

Curs 9

2022/2023

Dispozitive și circuite de microunde pentru radiocomunicații

Disciplina 2022/2023

- 2C/1L, **DCMR (CDM)**
- Minim 7 prezente (curs+laborator)
- Curs - **conf. Radu Damian**
 - Marti 15-17, ~~Online~~/**Video (istoric)**, P2
 - E – **50%** din nota
 - probleme + (2p prez. curs) + (3 teste) + (bonus activitate)
 - primul test L1: 05.10.2022 (t2 si t3 neanuntate la **curs**)
 - 3pz (C) ≈ +0.5p (**2p** max)
 - toate materialele permise

Disciplina 2022/2023

- 2C/1L, **DCMR (CDM)**
- Laborator – **conf. Radu Damian**
 - Miercuri/Joi, 12/14 par/impar, **II.13**
 - L – **25%** din nota
 - ADS, 4 sedinte aplicatii
 - prezenta + **rezultate personale!**
 - P – **25%** din nota
 - ADS, 3 sedinte aplicatii (-1? 21-22.12.2022)
 - tema personala

Laborator

- 30 noiembrie - 1 decembrie
- 5408, 5410

Documentatie

- <http://rf-opto.etti.tuiasi.ro>

The screenshot shows the homepage of the RF-OPTO website. At the top, there is a banner featuring the RF-OPTO logo, a globe, and two satellite dishes. Below the banner, there are language links for English and Romanian, and a navigation bar with links for Start, Didactic, Master, Colectiv, Cercetare, Studenti, and several sub-links under 'Microunde' such as Comunicatii Optice, Optoelectronica, Internet, Antene, Tehnologie/Zgomote, Practica, and Soft didactic. The main content area has a light blue background and displays information about a discipline: 'Dispozitive si circuite de microunde pentru radiocomunicatii'. It includes details about the Discipline: DCMR (2021-2022), Coordinator Disciplina, Cod, Tip Disciplina, Crediti, and An de Studiu. Below this, sections for Activitati, Evaluare, Note, Prezenta, and Liste are listed.

Laboratorul de Microunde și Optică

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

RF-OPTO

ETTI

UNIVERSITATEA TEHNICĂ "GHEORGHE ASACHI" TIGU

English | Romana |

Start Didactic Master Colectiv Cercetare Studenti

Microunde Comunicatii Optice Optoelectronica Internet Antene Tehnologie/Zgomote Practica Soft didactic

Dispozitive si circuite de microunde pentru radiocomunicatii

Disciplina: DCMR (2021-2022)

Coordinator Disciplina: conf. dr. Radu-Florin Damian
Cod: DOS412T
Tip Disciplina: DOS; Disciplina Optionala, Disciplina de Specialitate
Credite: 4
An de Studiu: 4, Sem. 7

Activitati

Curs: Cadru Didactic: conf. dr. Radu-Florin Damian, 2 Ore/Saptamana, Sectie Specializare, Orar:
Laborator: Cadru Didactic: conf. dr. Radu-Florin Damian, 1 Ore/Saptamana, Grupa, Orar:

Evaluare

Tip: Examen

A: 50%, (Examen/Colocviu)
B: 25%, (Activitate Seminar/Laborator/Proiect)
D: 25%, (Teme de casa/Lucrari de specialitate)

Note

[Rezultate totale](#)

Prezenta

Curs
Laborator

Liste

[Studenti care nu pot intra in examen \(final\)](#)
[Bonus-uri acumulate \(final\)](#)

Istoric

Alte informatii

[Online Exam manual \(pdf, 2.56 MB, en, !\[\]\(5eb1325dfdc3f1cad8426726c0db51cd_img.jpg\)](#)

[Exam Simulation \(video\) \(mp4, 41.96 MB, en, !\[\]\(eafc244b53721dd1ec133f0772f70fc7_img.jpg\)](#)

[Important Agilent Application Notes \(rar, 2.36 MB, ro, !\[\]\(d3fb9f94af8b26d1c844efa9a98805b0_img.jpg\)](#)

Ani anterioiri

2020-2021

2019-2020

2018-2019

2017-2018

2016-2017

Mai mult...

Dispozitive si circuite de microunde pentru radiocomunicatii

Disciplina: DCMR (2020-2021)

Coordinator Disciplina: conf. dr. Radu-Florin Damian

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Credite: 4

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Activitati

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

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

Acces

Personalizat



Date:

Grupa	5304 (2015/2016)
Specializarea	Tehnologii si sisteme de telecomunicatii
Marca	5184

[Acceseaza ca acest student](#)

Note obtinute

Disciplina	Tip	Data	Descriere	Nota	Puncte	Obs.
TW	Tehnologii Web					
	N	17/01/2014	Nota finala	10	-	
	A	17/01/2014	Colocviu Tehnologii Web 2013/2014	10	7.55	
	B	17/01/2014	Laborator Tehnologii Web 2013/2014	9	-	
	D	17/01/2014	Tema Tehnologii Web 2013/2014	9	-	

Nume

Email

Cod de verificare

Trimite

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

Online

- acces email/parola

Start Didactic Master Colectiv

Note Lista Studenti Examene Fotografii

POPESCU GOPO ION

Fotografia nu există

Date:

Grupa	5700 (2019/2020)
Specializarea	Inginerie electronică
Marca	7000021

Se acceseaza site-ul **a acest student!**

Start Didactic Master Colectiv

Note Lista Studenti Examene Fotografii

POPESCU GOPO ION

Fotografia nu există

Date:

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

Se acceseaza site-ul **a acest student (inclusiv examene)!**

Parola

■ primita prin **email**

Important message from RF-OPTO Inbox x

Radu-Florin Damian
to me, POPESCU ▾

Romanian ▾ English ▾ Translate message

 Laboratorul de Microunde si Optoelectronica
Facultatea de Electronica, Telecomunicatii si Tehnologia Informatiei
Universitatea Tehnica "Gh. Asachi" Iasi

In atentia: POPESCU GOPO ION
Parola pentru a accesa examenele pe server-ul rf-opto este
Parola: [REDACTED]

Identificati-vă pe [server](#), cu parola, cat mai rapid, pentru confirmare.

Memorati acest mesaj intr-un loc sigur, pentru utilizare ulterioara

Attention: POPESCU GOPO ION
The password to access the exams on the rf-opto server is
Password: [REDACTED]

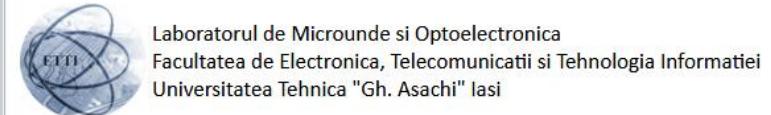
Login to the [server](#), with this password, as soon as possible, for confirmation.

Save this message in a safe place for later use

Reply Reply all Forward

Subject: Important message from RF-OPTO Correspondents
Validation of MDCK exam from 02/05/2020

From: Me <rdamian@etti.tuiasi.ro> ★
Subject: **Important message from RF-OPTO** ★
To: [REDACTED]
Cc: Me <rdamian@etti.tuiasi.ro> ★



In atentia: POPESCU GOPO ION
Parola pentru a accesa examenele pe server-ul **rf-opto** este
Parola: [REDACTED]

Identificati-vă pe [server](#), cu parola, cat mai rapid, pentru confirmare.

Memorati acest mesaj intr-un loc sigur, pentru utilizare ulterioara

Attention: POPESCU GOPO ION
The password to access the exams on the **rf-opto** server is
Password: [REDACTED]

Login to the [server](#), with this password, as soon as possible, for confirmation.

Save this message in a safe place for later use

Manual examen online

- Aplicatia de examen online utilizata intens la:
 - ~~curs (prezenta)~~
 - **laborator (rezultate)**
 - **proiect (predare)**
 - ~~examen~~

Materials

Other data

[Manual examen on-line \(pdf, 2.65 MB, ro, !\[\]\(f4349ea867b307dd2675269f68d0971f_img.jpg\)](#)

[Simulare Examen \(video\) \(mp4, 65.12 MB, ro, !\[\]\(9ea682cef02bbbdc0191f78cdae1d433_img.jpg\)](#)

Examen online

- intotdeauna **contratimp**
 - **perioada lungă** (rezultate laborator)
 - perioada scurta (teste: 15min, examen: 2h)

Start Didactic Master Colectiv Cercetare **Studenti**

Note Lista Studenti **Examene** Fotografii

Anunț
17:28 (29/04/2020)

Material suport
17:30 (29/04/2020)

Subiecte
17:32 (29/04/2020)

Rezultate
17:35 (29/04/2020)

Finalizare
17:45 (29/04/2020)

Confirmare
17:45 (30/04/2020)

Ormaroul interval de timp in.
01 m 08 s
Reincarca acum

Anunț

In acest examen se verifica diverse actiuni ale studentilor pentru examen

Ora pe server

Roate examenele sunt bazate pe fusul orar al server-ului (ar putea sa fie diferit de timpul local). Pentru referinta ora pe server este acum:

29/04/2020 17:28:51

Cuprins

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

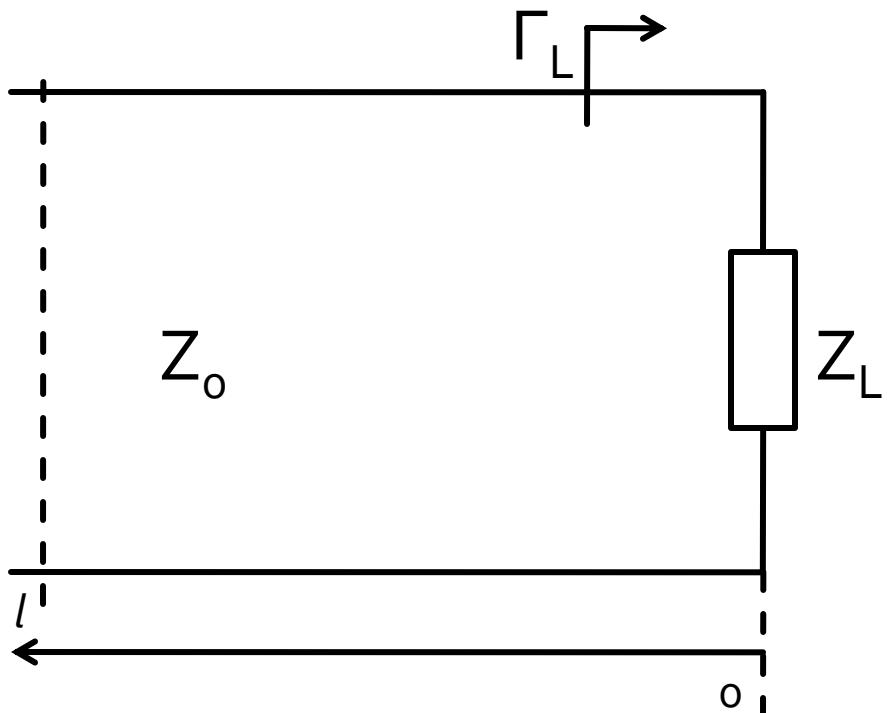
Bibliografie

- <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)**

Cuprins

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

Linie fara pierderi



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

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

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

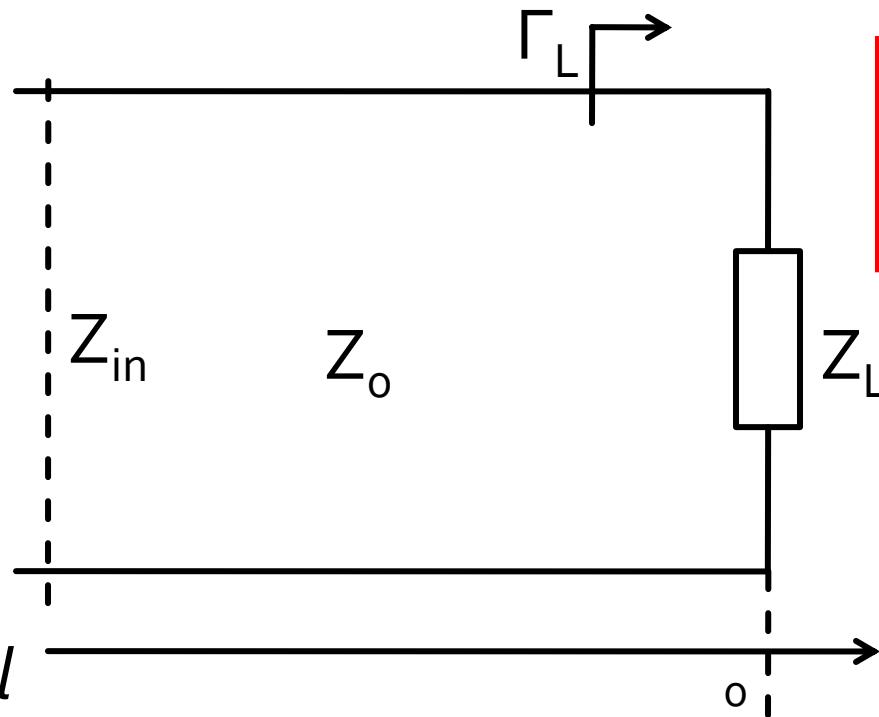
- coeficient de reflexie in tensiune

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

- 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

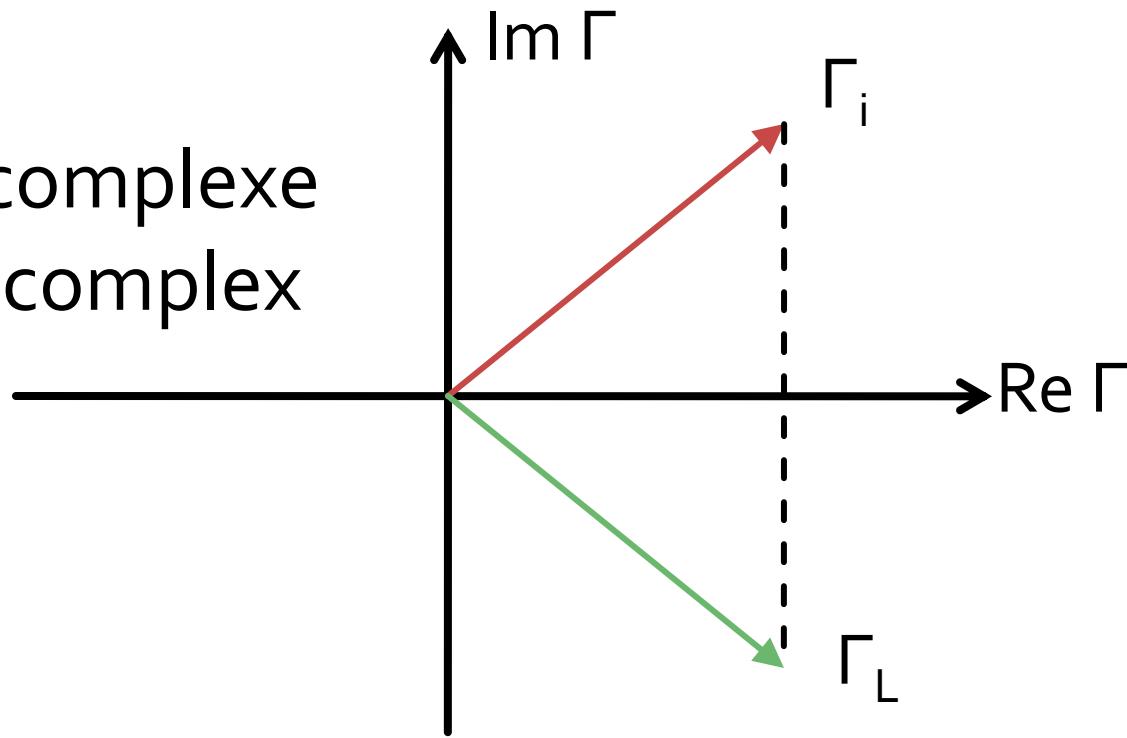
$$Z_L = Z_i^*$$

Daca se alege un Z_0 real

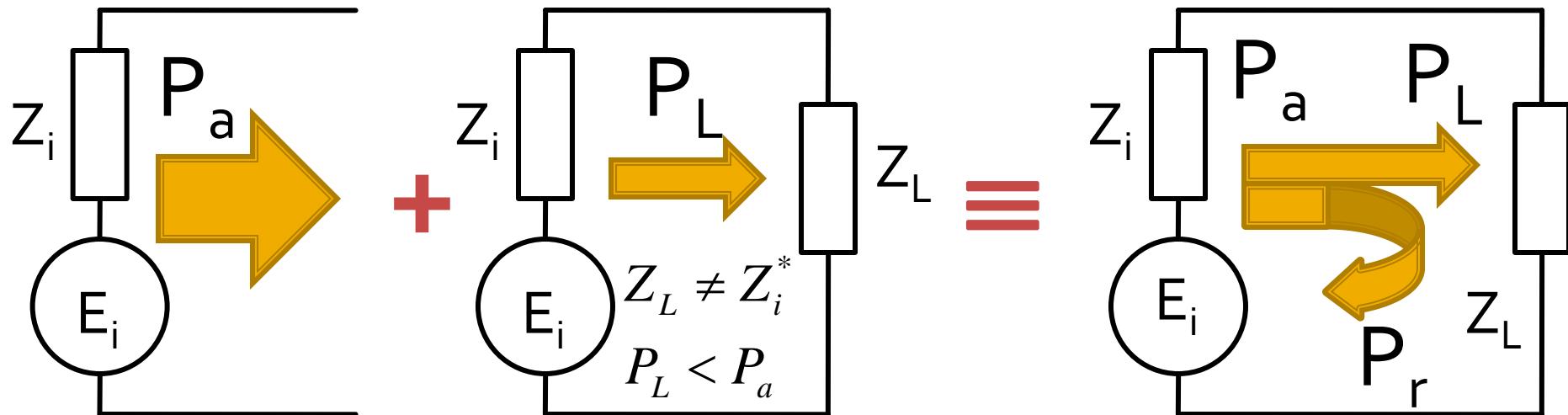
$$\Gamma = \frac{Z - Z_0}{Z + Z_0}$$

$$\Gamma_L = \Gamma_i^*$$

- numere complexe
- in planul complex

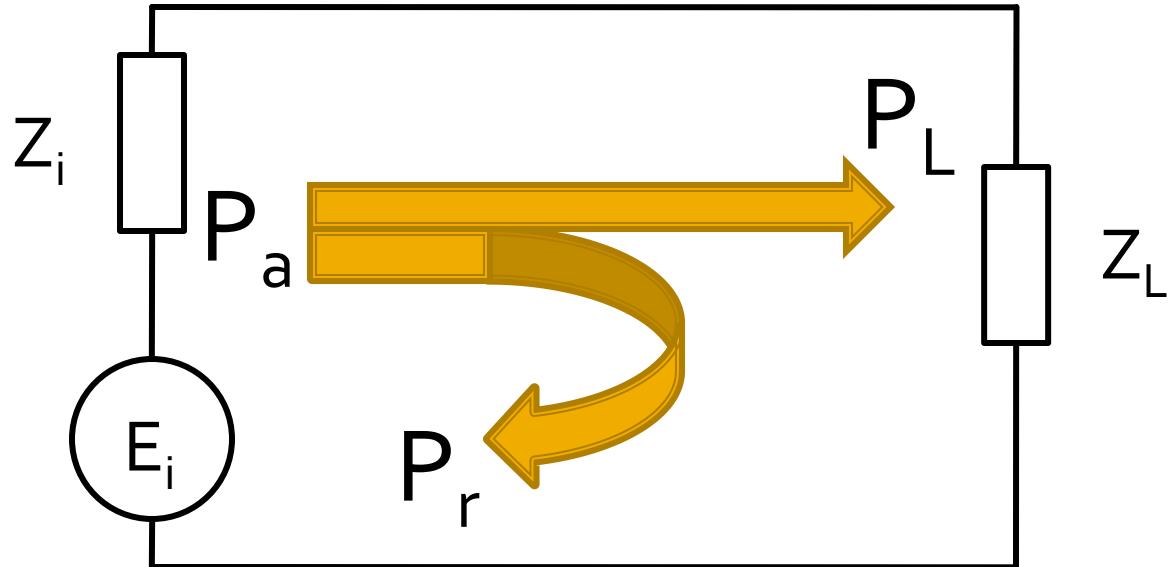


Reflexie de putere / Model



- 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

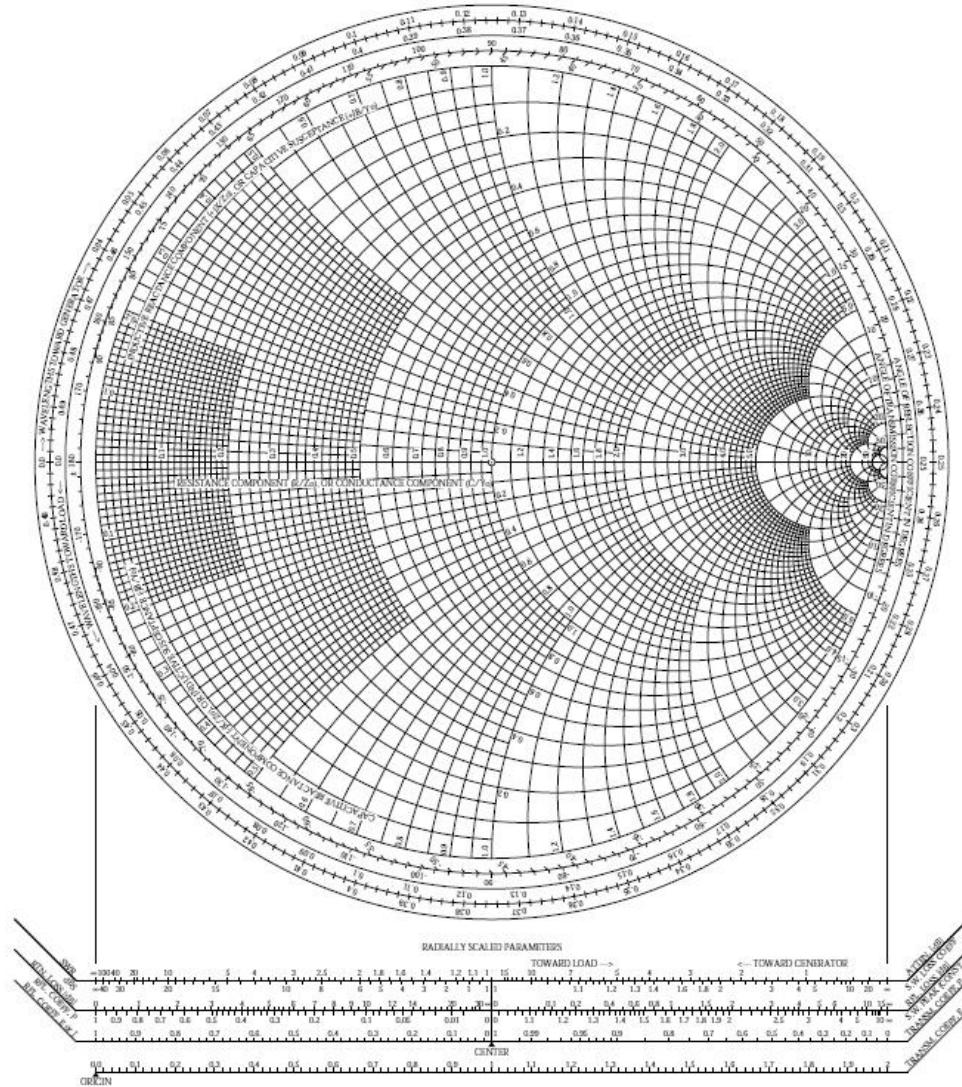
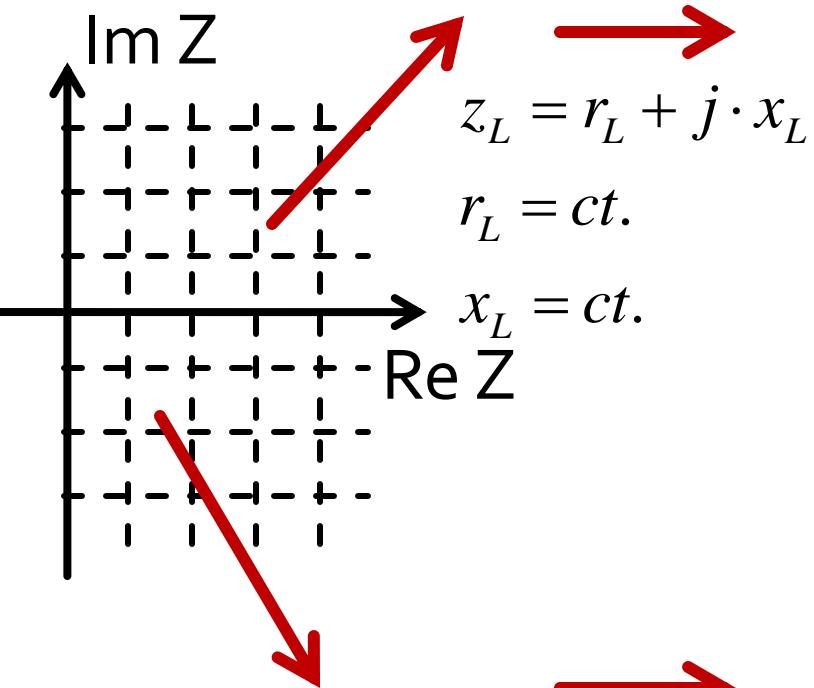


Diagrama Smith

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



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

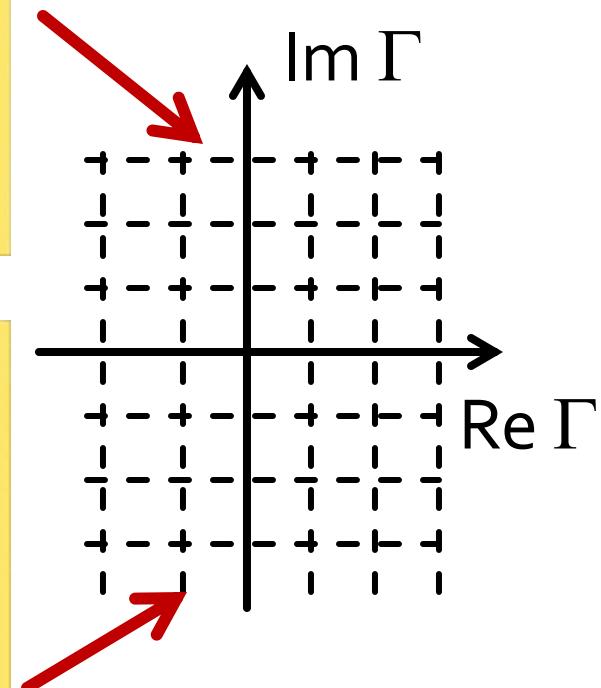
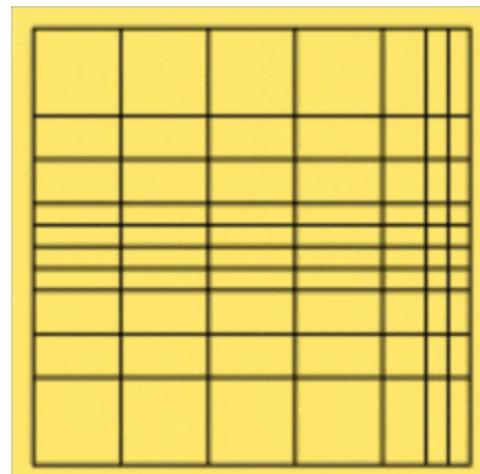
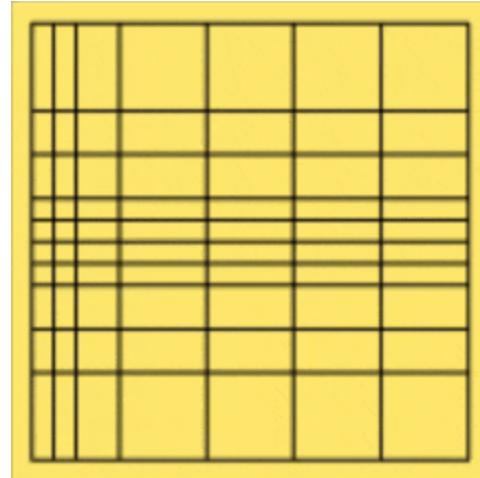


Diagrama Smith

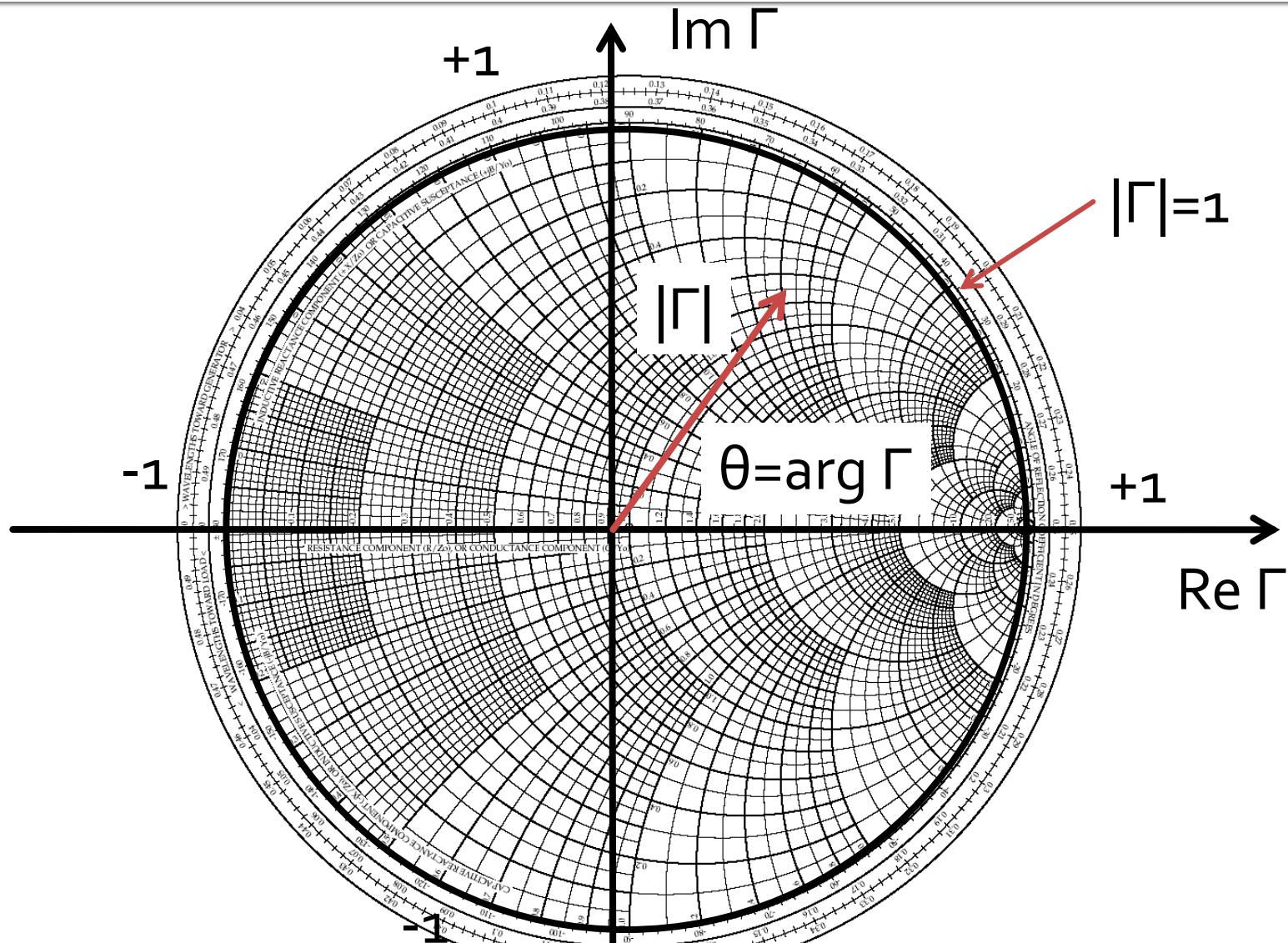


Diagrama Smith

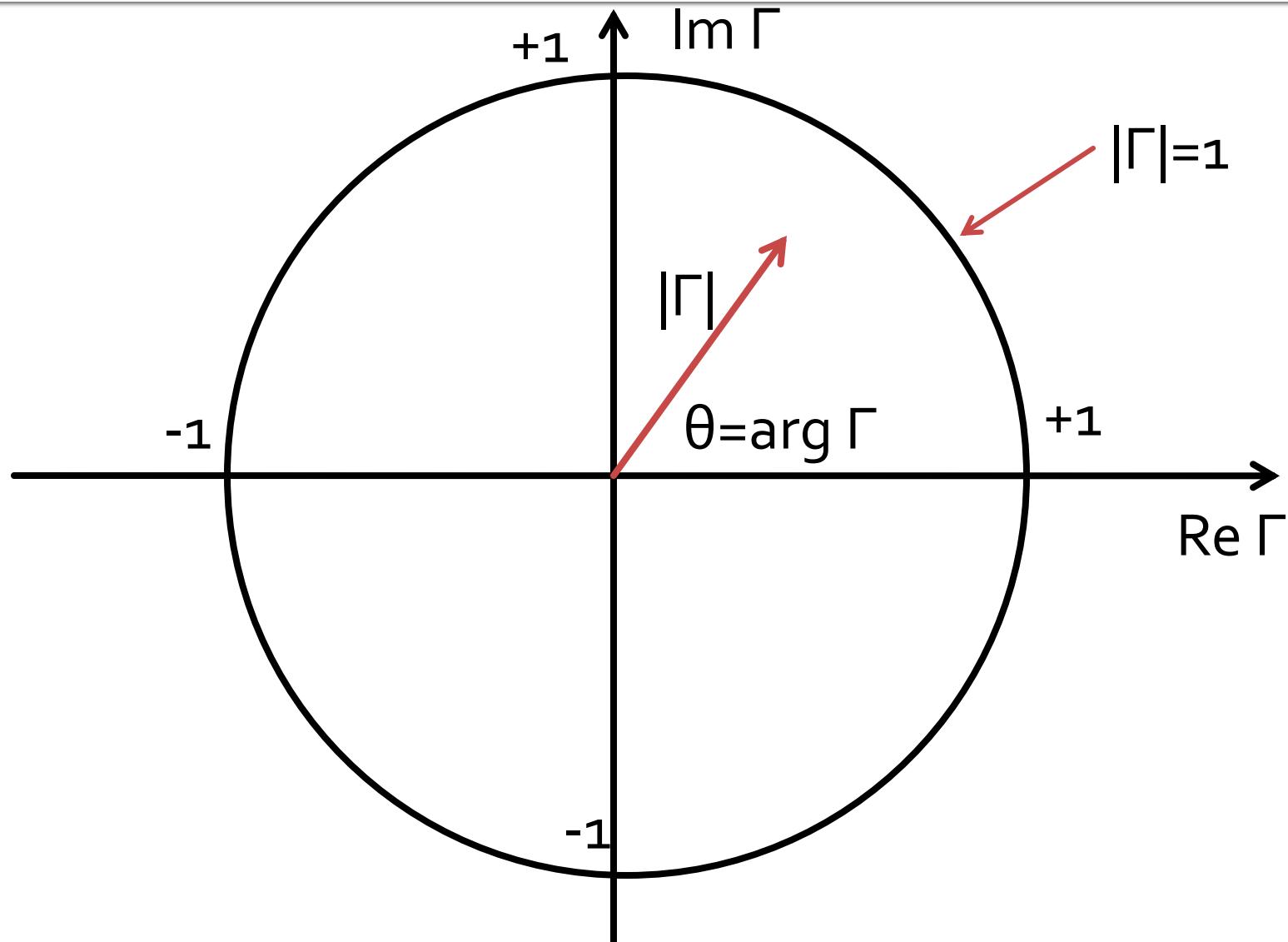


Diagrama Smith, impedanta

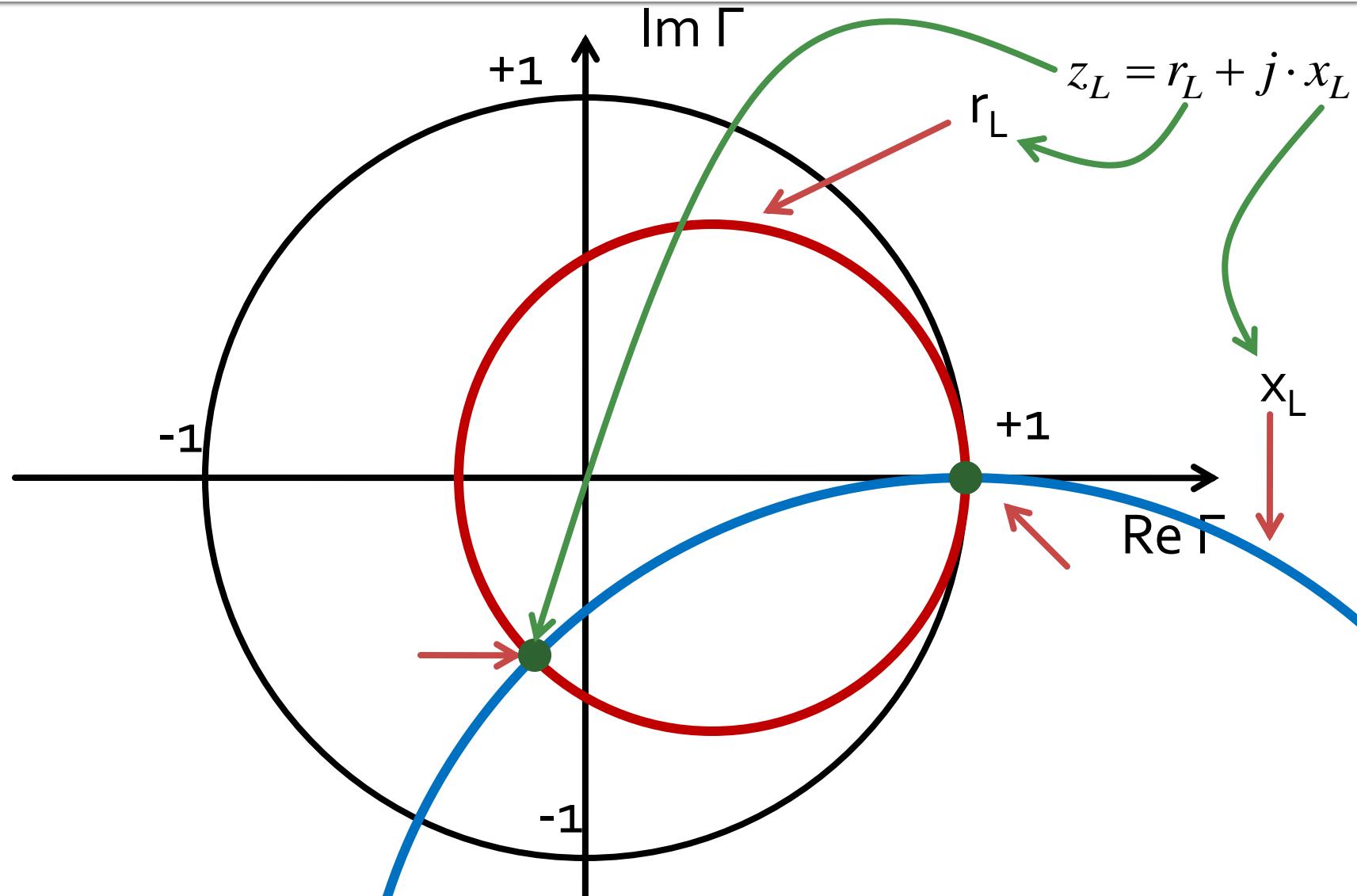
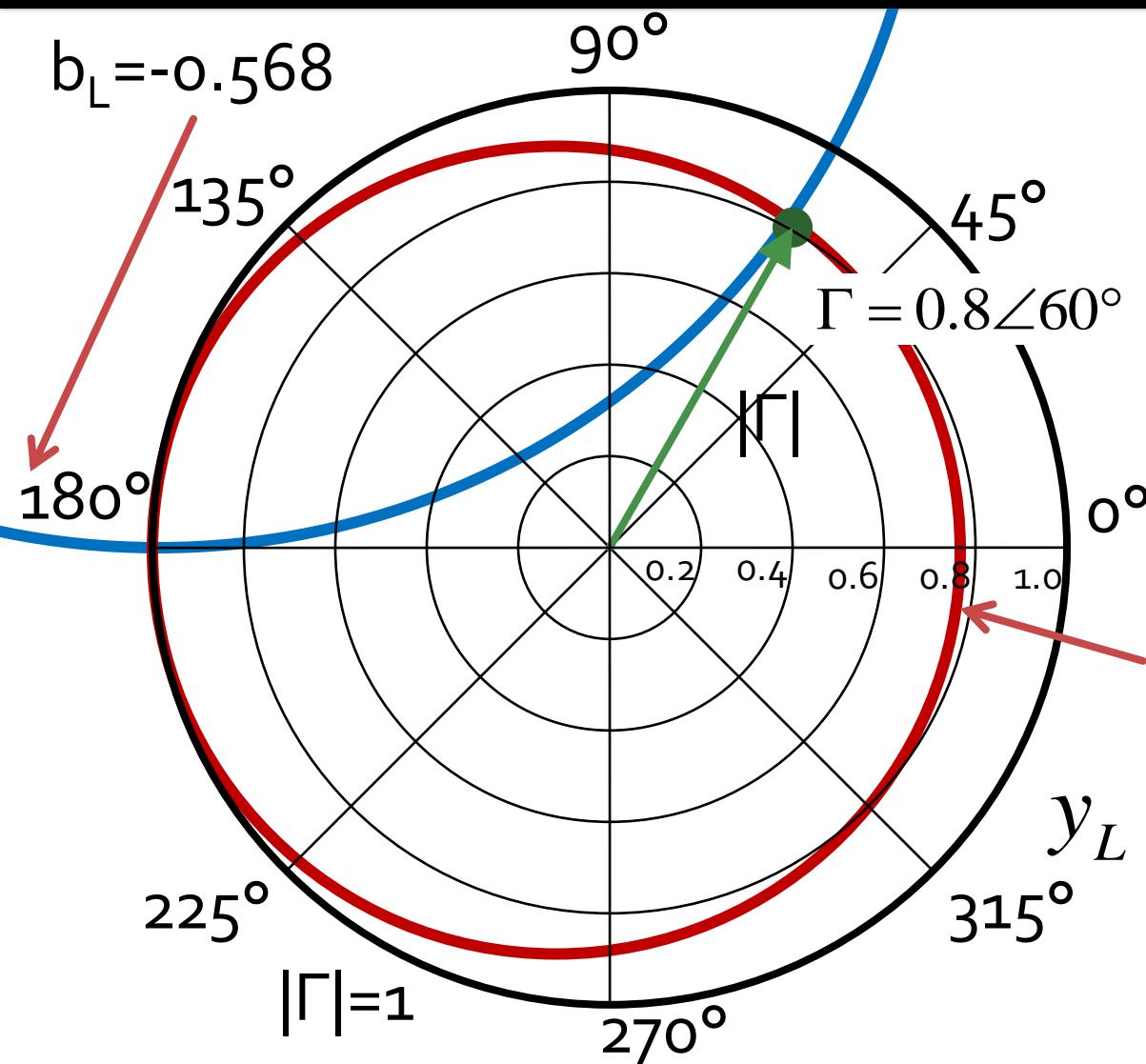


Diagrama Smith, coeficient de reflexie \Leftrightarrow admitanta



$$\Gamma = 0.8 \angle 60^\circ$$

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

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

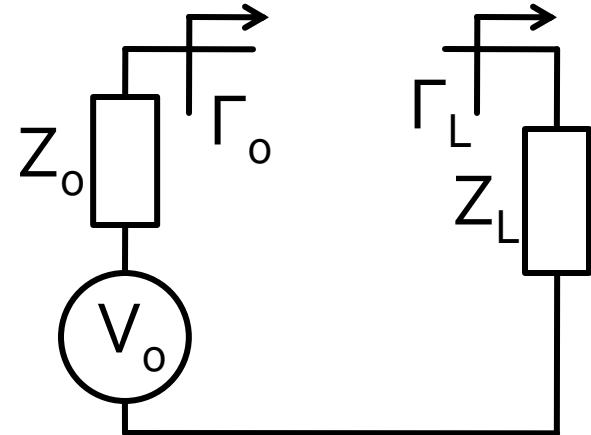
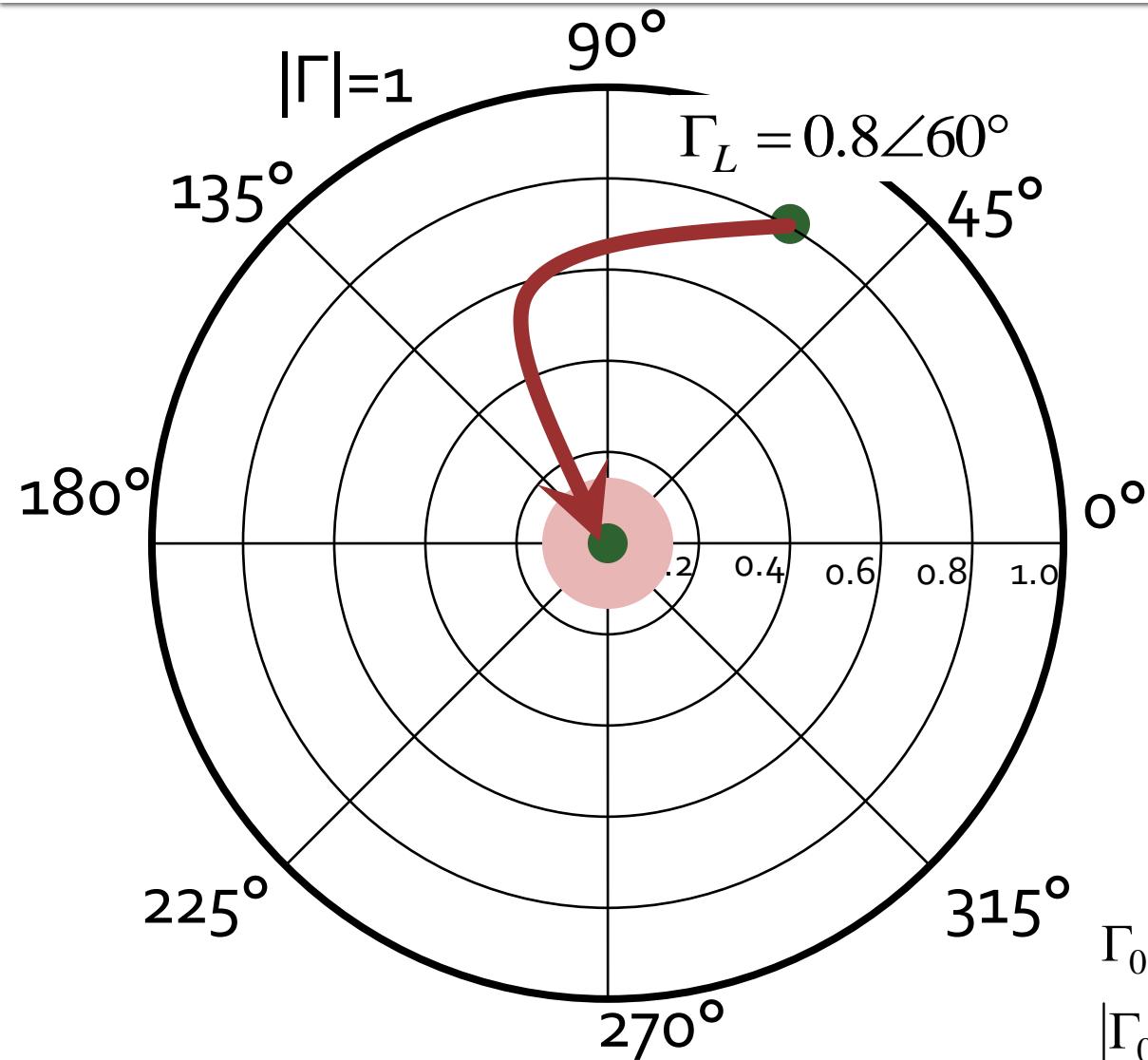
$$y_L = \frac{1}{z_L} = 0.148 - j \cdot 0.568$$

$$g_L = 0.148$$

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

(oricare Z_0)

Adaptare de impedanță

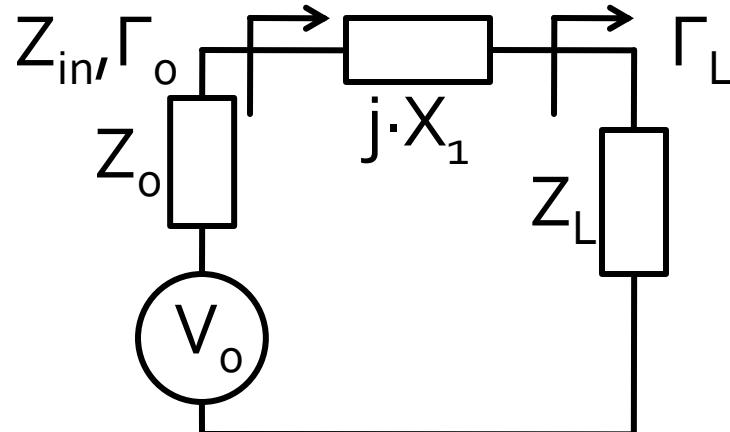
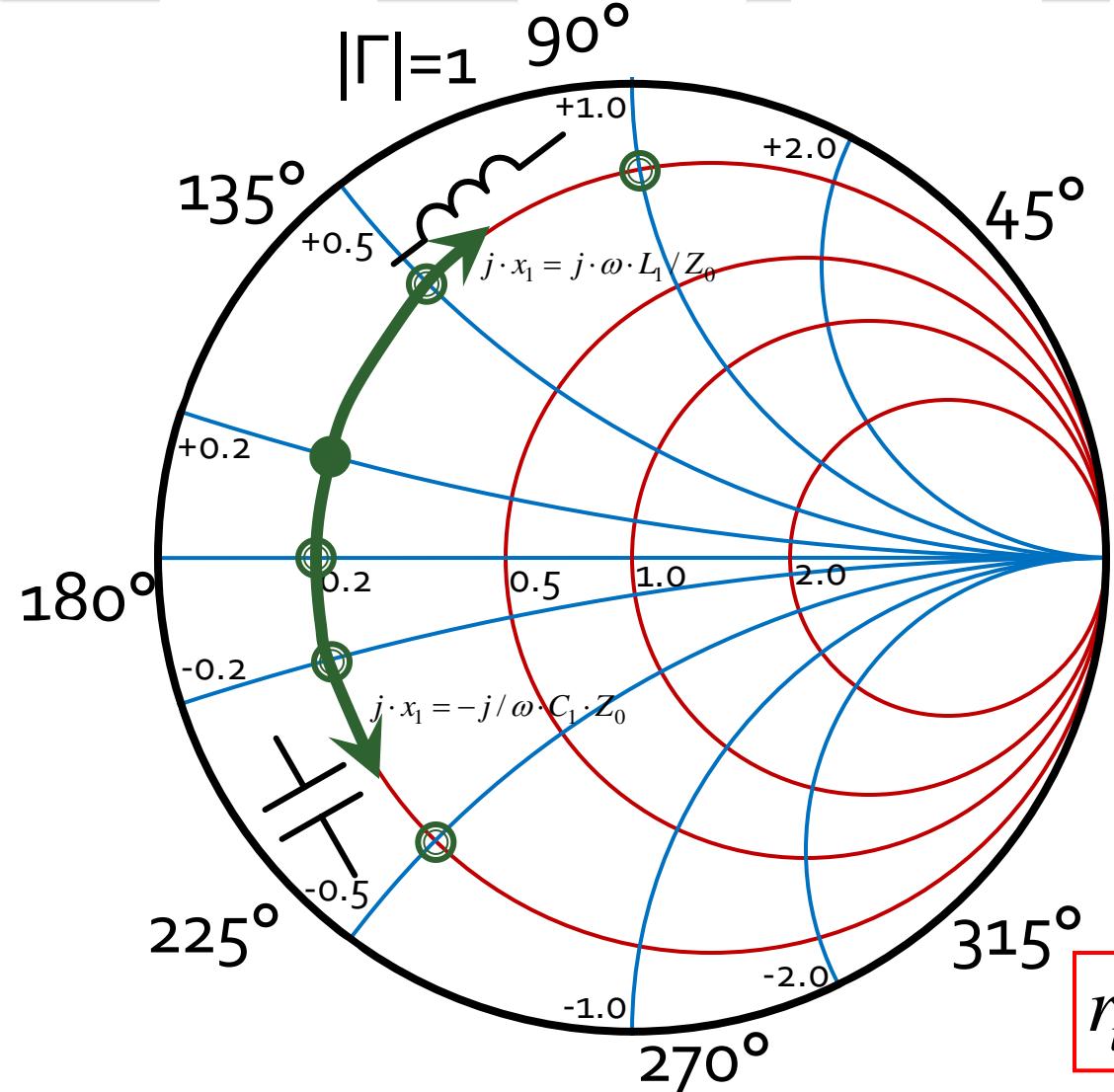


Cum?

$\Gamma_0 = 0$ adaptare perfectă ●

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

Diagrama Smith, coeficient de reflexie, reactanta in serie



$$Z_0 = 50\Omega$$

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

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

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

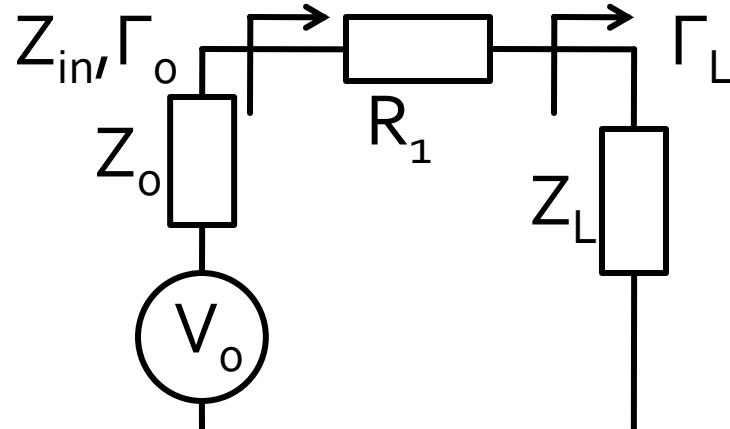
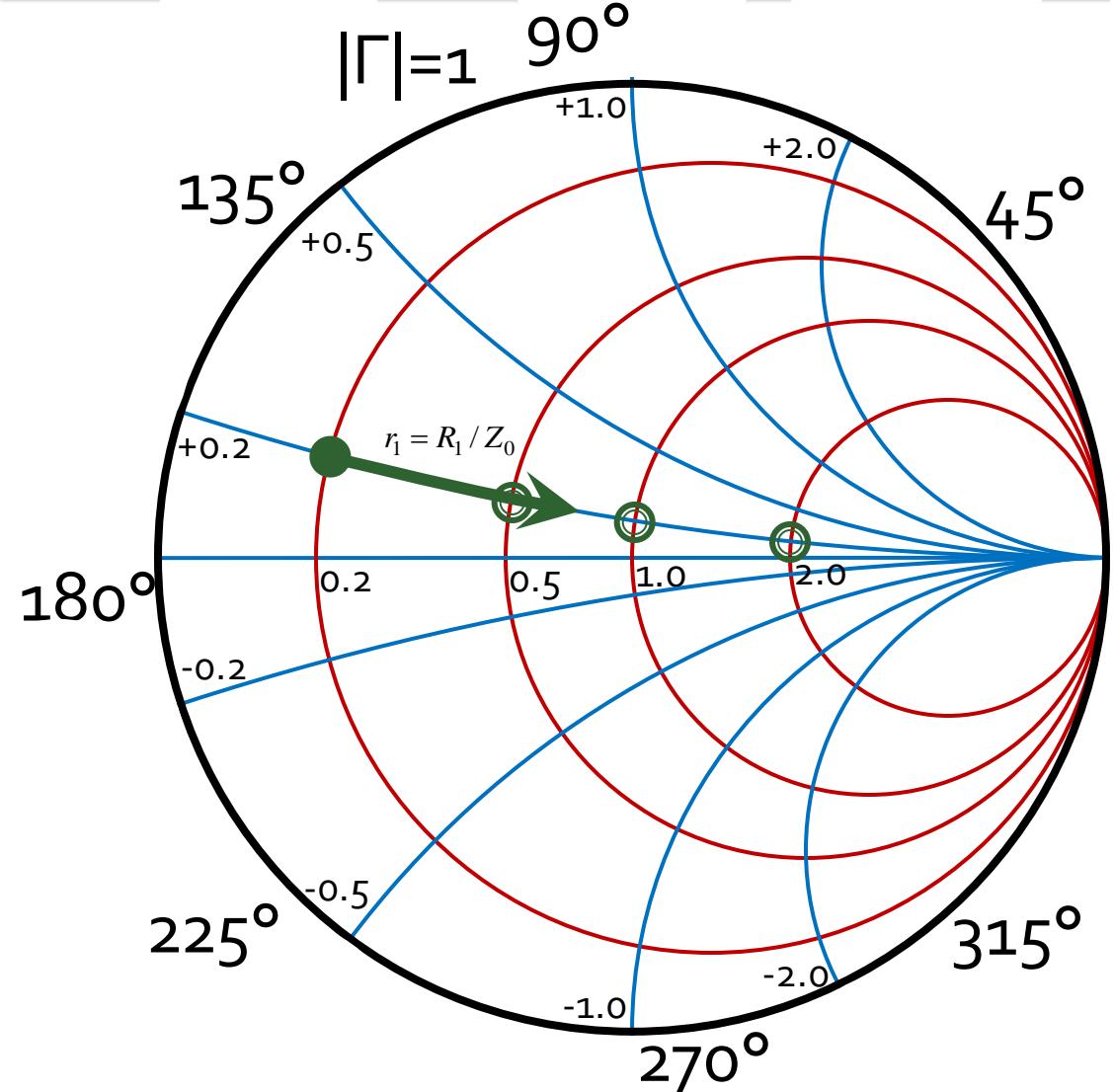
$$Z_{in} = Z_L + j \cdot X_1 = R_L + j \cdot (X_L + X_1)$$

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

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

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

Diagrama Smith, coeficient de reflexie, rezistenta in serie



$$Z_0 = 50\Omega$$

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

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

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

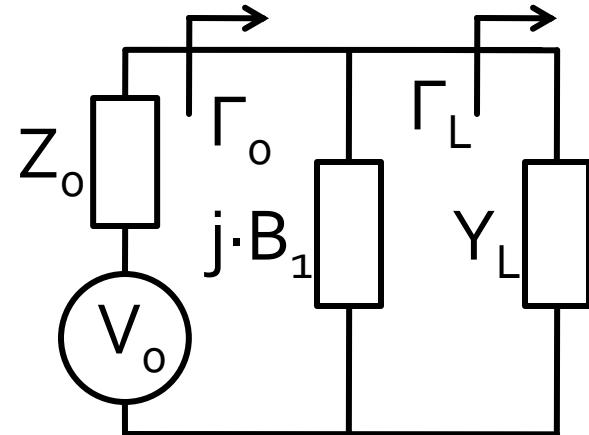
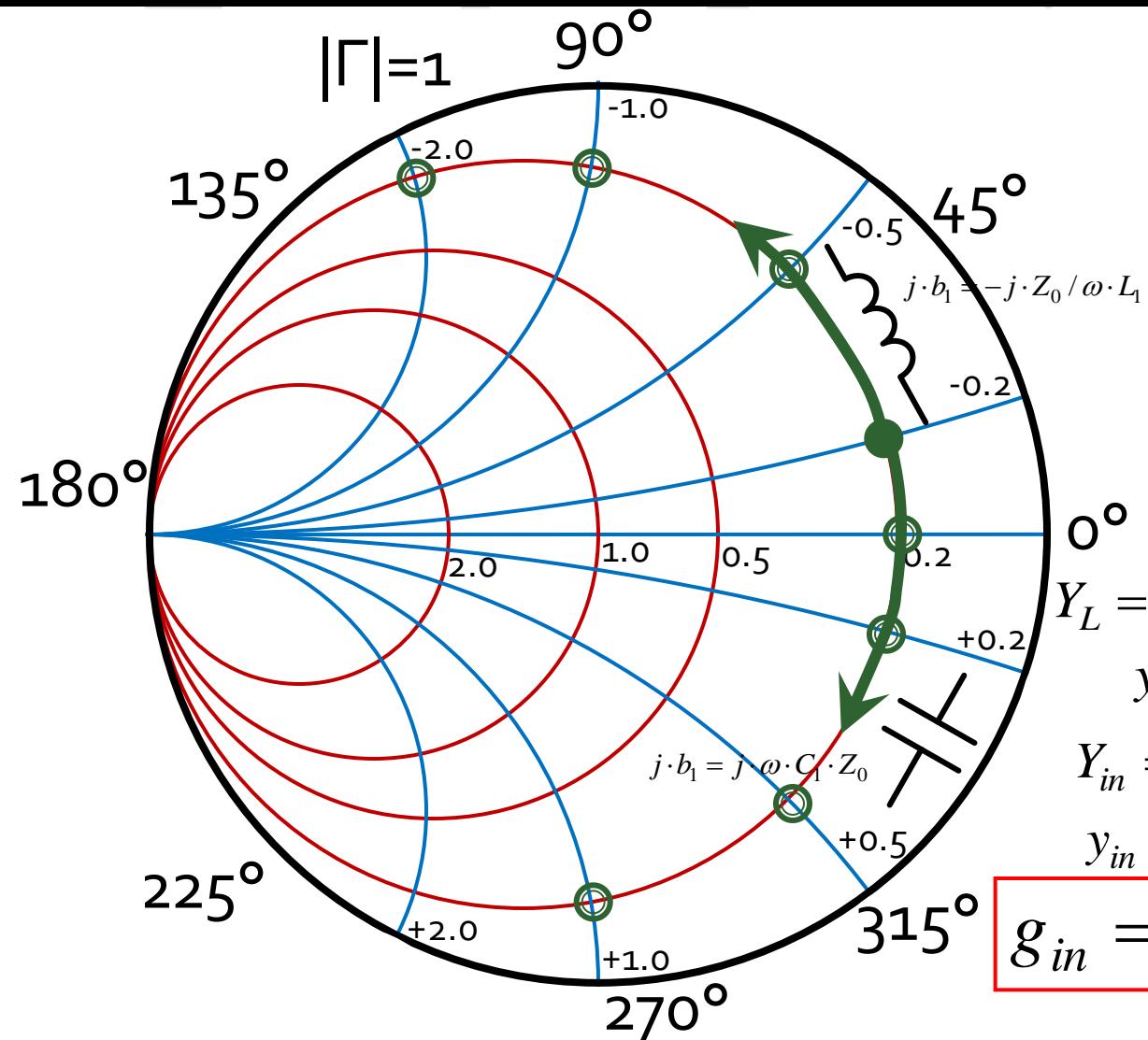
$$Z_{in} = Z_L + R_1 = (R_L + R_1) + j \cdot X_L$$

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

$x_{in} = x_L$

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

Diagrama Smith, coeficient de reflexie, susceptanta in paralel



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

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

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

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

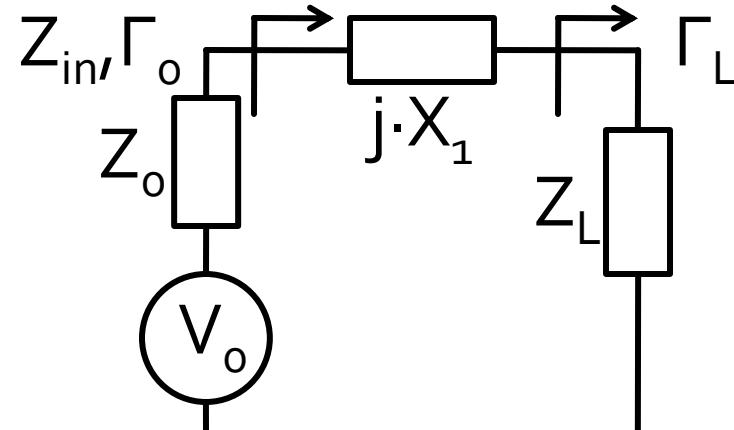
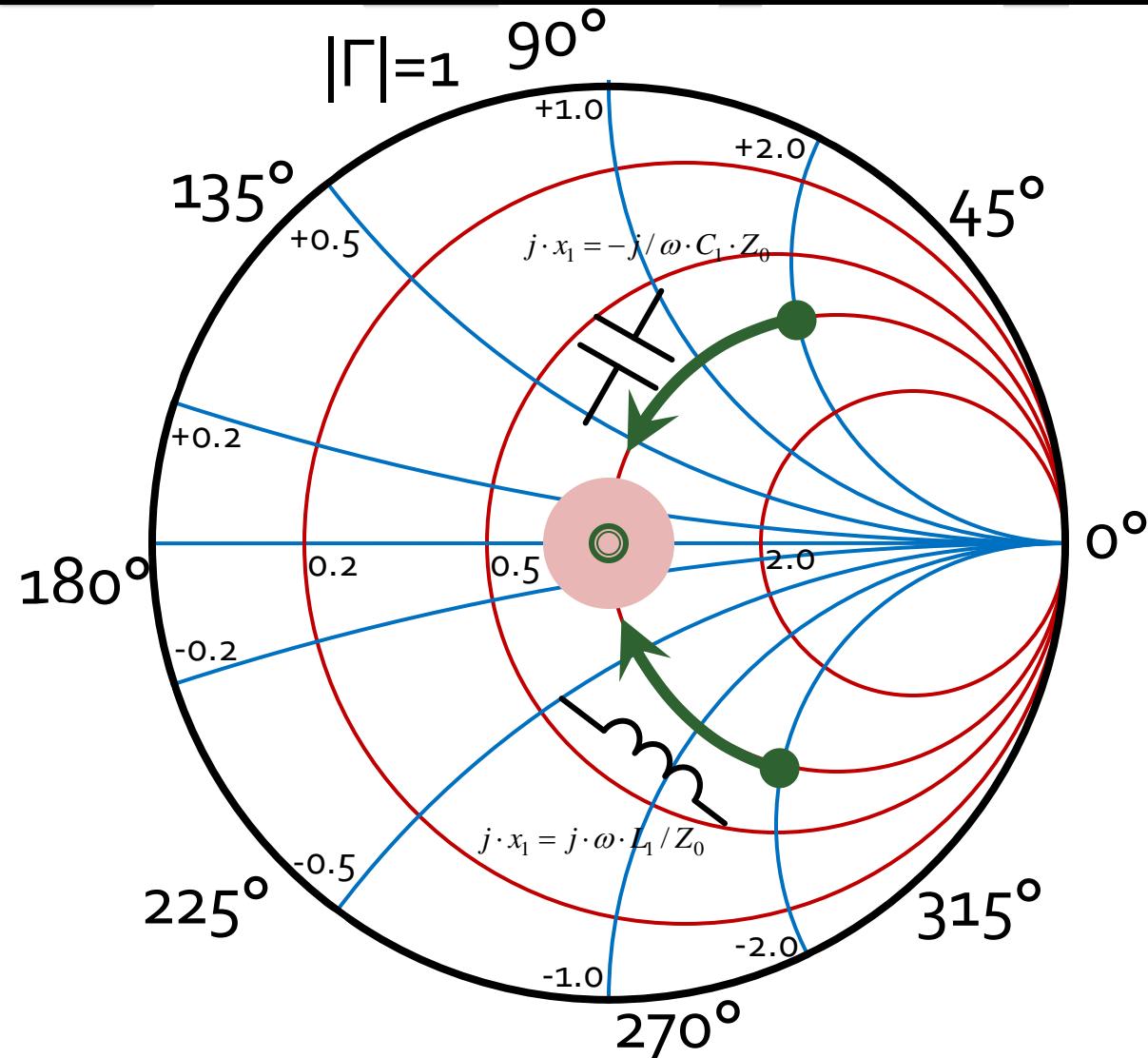
$$Y_{in} = Y_L + j \cdot B_1 = G_L + j \cdot (B_L + B_1)$$

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

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

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

Adaptare, reactanta in serie



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

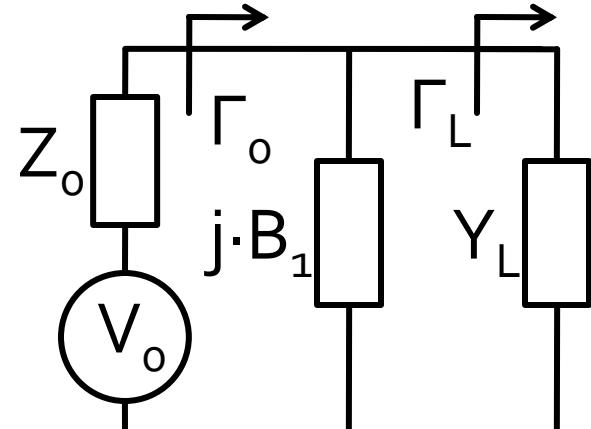
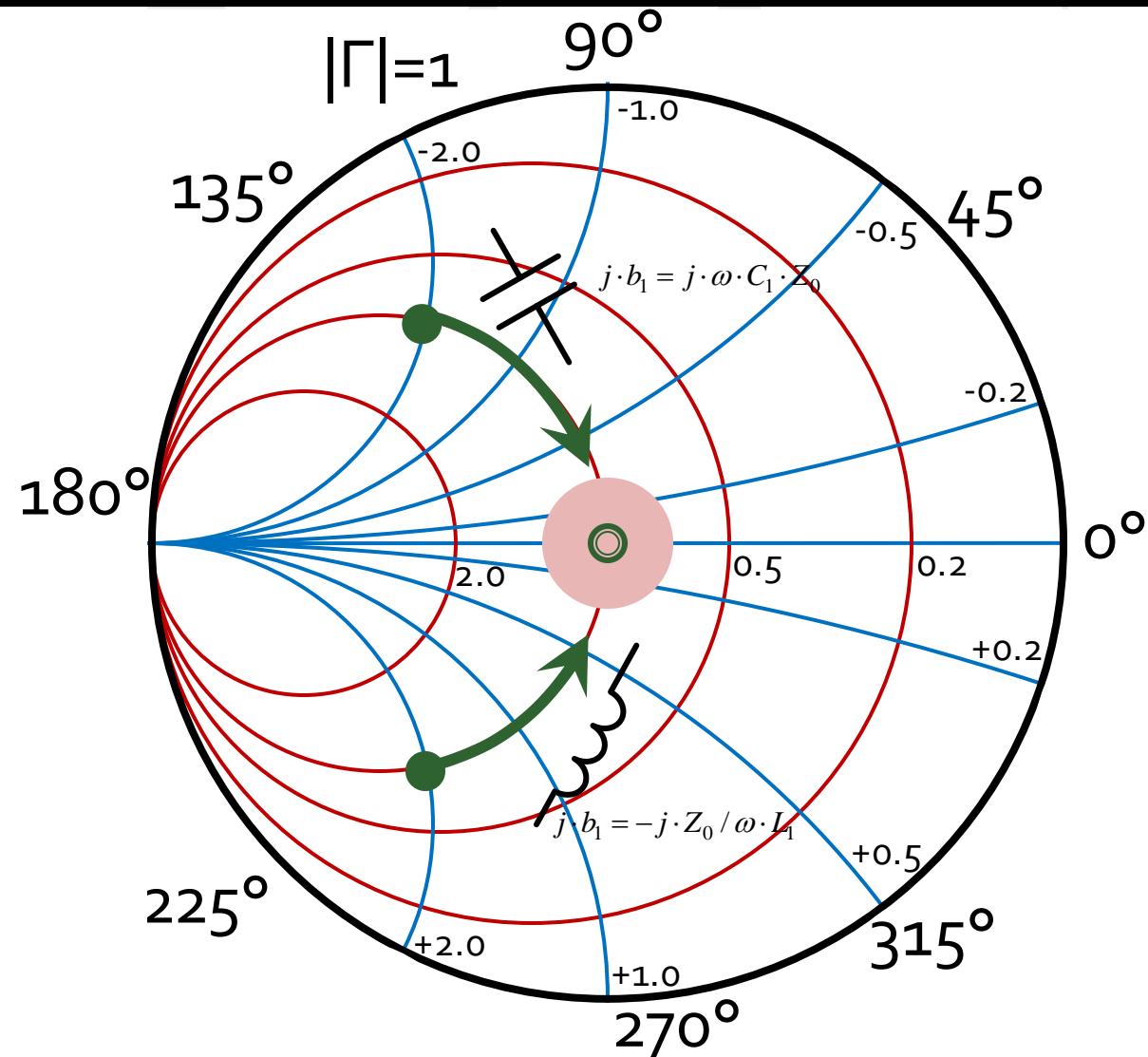
$$z_{in} = r_L + j \cdot (x_L + x_1)$$

$$r_{in} = r_L$$

- Adaptarea se poate realiza **numai daca** $r_L = 1$
- se realizeaza compensarea partii reactive a sarcinii

$$j \cdot x_1 = -j \cdot x_L$$

Adaptare, susceptanta in paralel



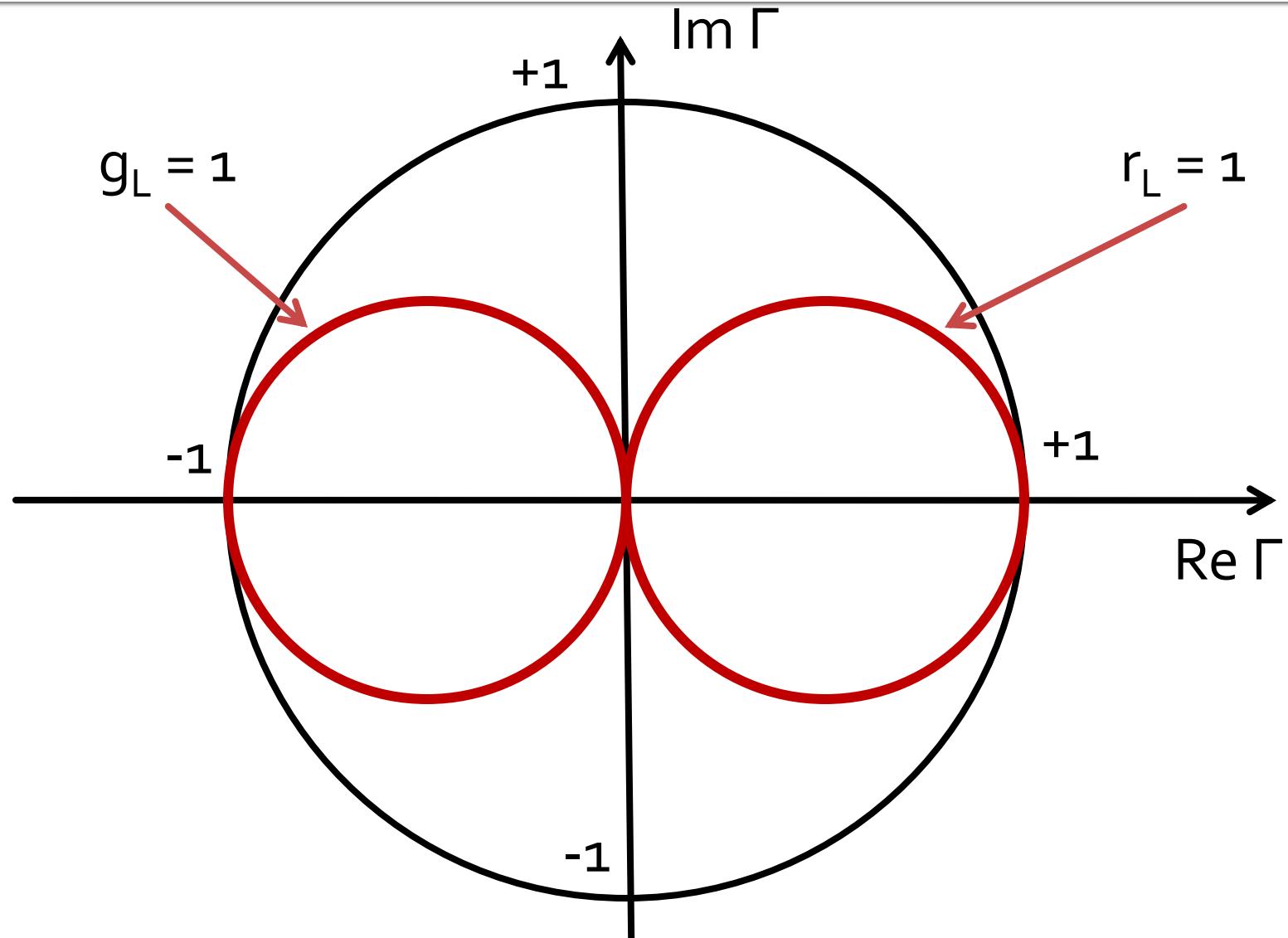
$$y_L = g_L + j \cdot b_L$$

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

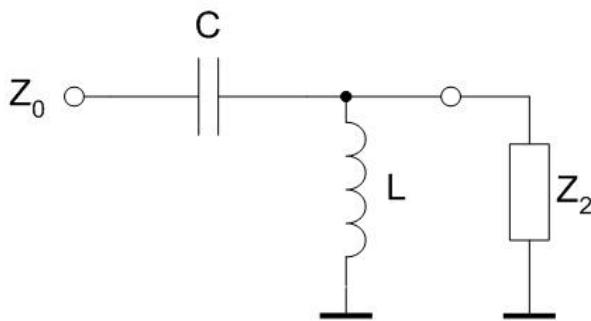
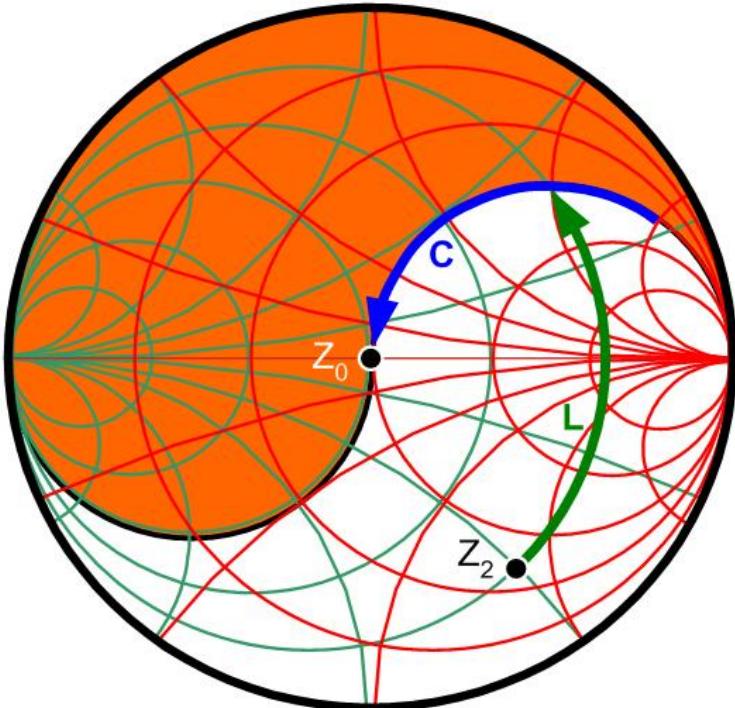
$$g_{in} = g_L$$

- Adaptarea se poate realiza **numai daca** $g_L = 1$
 - se realizeaza compensarea partii reactive a sarcinii
- $$j \cdot b_1 = -j \cdot b_L$$

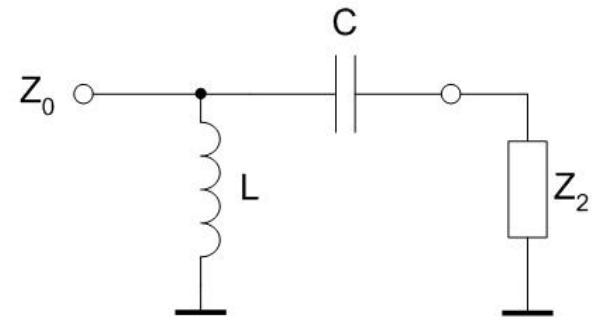
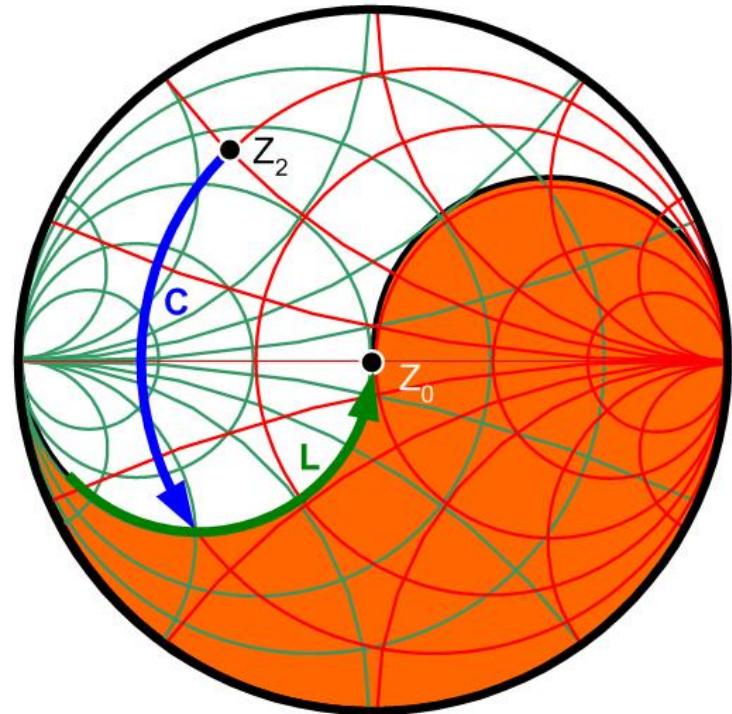
Diagrama Smith, $r=1$ si $g=1$



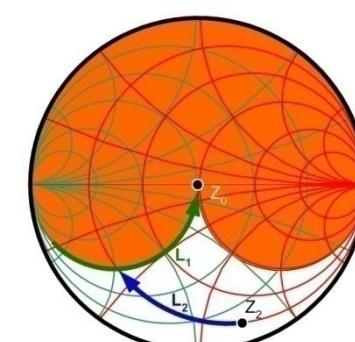
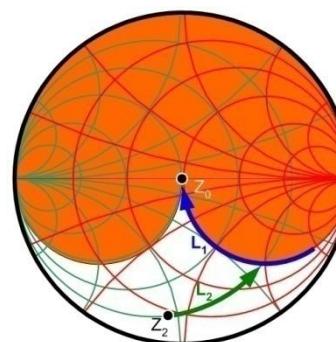
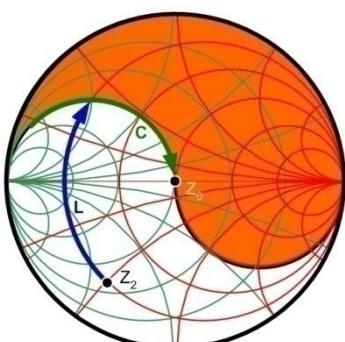
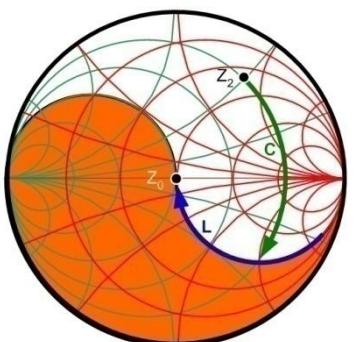
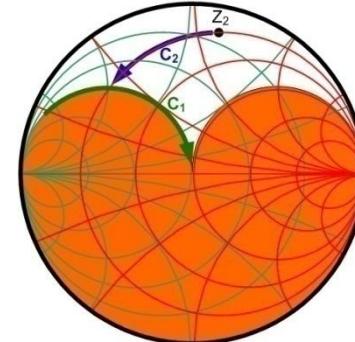
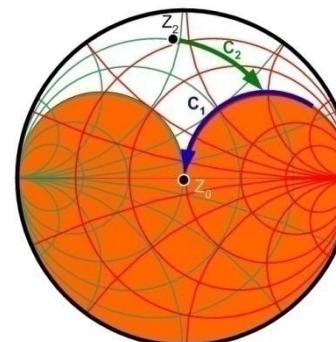
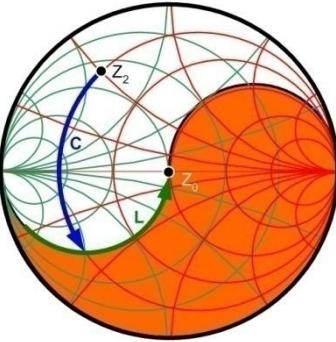
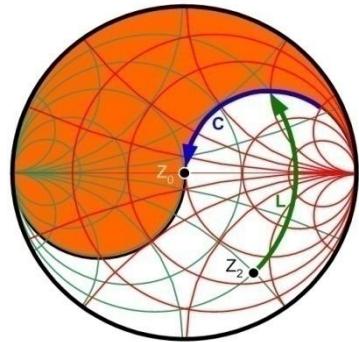
C serie, L paralel / L paralel, C serie



Zona interzisa cu
schema curenta

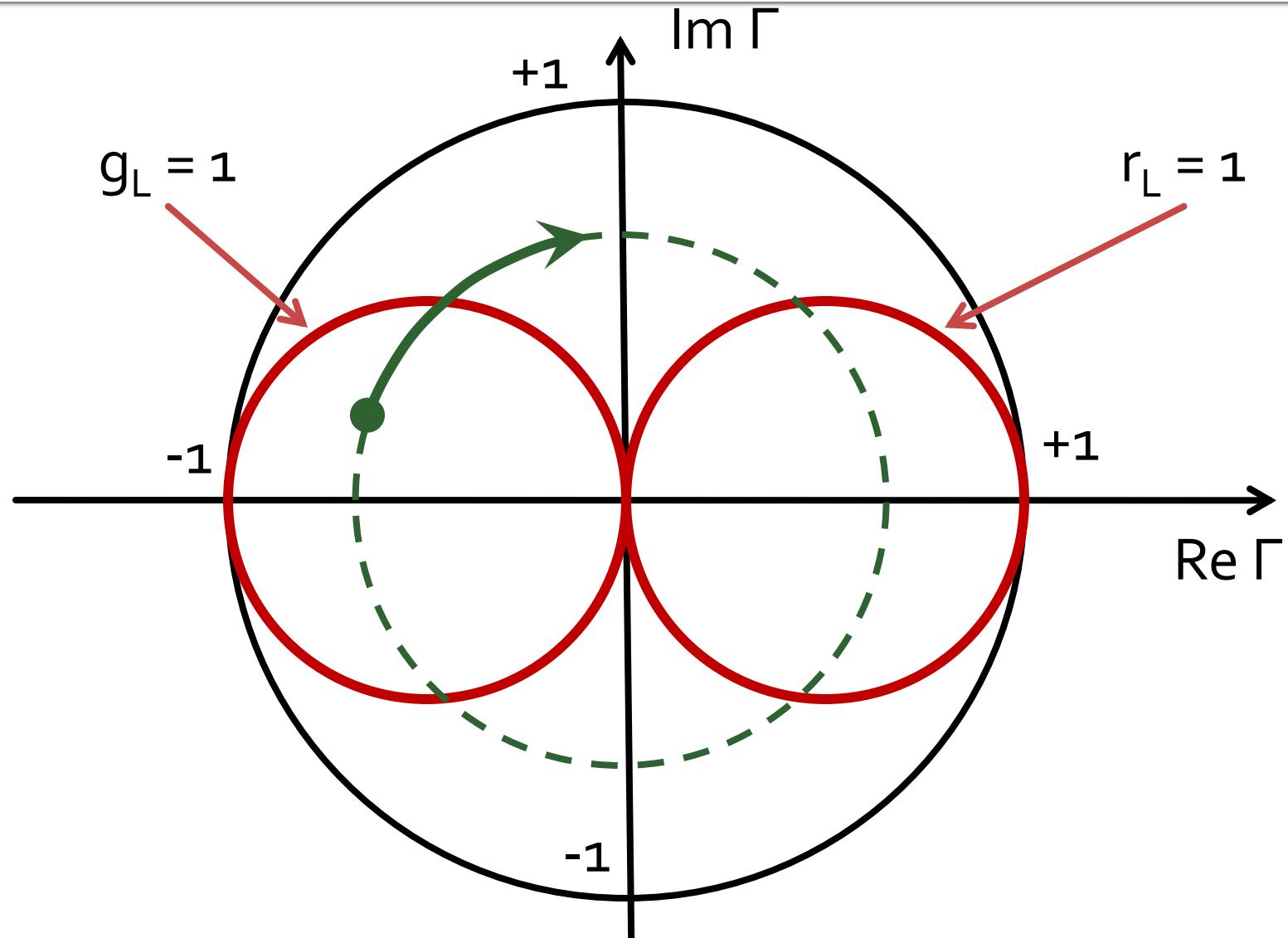


Adaptare cu două elemente reactive (retele in L)



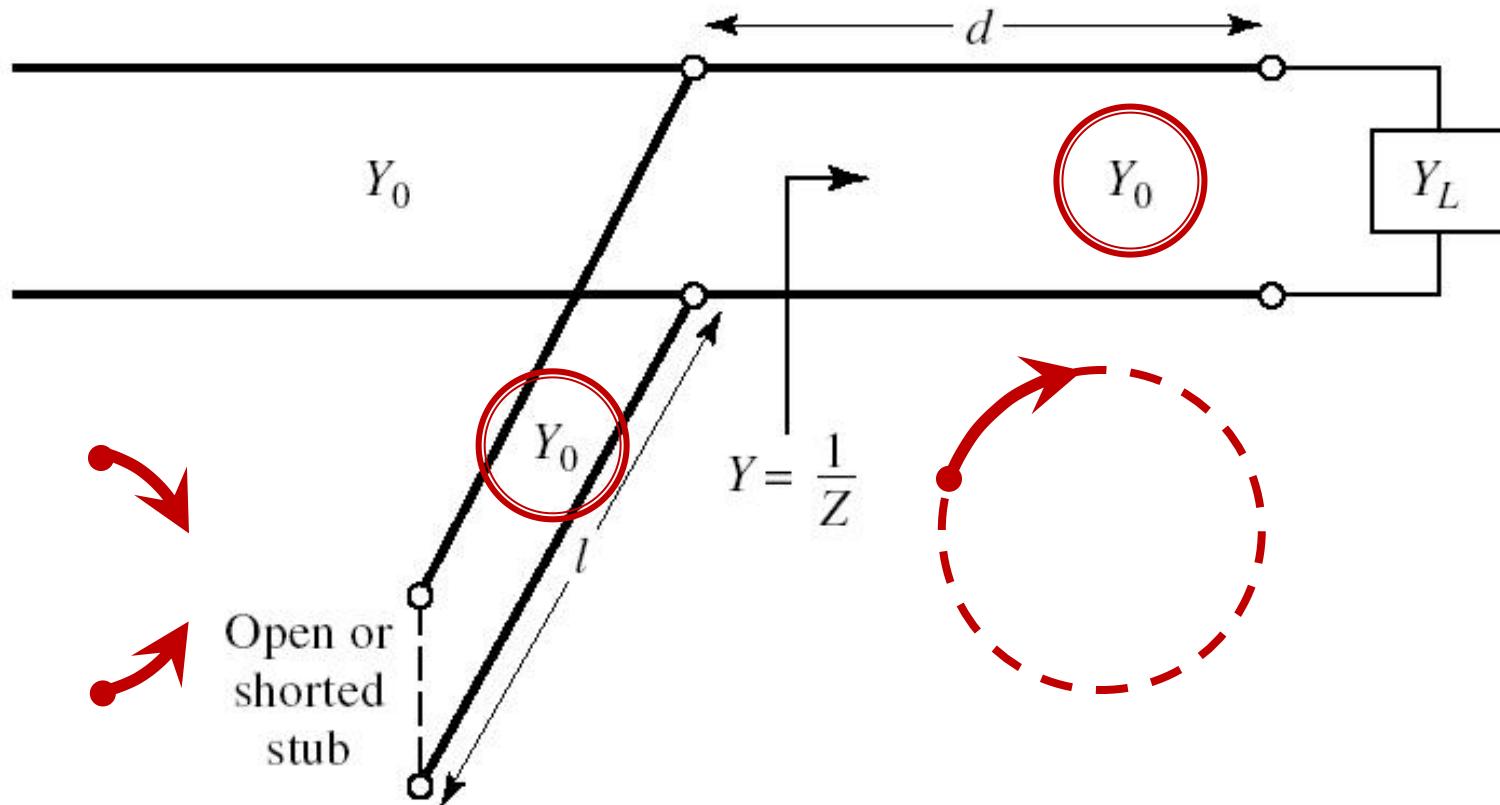
Zona interzisa cu
schema curenta

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



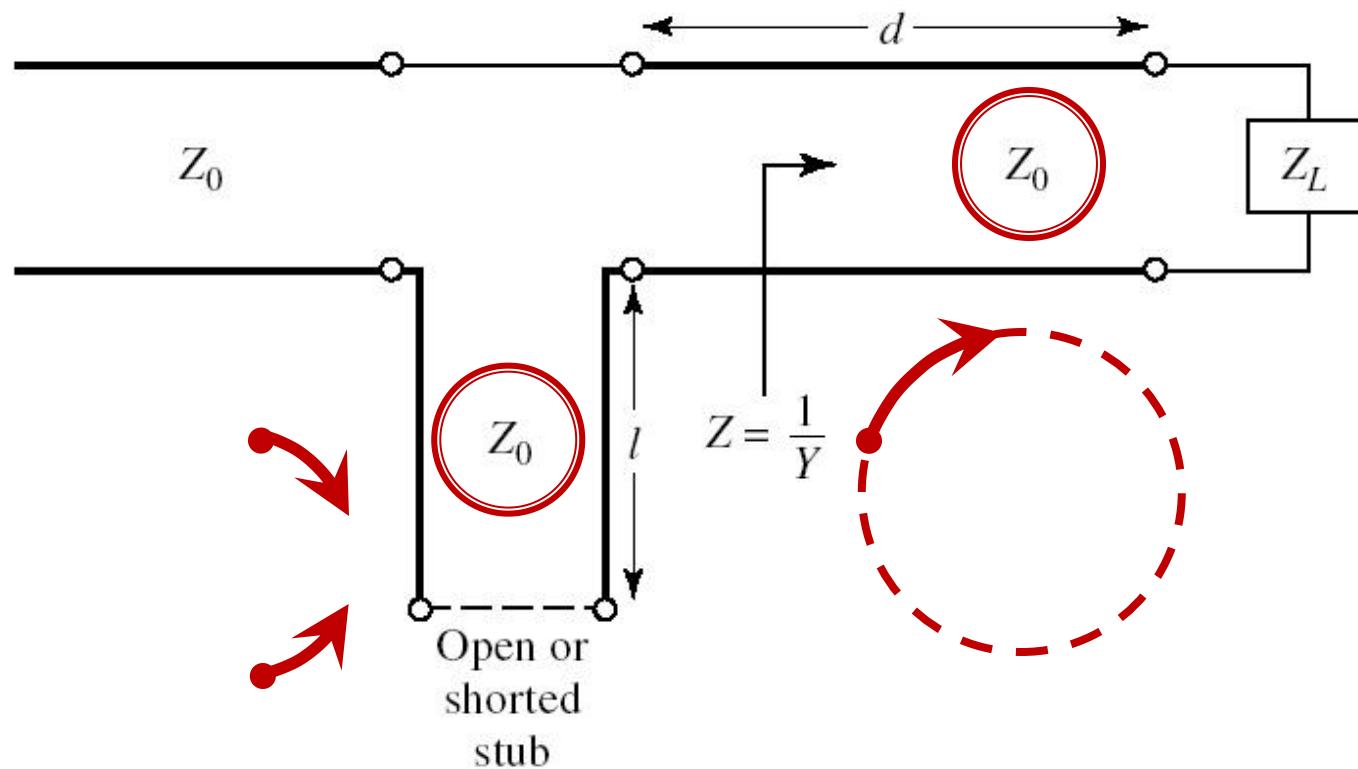
Single stub tuning

- Shunt Stub (secțiune de linie în paralel)

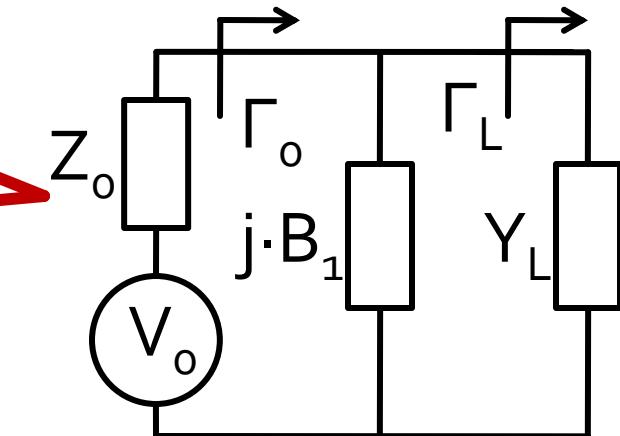
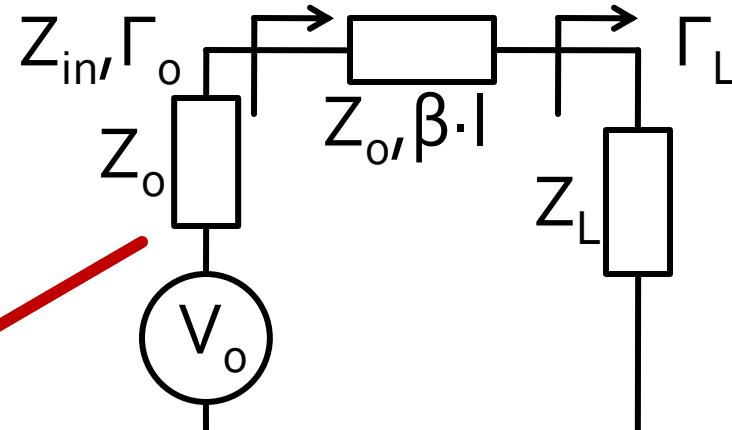
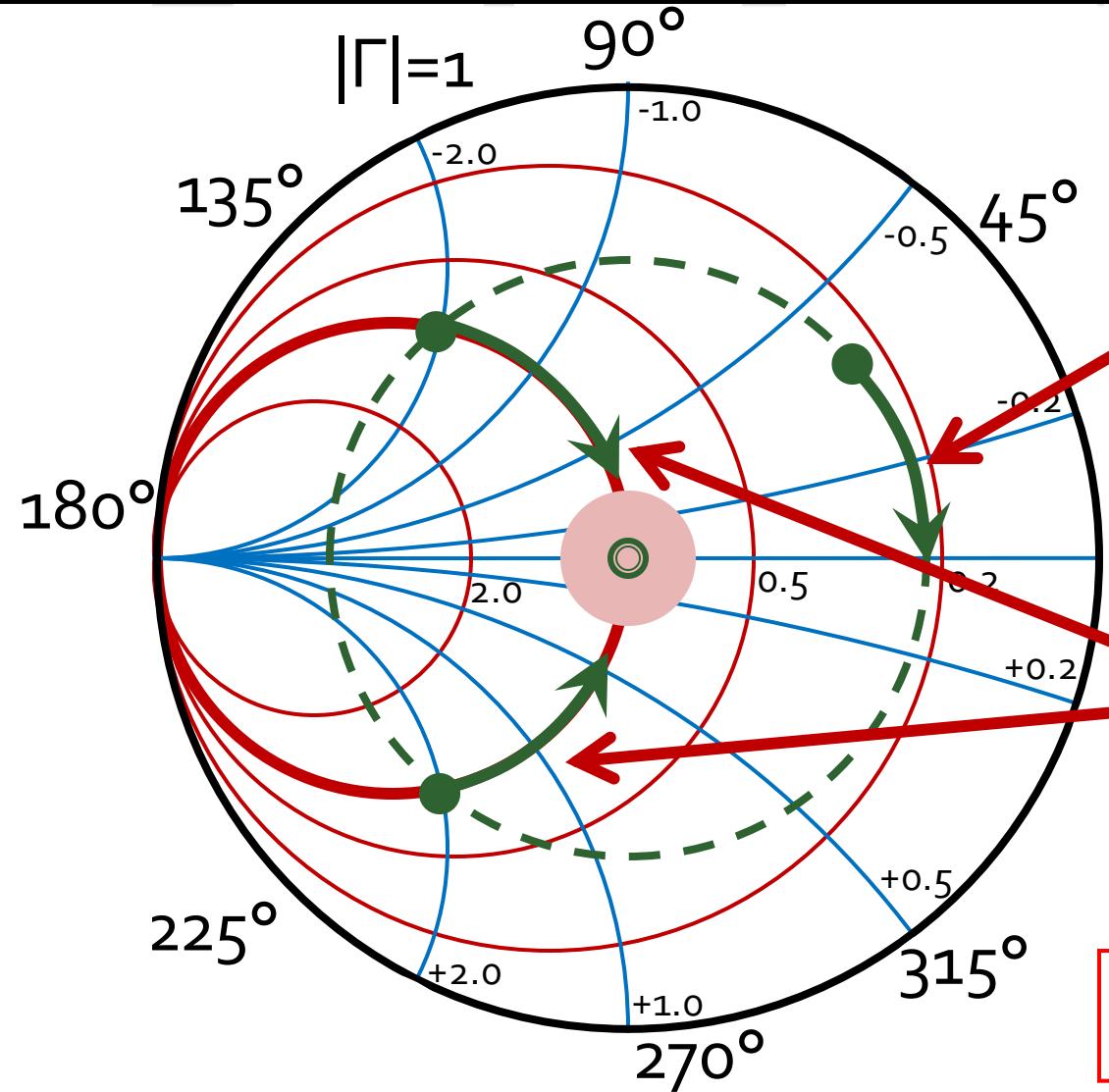


Single stub tuning

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



Adaptare, linie serie + susceptanta in paralel



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

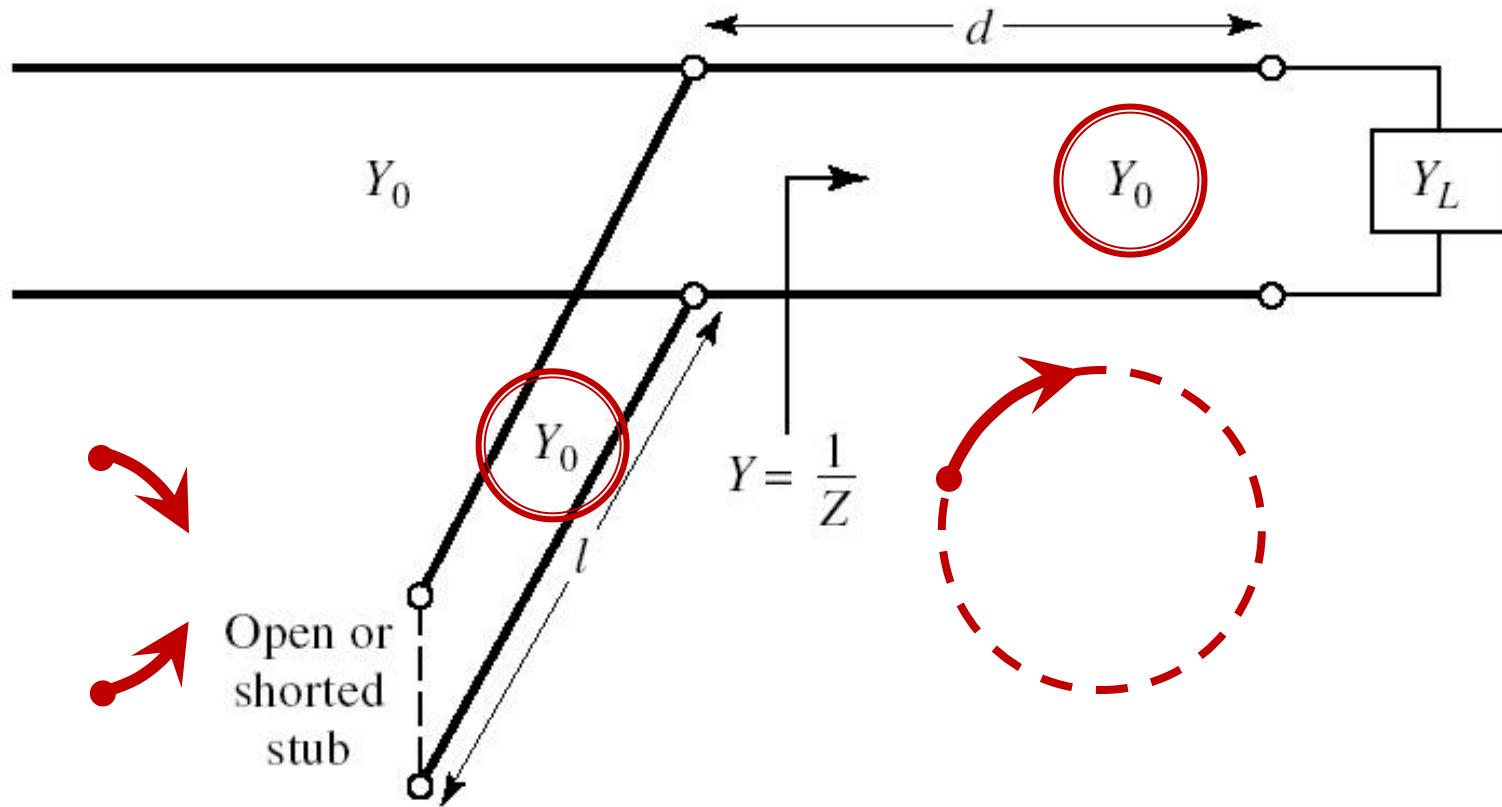
$$g_{in} = 1$$

Solutii analitice

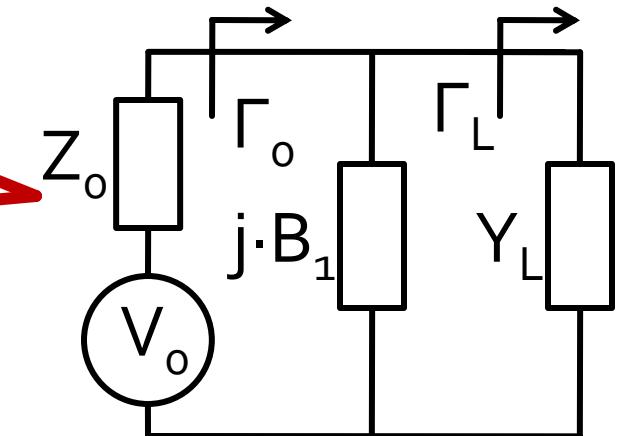
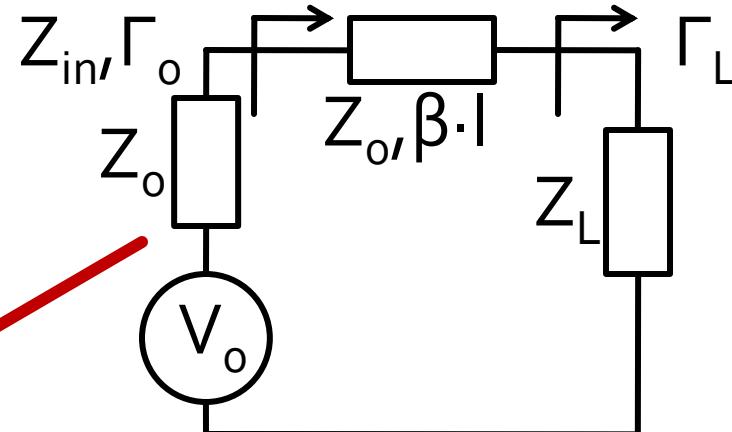
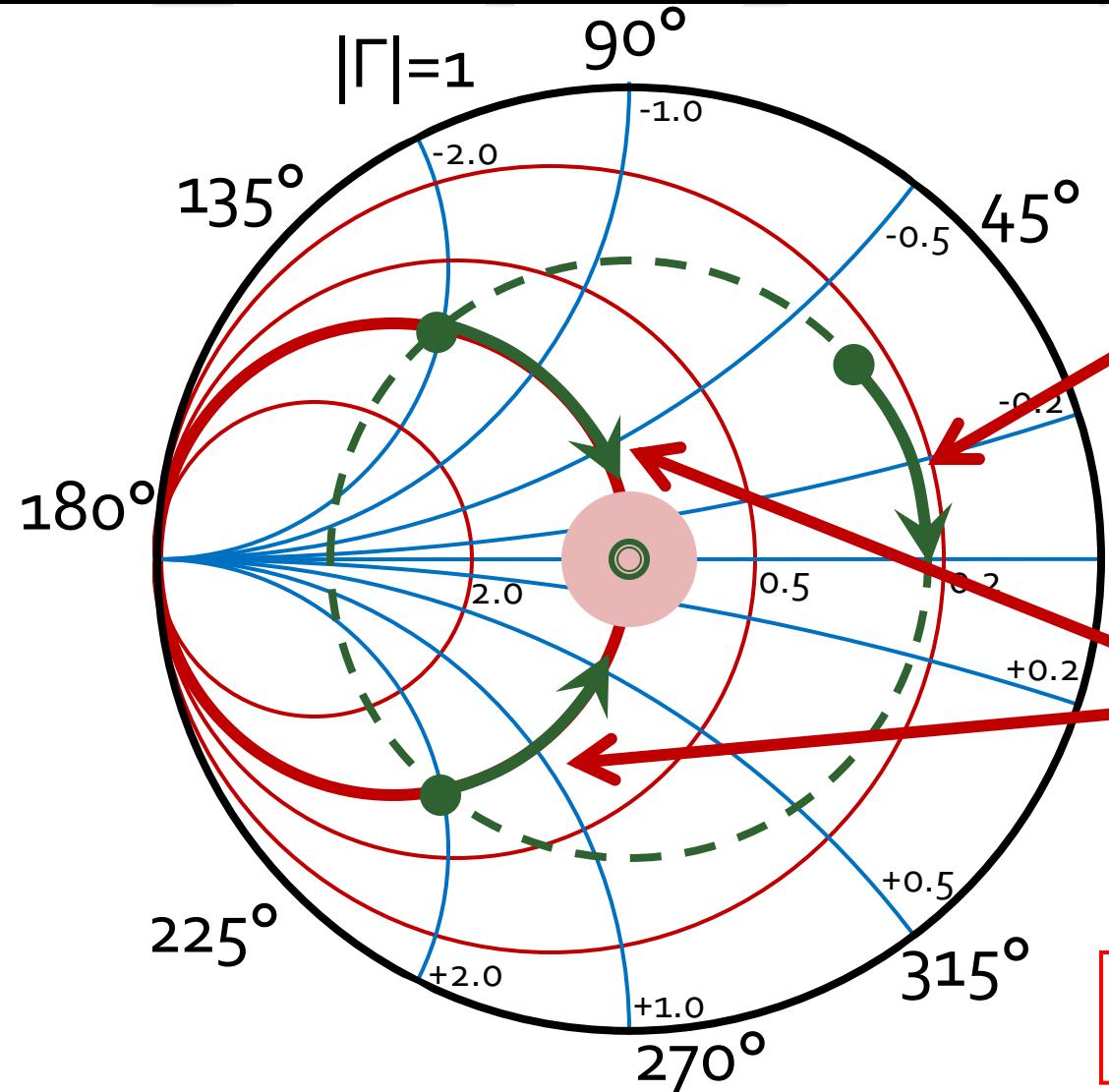
Examen / Proiect

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)

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

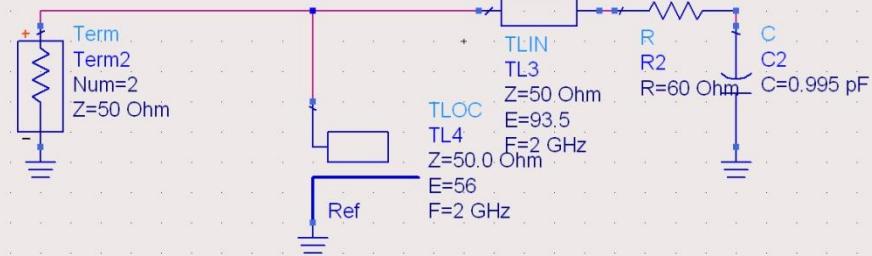
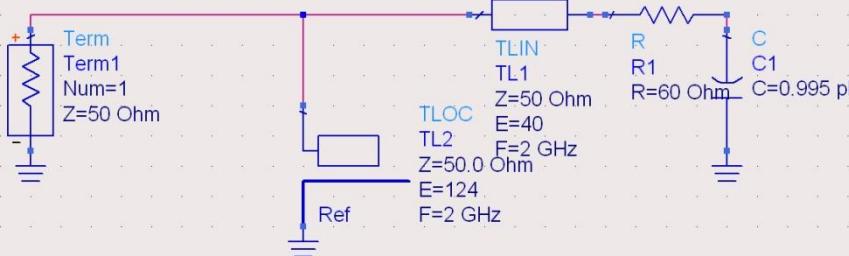
- Se alege **una** din cele doua solutii posibile
- **Semnul (+/-)** solutiei alese la **prima** ecuatie impune **semnul** solutiei utilizate la a **doua** ecuatie

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

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

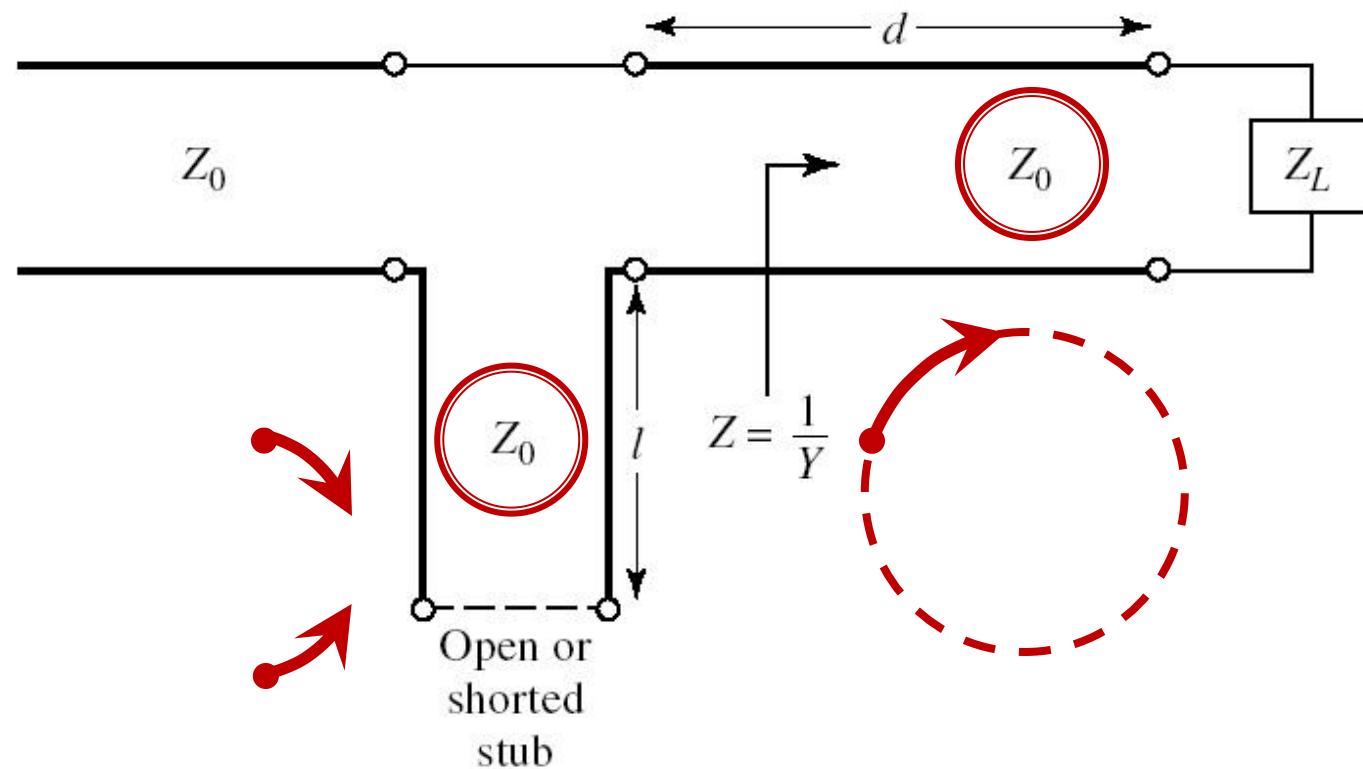
$$l_1 = \frac{93.4^\circ}{360^\circ} \cdot \lambda = 0.259 \cdot \lambda$$

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

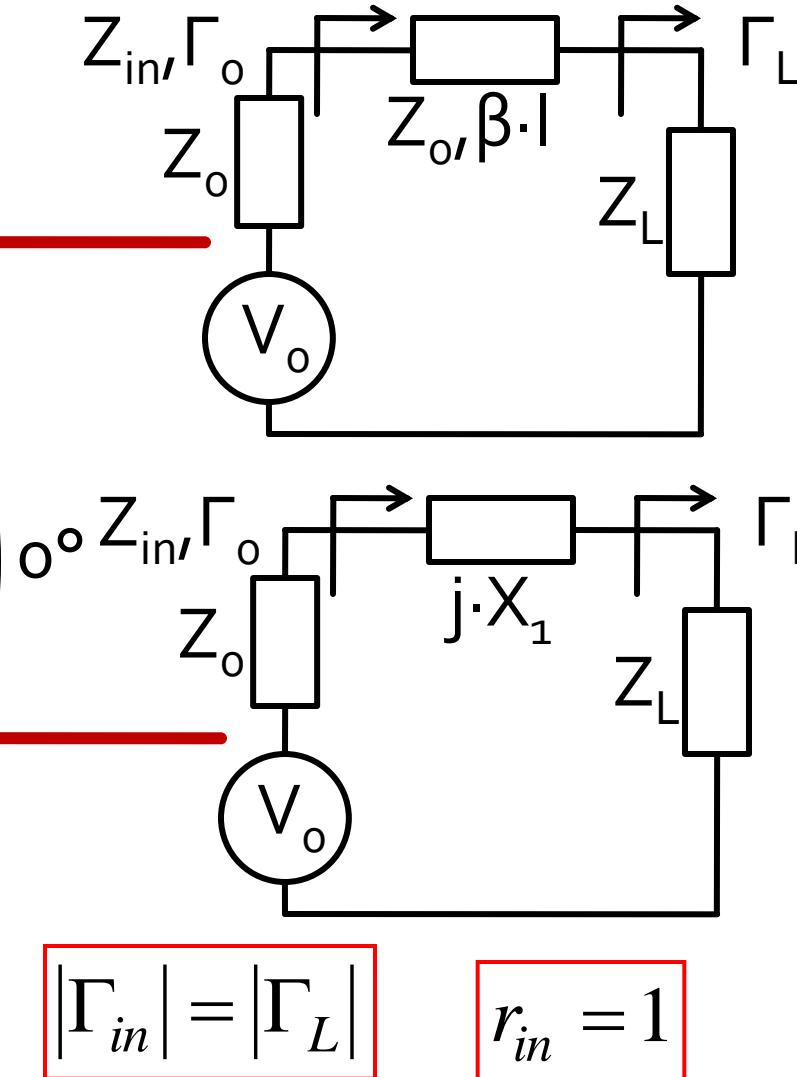
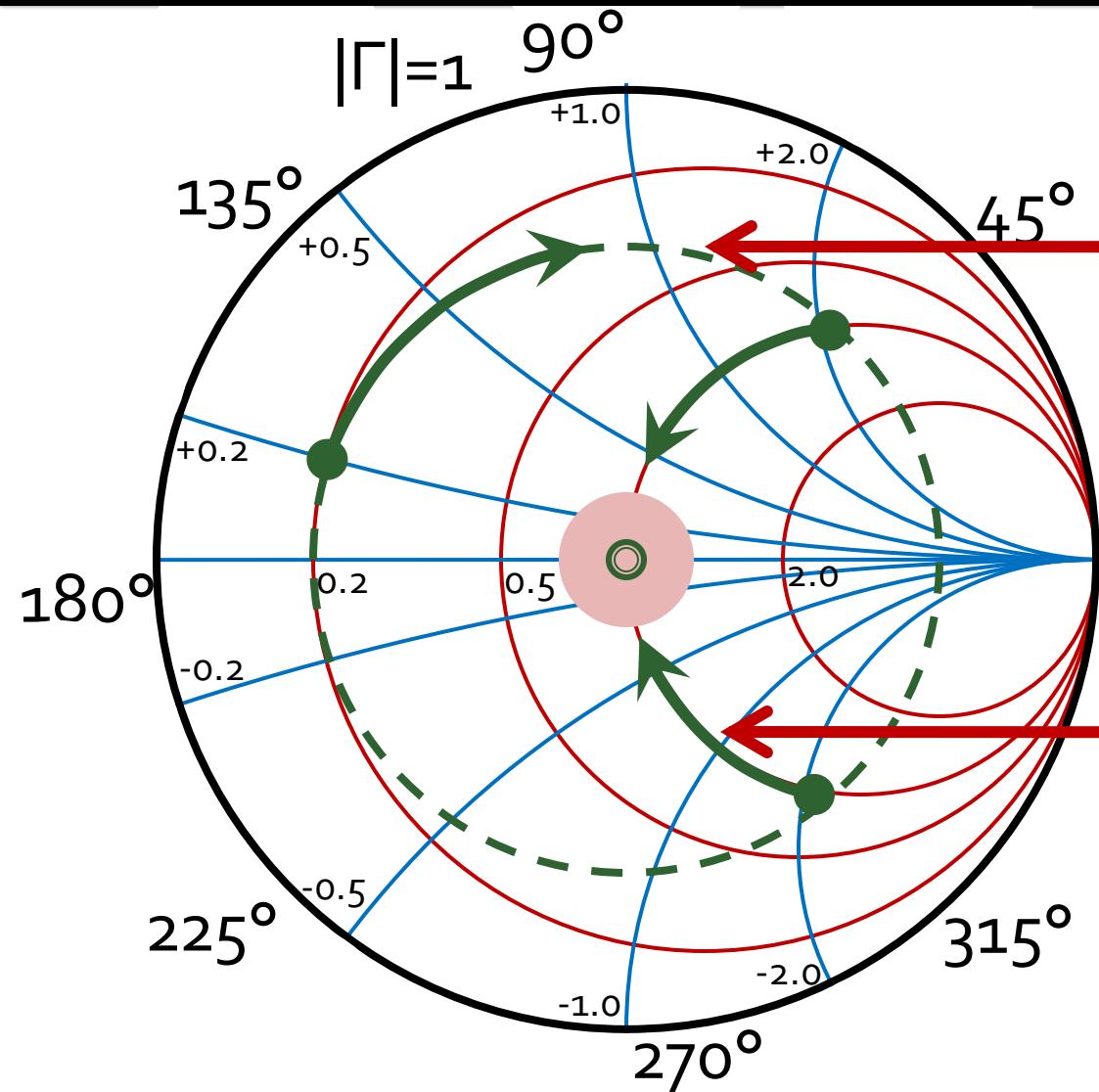


Caz 2, Series Stub

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



Adaptare, linie serie + reactanta in serie



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 +"**

$$(-29.92^\circ + 2\theta) = +56.28^\circ \quad \theta = 43.1^\circ \quad \text{Im } z_s = \frac{+2 \cdot |\Gamma_s|}{\sqrt{1 - |\Gamma_s|^2}} = +1.335$$

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

- **solutia "cu -"**

$$(-29.92^\circ + 2\theta) = -56.28^\circ \quad \theta = -13.2^\circ (+180^\circ) \rightarrow \theta = 166.8^\circ$$

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

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

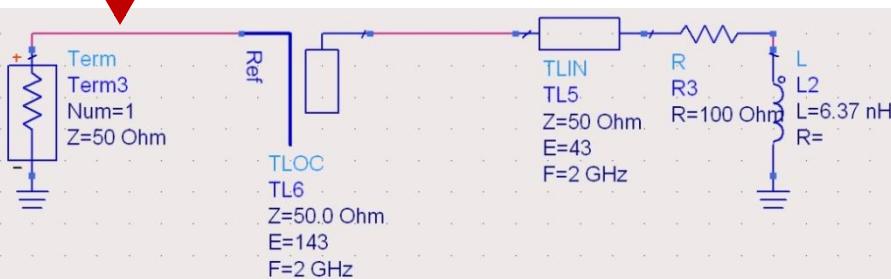
Calcul analitic (calcul efectiv)

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

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

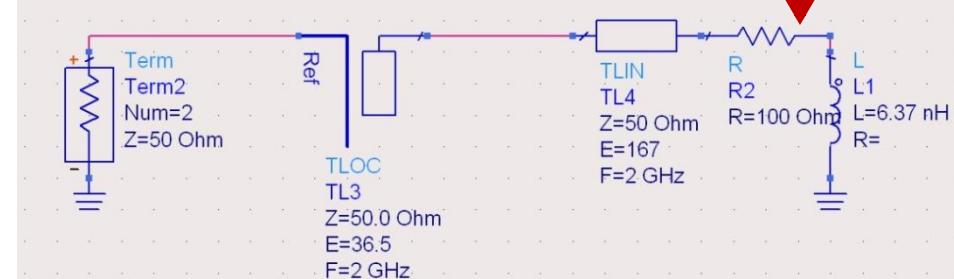
$$l_1 = \frac{43.1^\circ}{360^\circ} \cdot \lambda = 0.120 \cdot \lambda$$

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



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

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



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° pentru a avea valoare pozitiva (realizabila fizic)
- o adaugare sau scadere de **90°** ($\lambda/4$) transforma impedanta stub-ului:

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

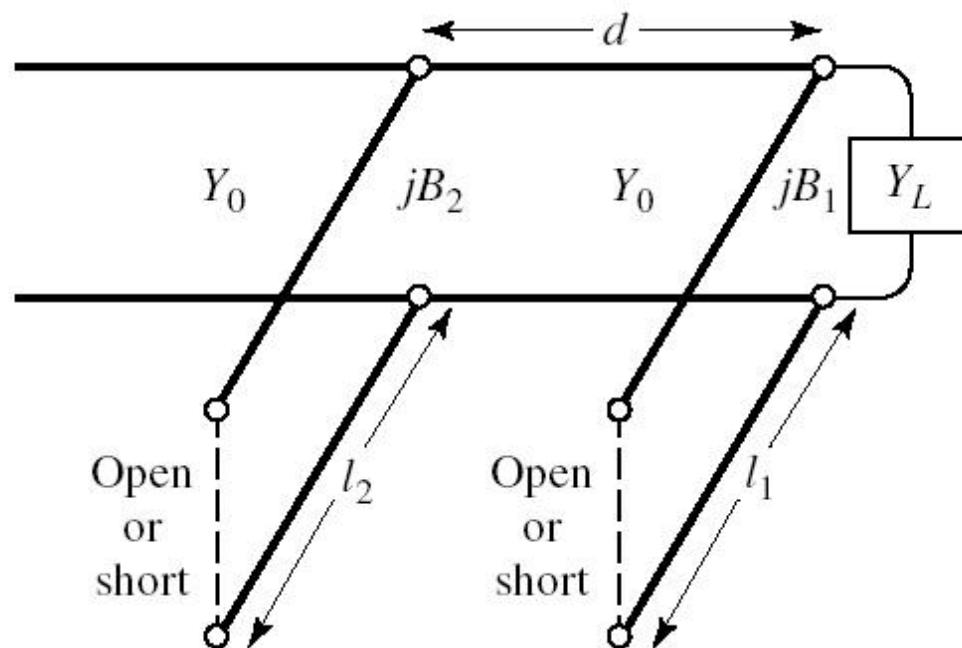
- pentru stub se poate adauga/scadea 90° ($\lambda/4$) simultan cu schimbare **gol** \Leftrightarrow **scurtcircuit**

Double stub tuning

Adaptarea cu două secțiuni de linie

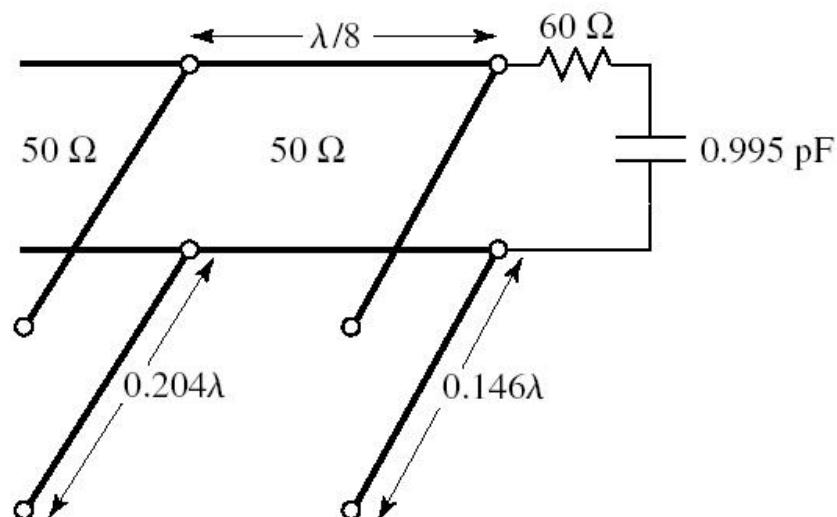
Adaptarea cu două secțiuni de linie

- Double stub tuning
- Se foloseste o lungime constantă de linie intre 2 stub-uri

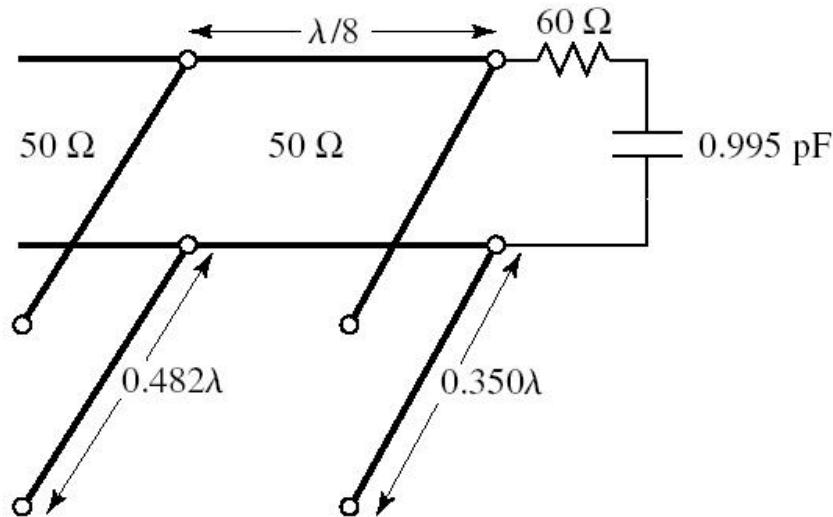


Adaptarea cu două secțiuni de linie

- Două soluții posibile



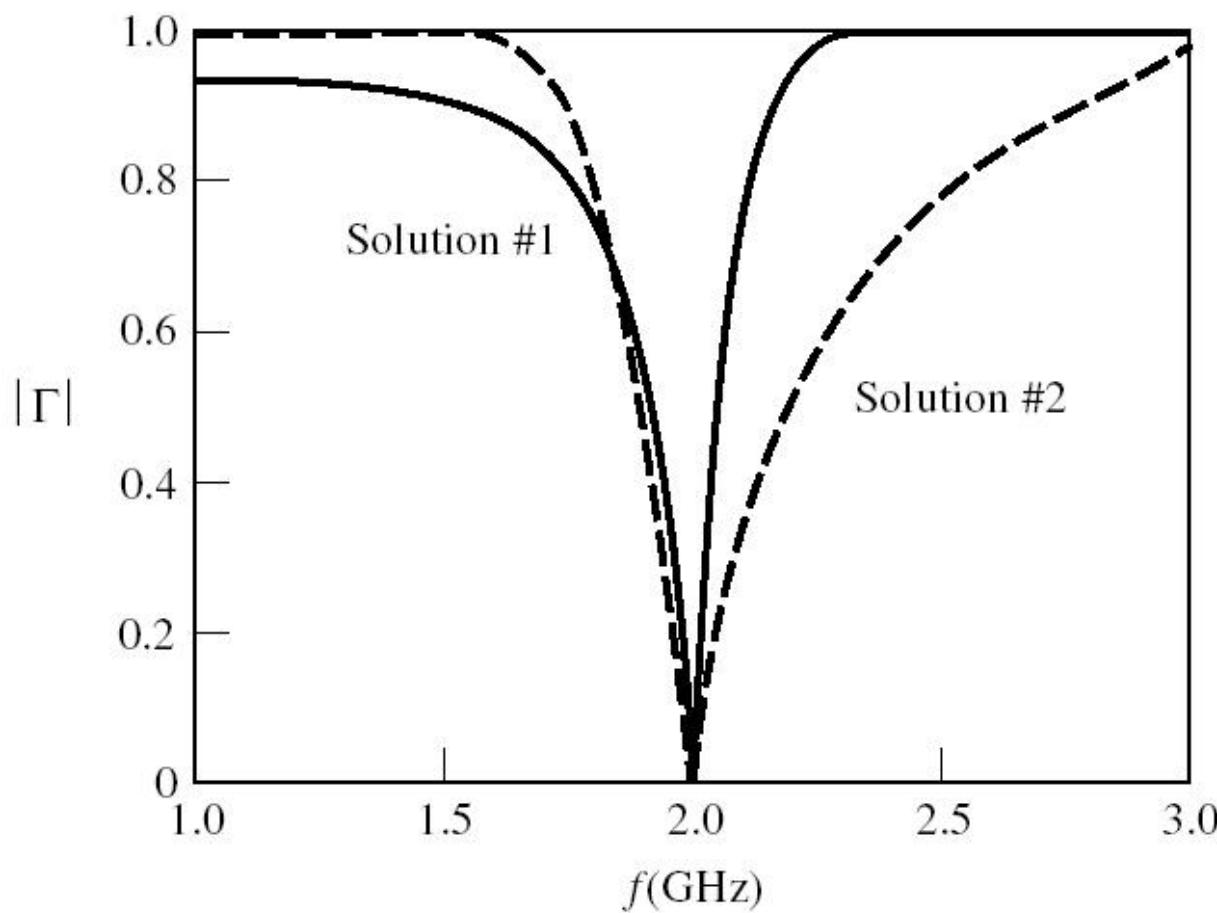
Solution 1



Solution 2

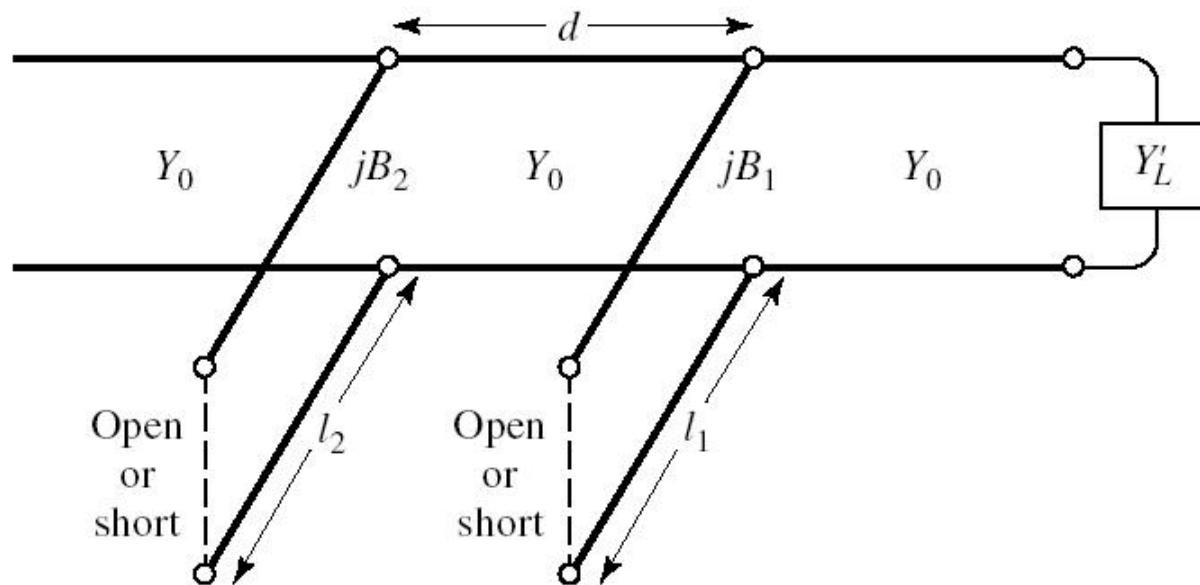
Adaptarea cu două sectiuni de linie

- Două solutii posibile

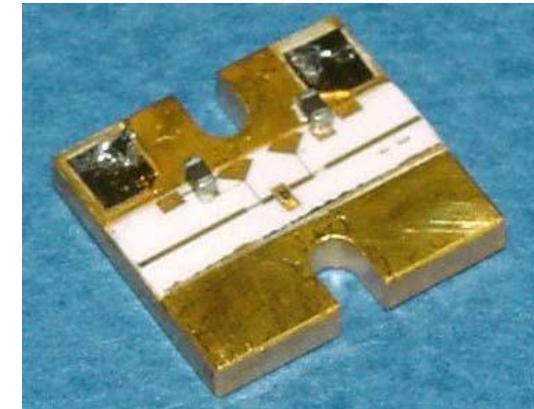
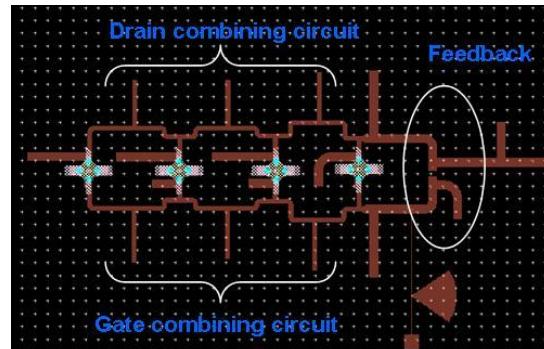
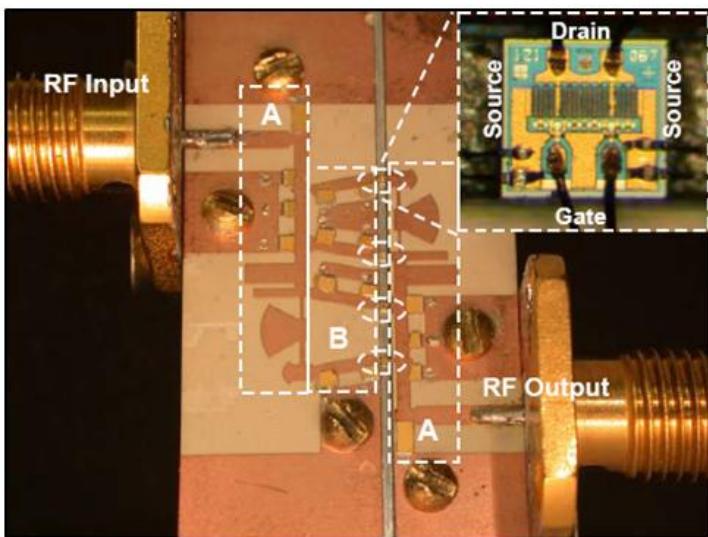
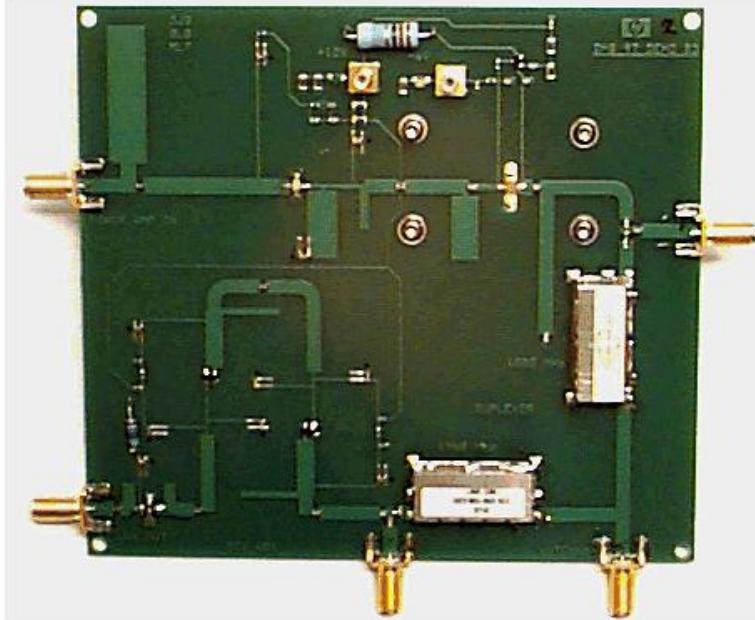
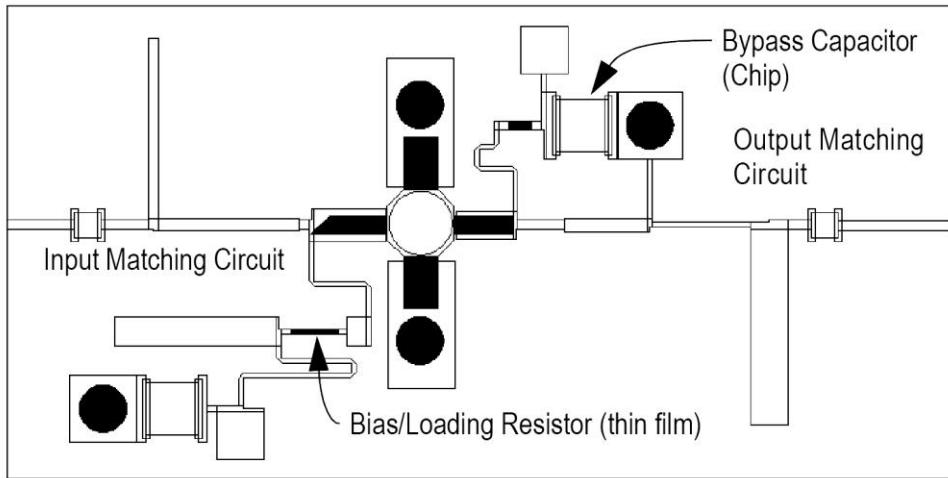


Adaptarea cu două secțiuni de linie

- Tipic $d = \lambda/8$ sau $d = 3\lambda/8$
- **Nu** pentru orice sarcină este posibila
 - decat dacă se poate introduce o secțiune de linie până la sarcină

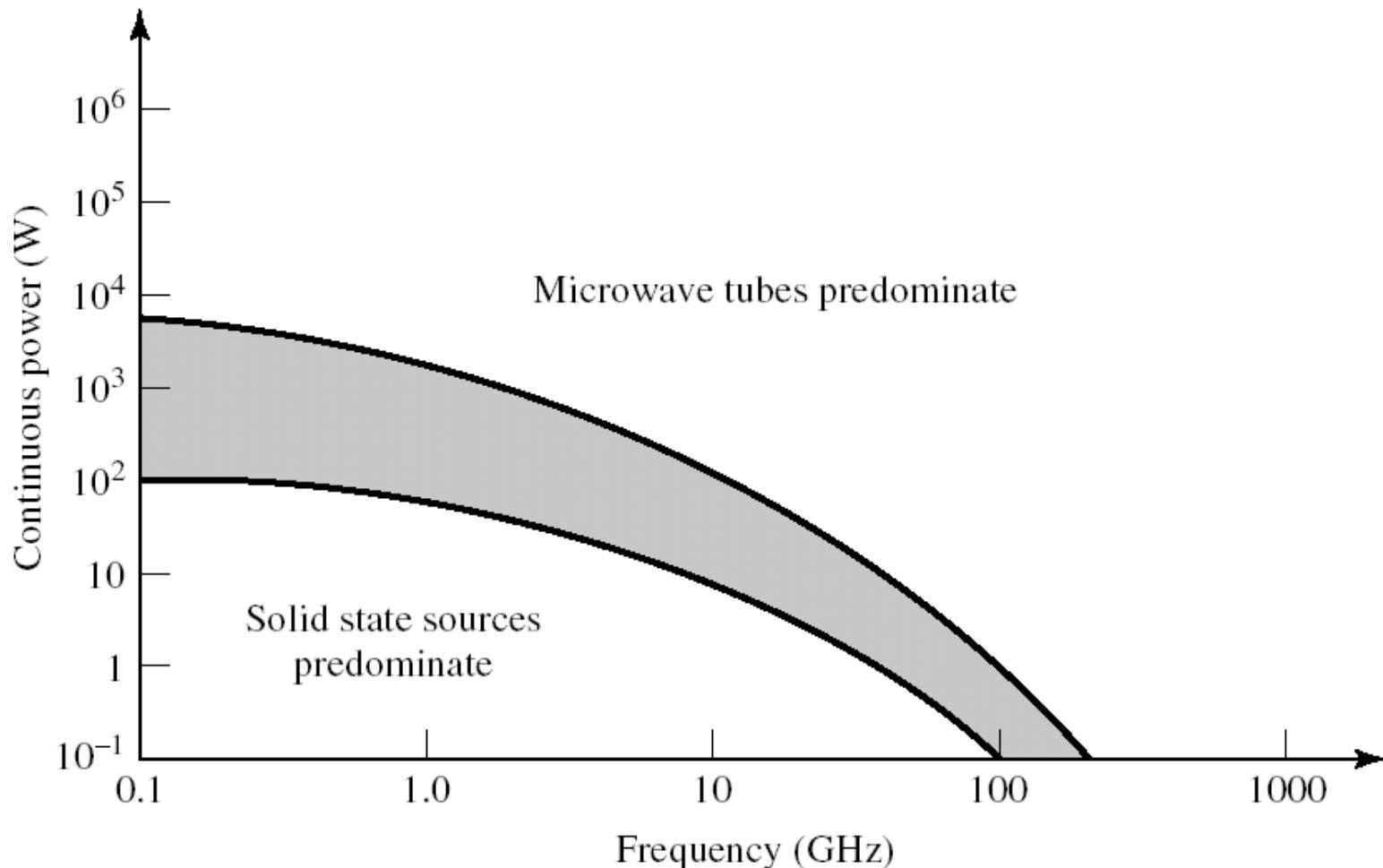


Adaptarea cu sectiuni de linie

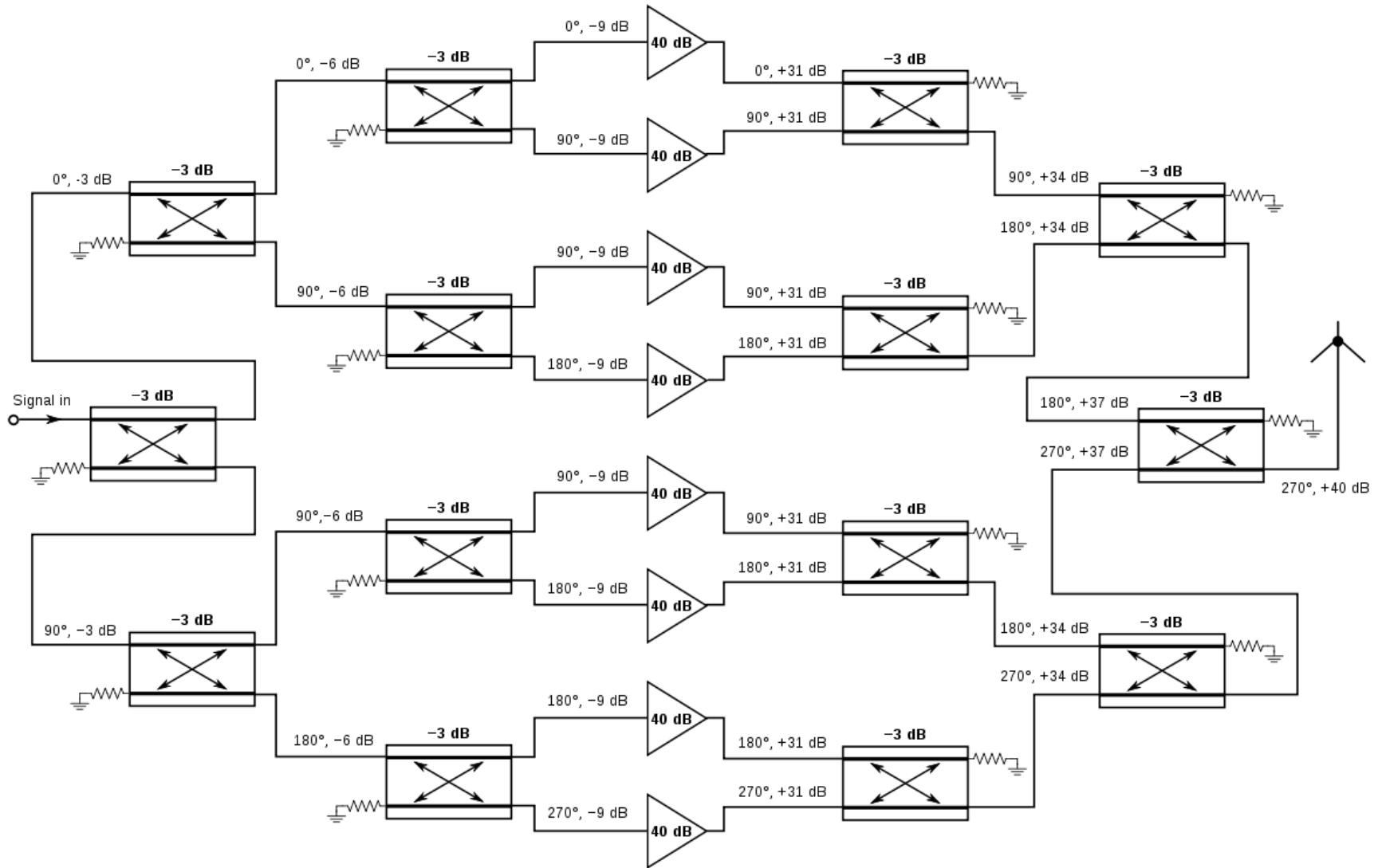


Amplificatoare de microunde

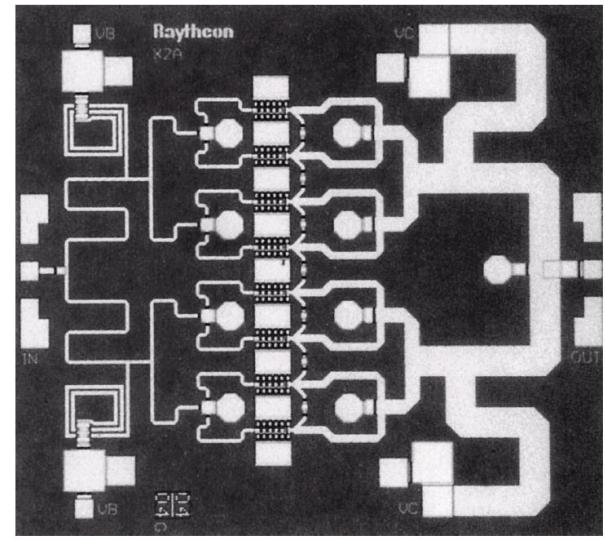
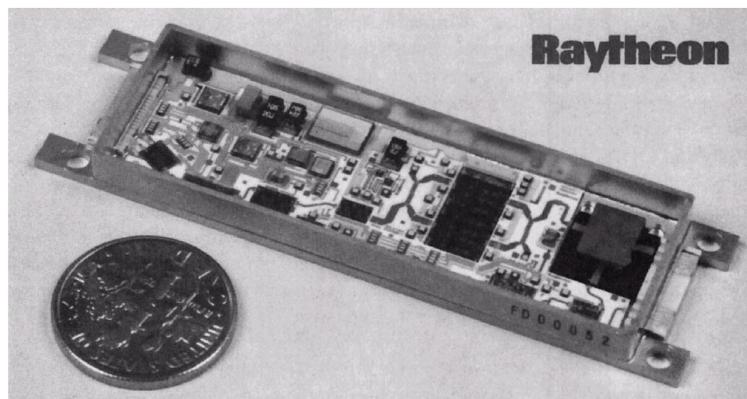
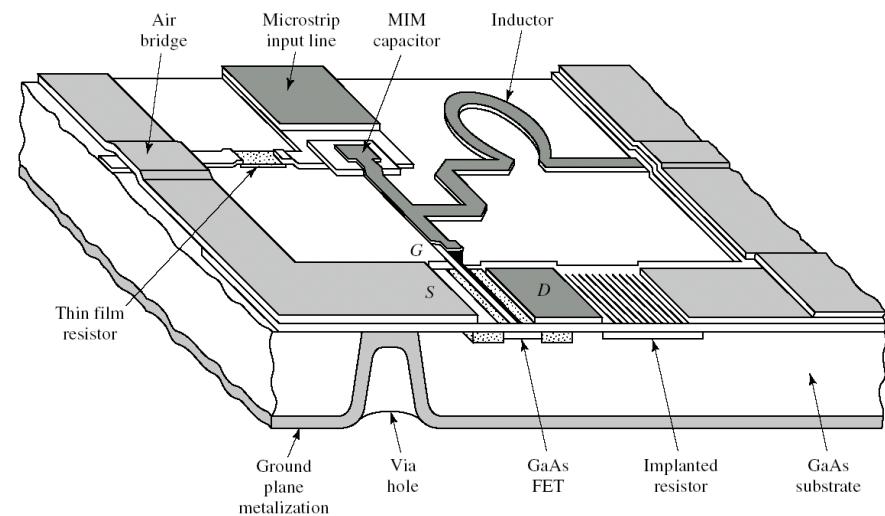
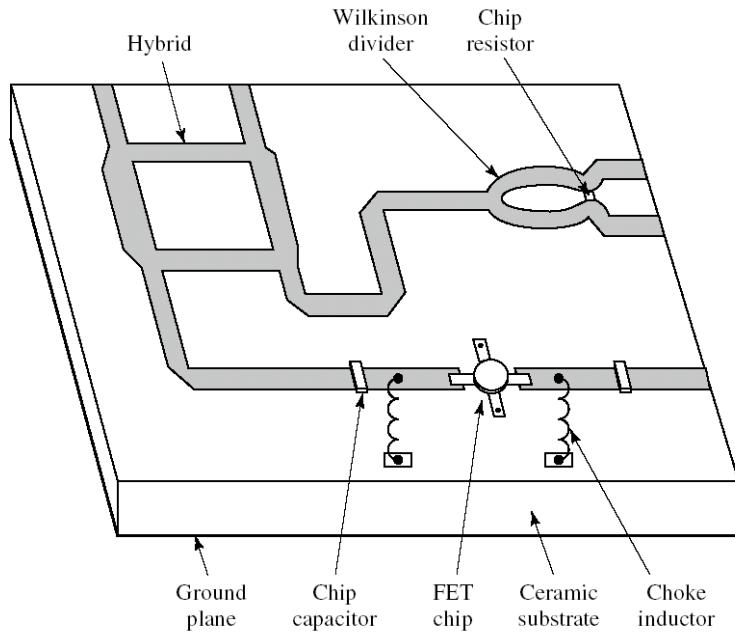
Amplificatoare pentru microunde



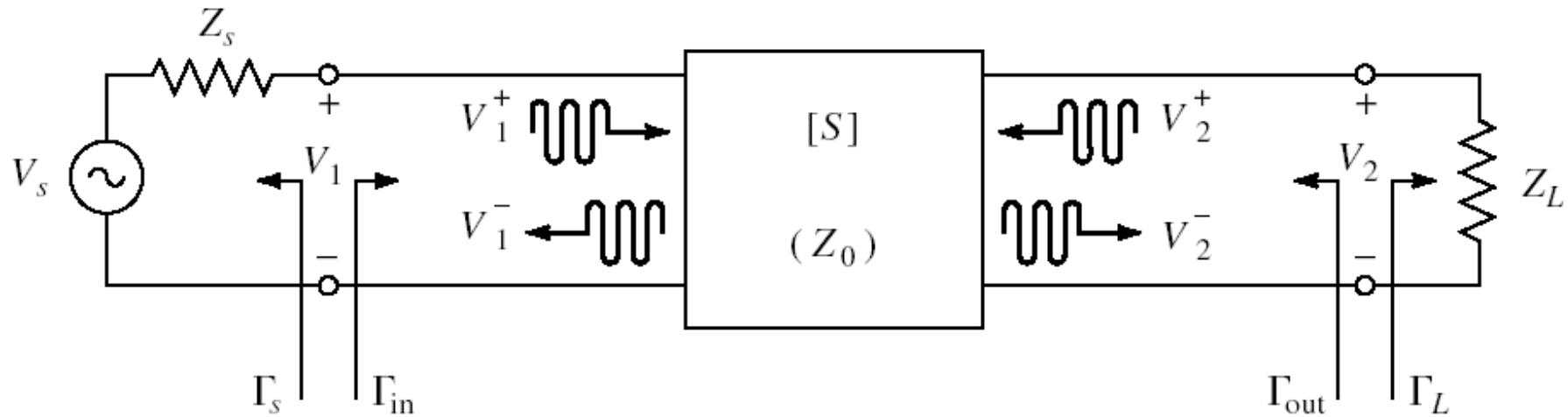
Amplificatoare echilibrate



Circuite integrate pentru microunde

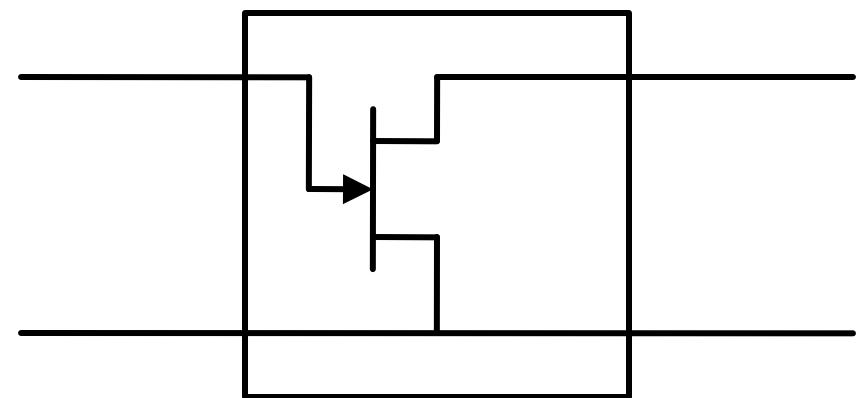
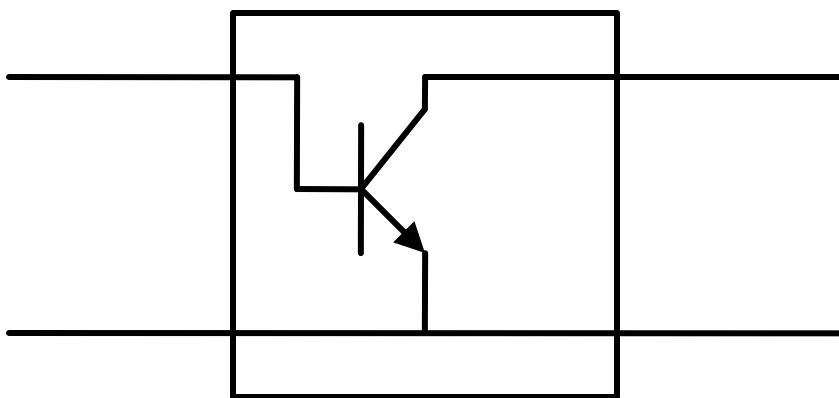
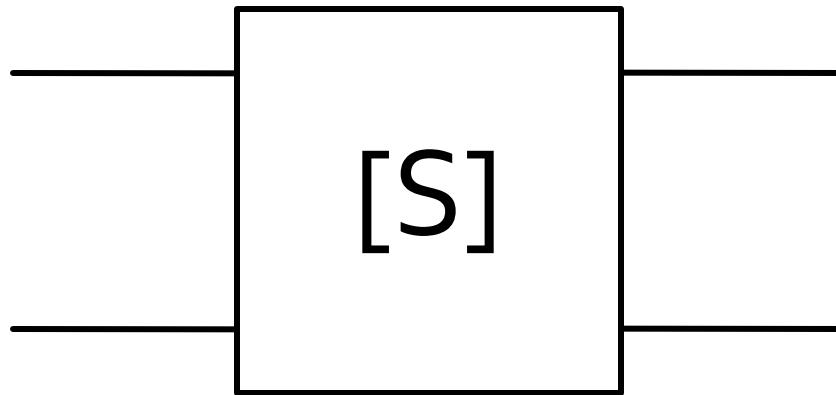


Cuadripol Amplificator (diport)



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

Parametri S



Catalogage

CEL

NE46100 / NE46134

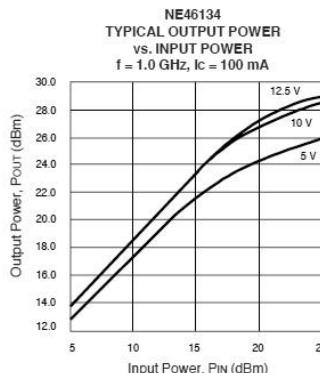
NPN MEDIUM POWER MICROWAVE TRANSISTOR

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 ³ 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 ² 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 ₁₁		S ₂₁		S ₁₂		S ₂₂		K	MAG ² (dB)
	MAG	ANG	MAG	ANG	MAG	ANG	MAG	ANG		
100	0.778	-137	26.776	114	0.028	30	0.555	-102	0.16	29.8
200	0.815	-159	14.407	100	0.035	29	0.434	-135	0.36	26.2
500	0.826	-177	5.855	84	0.040	38	0.400	-162	0.75	21.7
800	0.827	176	3.682	76	0.052	43	0.402	-169	0.91	18.5
1000	0.826	173	2.963	71	0.058	47	0.405	-172	1.02	16.3
1200	0.825	170	2.441	66	0.064	47	0.412	-174	1.08	14.0
1400	0.820	167	2.111	61	0.069	47	0.413	-176	1.17	12.4
1600	0.828	165	1.863	57	0.078	54	0.426	-177	1.15	11.4
1800	0.827	162	1.671	53	0.087	50	0.432	-178	1.14	10.6
2000	0.828	159	1.484	49	0.093	50	0.431	-180	1.17	9.5
2500	0.822	153	1.218	39	0.11	48	0.462	177	1.18	7.8
3000	0.818	148	1.010	30	0.135	46	0.490	174	1.16	6.3
3500	0.824	142	0.876	21	0.147	44	0.507	170	1.16	5.3
4000	0.812	137	0.762	13	0.168	38	0.535	167	1.14	4.3

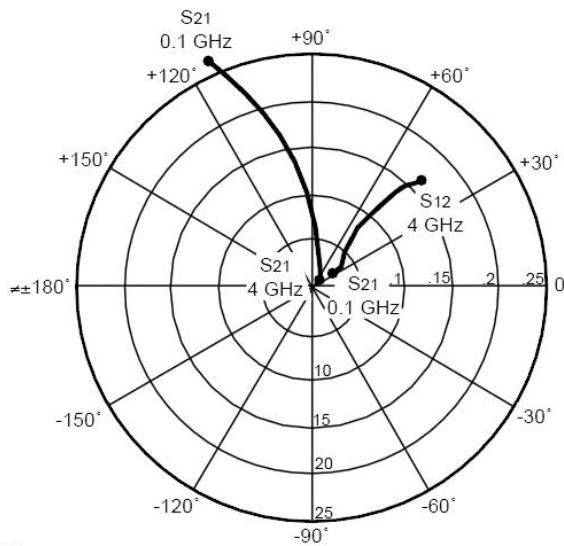
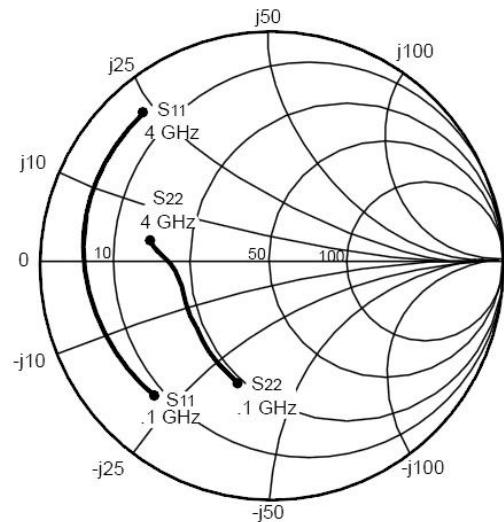
VCE = 5 V, Ic = 100 mA

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

Catalogage

NE46100, NE46134

TYPICAL COMMON EMITTER SCATTERING PARAMETERS¹ ($T_A = 25^\circ\text{C}$)



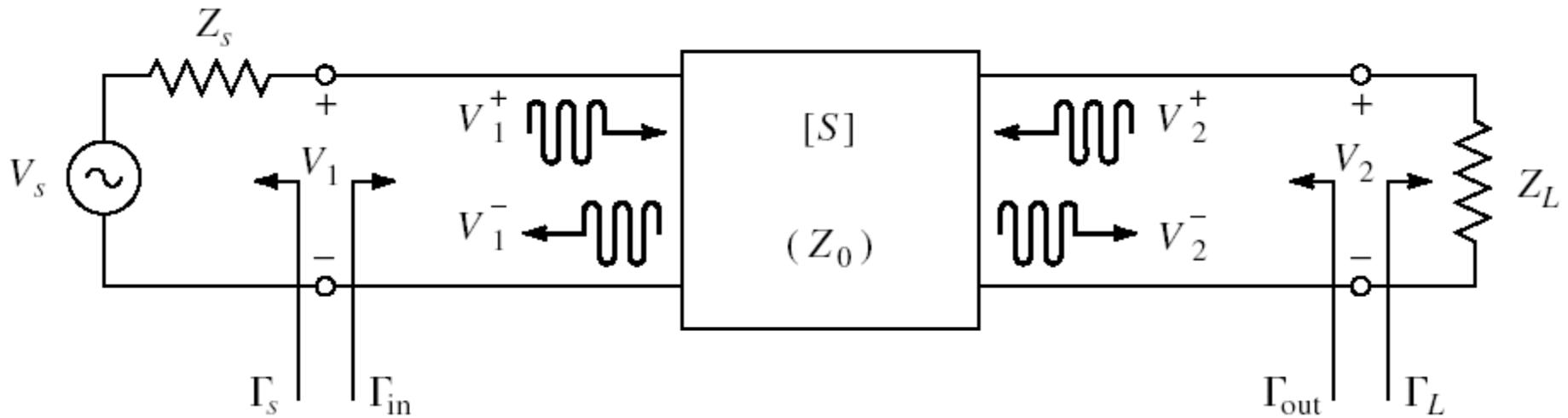
Coordinates in Ohms
Frequency in GHz
 $V_{CE} = 5 \text{ V}, I_C = 50 \text{ mA}$

S₂P - Touchstone

- Fisiere format Touchstone (*.s2p)

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

Diport amplifier



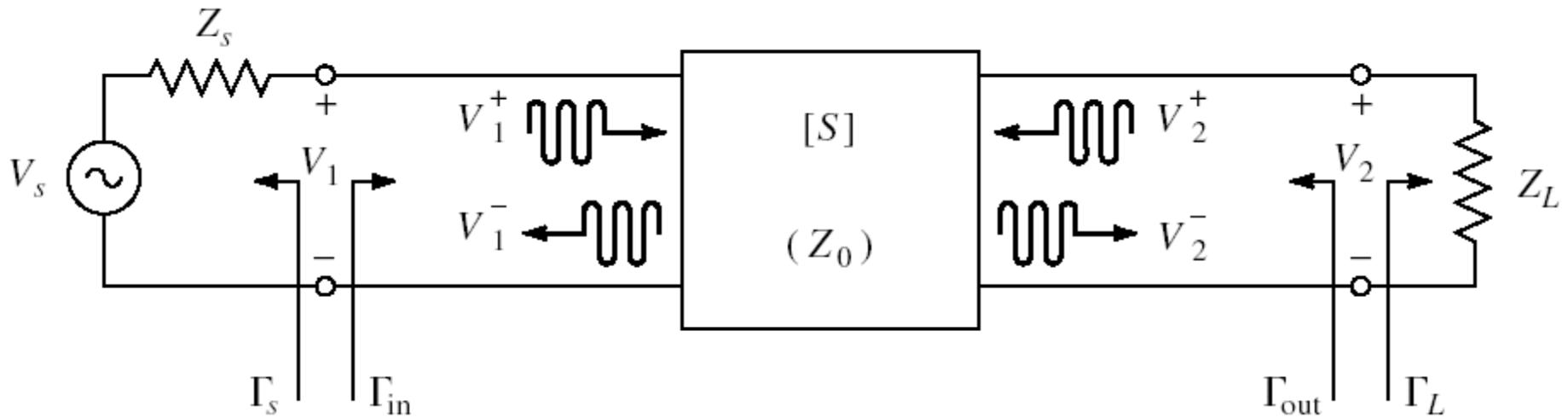
$$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0} \quad \Gamma_S = \frac{Z_S - Z_0}{Z_S + Z_0} \quad \begin{bmatrix} V_1^- \\ V_2^- \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} V_1^+ \\ V_2^+ \end{bmatrix}$$

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

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

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

Diport amplifier



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

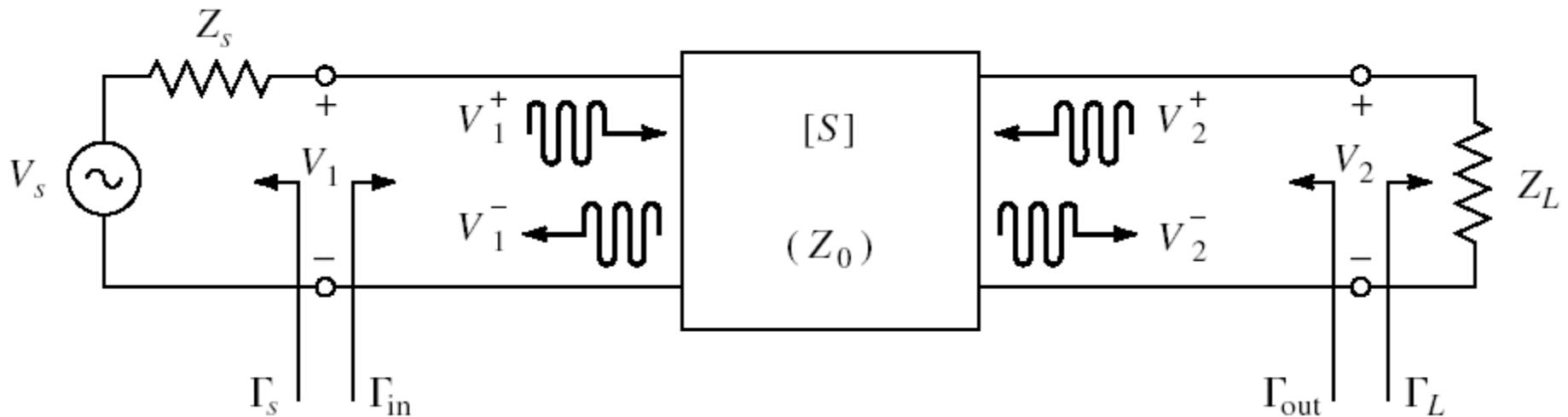
$$V_2^- = S_{21} \cdot V_1^+ + S_{22} \cdot V_2^+ = S_{21} \cdot V_1^+ + S_{22} \cdot \Gamma_L \cdot V_2^-$$

■ similar

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

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

Dipole amplifier

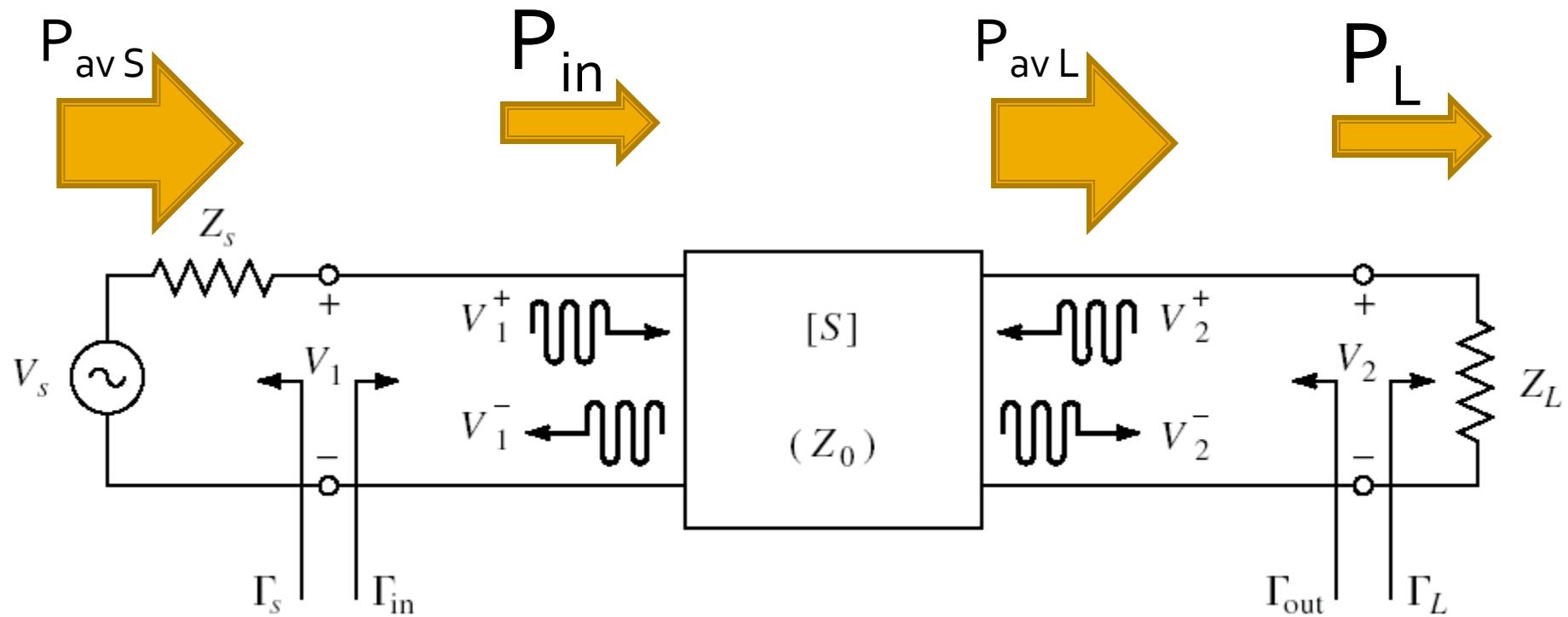


$$\Gamma_{in} = \frac{V_1^-}{V_1^+} = S_{11} + \frac{S_{12} \cdot S_{21} \cdot \Gamma_L}{1 - S_{22} \cdot \Gamma_L}$$

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

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

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

■ 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**

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

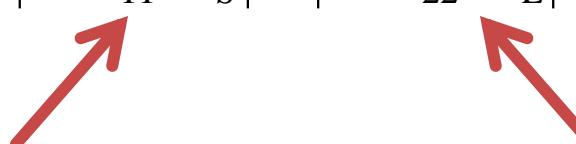
■ Castigul de putere de **transfer** (transducer power gain)

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

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

■ Castigul de putere de **transfer unilateral**

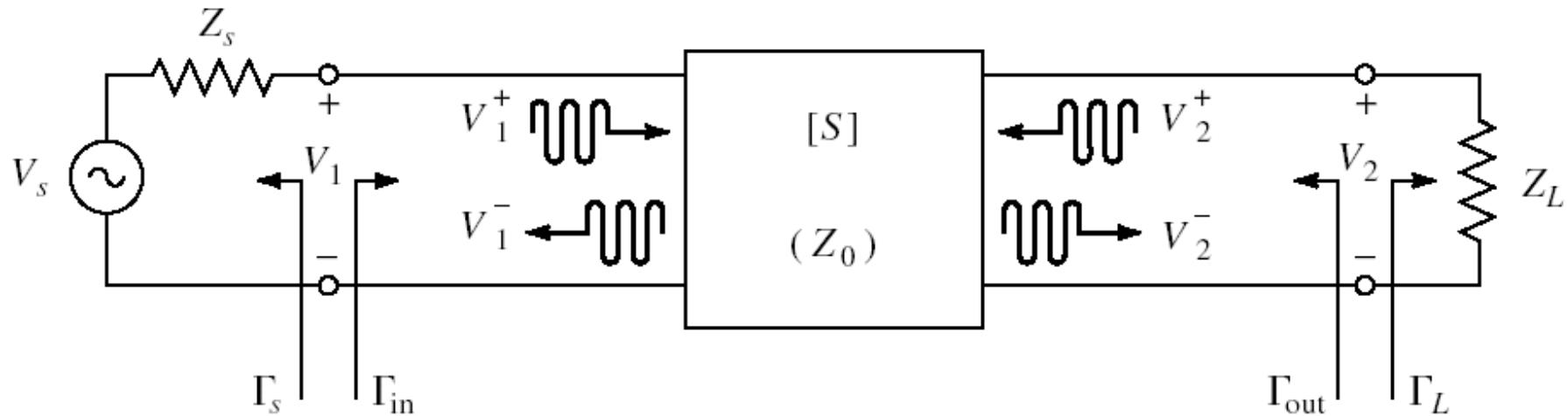
$$G_{TU} = |S_{21}|^2 \cdot \frac{1 - |\Gamma_S|^2}{|1 - S_{11} \cdot \Gamma_S|^2} \cdot \frac{1 - |\Gamma_L|^2}{|1 - S_{22} \cdot \Gamma_L|^2}$$



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

Permite tratarea separata
a intrarii si iesirii

Cuadripol Amplifier

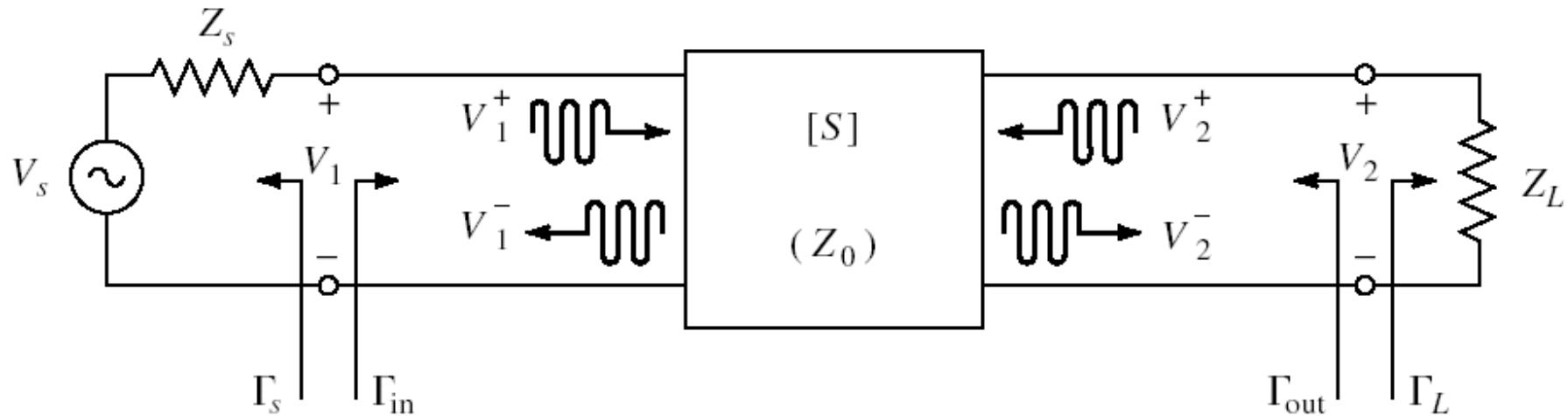


- marimi care intereseaza:
 - stabilitate
 - castig de putere
 - zgomot (uneori – semnal mic)
 - liniaritate (uneori – semnal mare)

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
 $\operatorname{Re}\{Z_{in}\} < 0 \Leftrightarrow 1 - \Gamma_r^2 - \Gamma_i^2 < 0 \quad |\Gamma_{in}| > 1$
- stabilitate, Z_{in}
 - conditii ce trebuie indeplinite de Γ_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 Γ_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 Γ_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 Γ_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

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

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

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

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

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

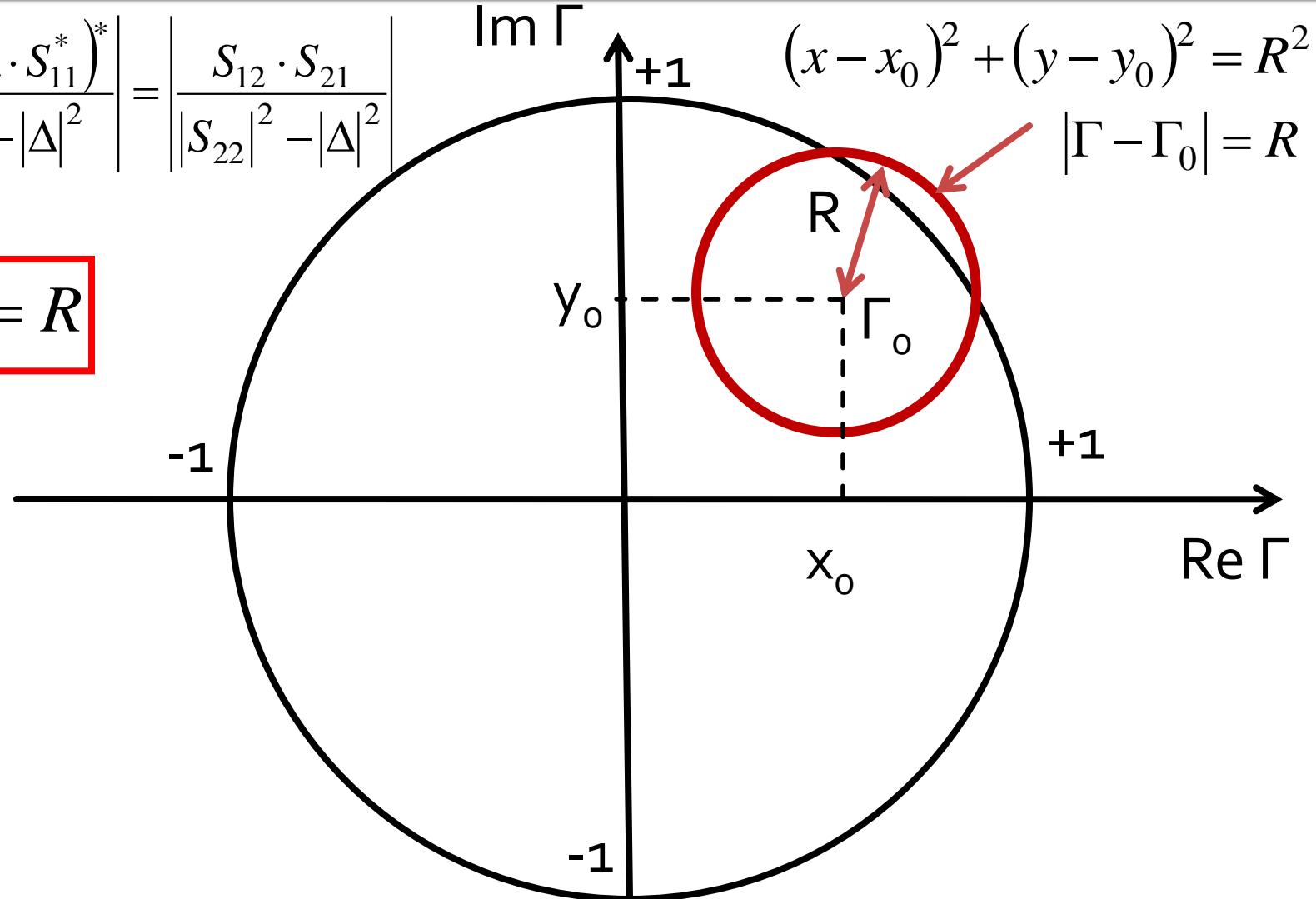
$$\frac{\Gamma_L \cdot \Gamma_L^* - (S_{22} - \Delta \cdot S_{11}^*) \cdot \Gamma_L + (S_{22}^* - \Delta^* \cdot S_{11}) \cdot \Gamma_L^*}{|S_{22}|^2 - |\Delta|^2} = \frac{|S_{11}|^2 - 1}{|S_{22}|^2 - |\Delta|^2} + \frac{|S_{22} - \Delta \cdot S_{11}^*|^2}{(|S_{22}|^2 - |\Delta|^2)^2}$$

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

Stabilitate

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

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



Cerc de stabilitate la ieșire (CSOUT)

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

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

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

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 Γ_S pentru **limita** de stabilitate
- Cercul se numeste **cerc de stabilitate la intrare** (Γ_S)

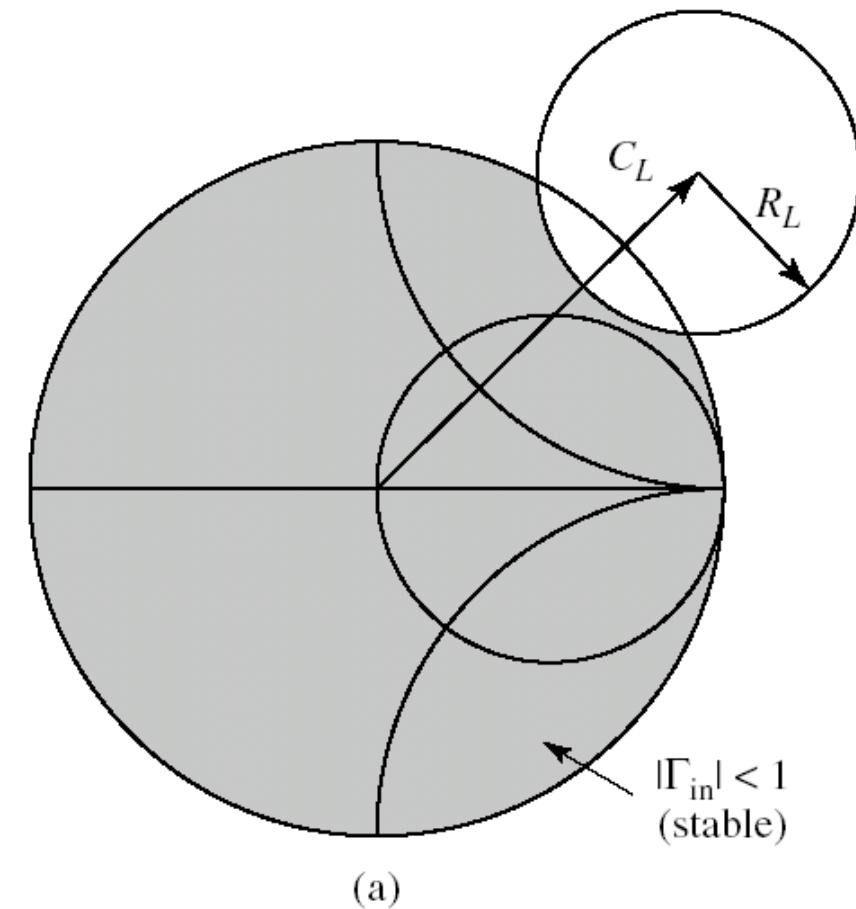
$$C_S = \frac{(S_{11} - \Delta \cdot S_{22}^*)^*}{|S_{11}|^2 - |\Delta|^2}$$

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

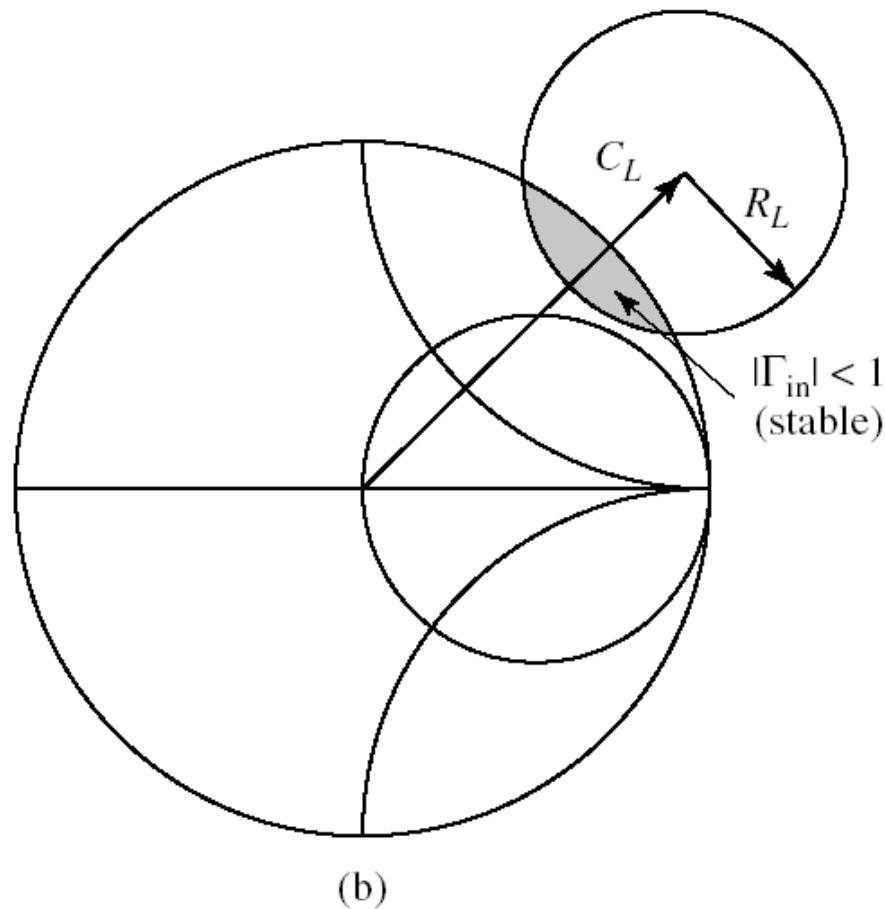
Cerc de stabilitate la ieșire (CSOUT)

- **Cercul de stabilitate la ieșire** reprezinta locul geometric al punctelor Γ_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 Γ_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 Γ_L este punct **stabil**, se gaseste in zona stabila (cel mai des)
 - $|S_{11}| > 1 \rightarrow$ centrul diagramei pe care se reprezinta Γ_L este punct **instabil**, se gaseste in zona instabila
- Cerc de stabilitate la intrare
 - $|S_{22}| < 1 \rightarrow$ centrul diagramei pe care se reprezinta Γ_S este punct **stabil**, se gaseste in zona stabila (cel mai des)
 - $|S_{22}| > 1 \rightarrow$ centrul diagramei pe care se reprezinta Γ_S este punct **instabil**, se gaseste in zona instabila

Exemplu

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

- @5GHz

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

$$\begin{cases} S_{11} = 0.64 \angle 139^\circ \\ S_{11} = 0.64 \cdot \cos 139^\circ + j \cdot 0.64 \cdot \sin 139^\circ \end{cases}$$

```
!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
```

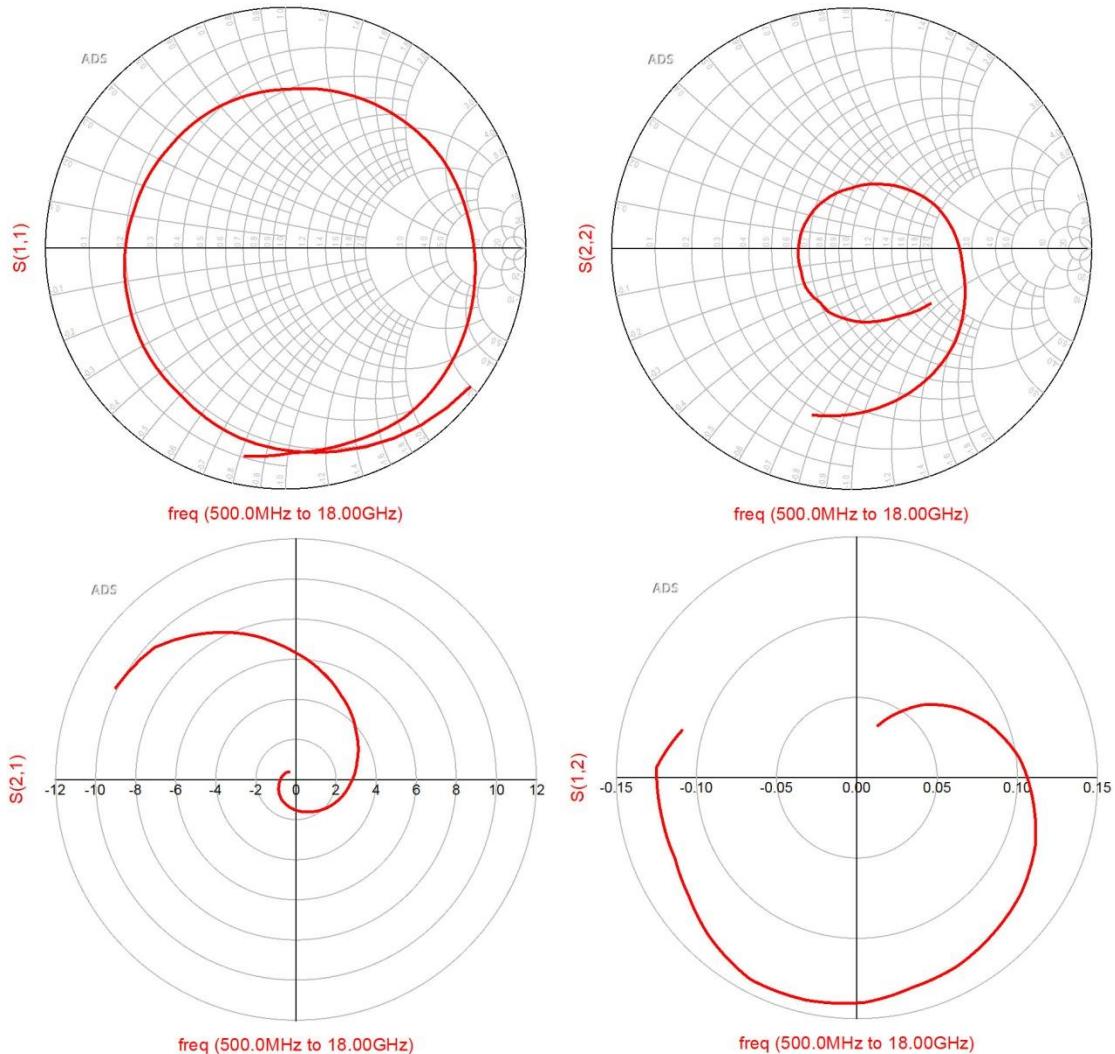
```
!FREQ Fopt GAMMA OPT RN/Zo
!GHZ dB MAG ANG -
```

```
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
 - $S_{11} = -0.483 + 0.42 \cdot j$
 - $S_{12} = 0.111 - 0.043 \cdot j$
 - $S_{21} = 3.042 + 0.872 \cdot j$
 - $S_{22} = -0.182 + 0.123 \cdot j$
- $|S_{11}| = 0.64 < 1$
- $|C_L| < R_L \quad o \in CSOUT$
- 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
 - $S_{11} = -0.483 + 0.42 \cdot j$
 - $S_{12} = 0.111 - 0.043 \cdot j$
 - $S_{21} = 3.042 + 0.872 \cdot j$
 - $S_{22} = -0.182 + 0.123 \cdot j$
- $|S_{22}| = 0.22 < 1$
- $|C_S| > R_S \quad o \notin CSIN$
- Centrul diagramei Smith este in exteriorul cercului de stabilitate ($o \notin CSIN$) si apartine zonei stabile
 - exterior cerc – stabil
 - interior cerc – instabil

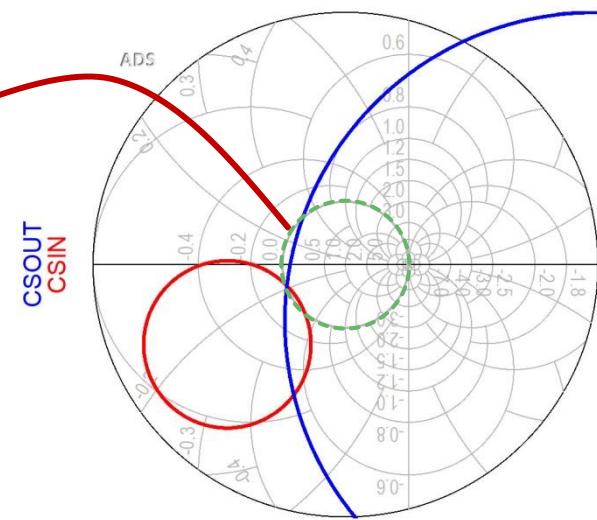
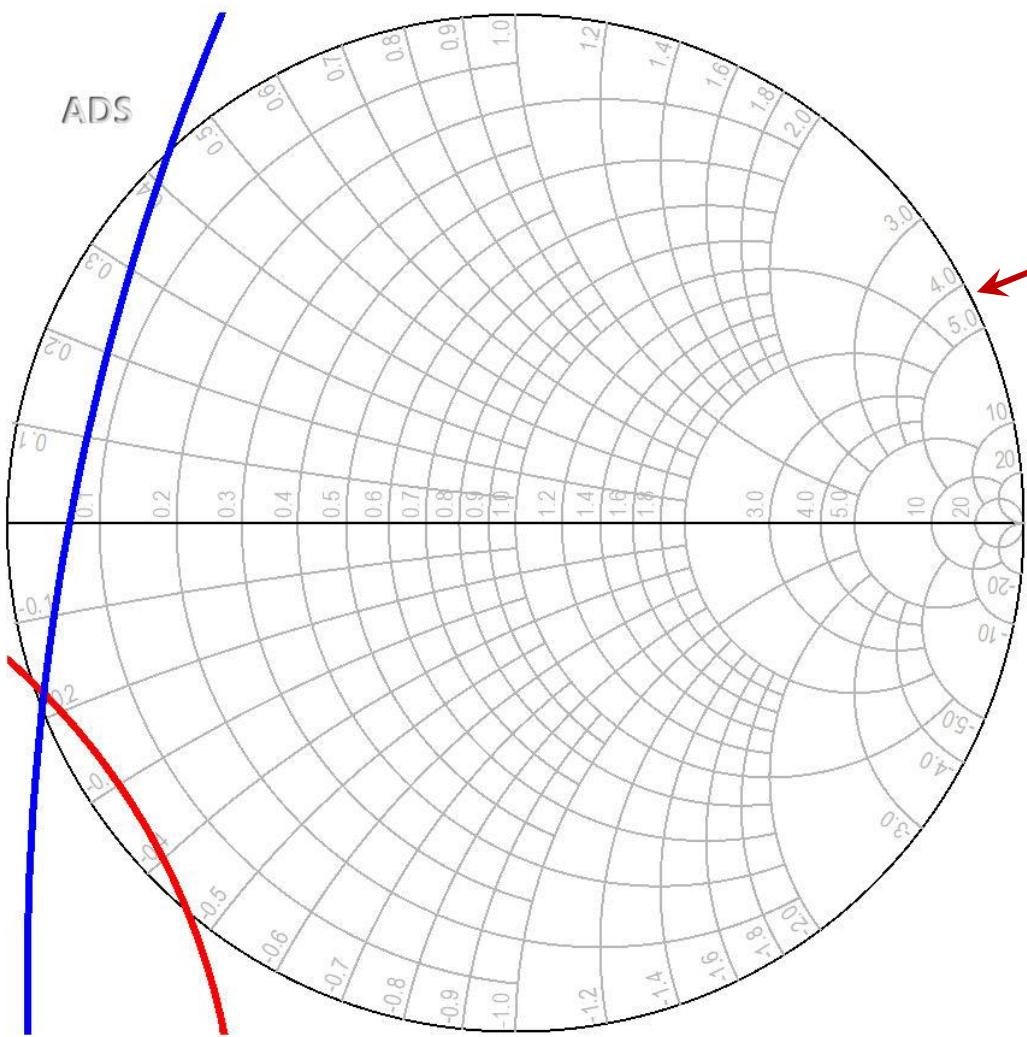
$$C_S = \frac{(S_{11} - \Delta \cdot S_{22}^*)^*}{|S_{11}|^2 - |\Delta|^2} = -1.871 - 1.265 \cdot j$$

$$|C_S| = 2.259$$

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

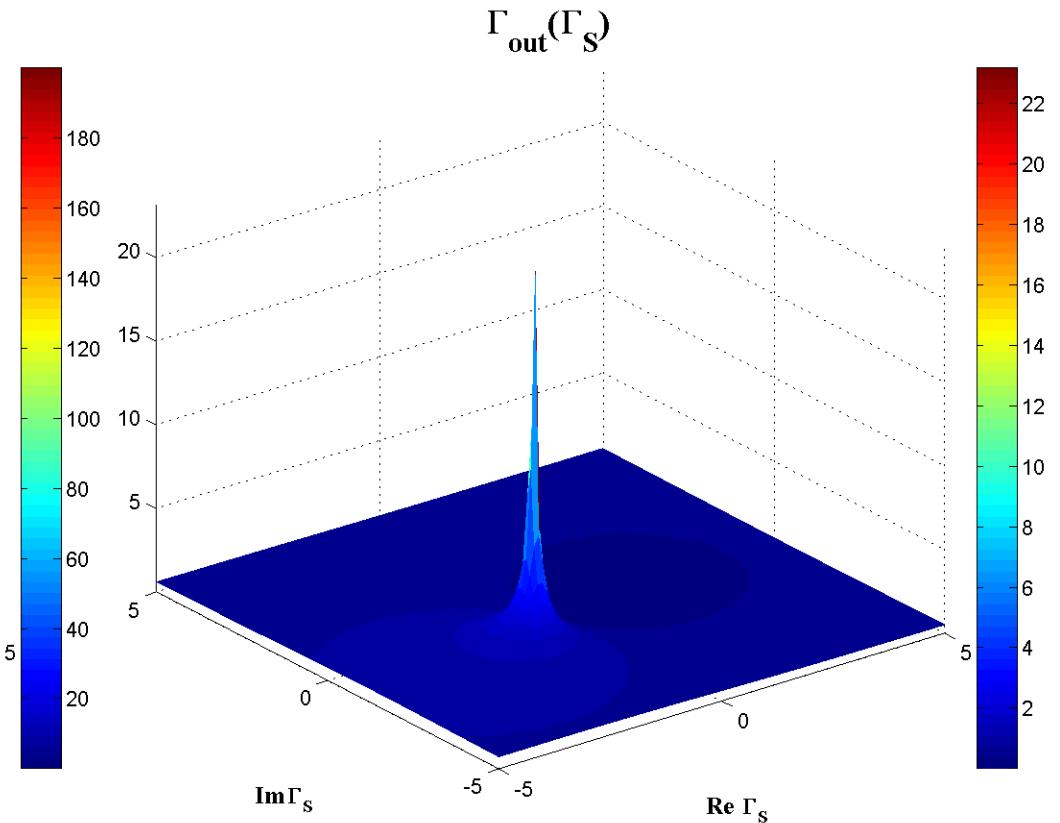
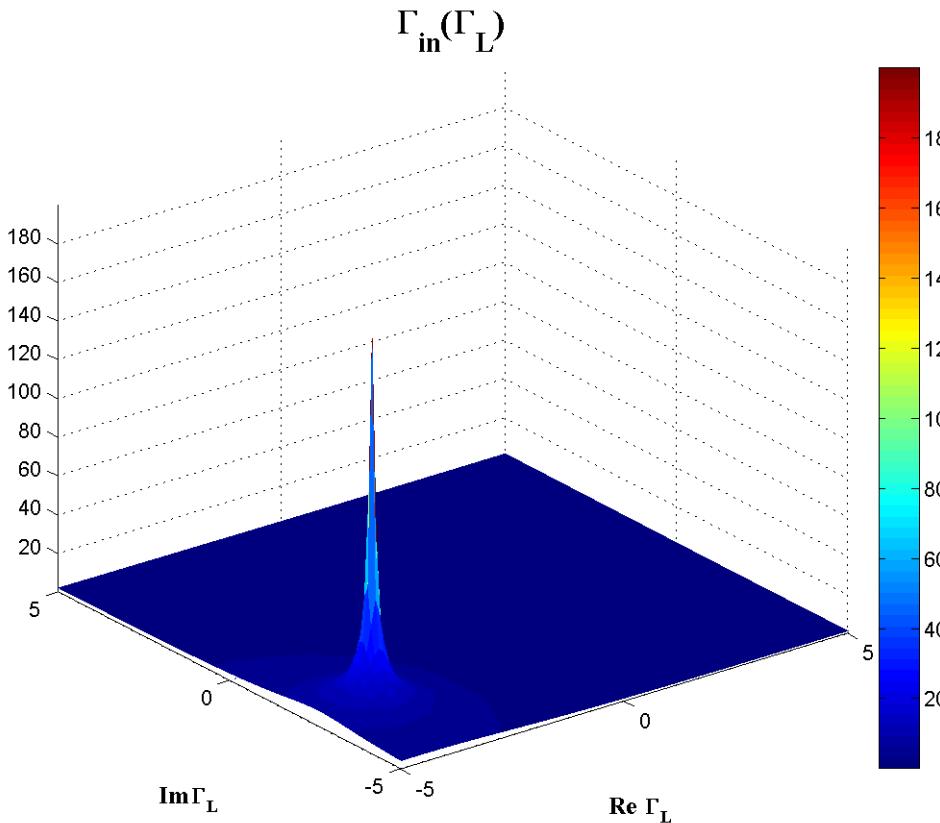
ADS

CSOUT
CSIN



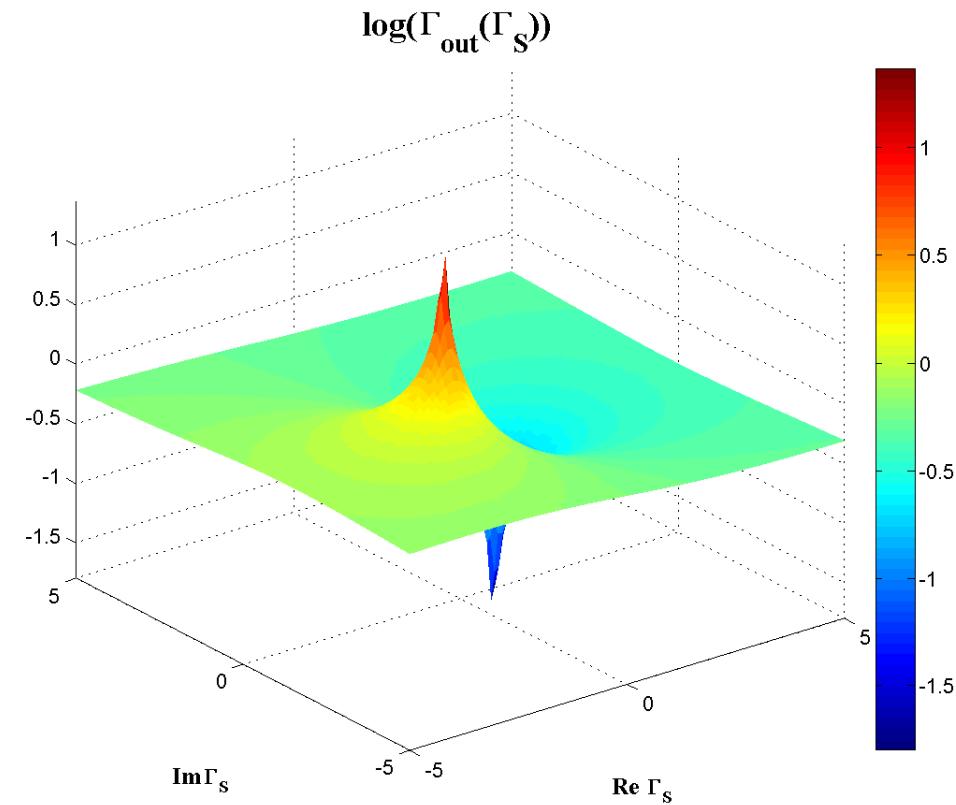
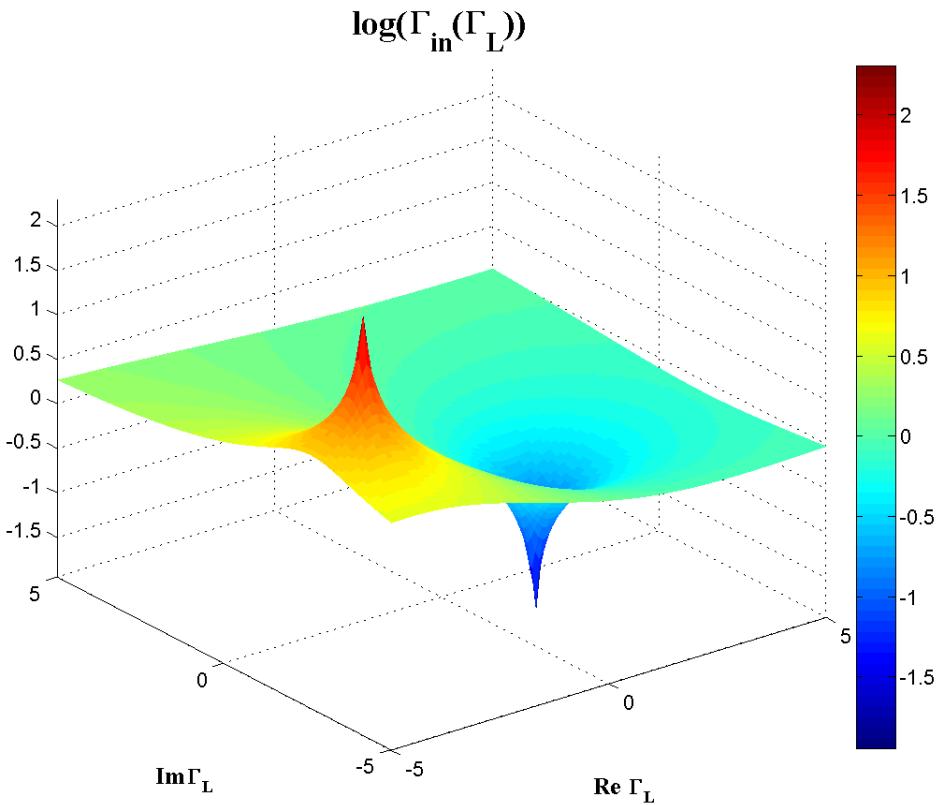
Reprezentare 3D $|\Gamma_{\text{in}}|, |\Gamma_{\text{out}}|$

- Variatii foarte mari \rightarrow logaritmic



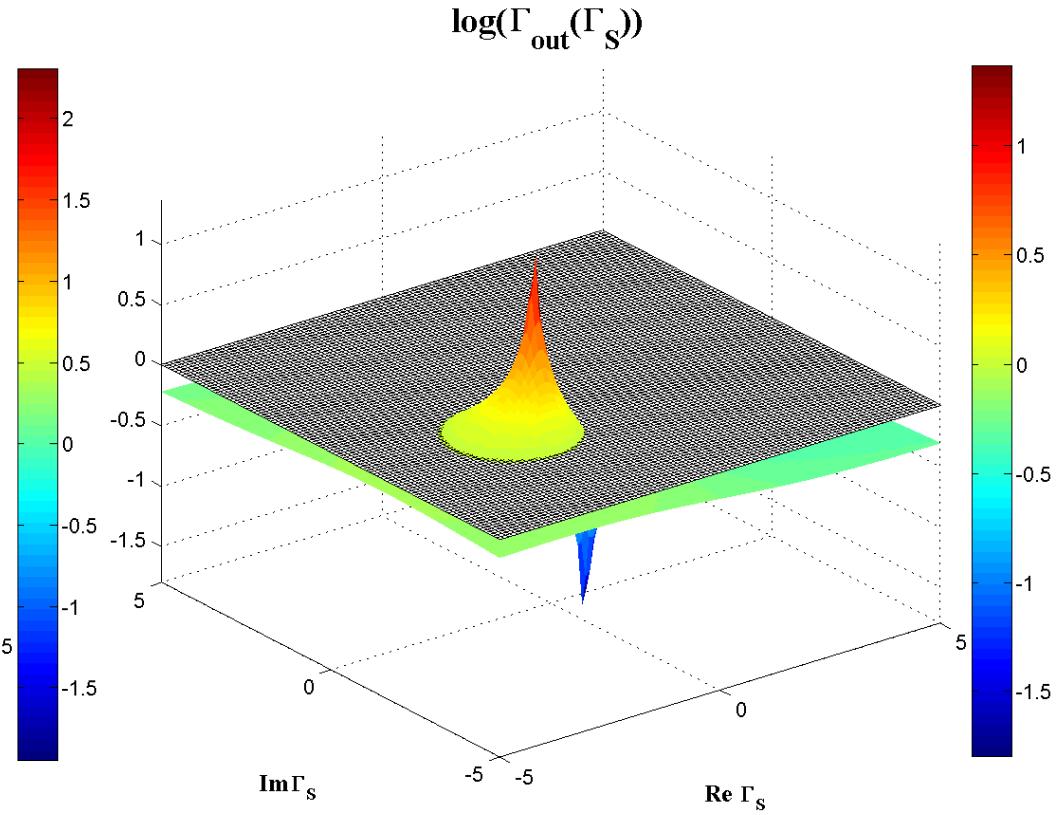
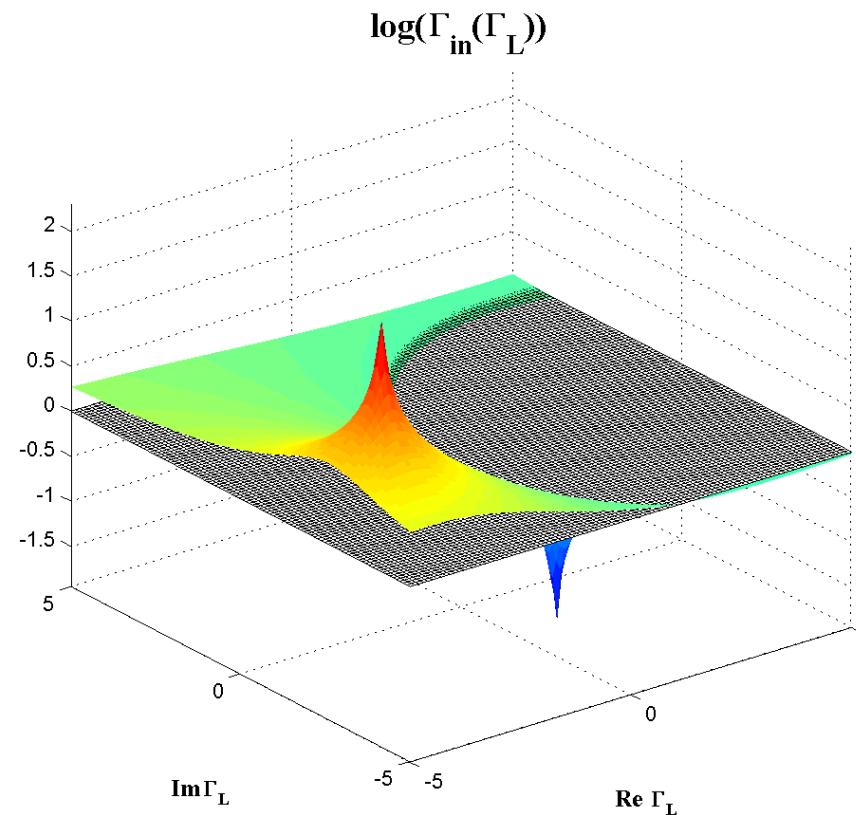
Reprezentare 3D $|\Gamma_{\text{in}}|, |\Gamma_{\text{out}}|$

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

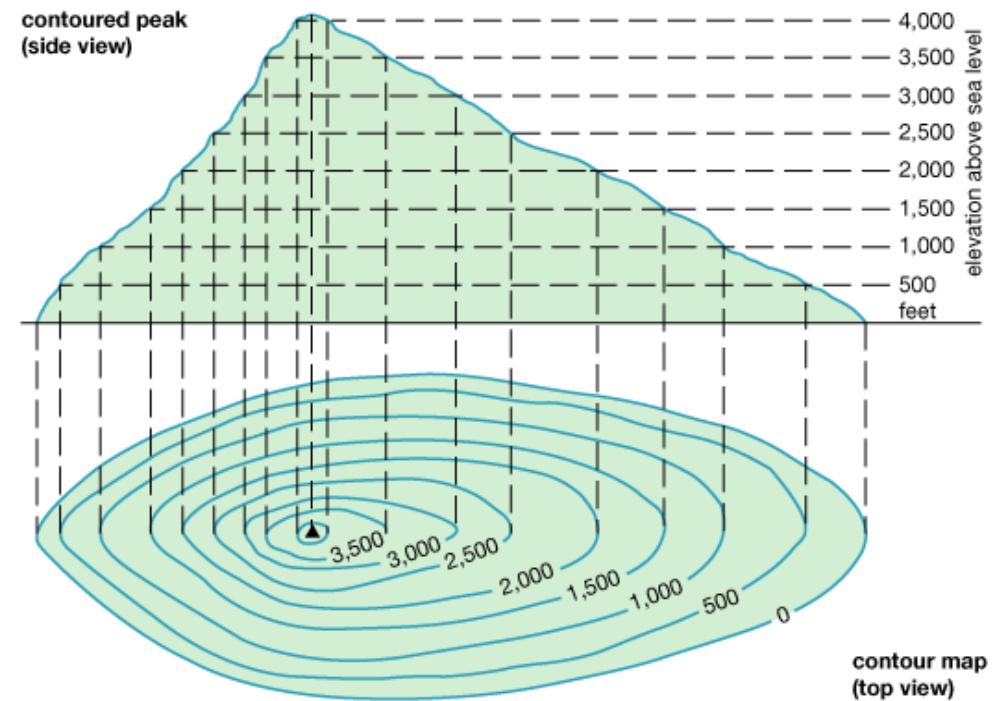


Reprezentare 3D $|\Gamma_{\text{in}}|, |\Gamma_{\text{out}}|, |\Gamma|=1$

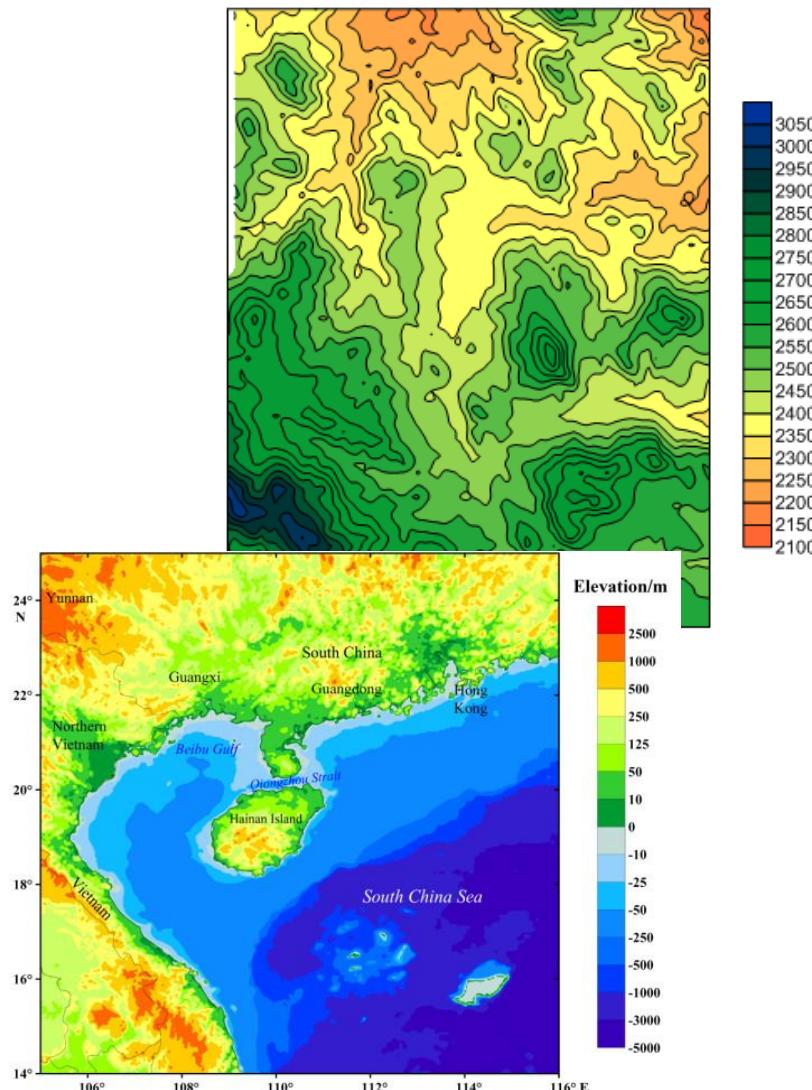
- $|\Gamma| = 1 \rightarrow \log_{10}|\Gamma| = 0$, intersectia = cerc



Contour map/lines

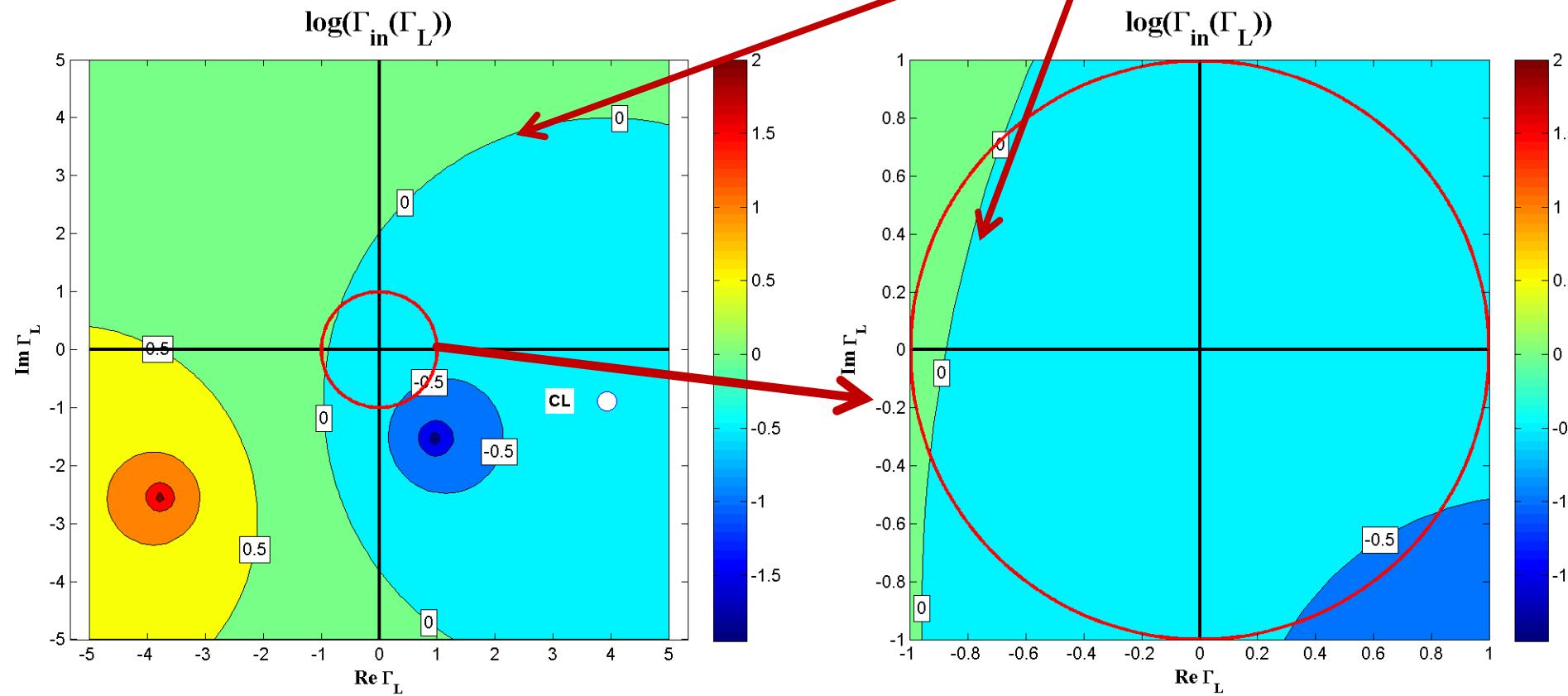


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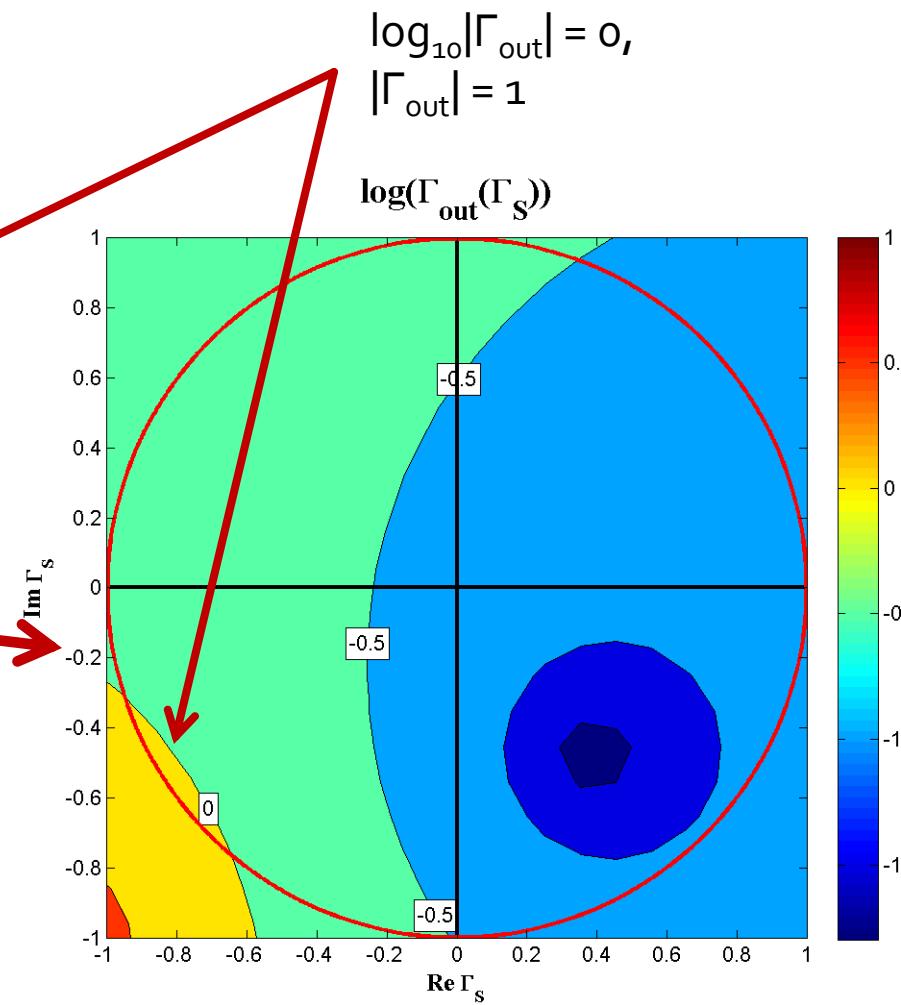
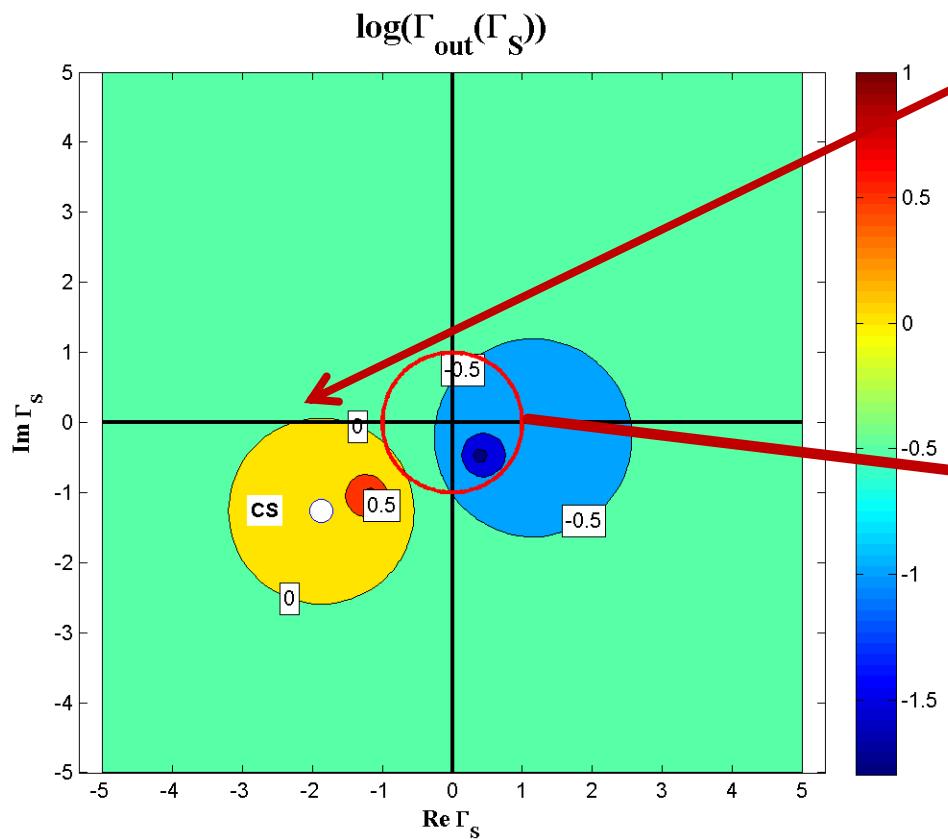
Reprezentare 3D $|\Gamma_{\text{in}}|, |\Gamma_{\text{out}}|$

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



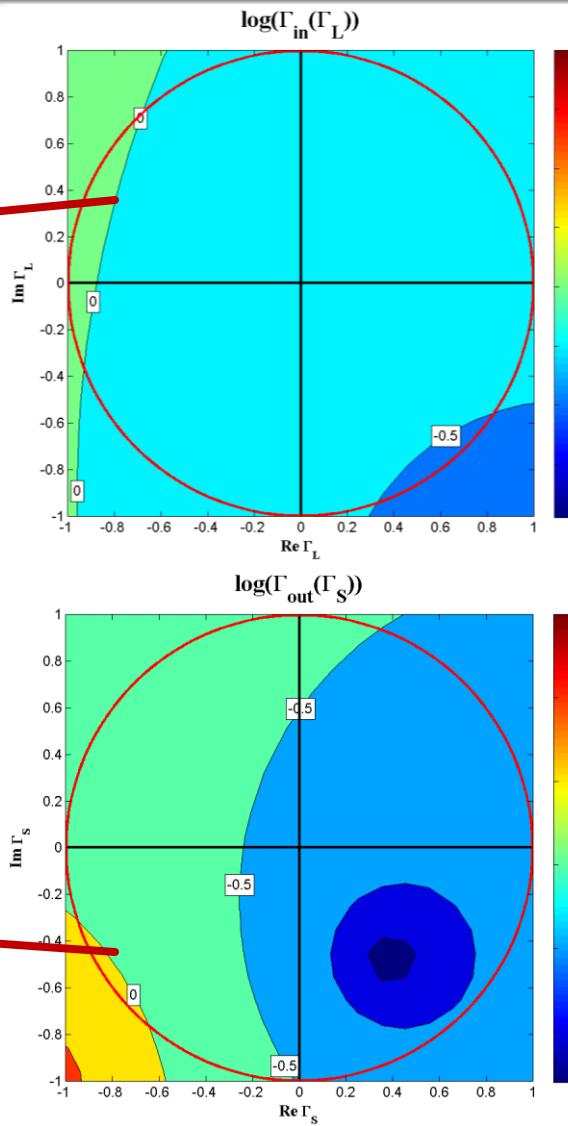
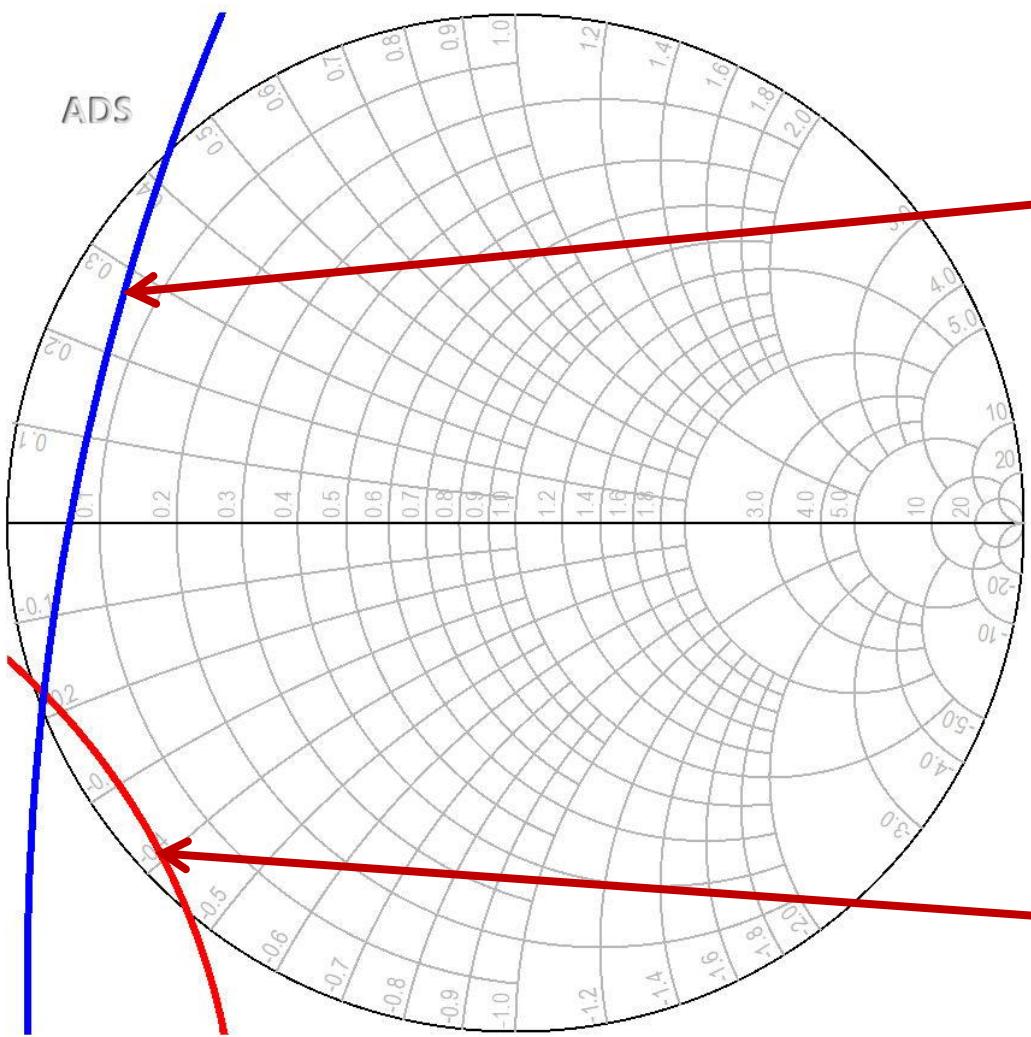
Reprezentare 3D $|\Gamma_{\text{in}}|, |\Gamma_{\text{out}}|$

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

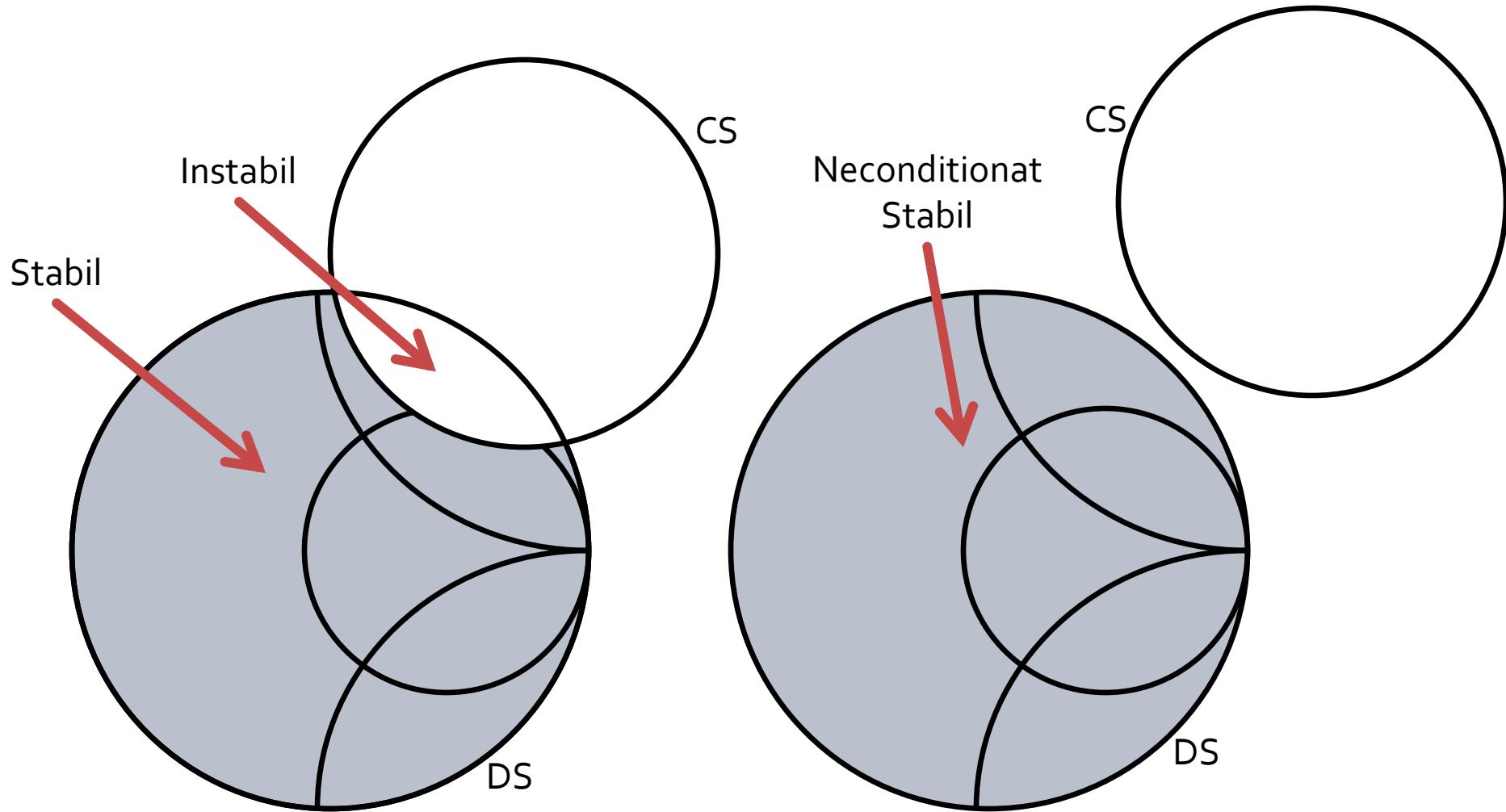


CSIN, CSOUT

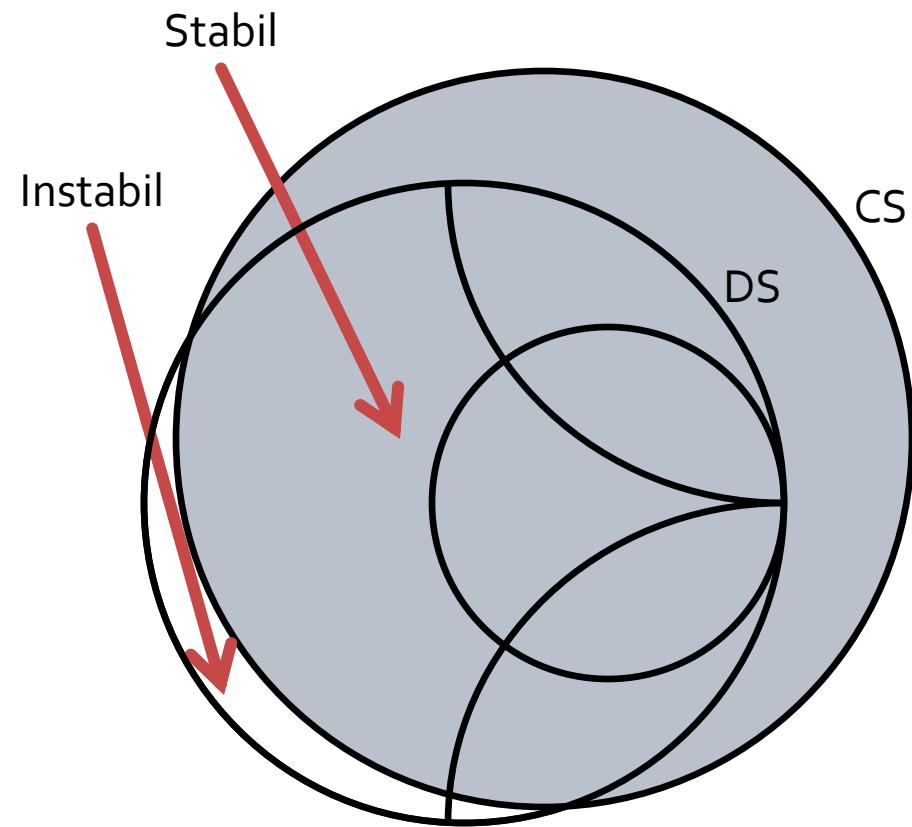
CSOUT
CSIN



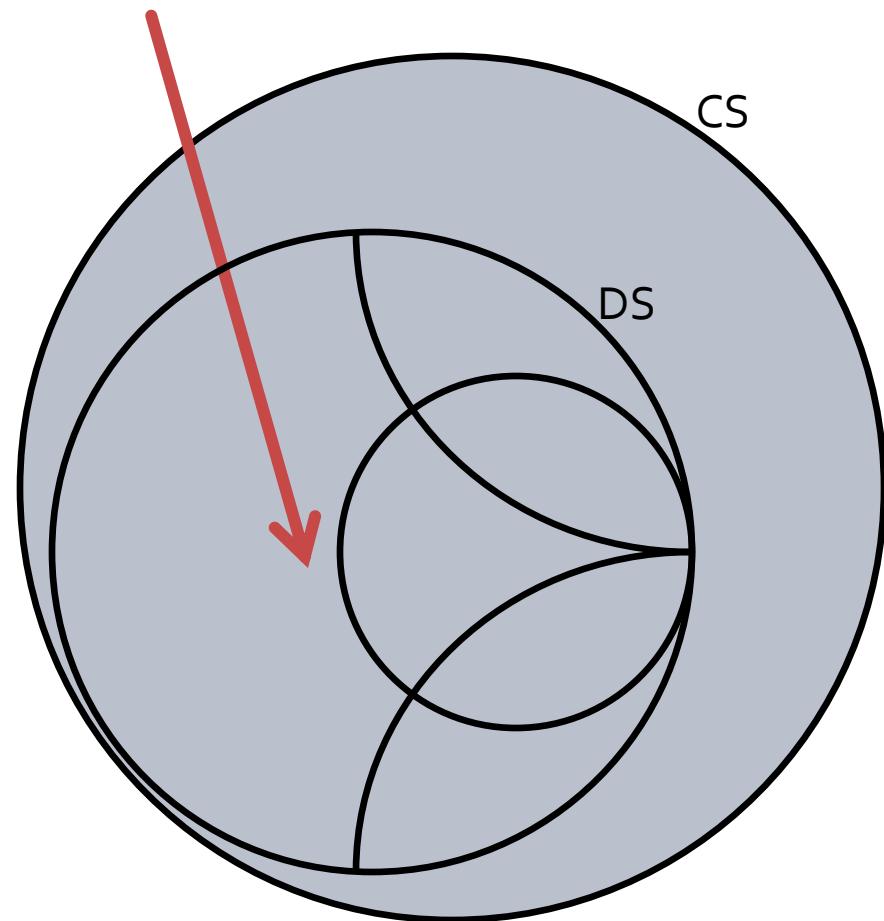
Mai multe pozitionari posibile



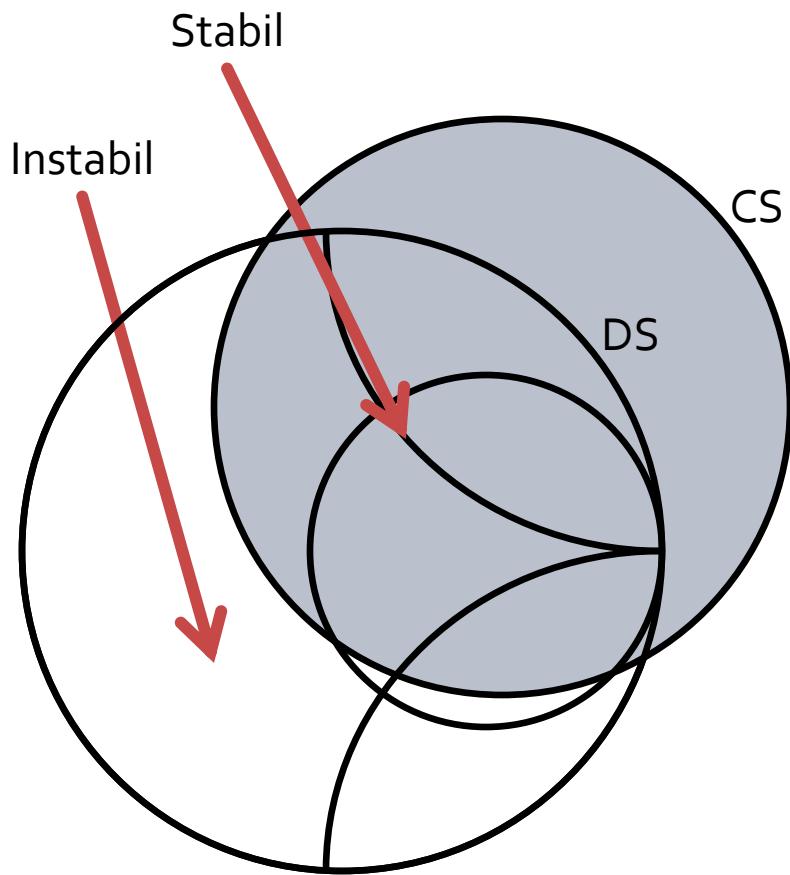
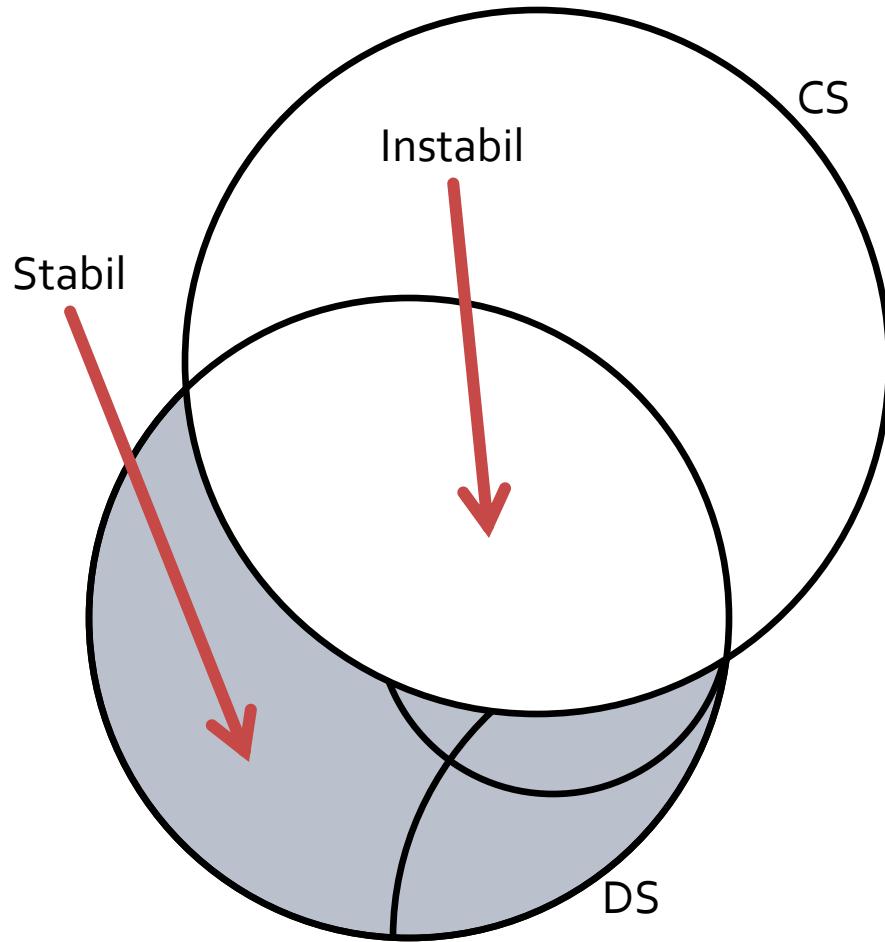
Mai multe pozitionari posibile



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:

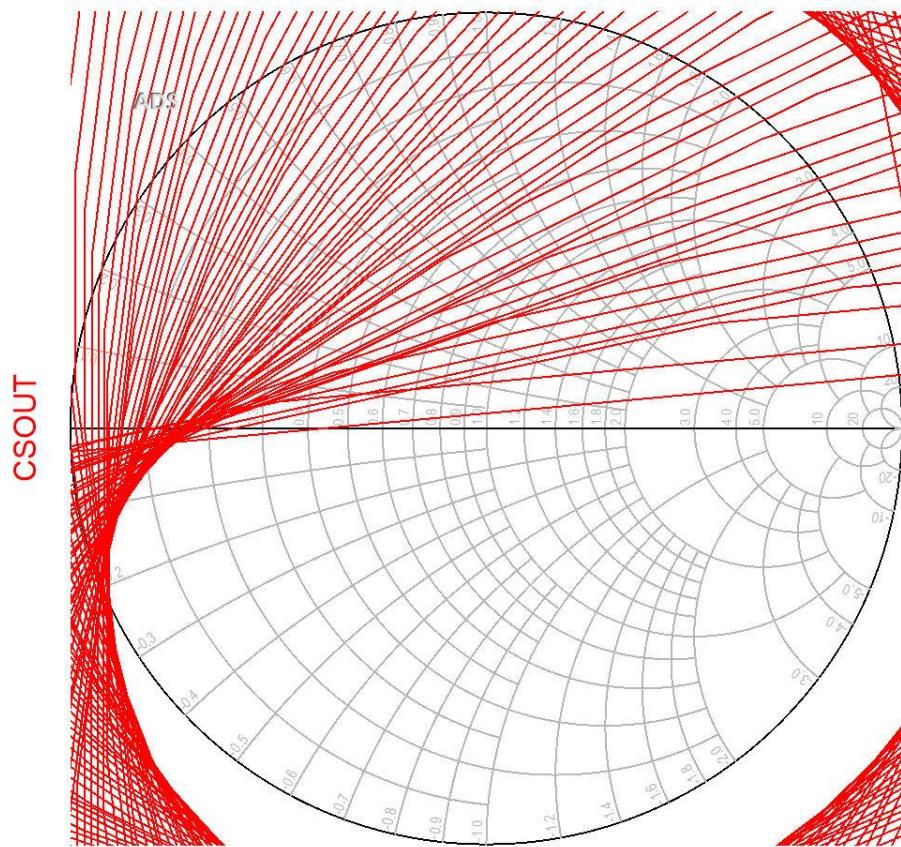
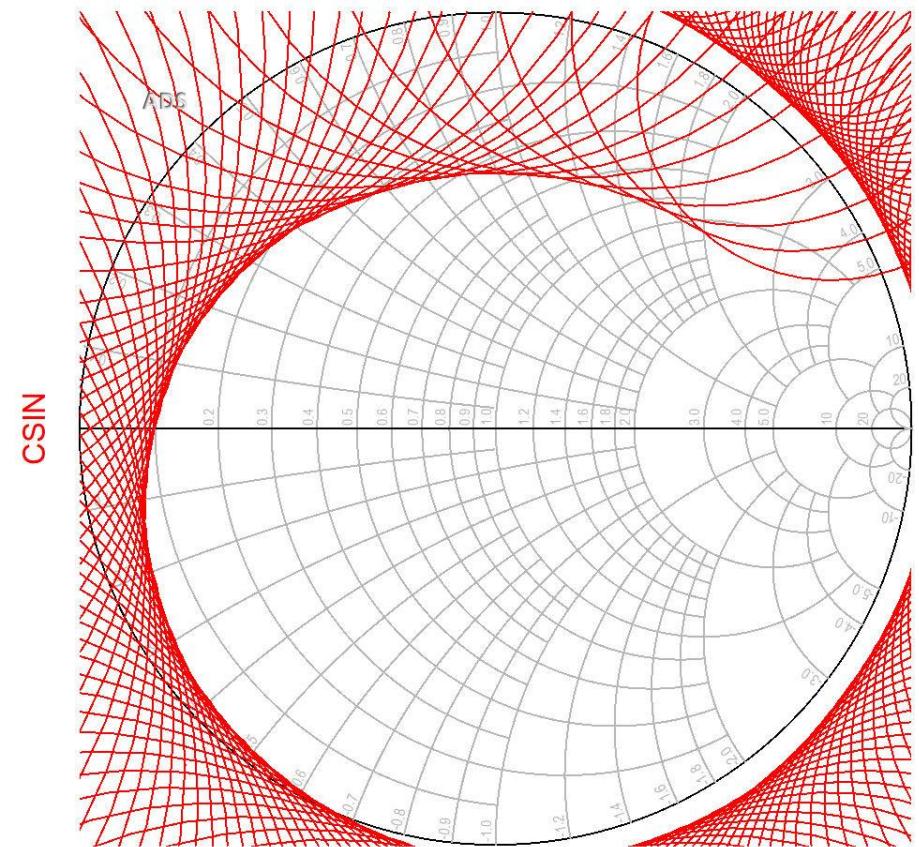
$$\begin{cases} |C_L - R_L| > 1 \\ |S_{11}| < 1 \end{cases}$$

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

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 Γ_L si Γ_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 μ

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

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

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

Criteriul μ'

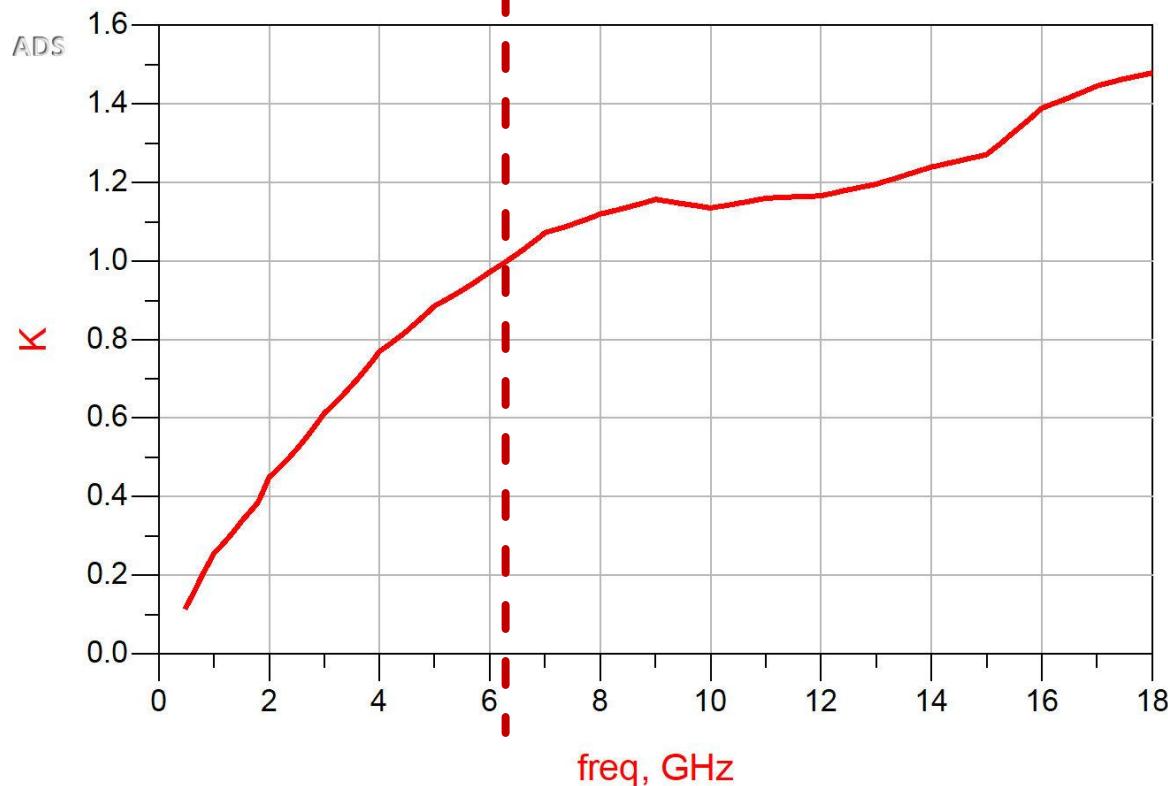
- Parametru dual pentru μ , determinat relativ la cercul de stabilitate la intrare

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

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

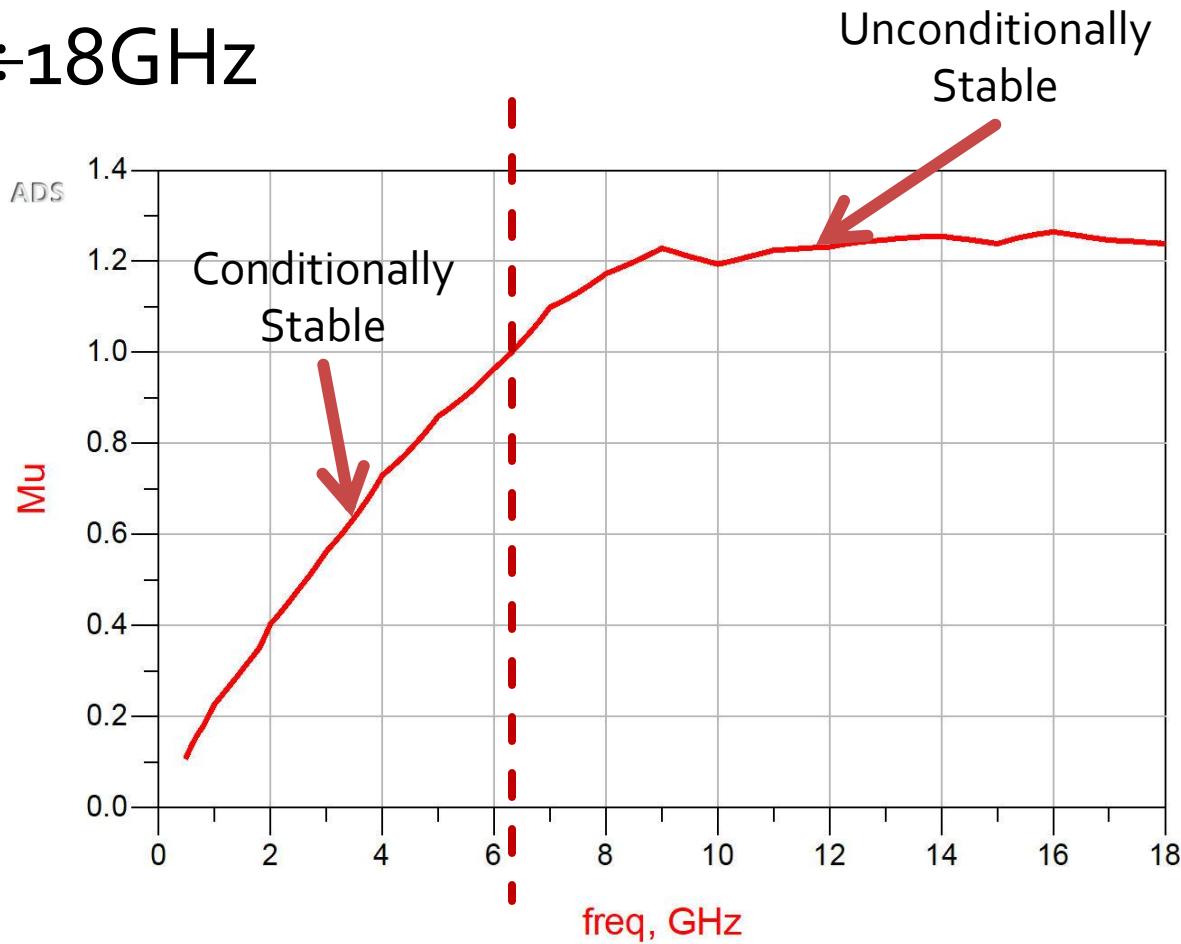
Conditia Rollet

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



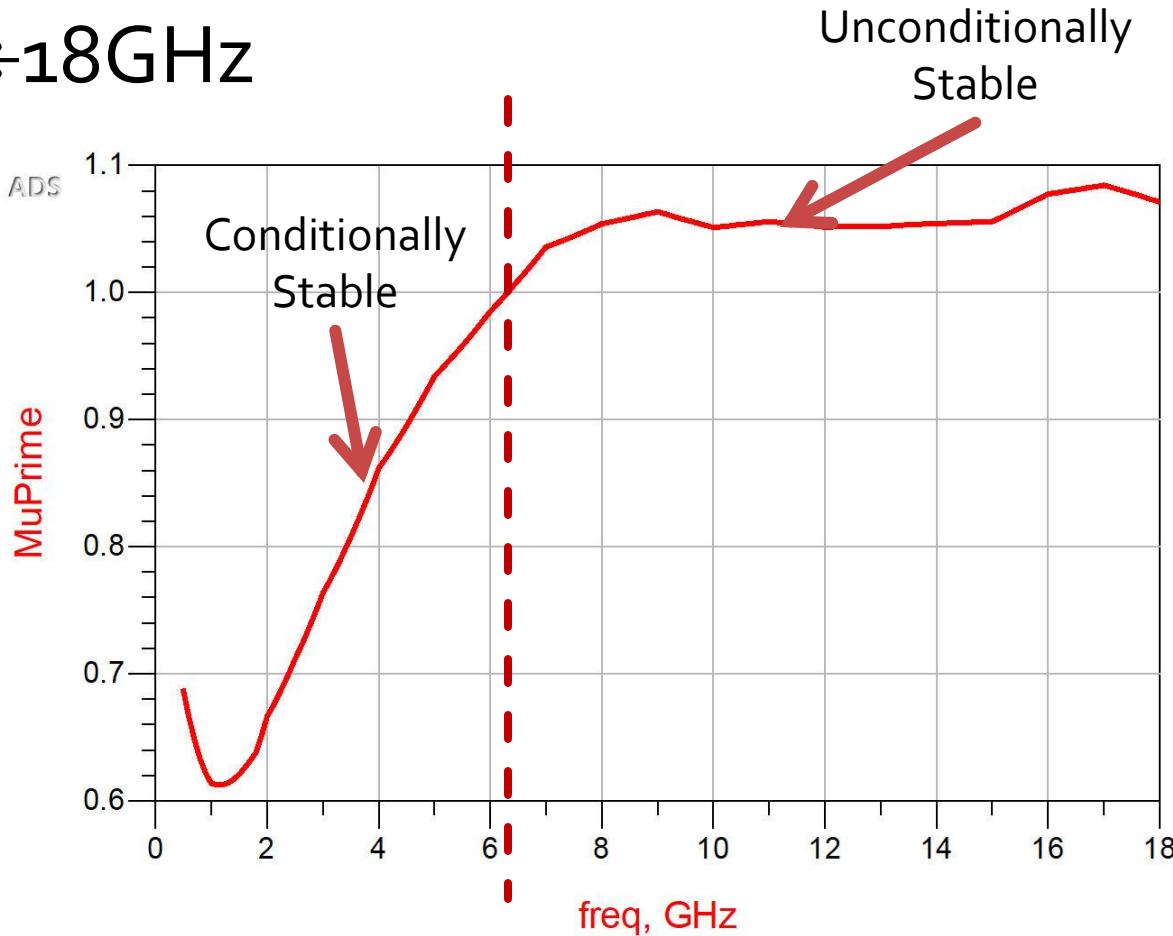
Criteriul μ

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



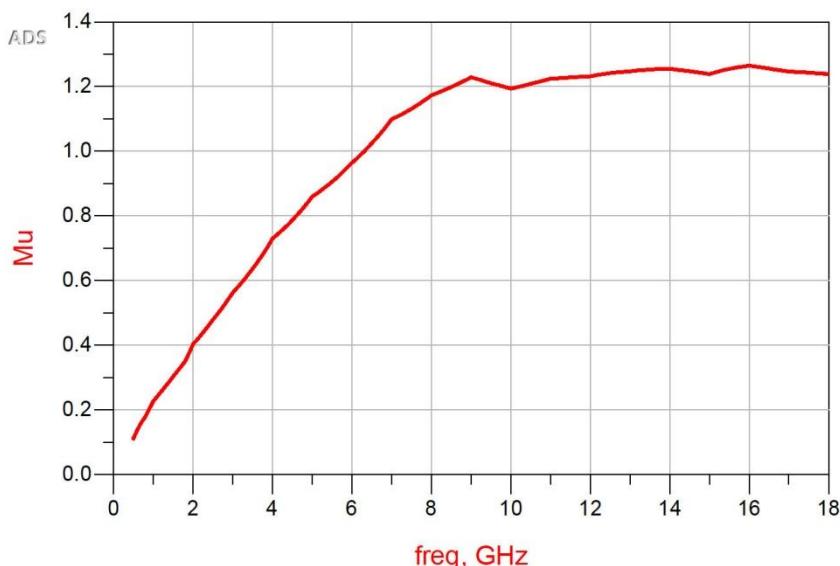
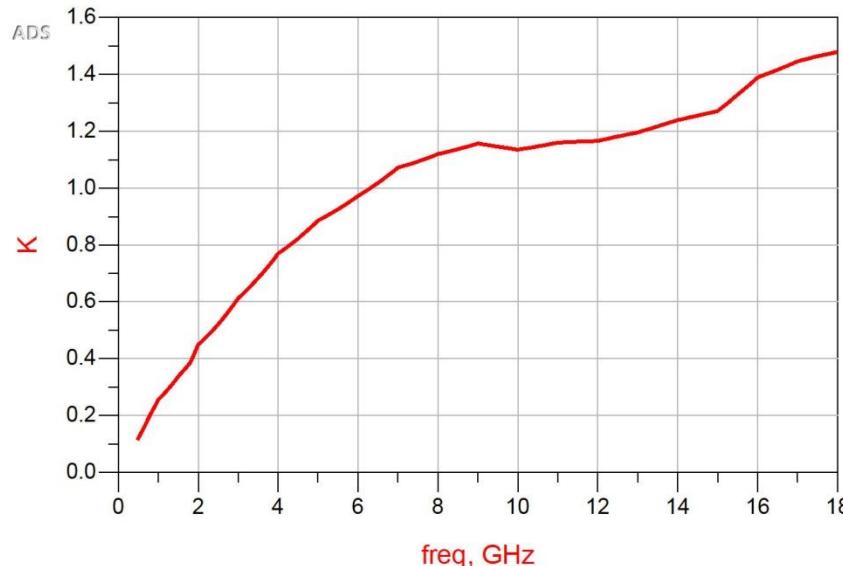
Criteriul μ'

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



Stabilitate

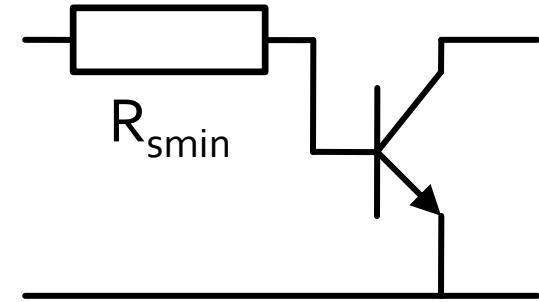
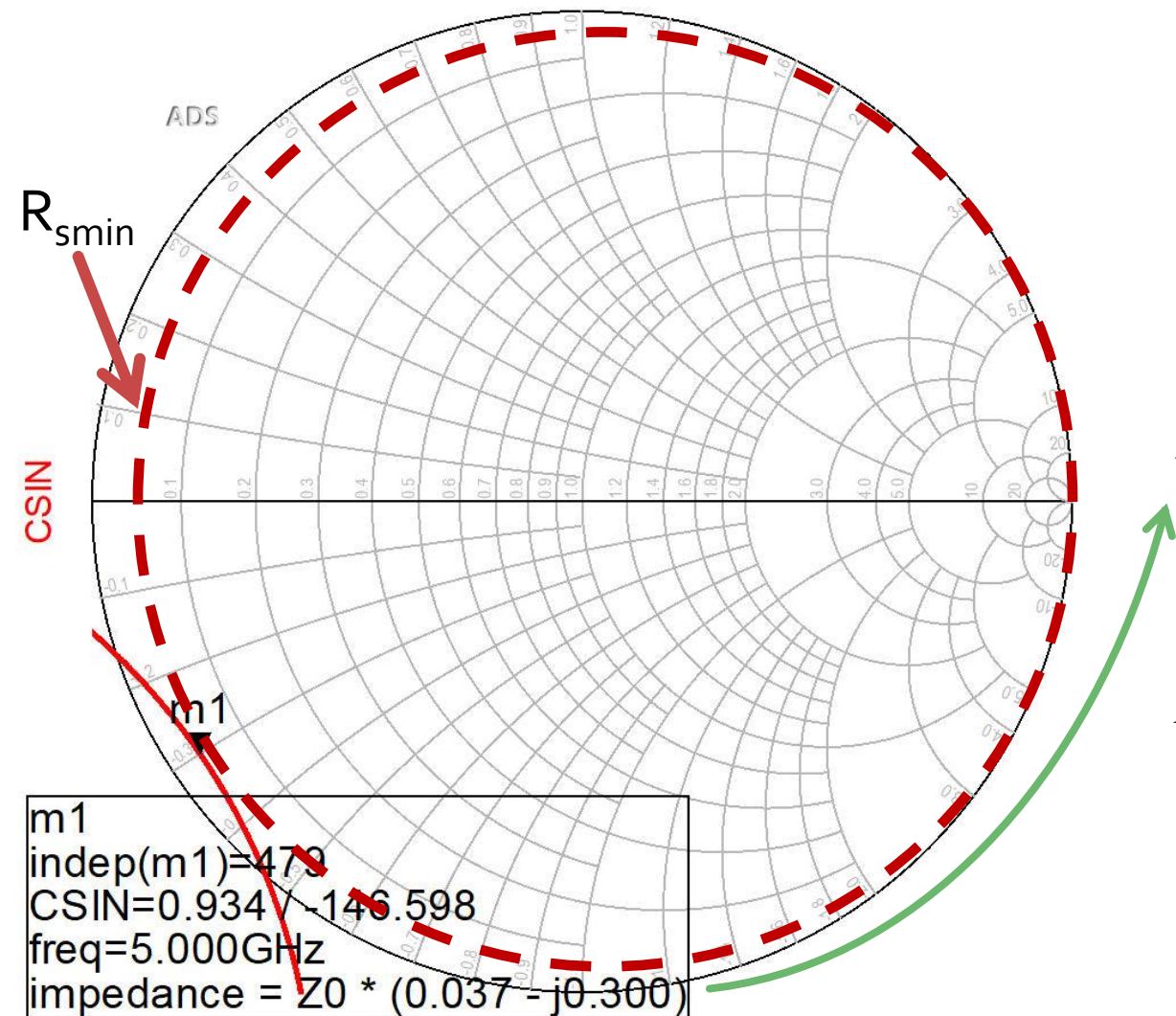
- ATF-34143 at $V_{ds}=3V$ $I_d=20mA$.
- @ $0.5 \div 18GHz$
- Neconditionat stabil pentru $f > 6.31GHz$



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

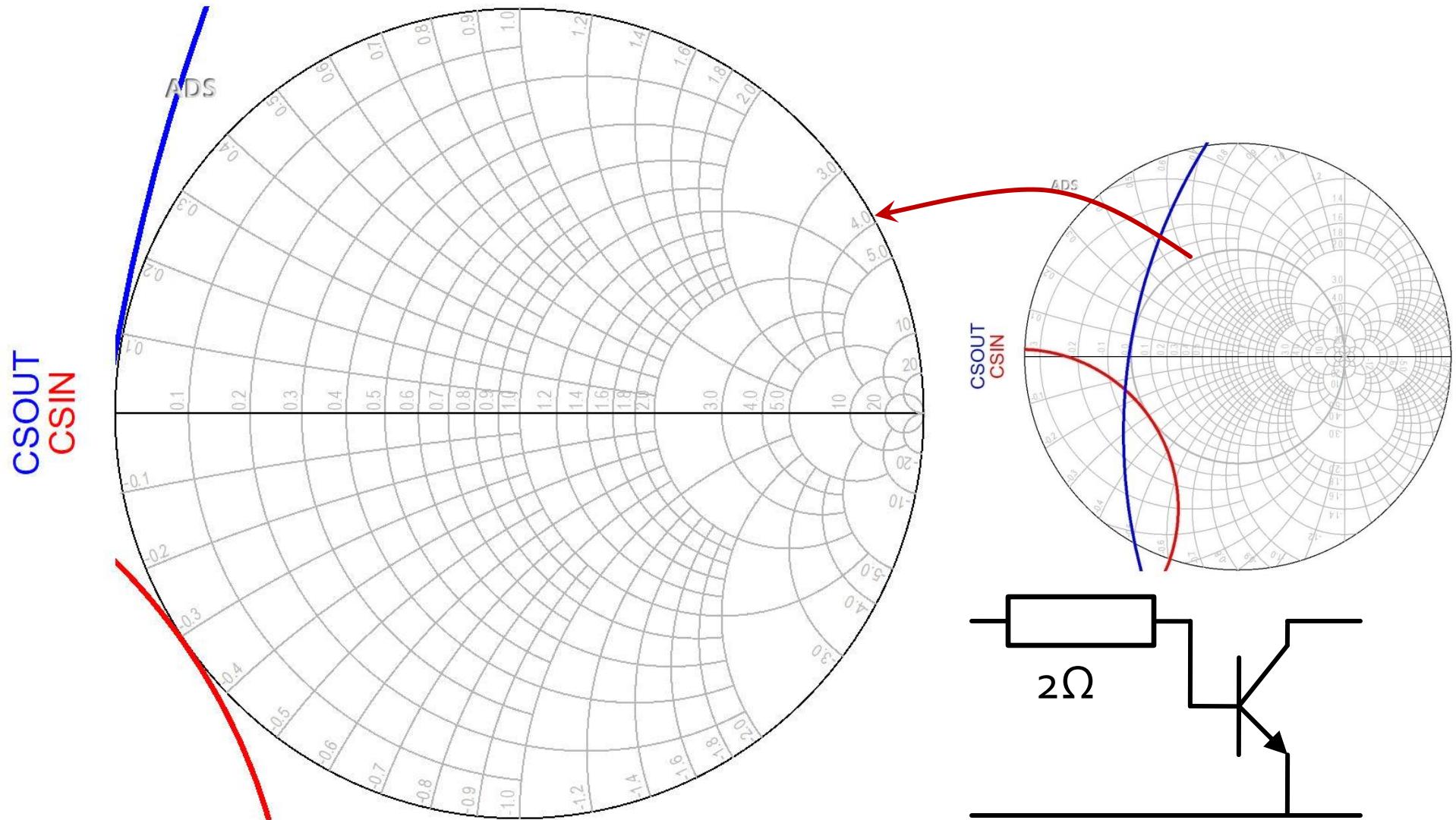
Rezistenta serie la intrare



$$z = 0.037 - j \cdot 0.3$$

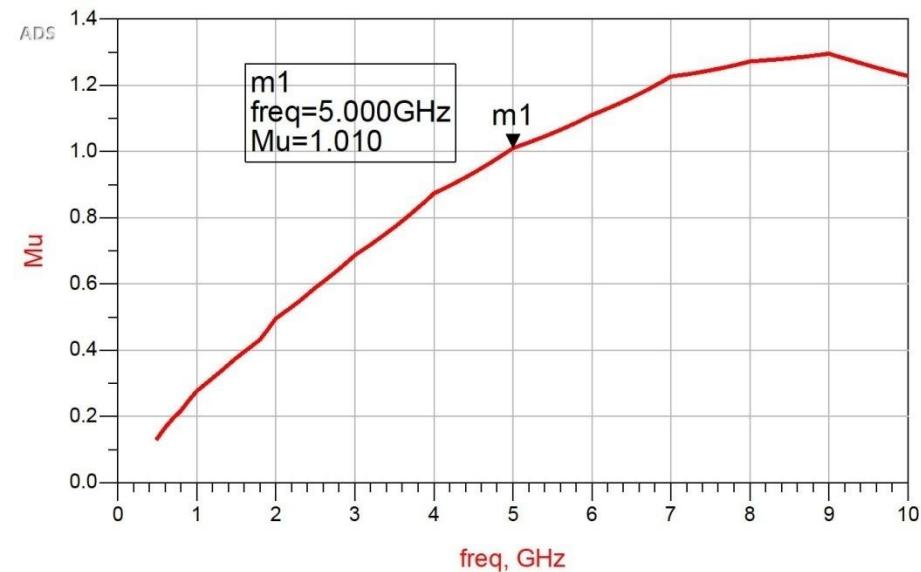
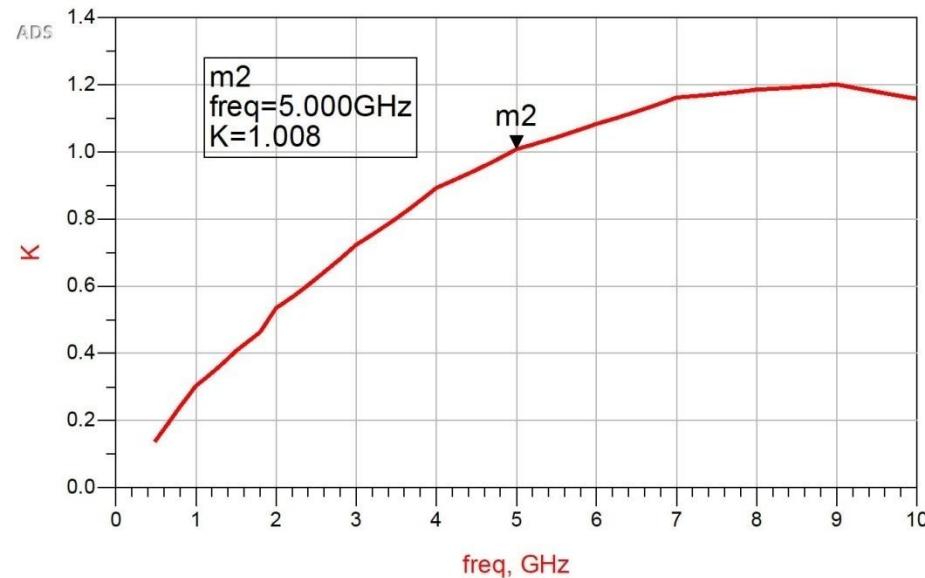
$$R_{smin} = 0.037 \cdot 50\Omega = 1.85\Omega$$

ADS, $R_s = 2\Omega$

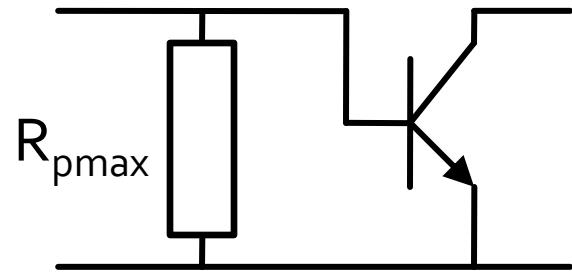
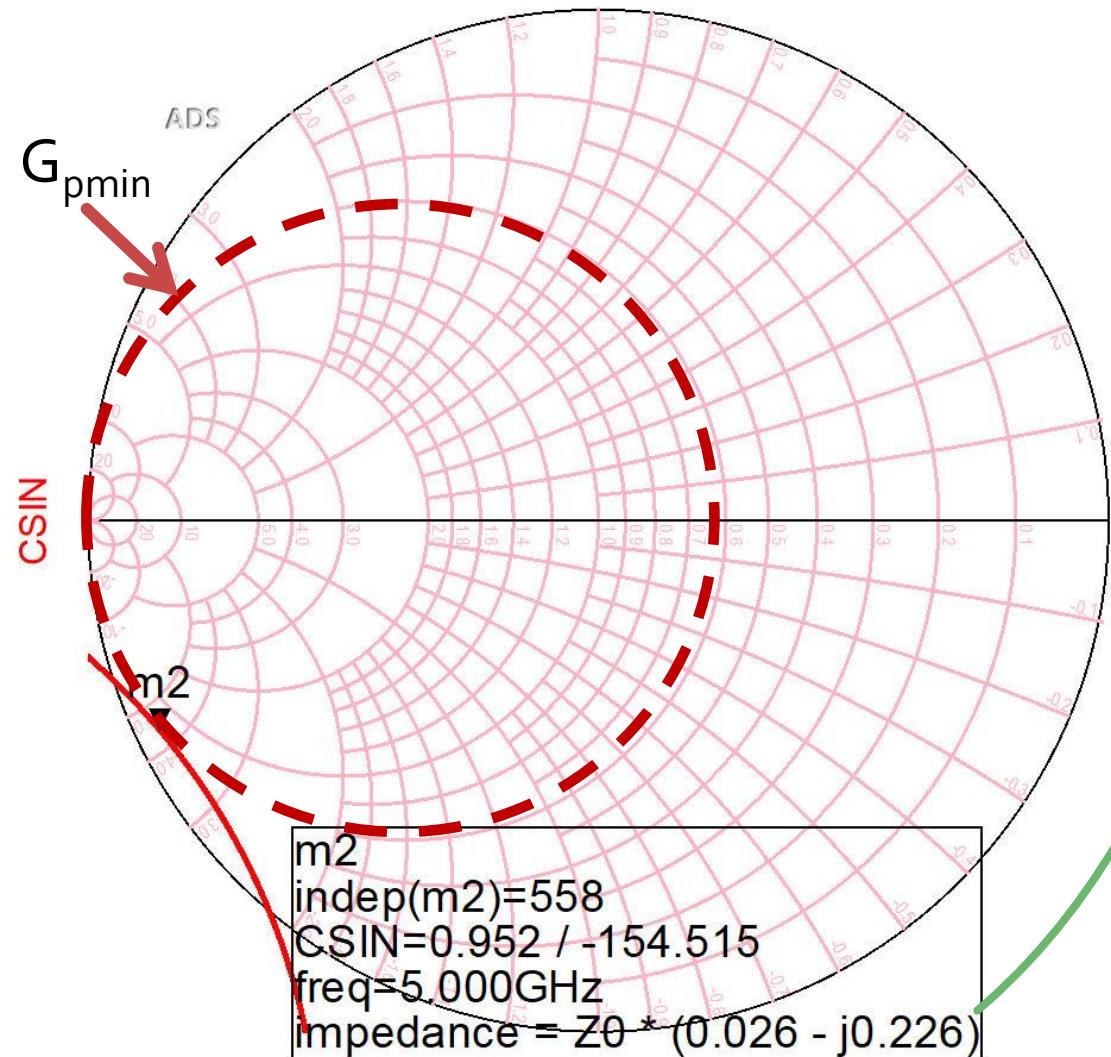


Rezistenta serie la intrare

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



Rezistenta paralel la intrare

 $R_{p\max}$

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

$$z = 0.026 - j \cdot 0.226$$

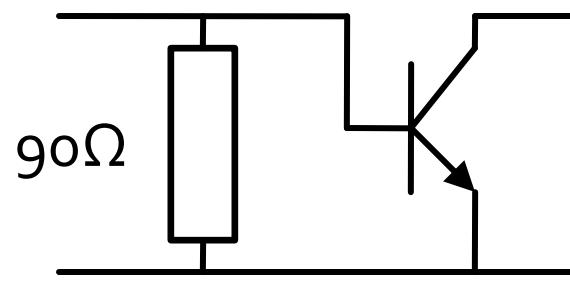
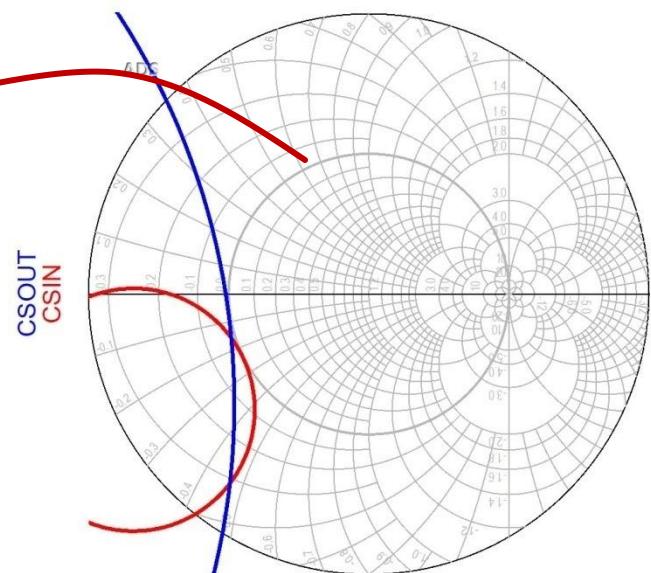
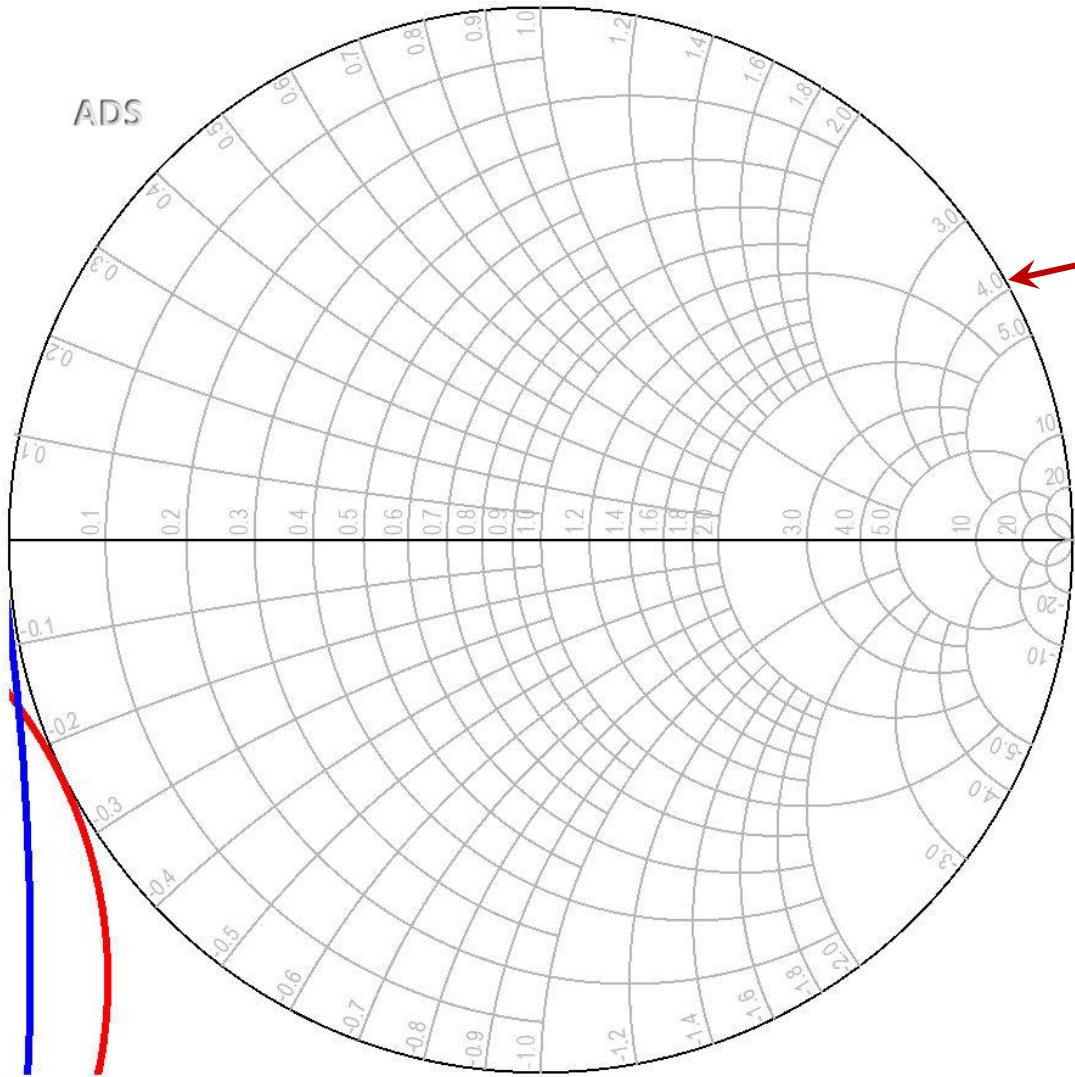
$$y = \frac{1}{z} = \frac{1}{0.026 - j \cdot 0.226}$$

$$y = 0.502 + j \cdot 4.367$$

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

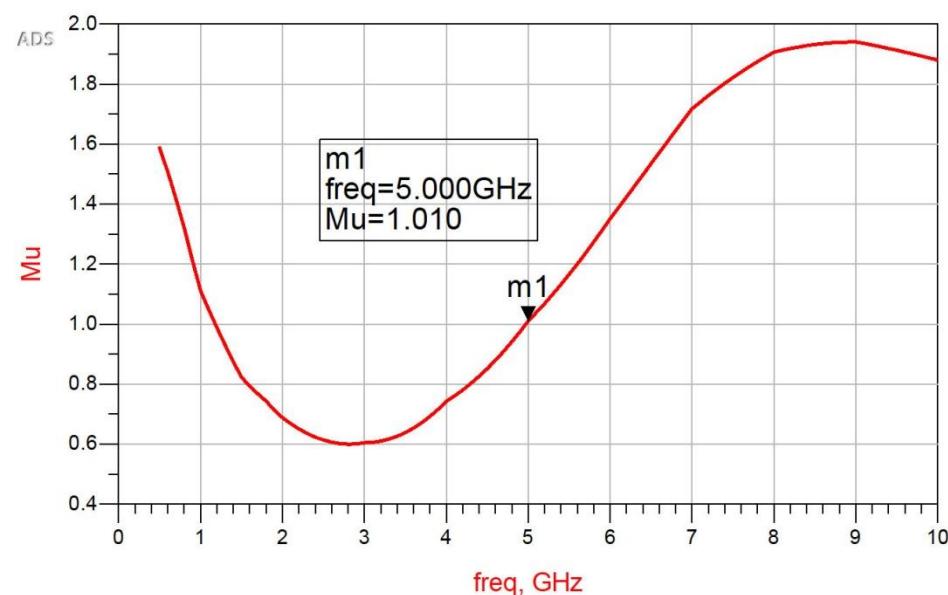
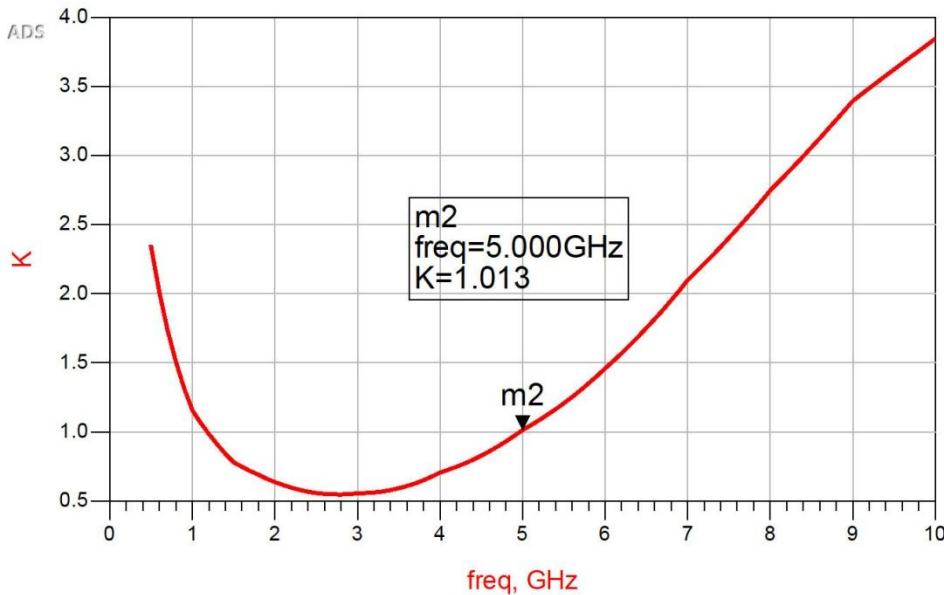
ADS, $R_p = 90\Omega$

CSOUT
CSIN



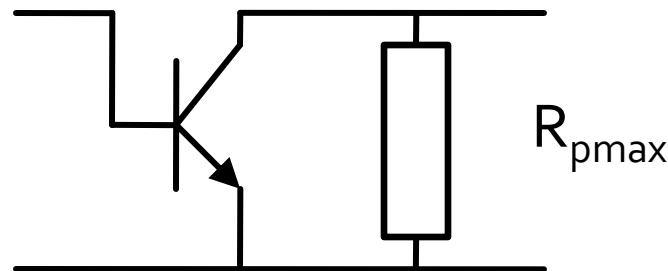
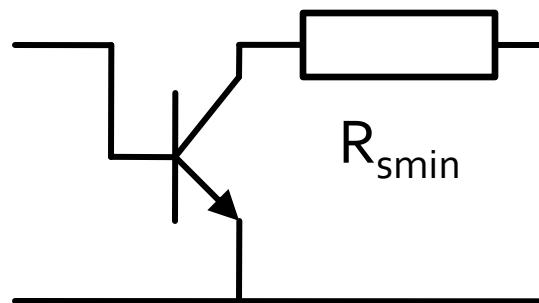
Rezistenta paralel la intrare

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



Rezistenta serie/paralel la iesire

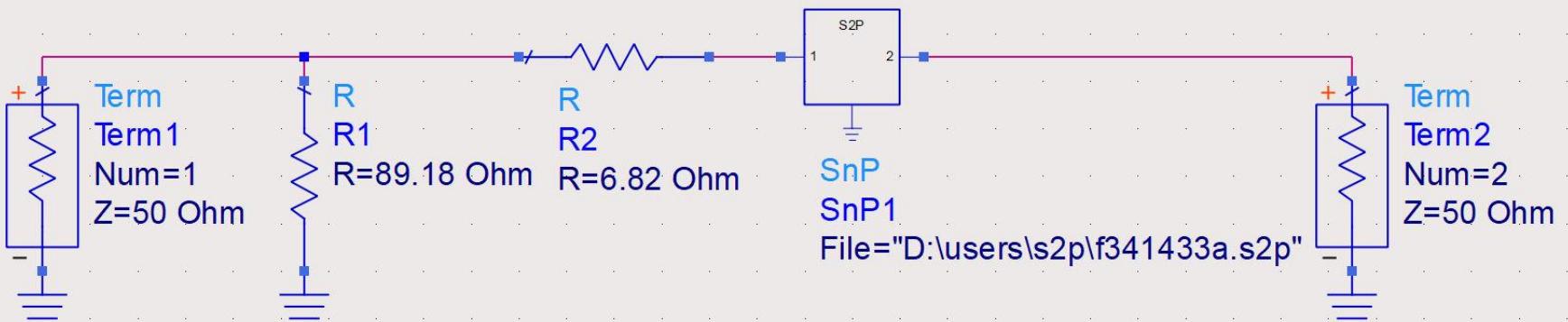
- Procedura se poate aplica similar la iesire (plecand de la CSOUT)
- Din exemplele anterioare, incarcarea rezistiva la intrare are efect pozitiv si asupra stabilitatii la iesire si viceversa (incarcare la iesire efect asupra stabilitatii la intrare)



Stabilizarea unui dipozit

- Efect negativ asupra castigului
 - trebuie urmarit MAG/MSG in timpul proiectarii
- Efect negativ asupra zgomotului (^{va urma})
- 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

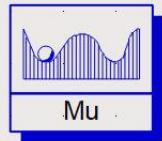
Step=0.1 GHz



MaxGain

MAG

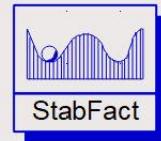
MAG=max_gain(S)



Mu

Mu1

Mu=mu(S)

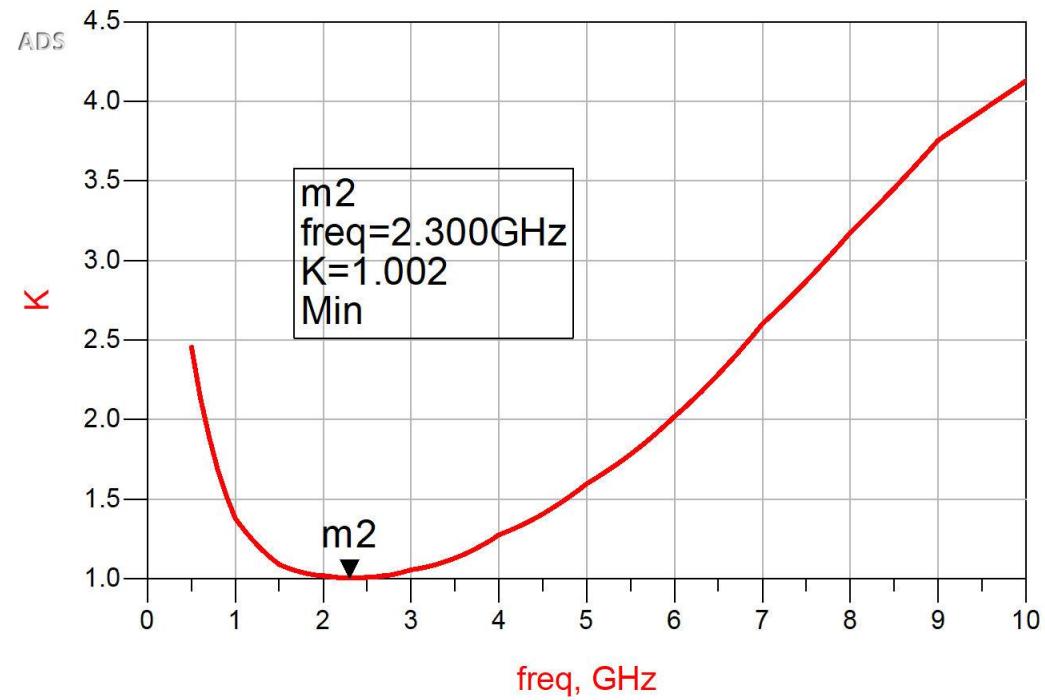
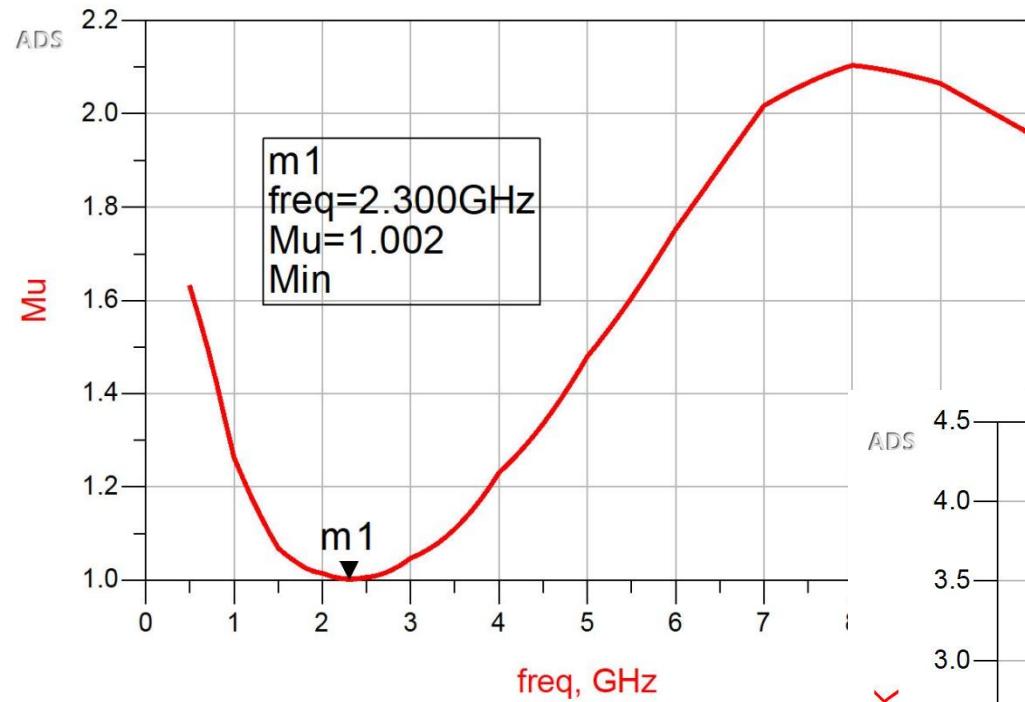


StabFact

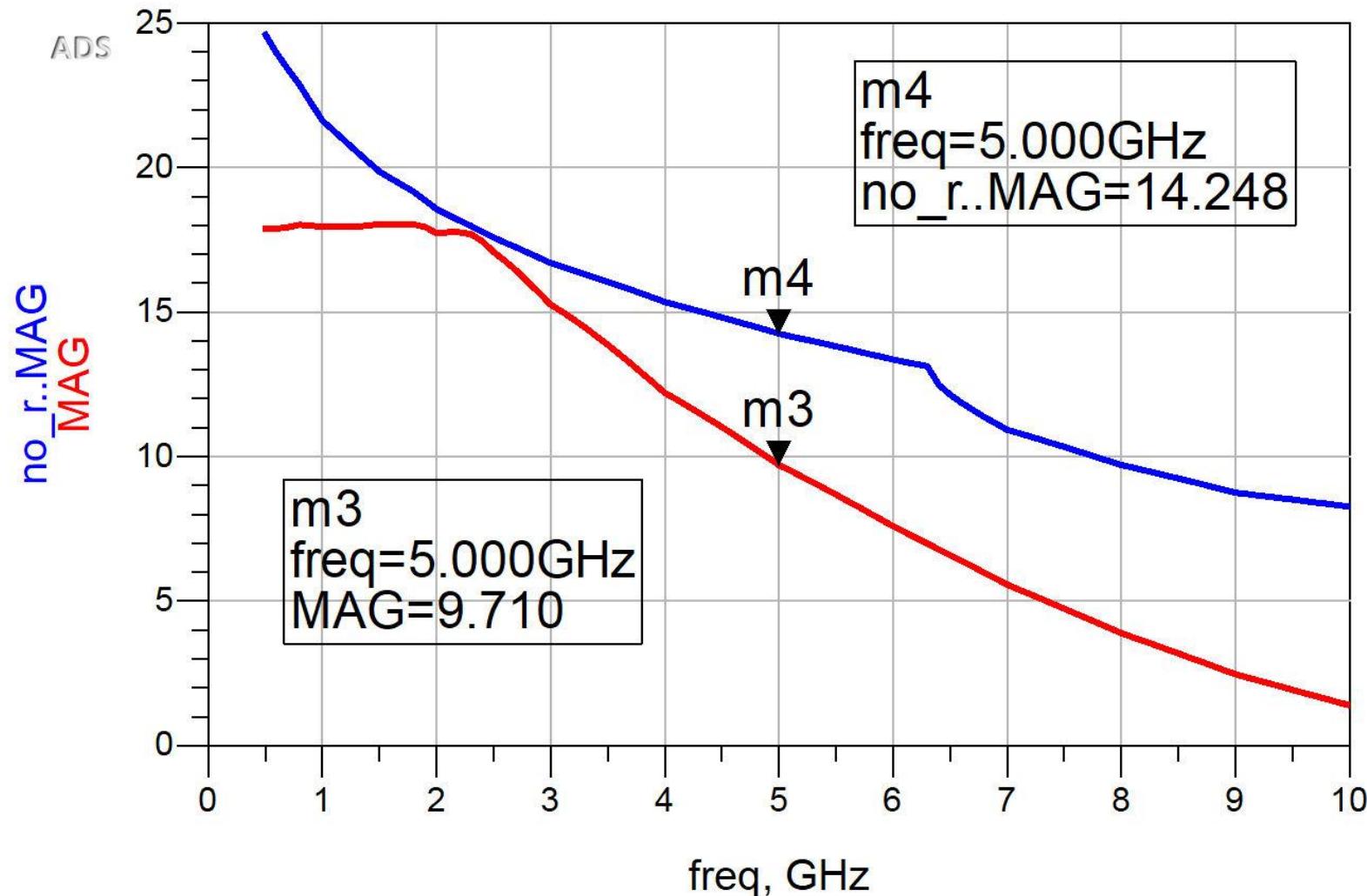
K

K=stab_fact(S)

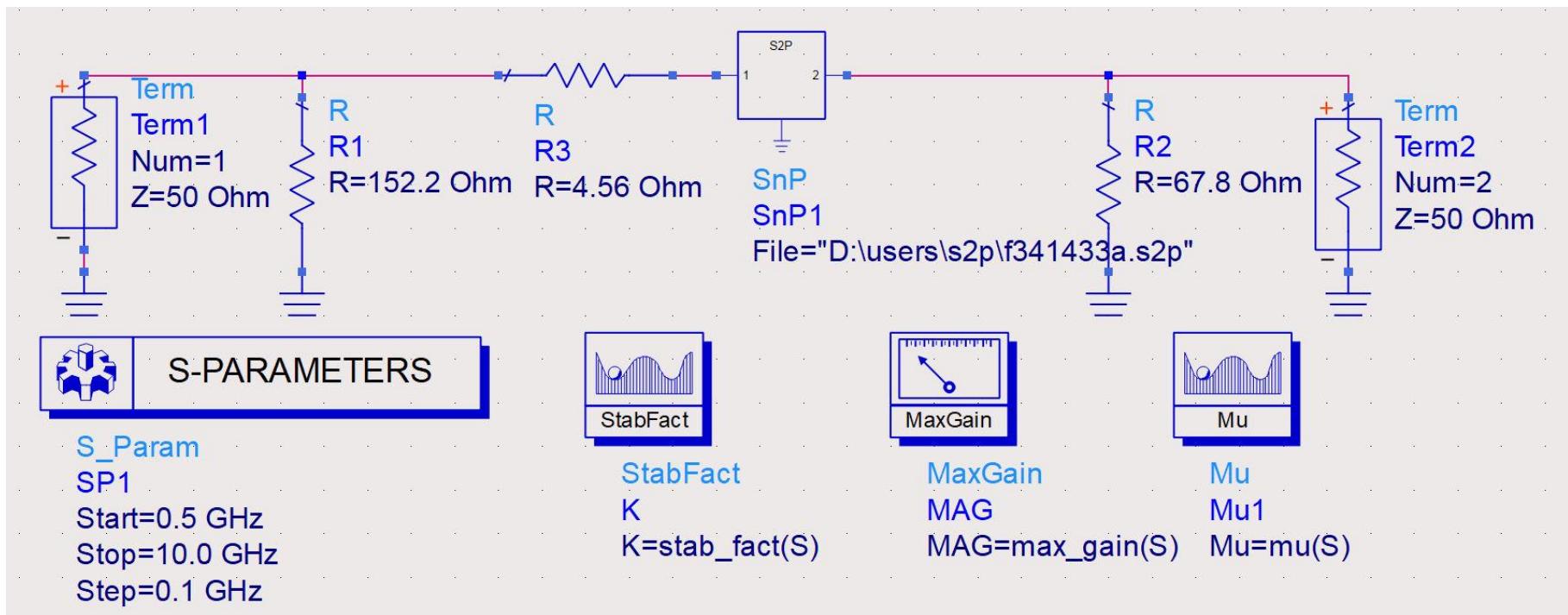
Stabilizarea unui dipoz



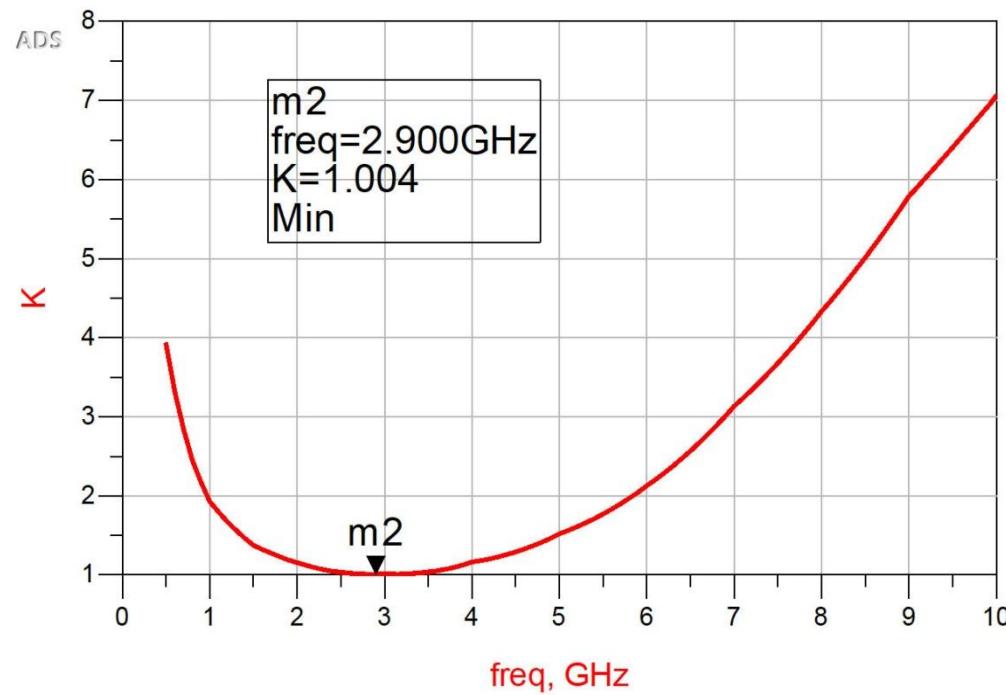
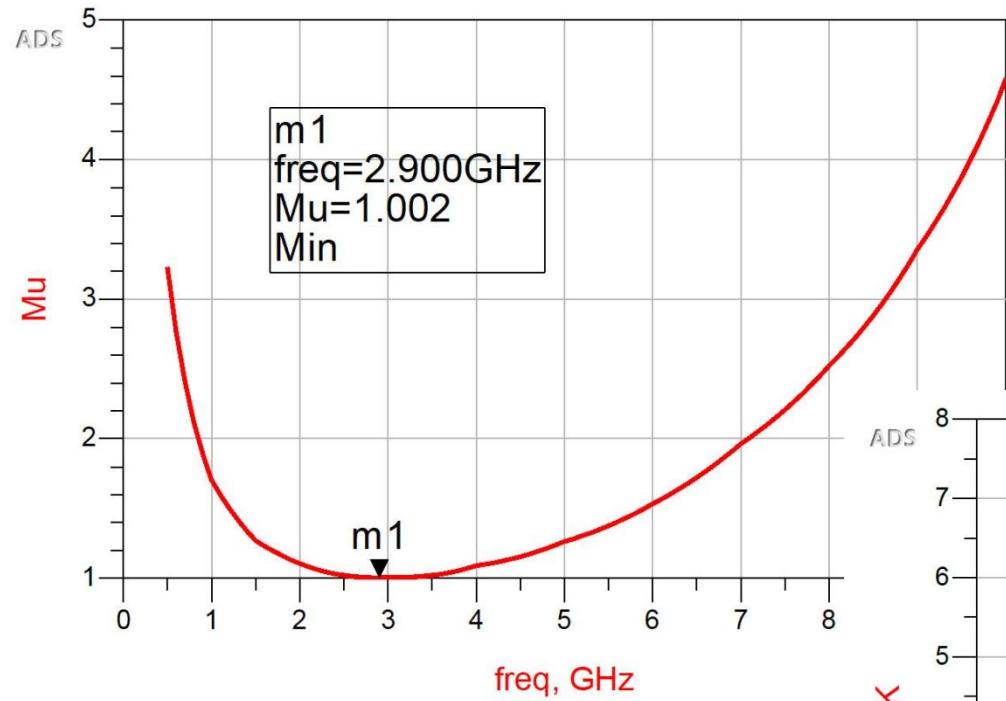
Stabilizarea unui dipoz



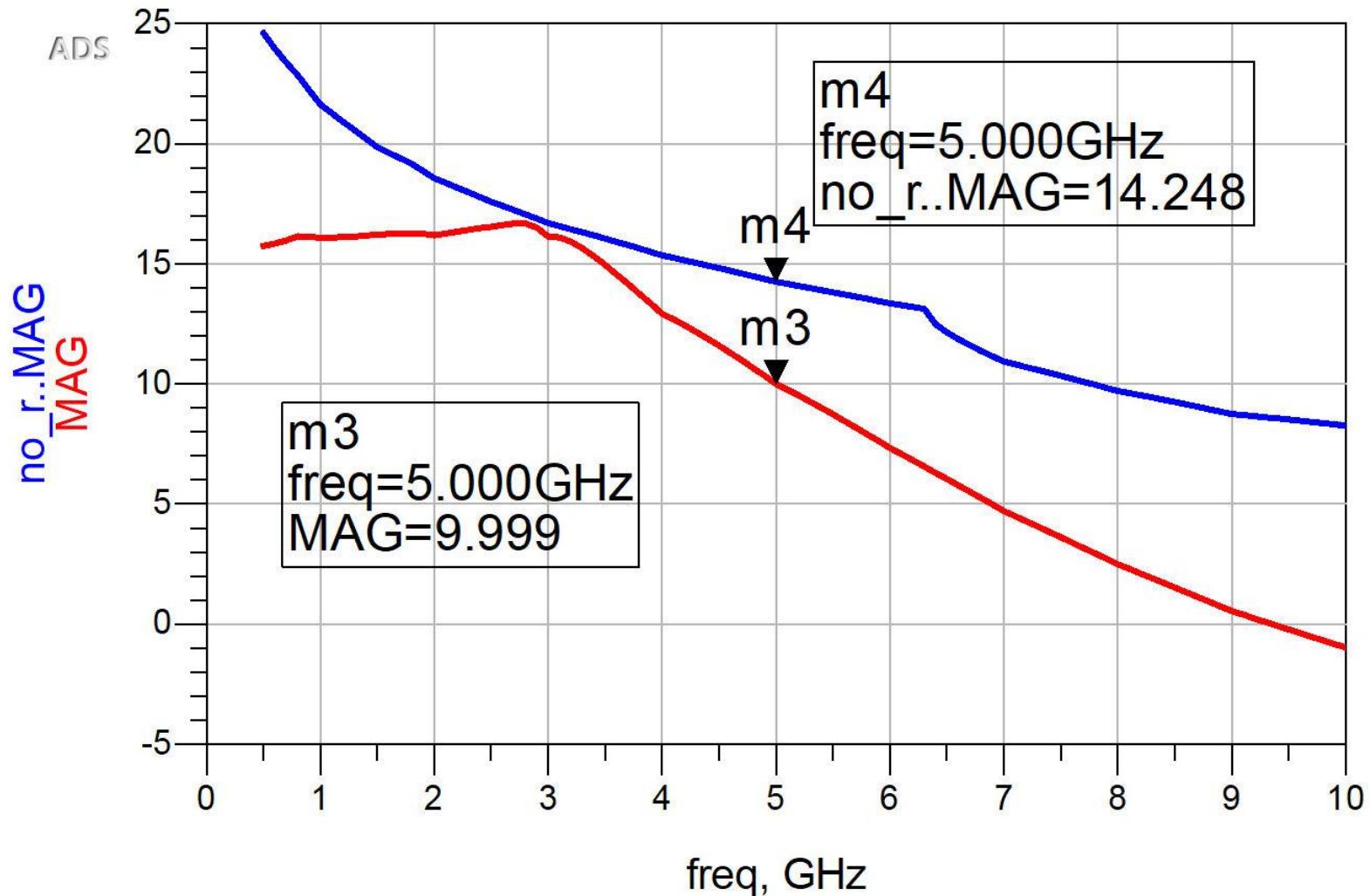
Stabilizarea unui diport



Stabilizarea unui dipoz



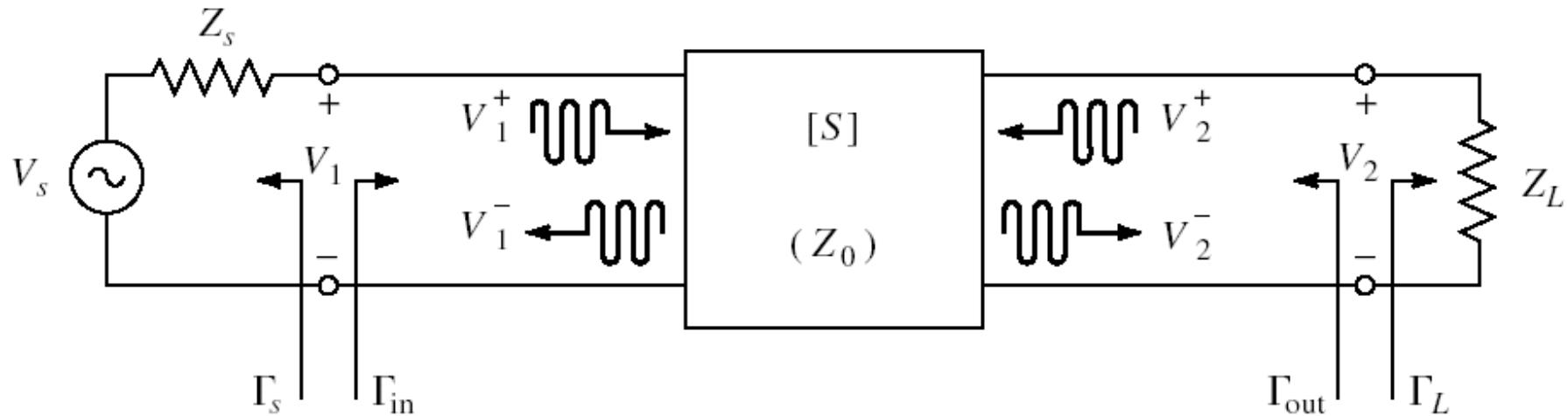
Stabilizarea unui dipoz



Amplificatoare de microunde

Castigul amplificatoarelor de microunde

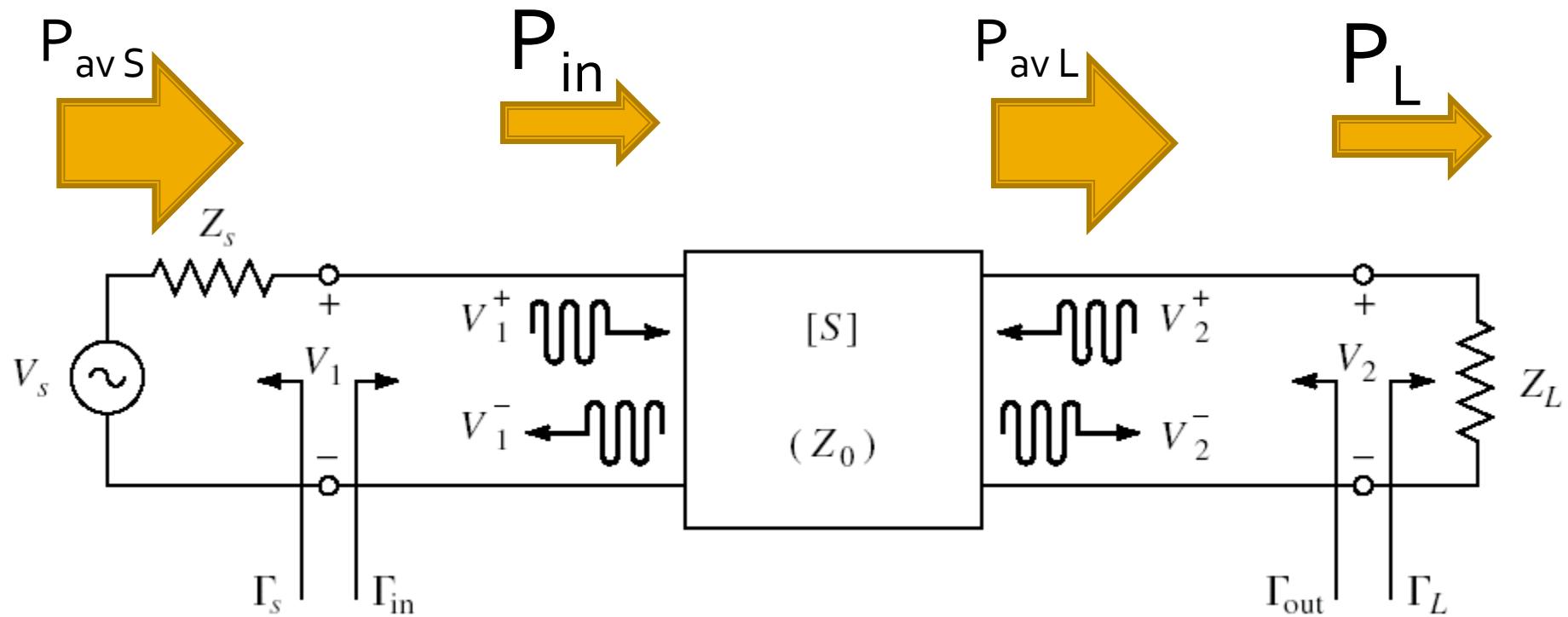
Cuadripol Amplifier



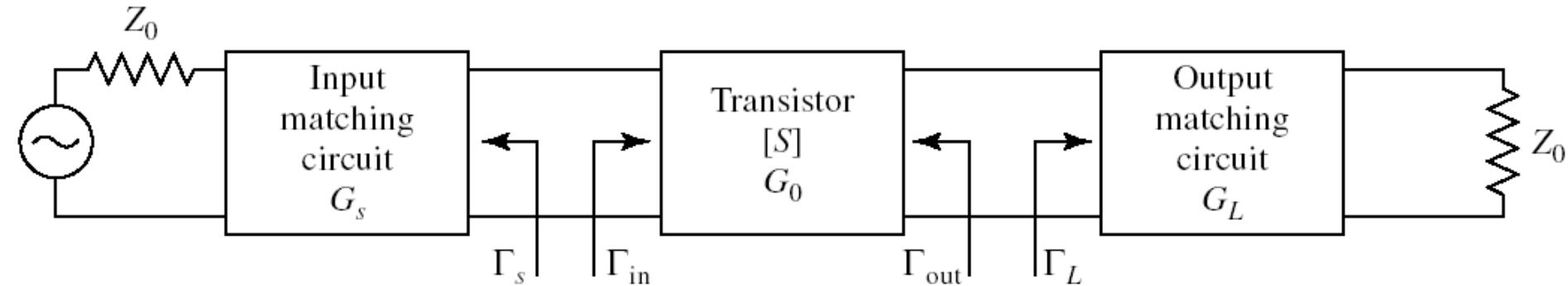
- marimi care intereseaza:
 - stabilitate
 - **castig de putere**
 - zgomot (uneori – semnal mic)
 - liniaritate (uneori – semnal mare)

Puteri / Adaptare

- Doua porturi in care adaptarea influenteaza transferul de putere



Proiectare pentru castig maxim



- Castig maxim de putere se obtine cand

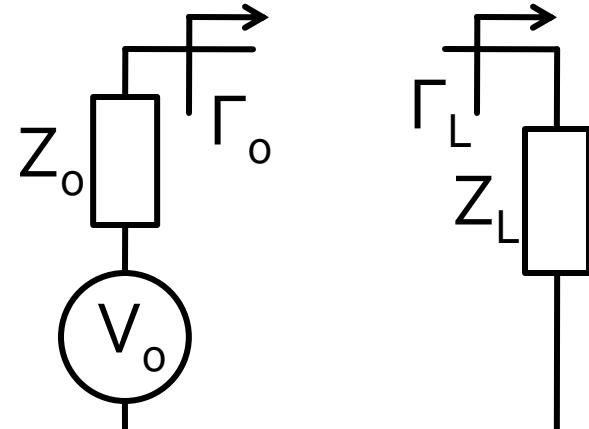
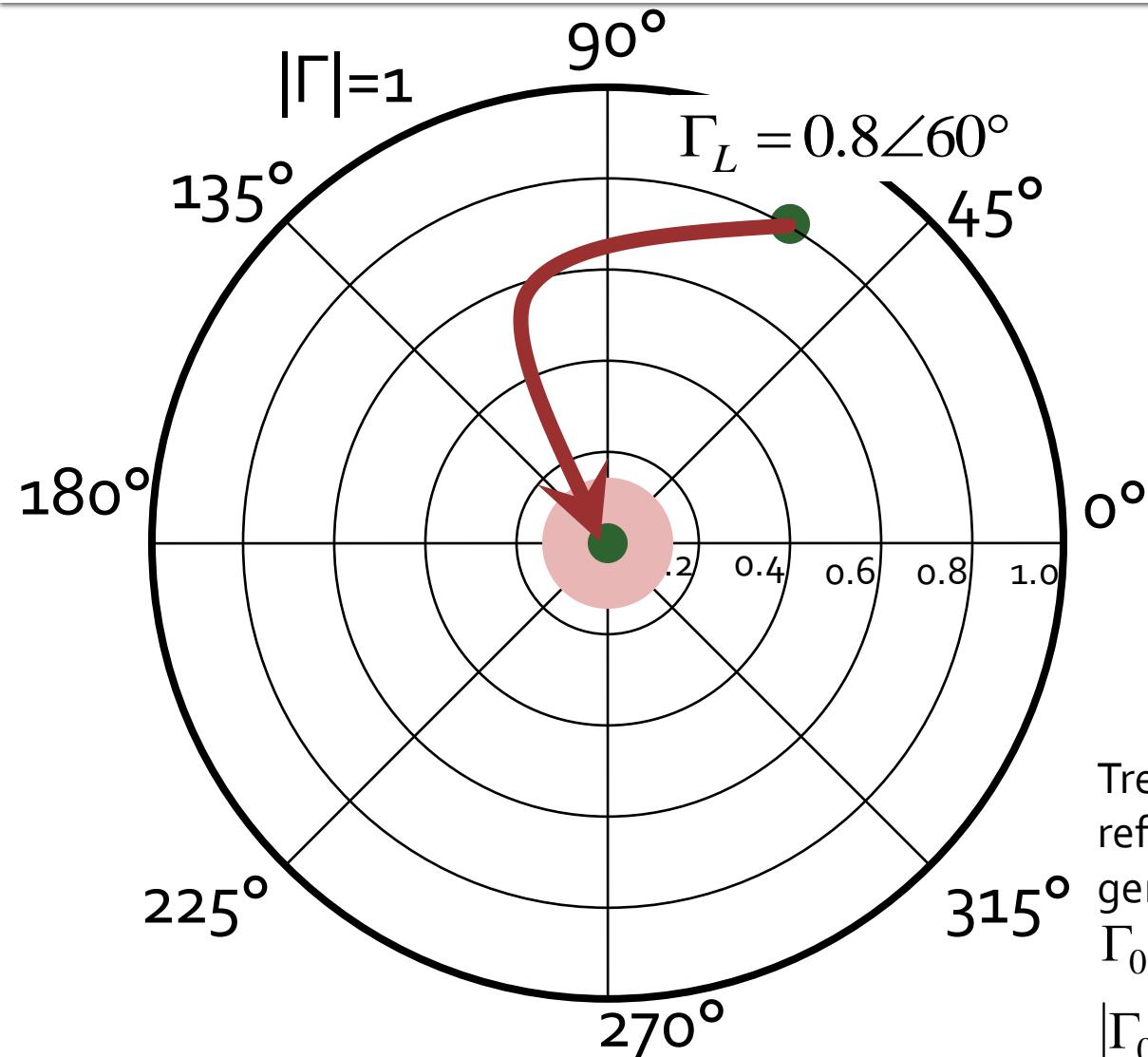
$$\rightarrow \Gamma_{in} = \Gamma_s^* \quad \Gamma_{out} = \Gamma_L^*$$

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

Diagrama Smith, adaptare, $Z_L \neq Z_o$

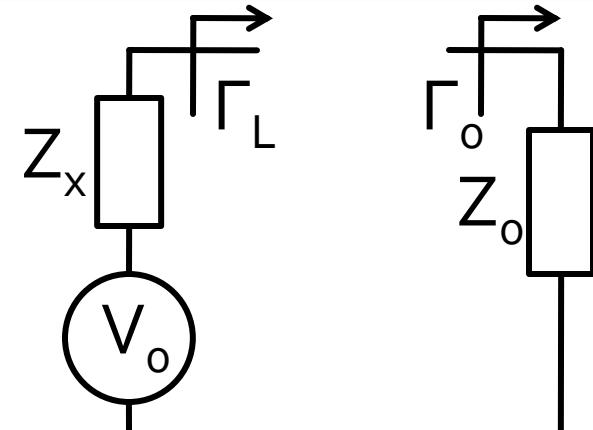
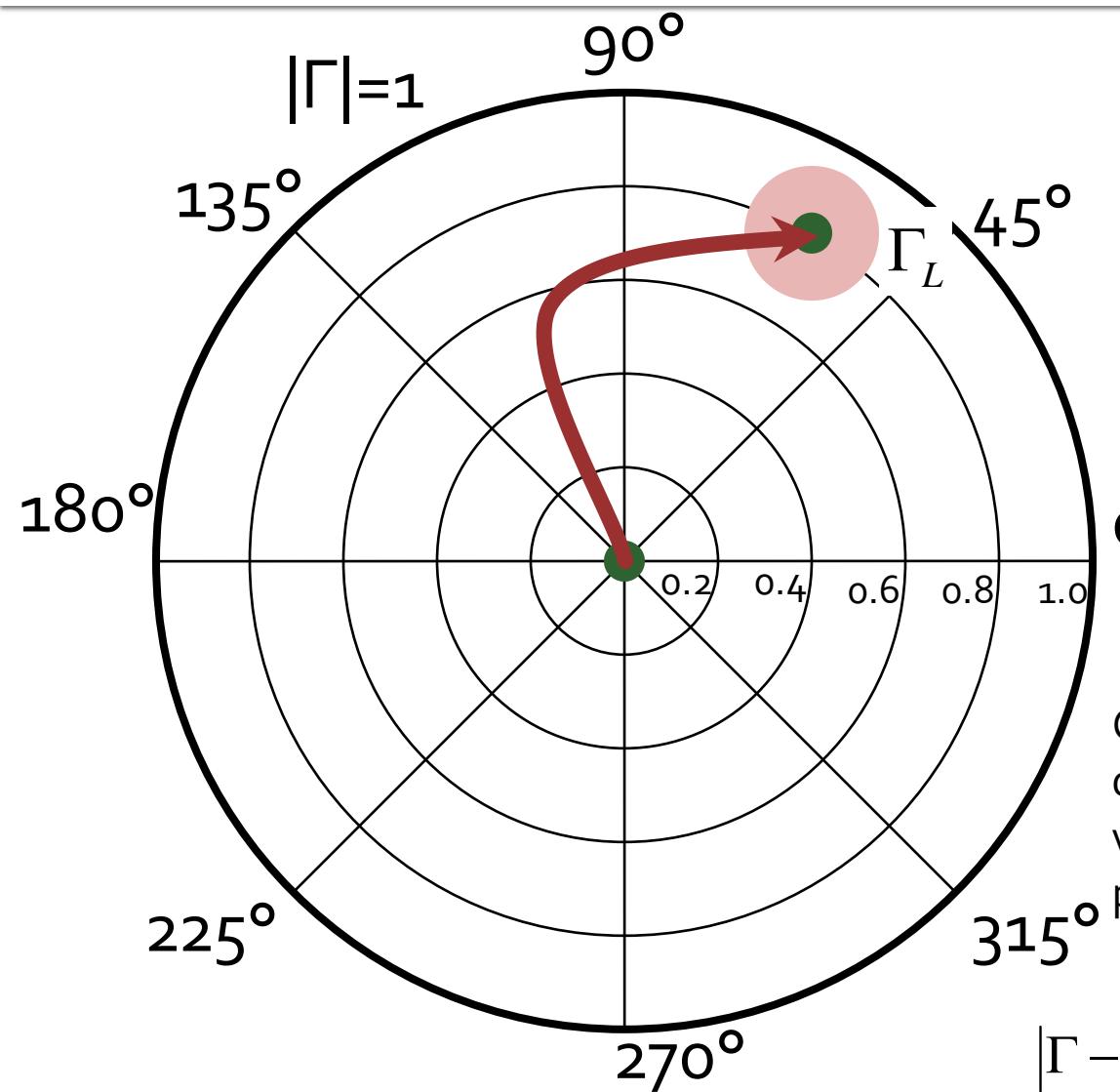


Adaptare Z_L la Z_o . Se raporteaza Z_L la Z_o
 $Z_L = 21.429\Omega + j \cdot 82.479\Omega$
 $z_L = 0.429 + j \cdot 1.65$
 $\Gamma_L = 0.8\angle 60^\circ$

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, $Z_L = Z_o$



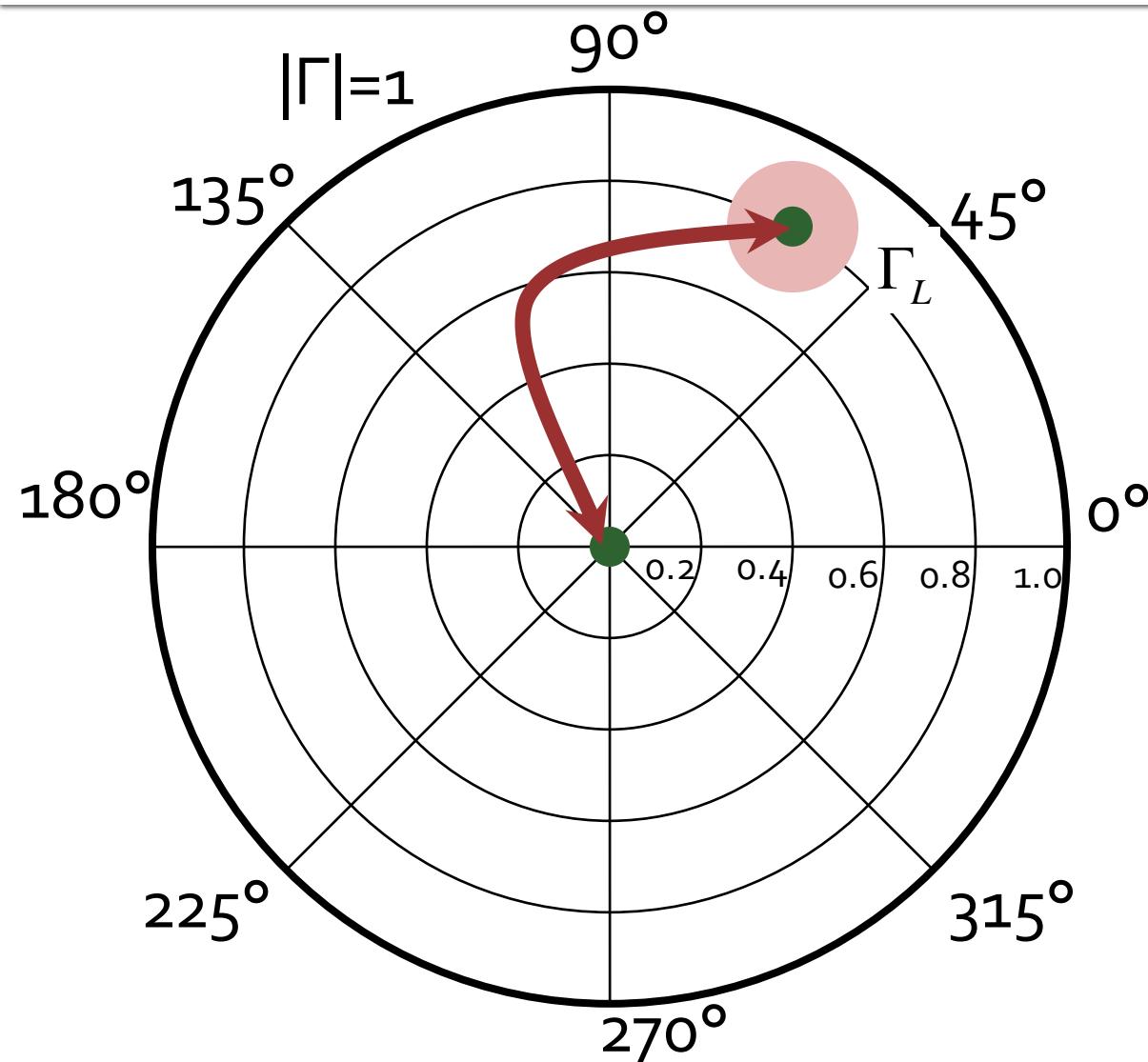
Sursa (de ex. tranzistorul) cu Z_x are nevoie de un anumit coeficient de reflexie Γ_L pentru a functiona corect

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
 - Γ_L în Γ_o
 - Γ_o în Γ_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

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

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

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

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

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

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

- Aflam Γ_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

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

$$\Gamma_S^2 \cdot \underbrace{(S_{11} - \Delta \cdot S_{22}^*)}_C + \Gamma_S \cdot \underbrace{\left(|\Delta|^2 - |S_{11}|^2 + |S_{22}|^2 - 1 \right)}_{-B} + \underbrace{(S_{11}^* - \Delta^* \cdot S_{22})}_{C^*} = 0$$

- 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

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

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

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

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

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

■ 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

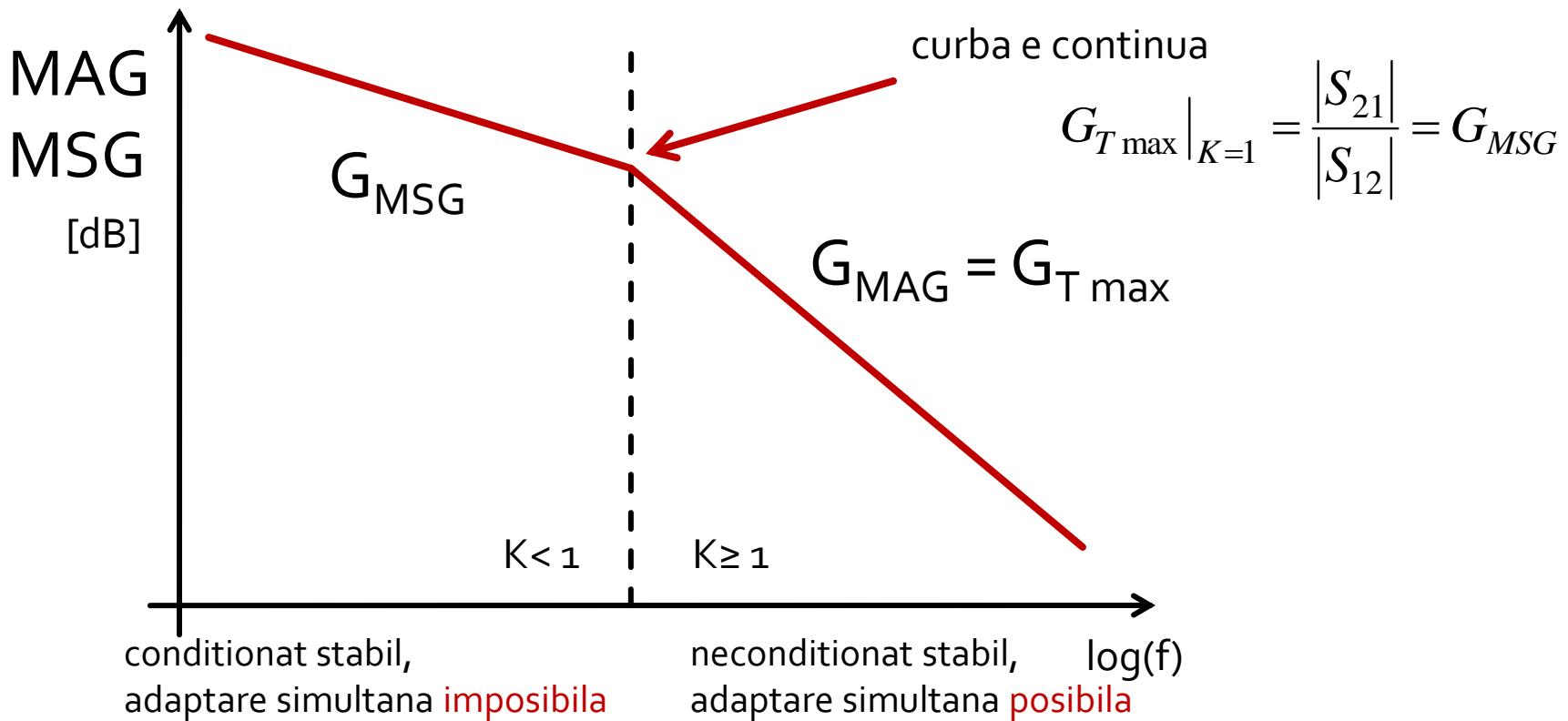
$$G_{T\max} = \frac{|S_{21}|}{|S_{12}|} \cdot \left(K - \sqrt{K^2 - 1} \right)$$

- 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

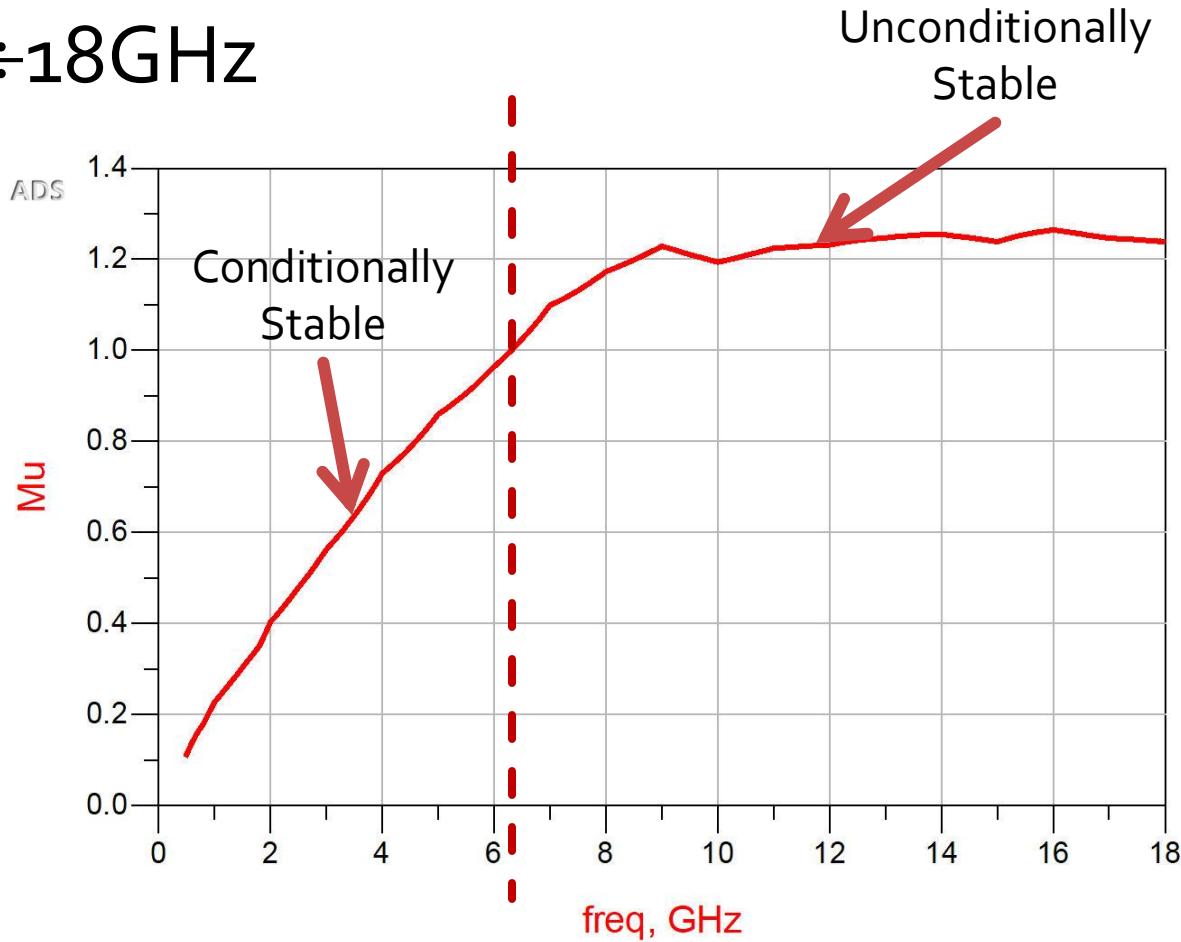
- Indicator in intreaga gama de frecventa a capacitatii de a obtine castig



Stabilitate

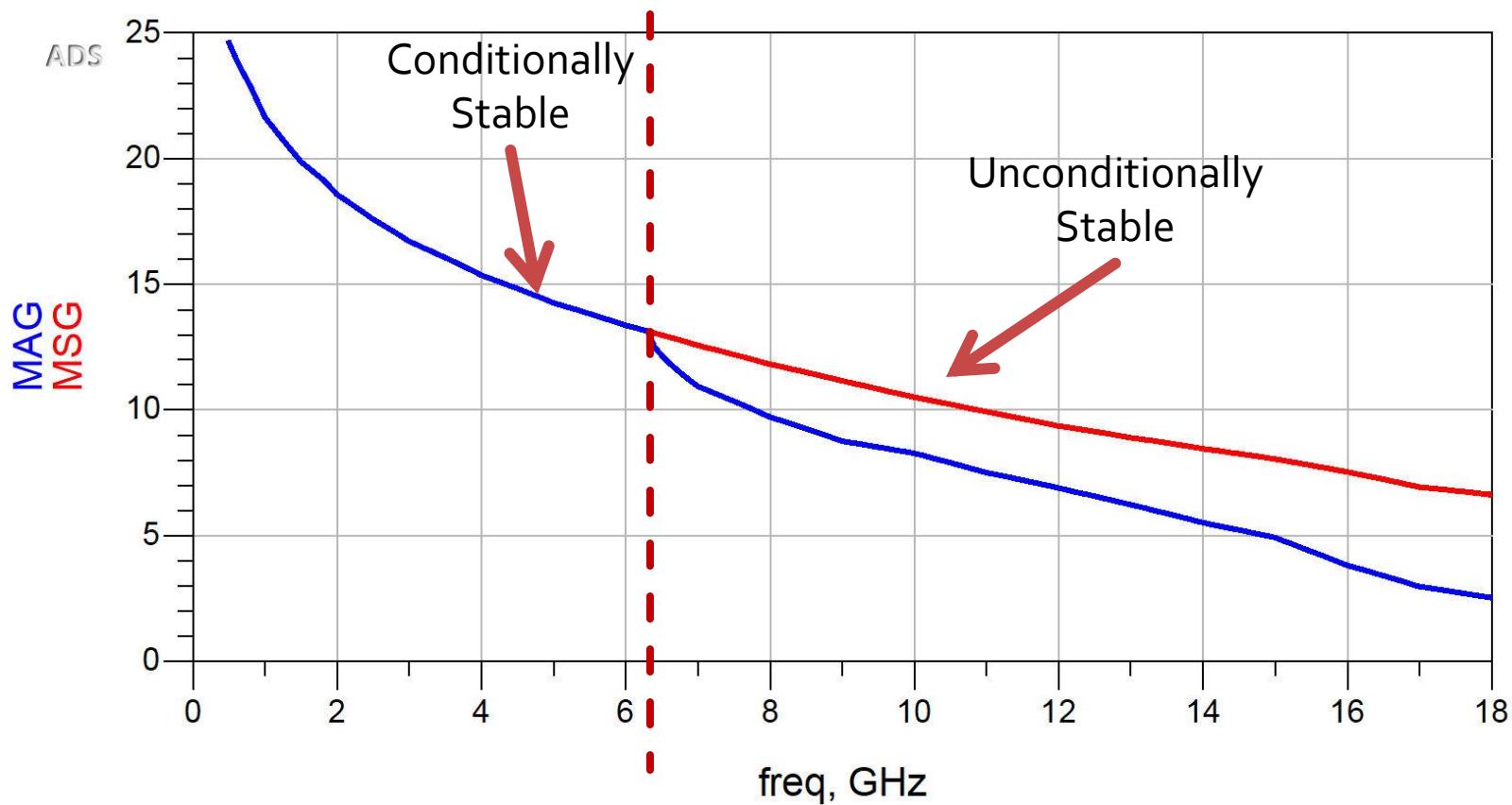
- ATF-34143 at $V_{ds}=3V$ $I_d=20mA$.

- @ $0.5 \div 18GHz$



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

- $S_{11} = 0.64 \angle 111^\circ$

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

- $S_{12} = 0.117 \angle -27^\circ$

- $S_{21} = 2.923 \angle -6^\circ$

- $S_{22} = 0.21 \angle 111^\circ$

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

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

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

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

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

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

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

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

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

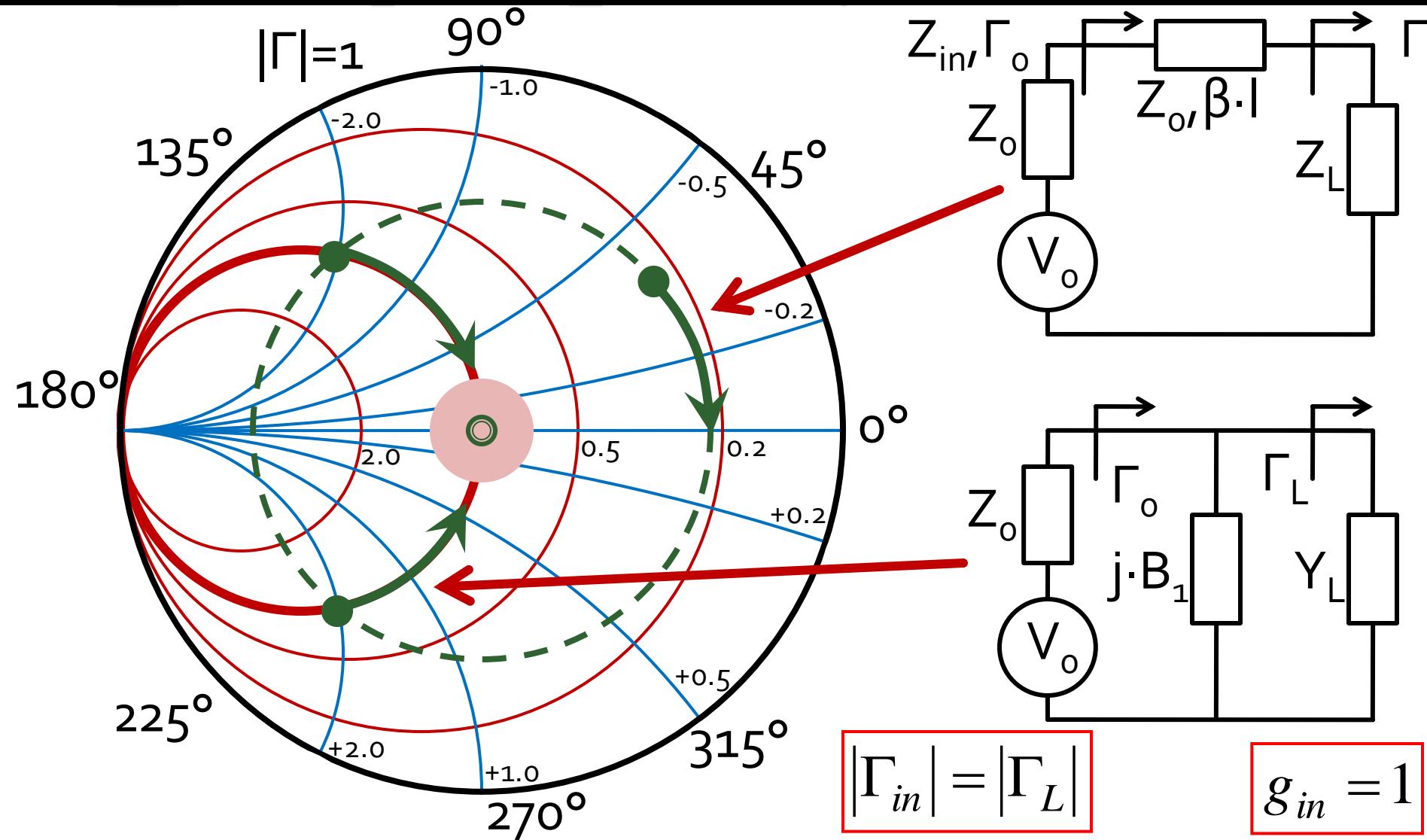
$$\Gamma_L = \frac{B_2 - \sqrt{B_2^2 - 4 \cdot |C_2|^2}}{2 \cdot C_2}$$

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

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

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

Adaptare cu stub-uri, C₇



Calcul analitic (Γ_S)

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

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

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

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

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

- **solutia "cu +"**

$$(-117.7^\circ + 2\theta) = +150.1^\circ \quad \theta = 133.9^\circ \quad \text{Im } y_S = \frac{-2 \cdot |\Gamma_S|}{\sqrt{1 - |\Gamma_S|^2}} = -3.477$$
$$\theta_{sp} = \tan^{-1}(\text{Im } y_S) = -74^\circ (+180^\circ) \rightarrow \theta_{sp} = 106^\circ$$

- **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 (Γ_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 (Γ_L)

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

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

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

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

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

- **solutia "cu +"** ↘

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

- **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

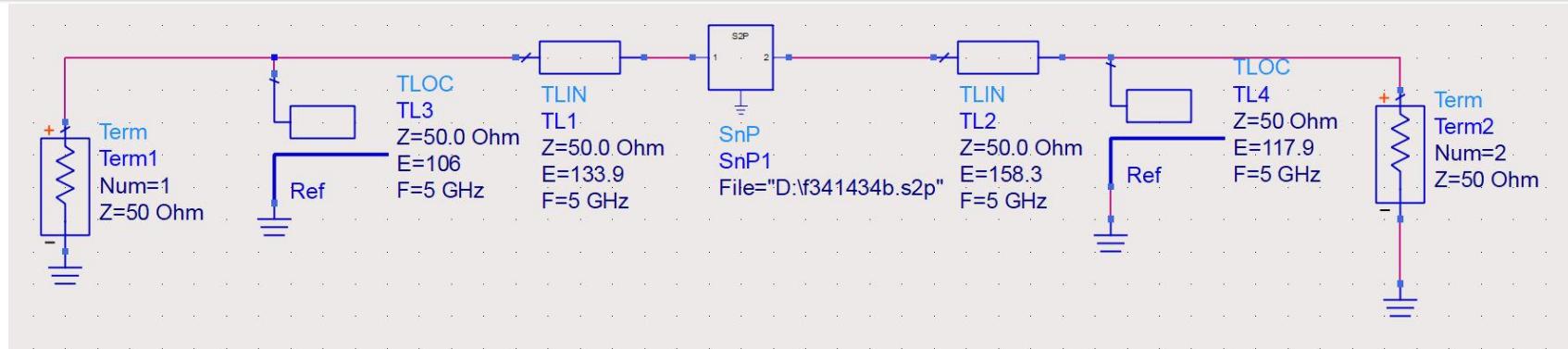
$$(\varphi + 2\theta) = \begin{cases} +150.1^\circ \\ -150.1^\circ \end{cases} \quad \theta = \begin{cases} 133.9^\circ \\ 163.8^\circ \end{cases} \quad \text{Im}[y_s(\theta)] = \begin{cases} -3.477 \\ +3.477 \end{cases} \quad \theta_{sp} = \begin{cases} -74^\circ + 180^\circ = 106^\circ \\ +74^\circ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

- Similar pentru adaptarea la ieșire

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

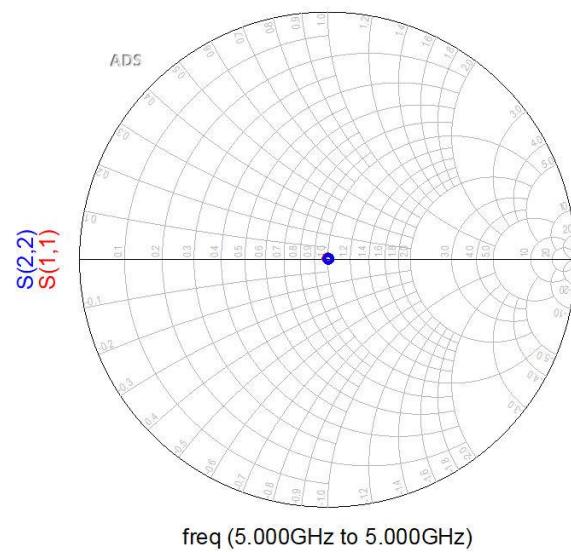
- În total există **4** posibilități de adaptare intrare/ieșire

ADS

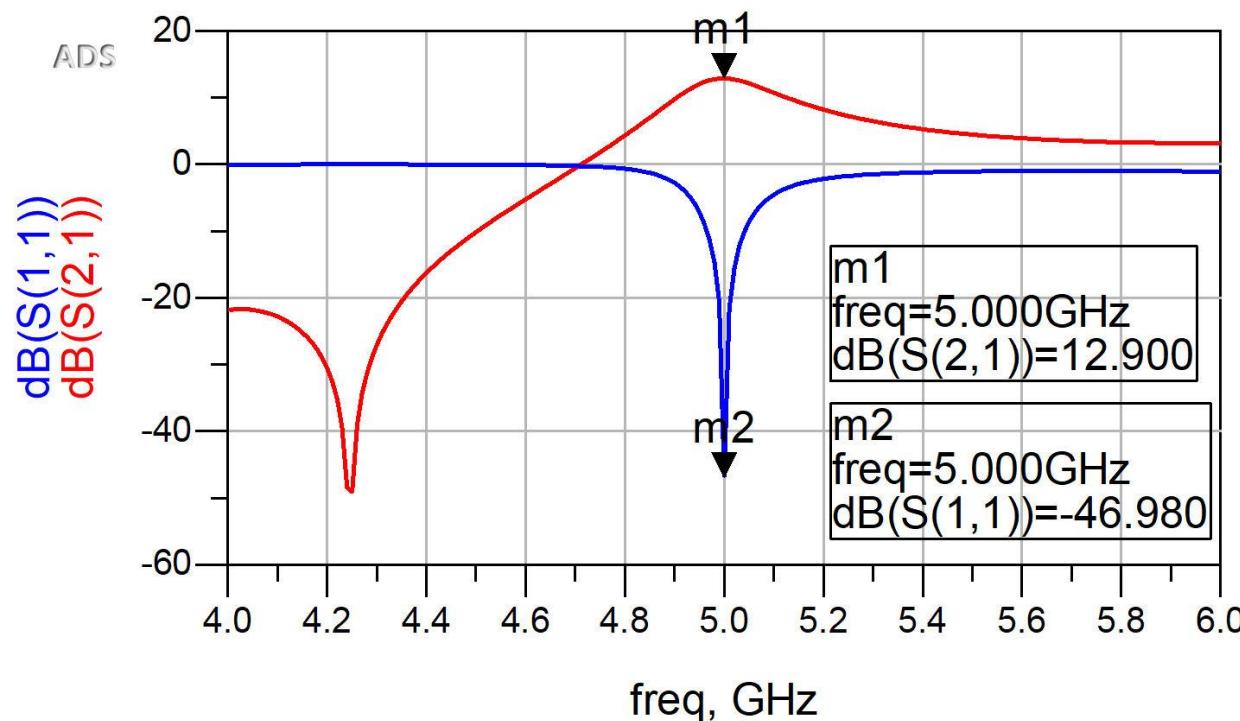
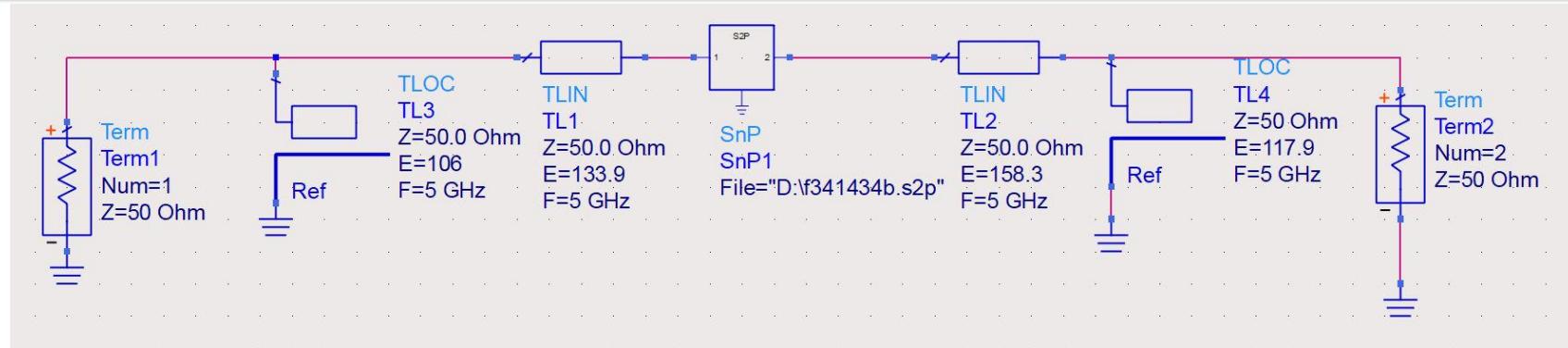


$$\text{Eqn GT} = 10 * \log(\text{mag}(S(2,1))^{\star 2})$$

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



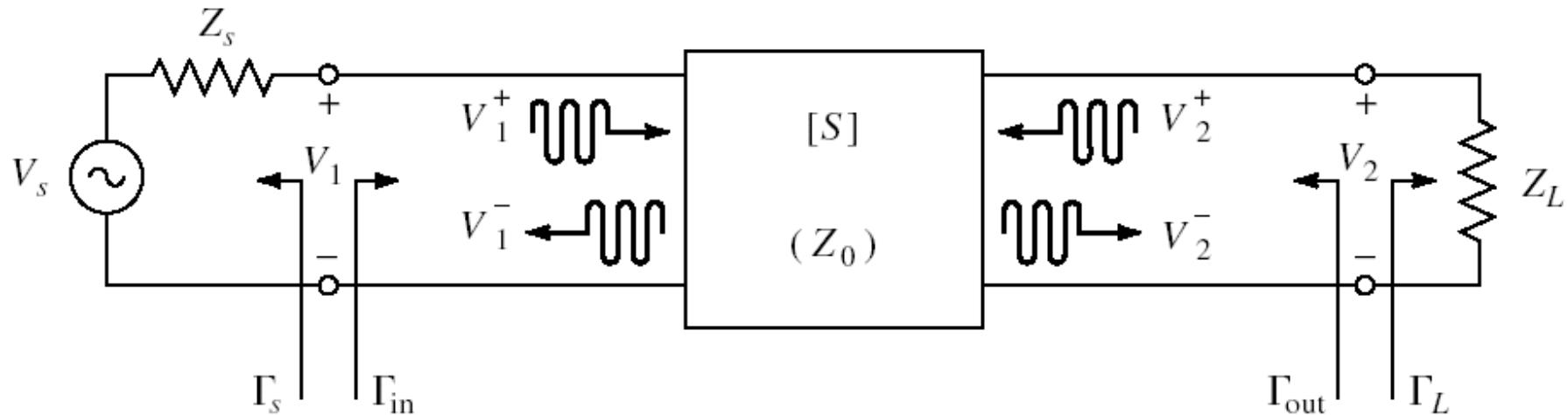
ADS



Amplificatoare de microunde

Proiectare pentru castig impus

Cuadripol Amplifier



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

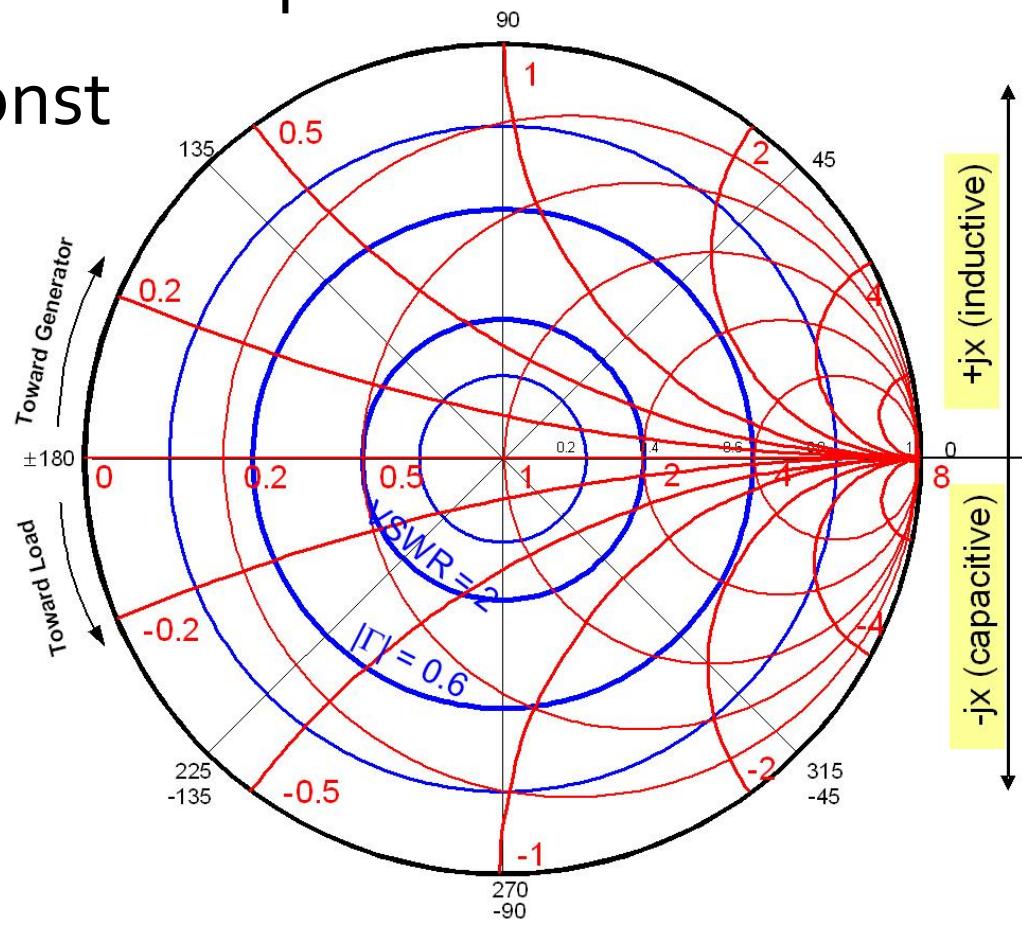
Proiectare pentru castig impus

- 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 ($L_3 + C_{10}$)
 - 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
- $VSWR = \text{const} \rightarrow \Gamma = \text{const}$

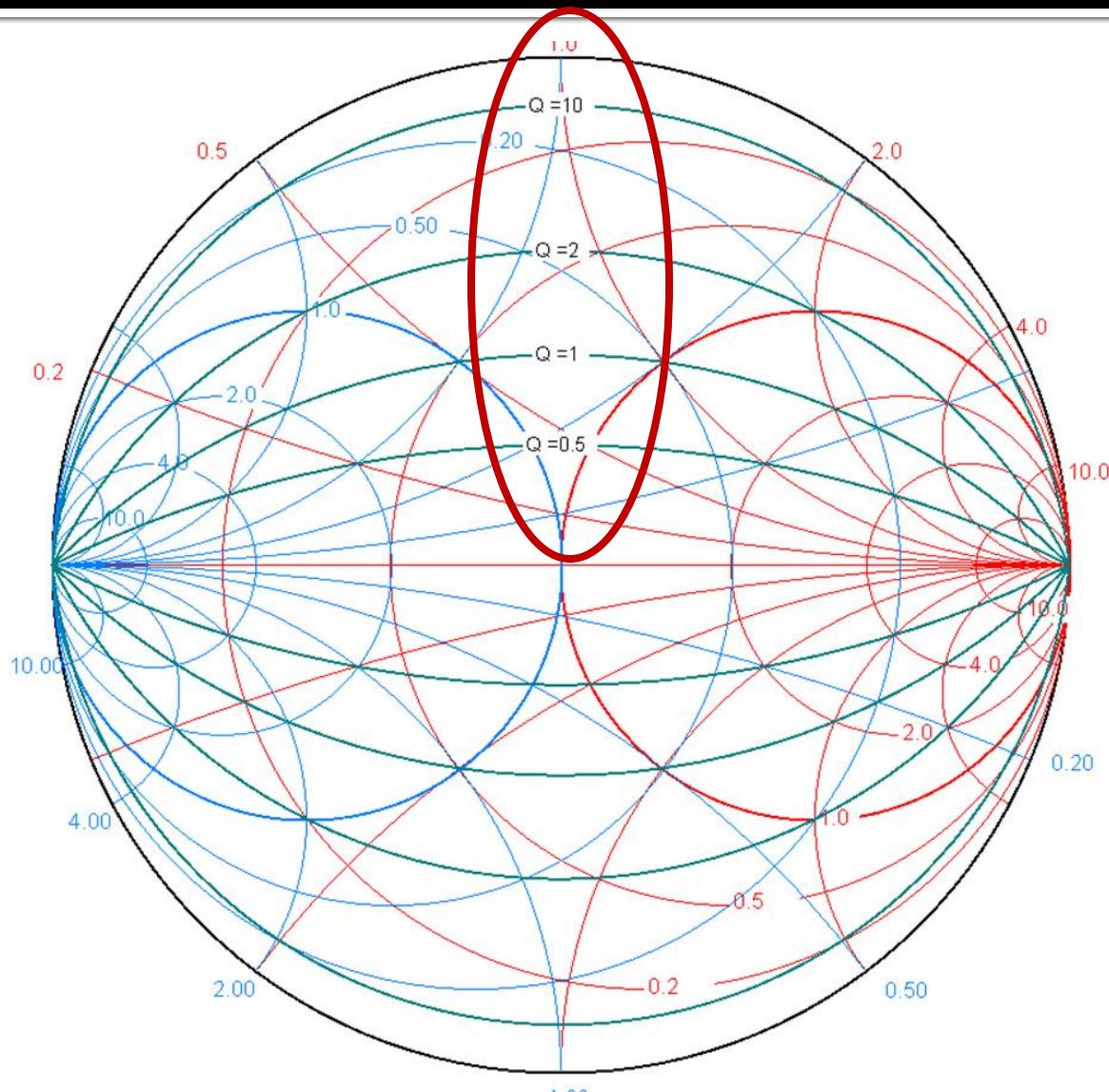
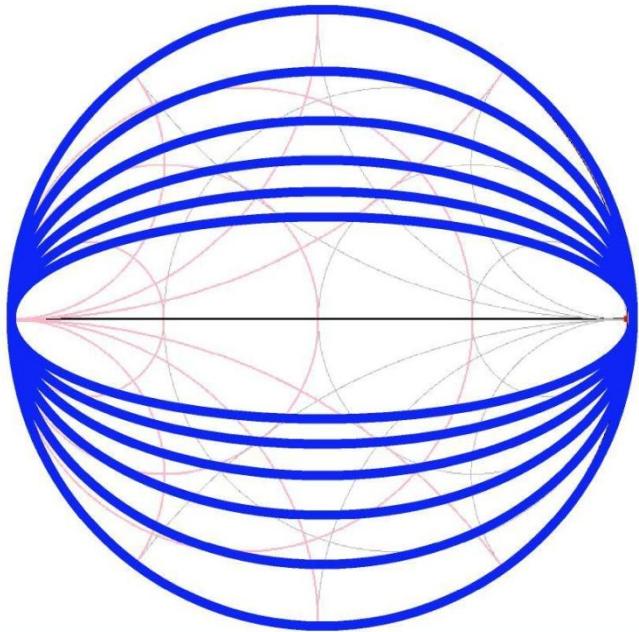
$$VSWR = \frac{V_{\max}}{V_{\min}} = \frac{1+|\Gamma|}{1-|\Gamma|}$$



Cercuri de factor de calitate constant

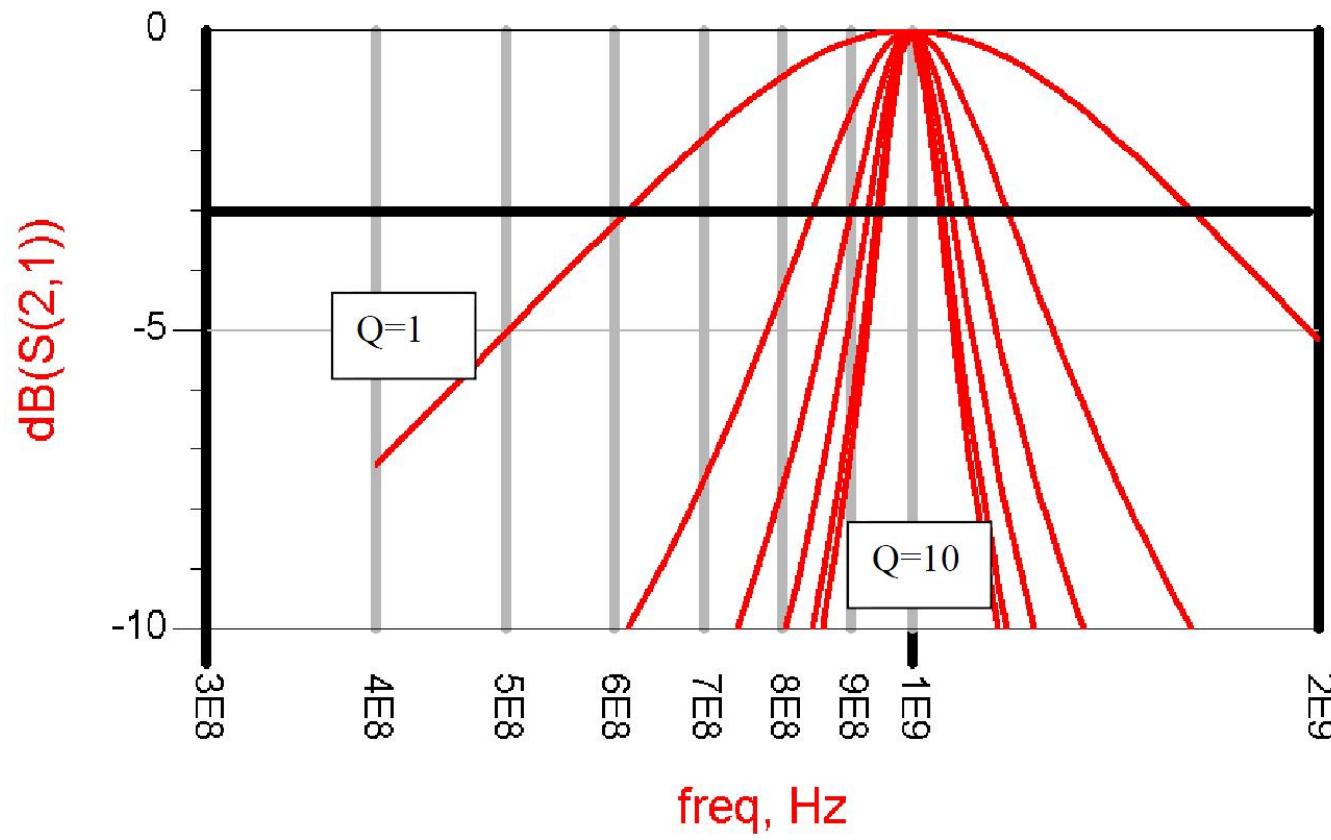
- Diagrama Smith

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



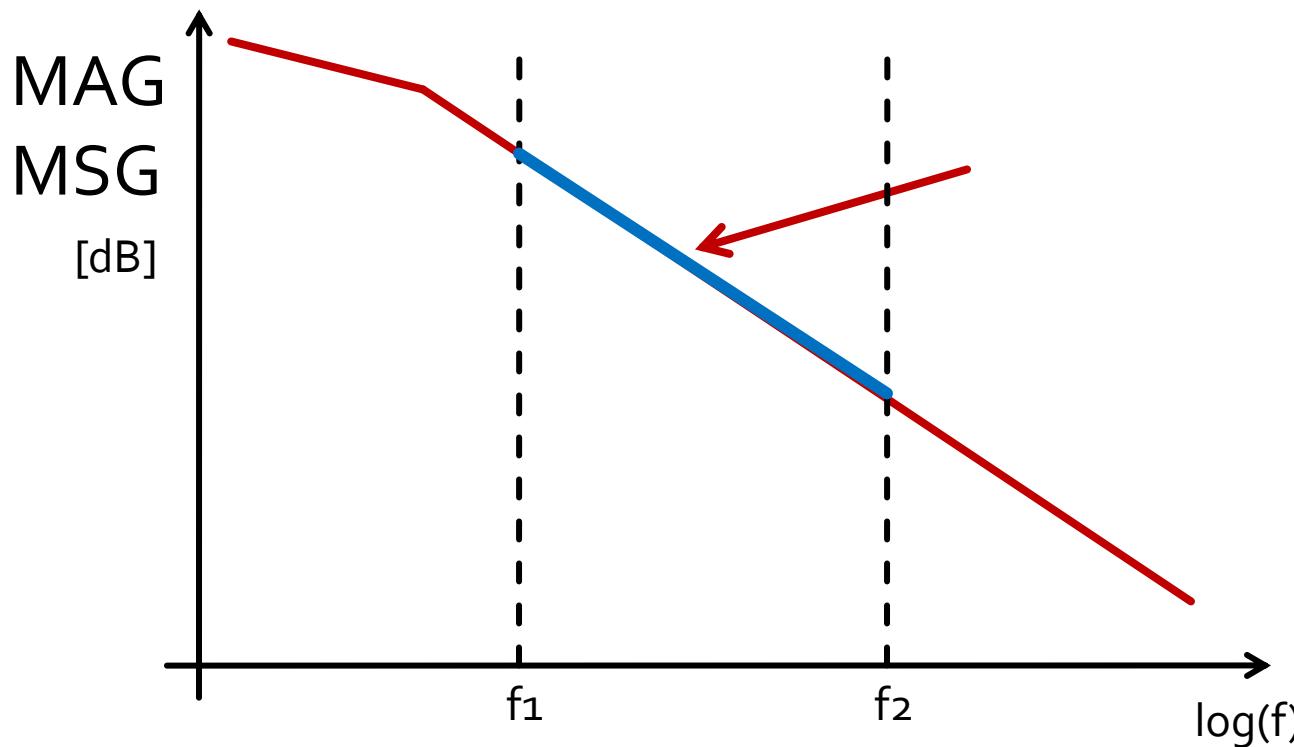
Factor de calitate - banda

- Factor de calitate ridicat echivalent cu banda ingusta



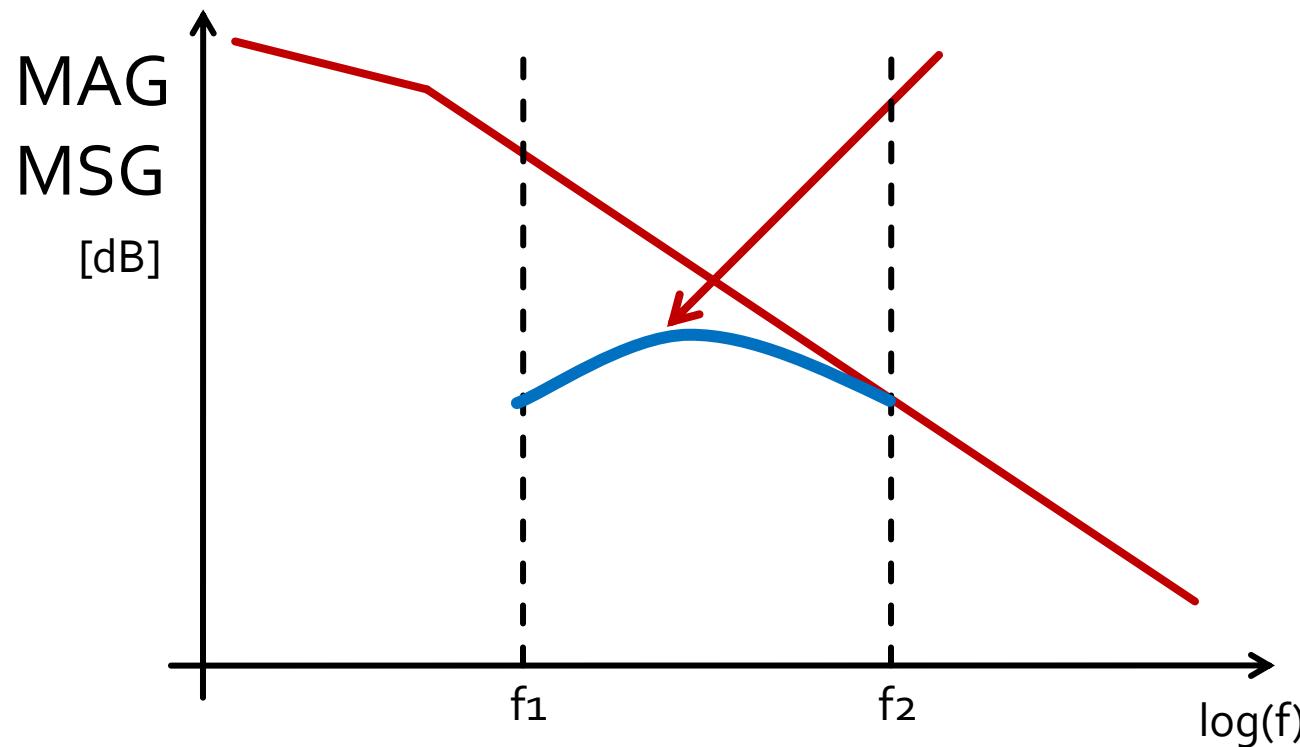
Amplificator de banda largă

- 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

$$S_{12} \approx 0$$

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

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

- 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

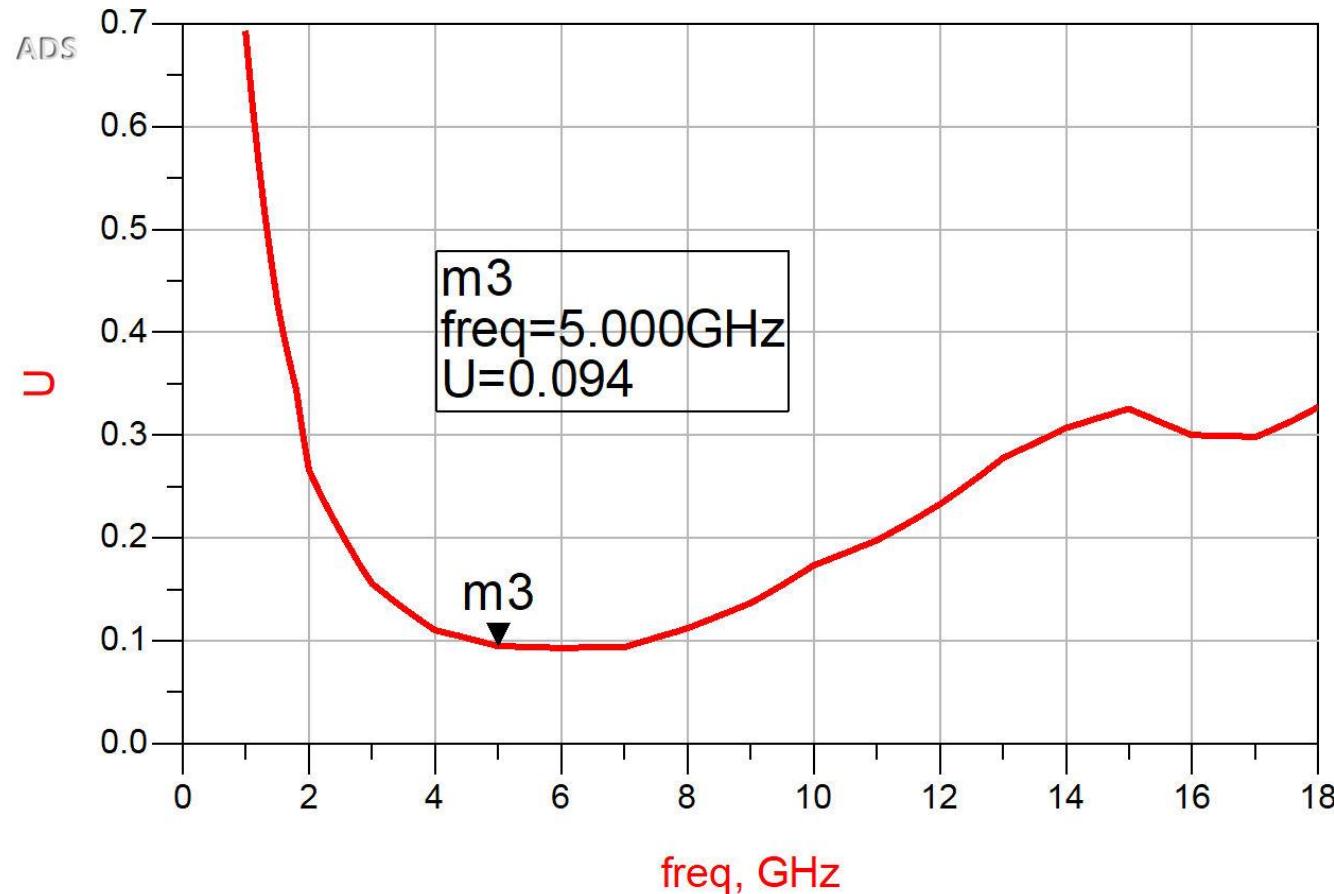
- ATF-34143 at $V_{ds}=3V$ $I_d=20mA$.
- @5GHz
 - $S_{11} = 0.64 \angle 139^\circ$
 - $S_{12} = 0.119 \angle -21^\circ$
 - $S_{21} = 3.165 \angle 16^\circ$
 - $S_{22} = 0.22 \angle 146^\circ$

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

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

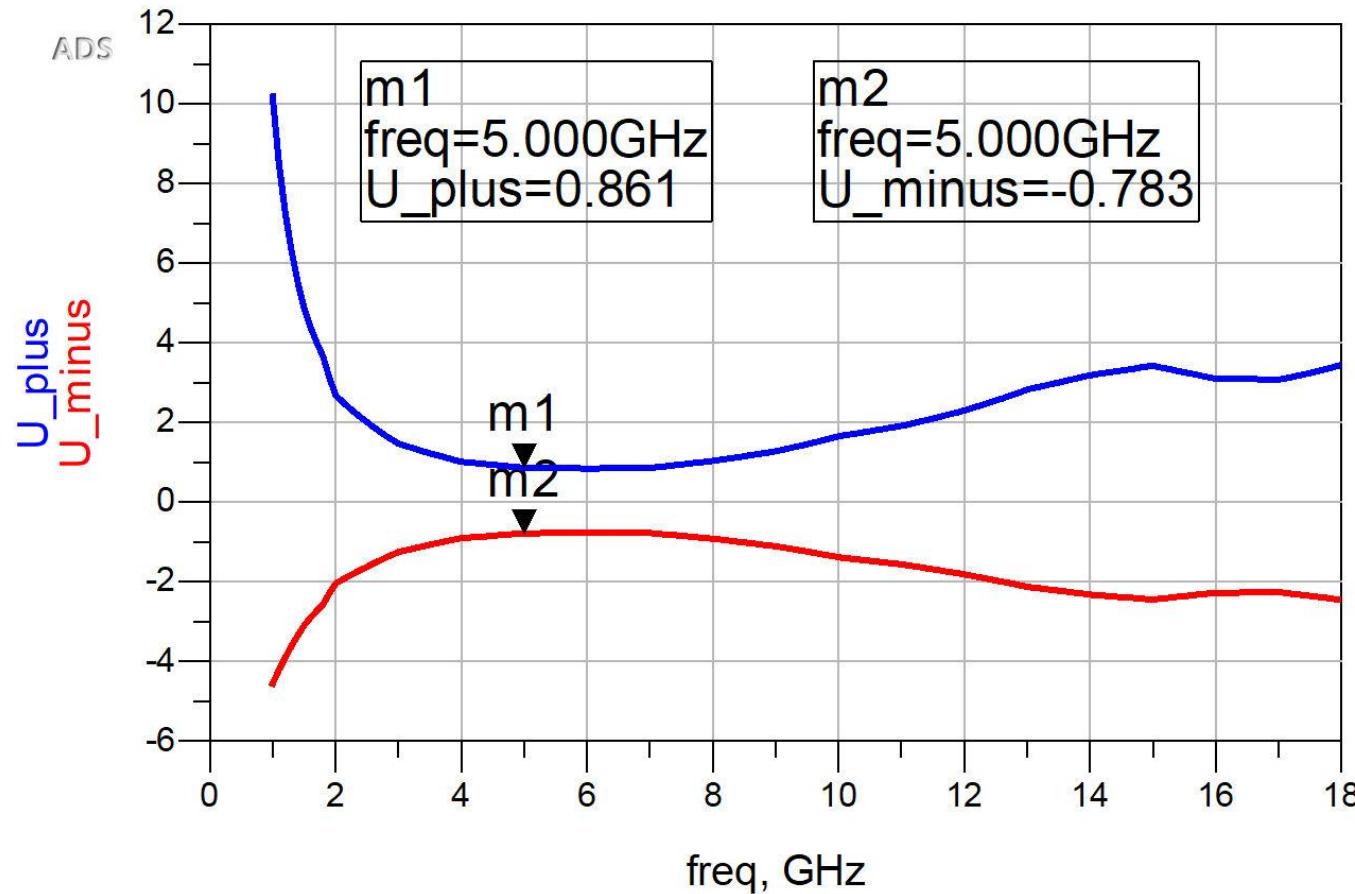
Exemplu

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

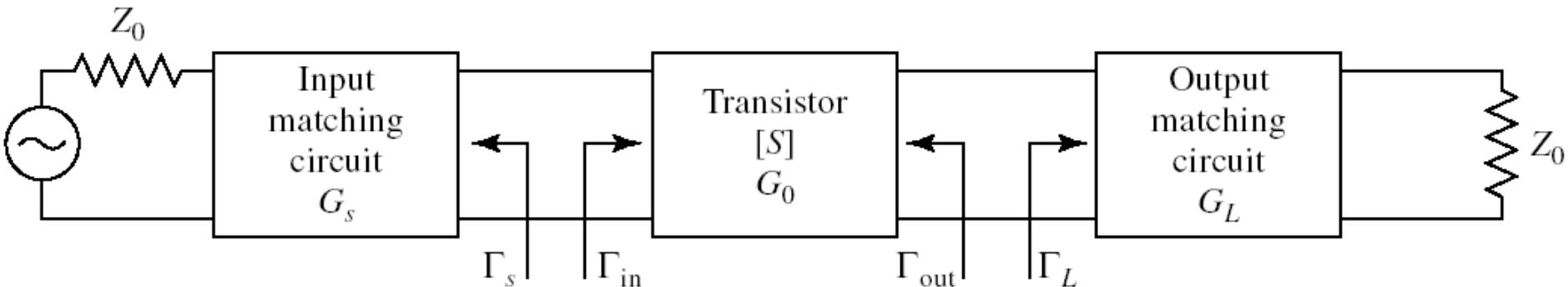


Exemplu

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



Proiectare pentru castig impus



- Daca ipoteza tranzistorului unilateral este justificata:

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

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

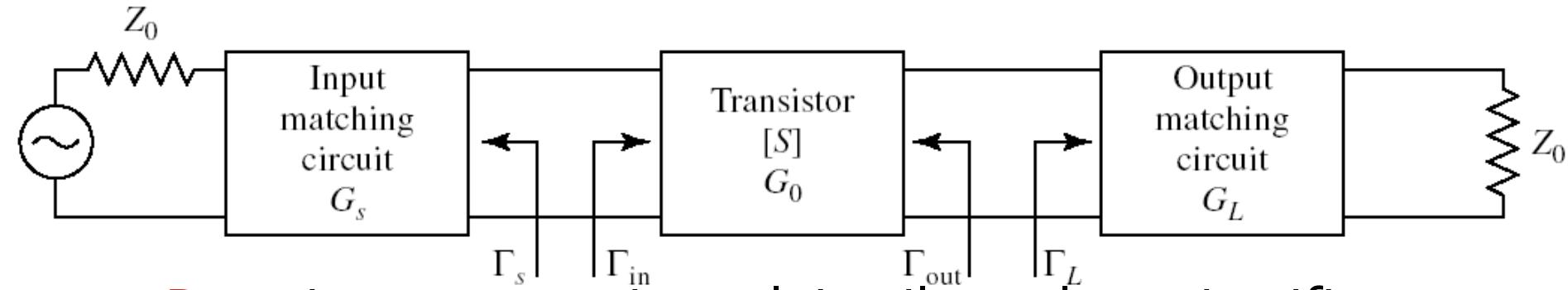
$$G_s = G_s(\Gamma_s)$$

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

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

$$G_L = G_L(\Gamma_L)$$

Proiectare pentru castig impus

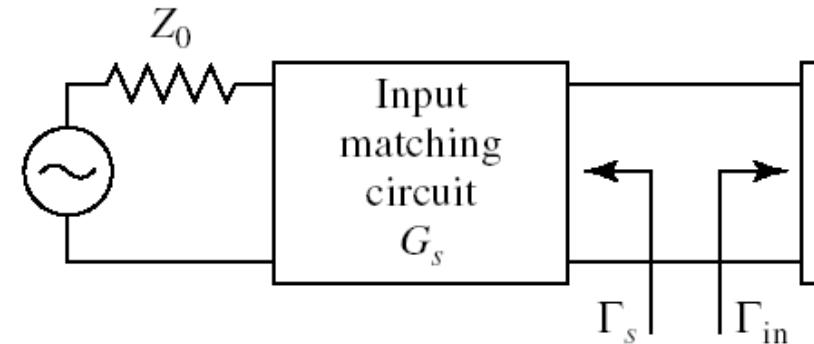


- **Daca** ipoteza tranzistorului unilateral este justificata:
 - castigul adaugat prin adaptare mai buna la intrare **nu** depinde de adaptarea la iesire $G_s = G_s(\Gamma_s)$
 - castigul adaugat prin adaptare mai buna la iesire **nu** depinde de adaptarea la intrare $G_L = G_L(\Gamma_L)$
- Adaptarile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

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

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

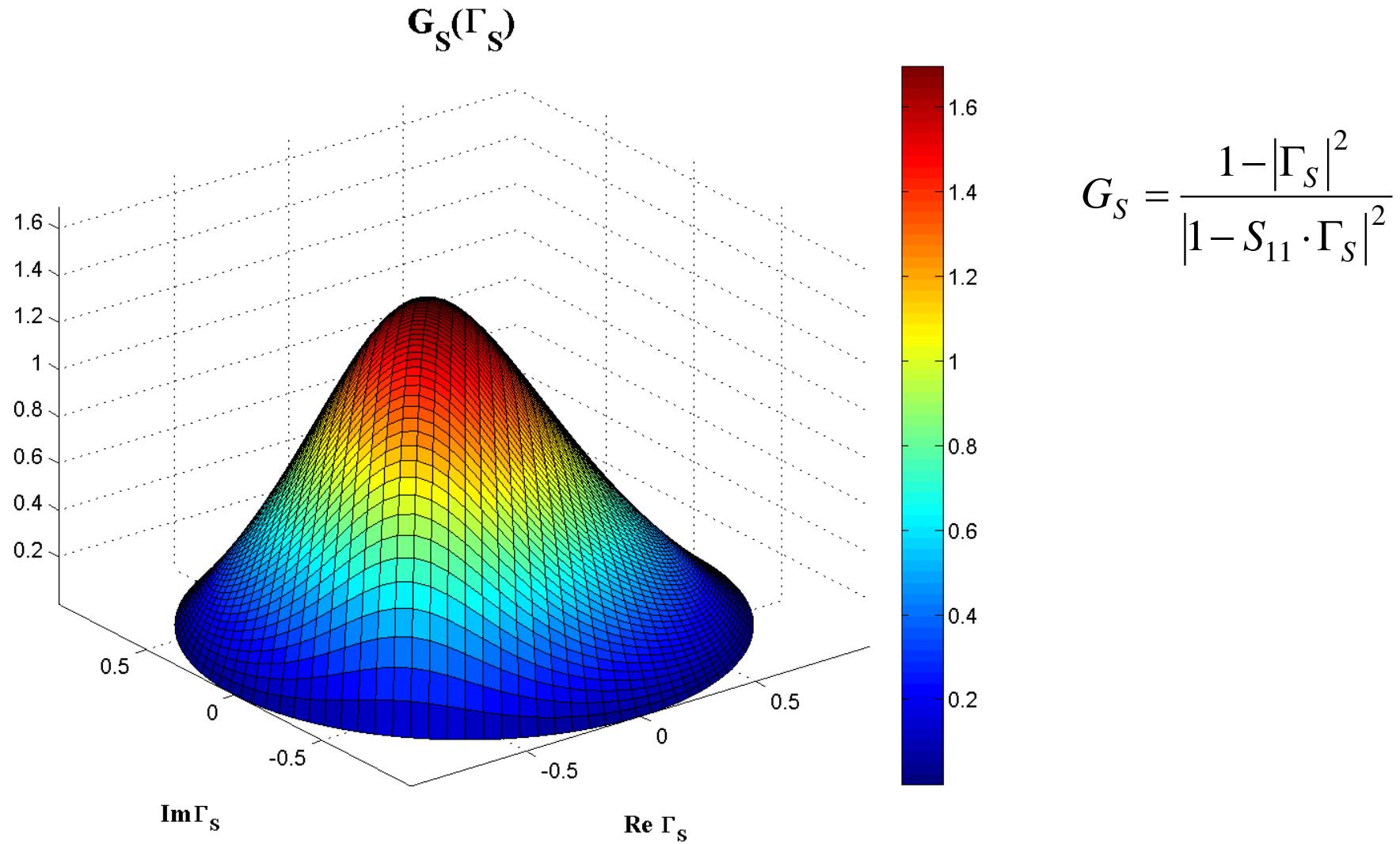
$$-0.783 \text{ dB} < G_T[\text{dB}] - G_{TU}[\text{dB}] < 0.861 \text{ dB}$$

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

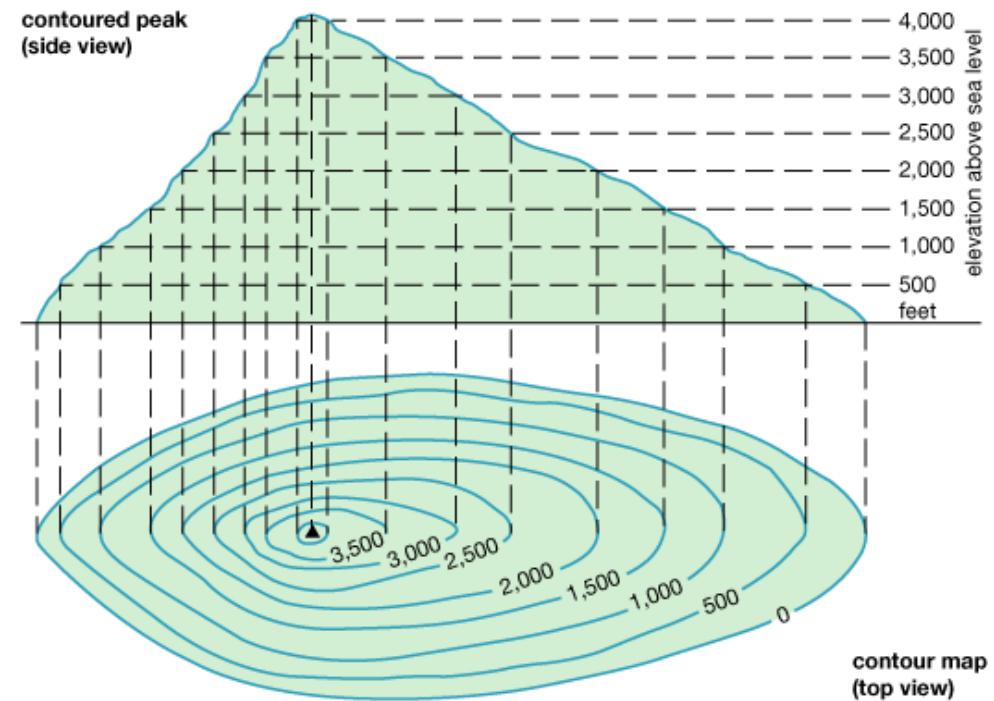
$$G_{TU \max} [\text{dB}] = 12.511 \text{ dB}$$

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

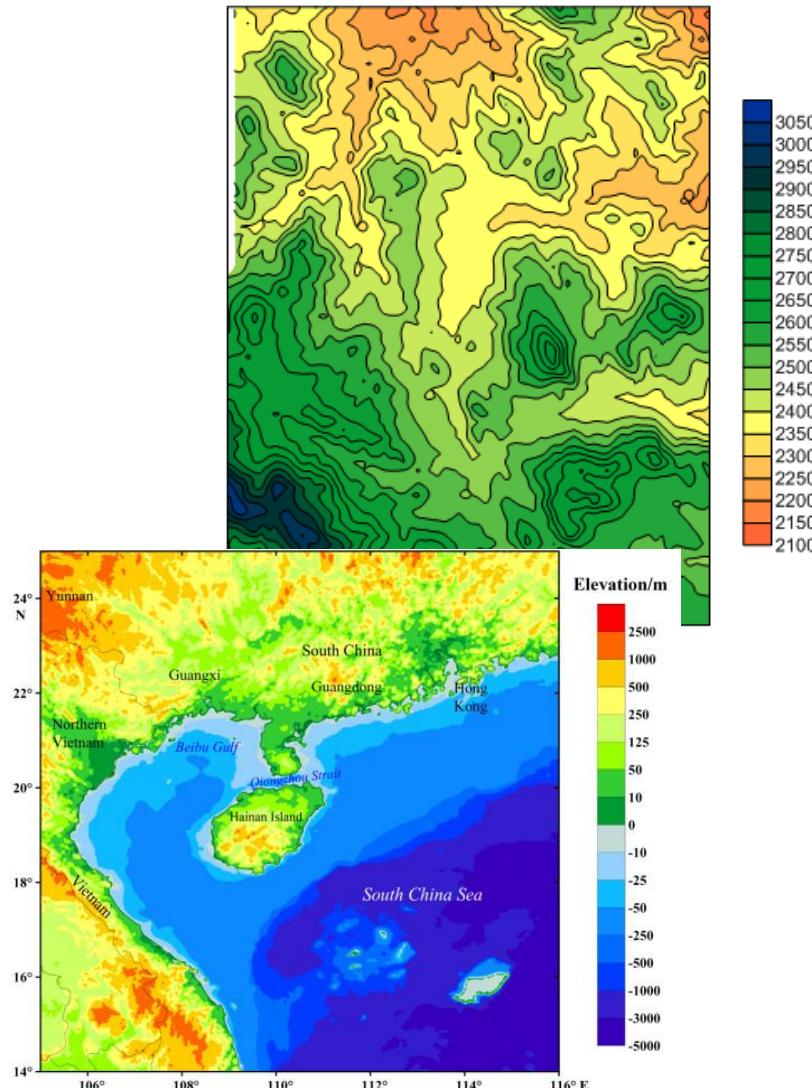
$\mathbf{G}_S(\Gamma_S)$



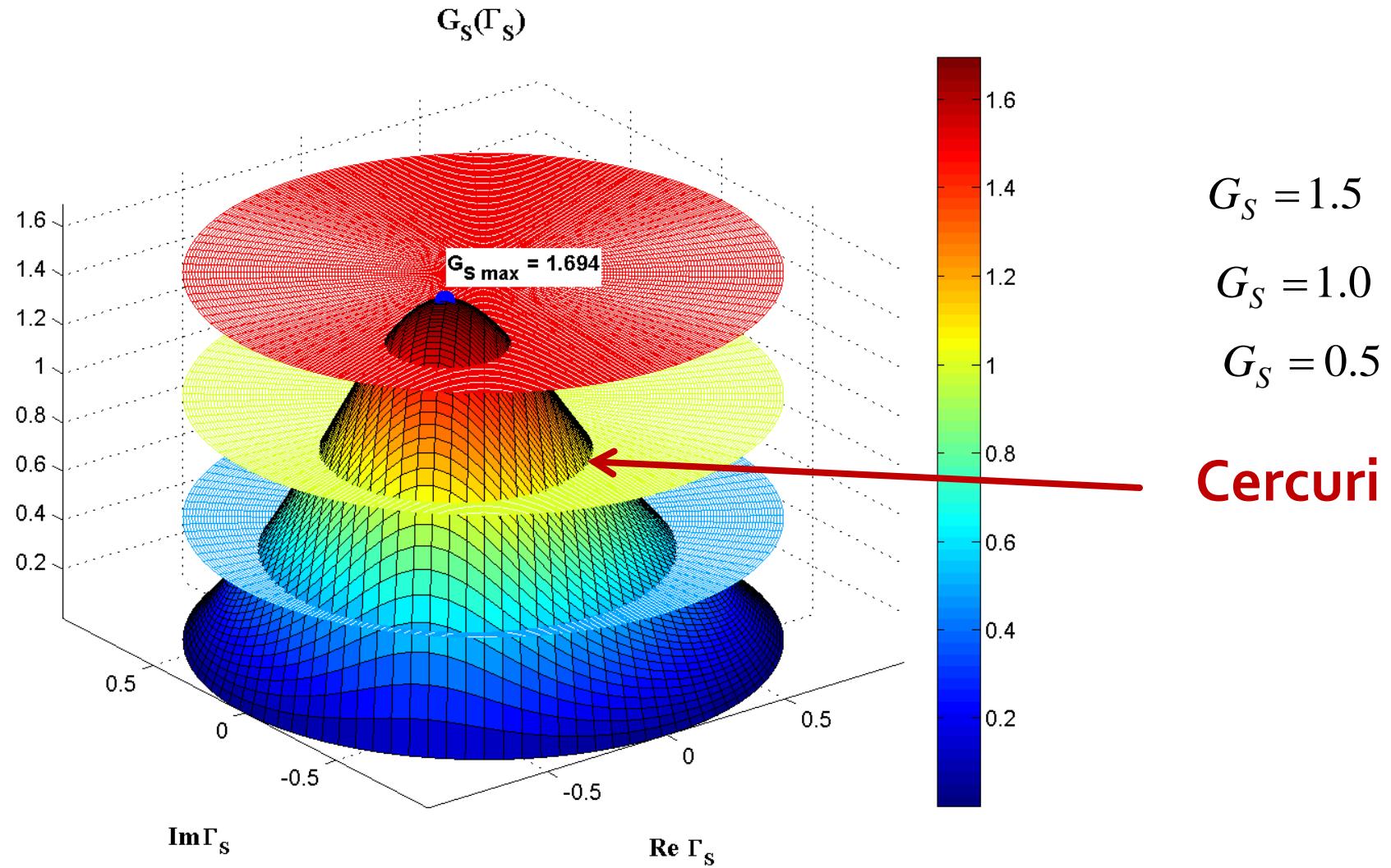
Contour map/lines



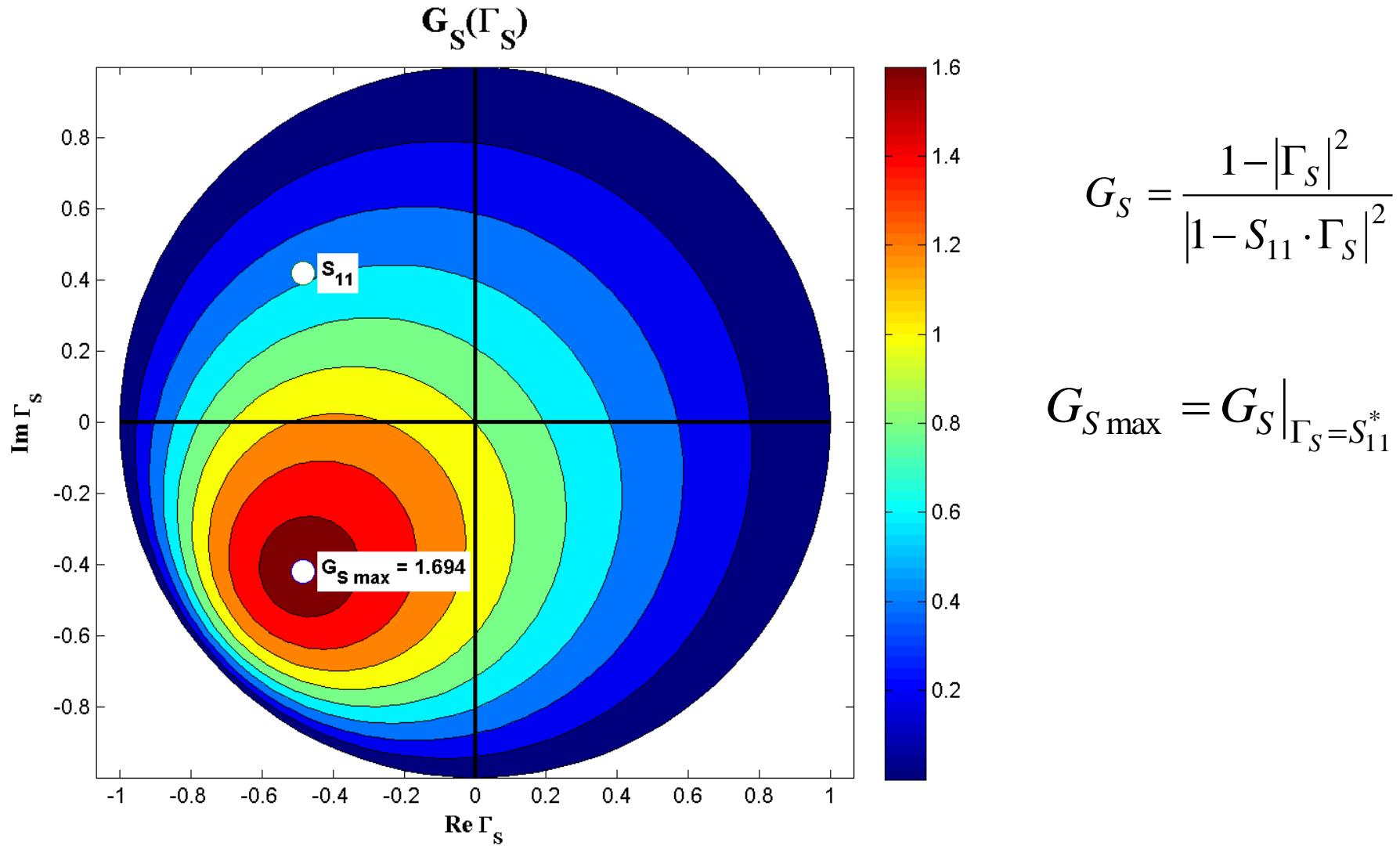
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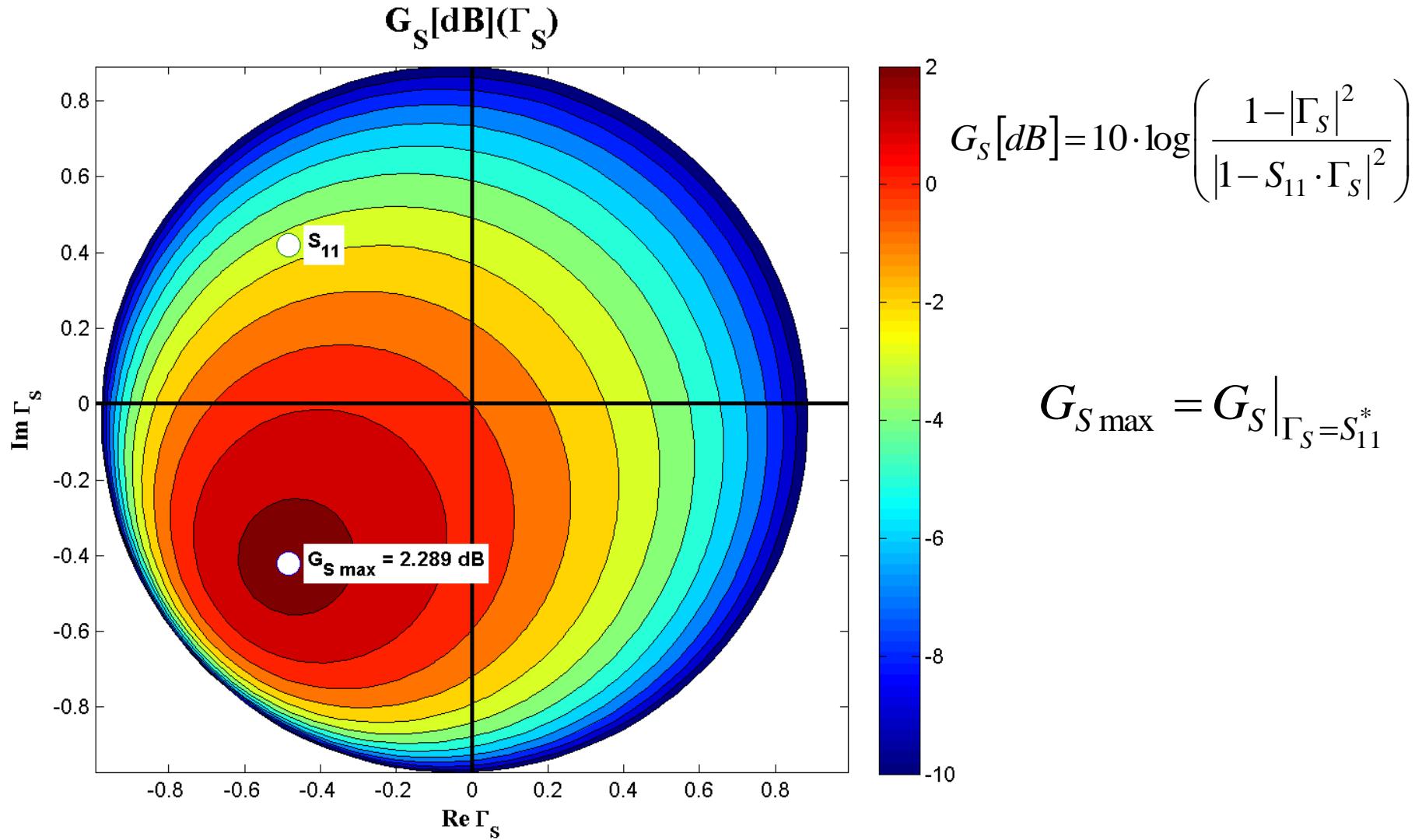
$G_S(\Gamma_S)$, nivel constant



$G_S(\Gamma_S)$, 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

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

Cercuri de castig constant la intrare

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

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

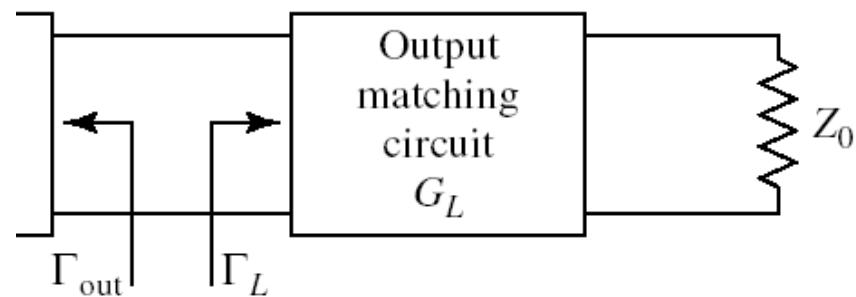
Cercuri de castig constant la intrare

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

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

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

Cercuri de castig constant la iesire



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

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

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

- Calcul similar

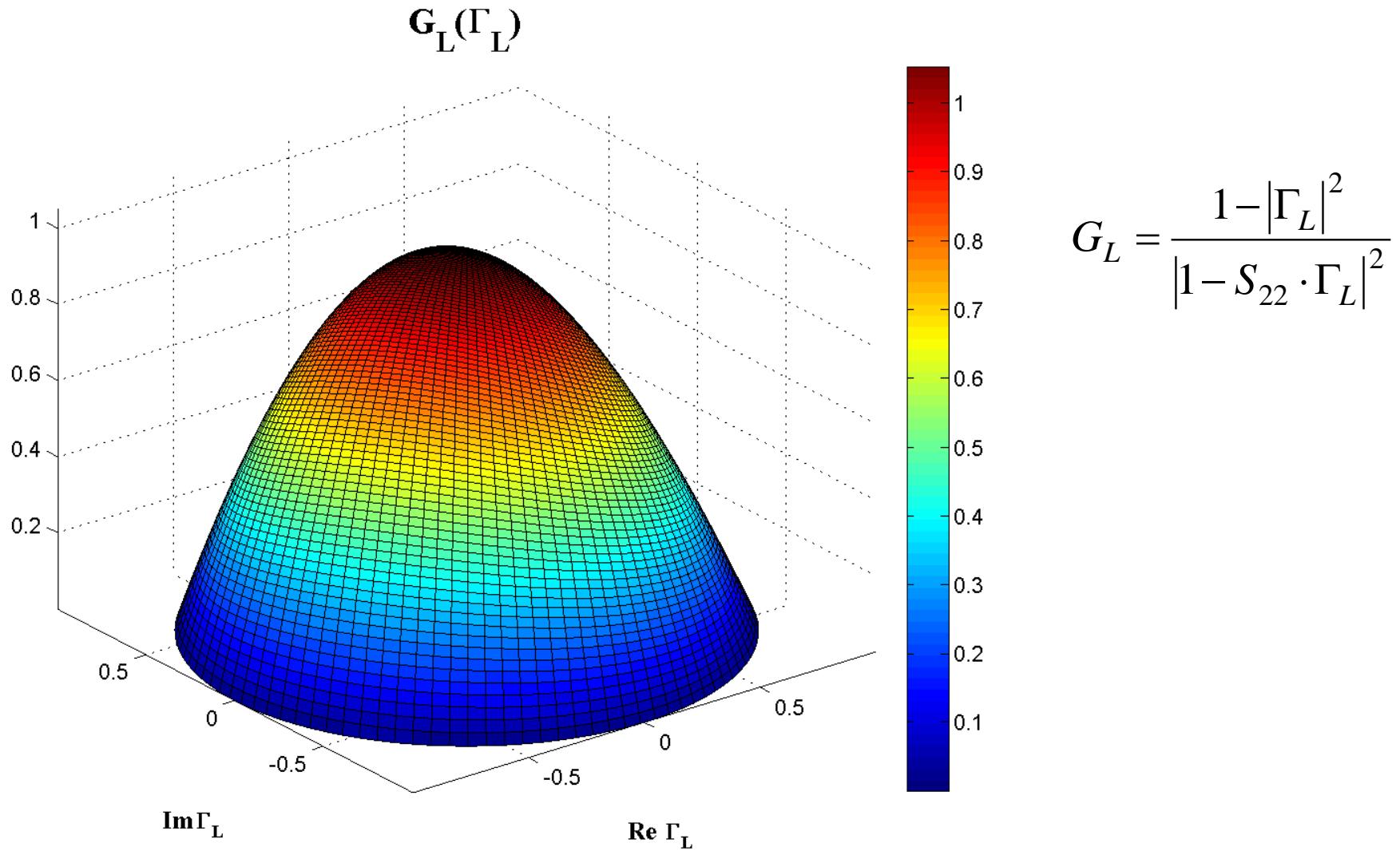
$$C_L = \frac{g_L \cdot S_{22}^*}{1 - (1 - g_L) \cdot |S_{22}|^2}$$

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

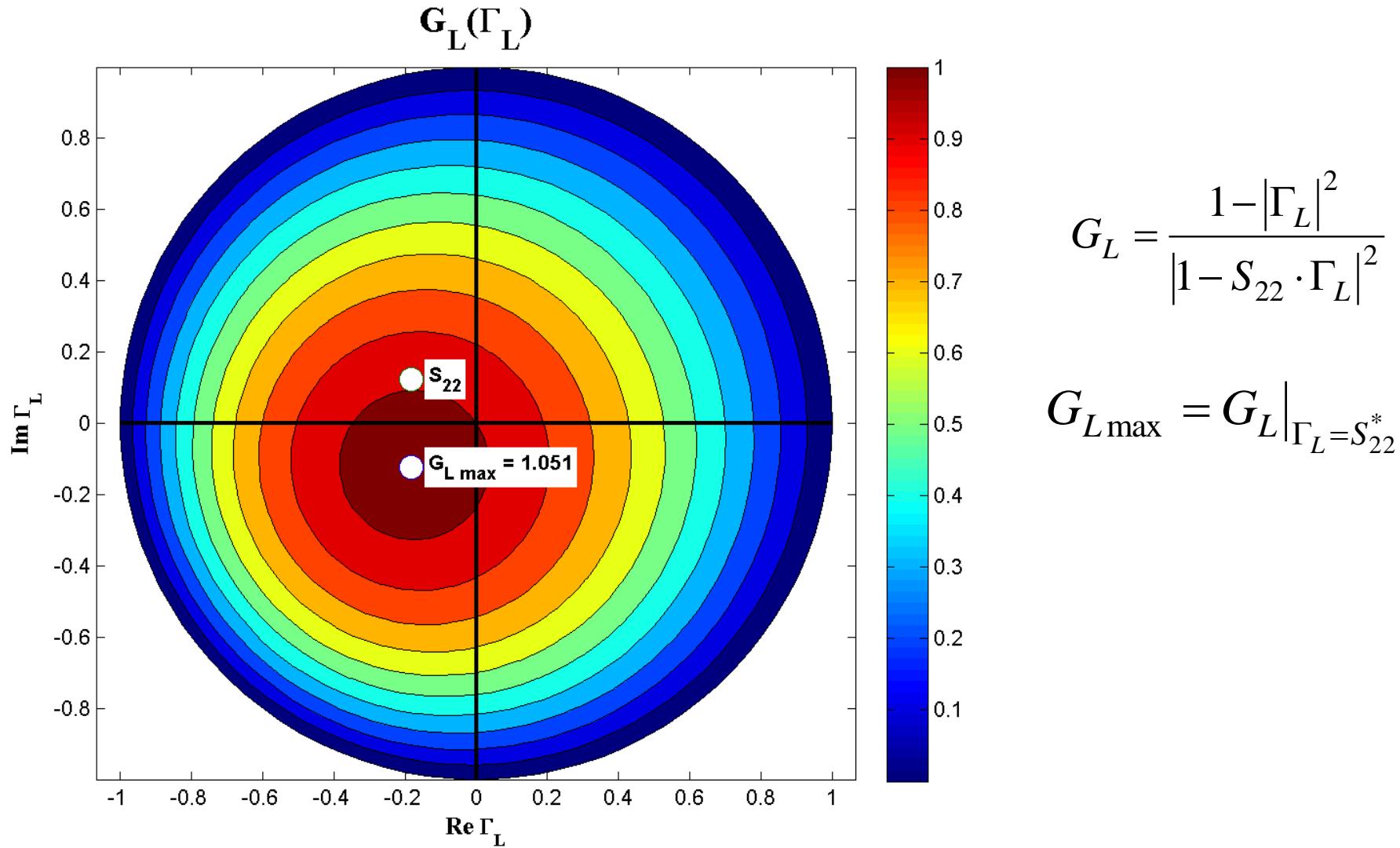
- Exemplu

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

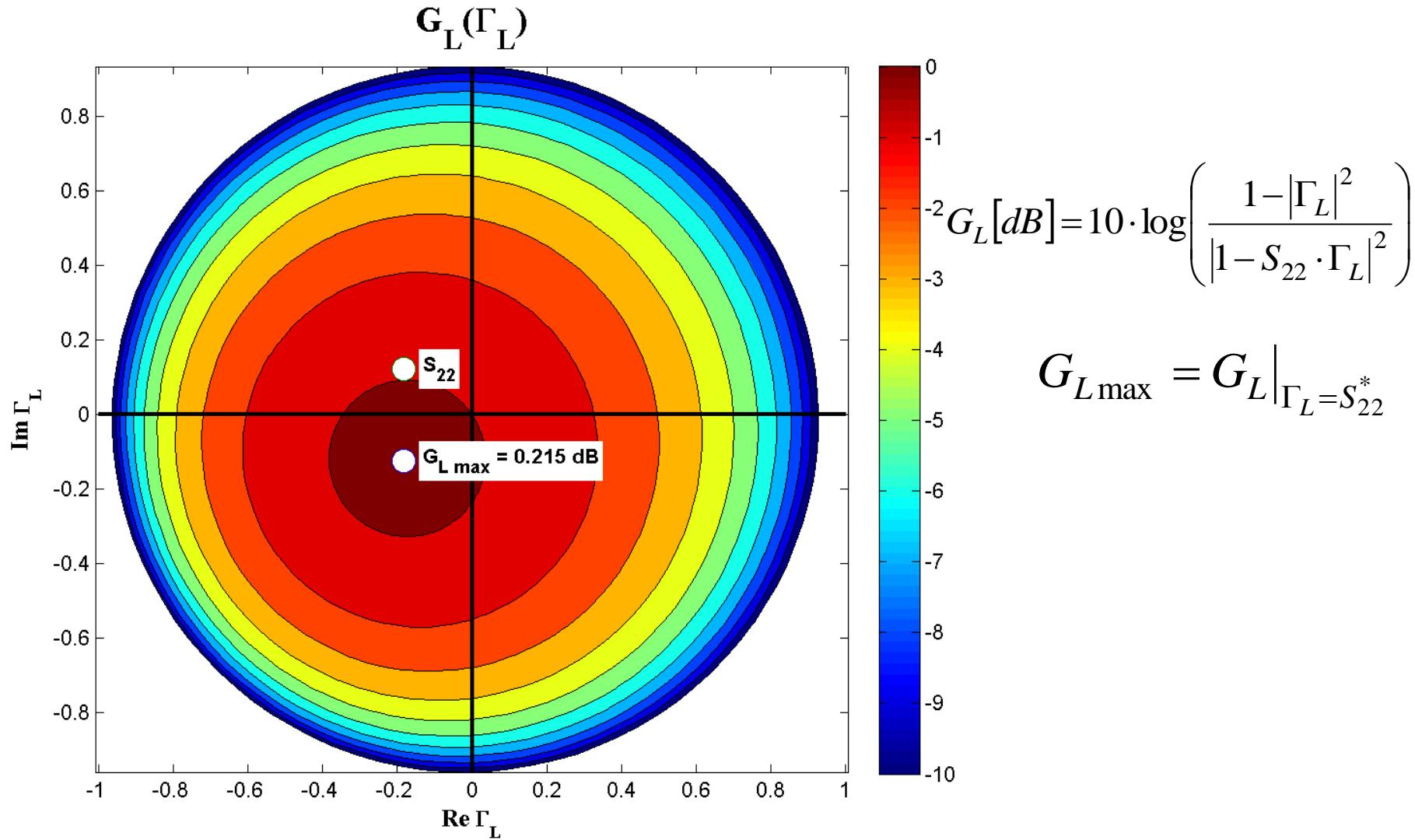
$\mathbf{G}_L(\Gamma_L)$



$G_L(\Gamma_L)$, diagrama de nível

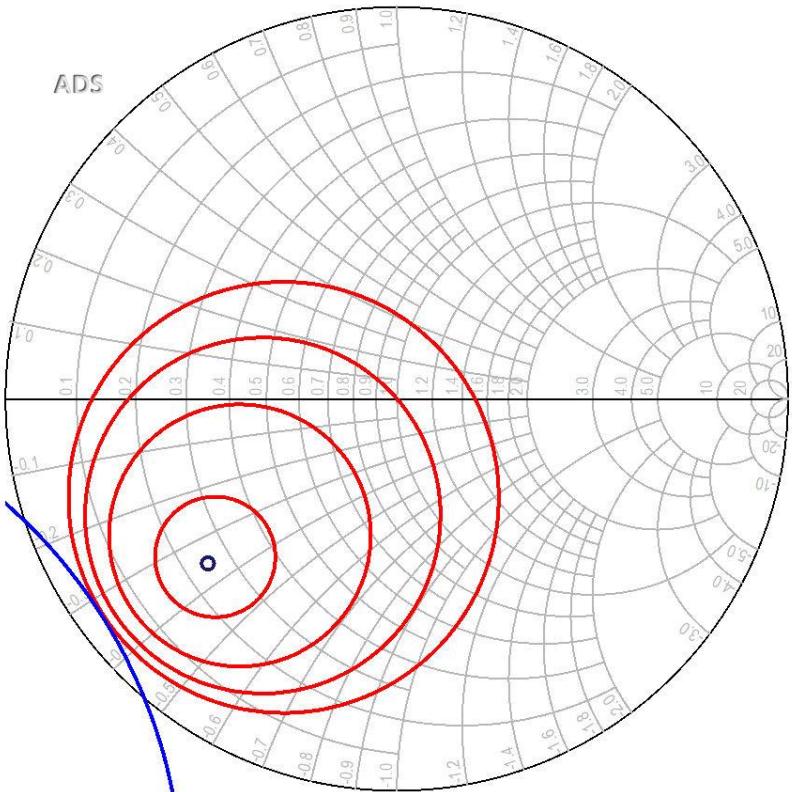


$G_L[\text{dB}](\Gamma_L)$, diagrama de nível

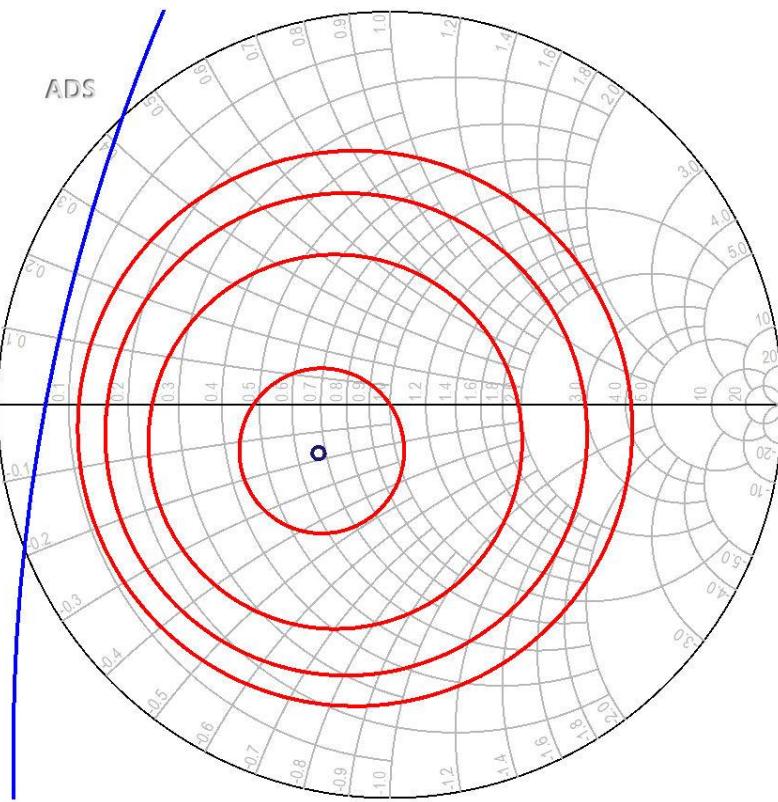


ADS

conj(S(1,1))
CSIN
CCCIN



conj(S(2,2))
CSOUT
CCCOUT



- Cerculile se reprezinta pentru valorile cerute in dB
- Este utila calcularea $G_{S\max}$ si $G_{L\max}$ anterior

Proiectare pentru castig impus

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

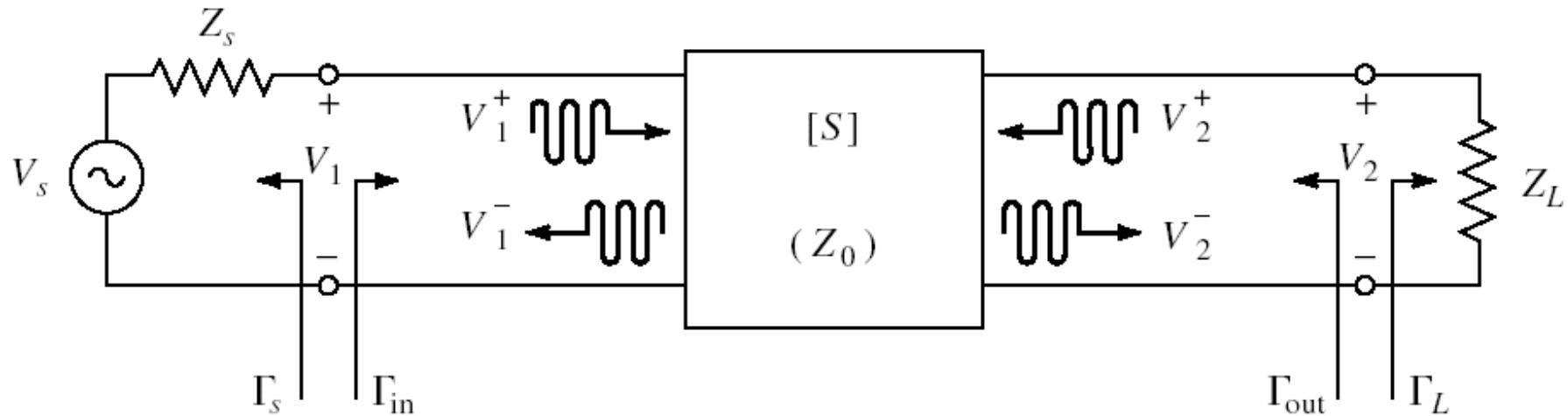
$$G_{dorit} [dB] = G_{S_dor} [dB] + G_0 [dB] + G_{L_dor} [dB]$$

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

Amplificatoare de microunde

Proiectare pentru zgomot redus

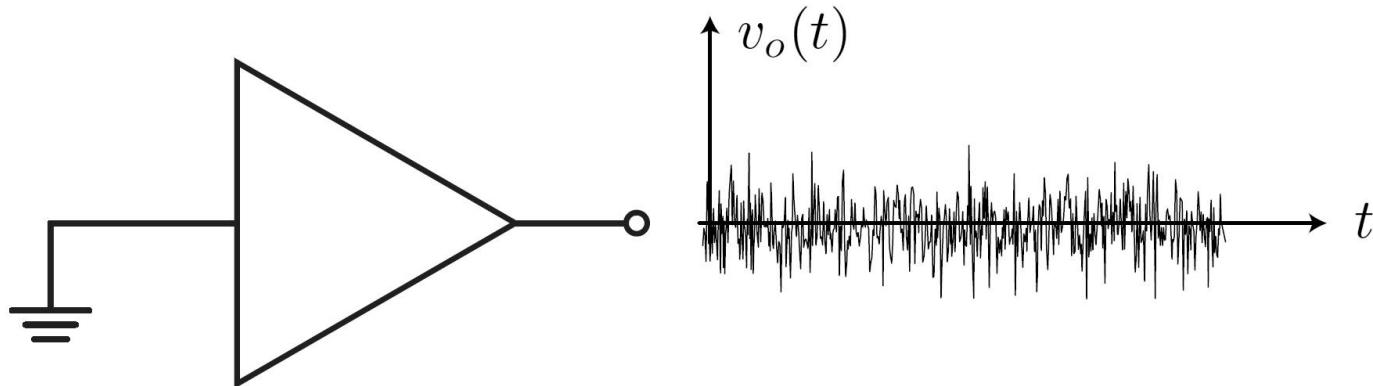
Cuadripol Amplifier



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

Zgomot

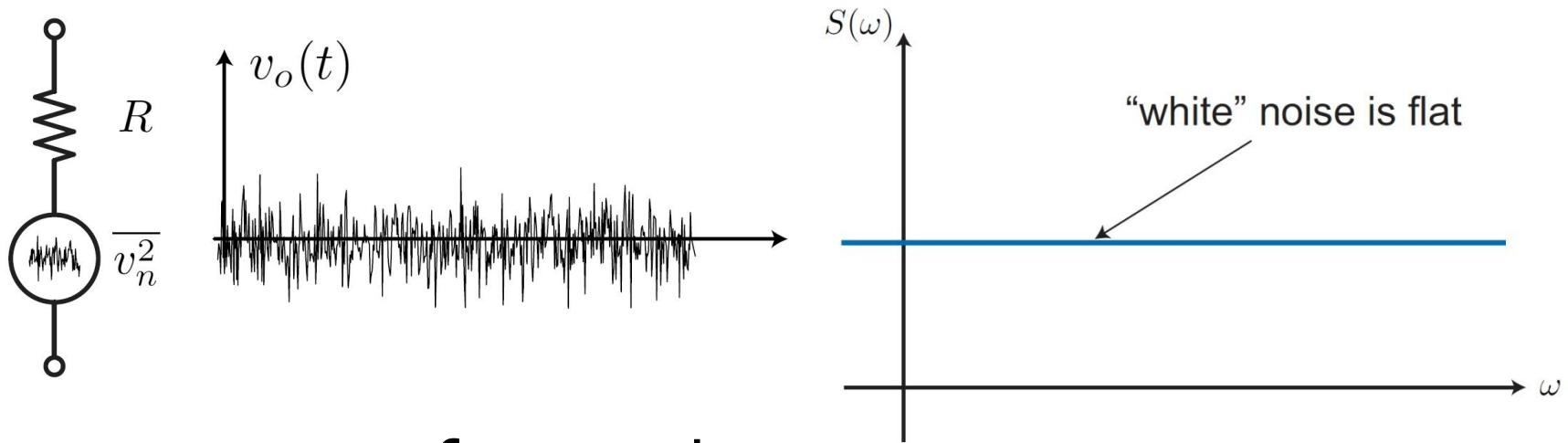
- Zgomot: variatii aleatorii ale semnalului



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

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

Zgomot



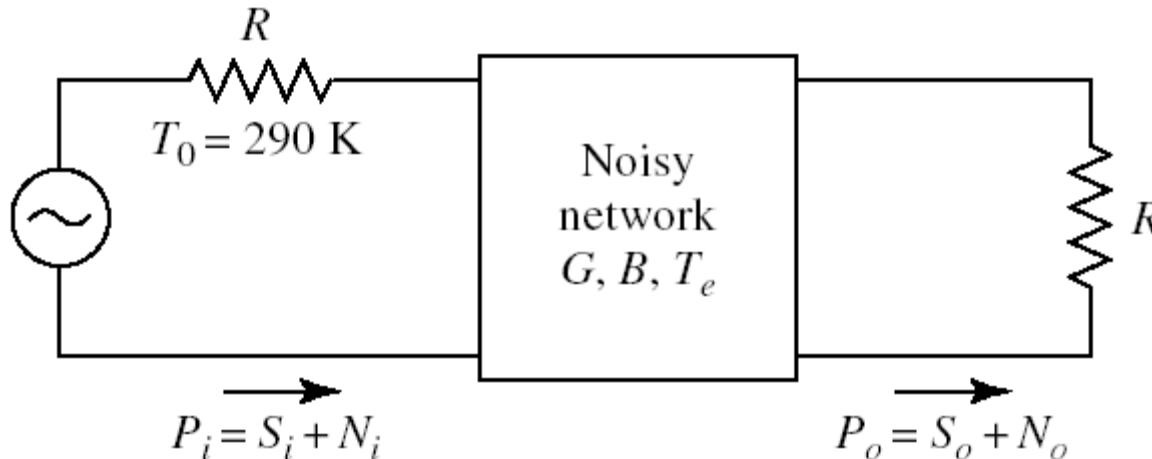
- tensiunea efectiva de zgomot

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

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

$$P_n = kTB$$

Factor de zgomot

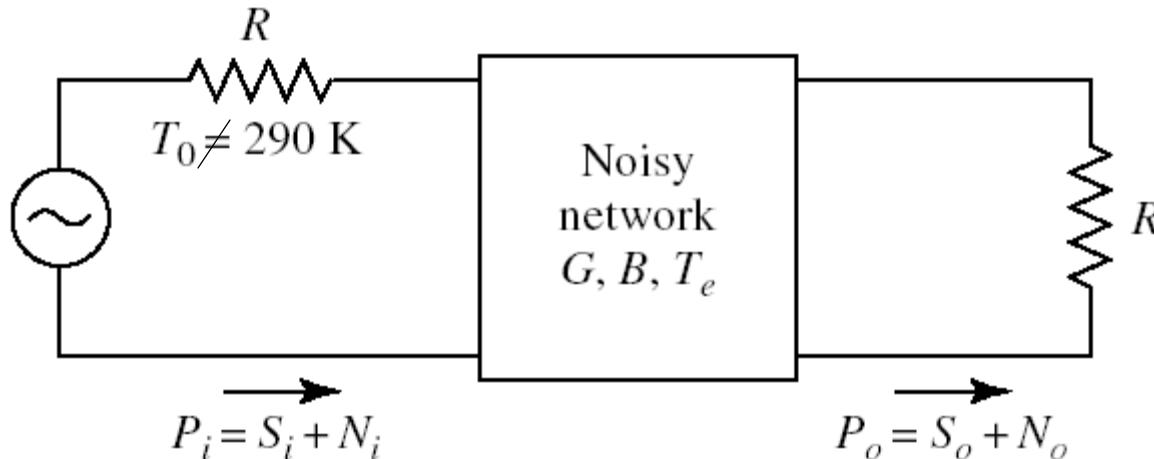


- Factorul de zgomot F caracterizeaza degradarea raportului semnal/zgomot intre intrarea si iesirea unei componente, cand la intrare se aplica o putere de zgomot de referinta ($T_0 = 290\text{K}$)

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

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

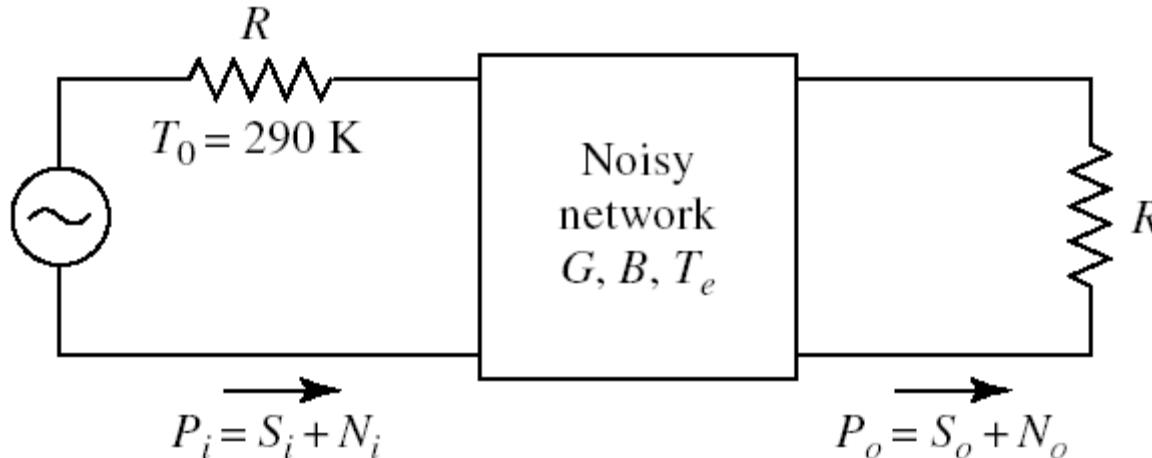
Factor de zgomot



- 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

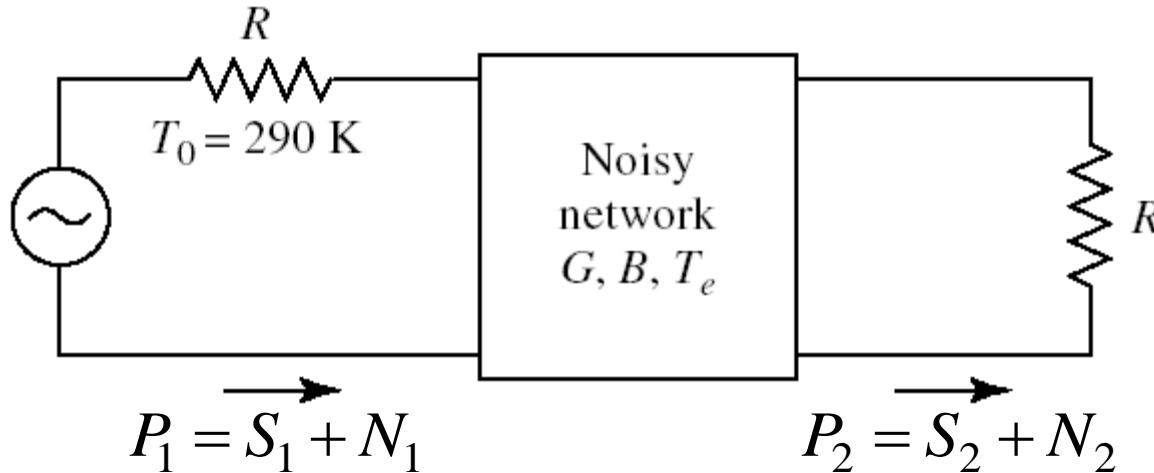
$$F \neq \left. \frac{S_i/N_i}{S_o/N_o} \right|_{T_0 \neq 290K}$$

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



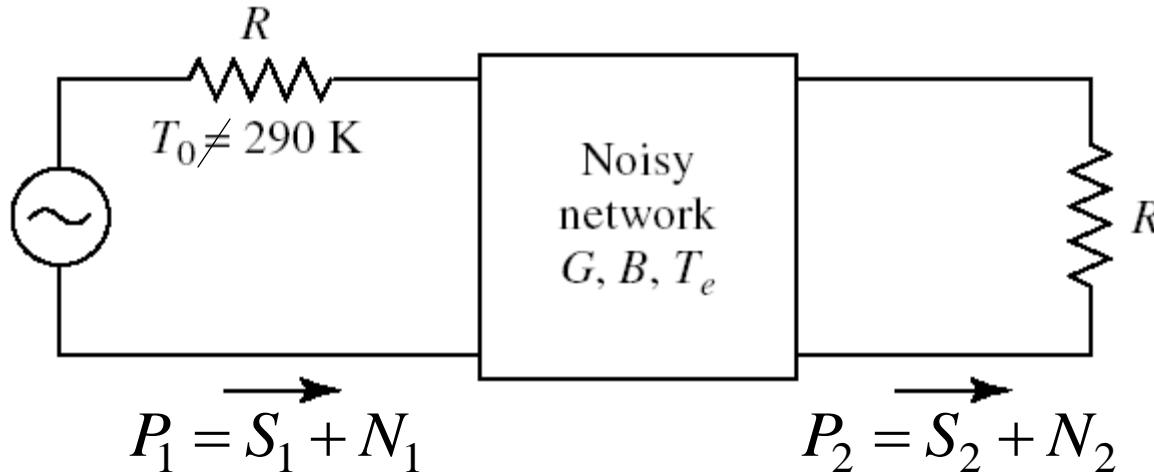
- Estimarea puterii de zgomot adaugate se poate face plecand de la definitia factorului de zgomot:

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

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

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

Factor de zgomot

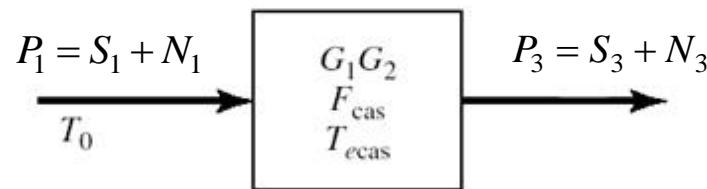
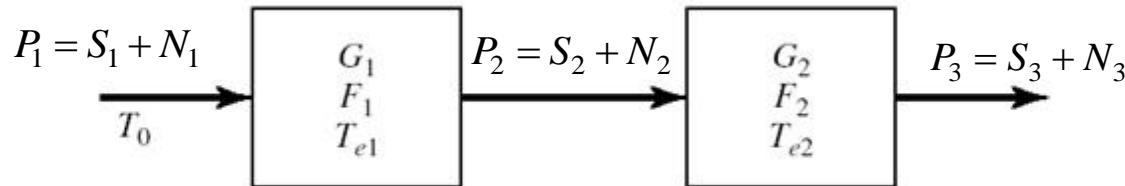


- Se identifica cele două termeni:
 - zgomotul de intrare amplificat
 - zgomotul adăugat intern
- Pentru o situație în care la intrare nu am zgomotul de referință ($N_1 \neq N_0$)

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

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

Factor de zgomot al circuitelor cascade



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

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

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

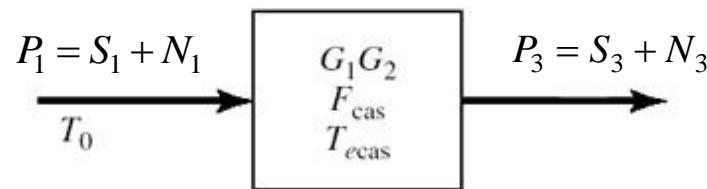
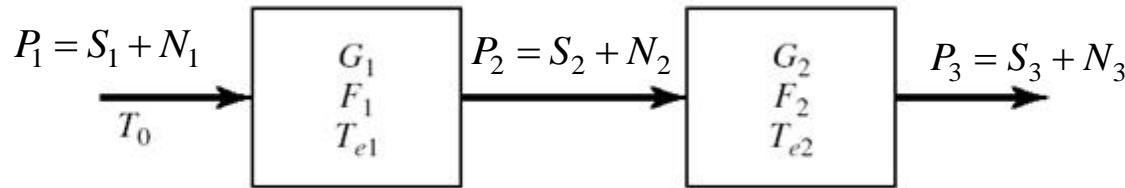
$$N_3 = N_1 \cdot G_{cas} + (F_{cas} - 1) \cdot N_0 \cdot G_{cas}$$



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

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

Factor de zgomot al circuitelor cascade



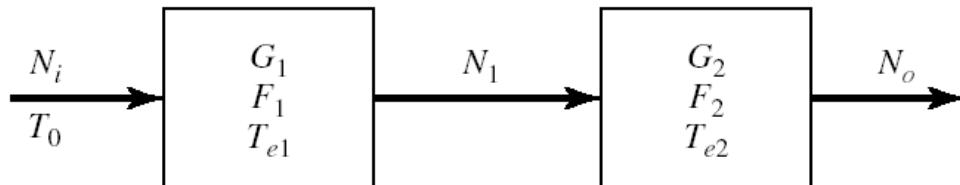
$$N_3 = N_1 \cdot G_1 \cdot G_2 + (F_1 - 1) \cdot N_0 \cdot G_1 \cdot G_2 + (F_2 - 1) \cdot N_0 \cdot G_2$$

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

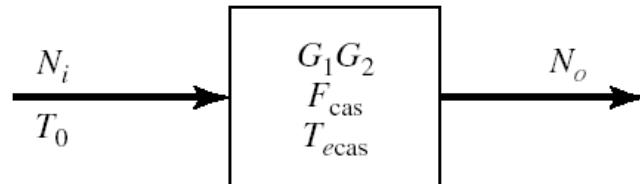
$$(F_1 - 1) \cdot N_0 \cdot G_1 \cdot G_2 + (F_2 - 1) \cdot N_0 \cdot G_2 = (F_{cas} - 1) \cdot N_0 \cdot G_1 \cdot G_2$$

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

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)

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

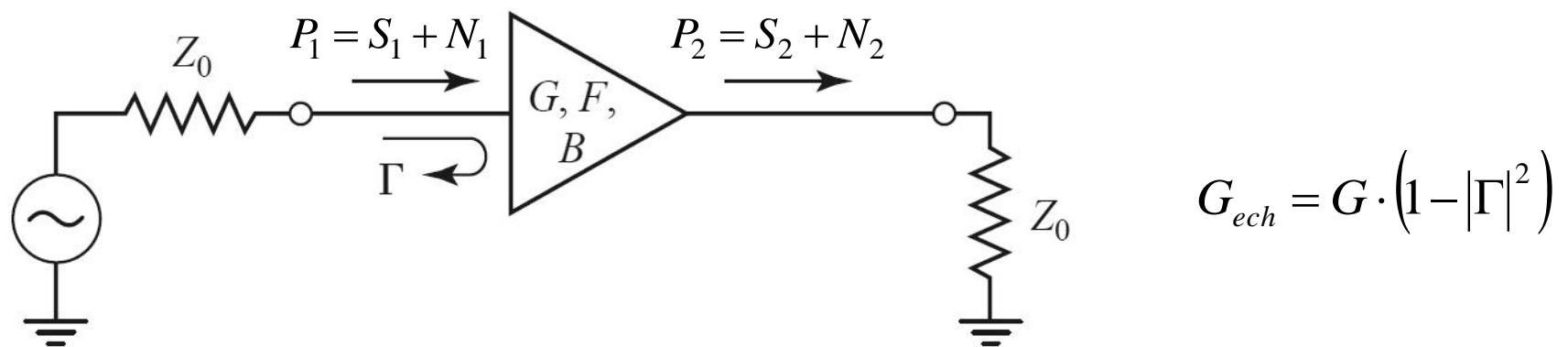
- Formula lui Friis, efecte:
 - in amplificatoare multietaj:
 - e esential ca primul etaj de amplificare sa fie nezgomotos, chiar cu sacrificarea in parte a castigului
 - urmatoarele etaje pot fi optimizate pentru castig
 - pentru un singur amplificator:
 - la intrare e important sa introducem elemente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

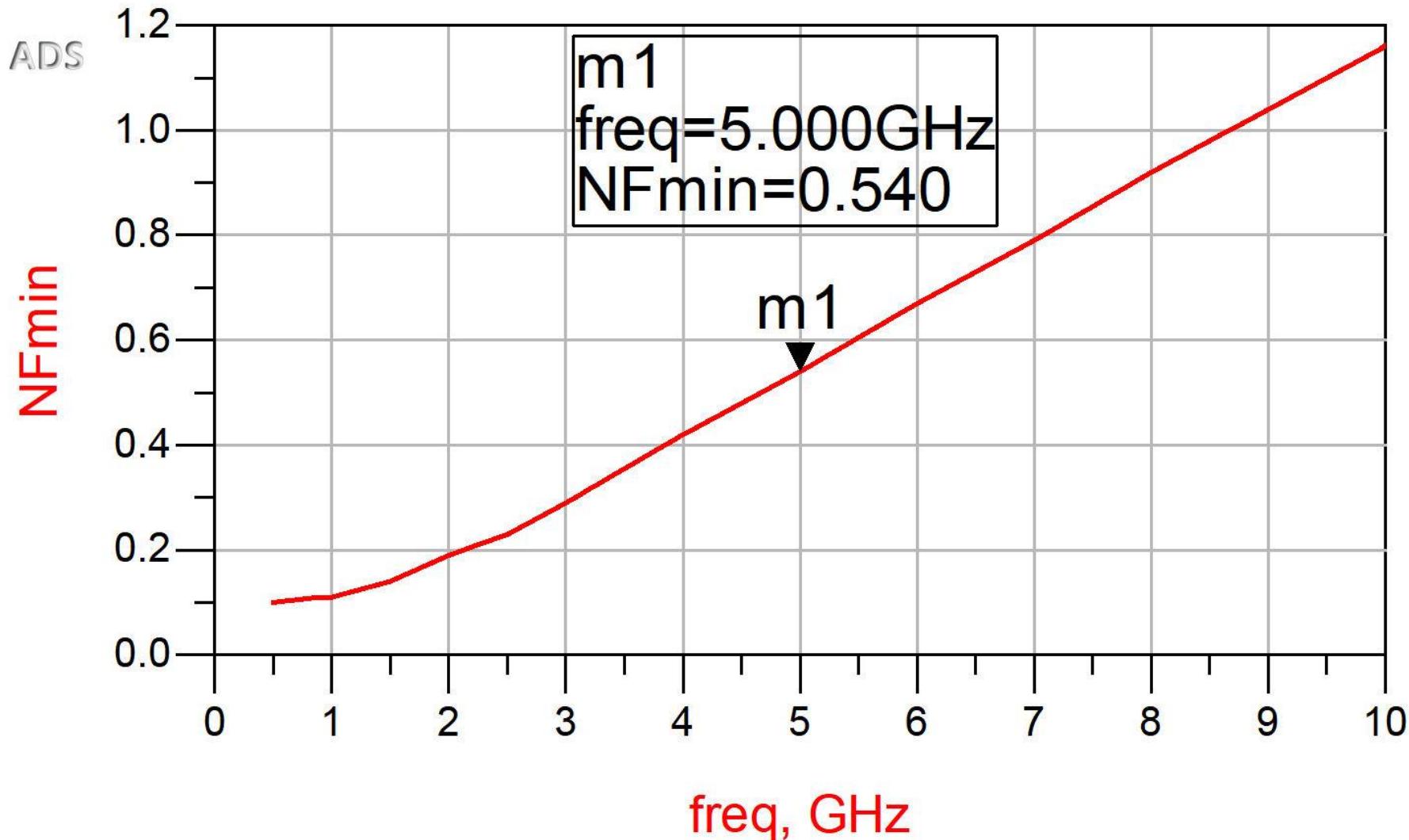
```
2.0 0.75 -126 6.306 90 0.088 23 0.26 -120
2.5 0.72 -145 5.438 75 0.095 15 0.25 -140
3.0 0.69 -162 4.762 62 0.102 7 0.23 -156
4.0 0.65 166 3.806 38 0.111 -8 0.22 174
5.0 0.64 139 3.165 16 0.119 -21 0.22 146
6.0 0.65 114 2.706 -5 0.125 -35 0.23 118
7.0 0.66 89 2.326 -27 0.129 -49 0.25 91
8.0 0.69 67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

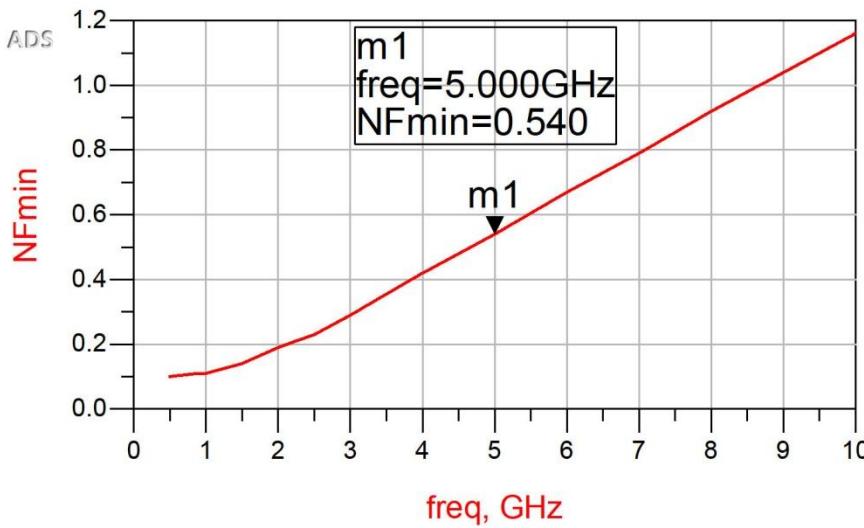
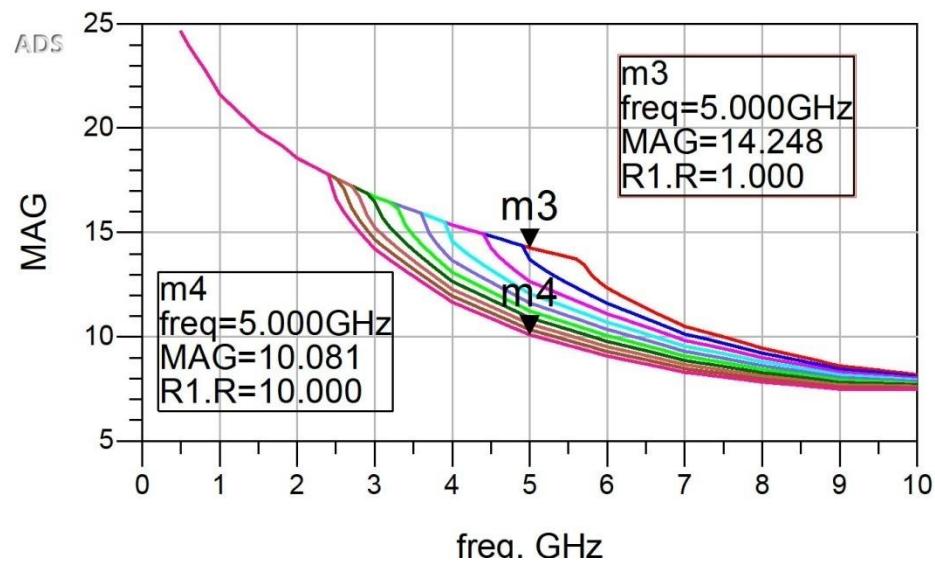
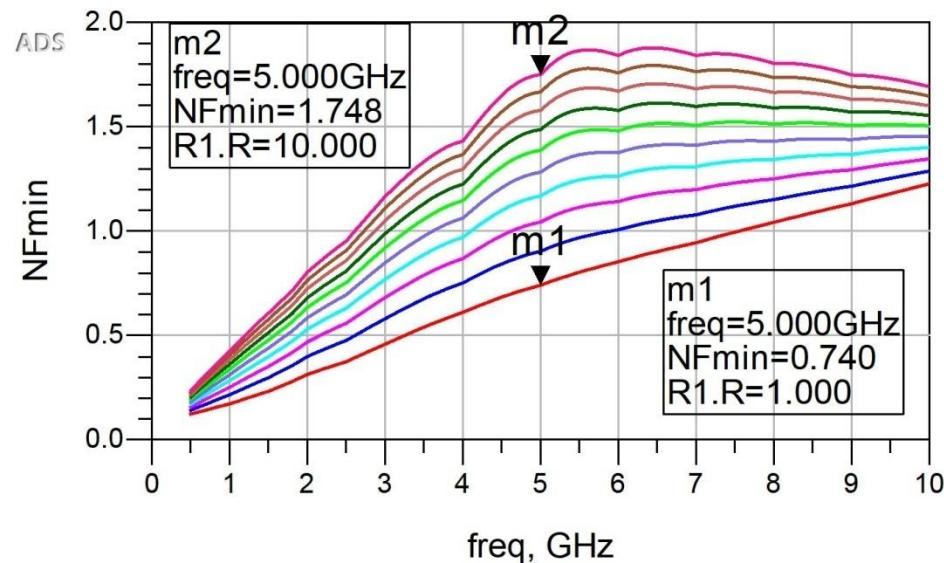
```
2.0 0.19 0.71 66 0.09
2.5 0.23 0.65 83 0.07
3.0 0.29 0.59 102 0.06
4.0 0.42 0.51 138 0.03
```

```
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

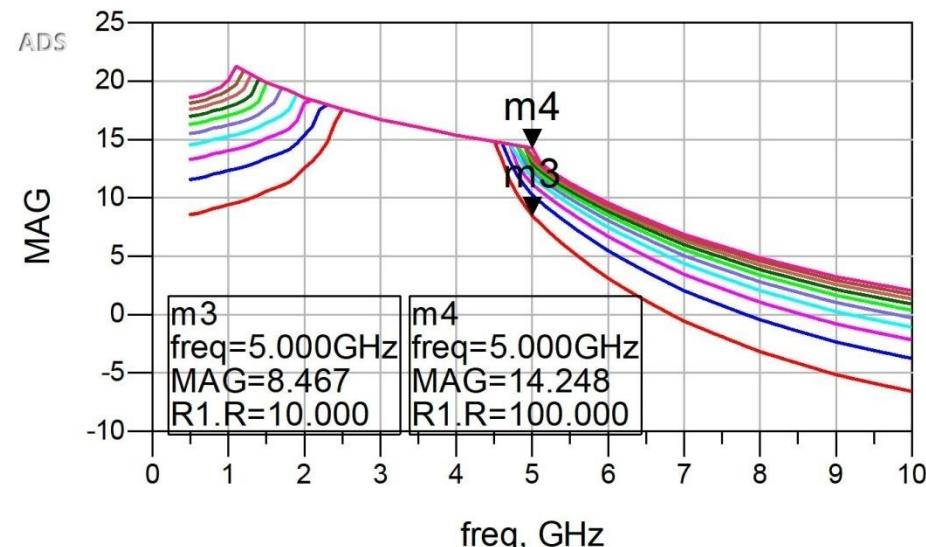
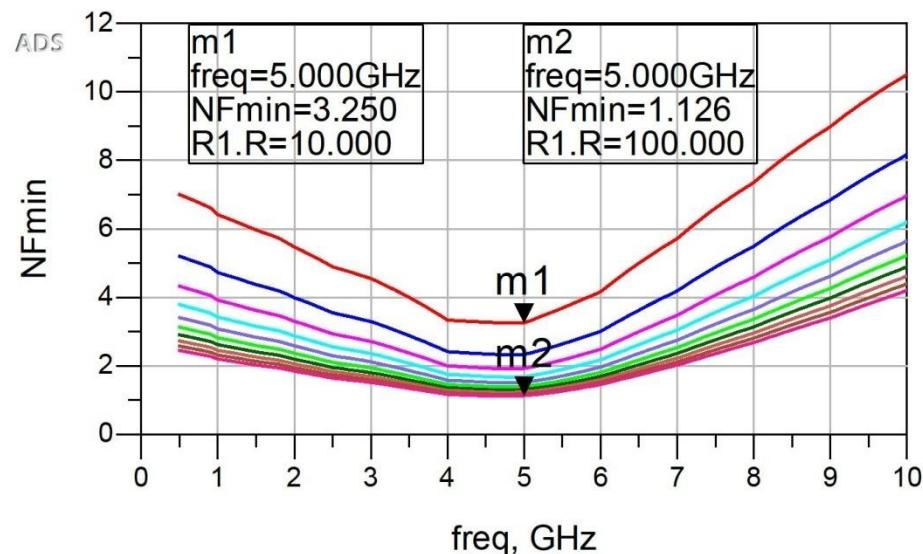


Stabilizzare R serie la intrare

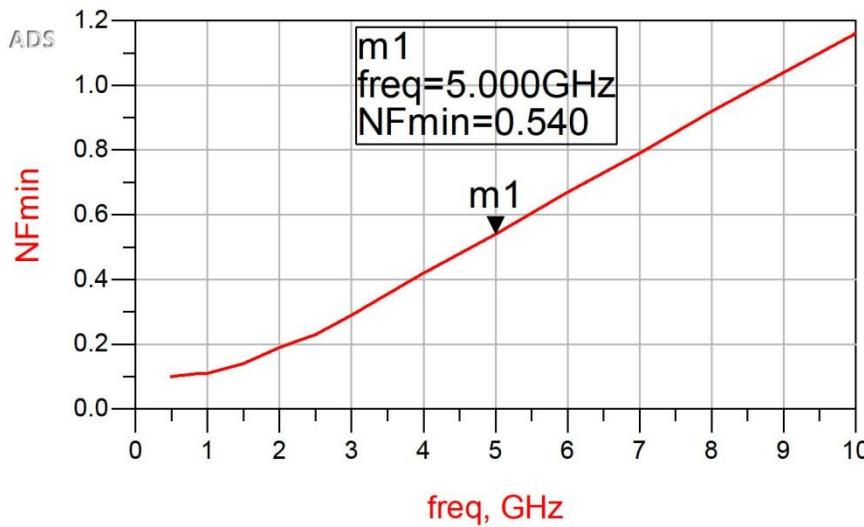


$$R_{SS} = 1 \div 10 \Omega$$

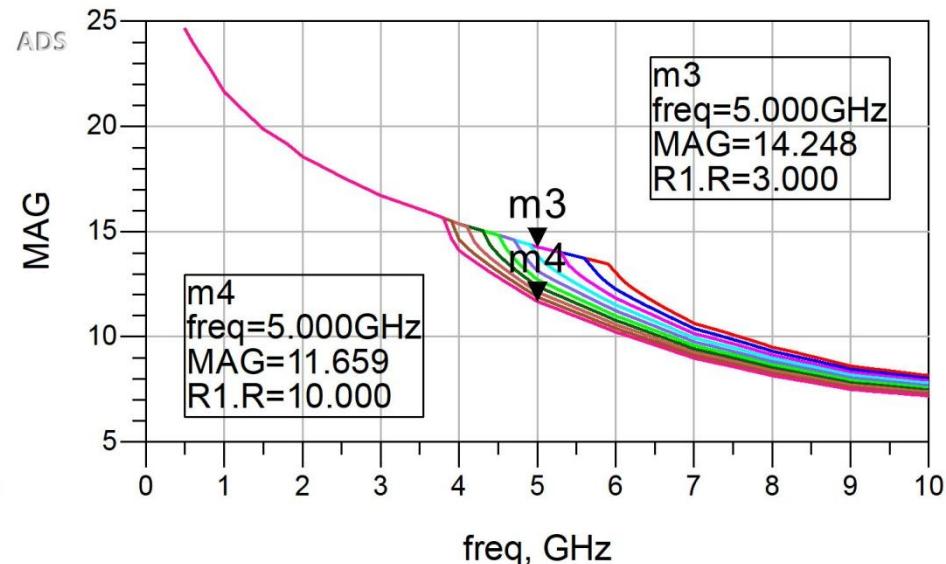
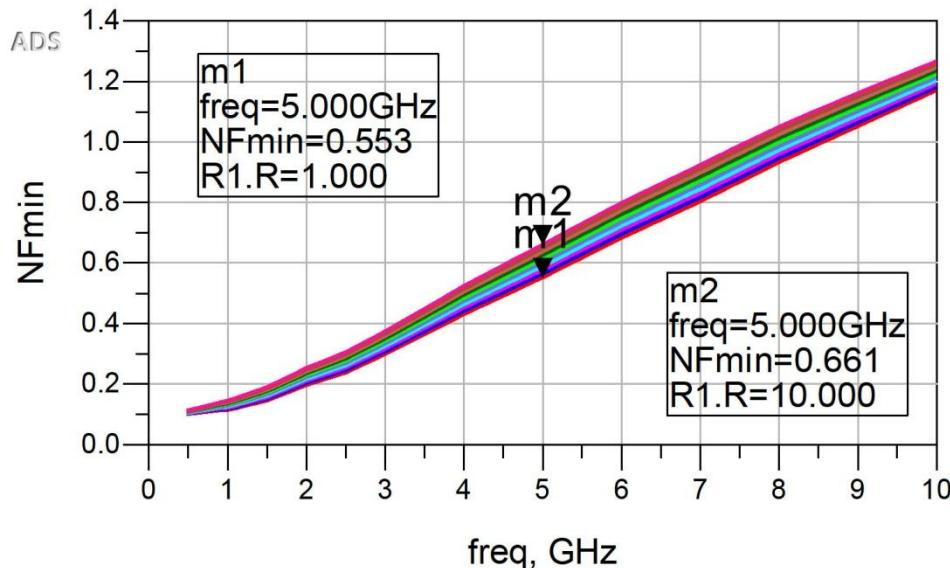
Stabilizare R paralel la intrare



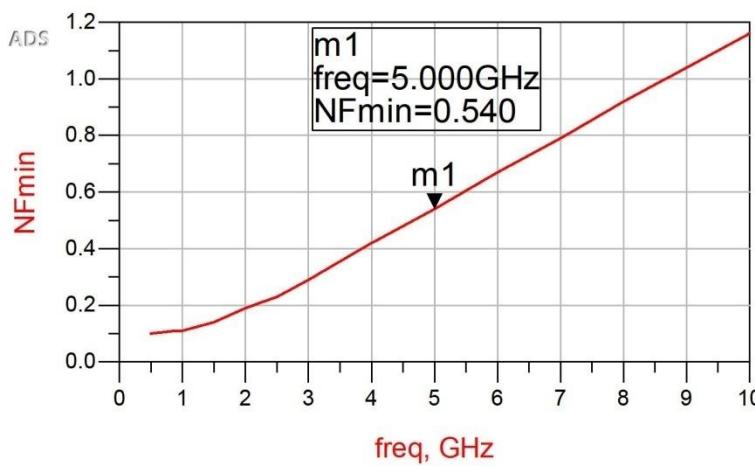
$$R_{PS} = 10 \div 100 \Omega$$



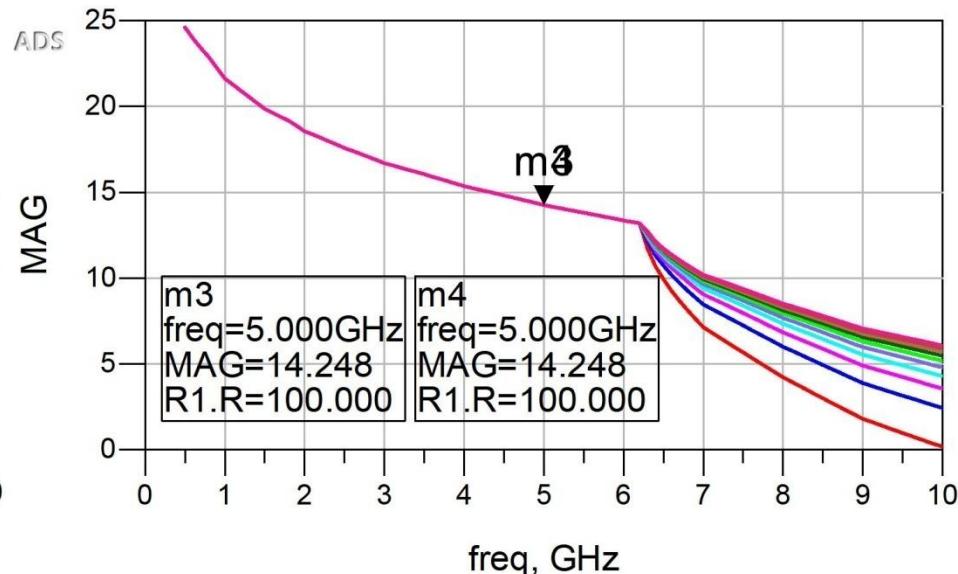
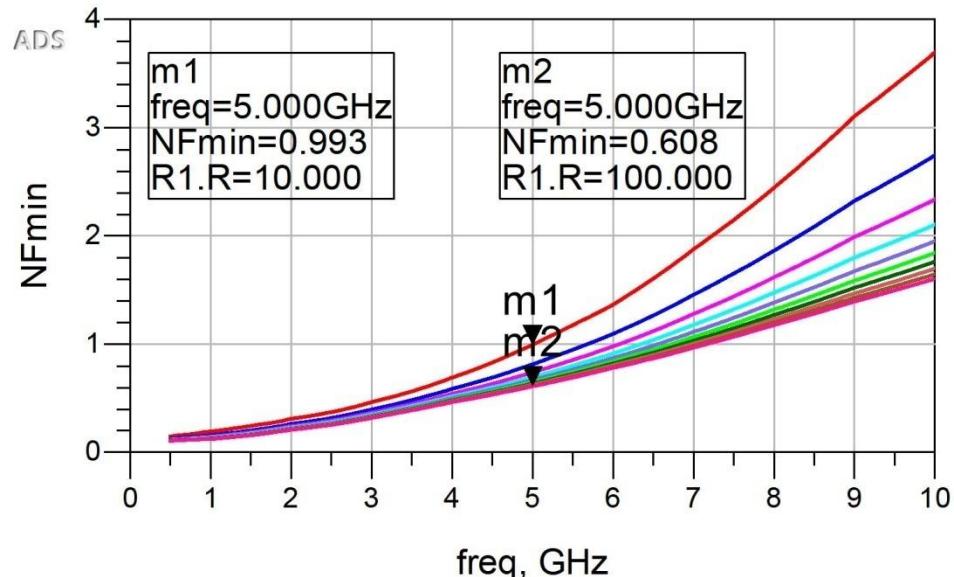
Stabilizare R serie la ieșire



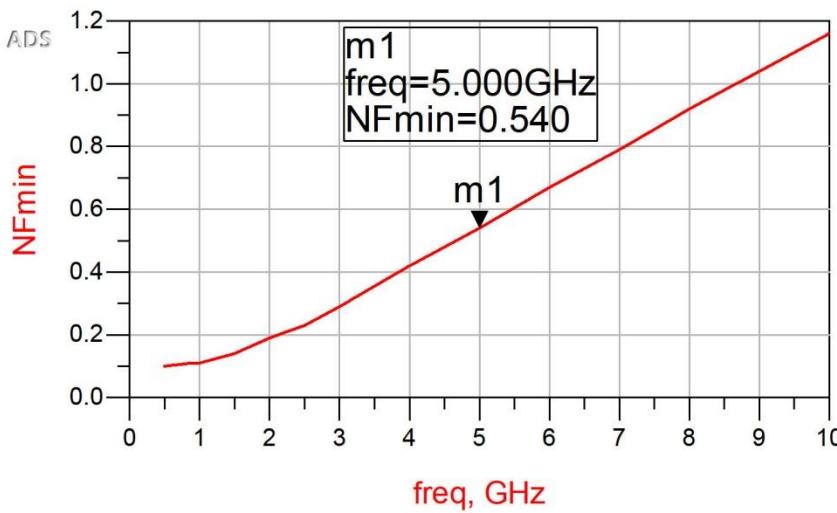
$$R_{SL} = 1 \div 10 \Omega$$



Stabilizare R paralel la ieșire



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



Zgomotul unui amplificator

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

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

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

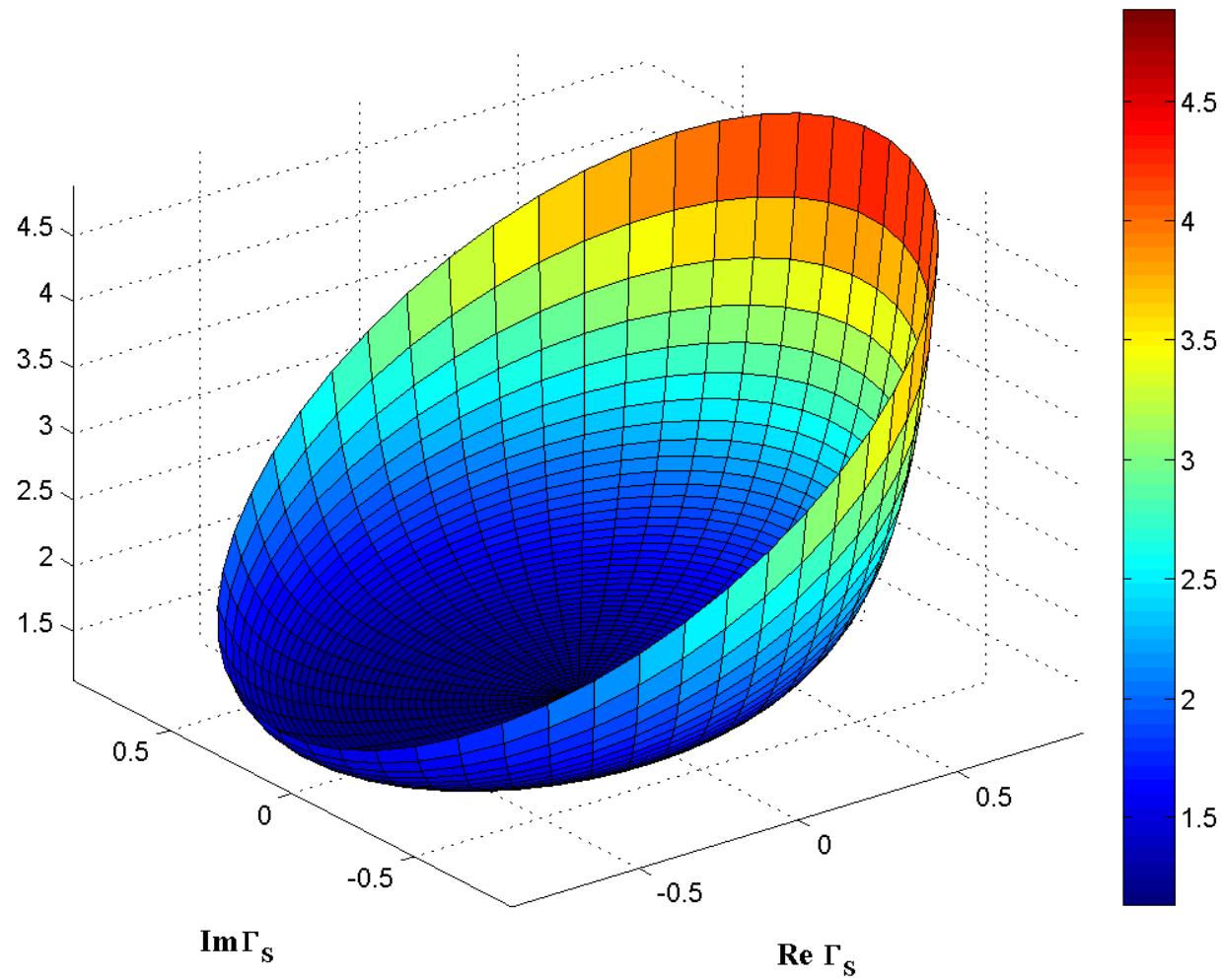
$$F = F_{\min} + 4 \cdot r_n \cdot \frac{|\Gamma_S - \Gamma_{opt}|^2}{(1 - |\Gamma_S|^2) \cdot |1 + \Gamma_{opt}|^2}$$

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

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

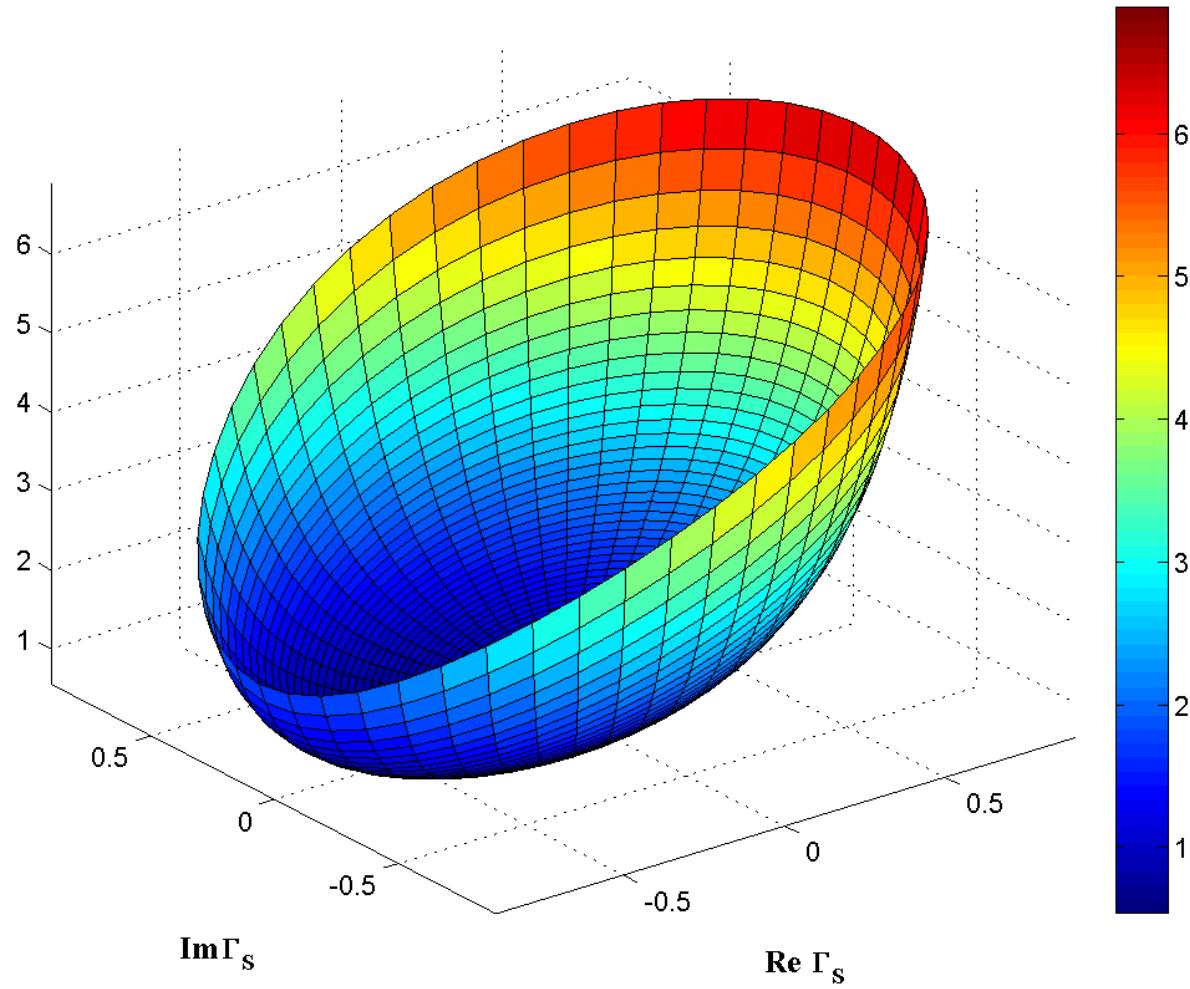
$F(\Gamma_s)$

$F(\Gamma_s)$

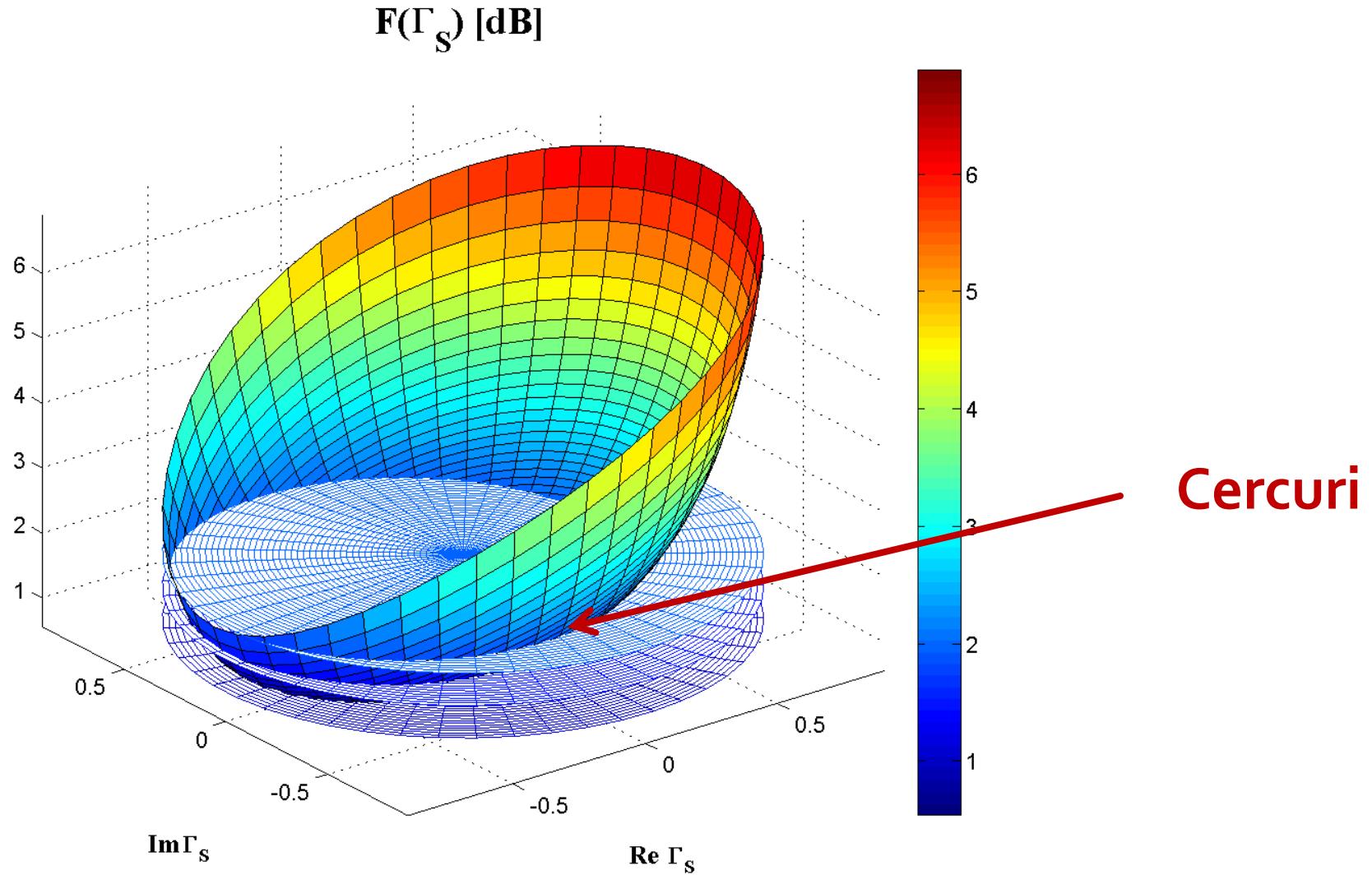


$F[dB](\Gamma_S)$

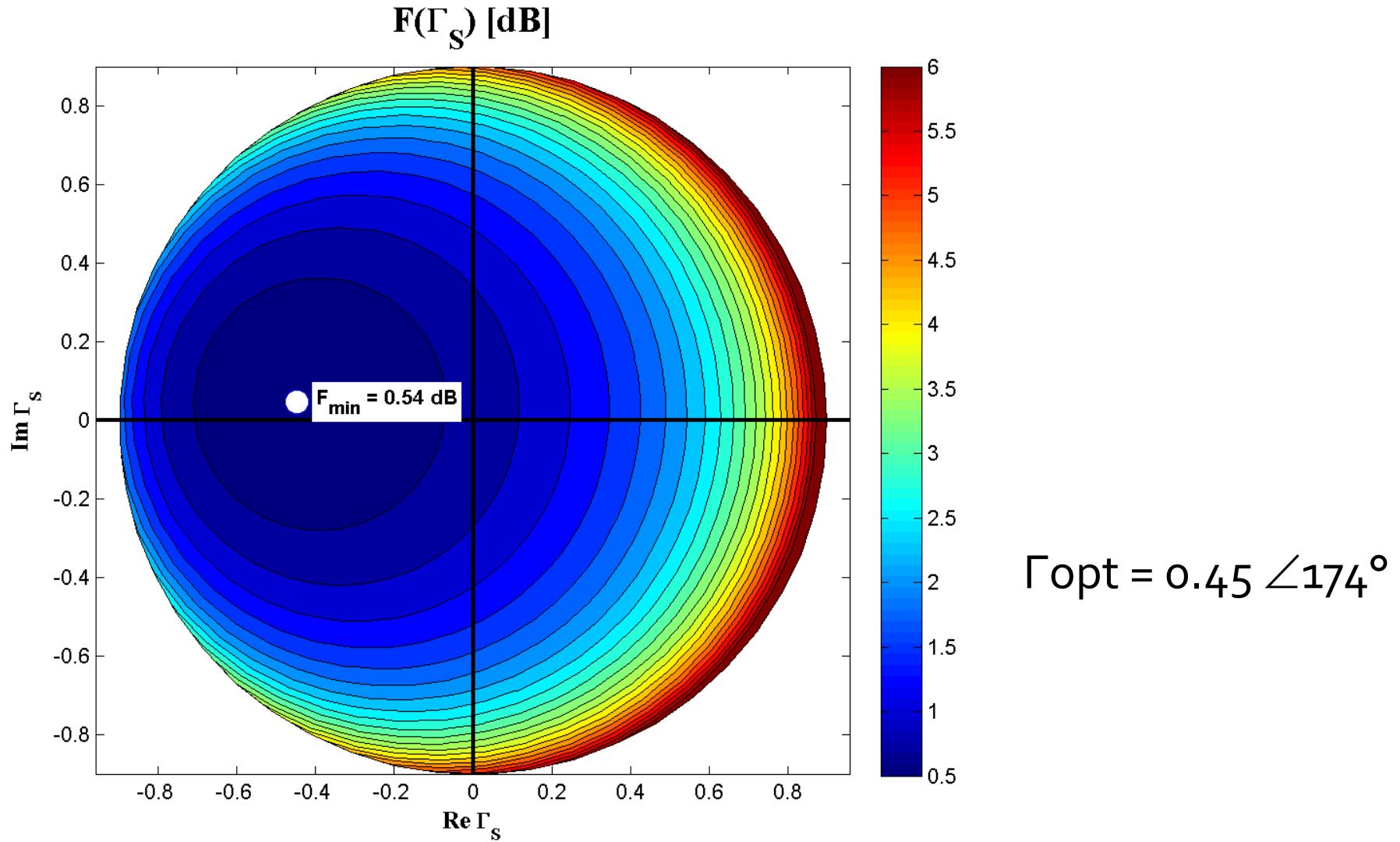
$F(\Gamma_S) [dB]$



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



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



Cercuri de zgromot constant

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

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

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

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

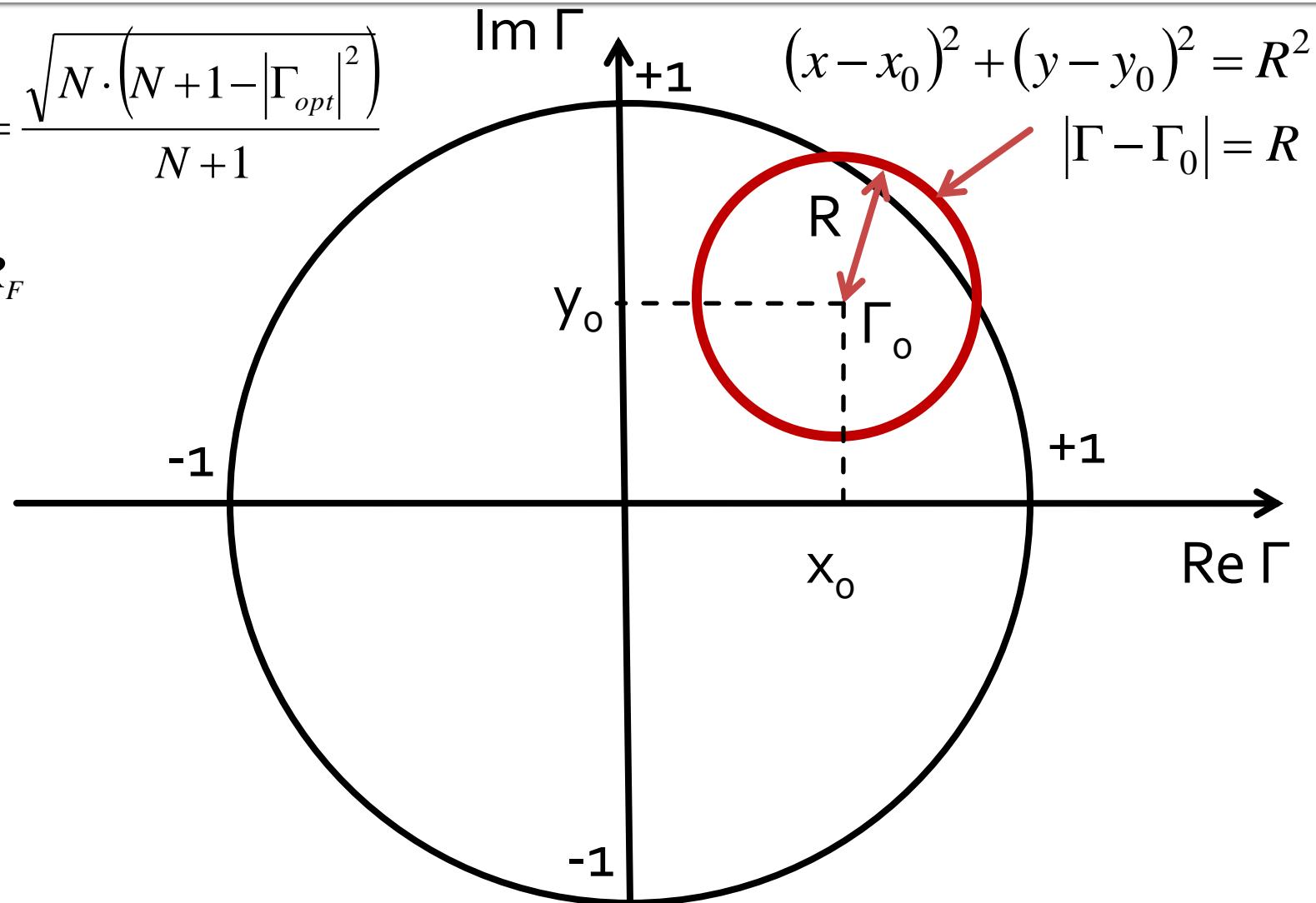
$$\Gamma_S \cdot \Gamma_S^* - \frac{\Gamma_S \cdot \Gamma_{opt}^* - \Gamma_S^* \cdot \Gamma_{opt}}{N+1} = \frac{N - |\Gamma_{opt}|^2}{N+1}$$

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

Zgomot

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

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

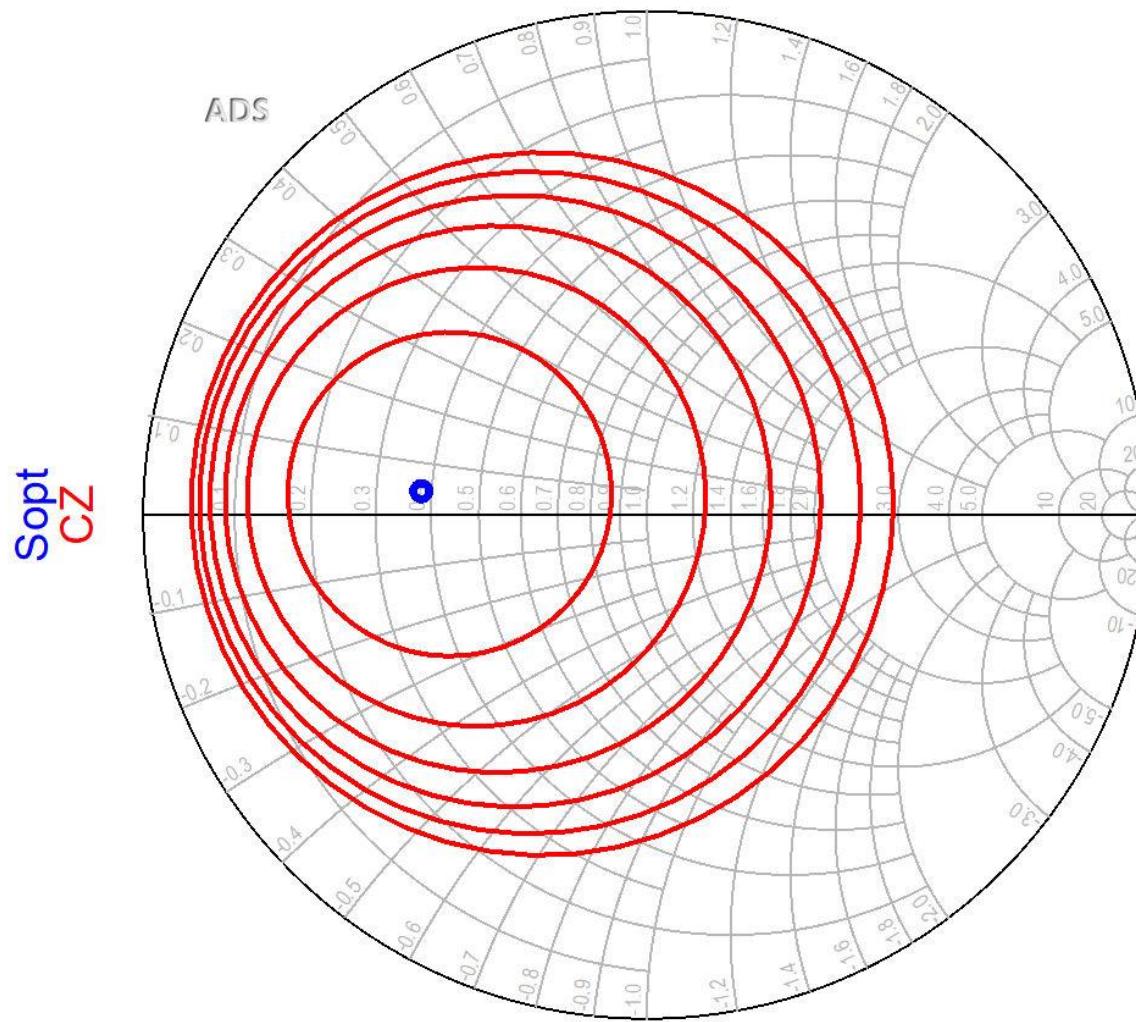


Cercuri de zgomot constant

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

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

ADS

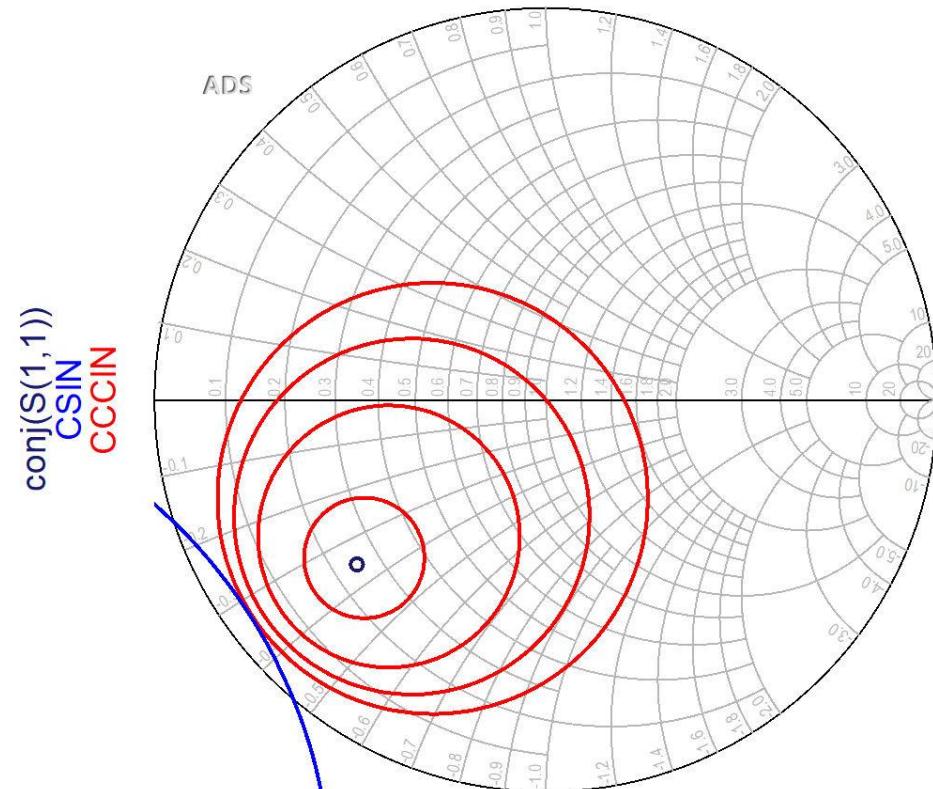
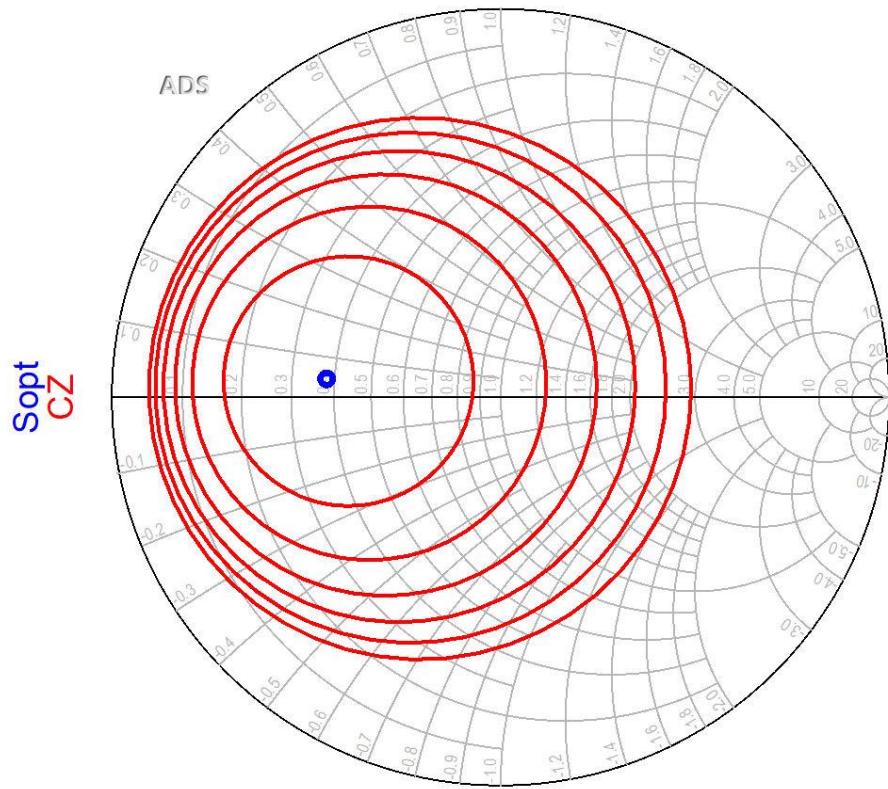


Cercuri de zgomot constant

- 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)

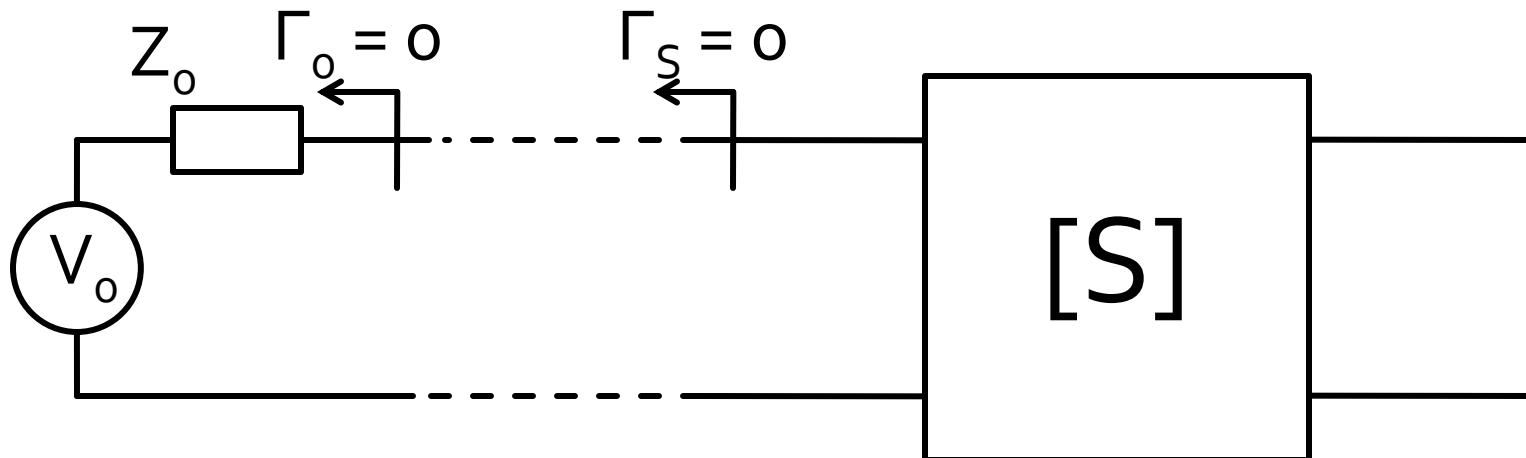
LNA – Low Noise Amplifier

- 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 Γ_s



Adaptare – 1

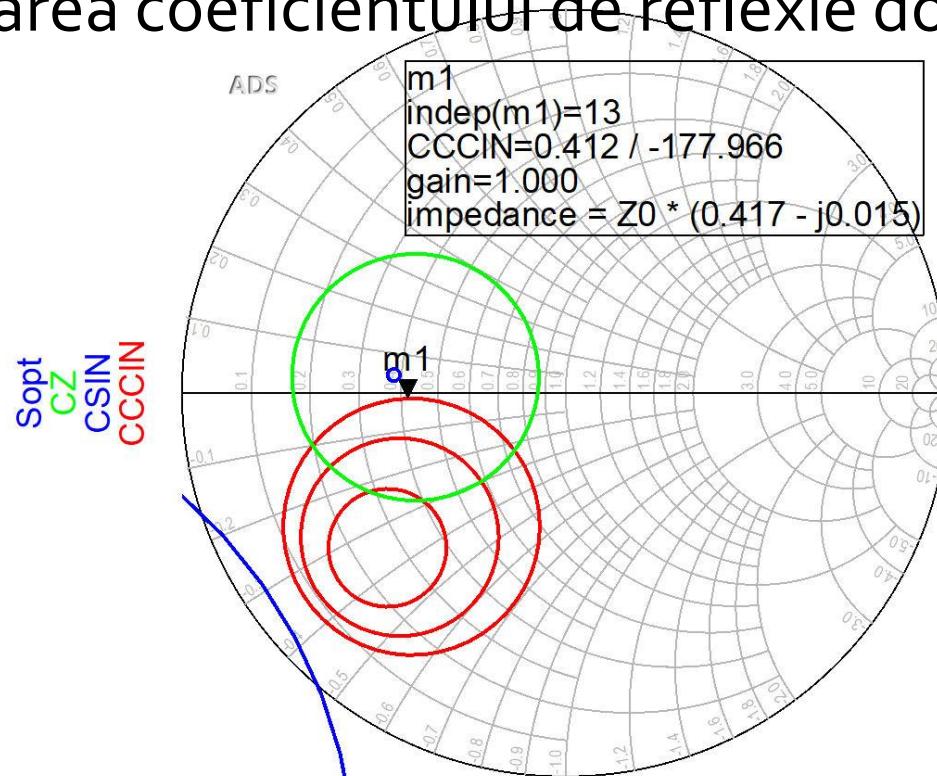
- Conectarea amplificatorului (tranzistorului) direct la sursa de semnal oferă un coeficient de reflexie la intrarea tranzistorului egal cu **0** (complex, $\Gamma_o = 0 + 0 \cdot j$)
 - de cele mai multe ori acest coeficient de reflexie nu oferă condiții optime de castig și/sau zgomot



Adaptare – 2

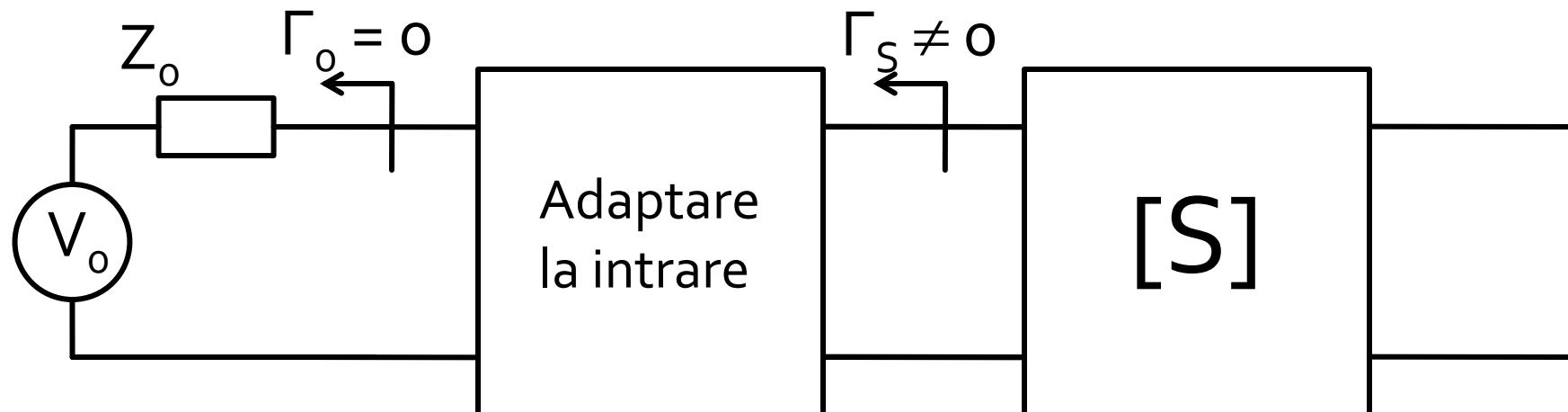
- Se deseneaza pe diagrama Smith cercurile de stabilitate/castig/zgomot, in functie de aplicatia
- Se alege punctul cu o pozitionare dorita relativ la aceste cercuri (de asemenea dependent de aplicatie)
- Se determina valoarea coeficientului de reflexie dorit la intrare Γ_S

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



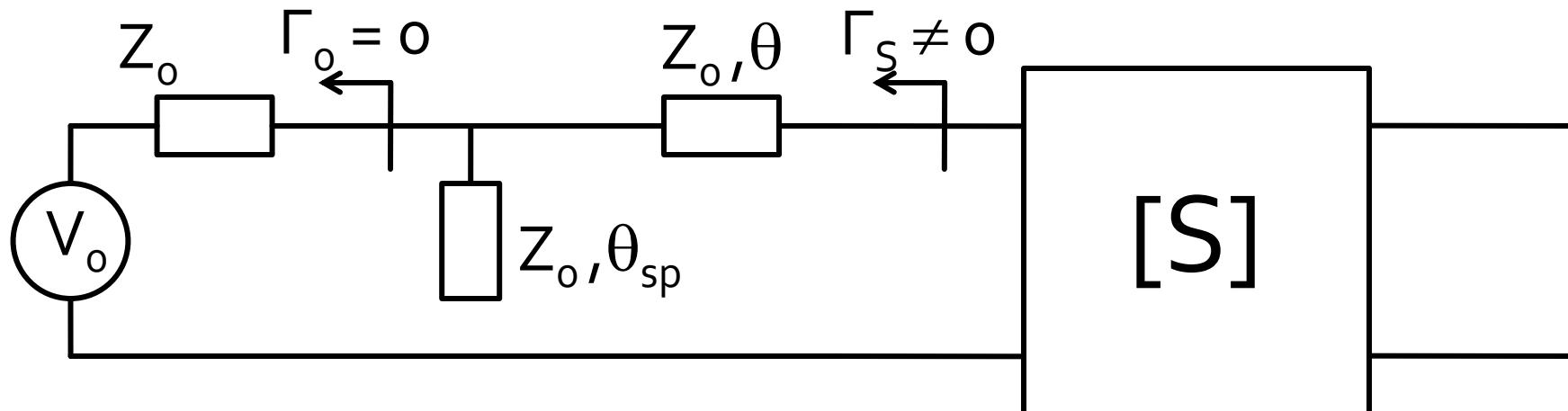
Adaptare – 3

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



Adaptare – 4

- Varianta cea mai simplă de implementare, și pentru care există relații analitice de calcul constă în introducerea (în ordine, de la tranzistor spre sursă Z_0):
 - o secțiune de linie serie, cu impedanța caracteristică Z_0 și lungime electrică θ
 - un **stub paralel**, lasat în gol la capăt, realizat dintr-o linie cu impedanța caracteristică Z_0 și lungime electrică θ_{sp}

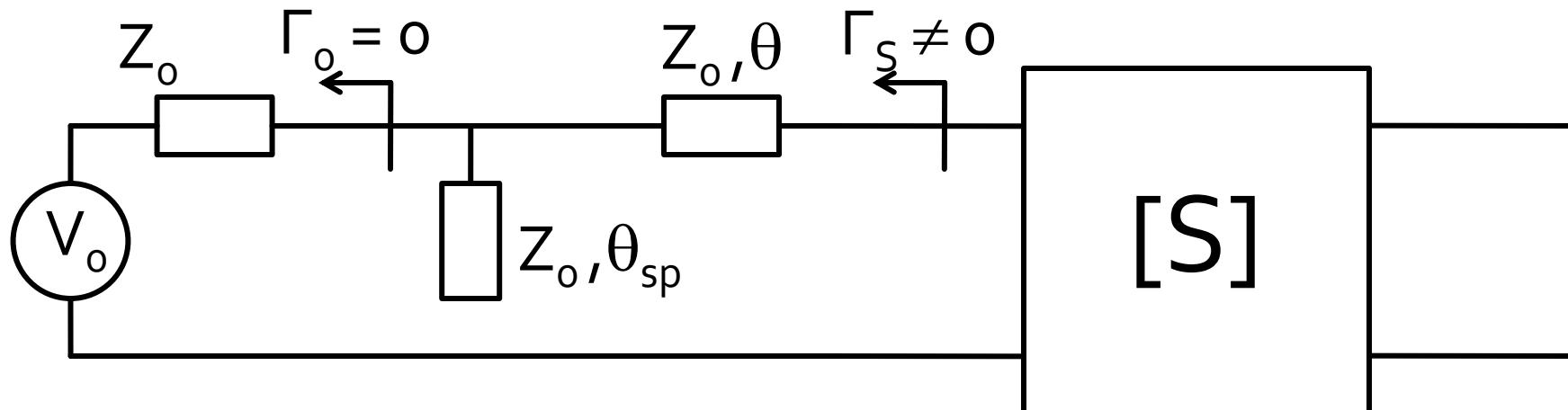


Adaptare – 5

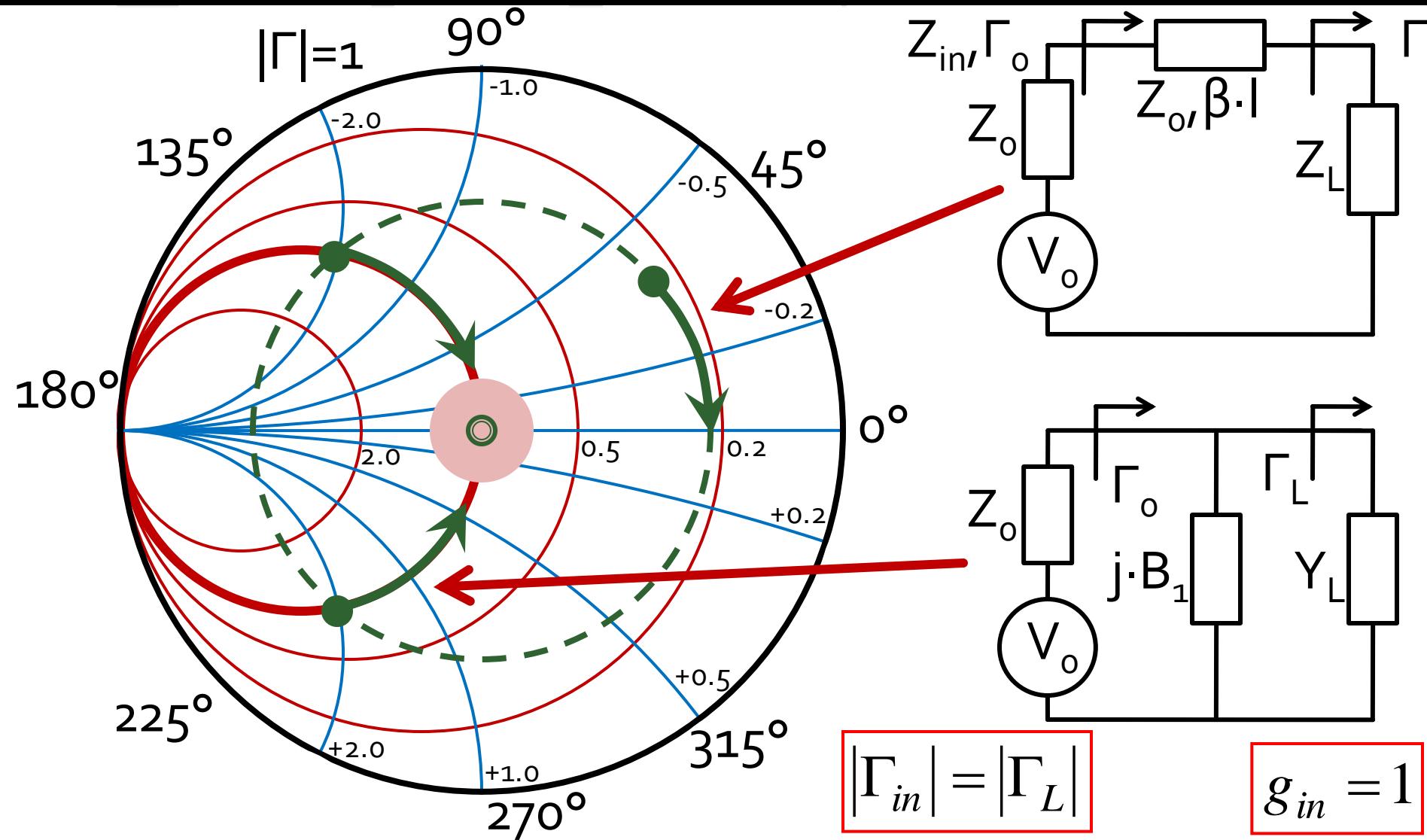
- Relatiile de calcul depind numai de Γ_s (modul si faza)

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

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



Adaptare cu stub-uri, C6-7



Exemplu, LNA @ 5 GHz

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

- @5GHz

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

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

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

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

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

```
2.0 0.19 0.71 66 0.09
2.5 0.23 0.65 83 0.07
3.0 0.29 0.59 102 0.06
4.0 0.42 0.51 138 0.03
5.0 0.54 0.45 174 0.03
```

```
6.0 0.67 0.42 -151 0.05
7.0 0.79 0.42 -118 0.10
8.0 0.92 0.45 -88 0.18
9.0 1.04 0.51 -63 0.30
10.0 1.16 0.61 -43 0.46
```

Exemplu, LNA @ 5 GHz

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

Exemplu, LNA @ 5 GHz

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

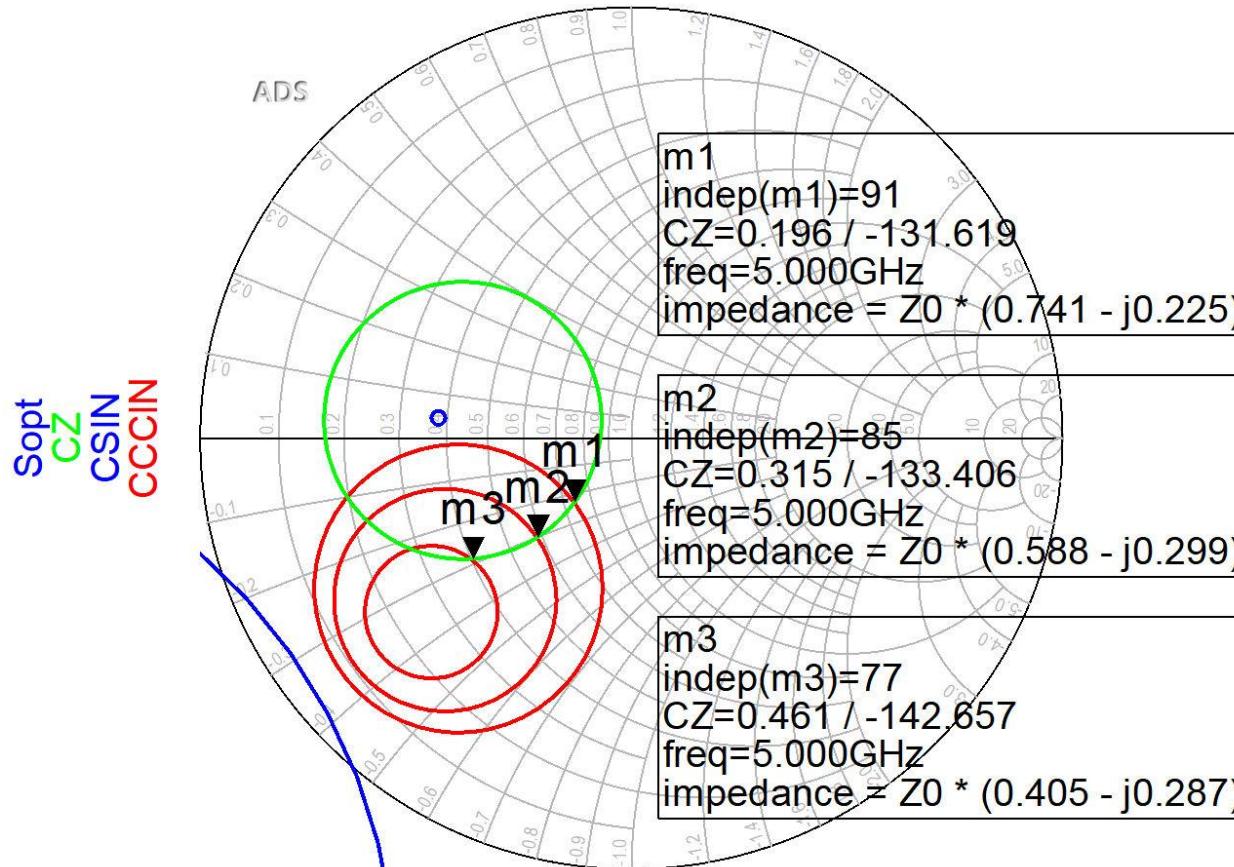
$$G_{TU\max} = \frac{1}{1 - |S_{11}|^2} \cdot |S_{21}|^2 \cdot \frac{1}{1 - |S_{22}|^2} = 17.83 \quad G_{TU\max} [\text{dB}] = 12.511 \text{ dB}$$

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

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

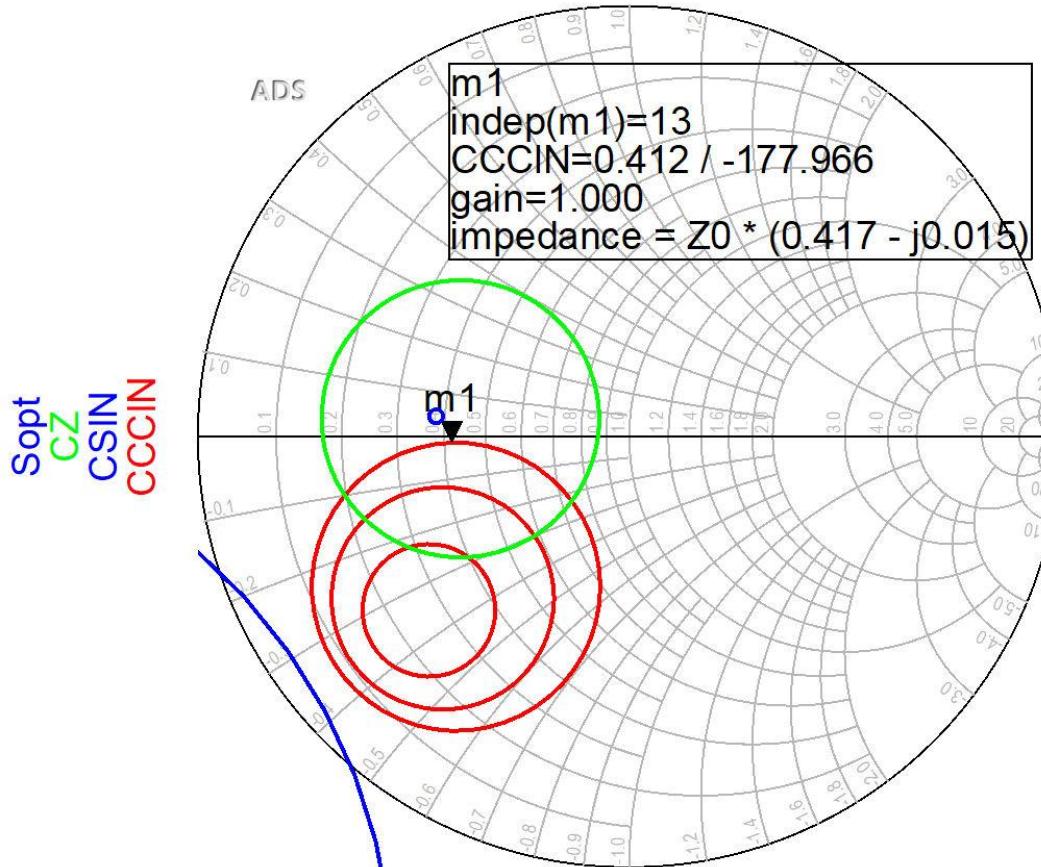
- În cazul particular prezent $G_{L\max} = 0.21 \text{ dB}$, amplificatorul ar putea functiona cu ieșirea conectată direct la o sarcină de 50Ω
- Absenta retelei de adaptare la ieșire nu conduce la o pierdere importantă de castig, dar elibera posibilitatea ca prin reglaj să se compenseze compromisul castig/zgomot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

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

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

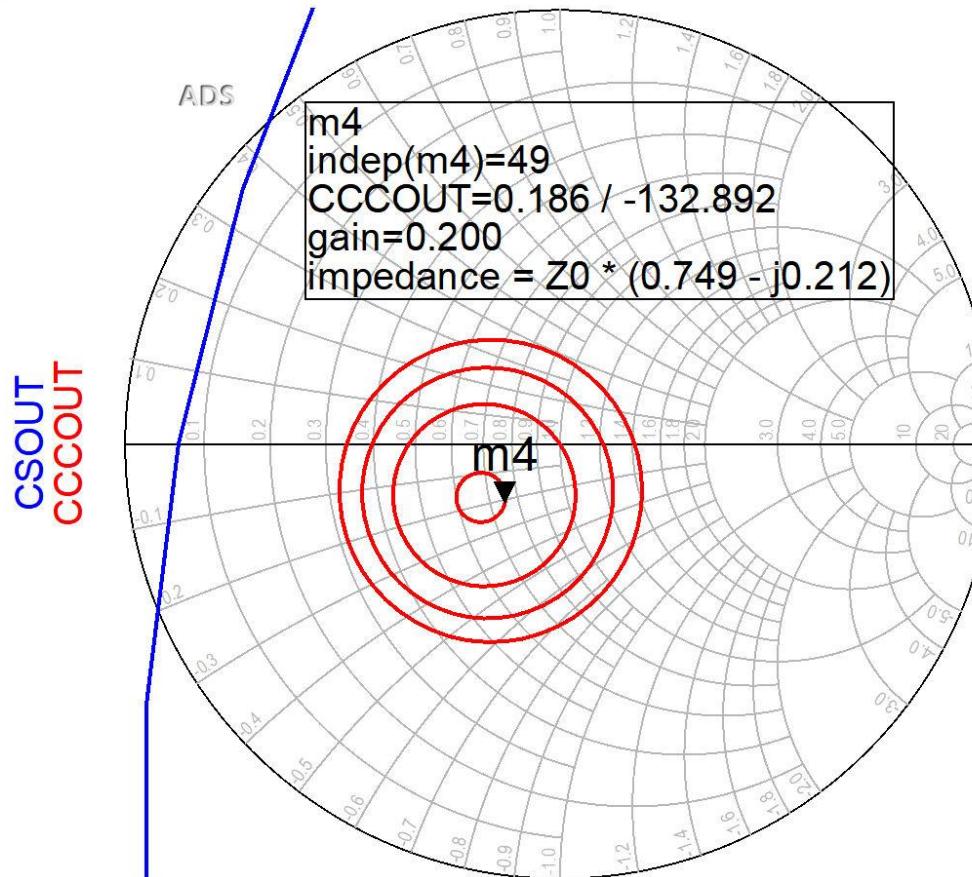
$$\cos(\varphi + 2\theta) = -|\Gamma_S|$$

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

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

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

Adaptare la ieșire



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

Adaptare la iesire

■ Pozitia m₄ de pe grafic

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

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

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

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

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

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

LNA

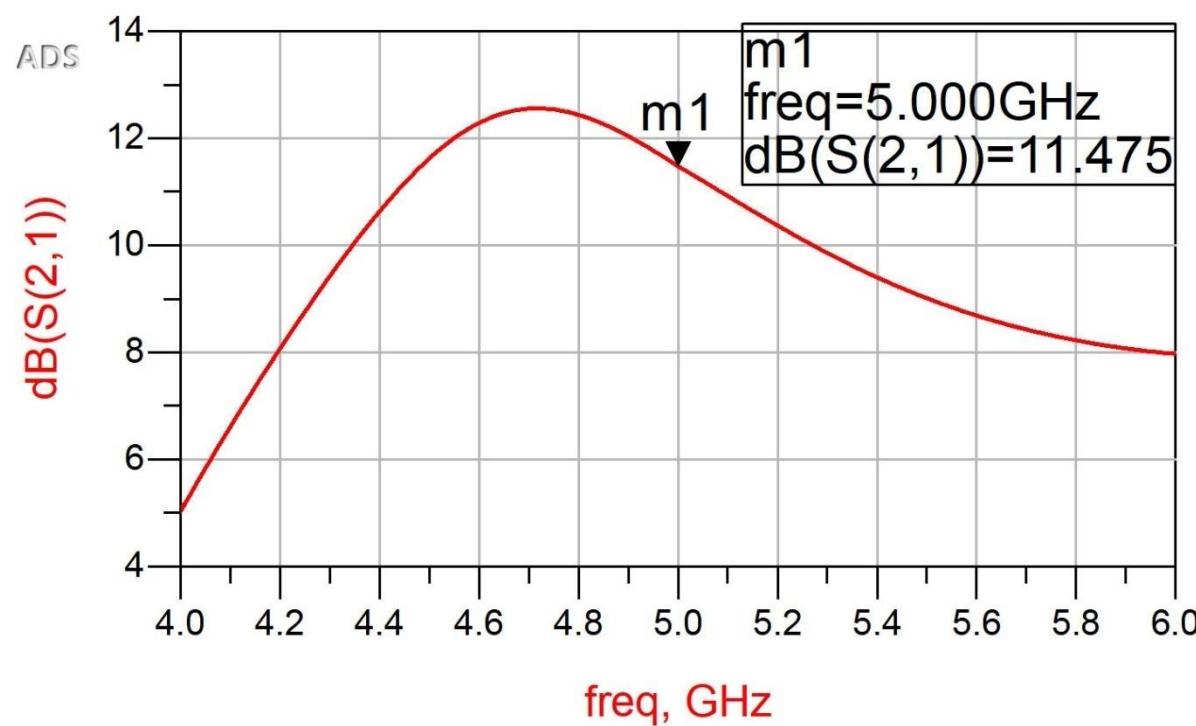
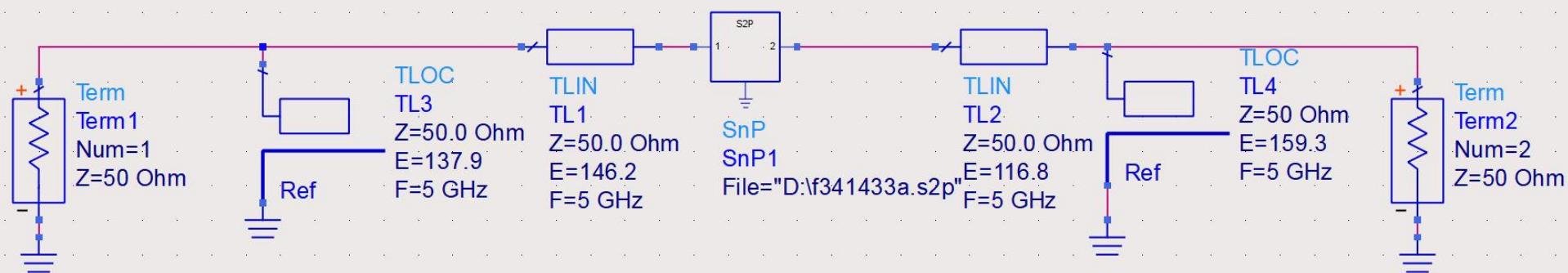
- Se estimeaza obtinerea unui castig (in ipoteza unilaterală, ± 0.9 dB)

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

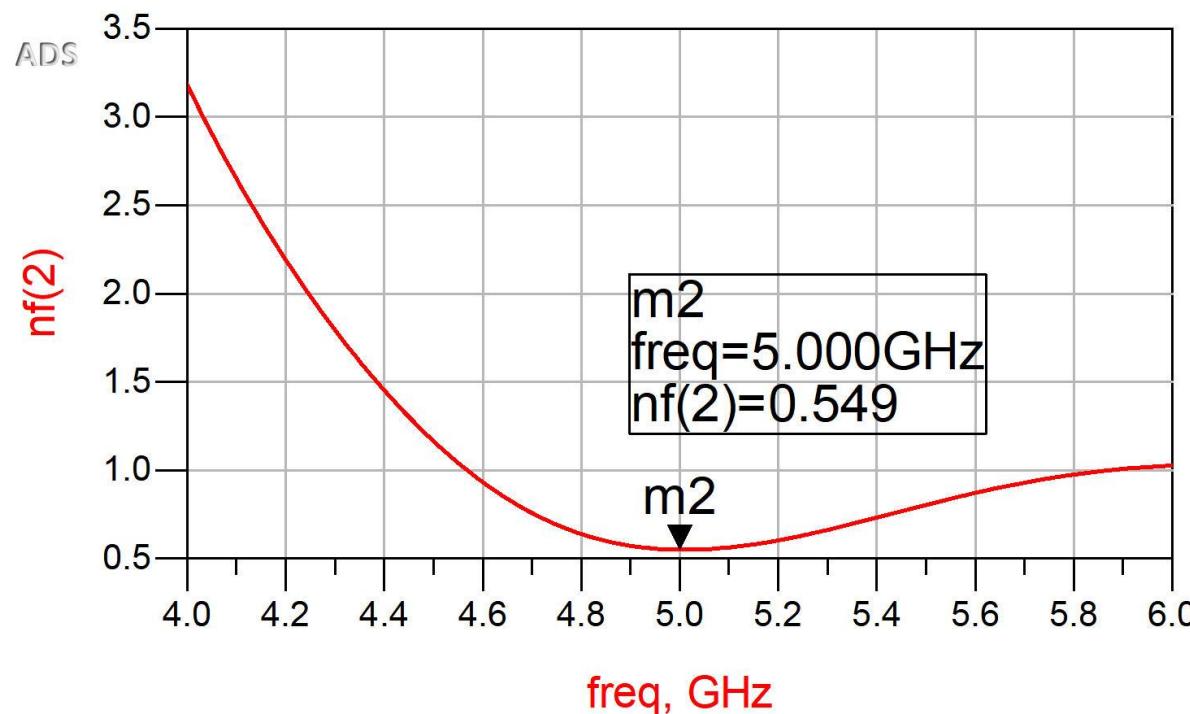
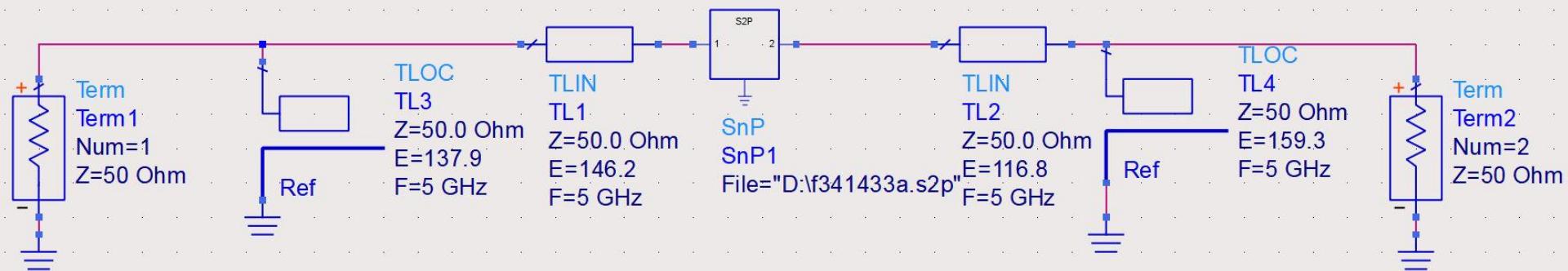
$$G_T[\text{dB}] = 1 \text{ dB} + 10 \text{ dB} + 0.2 \text{ dB} = 11.2 \text{ dB}$$

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

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Contact

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- rdamian@etti.tuiasi.ro