Curs 10

2025/2026

Dispozitive şi circuite de microunde pentru radiocomunicații

Disciplina 2025/2026

- 2C/1L (+1), **DCMR (CDM)**
- **<u>Minim 7 prezente (curs+laborator)</u>**
- Curs - **conf. Radu Damian**
  - Vineri 10-12/**Video (istoric)**, C1, corp C
  - E – **50%** din nota
  - **<u>probleme</u>** + (2p prez. curs) + (3 teste) + (bonus activitate)
    - primul test L1: ~01.10.2025 (t2 si t3 neanuntate la **curs**)
    - 3pz (C) ≈ +0.5p (**2p** max)
  - **<u>toate materialele permise</u>**

Disciplina 2025/2026

- 2C/1L, **DCMR (CDM)**
- Laborator – **conf. Radu Damian**
  - 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

Programare examen

- **NU** ultimul examen din sesiune
- Toate grupele: P2 sau P6 (C1)
- **Termen**: 10.12

Documentatie

- https://rf-opto.etti.tuiasi.ro

Microwave and Optoelectronics Laboratory
Faculty of Electronics, Telecommunications and Information Technology
Gheorghe Asachi Technical University of Iaşi

Main | **Courses** ▾ | Master ▾ | Staff ▾ | Research ▾ | Students ▾ | ▾

English
Romana

Microwave Devices and Circuits for Radiocommunicati

Course: DCMR (2024-2025)

Course Coordinator: Assoc.P. Dr. Radu-Florin Damian
Code: DOS412T
Discipline Type: DOS; Alternative, Specialty
Credits: 4
Enrollment Year: 4, **Sem.** 7

Activities

Course: Instructor: Assoc.P. Dr. Radu-Florin Damian, 2 Hours/Week, Specialization Section, Timetable:
Laboratory: Instructor: Assoc.P. Dr. Radu-Florin Damian, 1 Hours/Week, Group, Timetable:

Evaluation

Type: **Exam**

A: 50%, (Test/Colloquium)
B: 25%, (Seminary/Laboratory/Project Activity)
D: 25%, (Homework/Specialty papers)

Grades

Aggregate Results

Bibliografie

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

Examen: Reprezentare logaritmică

dB	$= 10 \cdot \log_{10}(P_2 / P_1)$
0 dB	= 1
+ 0.1 dB	= 1.023 (+2.3%)
+ 3 dB	= 2
+ 5 dB	= 3
+ 10 dB	= 10
-3 dB	= 0.5
-10 dB	= 0.1
-20 dB	= 0.01
-30 dB	= 0.001

dBm	$= 10 \cdot \log_{10}(P / 1\ \text{mW})$
0 dBm	= 1 mW
3 dBm	= 2 mW
5 dBm	= 3 mW
10 dBm	= 10 mW
20 dBm	= 100 mW
-3 dBm	= 0.5 mW
-10 dBm	= 100 μW
-30 dBm	= 1 μW
-60 dBm	= 1 nW

[dBm] + [dB] = [dBm]

[dBm/Hz] + [dB] = [dBm/Hz]

[x] + [dB] = [x]

Examen: Reprezentare logaritmică

- $P_0 = 1\text{mW}$
  - $P[\text{dBm}] = 10 \cdot log\left(\frac{P}{P_0}\right)$
  - $P = P_0 \cdot 10^{\frac{P[\text{dBm}]}{10}}$
- Cu unitati de masura
  - $P[\text{mW}] = 1[\text{mW}] \cdot 10^{\frac{P[\text{dBm}]}{10}} = 10^{\frac{P[\text{dBm}]}{10}}$
  - $P[\mu\text{W}] = 1000[\mu\text{W}] \cdot 10^{\frac{P[\text{dBm}]}{10}} = 10^3 \cdot 10^{\frac{P[\text{dBm}]}{10}}$
  - $P[\mu\text{W}] = 10^{\frac{30+P[\text{dBm}]}{10}}$

Examen: Reprezentare logaritmică

- Relatii empirice
  - $\lambda[\mu m] = \frac{1.240}{E_g[eV]}$
  - uneori cu corespondenta fizica $E_g = h\nu; \lambda = \frac{hc}{E_g}$
- Puteri
  - $1mW = 10^3 \mu W; 1\mu W = 10^{-3} mW$
- Empiric
  - $P[\mu W] = 10^3 \cdot P[mW]$**!!**
  - Ex: P = **1.2**mW = **1200**µW

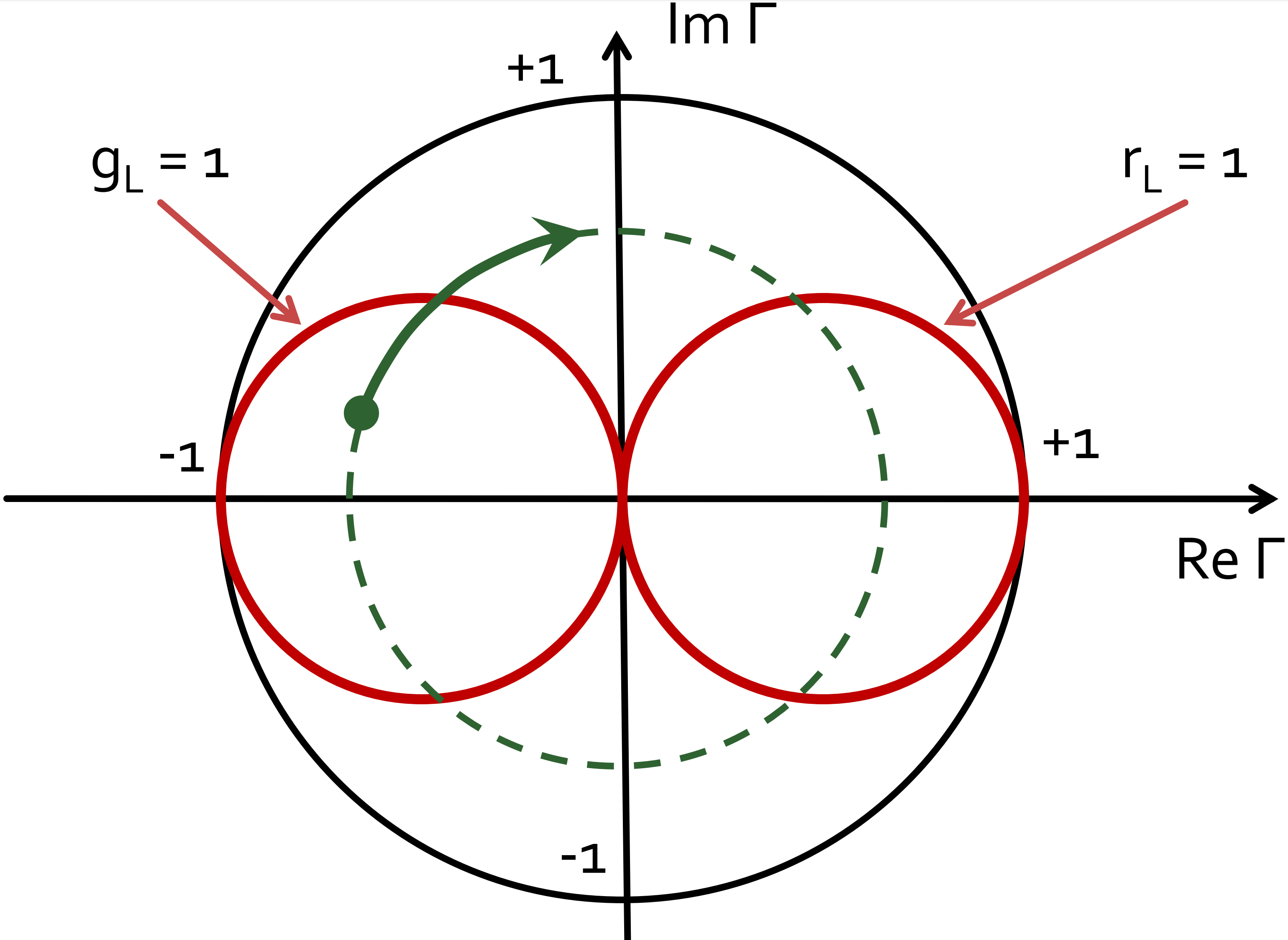
Examen

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

Adaptarea cu sectiuni de linii (stub)

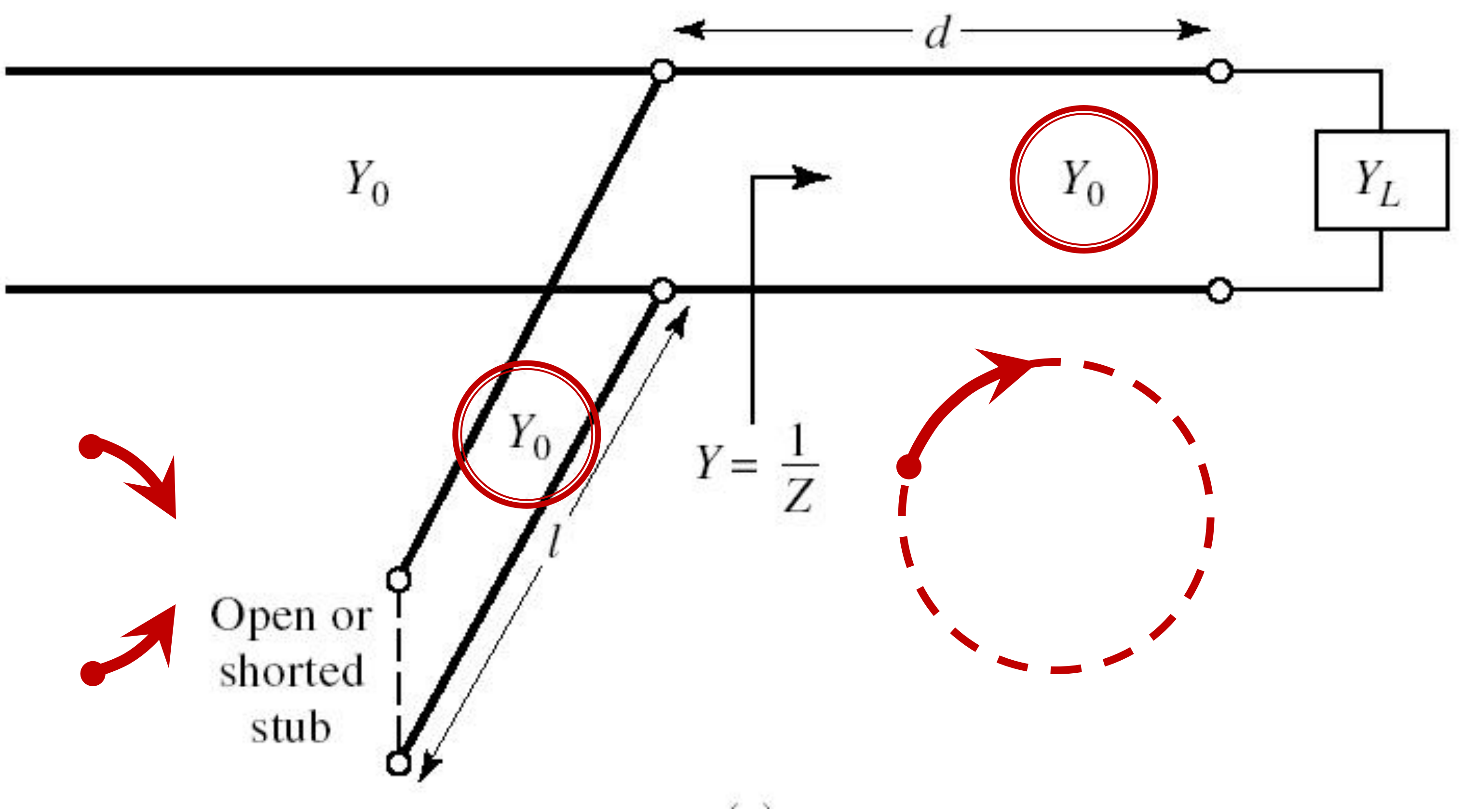
Adaptarea de impedanța

Diagrama Smith, r=1 si g=1



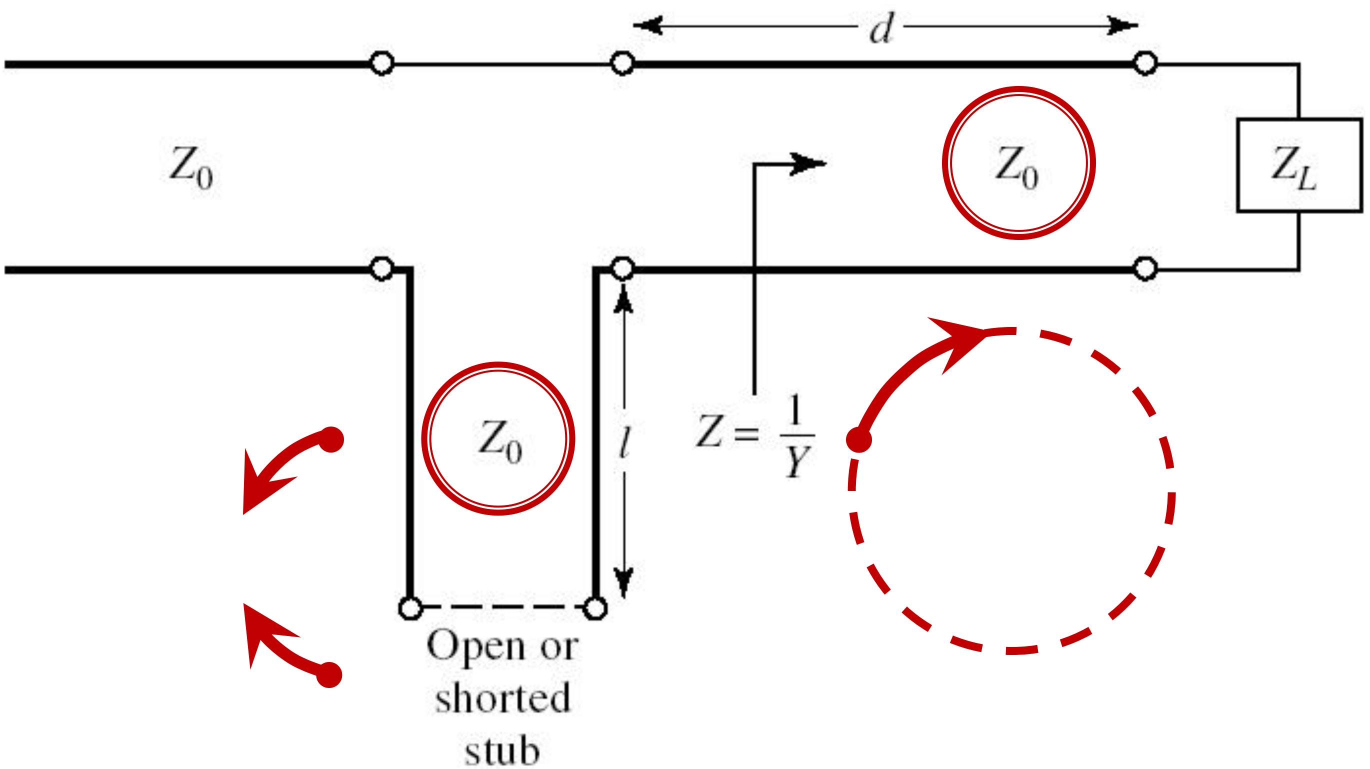
Single stub tuning

- Shunt Stub (sectiune de linie in paralel)



Single stub tuning

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

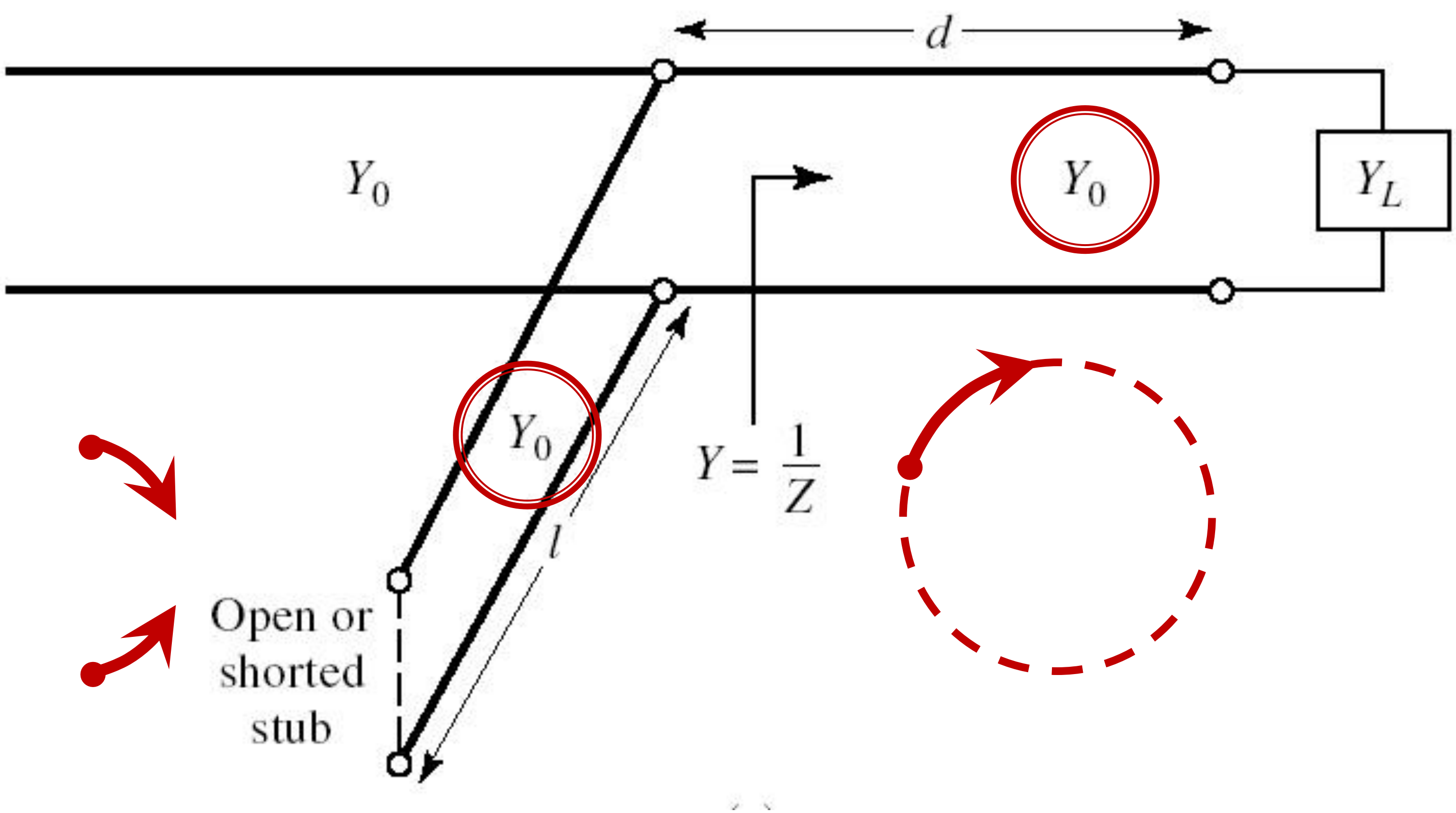


Solutii analitice

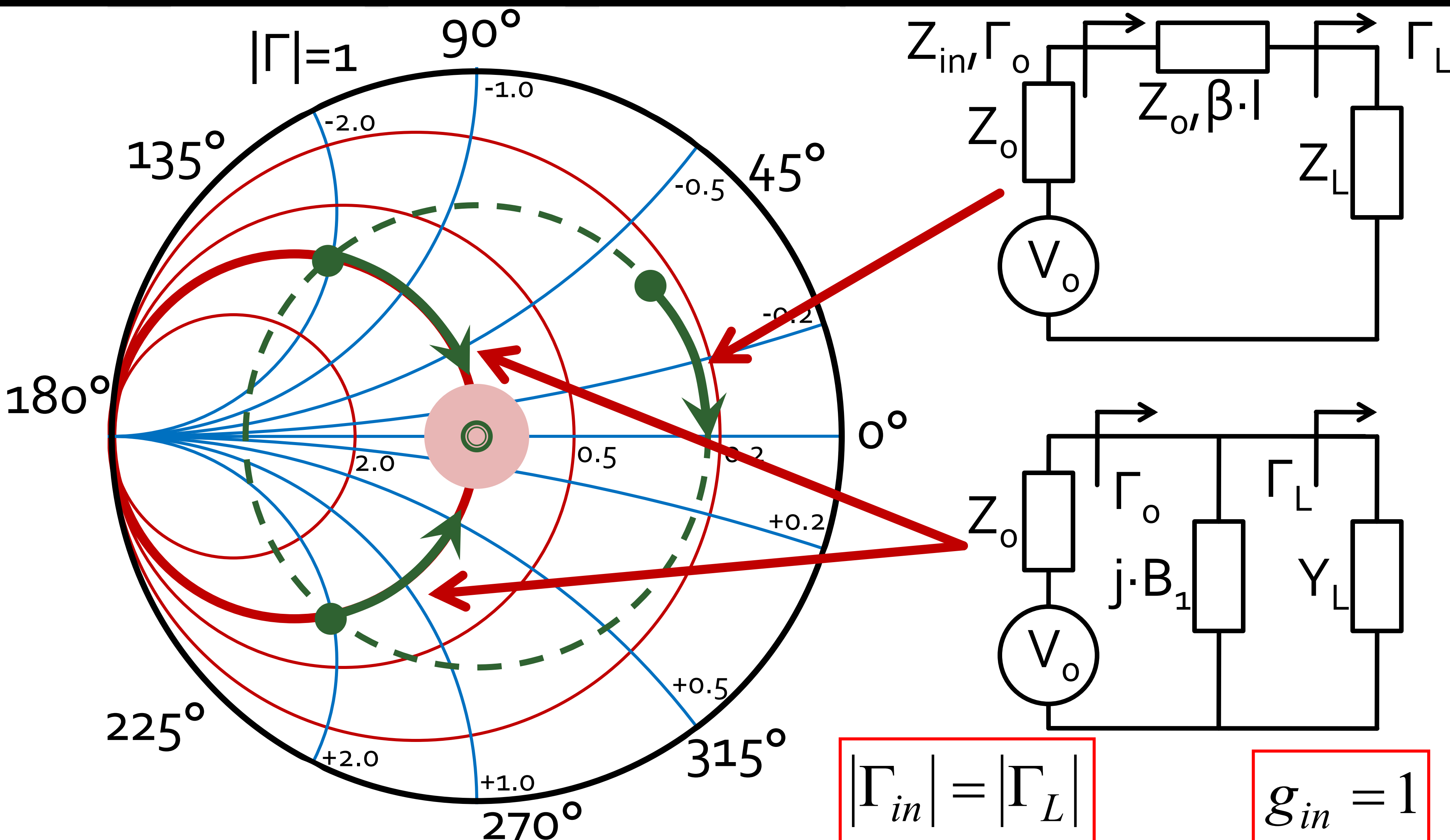
Examen / Proiect

Caz 1, Shunt Stub

- Shunt Stub (sectiune de linie in paralel)



Adaptare, linie serie + susceptanta in paralel



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

$$g_{in} = 1$$

Calcul analitic (calcul efectiv)

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

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

$$\Gamma_S = 0.593\angle 46.85°$$

$$|\Gamma_S| = 0.593; \quad \varphi = 46.85° \qquad \cos(\varphi + 2\theta) = -0.593 \Rightarrow (\varphi + 2\theta) = \pm 126.35°$$

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

    $$(46.85° + 2\theta) = +126.35° \qquad \theta = +39.7° \qquad \mathrm{Im}\, y_S = \frac{-2 \cdot |\Gamma_S|}{\sqrt{1 - |\Gamma_S|^2}} = -1.472$$

    $$\theta_{sp} = \tan^{-1}(\mathrm{Im}\, y_S) = -55.8°(+180°) \rightarrow \theta_{sp} = 124.2°$$

  - **solutia "cu -"**

    $$(46.85° + 2\theta) = -126.35° \qquad \theta = -86.6°(+180°) \rightarrow \theta = 93.4°$$

    $$\mathrm{Im}\, y_S = \frac{+2 \cdot |\Gamma_S|}{\sqrt{1 - |\Gamma_S|^2}} = +1.472 \qquad \theta_{sp} = \tan^{-1}(\mathrm{Im}\, y_S) = 55.8°$$

Calcul analitic (calcul efectiv)

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

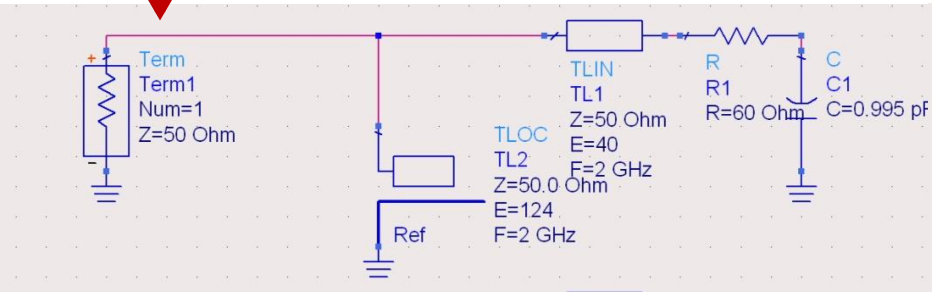
- Se alege **una** din cele doua solutii posibile
- **Semnul** (+/-) solutiei alese la **prima** ecuatie impune **semnul** solutiei utilizate la a **doua** ecuatie

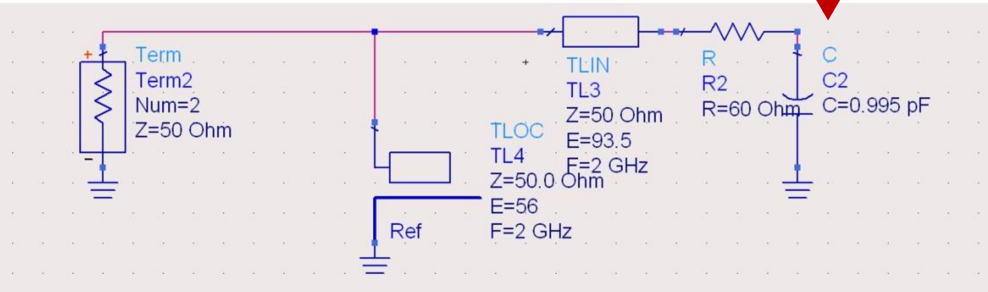
$$l_1 = \frac{39.7^\circ}{360^\circ} \cdot \lambda = 0.110 \cdot \lambda$$

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

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

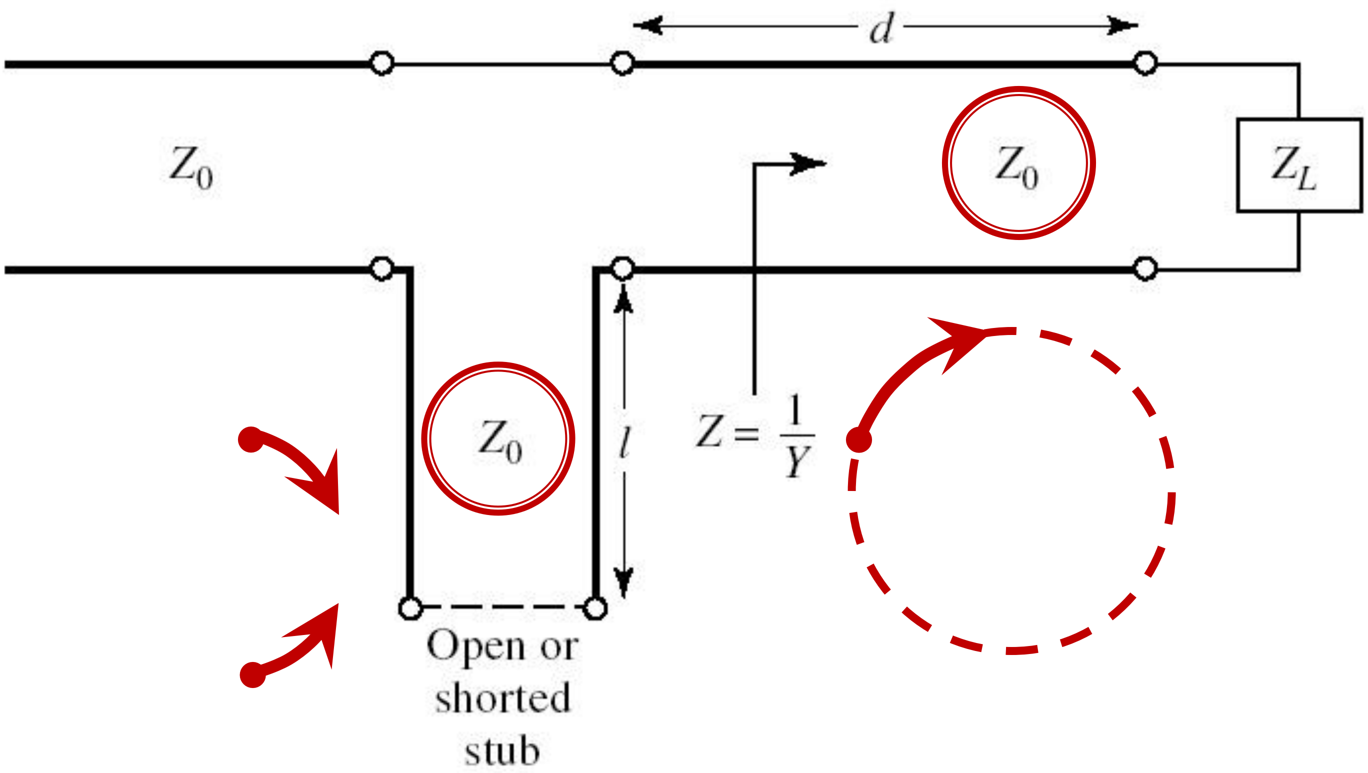
$$l_2 = \frac{55.8^\circ}{360^\circ} \cdot \lambda = 0.155 \cdot \lambda$$



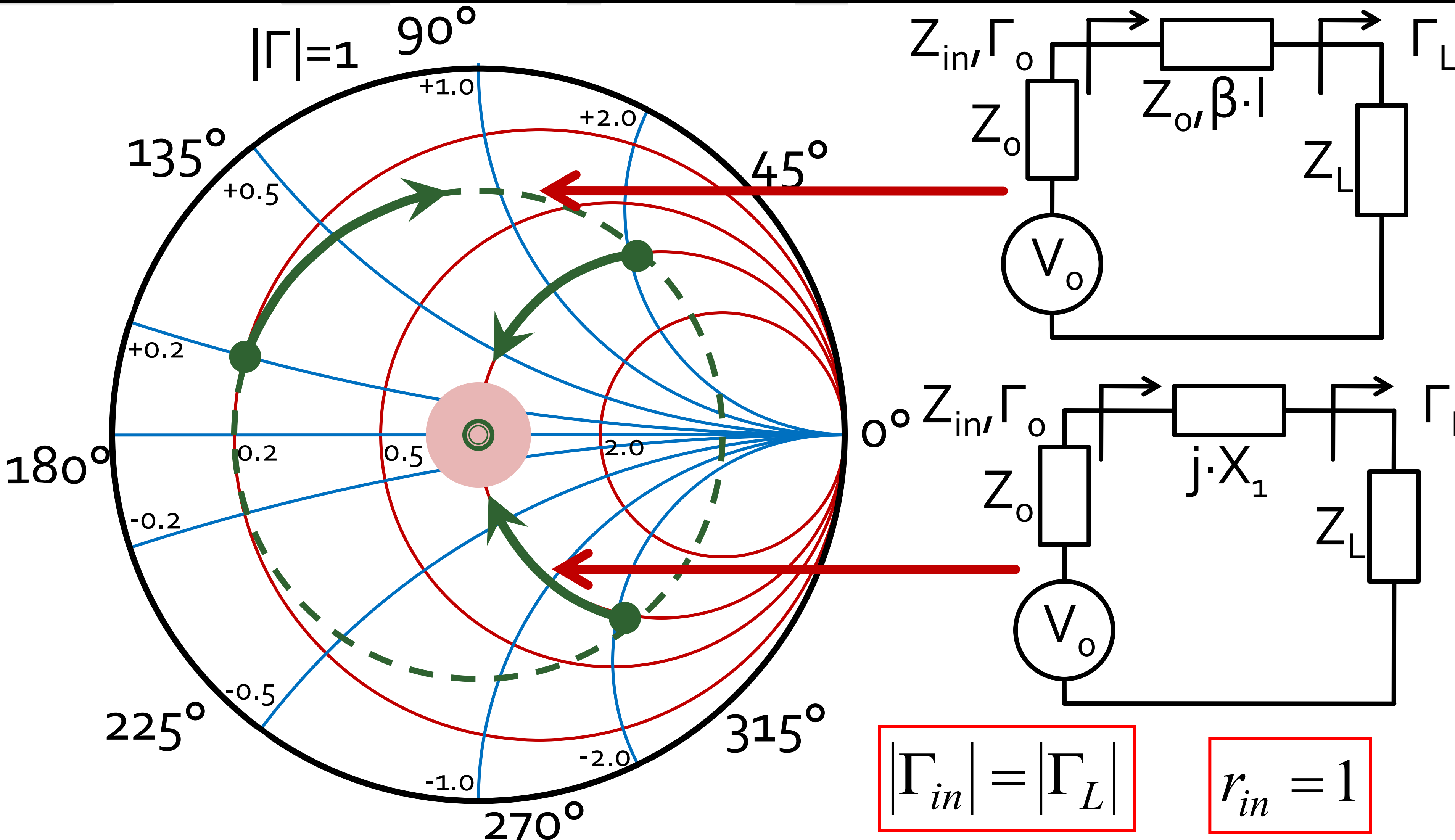


Caz 2, Series Stub

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



Adaptare, linie serie + reactanta in serie



$$\left|\Gamma_{in}\right| = \left|\Gamma_{L}\right|$$

$$r_{in} = 1$$

Calcul analitic (calcul efectiv)

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

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

$$\Gamma_S=0.555\angle-29.92°$$

$$|\Gamma_S|=0.555;\quad \varphi=-29.92°$$

$$\cos(\varphi+2\theta)=0.555\Rightarrow(\varphi+2\theta)=\pm 56.28°$$

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

$$(-29.92°+2\theta)=+56.28°\qquad \theta=43.1°$$

$$\operatorname{Im} z_S=\frac{+2\cdot|\Gamma_S|}{\sqrt{1-|\Gamma_S|^2}}=+1.335$$

$$\theta_{ss}=-\cot^{-1}(\operatorname{Im} z_S)=-36.8°(+180°)\rightarrow\theta_{ss}=143.2°$$

  - **solutia "cu -"**

$$(-29.92°+2\theta)=-56.28°\qquad \theta=-13.2°(+180°)\rightarrow\theta=166.8°$$

$$\operatorname{Im} z_S=\frac{-2\cdot|\Gamma_S|}{\sqrt{1-|\Gamma_S|^2}}=-1.335\qquad \theta_{ss}=-\cot^{-1}(\operatorname{Im} z_S)=36.8°$$

Calcul analitic (calcul efectiv)

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

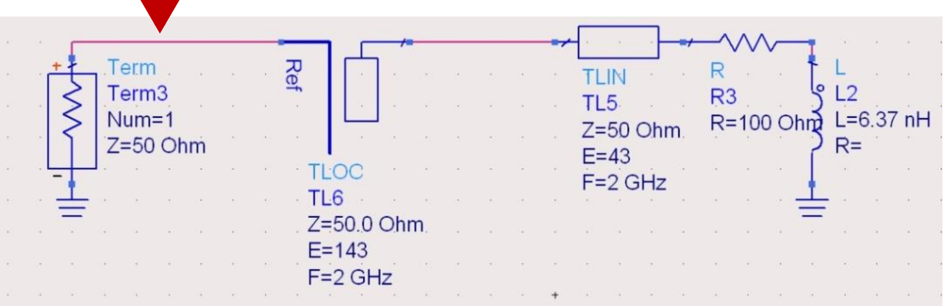
- Se alege **una** din cele doua solutii posibile
- **Semnul** (+/-) solutiei alese la **prima** ecuatie impune **semnul** solutiei utilizate la a **doua** ecuatie

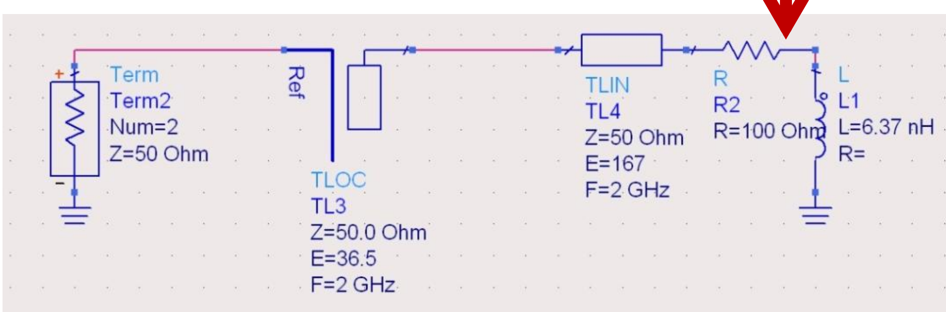
$$l_1=\frac{43.1^\circ}{360^\circ}\cdot\lambda=0.120\cdot\lambda$$

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

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

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





Stub, observatii

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

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

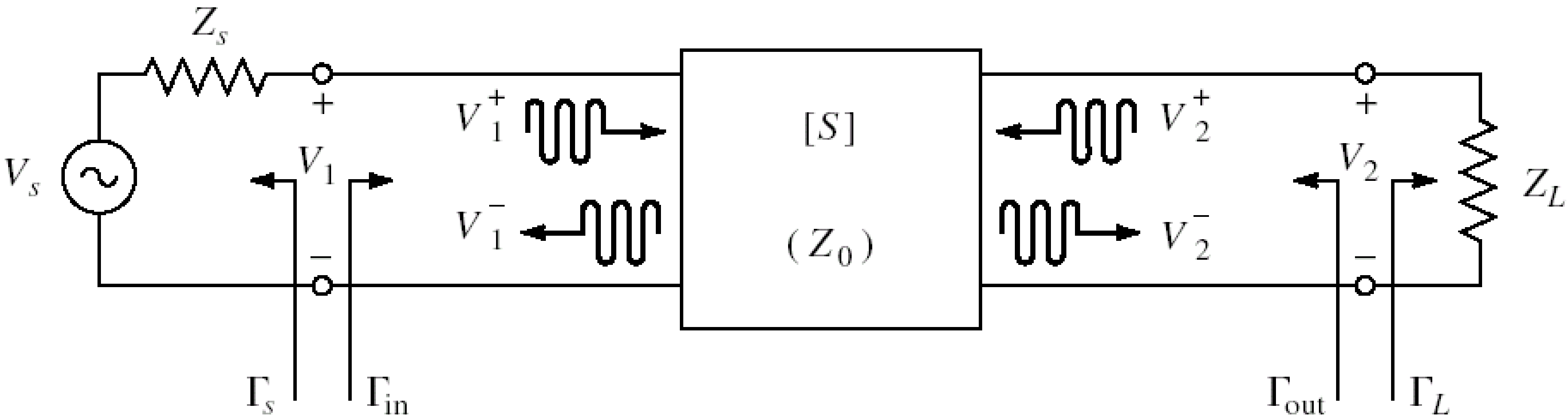
  - pentru linii de "lungime" / "lungime electrica" **negative** se adauga λ/2 / 180° pentru a avea valoare pozitiva (realizabila fizic)
- o adaugare sau scadere de **90°** (λ/4) transforma impedanta stub-ului:

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

  - pentru stub se poate adauga/scadea 90° (λ/4) simultan cu schimbare **gol** ⇔ **scurtcircuit**

Amplificatoare de microunde

Diport amplificator

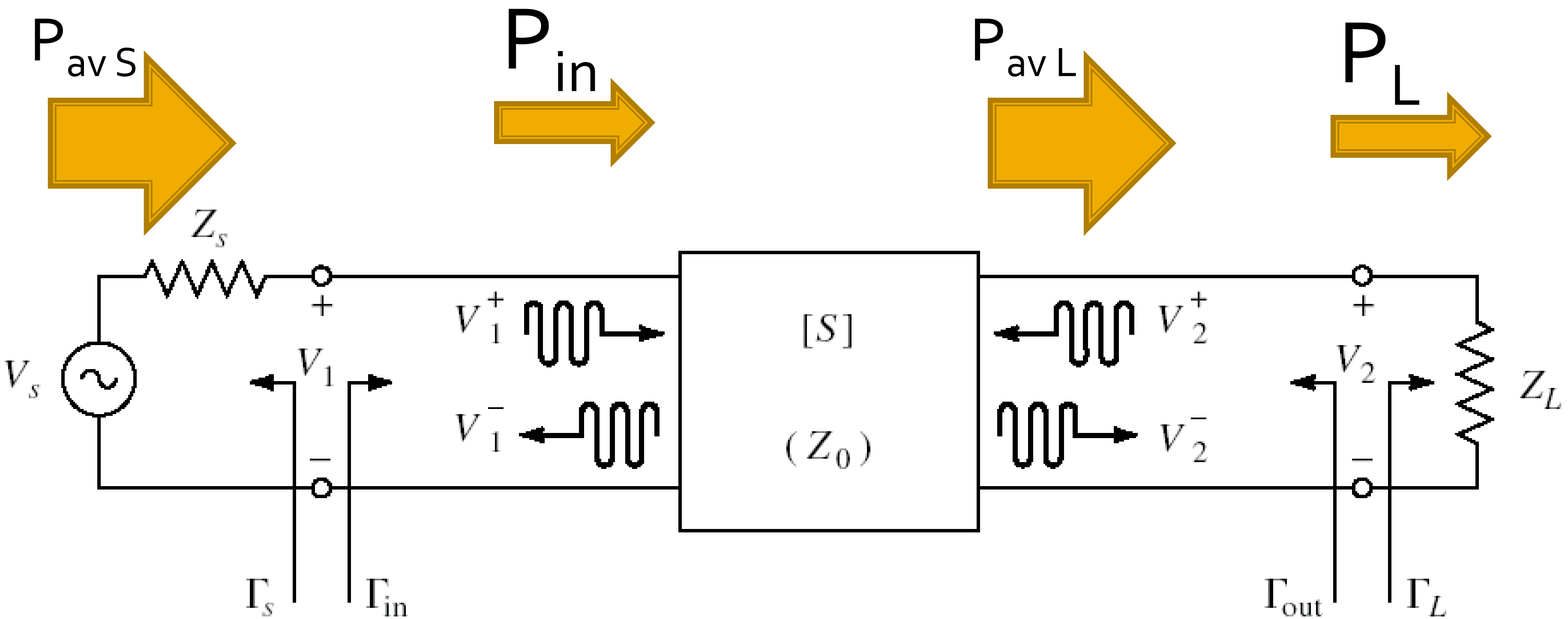


$$\Gamma_{in} = \frac{V_1^-}{V_1^+} = S_{11} + \frac{S_{12} \cdot S_{21} \cdot \Gamma_L}{1 - S_{22} \cdot \Gamma_L}$$

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

Puteri / Adaptare

- Doua porturi in care adaptarea influențează transferul de putere



Castig de putere

- Castigul de putere **disponibil**

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

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

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

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

- Castigul de putere de **transfer unilateral**

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

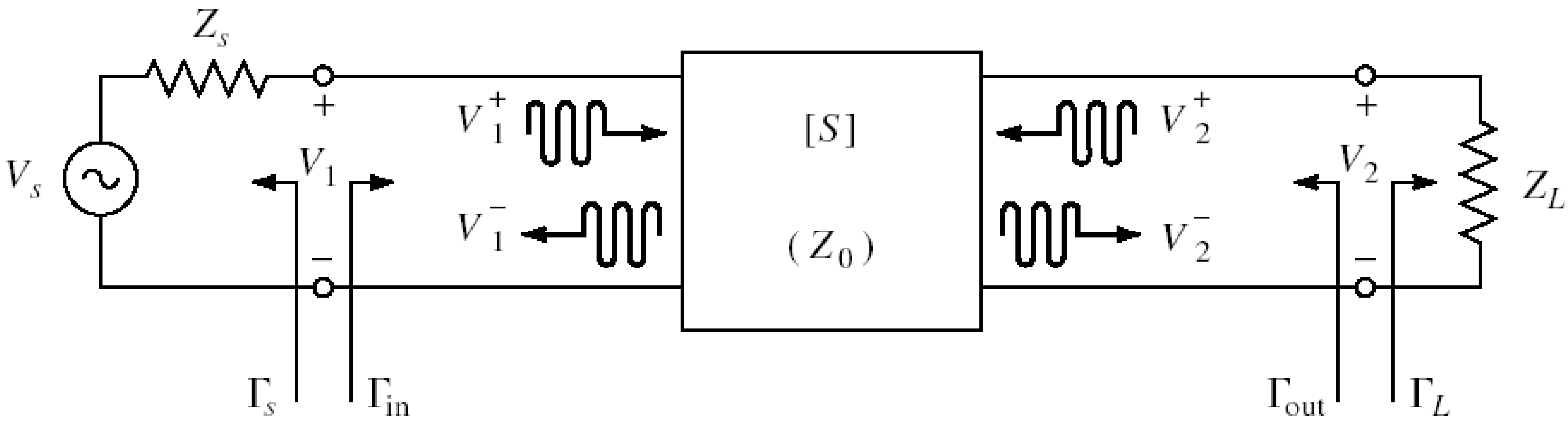
$$S_{12} \cong 0 \qquad \Gamma_{in} = S_{11}$$

Permite tratarea separata a intrarii si iesirii

Amplificatoare de microunde

Stabilitate

Cuadripol Amplificator



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

Cerc de stabilitate la iesire (CSOUT)

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

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

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

Cerc de stabilitate la intrare (CSIN)

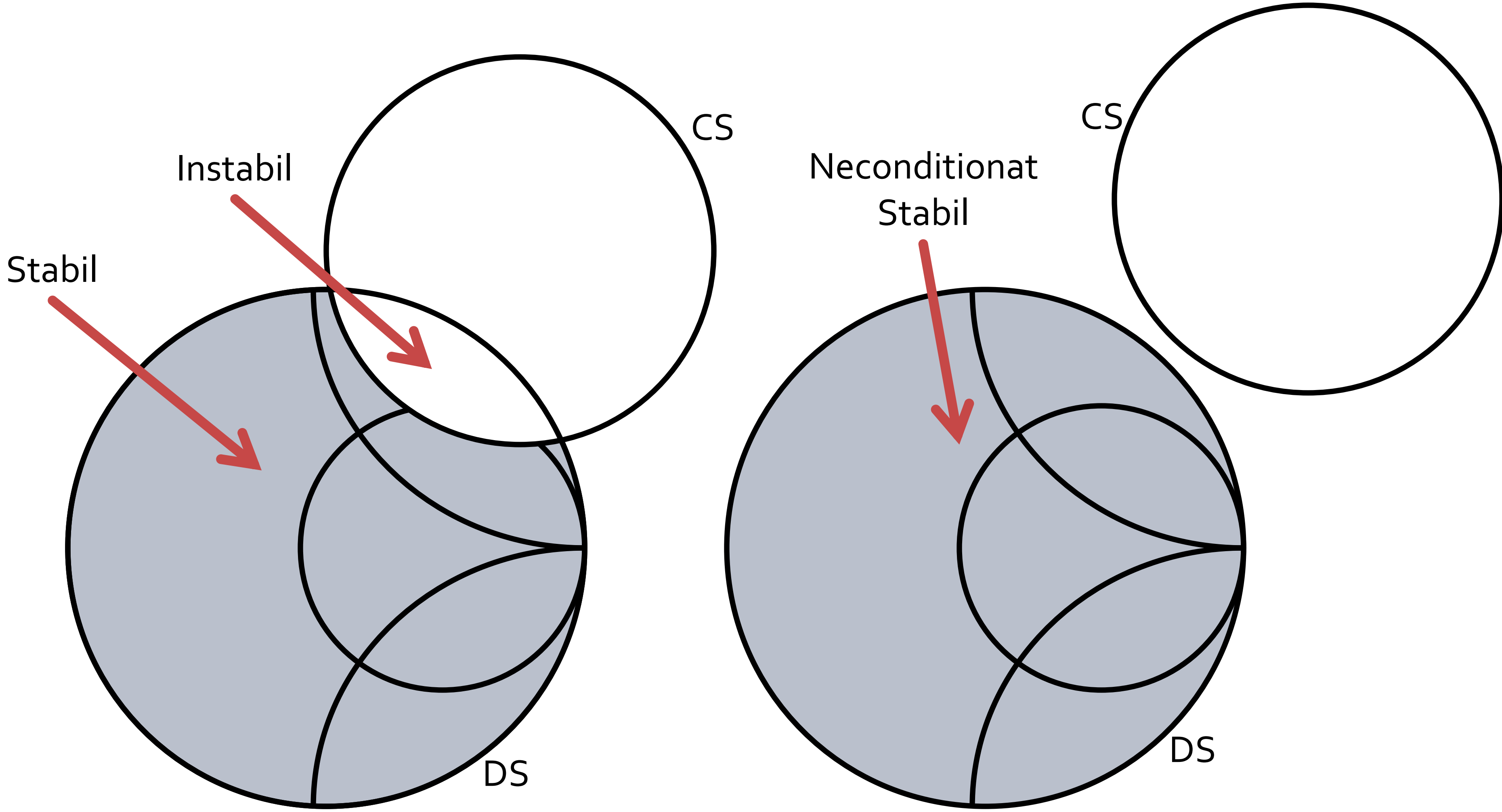
- Similar

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

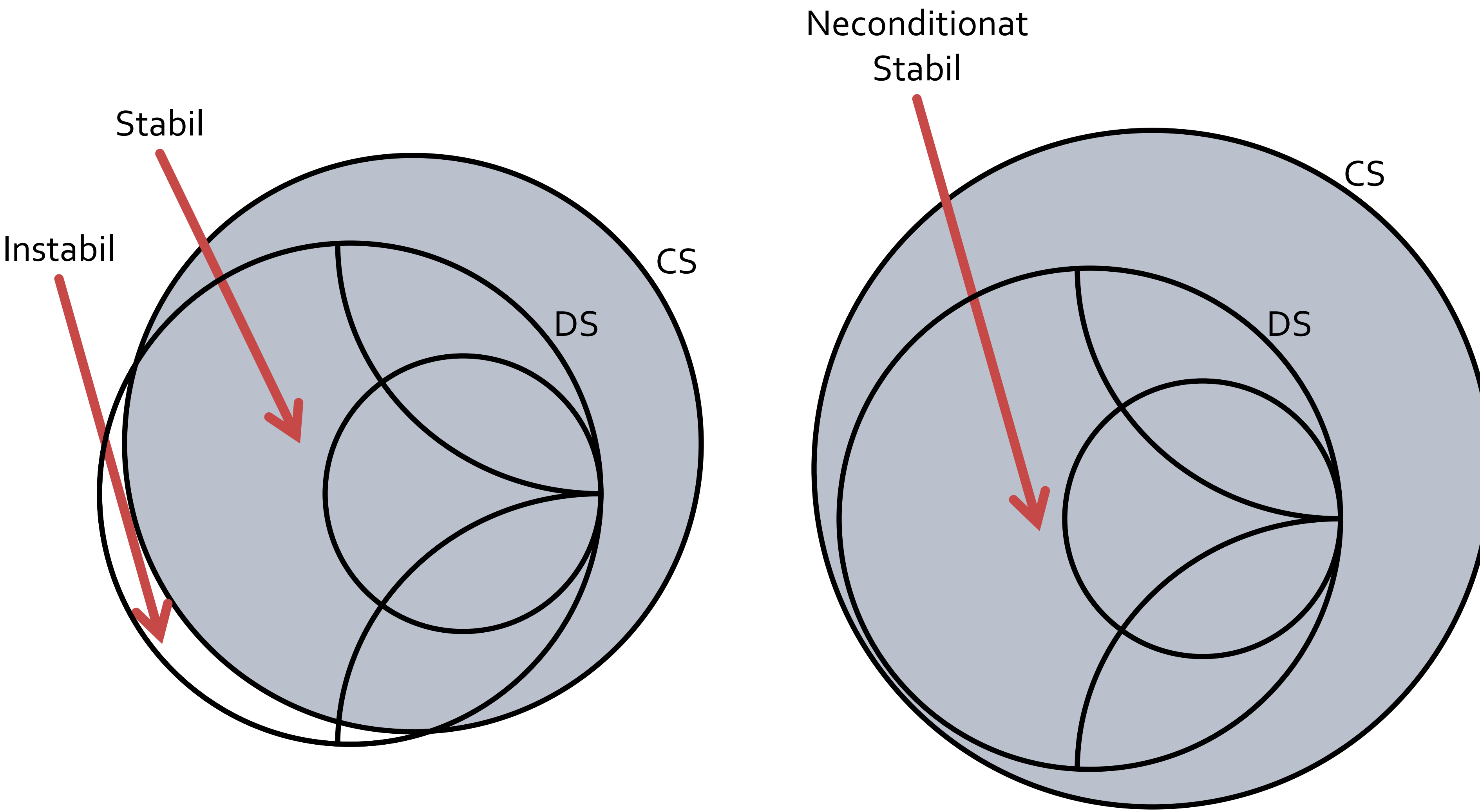
- Ecuatia unui cerc, care reprezinta locul geometric al punctelor Γ_S pentru **limita** de stabilitate
- Cercul se numeste **cerc de stabilitate la intrare** (Γ_S)

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

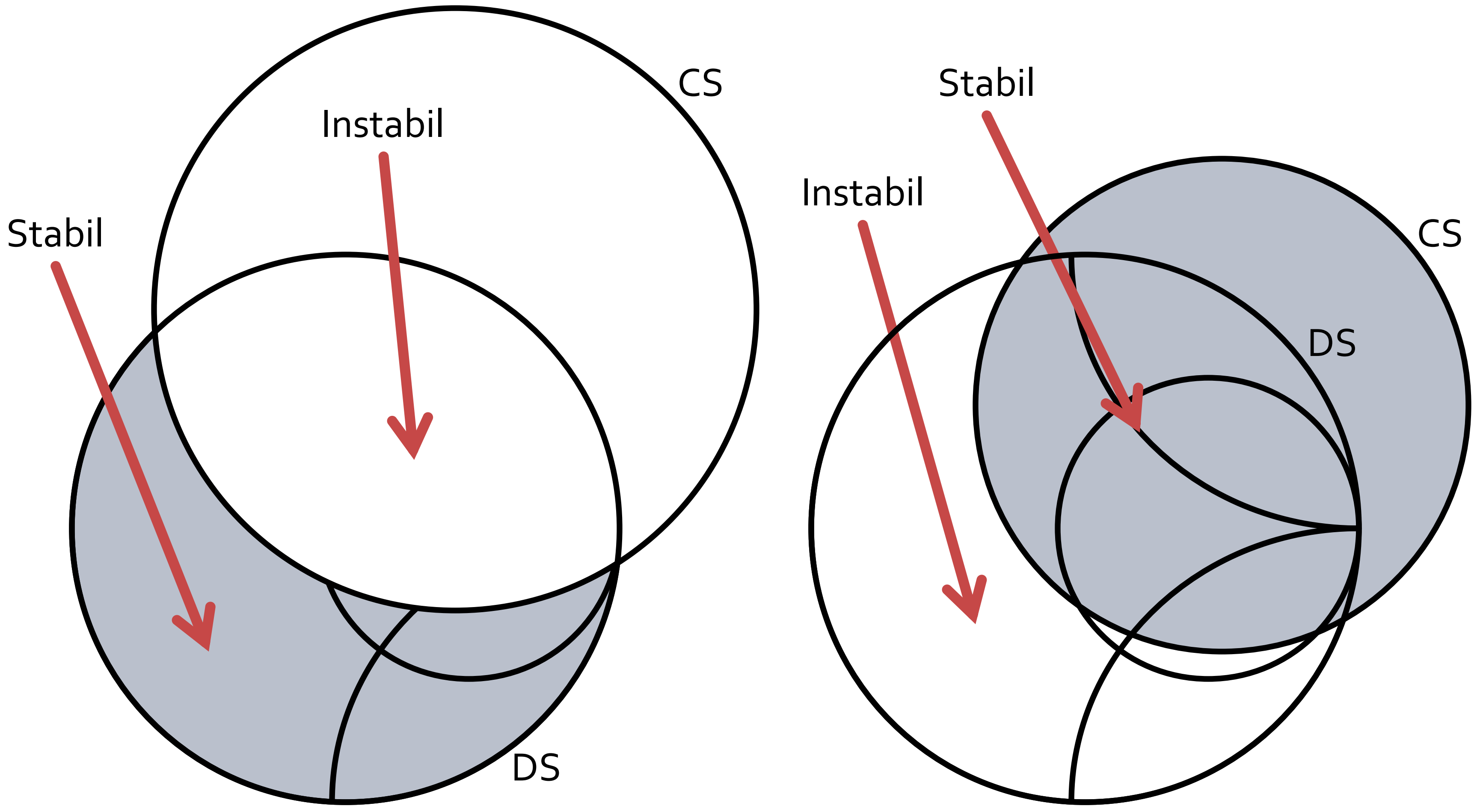
Mai multe pozitionari posibile



Mai multe pozitionari posibile



Pozitionari mai rare



Stabilitate

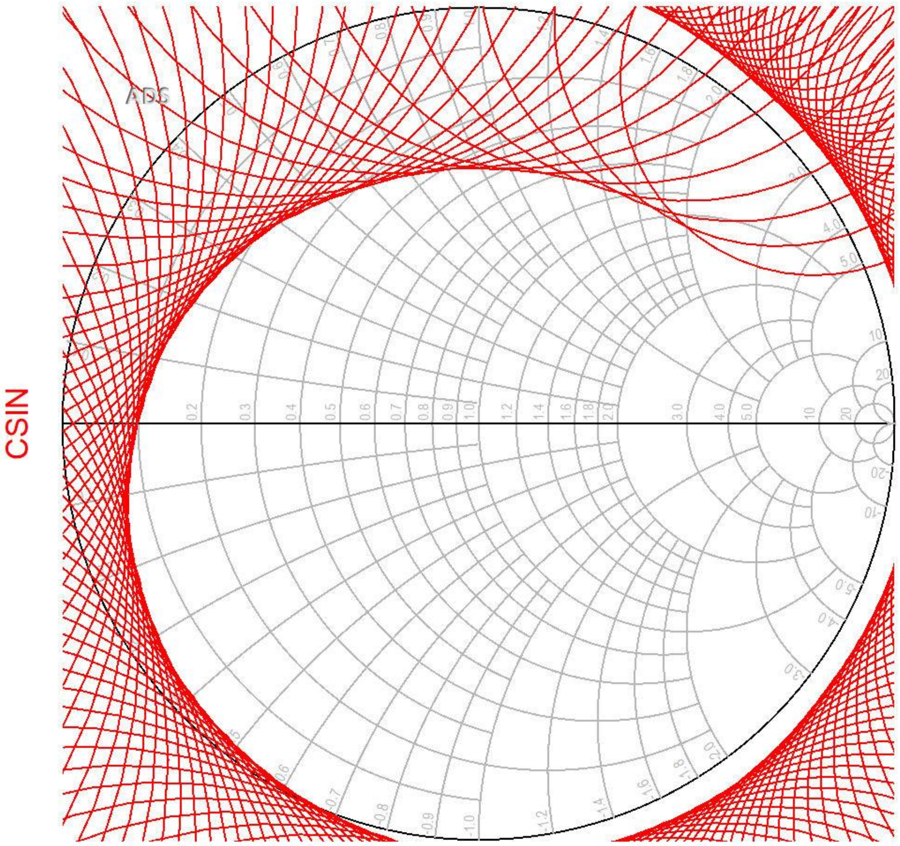
- **Stabilitatea necondiționată:** circuitul este necondiționat stabil dacă $|\Gamma_{in}|<1$ şi $|\Gamma_{out}|<1$ pentru **orice** impedanță pasivă a sarcinii şi sursei
- **Stabilitatea condiționată:** circuitul este condiționat stabil dacă $|\Gamma_{in}|<1$ şi $|\Gamma_{out}|<1$ doar pentru un anumit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

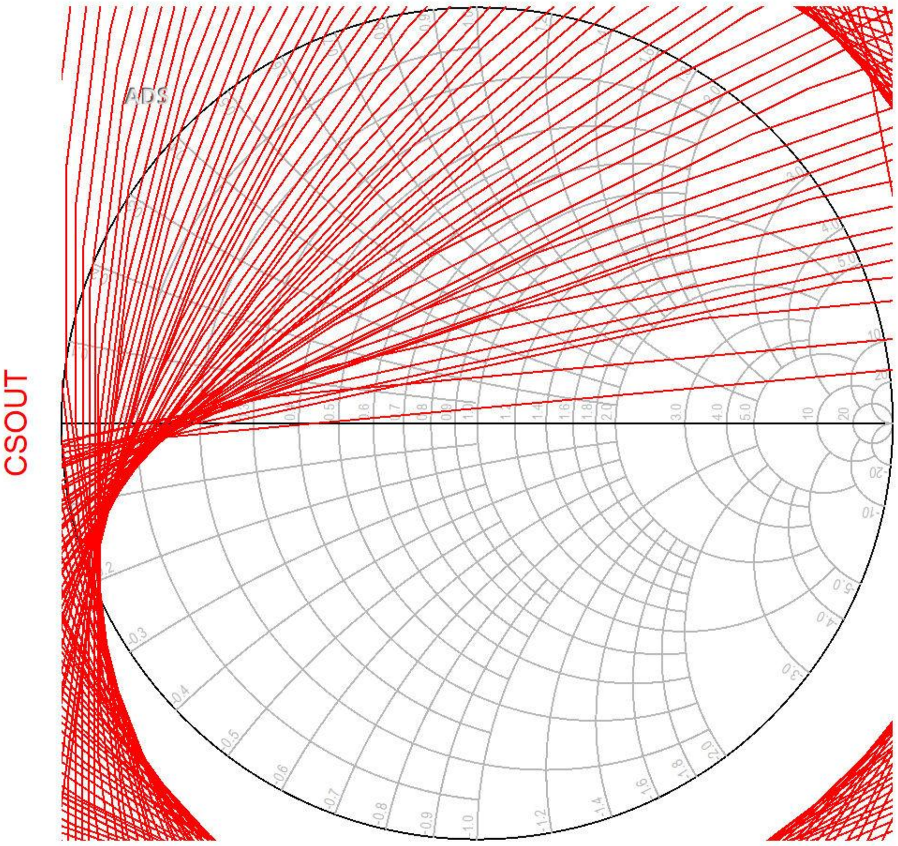
Continuare

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
  - |Δ| < 1
- Sunt valabile si conditiile implicite
  - |S11| < 1
  - |S22| < 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'

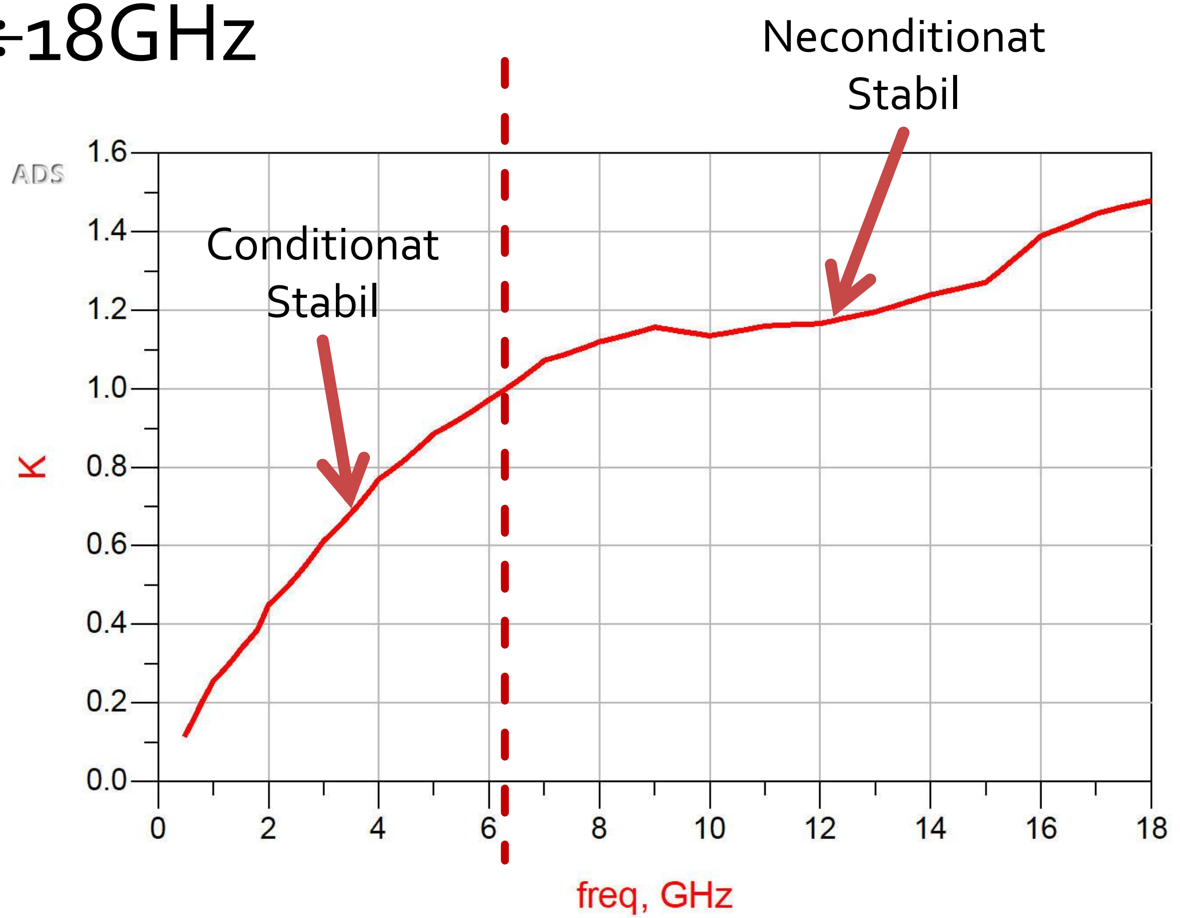
- Parametru dual pentru μ, determinat relativ la cercul de stabilitate la intrare

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

- Diportul este **neconditionat stabil** daca:
  - μ' > 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 intrare

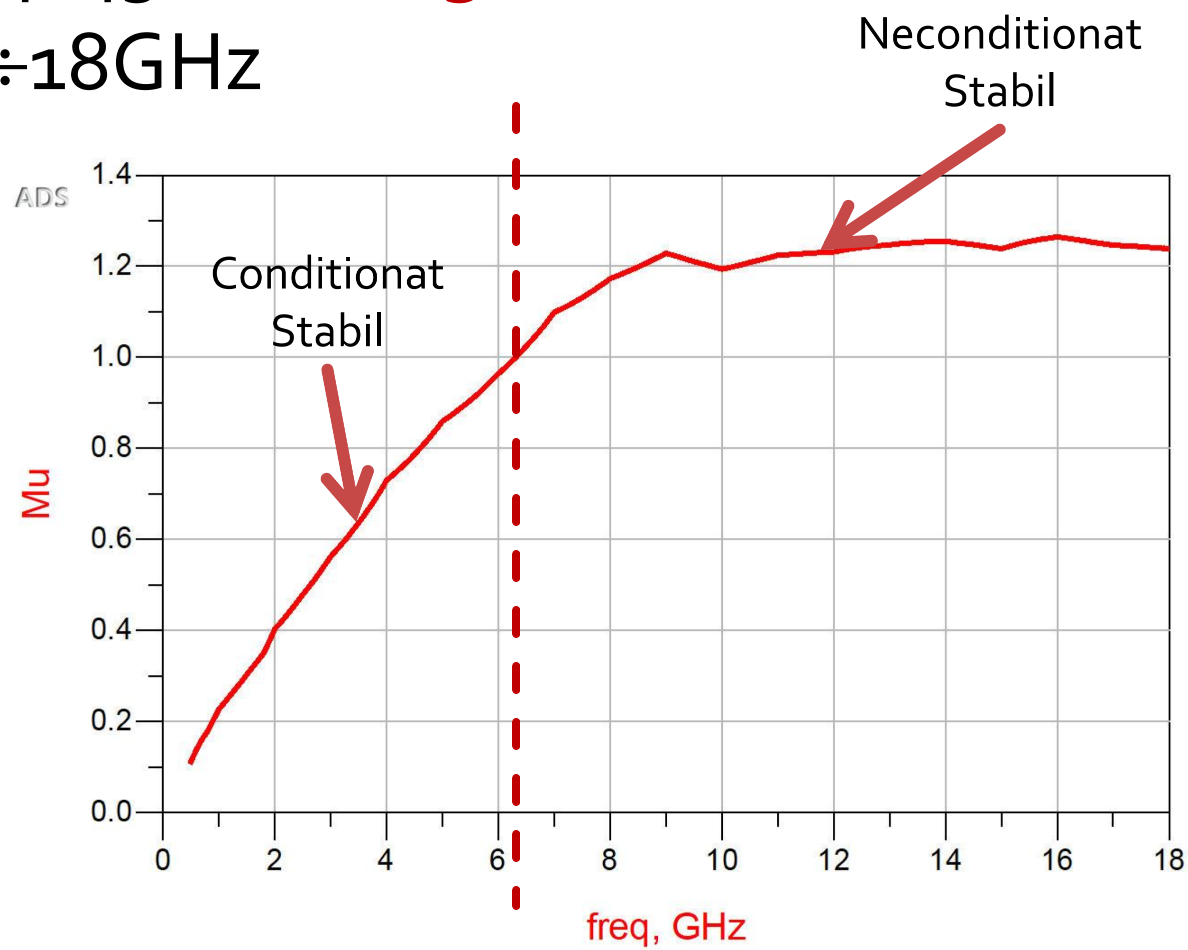
Conditia Rollet

- ATF-34143 **at Vds=3V Id=20mA**.
- @0.5÷18GHz



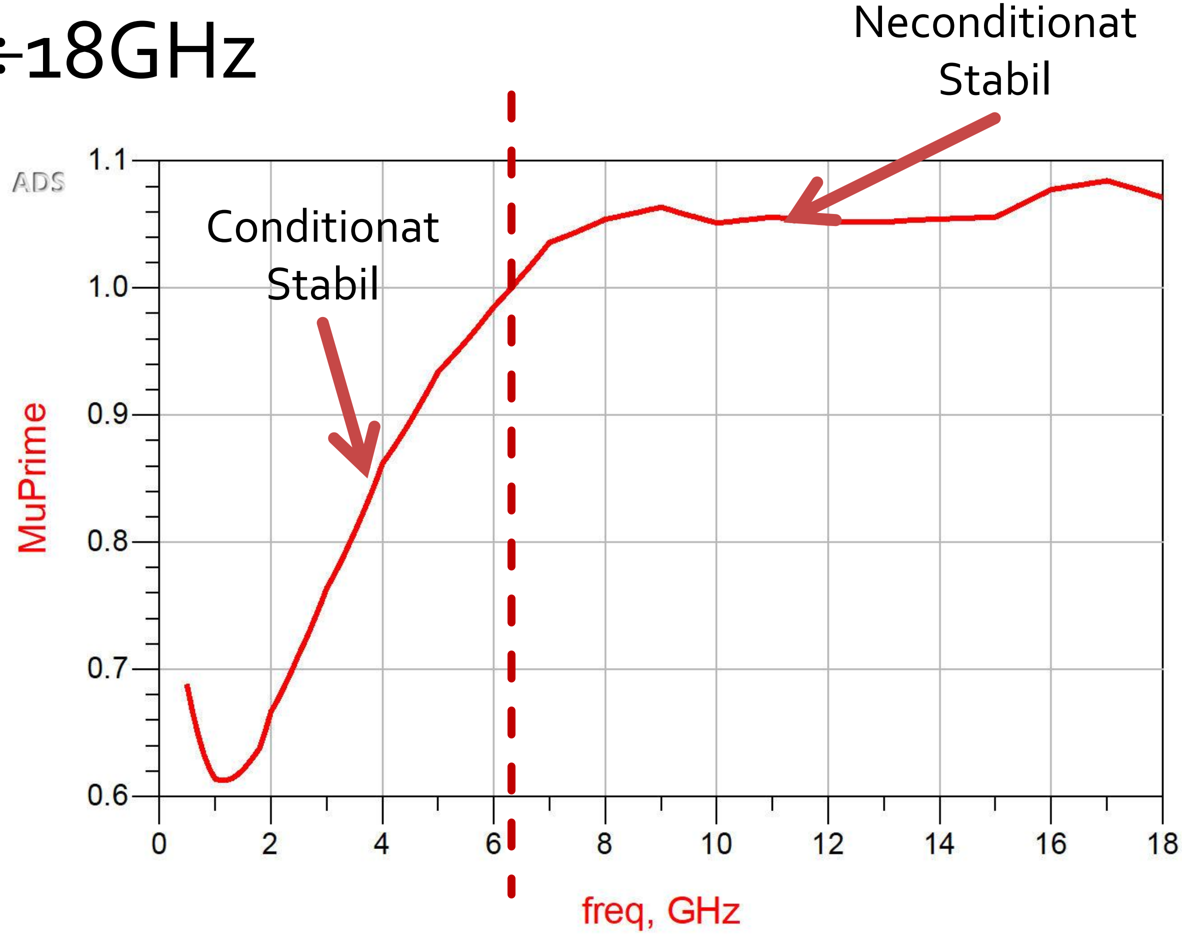
Criteriul μ

- ATF-34143 **at Vds=3V Id=20mA**.
- @0.5÷18GHz



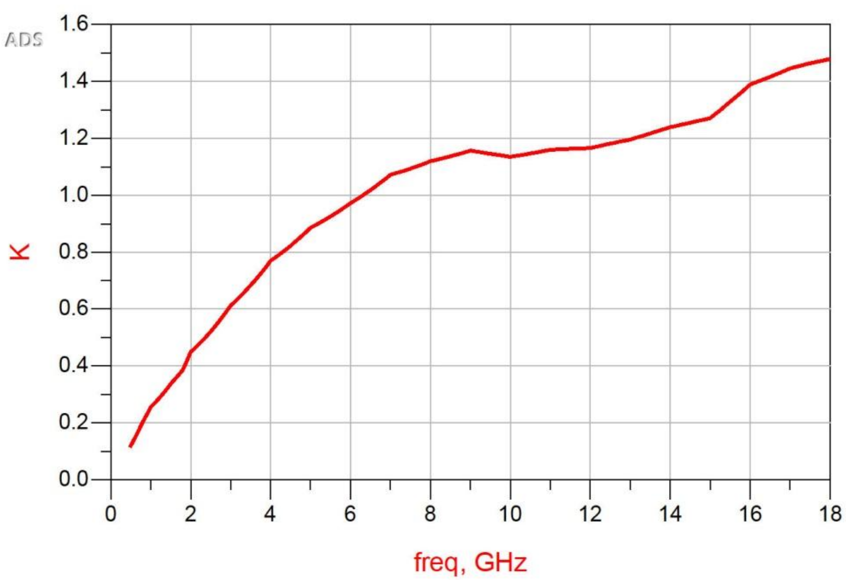
Criteriul μ'

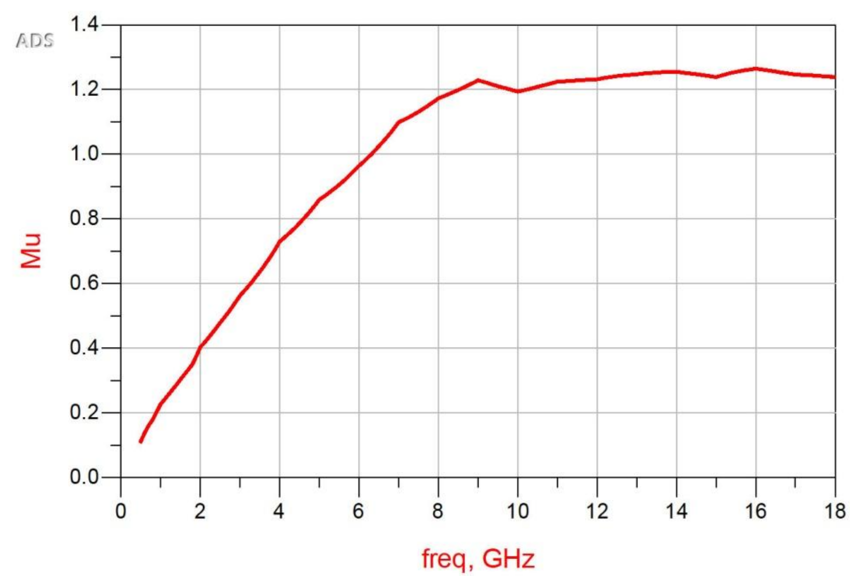
- ATF-34143 **at Vds=3V Id=20mA**.
- @0.5÷18GHz



Stabilitate

- ATF-34143 **at Vds=3V Id=20mA**.
- @0.5÷18GHz
- Neconditionat stabil pentru f > 6.31GHz

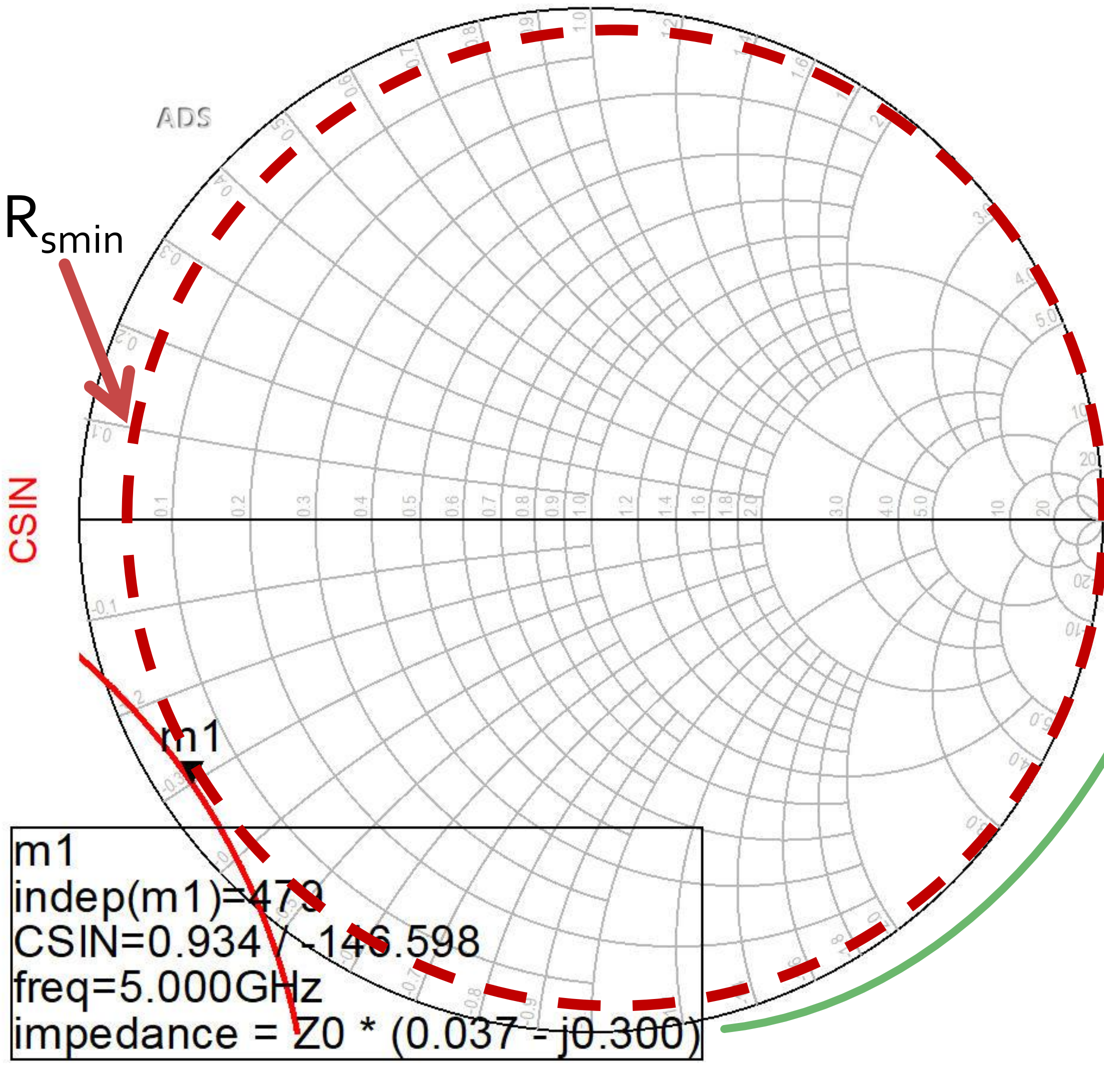


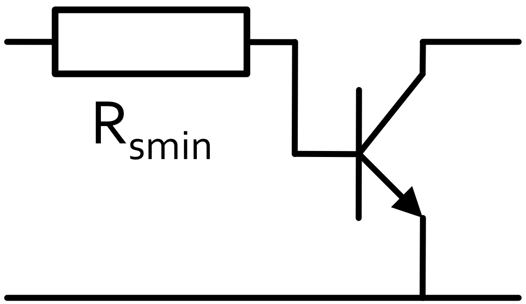


Stabilizarea unui diport

- Stabilitatea neconditionata pentru un interval larg de frecvente are avantaje importante
  - Ex: pot proiecta 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

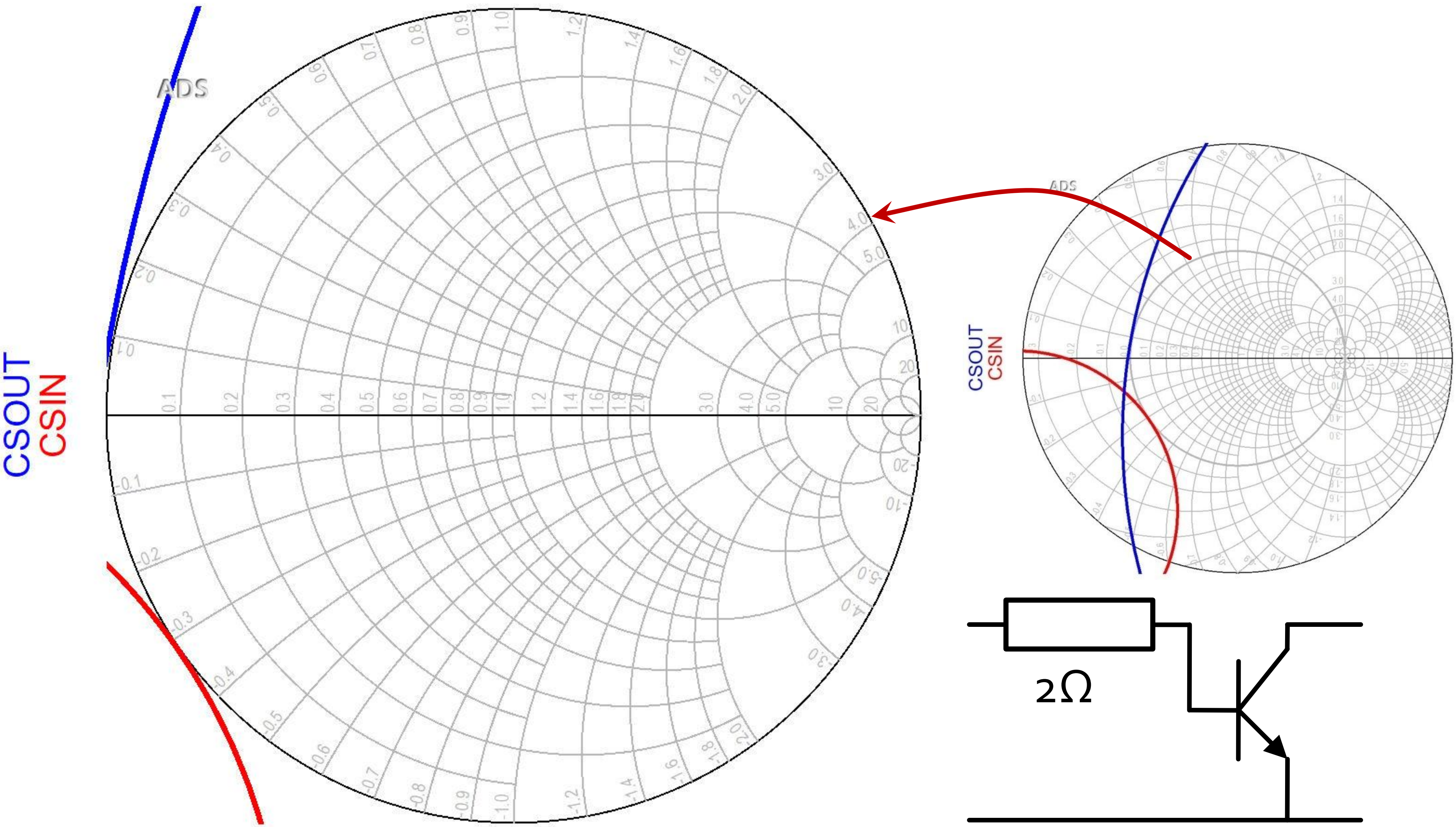




$$z = 0.037 - j \cdot 0.3$$

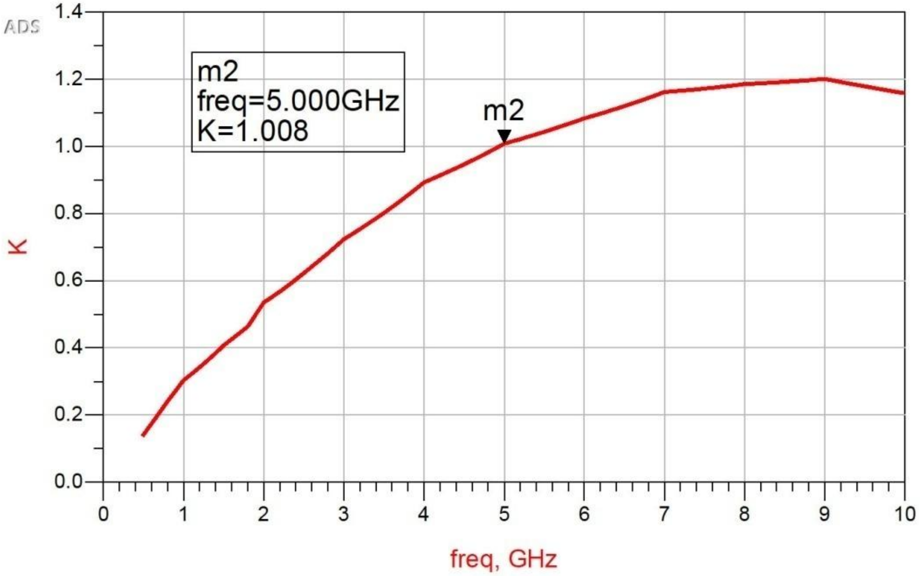
$$R_{s\min} = 0.037 \cdot 50\Omega = 1.85\Omega$$

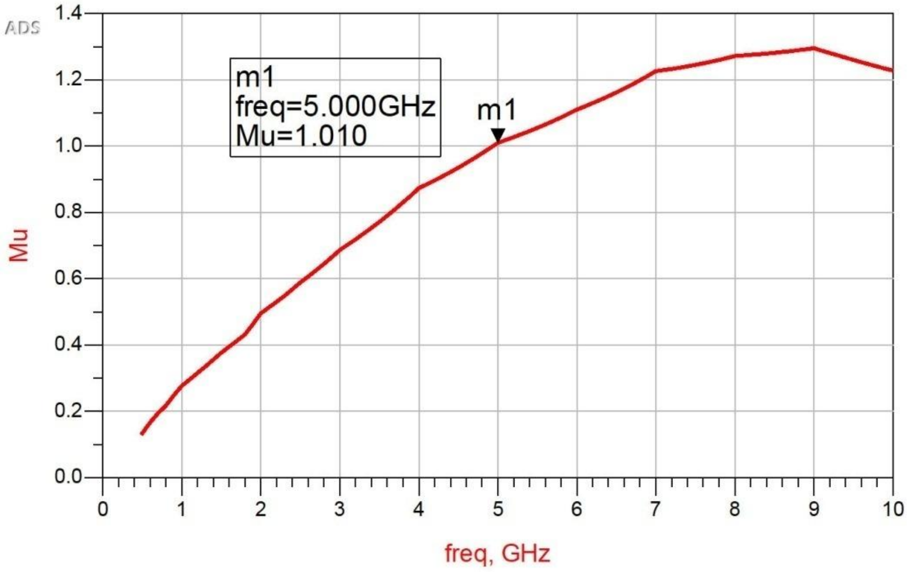
ADS, Rs = 2Ω



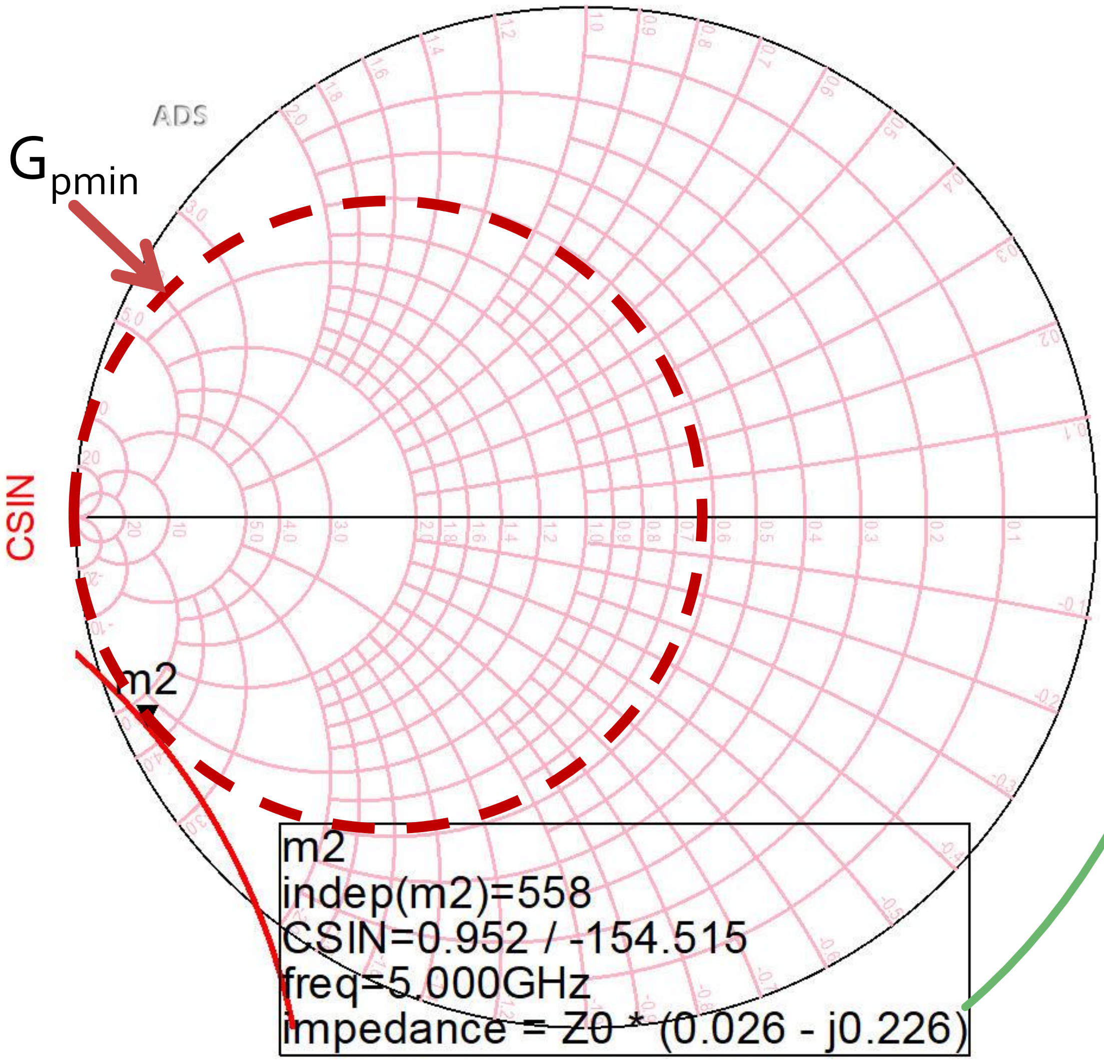
Rezistenta serie la intrare

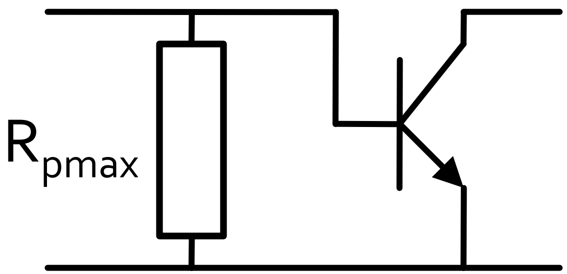
- Rs = 2Ω
- K = 1.008, MAG = 13.694dB @ 5GHz
  - fara stabilizare, K = 0.886, MAG = 14.248dB @ 5GHz





Rezistenta paralel la intrare





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

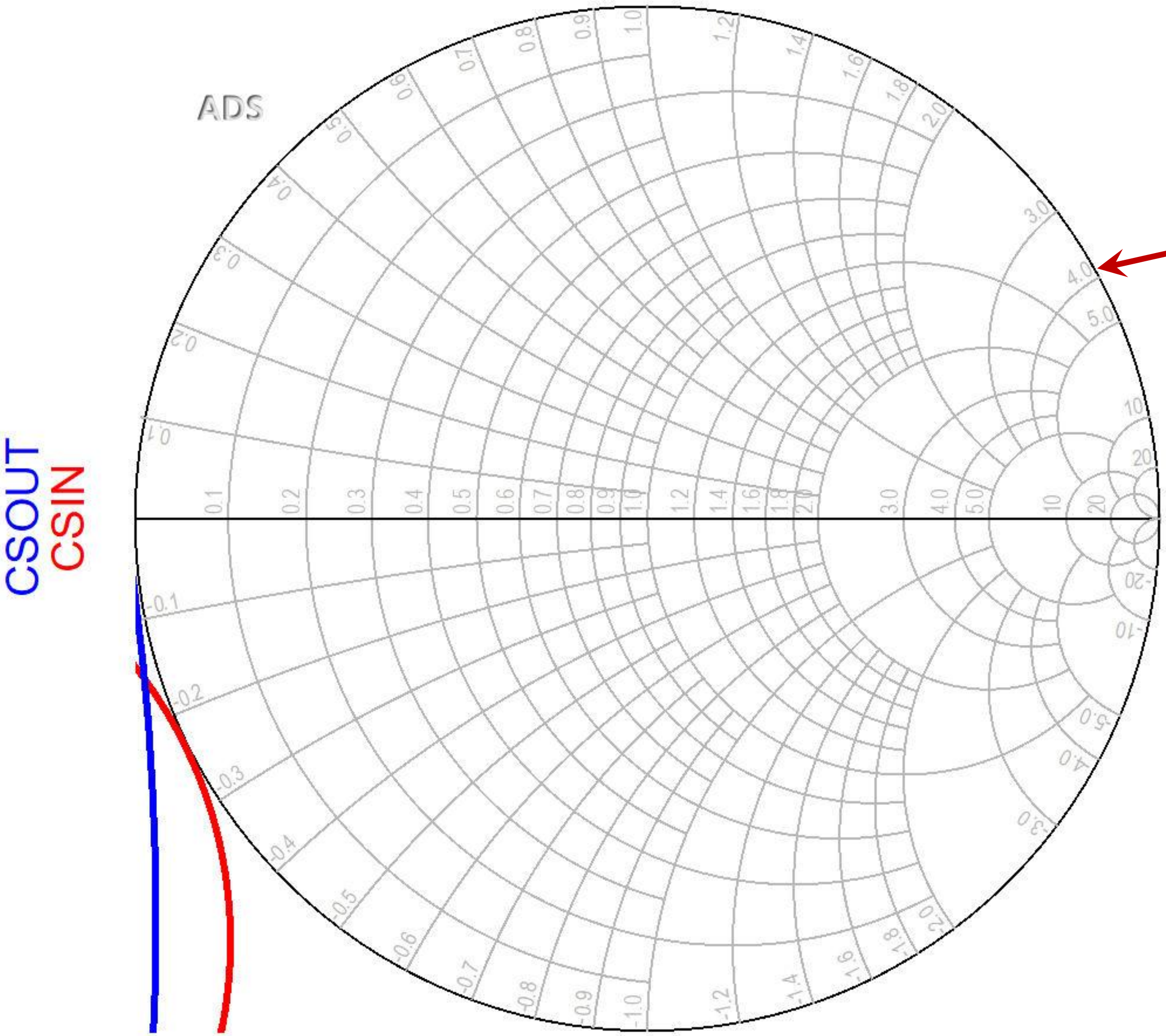
$$z = 0.026 - j \cdot 0.226$$

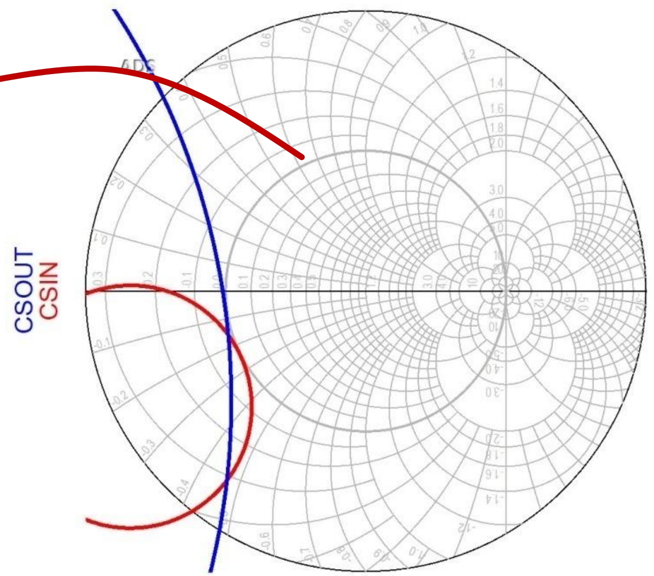
$$y = \frac{1}{z} = \frac{1}{0.026 - j \cdot 0.226}$$

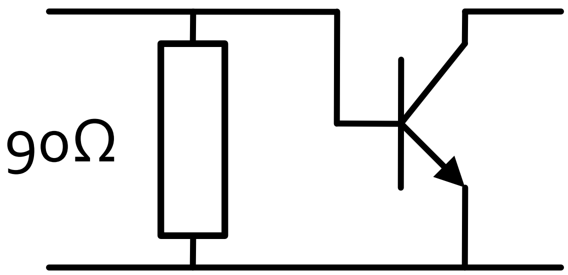
$$y = 0.502 + j \cdot 4.367$$

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

ADS, Rp = 90Ω

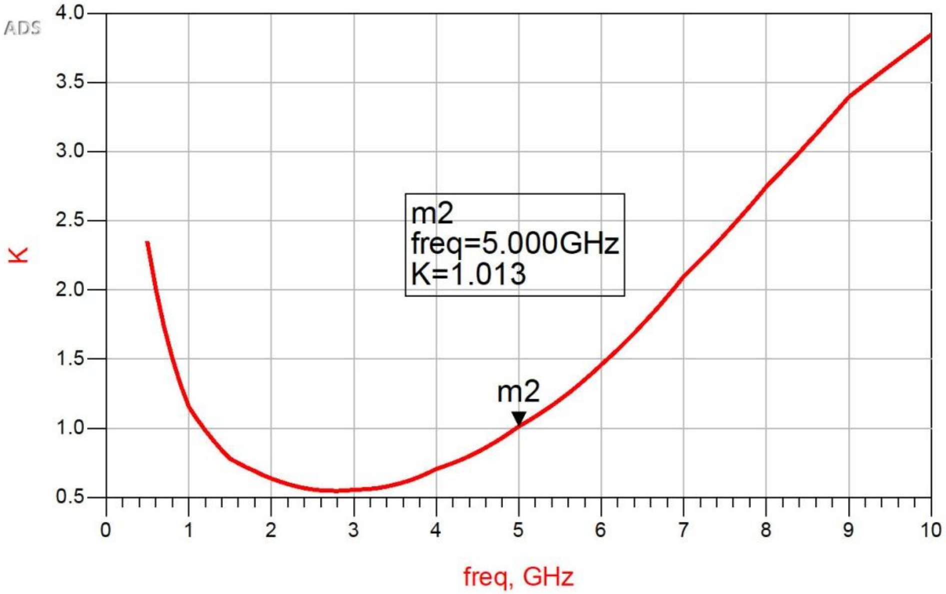


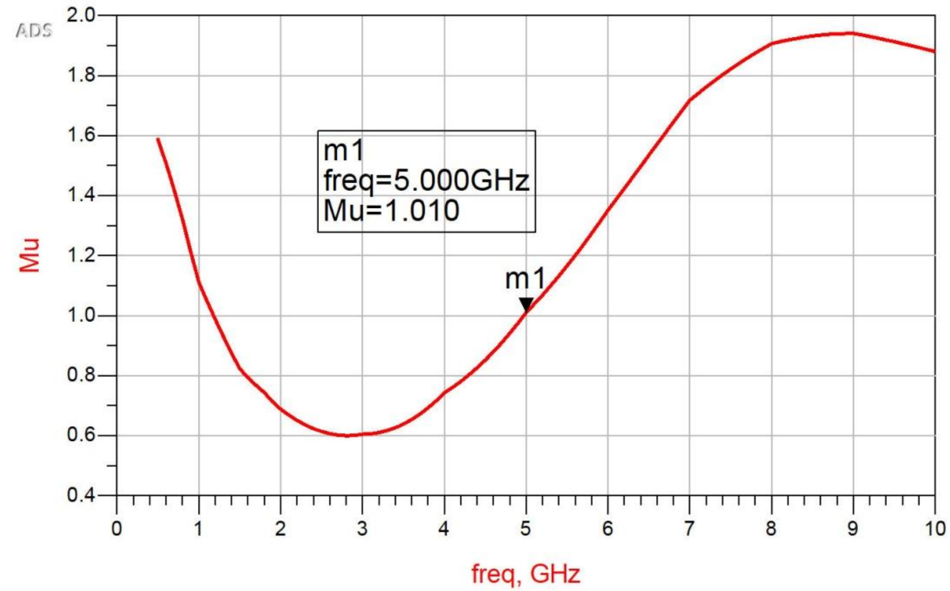




Rezistenta paralel la intrare

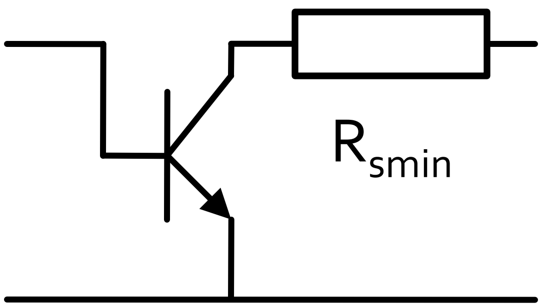
- Rp = 90Ω
- K = 1.013, MAG = 13.561dB @ 5GHz
  - fara stabilizare, K = 0.886, MAG = 14.248dB @ 5GHz

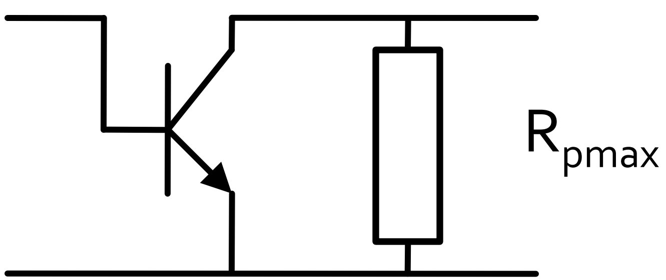




Rezistenta serie/paralel la iesire

- 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)

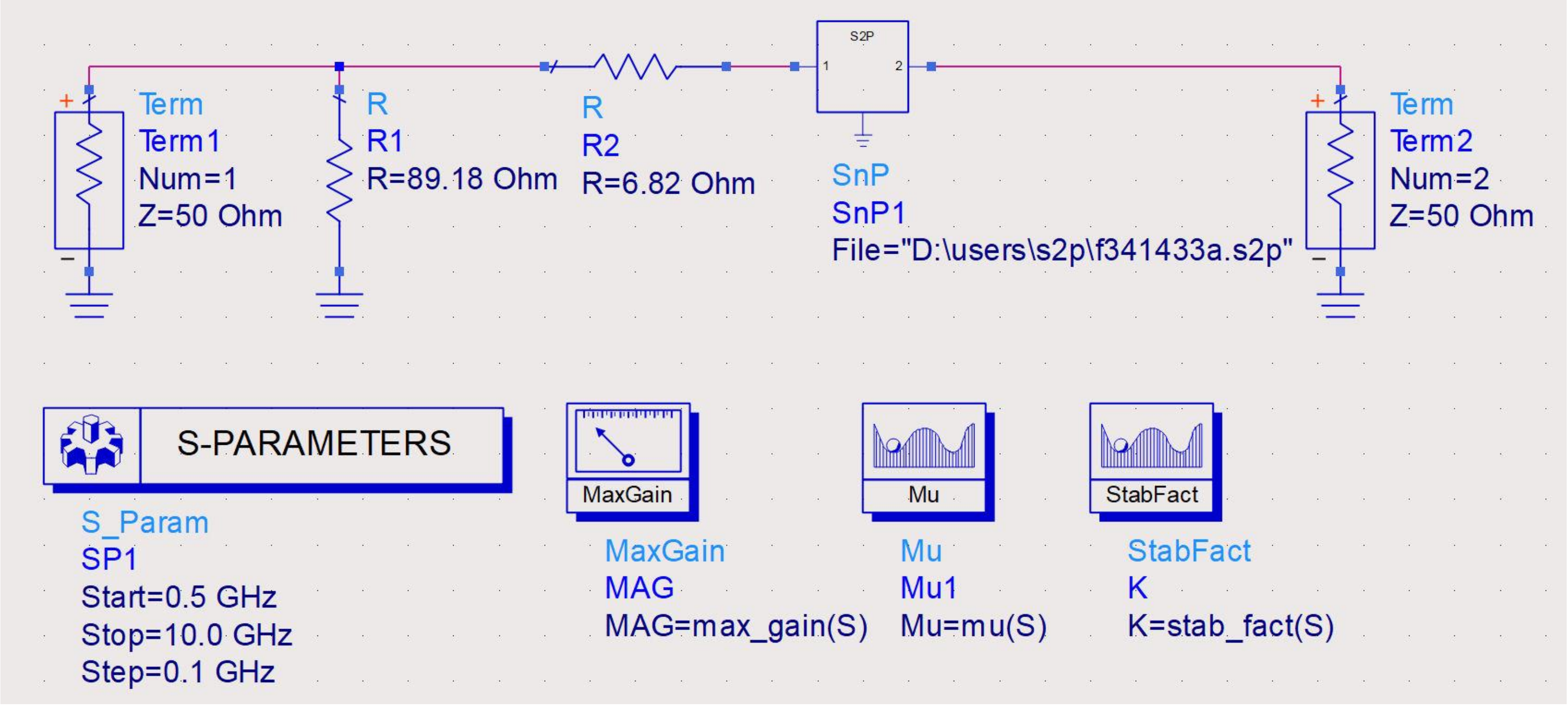




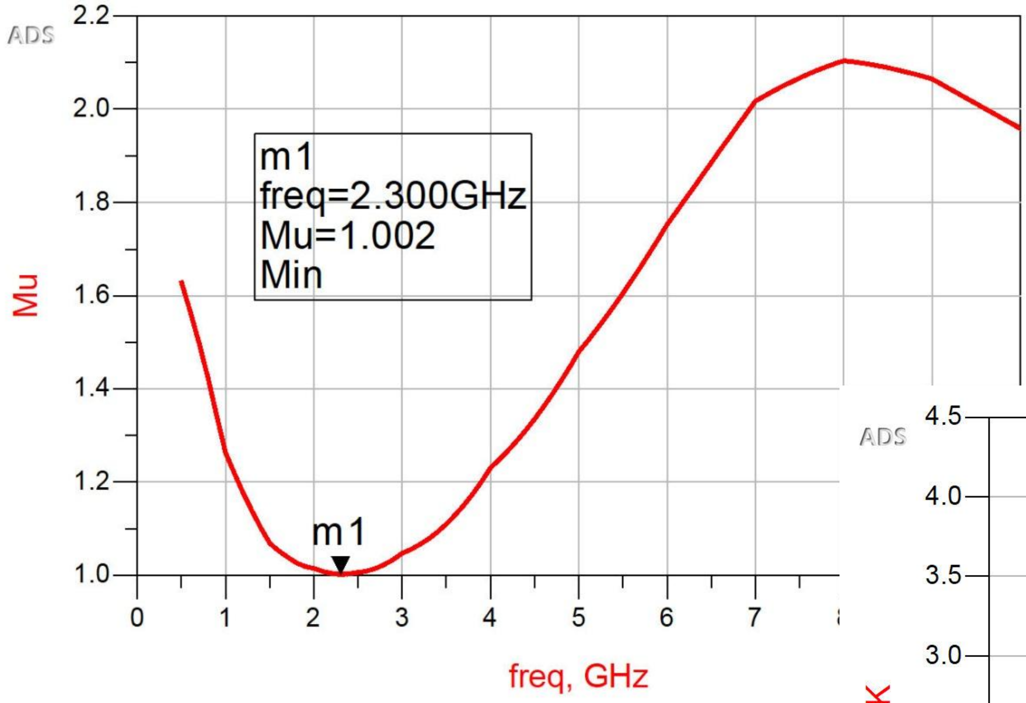
Stabilizarea unui diport

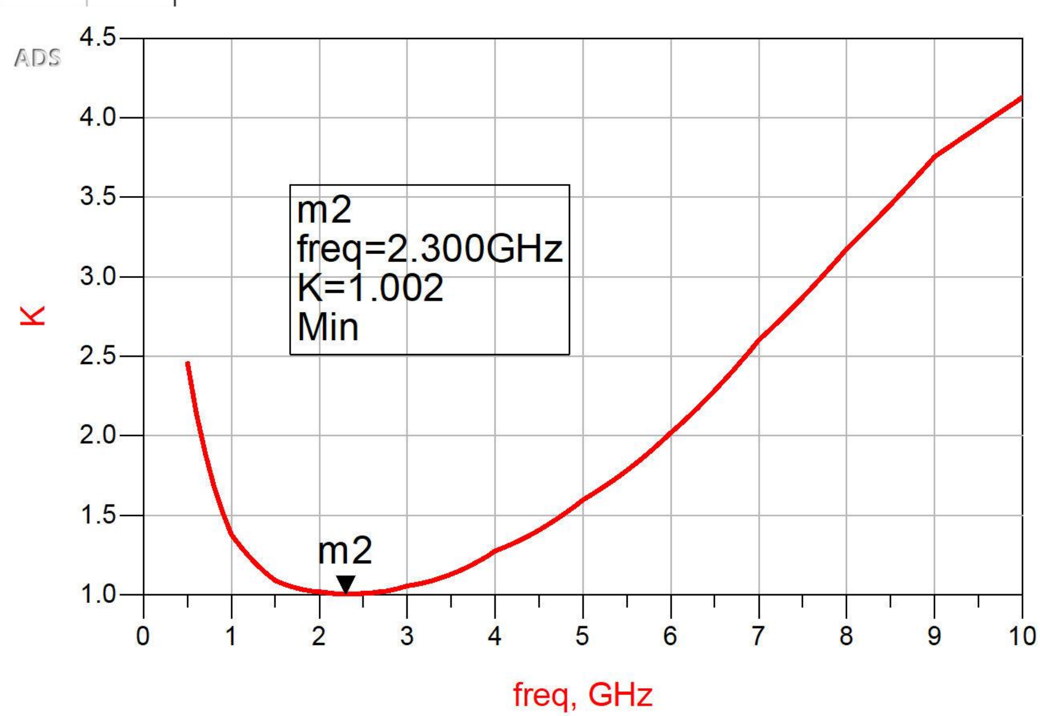
- Efect negativ asupra castigului
  - trebuie urmarit MAG/MSG in timpul proiectarii
- Efect negativ asupra zgomotului (va urma)
- Se poate alege una din cele 4 variante care ofera performante mai bune (in functie de aplicatie)
- Se pot realiza cu elemente de pasivizare selective in frecventa
  - Ex: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

Stabilizarea unui diport

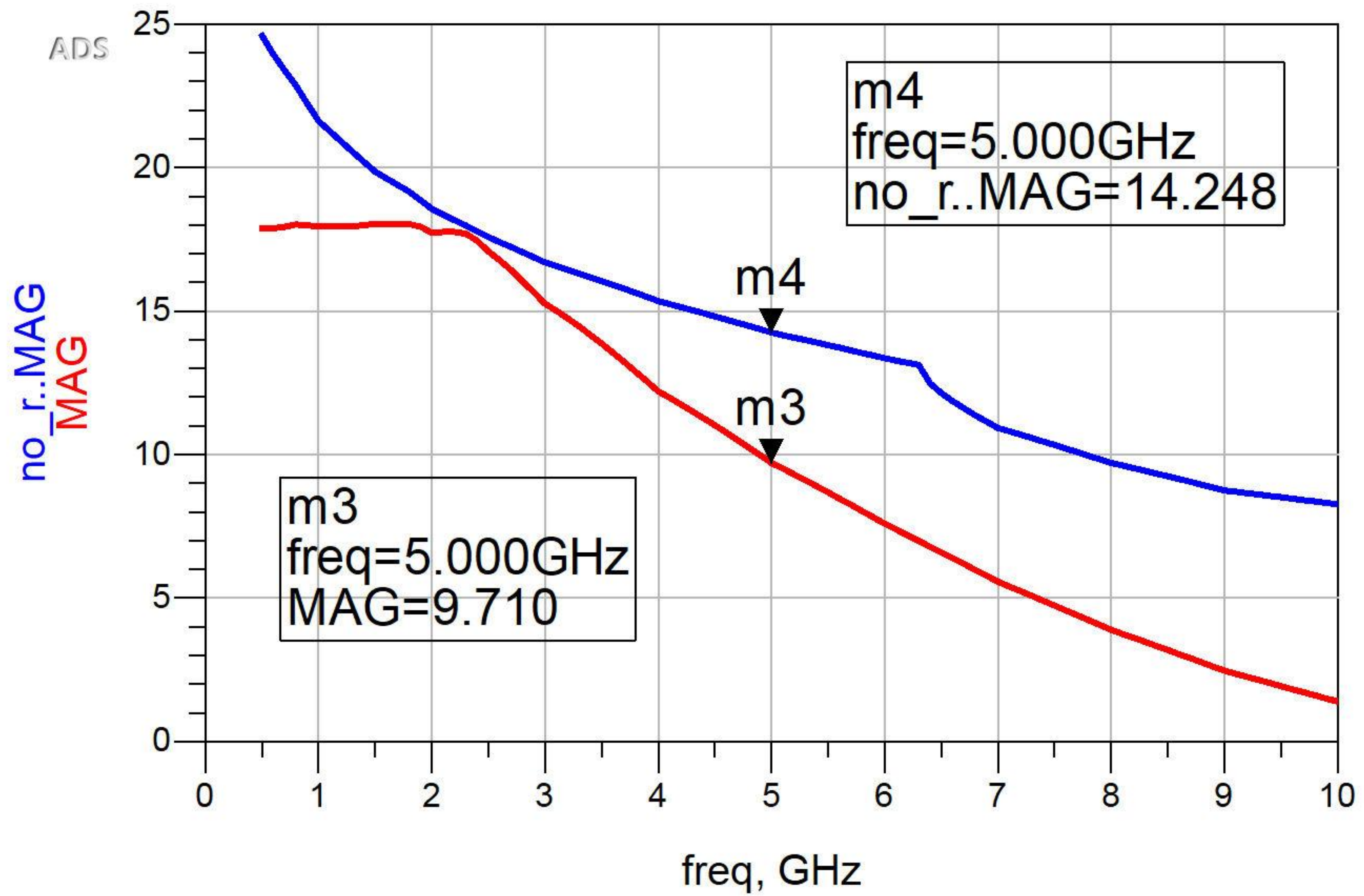


Stabilizarea unui diport

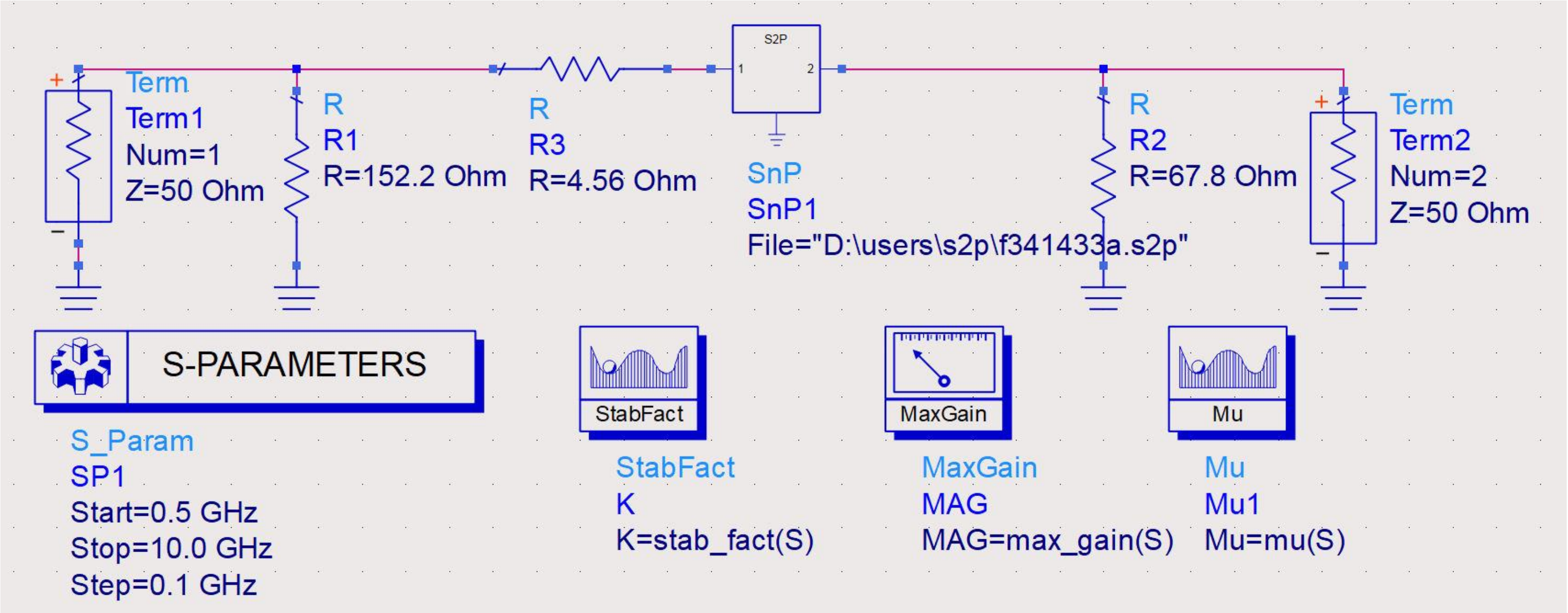




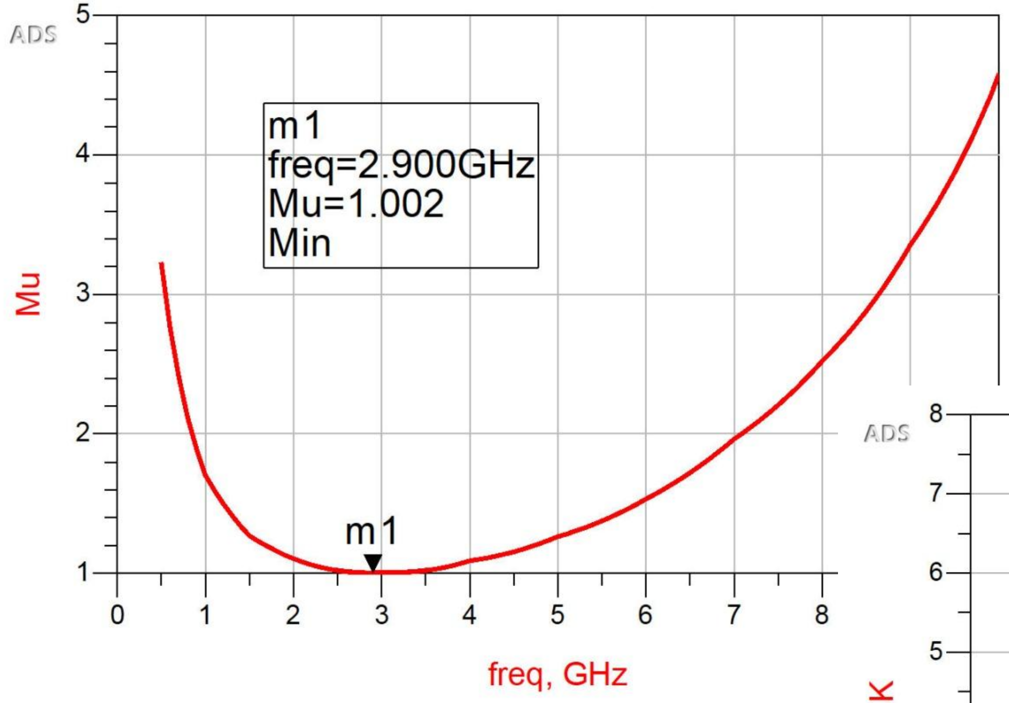
Stabilizarea unui diport

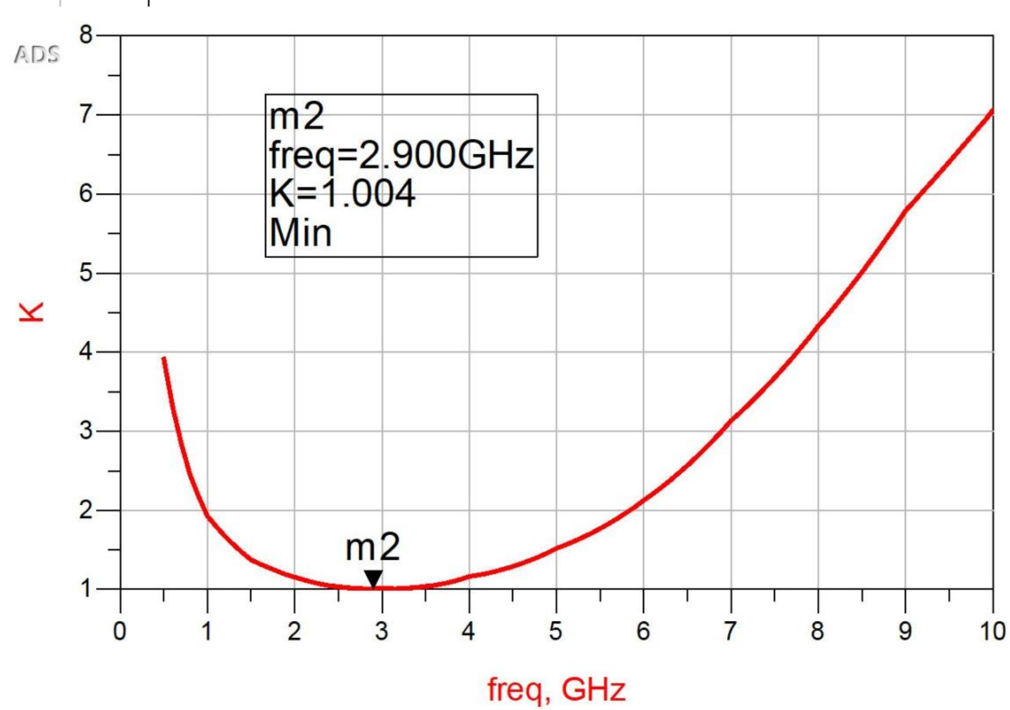


Stabilizarea unui diport

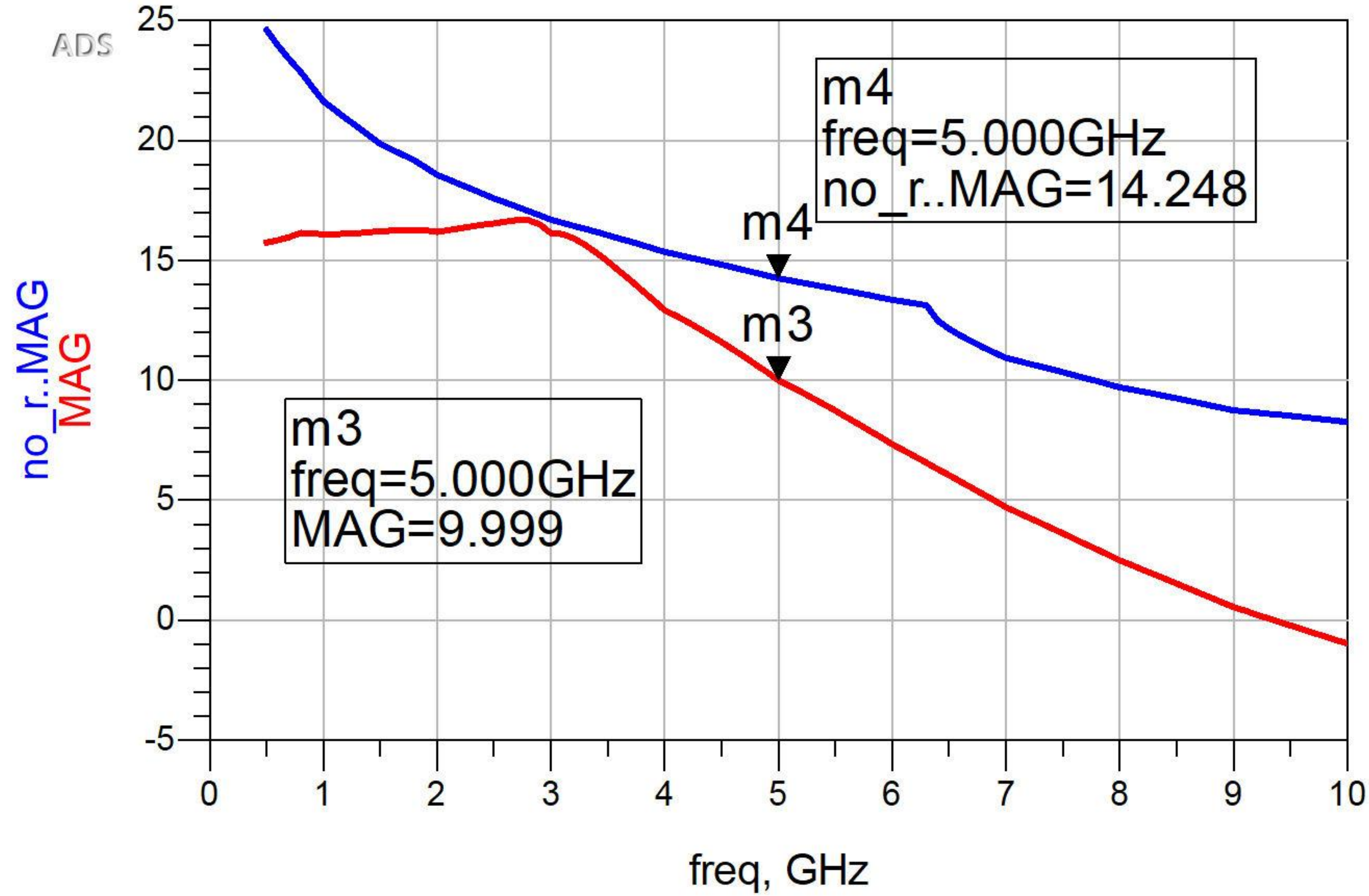


Stabilizarea unui diport





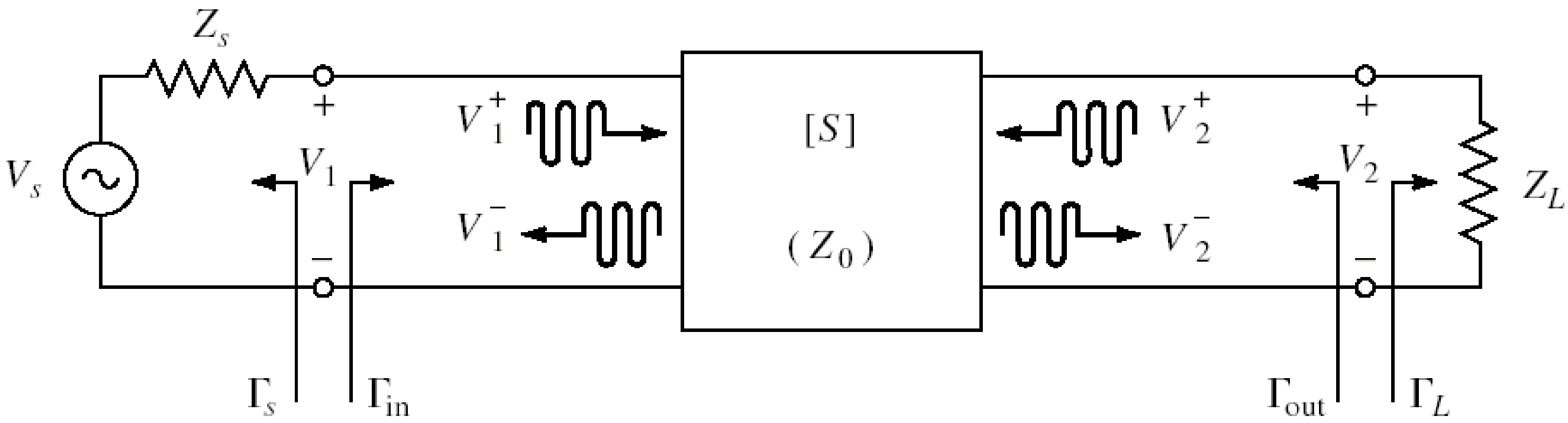
Stabilizarea unui diport



Amplificatoare de microunde

Castigul amplificatoarelor de microunde

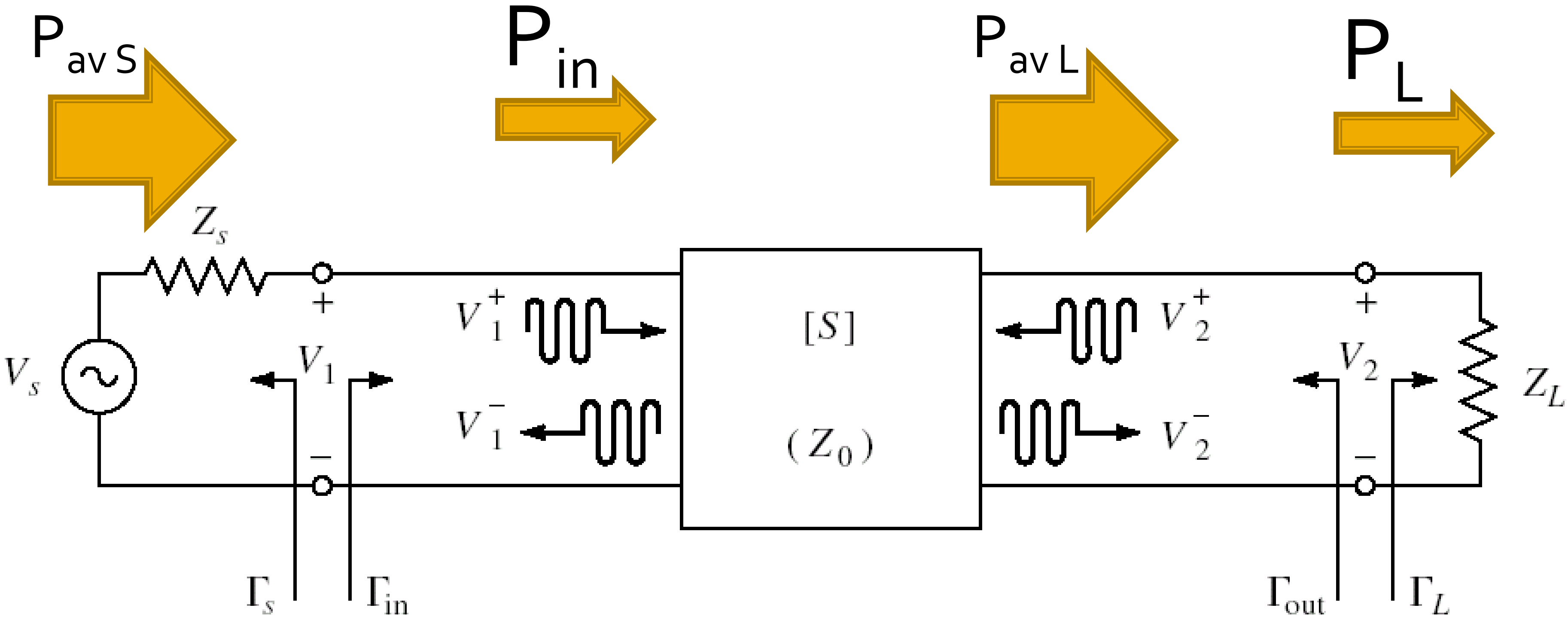
Cuadripol Amplificator



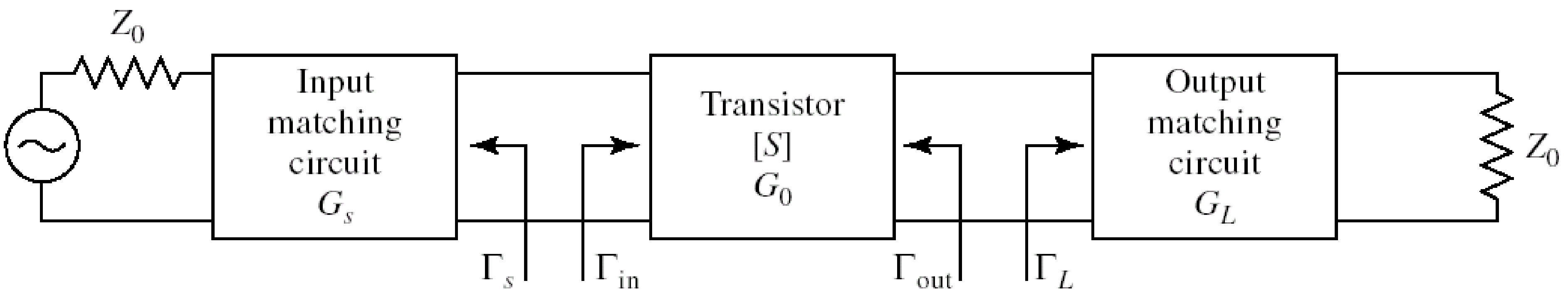
- marimi care intereseaza:
  - stabilitate
  - **castig de putere**
  - zgomot (uneori – semnal mic)
  - liniaritate (uneori – semnal mare)

Puteri / Adaptare

- Doua porturi in care adaptarea influenteaza transferul de putere



Proiectare pentru castig maxim



- Castig maxim de putere se obtine cand

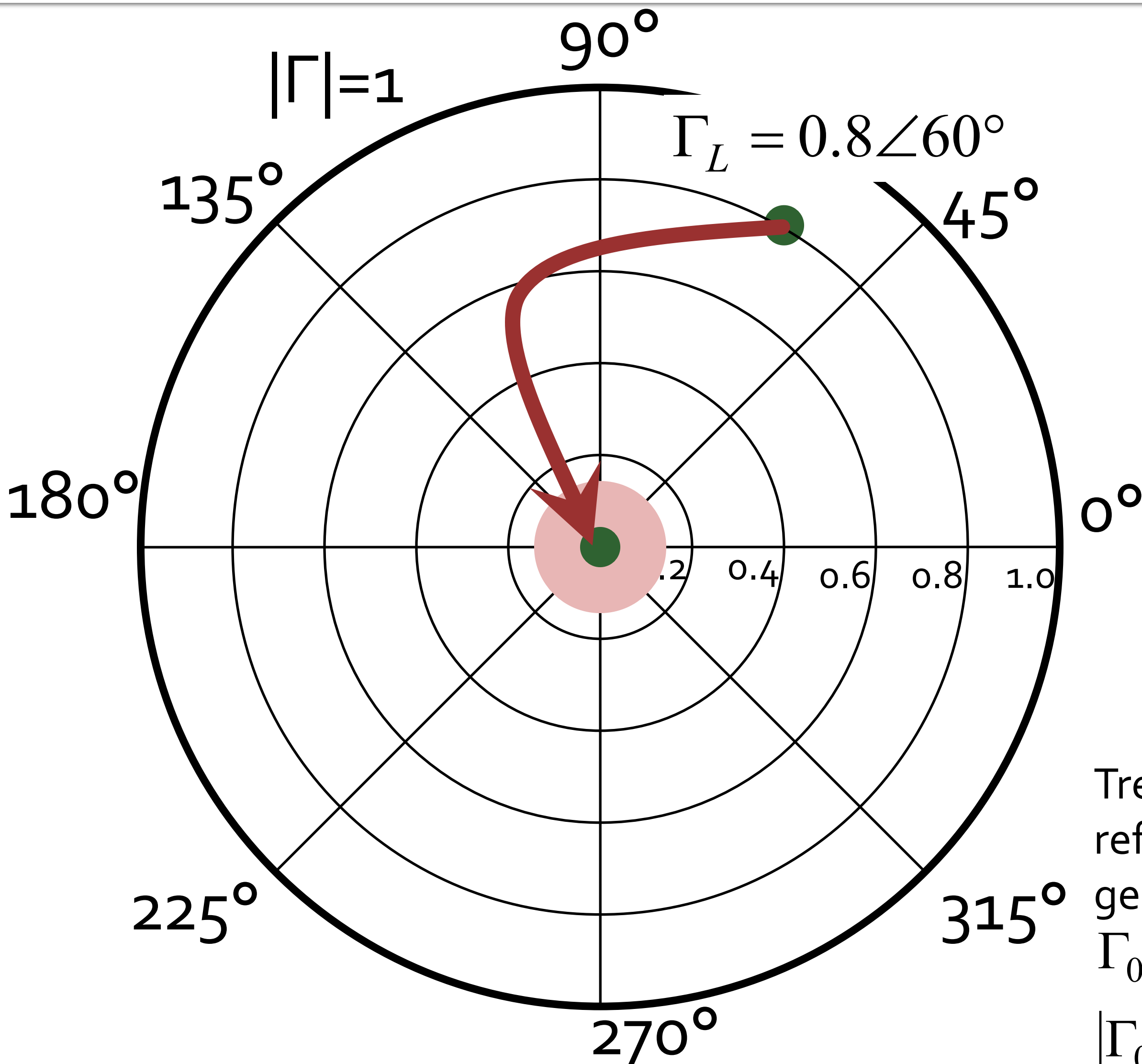
→ $\Gamma_{in} = \Gamma_S^*$ $\Gamma_{out} = \Gamma_L^*$

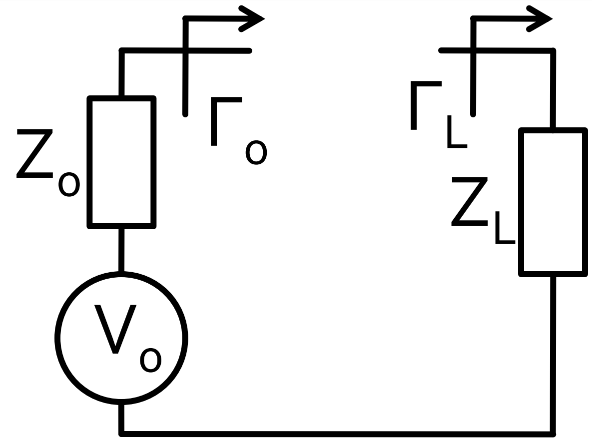
- Pentru retele de adaptare fara pierderi

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

- Pentru tranzistor bilateral (S12 ≠ 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

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

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

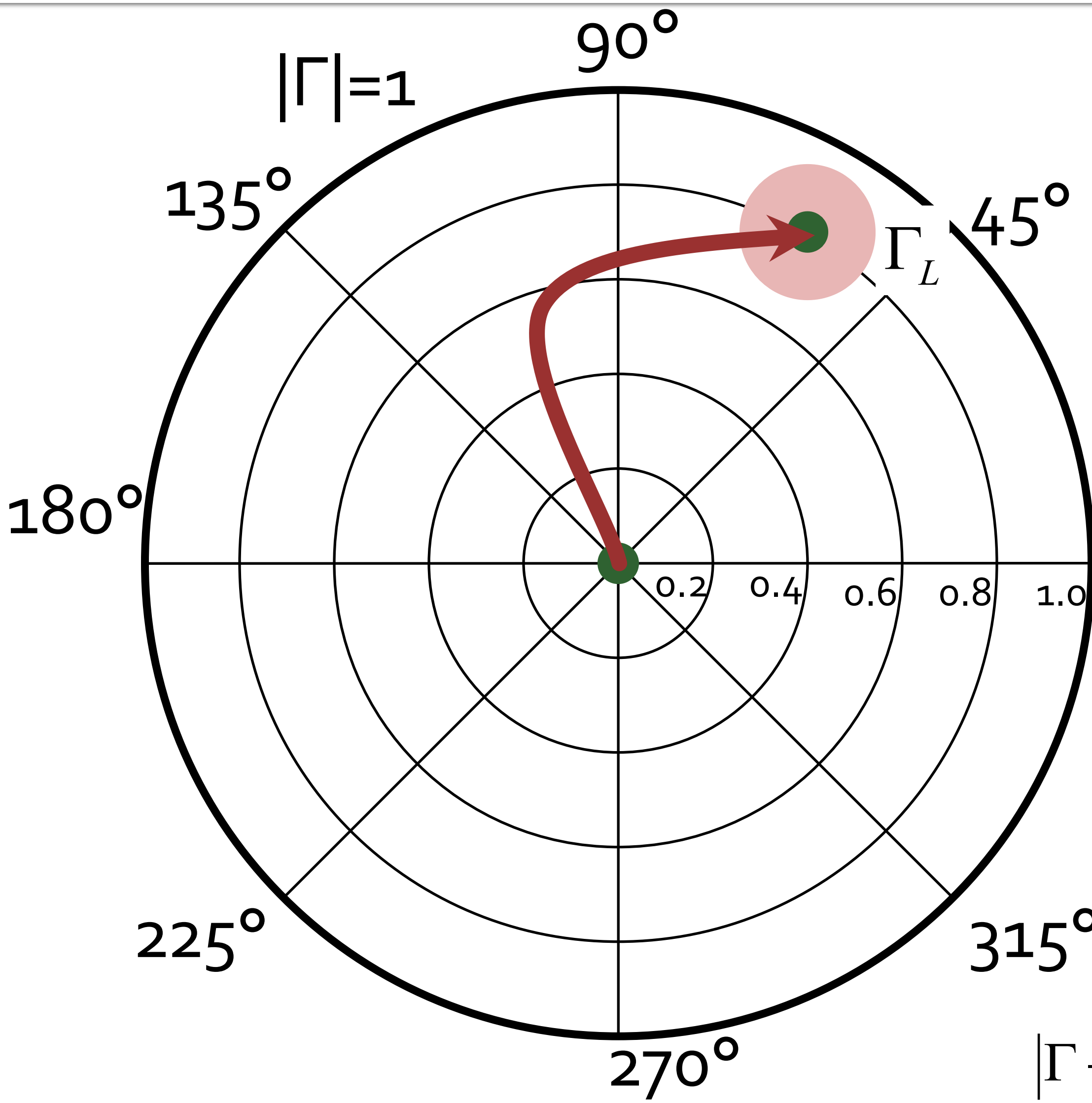
$$\Gamma_L = 0.8\angle 60°$$

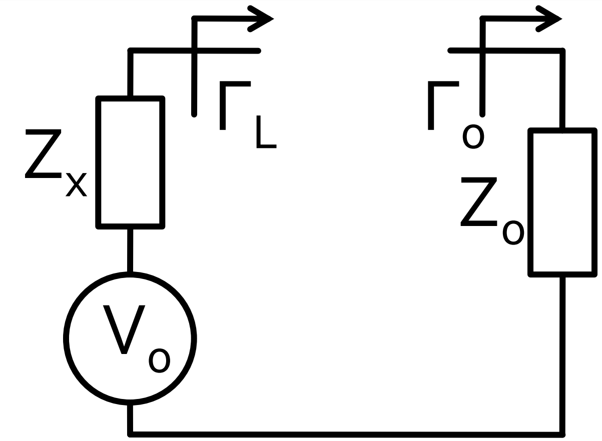
Trebuie sa deplasez coeficientul de reflexie in zona in care pentru generator cu Z_o am:

$\Gamma_0 = 0$ adaptare perfecta

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

Diagrama Smith, adaptare, $Z_L=Z_o$





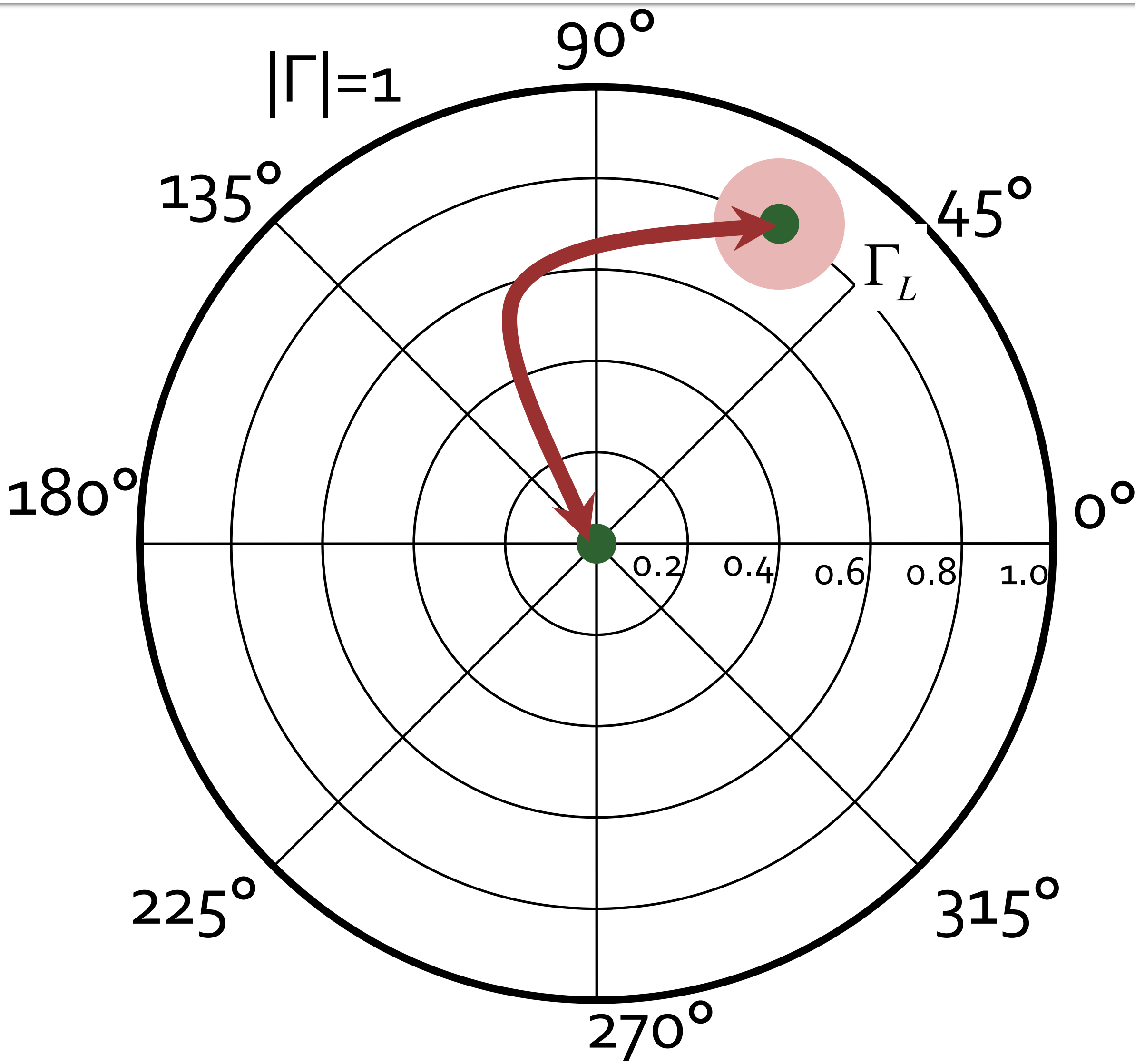
Sursa (de ex. tranzitorul) cu Z_X are nevoie de un anumit coeficient de reflexie Γ_L pentru a functiona corect

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

$\Gamma = \Gamma_L$ adaptare perfecta

$|\Gamma - \Gamma_L| \le \Gamma_m$ adaptare "suficienta"

Diagrama Smith, adaptare, $Z_L=Z_0$



- Circuitele de adaptare care muta
  - Γ_L in Γ_0
  - Γ_0 in Γ_L
- sunt **identice** ca realizare. Difera doar prin **ordinea** in care se introduc elementele in circuitul de adaptare
- Ca urmare se pot folosi in proiectarea circuitelor de adaptare aceleasi:
  - **metode**
  - **relatii**

Adaptare simultana

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

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

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

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

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

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

- Aflam Γ_S

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

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

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

Adaptare simultana

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

$$\Gamma_S^2 \cdot \underbrace{\left(S_{11} - \Delta \cdot S_{22}^*\right)}_{C1} + \Gamma_S \cdot \underbrace{\left(|\Delta|^2 - |S_{11}|^2 + |S_{22}|^2 - 1\right)}_{-B1} + \underbrace{\left(S_{11}^* - \Delta^* \cdot S_{22}\right)}_{C1^*} = 0$$

- Ecuatie de gradul 2

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

- Similar

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

- Cu variabilele

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

Adaptare simultana

- Este posibila daca

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

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

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

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

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

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

$$\Gamma_S = \frac{B_1 \pm \sqrt{B_1^2 - 4\cdot|C_1|^2}}{2\cdot C_1} \qquad \Gamma_L = \frac{B_2 \pm \sqrt{B_2^2 - 4\cdot|C_2|^2}}{2\cdot C_2}$$

- Necesar pentru solutii

$$|\Gamma_S| < 1 \qquad |\Gamma_L| < 1$$

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

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

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 "–"

$$\Gamma_S = \frac{B_1 - \sqrt{B_1^2 - 4\cdot|C_1|^2}}{2\cdot C_1} \qquad \Gamma_L = \frac{B_2 - \sqrt{B_2^2 - 4\cdot|C_2|^2}}{2\cdot C_2}$$

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

Adaptare simultana

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

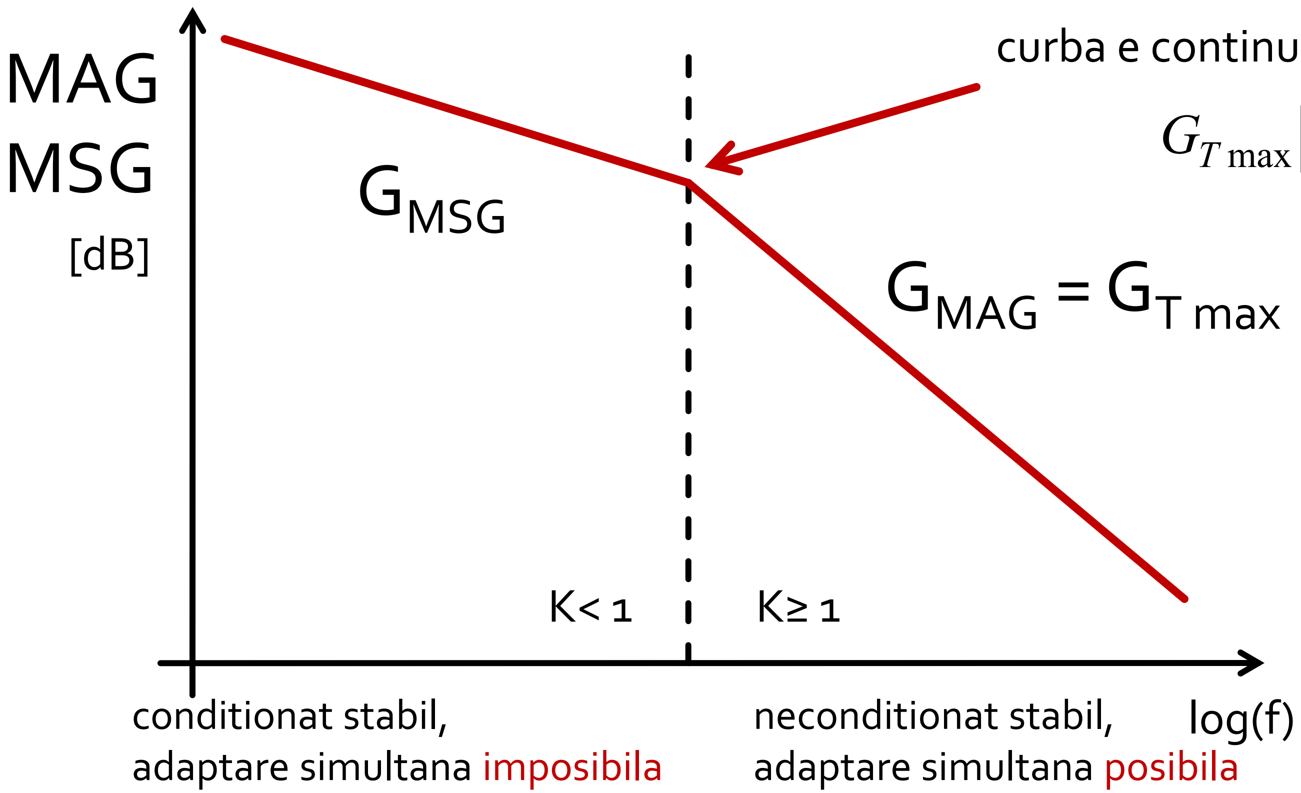
$$G_{T\max} = \frac{|S_{21}|}{|S_{12}|} \cdot \left(K - \sqrt{K^2 - 1}\right)$$

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

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

Maximum Available Gain

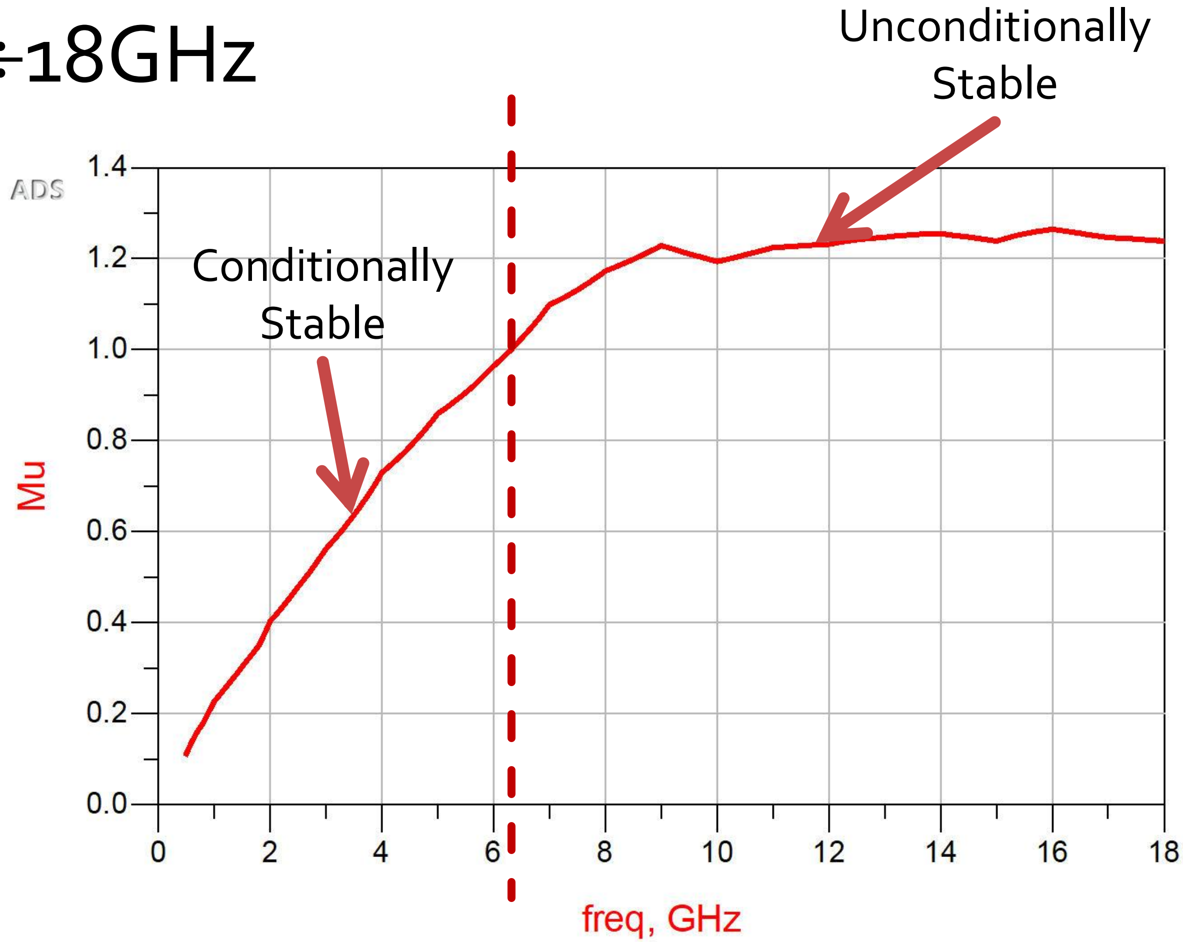
- Indicator in intreaga gama de frecventa a capacitatii de a obtine castig



$$G_{T\,\max}\Big|_{K=1} = \frac{|S_{21}|}{|S_{12}|} = G_{MSG}$$

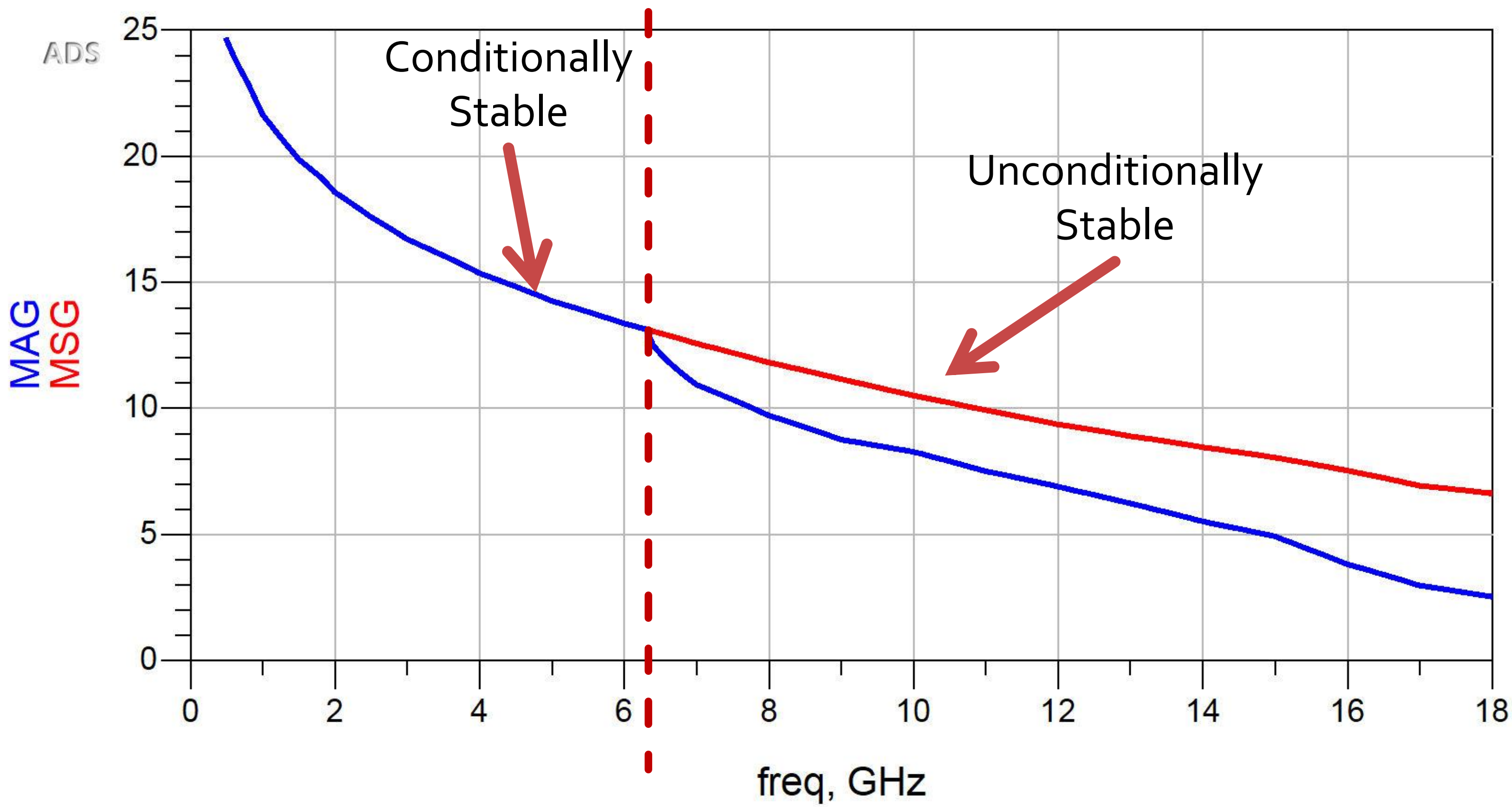
Stabilitate

- ATF-34143 **at Vds=3V Id=20mA**.
- @0.5÷18GHz



Castig

- ATF-34143 **at Vds=3V Id=20mA**.
- @0.5÷18GHz



Adaptare simultana, tranzistor unilateral

- Daca amplificatorul/tranzistorul este **unilateral** (S12 = 0) adaptarea simultana implica:

$$\Gamma_{in} = S_{11} \qquad \Gamma_{out} = S_{22}$$

$$\Gamma_S = S_{11}^* \qquad \Gamma_L = S_{22}^*$$

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

Exemplu

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

Exemplu

- ATF-34143 **at Vds=4V Id=40mA**.
- @5GHz
  - S11 = 0.64∠111°
  - S12 = 0.117∠-27°
  - S21 = 2.923 ∠-6°
  - S22 = 0.21 ∠111°

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

Calcul

- Parametri S
  - S11 = -0.229+0.597·j
  - S12 = 0.104-0.053·j
  - S21 = 2.907-0.306·j
  - S22 = -0.075+0.196·j

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

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

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

Calcul

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

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

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

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

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

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

$$\Gamma_S = ?$$

$$\Gamma_L = ?$$

Calcul

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

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

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

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

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

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

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

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

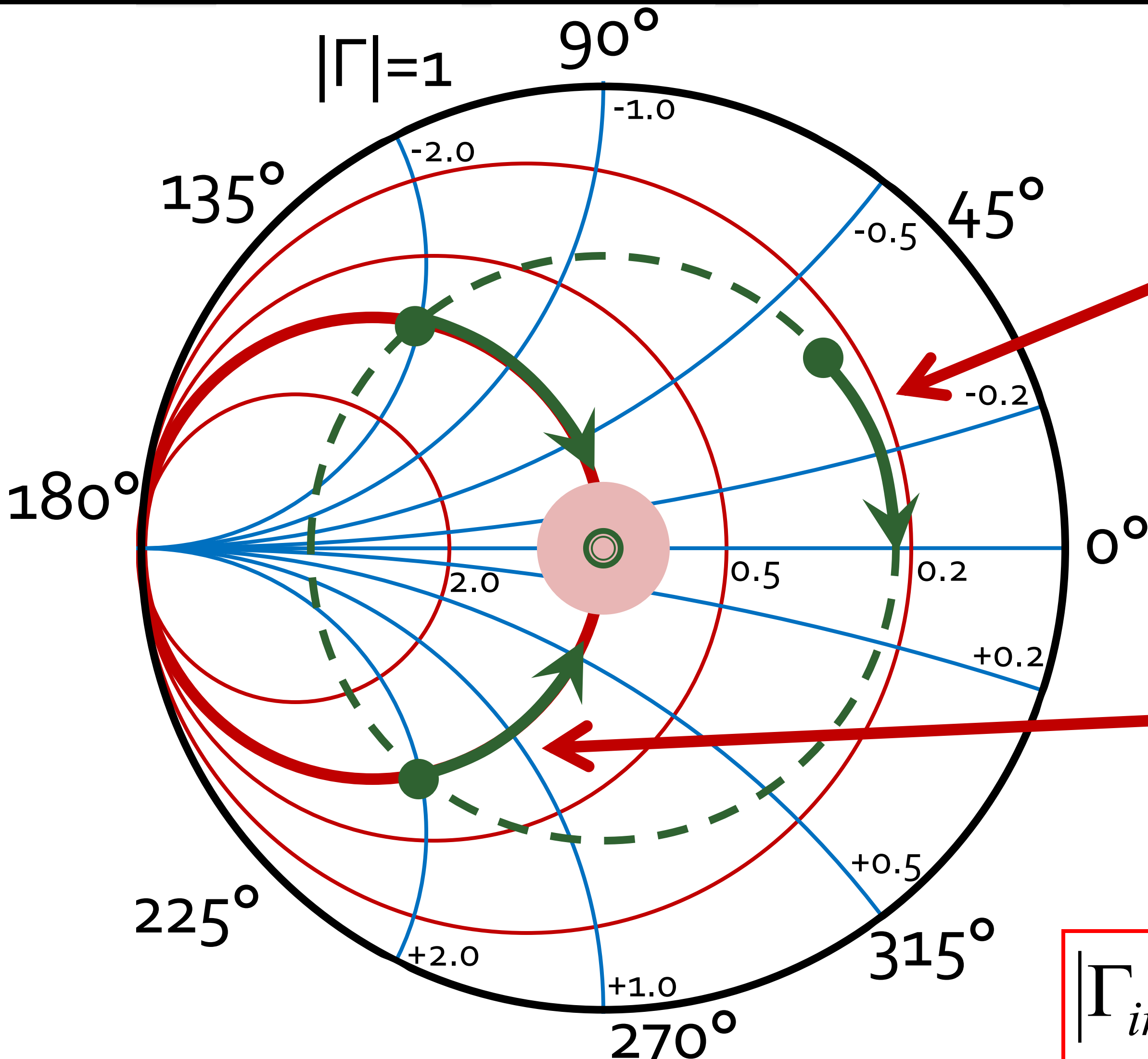
$$\Gamma_S = 0.867 \angle -117.7°$$

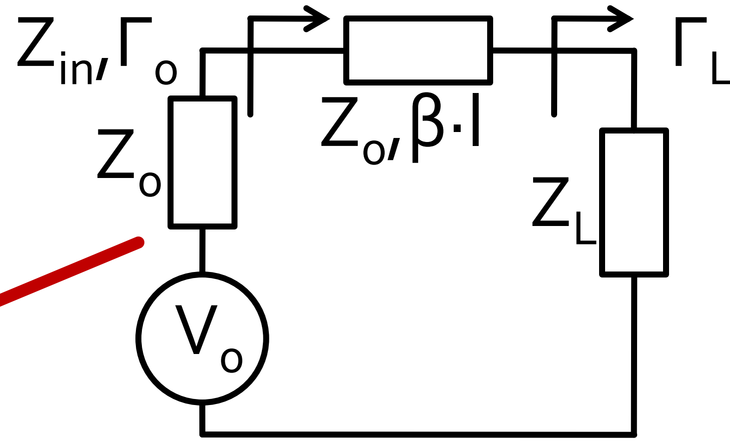
$$\Gamma_L = -0.685 + j \cdot 0.04$$

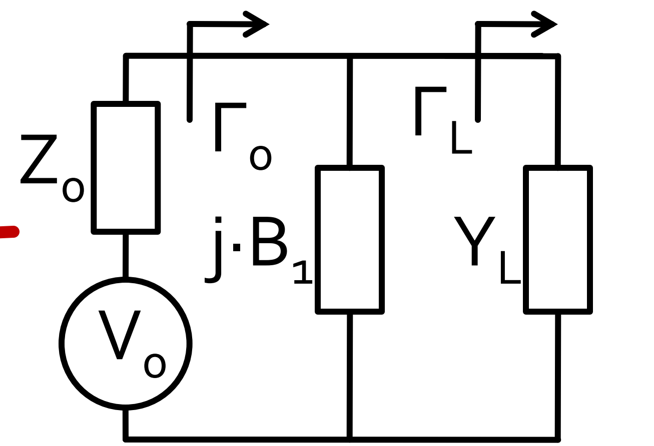
$$|\Gamma_L| = 0.686 < 1$$

$$\Gamma_L = 0.686 \angle 176.7°$$

Adaptare cu stub-uri, C8







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

$$g_{in} = 1$$

Calcul analitic (Γ_S)

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

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

$$\Gamma_S = 0.867 \angle -117.7°$$

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

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

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

$$\theta_{sp} = \tan^{-1}(\operatorname{Im} y_S) = -74°(+180°) \to \theta_{sp} = 106°$$

  - **solutia "cu -"**

$$(-117.7° + 2\theta) = -150.1° \qquad \theta = -16.2°(+180°) \to \theta = 163.8°$$

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

Calcul analitic (Γ_L)

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

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

$$\Gamma_L = 0.686\angle 176.7°$$

$$|\Gamma_L| = 0.686; \quad \varphi = 176.7°$$

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

Calcul analitic (Γ_L)

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

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

$$\Gamma_L = 0.686\angle 176.7°$$

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

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

$$(176.7° + 2\theta) = +133.3° \qquad \theta = -21.7°(+180°) \rightarrow \theta = 158.3°$$

$$\theta_{sp} = \tan^{-1}(\operatorname{Im} y_L) = -62.1°(+180°) \rightarrow \theta_{sp} = 117.9° \qquad \operatorname{Im} y_L = \frac{-2 \cdot |\Gamma_L|}{\sqrt{1 - |\Gamma_L|^2}} = -1.885$$

  - **solutia "cu -"**

$$(176.7° + 2\theta) = -133.3° \qquad \theta = -155°(+180°) \rightarrow \theta = 25°$$

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

Calcul analitic

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

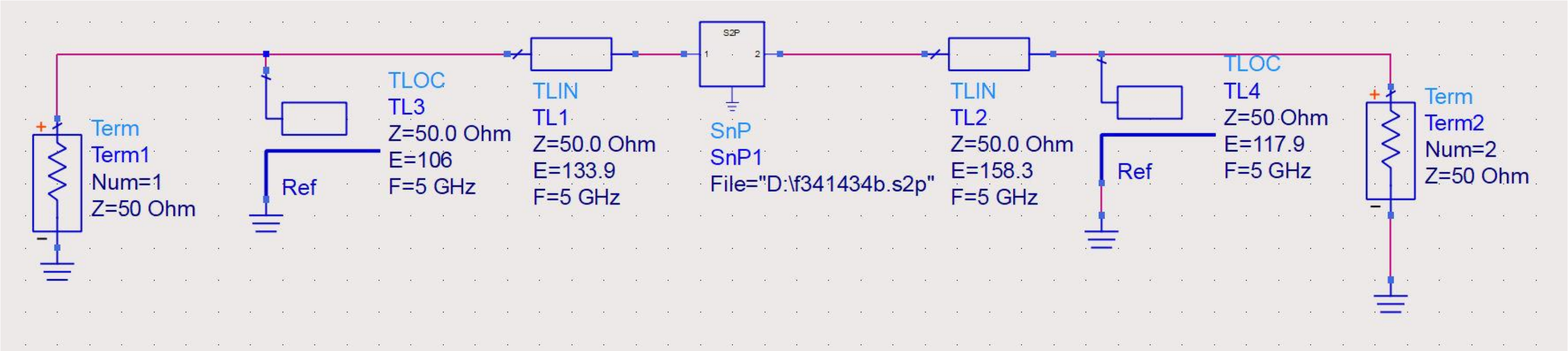
$$(\varphi + 2\theta) = \begin{cases} +150.1^\circ \\ -150.1^\circ \end{cases} \quad \theta = \begin{cases} 133.9^\circ \\ 163.8^\circ \end{cases} \quad \mathrm{Im}[y_S(\theta)] = \begin{cases} -3.477 \\ +3.477 \end{cases} \quad \theta_{sp} = \begin{cases} -74^\circ + 180^\circ = 106^\circ \\ +74^\circ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

- Similar pentru adaptarea la iesire

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

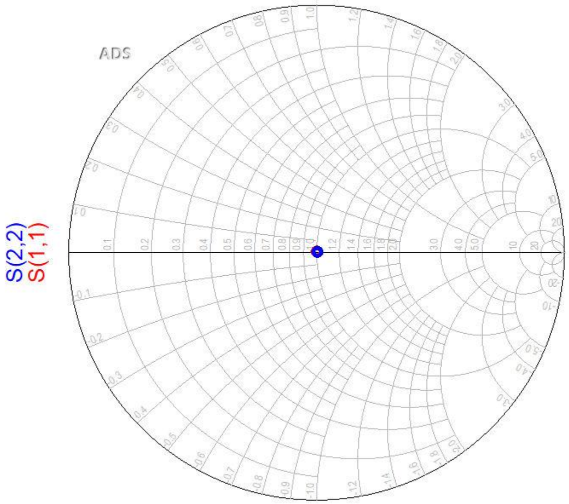
- In total exista **4** posibilitati de adaptare intrare/iesire

ADS



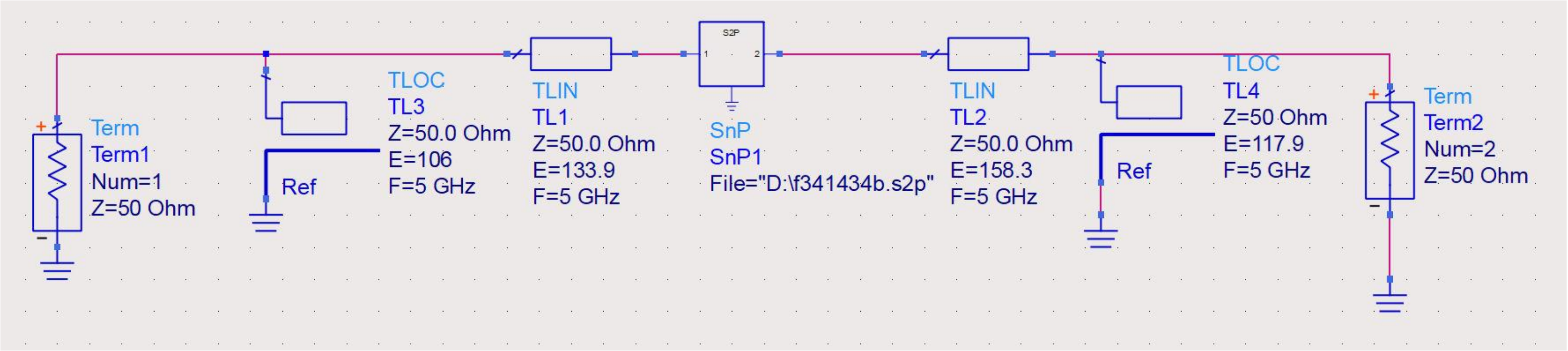
Eqn GT=10*log(mag(S(2,1))**2)

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

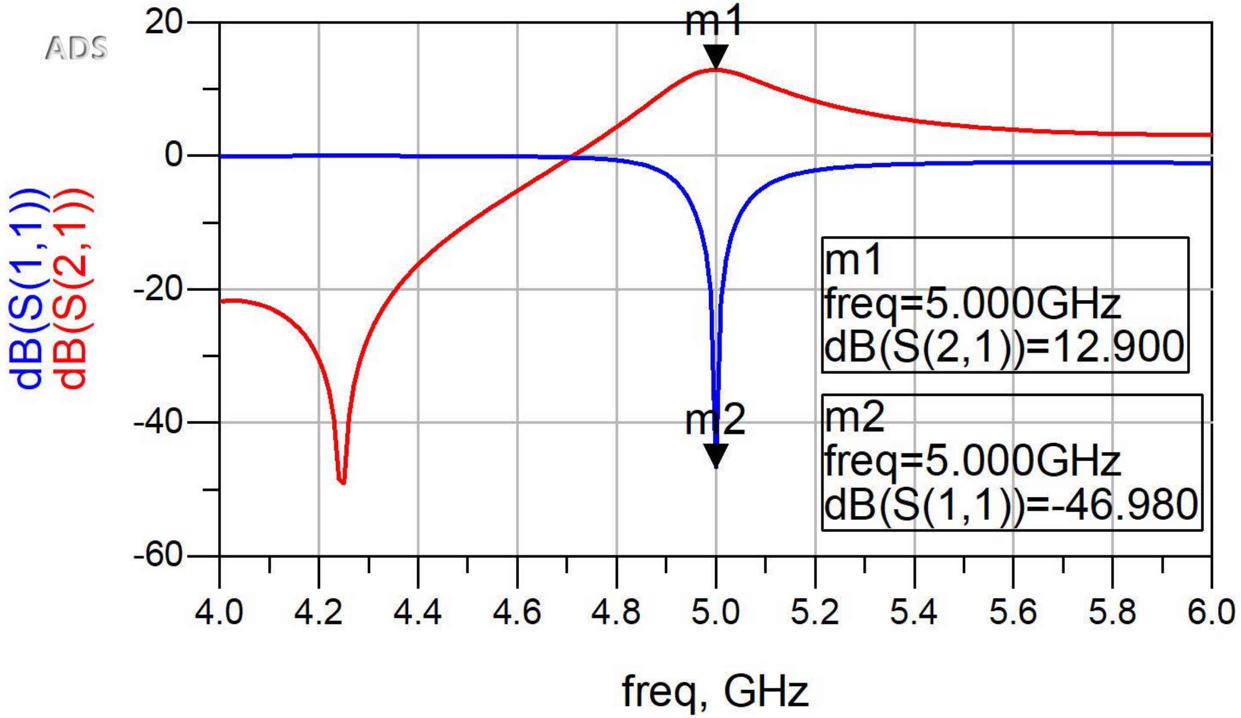


freq (5.000GHz to 5.000GHz)

ADS



Term
Term1
Num=1
Z=50 Ohm
Ref
TLOC
TL3
Z=50.0 Ohm
E=106
F=5 GHz
TLIN
TL1
Z=50.0 Ohm
E=133.9
F=5 GHz
S2P
SnP
SnP1
File="D:\f341434b.s2p"
TLIN
TL2
Z=50.0 Ohm
E=158.3
F=5 GHz
Ref
TLOC
TL4
Z=50 Ohm
E=117.9
F=5 GHz
Term
Term2
Num=2
Z=50 Ohm

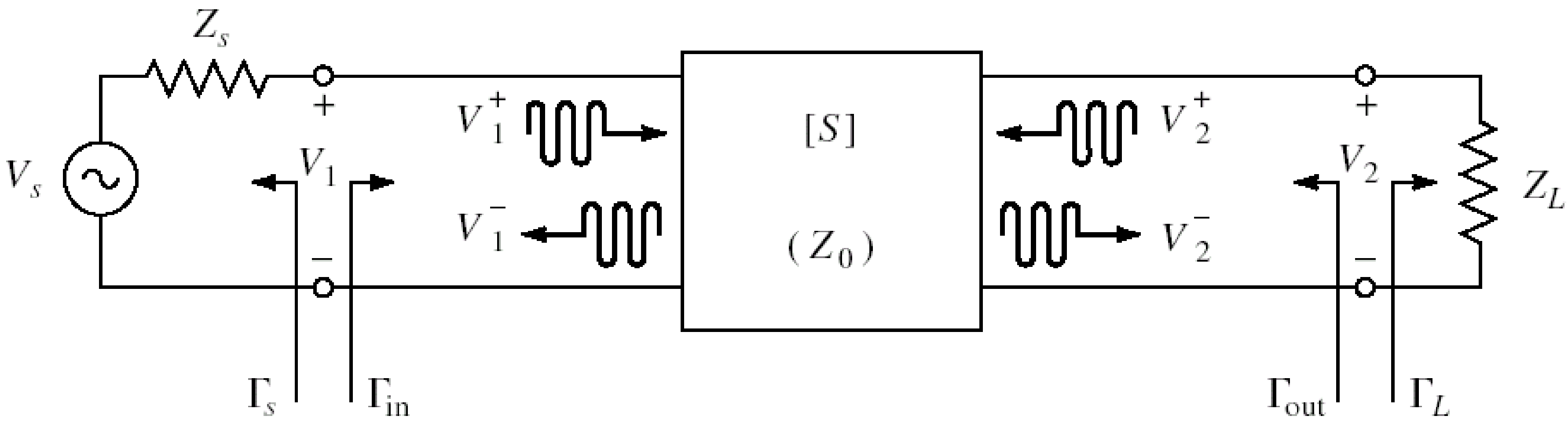


ADS
m1
m2
dB(S(1,1))
dB(S(2,1))
20
0
-20
-40
-60
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0
freq, GHz
m1
freq=5.000GHz
dB(S(2,1))=12.900
m2
freq=5.000GHz
dB(S(1,1))=-46.980

Amplificatoare de microunde

Proiectare pentru castig impus

Cuadripol Amplificator



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

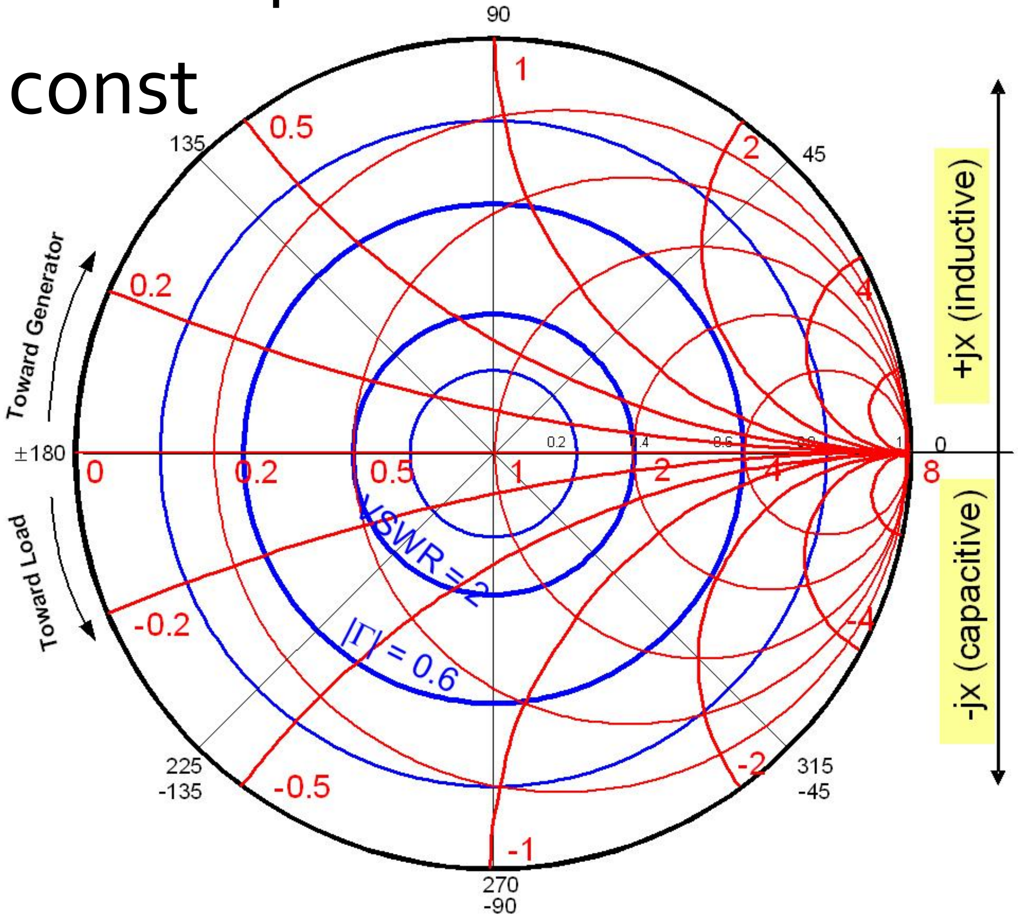
Proiectare pentru castig impus

- 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 (L3 + C10-11)
  - 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 = const → |Γ| = const

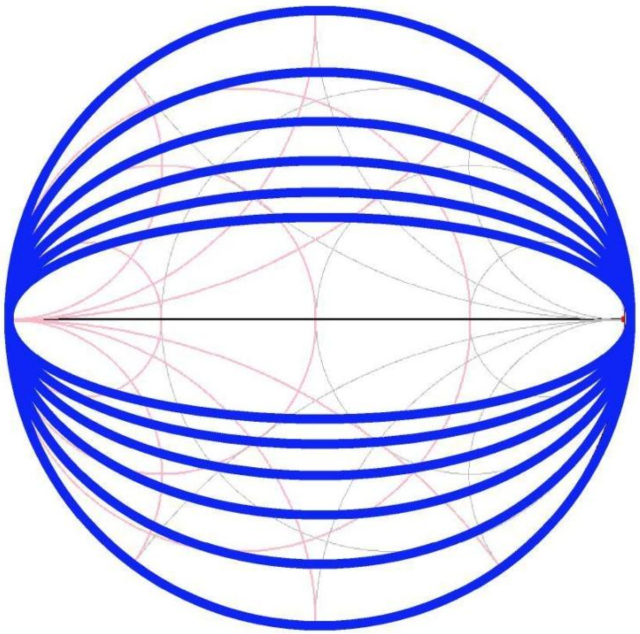
$$VSWR = \frac{V_{\max}}{V_{\min}} = \frac{1+|\Gamma|}{1-|\Gamma|}$$

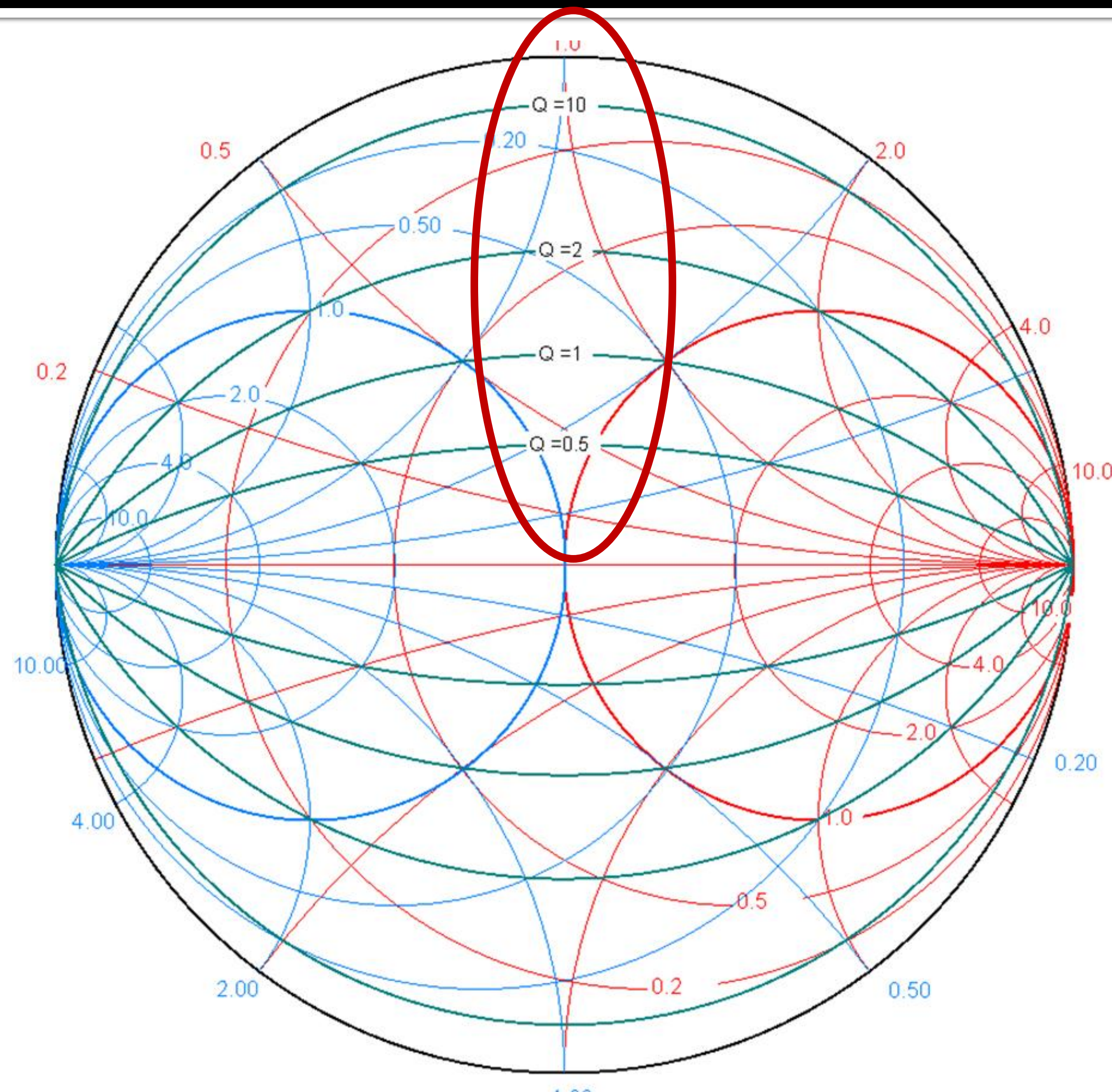


Cercuri de factor de calitate constant

- Diagrama Smith

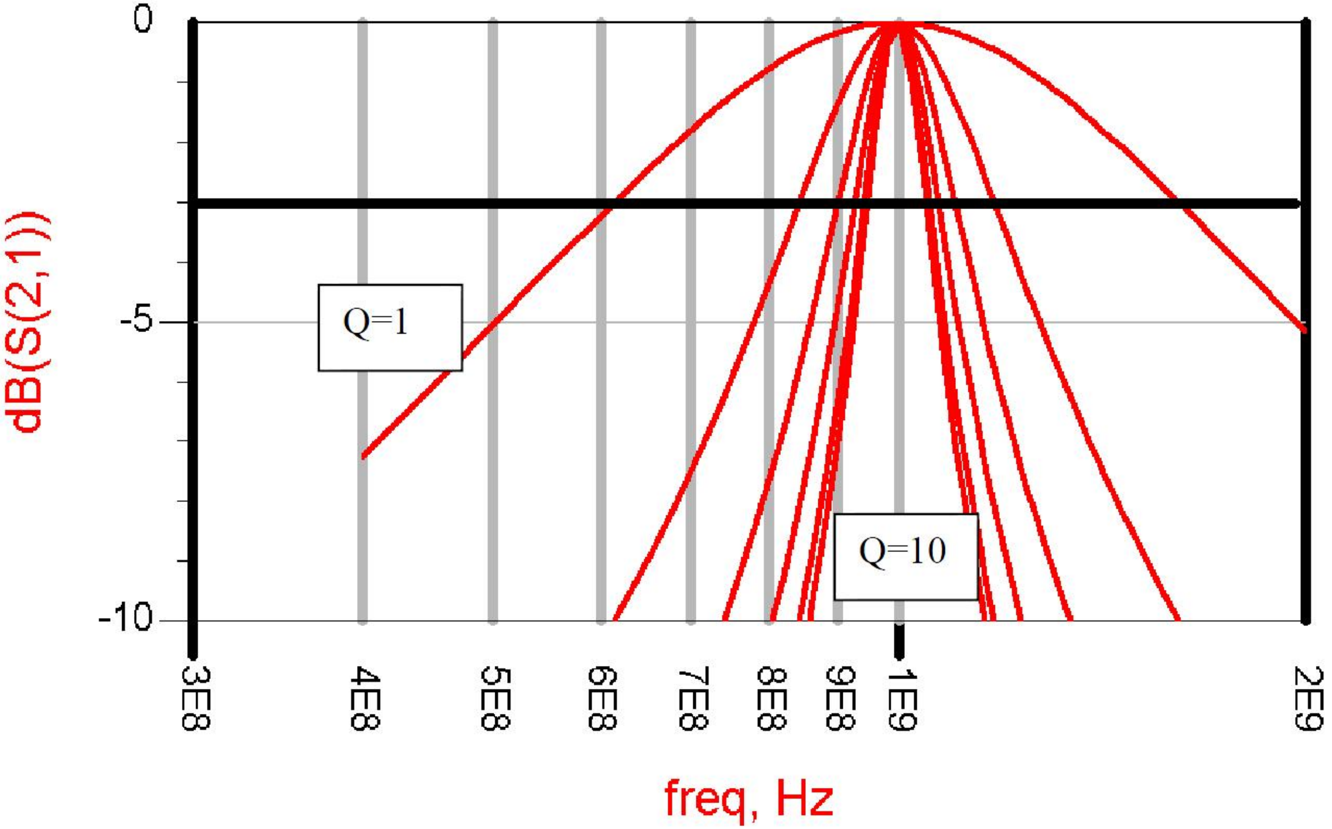
$$Q = \frac{X}{R} = \frac{G}{B} = const$$





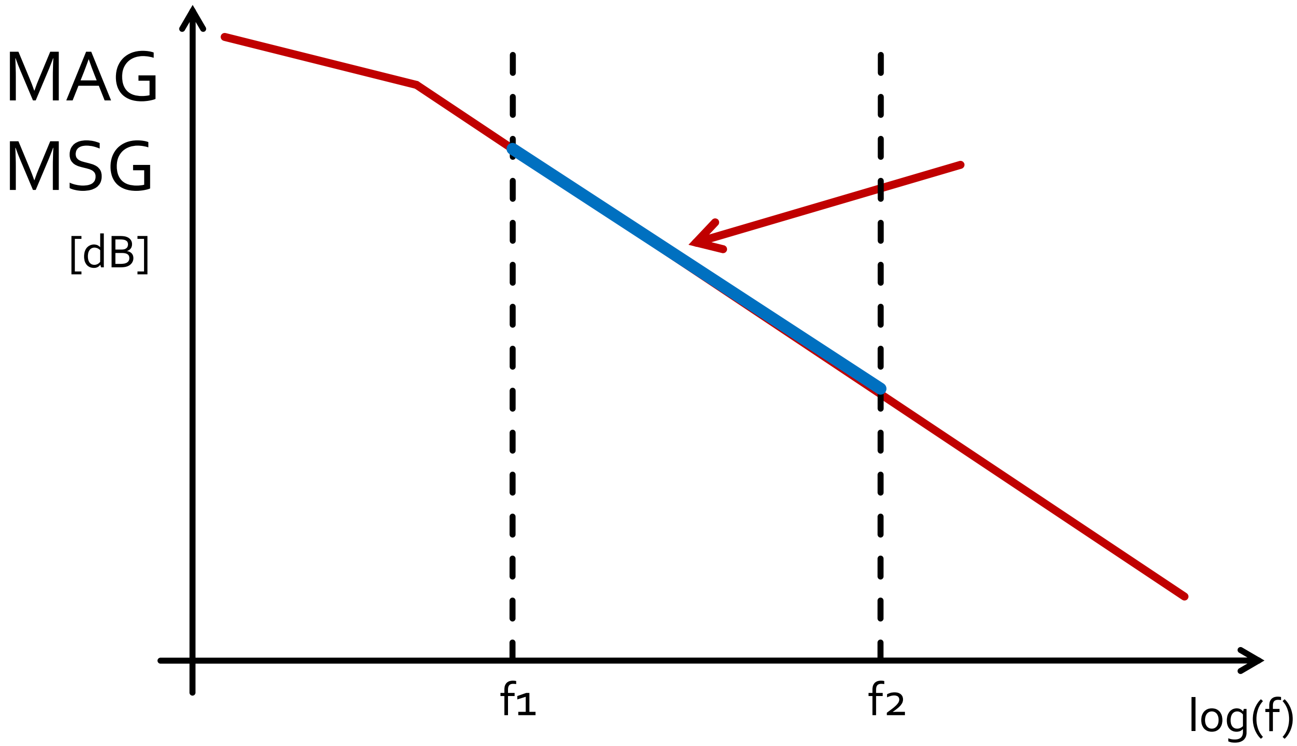
Factor de calitate - banda

- Factor de calitate ridicat echivalent cu banda ingusta



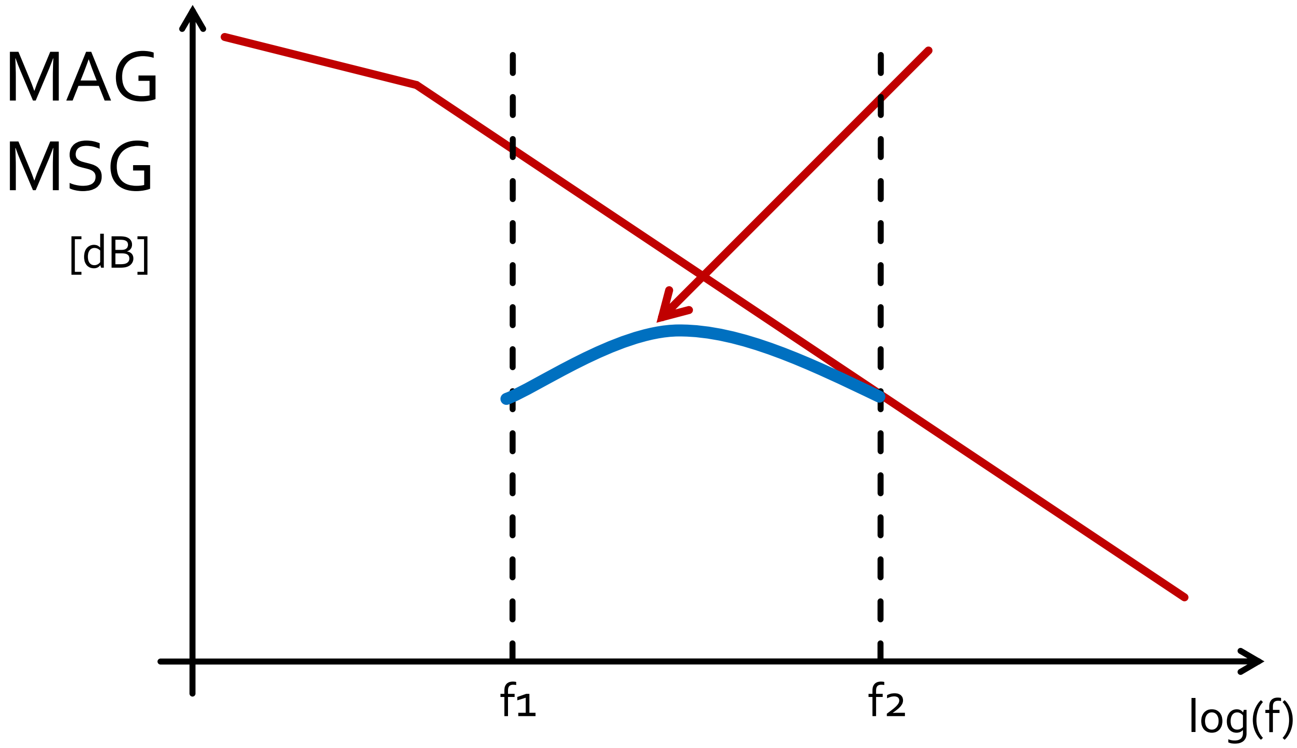
Amplificator de banda larga

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



Amplificator de banda larga

- Adaptare pentru castig maxim la frecventa maxima
- Dezadaptare controlata la frecventa minima
  - eventual la mai multe frecvente din banda



Proiectare pentru castig impus

- Se realizeaza cu asumarea **unilaterala** a amplificatorului

Permite tratarea separata a intrarii si iesirii

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

- Castig maxim

$$\Gamma_S = S_{11}^* \qquad \Gamma_L = S_{22}^*$$

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

Factor de merit unilateral

- Permite estimarea erorii induse de ipoteza tranzistorului unilateral

$$S_{12} \cong 0$$

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

- 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

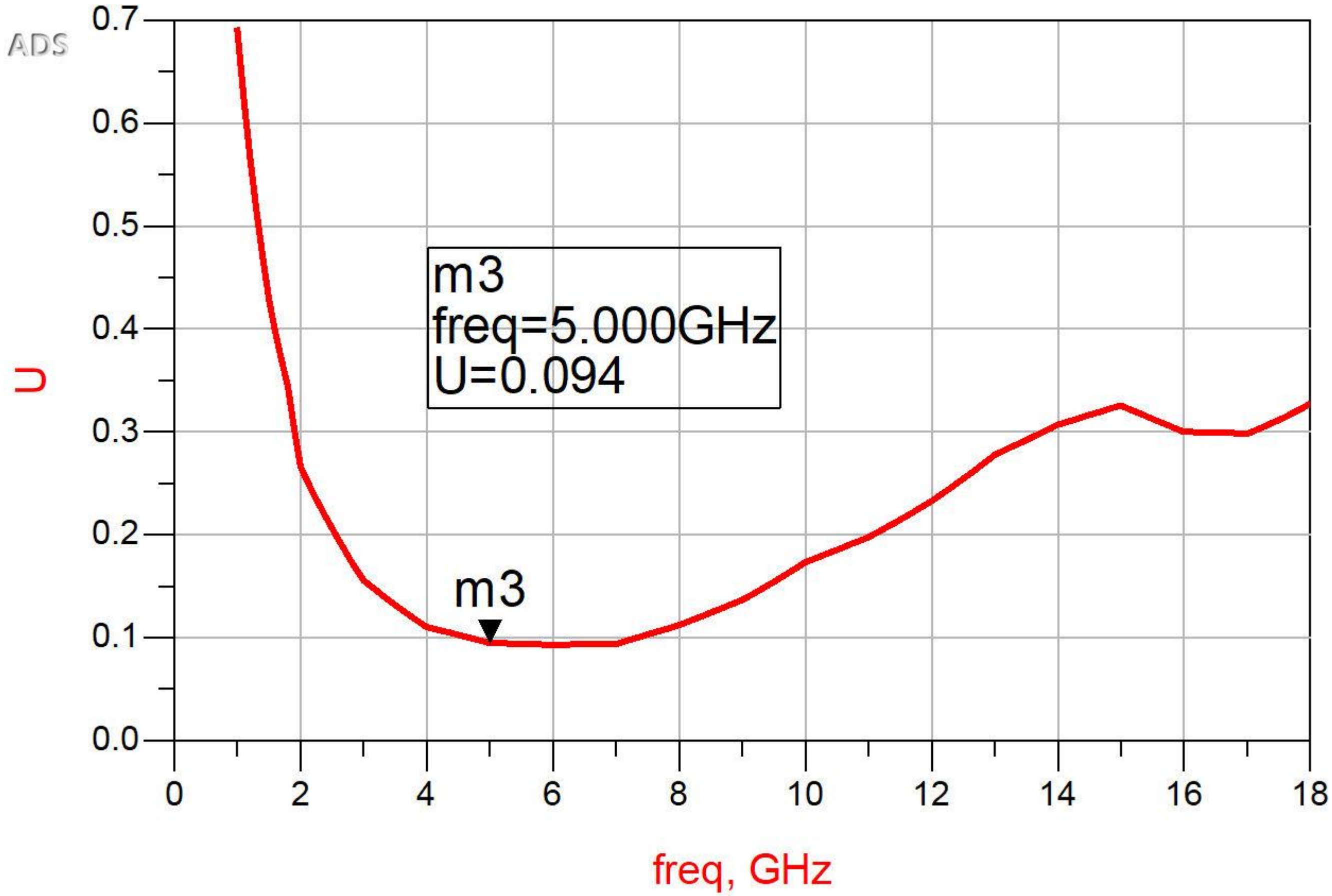
- ATF-34143 **at Vds=3V Id=20mA**.
- @5GHz
  - S11 = 0.64∠139°
  - S12 = 0.119∠-21°
  - S21 = 3.165 ∠16°
  - S22 = 0.22 ∠146°

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

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

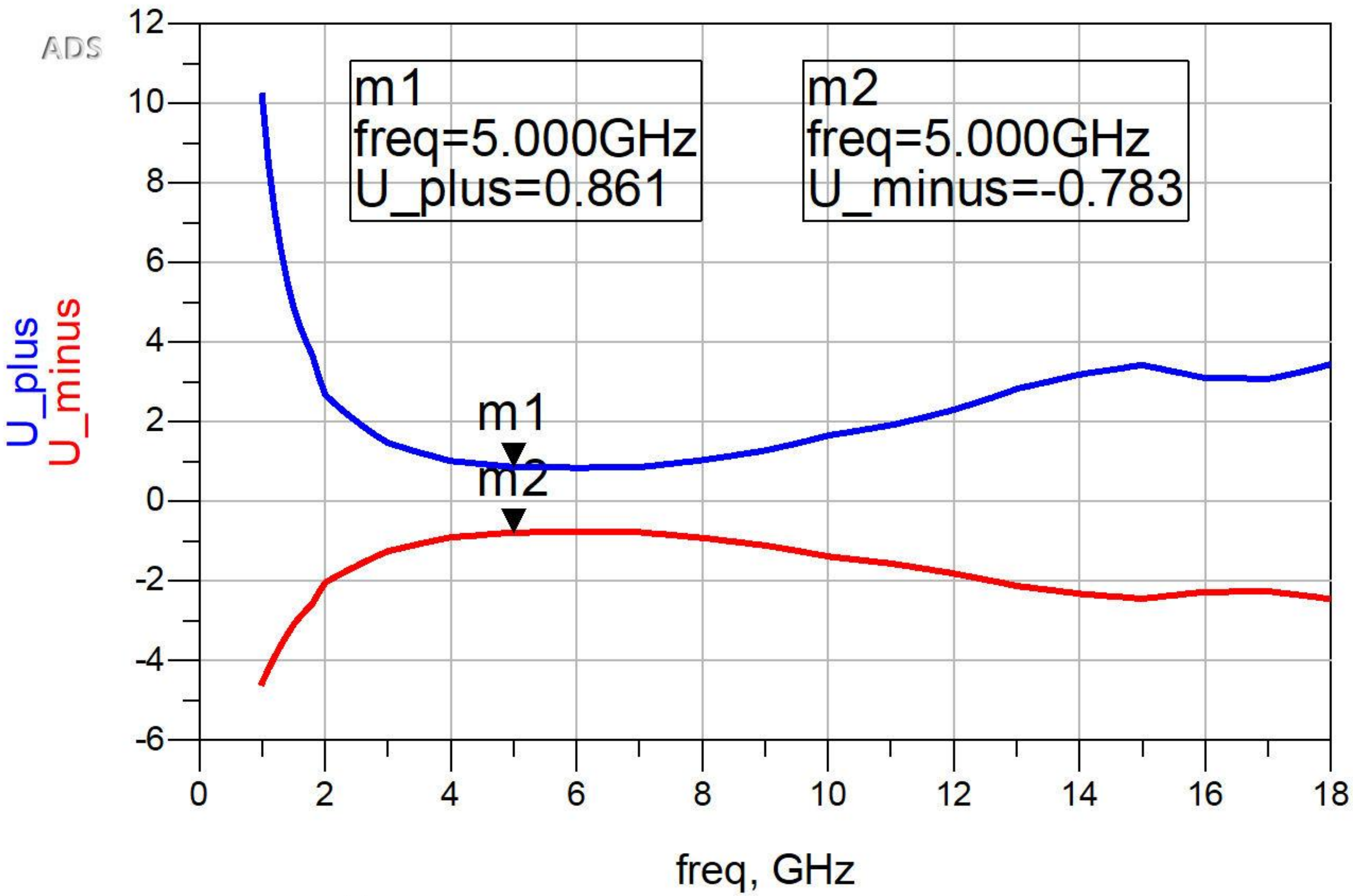
Exemplu

- ATF-34143 **at Vds=3V Id=20mA**.
- @5GHz

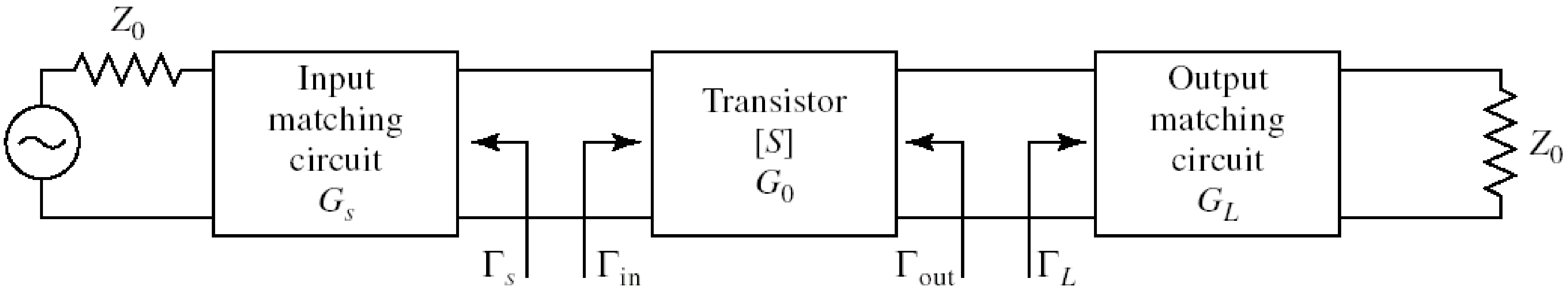


Exemplu

- ATF-34143 **at Vds=3V Id=20mA**.
- @5GHz



Proiectare pentru castig impus



- Daca ipoteza tranzistorului unilateral este justificata:

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

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

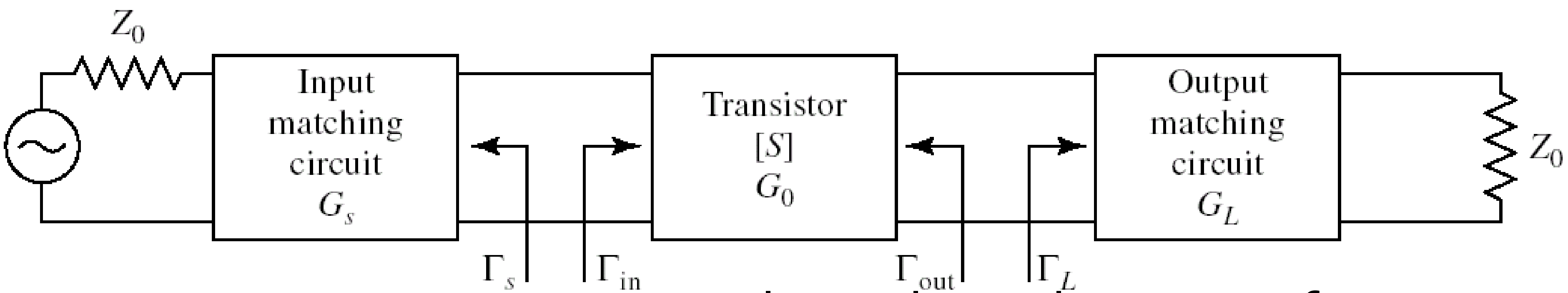
$$G_0 = |S_{21}|^2$$

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

$$G_S = G_S(\Gamma_S)$$

$$G_L = G_L(\Gamma_L)$$

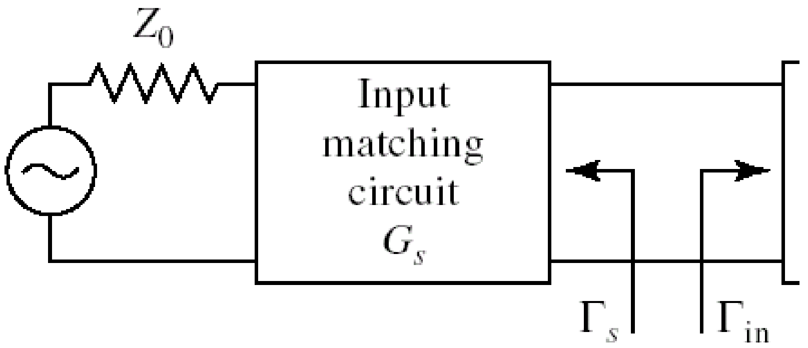
Proiectare pentru castig impus



- **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

$$G_T = G_S \cdot G_0 \cdot G_L \qquad G_T[dB] = G_S[dB] + G_0[dB] + G_L[dB]$$

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

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

- 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 Vds=3V Id=20mA**.
- @5GHz
  - S11 = 0.64∠139°
  - S12 = 0.119∠-21°
  - S21 = 3.165 ∠16°
  - S22 = 0.22 ∠146°

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

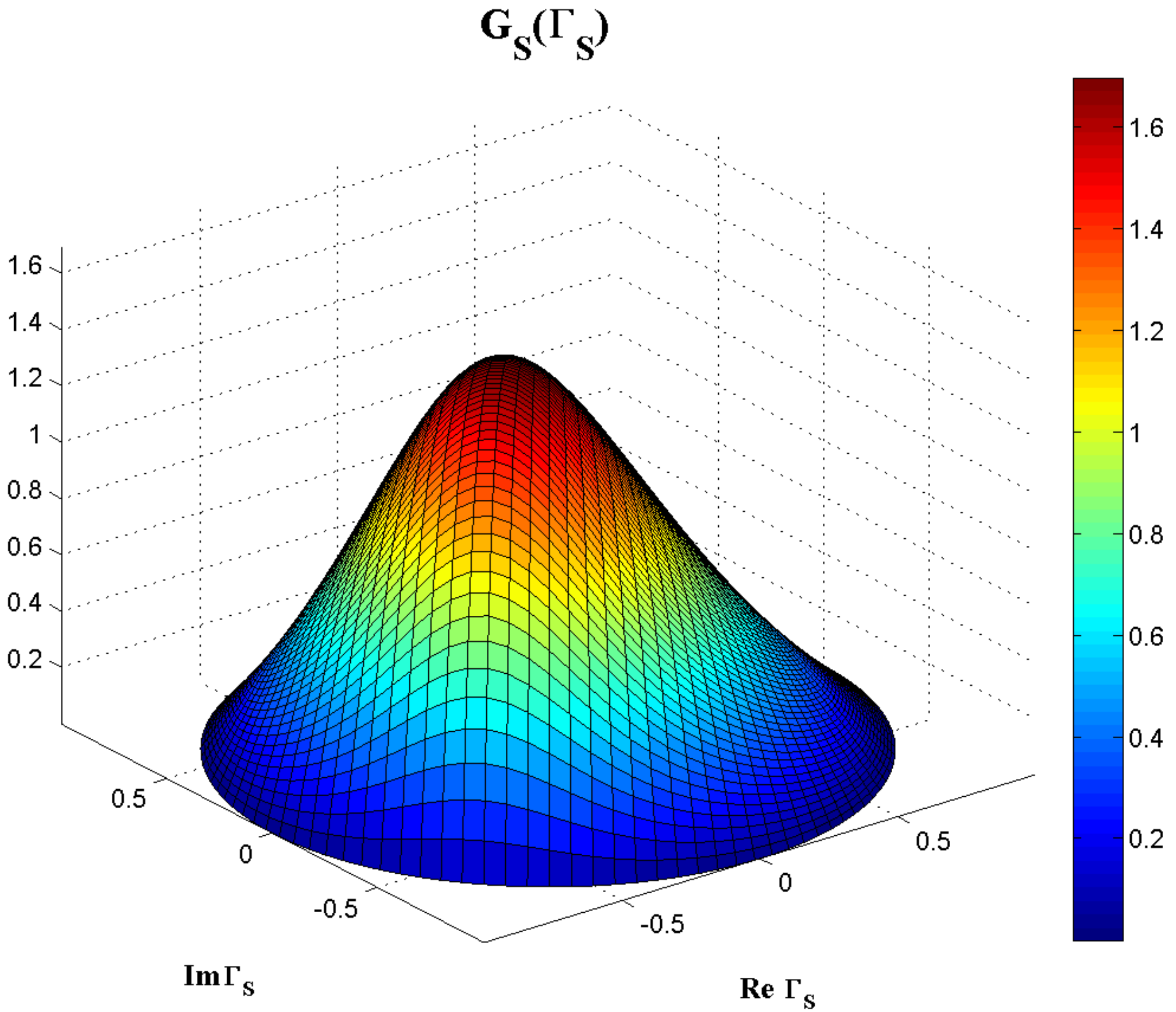
$$-0.783\ dB < G_T[dB] - G_{TU}[dB] < 0.861\ dB$$

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

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

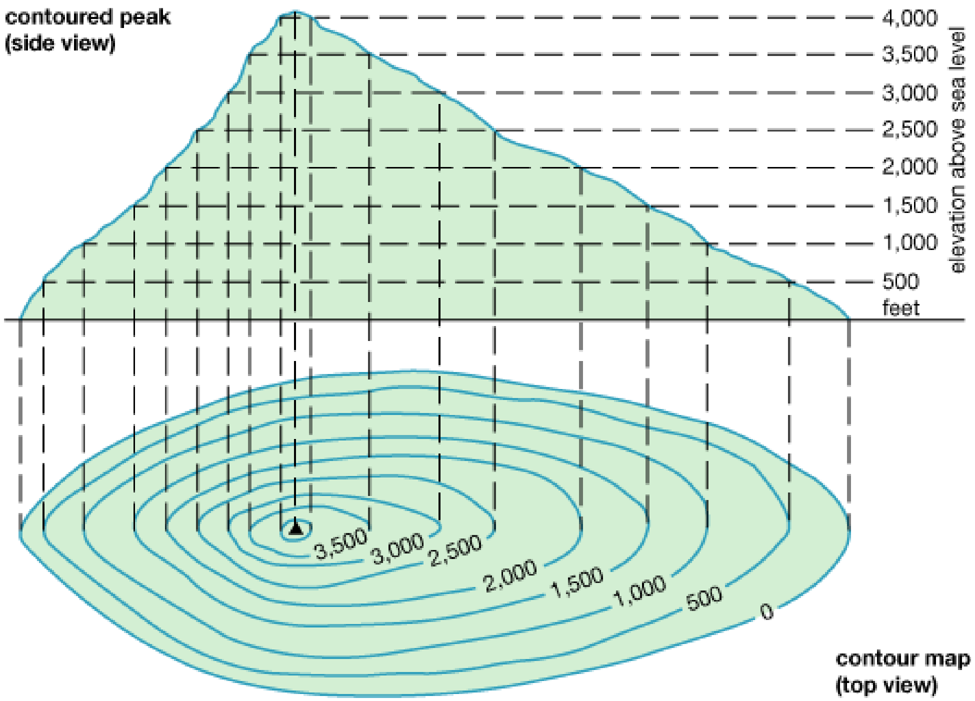
$$G_{S\max} = \frac{1}{1-|S_{11}|^2} = 1.694 = 2.289\ dB$$

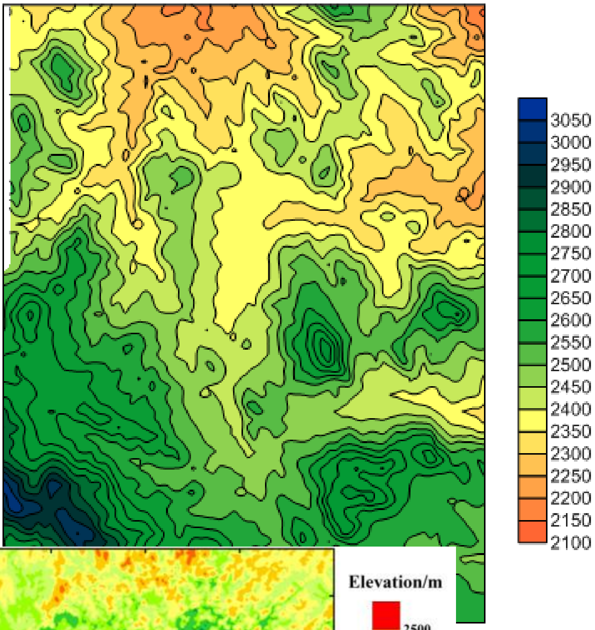
$G_S(\Gamma_S)$

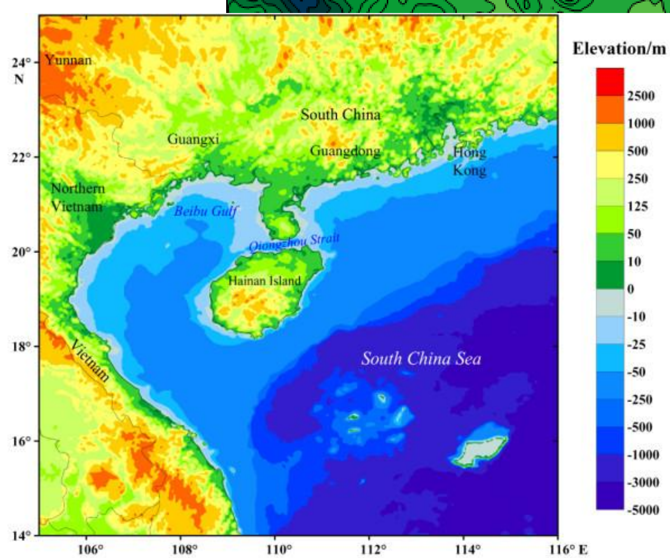


$$G_S = \frac{1 - |\Gamma_S|^2}{|1 - S_{11} \cdot \Gamma_S|^2}$$

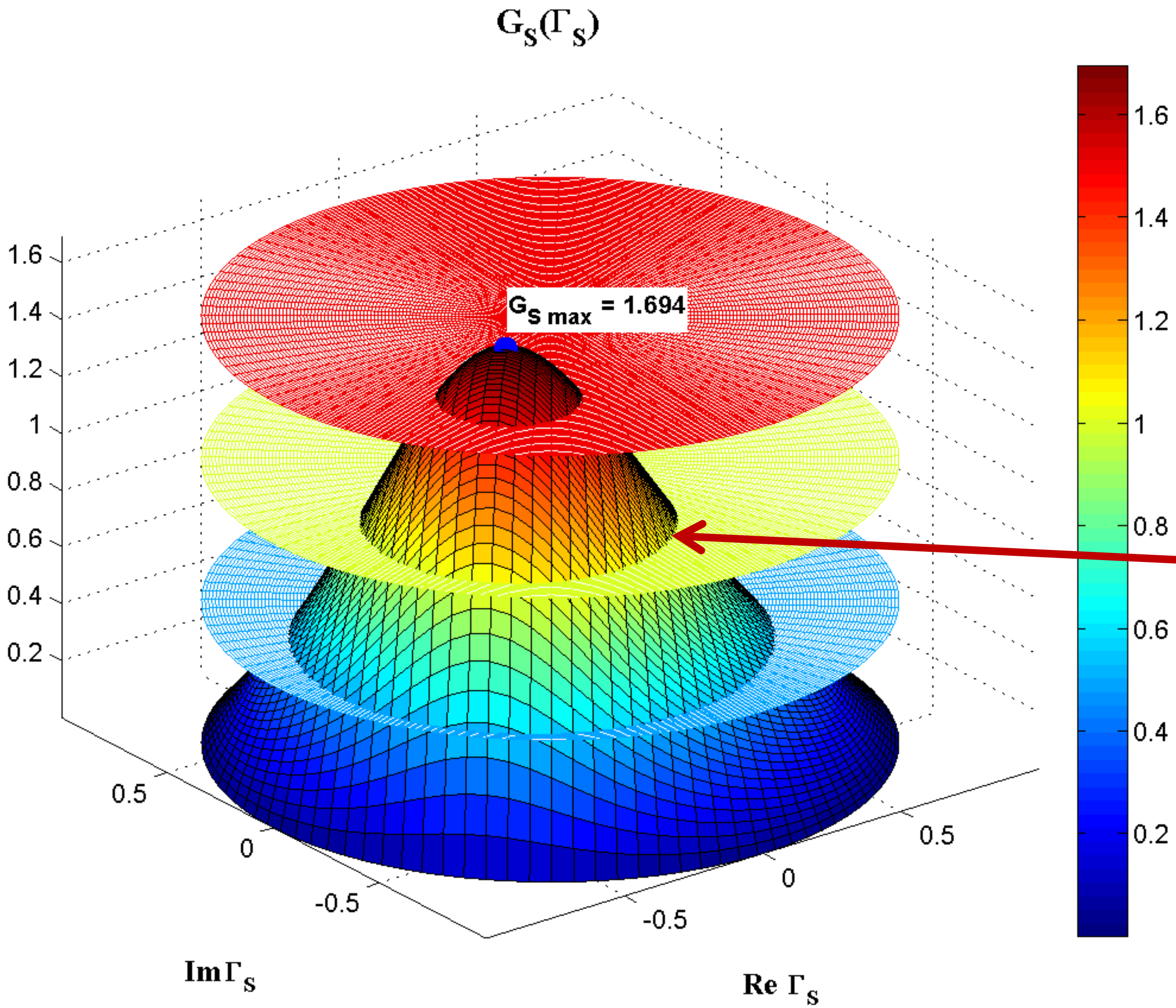
Contour map/lines







$G_S(\Gamma_S)$, nivel constant



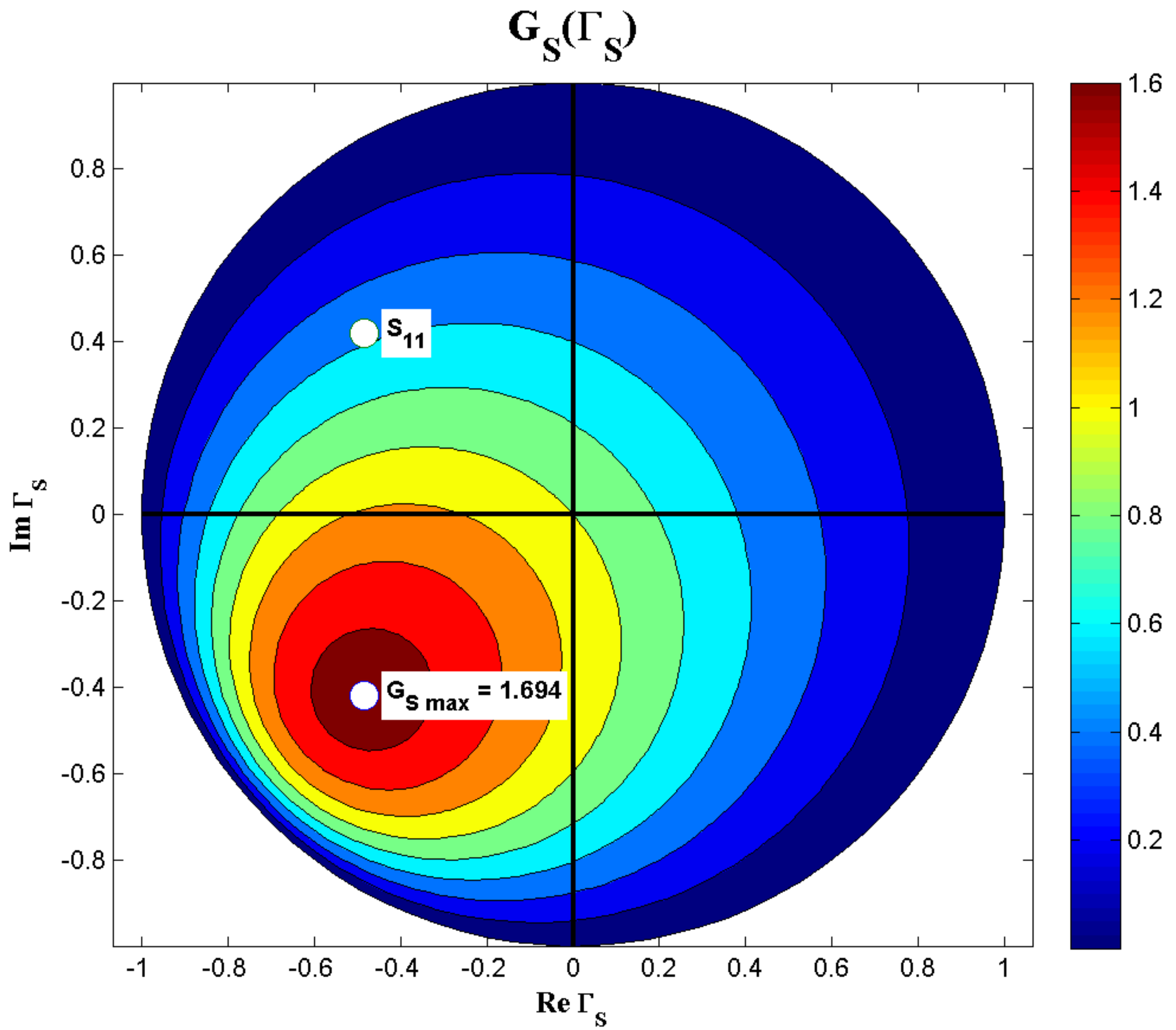
$G_S = 1.5$

$G_S = 1.0$

$G_S = 0.5$

Cercuri

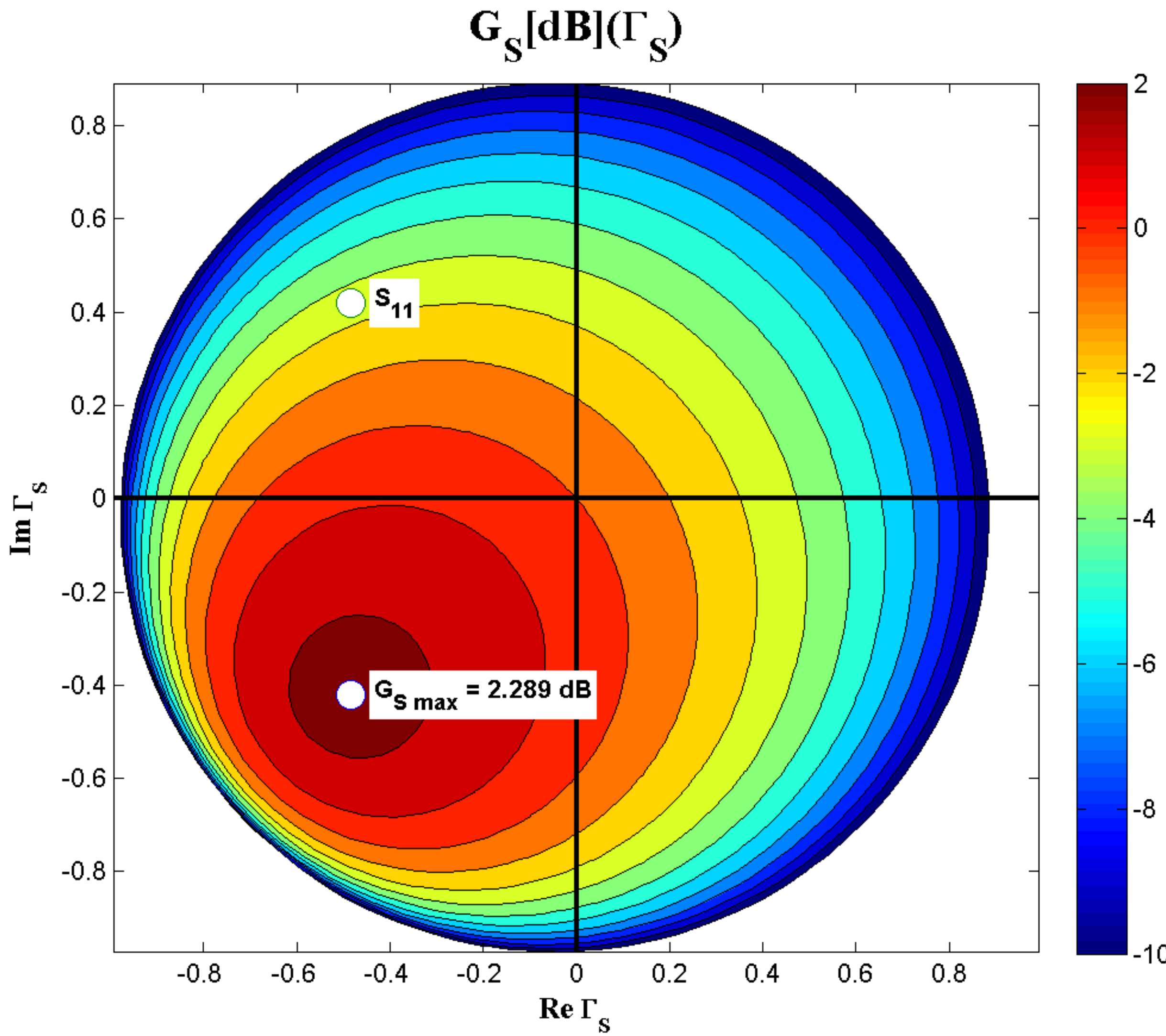
$G_S(\Gamma_S)$, diagrama de nivel



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

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

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



$$G_S[dB] = 10 \cdot \log\left(\frac{1-|\Gamma_S|^2}{|1-S_{11}\cdot\Gamma_S|^2}\right)$$

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

Cercuri de castig constant la intrare

- Castig normat (**coordonate liniare**)

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

- Punctele de nivel constant, pentru un g_s<1 fixat

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

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

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

Cercuri de castig constant la intrare

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

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

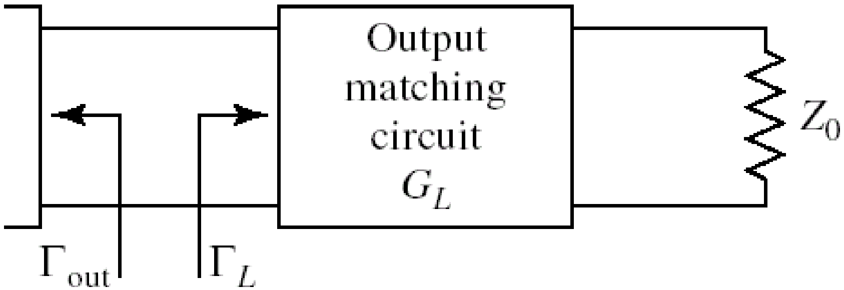
- Ecuatia unui cerc in planul complex in care reprezint Γ_S
- **Interpretare**: Orice punct Γ_S care reprezentat in planul complex se gaseste **pe** cercul desenat pentru $g_{cerc} = G_{cerc}/G_{Smax}$ va conduce la obtinerea castigului $G_S = G_{cerc}$
  - Orice punct **in exteriorul** acestui cerc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

Cercuri de castig constant la intrare

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

- Centrele cercurilor se gasesc pe segmentul care uneste $\Gamma_S = S_{11}^*$ cu centrul diagramei Smith
- Cercurile se traseaza (traditional, CAD) in **coordonate logaritmice** ([dB])
  - relatiile de calcul sunt in coordonate **liniare !**
- Cercul corespunzator lui G_S = 0 dB trece prin origine $G_S|_{\Gamma_S=0} = \frac{1-|\Gamma_S|^2}{|1-S_{11}\cdot\Gamma_S|^2} = 1 = 0\text{dB}$

Cercuri de castig constant la iesire



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

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

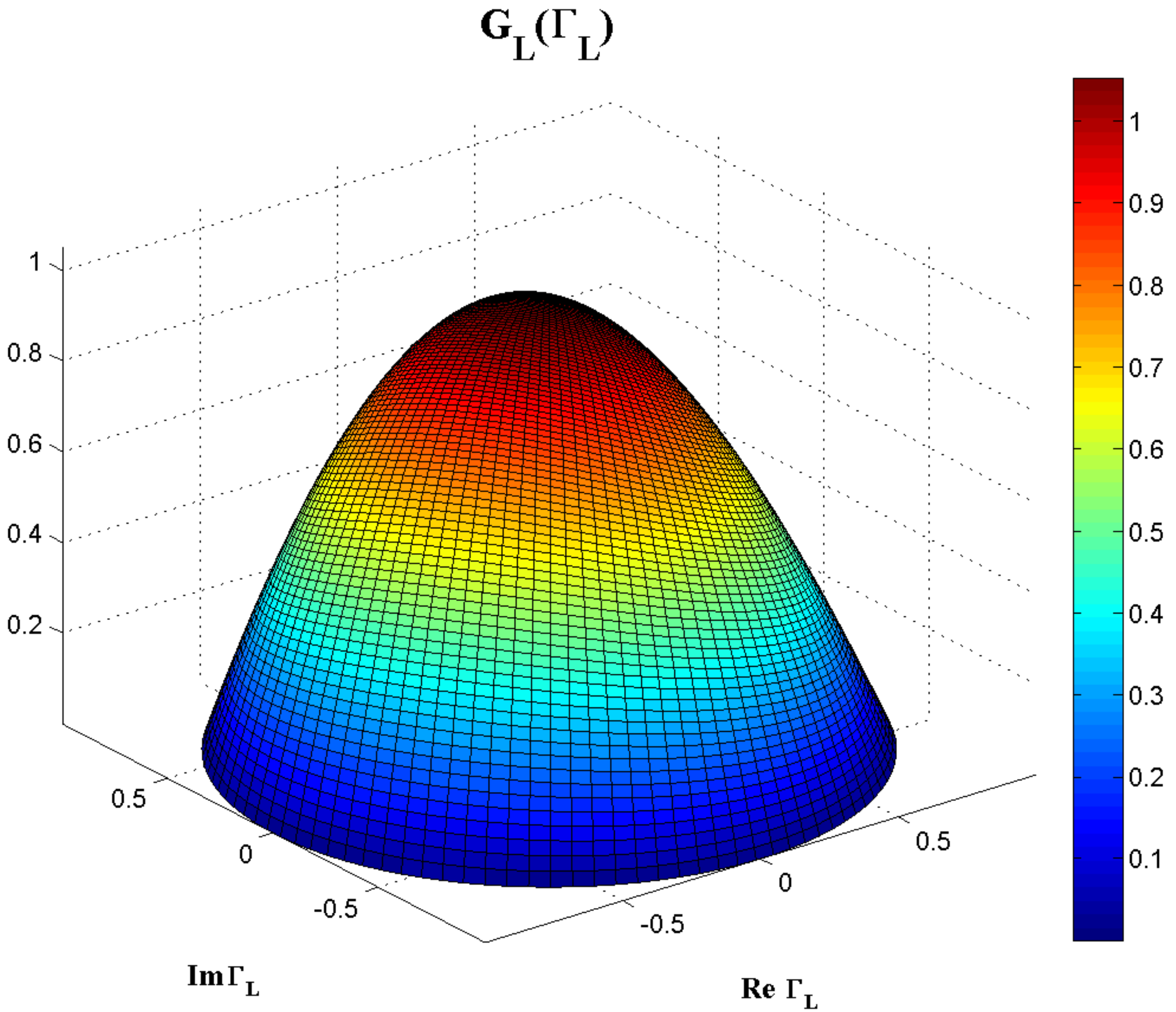
$$g_L = \frac{G_L}{G_{L\max}} = \frac{1-|\Gamma_L|^2}{|1-S_{22}\cdot\Gamma_L|^2}\cdot\left(1-|S_{22}|^2\right) < 1$$

- Calcul similar

$$C_L = \frac{g_L\cdot S_{22}^*}{1-(1-g_L)\cdot|S_{22}|^2} \qquad R_L = \frac{\sqrt{1-g_L}\cdot\left(1-|S_{22}|^2\right)}{1-(1-g_L)\cdot|S_{22}|^2}$$

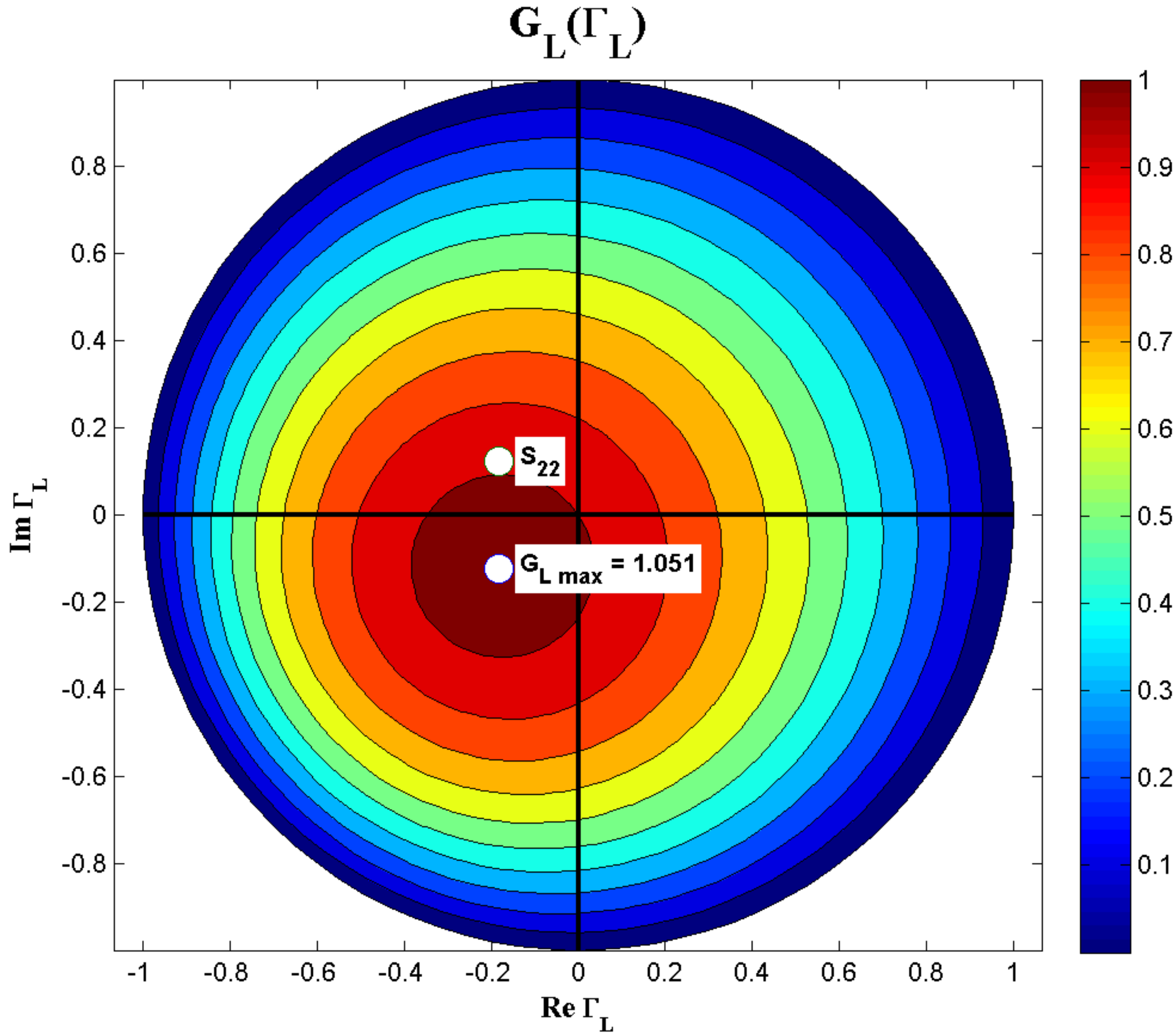
- Exemplu $G_{L\max} = \dfrac{1}{1-|S_{22}|^2} = 1.051 = 0.215\ dB$

$G_L(\Gamma_L)$



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

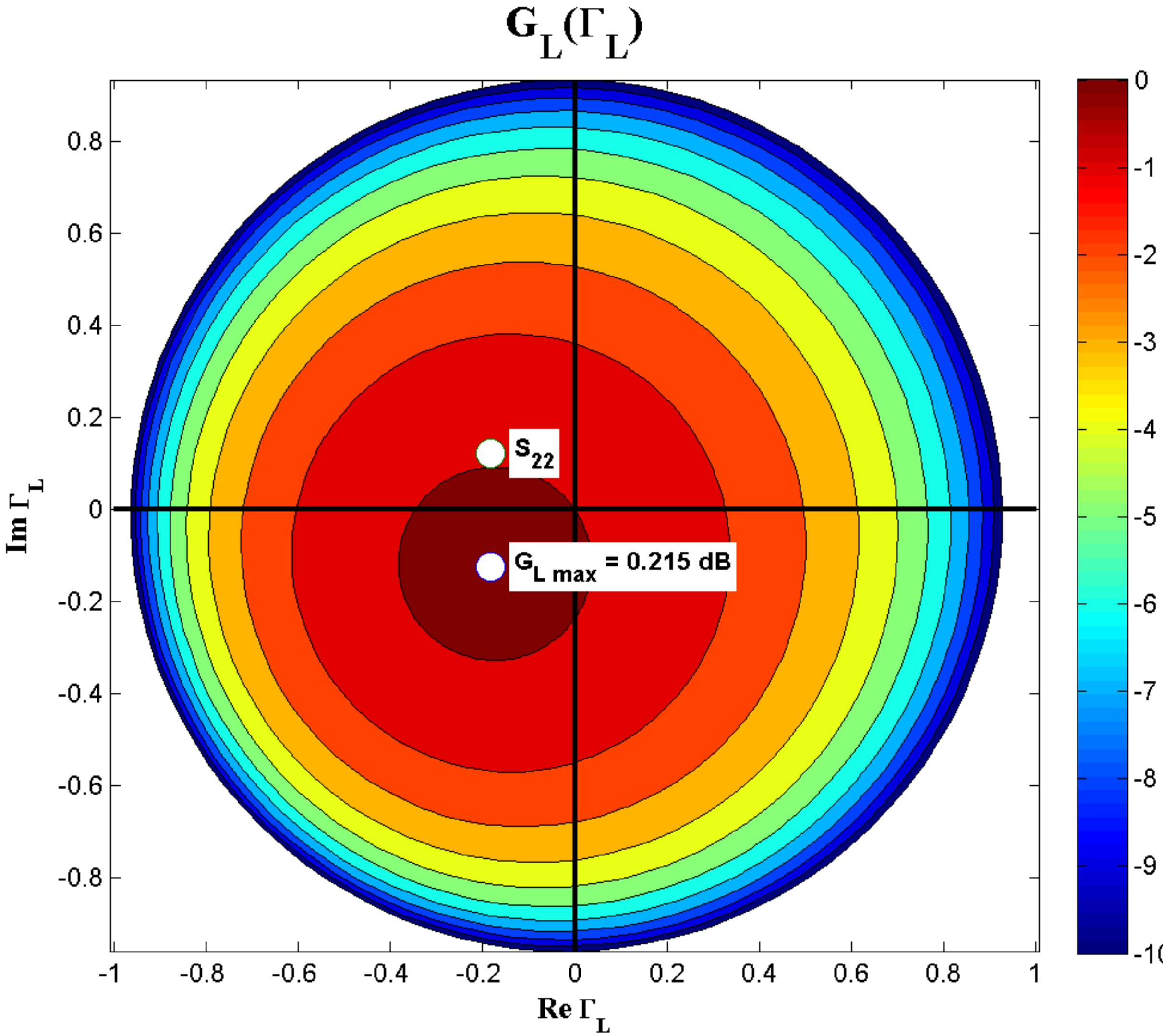
$G_L(\Gamma_L)$, diagrama de nivel



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

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

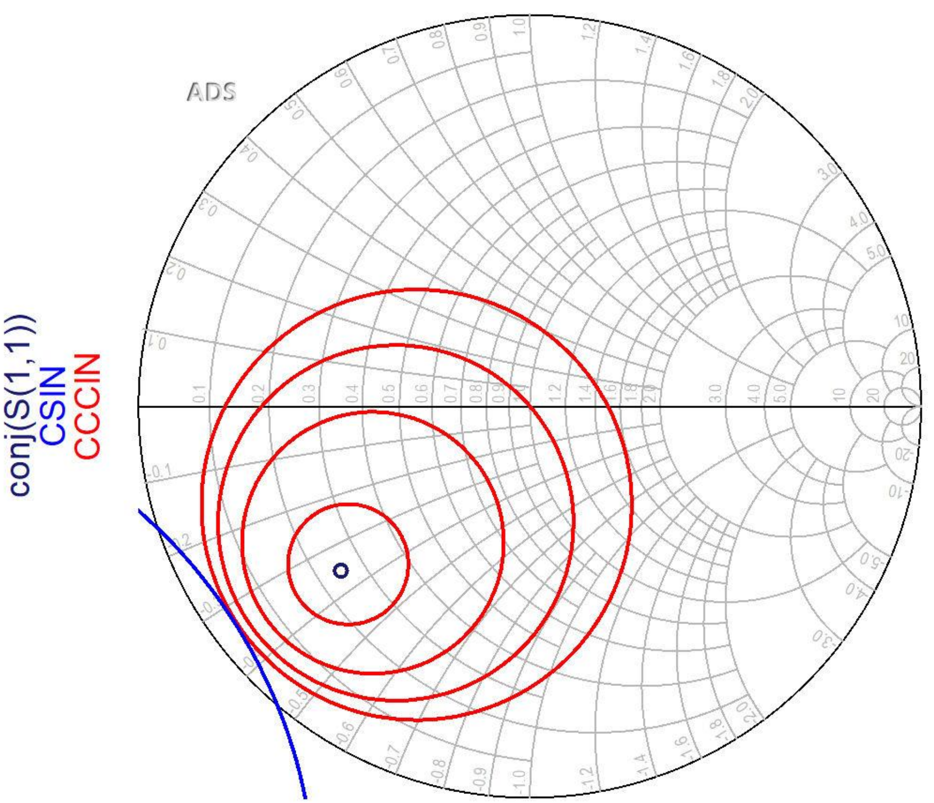
G_L[dB](Γ_L), diagrama de nivel

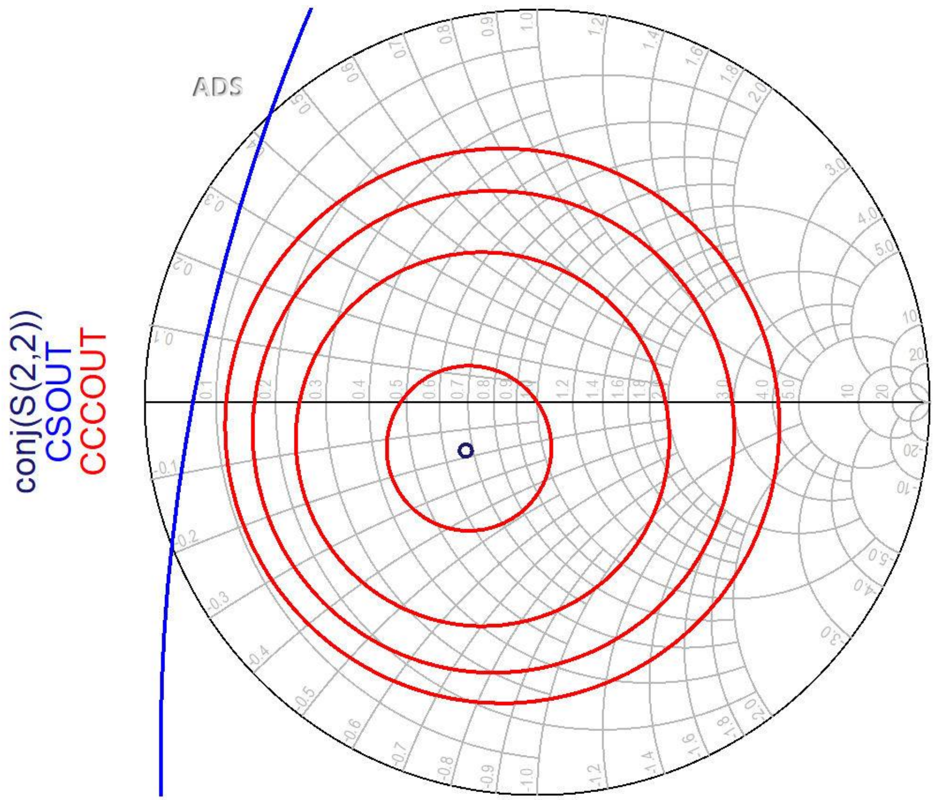


$$G_L[dB] = 10 \cdot \log\left(\frac{1-|\Gamma_L|^2}{|1-S_{22}\cdot\Gamma_L|^2}\right)$$

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

ADS





- Cercurile se reprezinta pentru valorile cerute in dB
- Este utila calcularea G_{Smax} si G_{Lmax} anterior

Proiectare pentru castig impus

- Se calculeaza G_o, G_{Smax} , G_{Lmax}
- Pentru obtinerea castigului impus se **aleg** valorile suplimentare necesare (suplimentar la G_o)
  - se tine cont de abaterea posibila caracterizata de factorul de merit U (ca rezerva)

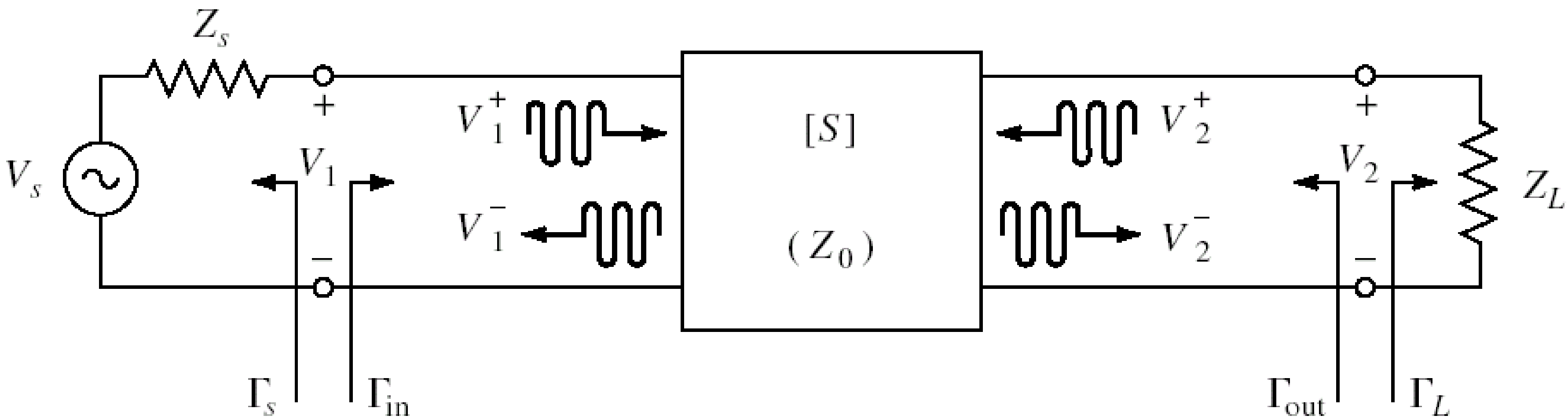
$$G_{dorit}[dB] = G_{S\_dor}[dB] + G_0[dB] + G_{L\_dor}[dB]$$

- 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

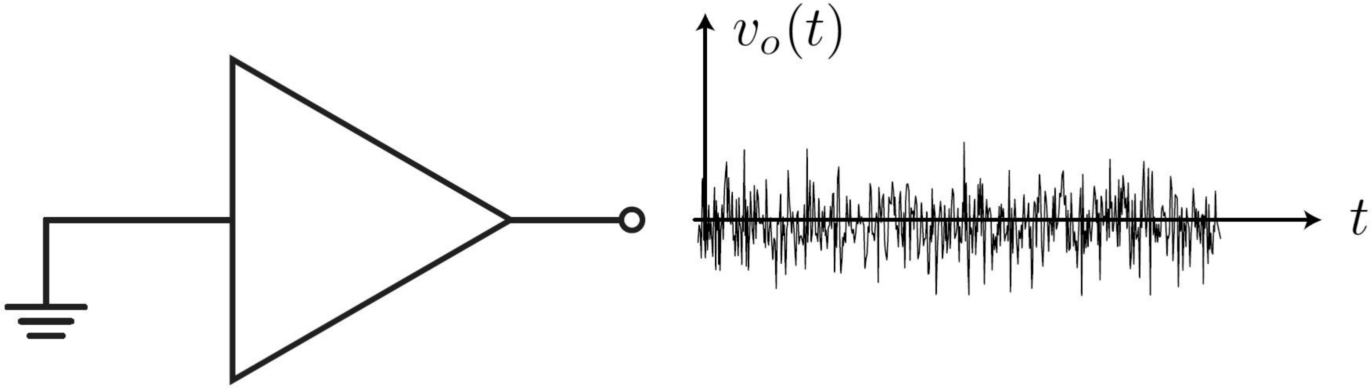
Cuadripol Amplificator



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

Zgomot

- Zgomot: variatii aleatorii ale semnalului

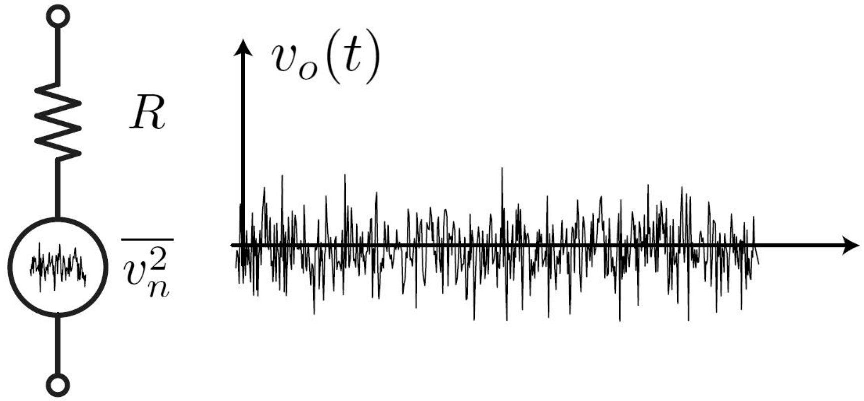


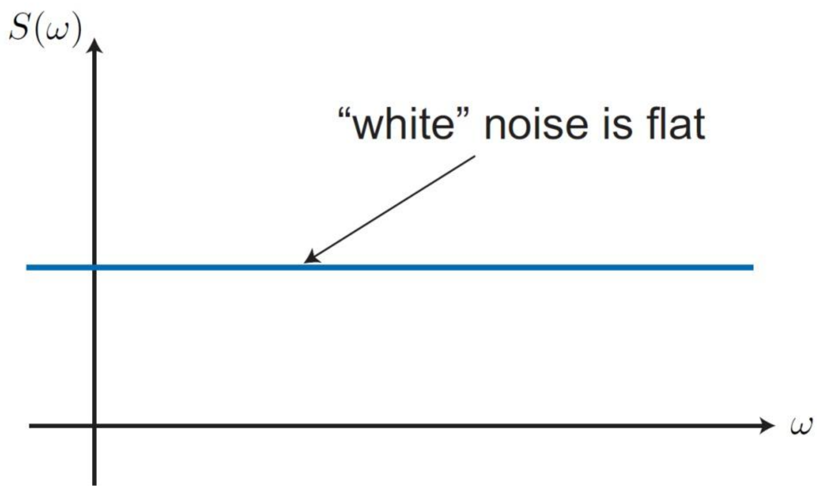
$$\overline{v_n(t)} = \langle v_n(t) \rangle = \frac{1}{T}\int_0^T v_n(t)\,dt = 0$$

$$\overline{v_n^2(t)} = \langle v_n^2(t) \rangle = \frac{1}{T}\int_0^T v_n^2(t)\,dt \neq 0$$

$$V_{n(ef)} = \sqrt{\overline{v_n^2(t)}}$$

Zgomot





- tensiunea efectiva de zgomot

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

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

$$P_n = kTB$$

Contact

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