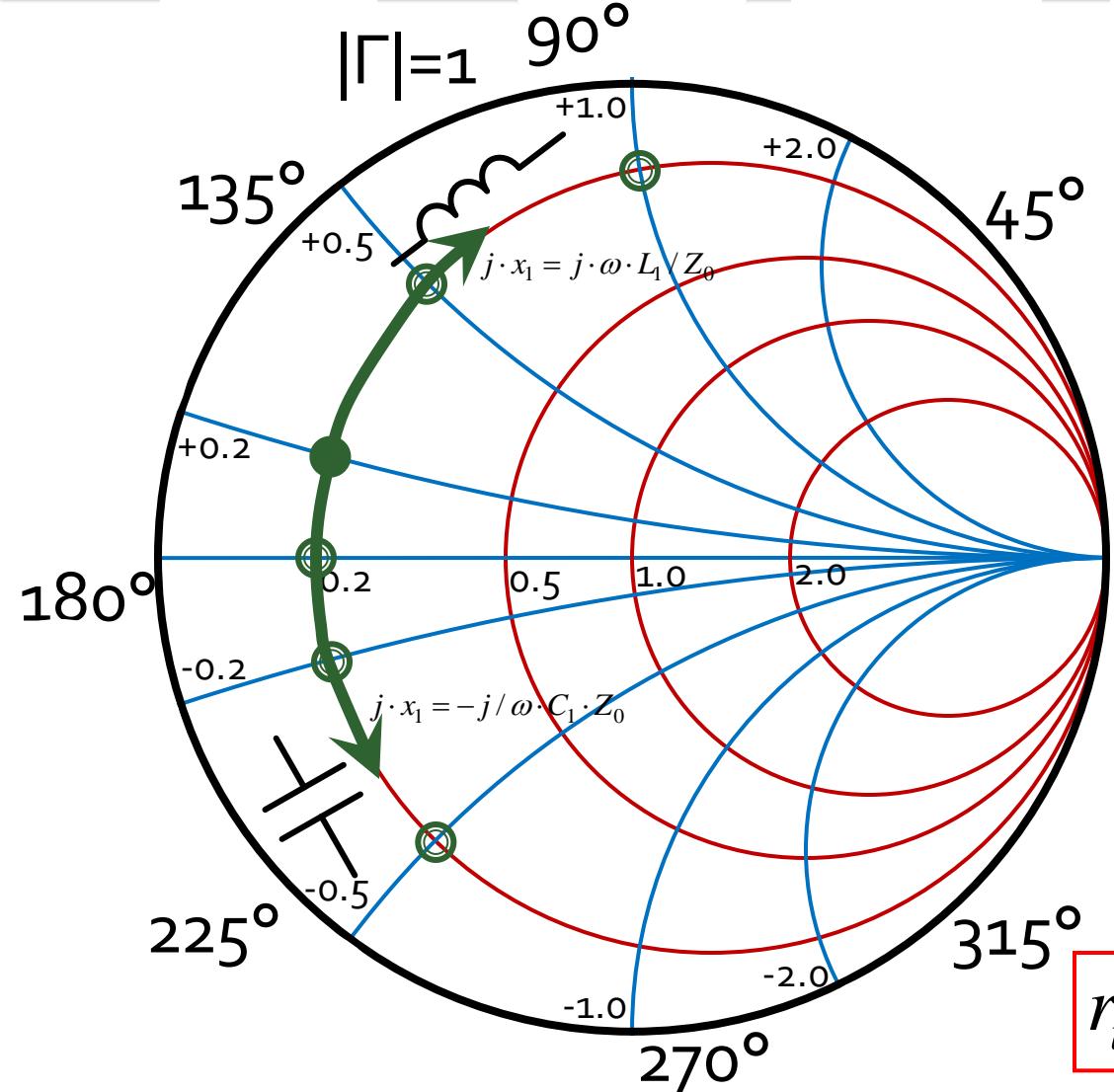


**Cum?**

$\Gamma_0 = 0$  adaptare perfectă ●

$|\Gamma_0| \leq \Gamma_m$  adaptare "suficientă" ●

# Diagrama Smith, coeficient de reflexie, reactanta in serie



$$Z_0 = 50\Omega$$

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

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

$$\Gamma_L = 0.678 \angle 156.5^\circ$$

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

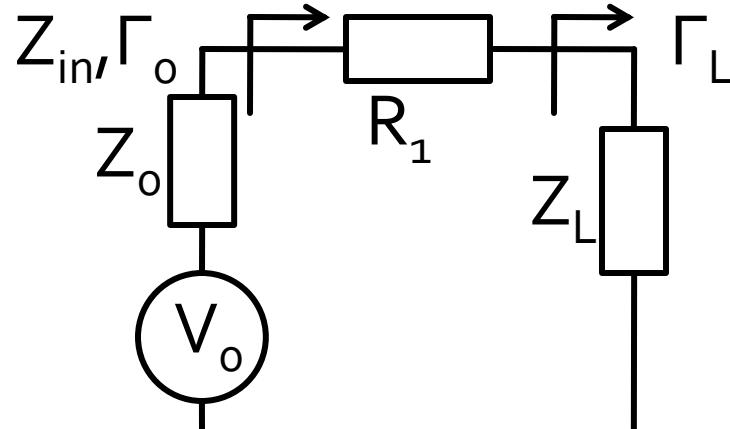
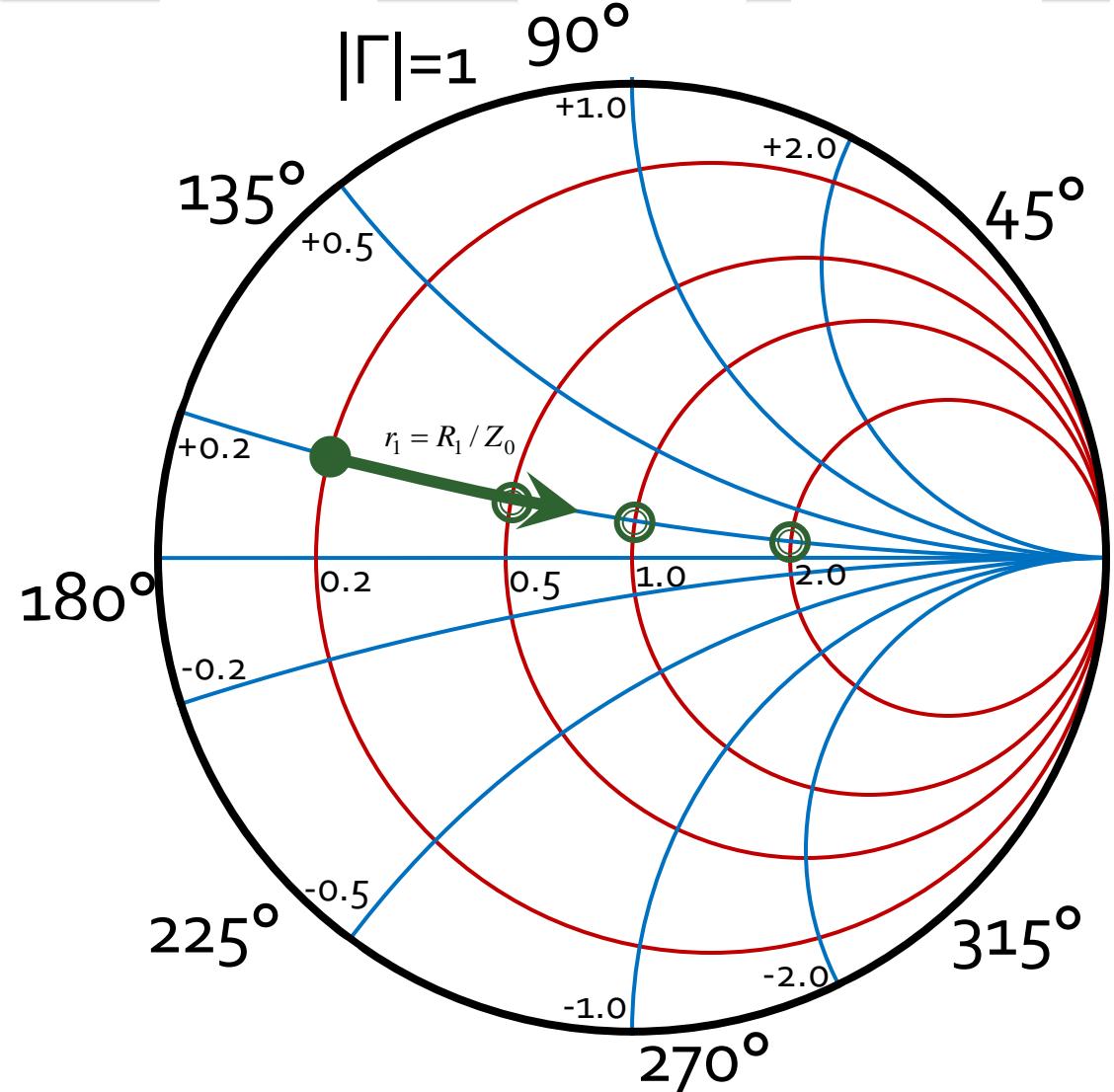
$$z_{in} = r_L + j \cdot (x_L + x_1)$$

$$r_{in} = r_L$$

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

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

# Diagrama Smith, coeficient de reflexie, rezistenta in serie



$$Z_0 = 50\Omega$$

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

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

$$\Gamma_L = 0.678 \angle 156.5^\circ$$

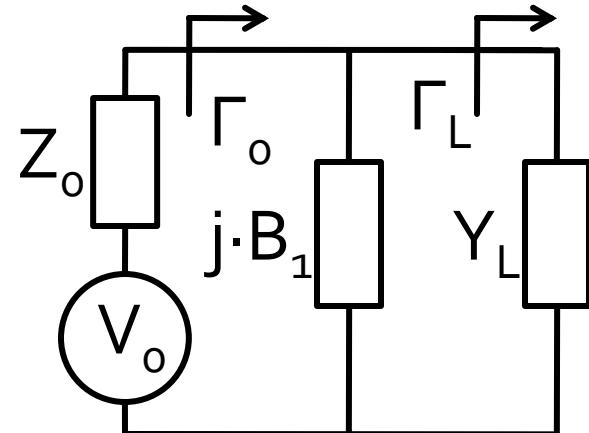
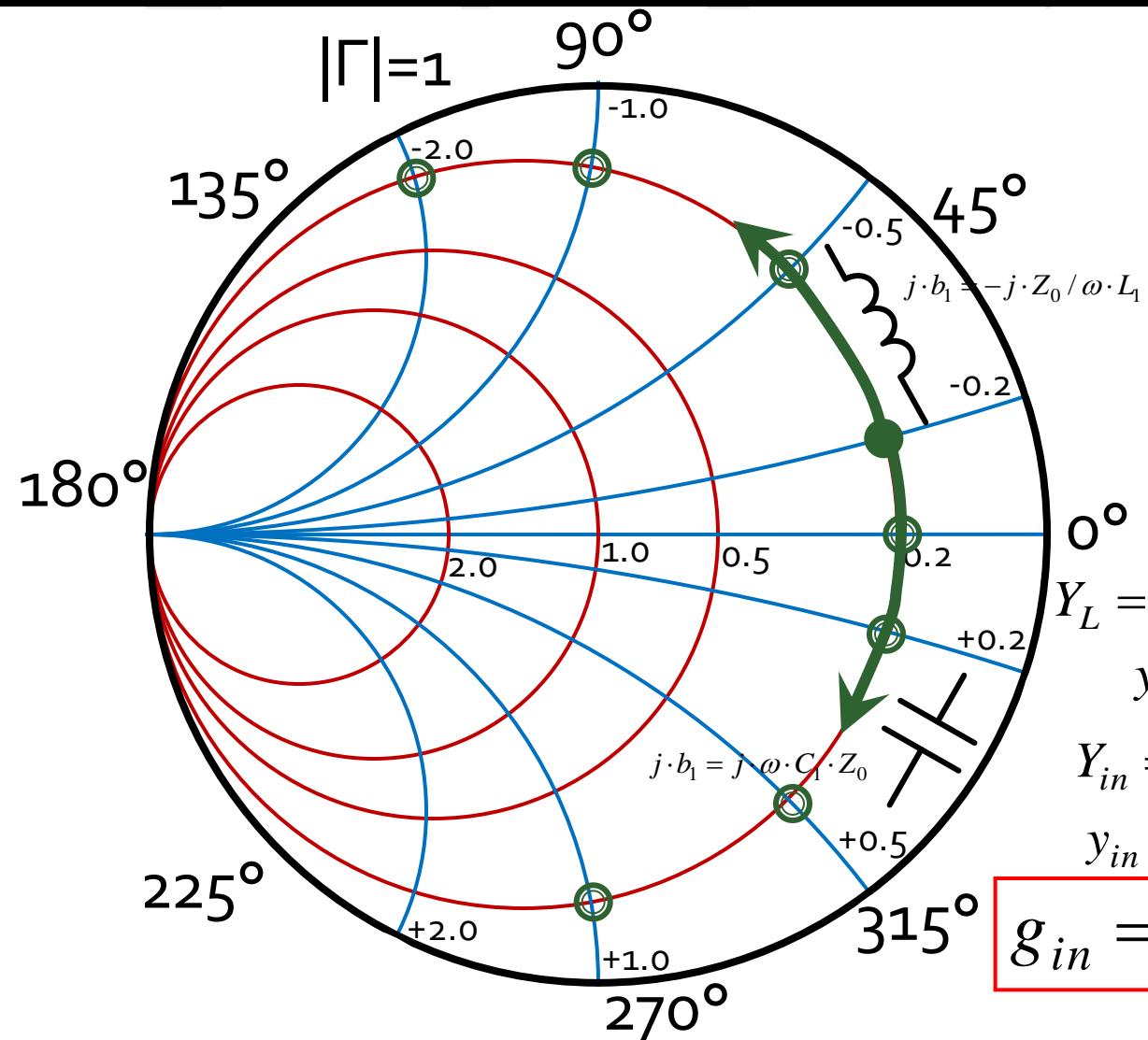
$$Z_{in} = Z_L + R_1 = (R_L + R_1) + j \cdot X_L$$

$$z_{in} = z_L + r_1 = (r_L + r_1) + j \cdot x_L$$

$x_{in} = x_L$

$r_{in} = r_L + R_1 / Z_0$

# Diagrama Smith, coeficient de reflexie, susceptanta in paralel



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

$$\Gamma_L = 0.678 \angle 23.5^\circ$$

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

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

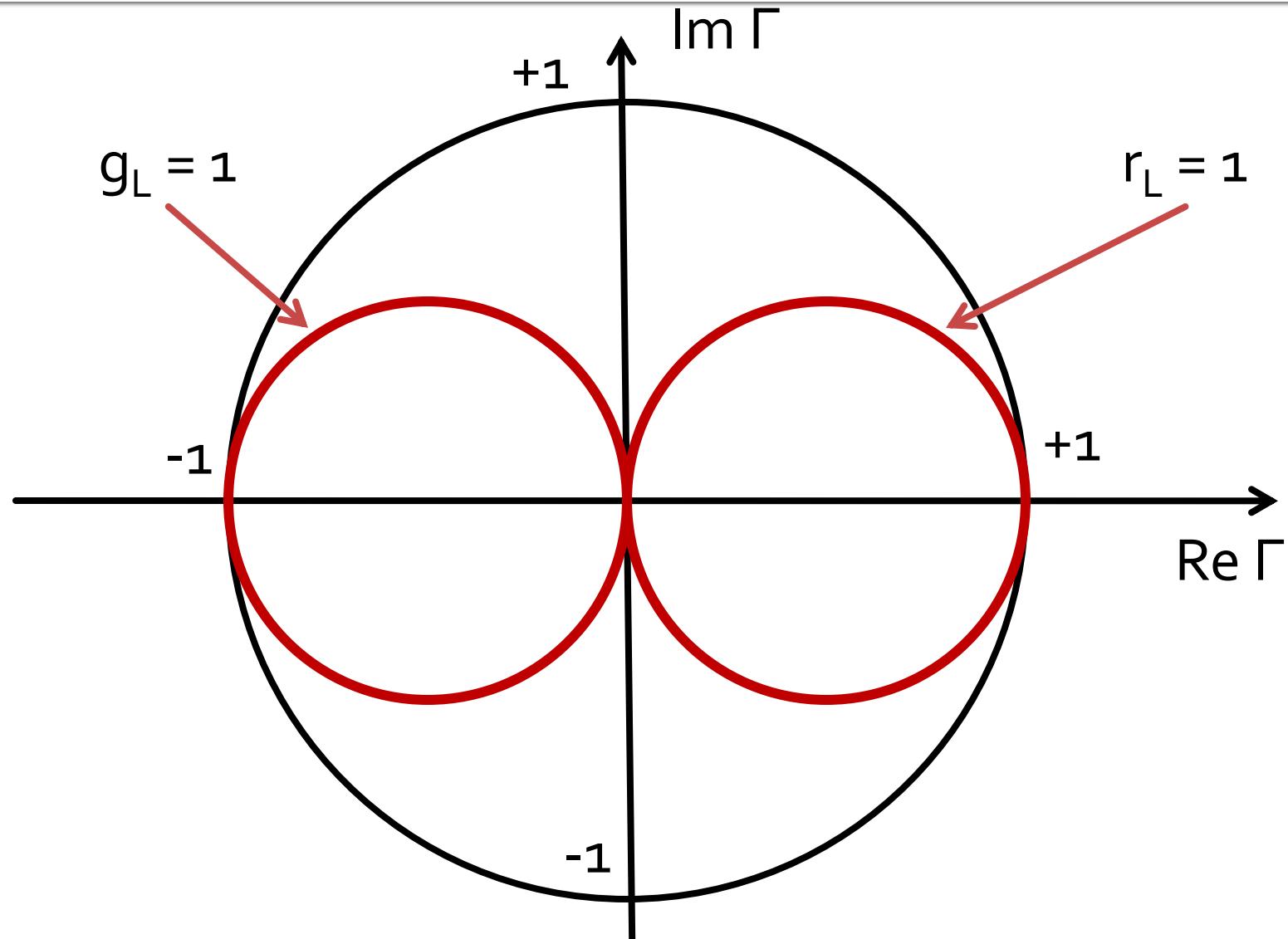
$$Y_{in} = Y_L + j \cdot B_1 = G_L + j \cdot (B_L + B_1)$$

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

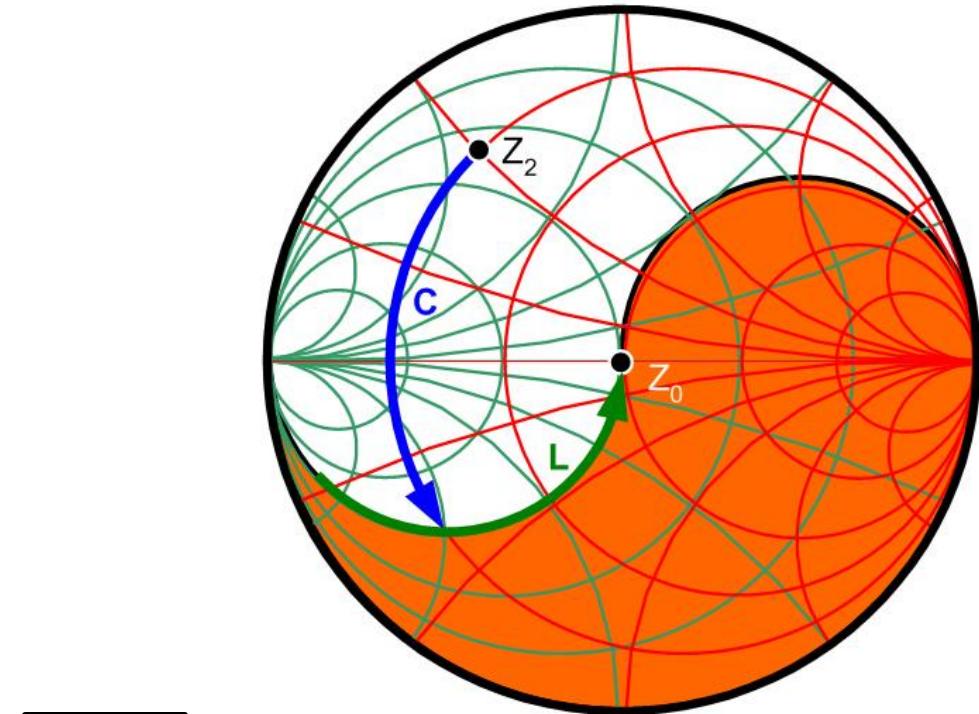
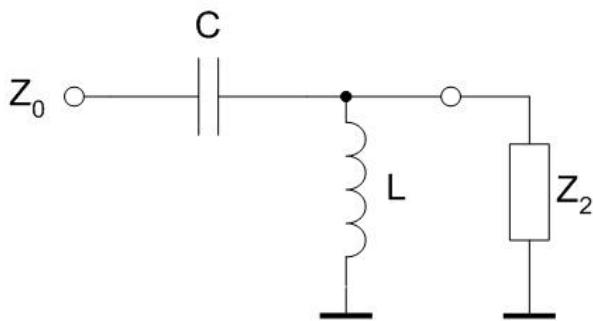
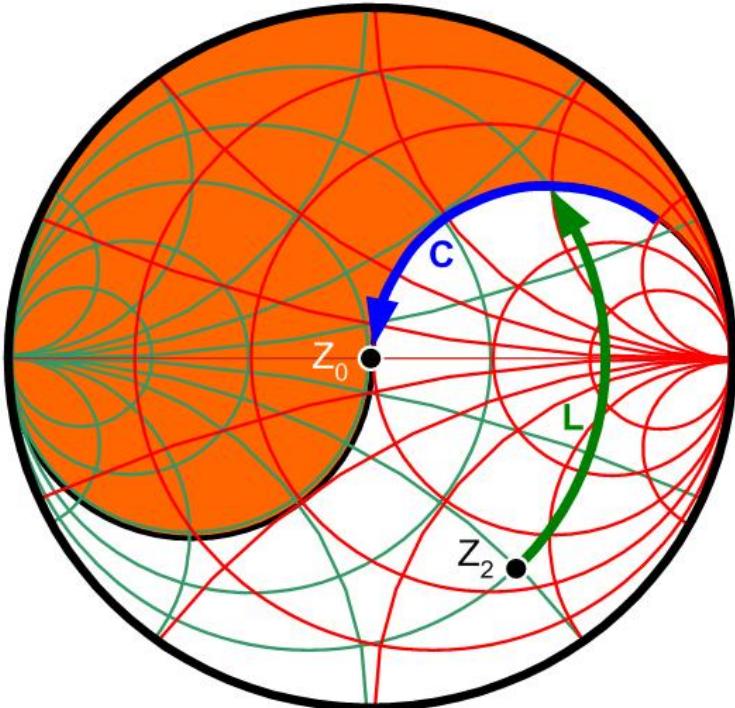
$$g_{in} = g_L \quad j \cdot b_1 = j \cdot \omega \cdot C_1 \cdot Z_0 > 0$$

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

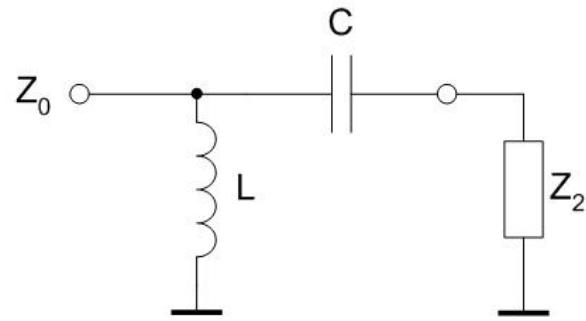
# Diagrama Smith, $r=1$ si $g=1$



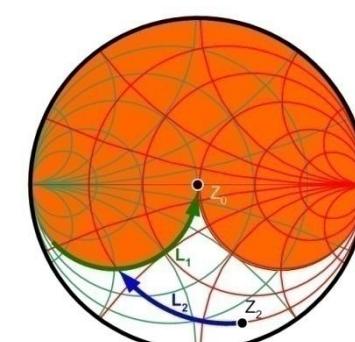
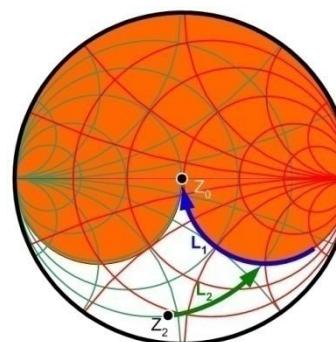
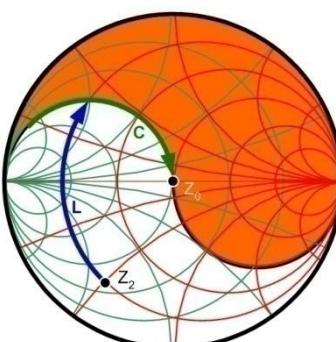
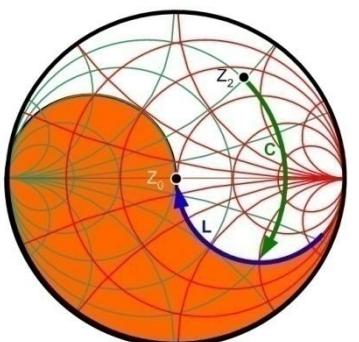
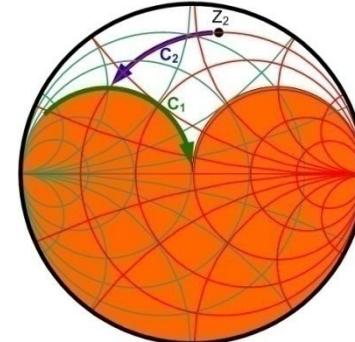
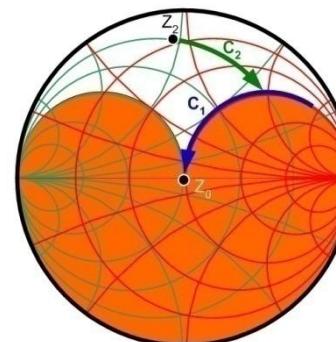
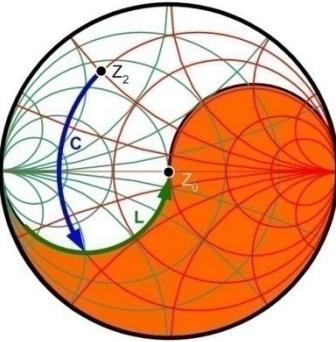
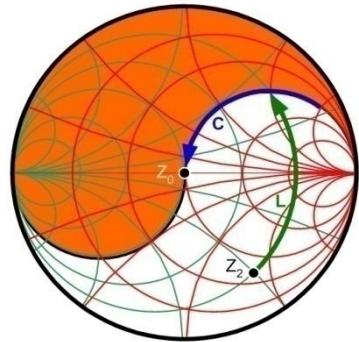
# C serie, L paralel / L paralel, C serie



 Zona interzisa cu schema curenta

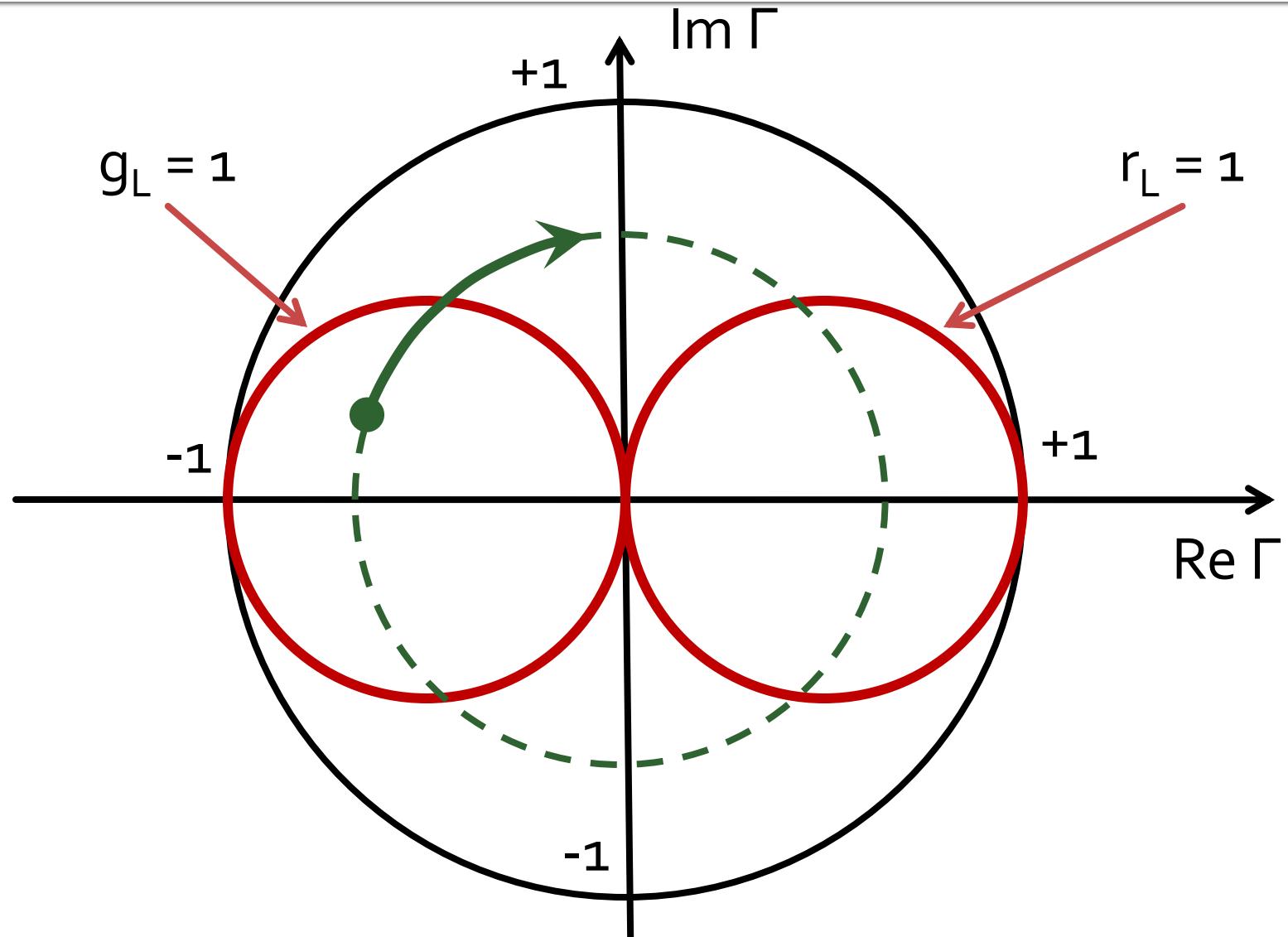


# Adaptare cu două elemente reactive (retele in L)



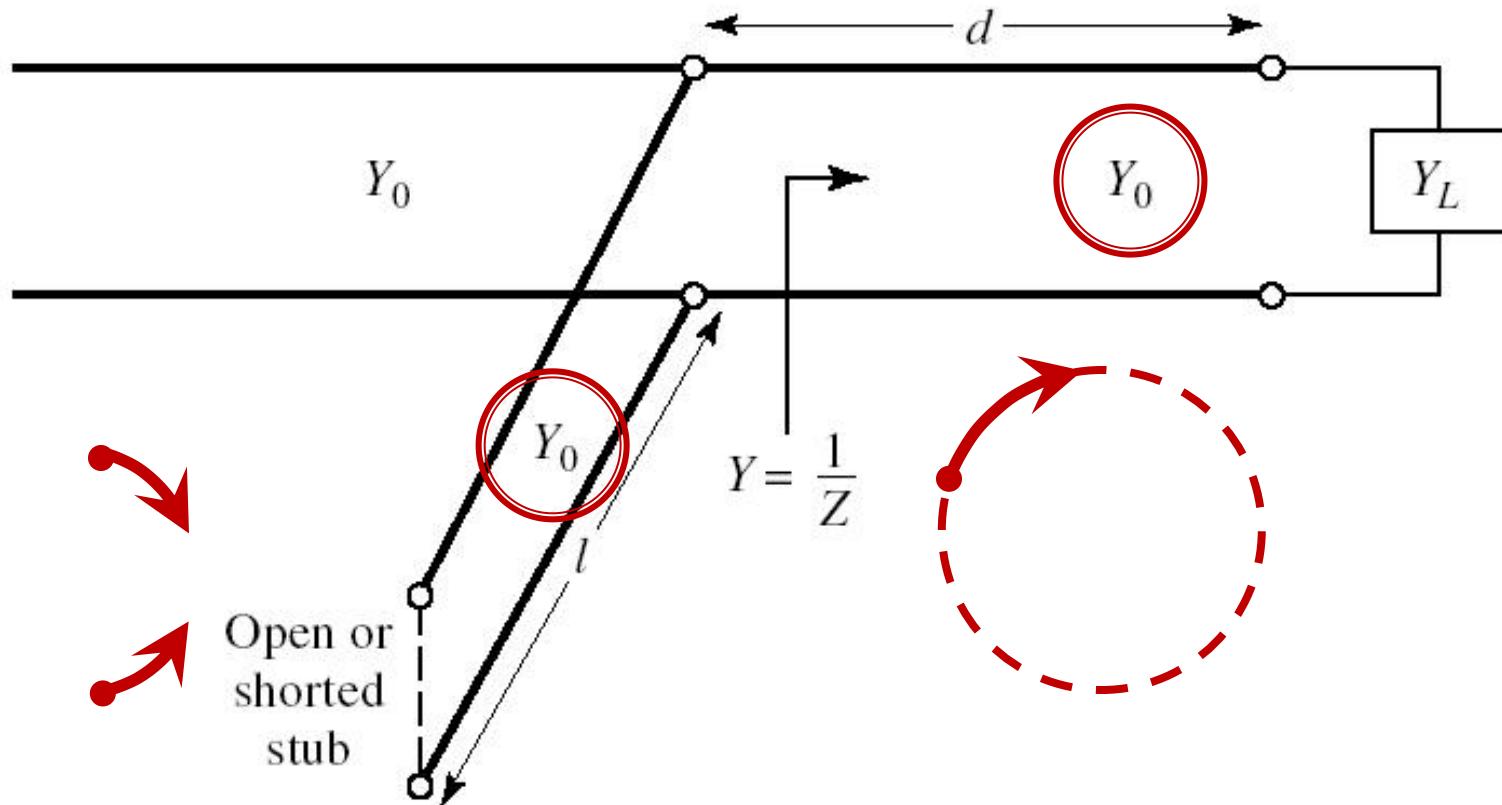
Zona interzisa cu  
schema curenta

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



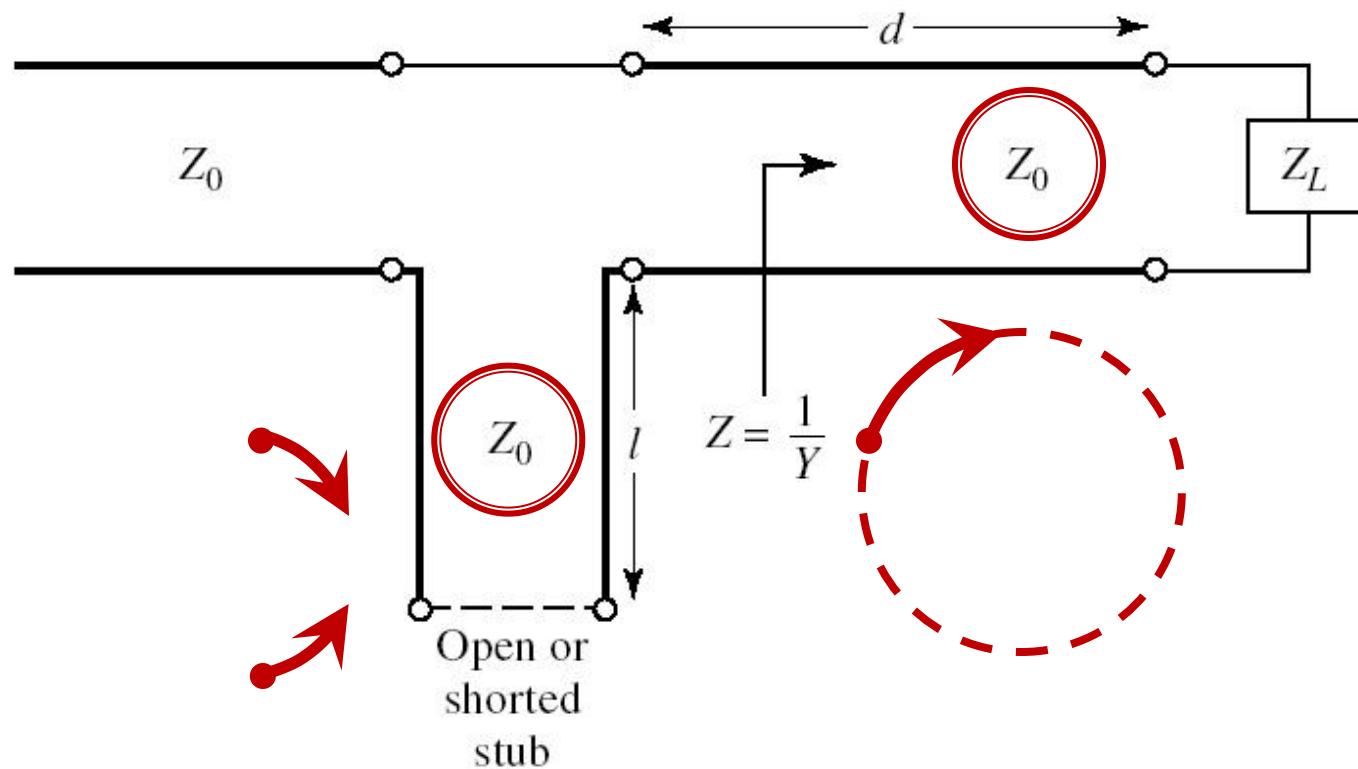
# Single stub tuning

- Shunt Stub (secțiune de linie în paralel)

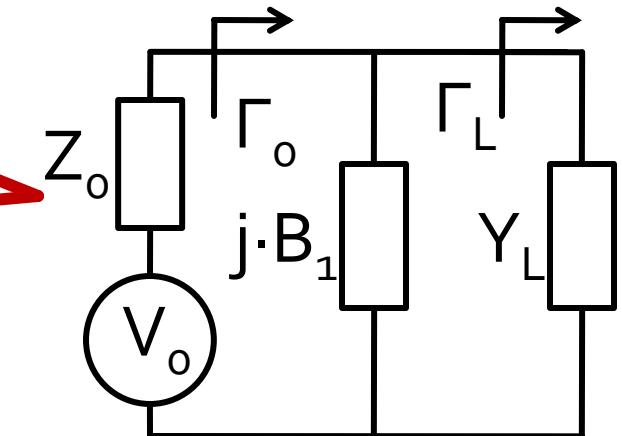
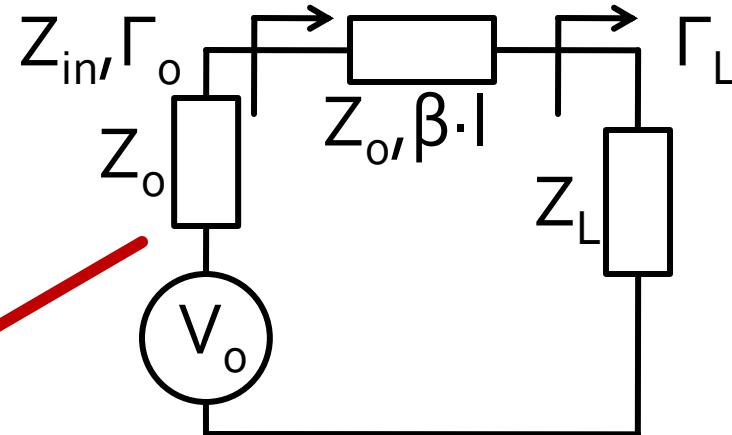
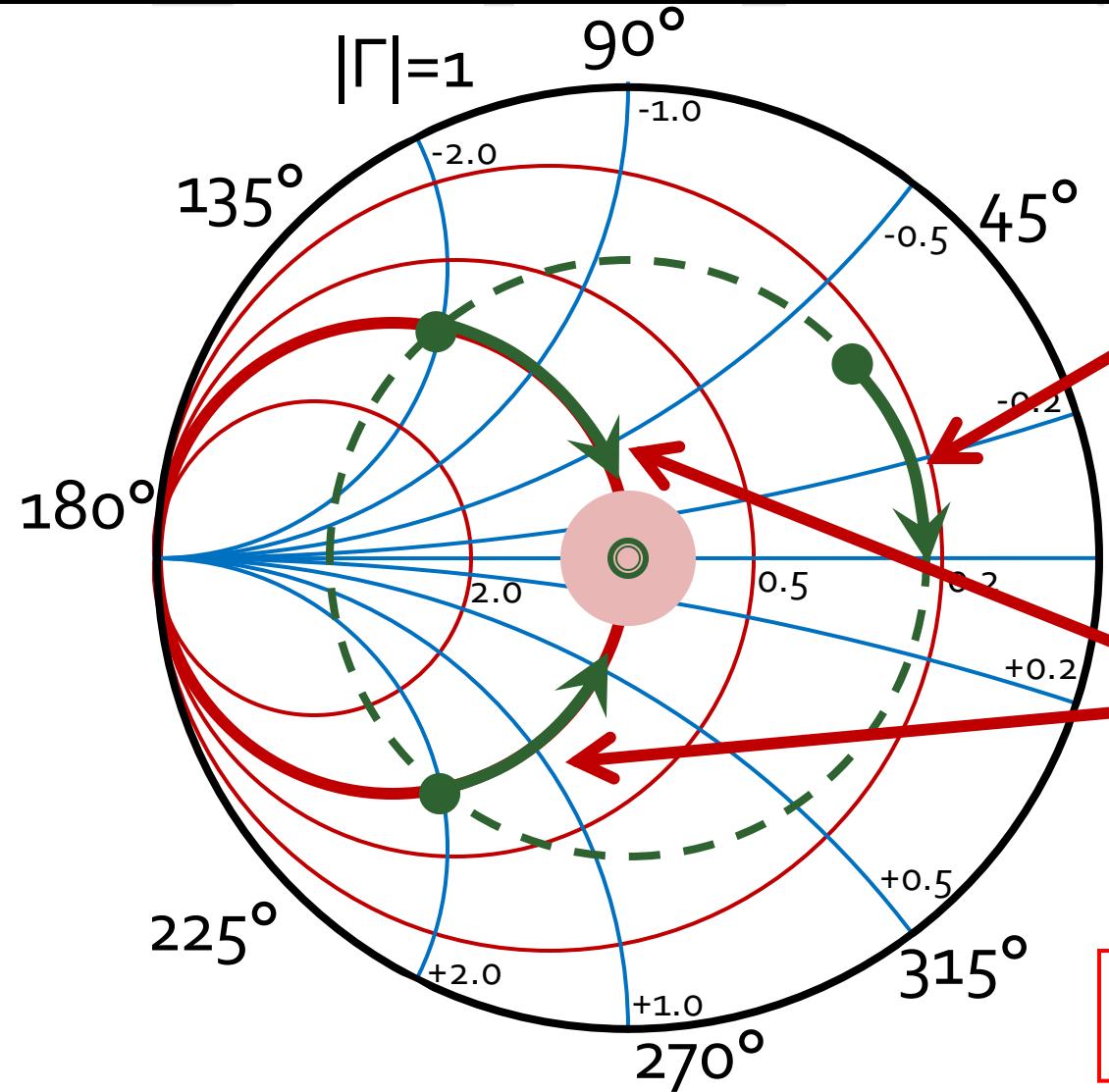


# Single stub tuning

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



# Adaptare, linie serie + susceptanta in paralel



$$|\Gamma_{in}| = |\Gamma_L|$$

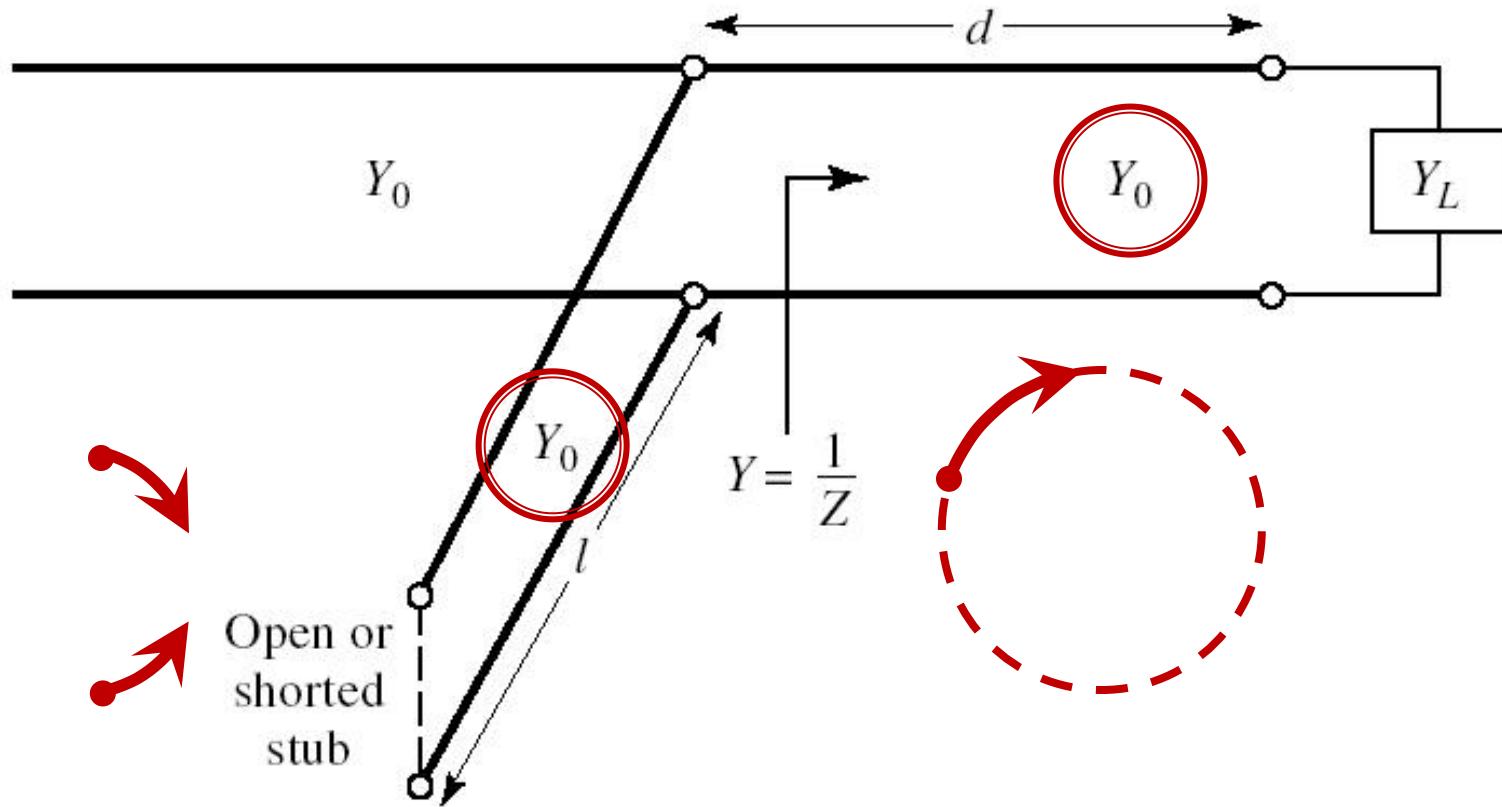
$$g_{in} = 1$$

# **Solutii analitice**

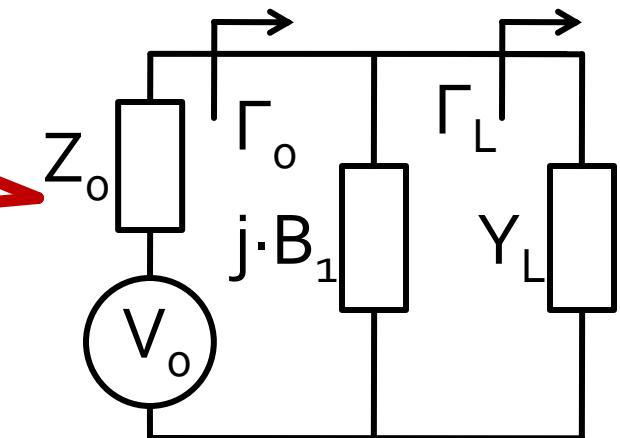
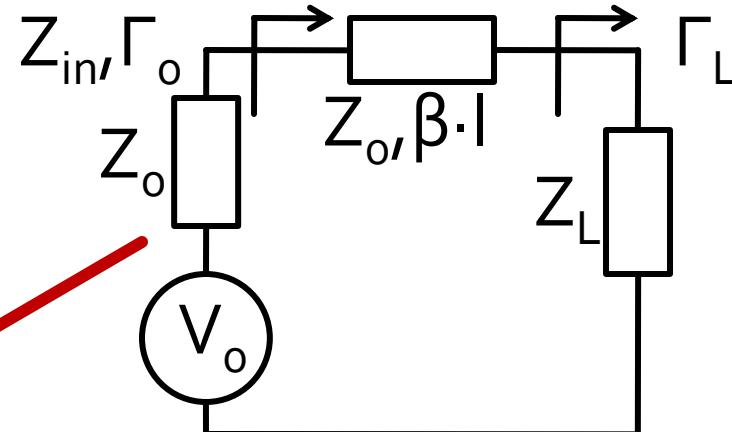
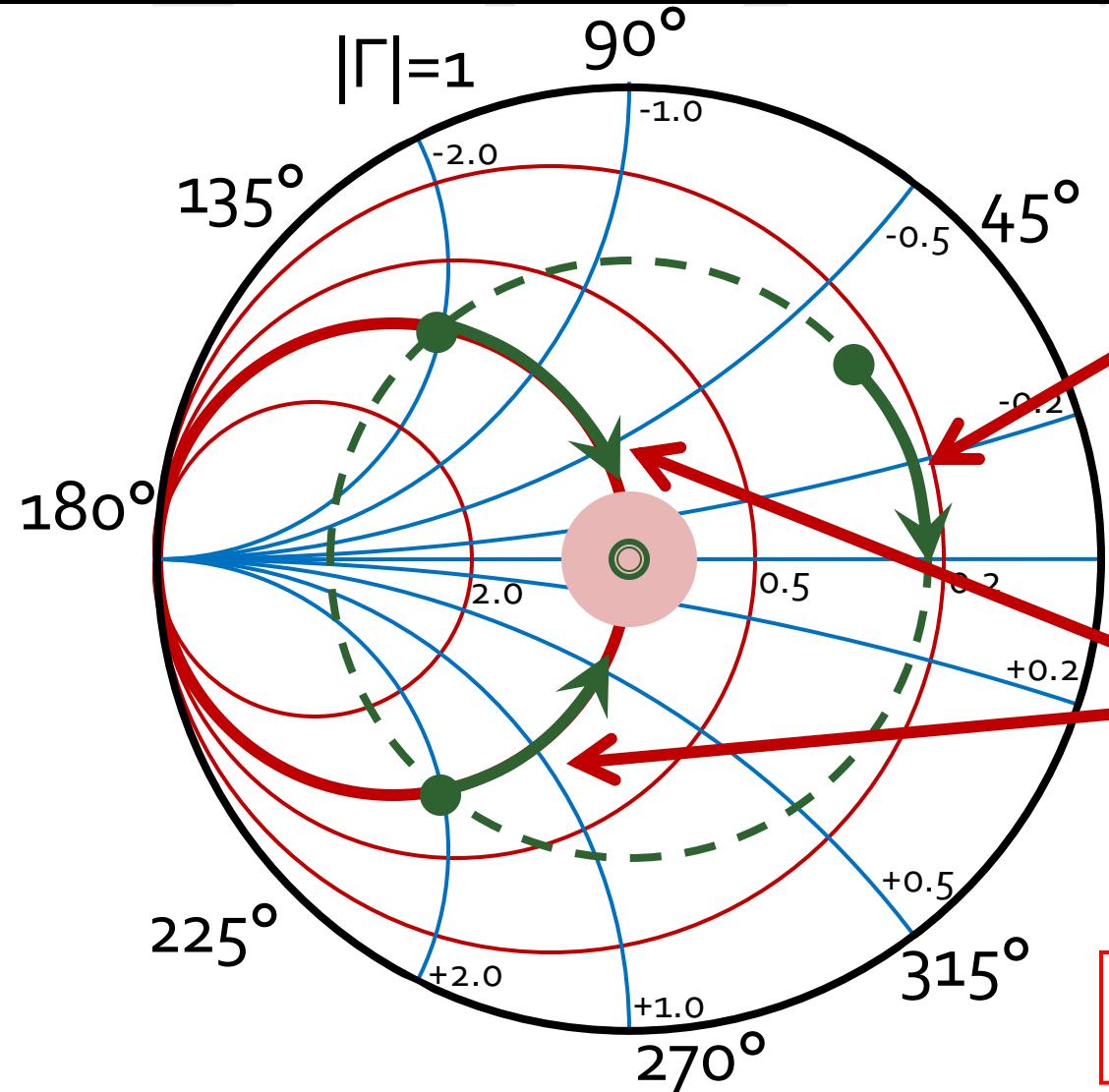
Examen / Proiect

# Caz 1, Shunt Stub

- Shunt Stub (secțiune de linie în paralel)



# Adaptare, linie serie + susceptanta in paralel



$$|\Gamma_{in}| = |\Gamma_L|$$

$$g_{in} = 1$$

# Calcul analitic (calcul efectiv)

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

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

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

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

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

- **solutia "cu +"** 

$$(46.85^\circ + 2\theta) = +126.35^\circ \quad \theta = +39.7^\circ \quad \text{Im } y_s = \frac{-2 \cdot |\Gamma_s|}{\sqrt{1 - |\Gamma_s|^2}} = -1.472$$

$$\theta_{sp} = \tan^{-1}(\text{Im } y_s) = -55.8^\circ (+180^\circ) \rightarrow \theta_{sp} = 124.2^\circ$$

- **solutia "cu -"** 

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

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

# Calcul analitic (calcul efectiv)

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

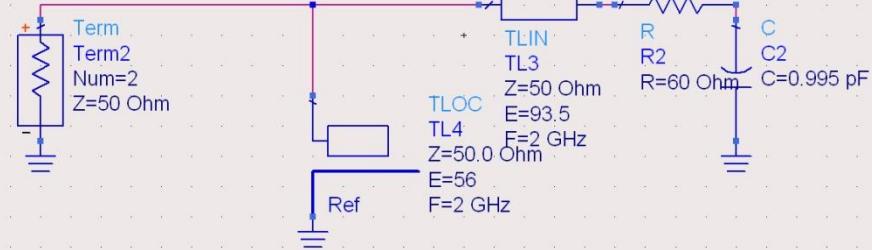
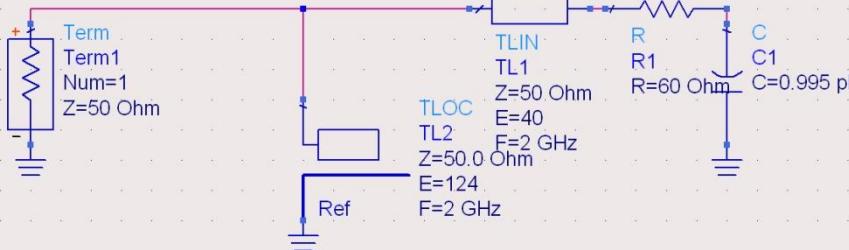
- Se alege **una** din cele doua solutii posibile
- **Semnul (+/-)** solutiei alese la **prima** ecuatie impune **semnul** solutiei utilizate la a **doua** ecuatie

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

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

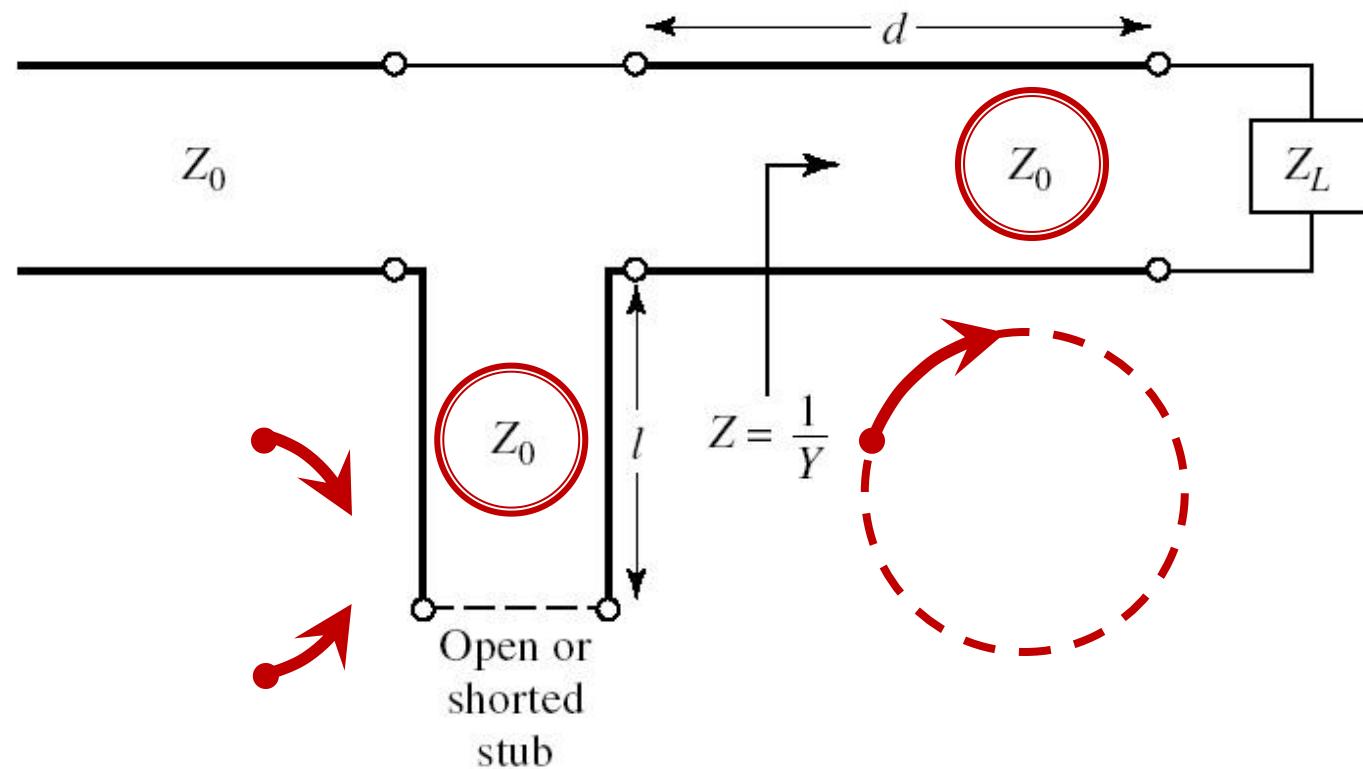
$$l_1 = \frac{93.4^\circ}{360^\circ} \cdot \lambda = 0.259 \cdot \lambda$$

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

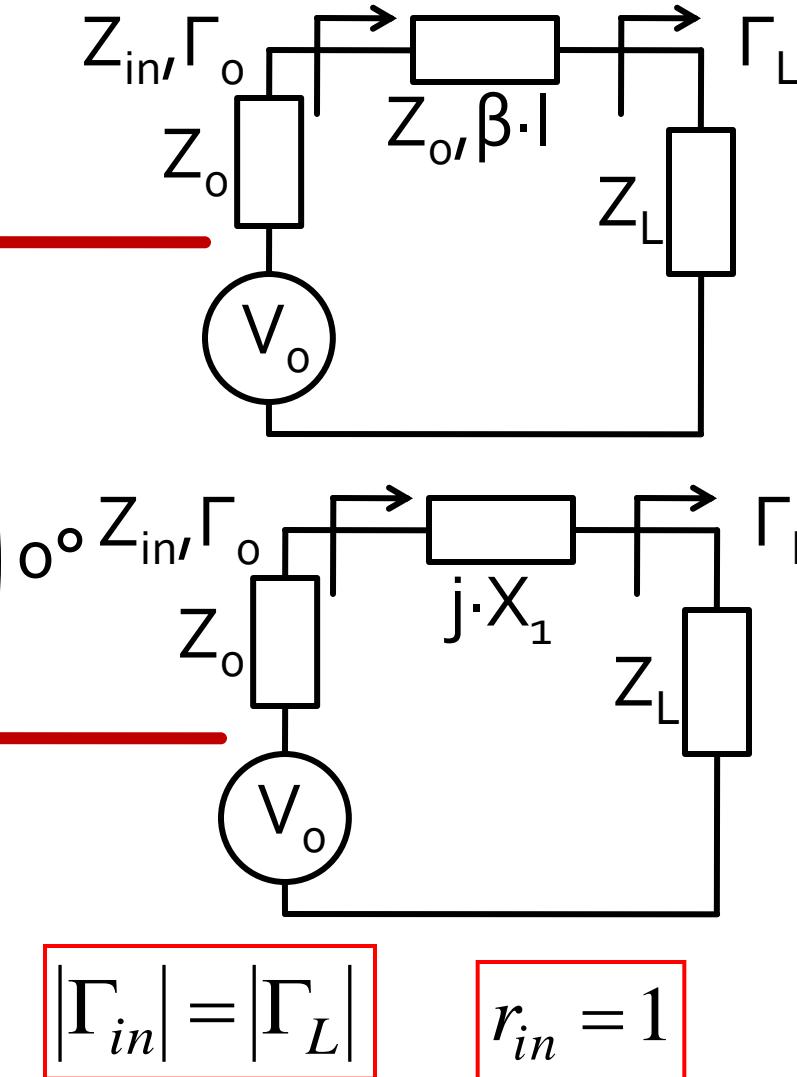
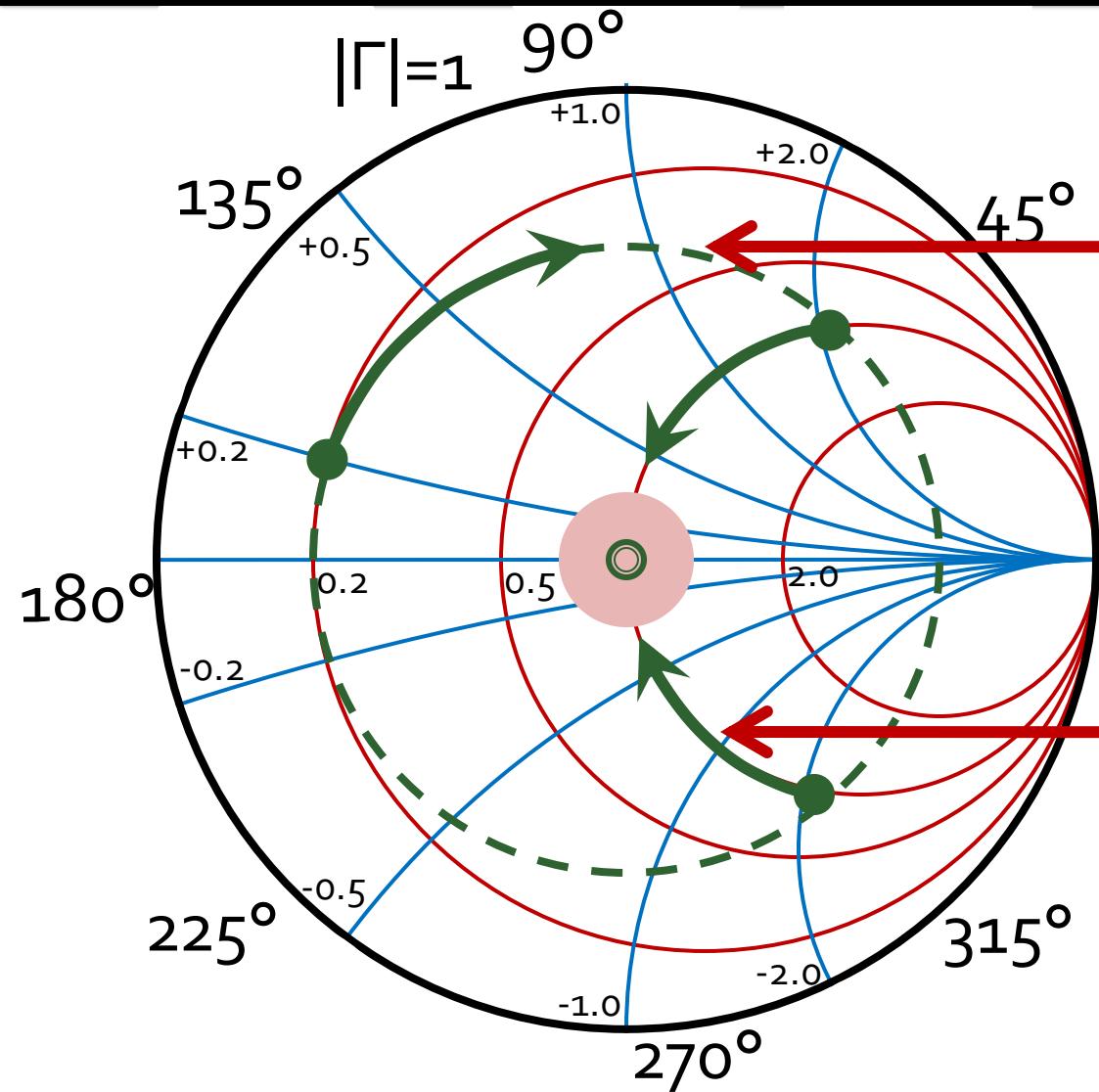


# Caz 2, Series Stub

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



# Adaptare, linie serie + reactanta in serie



$$|\Gamma_{in}| = |\Gamma_L|$$

$$r_{in} = 1$$

# Calcul analitic (calcul efectiv)

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

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

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

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

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

- **solutia "cu +"**

$$(-29.92^\circ + 2\theta) = +56.28^\circ$$

$$\theta = 43.1^\circ$$

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

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

- **solutia "cu -"**

$$(-29.92^\circ + 2\theta) = -56.28^\circ$$

$$\theta = -13.2^\circ (+180^\circ) \rightarrow \theta = 166.8^\circ$$

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

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

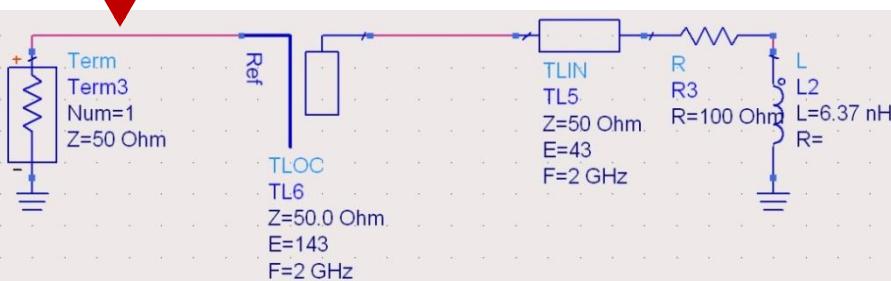
# Calcul analitic (calcul efectiv)

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

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

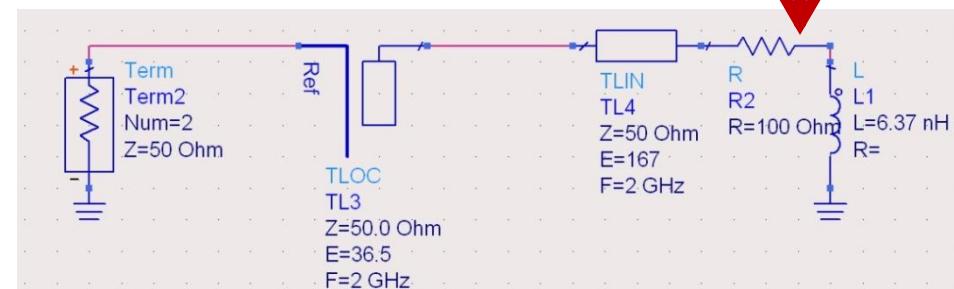
$$l_1 = \frac{43.1^\circ}{360^\circ} \cdot \lambda = 0.120 \cdot \lambda$$

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



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

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



# Stub, observatii

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

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

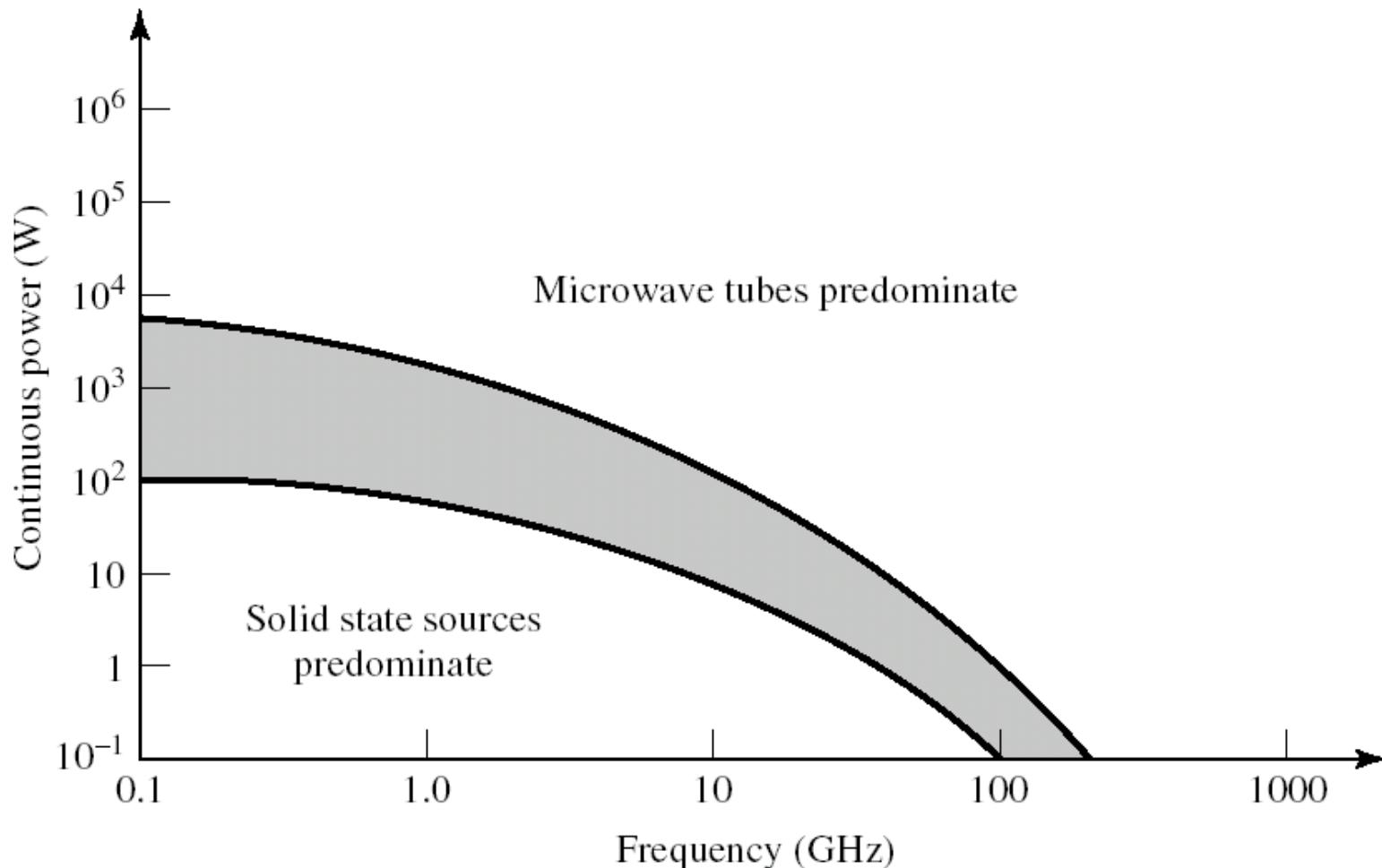
- pentru linii de “lungime” / “lungime electrica” **negative** se adauga  $\lambda/2$  /  $180^\circ$  pentru a avea valoare pozitiva (realizabila fizic)
- o adaugare sau scadere de **90°** ( $\lambda/4$ ) transforma impedanta stub-ului:

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

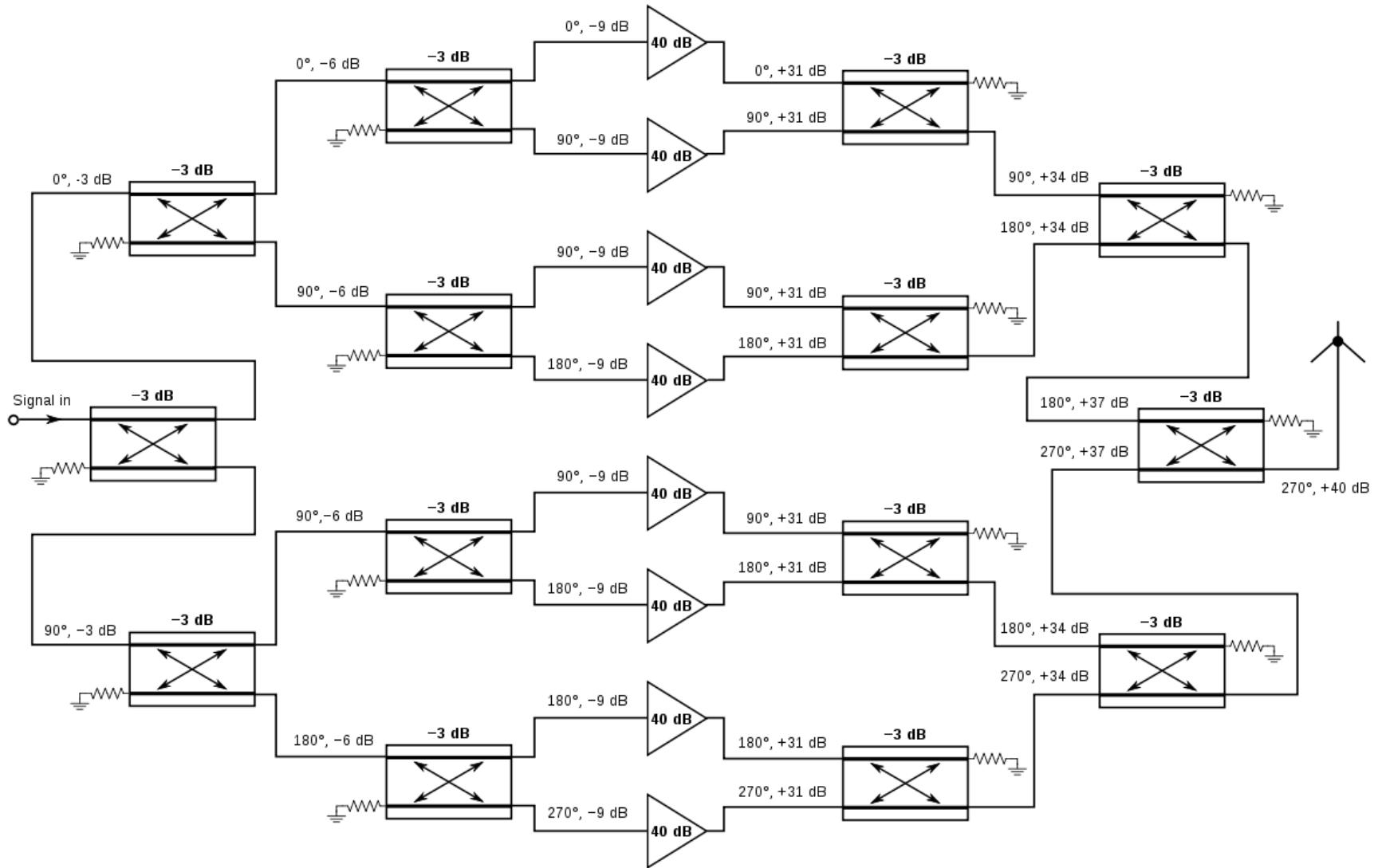
- pentru stub se poate adauga/scadea  $90^\circ$  ( $\lambda/4$ ) simultan cu schimbare **gol**  $\Leftrightarrow$  **scurtcircuit**

# **Amplificatoare de microunde**

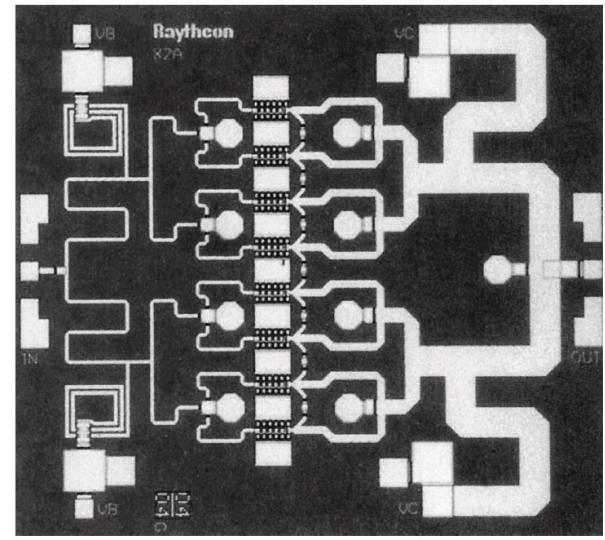
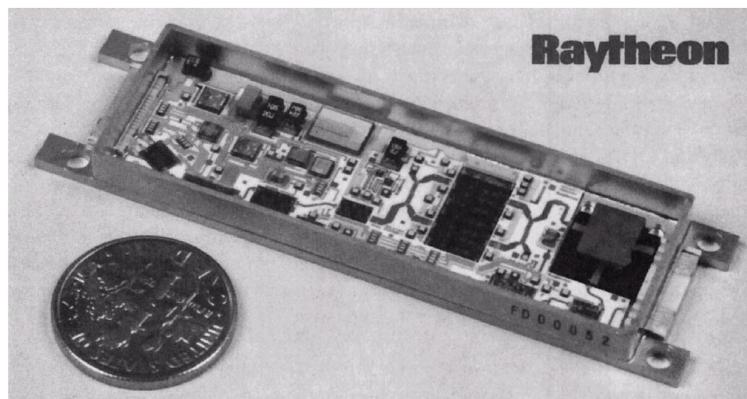
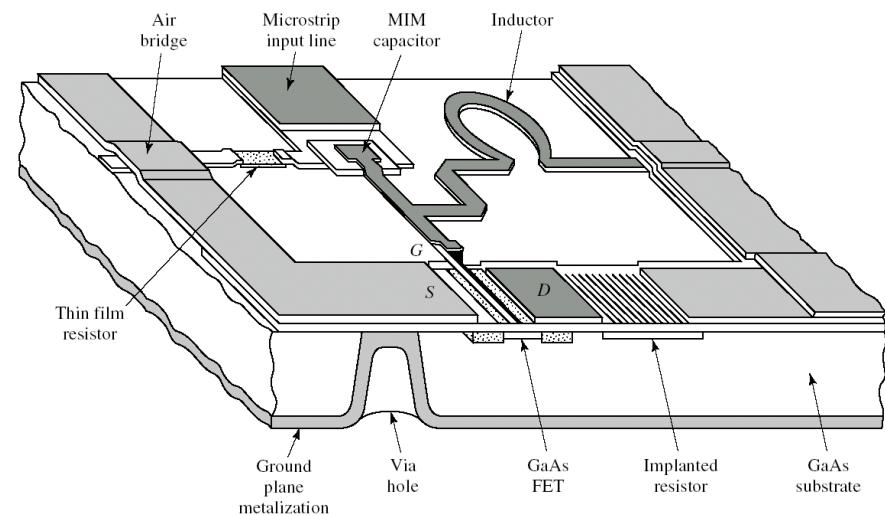
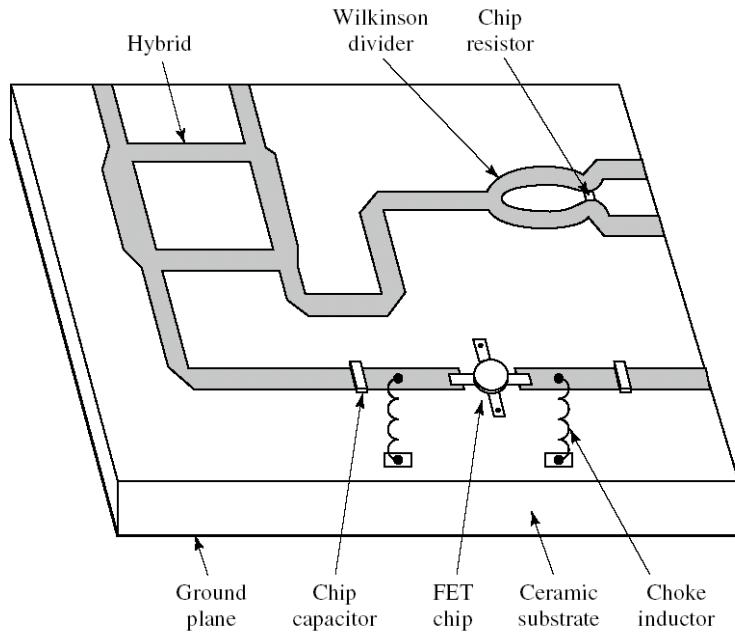
# Amplificatoare pentru microunde



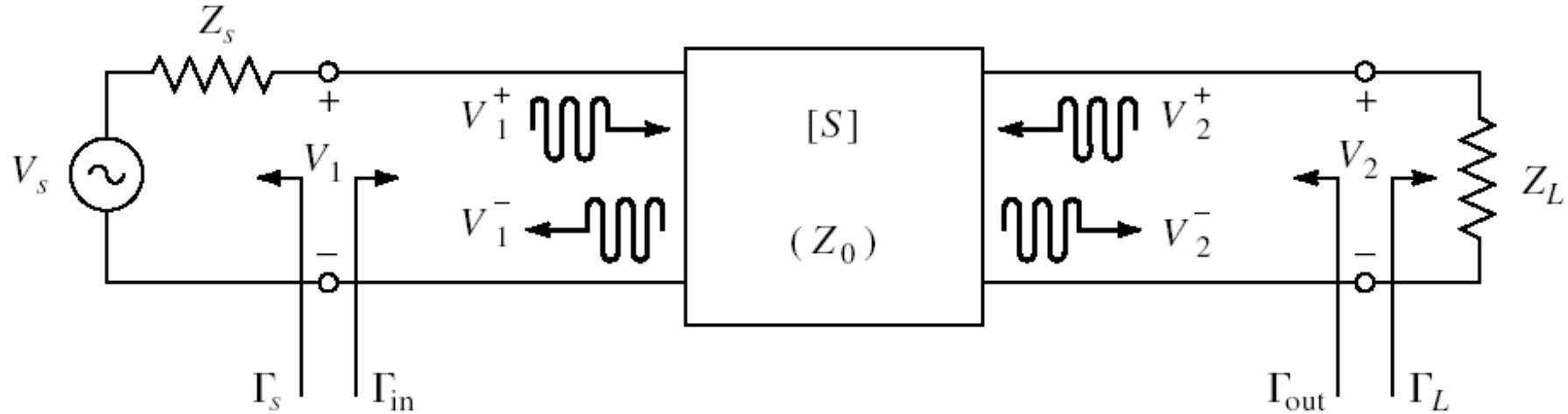
# Amplificatoare echilibrate



# Circuite integrate pentru microunde



# Cuadripol Amplificator (diport)



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

# Catalogage

CEL

## NE46100 / NE46134

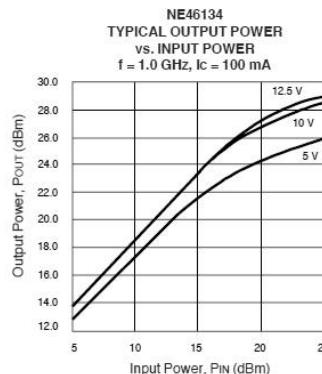
### NPN MEDIUM POWER MICROWAVE TRANSISTOR

#### FEATURES

- HIGH DYNAMIC RANGE
- LOW IM DISTORTION: -40 dBc
- HIGH OUTPUT POWER : 27.5 dBm at TYP
- LOW NOISE: 1.5 dB TYP at 500 MHz
- LOW COST

#### DESCRIPTION

The NE461 series of NPN silicon epitaxial bipolar transistors is designed for medium power applications requiring high dynamic range. This device exhibits an outstanding combination of high gain and low intermodulation distortion, as well as low noise figure. The NE461 series offers excellent performance and reliability at low cost through titanium, platinum, gold metallization system and direct nitride passivation of the surface of the chip. Devices are available in a low cost surface mount package (SOT-89) as well as in chip form.



#### ELECTRICAL CHARACTERISTICS ( $T_A = 25^\circ\text{C}$ )

SYMBOLS	PARAMETERS AND CONDITIONS	UNITS	NE46100			NE46134		
			MIN	TYP	MAX	MIN	TYP	MAX
$f_T$	Gain Bandwidth Product at $V_{CE} = 10 \text{ V}$ , $I_C = 100 \text{ mA}$	GHz	5.5		5.5			
$NF_{MIN}$	Minimum Noise Figure <sup>3</sup> at $V_{CE} = 10 \text{ V}$ , $I_C = 50 \text{ mA}$ , 500 MHz $V_{CE} = 10 \text{ V}$ , $I_C = 50 \text{ mA}$ , 1 GHz	dB	1.5		1.5			
$G_L$	Linear Gain, $V_{CE} = 12.5 \text{ V}$ , $I_C = 100 \text{ mA}$ , 2.0 GHz $V_{CE} = 12.5 \text{ V}$ , $I_C = 100 \text{ mA}$ , 1.0 GHz	dB	9.0		8.0			
$IS_{21E}I^2$	Insertion Power Gain at 10 V, 50 mA, $f = 1.0 \text{ GHz}$	dB	10.0		5.5	7.0		
$h_{FE}$	DC Current Gain <sup>2</sup> at $V_{CE} = 10 \text{ V}$ , $I_C = 50 \text{ mA}$		40	200	40		200	
$I_{CBO}$	Collector Cutoff Current at $V_{CB} = 20 \text{ V}$ , $I_E = 0 \text{ mA}$	mA		5.0		5.0		
$I_{EBO}$	Emitter Cutoff Current at $V_{EB} = 2 \text{ V}$ , $I_C = 0 \text{ mA}$	mA		5.0		5.0		
$P_{1dB}$	Output Power at 1 dB Compression, $V_{CE} = 12.5 \text{ V}$ , $I_C = 100 \text{ mA}$ , 2.0 GHz $V_{CE} = 12.5 \text{ V}$ , $I_C = 100 \text{ mA}$ , 1.0 GHz	dBm	27.0			27.5		
$IM_3$	Intermodulation Distortion, 10 V, 100 mA, $F_1 = 1.0 \text{ GHz}$ , $F_2 = 0.99 \text{ GHz}$							

# Catalogage

**NE46100**

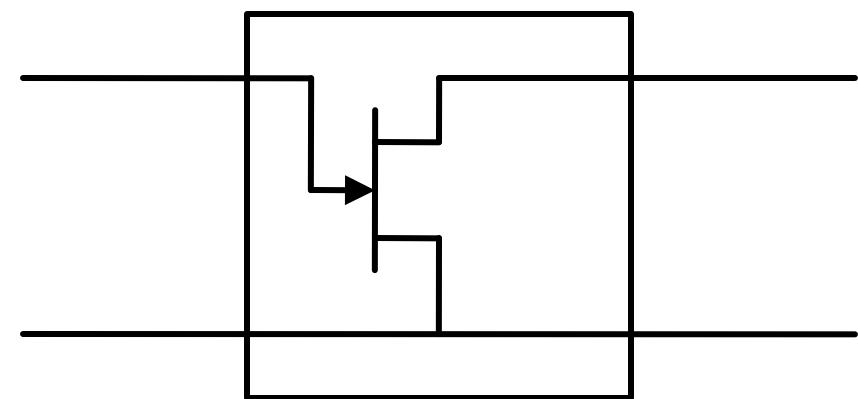
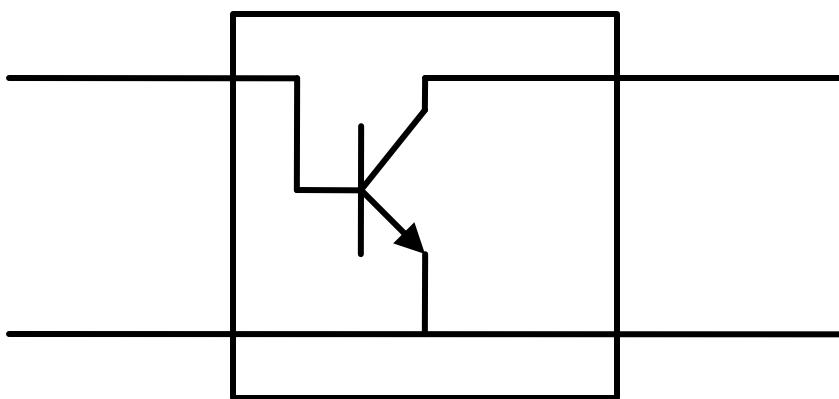
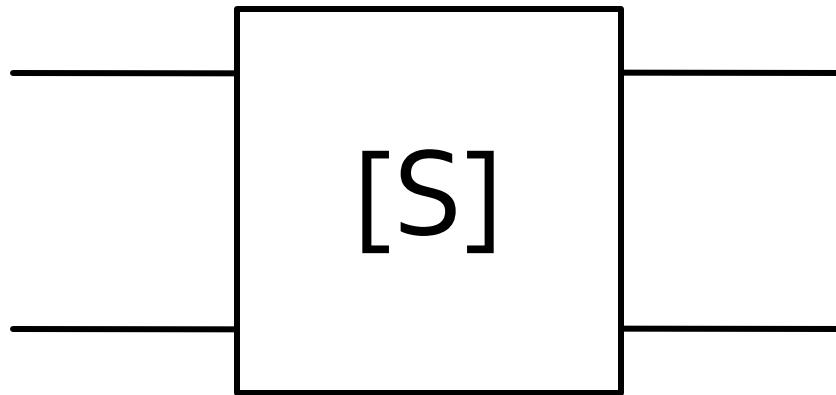
**VCE = 5 V, Ic = 50 mA**

FREQUENCY (MHz)	S <sub>11</sub>		S <sub>21</sub>		S <sub>12</sub>		S <sub>22</sub>		K	MAG <sup>2</sup> (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

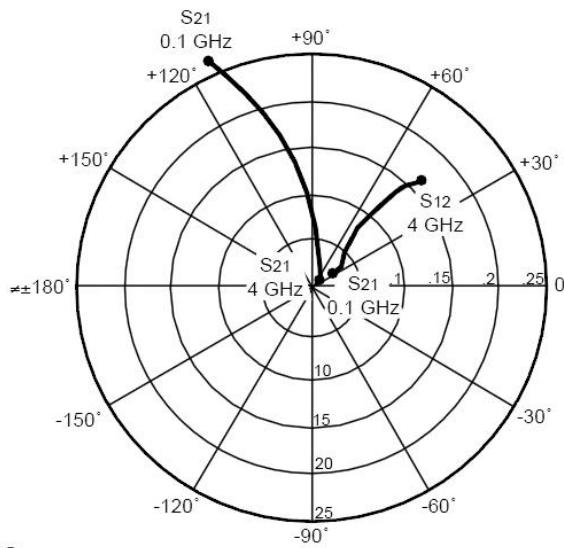
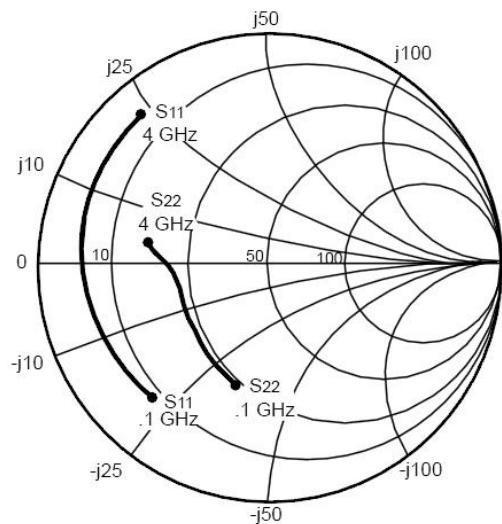
# Parametri S



# Catalogage

NE46100, NE46134

## TYPICAL COMMON EMITTER SCATTERING PARAMETERS<sup>1</sup> ( $T_A = 25^\circ\text{C}$ )



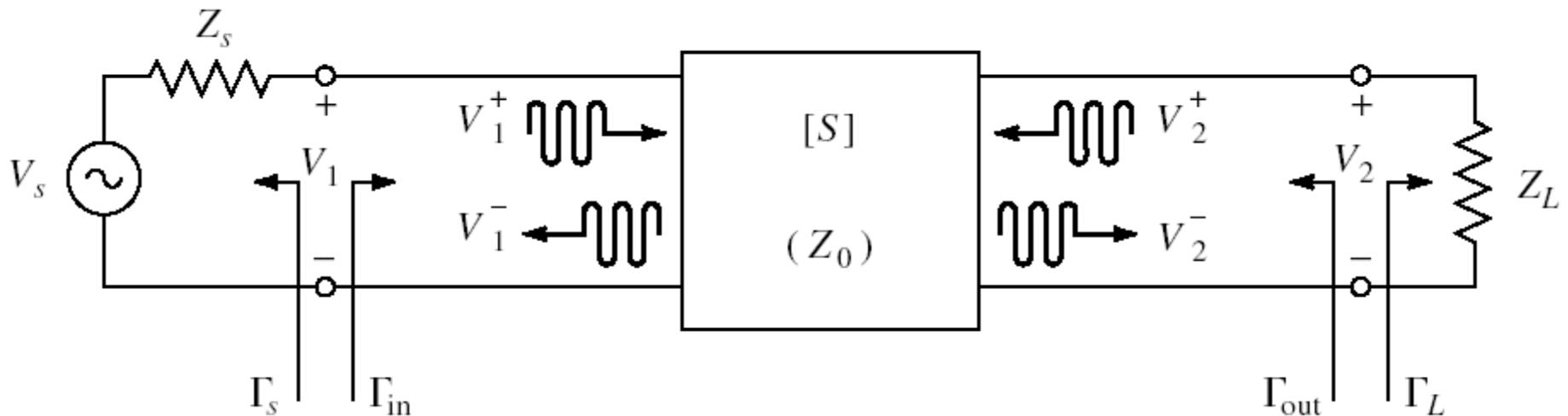
Coordinates in Ohms  
Frequency in GHz  
 $V_{CE} = 5 \text{ V}, I_C = 50 \text{ mA}$

# S<sub>2</sub>P - 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
```

# Dipole amplifier



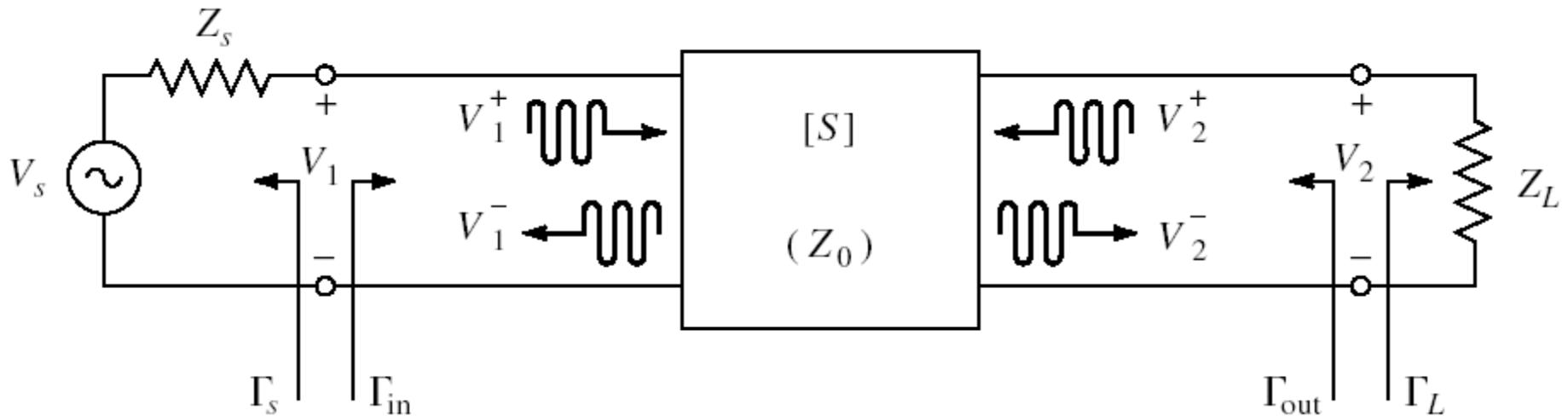
$$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0} \quad \Gamma_S = \frac{Z_S - Z_0}{Z_S + Z_0} \quad \begin{bmatrix} V_1^- \\ V_2^- \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} V_1^+ \\ V_2^+ \end{bmatrix}$$

$$\Gamma_L = \frac{V_2^+}{V_2^-}$$

$$V_1^- = S_{11} \cdot V_1^+ + S_{12} \cdot V_2^+ = S_{11} \cdot V_1^+ + S_{12} \cdot \Gamma_L \cdot V_2^-$$

$$V_2^- = S_{21} \cdot V_1^+ + S_{22} \cdot V_2^+ = S_{21} \cdot V_1^+ + S_{22} \cdot \Gamma_L \cdot V_2^-$$

# Diport amplifier



$$V_1^- = S_{11} \cdot V_1^+ + S_{12} \cdot V_2^+ = S_{11} \cdot V_1^+ + S_{12} \cdot \Gamma_L \cdot V_2^-$$

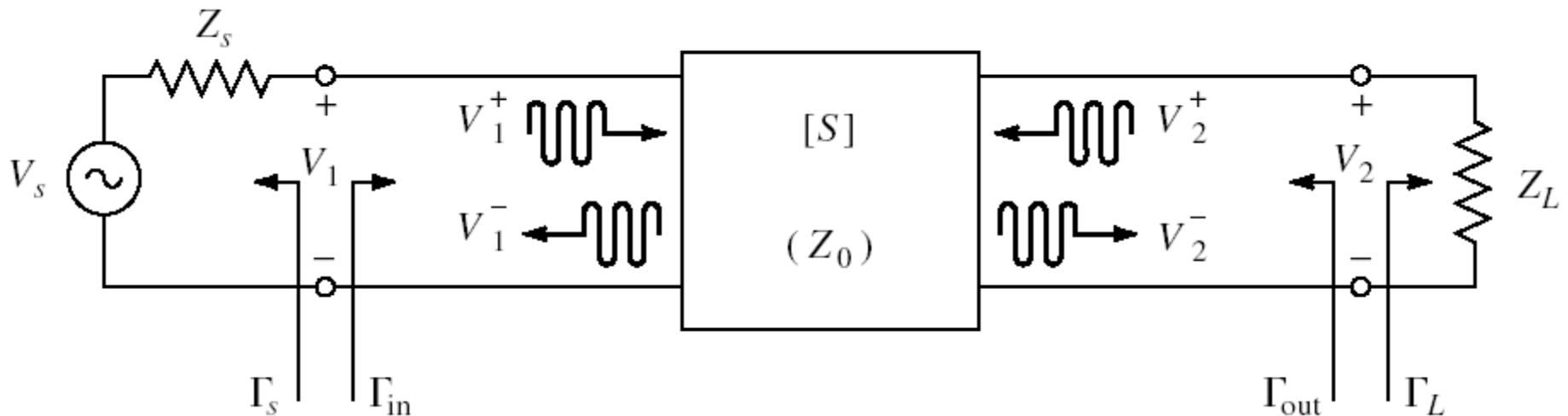
$$V_2^- = S_{21} \cdot V_1^+ + S_{22} \cdot V_2^+ = S_{21} \cdot V_1^+ + S_{22} \cdot \Gamma_L \cdot V_2^-$$

■ similar

$$\Gamma_{in} = \frac{V_1^-}{V_1^+} = S_{11} + \frac{S_{12} \cdot S_{21} \cdot \Gamma_L}{1 - S_{22} \cdot \Gamma_L}$$

$$\Gamma_{out} = \frac{V_2^-}{V_2^+} = S_{22} + \frac{S_{12} \cdot S_{21} \cdot \Gamma_S}{1 - S_{11} \cdot \Gamma_S}$$

# Dipole amplifier

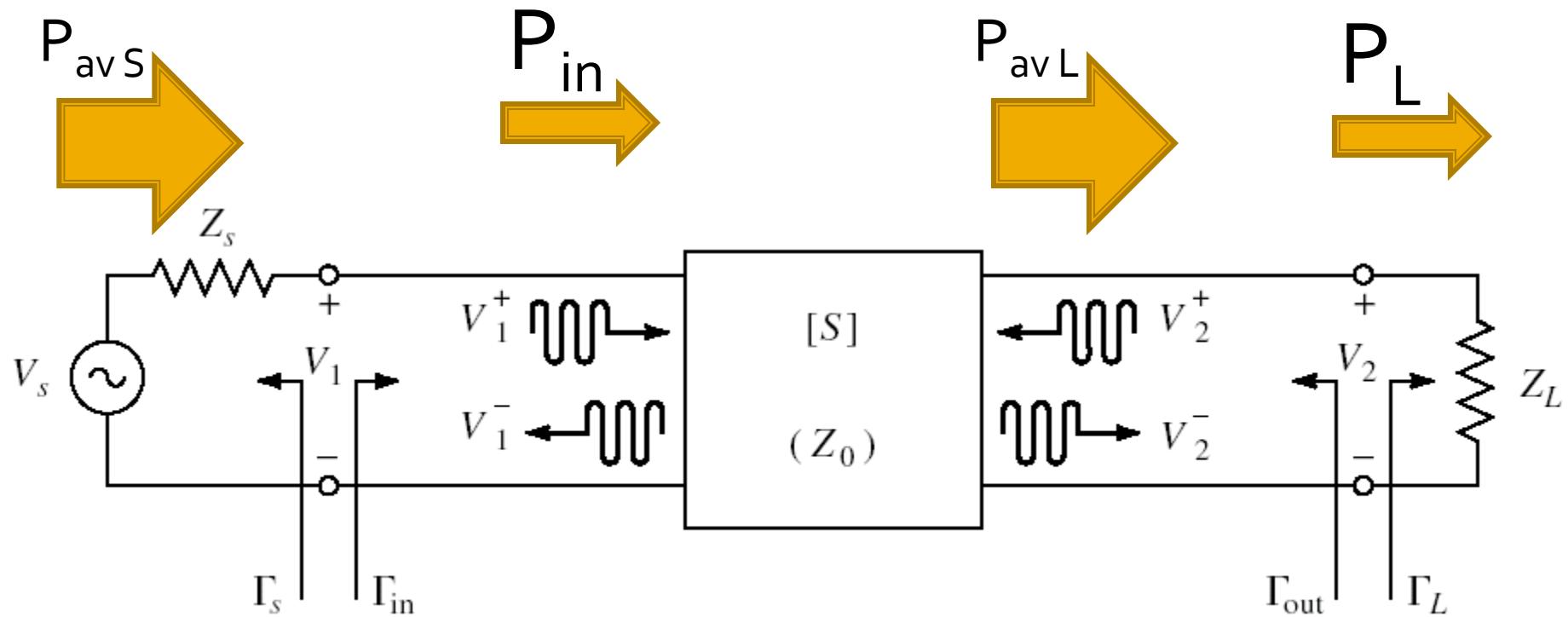


$$\Gamma_{in} = \frac{V_1^-}{V_1^+} = S_{11} + \frac{S_{12} \cdot S_{21} \cdot \Gamma_L}{1 - S_{22} \cdot \Gamma_L}$$

$$\Gamma_{out} = \frac{V_2^-}{V_2^+} = S_{22} + \frac{S_{12} \cdot S_{21} \cdot \Gamma_S}{1 - S_{11} \cdot \Gamma_S}$$

# Puteri / Adaptare

- Doua porturi in care adaptarea influenteaza transferul de putere



# Puteri

$$\Gamma_{in} = \frac{V_1^-}{V_1^+} = S_{11} + \frac{S_{12} \cdot S_{21} \cdot \Gamma_L}{1 - S_{22} \cdot \Gamma_L}$$

$$V_1 = \frac{V_S \cdot Z_{in}}{Z_S + Z_{in}} = V_1^+ + V_1^- = V_1^+ \cdot (1 + \Gamma_{in})$$

■ **C2**       $P_{in} = \frac{1}{2 \cdot Z_0} \cdot |V_1^+|^2 \cdot (1 - |\Gamma_{in}|^2)$

$$P_{in} = \frac{|V_S|^2}{8 \cdot Z_0} \cdot \frac{|1 - \Gamma_S|^2}{|1 - \Gamma_S \cdot \Gamma_{in}|^2} (1 - |\Gamma_{in}|^2)$$

$$V_2^- = S_{21} \cdot V_1^+ + S_{22} \cdot V_2^+ = S_{21} \cdot V_1^+ + S_{22} \cdot \Gamma_L \cdot V_2^-$$

$$P_L = \frac{|V_1^+|^2}{2 \cdot Z_0} \cdot \frac{|S_{21}|^2}{|1 - S_{22} \cdot \Gamma_L|^2} (1 - |\Gamma_L|^2)$$

$$\Gamma_{in} = \frac{Z_{in} - Z_0}{Z_{in} + Z_0}$$

$$V_1^+ = \frac{V_S}{2} \frac{(1 - \Gamma_S)}{(1 - \Gamma_S \cdot \Gamma_{in})}$$

$$P_L = \frac{1}{2 \cdot Z_0} \cdot |V_2^-|^2 \cdot (1 - |\Gamma_L|^2)$$

$$V_2^- = \frac{S_{21} \cdot V_1^+}{1 - S_{22} \cdot \Gamma_L}$$

$$P_L = \frac{|V_S|^2}{8 \cdot Z_0} \cdot \frac{|S_{21}|^2 \cdot (1 - |\Gamma_L|^2)}{|1 - S_{22} \cdot \Gamma_L|^2} \cdot \frac{|1 - \Gamma_S|^2}{|1 - \Gamma_S \cdot \Gamma_{in}|^2}$$

# Puteri

## ■ Puteri

$$P_{in} = \frac{|V_S|^2}{8 \cdot Z_0} \cdot \frac{|1 - \Gamma_S|^2}{|1 - \Gamma_S \cdot \Gamma_{in}|^2} \left(1 - |\Gamma_{in}|^2\right)$$

$$P_L = \frac{|V_S|^2}{8 \cdot Z_0} \cdot \frac{|S_{21}|^2 \cdot (1 - |\Gamma_L|^2)}{|1 - S_{22} \cdot \Gamma_L|^2} \cdot \frac{|1 - \Gamma_S|^2}{|1 - \Gamma_S \cdot \Gamma_{in}|^2}$$

## ■ Puterea disponibila de la sursa

$$P_{avS} = P_{in} \Big|_{\Gamma_{in}=\Gamma_S^*} = \frac{|V_S|^2}{8 \cdot Z_0} \cdot \frac{|1 - \Gamma_S|^2}{\left(1 - |\Gamma_S|^2\right)}$$

## ■ Puterea disponibila la sarcina

$$P_{avL} = P_L \Big|_{\Gamma_L=\Gamma_{out}^*} = \frac{|V_S|^2}{8 \cdot Z_0} \cdot \frac{|S_{21}|^2 \cdot |1 - \Gamma_S|^2}{|1 - S_{11} \cdot \Gamma_S|^2 \cdot \left(1 - |\Gamma_{out}|^2\right)}$$

# Castig de putere

## ■ Castigul de putere

$$G = \frac{P_L}{P_{in}} = \frac{|S_{21}|^2 \cdot (1 - |\Gamma_L|^2)}{(1 - |\Gamma_{in}|^2) \cdot |1 - S_{22} \cdot \Gamma_L|^2}$$

$$P_{in} = P_{in}(\Gamma_S, \Gamma_{in}(\Gamma_L), S)$$

$$P_L = P_L(\Gamma_S, \Gamma_{in}(\Gamma_L), S)$$

- Castigul **introdus** efectiv de amplificator este mai putin important deoarece un castig mai mare poate fi insotit de o **scadere** a puterii de intrare (absorbita efectiv de la sursa)
- Se prefera caracterizarea efectului amplificatorului prin analiza puterii **efectiv obtinuta pe sarcina** in raport cu puterea **disponibila de la sursa** (constanta)

# Castig de putere

## ■ Castigul de putere **disponibil**

$$G_A = \frac{P_{avL}}{P_{avS}} = \frac{|S_{21}|^2 \cdot (1 - |\Gamma_S|^2)}{|1 - S_{22} \cdot \Gamma_L|^2 \cdot (1 - |\Gamma_{out}|^2)}$$

## ■ Castigul de putere de **transfer** (transducer power gain)

$$G_T = \frac{P_L}{P_{avS}} = \frac{|S_{21}|^2 \cdot (1 - |\Gamma_S|^2) \cdot (1 - |\Gamma_L|^2)}{|1 - \Gamma_S \cdot \Gamma_{in}|^2 \cdot |1 - S_{22} \cdot \Gamma_L|^2}$$

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

## ■ Castigul de putere de **transfer unilateral**

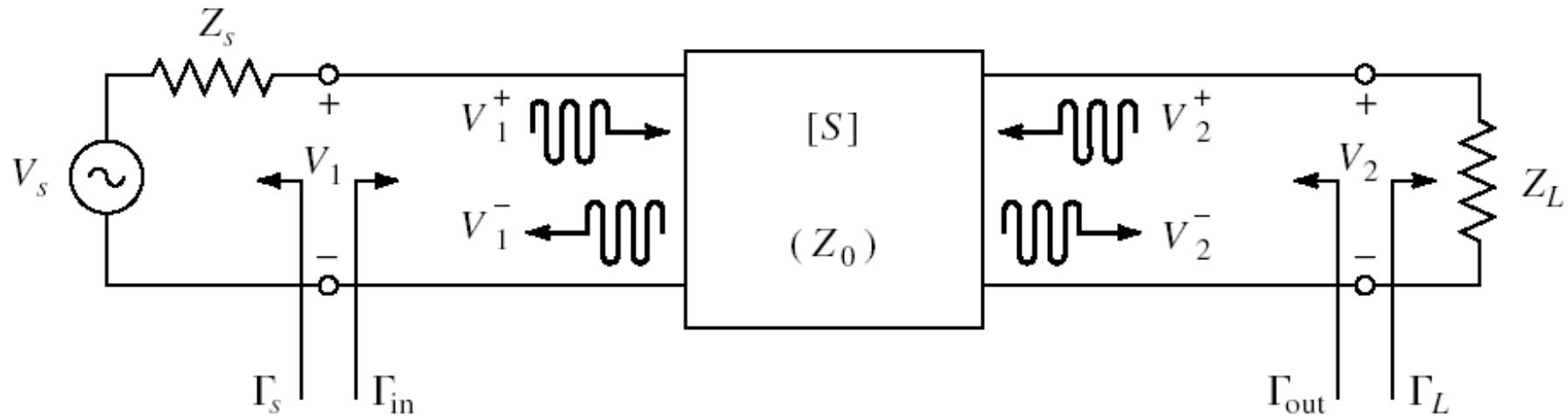
$$G_{TU} = |S_{21}|^2 \cdot \frac{1 - |\Gamma_S|^2}{|1 - S_{11} \cdot \Gamma_S|^2} \cdot \frac{1 - |\Gamma_L|^2}{|1 - S_{22} \cdot \Gamma_L|^2}$$

$$S_{12} \cong 0$$

$$\Gamma_{in} = S_{11}$$

Permite tratarea separata  
a intrarii si iesirii

# Cuadripol Amplifier

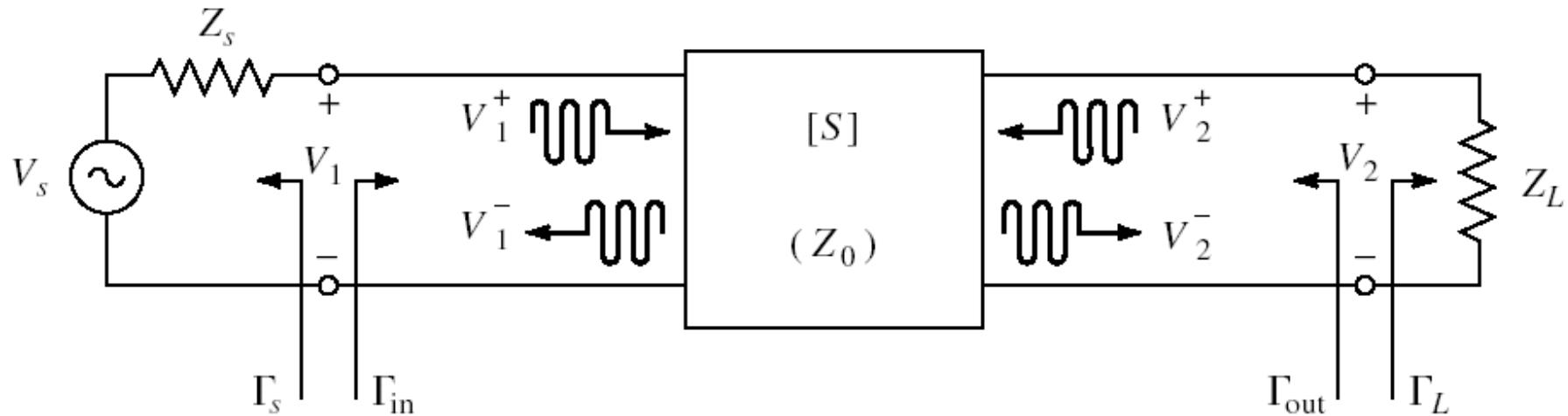


- marimi care intereseaza:
  - stabilitate
  - castig de putere
  - zgomot (uneori – semnal mic)
  - liniaritate (uneori – semnal mare)

Amplificatoare de microunde

# **Stabilitate**

# Cuadripol Amplifier



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

# Stabilitate

- C7       $\Gamma = \Gamma_r + j \cdot \Gamma_i$        $r_L = \frac{1 - \Gamma_r^2 - \Gamma_i^2}{(1 - \Gamma_r)^2 + \Gamma_i^2}$   
 $Z_{in}$        $\Gamma_{in} = \Gamma_r + j \cdot \Gamma_i$
- instabilitate  
 $\text{Re}\{Z_{in}\} < 0 \Leftrightarrow 1 - \Gamma_r^2 - \Gamma_i^2 < 0 \quad |\Gamma_{in}| > 1$
- stabilitate,  $Z_{in}$ 
  - conditii ce trebuie indeplinite de  $\Gamma_L$  pentru a obtine stabilitatea (la intrare)  
 $|\Gamma_{in}| < 1 \quad \left| S_{11} + \frac{S_{12} \cdot S_{21} \cdot \Gamma_L}{1 - S_{22} \cdot \Gamma_L} \right| < 1$
  - similar  $Z_{out}$ 
    - conditii ce trebuie indeplinite de  $\Gamma_S$  pentru a obtine stabilitatea (la iesire)

# Stabilitate

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

- Obtinem conditiile ce trebuie indeplinite de  $\Gamma_L$  pentru a obtine stabilitatea

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

- Obtinem conditiile ce trebuie indeplinite de  $\Gamma_S$  pentru a obtine stabilitatea

# 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

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

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

## ■ 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

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

$$a \cdot a^* = |a| \cdot e^{j\theta} \cdot |a| \cdot e^{-j\theta} = |a|^2$$

$$|a+b|^2 = (a+b) \cdot (a+b)^* = (a+b) \cdot (a^* + b^*) = \underline{|a|^2} + \underline{|b|^2} + \underline{a^* \cdot b} + \underline{a \cdot b^*}$$

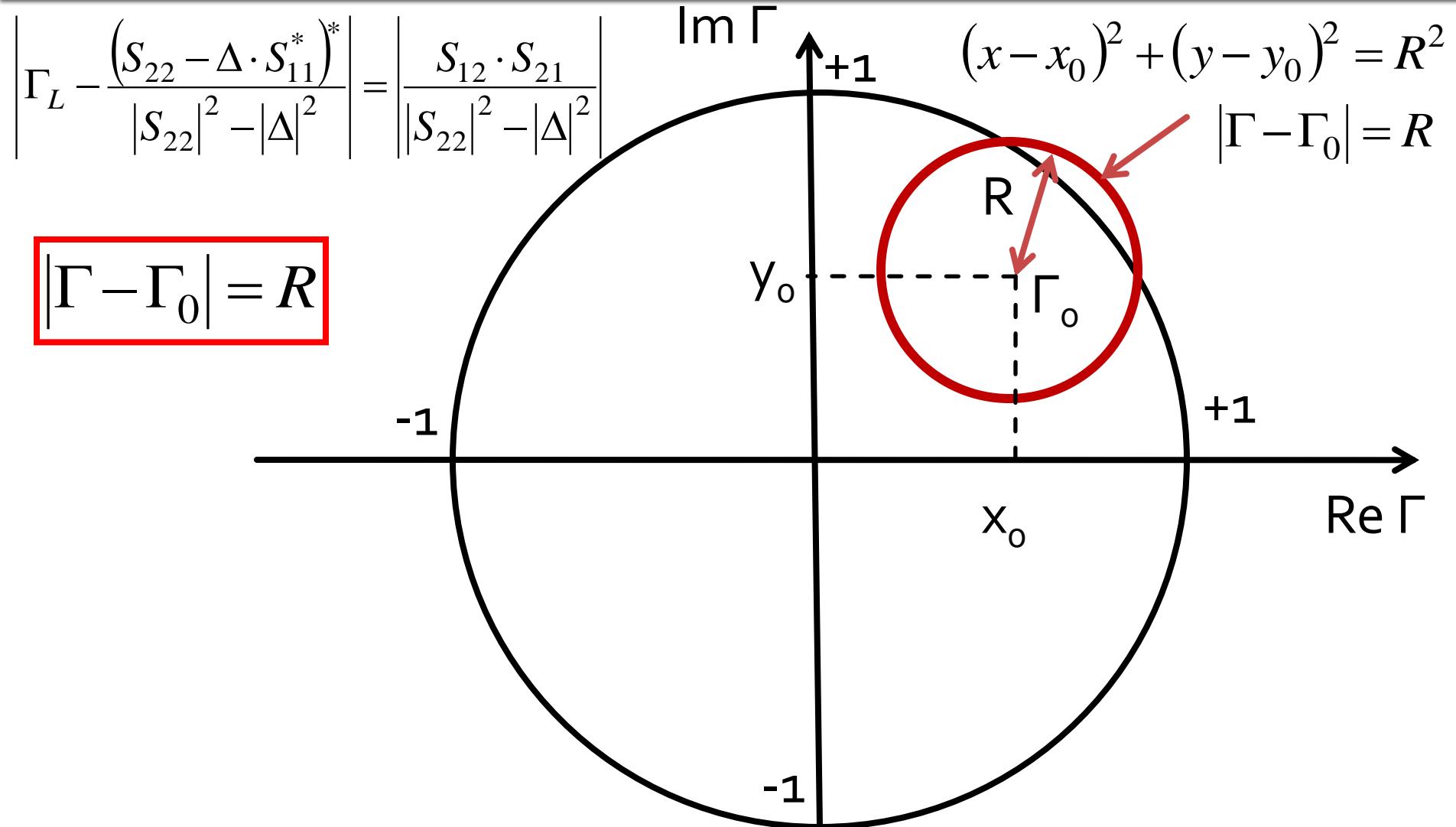
$$|S_{11}|^2 + |\Delta|^2 \cdot |\Gamma_L|^2 - (\Delta \cdot \Gamma_L \cdot S_{11}^* + \Delta^* \cdot \Gamma_L^* \cdot S_{11}) = 1 + |S_{22}|^2 \cdot |\Gamma_L|^2 - (S_{22}^* \cdot \Gamma_L^* + S_{22} \cdot \Gamma_L)$$

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

$$\frac{\Gamma_L \cdot \Gamma_L^* - (S_{22} - \Delta \cdot S_{11}^*) \cdot \Gamma_L + (S_{22}^* - \Delta^* \cdot S_{11}) \cdot \Gamma_L^*}{|S_{22}|^2 - |\Delta|^2} = \frac{|S_{11}|^2 - 1}{|S_{22}|^2 - |\Delta|^2} + \frac{|S_{22} - \Delta \cdot S_{11}^*|^2}{(|S_{22}|^2 - |\Delta|^2)^2}$$

$$\left| \Gamma_L - \frac{(S_{22} - \Delta \cdot S_{11}^*)^*}{|S_{22}|^2 - |\Delta|^2} \right|^2 = \frac{|S_{11}|^2 - 1}{|S_{22}|^2 - |\Delta|^2} + \frac{|S_{22} - \Delta \cdot S_{11}^*|^2}{(|S_{22}|^2 - |\Delta|^2)^2}$$

# Stabilitate



# 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  $\Gamma_L$  pentru **limita** de stabilitate
- Cercul se numeste **cerc de stabilitate la ieșire** ( $\Gamma_L$ )

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

# Cerc de stabilitate la intrare (CSIN)

- Similar  $|\Gamma_{out}| = 1$   $\left| S_{22} + \frac{S_{12} \cdot S_{21} \cdot \Gamma_S}{1 - S_{11} \cdot \Gamma_S} \right| = 1$
- Ecuatia unui cerc, care reprezinta locul geometric al punctelor  $\Gamma_S$  pentru **limita** de stabilitate
- Cercul se numeste **cerc de stabilitate la intrare** ( $\Gamma_S$ )

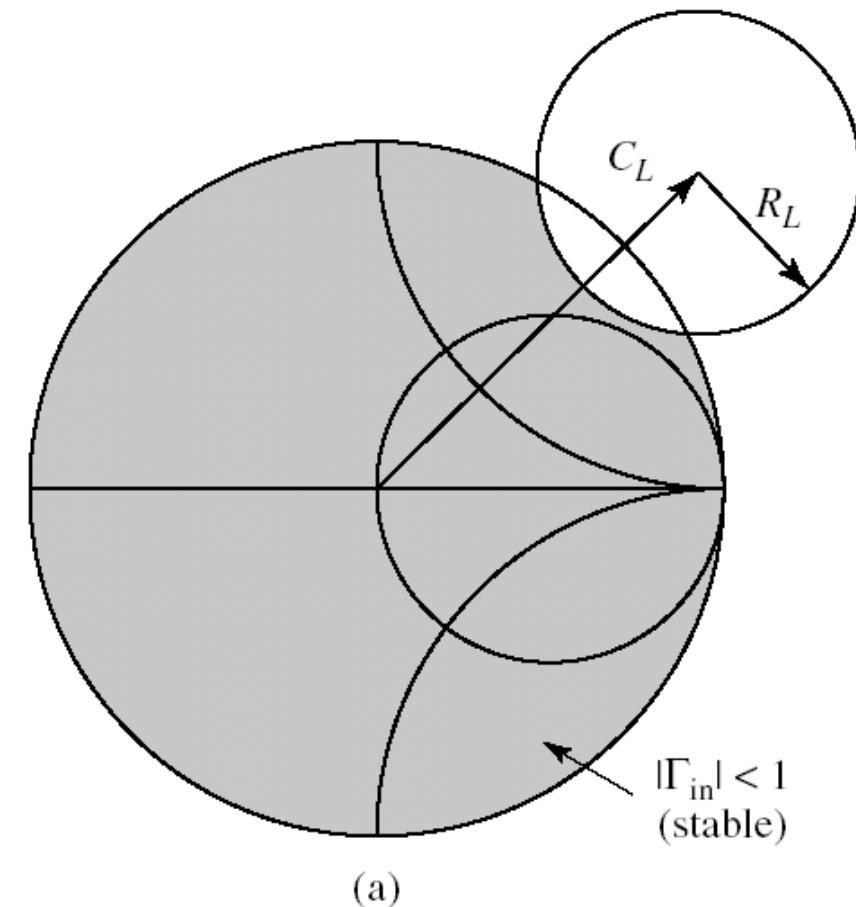
$$C_S = \frac{(S_{11} - \Delta \cdot S_{22}^*)^*}{|S_{11}|^2 - |\Delta|^2}$$

$$R_S = \frac{|S_{12} \cdot S_{21}|}{\left| |S_{11}|^2 - |\Delta|^2 \right|}$$

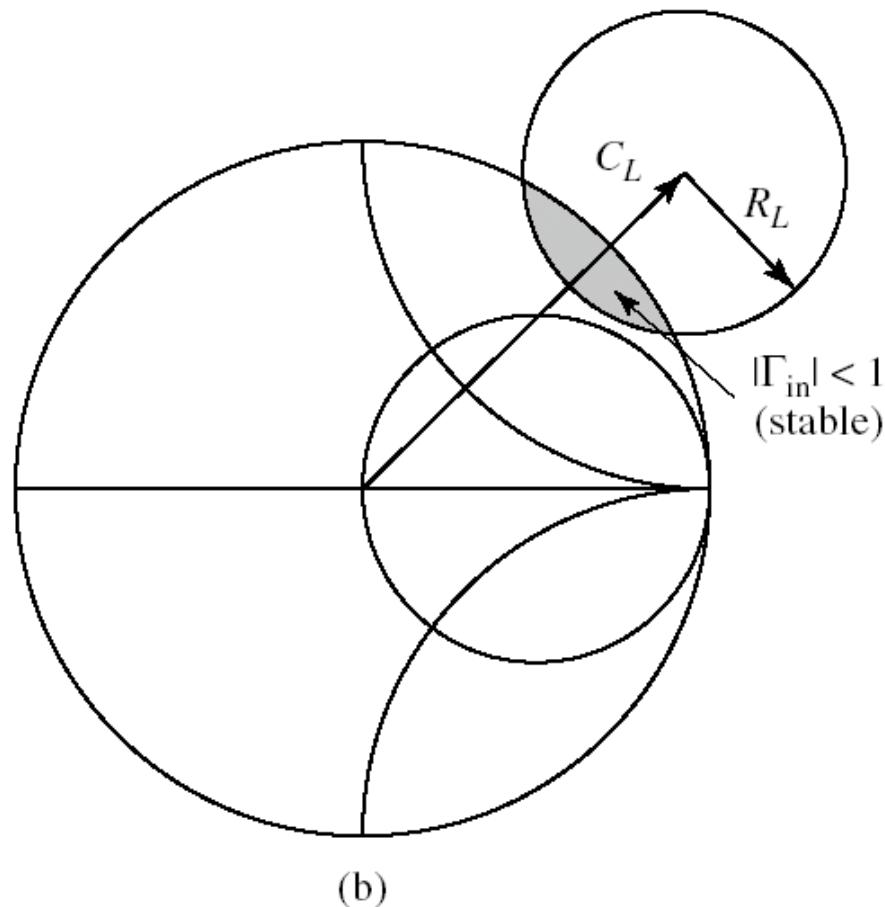
# Cerc de stabilitate la ieșire (CSOUT)

- **Cercul de stabilitate la ieșire** reprezinta locul geometric al punctelor  $\Gamma_L$  pentru **limita** de stabilitate ( $|\Gamma_{in}|=1$ )
- Cercul imparte planul complex in doua suprafete, **interiorul** si **exteriorul** cercului
- Cele doua suprafete vor reprezenta zonele  $\Gamma_L$  de stabilitate ( $|\Gamma_{in}|<1$ ) / instabilitate ( $|\Gamma_{in}|>1$ )

# Cerc de stabilitate la ieșire (CSOUT)



(a)



(b)

- Doua cazuri: (a) exterior stabil / (b) interior stabil

# Cerc de stabilitate la iesire (CSOUT)

- Identificarea zonelor de stabilitate / instabilitate
  - Centrul diagramei Smith: in coordonate polare corespunde lui  $\Gamma_L = 0$
  - Coeficientul de reflexie la intrare
$$\Gamma_{in} = S_{11} + \frac{S_{12} \cdot S_{21} \cdot \Gamma_L}{1 - S_{22} \cdot \Gamma_L} \quad \left. \Gamma_{in} \right|_{\Gamma_L=0} = S_{11} \quad \left| \Gamma_{in} \right|_{\Gamma_L=0} = |S_{11}|$$
    - Decizia se poate lua in functie de valoarea pe care o are  $|S_{11}|$  si de pozitia centrului diagramei Smith fata de cercul de stabilitate

# Identificarea zonelor

- Cerc de stabilitate la iesire
  - $|S_{11}| < 1 \rightarrow$  centrul diagramei pe care se reprezinta  $\Gamma_L$  este punct **stabil**, se gaseste in zona stabila (cel mai des)
  - $|S_{11}| > 1 \rightarrow$  centrul diagramei pe care se reprezinta  $\Gamma_L$  este punct **instabil**, se gaseste in zona instabila
- Cerc de stabilitate la intrare
  - $|S_{22}| < 1 \rightarrow$  centrul diagramei pe care se reprezinta  $\Gamma_S$  este punct **stabil**, se gaseste in zona stabila (cel mai des)
  - $|S_{22}| > 1 \rightarrow$  centrul diagramei pe care se reprezinta  $\Gamma_S$  este punct **instabil**, se gaseste in zona instabila

# Exemplu

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

- @5GHz

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



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

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

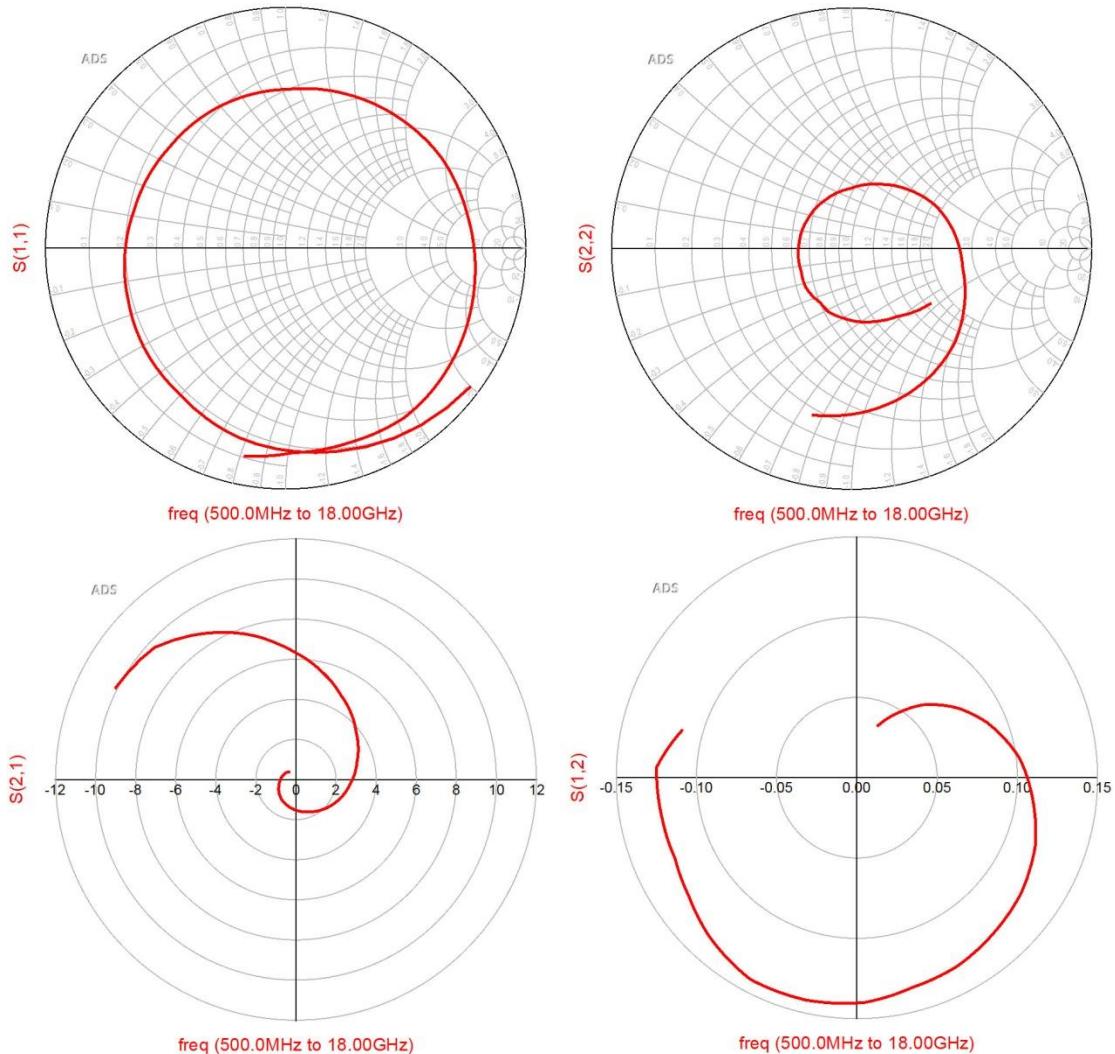
```
2.0 0.75 -126 6.306 90 0.088 23 0.26 -120
2.5 0.72 -145 5.438 75 0.095 15 0.25 -140
3.0 0.69 -162 4.762 62 0.102 7 0.23 -156
4.0 0.65 166 3.806 38 0.111 -8 0.22 174
5.0 0.64 139 3.165 16 0.119 -21 0.22 146
6.0 0.65 114 2.706 -5 0.125 -35 0.23 118
7.0 0.66 89 2.326 -27 0.129 -49 0.25 91
8.0 0.69 67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

# Example

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



# Calcul + identificare zone

- Parametri S
    - $S_{11} = -0.483 + 0.42 \cdot j$
    - $S_{12} = 0.111 - 0.043 \cdot j$
    - $S_{21} = 3.042 + 0.872 \cdot j$
    - $S_{22} = -0.182 + 0.123 \cdot j$
  - $|S_{22}| = 0.22 < 1$
  - $|C_L| < R_L \quad o \in CSOUT$
  - Centrul diagramei Smith este in interiorul cercului de stabilitate ( $o \in CSOUT$ ) si apartine zonei stabile
    - interior cerc – stabil
    - exterior cerc – instabil
- $$C_L = \frac{(S_{22} - \Delta \cdot S_{11}^*)}{|S_{22}|^2 - |\Delta|^2} = 3.931 - 0.897 \cdot j$$
- $$|C_L| = 4.032$$
- $$R_L = \frac{|S_{12} \cdot S_{21}|}{|S_{22}|^2 - |\Delta|^2} = 4.891$$

# Calcul + identificare zone

- Parametri S
  - $S_{11} = -0.483 + 0.42 \cdot j$
  - $S_{12} = 0.111 - 0.043 \cdot j$
  - $S_{21} = 3.042 + 0.872 \cdot j$
  - $S_{22} = -0.182 + 0.123 \cdot j$
- $|S_{11}| = 0.64 < 1$
- $|C_S| > R_S \quad o \notin CSIN$
- Centrul diagramei Smith este in exteriorul cercului de stabilitate ( $o \notin CSIN$ ) si apartine zonei stabile
  - exterior cerc – stabil
  - interior cerc – instabil

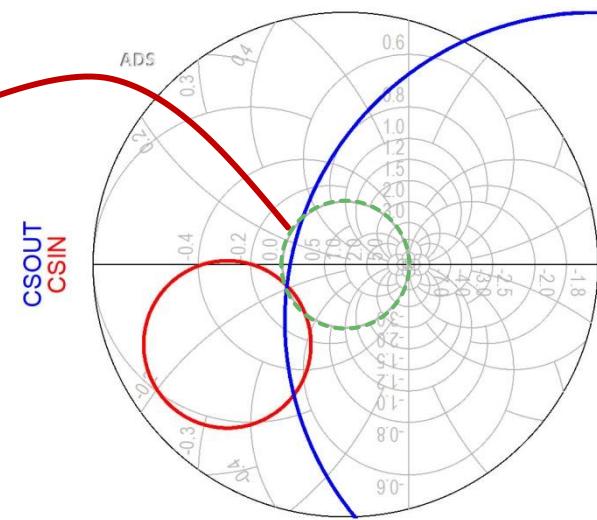
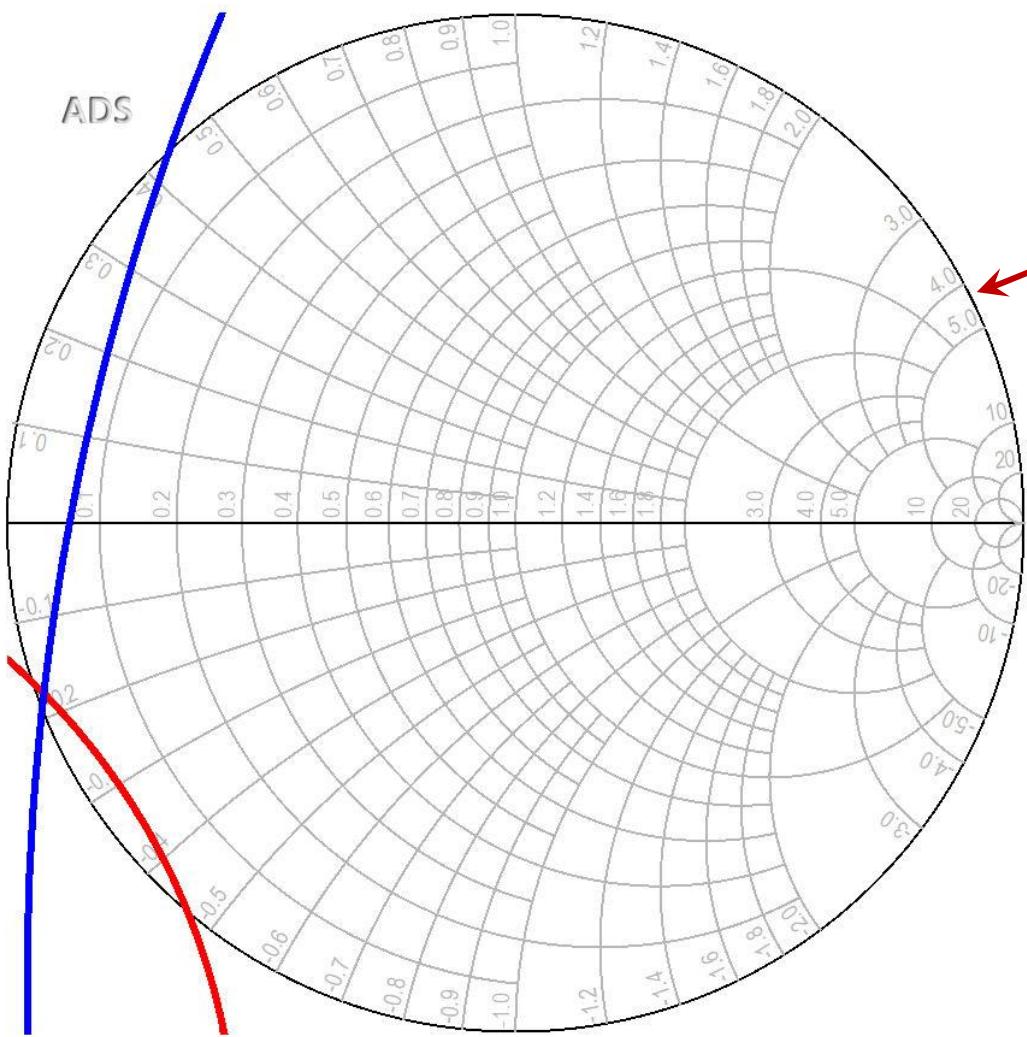
$$C_S = \frac{(S_{11} - \Delta \cdot S_{22}^*)}{|S_{11}|^2 - |\Delta|^2} = -1.871 - 1.265 \cdot j$$

$$|C_S| = 2.259$$

$$R_S = \frac{|S_{12} \cdot S_{21}|}{|S_{11}|^2 - |\Delta|^2} = 1.325$$

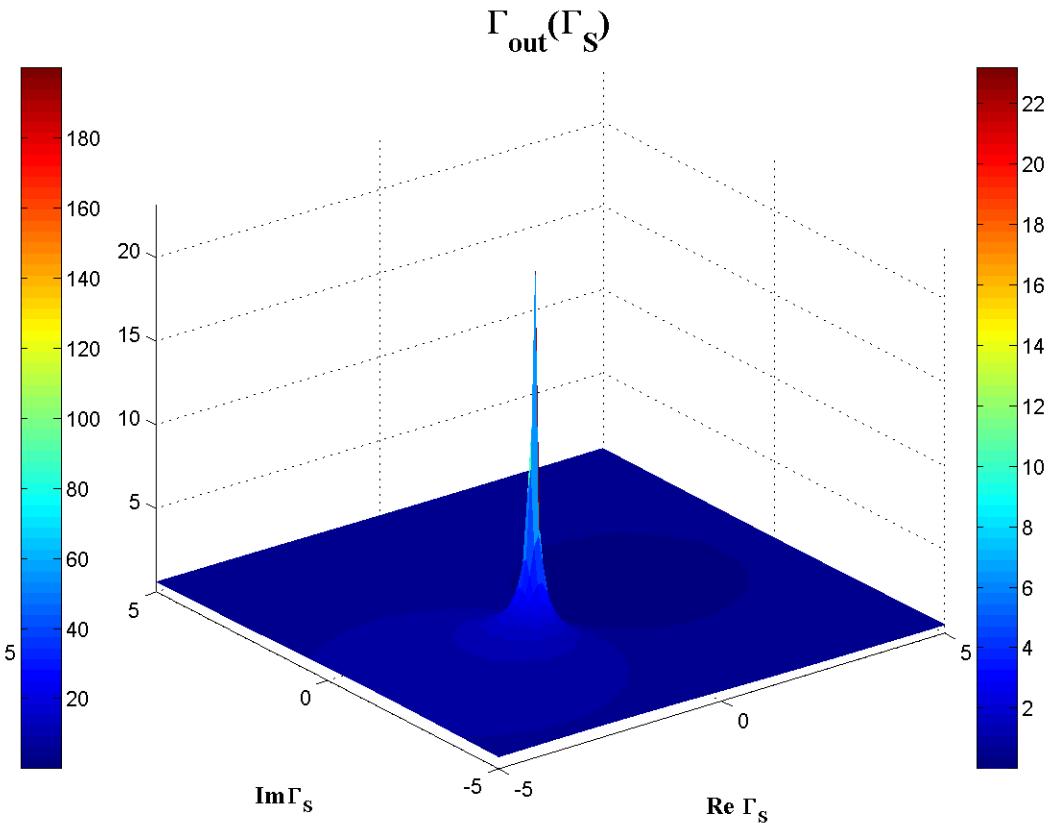
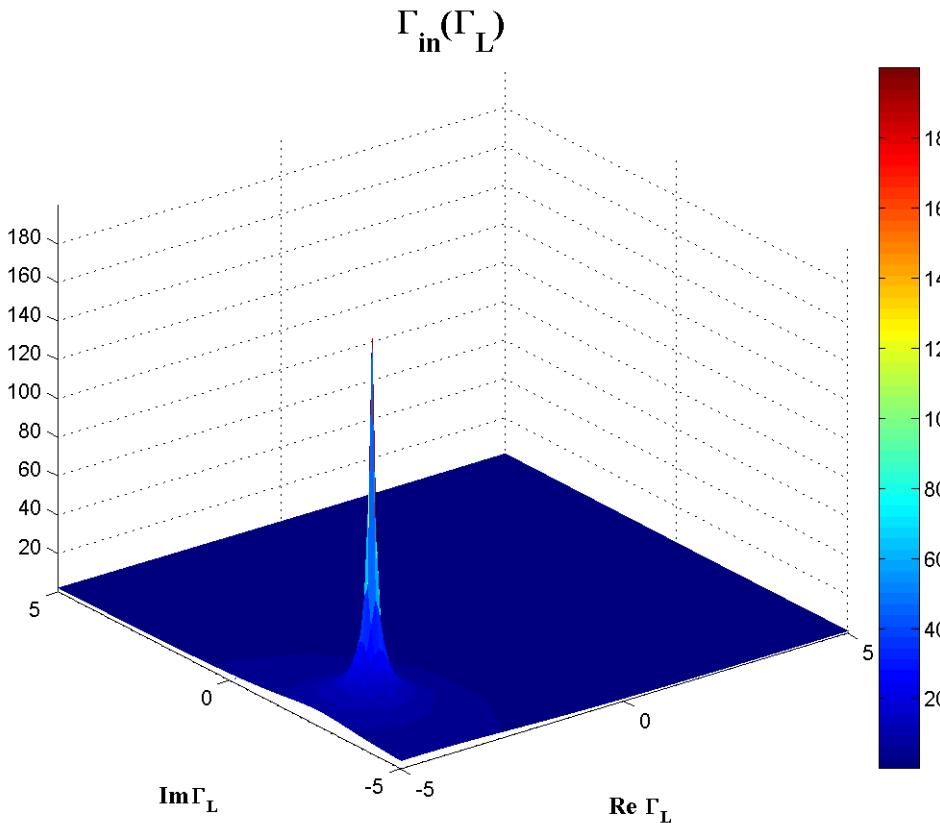
# ADS

CSOUT  
CSIN



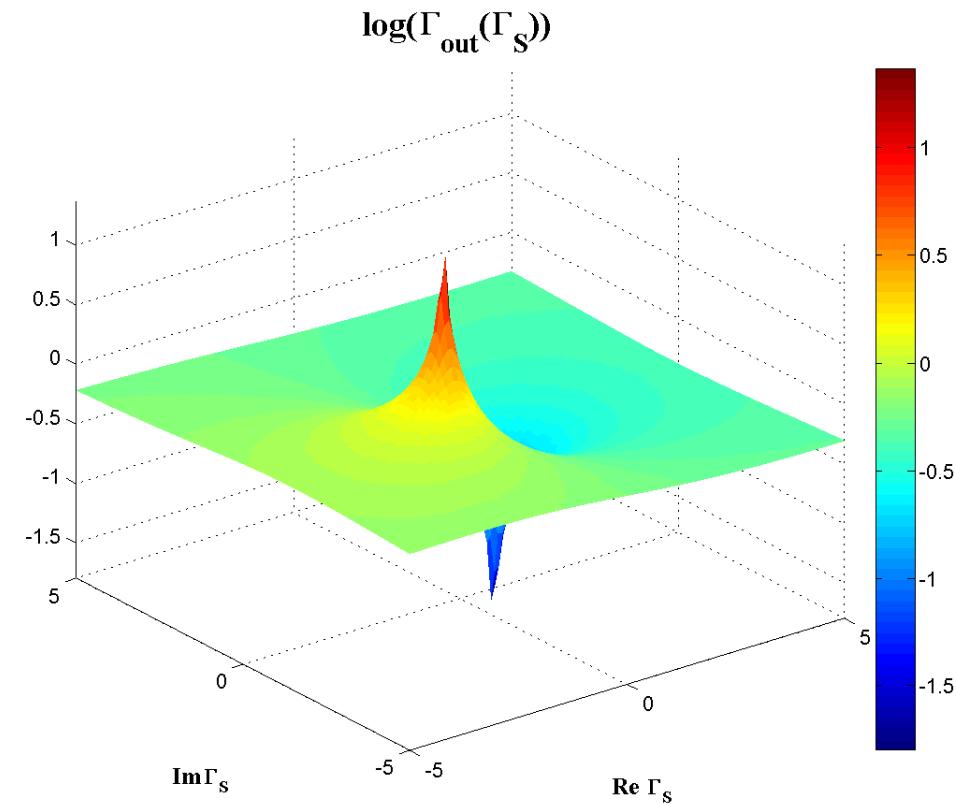
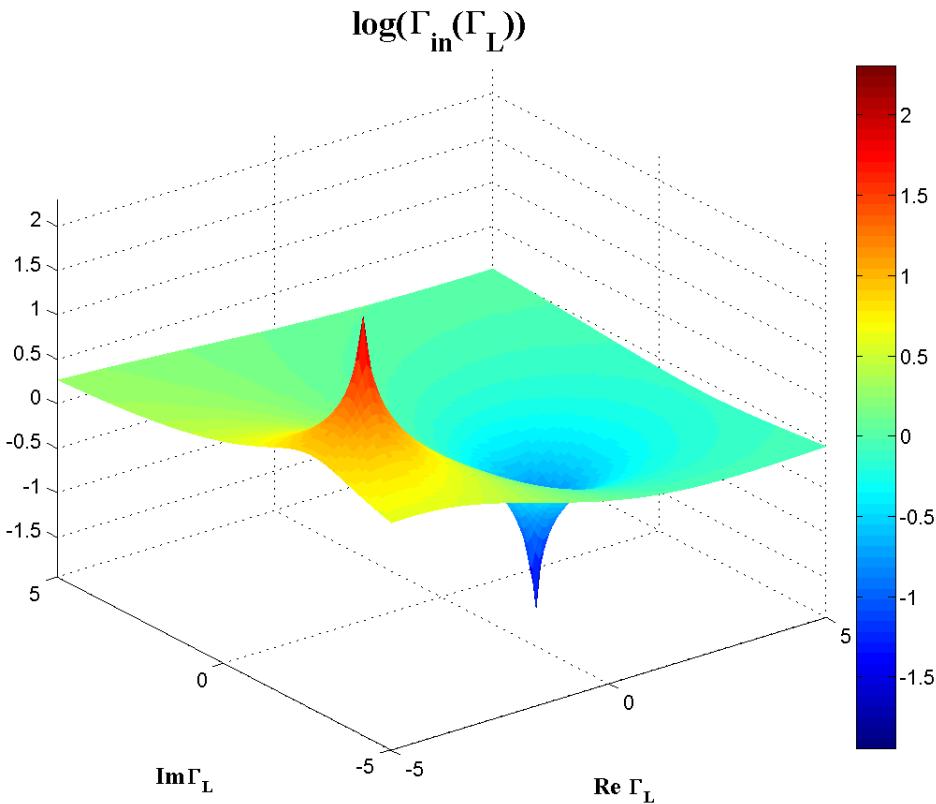
# Reprezentare 3D $|\Gamma_{\text{in}}|, |\Gamma_{\text{out}}|$

- Variatii foarte mari  $\rightarrow$  logaritmic



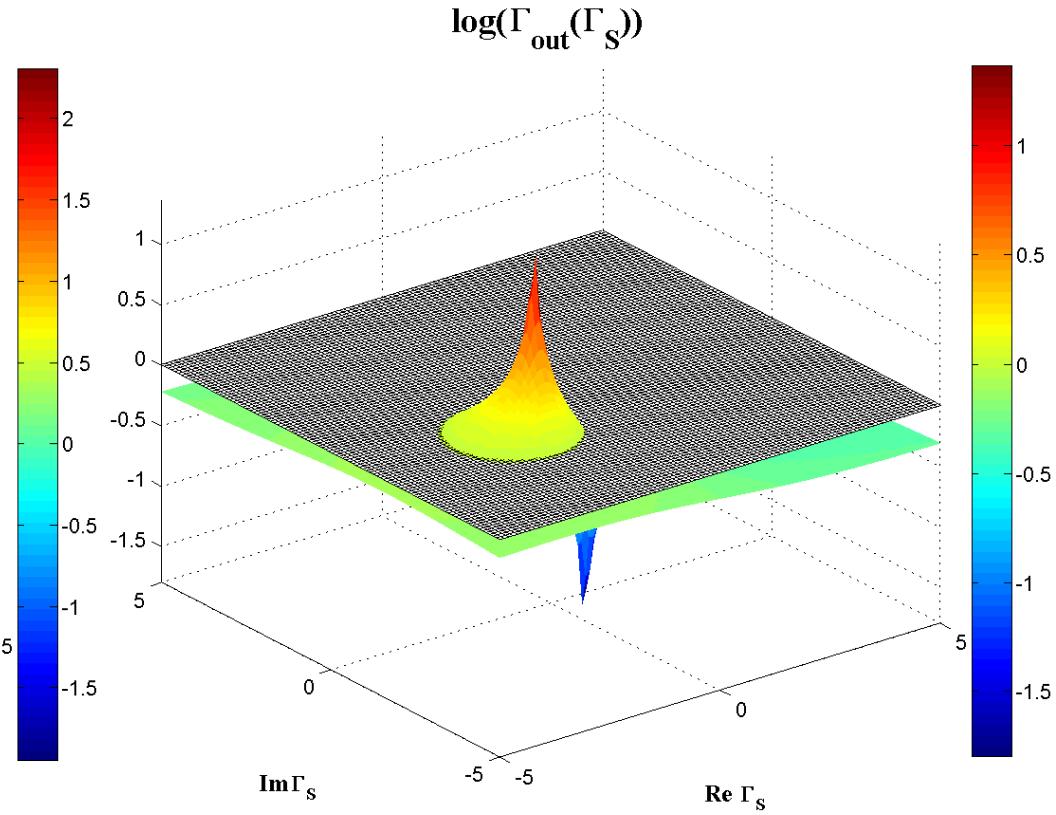
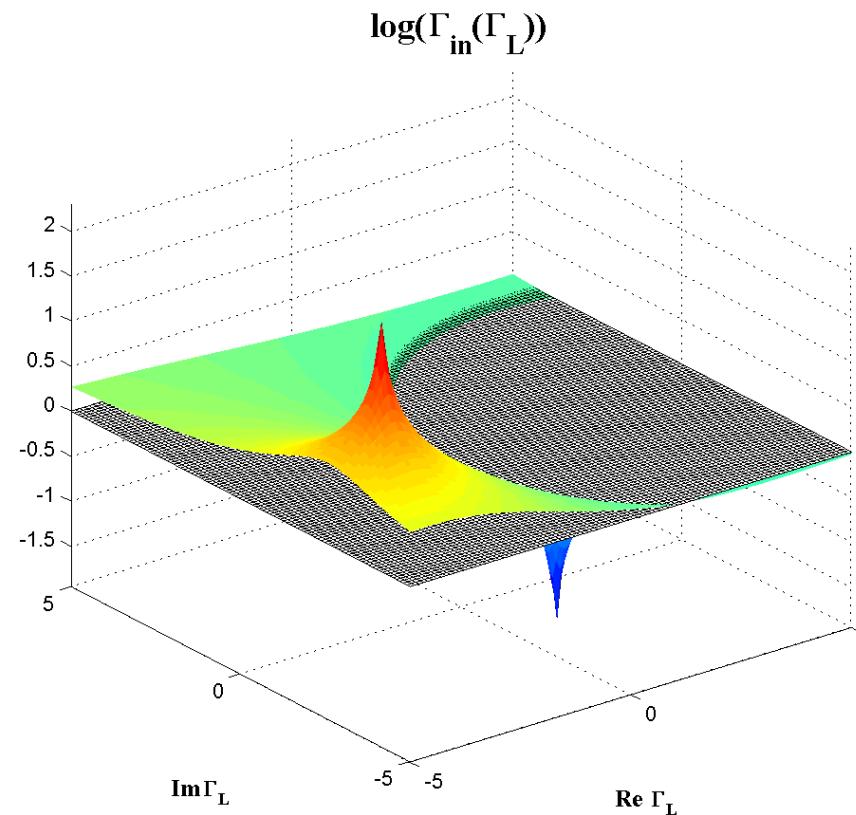
# Reprezentare 3D $|\Gamma_{\text{in}}|, |\Gamma_{\text{out}}|$

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

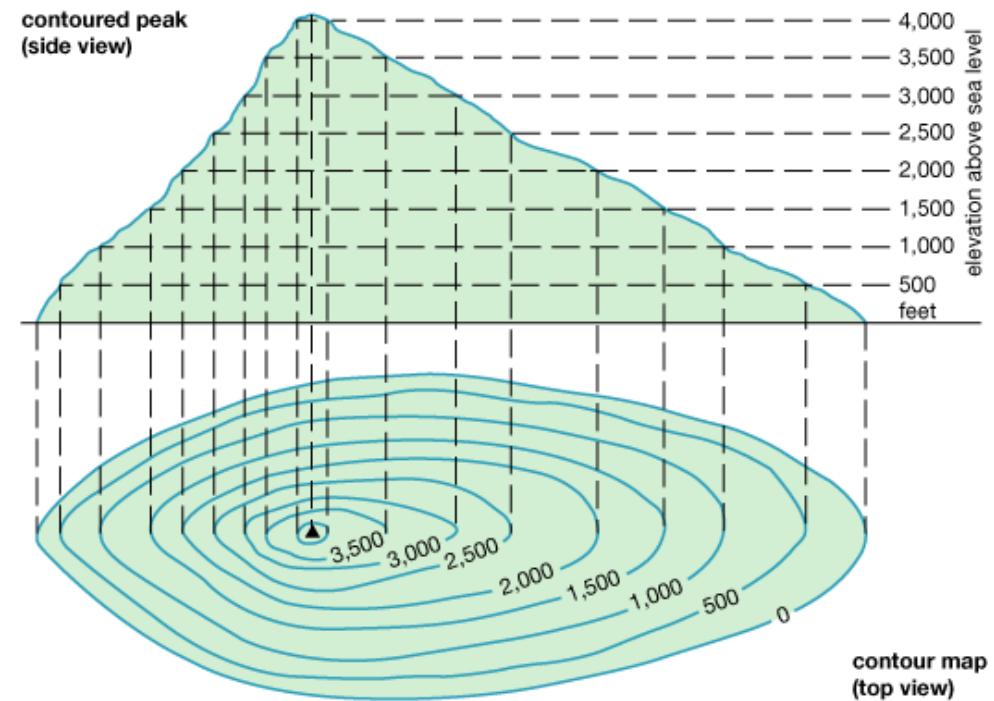


# Reprezentare 3D $|\Gamma_{\text{in}}|, |\Gamma_{\text{out}}|, |\Gamma|=1$

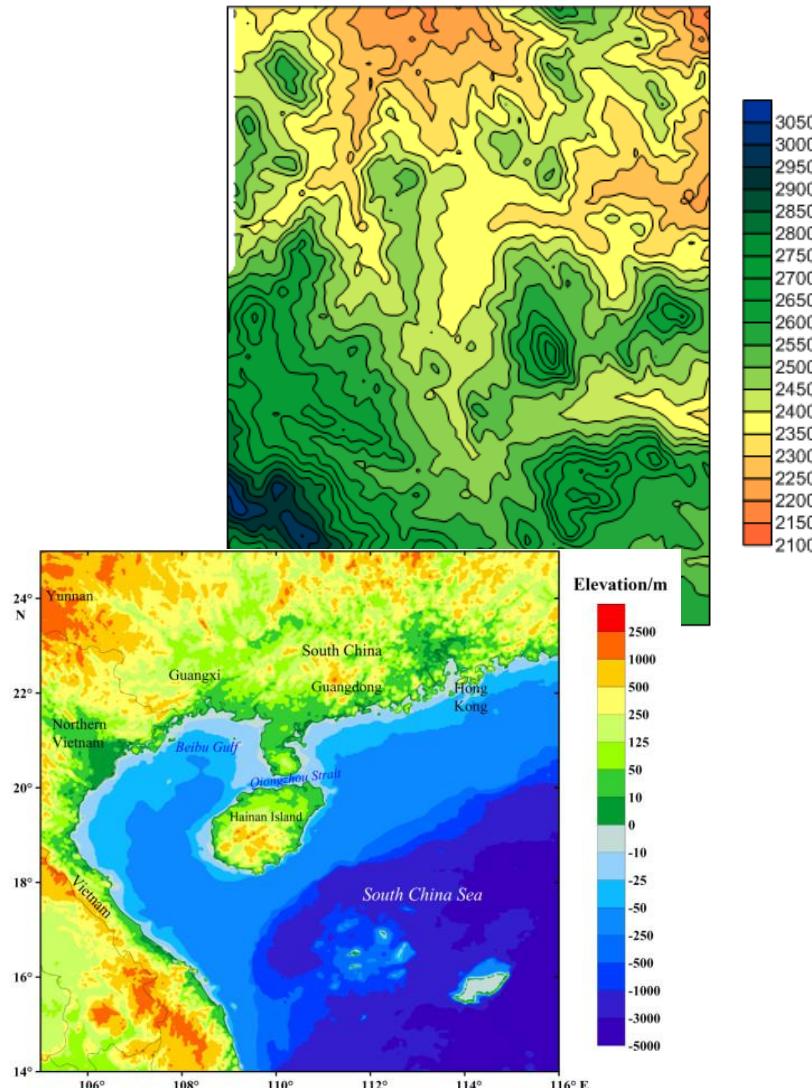
- $|\Gamma| = 1 \rightarrow \log_{10}|\Gamma| = 0$ , intersectia = cerc



# Contour map/lines

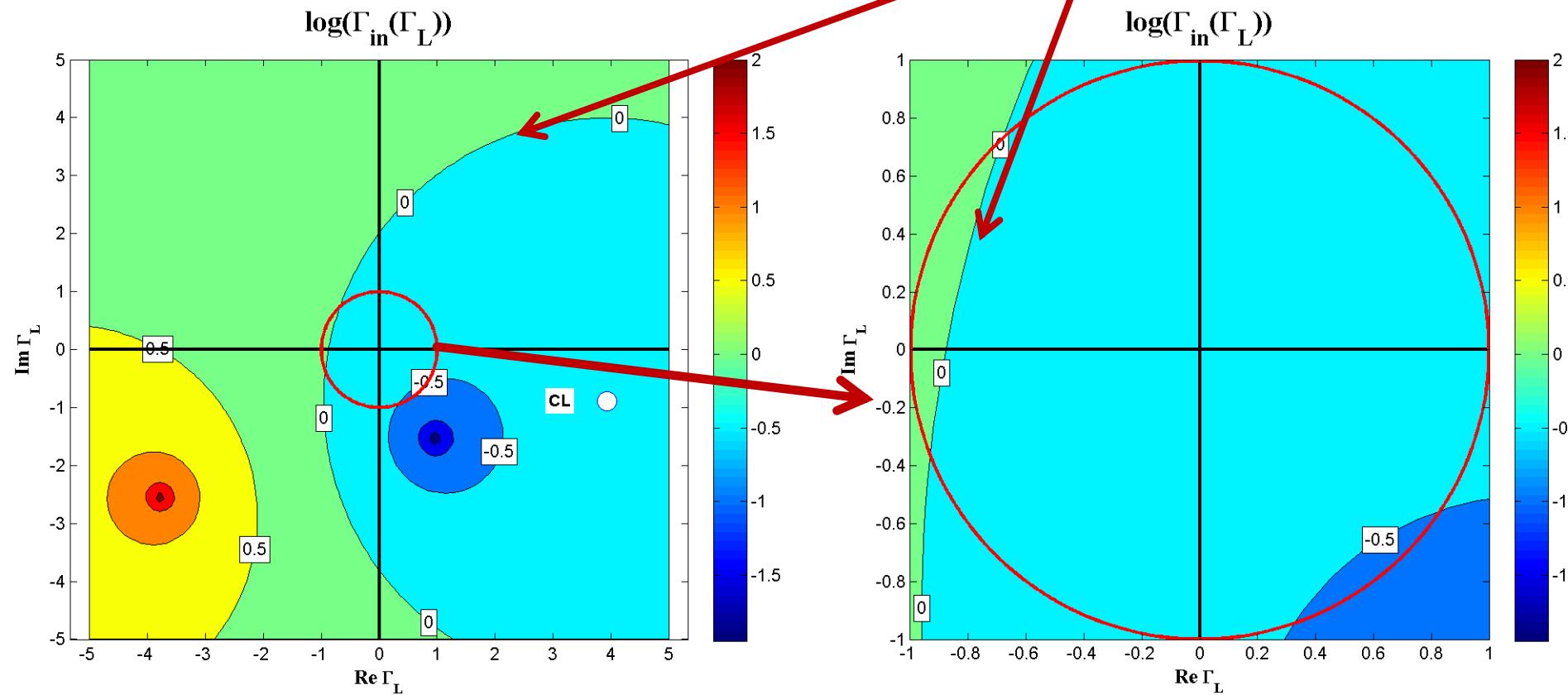


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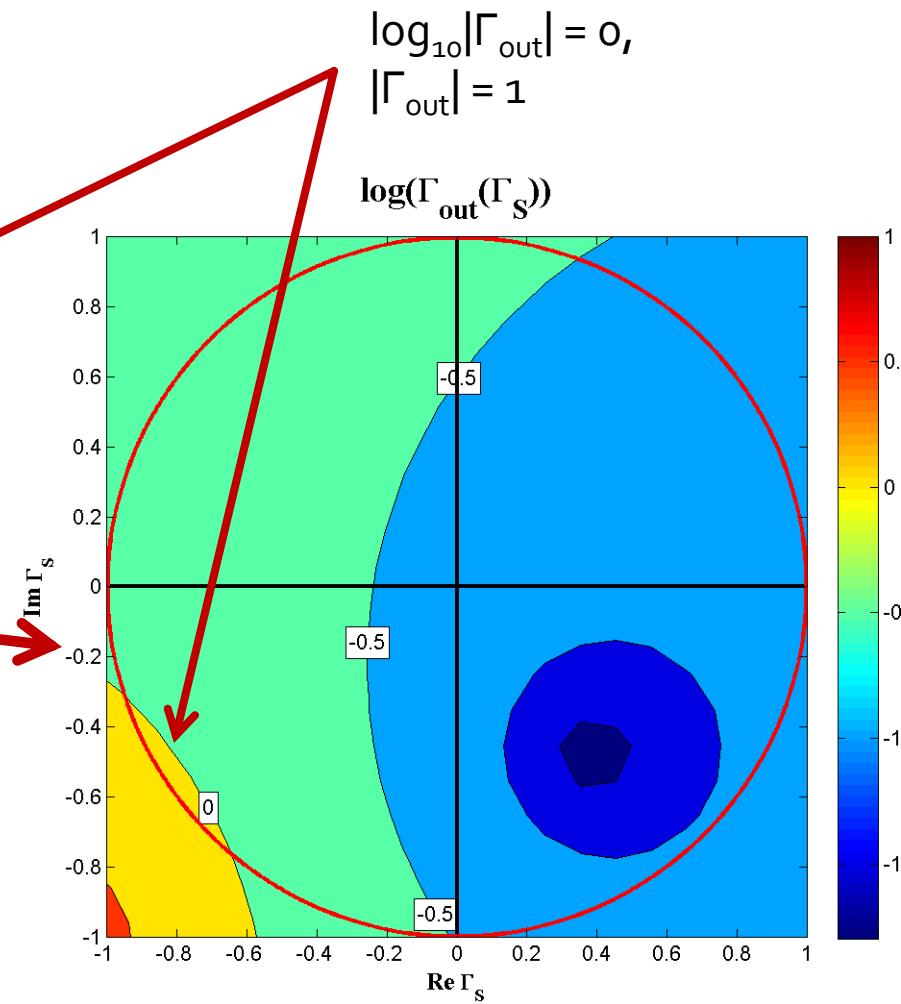
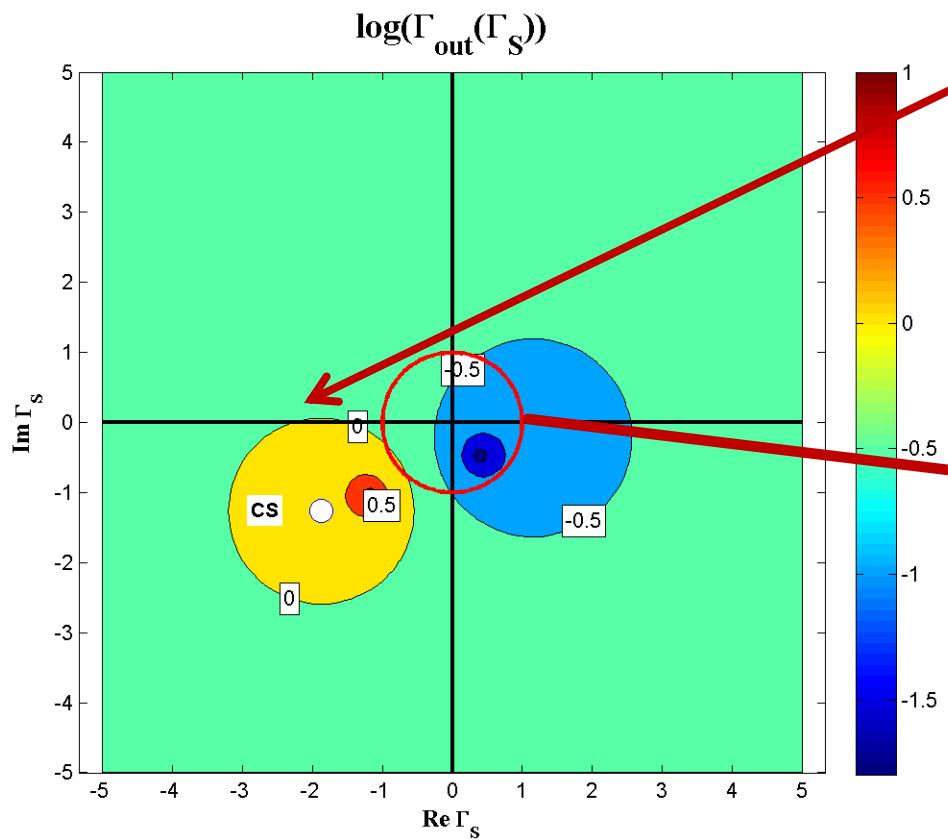
# Reprezentare 3D $|\Gamma_{\text{in}}|, |\Gamma_{\text{out}}|$

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



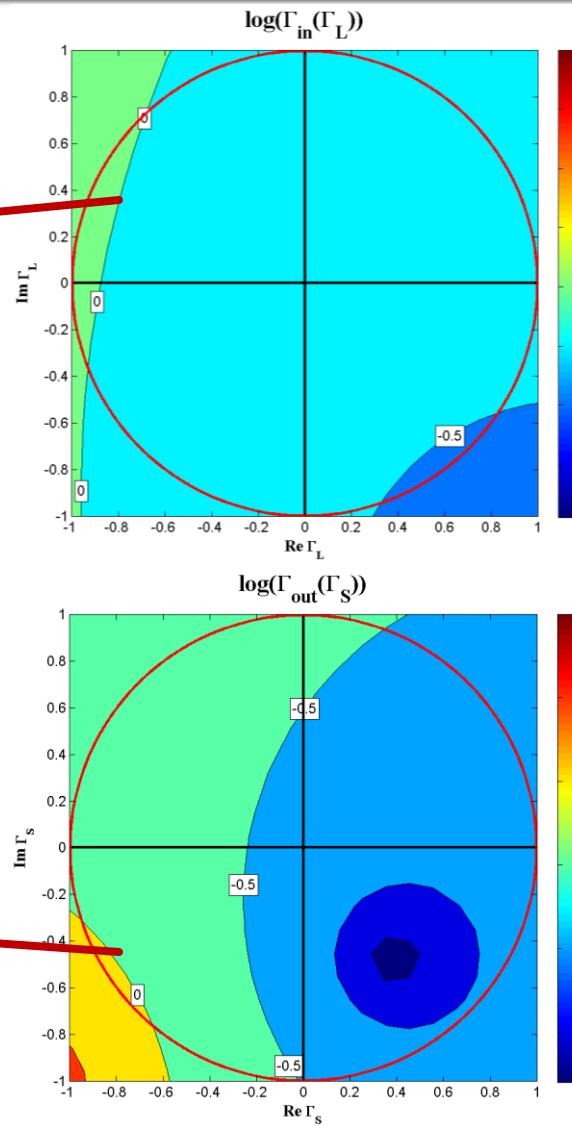
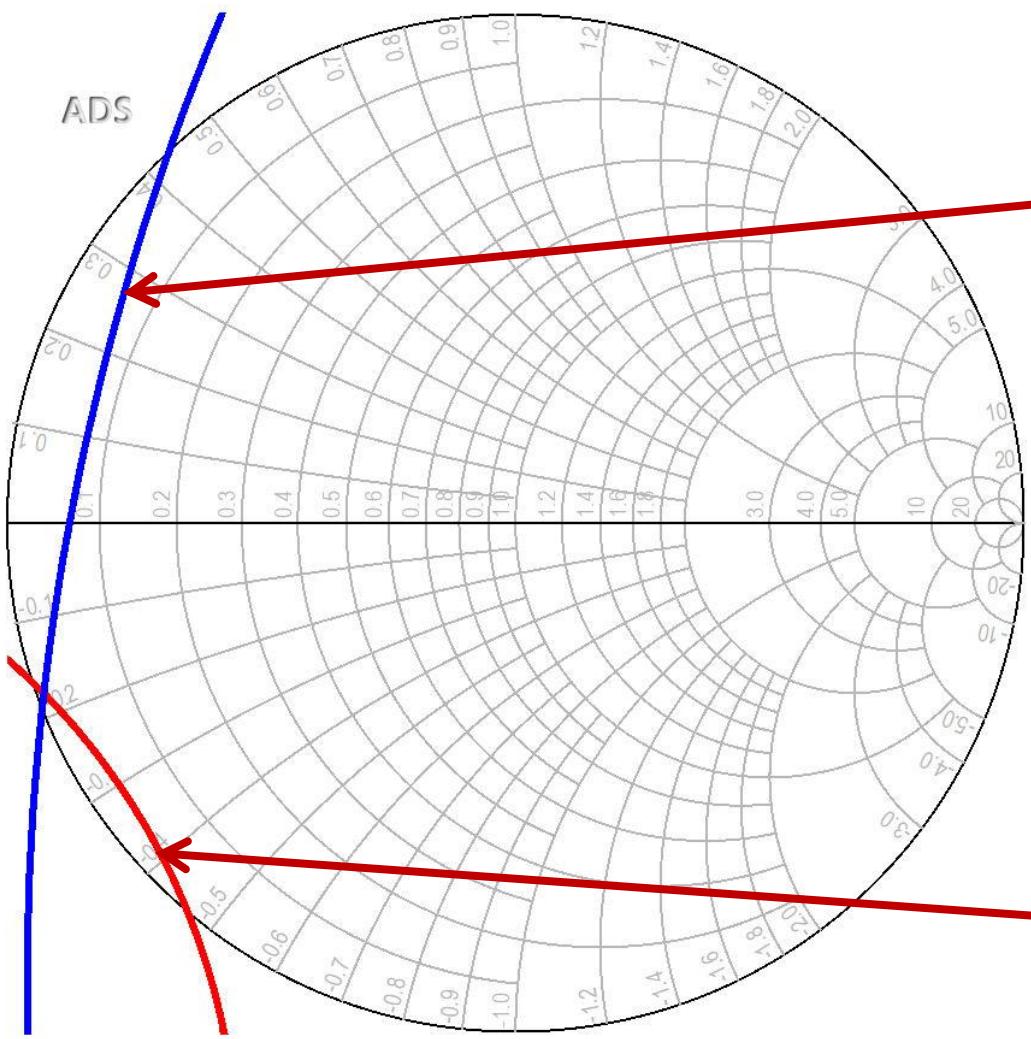
# Reprezentare 3D $|\Gamma_{\text{in}}|, |\Gamma_{\text{out}}|$

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

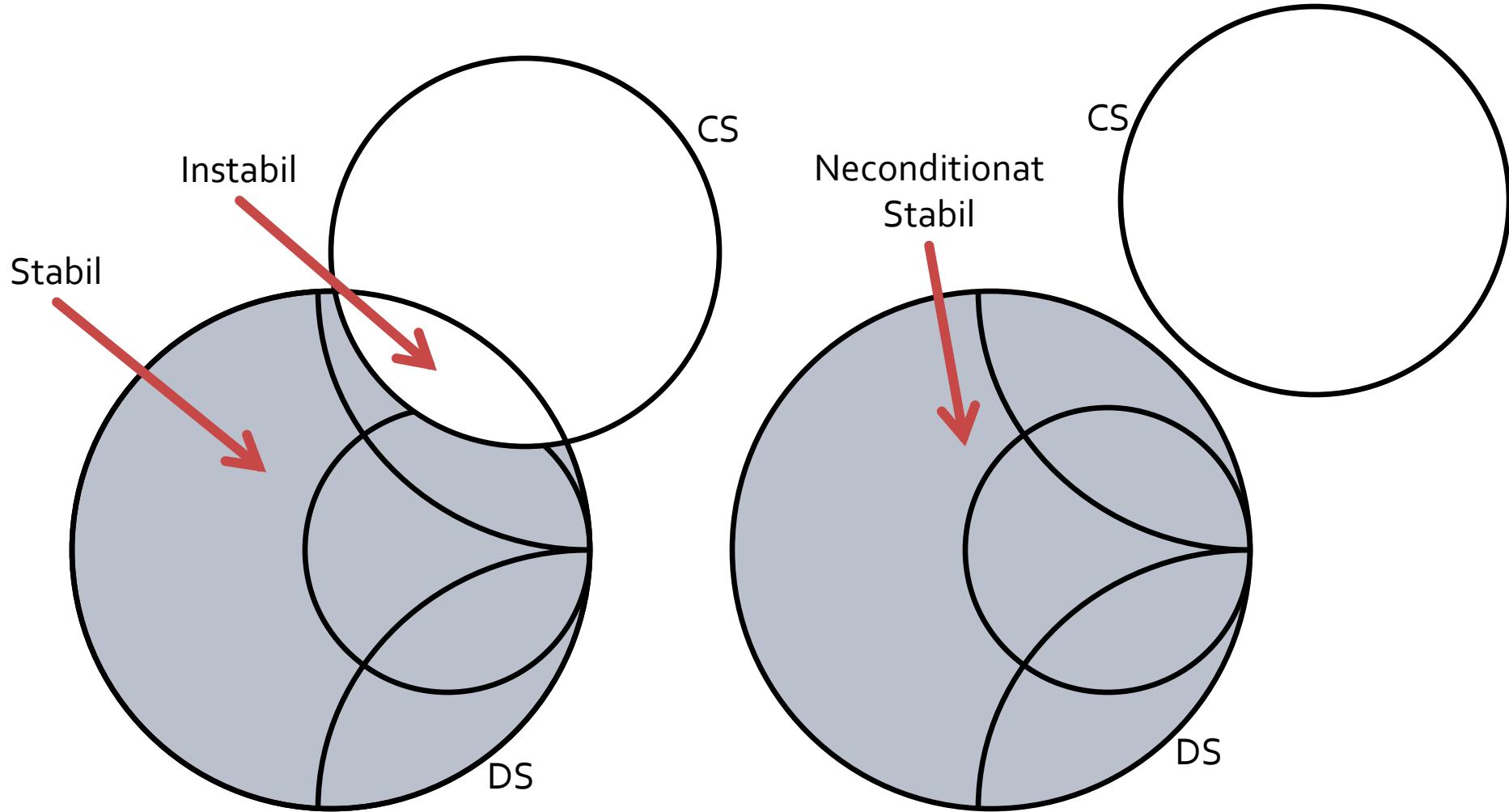


# CSIN, CSOUT

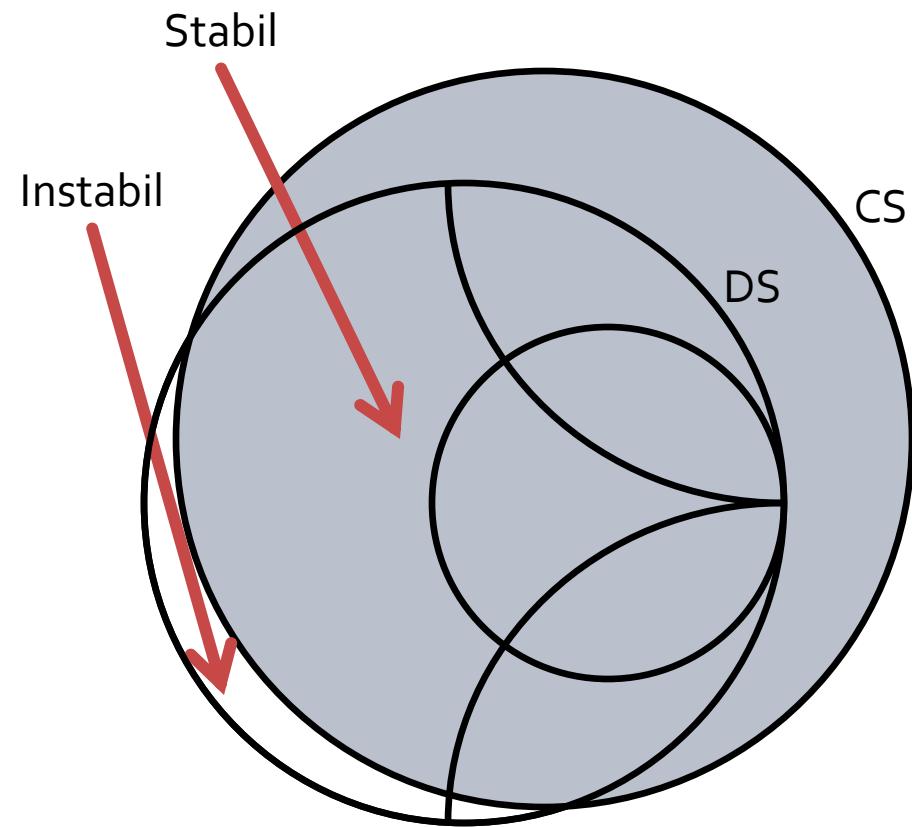
CSOUT  
CSIN



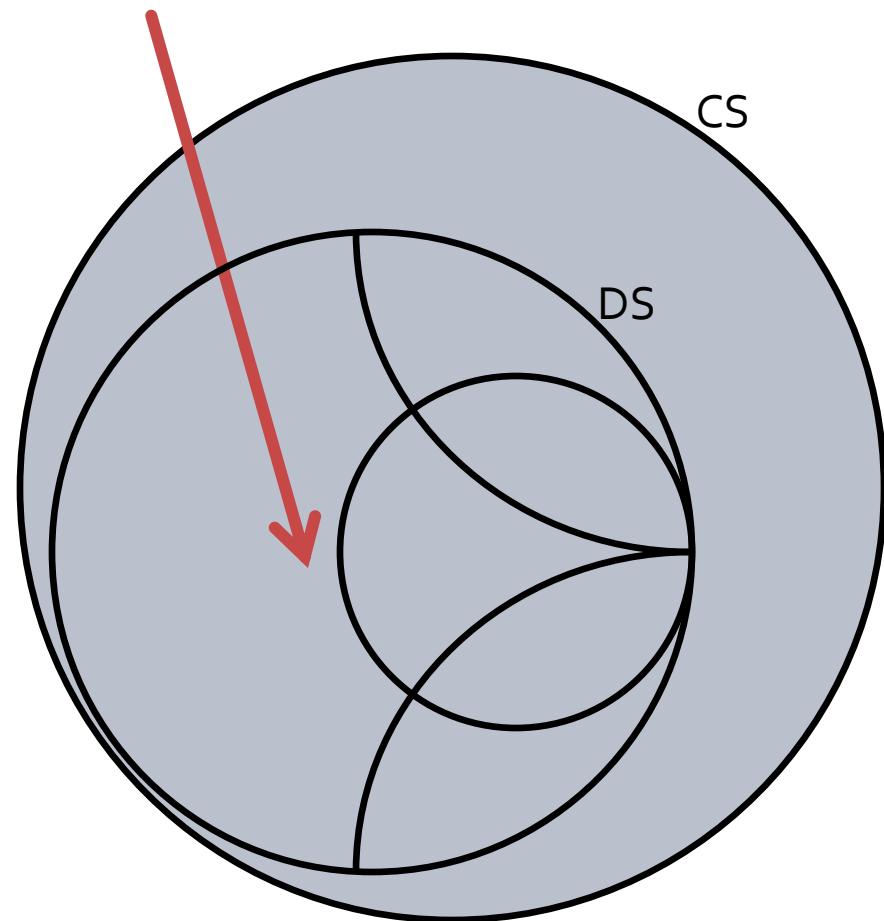
# Mai multe pozitionari posibile



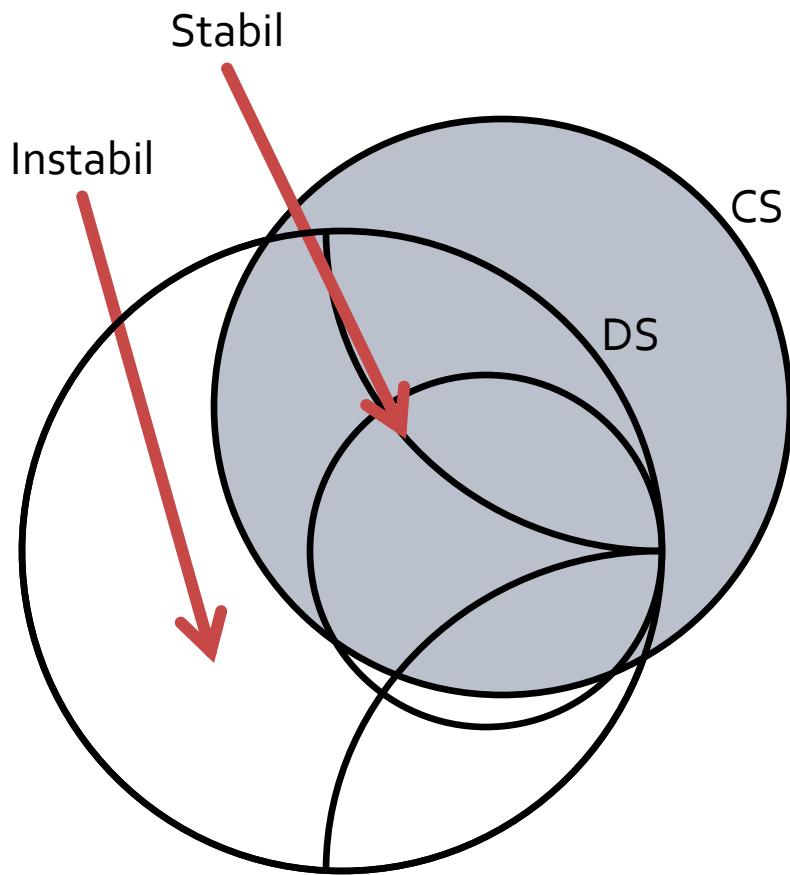
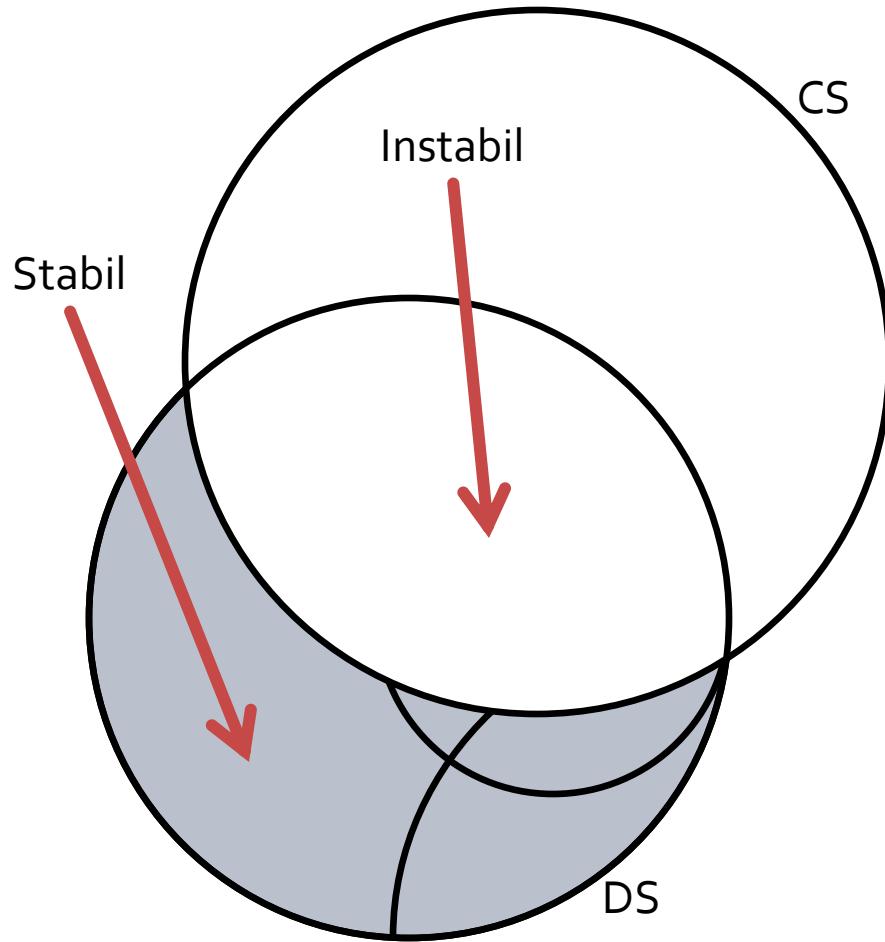
# Mai multe pozitionari posibile



Neconditionat  
Stabil



# Pozitionari mai rare



# Stabilitate

- **Stabilitatea necondiționată:** circuitul este necondiționat stabil dacă  $|\Gamma_{in}| < 1$  și  $|\Gamma_{out}| < 1$  pentru **orice** impedanță pasivă a sarcinii și sursei
- **Stabilitatea condiționată:** circuitul este condiționat stabil dacă  $|\Gamma_{in}| < 1$  și  $|\Gamma_{out}| < 1$  doar pentru un anumit interval de valori pentru impedanța pasivă a sarcinii și sursei

# Stabilitate neconditionata

- Stabilitatea neconditionata se obtine daca:
  - Cercul de stabilitate este disjunct cu diagrama Smith (exterior) si zona stabila e exteriorul cercului
  - Cercul de stabilitate contine in intregime diagrama Smith si zona stabila e interiorul cercului
- O conditie obligatorie pentru obtinerea stabilitatii neconditionate este  $|S_{11}| < 1$  (CSOUT) sau  $|S_{22}| < 1$  (CSIN)
- Matematic:

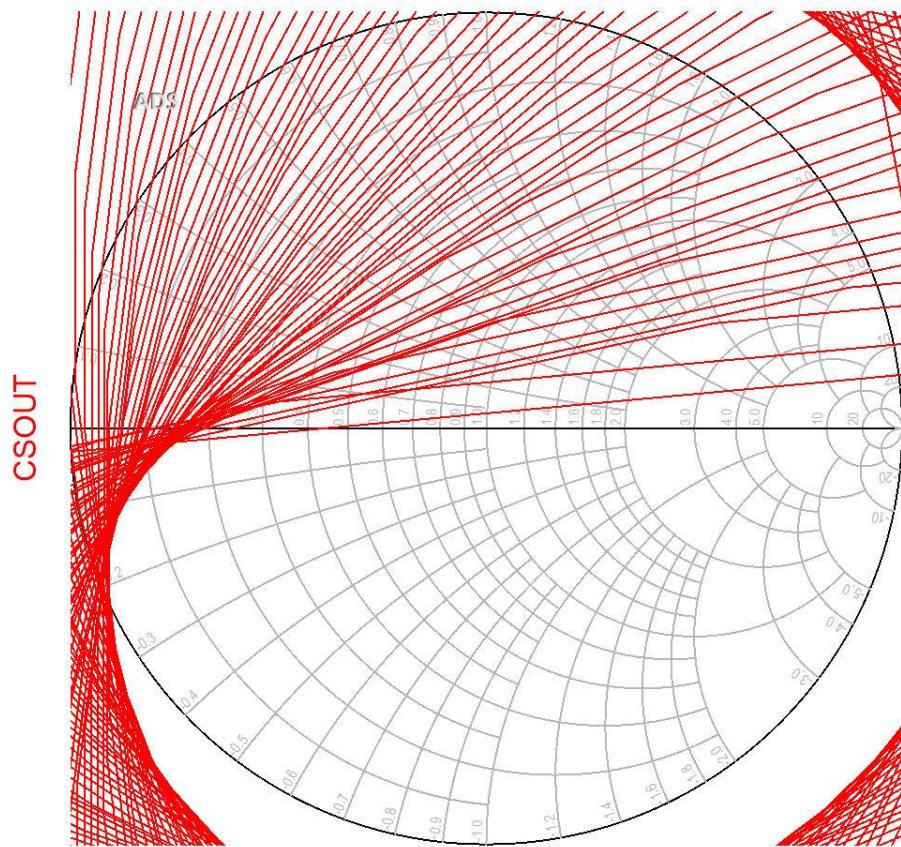
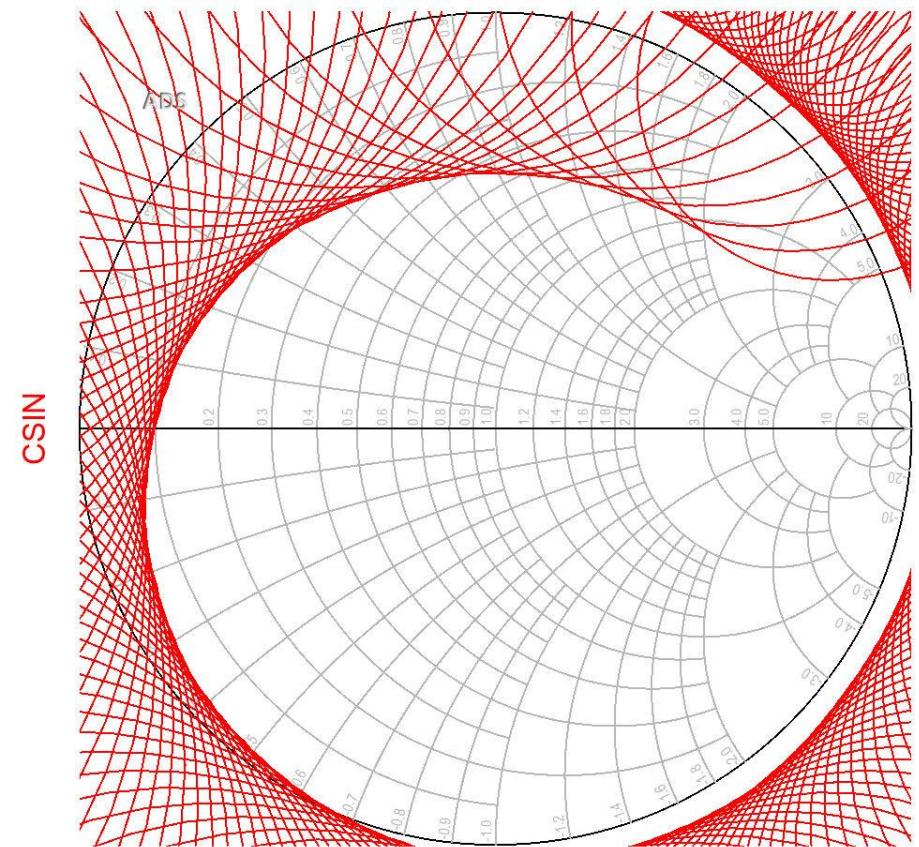
$$\begin{cases} |C_L - R_L| > 1 \\ |S_{11}| < 1 \end{cases}$$

$$\begin{cases} |C_S - R_S| > 1 \\ |S_{22}| < 1 \end{cases}$$

# Conditii analitice de stabilitate neconditionata

- Utile pentru analiza de banda larga
- Stabilitatea nu e suficient sa fie apreciata doar la frecventele de lucru
  - e necesar sa avem stabilitate pentru  $\Gamma_L$  si  $\Gamma_S$  alese la **orice** frecventa

# Cercuri in banda larga



# 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 $\mu$

- Conditia Rollet depinde de doi parametri,  $K$  si  $\Delta$ , 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  $\mu$  creste se obtine stabilitate mai buna
  - $\mu$  este distanta de la centrul diagramei Smith la cercul de stabilitate la iesire

# Criteriul $\mu'$

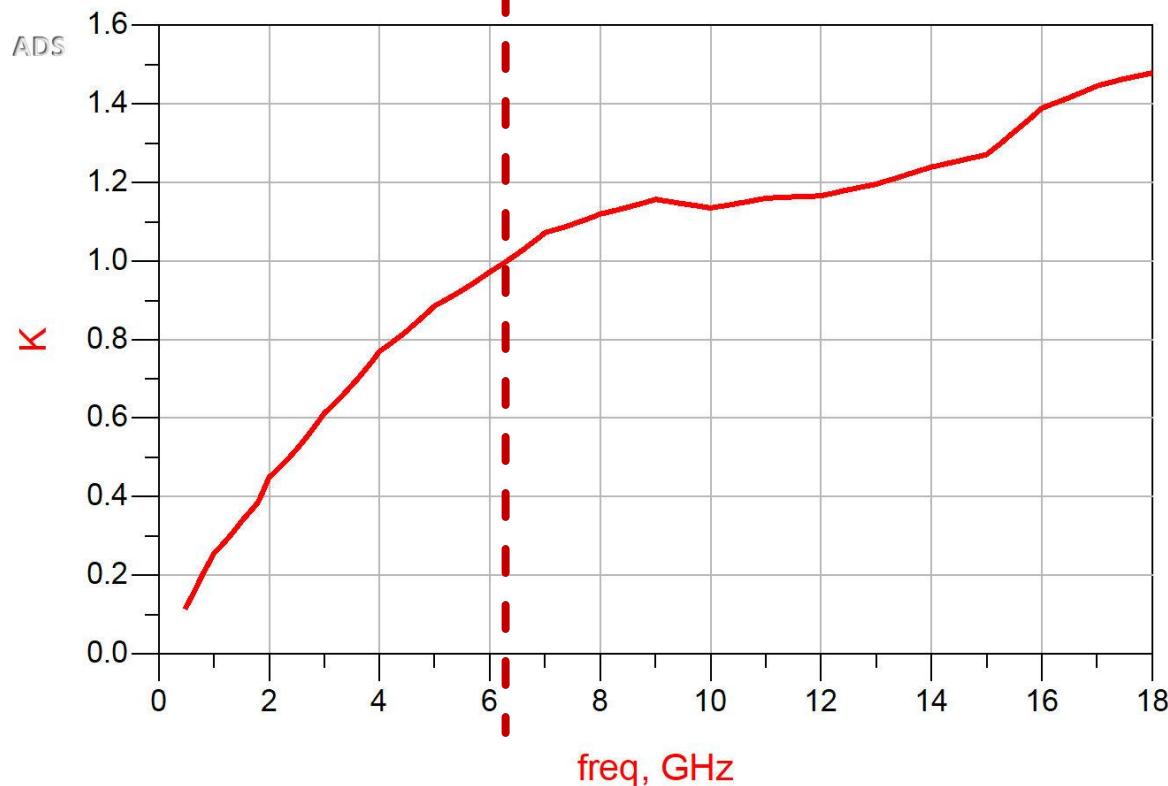
- Parametru dual pentru  $\mu$ , determinat relativ la cercul de stabilitate la intrare

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

- 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  $\mu'$  creste se obtine stabilitate mai buna
  - $\mu'$  este distanta de la centrul diagramei Smith la cercul de stabilitate la intrare

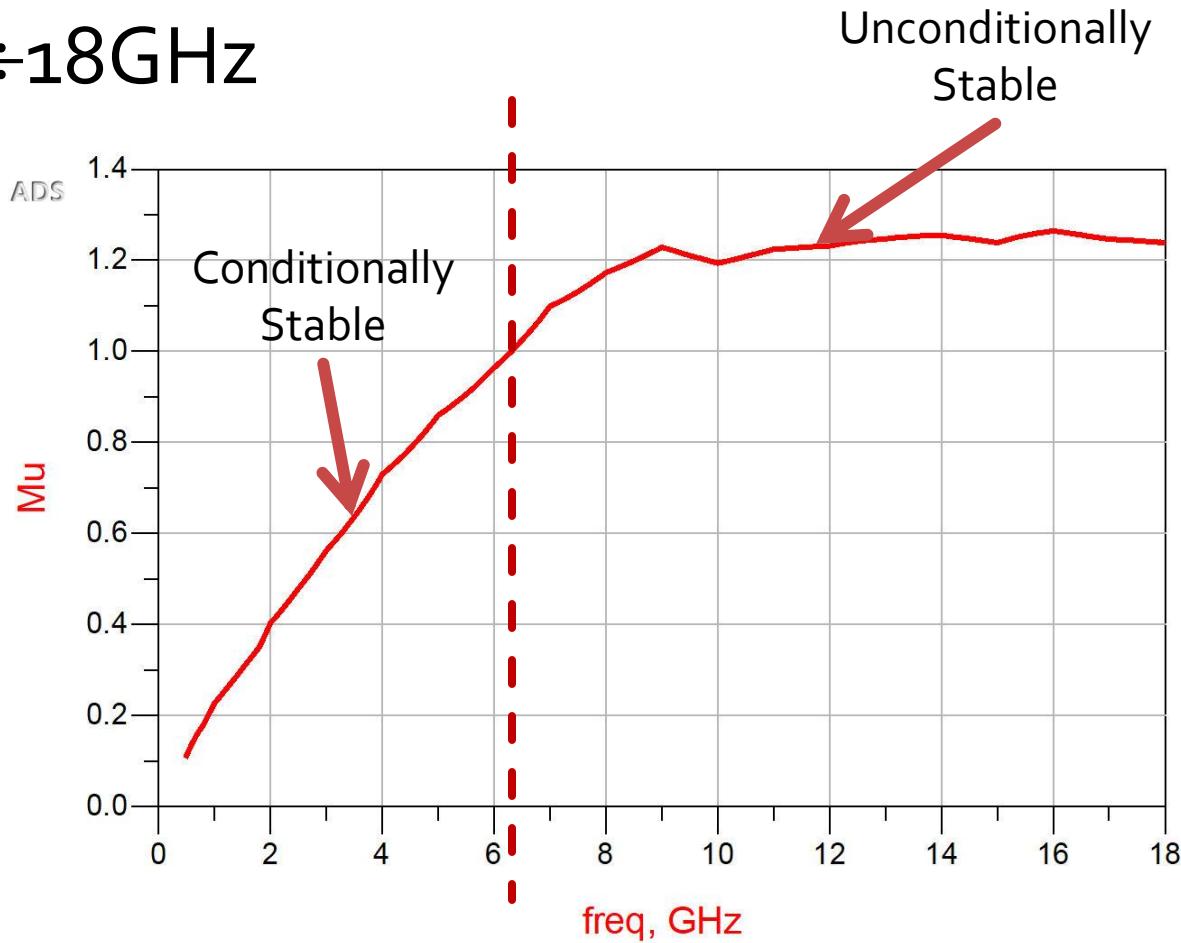
# Conditia Rollet

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



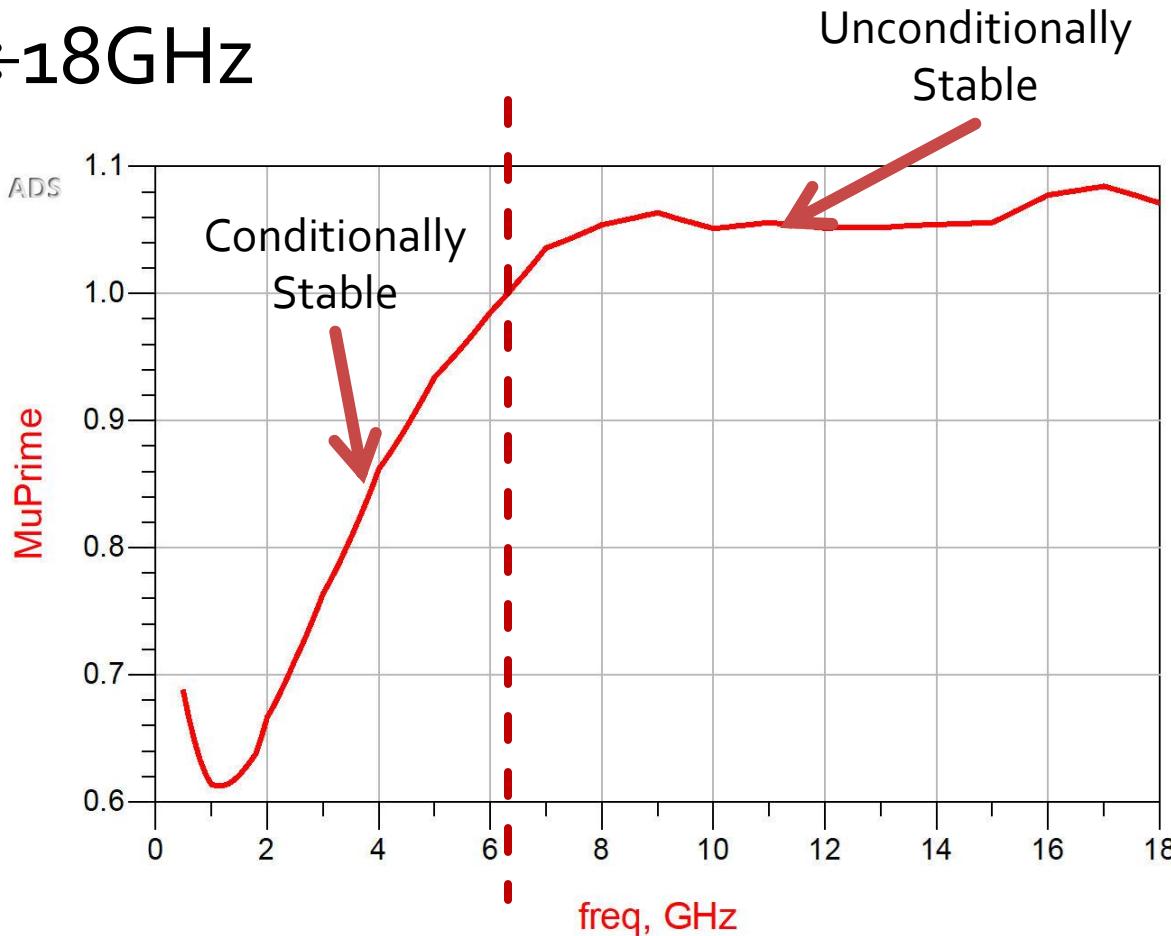
# Criteriul $\mu$

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



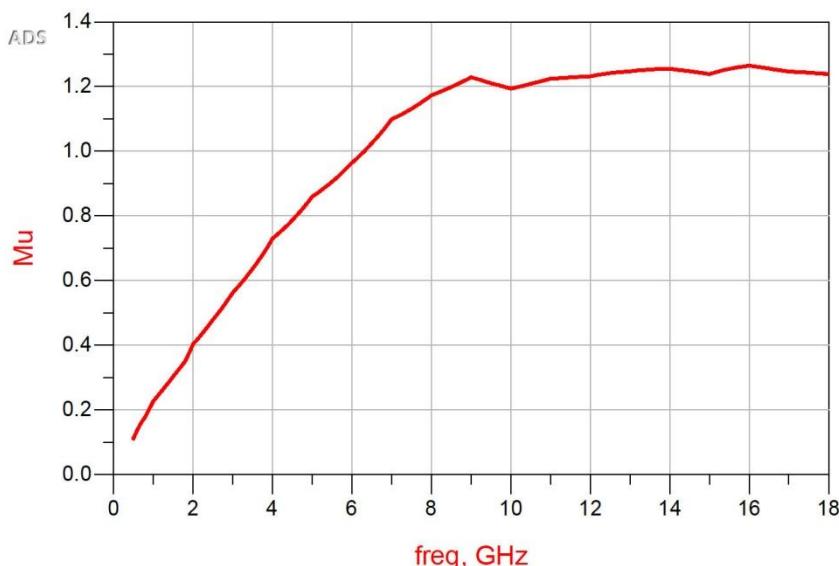
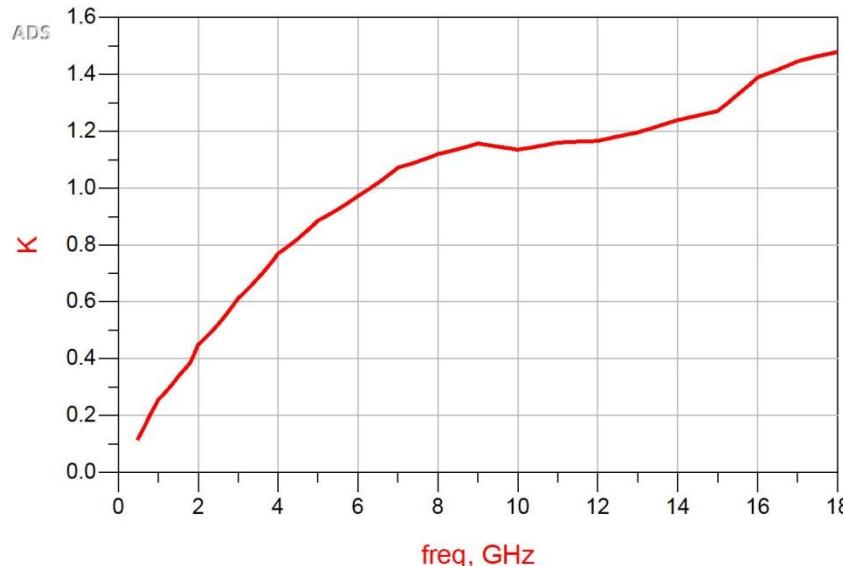
# Criteriul $\mu'$

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



# Stabilitate

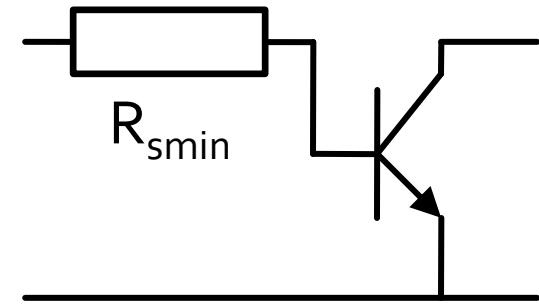
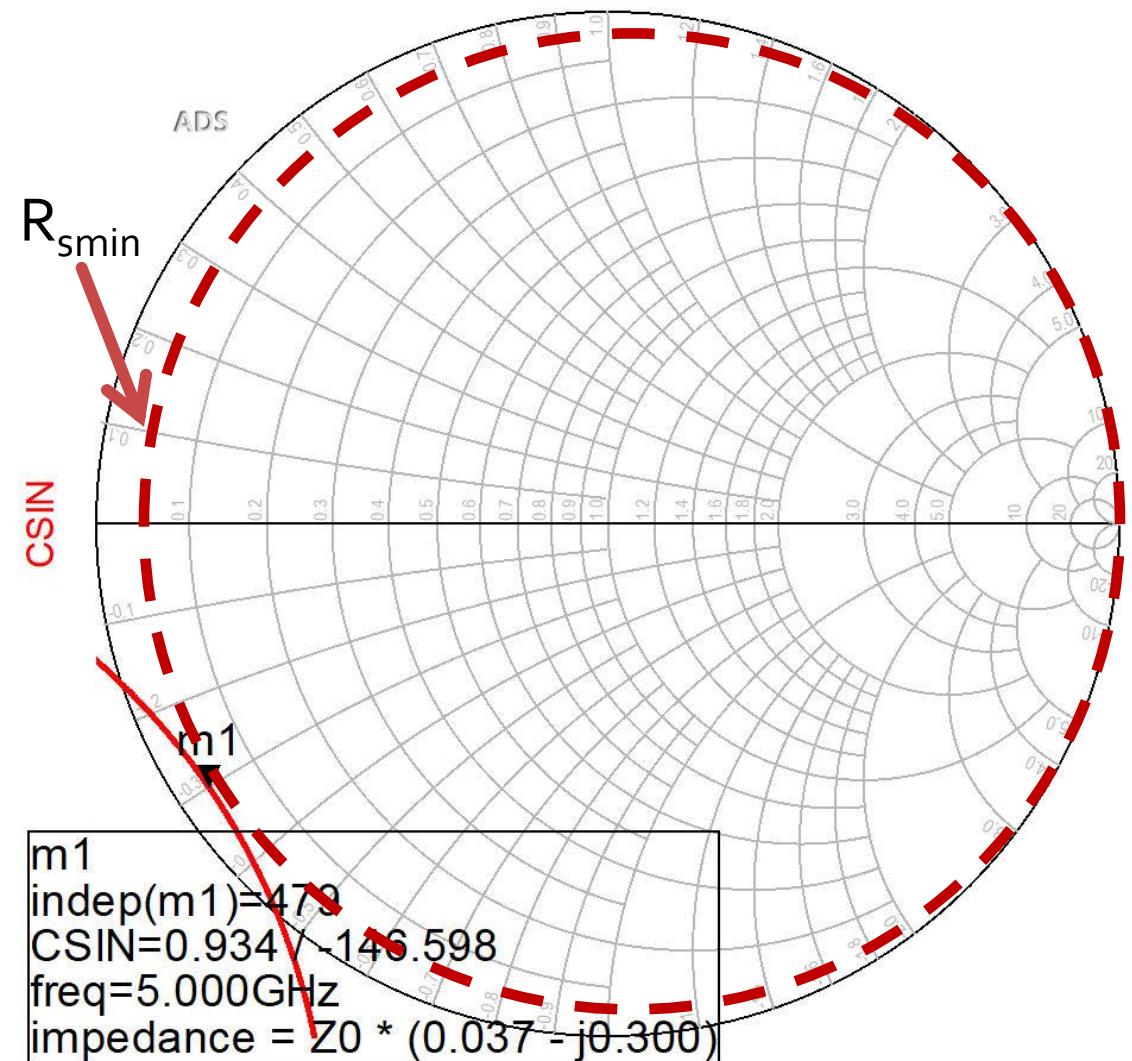
- ATF-34143 at  $V_{ds}=3V$   $I_d=20mA$ .
- @ $0.5 \div 18GHz$
- Neconditionat stabil pentru  $f > 6.31GHz$



# Stabilizarea unui dipozit

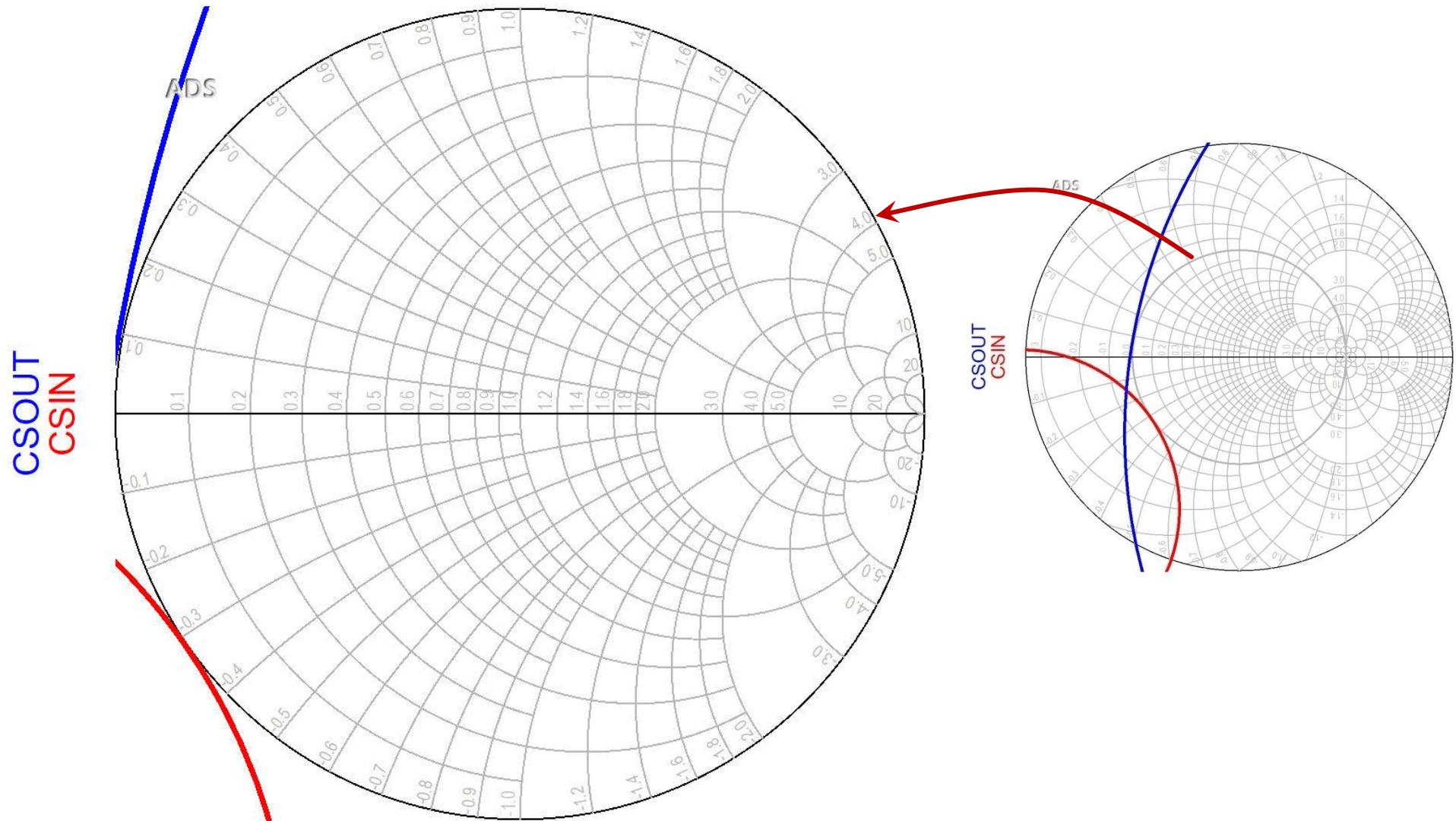
- Stabilitatea neconditionata pentru un interval larg de frecvente are avantaje importante
  - Ex: pot projecata cu ATF 34143 un amplificator stabil (conditionat) la 5GHz, dar acest lucru este inutil daca apar oscilatii la 500MHz ( $\mu \approx 0.1$ )
  - **Minimul necesar** in conditii de lucru cu stabilitate conditionata este **sa se verifice stabilitatea** la frecvente inafara benzii
- Stabilitatea neconditionata poate fi fortata prin introducerea de elemente rezistive in serie/paralel la intrare si/sau iesire

# Rezistenta serie la intrare



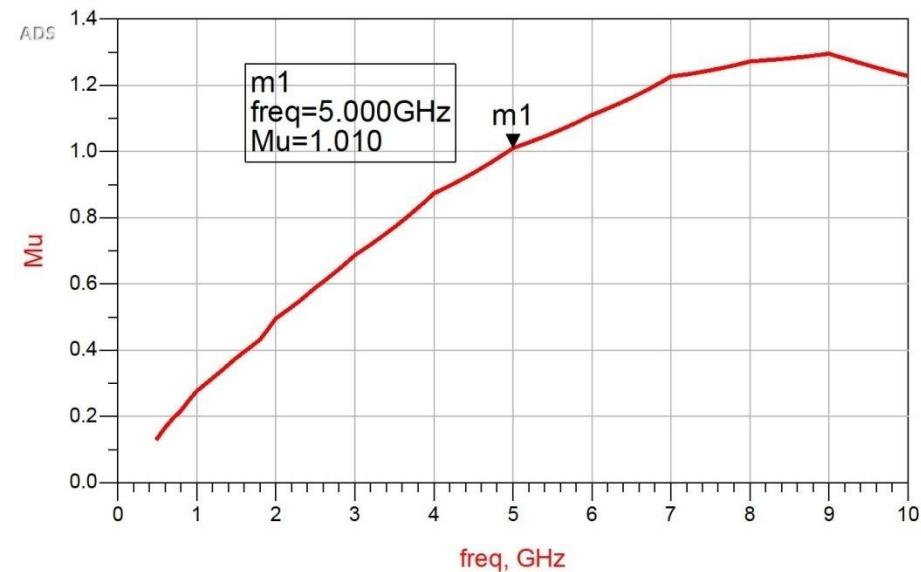
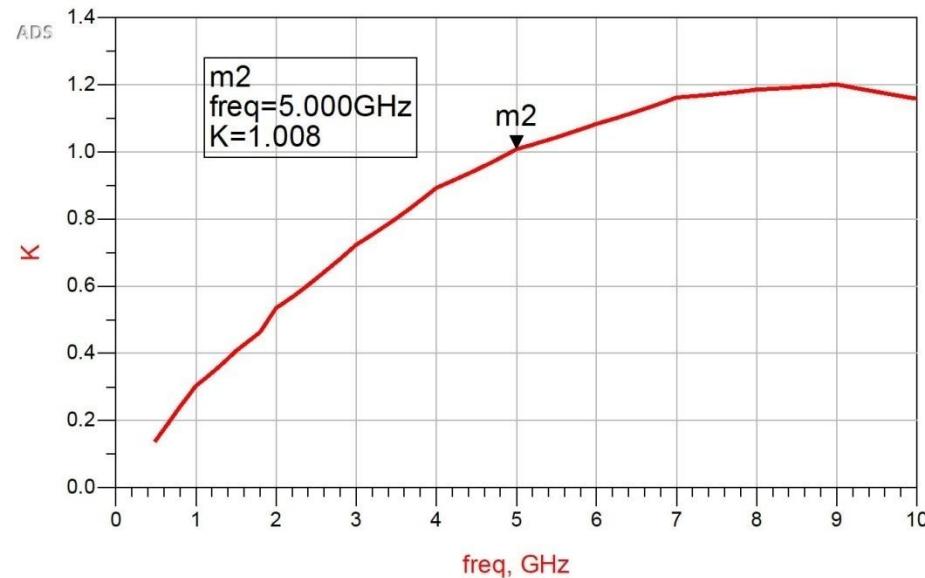
$$R_{smin} = 0.037 \cdot 50\Omega = 1.85\Omega$$

# ADS, $R_s = 2\Omega$

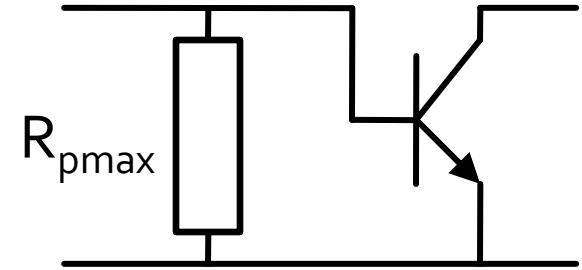
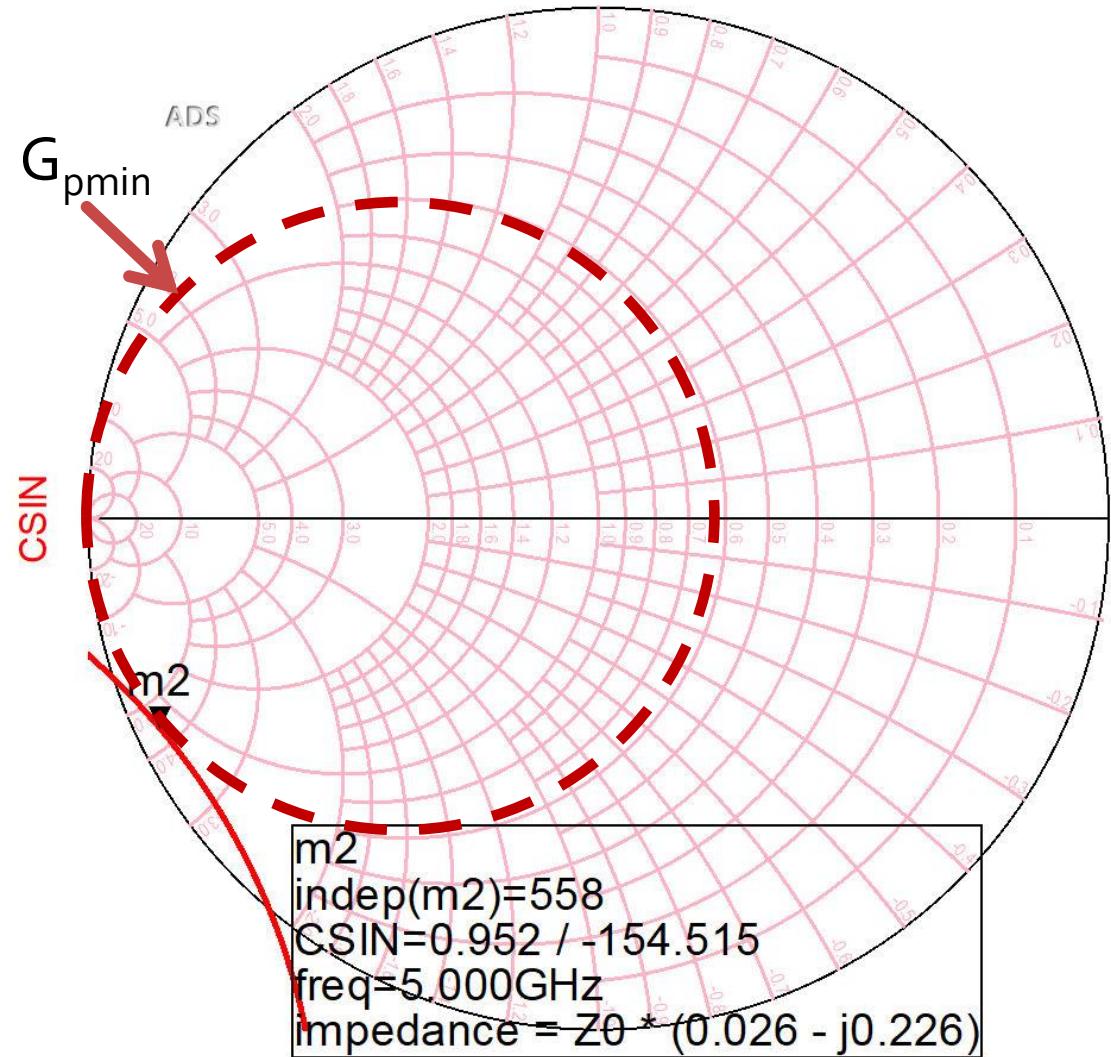


# Rezistenta serie la intrare

- $R_s = 2\Omega$
- $K = 1.008$ , MAG = 13.694dB @ 5GHz
  - fara stabilizare,  $K = 0.886$ , MAG = 14.248dB @ 5GHz



# Rezistenta paralel la intrare



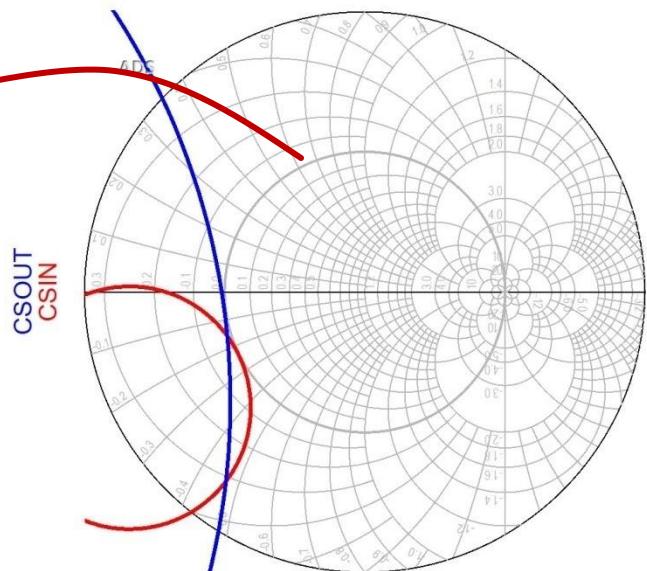
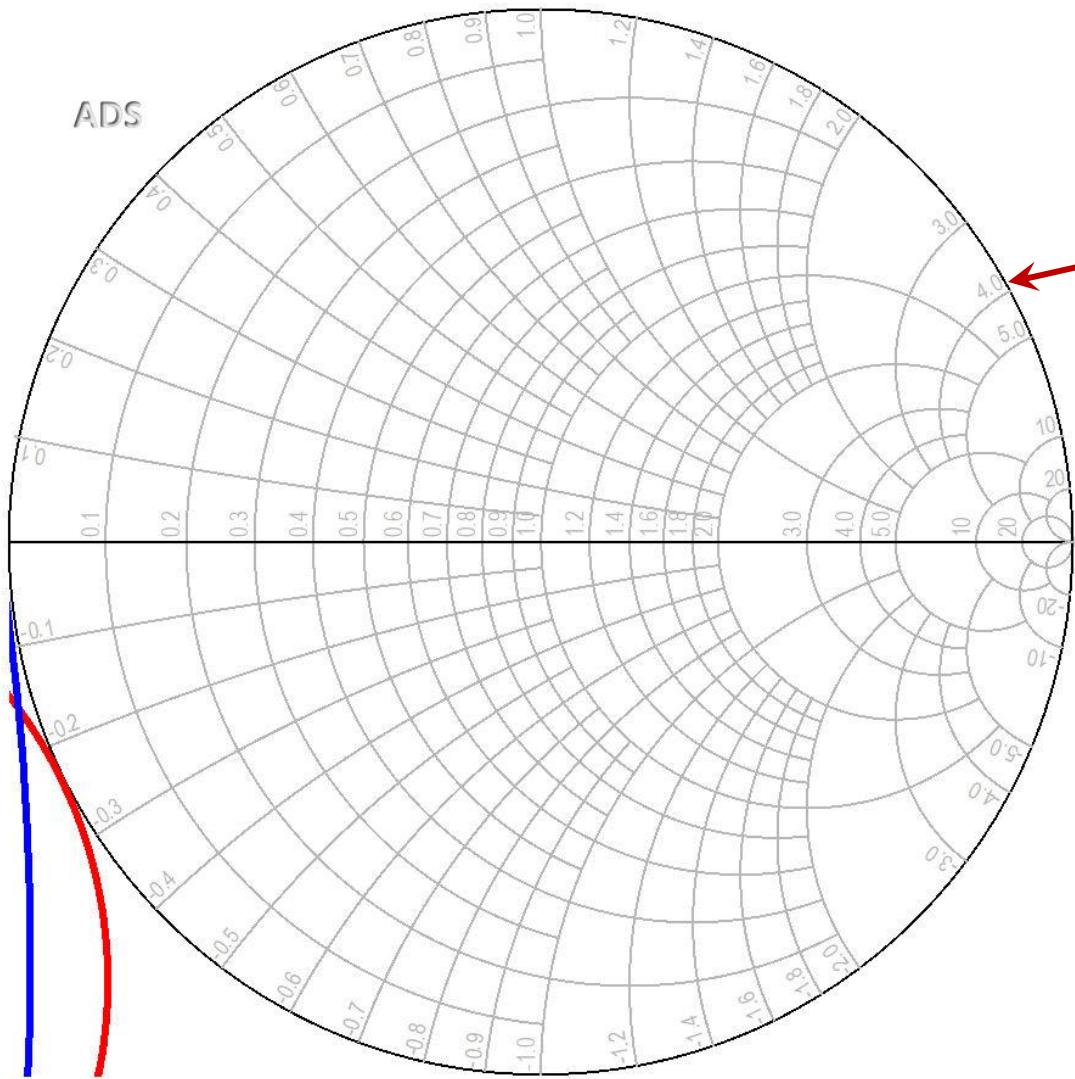
$$R_{p\max} = \frac{1}{G_{p\min}}$$

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

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

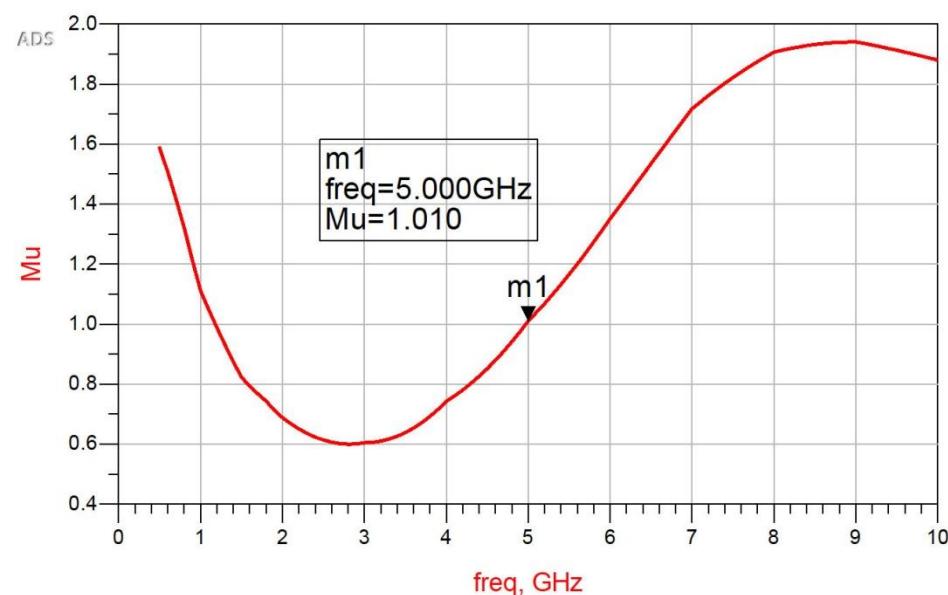
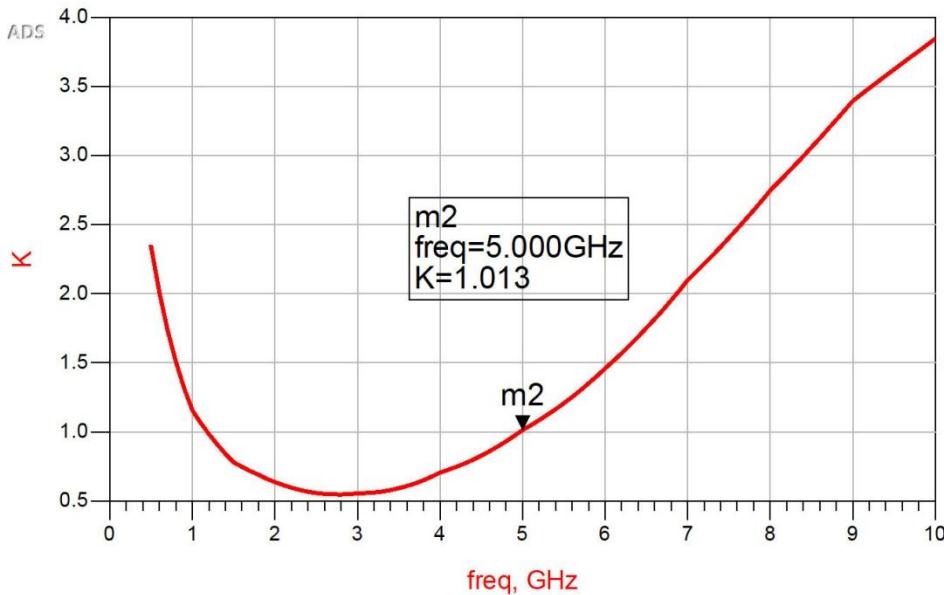
# ADS, $R_p = 90\Omega$

CSOUT  
CSIN



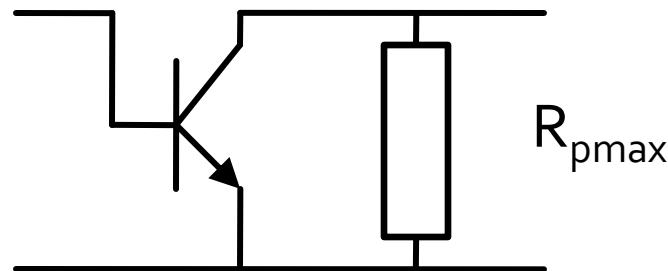
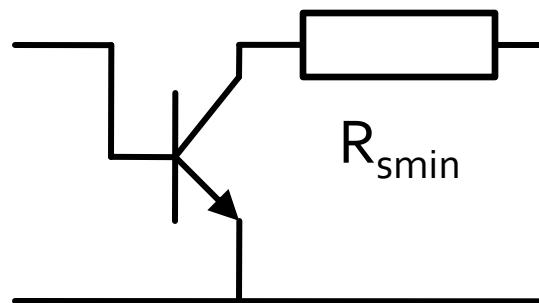
# Rezistenta paralel la intrare

- $R_p = 90\Omega$
- $K = 1.013$ , MAG = 13.561dB @ 5GHz
  - fara stabilizare,  $K = 0.886$ , MAG = 14.248dB @ 5GHz



# Rezistenta serie/paralel la iesire

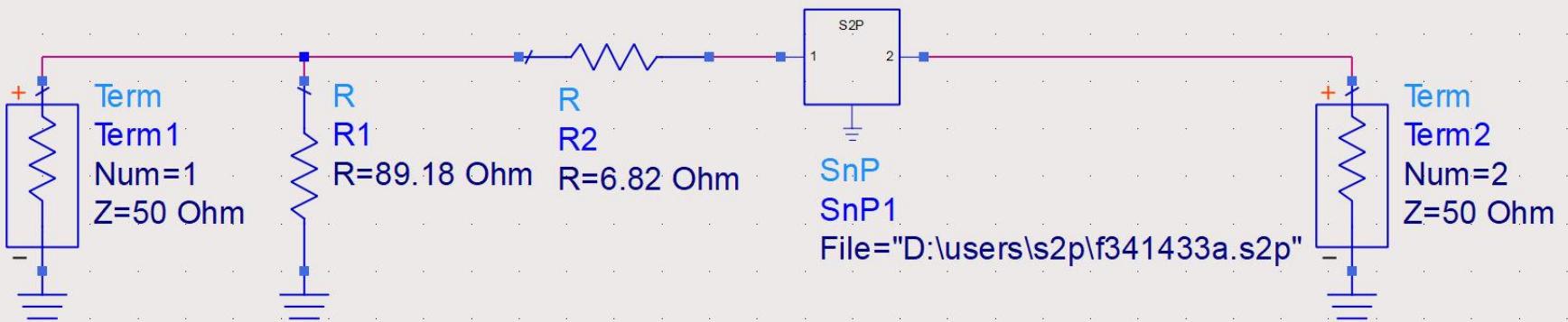
- Procedura se poate aplica similar la iesire (plecand de la CSOUT)
- Din exemplele anterioare, incarcarea rezistiva la intrare are efect pozitiv si asupra stabilitatii la iesire si viceversa (incarcare la iesire efect asupra stabilitatii la intrare)



# Stabilizarea unui dipozit

- Efect negativ asupra castigului
  - trebuie urmarit MAG/MSG in timpul proiectarii
- Efect negativ asupra zgomotului (<sup>va urma</sup>)
- Se poate alege una din cele 4 variante care ofera performante mai bune (in functie de aplicatie)
- Se pot realiza cu elemente de pasivizare selective in frecventa
  - Ex: Circuite RL, RC sacrificia performanta doar unde este necesar sa se imbunatateasca stabilitatea fara afectarea frecventelor la care dispozitivul e deja stabil
- E posibil ca aceste efecte sa apară automat ca urmare a elementelor parazite ale circuitelor de polarizare (capacitati de decuplare, socruri de radiofrecventa)

# Stabilizarea unui diport



S-PARAMETERS

S\_Param

SP1

Start=0.5 GHz

Stop=10.0 GHz

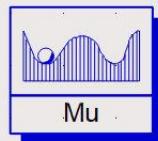
Step=0.1 GHz



MaxGain

MAG

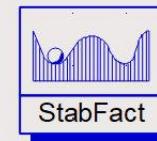
MAG=max\_gain(S)



Mu

Mu1

Mu=mu(S)

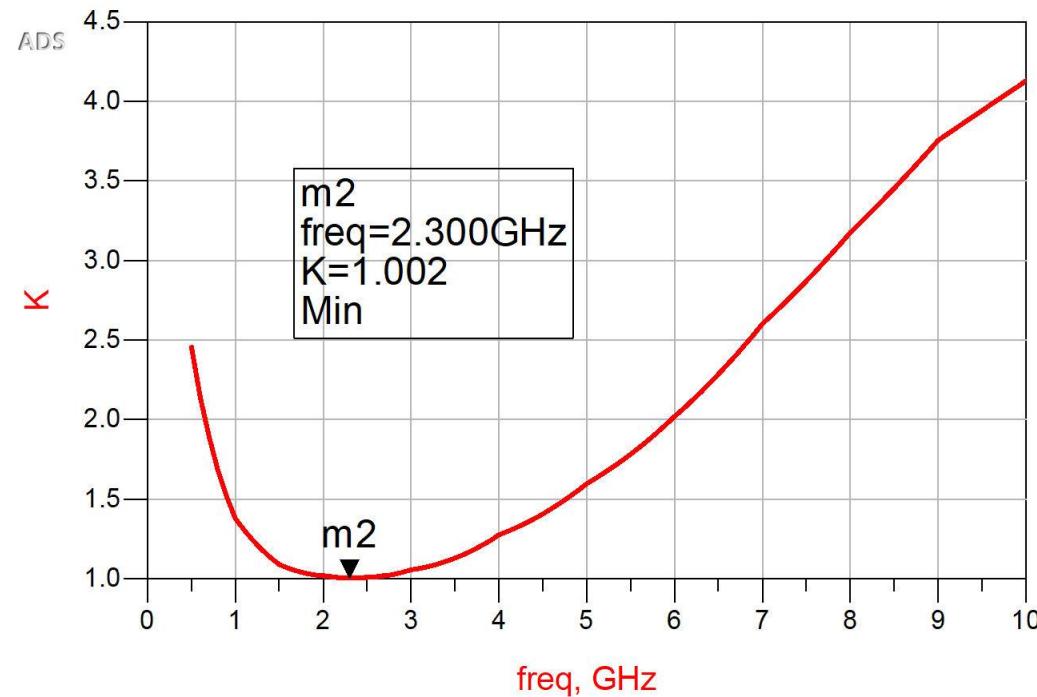
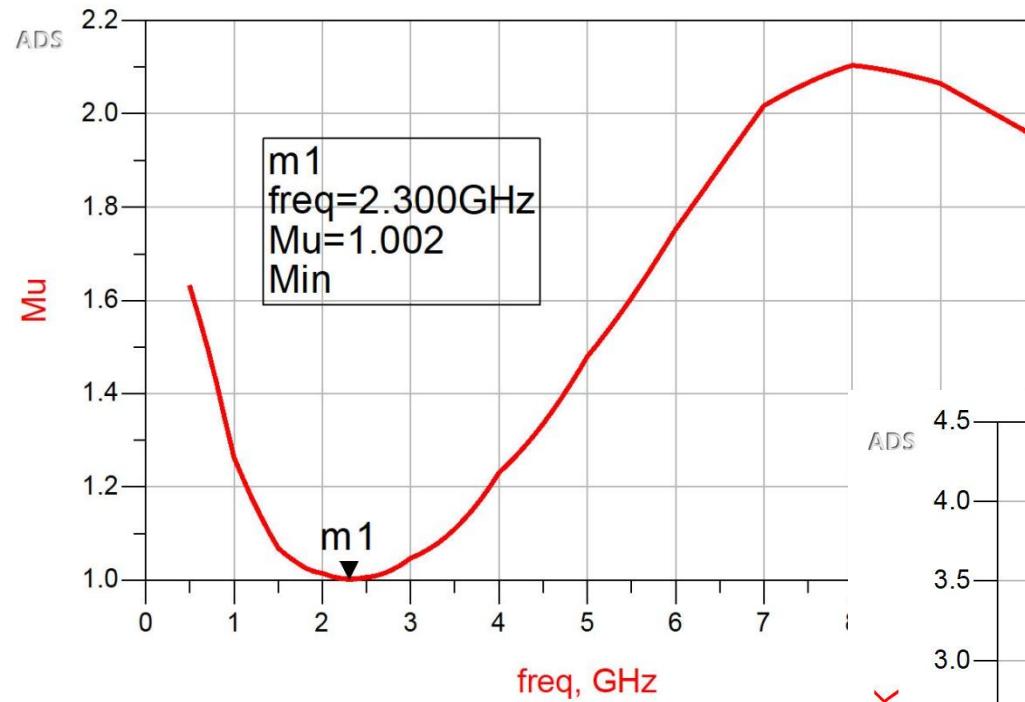


StabFact

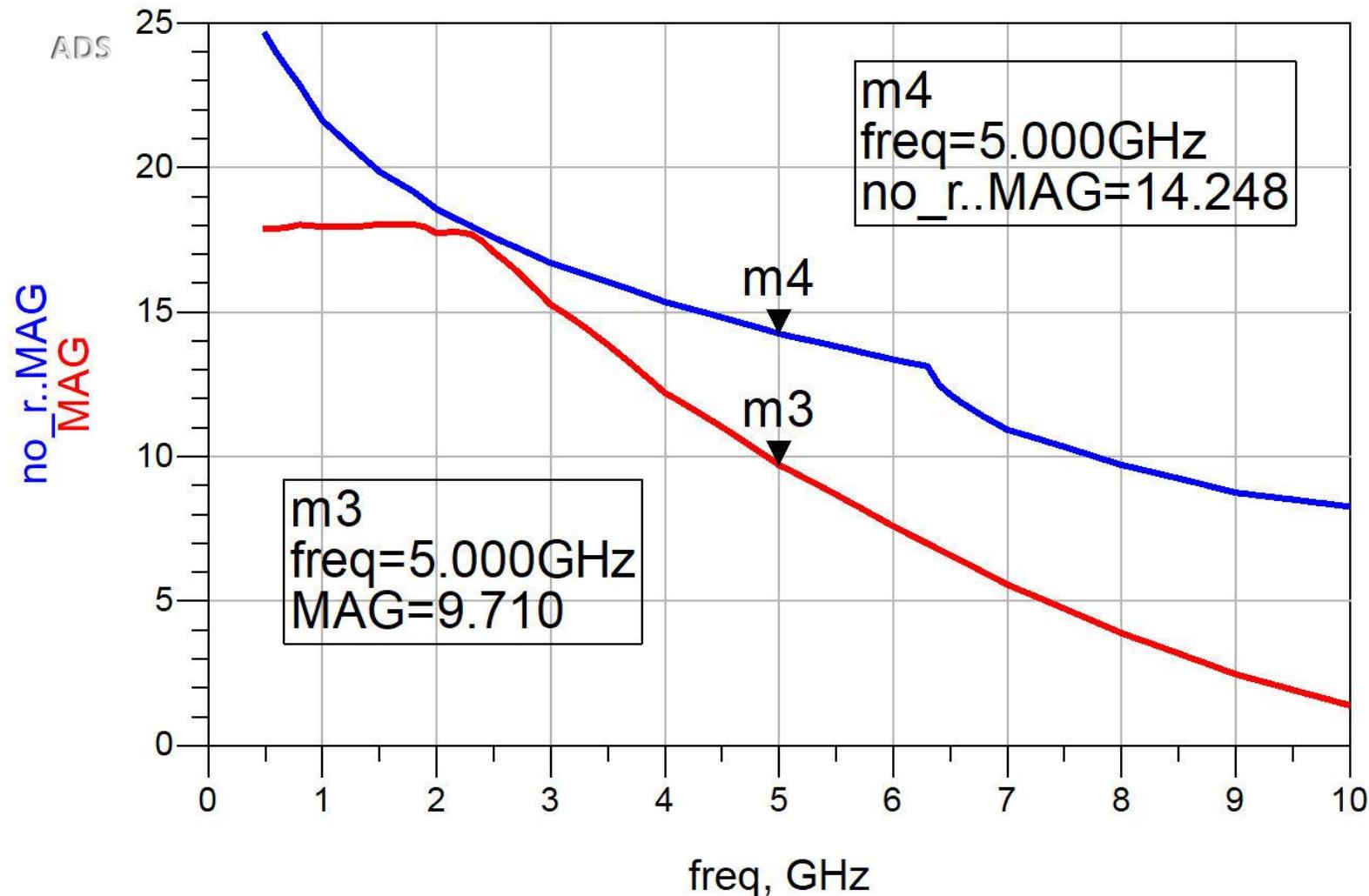
K

K=stab\_fact(S)

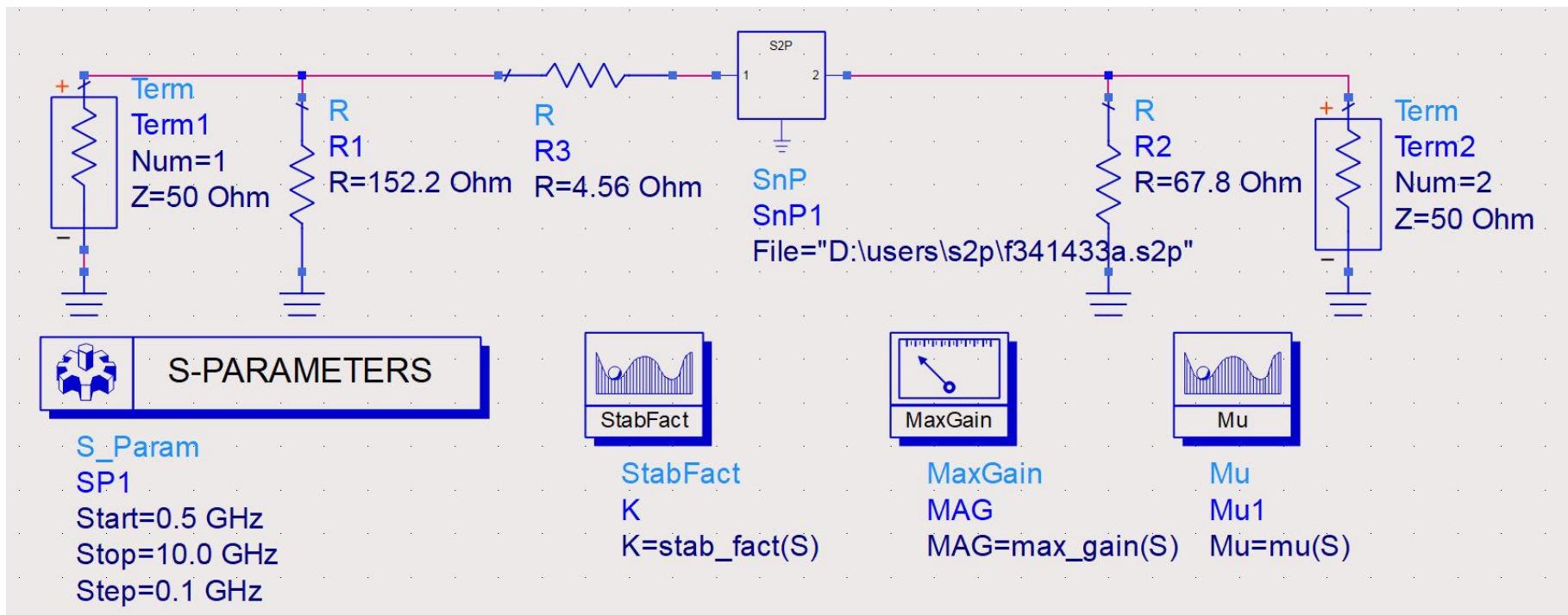
# Stabilizarea unui dipoz



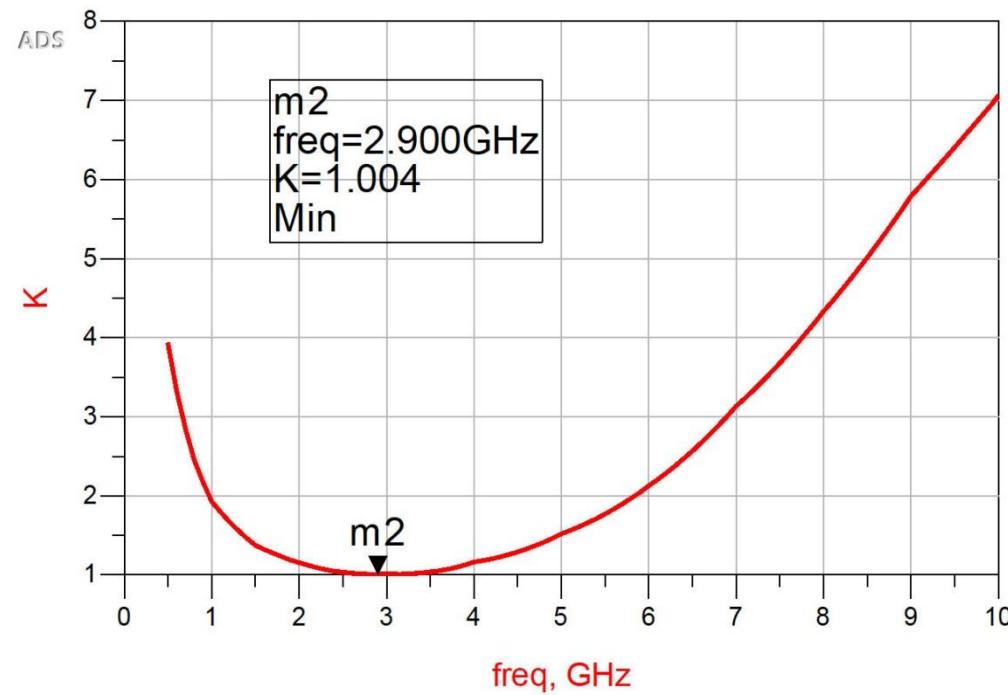
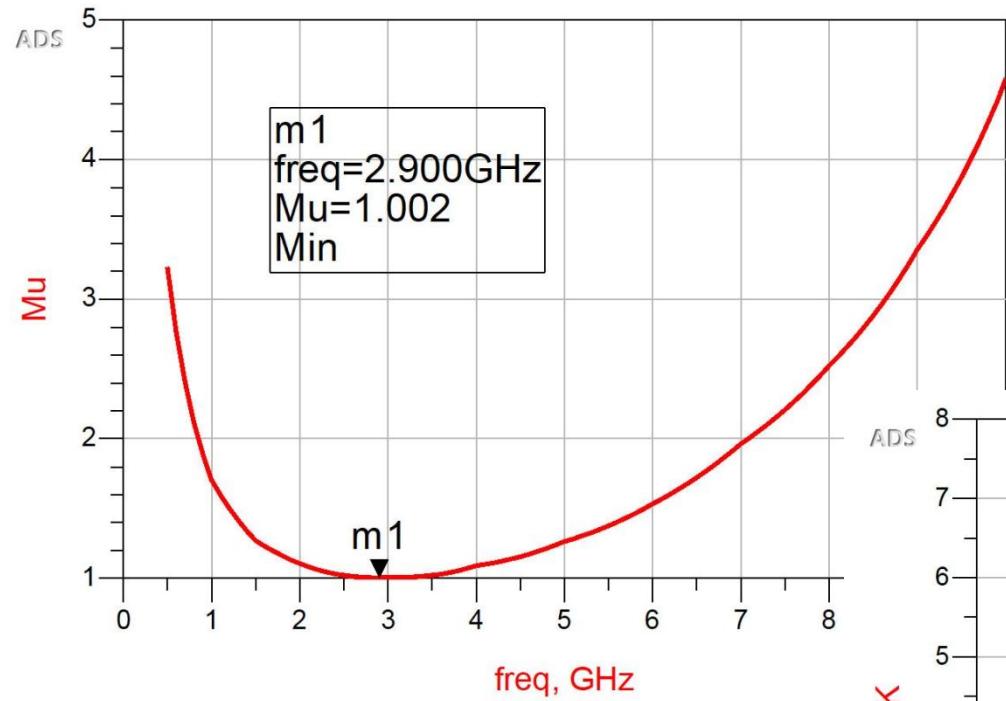
# Stabilizarea unui dipoz



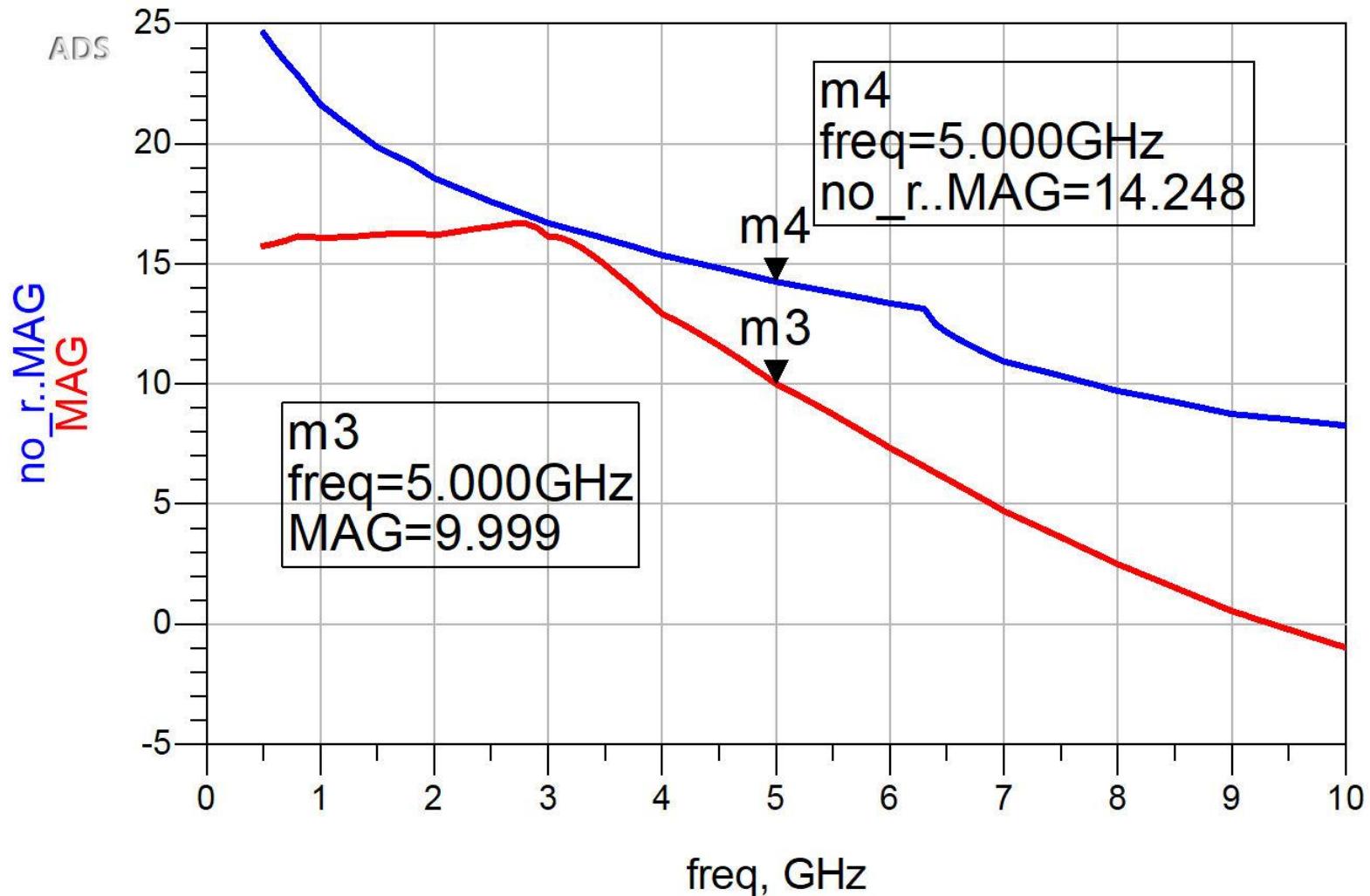
# Stabilizarea unui diport



# Stabilizarea unui dipoz



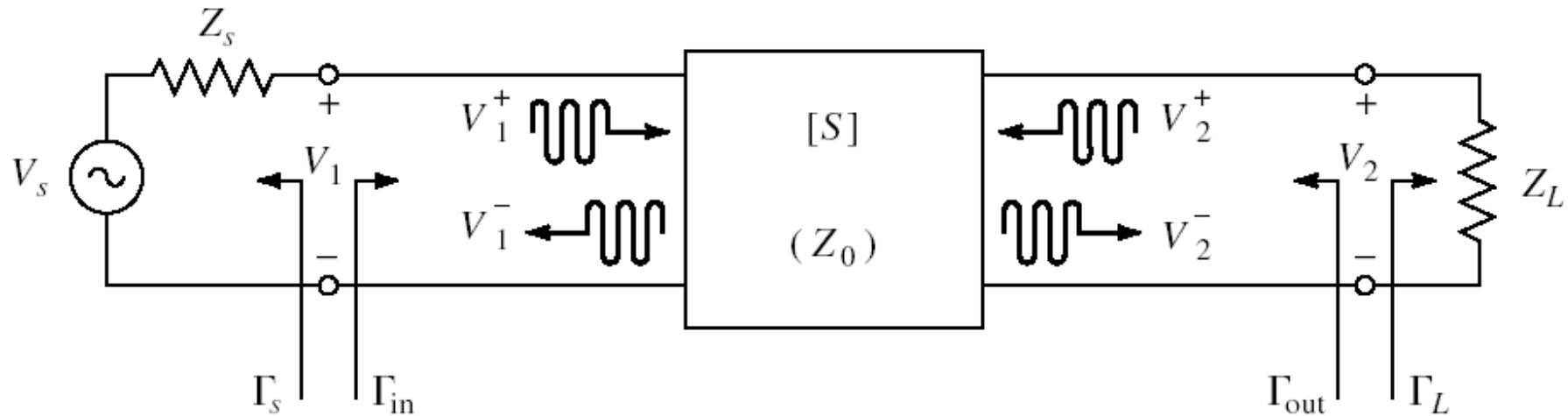
# Stabilizarea unui dipoz



Amplificatoare de microunde

# **Castigul amplificatoarelor de microunde**

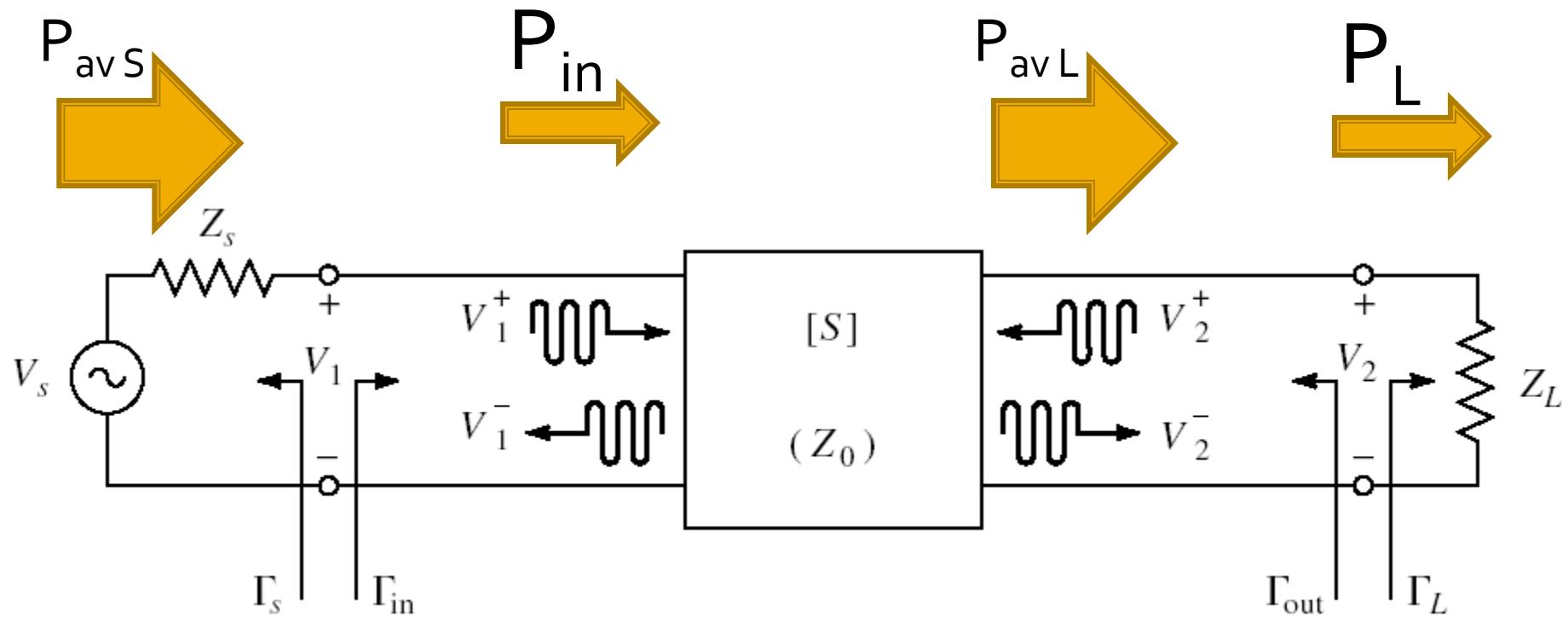
# Cuadripol Amplifier



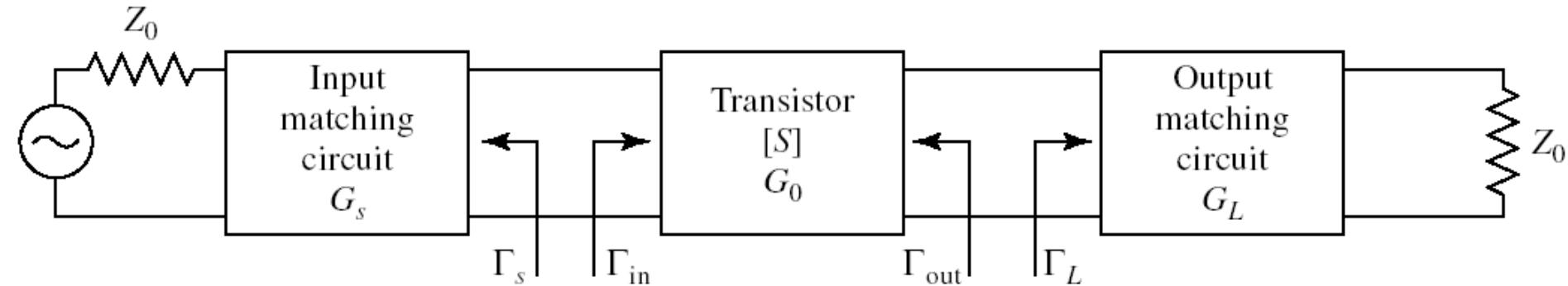
- marimi care intereseaza:
  - stabilitate
  - **castig de putere**
  - zgomot (uneori – semnal mic)
  - liniaritate (uneori – semnal mare)

# Puteri / Adaptare

- Doua porturi in care adaptarea influenteaza transferul de putere



# Proiectare pentru castig maxim



- Castig maxim de putere se obtine cand

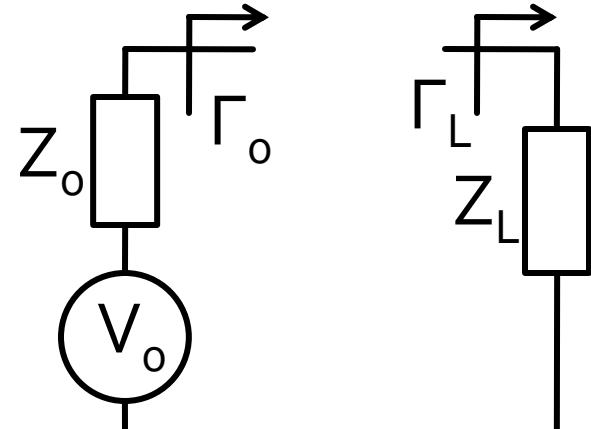
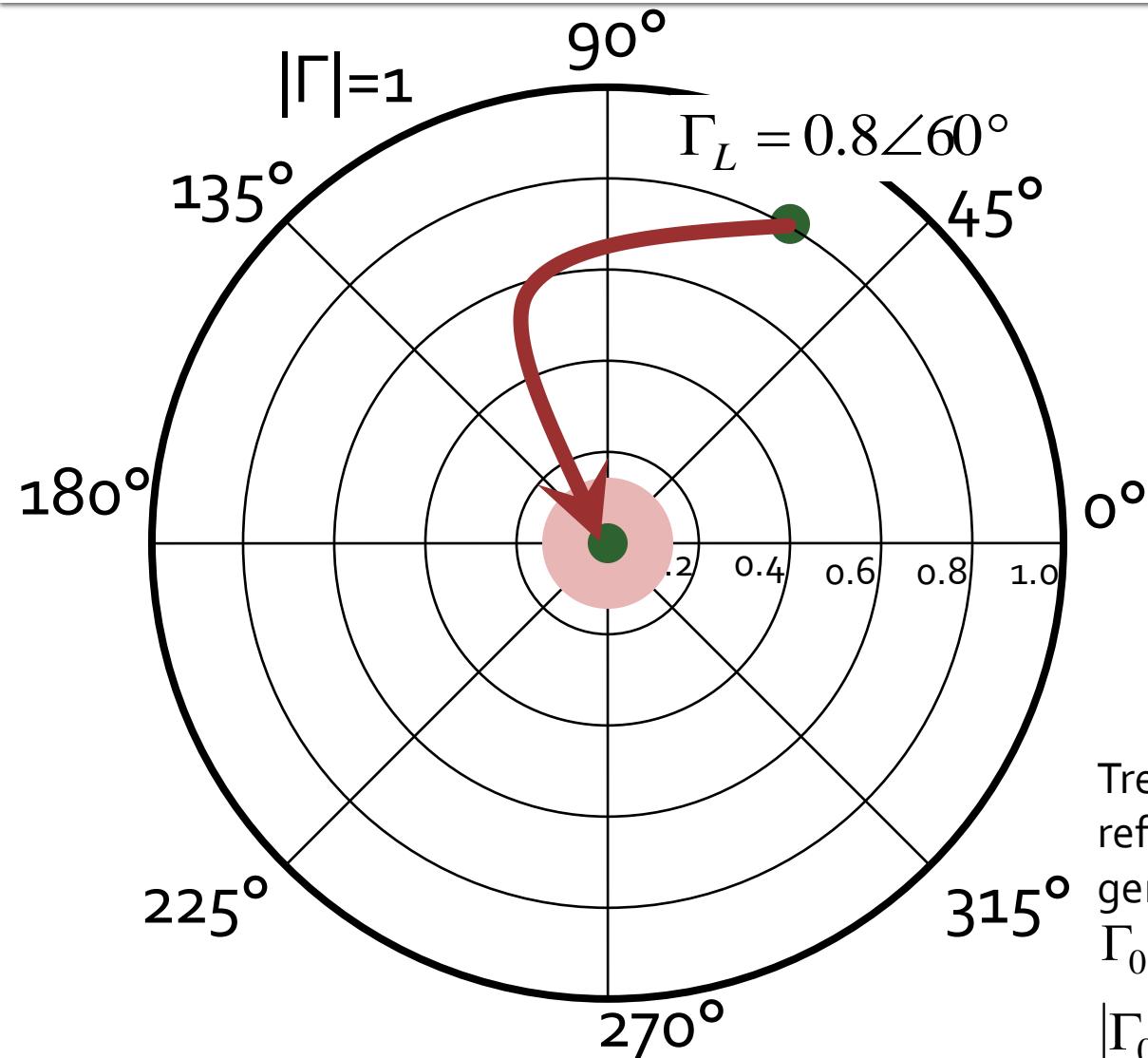
$$\Gamma_{in} = \Gamma_s^* \quad \Gamma_{out} = \Gamma_L^*$$

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

# Diagrama Smith, adaptare, $Z_L \neq Z_o$

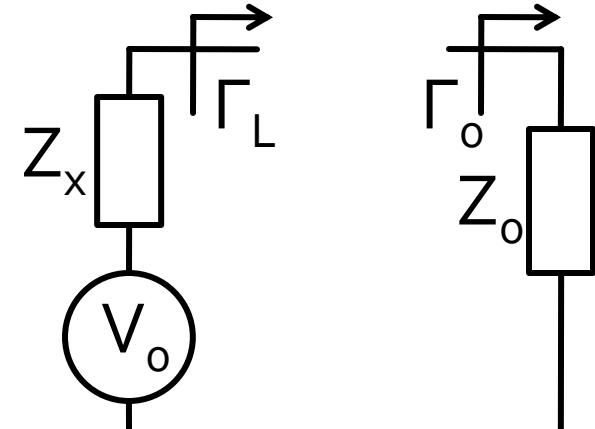
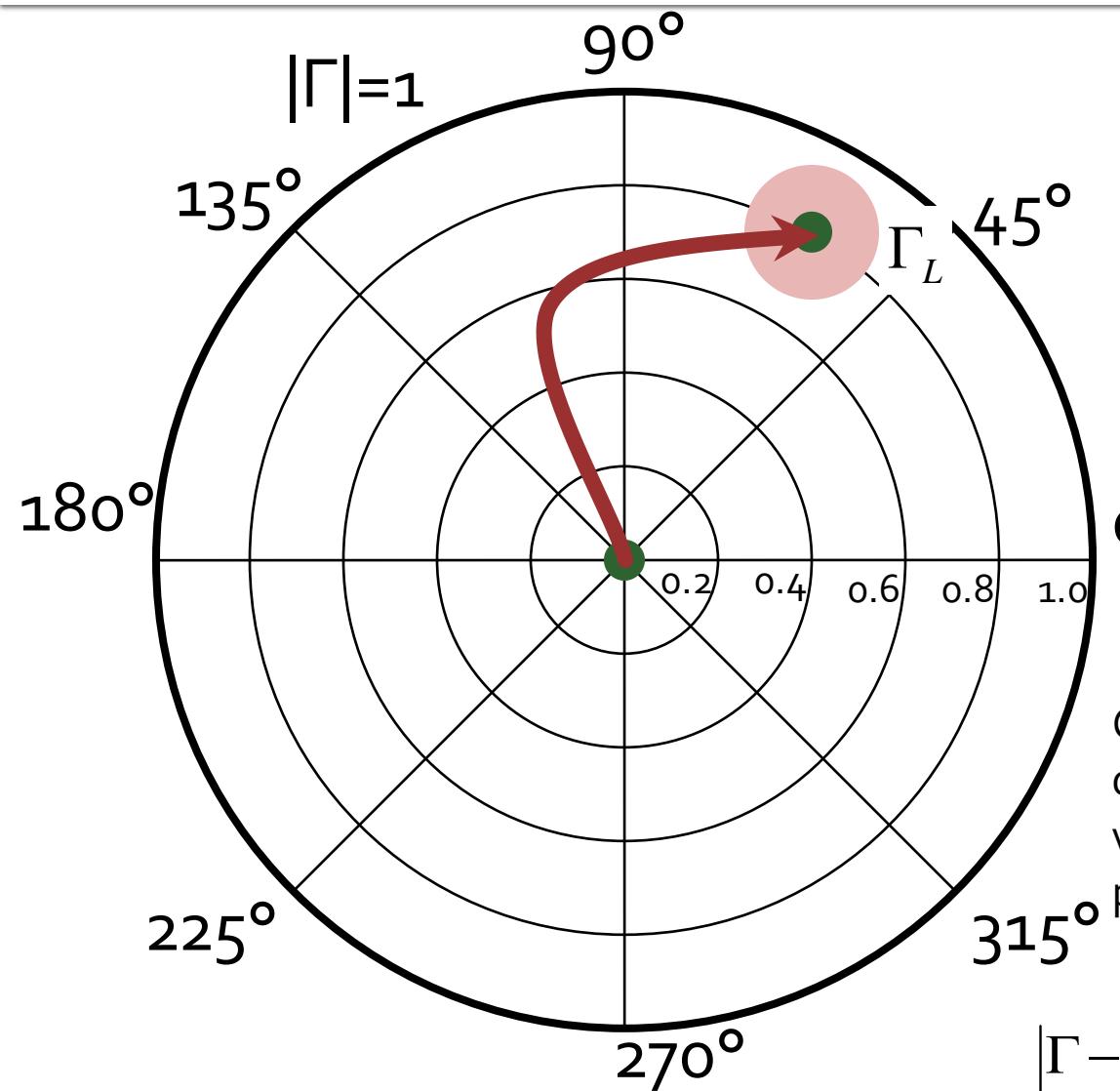


Adaptare  $Z_L$  la  $Z_o$ . Se raporteaza  $Z_L$  la  $Z_o$   
 $Z_L = 21.429 \Omega + j \cdot 82.479 \Omega$   
 $z_L = 0.429 + j \cdot 1.65$   
 $\Gamma_L = 0.8\angle 60^\circ$

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

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

# Diagrama Smith, adaptare, $Z_L = Z_o$



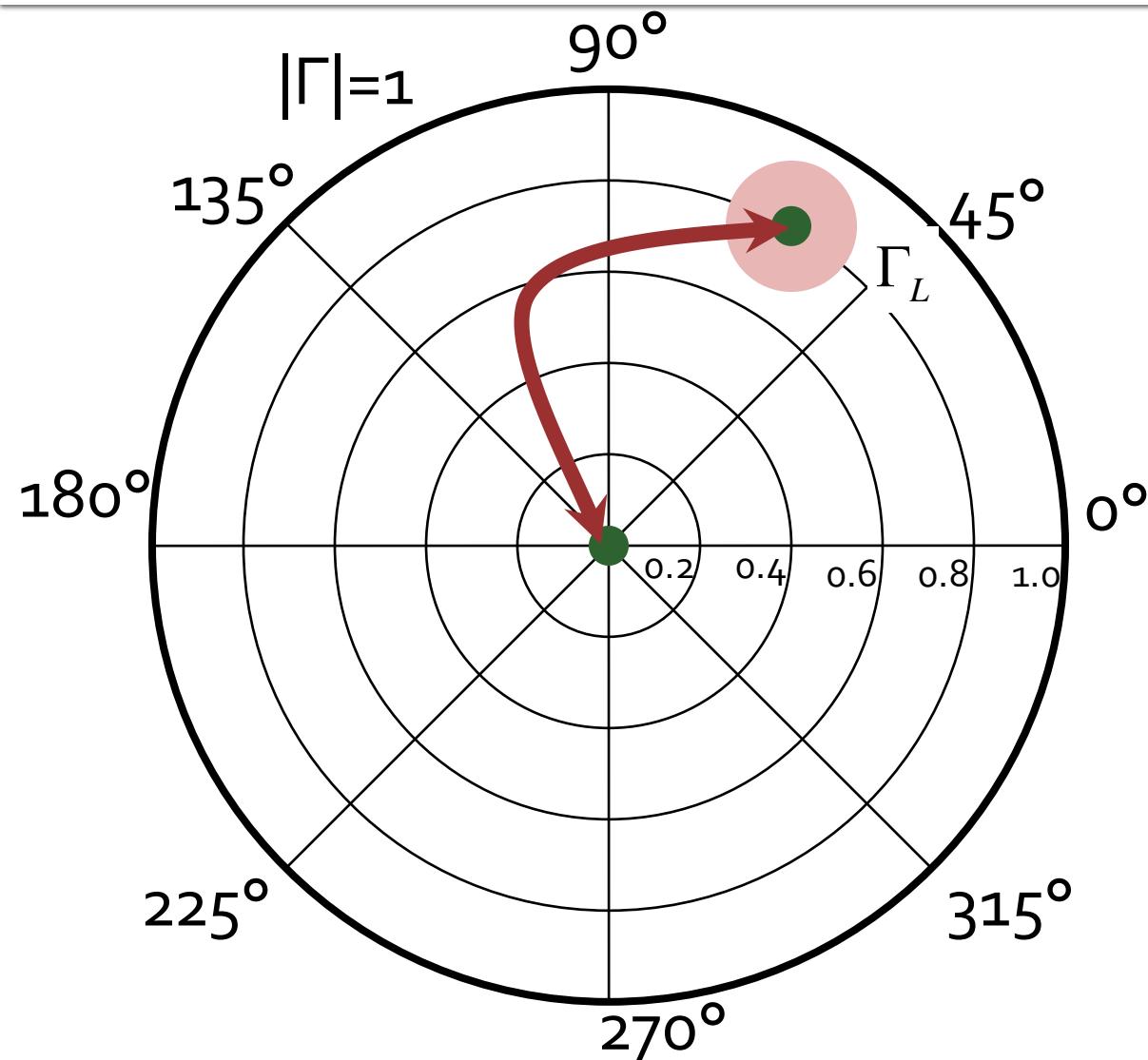
Sursa (de ex. tranzistorul) cu  $Z_x$  are nevoie de un anumit coeficient de reflexie  $\Gamma_L$  pentru a functiona corect

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

$\Gamma = \Gamma_L$  adaptare perfecta

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

# Diagrama Smith, adaptare, $Z_L = Z_o$



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

# Adaptare simultana

$$\Gamma_{in} = \Gamma_S^*$$

$$\Gamma_{in} = S_{11} + \frac{S_{12} \cdot S_{21} \cdot \Gamma_L}{1 - S_{22} \cdot \Gamma_L}$$

$$\Gamma_S^* = S_{11} + \frac{S_{12} \cdot S_{21} \cdot \Gamma_L}{1 - S_{22} \cdot \Gamma_L}$$

$$\Gamma_{out} = \Gamma_L^*$$

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

$$\Gamma_L^* = S_{22} + \frac{S_{12} \cdot S_{21} \cdot \Gamma_S}{1 - S_{11} \cdot \Gamma_S}$$

## Aflam $\Gamma_S$

$$\Gamma_S = S_{11}^* + \frac{S_{12}^* \cdot S_{21}^*}{1/\Gamma_L^* - S_{22}^*}$$

$$\Gamma_L^* = \frac{S_{22} - \Delta \cdot \Gamma_S}{1 - S_{11} \cdot \Gamma_S}$$

$$\Gamma_S \cdot (1 - |S_{22}|^2) + \Gamma_S^2 \cdot (\Delta \cdot S_{22}^* - S_{11}) = \Gamma_S \cdot (\Delta \cdot S_{11}^* \cdot S_{22}^* - |S_{22}|^2 - \Delta \cdot S_{12}^* \cdot S_{21}^*) + S_{11}^* \cdot (1 - |S_{22}|^2) + S_{12}^* \cdot S_{21}^* \cdot S_{22}$$

# Adaptare simultana

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

$$\Gamma_S^2 \cdot (S_{11} - \Delta \cdot S_{22}^*) + \Gamma_S \cdot (|\Delta|^2 - |S_{11}|^2 + |S_{22}|^2 - 1) + (S_{11}^* - \Delta^* \cdot S_{22}) = 0$$

- Ecuatie de gradul 2

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

- Similar

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

- Cu variabilele

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

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

# Adaptare simultana

- Este posibila daca

$$B_1^2 - 4 \cdot |C_1|^2 > 0 \quad B_2^2 - 4 \cdot |C_2|^2 > 0$$

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

$$|C_1|^2 = |S_{11} - \Delta \cdot S_{22}^*|^2 = |S_{12}|^2 \cdot |S_{21}|^2 + (1 - |S_{22}|^2) \cdot (|S_{11}|^2 - |\Delta|^2)$$

$$\begin{aligned} B_1^2 - 4 \cdot |C_1|^2 &= (1 + |S_{11}|^2)^2 + (|S_{22}|^2 + |\Delta|^2)^2 - \\ &\quad - 2 \cdot (1 + |S_{11}|^2) \cdot (|S_{22}|^2 + |\Delta|^2) - 4 \cdot |S_{12} \cdot S_{21}|^2 - 4 \cdot (1 - |S_{22}|^2) \cdot (|S_{22}|^2 - |\Delta|^2) \end{aligned}$$

$$\begin{aligned} B_1^2 - 4 \cdot |C_1|^2 &= (1 + |S_{11}|^2)^2 + (|S_{22}|^2 + |\Delta|^2)^2 - \\ &\quad - 4 \cdot |S_{11}|^2 - 4 \cdot |S_{22}|^2 \cdot |\Delta|^2 - 2 \cdot (1 - |S_{11}|^2) \cdot (|S_{22}|^2 - |\Delta|^2) - 4 \cdot |S_{12} \cdot S_{21}|^2 \end{aligned}$$

# Adaptare simultana

$$B_1^2 - 4 \cdot |C_1|^2 = \left(1 + |S_{11}|^2\right)^2 + \left(|S_{22}|^2 + |\Delta|^2\right)^2 - \\ - 4 \cdot |S_{11}|^2 - 4 \cdot |S_{22}|^2 \cdot |\Delta|^2 - 2 \cdot \left(1 - |S_{11}|^2\right) \cdot \left(|S_{22}|^2 - |\Delta|^2\right) - 4 \cdot |S_{12} \cdot S_{21}|^2$$

$$B_1^2 - 4 \cdot |C_1|^2 = \left(1 - |S_{11}|^2\right)^2 + \left(|S_{22}|^2 - |\Delta|^2\right)^2 - 2 \cdot \left(1 - |S_{11}|^2\right) \cdot \left(|S_{22}|^2 - |\Delta|^2\right) - 4 \cdot |S_{12} \cdot S_{21}|^2$$

$$B_1^2 - 4 \cdot |C_1|^2 = \left(1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2\right)^2 - 4 \cdot |S_{12} \cdot S_{21}|^2$$

$$B_1^2 - 4 \cdot |C_1|^2 = (K \cdot 2 \cdot |S_{12} \cdot S_{21}|)^2 - 4 \cdot |S_{12} \cdot S_{21}|^2$$

$$B_1^2 - 4 \cdot |C_1|^2 = 4 \cdot |S_{12}|^2 \cdot |S_{21}|^2 \cdot (K^2 - 1)$$

## ■ Similar

$$B_2^2 - 4 \cdot |C_2|^2 = 4 \cdot |S_{12}|^2 \cdot |S_{21}|^2 \cdot (K^2 - 1)$$

# Adaptare simultana

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

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

## ■ Necesar pentru solutii

$$|\Gamma_S| < 1 \quad |\Gamma_L| < 1$$

$$|\Delta| = |S_{11} \cdot S_{22} - S_{12} \cdot S_{21}| < 1 \quad \begin{cases} B_1 > 0 \\ B_2 > 0 \end{cases}$$

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2 \cdot |S_{12} \cdot S_{21}|} > 1 \quad \begin{cases} B_1^2 - 4 \cdot |C_1|^2 = 4 \cdot |S_{12}|^2 \cdot |S_{21}|^2 \cdot (K^2 - 1) > 0 \\ B_2^2 - 4 \cdot |C_2|^2 = 4 \cdot |S_{12}|^2 \cdot |S_{21}|^2 \cdot (K^2 - 1) > 0 \end{cases}$$

# 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

- În condițiile adaptării simultane se obține castigul de transfer maxim pentru tranzistorul bilateral

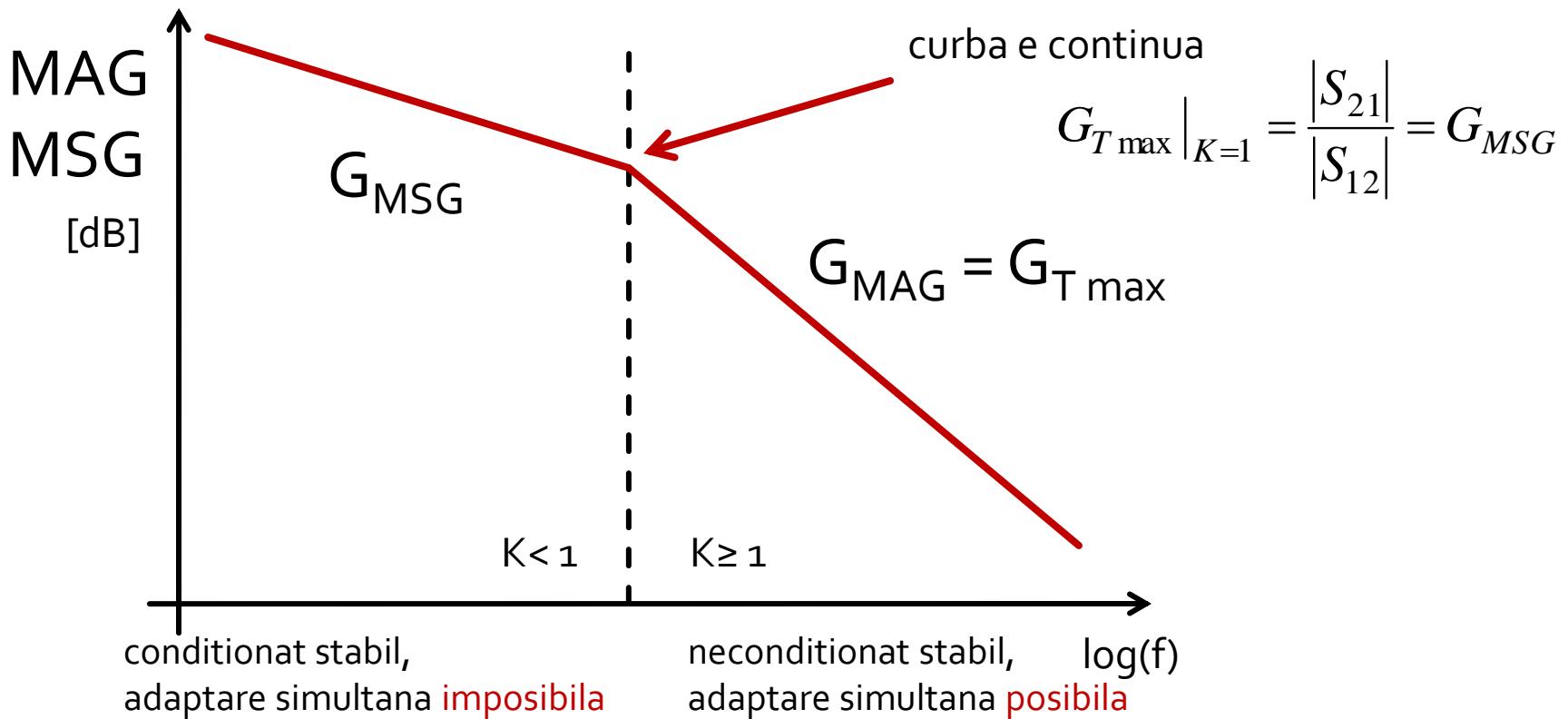
$$G_{T\max} = \frac{|S_{21}|}{|S_{12}|} \cdot \left( K - \sqrt{K^2 - 1} \right)$$

- Dacă 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

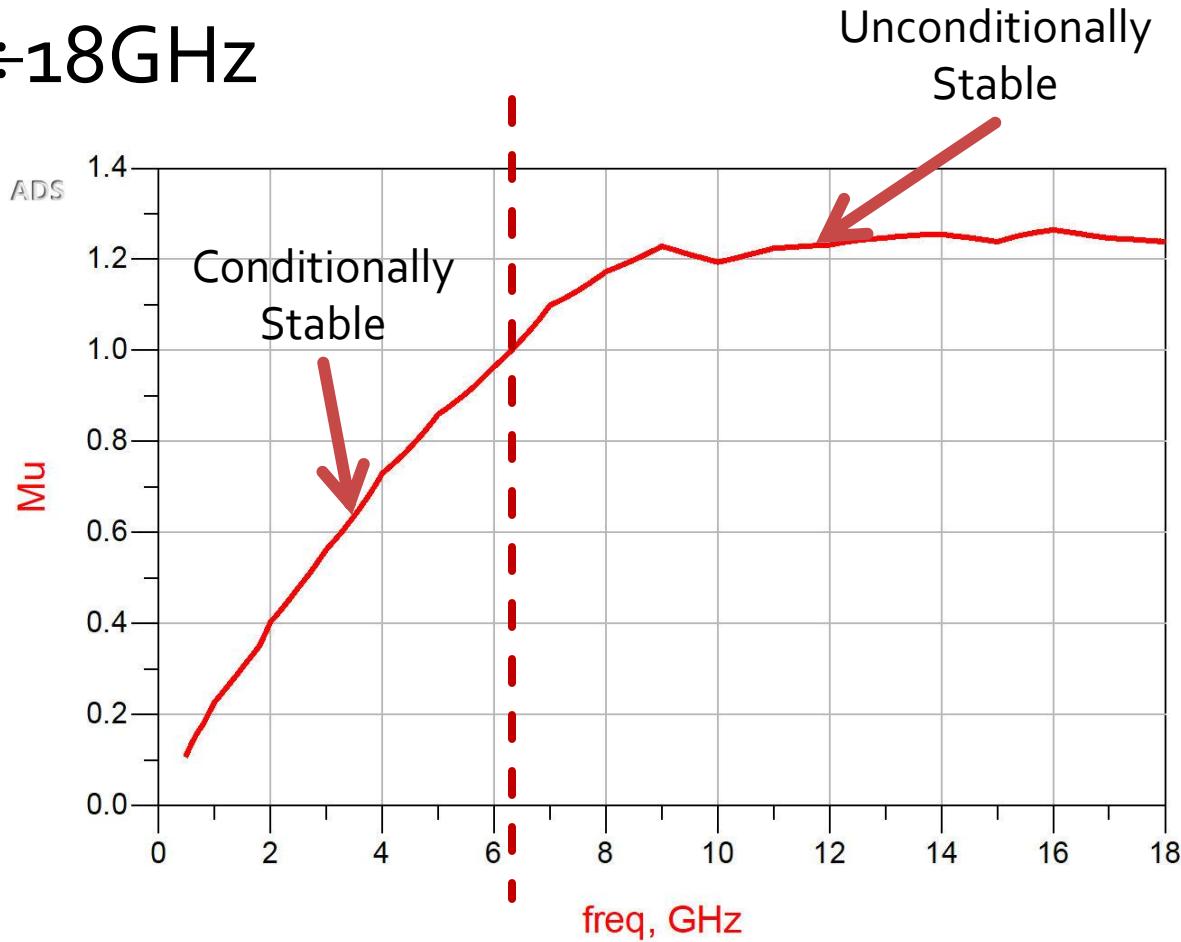
- Indicator in intreaga gama de frecventa a capacitatii de a obtine castig



# Stabilitate

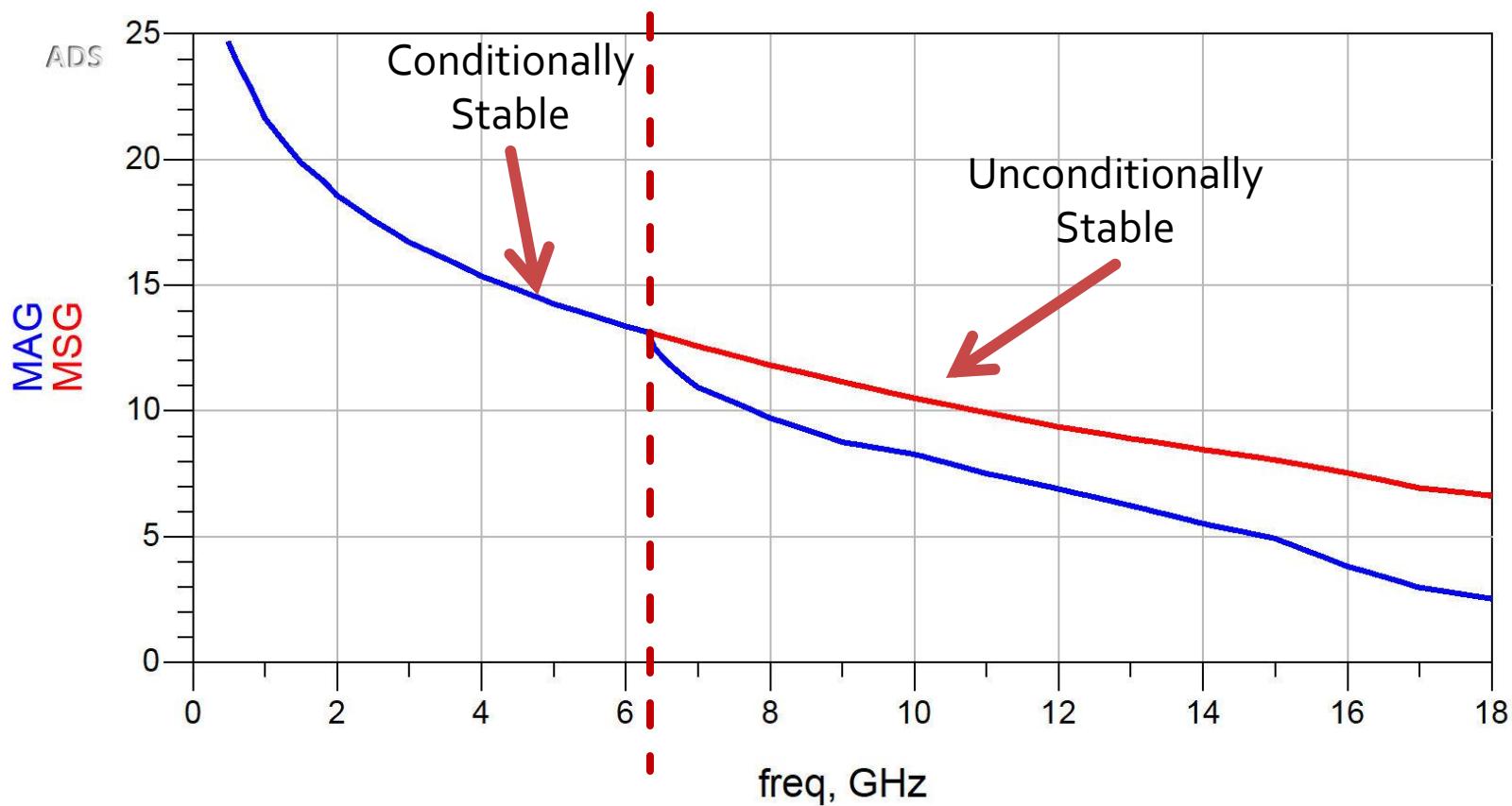
- ATF-34143 at  $V_{ds}=3V$   $I_d=20mA$ .

- @ $0.5 \div 18GHz$



# Castig

- ATF-34143 at  $V_{ds}=3V$   $I_d=20mA$ .
- @ $0.5\div18GHz$



# Adaptare simultana, tranzistor unilateral

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

$$\Gamma_{in} = S_{11}$$

$$\Gamma_{out} = S_{22}$$

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

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

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

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

# 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
  - $S_{11} = 0.64 \angle 111^\circ$
  - $S_{12} = 0.117 \angle -27^\circ$
  - $S_{21} = 2.923 \angle -6^\circ$
  - $S_{22} = 0.21 \angle 111^\circ$

# Calcul

## ■ Parametri S

- $S_{11} = -0.229 + 0.597 \cdot j$
- $S_{12} = 0.104 - 0.053 \cdot j$
- $S_{21} = 2.907 - 0.306 \cdot j$
- $S_{22} = -0.075 + 0.196 \cdot j$

$$\begin{cases} S_{11} = 0.64 \angle 111^\circ \\ S_{11} = 0.64 \cdot \cos 111^\circ + j \cdot 0.64 \cdot \sin 111^\circ \end{cases}$$

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

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

# Calcul

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

$$\begin{cases} B_1 = ? \\ C_1 = ? \end{cases}$$

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

$$\Gamma_S = ?$$

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

$$\begin{cases} B_2 = ? \\ C_2 = ? \end{cases}$$

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

$$\Gamma_L = ?$$

# Calcul

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

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

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

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

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

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

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

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

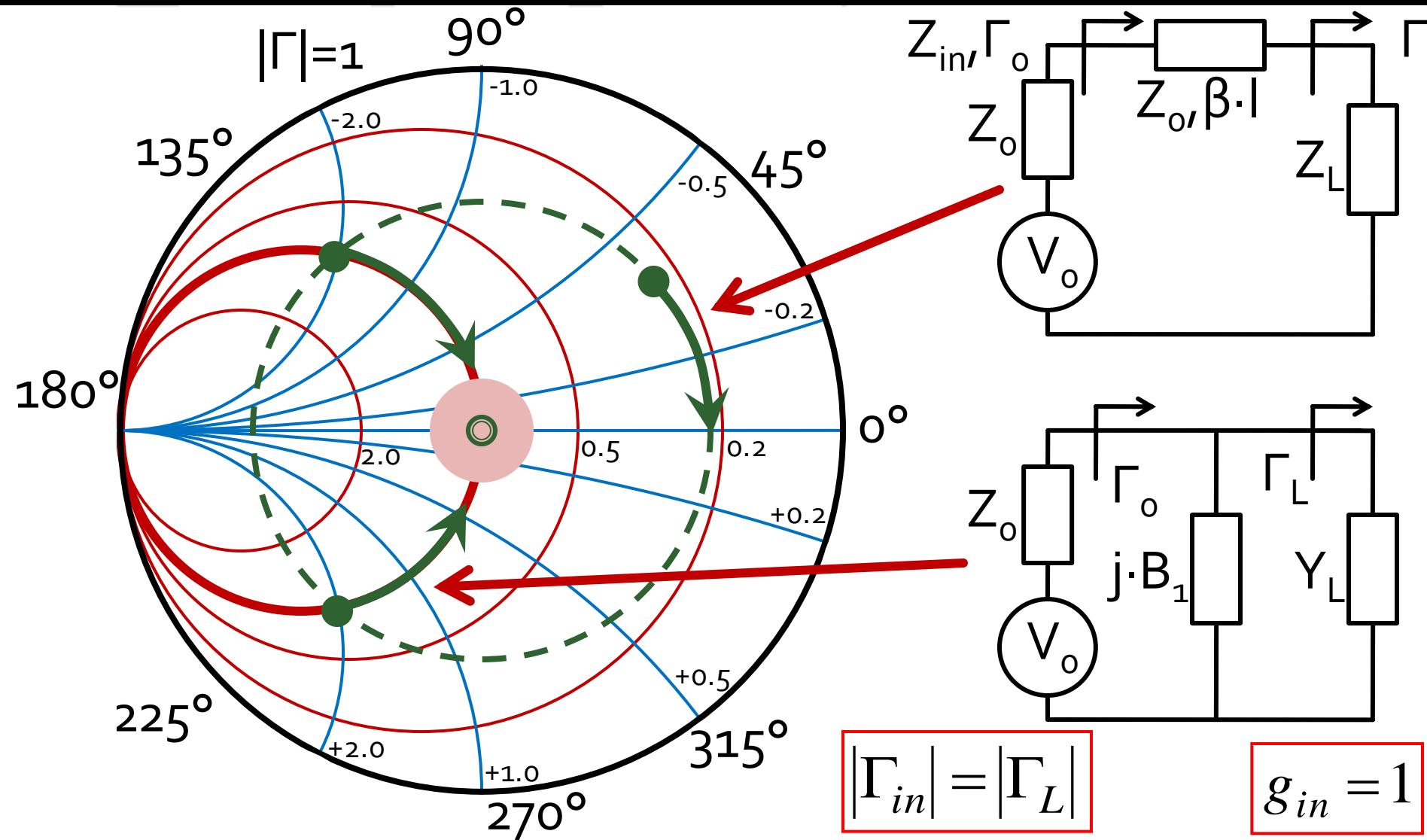
$$\Gamma_L = \frac{B_2 - \sqrt{B_2^2 - 4 \cdot |C_2|^2}}{2 \cdot C_2}$$

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

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

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

# Adaptare cu stub-uri, C<sub>7</sub>



# Calcul analitic ( $\Gamma_S$ )

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

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

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

$$|\Gamma_S| = 0.867; \quad \varphi = -117.7^\circ \quad \cos(\varphi + 2\theta) = -0.867 \Rightarrow (\varphi + 2\theta) = \pm 150.1^\circ$$

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

- **solutia "cu +"** 

$$(-117.7^\circ + 2\theta) = +150.1^\circ \quad \theta = 133.9^\circ \quad \text{Im } y_S = \frac{-2 \cdot |\Gamma_S|}{\sqrt{1 - |\Gamma_S|^2}} = -3.477$$

$$\theta_{sp} = \tan^{-1}(\text{Im } y_S) = -74^\circ (+180^\circ) \rightarrow \theta_{sp} = 106^\circ$$

- **solutia "cu -"** 

$$(-117.7^\circ + 2\theta) = -150.1^\circ \quad \theta = -16.2^\circ (+180^\circ) \rightarrow \theta = 163.8^\circ$$

$$\text{Im } y_S = \frac{+2 \cdot |\Gamma_S|}{\sqrt{1 - |\Gamma_S|^2}} = +3.477 \quad \theta_{sp} = \tan^{-1}(\text{Im } y_S) = 74^\circ$$

# Calcul analitic ( $\Gamma_L$ )

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

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

$$|\Gamma_L| = 0.686; \quad \varphi = 176.7^\circ$$

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

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

# Calcul analitic ( $\Gamma_L$ )

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

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

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

$$|\Gamma_L| = 0.686; \quad \varphi = 176.7^\circ \quad \cos(\varphi + 2\theta) = -0.686 \Rightarrow (\varphi + 2\theta) = \pm 133.3^\circ$$

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

- **solutia "cu +"**

$$(176.7^\circ + 2\theta) = +133.3^\circ \quad \theta = -21.7^\circ (+180^\circ) \rightarrow \theta = 158.3^\circ$$
$$\theta_{sp} = \tan^{-1}(\text{Im } y_L) = -62.1^\circ (+180^\circ) \rightarrow \theta_{sp} = 117.9^\circ \quad \text{Im } y_L = \frac{-2 \cdot |\Gamma_L|}{\sqrt{1 - |\Gamma_L|^2}} = -1.885$$

- **solutia "cu -"**

$$(176.7^\circ + 2\theta) = -133.3^\circ \quad \theta = -155^\circ (+180^\circ) \rightarrow \theta = 25^\circ$$

$$\text{Im } y_L = \frac{+2 \cdot |\Gamma_L|}{\sqrt{1 - |\Gamma_L|^2}} = +1.885 \quad \theta_{sp} = \tan^{-1}(\text{Im } y_L) = 62.1^\circ$$

# Calcul analitic

- Se alege **una** din cele două solutii posibile la intrare

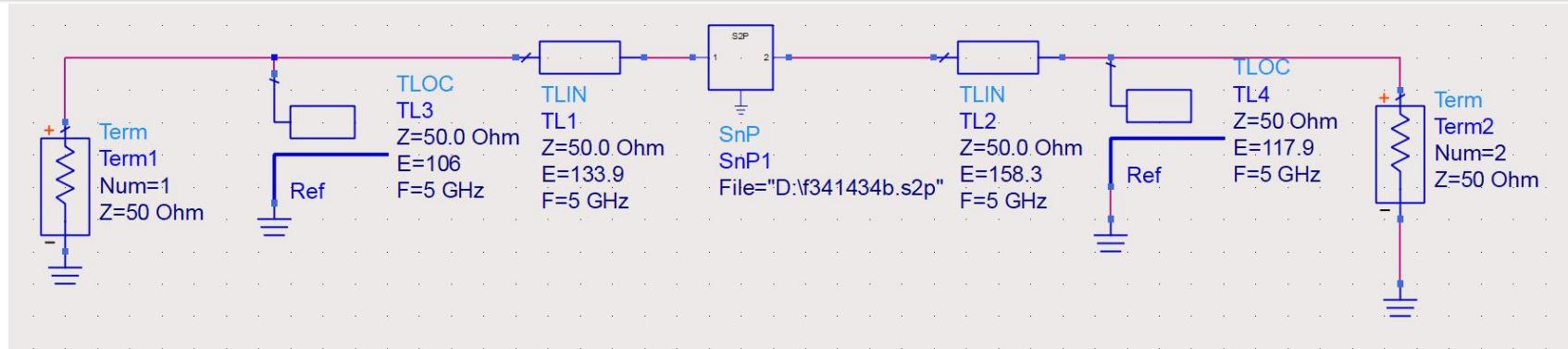
$$(\varphi + 2\theta) = \begin{cases} +150.1^\circ \\ -150.1^\circ \end{cases} \quad \theta = \begin{cases} 133.9^\circ \\ 163.8^\circ \end{cases} \quad \text{Im}[y_s(\theta)] = \begin{cases} -3.477 \\ +3.477 \end{cases} \quad \theta_{sp} = \begin{cases} -74^\circ + 180^\circ = 106^\circ \\ +74^\circ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

- Similar pentru adaptarea la ieșire

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

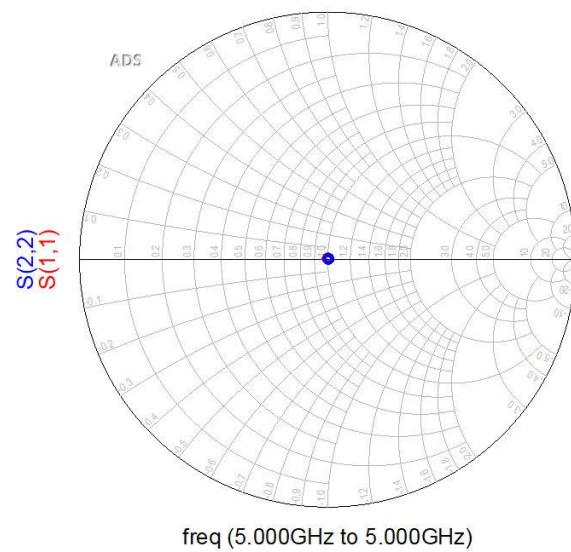
- În total există **4** posibilități de adaptare intrare/ieșire

# ADS

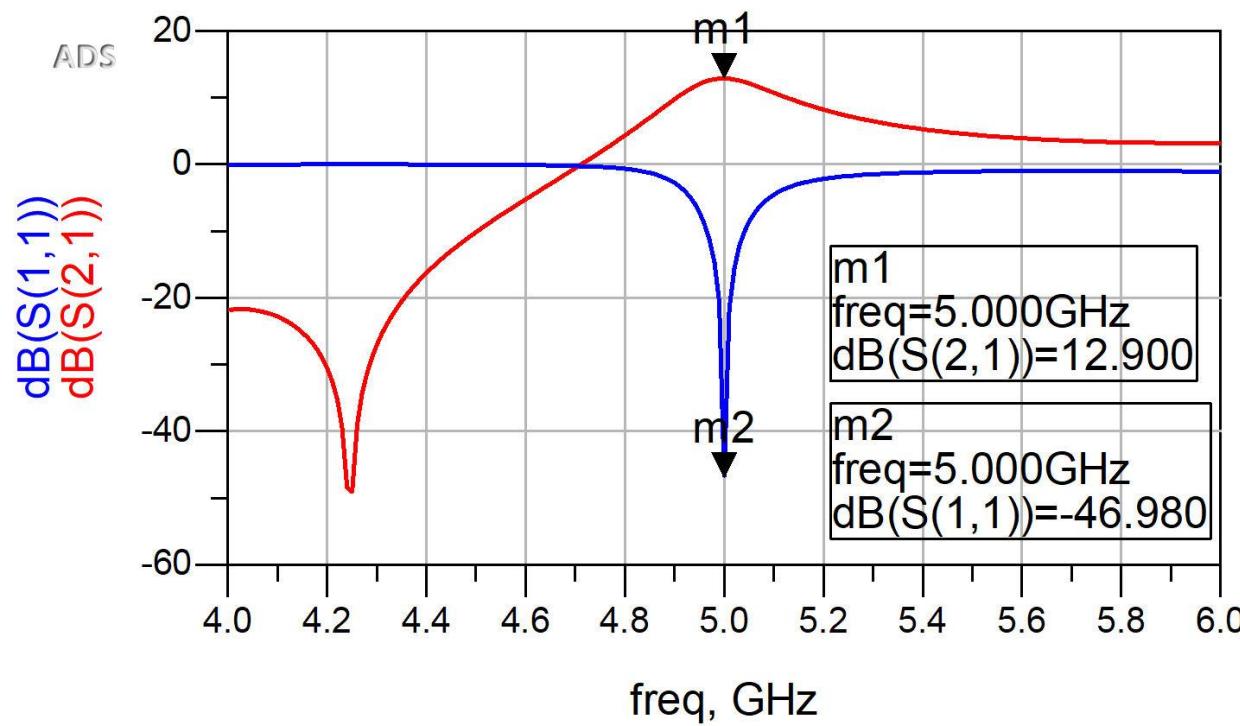
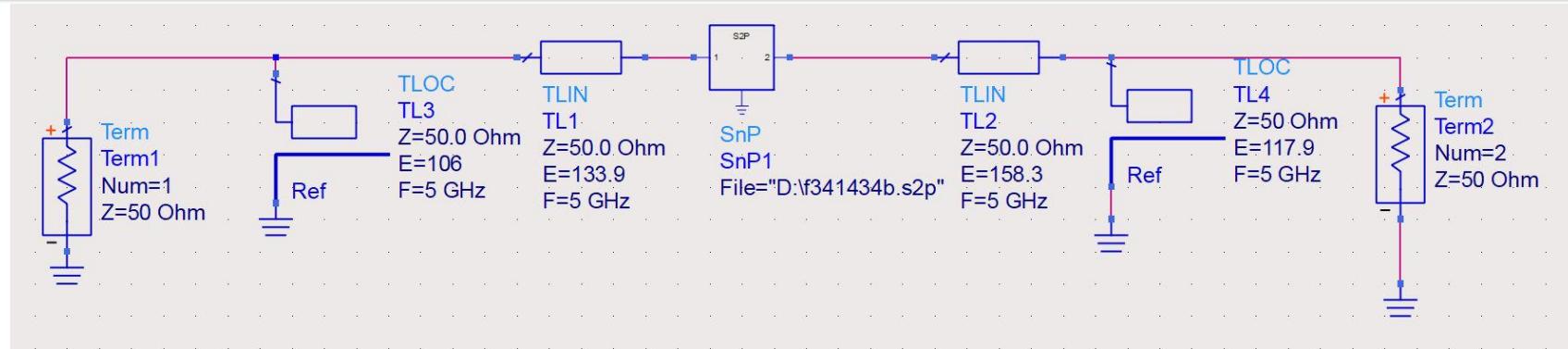


$$\text{Eqn GT} = 10 * \log(\text{mag}(S(2,1))^{\star 2})$$

freq	S(2,1)	GT	S(1,1)	S(2,2)
5.000 GHz	4.415 / 157.353	12.900	0.004 / 86.088	0.004 / 37.766



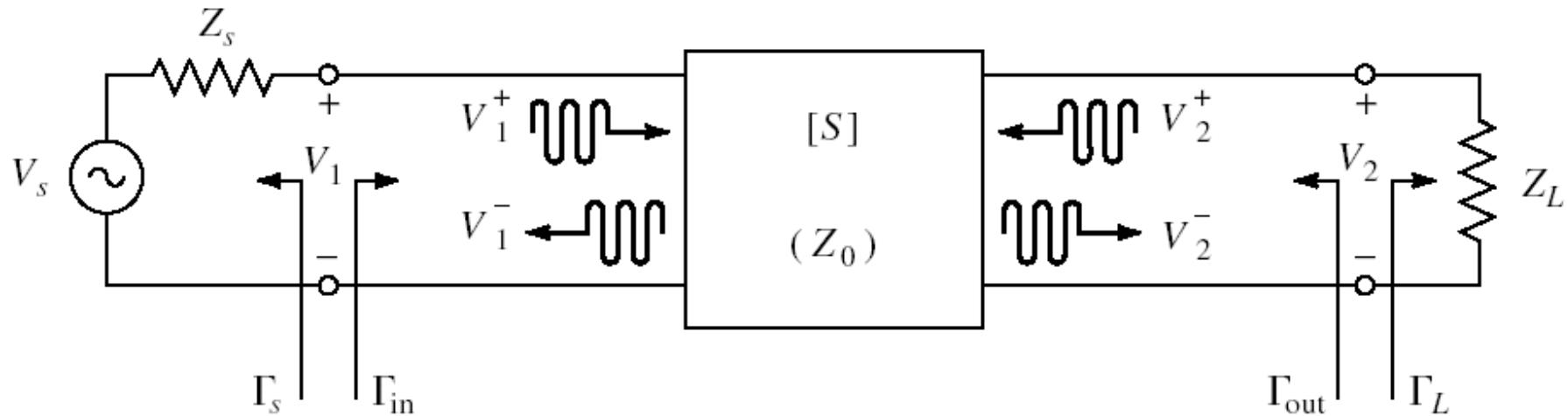
# ADS



Amplificatoare de microunde

# Proiectare pentru castig impus

# Cuadripol Amplifier



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

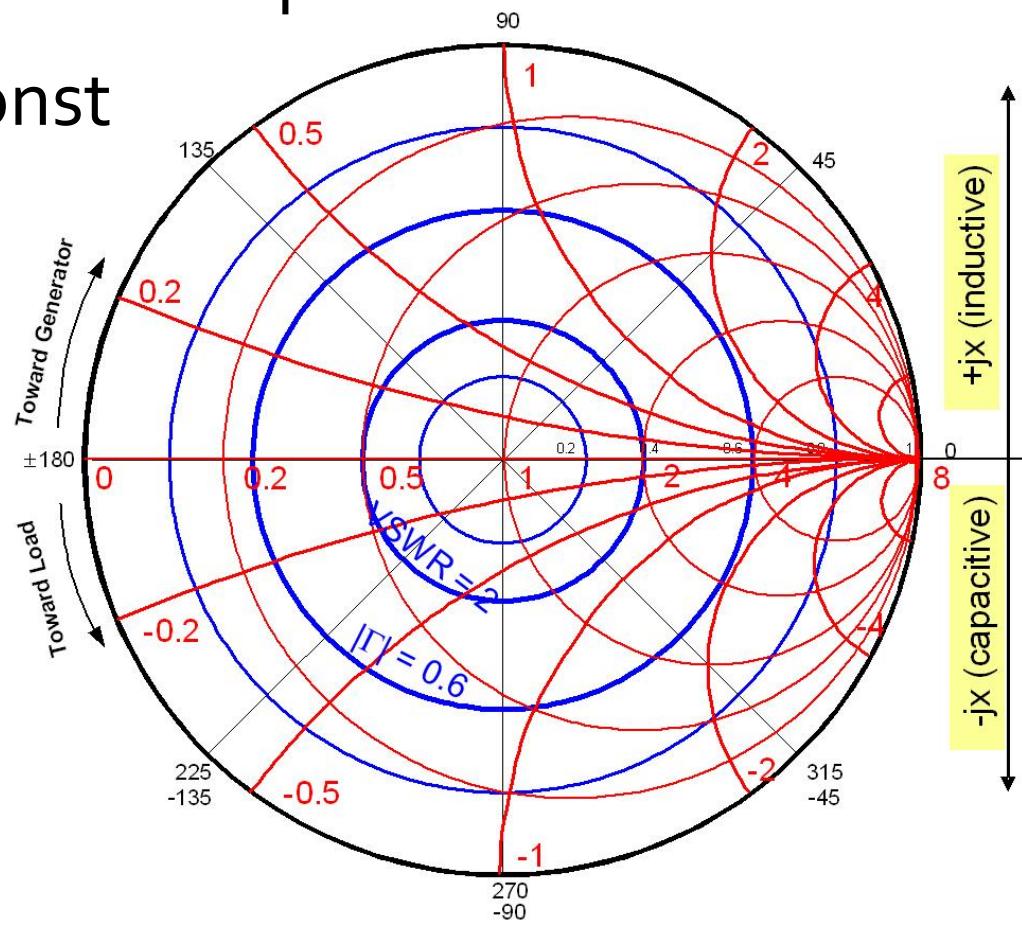
# Proiectare pentru castig impus

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

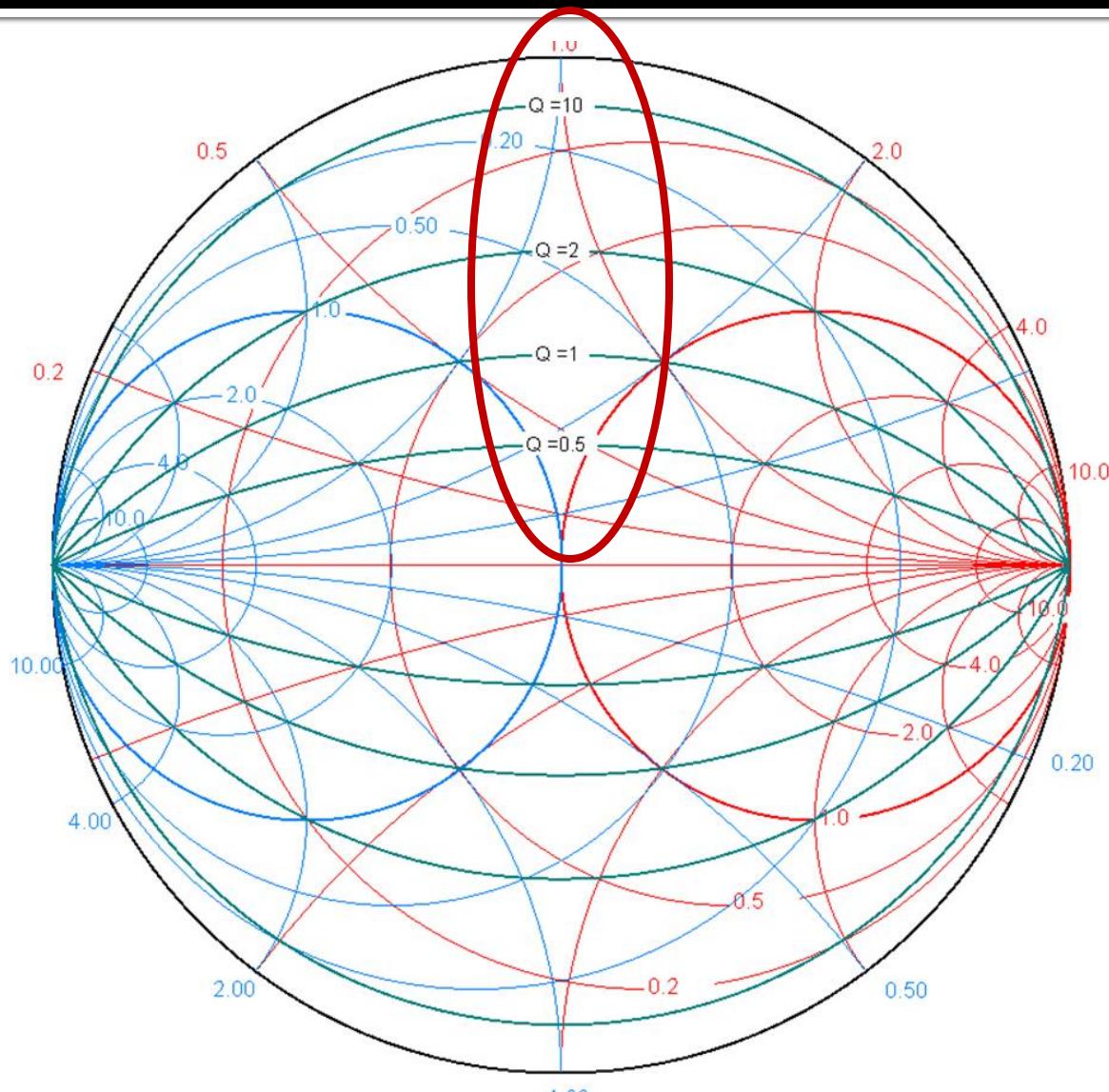
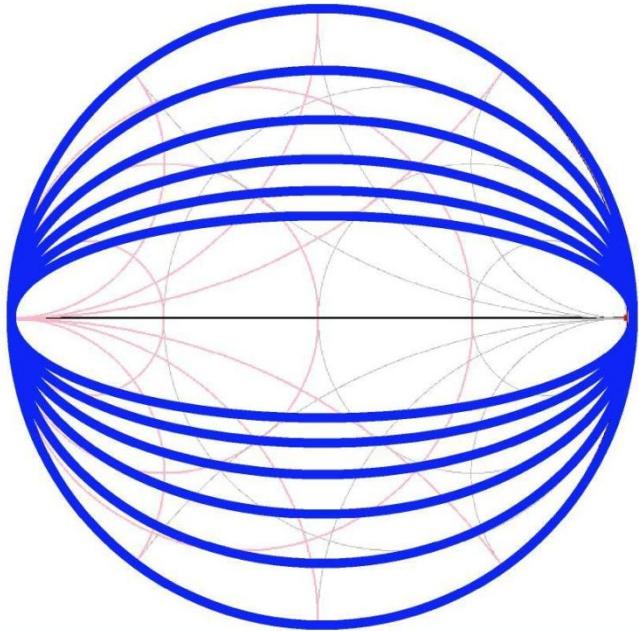
$$VSWR = \frac{V_{\max}}{V_{\min}} = \frac{1+|\Gamma|}{1-|\Gamma|}$$



# Cercuri de factor de calitate constant

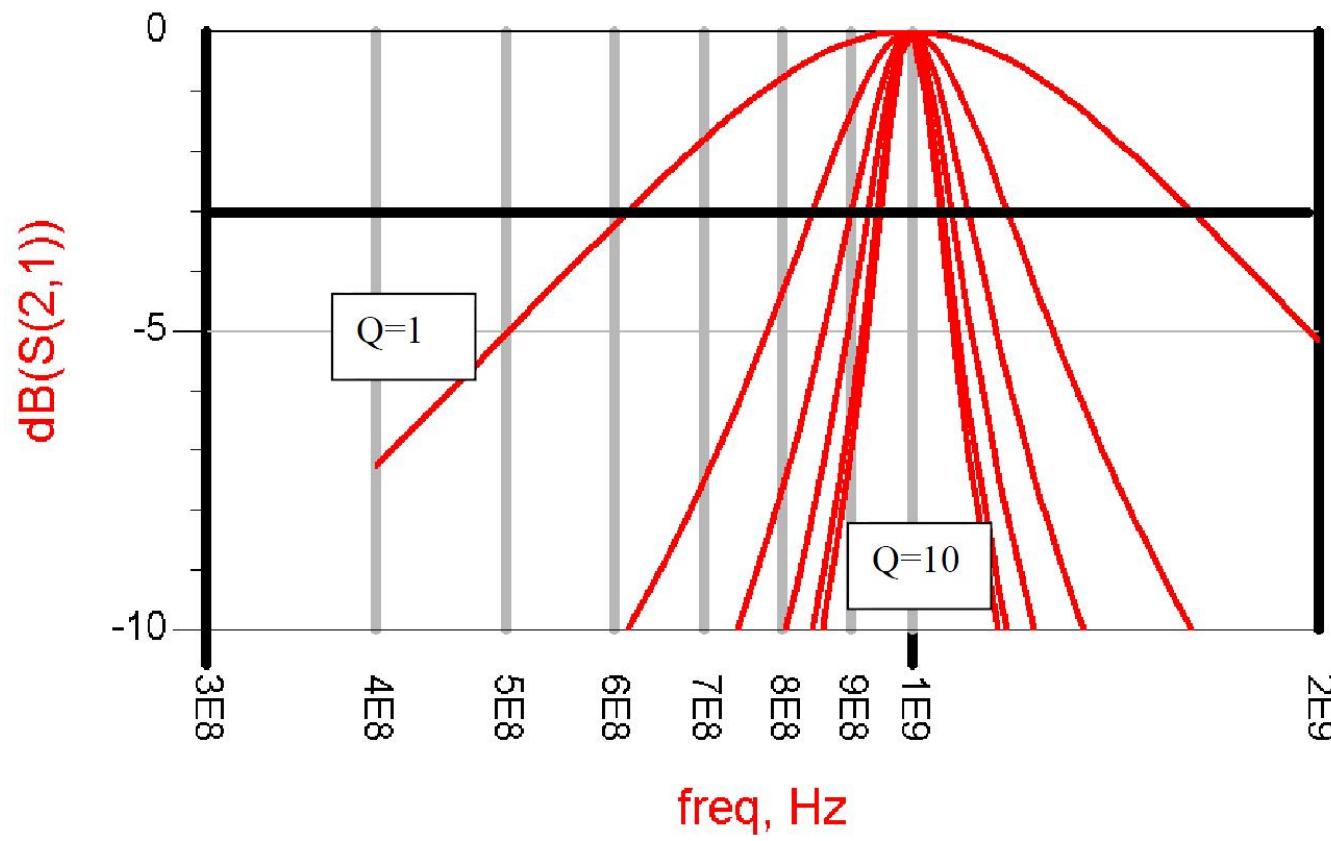
- Diagrama Smith

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



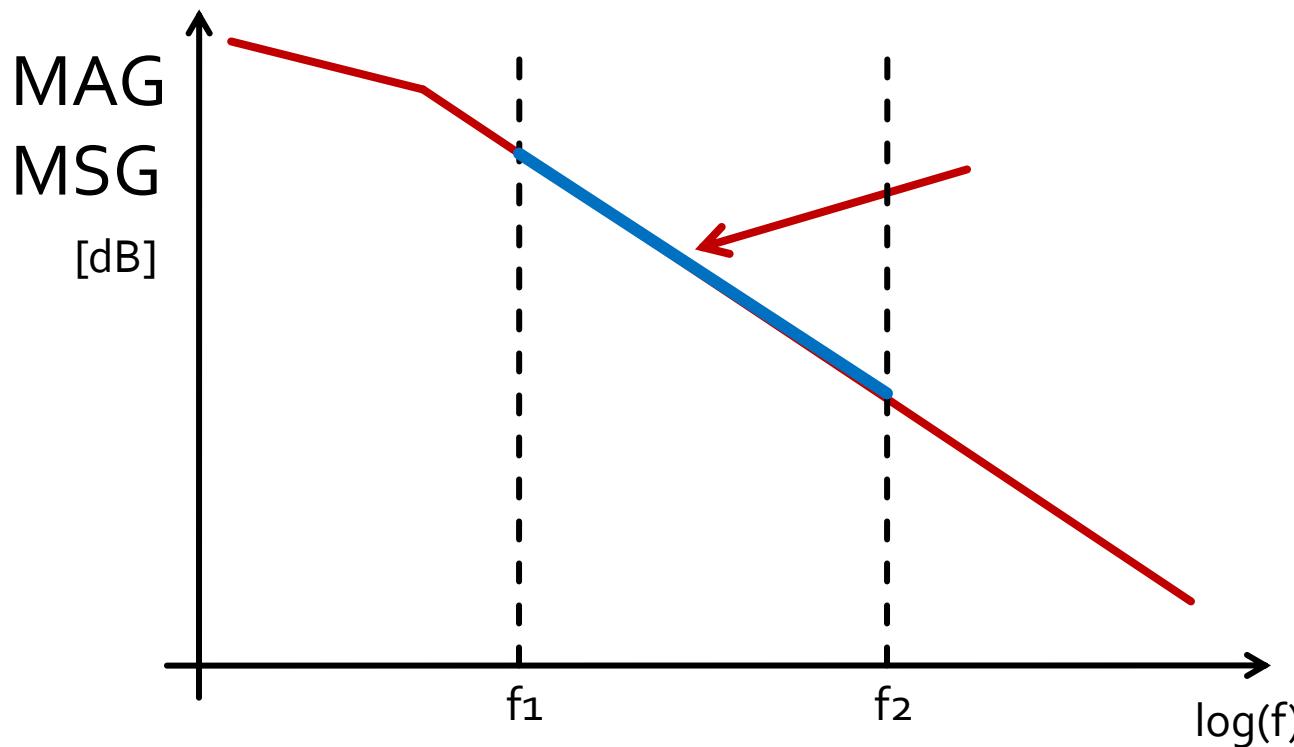
# Factor de calitate - banda

- Factor de calitate ridicat echivalent cu banda ingusta



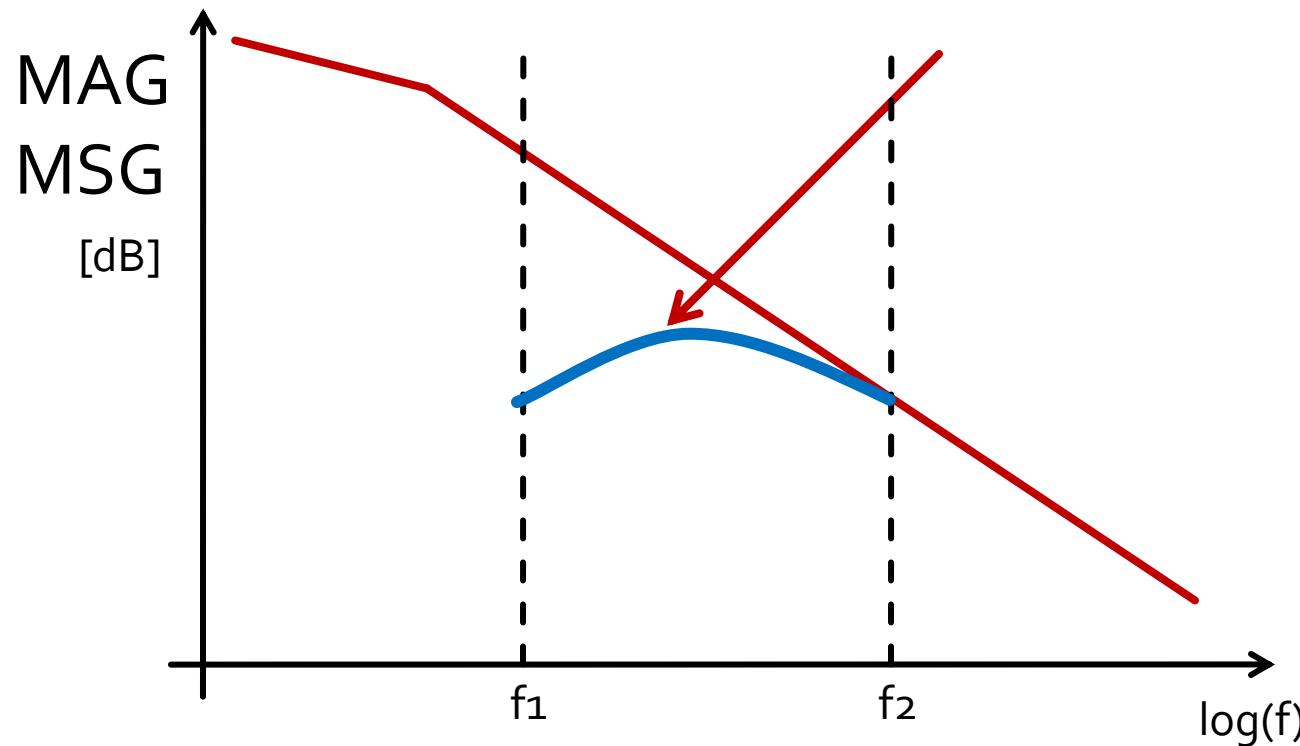
# Amplificator de banda largă

- 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

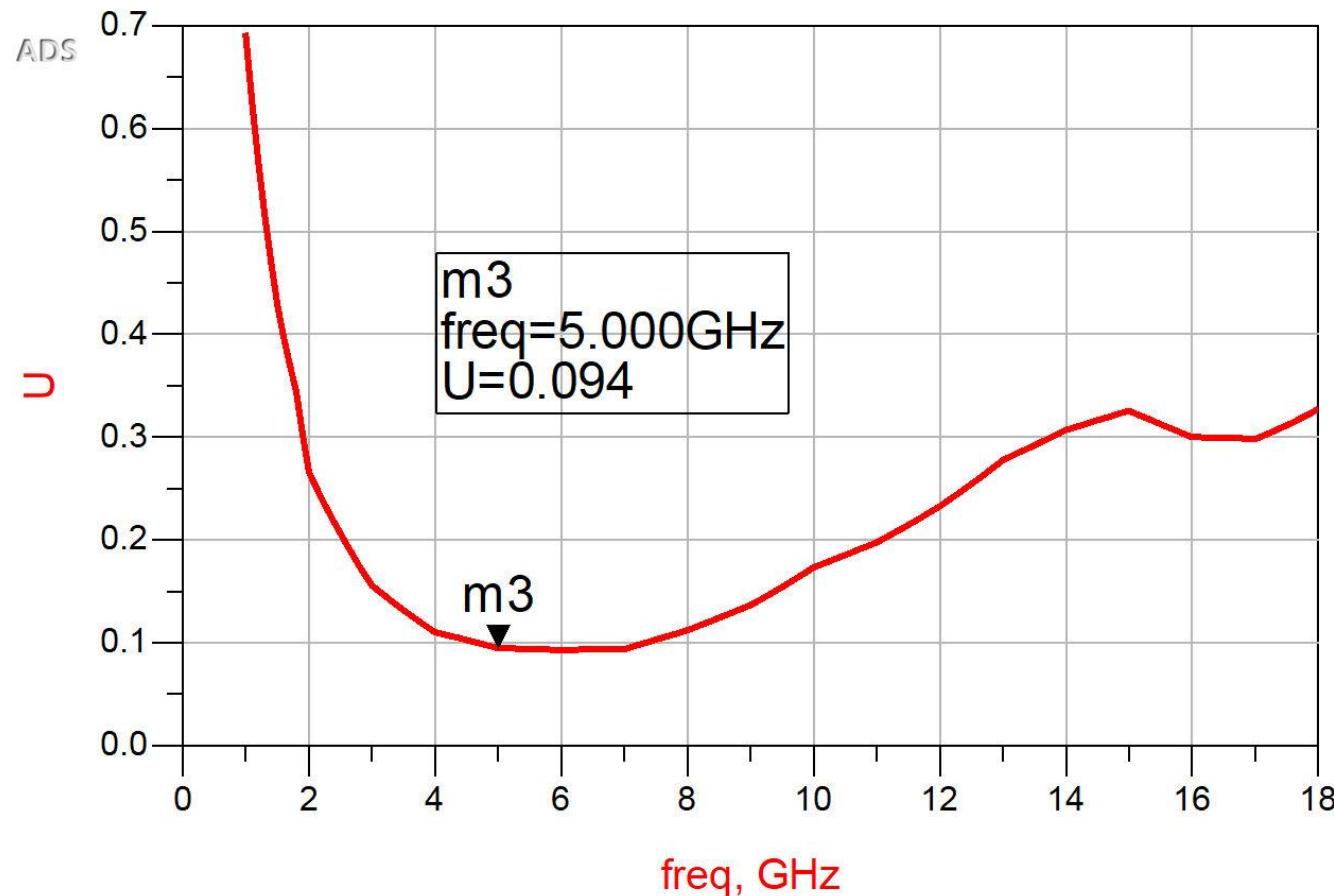
- ATF-34143 at  $V_{ds}=3V$   $I_d=20mA$ .
- @5GHz
  - $S_{11} = 0.64 \angle 139^\circ$
  - $S_{12} = 0.119 \angle -21^\circ$
  - $S_{21} = 3.165 \angle 16^\circ$
  - $S_{22} = 0.22 \angle 146^\circ$

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

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

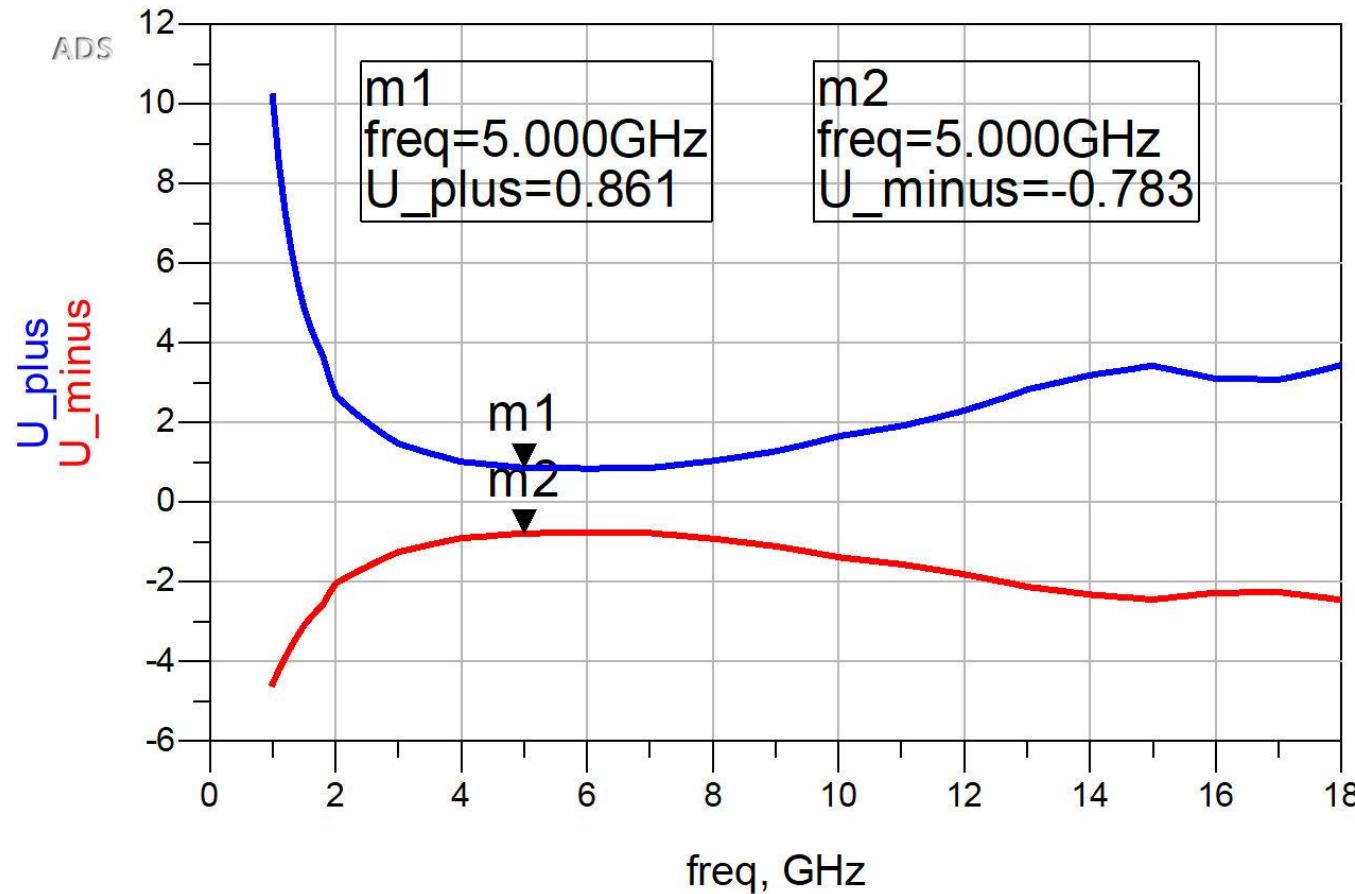
# Exemplu

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

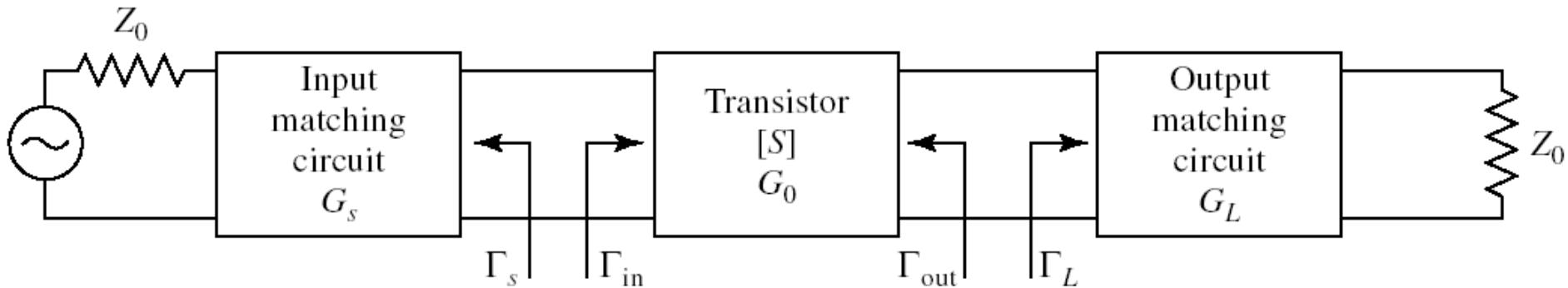


# Exemplu

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



# Proiectare pentru castig impus



- Daca ipoteza tranzistorului unilateral este justificata:

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

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

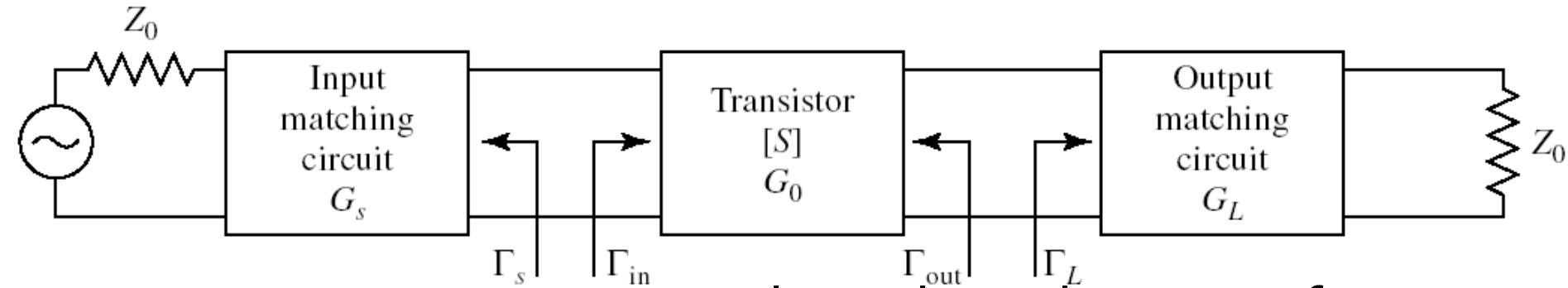
$$G_s = G_s(\Gamma_s)$$

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

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

$$G_L = G_L(\Gamma_L)$$

# Proiectare pentru castig impus

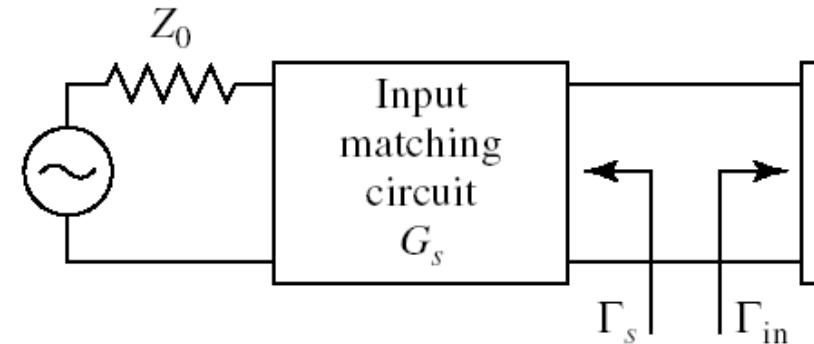


- **Daca** ipoteza tranzistorului unilateral este justificata:
  - castigul adaugat prin adaptare mai buna la intrare **nu** depinde de adaptarea la iesire  $G_s = G_s(\Gamma_s)$
  - castigul adaugat prin adaptare mai buna la iesire **nu** depinde de adaptarea la intrare  $G_L = G_L(\Gamma_L)$
- Adaptarile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

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

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

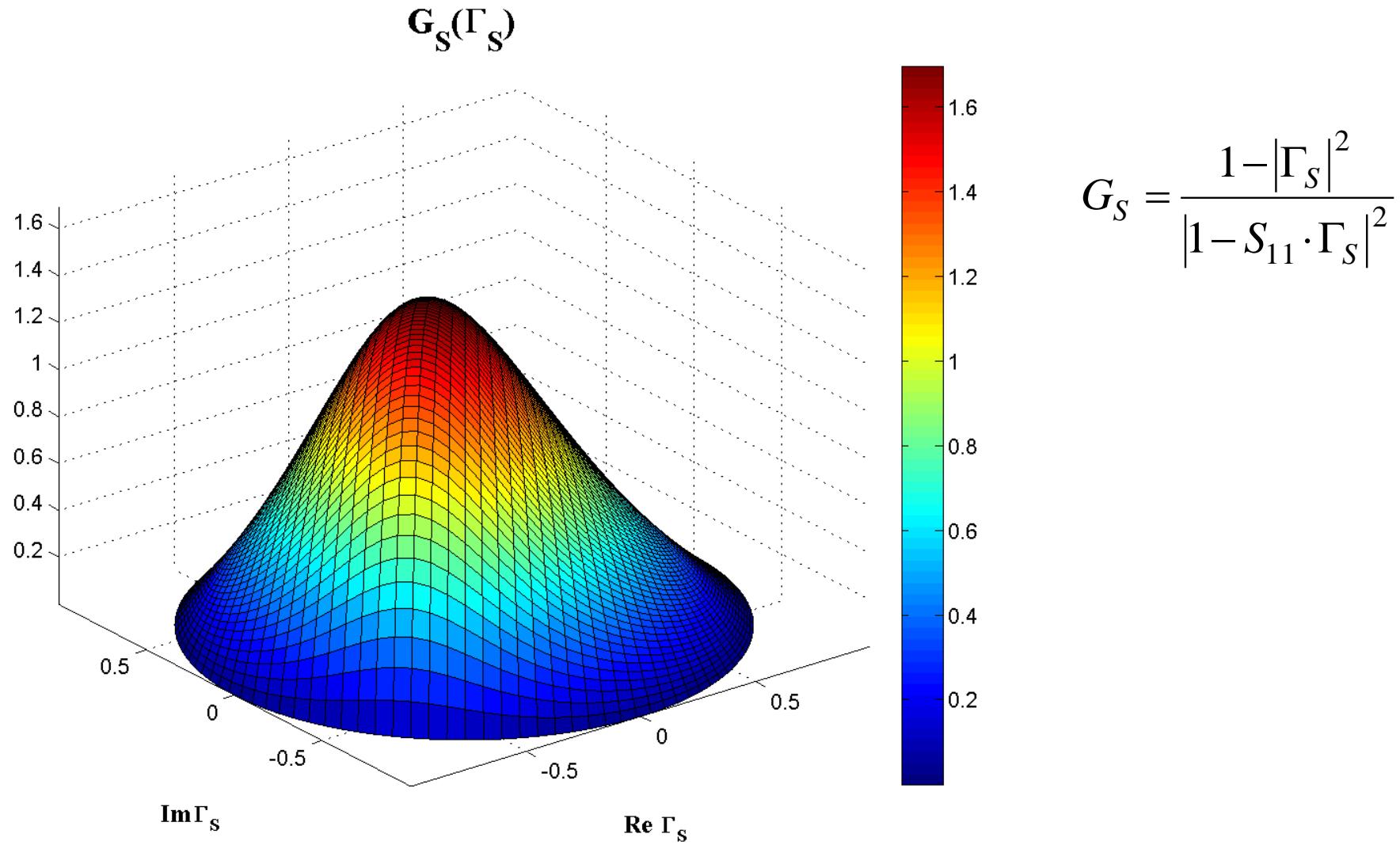
$$-0.783 \text{ dB} < G_T[\text{dB}] - G_{TU}[\text{dB}] < 0.861 \text{ dB}$$

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

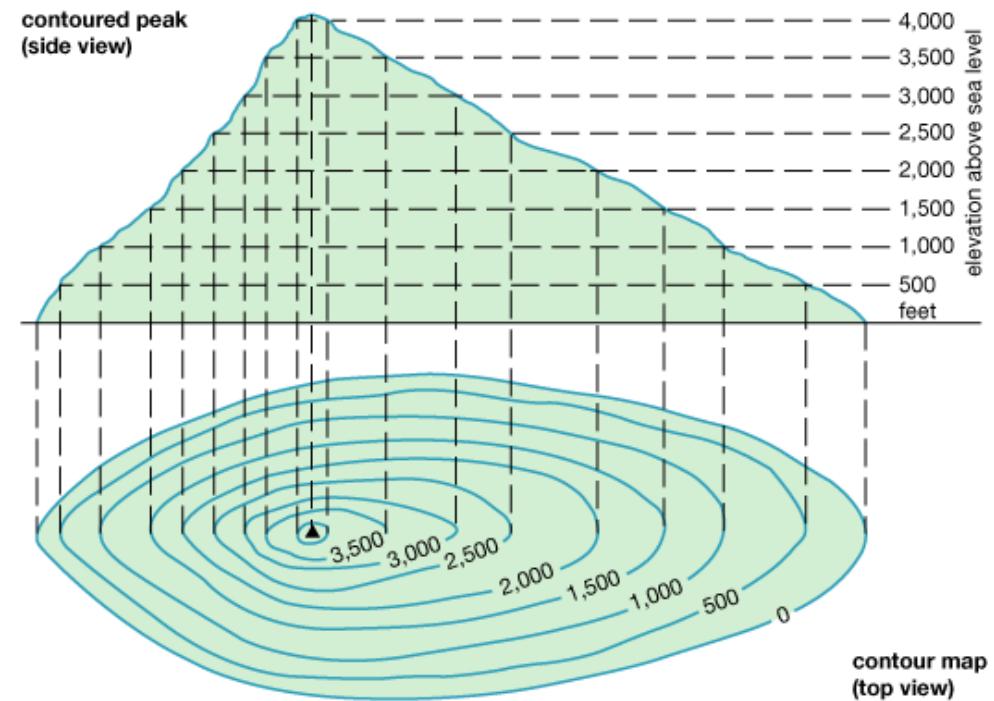
$$G_{TU \max} [\text{dB}] = 12.511 \text{ dB}$$

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

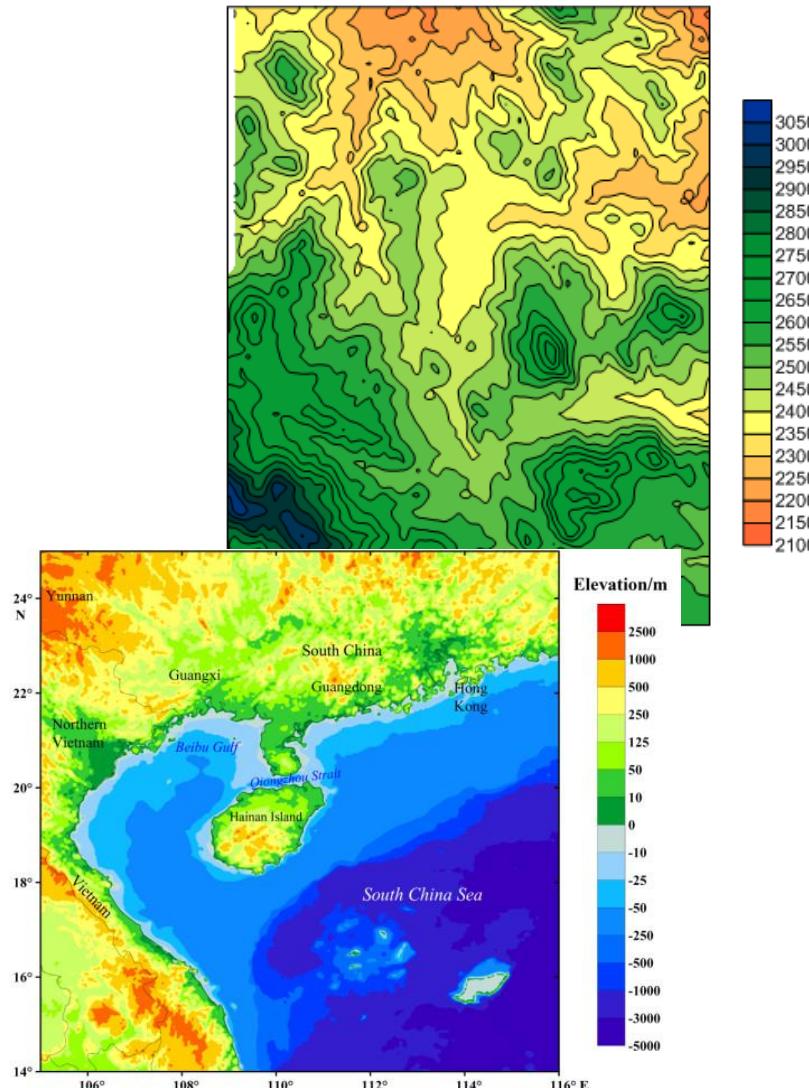
# $\mathbf{G}_S(\Gamma_S)$



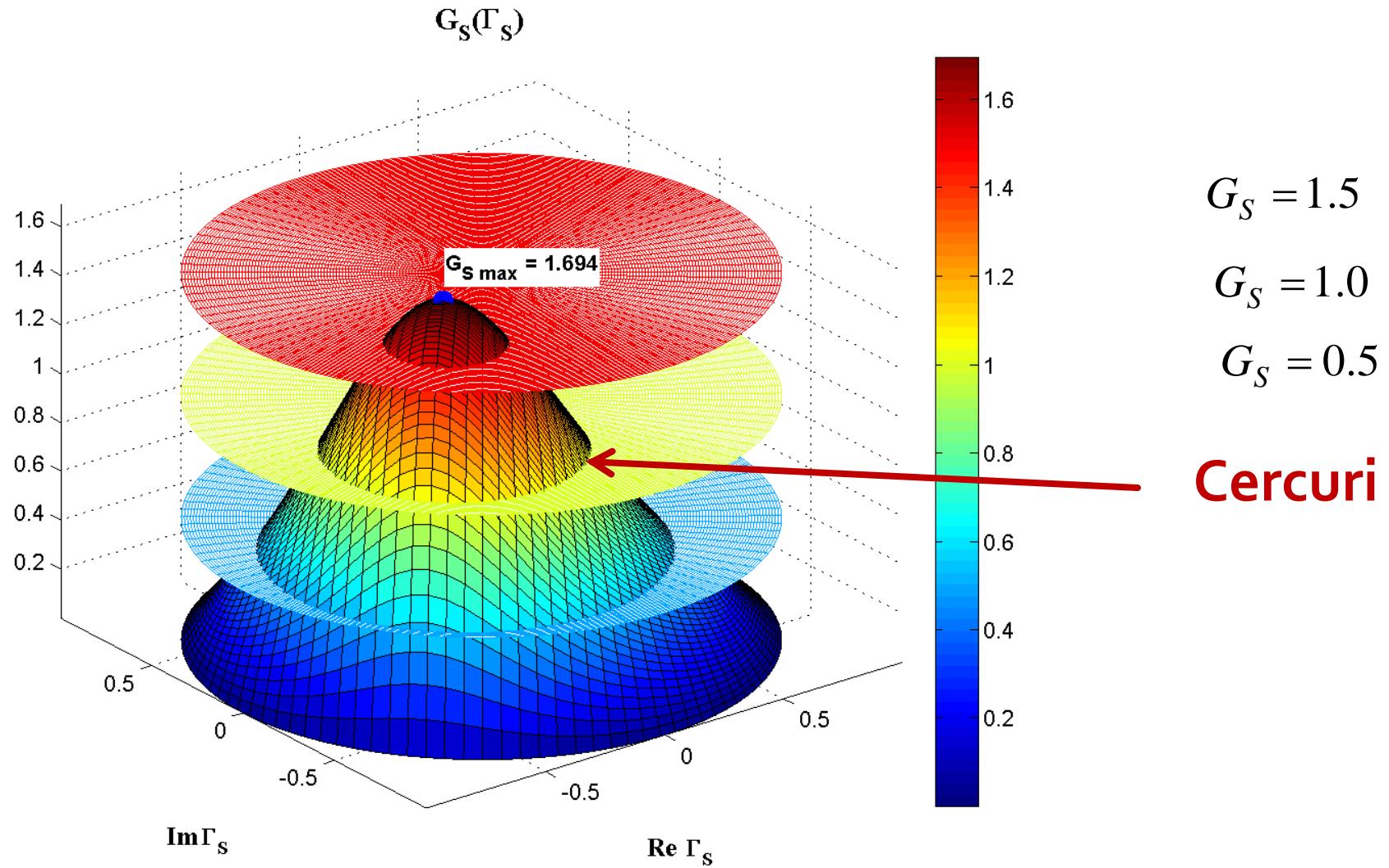
# Contour map/lines



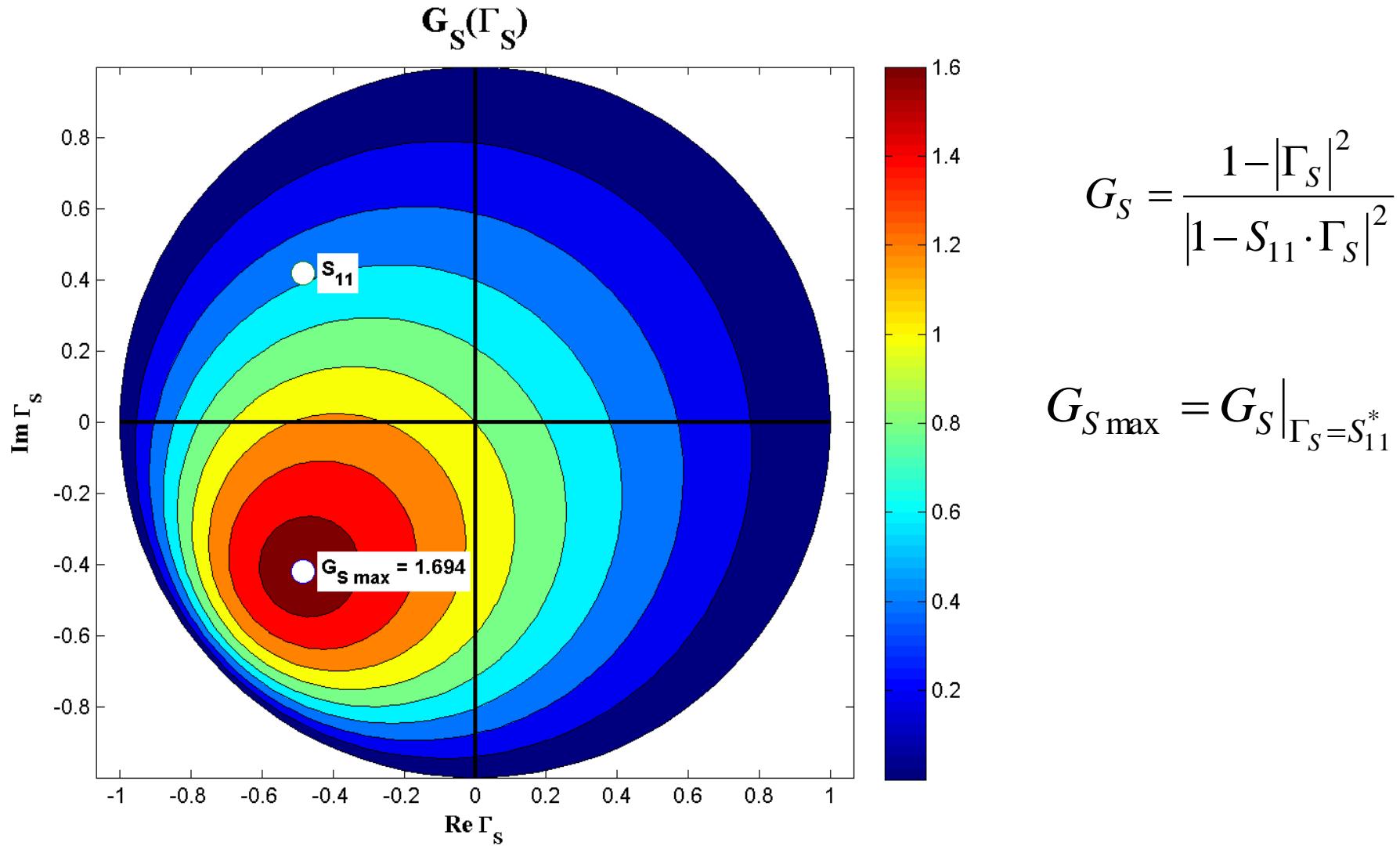
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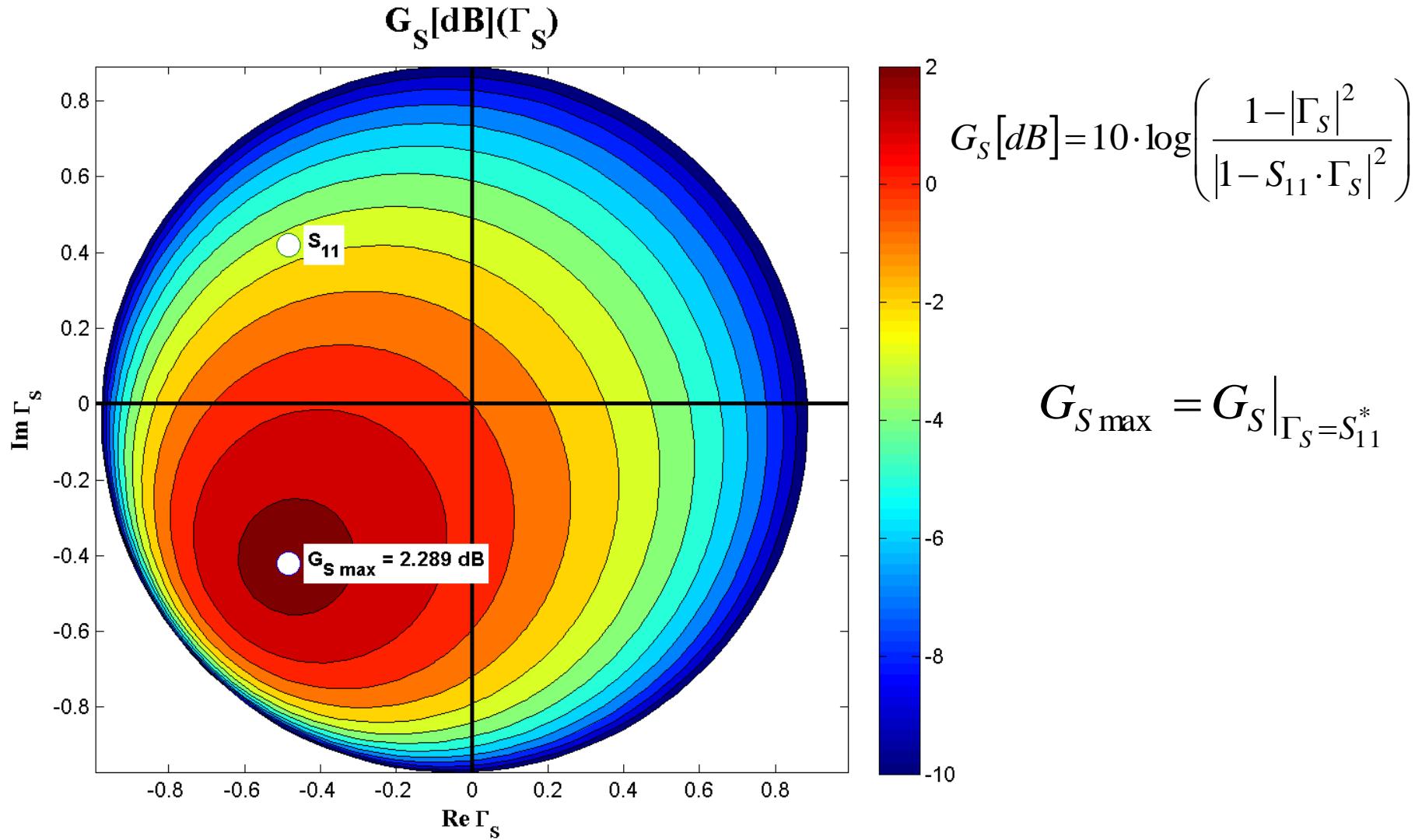
# $G_S(\Gamma_S)$ , nivel constant



# $G_S(\Gamma_S)$ , 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

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

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

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

# 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  $\Gamma_S$
- **Interpretare:** Orice punct  $\Gamma_S$  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  $G_S > G_{\text{cerc}}$

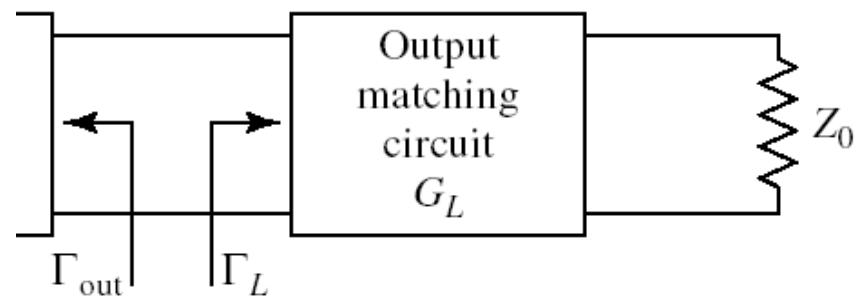
# Cercuri de castig constant la intrare

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

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

- 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

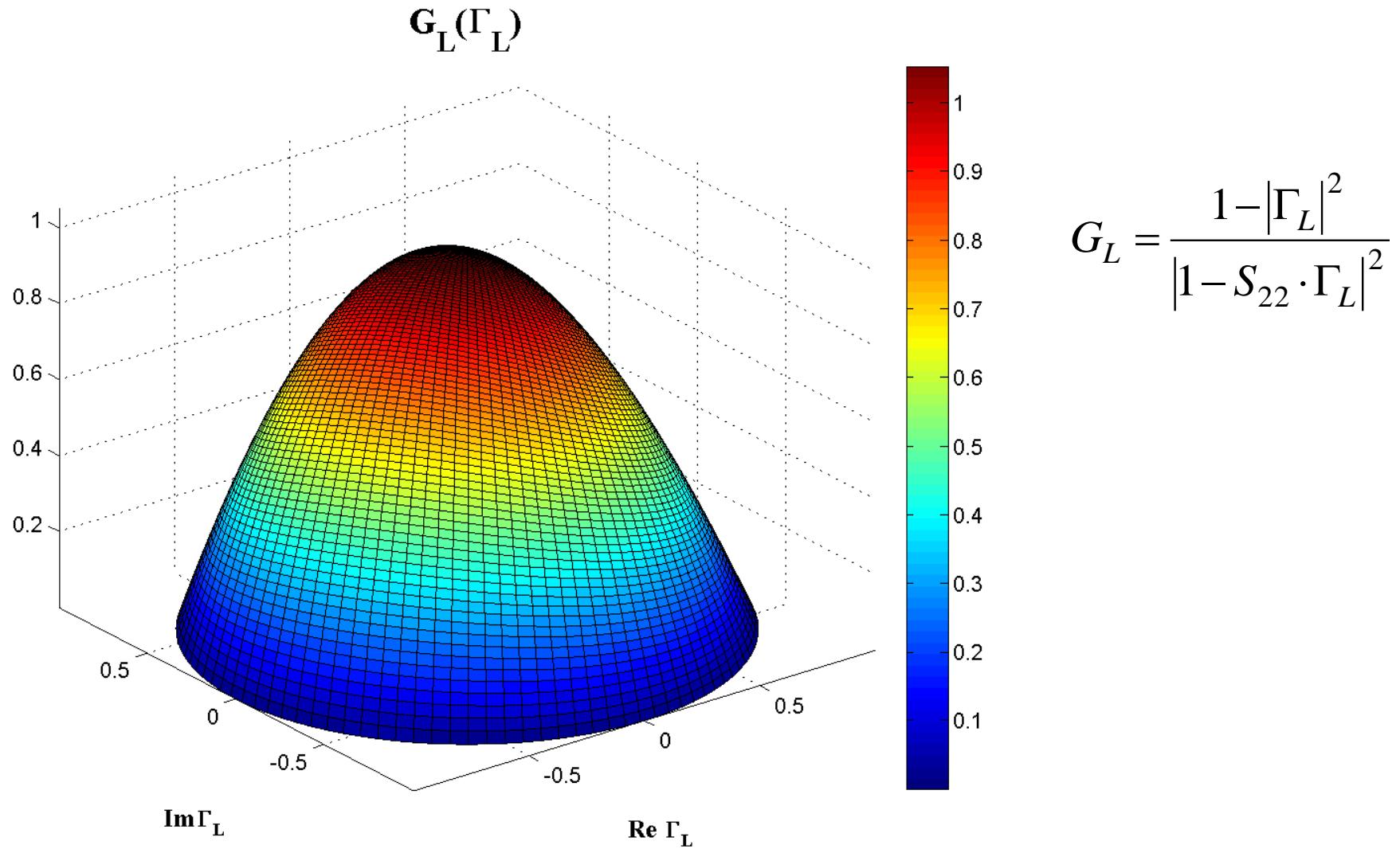
$$C_L = \frac{g_L \cdot S_{22}^*}{1 - (1 - g_L) \cdot |S_{22}|^2}$$

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

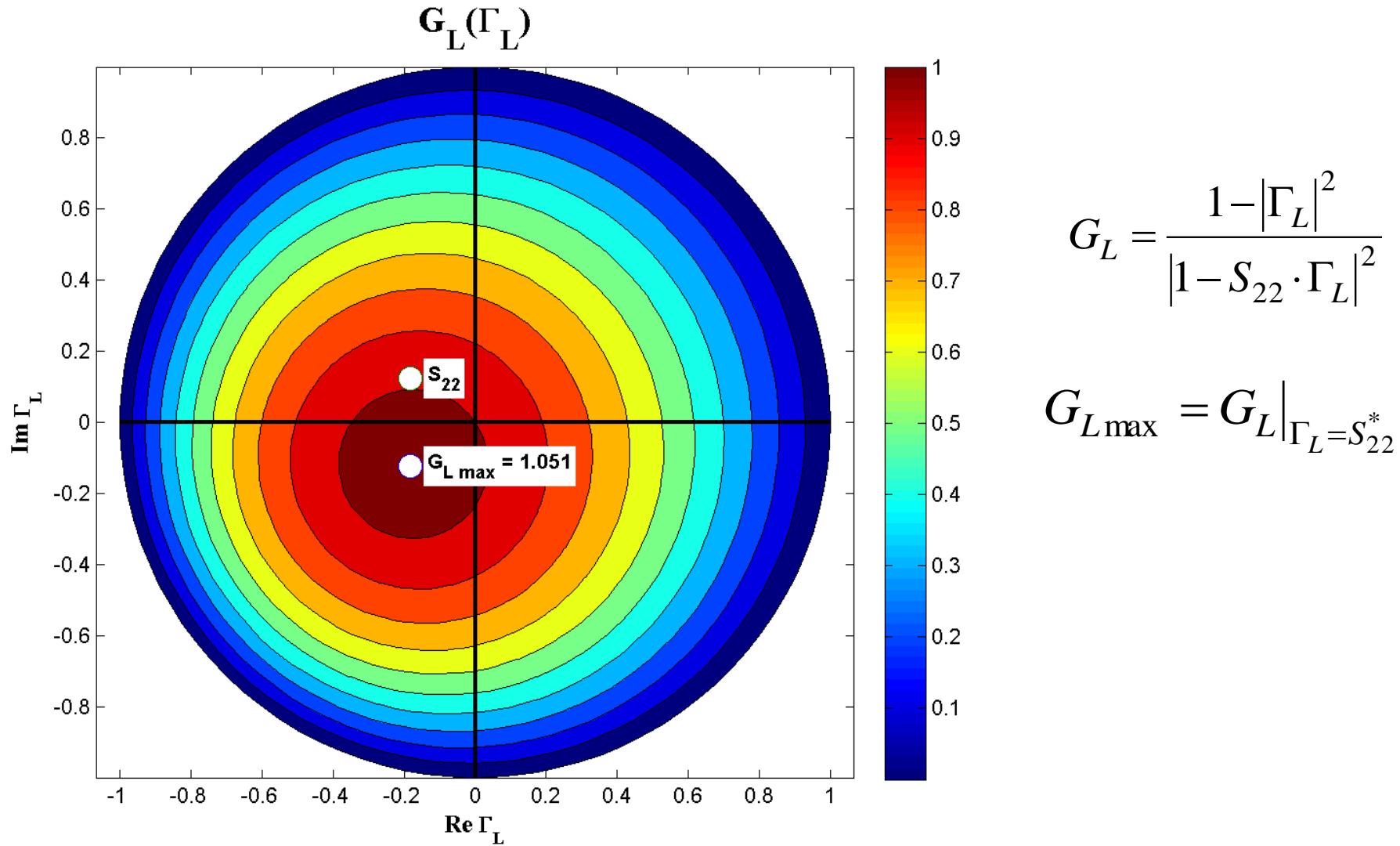
- Exemplu

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

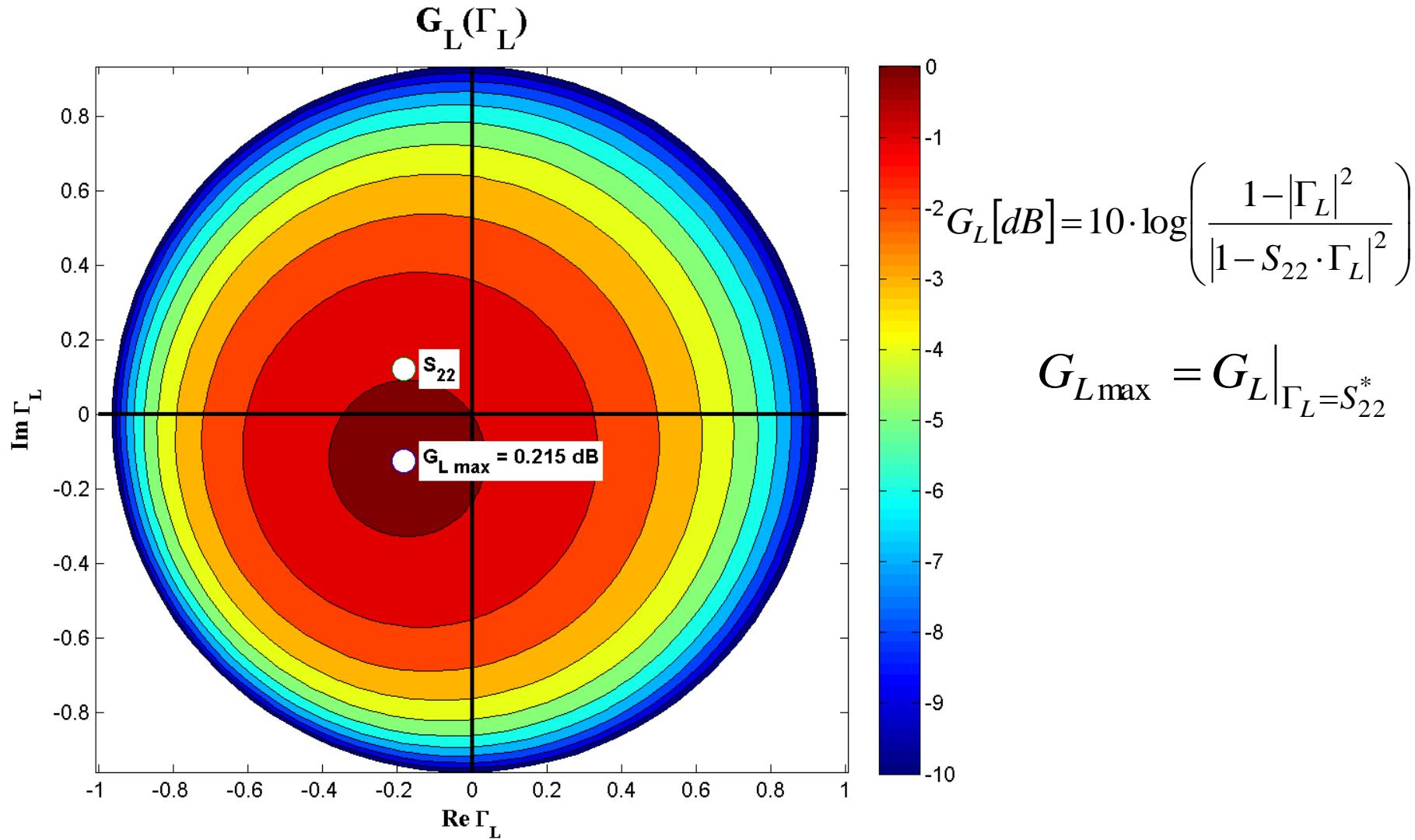
# $\mathbf{G}_L(\Gamma_L)$



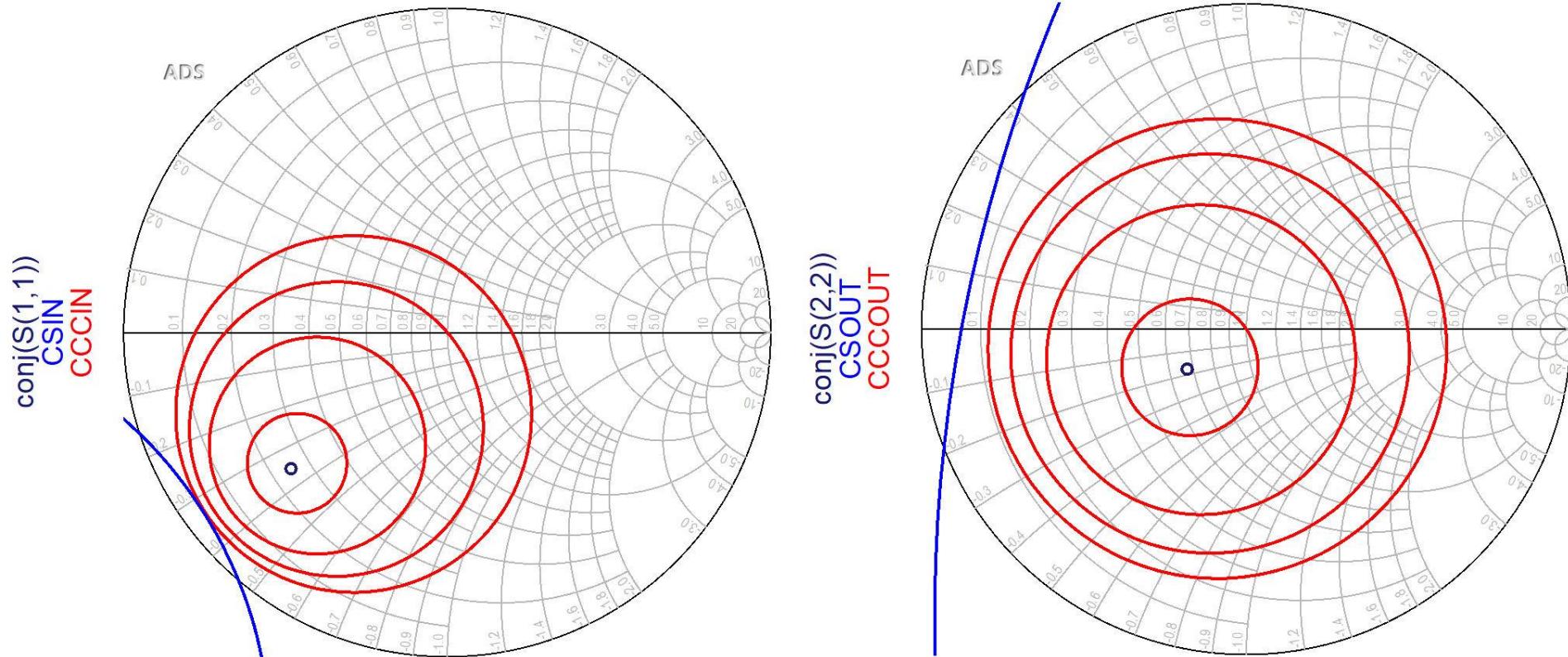
# $G_L(\Gamma_L)$ , diagrama de nível



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



# ADS



- 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

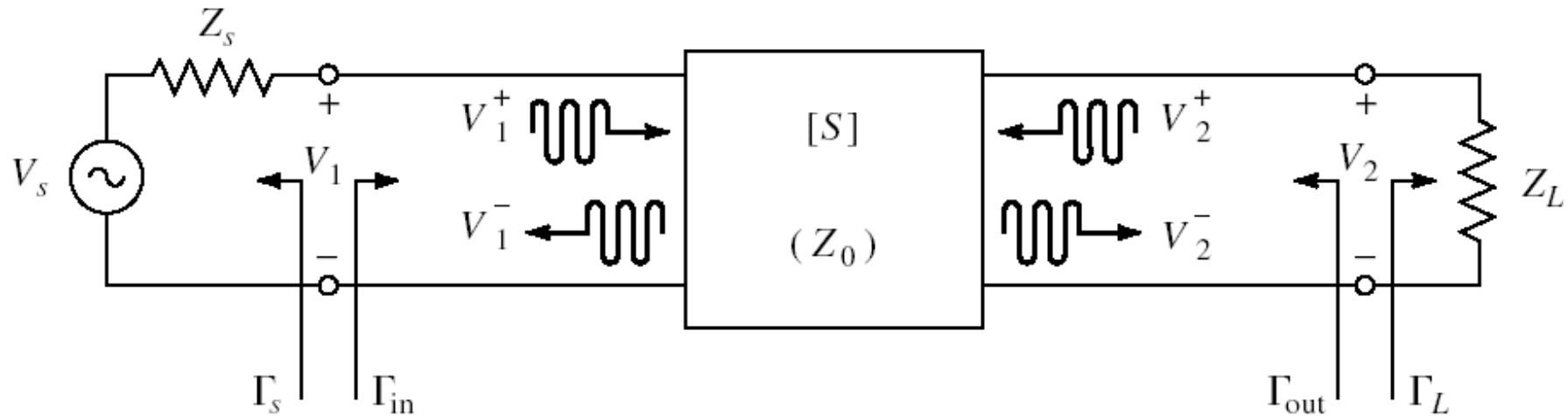
$$G_{dorit}[dB] = G_{S\_dor}[dB] + G_0[dB] + G_{L\_dor}[dB]$$

- 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)

Amplificatoare de microunde

# **Proiectare pentru zgomot redus**

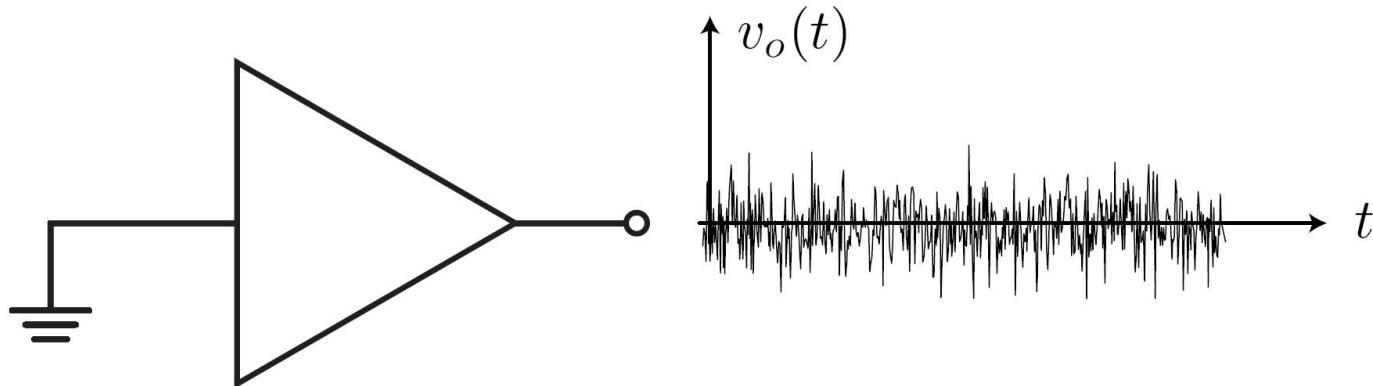
# Cuadripol Amplifier



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

# Zgomot

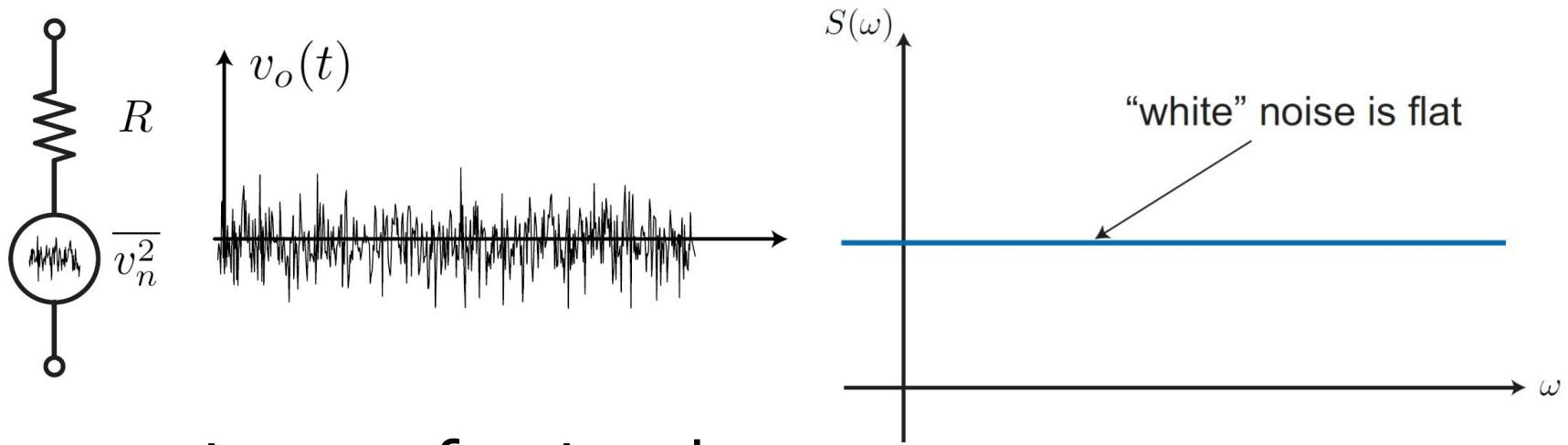
- Zgomot: variatii aleatorii ale semnalului



$$\overline{v_n(t)} = \langle v_n(t) \rangle = \frac{1}{T} \int_0^T v_n(t) dt = 0$$

$$\overline{v_n^2(t)} = \langle v_n^2(t) \rangle = \frac{1}{T} \int_0^T v_n^2(t) dt \neq 0 \quad V_{n(ef)} = \sqrt{\overline{v_n^2(t)}}$$

# Zgomot



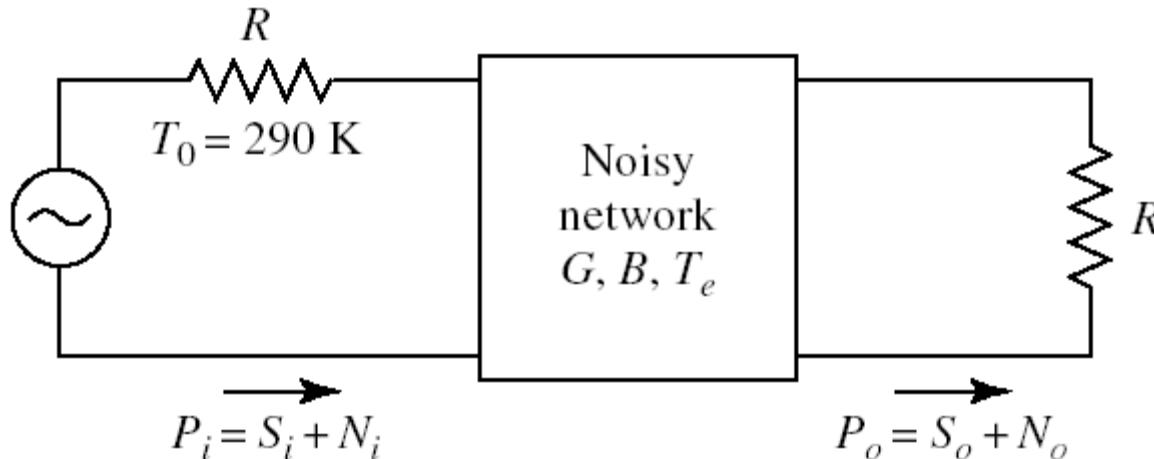
- tensiunea efectiva de zgomot

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

- puterea disponibila de zgomot (furnizata restului circuitului - maxim)

$$P_n = kTB$$

# Factor de zgomot

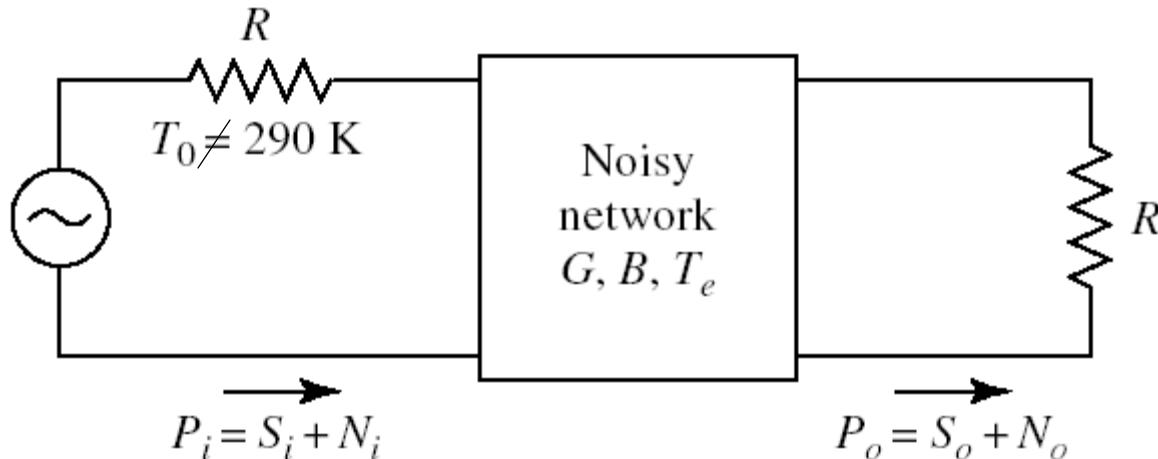


- Factorul de zgomot  $F$  caracterizeaza degradarea raportului semnal/zgomot intre intrarea si iesirea unei componente, cand la intrare se aplica o putere de zgomot de referinta ( $T_0 = 290\text{K}$ )

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

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

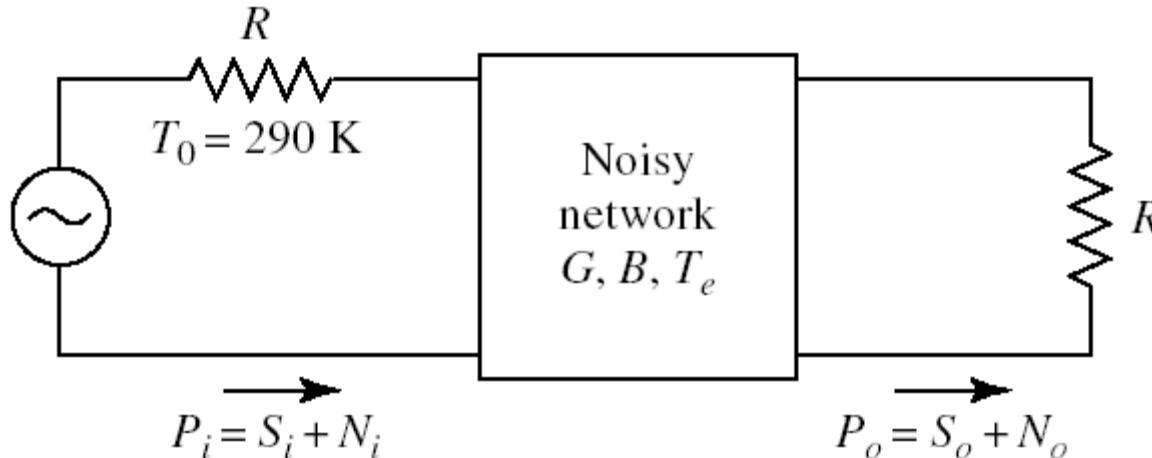
# Factor de zgomot



- 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

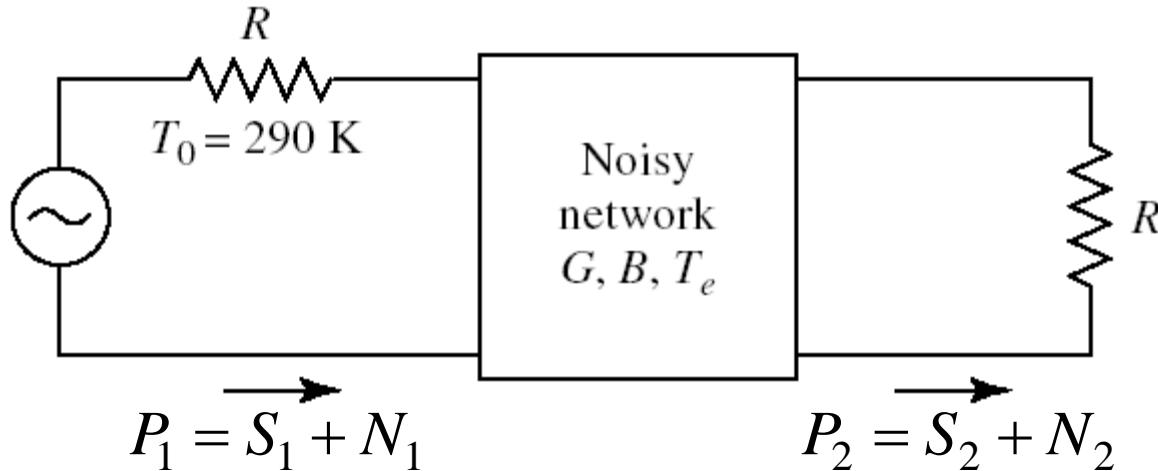
$$F \neq \left. \frac{S_i/N_i}{S_o/N_o} \right|_{T_0 \neq 290K}$$

# 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



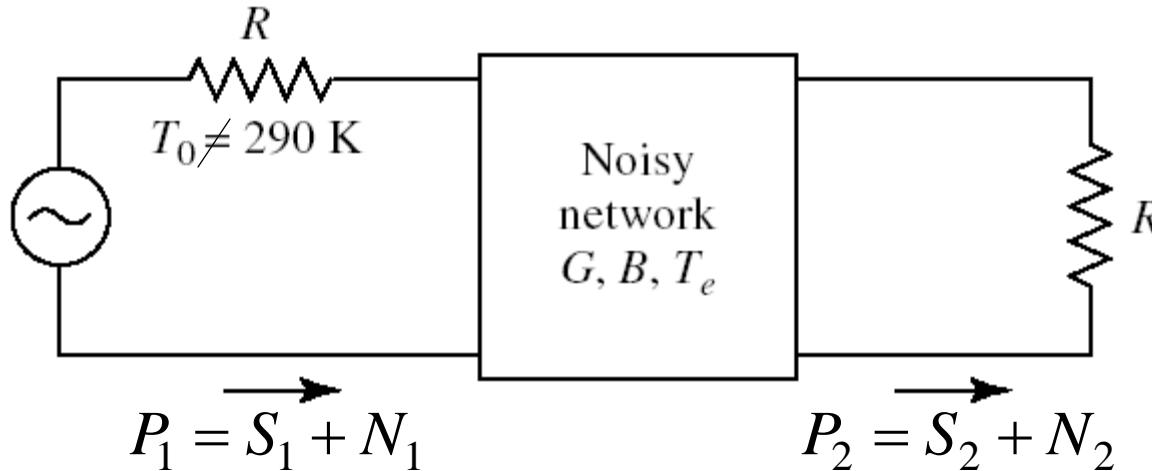
- Estimarea puterii de zgomot adaugate se poate face plecand de la definitia factorului de zgomot:

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

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

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

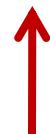
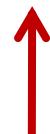
# Factor de zgomot



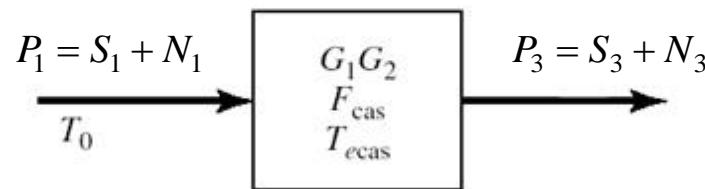
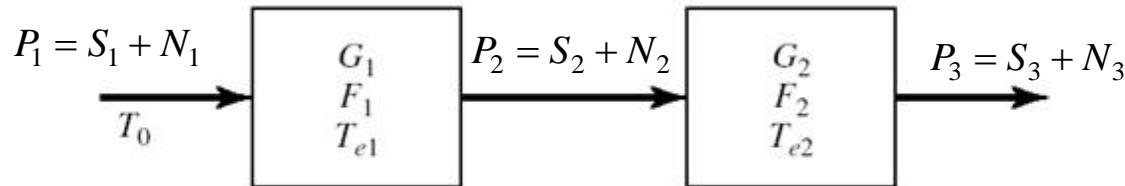
- Se identifica cele două termeni:
  - zgomotul de intrare amplificat
  - zgomotul adăugat intern
- Pentru o situație în care la intrare nu am zgomotul de referință ( $N_1 \neq N_0$ )

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

$$N_2 = N_1 \cdot G + (F - 1) \cdot N_0 \cdot G$$



# Factor de zgomot al circuitelor cascade



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

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

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

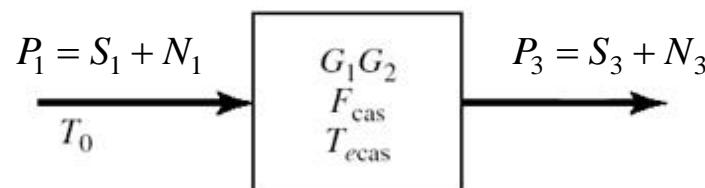
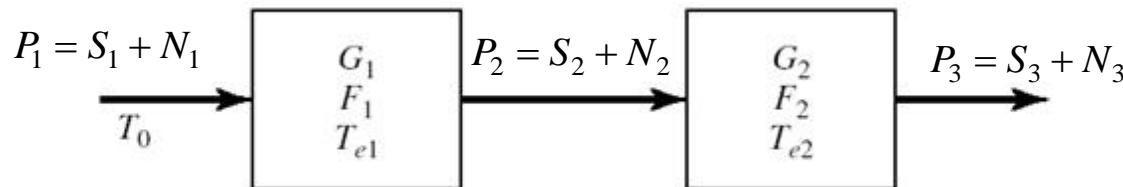
$$N_3 = N_1 \cdot G_{cas} + (F_{cas} - 1) \cdot N_0 \cdot G_{cas}$$



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

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

# Factor de zgomot al circuitelor cascade



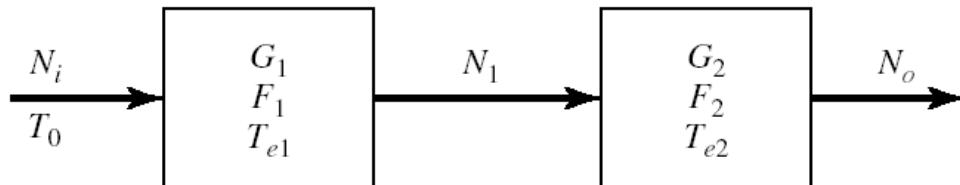
$$N_3 = N_1 \cdot G_1 \cdot G_2 + (F_1 - 1) \cdot N_0 \cdot G_1 \cdot G_2 + (F_2 - 1) \cdot N_0 \cdot G_2$$

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

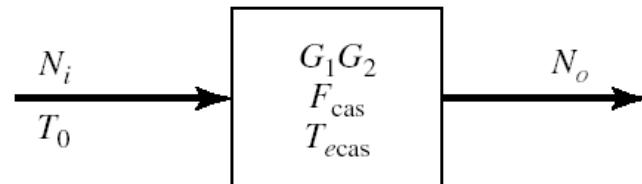
$$(F_1 - 1) \cdot N_0 \cdot G_1 \cdot G_2 + (F_2 - 1) \cdot N_0 \cdot G_2 = (F_{cas} - 1) \cdot N_0 \cdot G_1 \cdot G_2$$

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

# 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)

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

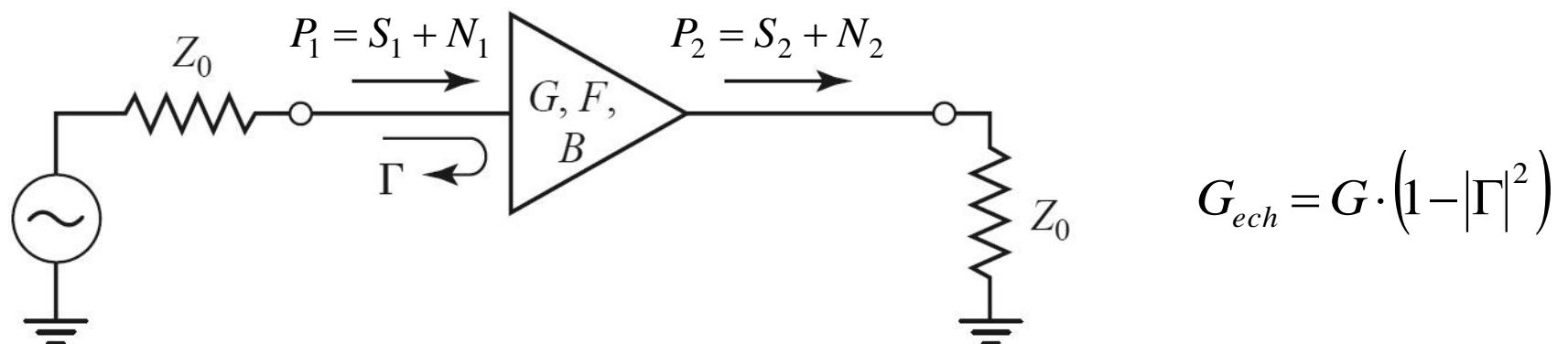
- Formula lui Friis, efecte:
  - in amplificatoare multietaj:
    - e esential ca primul etaj de amplificare sa fie nezgomotos, chiar cu sacrificarea in parte a castigului
    - urmatoarele etaje pot fi optimizate pentru castig
  - pentru un singur amplificator:
    - la intrare e important sa introducem 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
```

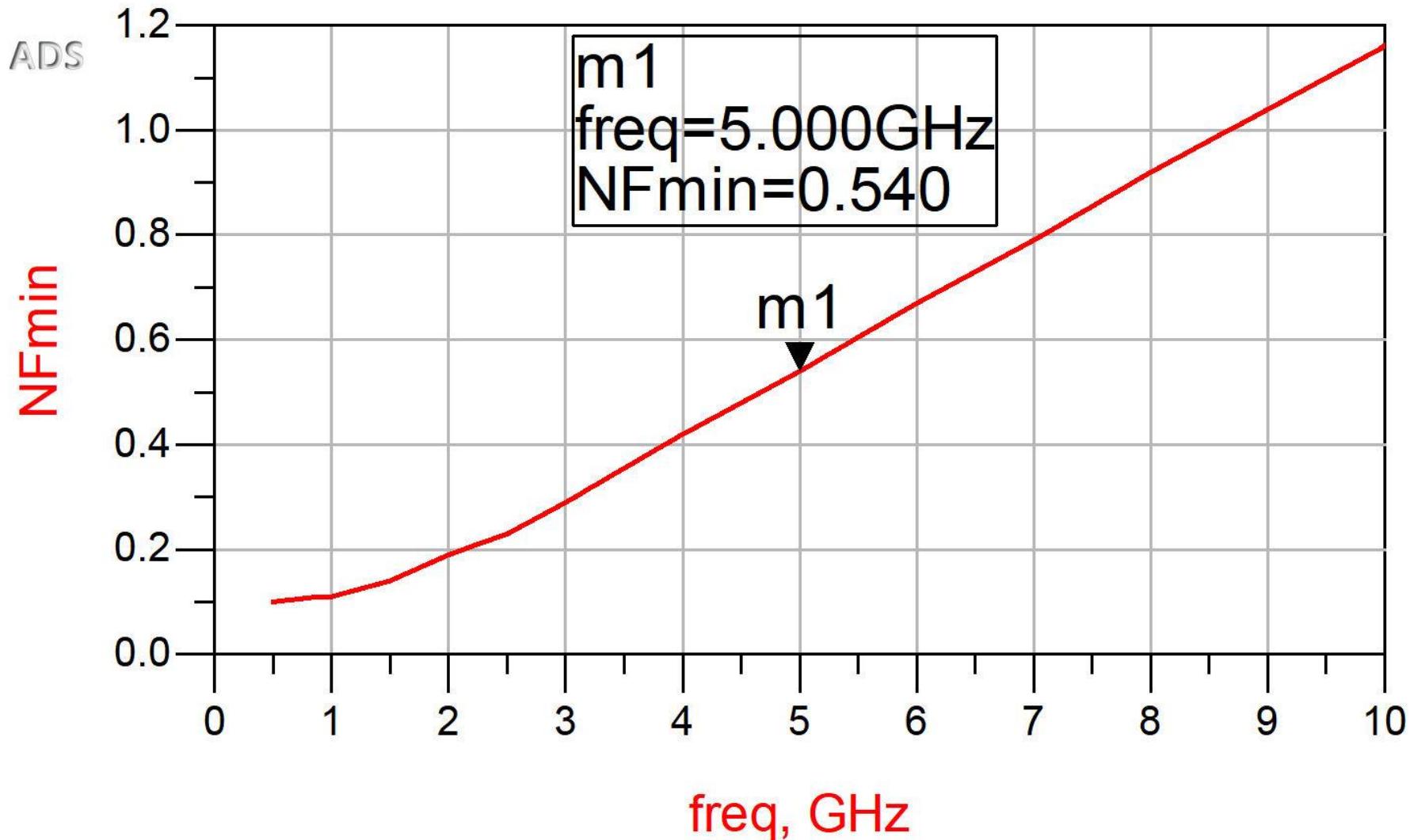
```
2.0 0.75 -126 6.306 90 0.088 23 0.26 -120
2.5 0.72 -145 5.438 75 0.095 15 0.25 -140
3.0 0.69 -162 4.762 62 0.102 7 0.23 -156
4.0 0.65 166 3.806 38 0.111 -8 0.22 174
5.0 0.64 139 3.165 16 0.119 -21 0.22 146
6.0 0.65 114 2.706 -5 0.125 -35 0.23 118
7.0 0.66 89 2.326 -27 0.129 -49 0.25 91
8.0 0.69 67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

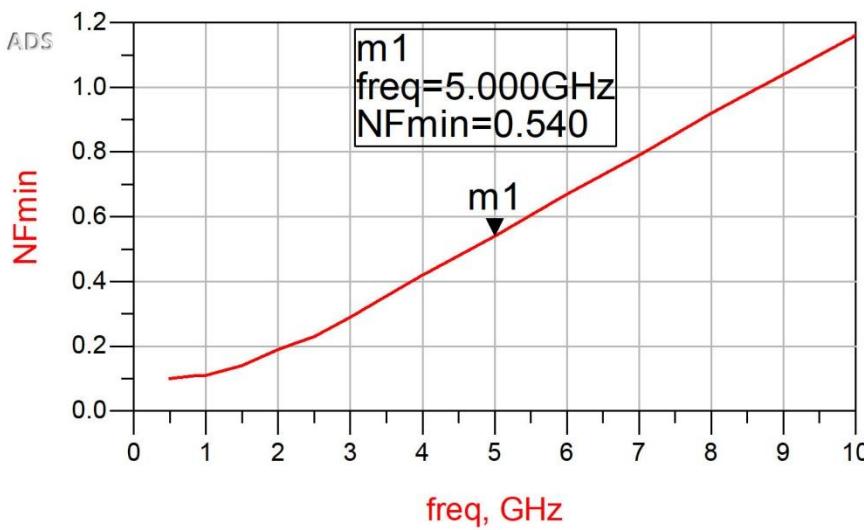
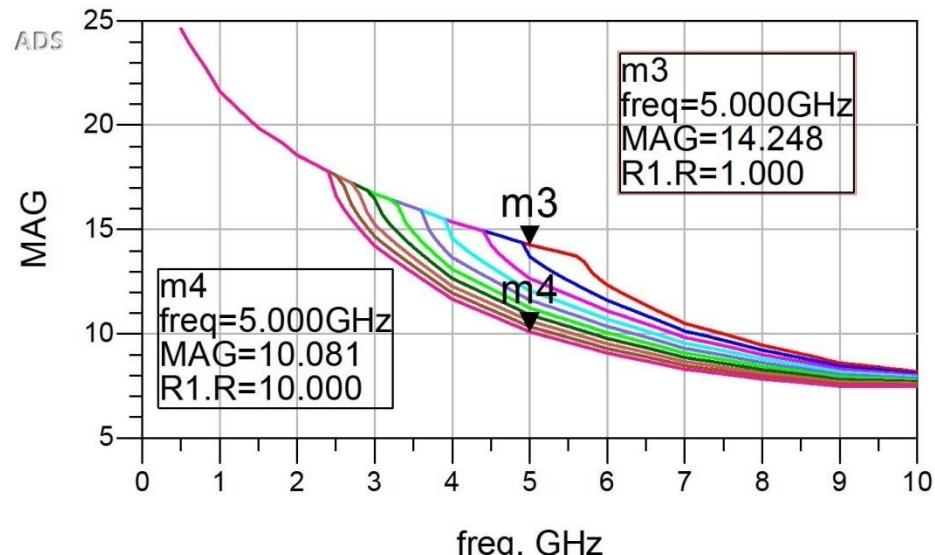
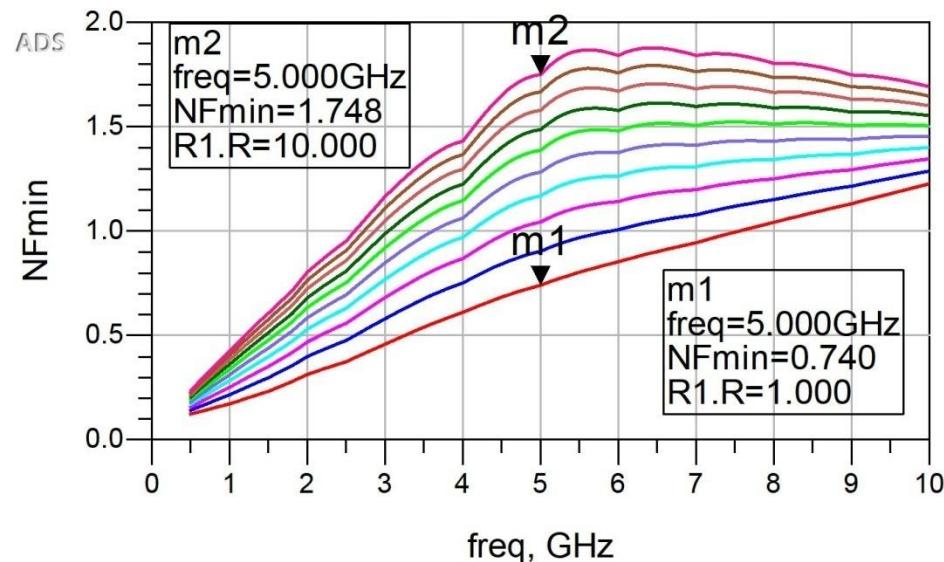
```
2.0 0.19 0.71 66 0.09
2.5 0.23 0.65 83 0.07
3.0 0.29 0.59 102 0.06
4.0 0.42 0.51 138 0.03
```

```
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

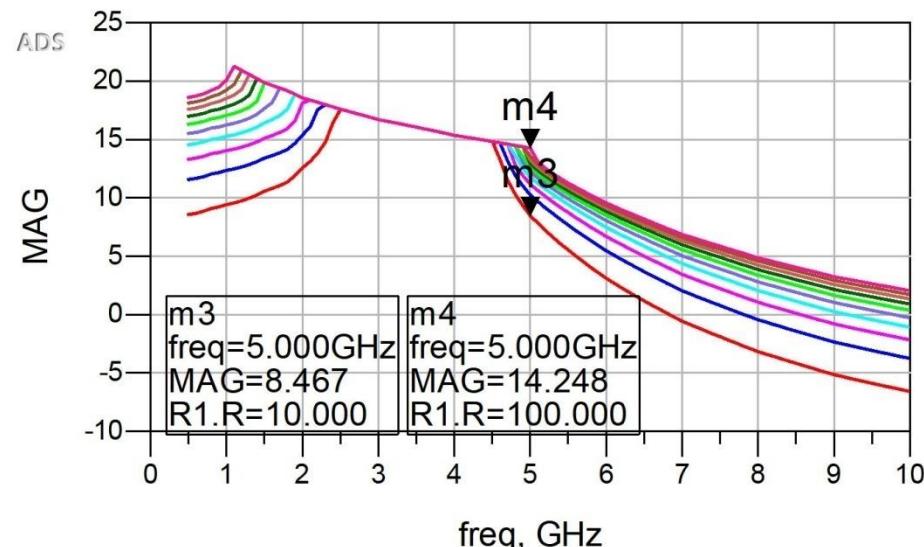
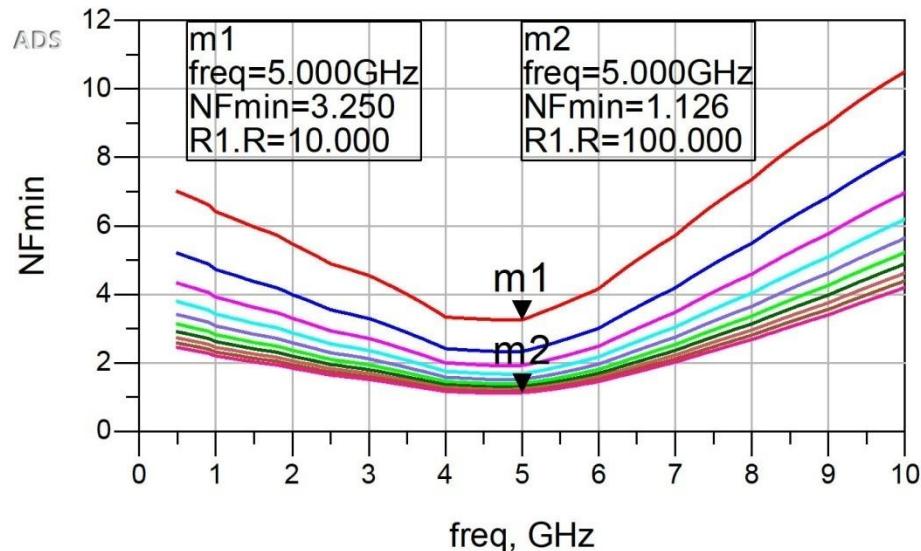


# Stabilizzare R serie la intrare

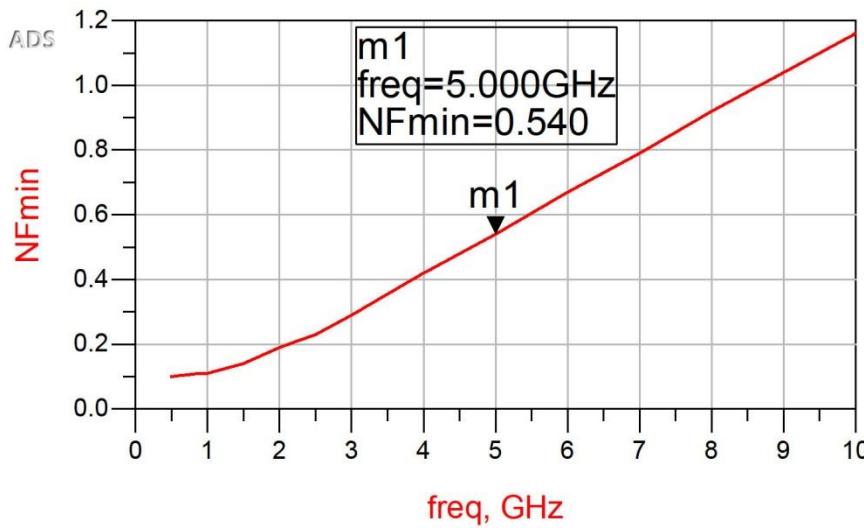


$$R_{SS} = 1 \div 10 \Omega$$

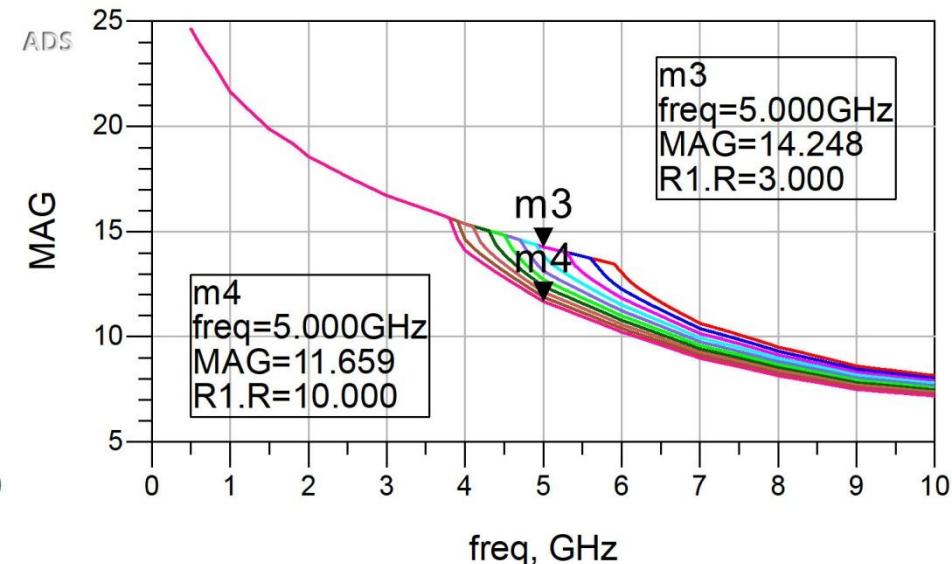
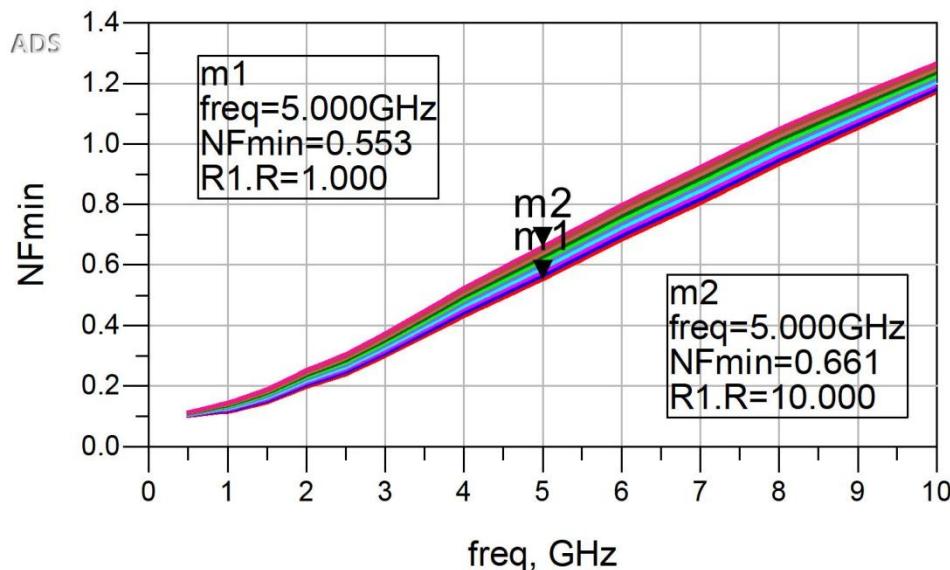
# Stabilizare R paralel la intrare



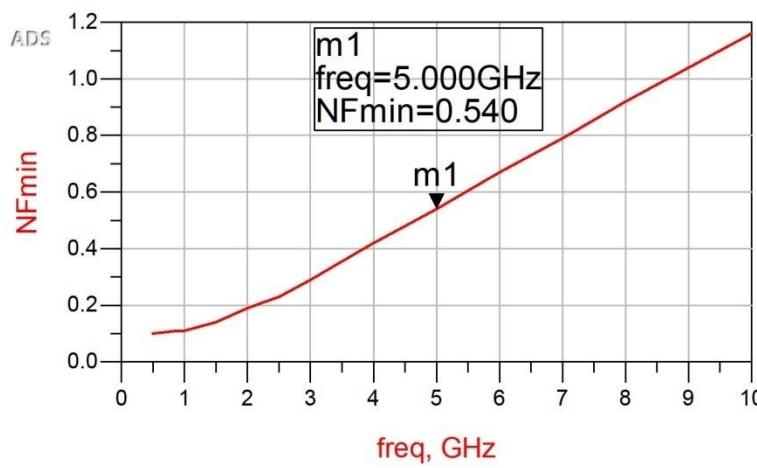
$$R_{PS} = 10 \div 100 \Omega$$



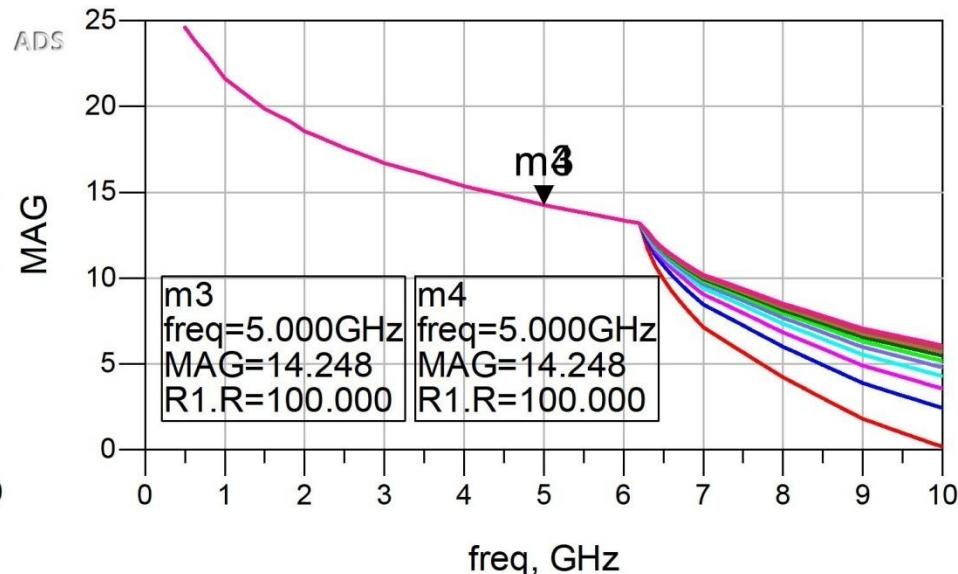
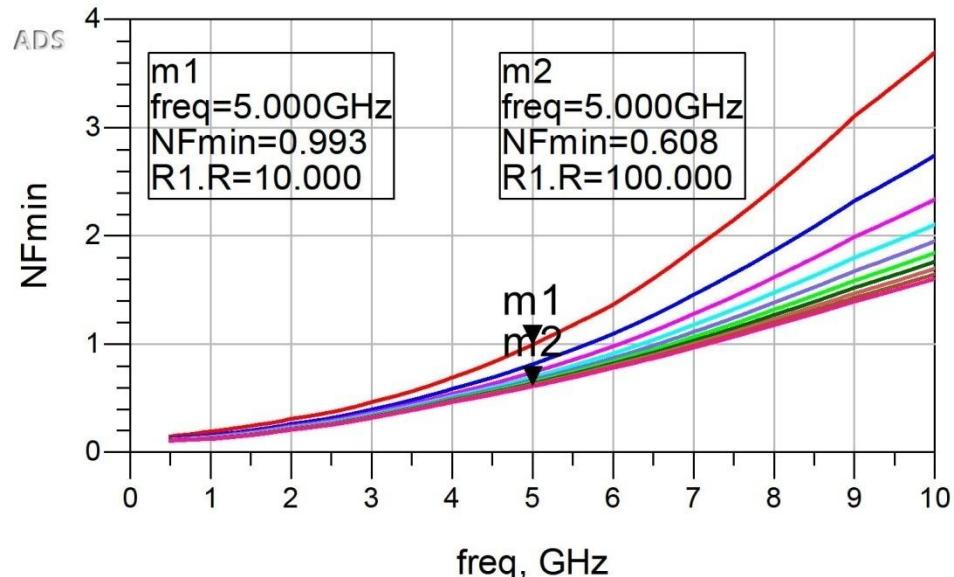
# Stabilizare R serie la ieșire



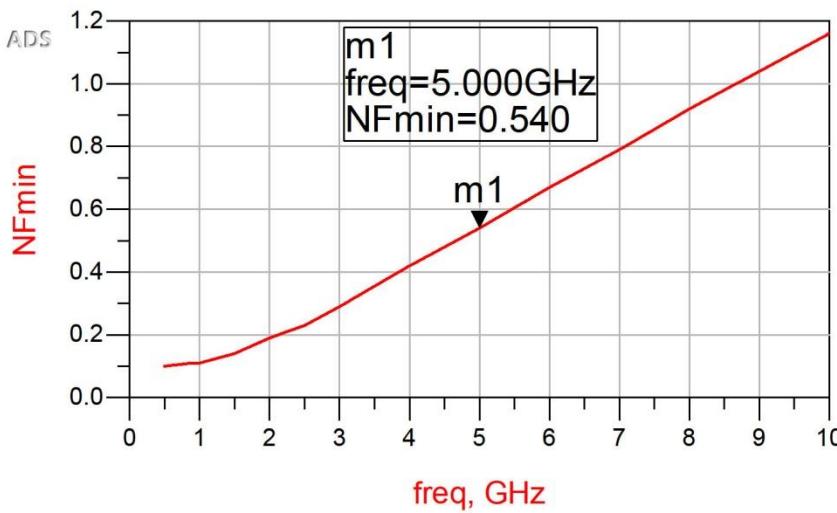
$$R_{SL} = 1 \div 10 \Omega$$



# Stabilizare R paralel la ieșire



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



# Zgomotul unui amplificator

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

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

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

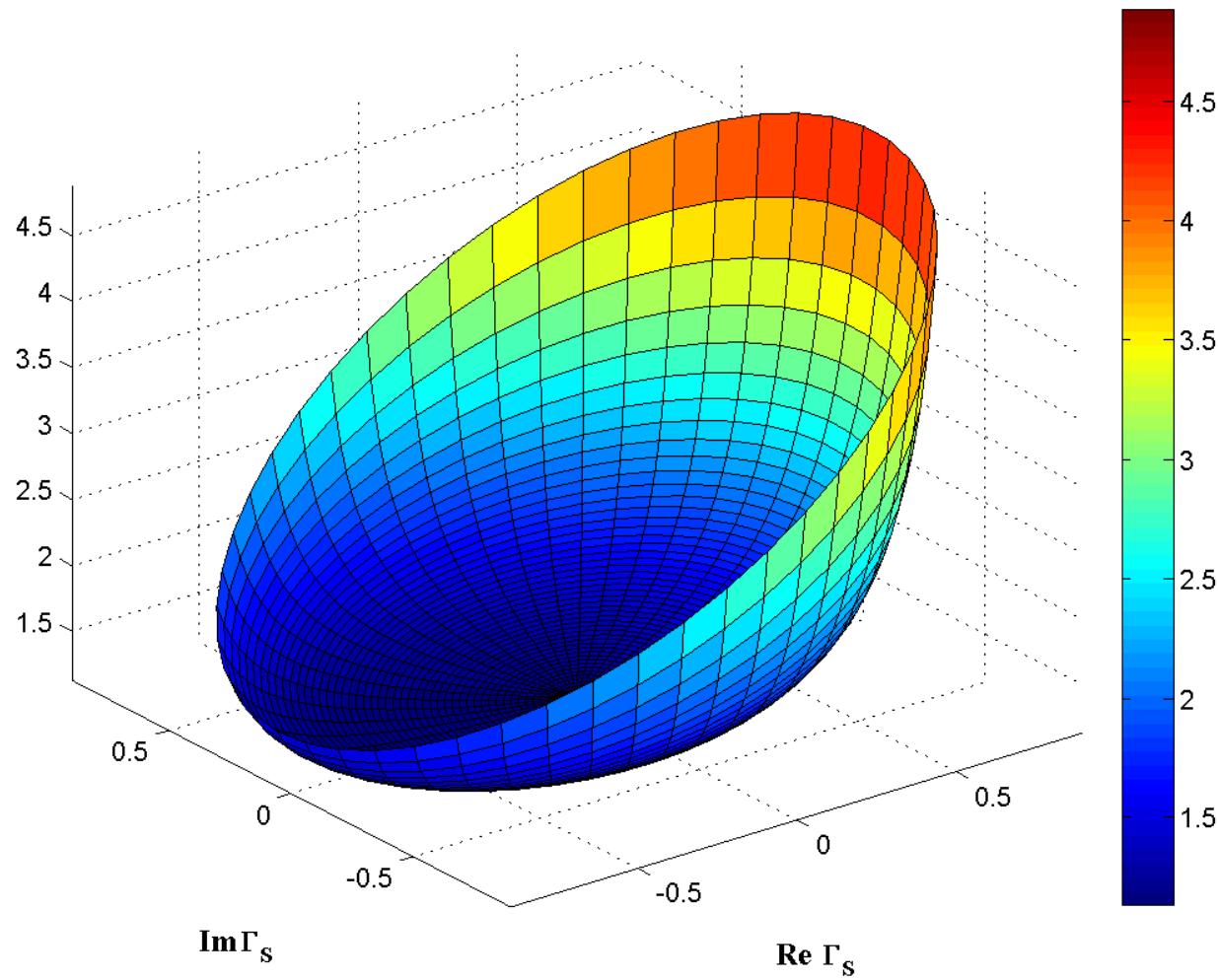
$$F = F_{\min} + 4 \cdot r_n \cdot \frac{|\Gamma_S - \Gamma_{opt}|^2}{(1 - |\Gamma_S|^2) \cdot |1 + \Gamma_{opt}|^2}$$

- $\Gamma_{opt}$  reprezinta coeficientul optim de reflexie la intrare

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

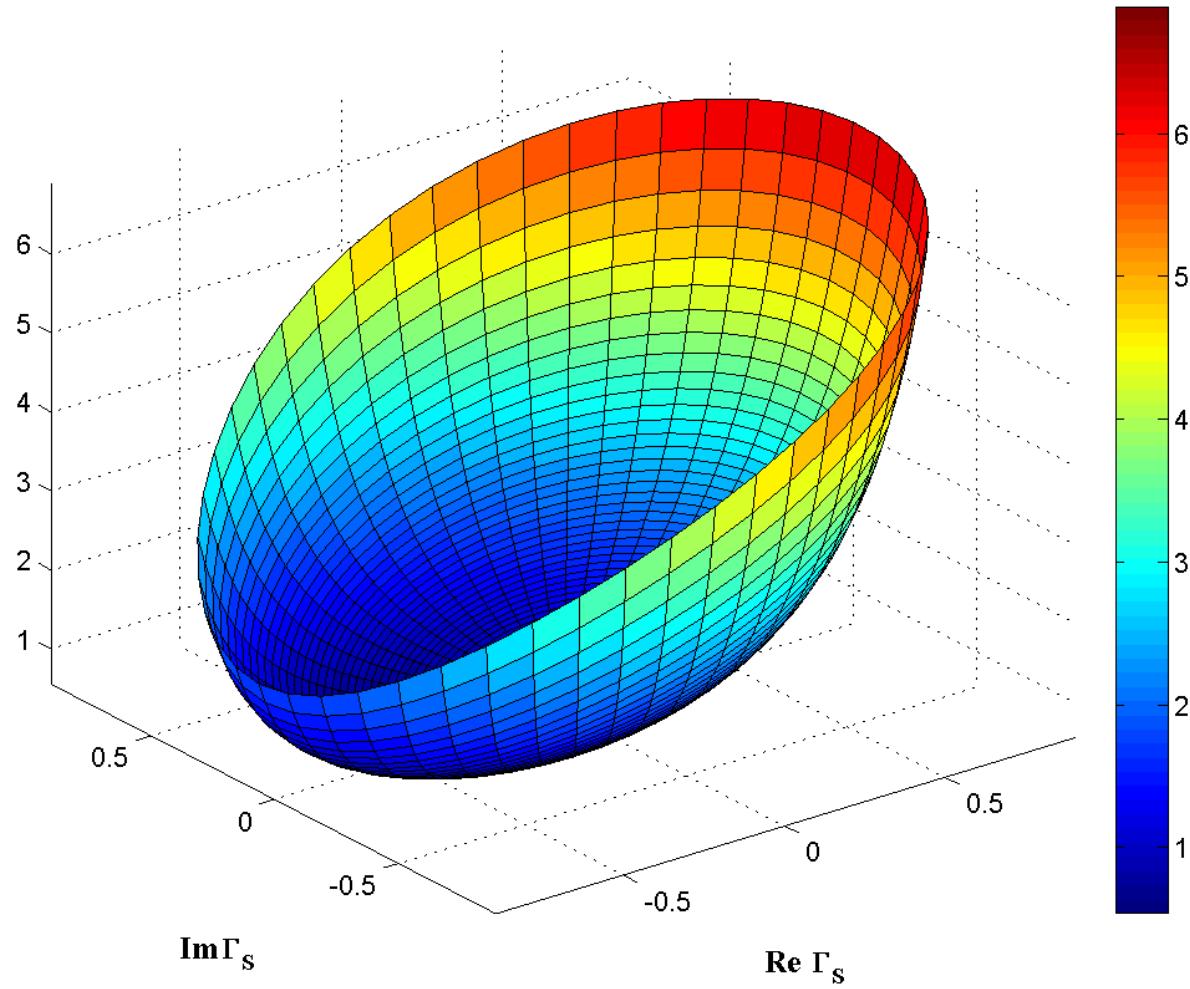
# $F(\Gamma_s)$

$F(\Gamma_s)$

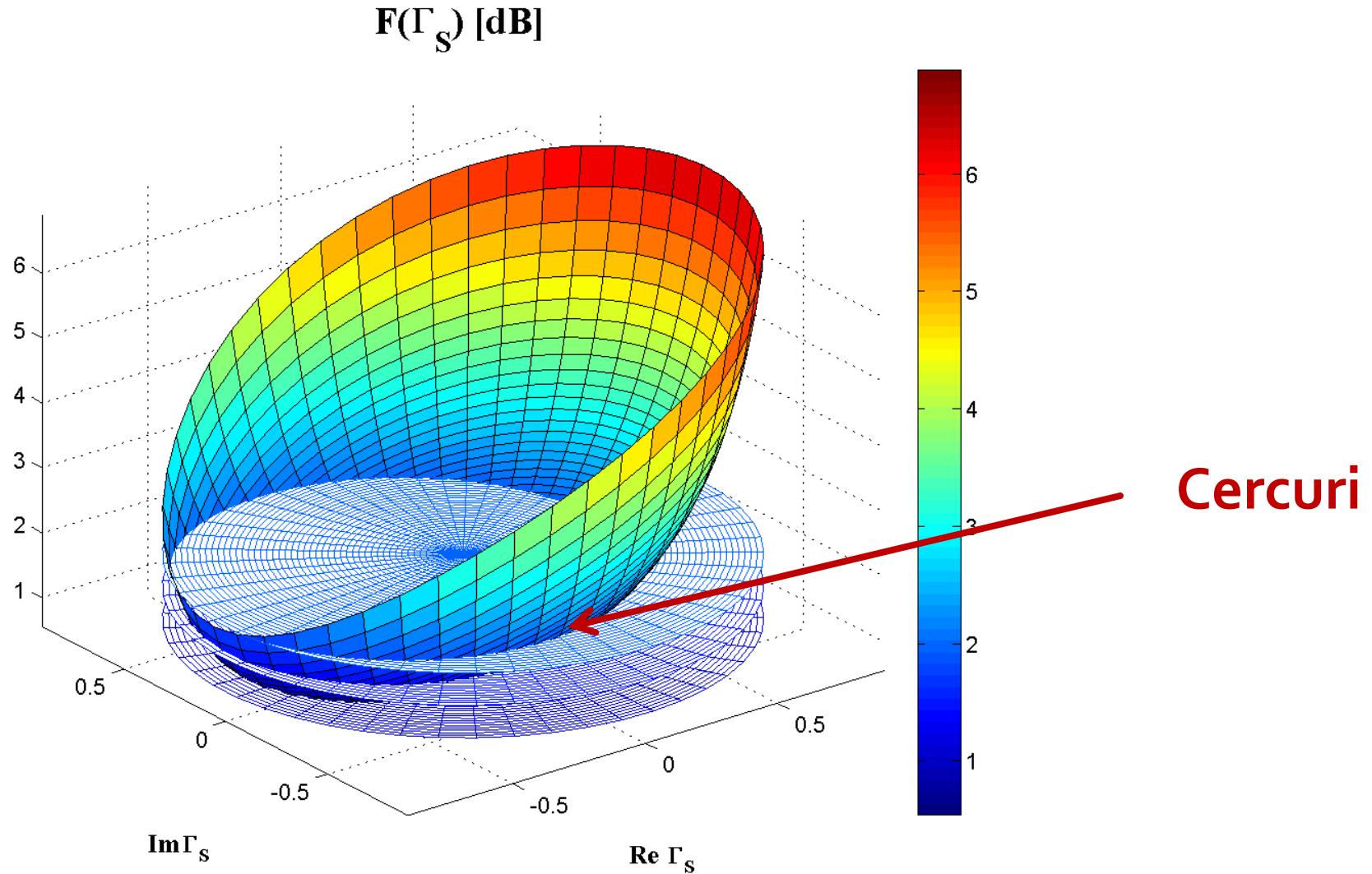


# $F[dB](\Gamma_S)$

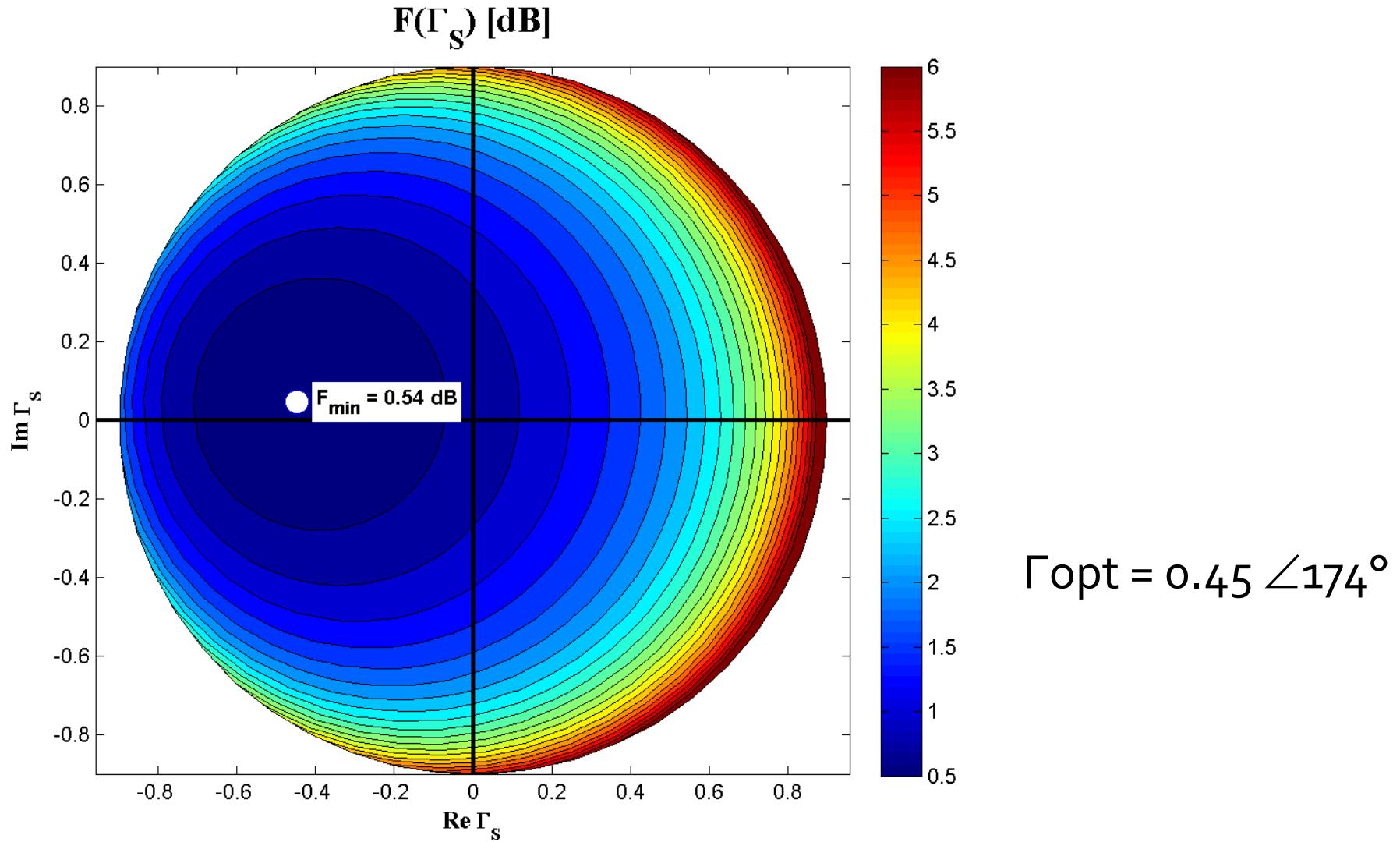
$F(\Gamma_S) [dB]$



# $F[dB](\Gamma_s)$ , 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

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

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

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

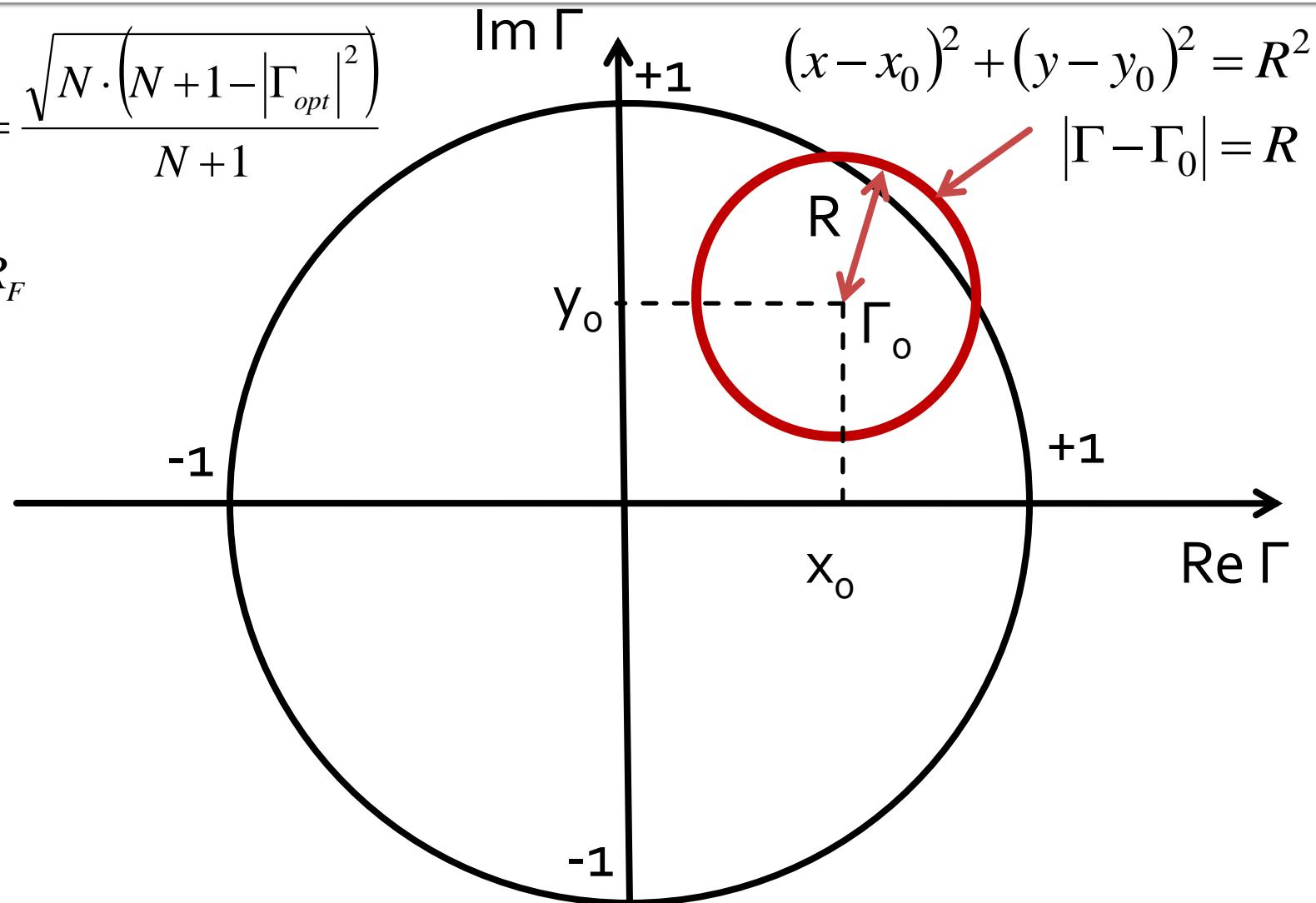
$$\Gamma_S \cdot \Gamma_S^* - \frac{\Gamma_S \cdot \Gamma_{opt}^* - \Gamma_S^* \cdot \Gamma_{opt}}{N+1} = \frac{N - |\Gamma_{opt}|^2}{N+1}$$

$$+ \frac{|\Gamma_{opt}|^2}{(N+1)^2}$$

# Zgomot

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

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

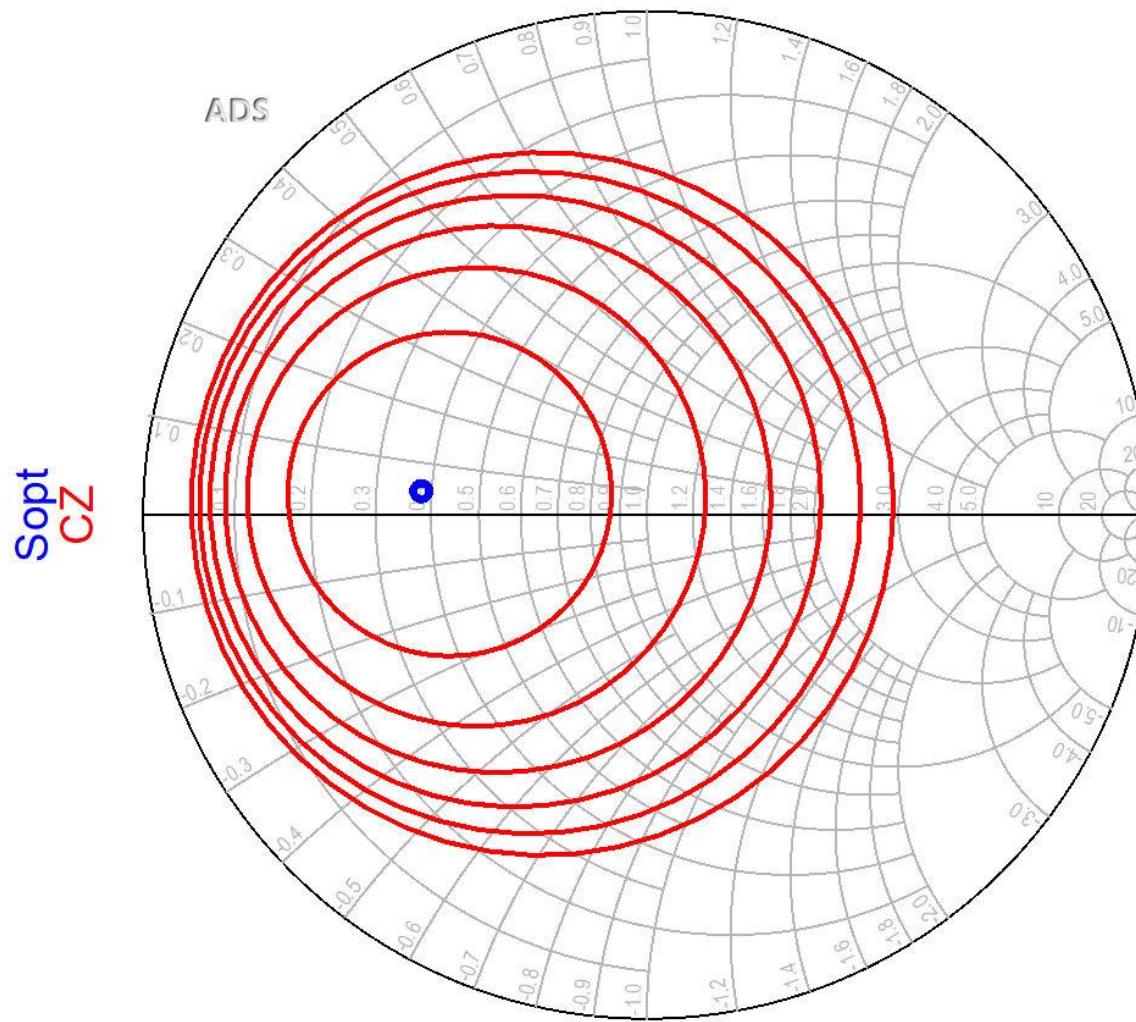


# Cercuri de zgomot constant

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

- Locul geometric al punctelor caracterizate de factor de zgomot constant este un cerc
- **Interpretare:** Orice punct  $\Gamma_S$  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

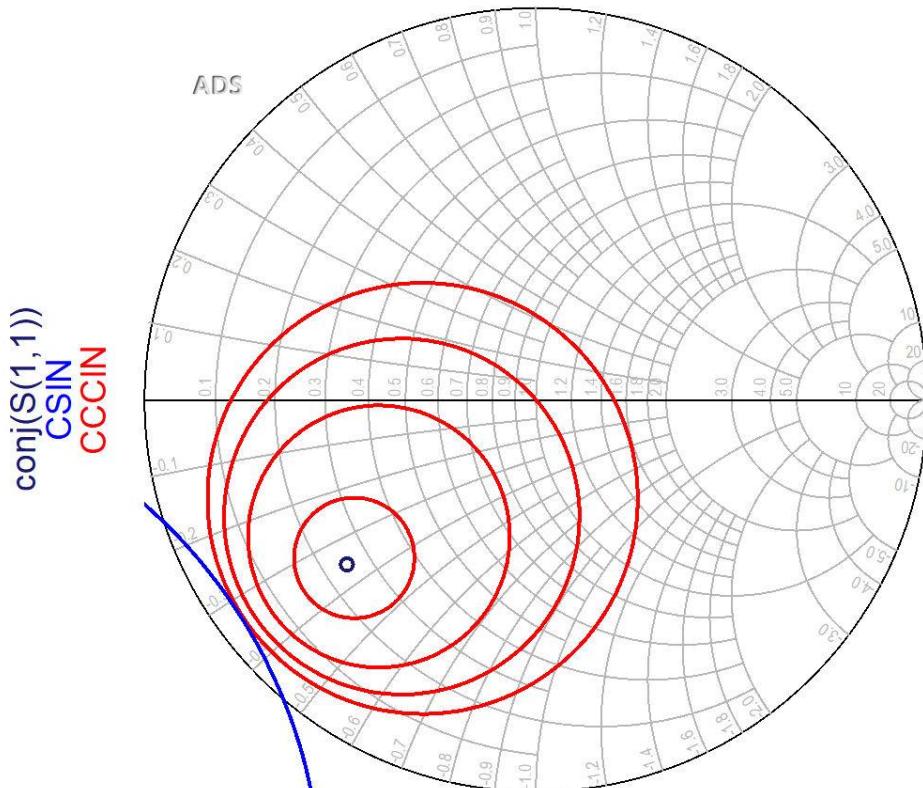
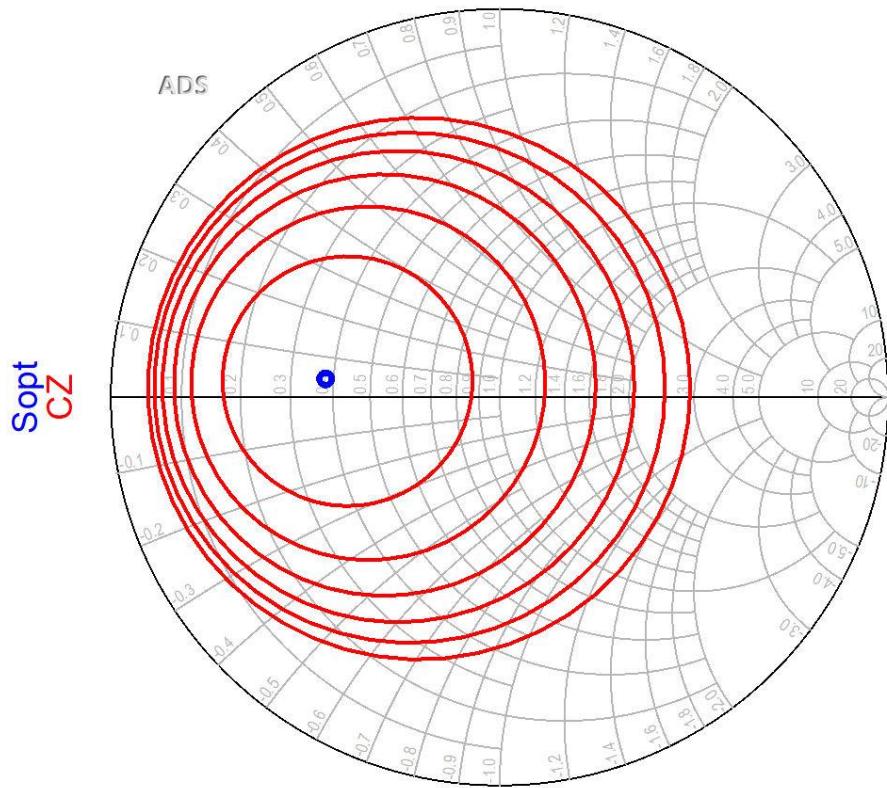


# Cercuri de zgomot constant

- Se observa ca zgomotul 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 zgomot redus (**LNA**) o metoda uzuala este:
  - adaptarea la intrare a tranzistorului din considerente de zgomot
  - adaptarea la iesire utilizata pentru compensarea castigului (daca sunt elemente cu pierderi adaptarea la iesire poate adauga zgomot propriu, dar nu se influenteaza in nici un fel zgomotul generat de tranzistor)

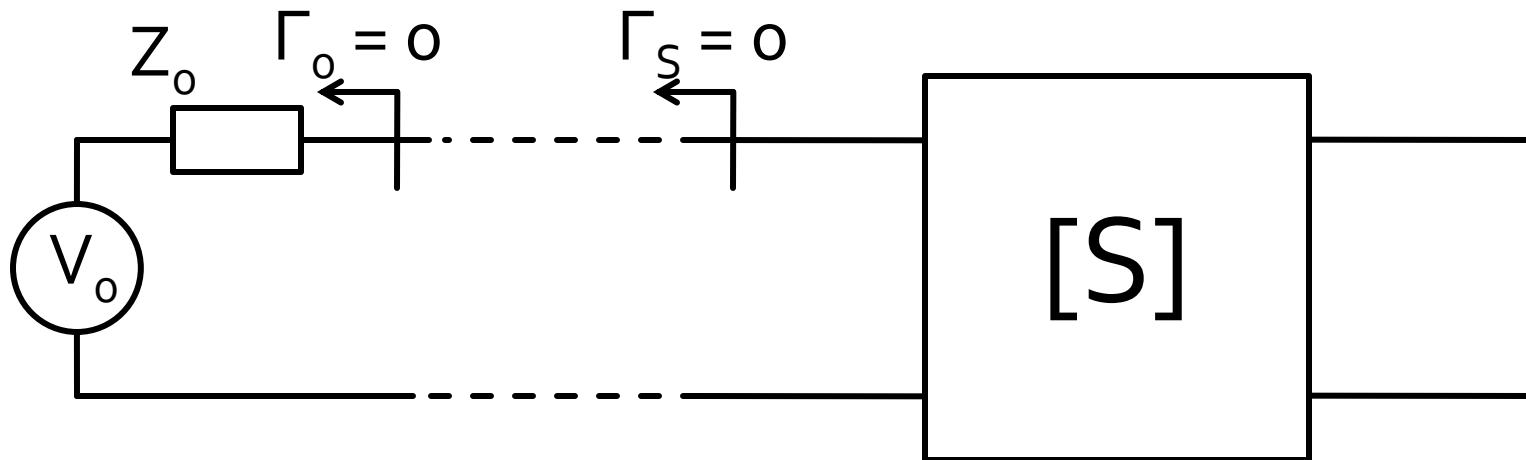
# LNA – Low Noise Amplifier

- 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  $\Gamma_s$



# Adaptare – 1

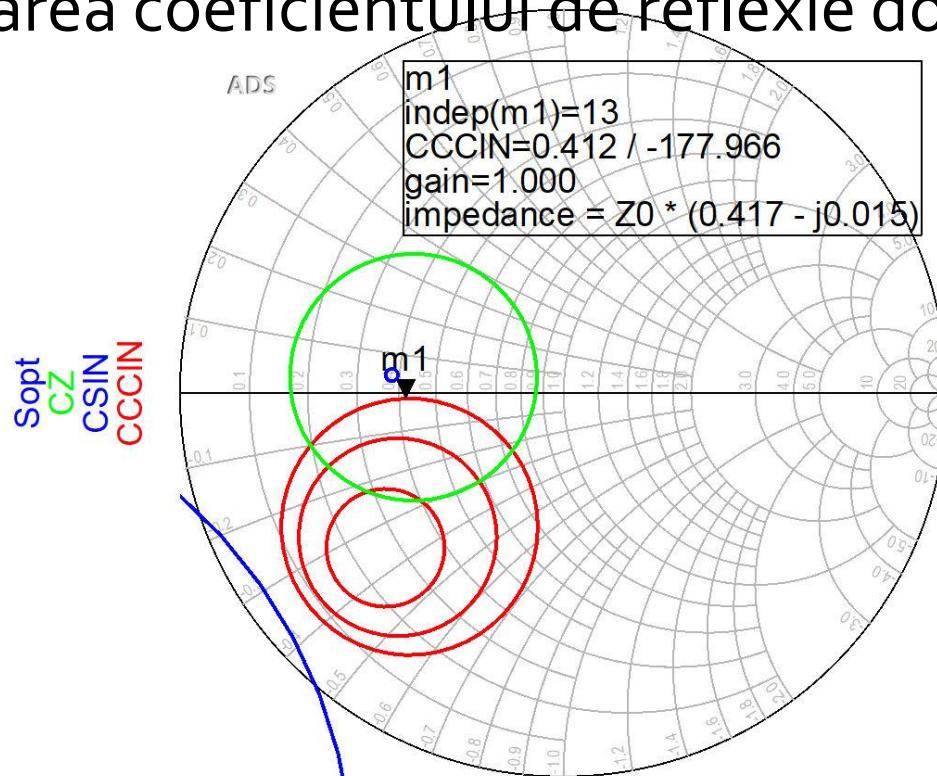
- Conectarea amplificatorului (tranzistorului) direct la sursa de semnal oferă un coeficient de reflexie la intrarea tranzistorului egal cu **0** (complex,  $\Gamma_o = 0 + 0 \cdot j$ )
  - de cele mai multe ori acest coeficient de reflexie nu oferă condiții optime de castig și/sau zgomot



# Adaptare – 2

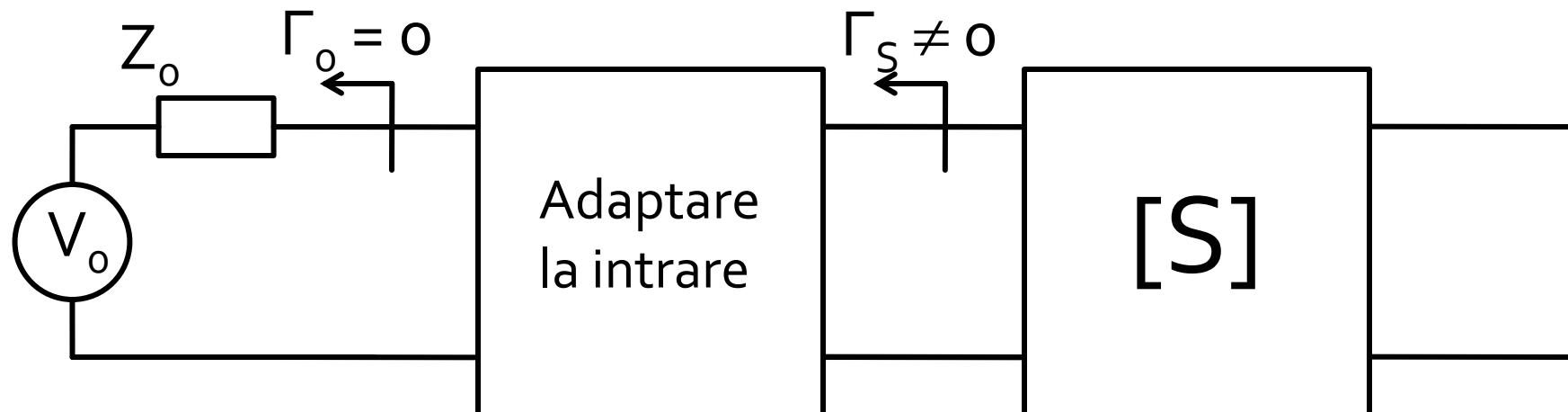
- Se deseneaza pe diagrama Smith cercurile de stabilitate/castig/zgomot, in functie de aplicatia
- Se alege punctul cu o pozitionare dorita relativ la aceste cercuri (de asemenea dependent de aplicatie)
- Se determina valoarea coeficientului de reflexie dorit la intrare  $\Gamma_S$

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



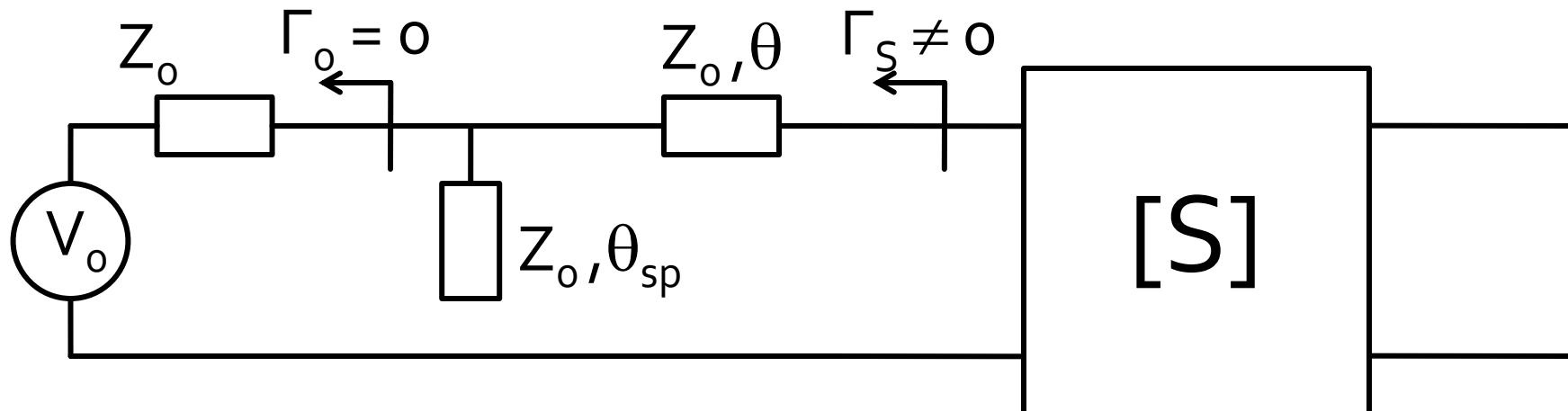
# Adaptare – 3

- Se interpune reteaua de adaptare la intrare care permite obtinerea lui  $\Gamma_S$  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  $Z_0$ ):
  - o secțiune de linie serie, cu impedanța caracteristică  $Z_0$  și lungime electrică  $\theta$
  - un **stub paralel**, lasat în gol la capăt, realizat dintr-o linie cu impedanța caracteristică  $Z_0$  și lungime electrică  $\theta_{sp}$

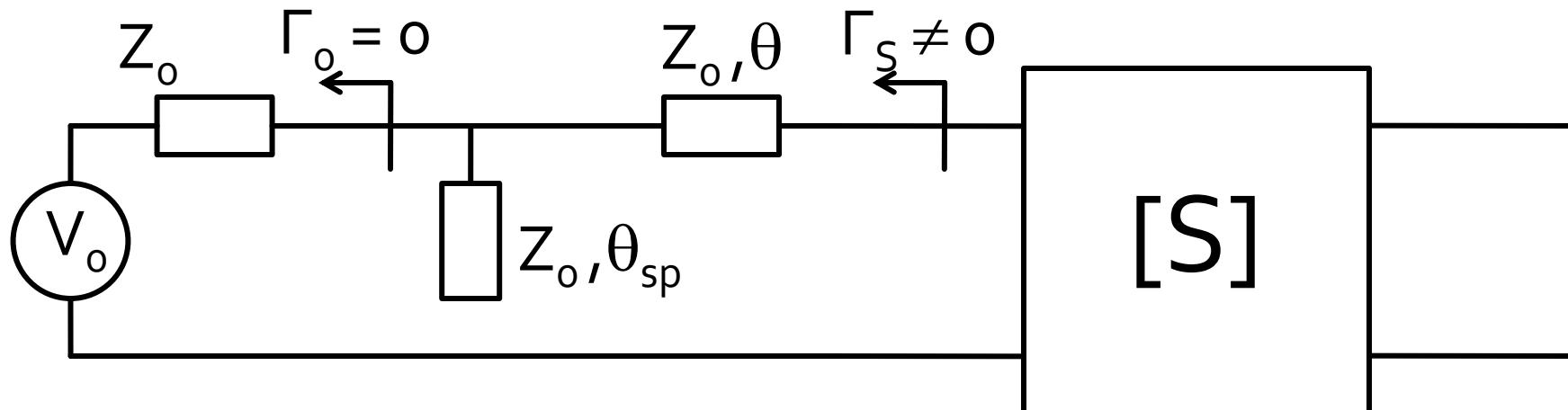


# Adaptare – 5

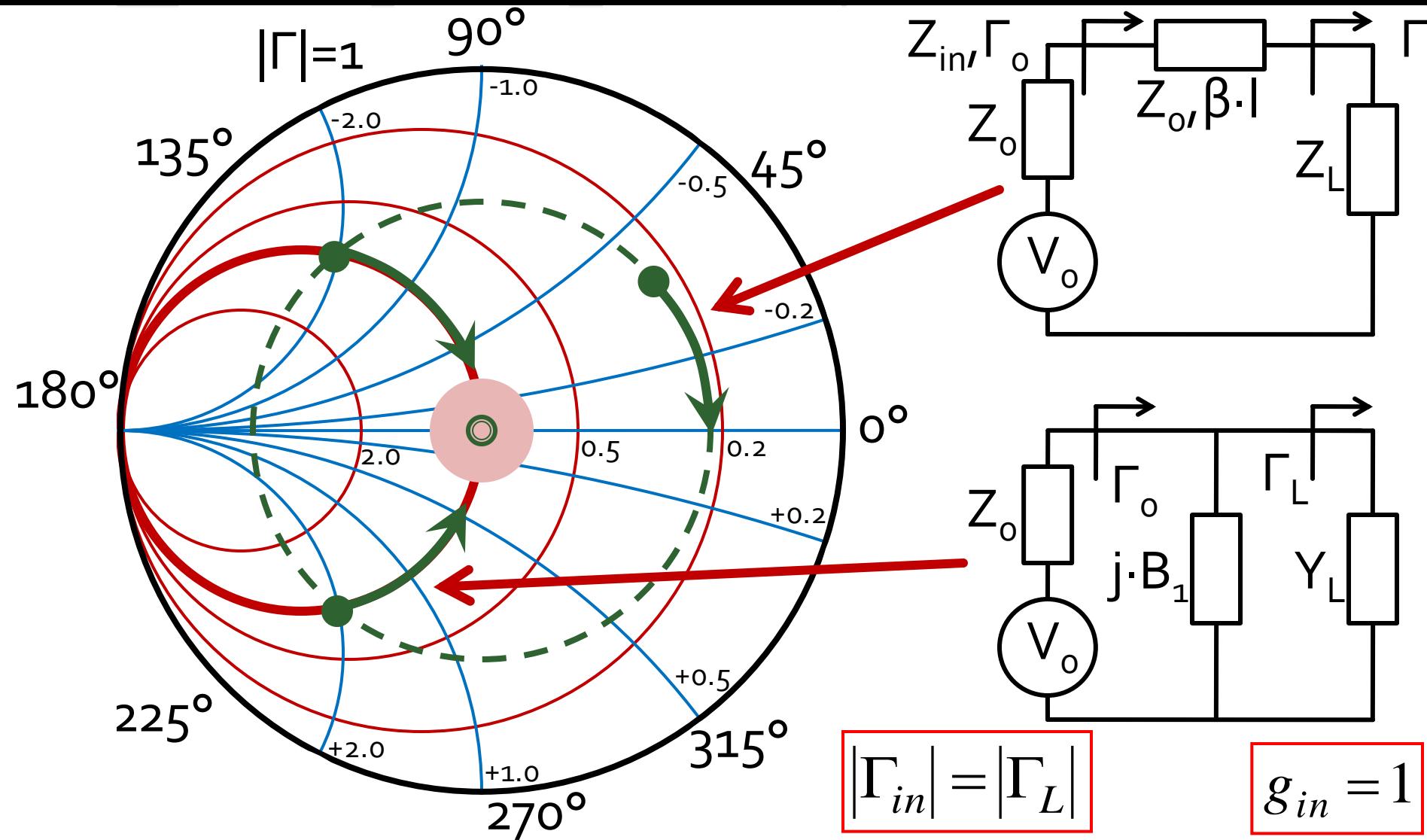
- Relatiile de calcul depind numai de  $\Gamma_s$  (modul si faza)

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

- 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

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

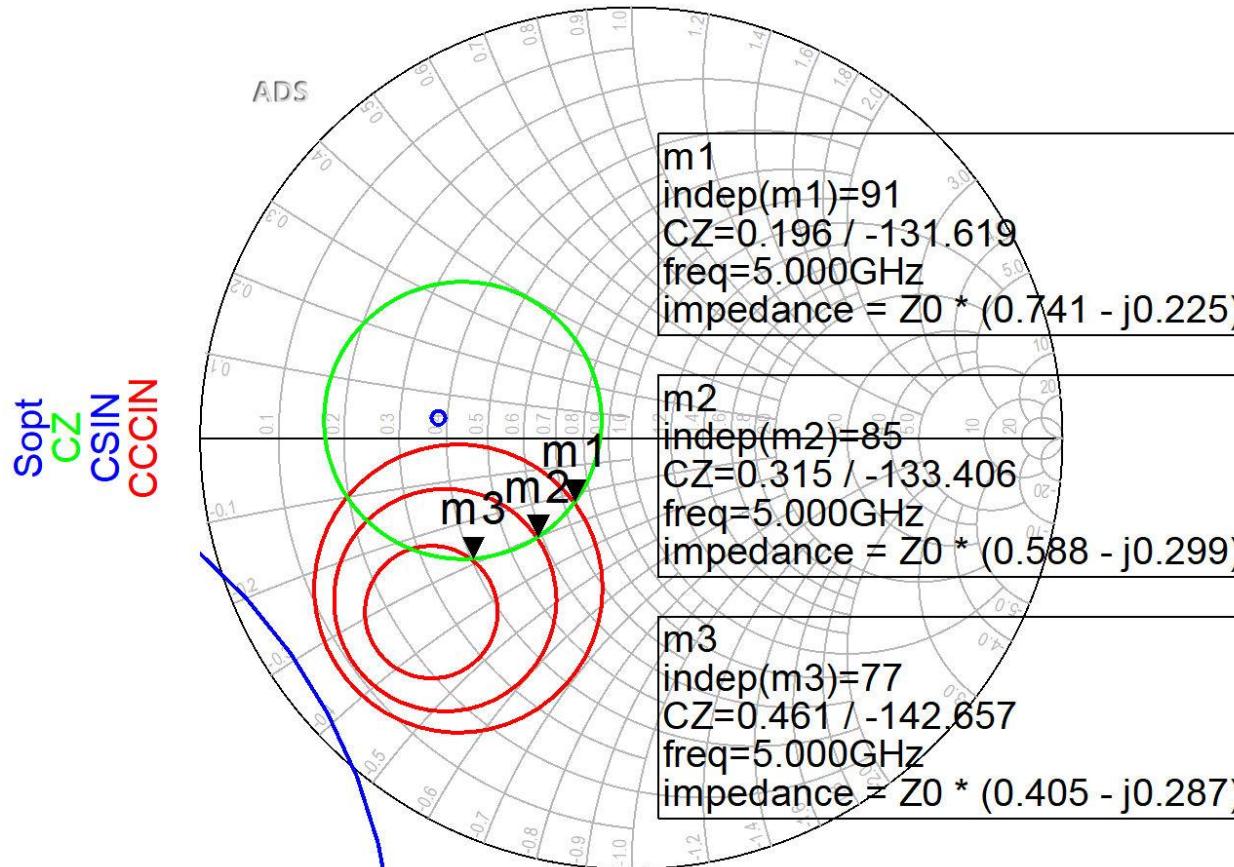
$$G_{TU\max} = \frac{1}{1 - |S_{11}|^2} \cdot |S_{21}|^2 \cdot \frac{1}{1 - |S_{22}|^2} = 17.83 \quad G_{TU\max} [\text{dB}] = 12.511 \text{ dB}$$

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

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

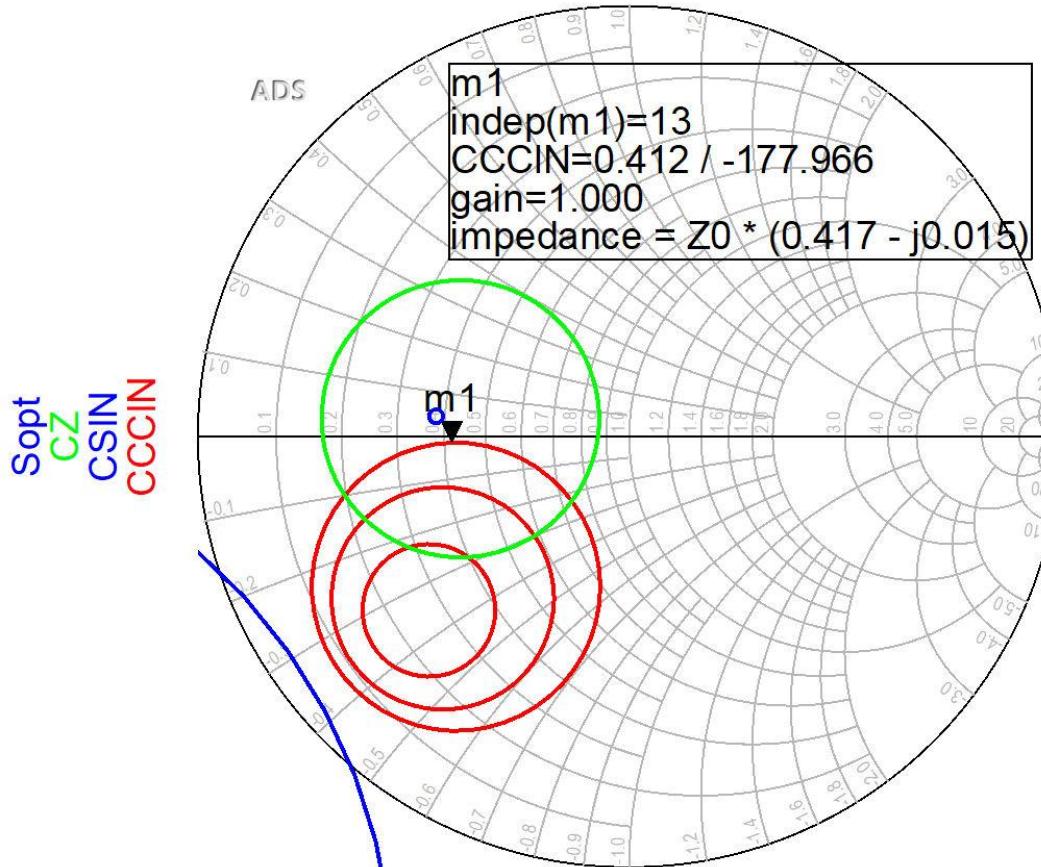
- In cazul particular prezent  $G_{L\max} = 0.21 \text{ dB}$ , amplificatorul ar putea functiona cu iesirea conectata direct la o sarcina de  $50\Omega$
- Absenta retelei de adaptare la iesire nu conduce la o pierdere importanta de castig, dar elimina posibilitatea ca prin reglaj sa se compenseze compromisul castig/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

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

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

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

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

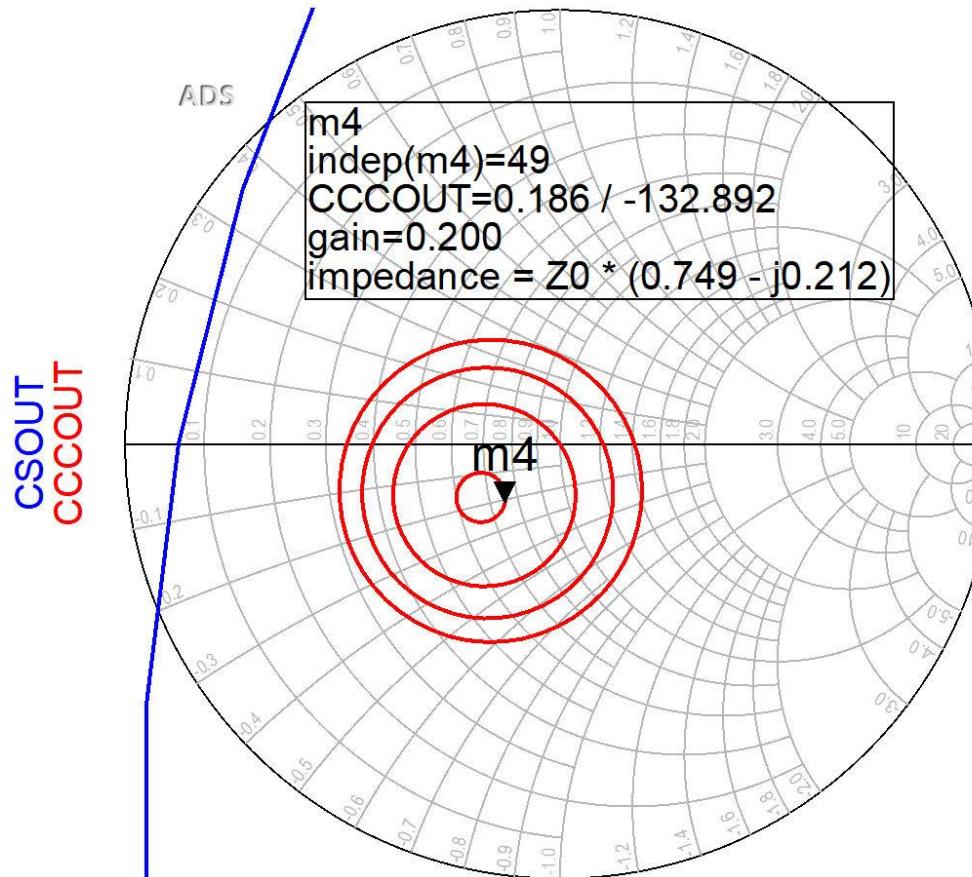
$$\cos(\varphi + 2\theta) = -0.412 \Rightarrow (\varphi + 2\theta) = \pm 114.33^\circ$$

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

---

# 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 m<sub>4</sub> de pe grafic

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

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

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

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

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

---

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

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# LNA

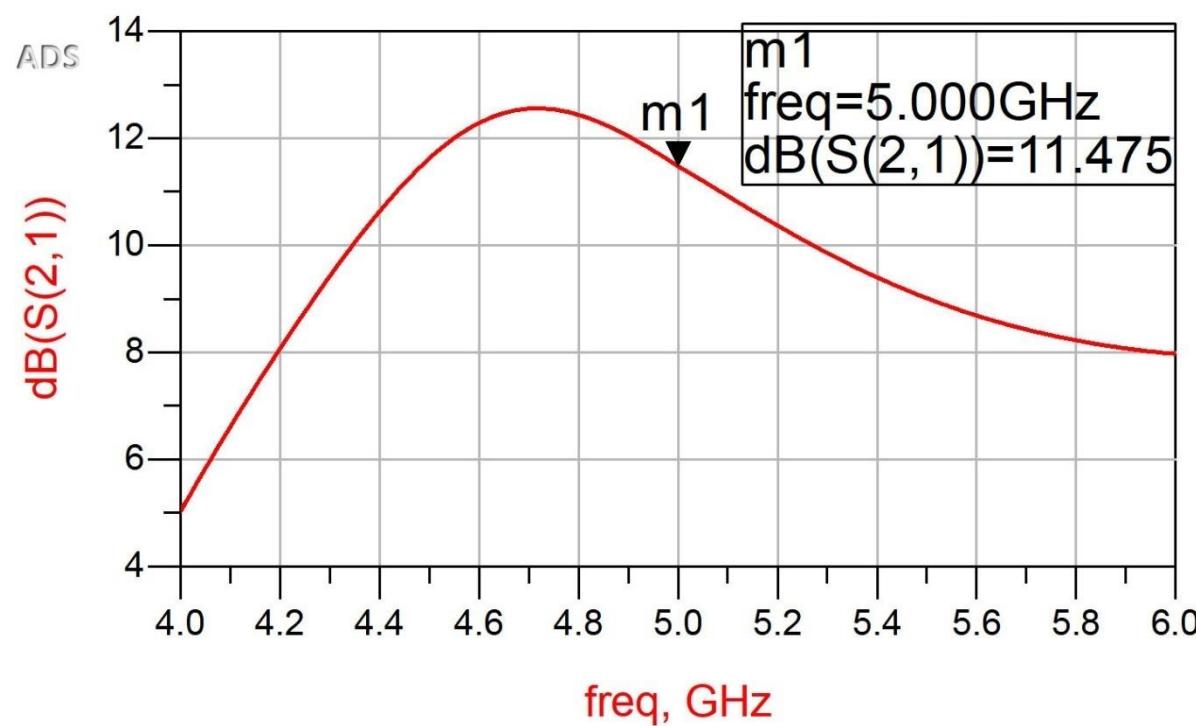
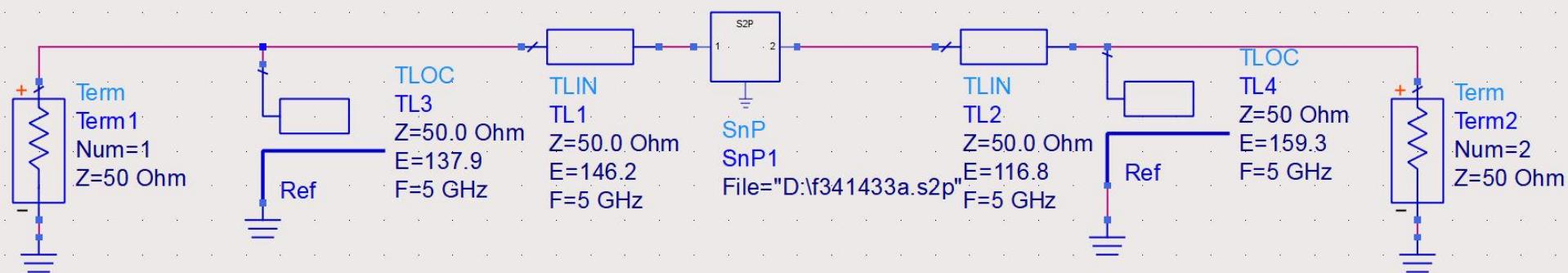
- Se estimeaza obtinerea unui castig (in ipoteza unilaterală,  $\pm 0.9$  dB)

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

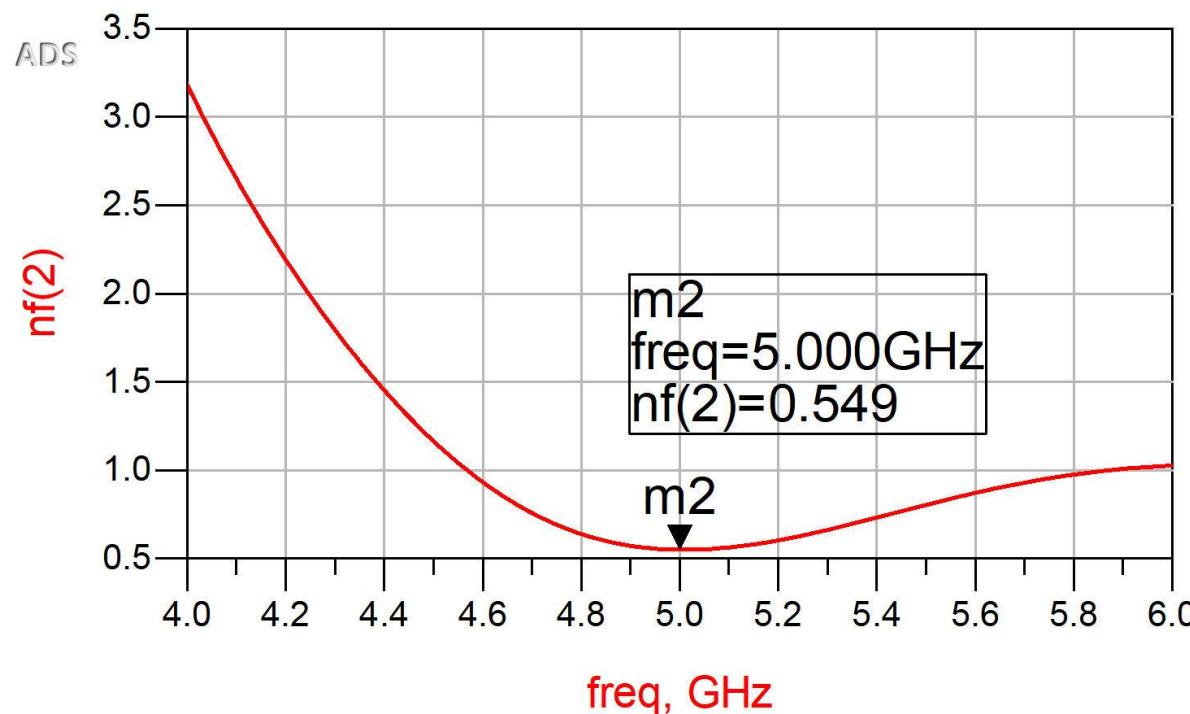
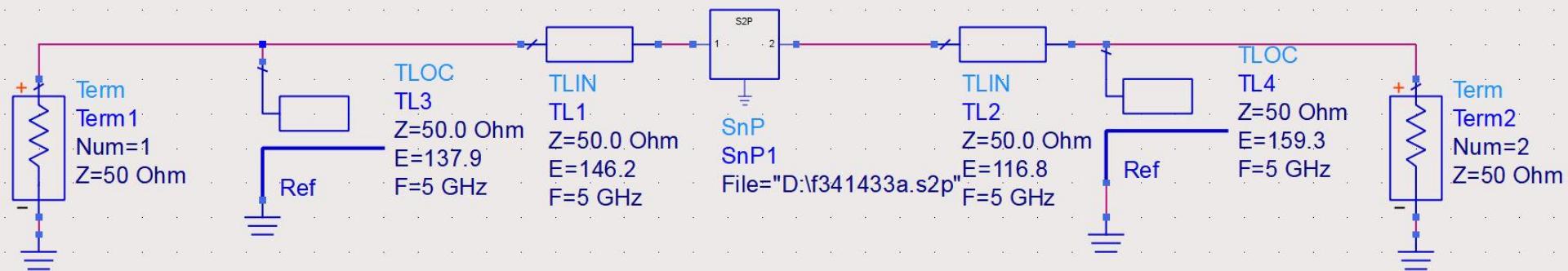
$$G_T[\text{dB}] = 1 \text{ dB} + 10 \text{ dB} + 0.2 \text{ dB} = 11.2 \text{ dB}$$

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

# ADS



# ADS



# Contact

- Laboratorul de microunde si optoelectronica
- <http://rf-opto.etti.tuiasi.ro>
- [rdamian@etti.tuiasi.ro](mailto:rdamian@etti.tuiasi.ro)