

Curs 9  
2015/2016

# Dispozitive și circuite de microunde pentru radiocomunicații

# Disciplina 2015/2016

- 2C/1L, DCMR (CDM)
- **Minim 7 prezente (curs+laborator)**
- Curs - **sl. Radu Damian**
  - Marti 18-20, P2
  - E – 60% din nota
  - probleme + (2p prez. curs)
    - 3p=+0.5p
  - **toate materialele permise**
- Laborator – **sl. Radu Damian**
  - Miercuri 8-14 impar (14.10.2015 – prez. obligatorie)
  - L – 25% din nota
  - P – 15% din nota

# Fotografii +0.5p

Grupa 5403											
Nr.	Student	Prezent	Nr.	Student	Prezent	Nr.	Student	Prezent			
1	ANGHELUS IONUT-MARCUS		<input type="checkbox"/> Prezent	2	ANTIGHIN FLORIN-RAZVAN		<b>Fotografia nu exista</b>	<input type="checkbox"/> Prezent	<input type="checkbox"/> Puncte: 0	<input checked="" type="checkbox"/> Nota: 0	<input type="checkbox"/> Obs:
4	APOSTOL PAVEL-MANUEL		<b>Fotografia nu exista</b>	5	BALASCA TUDIAN-PETRU		<b>Fotografia nu exista</b>	<input checked="" type="checkbox"/> Prezent	<input type="checkbox"/> Puncte: 0	<input checked="" type="checkbox"/> Nota: 0	<input type="checkbox"/> Obs:
7	BOTEZAT EMANUEL		<input type="checkbox"/> Prezent	8	BUTUNOI GEORGE-MADALIN		<b>Fotografia nu exista</b>	<input type="checkbox"/> Prezent	<input type="checkbox"/> Puncte: 0	<input checked="" type="checkbox"/> Nota: 0	<input type="checkbox"/> Obs:
10	CHIRITOIU CATERINA		<input type="checkbox"/> Prezent	11	CODOC MARIUS		<input checked="" type="checkbox"/> Prezent	<input type="checkbox"/> Puncte: 0	<input checked="" type="checkbox"/> Nota: 0	<input type="checkbox"/> Obs:	
12	COJOCARU AURA-FLORINA		<b>Fotografia nu exista</b>								

Nr. Student

Prezent

2 ANTIGHIN  
FLORIN-RAZVAN

Prezent

Puncte: 0

Nota: 0

Obs:

<b>Fotografia nu exista</b>
---------------------------------

# Reprezentare logarithmică

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

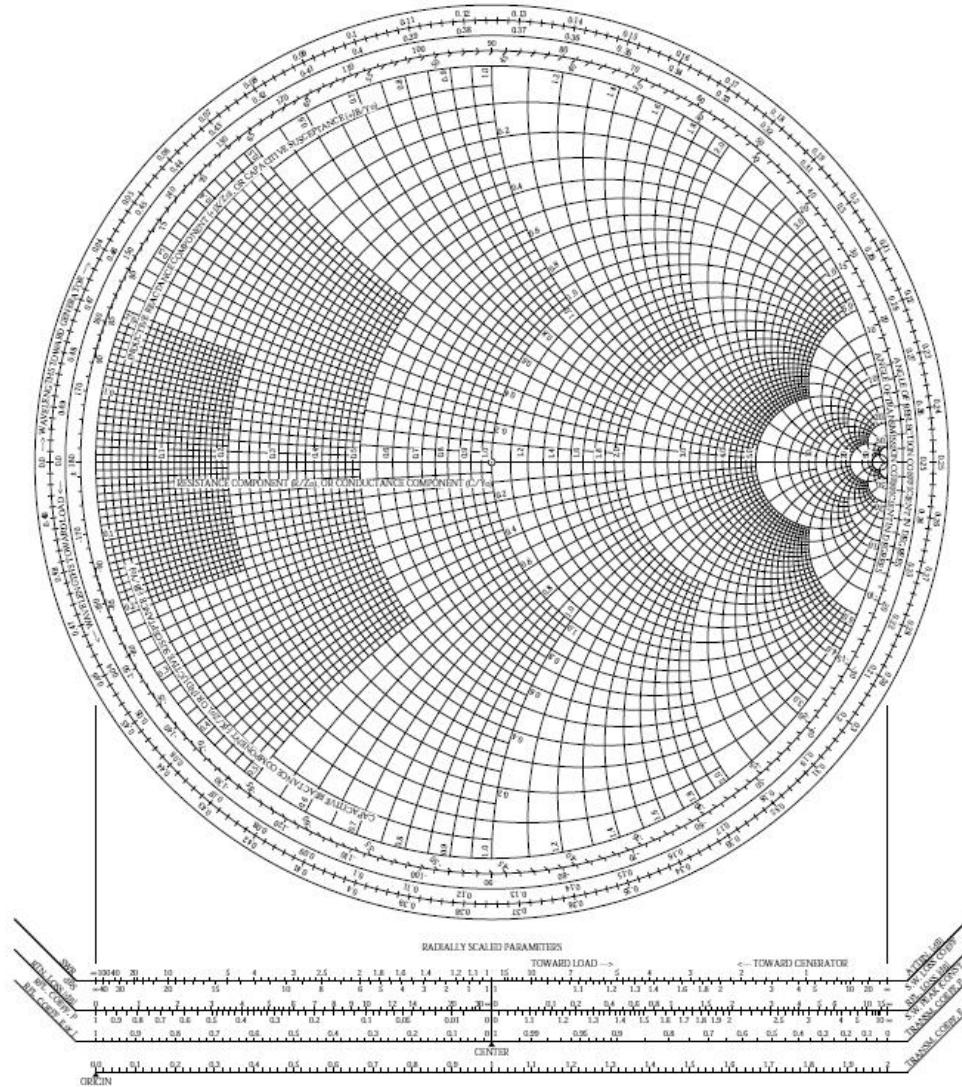
$$[x] + [\text{dB}] = [x]$$

# Recapitulare

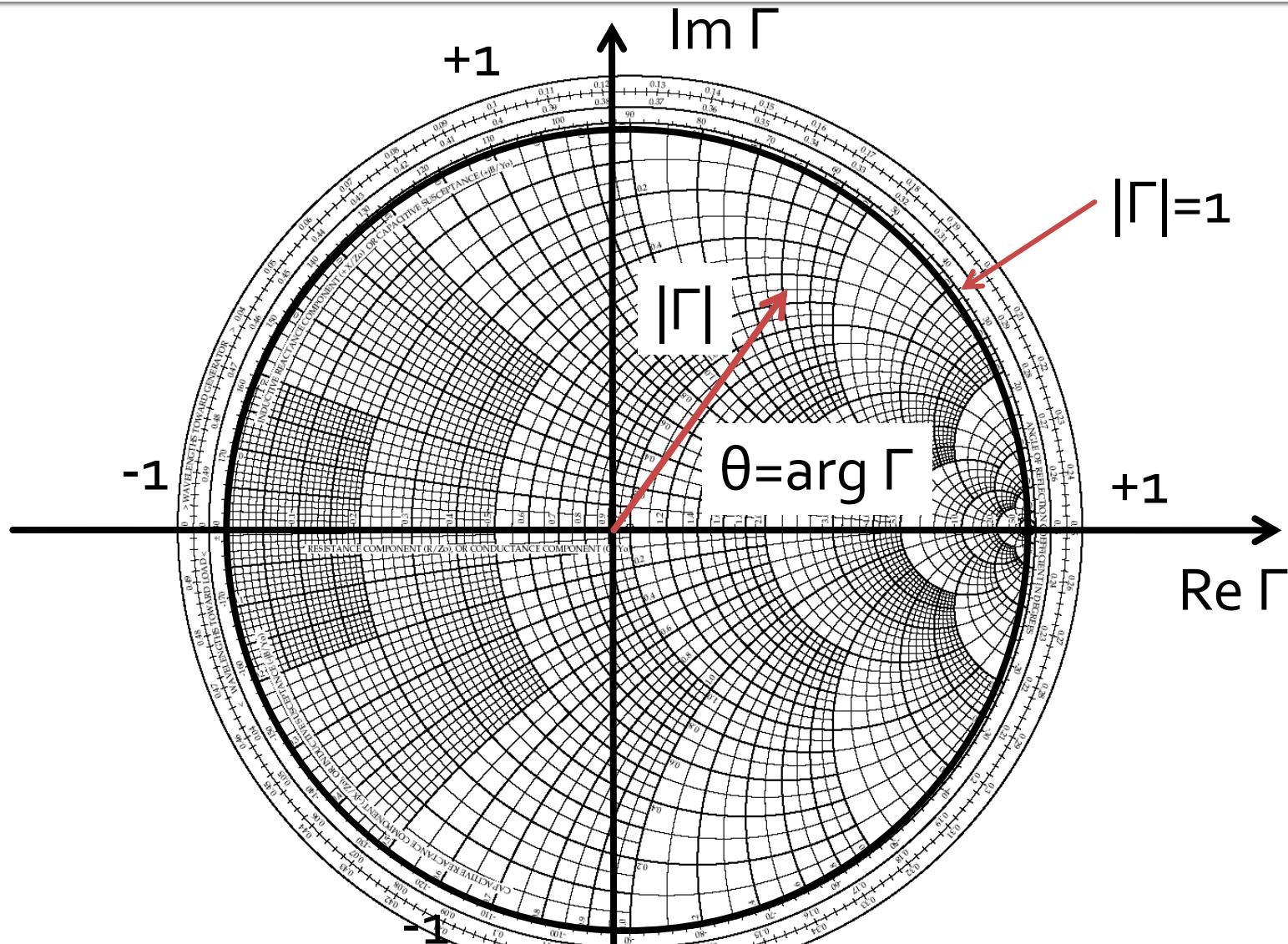
Adaptarea de impedanță

# Diagrama Smith

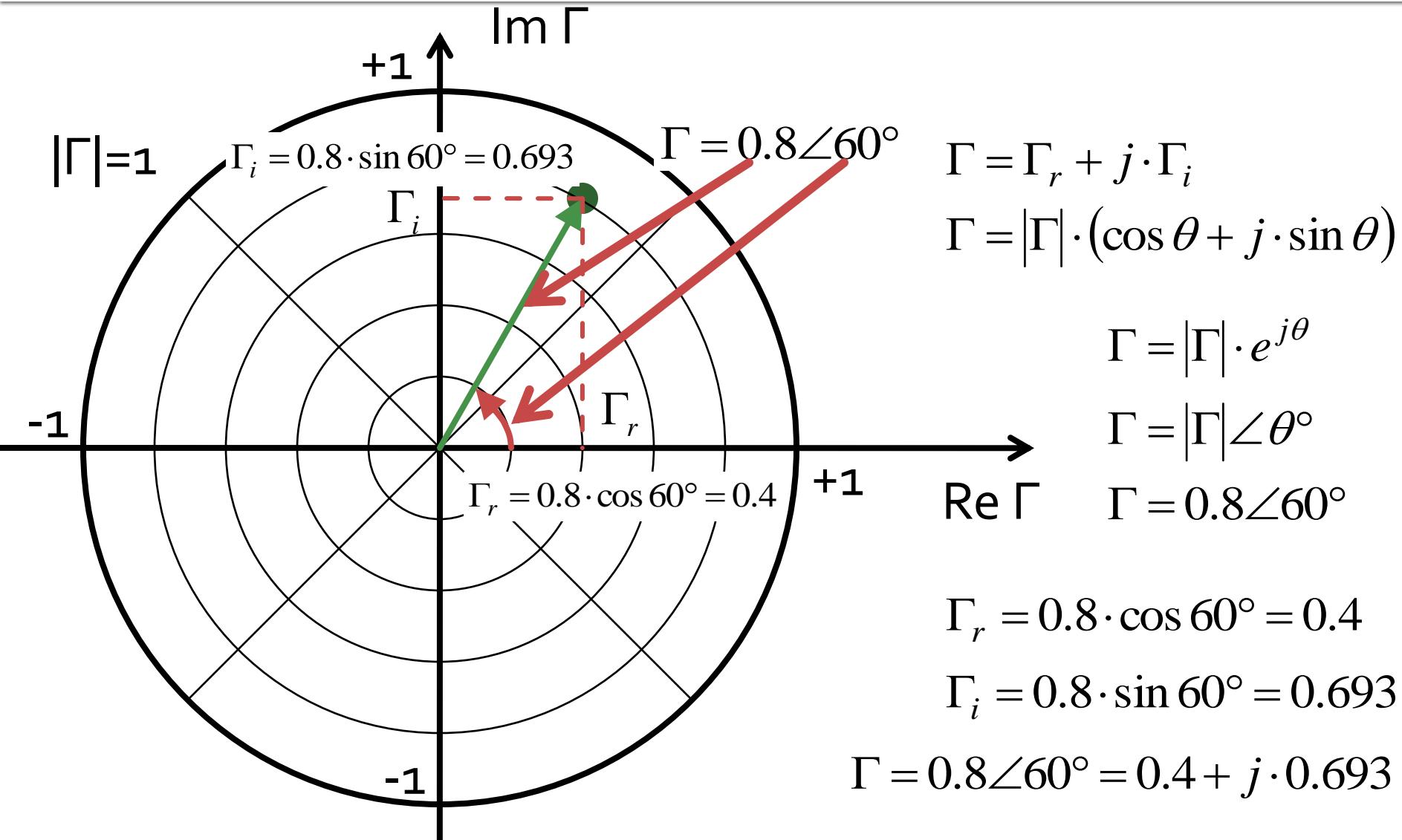
# Diagrama Smith



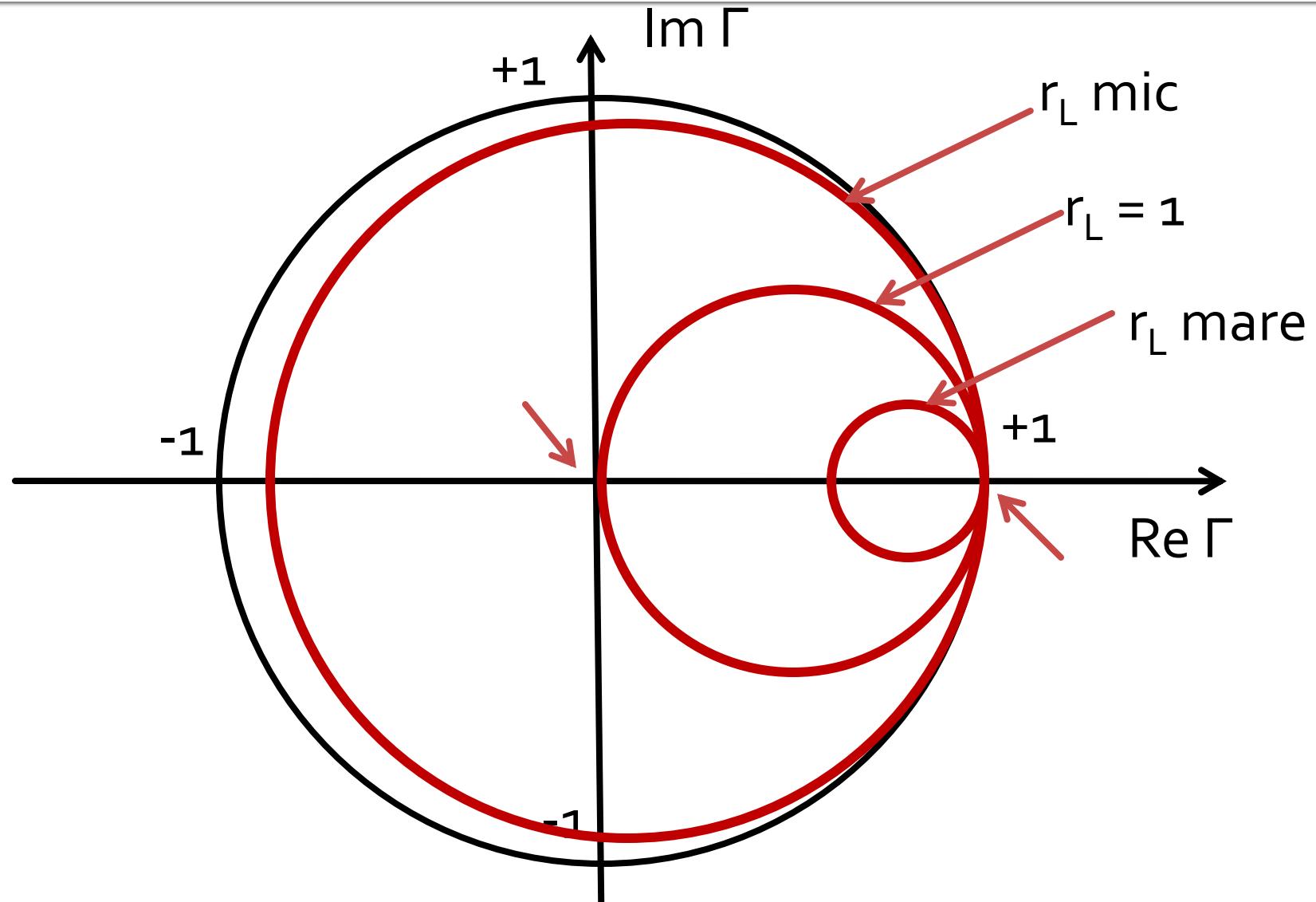
# Diagrama Smith



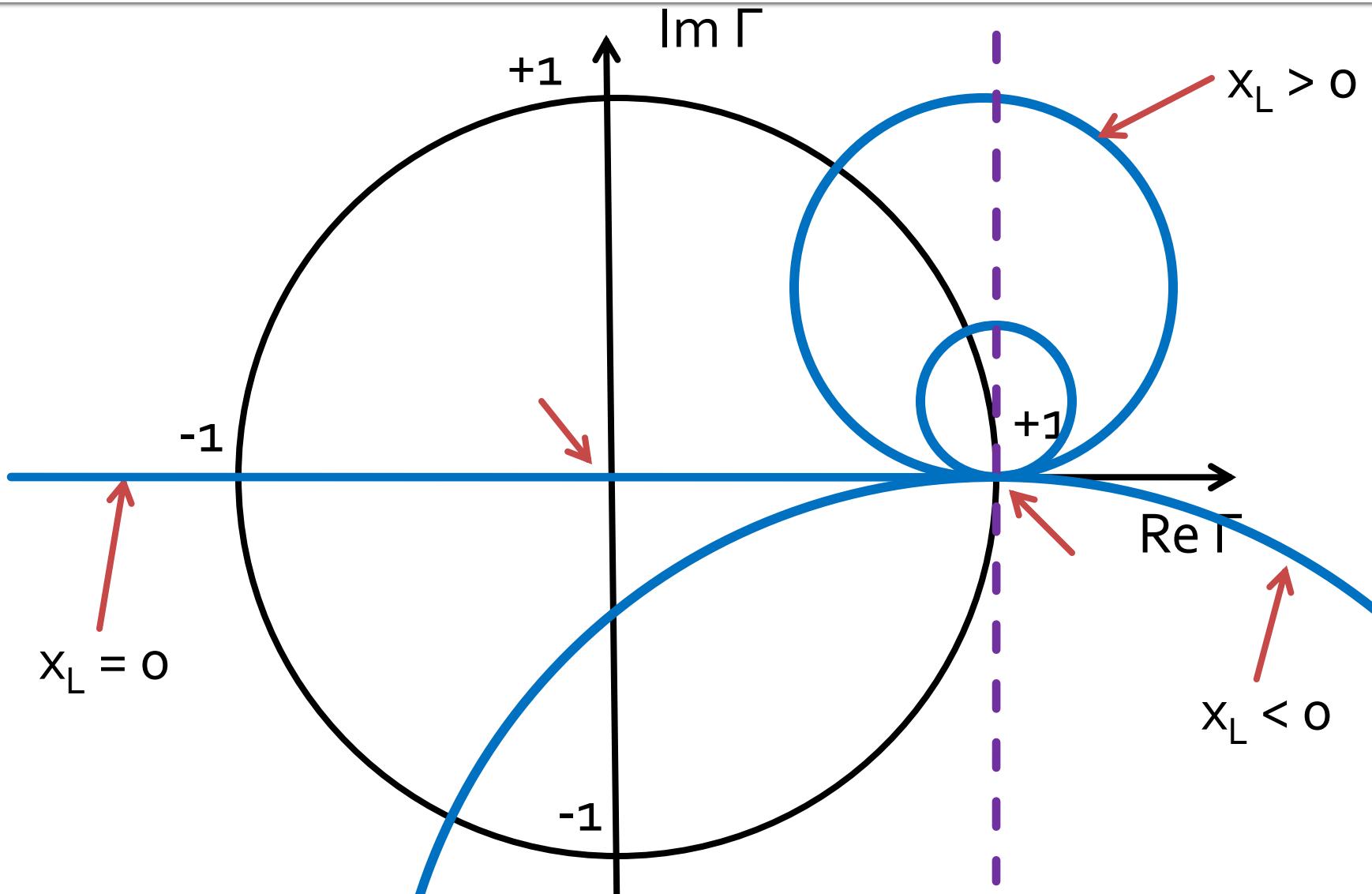
# Diagrama Smith, coeficient de reflexie, coordonate rectangulare



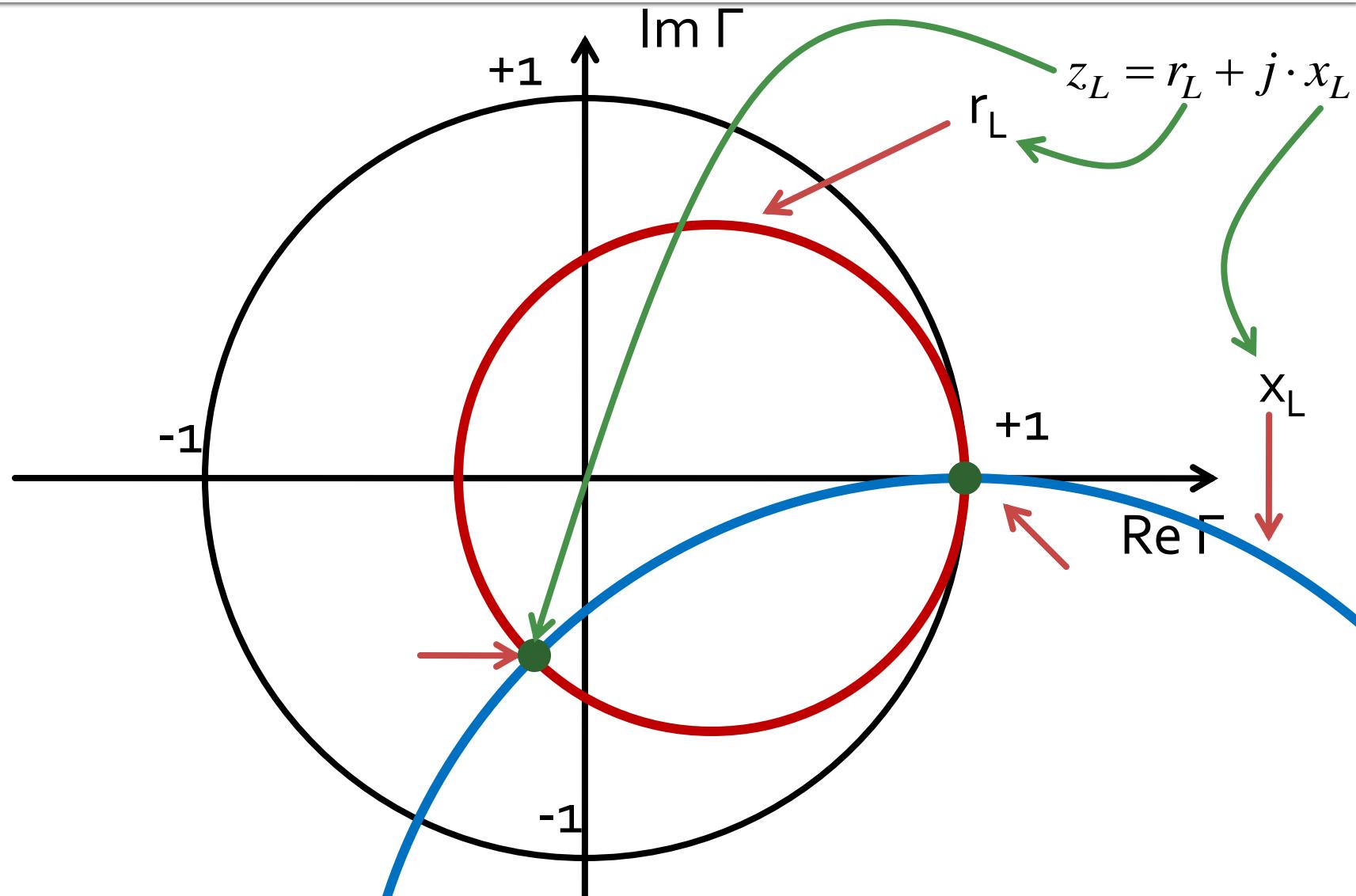
# Diagrama Smith, rezistenta



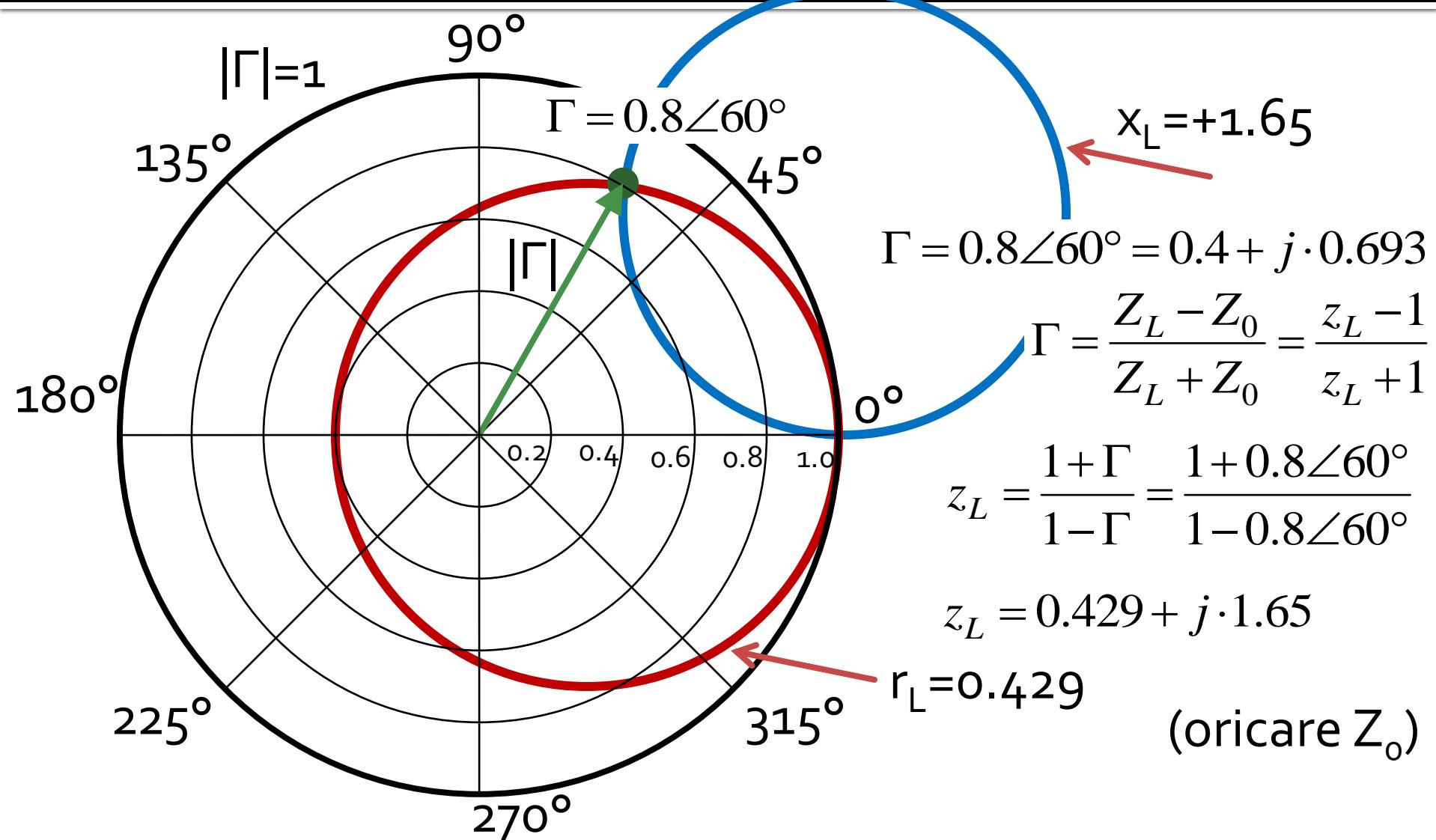
# Diagrama Smith, reactanta



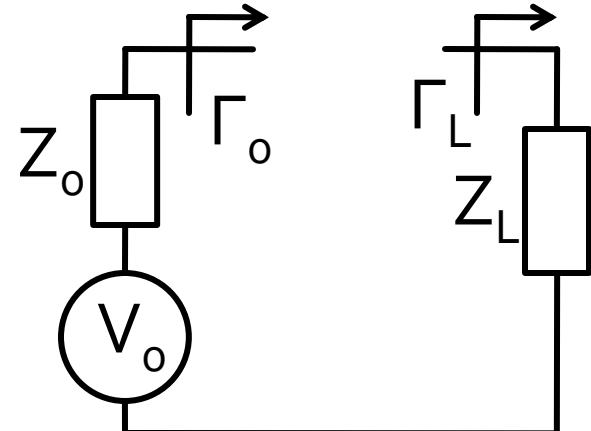
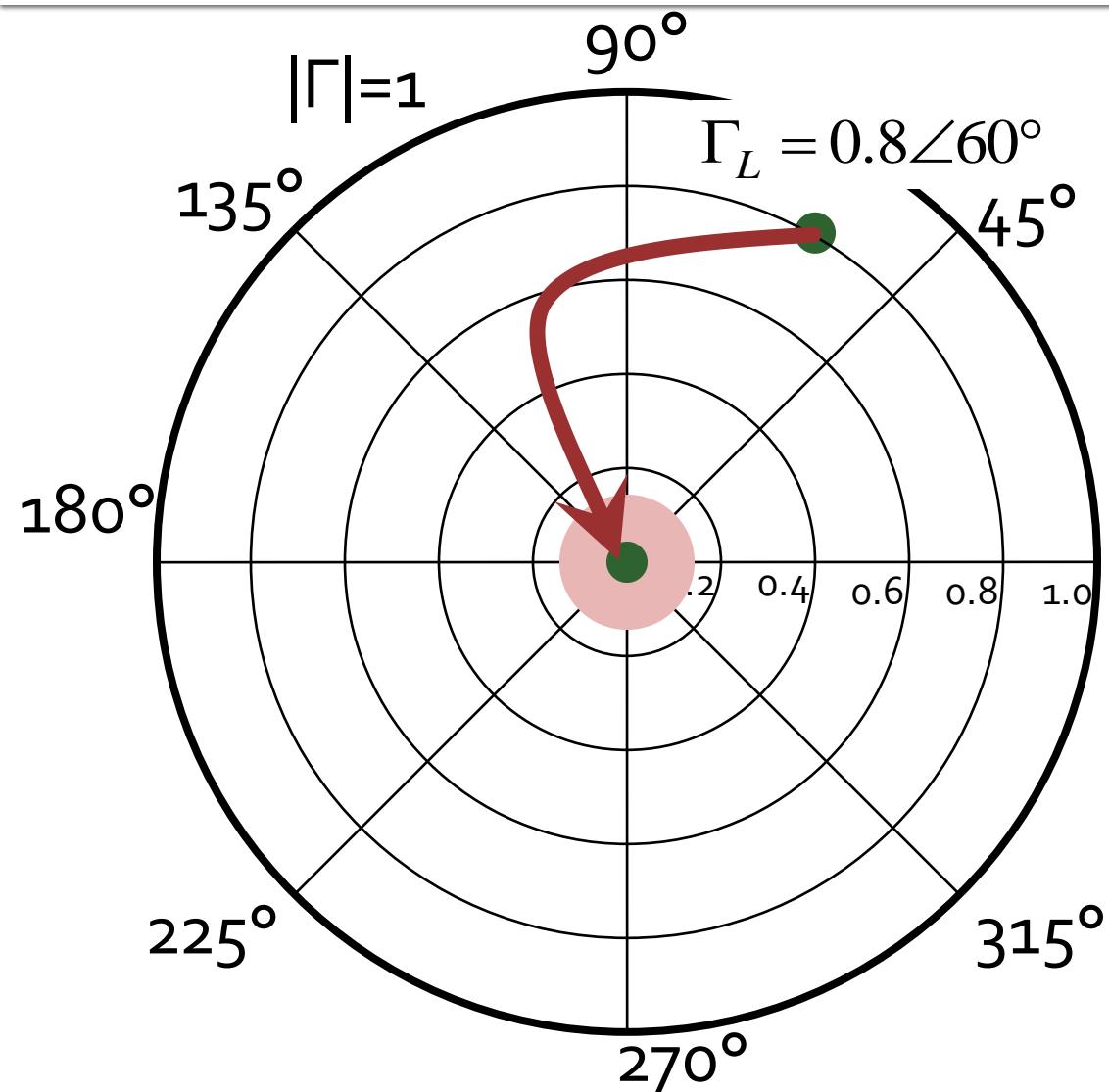
# Diagrama Smith, impedanta



# Echivalenta coeficient de reflexie $\Leftrightarrow$ impedanta



# Diagrama Smith, adaptare



Adaptare  $Z_L$  la  $Z_0$ .

Trebuie sa deplasez coeficientul de reflexie in zona in care pentru generator cu  $Z_0$  am:

$\Gamma_0 = 0$  adaptare perfecta ●

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

Adaptarea cu elemente concentrate (Retele in L)

# **Adaptarea de impedanță**

Adaptarea cu sectiuni de linii (stub)

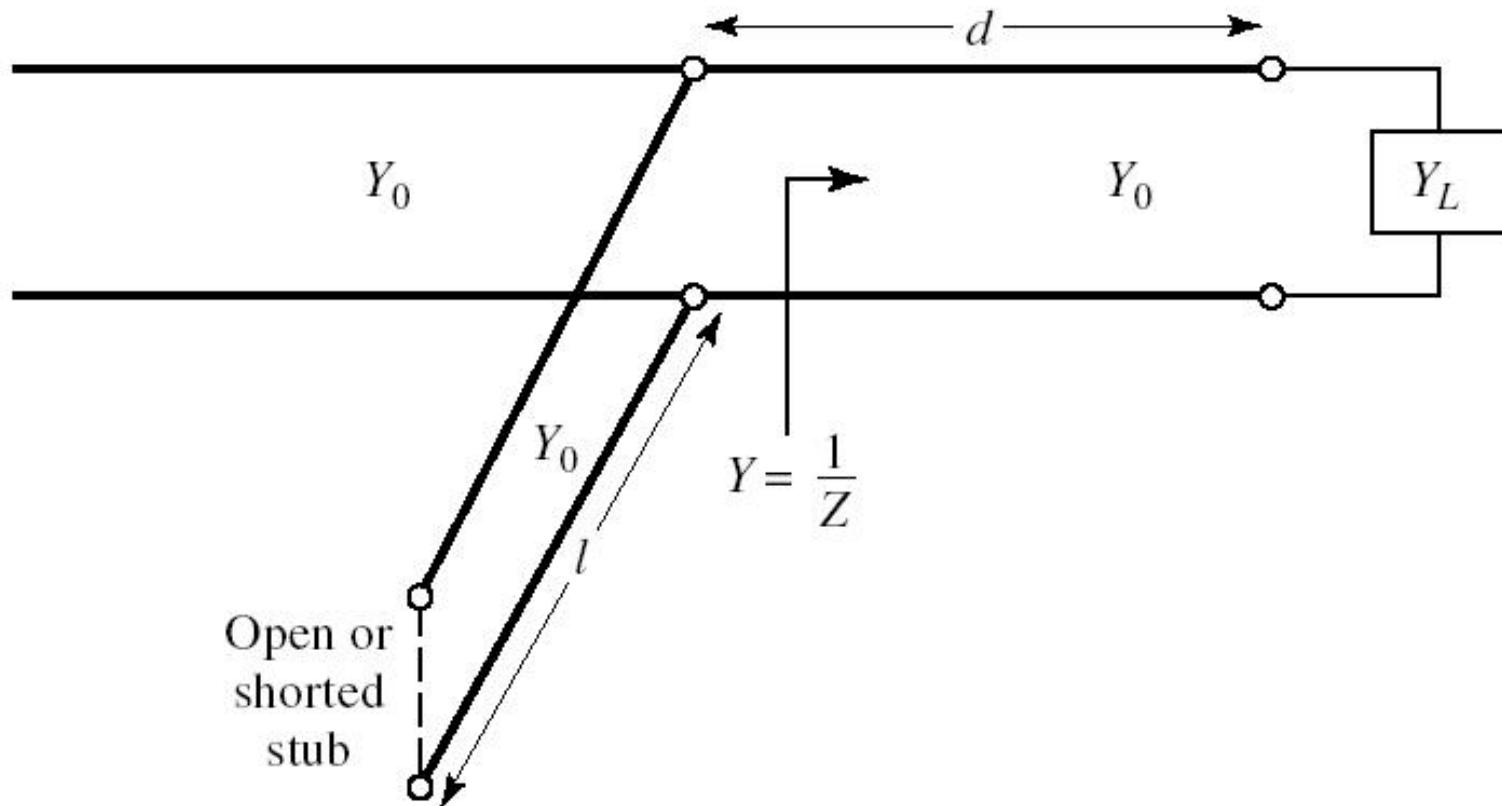
# **Adaptarea de impedanță**

# Stub

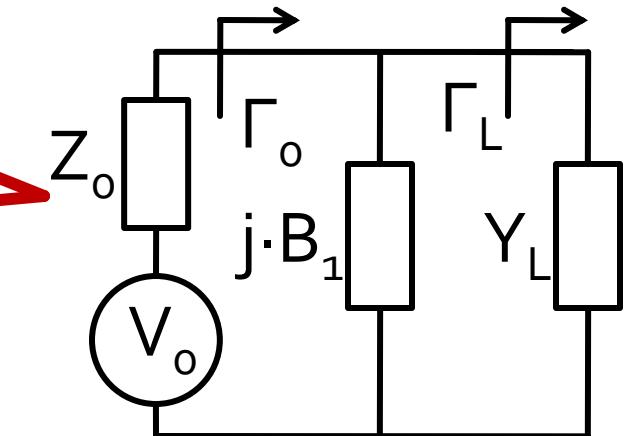
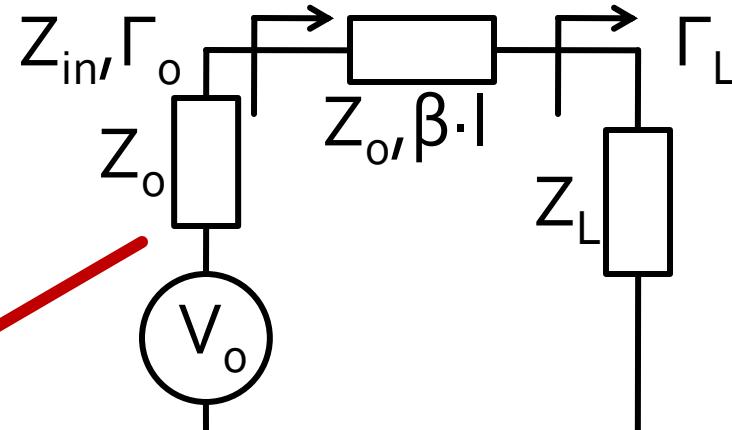
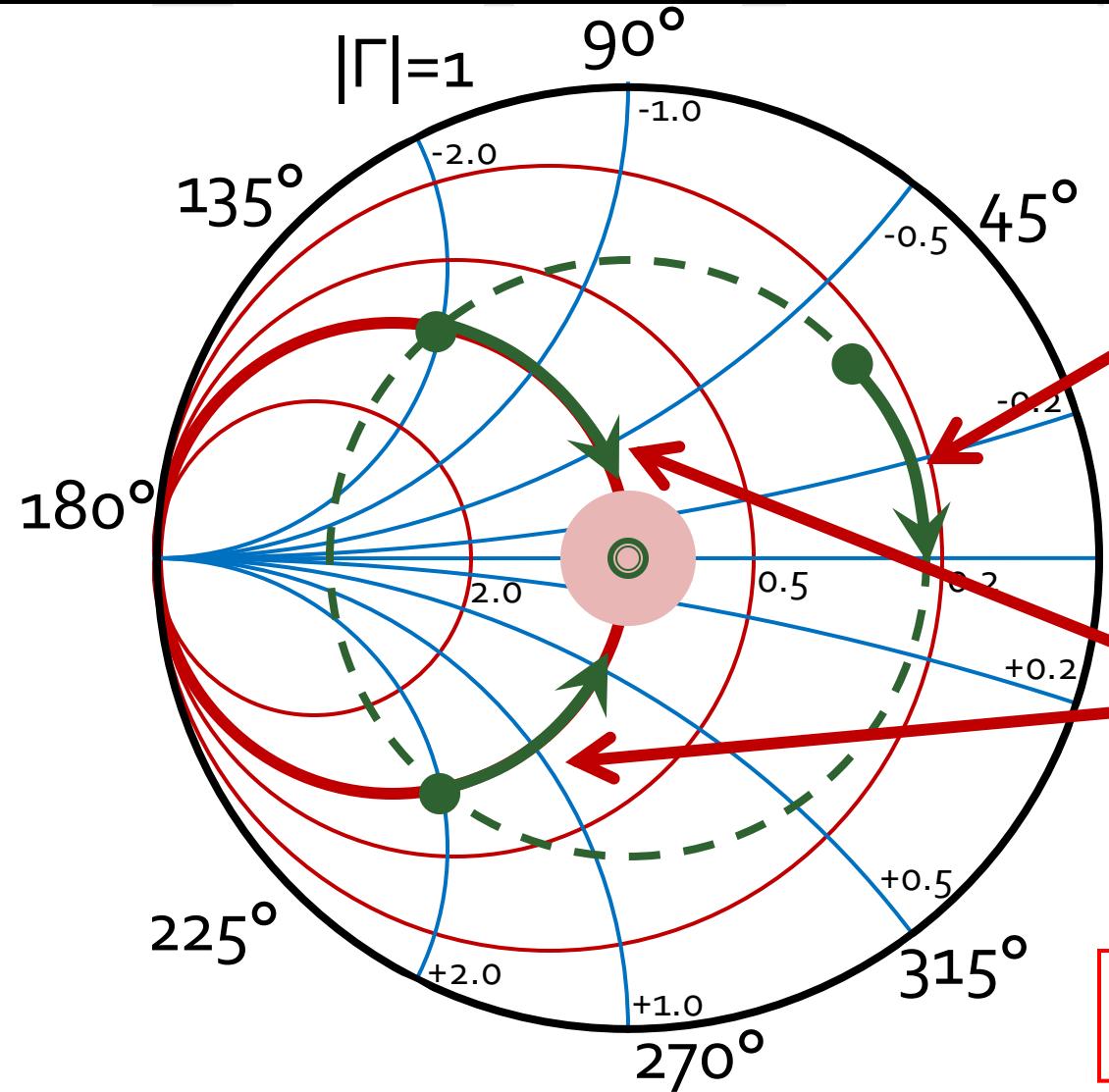
- stub=rest, ciot, cotor, capăt
- Se evita utilizarea elementelor concentrate
- Se realizeaza (foarte precis) utilizând liniile de transmisie uzuale ale circuitului
- Se utilizeaza sectiuni de linie (stub-uri) in serie sau paralel care pot fi:
  - in gol
  - scurtcircuitate
- De obicei liniile in gol sunt mai usor de implementat si sunt preferate

# Single stub tuning

- Shunt Stub (secțiune de linie în paralel)



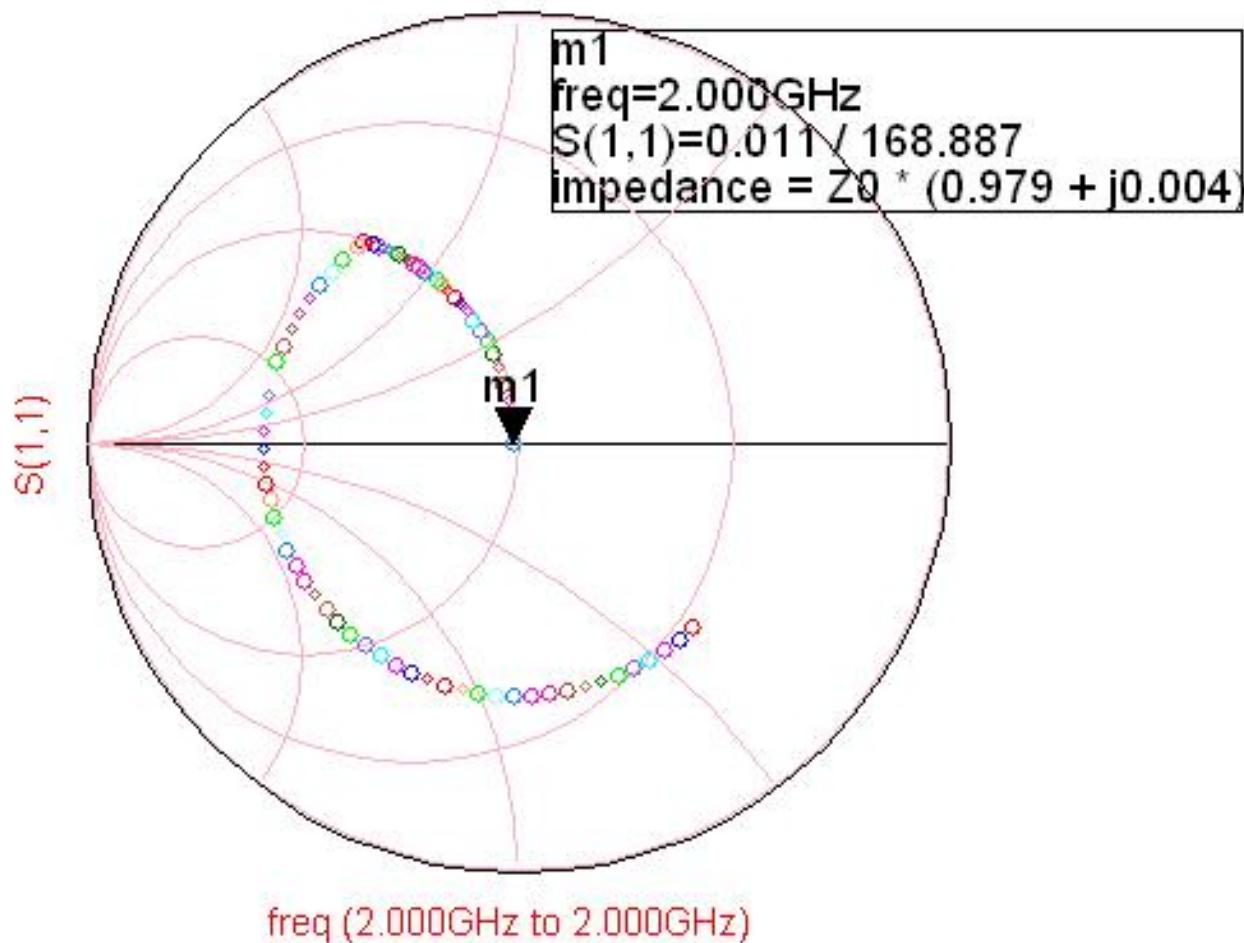
# Adaptare, linie serie + susceptanta in paralel



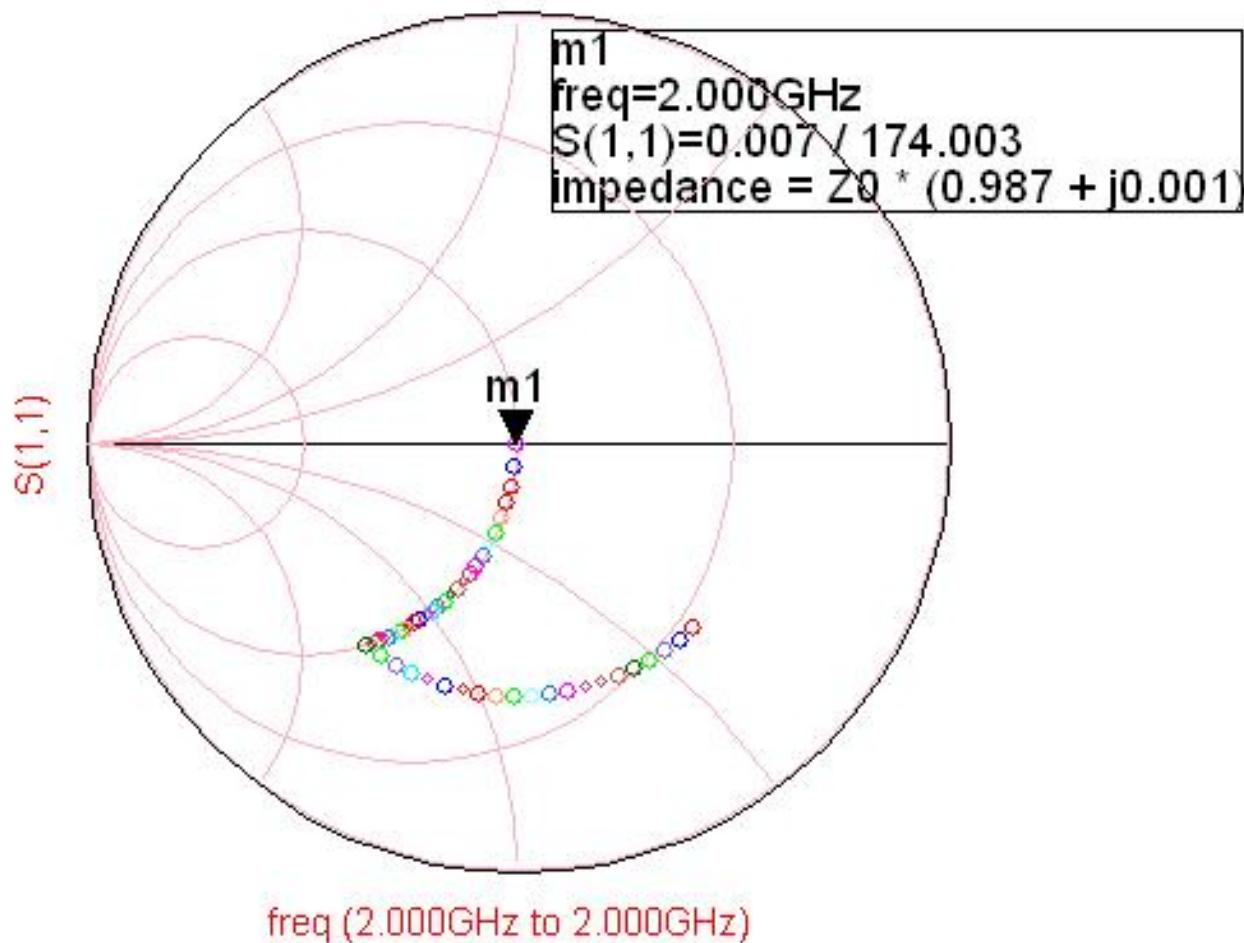
$$|\Gamma_{in}| = |\Gamma_L|$$

$$g_{in} = 1$$

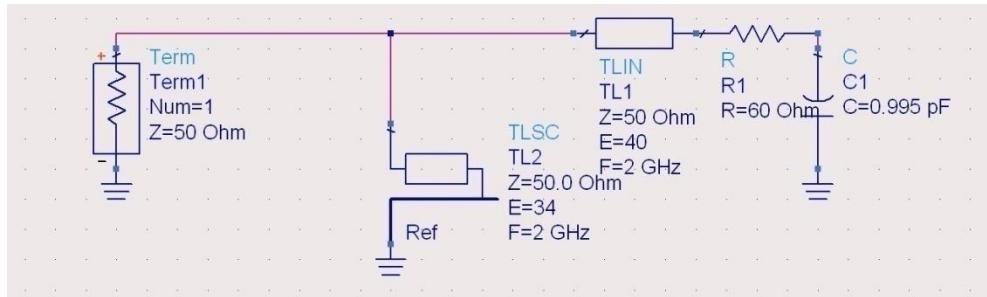
# Exemplu, Shunt Stub, sc



# Exemplu, Shunt Stub, sc



# Exemplu, Shunt Stub, sc

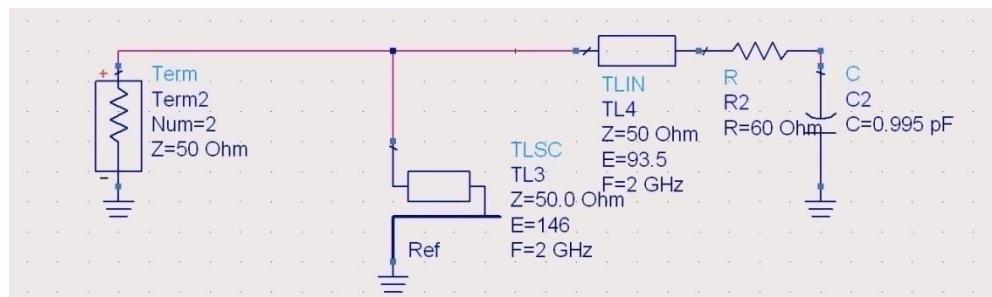


$$l_1 = \frac{40^\circ}{360^\circ} \cdot \lambda = 0.111 \cdot \lambda$$

$$l_2 = \frac{34^\circ}{360^\circ} \cdot \lambda = 0.094 \cdot \lambda$$

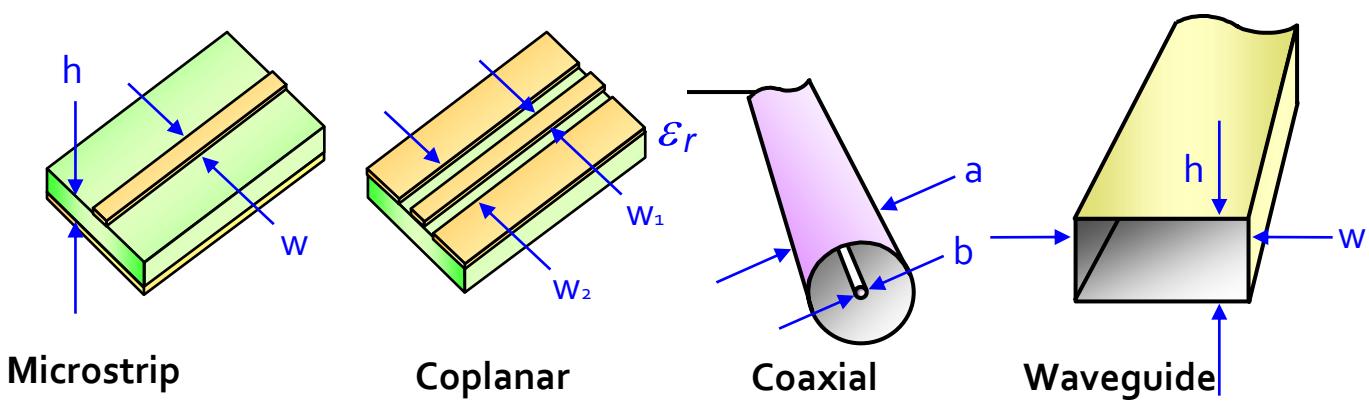
$$l_1 = \frac{93.5^\circ}{360^\circ} \cdot \lambda = 0.260 \cdot \lambda$$

$$l_2 = \frac{146^\circ}{360^\circ} \cdot \lambda = 0.406 \cdot \lambda$$



# Adaptarea cu sectiuni de linii (stub)

- Se alege una din cele 8 solutii posibile convenabila tinand cont de:
  - realizabilitate fizica (conform tehnologiei de linie utilizata)

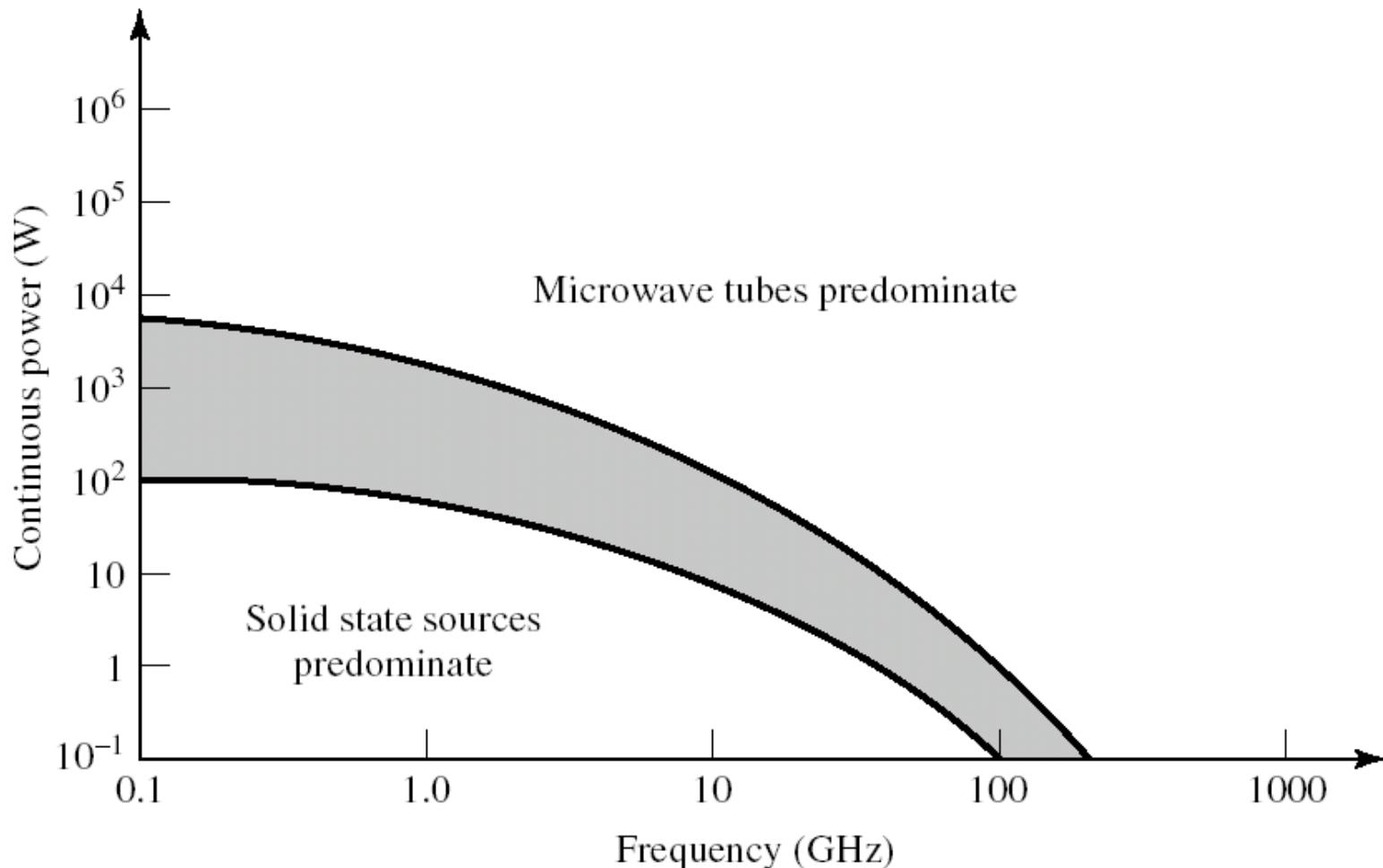


- Dezavantaj:
  - lungimea sectiunii de linie serie e variabila

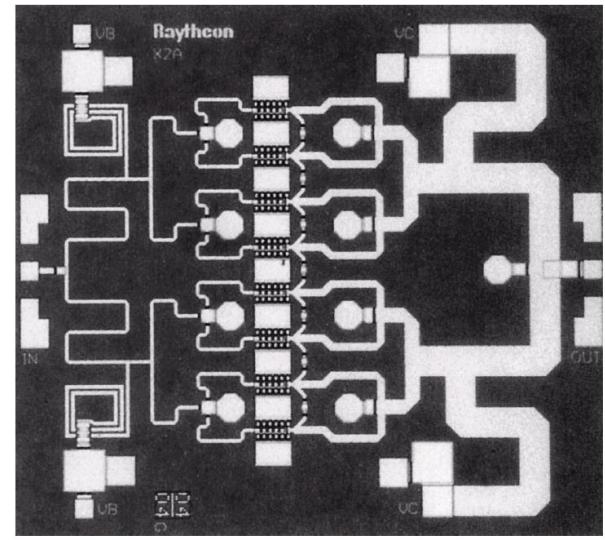
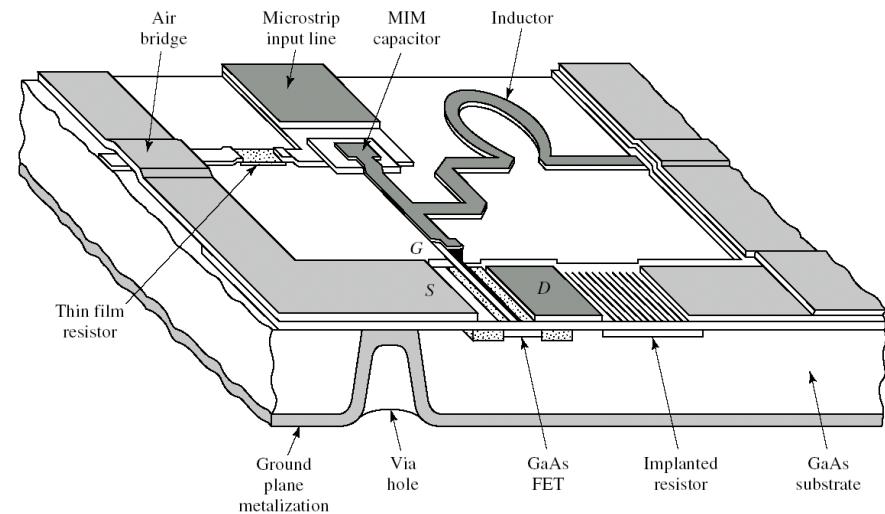
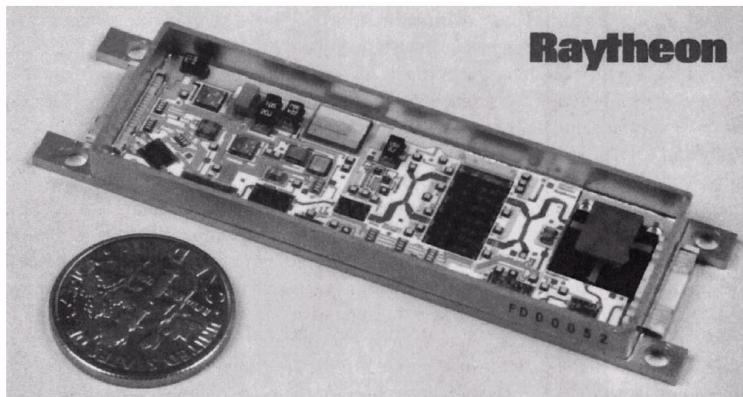
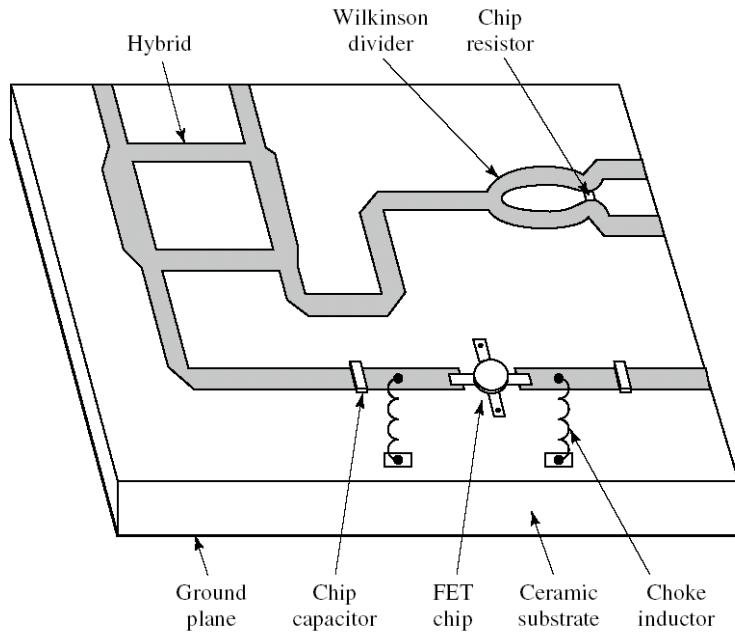
Preview (pentru laborator 3-4)

# **Amplificatoare de microunde**

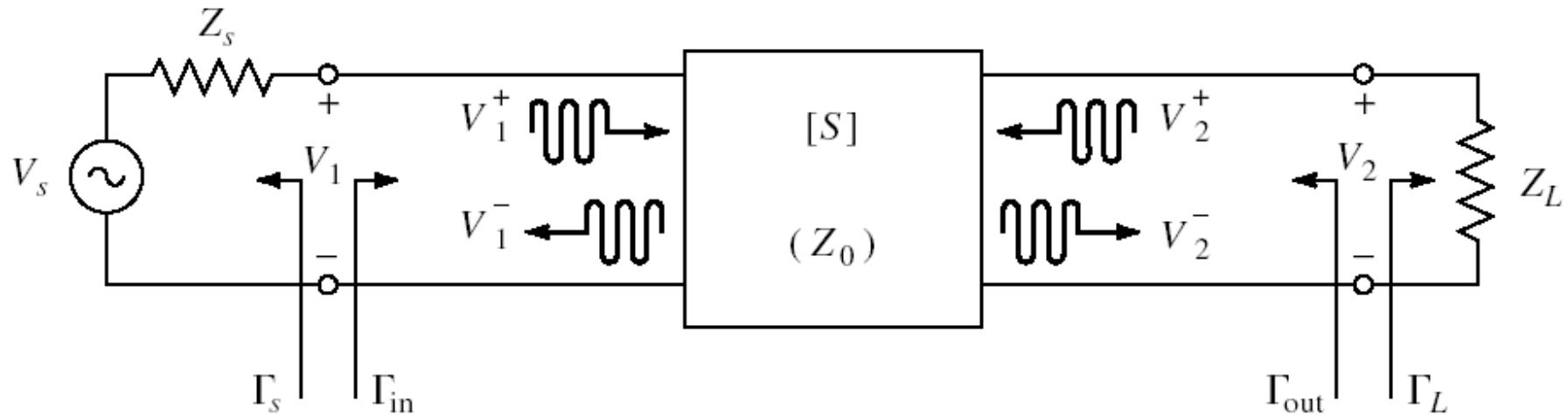
# Amplificatoare pentru microunde



# 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

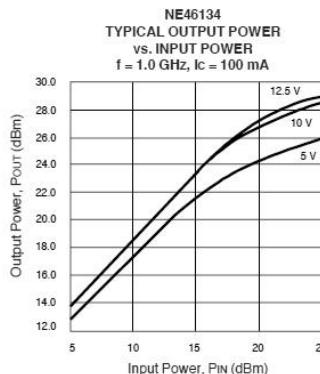
### NPN MEDIUM POWER MICROWAVE TRANSISTOR

#### 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			
$IS_{21E1^2}$	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

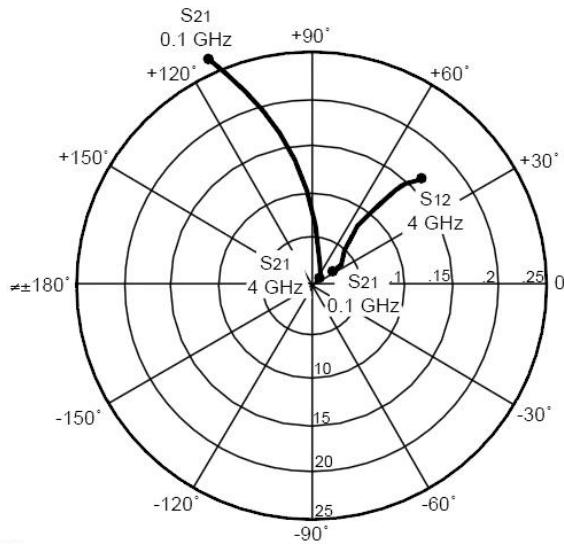
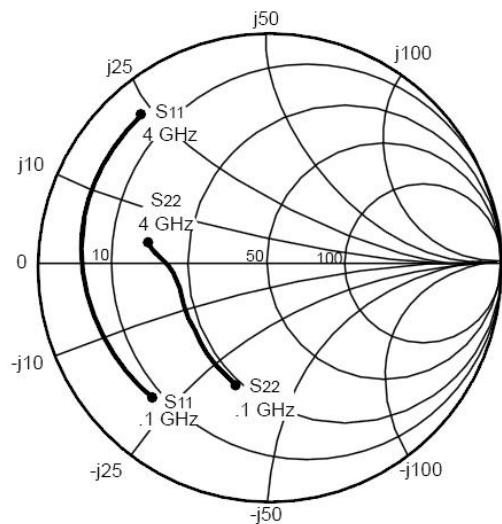
**VCE = 5 V, Ic = 100 mA**

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

# Catalogage

NE46100, NE46134

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



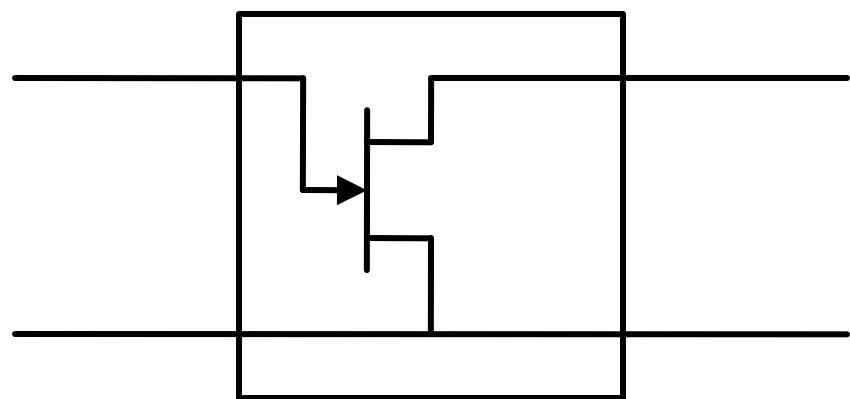
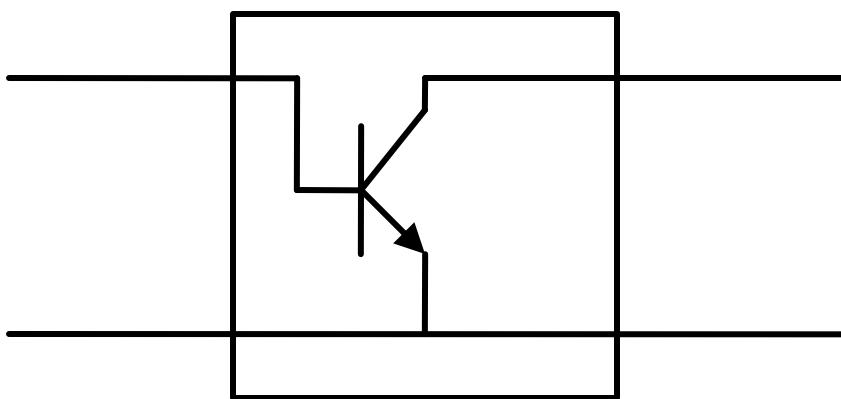
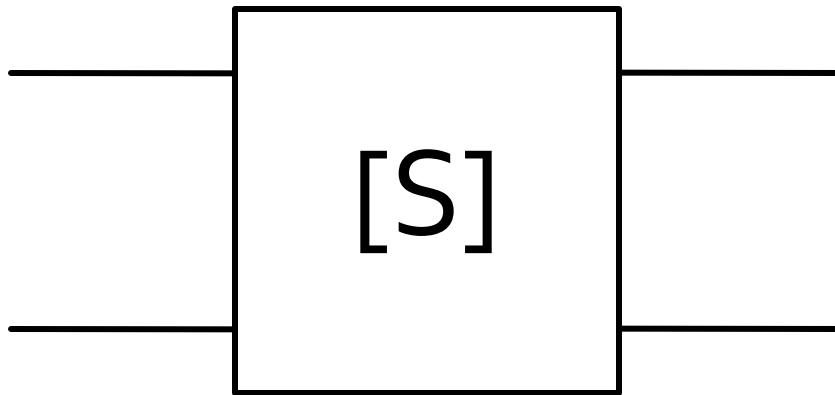
Coordinates in Ohms  
Frequency in GHz  
 $V_{CE} = 5 \text{ V}, I_C = 50 \text{ mA}$

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

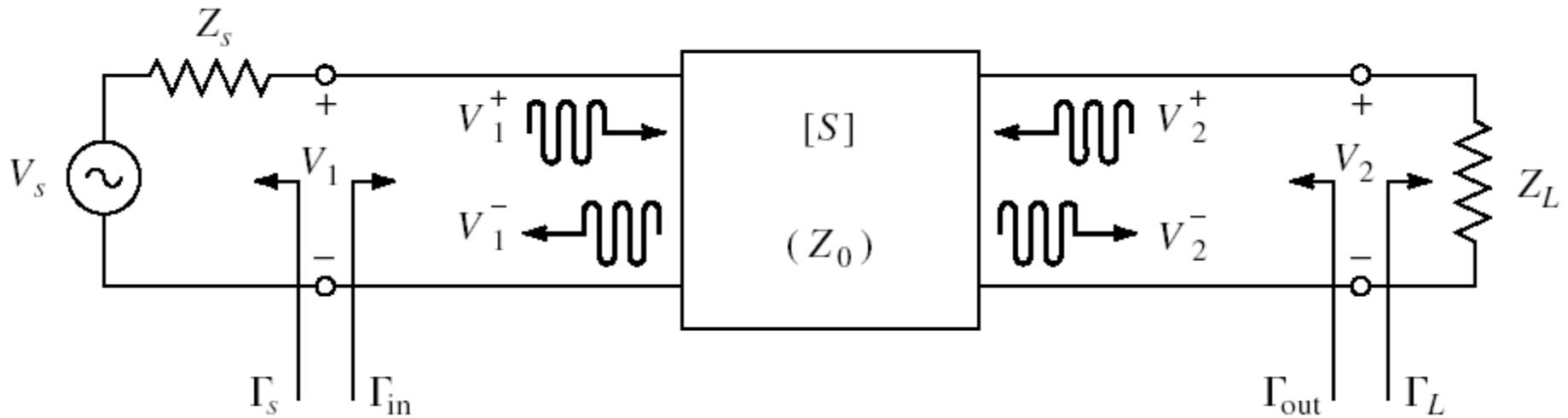
## ■ Fisiere format Touchstone (\*.s2p)

```
! 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
```

# Parametri S



# Diport amplifier



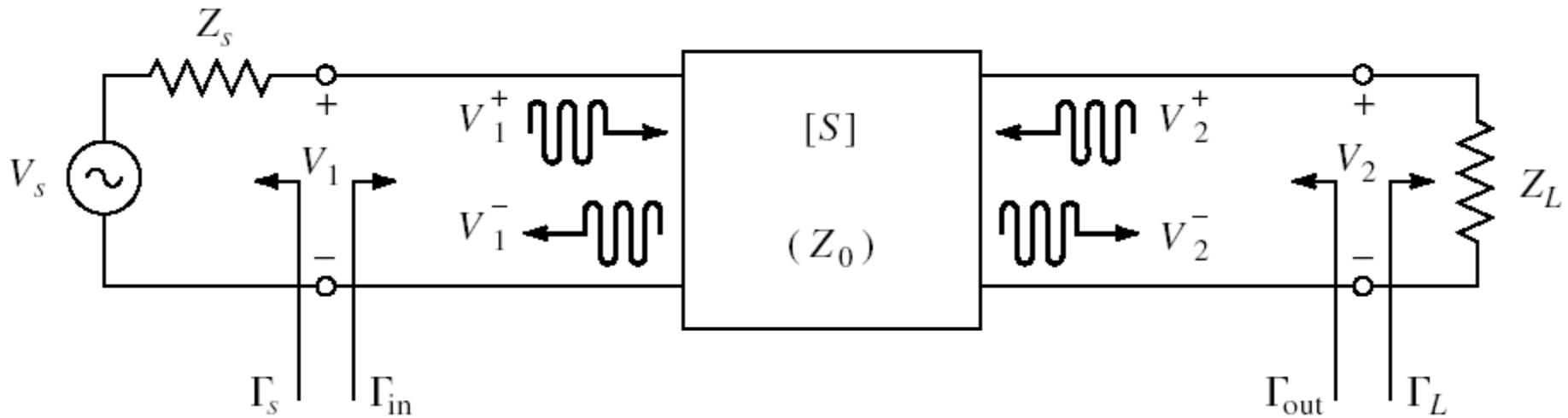
$$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0} \quad \Gamma_S = \frac{Z_S - Z_0}{Z_S + Z_0} \quad \begin{bmatrix} V_1^- \\ V_2^- \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} V_1^+ \\ V_2^+ \end{bmatrix}$$

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

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

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

# 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

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

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

# 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

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

## ■ Puterea disponibila la sarcina

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

# 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**

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

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

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

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

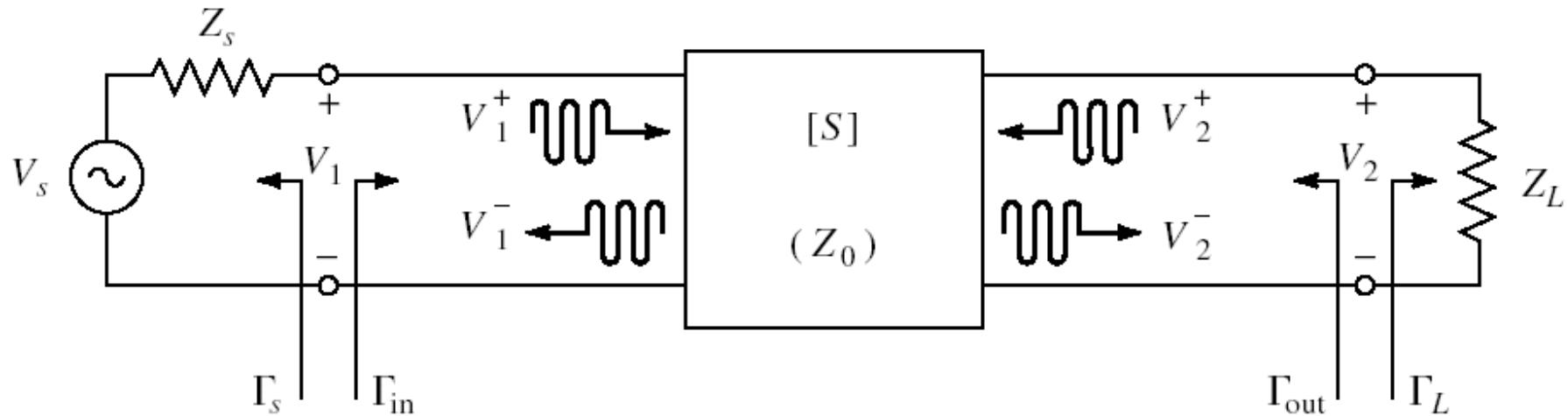
## ■ Castigul de putere de **transfer unilateral**

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

$$S_{12} \cong 0 \quad \Gamma_{in} = S_{11}$$

Permite tratarea separata  
a intrarii si iesirii

# Cuadripol Amplificator



- 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  $\Gamma_S, \Gamma_L$  pentru a obtine stabilitatea

# Stabilitate

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

## ■ Limita 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

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

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

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

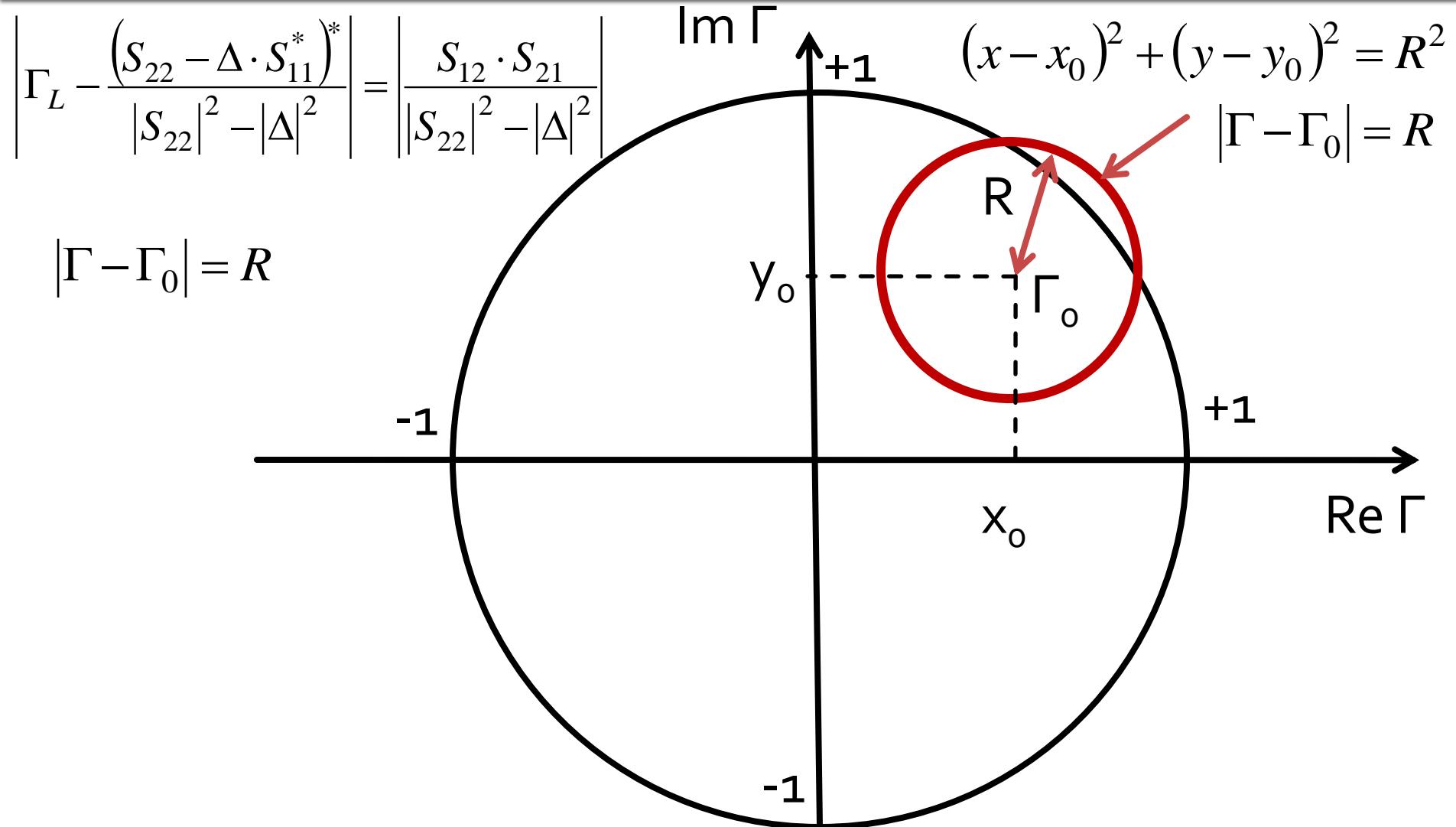
$$|S_{11}|^2 + |\Delta|^2 \cdot |\Gamma_L|^2 - (\Delta \cdot \Gamma_L \cdot S_{11}^* + \Delta^* \cdot \Gamma_L^* \cdot S_{11}) = 1 + |S_{22}|^2 \cdot |\Gamma_L|^2 - (S_{22}^* \cdot \Gamma_L^* + S_{22} \cdot \Gamma_L)$$

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

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

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

# Stabilitate



# Cerc de stabilitate la ieșire

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

- 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

- 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** ( $\Gamma_S$ )

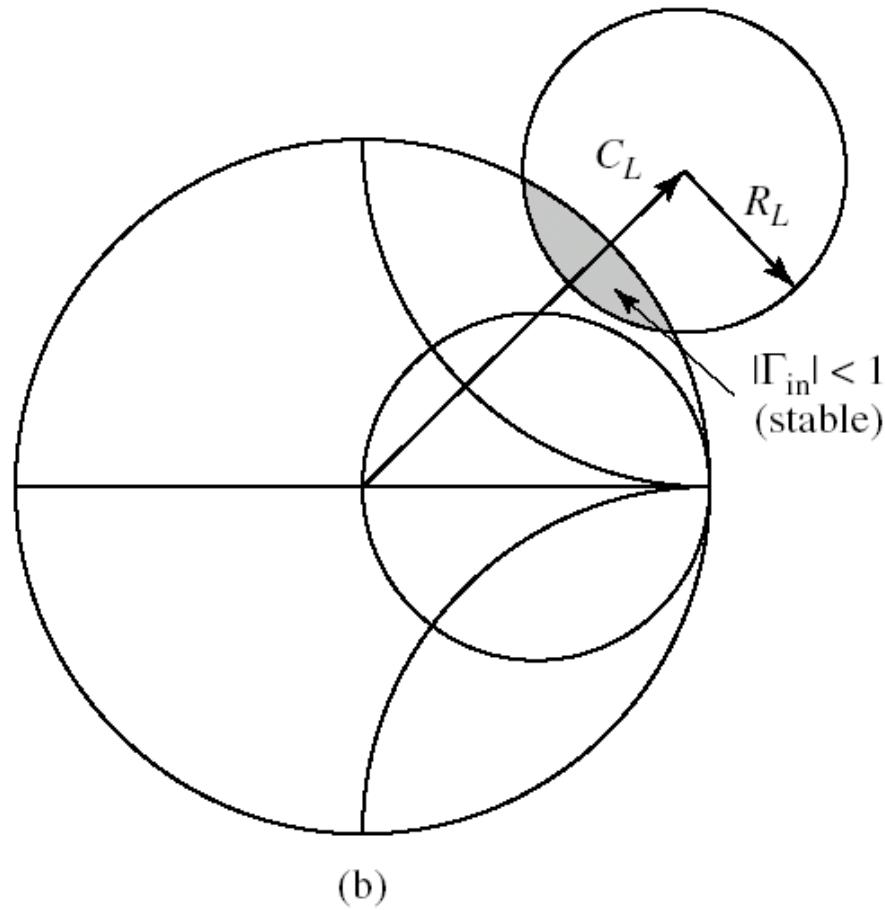
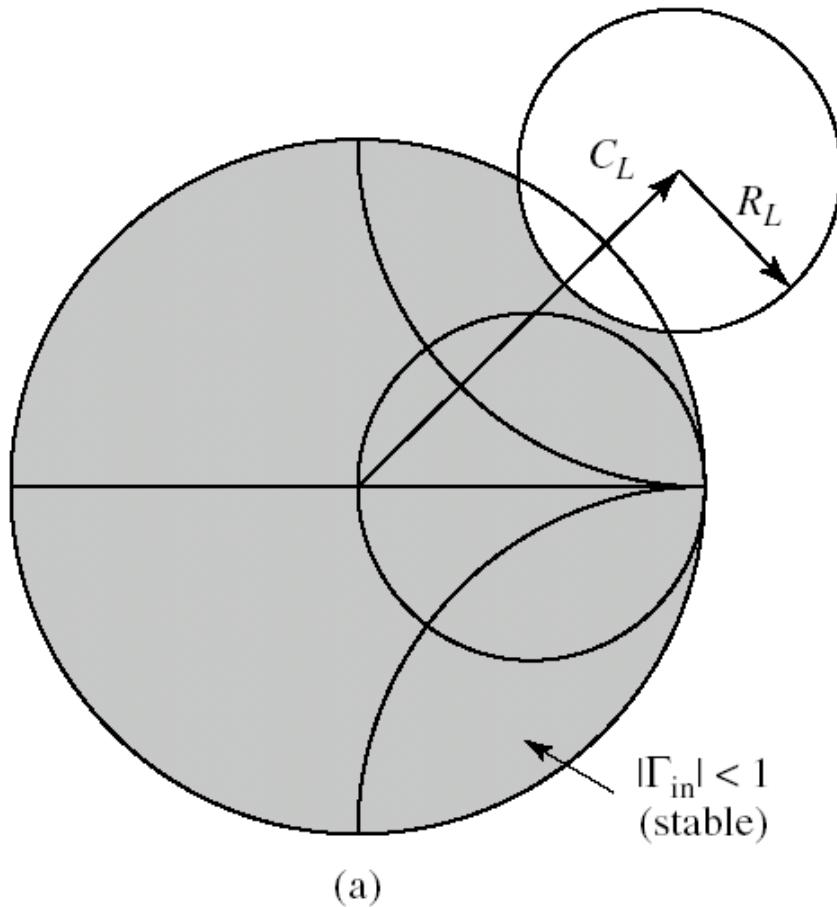
$$C_S = \frac{(S_{11} - \Delta \cdot S_{22}^*)^*}{|S_{11}|^2 - |\Delta|^2}$$

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

# Cerc de stabilitate la ieșire

- **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



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

# Cerc de stabilitate la iesire

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

# Calcul

## ■ Parametri S

- $S_{11} = -0.483 + 0.42 \cdot j$
- $S_{12} = 0.111 - 0.043 \cdot j$
- $S_{21} = 3.042 + 0.872 \cdot j$
- $S_{22} = -0.182 + 0.123 \cdot j$

$$C_L = \frac{(S_{22} - \Delta \cdot S_{11}^*)^*}{|S_{22}|^2 - |\Delta|^2} = 3.931 - 0.897 \cdot j$$

$$|C_L| = 4.032$$

$$R_L = \frac{|S_{12} \cdot S_{21}|}{|S_{22}|^2 - |\Delta|^2} = 4.891$$

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

$$|S_{11}| < 1$$

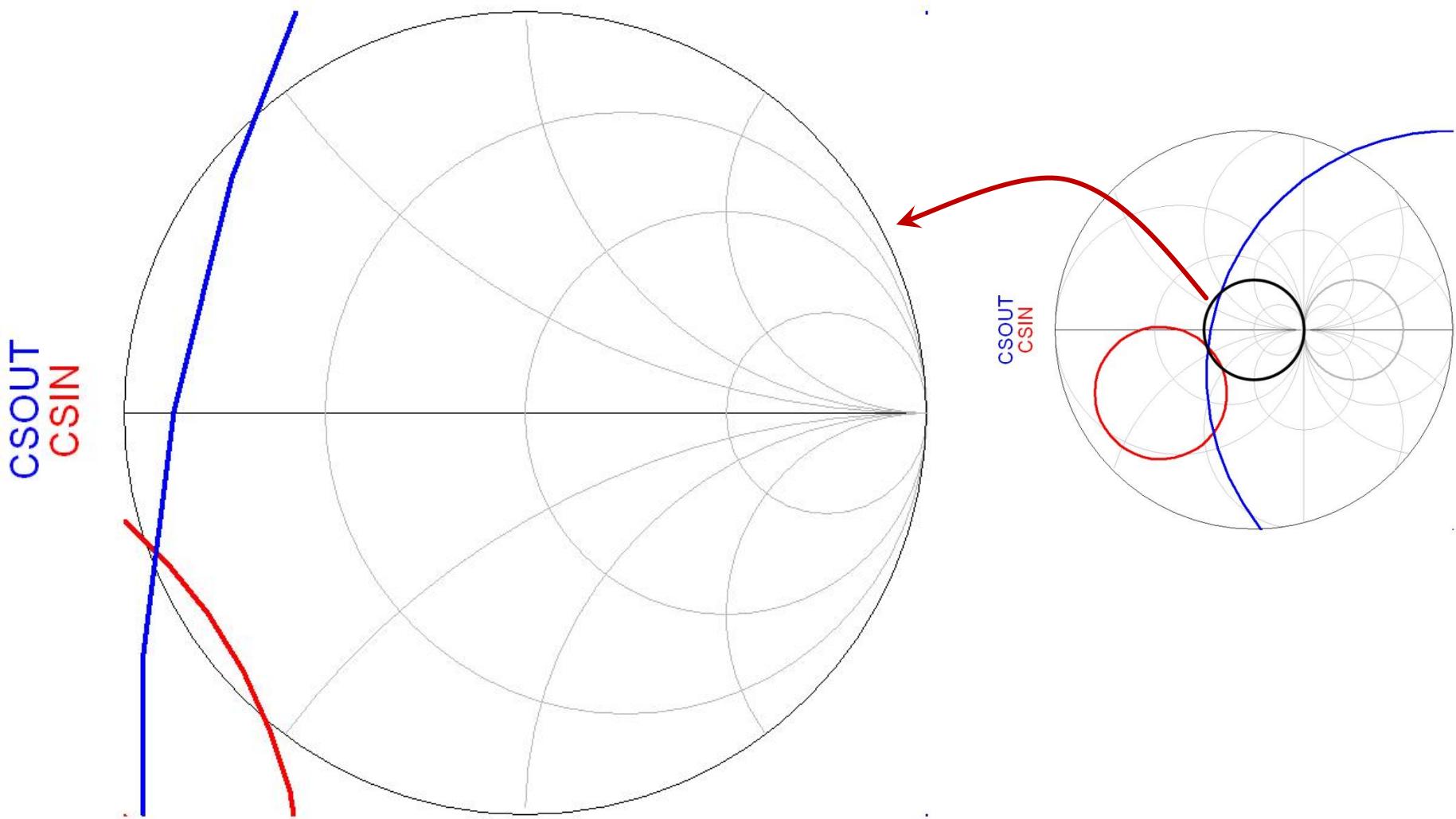
$$|S_{22}| < 1$$

$$|C_L| < R_L \text{ o } \in CSOUT \quad |C_S| = 2.259$$

$$|C_S| > R_S \text{ o } \notin CSIN$$

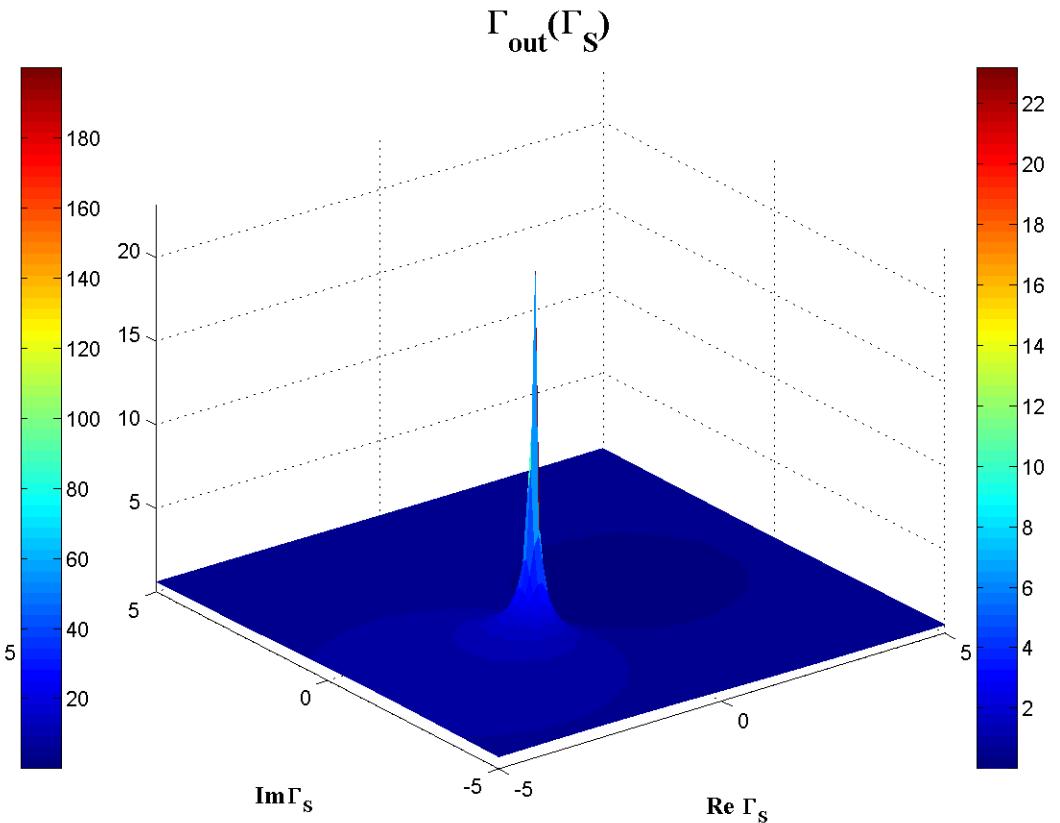
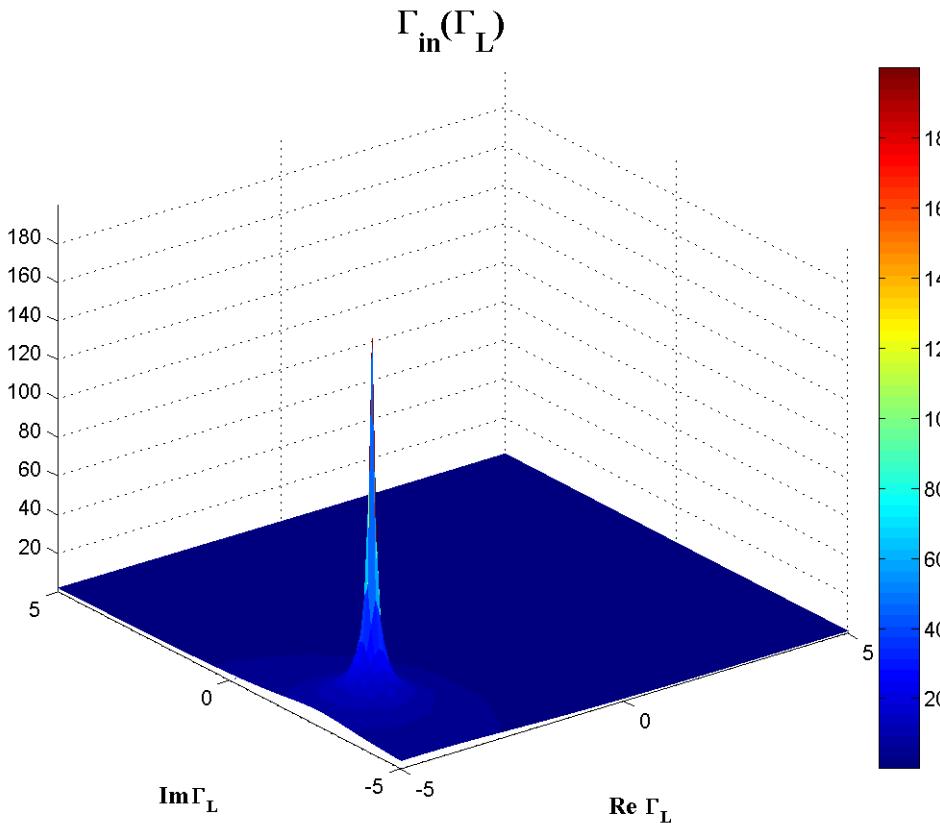
$$R_S = \frac{|S_{12} \cdot S_{21}|}{|S_{11}|^2 - |\Delta|^2} = 1.325$$

# ADS



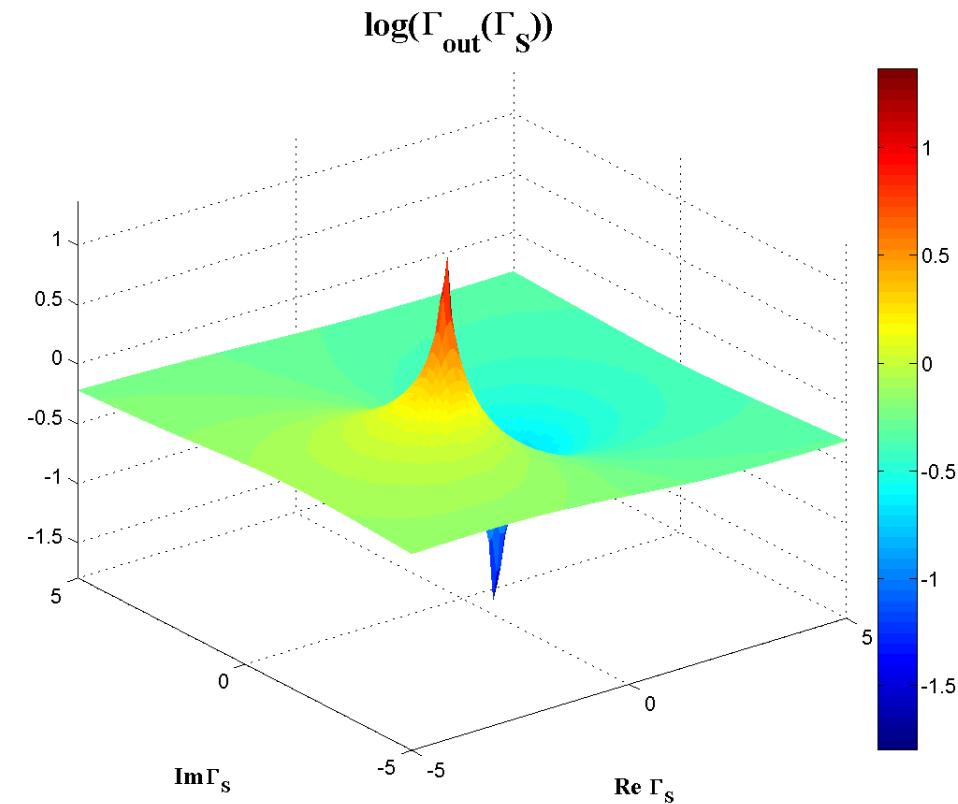
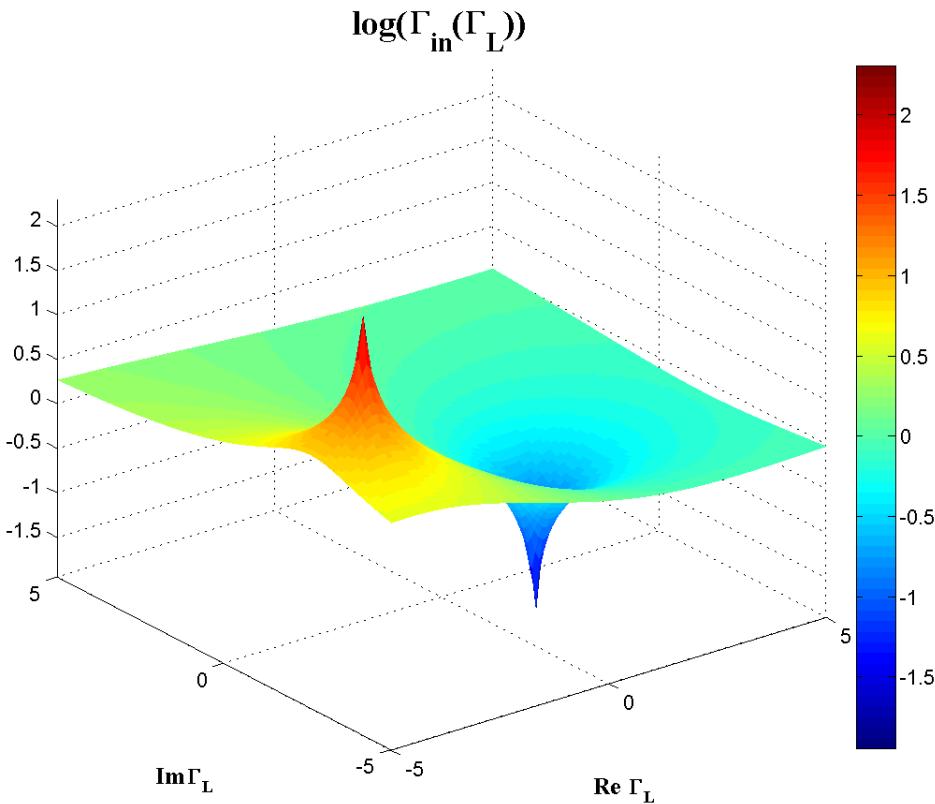
# Reprezentare 3D $|\Gamma_{\text{in}}|, |\Gamma_{\text{out}}|$

- Variatii foarte mari  $\rightarrow$  logaritmic



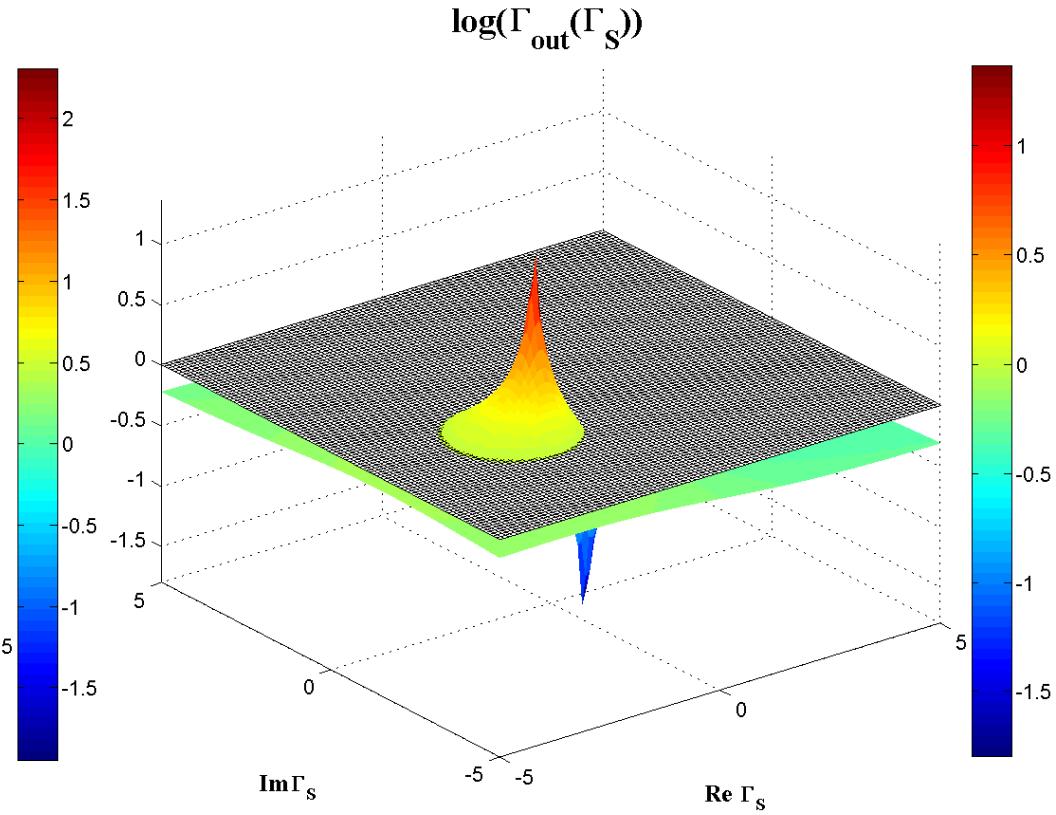
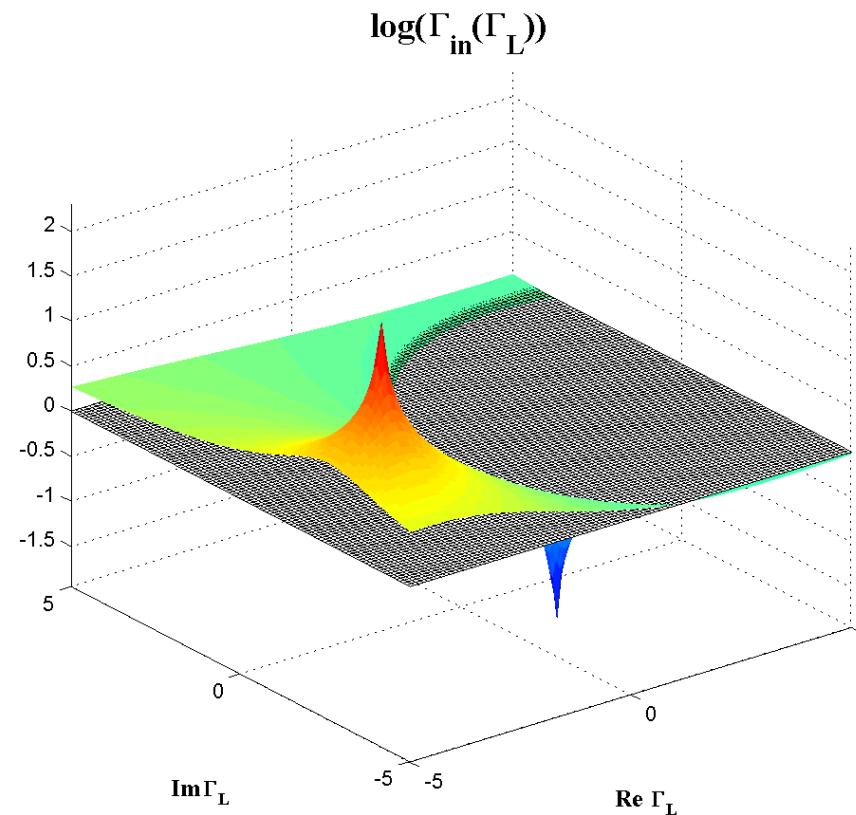
# Reprezentare 3D $|\Gamma_{\text{in}}|, |\Gamma_{\text{out}}|$

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



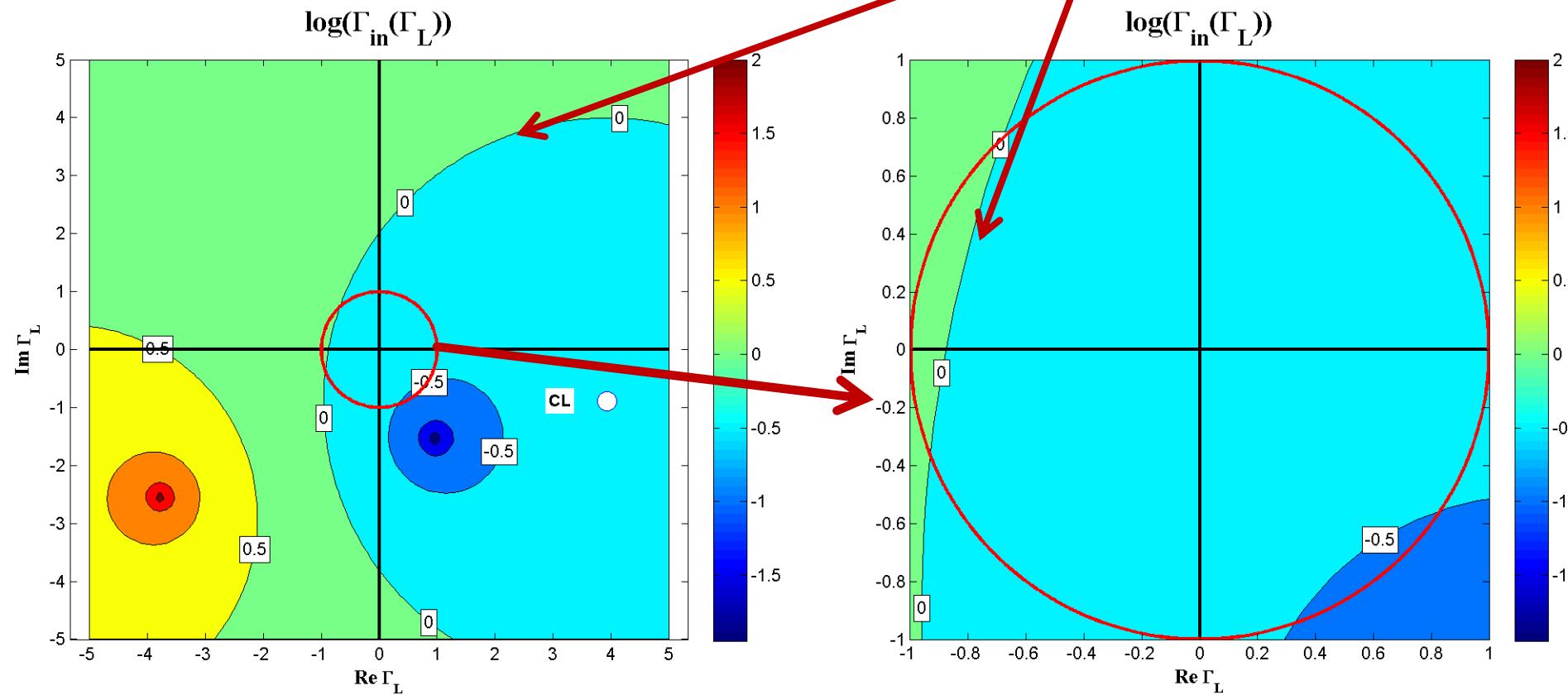
# Reprezentare 3D $|\Gamma_{\text{in}}|, |\Gamma_{\text{out}}|, |\Gamma|=1$

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



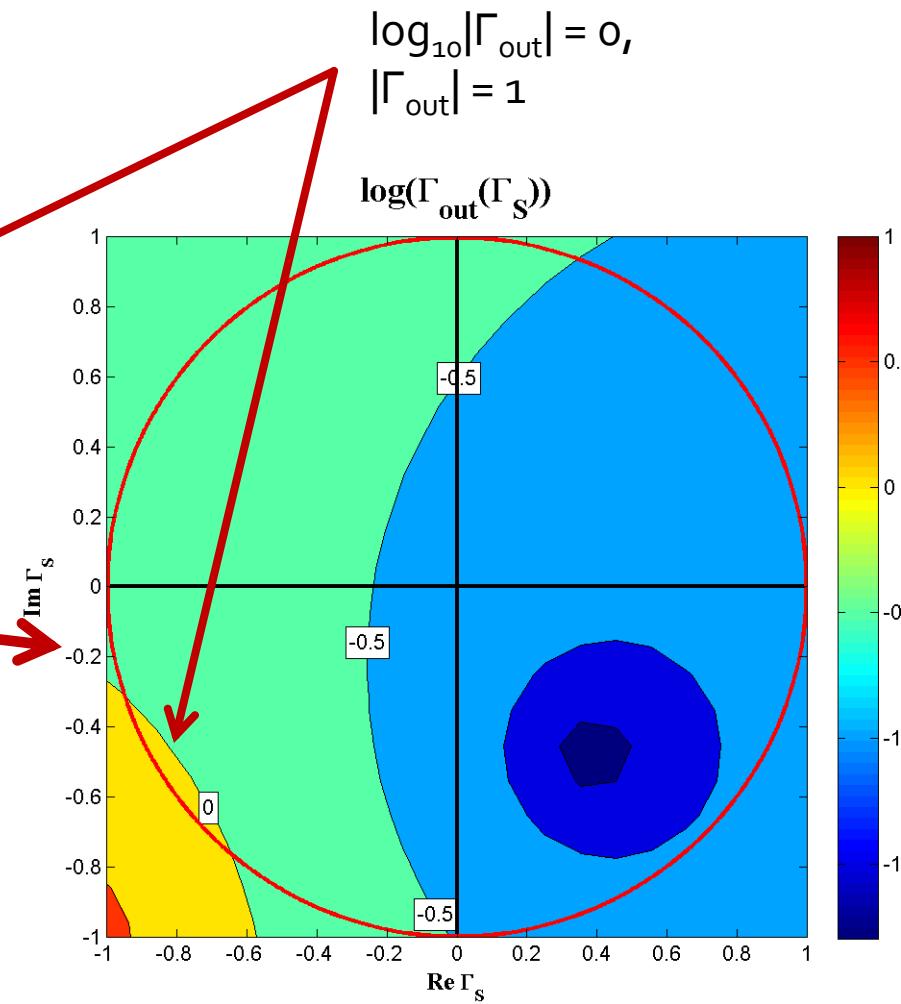
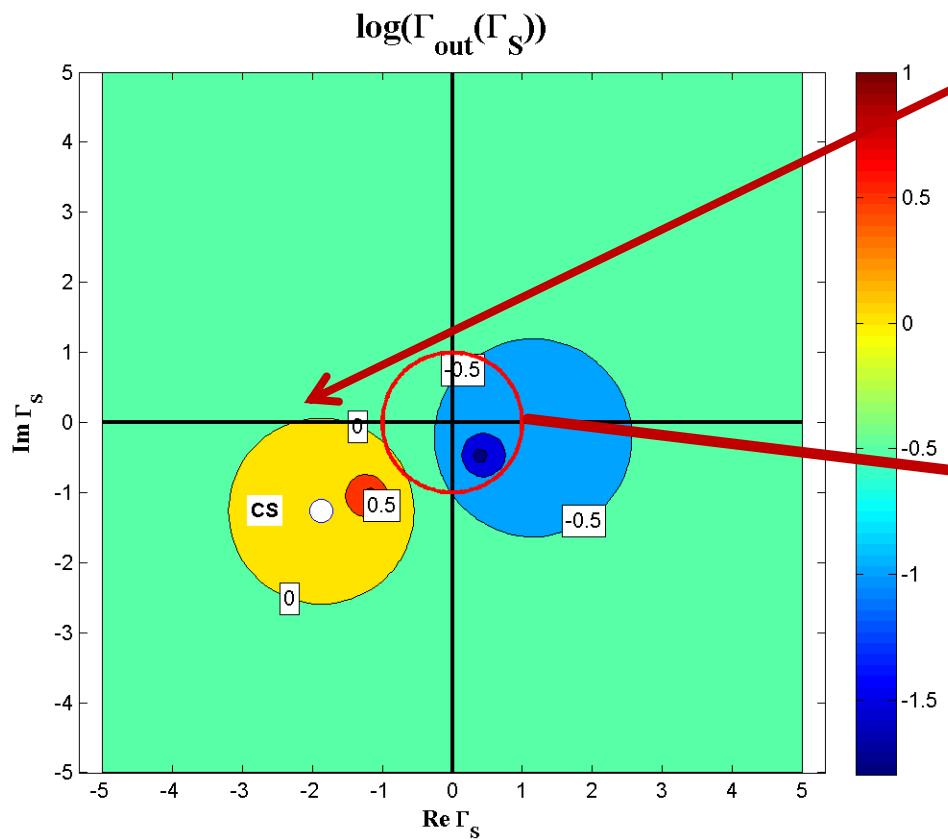
# Reprezentare 3D $|\Gamma_{\text{in}}|, |\Gamma_{\text{out}}|$

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



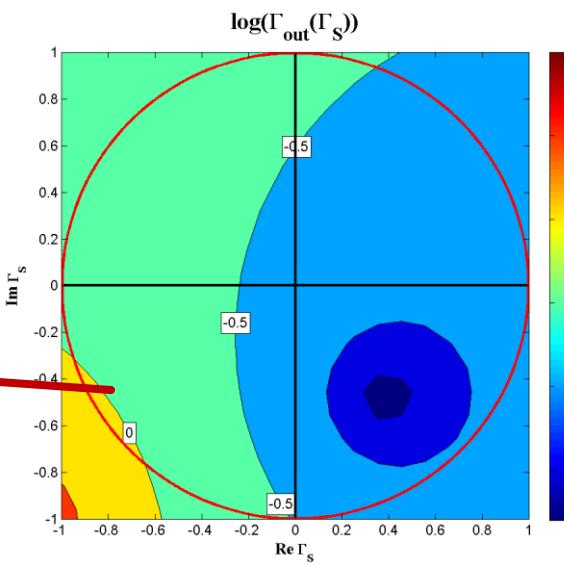
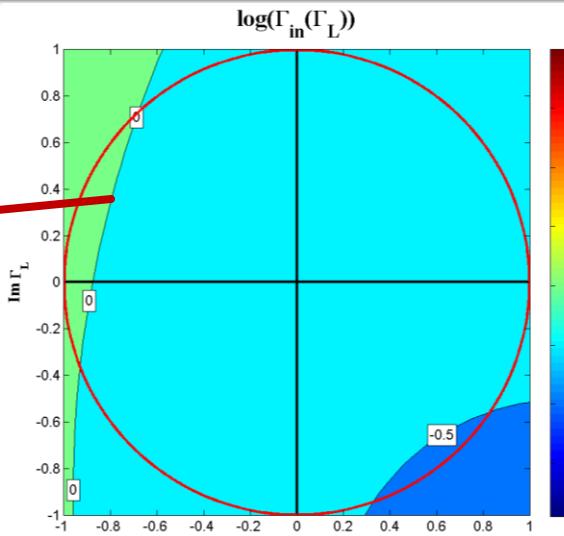
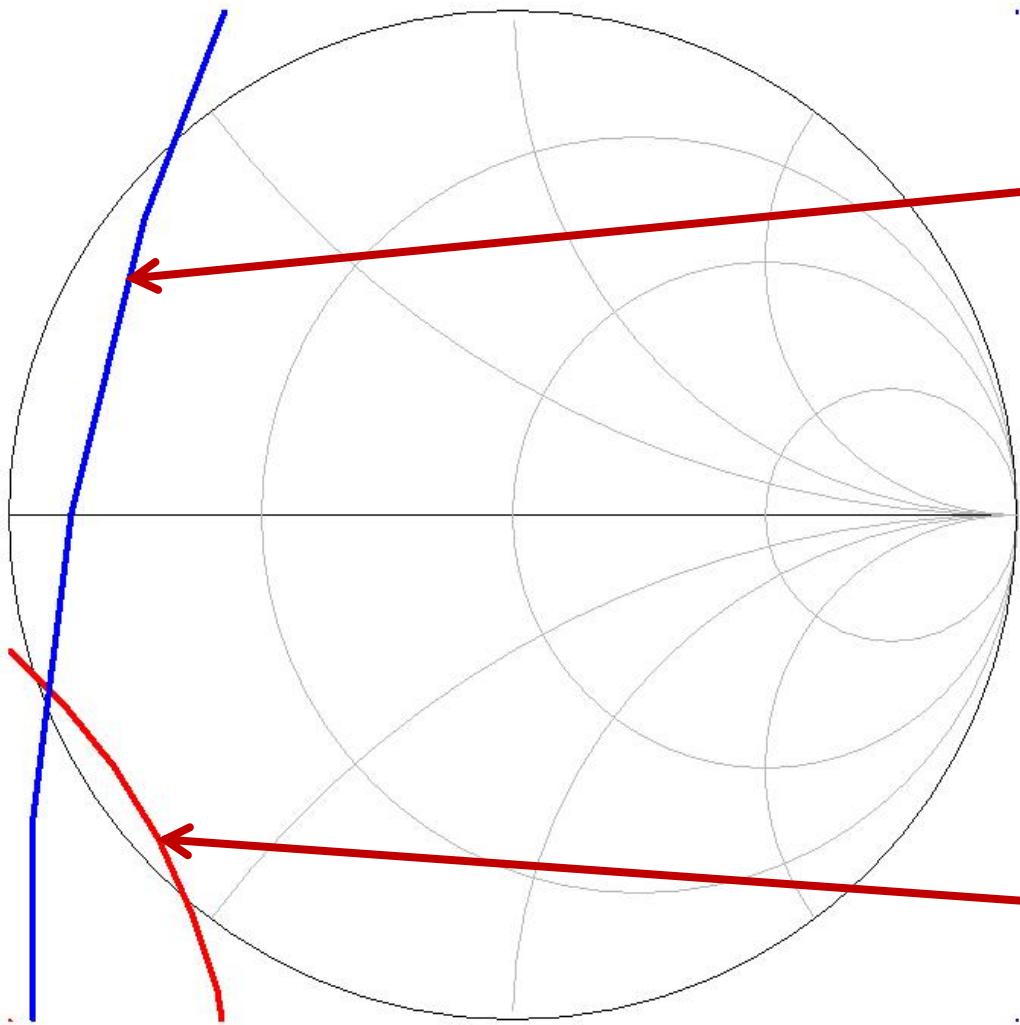
# Reprezentare 3D $|\Gamma_{\text{in}}|, |\Gamma_{\text{out}}|$

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

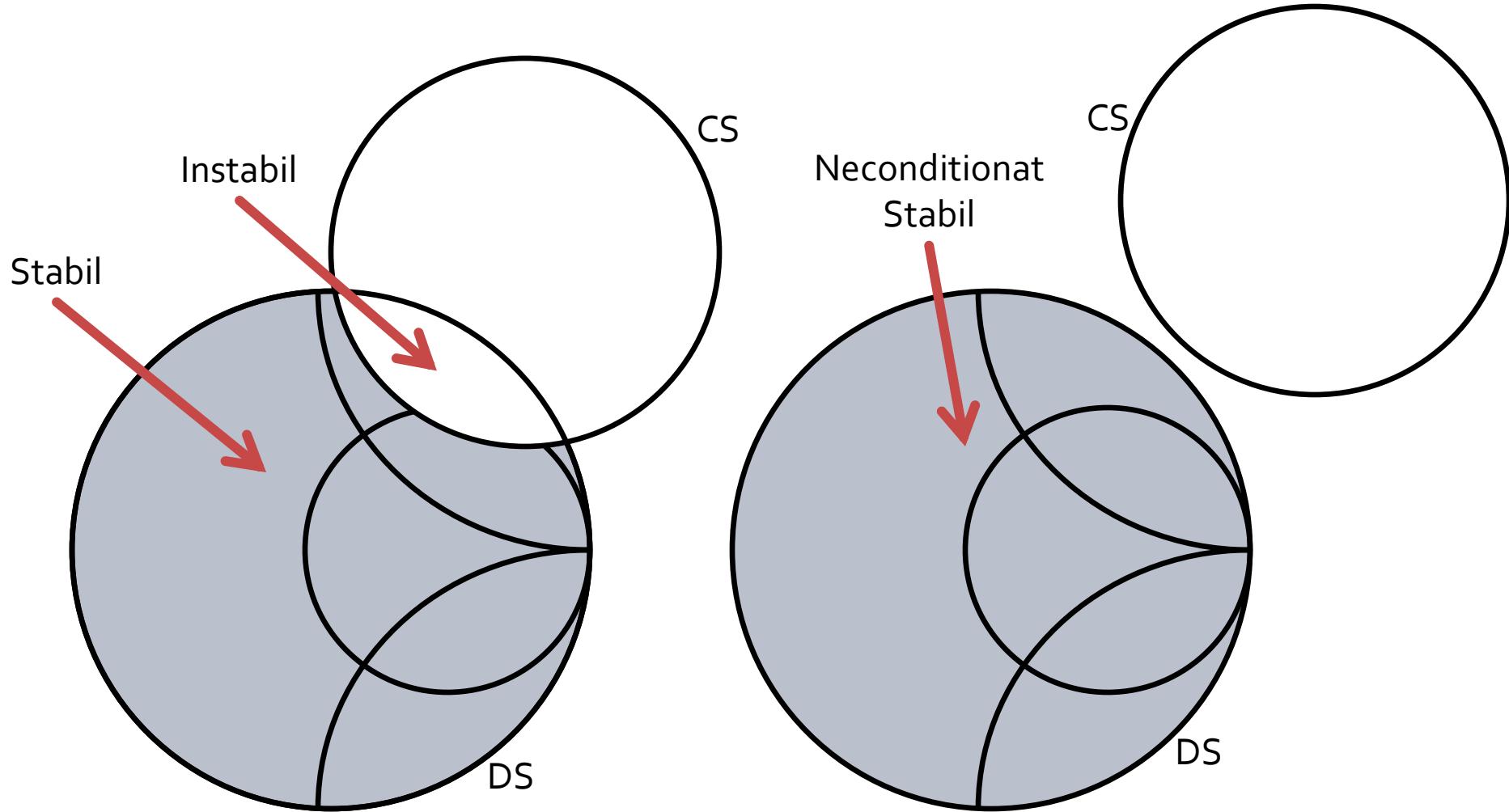


# CSIN, CSOUT

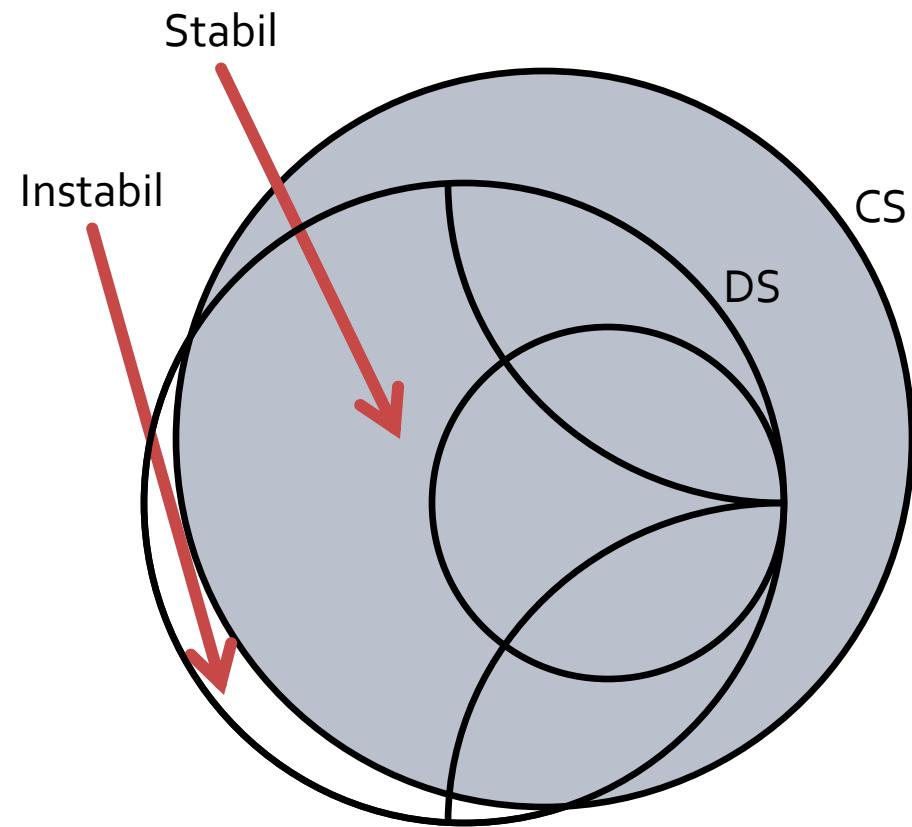
CSOUT  
CSIN



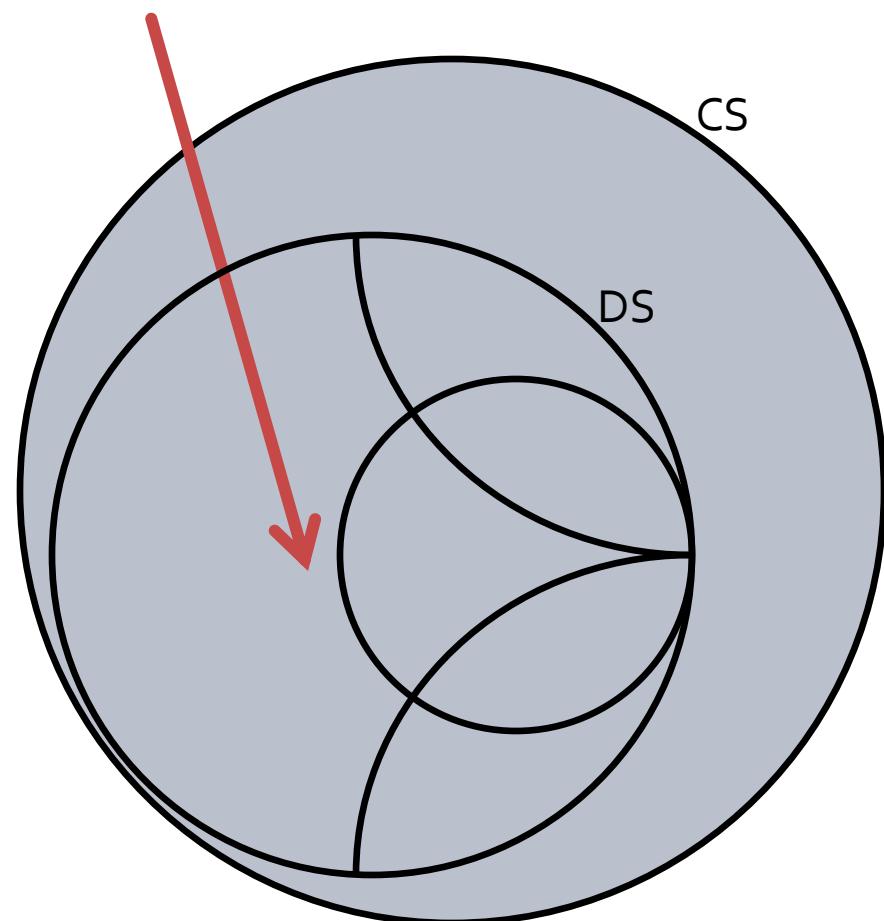
# Mai multe pozitionari posibile



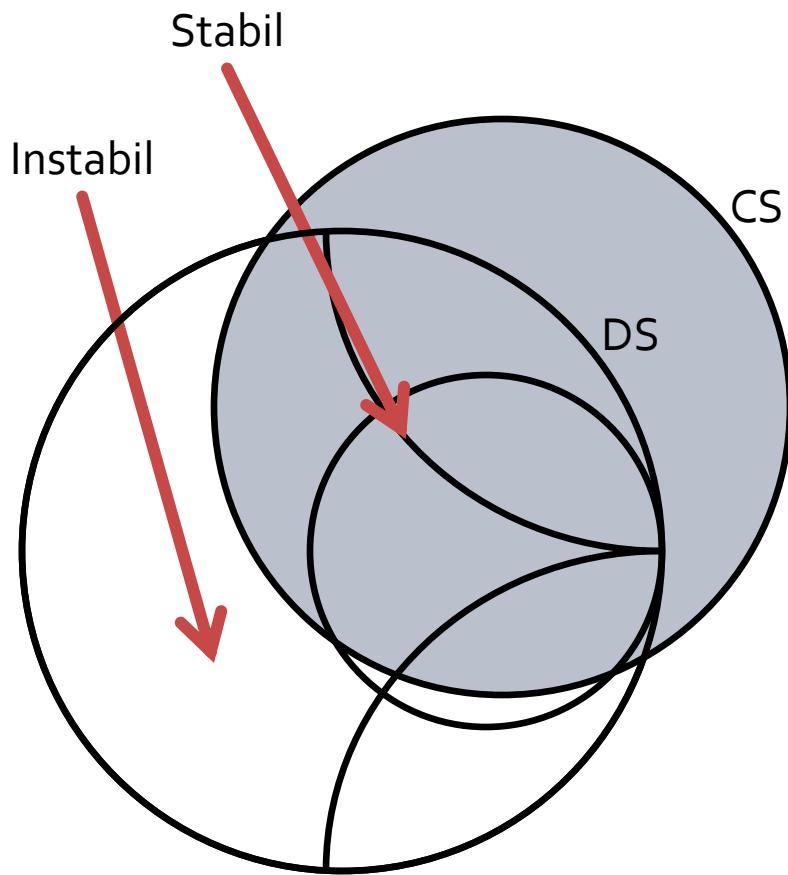
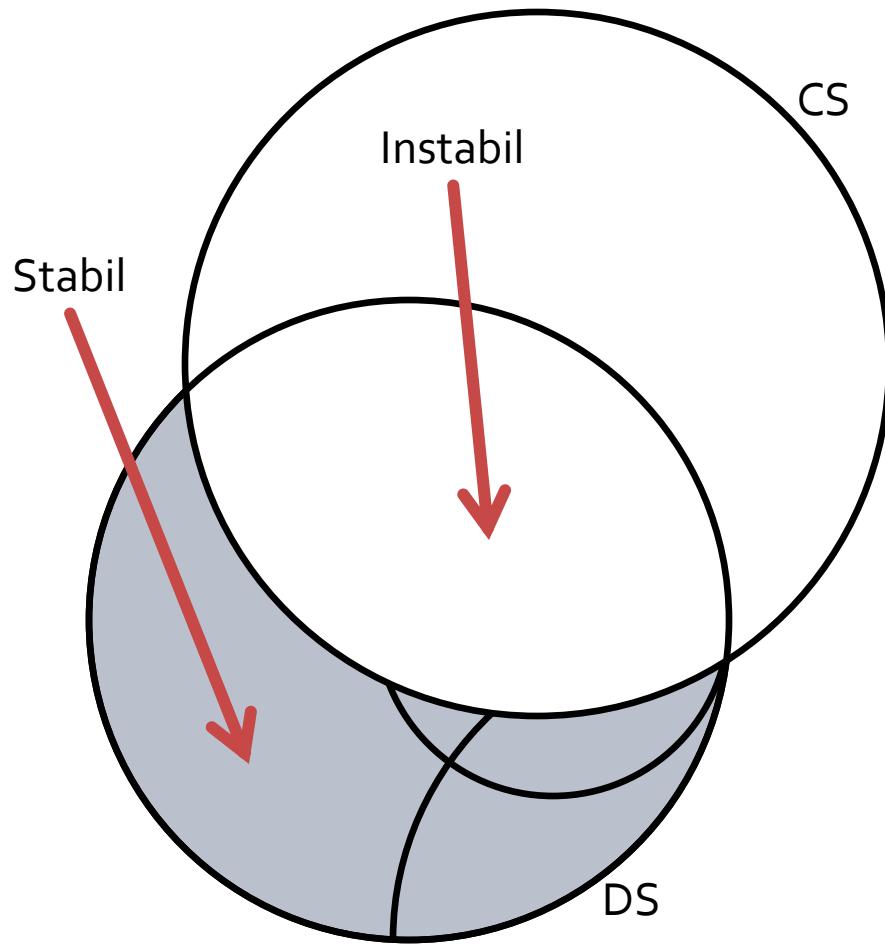
# Mai multe pozitionari posibile



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:

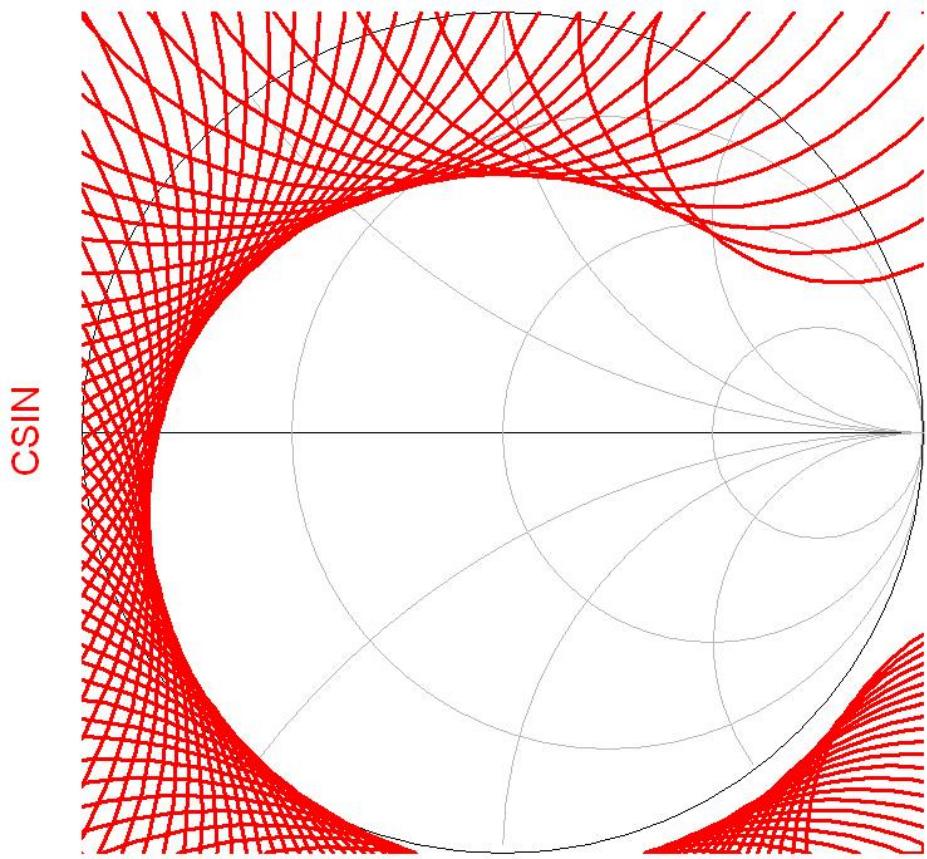
$$\begin{cases} |C_L - R_L| > 1 \\ |S_{11}| < 1 \end{cases}$$

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

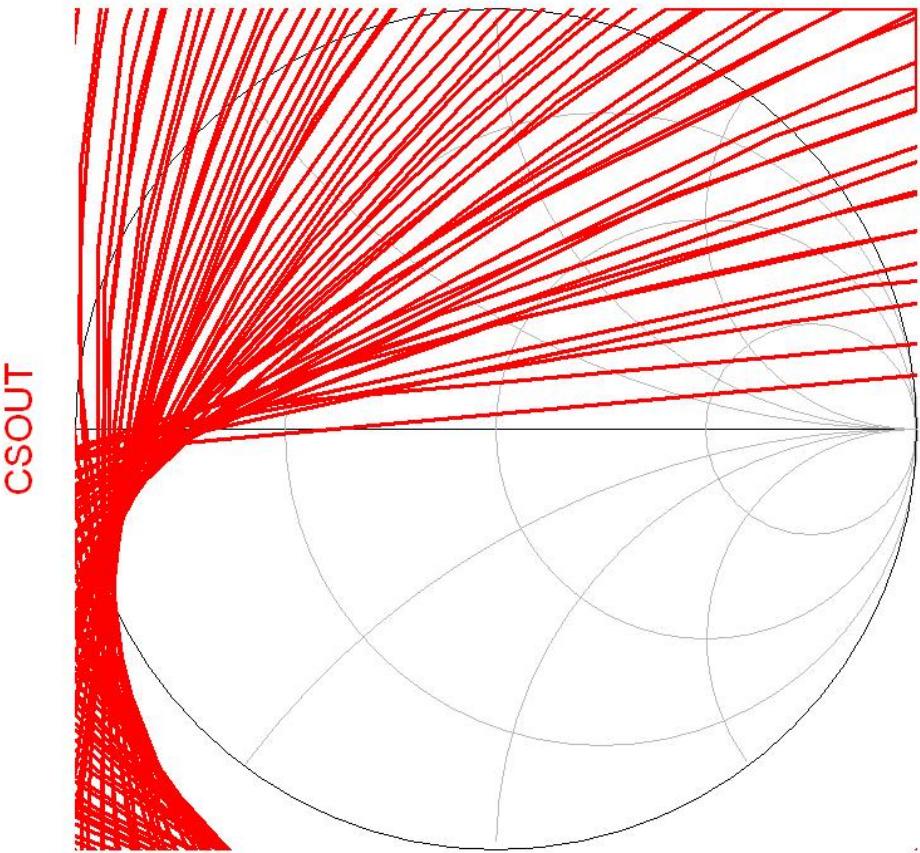
# Conditii analitice de stabilitate neconditionata

- 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



indep(CSIN) (0.000 to 51.000)



indep(CSOUT) (0.000 to 51.000)

# 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 $\mu$

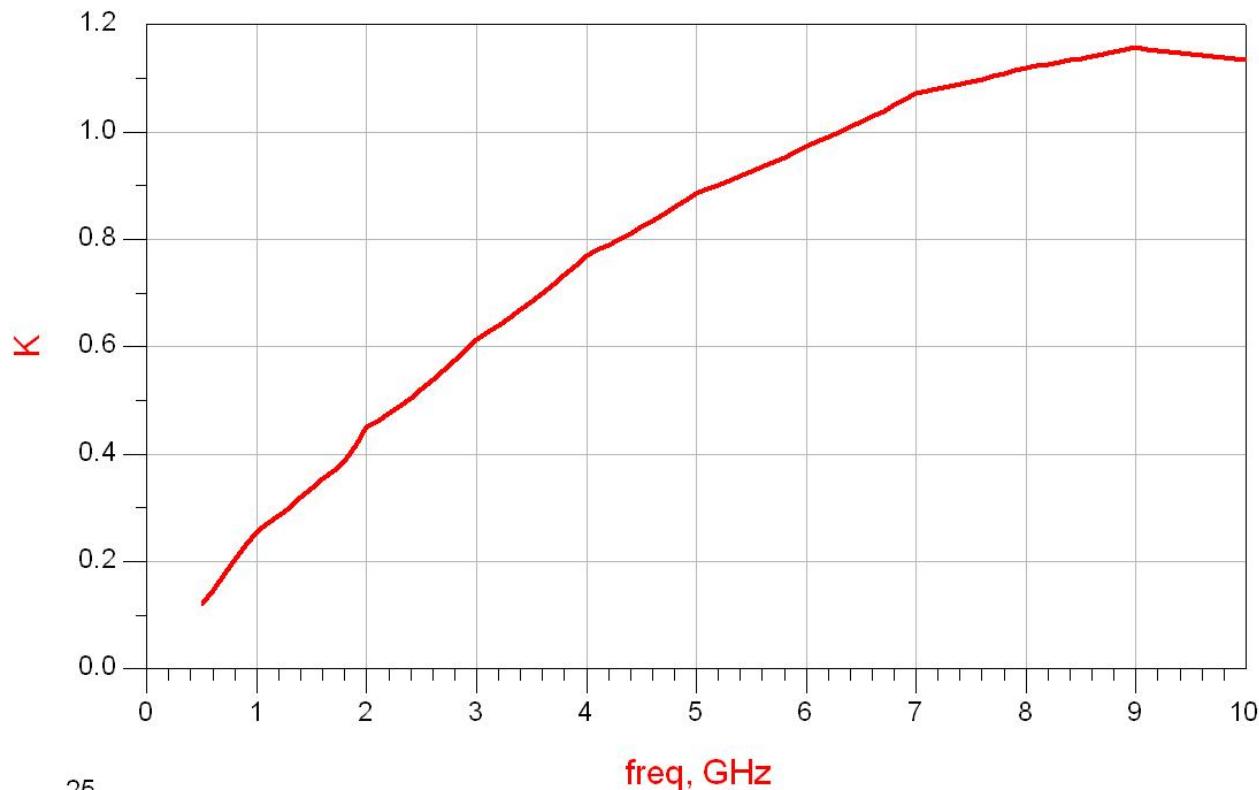
- Conditia Rollet depinde de doi parametri,  $K$  si  $\Delta$ , si nu poate fi utilizata pentru compararea stabilitatii a doua scheme

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

- 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

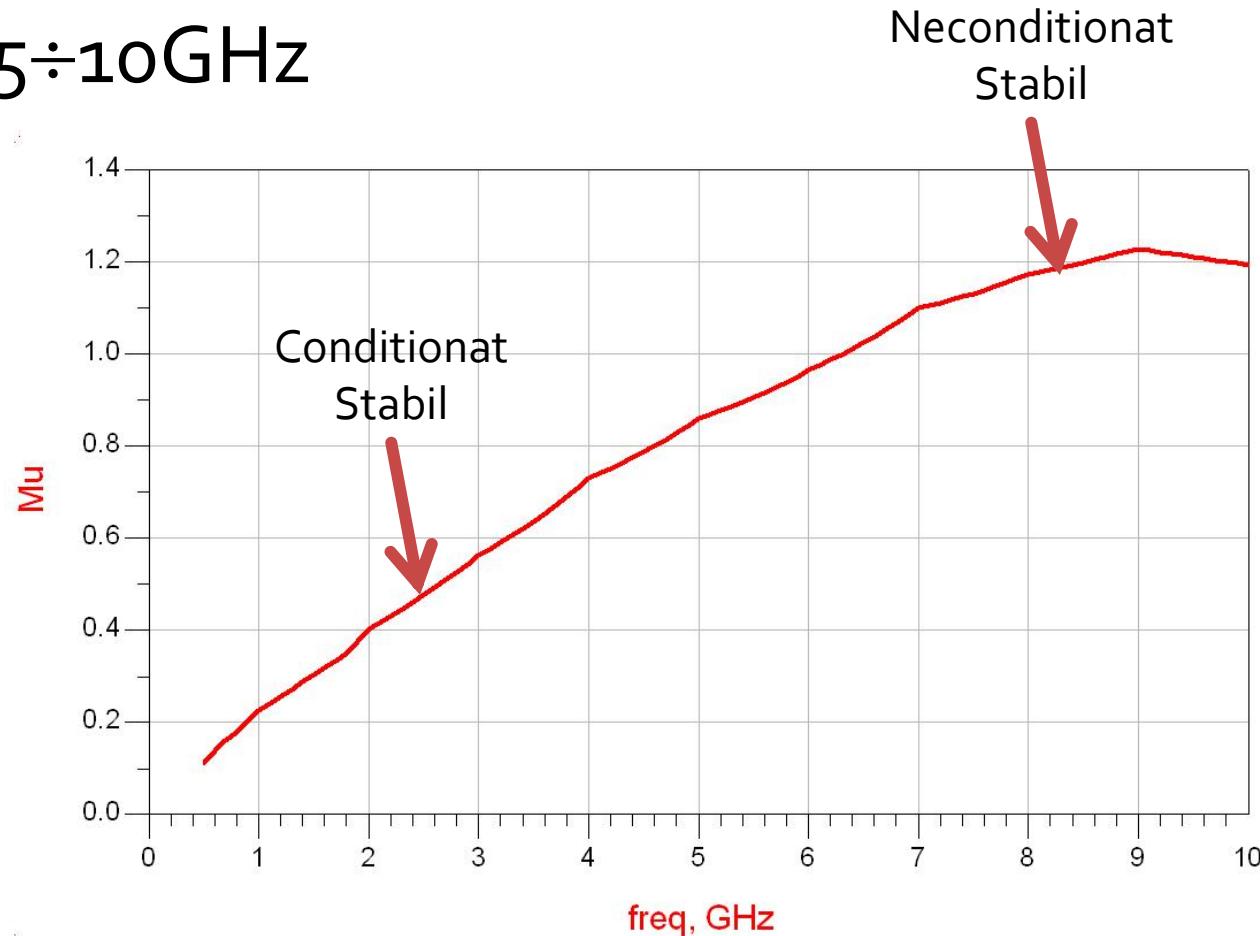
# Conditia Rollet

- ATF-34143 at  $V_{ds}=3V$   $I_d=20mA$ .
- @ $0.5 \div 10GHz$



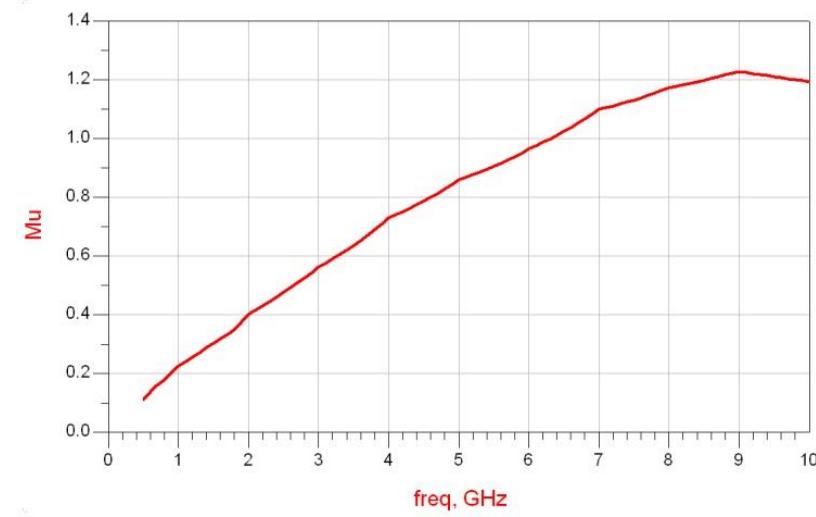
# Criteriul $\mu$

- ATF-34143 at  $V_{ds}=3V$   $I_d=20mA$ .
- @ $0.5 \div 10GHz$



# Stabilitate

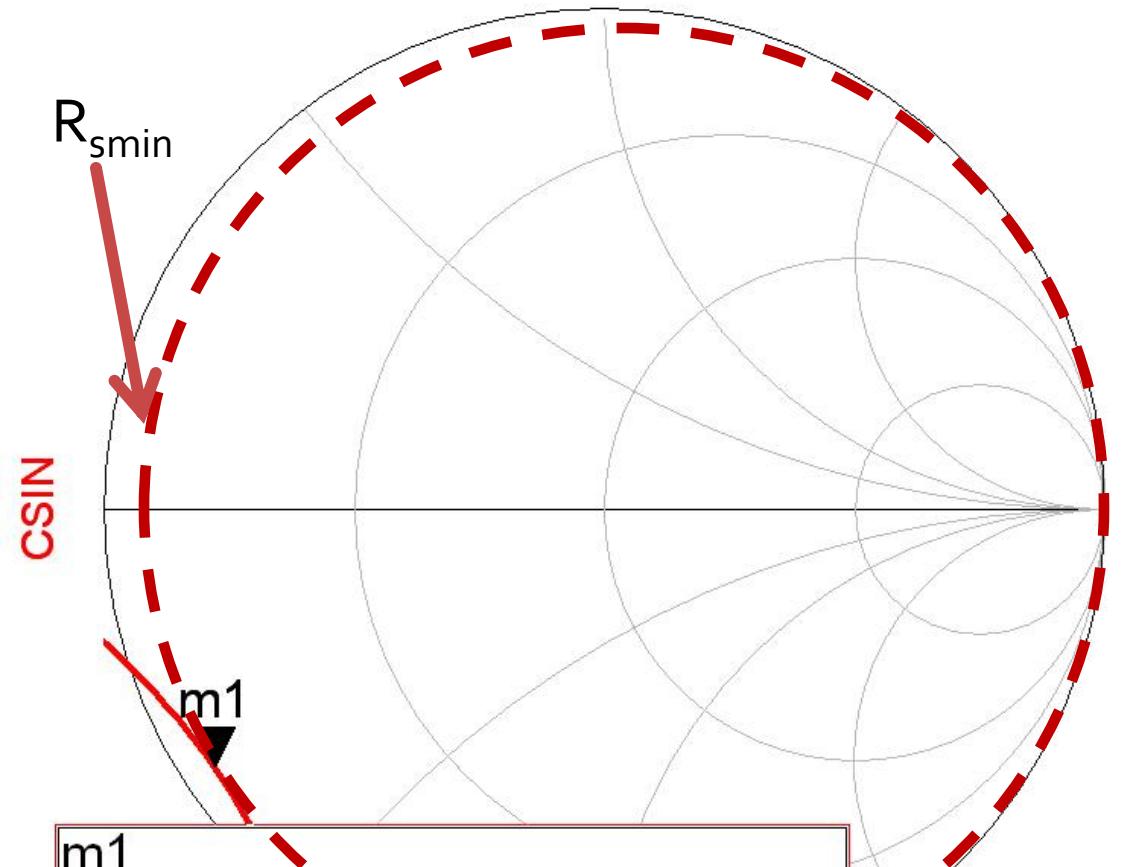
- ATF-34143 at  $V_{ds}=3V$   $I_d=20mA$ .
- @ $0.5 \div 10GHz$
- Neconditionat stabil pentru  $f > 6.31GHz$



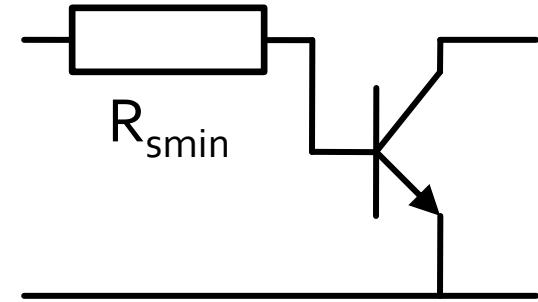
# Stabilizarea unui dipozit

- 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

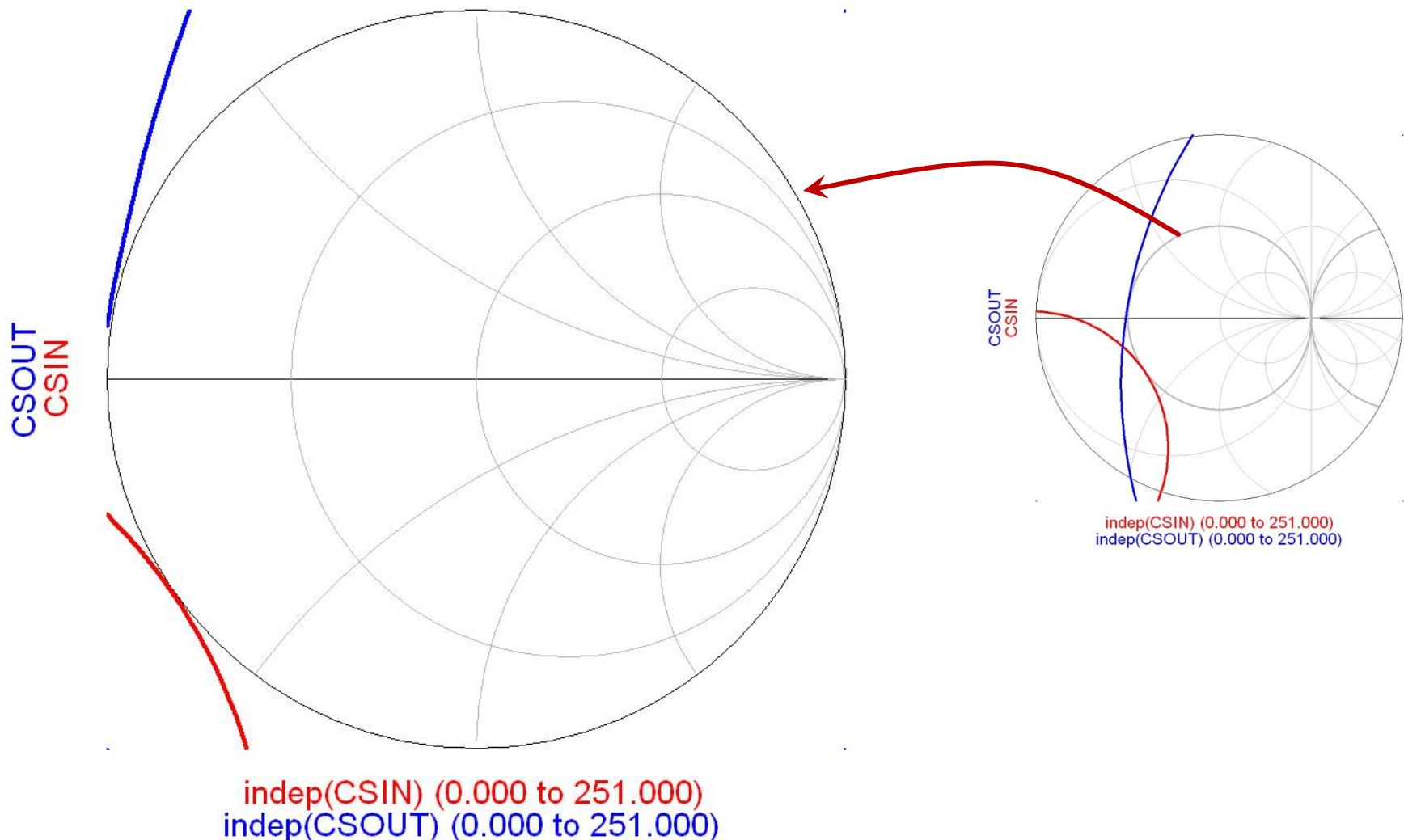


m1  
indep(m1)=24  
CSIN=0.934 / -146.514  
freq=5.000000GHz  
impedance =  $Z_0 \cdot (0.037 - j0.300) \Omega$

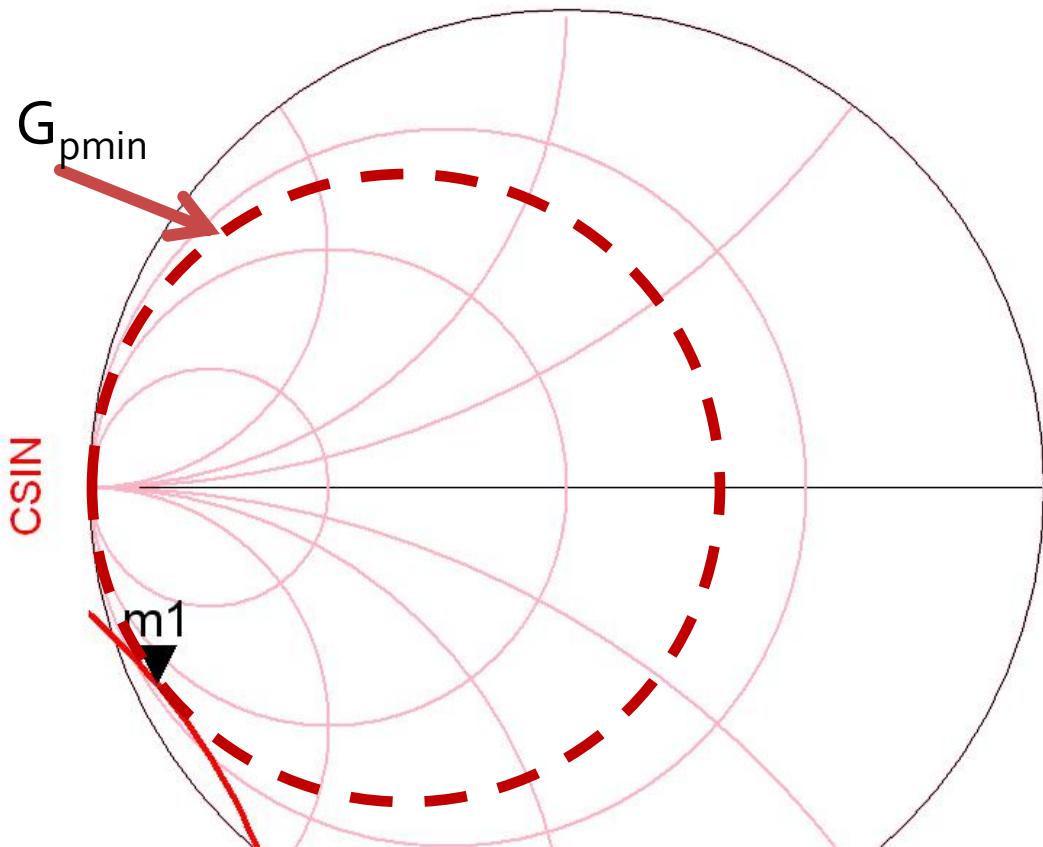


$$R_{s\min} = 0.037 \cdot 50\Omega = 1.85\Omega$$

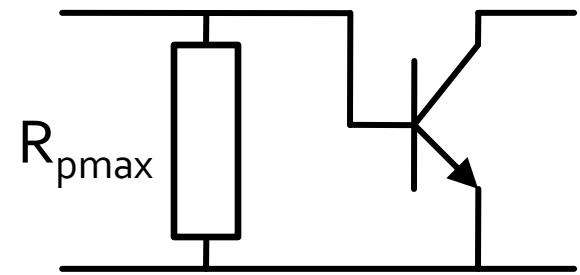
# ADS, $R_s = 2\Omega$



# Rezistenta paralel la intrare



**m1**  
indep(**m1**)=28  
CSIN=0.952 / -154.504  
freq=5.000000GHz  
impedance =  $Z_0 * (0.026 - j0.226)$

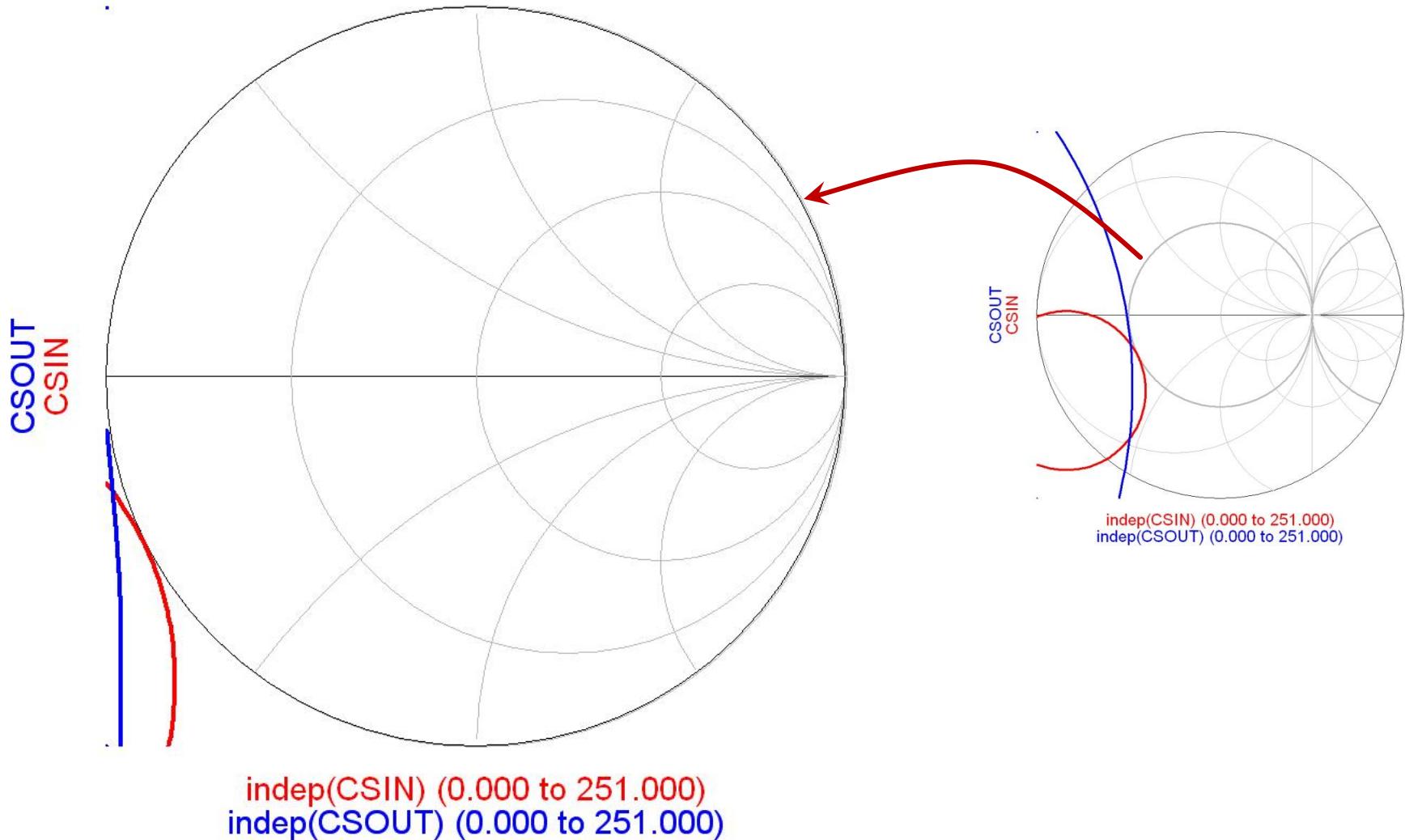


$$R_{p\max} = \frac{1}{G_{p\min}}$$

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

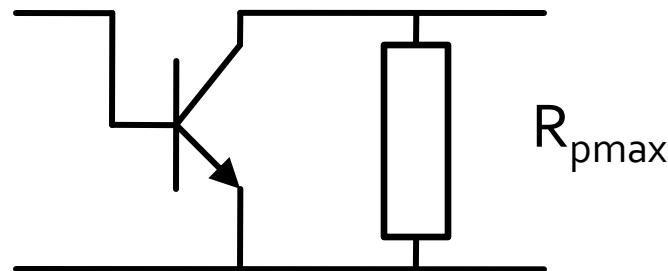
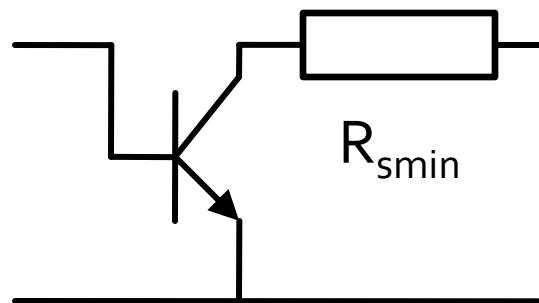
$$R_{p\max} = \frac{50\Omega}{0.502} = 99.6\Omega$$

# ADS, $R_p = 90\Omega$



# 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)

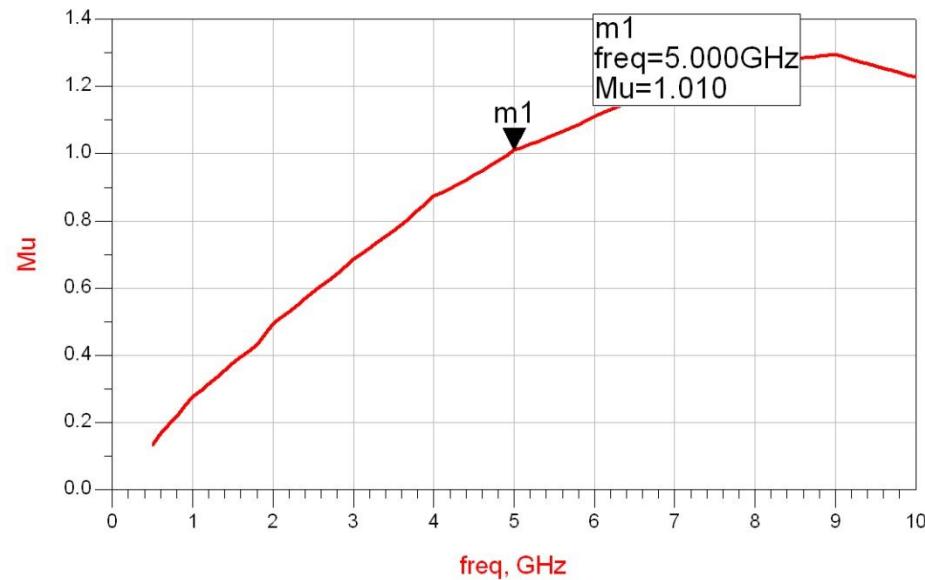
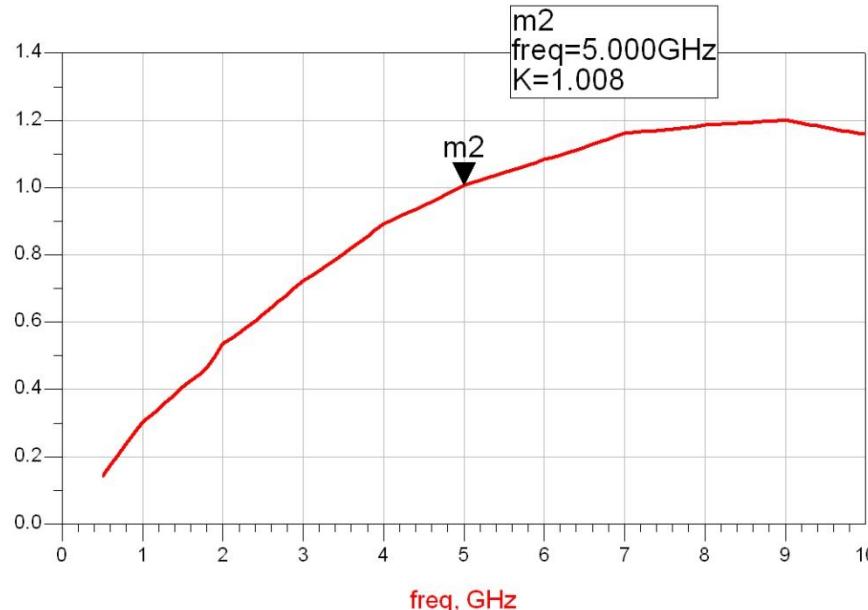


# Stabilizarea unui dipozit

- 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)

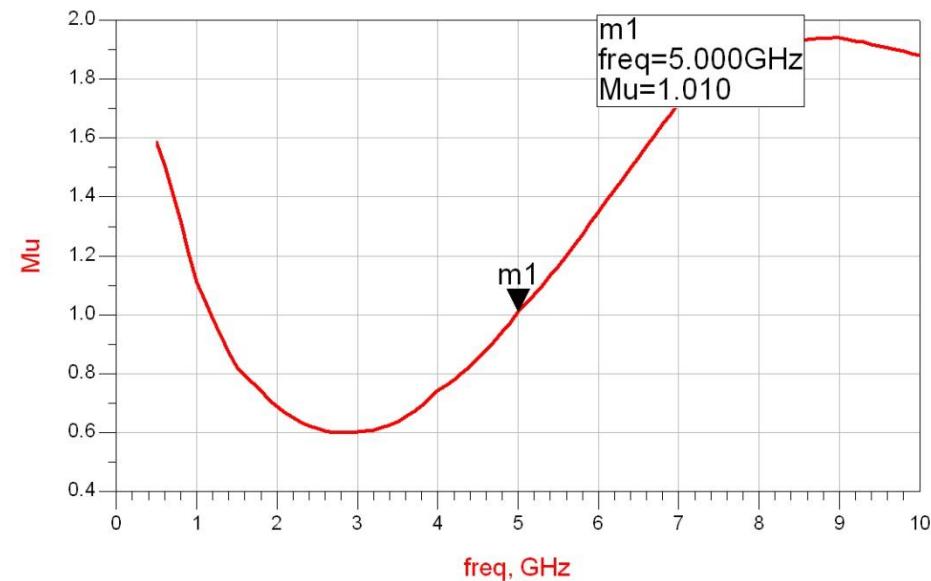
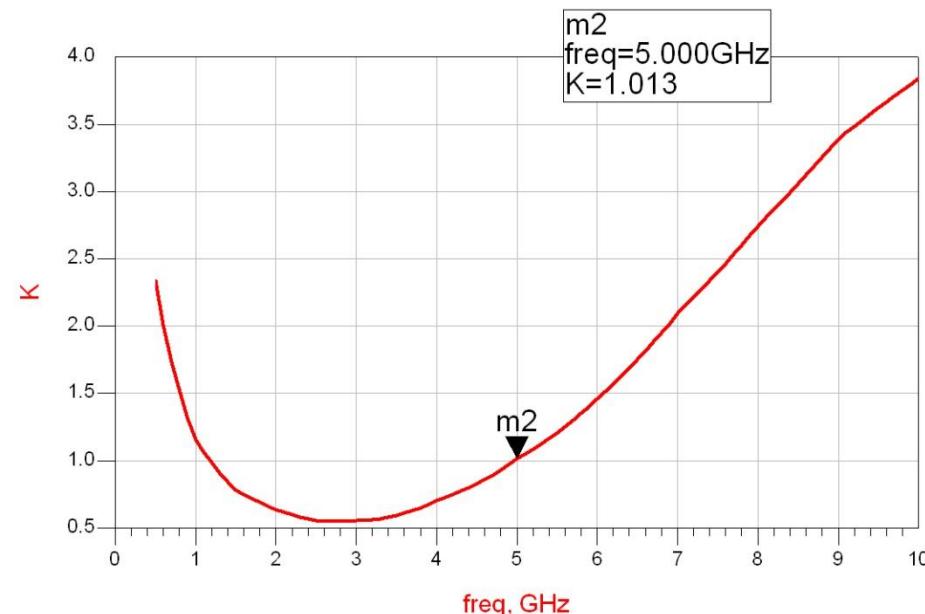
# Rezistenta serie la intrare

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



# Rezistenta paralel la intrare

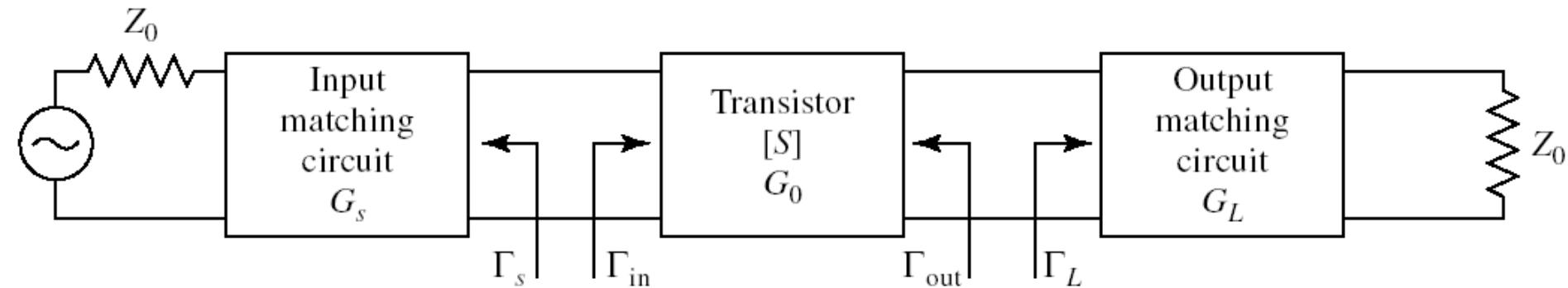
- $R_p = 90\Omega$
- $K = 1.013$ , MAG = 13.561dB @ 5GHz
  - fara stabilizare  $K = 0.886$ , MAG = 14.248dB @ 5GHz



Castigul amplificatoarelor de microunde

# **Amplificatoare de microunde**

# Proiectare pentru castig maxim



- Castig maxim de putere se obtine cand

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

- Pentru retelele de adaptare fara pierderi

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

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

# Adaptare simultana

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

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

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

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

## 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
- $$\begin{cases} B_1 = 1 + |S_{11}|^2 - |S_{22}|^2 - |\Delta|^2 \\ C_1 = S_{11} - \Delta \cdot S_{22}^* \end{cases} \quad \begin{cases} B_2 = 1 + |S_{22}|^2 - |S_{11}|^2 - |\Delta|^2 \\ C_2 = S_{22} - \Delta \cdot S_{11}^* \end{cases}$$

# 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

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

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

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

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

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

## ■ Similar

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

# 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

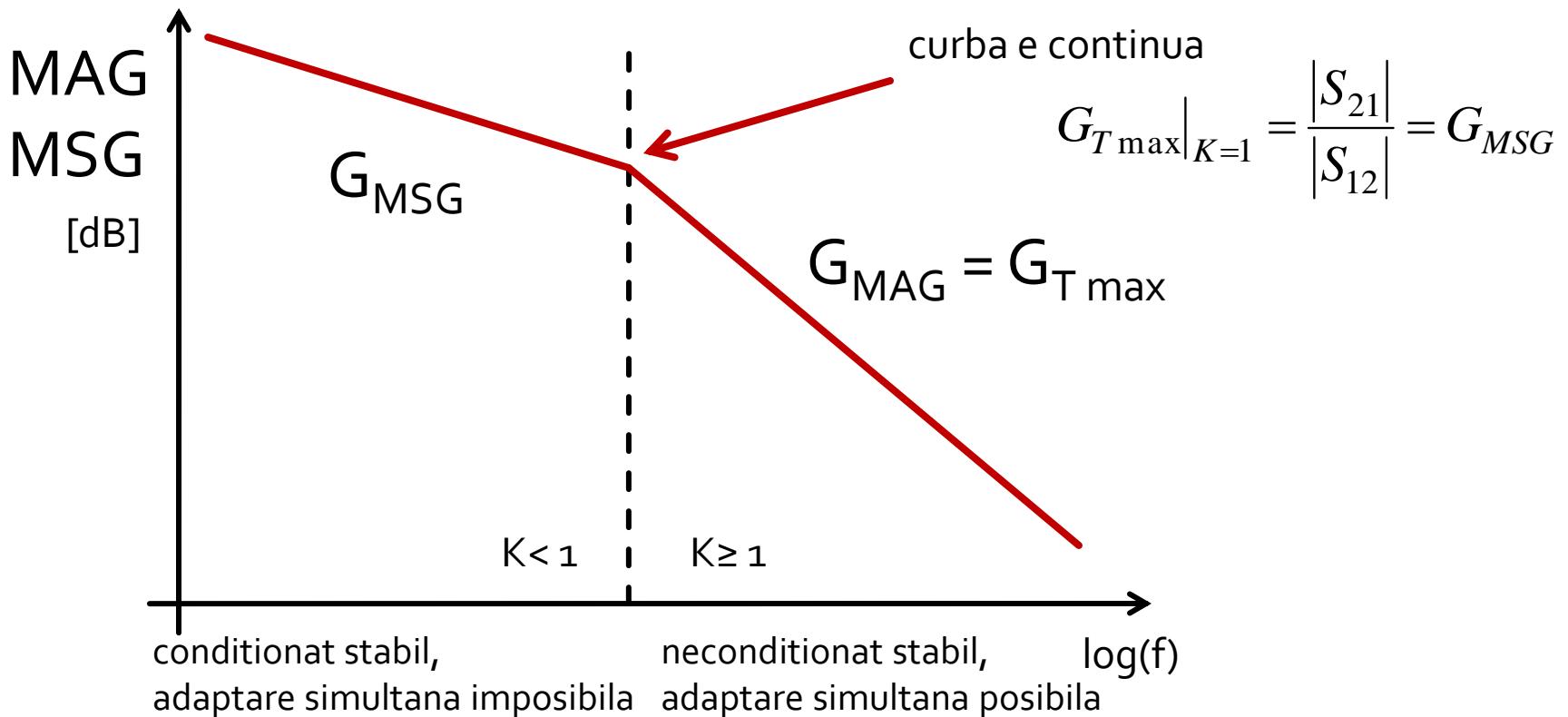
$$G_{T\max} = \frac{|S_{21}|}{|S_{12}|} \cdot \left( K - \sqrt{K^2 - 1} \right)$$

- 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



# 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

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

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

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

# Calcul

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

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

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

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

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

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

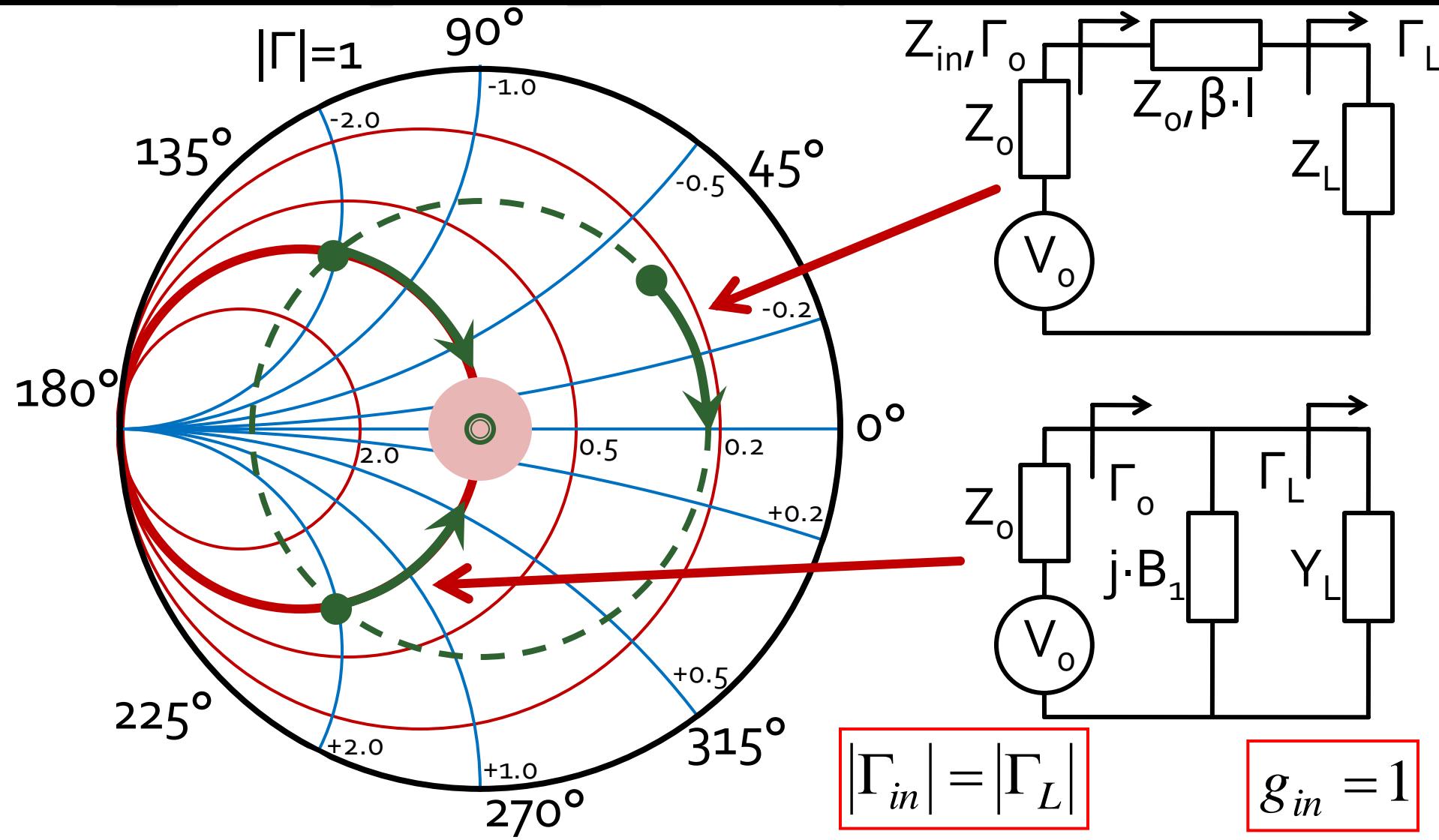
$$\begin{cases} B_2 = 0.476 \\ C_2 = -0.222 - j \cdot 0.013 \end{cases}$$

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

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

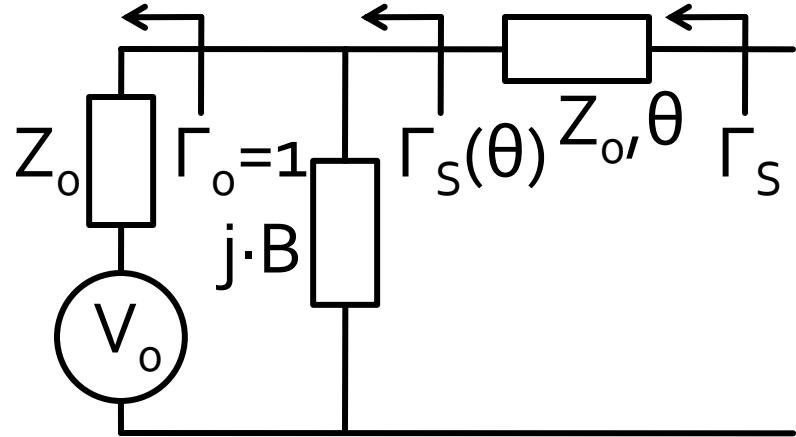
$$|\Gamma_L| = 0.686 < 1$$

# Adaptare cu stub-uri, C8



# Calcul analitic, coeficienti de reflexie

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



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

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

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

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

# Calcul analitic, stub

- Dupa sectiunea de linie cu lungimea electrica  $\theta$

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

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

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

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

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

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

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

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

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

# Calcul analitic, stub

- Ecuatia pentru calcularea  $\theta$

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

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

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

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

$$\forall k \in N$$

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

$$(-117.7^\circ + 2\theta) = \begin{cases} +150.1^\circ \\ -150.1^\circ \end{cases} \quad \theta = \begin{cases} +133.9^\circ \\ -16.2^\circ + 180^\circ = +163.8^\circ \end{cases}$$

# Calcul analitic, stub paralel

- Ecuatia pentru calcularea stub-ului paralel

$$\operatorname{Re}[y_s(\theta)] = 1 \quad \cos(\varphi + 2\theta) = -|\Gamma_s|$$

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

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

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

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

# Calcul analitic, stub paralel

## Ecuatia pentru calcularea stub-ului paralel

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

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

## doua situatii

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

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

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

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

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

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

# Calcul analitic, stub paralel

- Se preferă (pentru microstrip) stub în gol

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

- Susceptanța raportată introdusă pentru adaptare

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

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

# Calcul analitic

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

- Se alege **una** din cele două solutii posibile
- Similar pentru adaptarea la ieșire

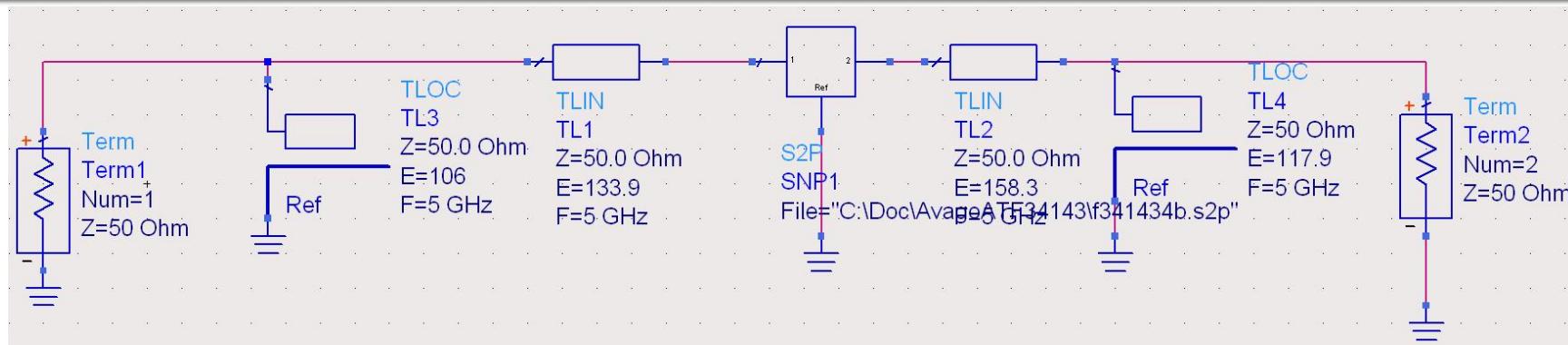
$$\Gamma_L = 0.686 \angle 176.7^\circ \quad \text{Re}[y_L(\theta)] = 1 \Rightarrow \cos(\varphi + 2\theta) = -|\Gamma_L|$$

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

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

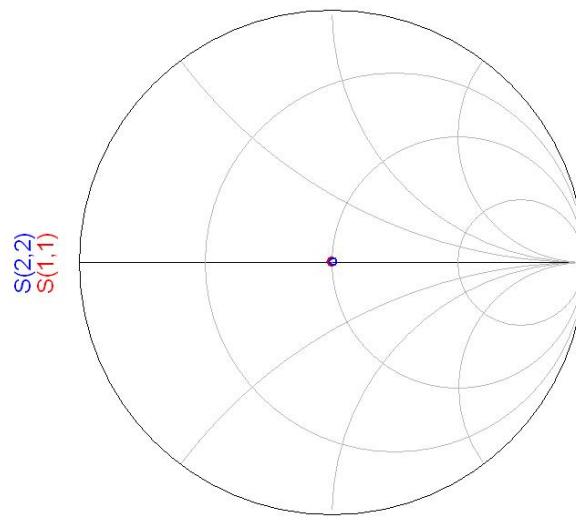
$$(\varphi + 2\theta) = \begin{cases} +133.3^\circ \\ -133.3^\circ \end{cases} \quad \theta = \begin{cases} 158.3^\circ \\ 25.0^\circ \end{cases} \quad \text{Im}[y_S(\theta)] = \begin{cases} -1.885 \\ +1.885 \end{cases} \quad \theta_{sp} = \begin{cases} 117.9^\circ \\ 62.1^\circ \end{cases}$$

# ADS

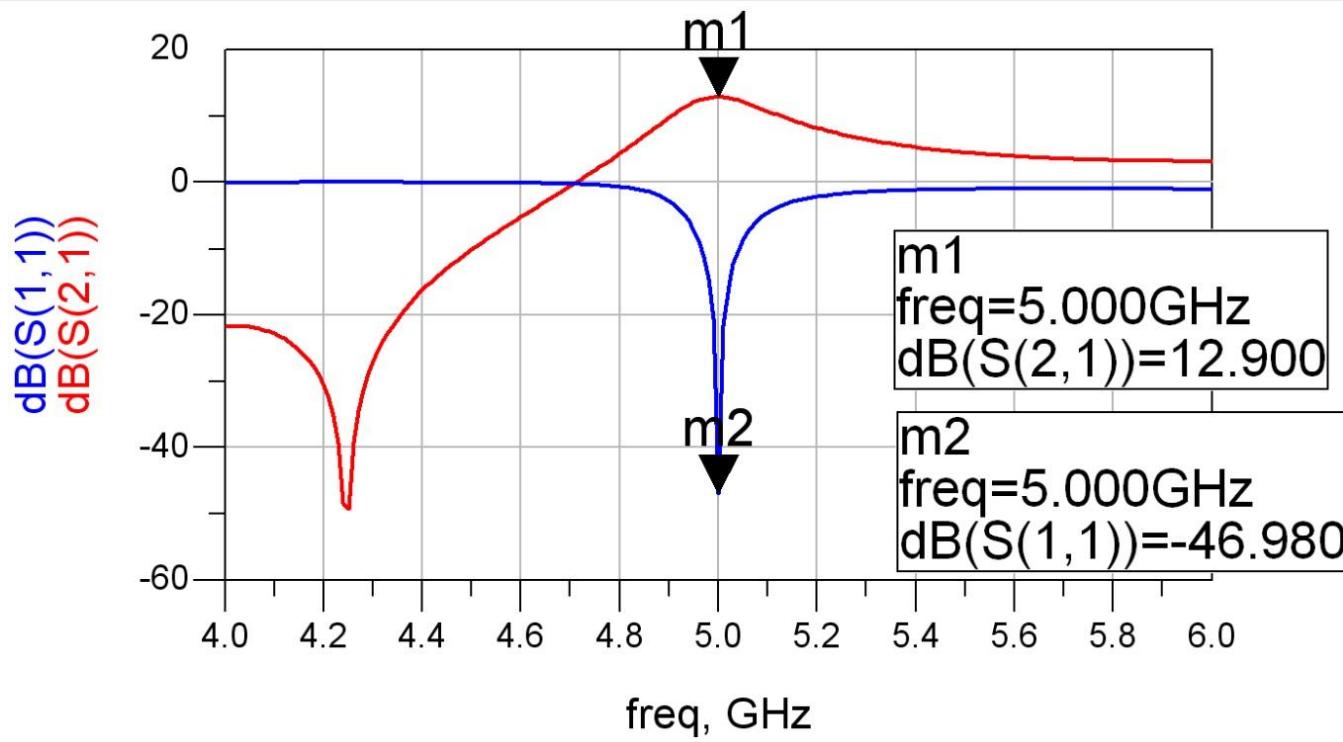
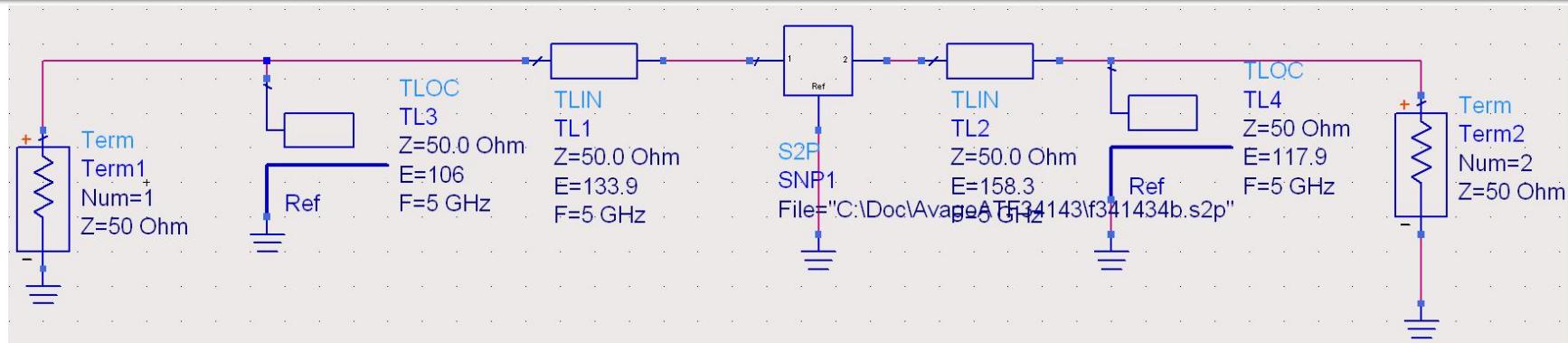


$$\text{Eqn } GT = 10 * \log(\text{mag}(S(2,1))^{\star 2})$$

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



# ADS



# Contact

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