

Curs 7
2019/2020

Dispozitive și circuite de microunde pentru radiocomunicații

Disciplina 2019/2020

- 2C/1L, DCMR (CDM)
- Minim 7 prezente (curs+laborator)
- Curs - **conf. Radu Damian**
 - Marti 14-16, P7
 - E – **50%** din nota
 - probleme + (2p prez. curs) + (3 teste) + (bonus activitate)
 - primul test L1 (t₂ si t₃ neanuntate)
 - 3pz (C) = +0.5p
 - toate materialele permise

Disciplina 2019/2020

- 2C/1L, **DCMR (CDM)**
- Laborator – **conf. Radu Damian**
 - Miercuri 10-14 impar II.12 (par eng.)
 - Joi 14- 16 par
 - L – **25%** din nota
 - prezenta + rezultate personale
 - P – **25%** din nota
 - tema personală

Documentatie

■ <http://rf-opto.etti.tuiasi.ro>

Laboratorul de Microunde si Optică

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

RF-OPTO

EN English | RO Romana |

Start Didactic Master Colectiv Cercetare Studenti Admin

Microunde Comunicatii Optice Optoelectronica Internet Antene Practica Retele Soft didactic

Dispozitive si circuite de microunde pentru radiocomunicatii

Disciplina: DCMR (2017-2018)

Coordinator Disciplina: conf. dr. Radu-Florin Damian

Cod: DOS412T

Tip Disciplina: DOS; Disciplina Optionala, Disciplina de Specialitate

Credite: 4

An de Studiu: 4, Sem. 7

Activitati

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

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

Evaluare

Tip: Examen

A: 50%, (Examen/Colocviu)

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

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

Note

[Rezultate totale](#)

Prezenta

[Curs](#)

[Laborator](#)

Liste

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

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

Bibliografie

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

Examen: Reprezentare logaritmică

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Examen: Operatii cu numere complexe

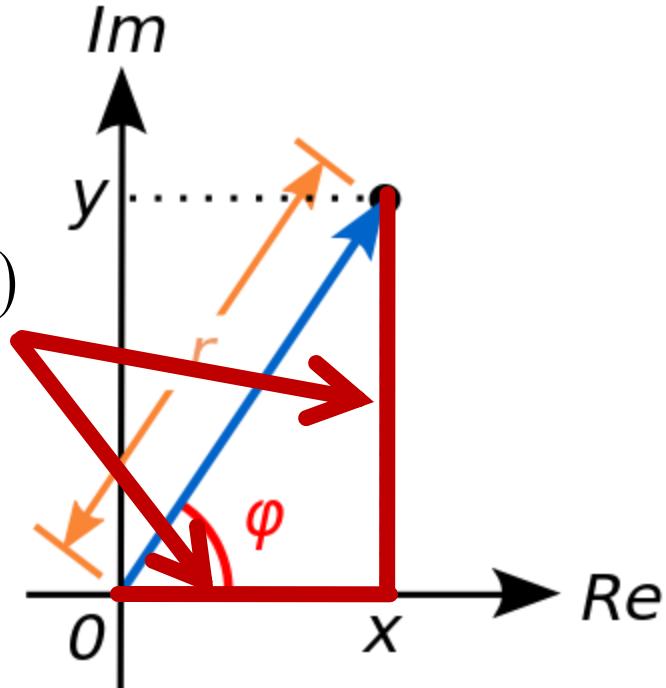
■ Reprezentare polară

- modul
- faza

$$z = a + j \cdot b = |z| \cdot (\cos \varphi + j \cdot \sin \varphi)$$

$$|z| = \sqrt{a^2 + b^2}$$

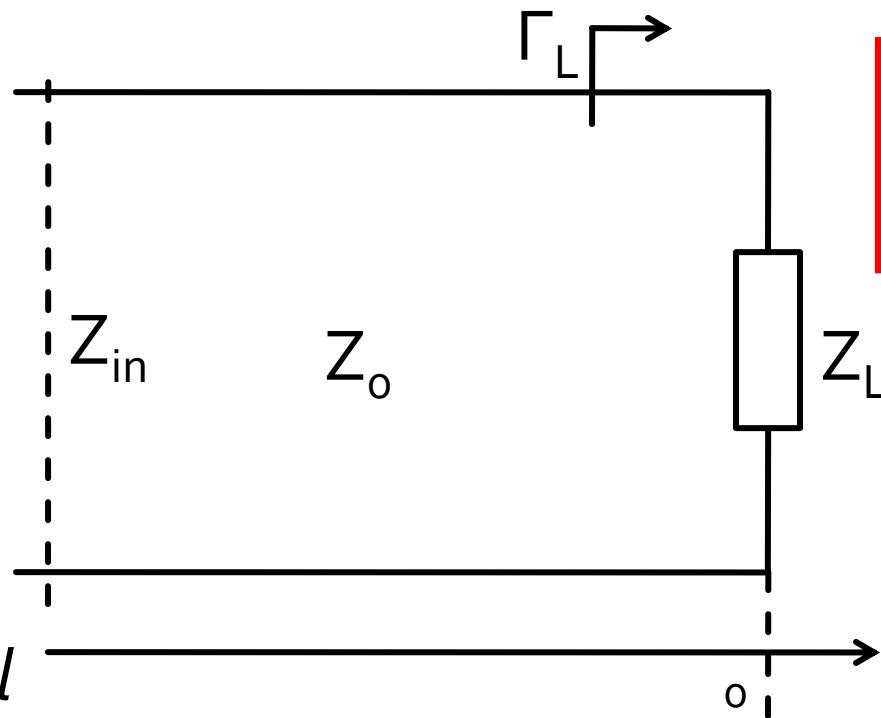
$$\varphi = \arg(z) = \begin{cases} \arctan\left(\frac{b}{a}\right), & a > 0 \\ \arctan\left(\frac{b}{a}\right) + \pi, & a < 0, b \geq 0 \\ \arctan\left(\frac{b}{a}\right) - \pi, & a < 0, b < 0 \\ \frac{\pi}{2}, -\frac{\pi}{2}, \text{nedefinit} & a = 0 \end{cases}$$



Linii de transmisie in mod TEM

Linie fara pierderi

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

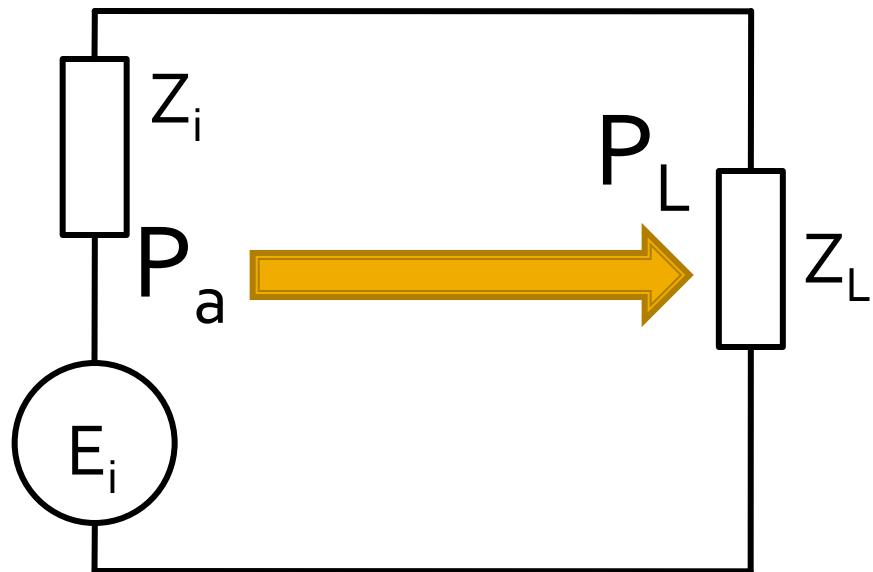
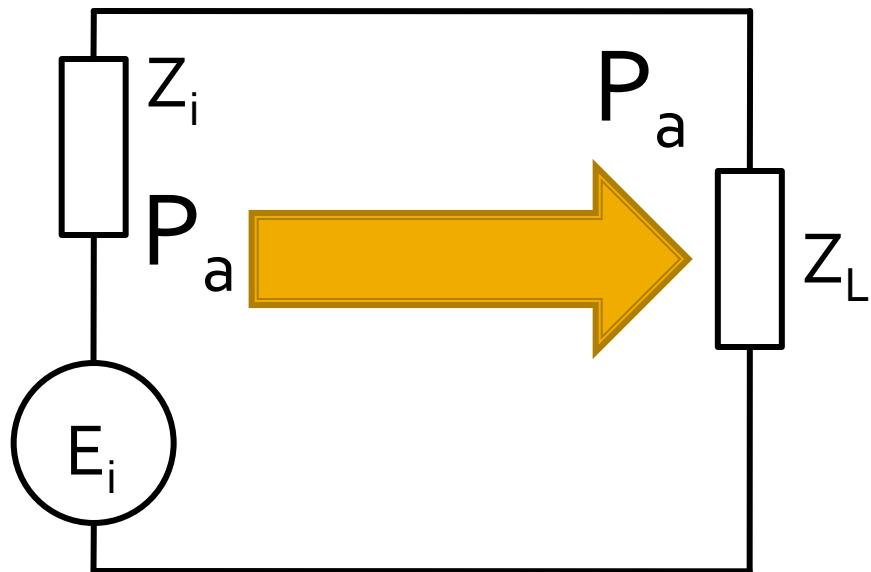


$$Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan \beta \cdot l}{Z_0 + j \cdot Z_L \cdot \tan \beta \cdot l}$$

Transfer de putere

Adaptarea de impedanță

Reflexie de putere / Model



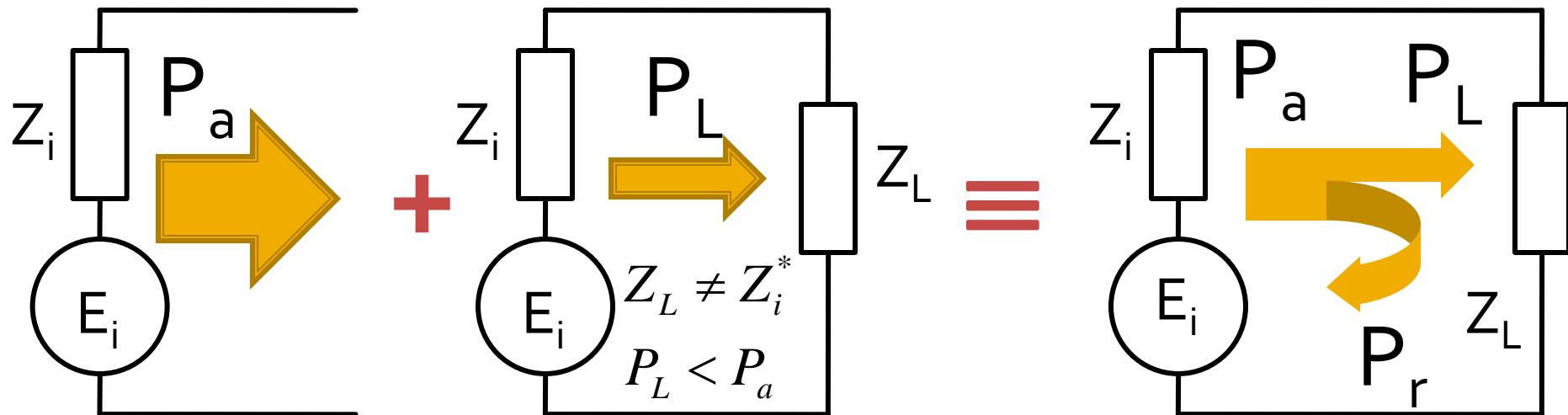
$$Z_L = Z_i^*$$

$$P_L = P_a$$

$$Z_L \neq Z_i^*$$

$$P_L < P_a$$

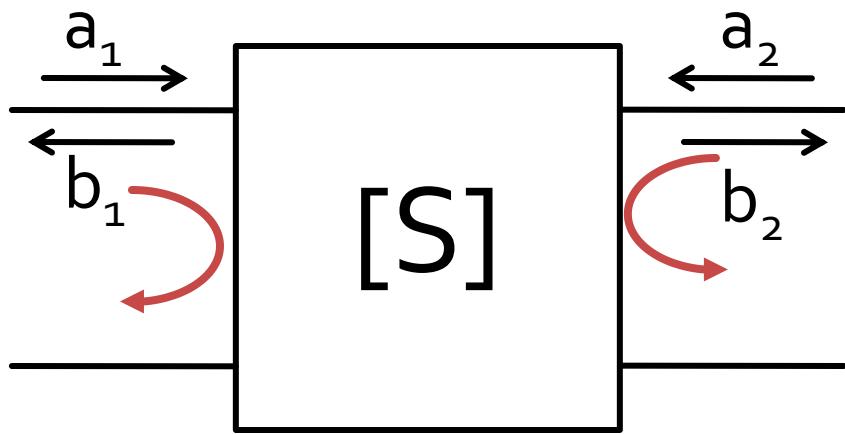
Reflexie de putere / Model



- 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!**

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

Matricea S (repartitie)

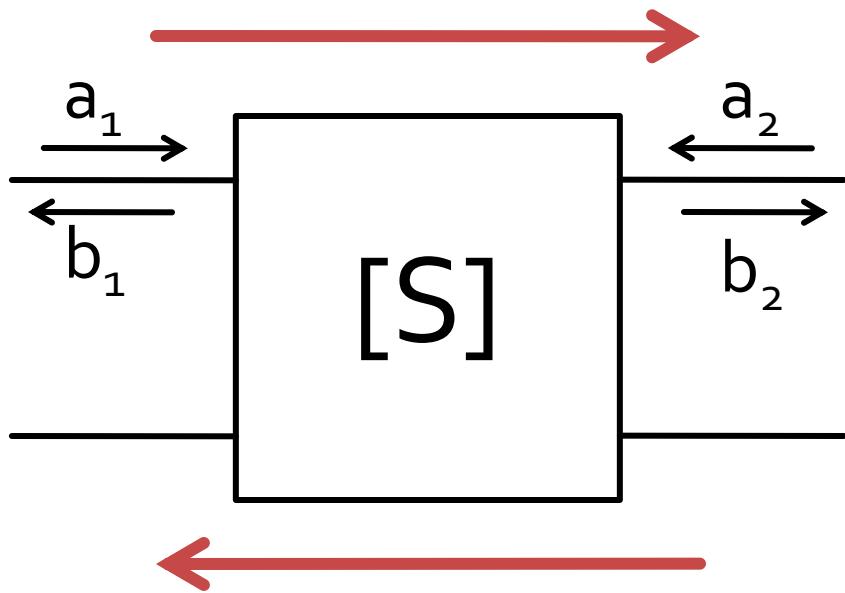


$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

$$S_{11} = \left. \frac{b_1}{a_1} \right|_{a_2=0} \quad S_{22} = \left. \frac{b_2}{a_2} \right|_{a_1=0}$$

- S_{11} și S_{22} sunt coeficienti de reflexie la intrare si iesire cand celalalt port este adaptat

Matricea S (repartitie)



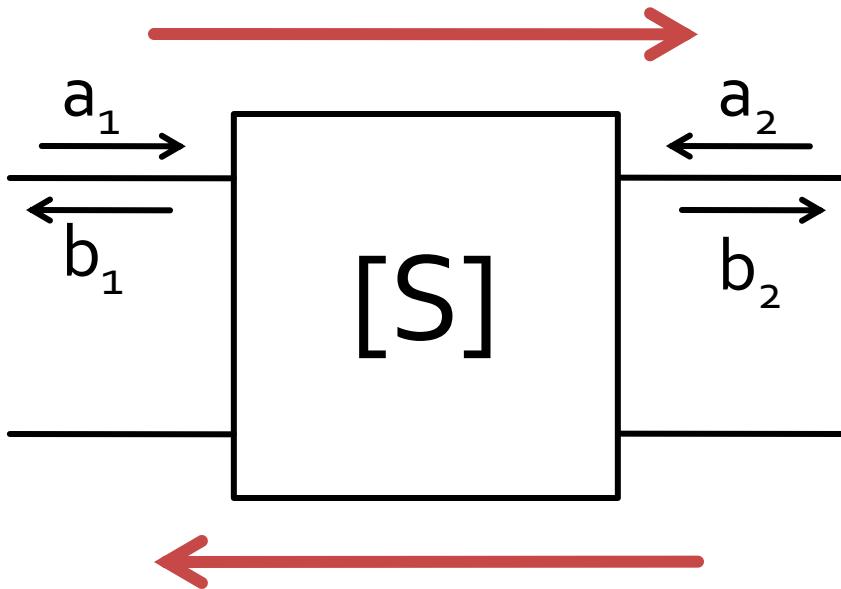
$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

$$S_{21} = \frac{b_2}{a_1} \Big|_{a_2=0}$$

$$S_{12} = \frac{b_1}{a_2} \Big|_{a_1=0}$$

- S_{21} și S_{12} sunt amplificări de semnal cand celalalt port este adaptat

Matricea S (repartitie)



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

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

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

Adaptarea de impedanță

Diagrama Smith

Diagrama Smith

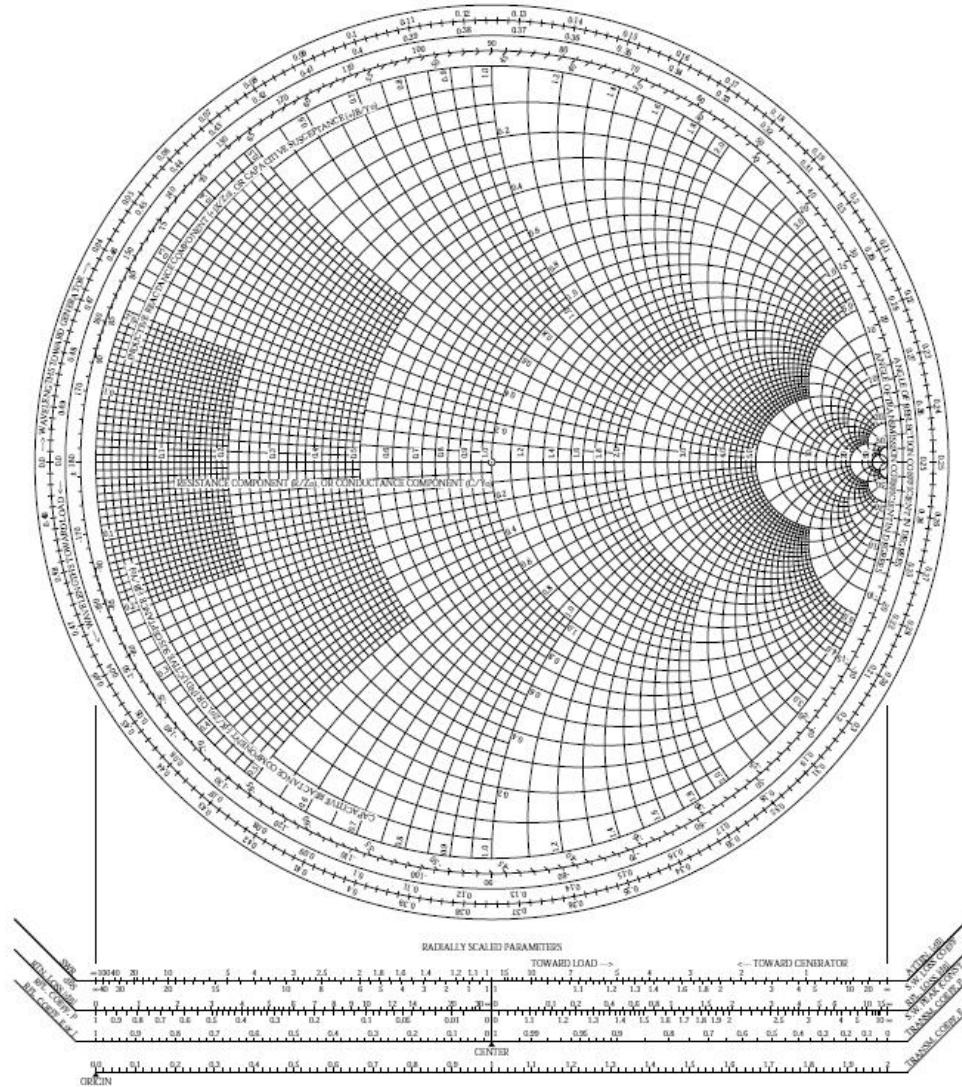
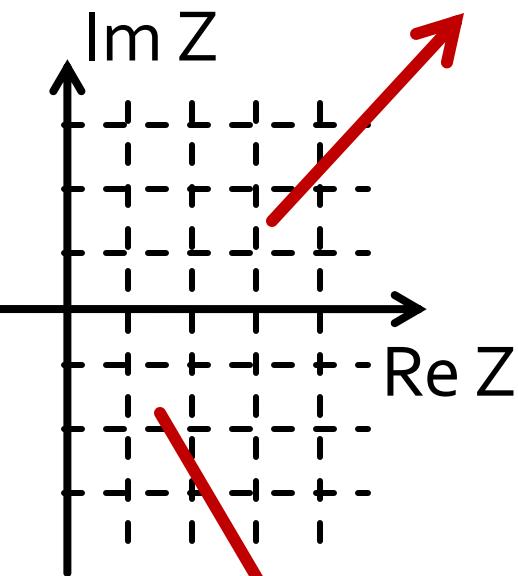


Diagrama Smith

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



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

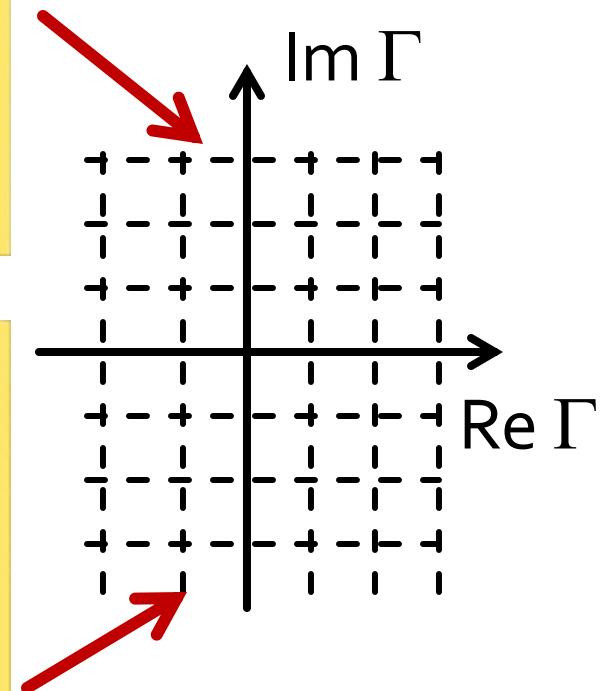
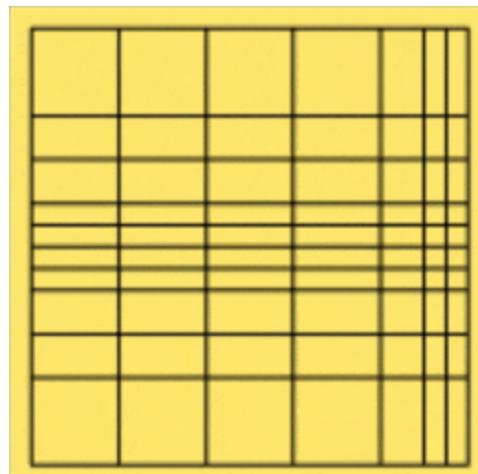
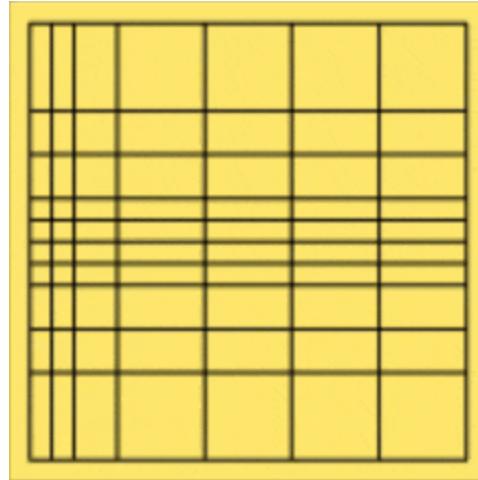


Diagrama Smith

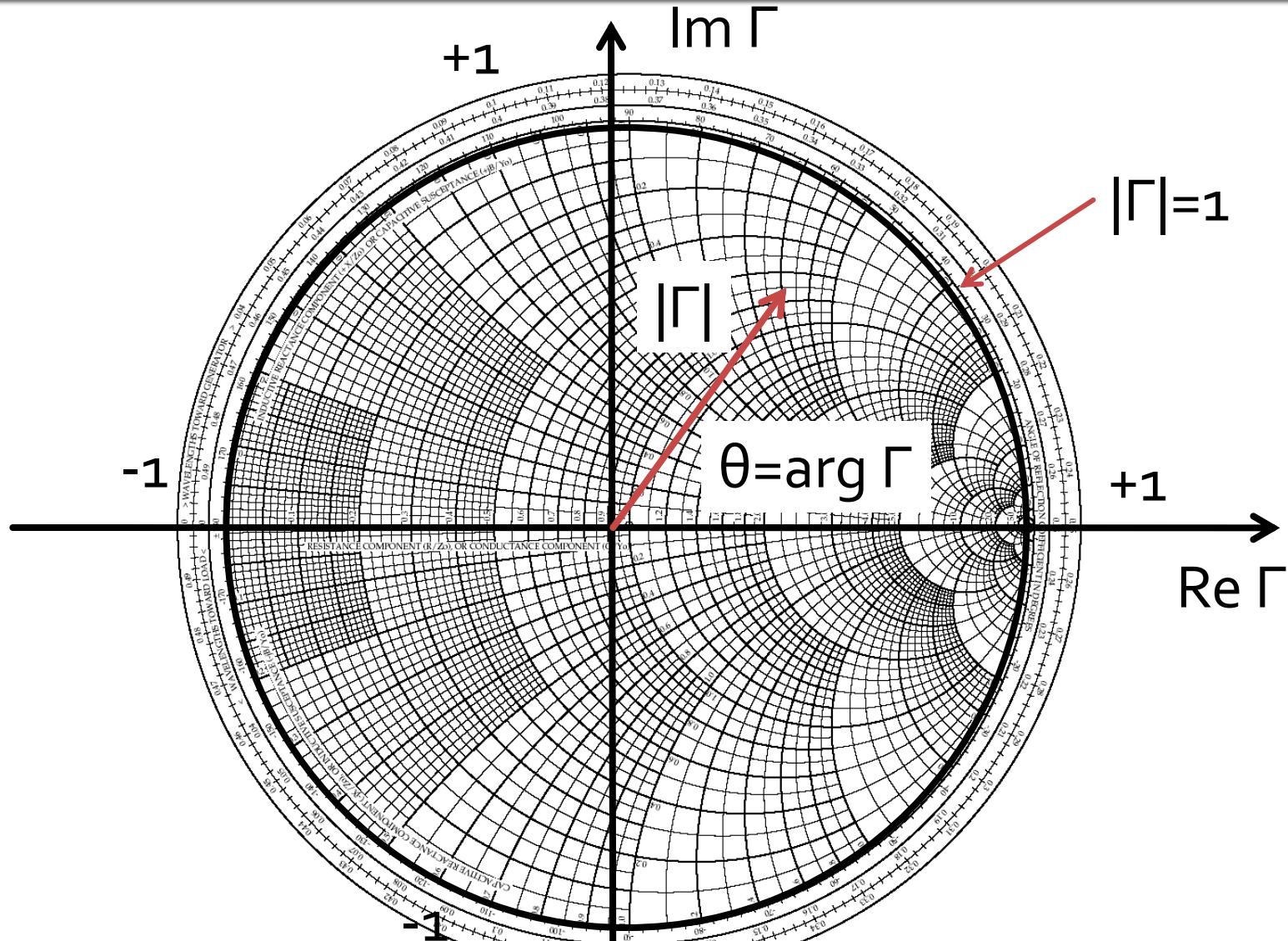
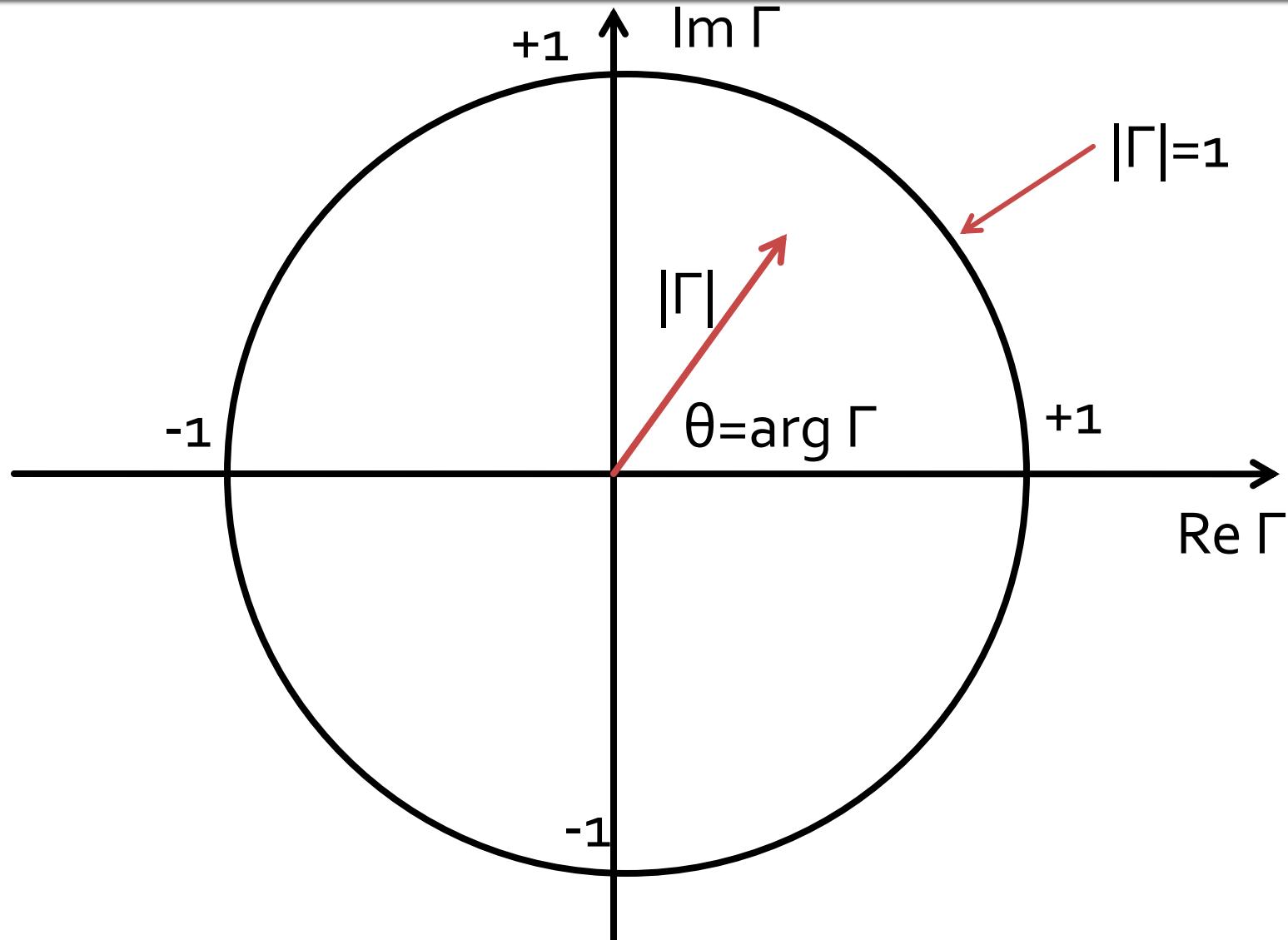


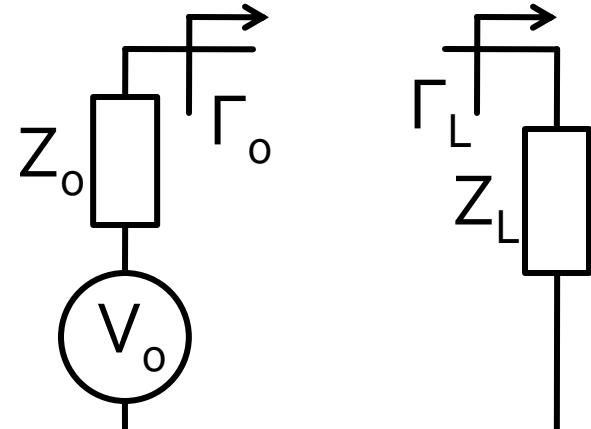
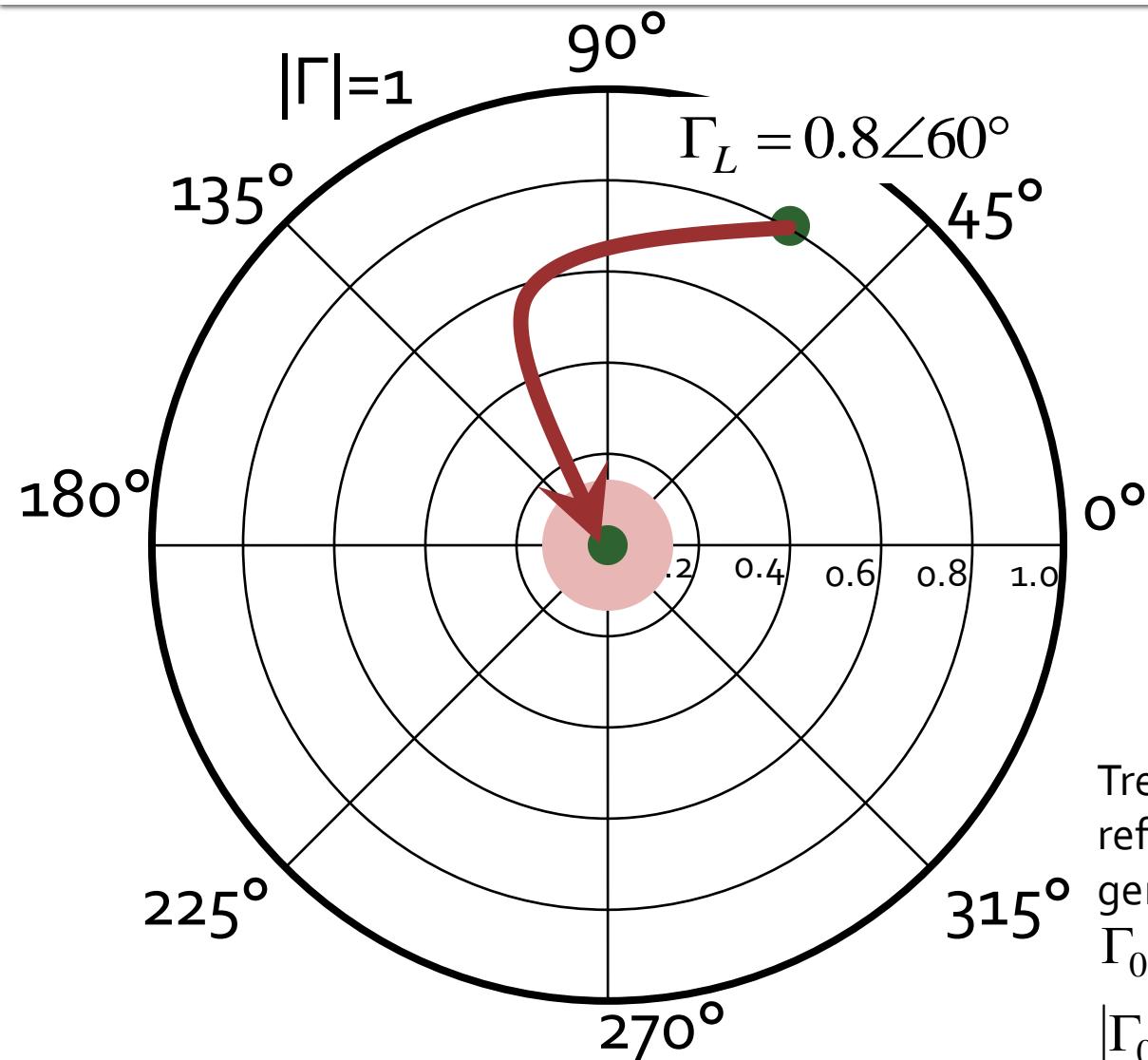
Diagrama Smith



Adaptarea cu elemente concentrate (Retele in L)

Adaptarea de impedanță

Diagrama Smith, adaptare



Adaptare Z_L la Z_0 . Se raporteaza Z_L la Z_0

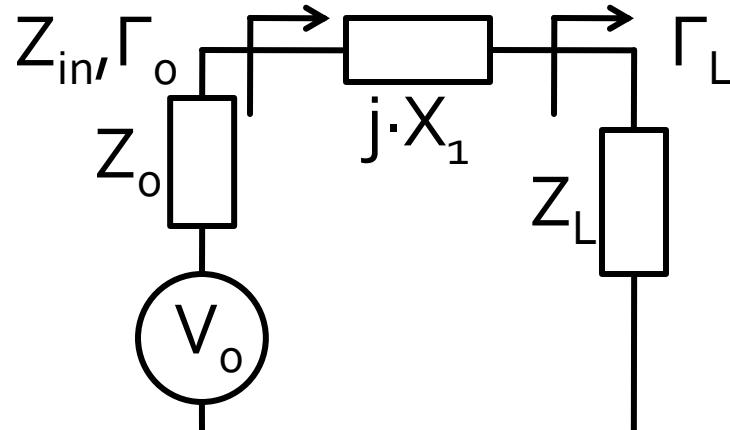
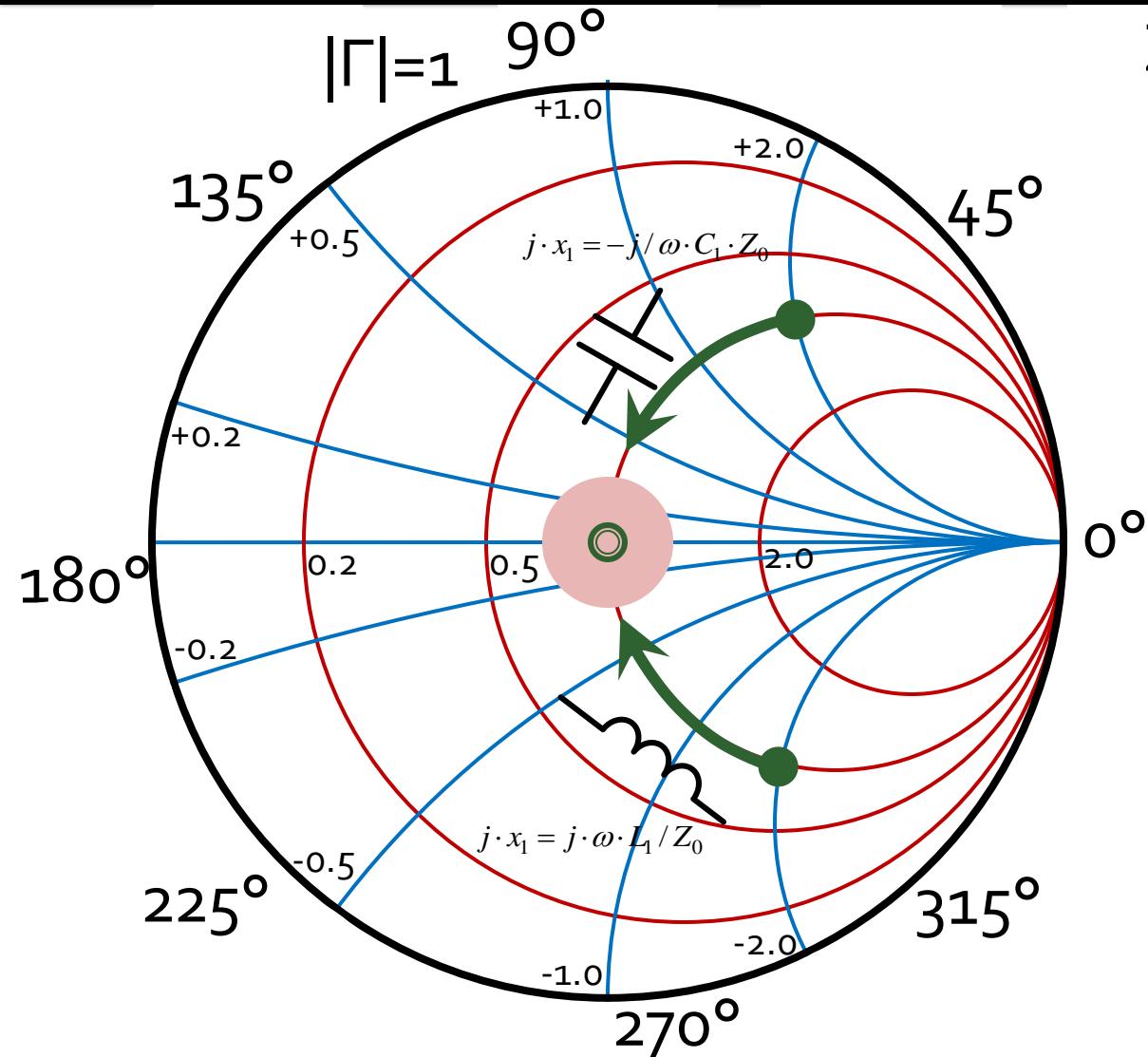
$$Z_L = 21.429\Omega + j \cdot 82.479\Omega$$
$$z_L = 0.429 + j \cdot 1.65$$
$$\Gamma_L = 0.8 \angle 60^\circ$$

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

$\Gamma_0 = 0$ adaptare perfecta

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

Adaptare, reactanta in serie



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

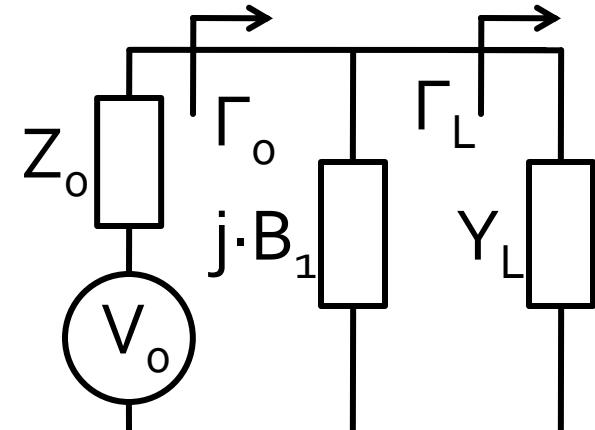
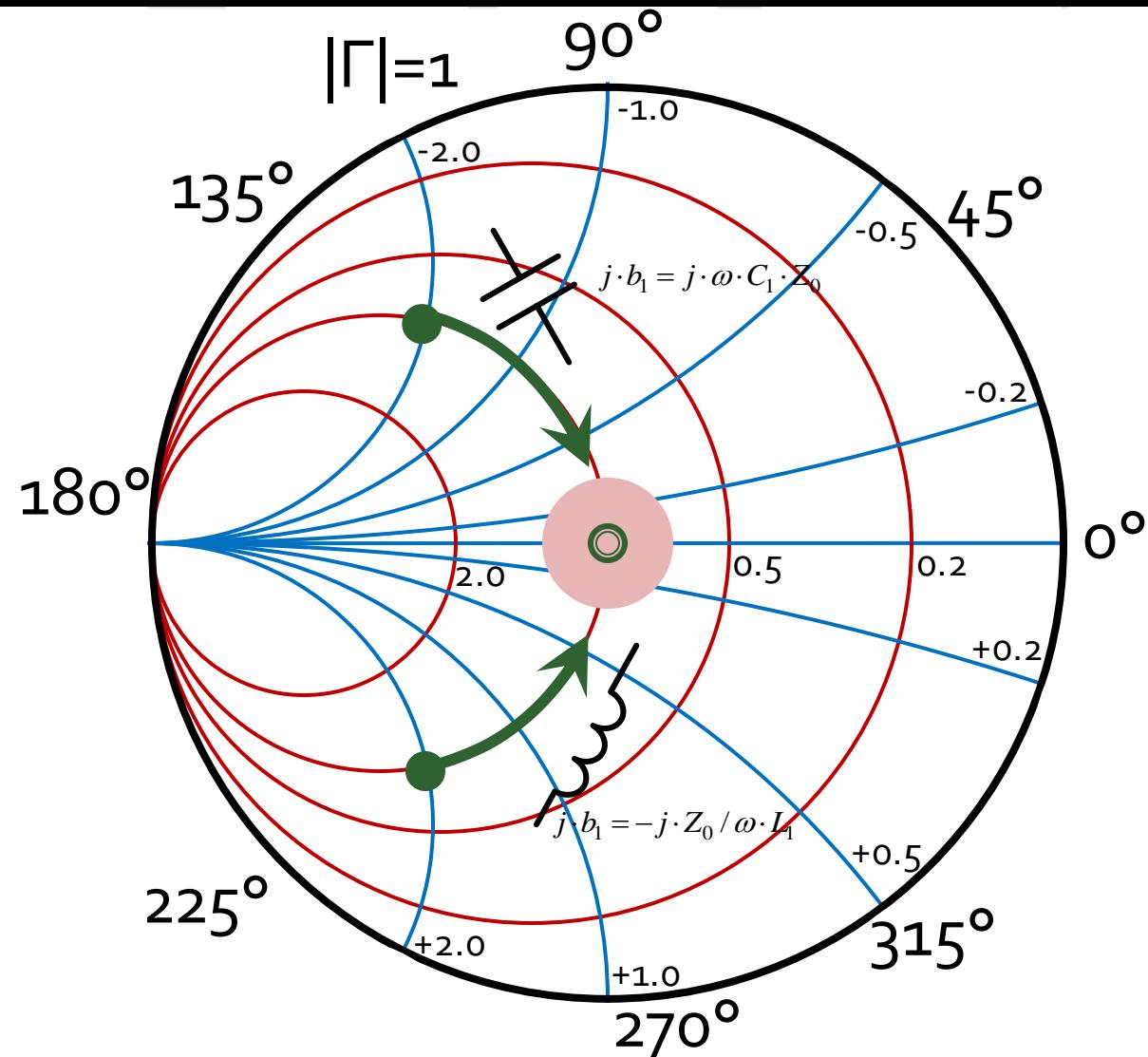
$$z_{in} = r_L + j \cdot (x_L + x_1)$$

$$r_{in} = r_L$$

- 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



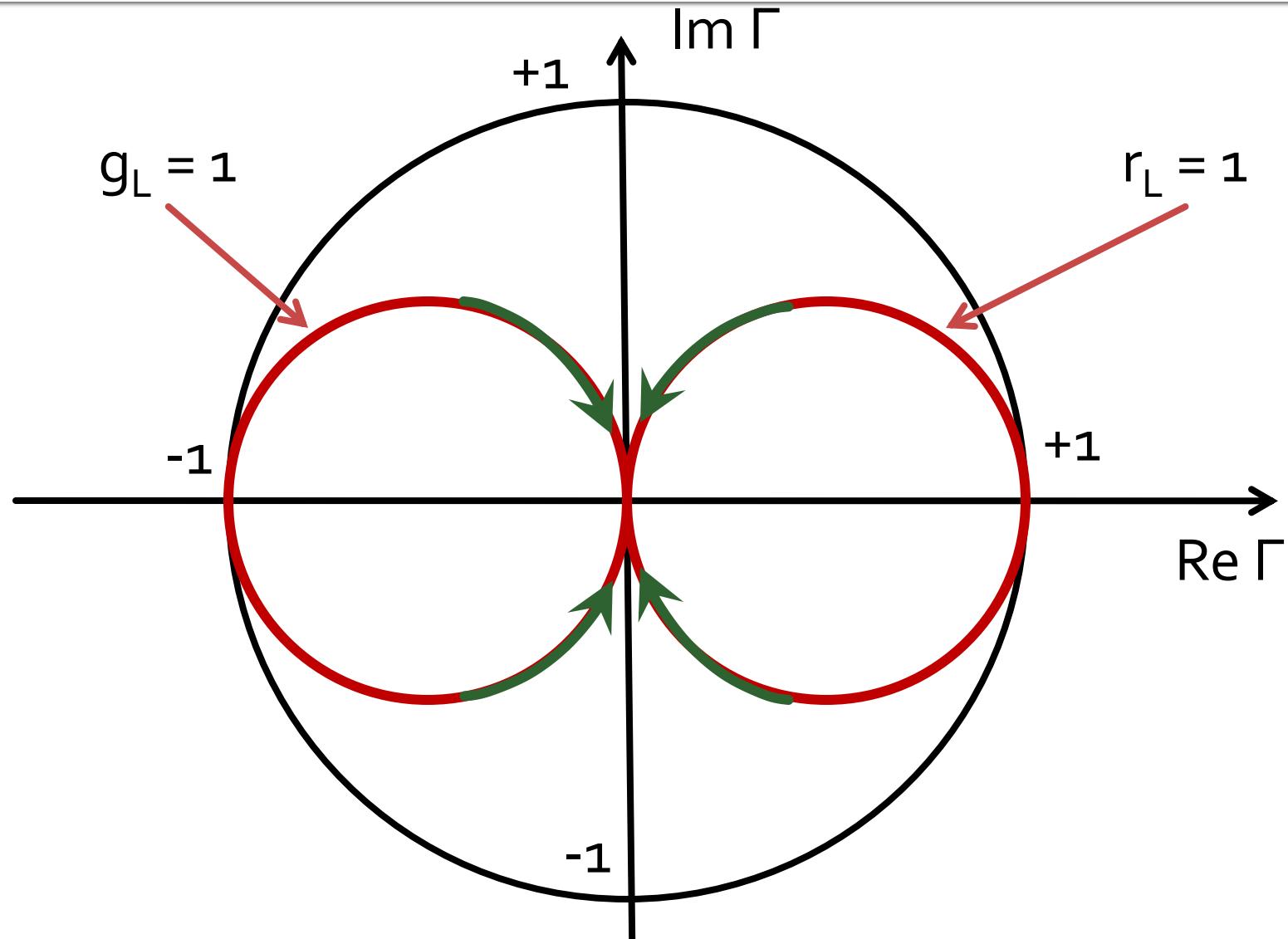
$$y_L = g_L + j \cdot b_L$$

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

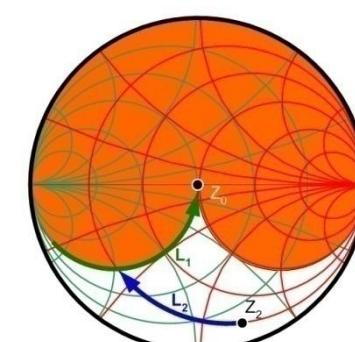
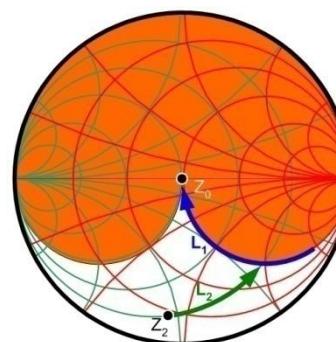
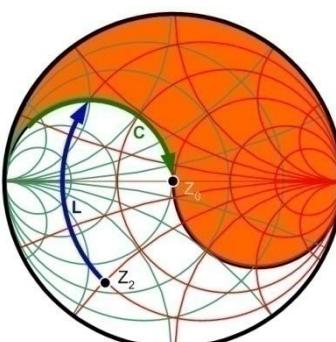
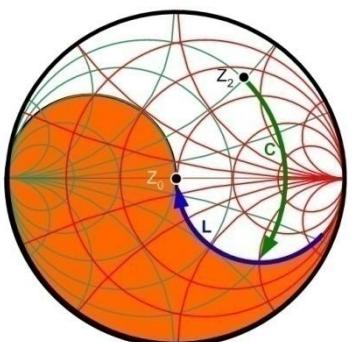
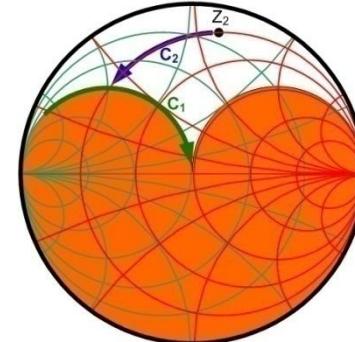
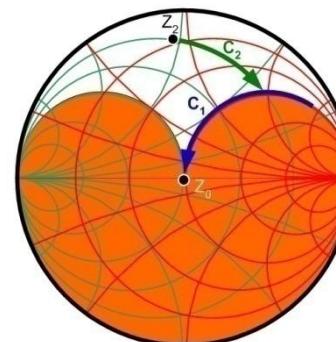
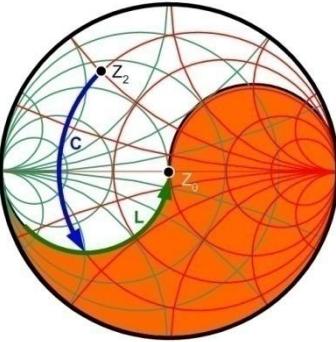
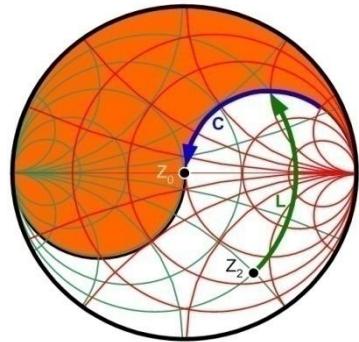
$$g_{in} = g_L$$

- 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 $g=1$



Adaptare cu două elemente reactive (retele in L)

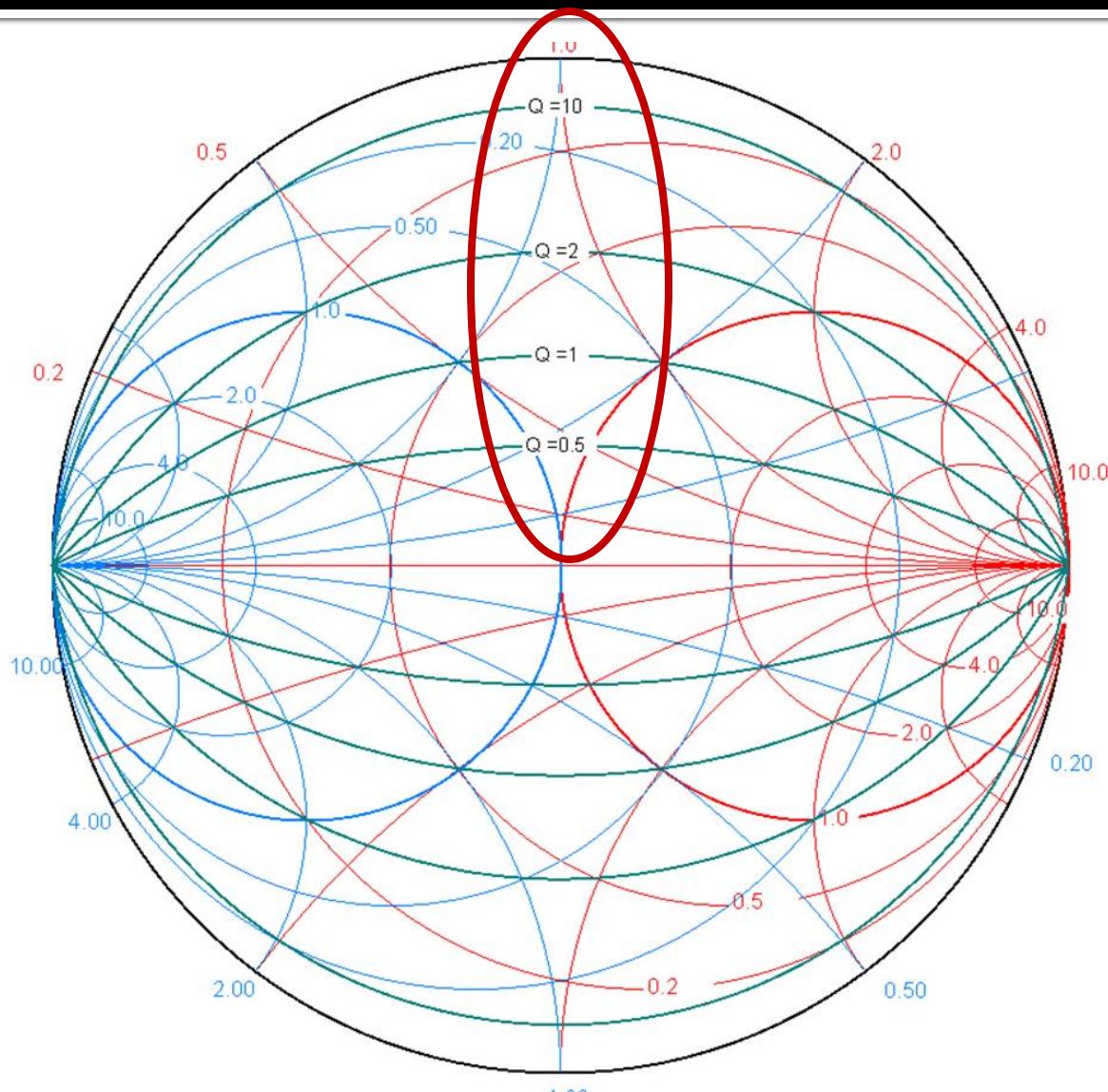
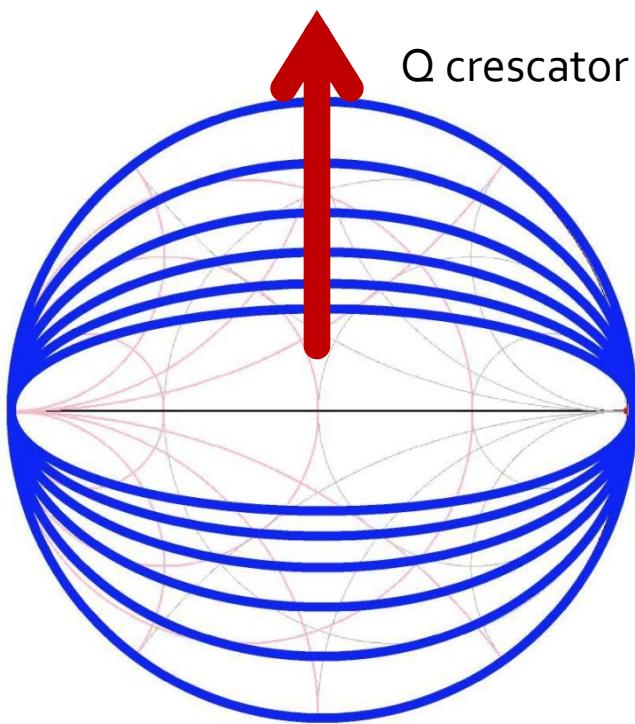


Zona interzisa cu
schema curenta

Cercuri de factor de calitate constant

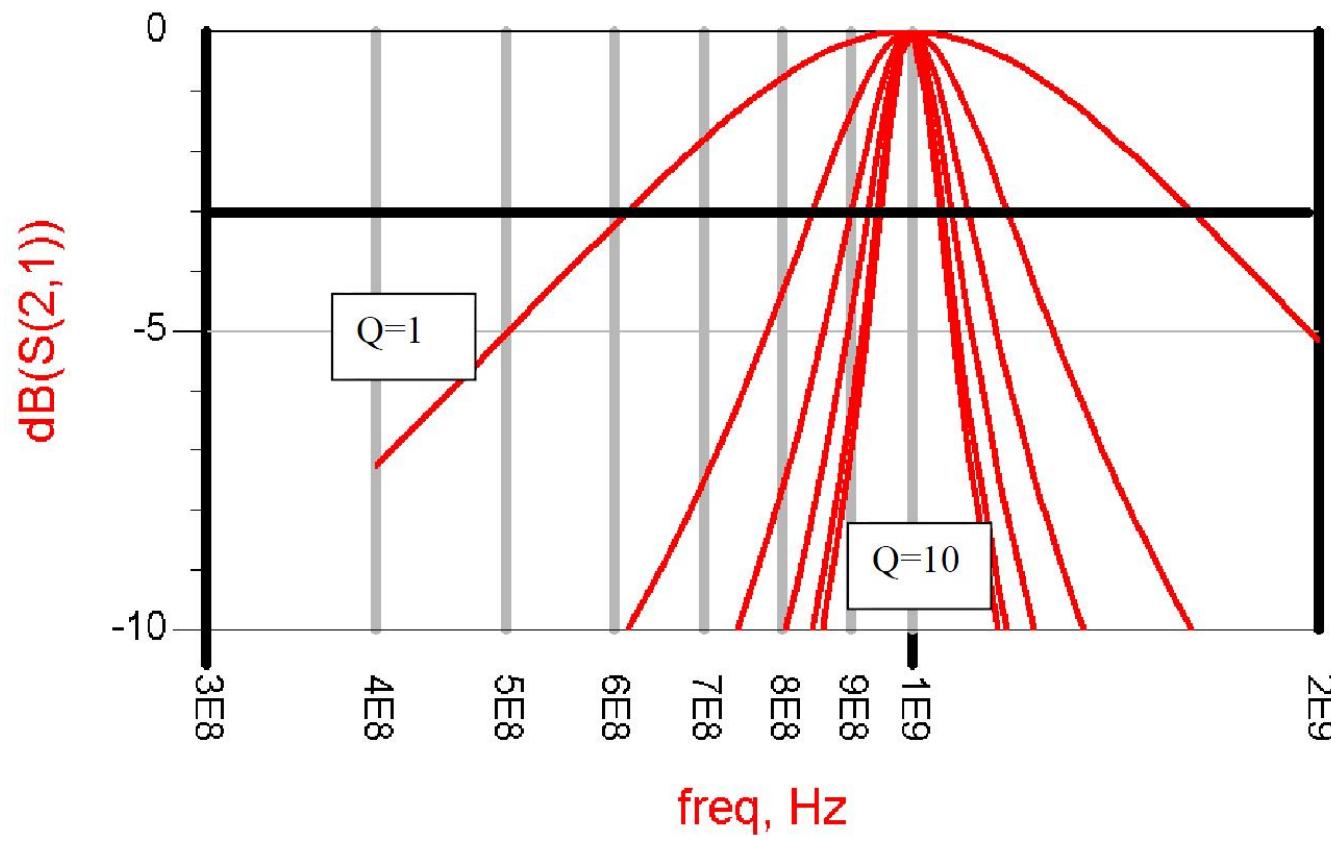
- Diagrama Smith

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

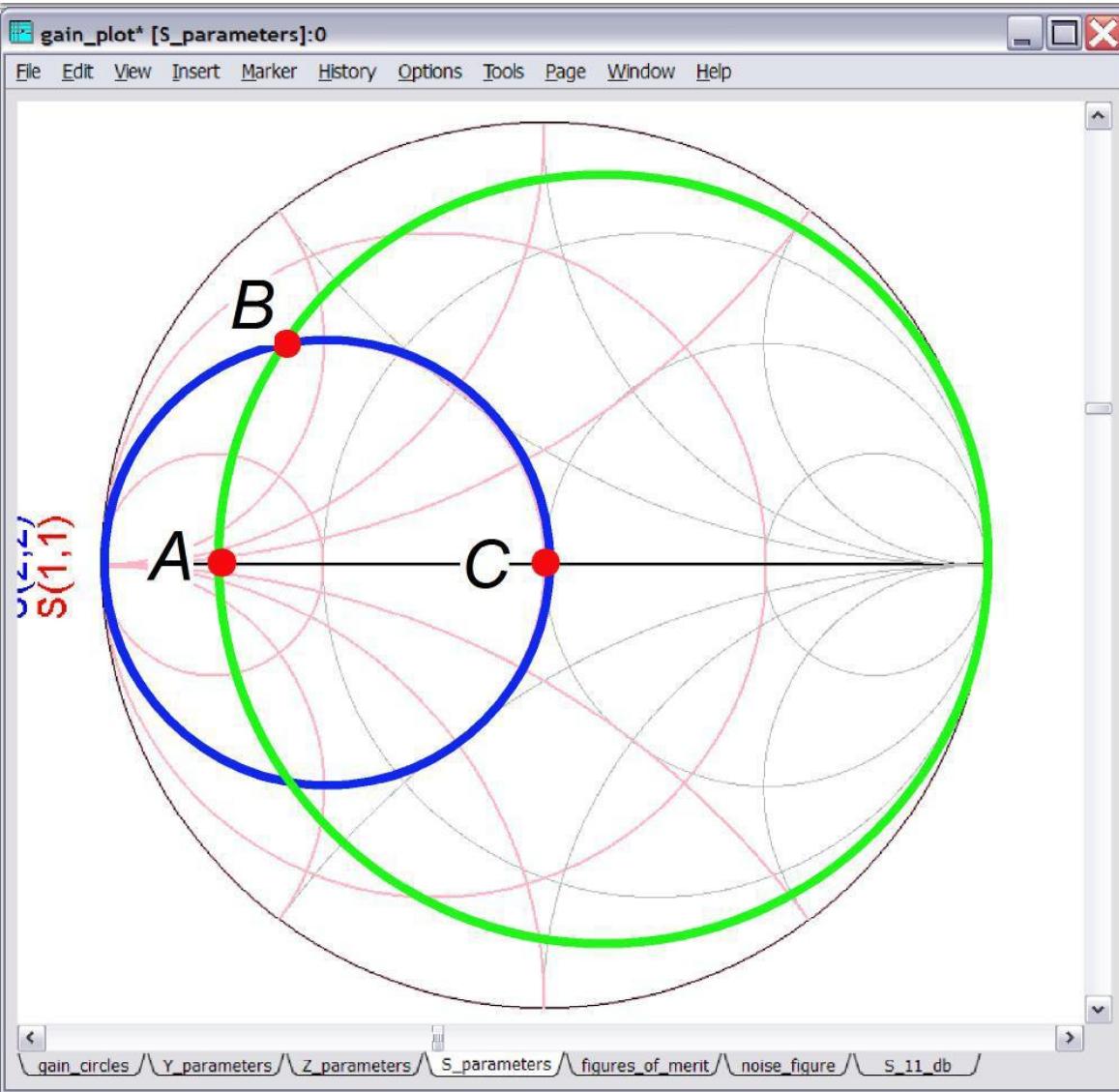


Factor de calitate - banda

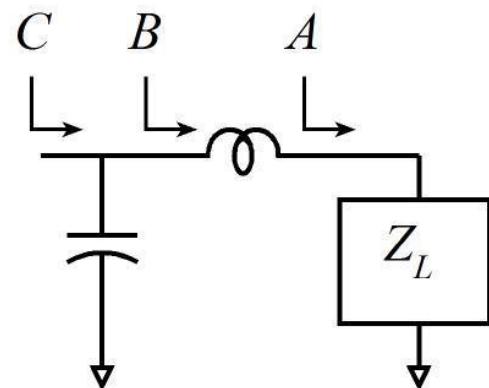
- Factor de calitate ridicat echivalent cu banda ingusta



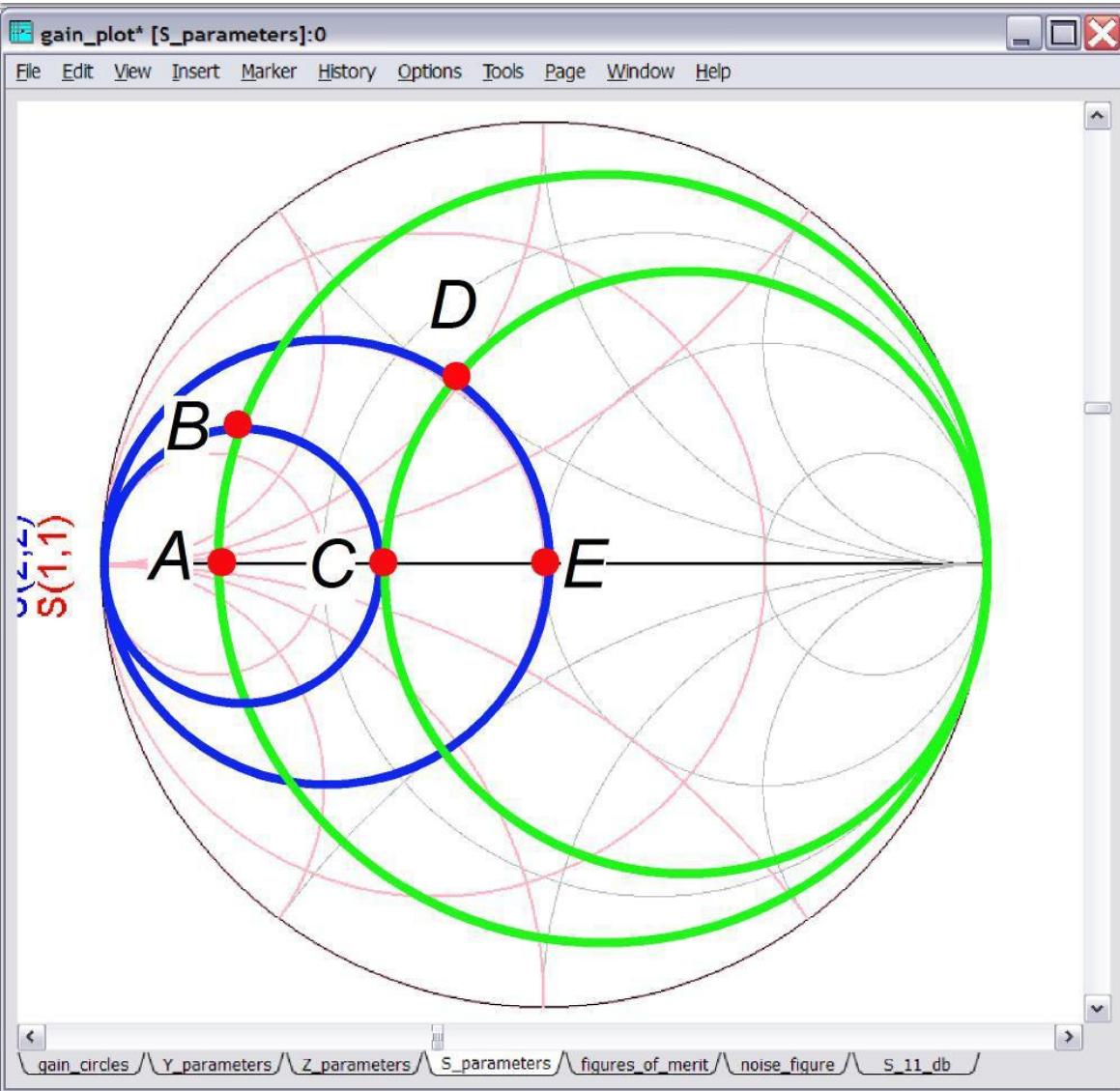
Adaptare - banda



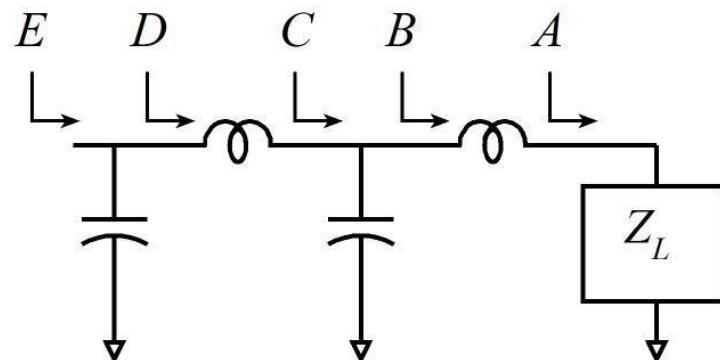
- Pozitia punctului intermediar (B) atins de Γ corespunzatoare celui mai ridicat factor de calitate impune largimea de banda a adaptarii



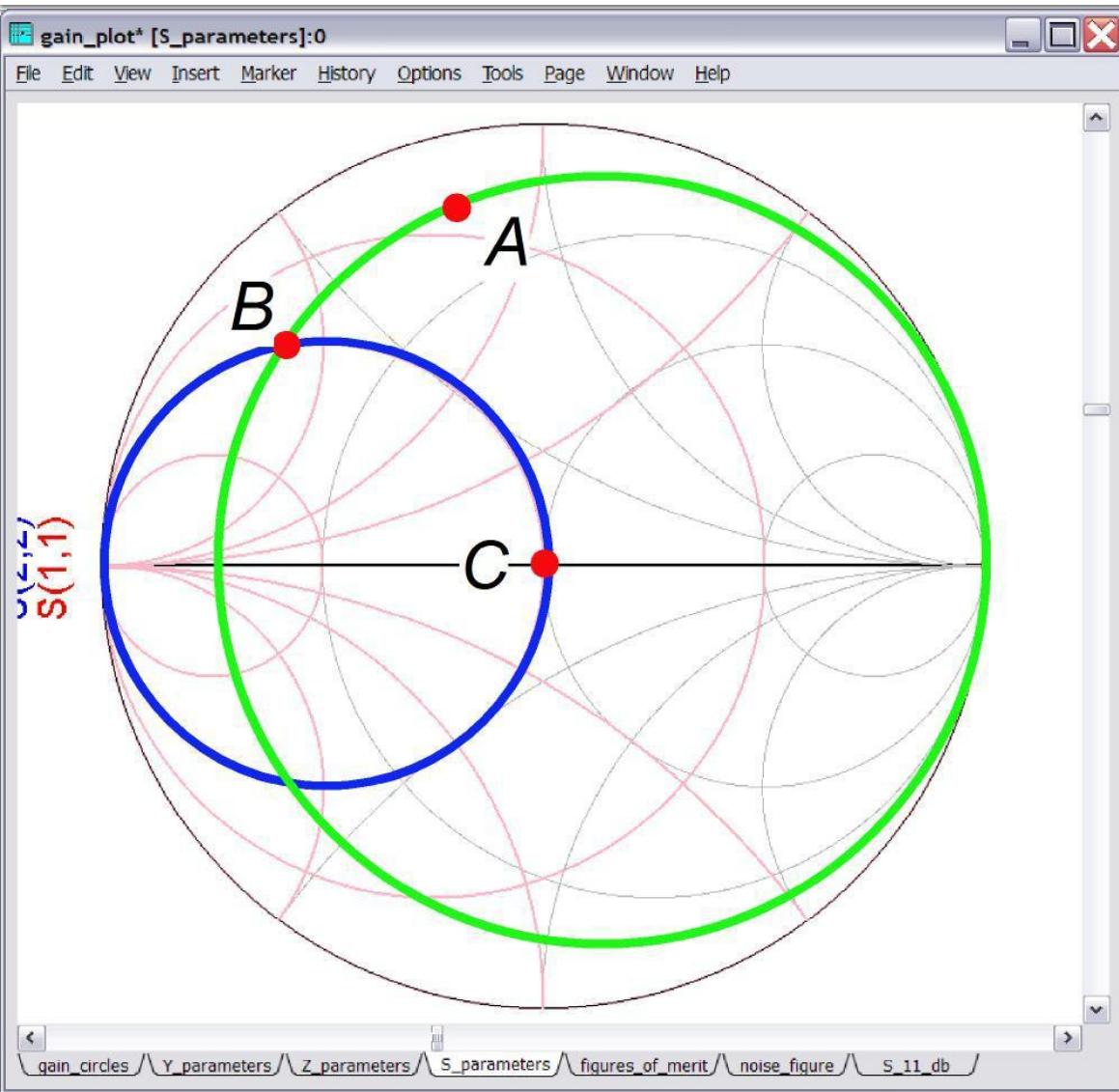
Adaptare - banda



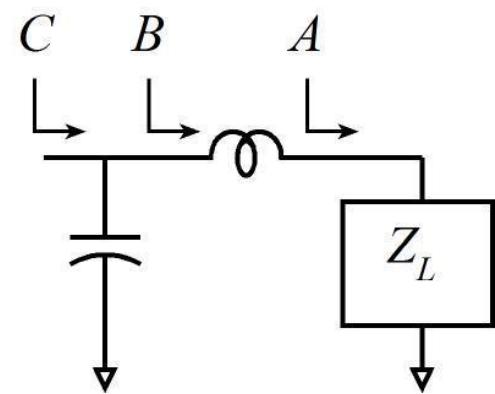
- Adaptare in banda mai larga poate fi obtinuta prin realizarea unor retele in L multiple, fiecare pentru variatii mai mici ale lui Γ , astfel incat toti coeficientii de reflexie intermediari (B, D) sa ocupe pozitii care corespund unui factor de calitate mai mic



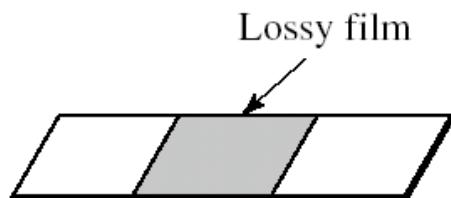
Adaptare - banda



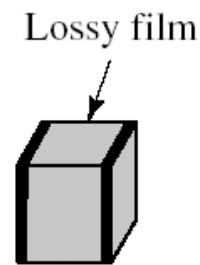
- Pentru pozitii initiale (determinate de sarcina) corespunzatoare unui factor de calitate ridicat (A) banda ingusta a adaptarii este inevitabila



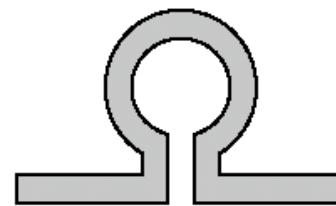
Realizare elemente concentrate



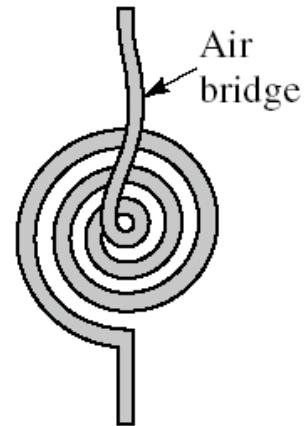
Planar resistor



Chip resistor



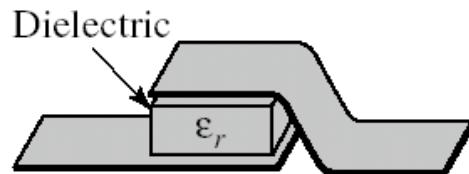
Loop inductor



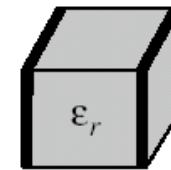
Spiral inductor



Interdigital
gap capacitor



Metal-insulator-
metal capacitor



Chip capacitor

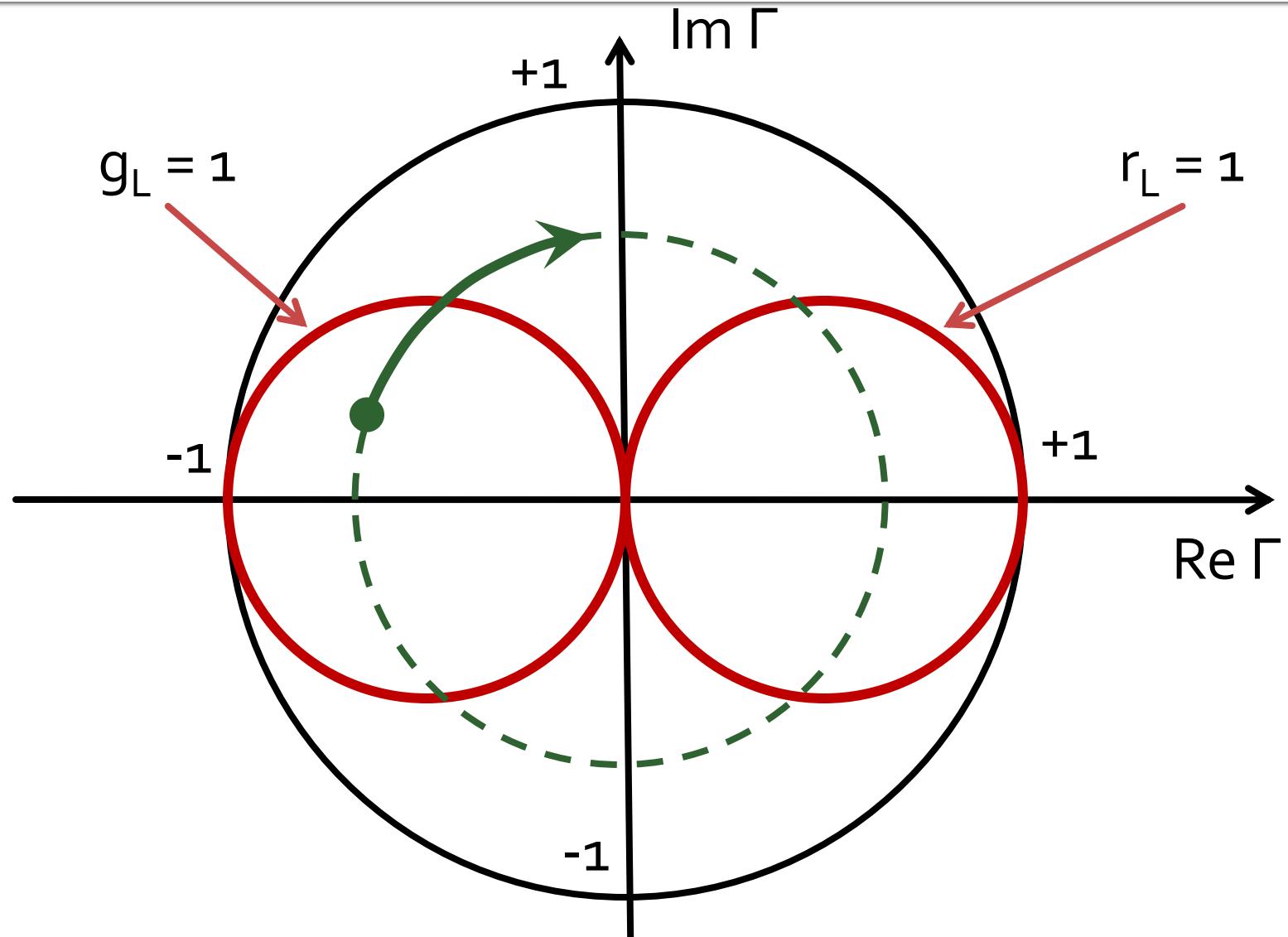
Adaptarea cu sectiuni de linii (stub)

Adaptarea de impedanță

Stub

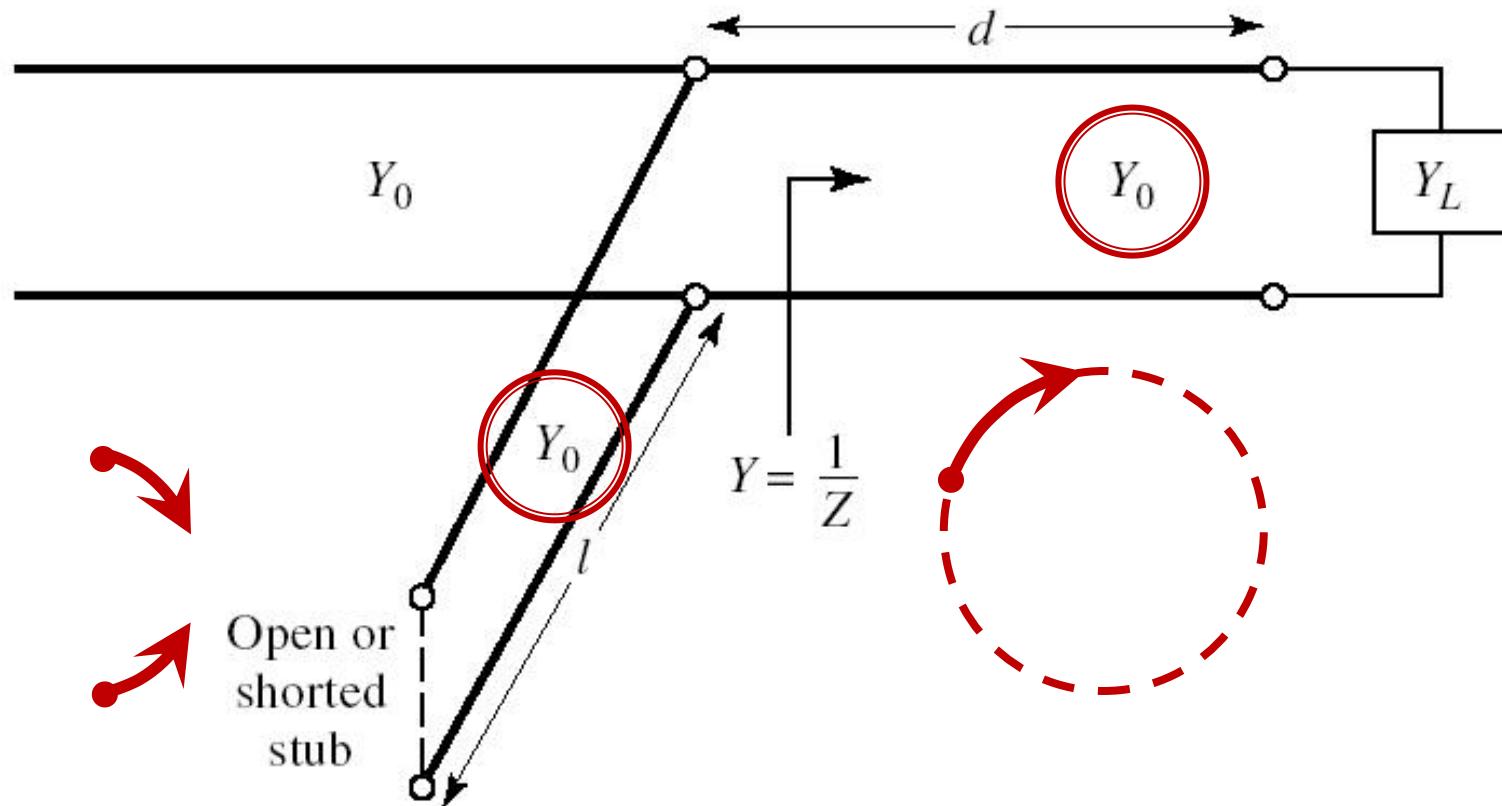
- stub=rest, ciot, cotor, capăt
- Se evita utilizarea elementelor concentrate
- Se realizeaza (foarte precis) utilizând liniile de transmisie uzuale ale circuitului
- Se utilizeaza secțiuni de linie (stub-uri) in serie sau paralel care pot fi:
 - in gol
 - scurtcircuitate
- De obicei liniile in gol sunt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

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



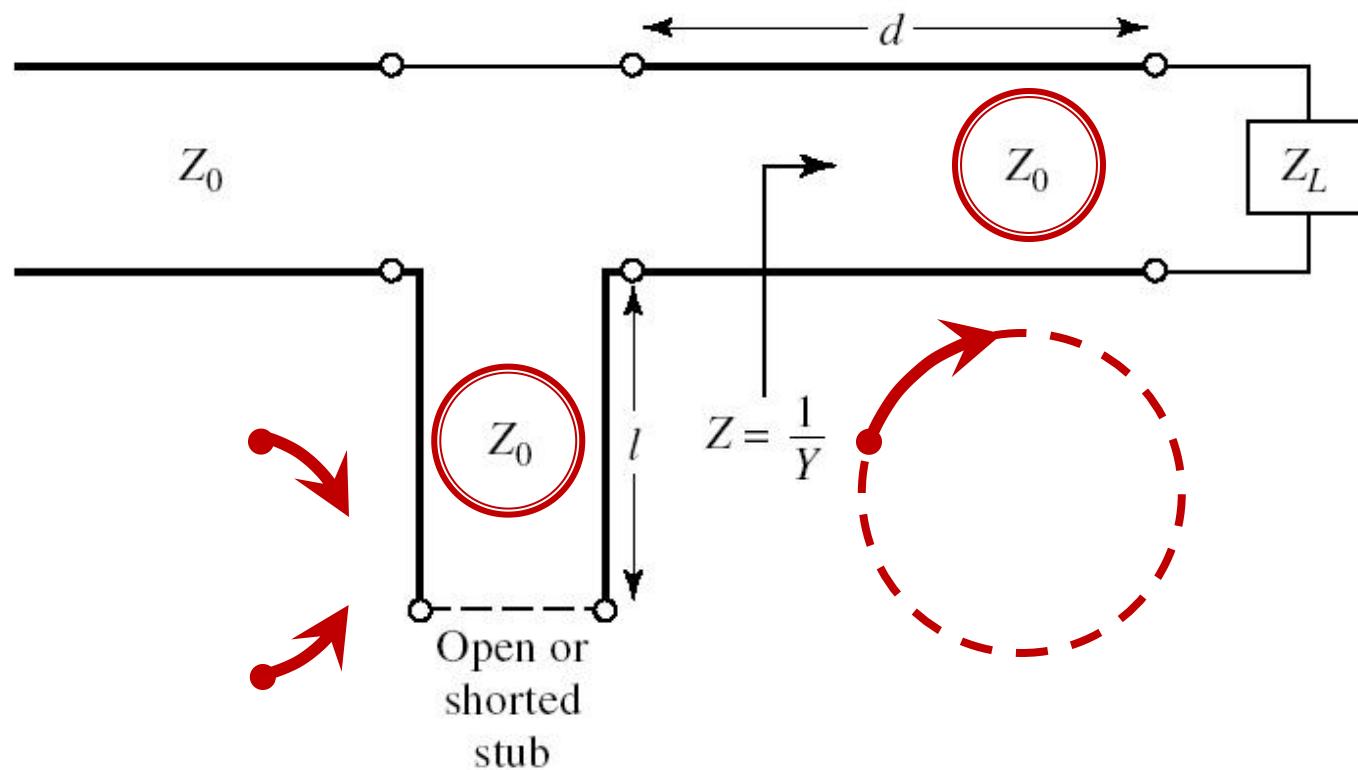
Single stub tuning

- Shunt Stub (secțiune de linie în paralel)

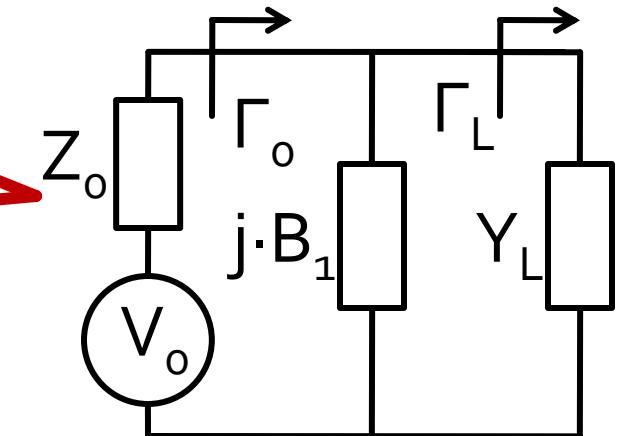
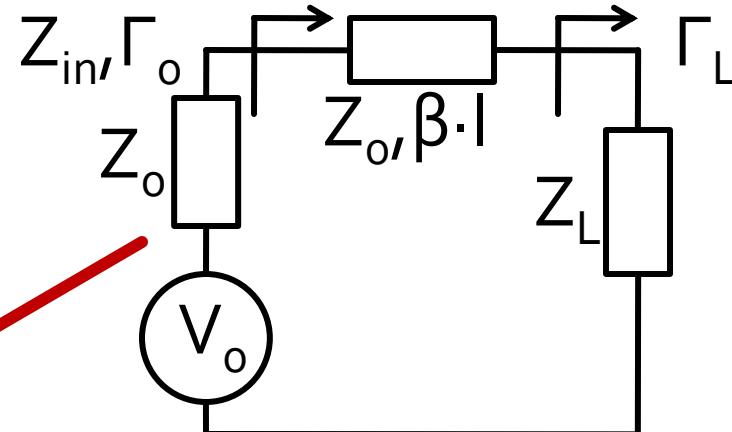
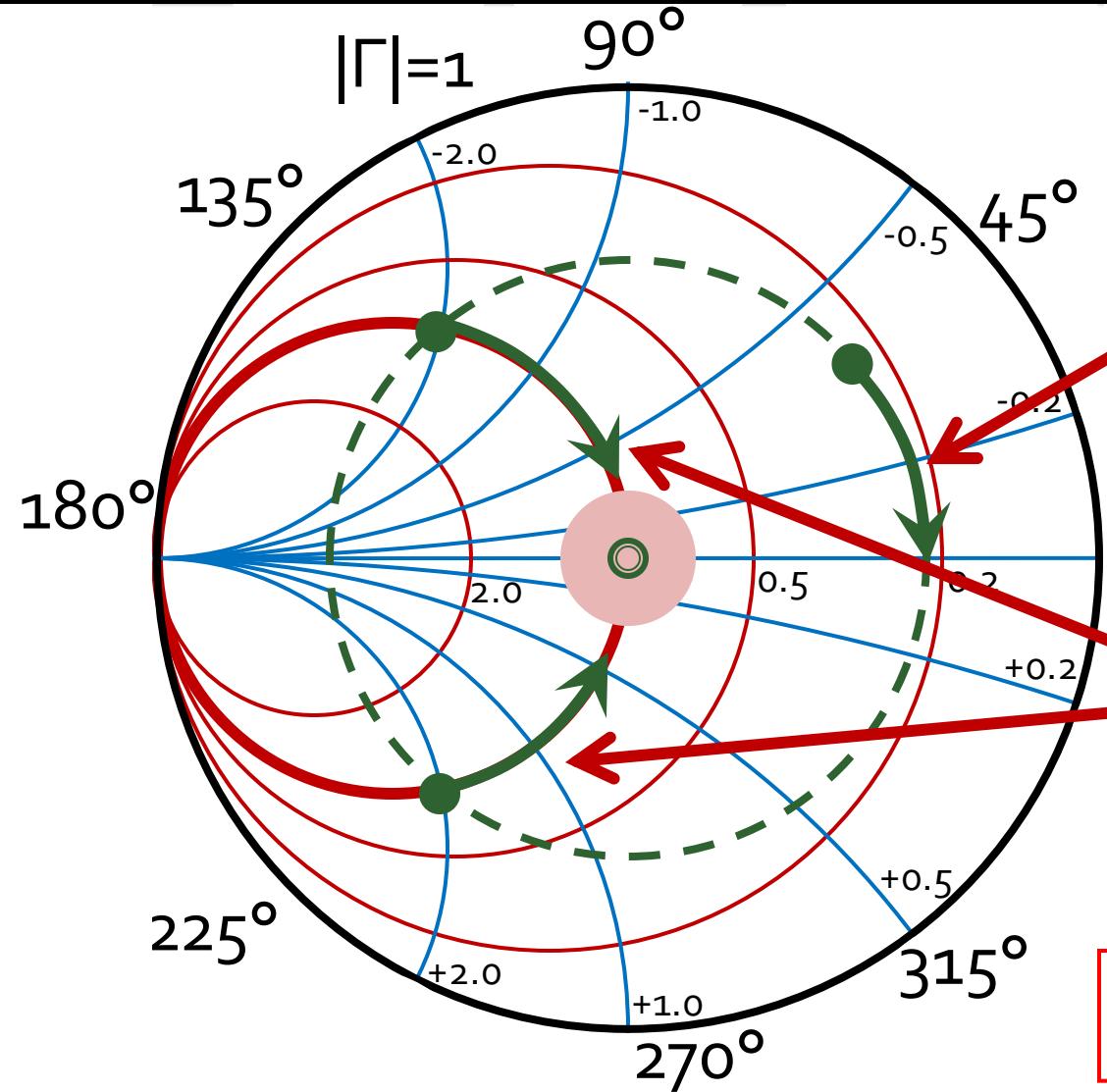


Single stub tuning

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



Adaptare, linie serie + susceptanta in paralel

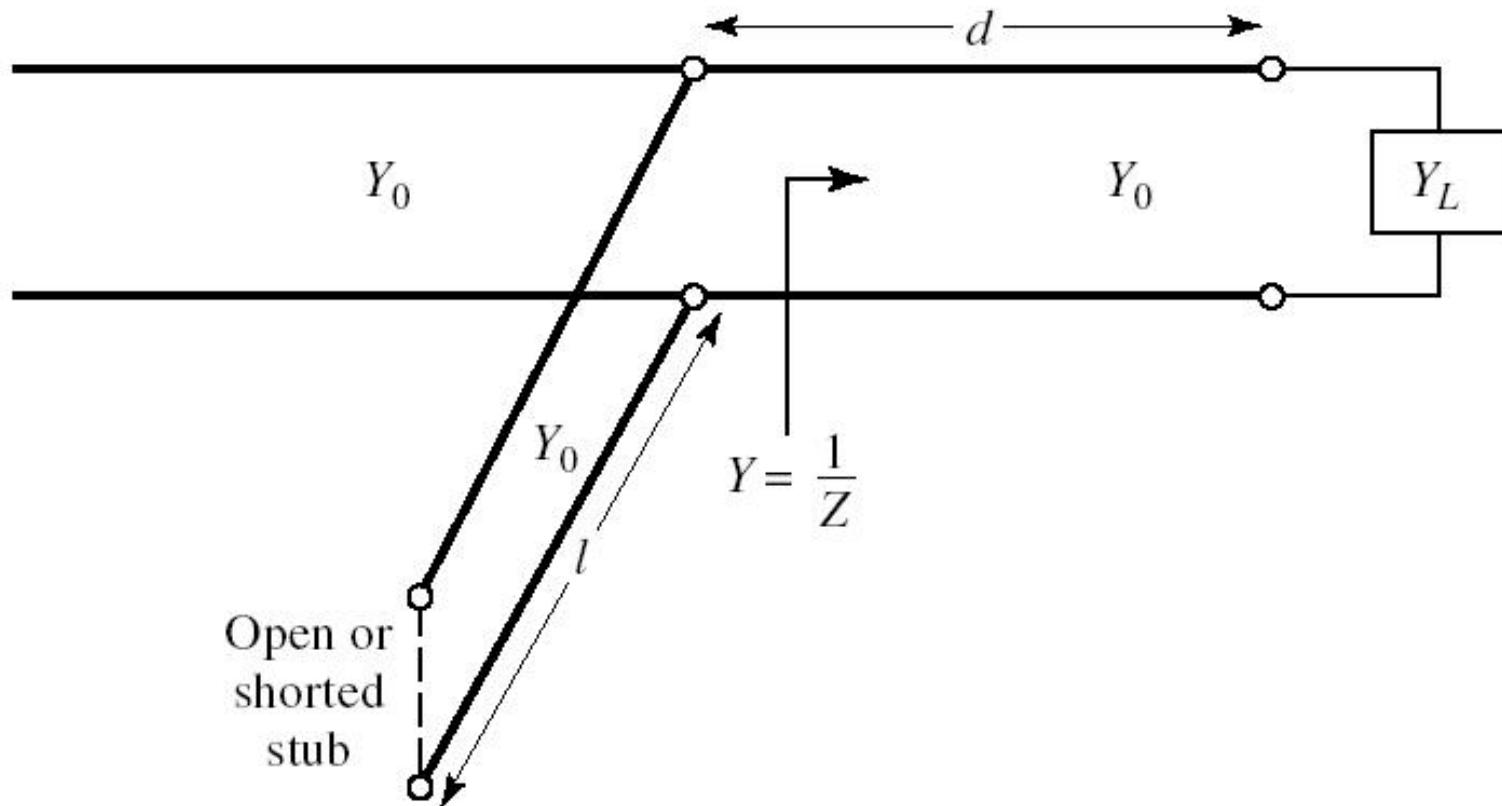


$$|\Gamma_{in}| = |\Gamma_L|$$

$$g_{in} = 1$$

Caz 1, Shunt Stub

- Shunt Stub (secțiune de linie în paralel)



Caz 1, Shunt Stub

- Se utilizeaza o linie de transmisie serie pentru a muta coeficientul de reflexie pe cercul $g_L = 1$
- Se introduce o reactanta in paralel pentru a realiza adaptarea
- Aceasta reactanta se realizeaza cu o linie de transmisie care poate fi dupa nevoie:
 - in gol
 - in scurtcircuit

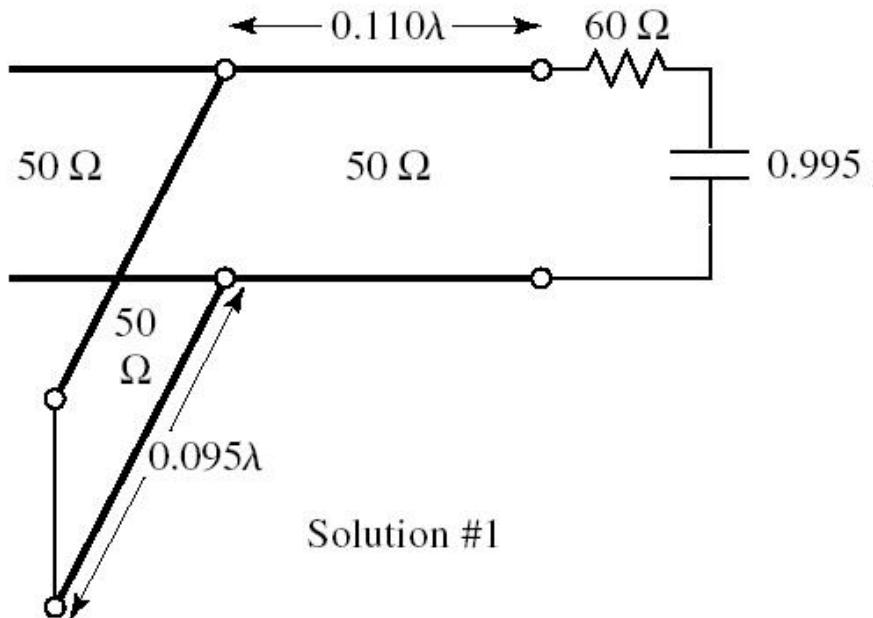
$$Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan \beta \cdot l}{Z_0 + j \cdot Z_L \cdot \tan \beta \cdot l}$$

$$Z_{in,sc} = j \cdot Z_0 \cdot \tan \beta \cdot l$$

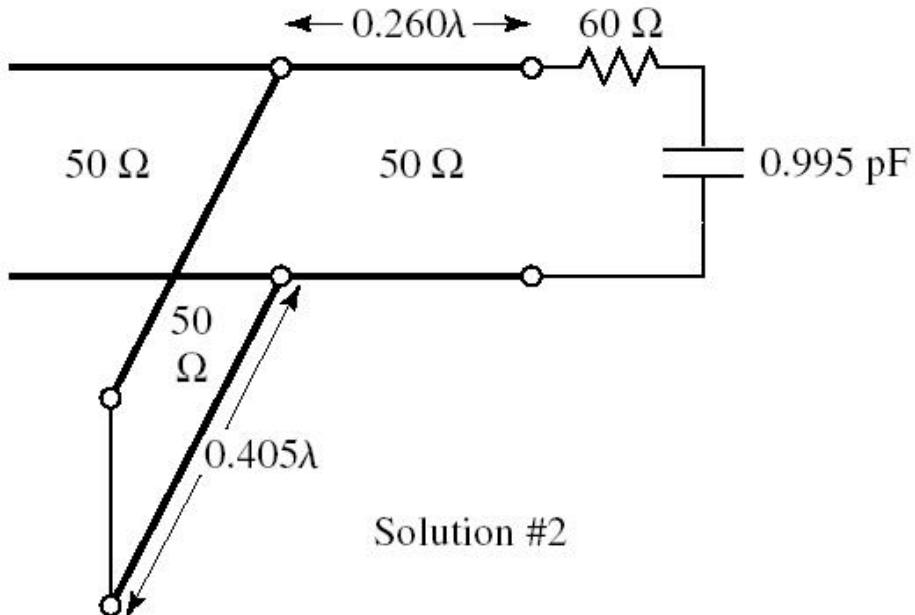
$$Z_{in,g} = -j \cdot Z_0 \cdot \cot \beta \cdot l$$

Exemplu, Shunt Stub, sc

- sarcina: 60Ω serie 0.995 pF la 2GHz
- doua solutii posibile

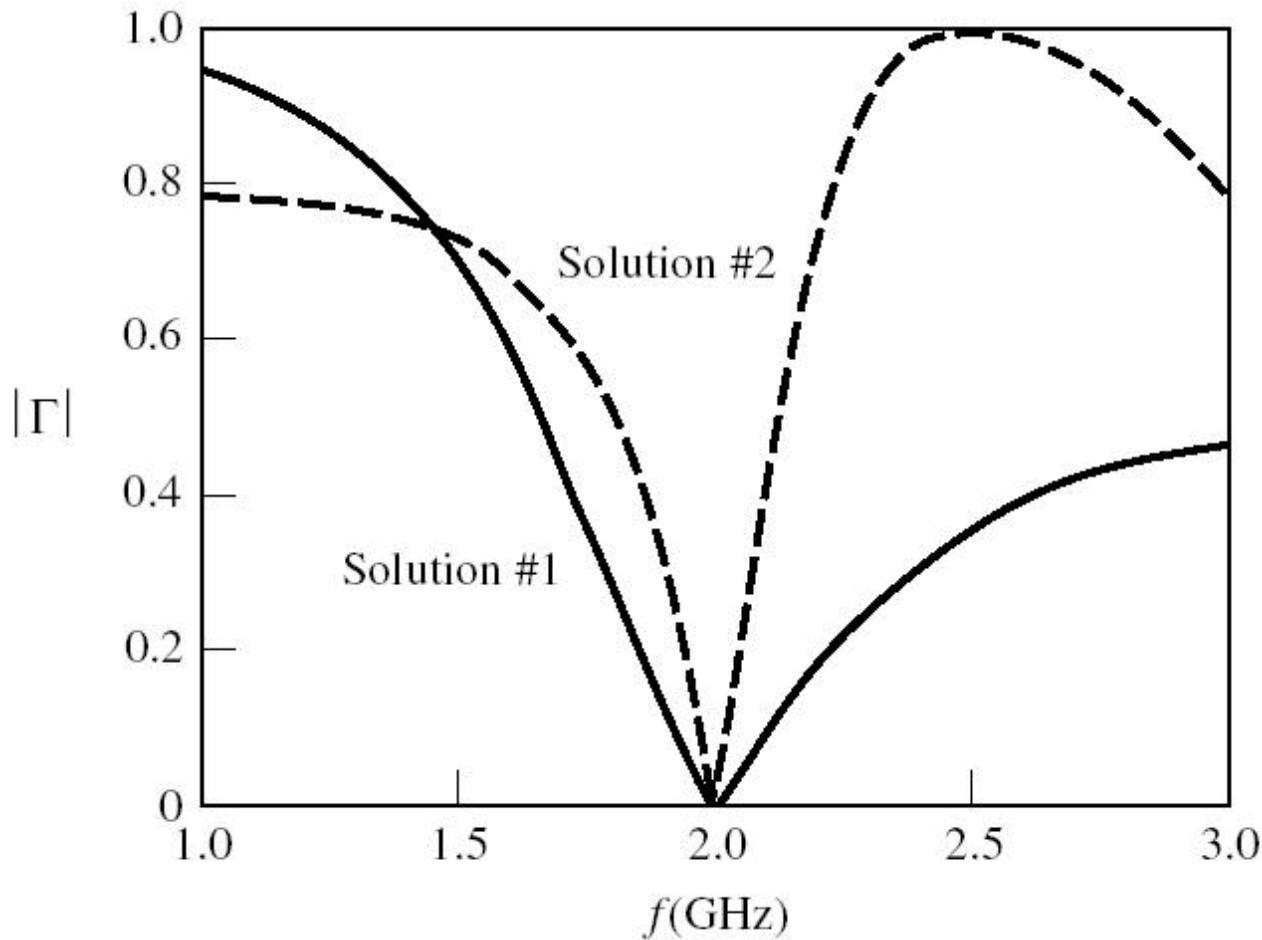


Solution #1

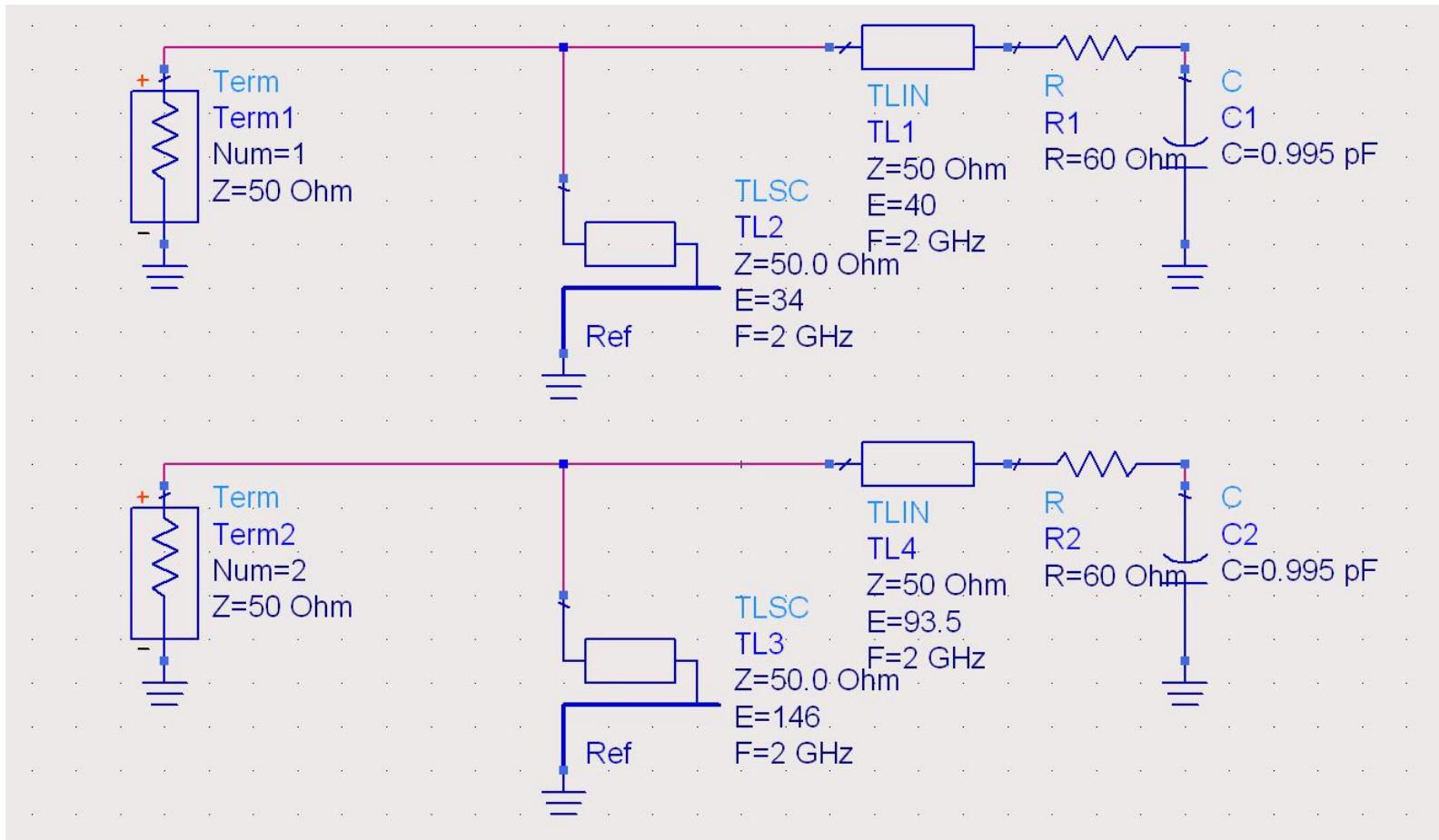


Solution #2

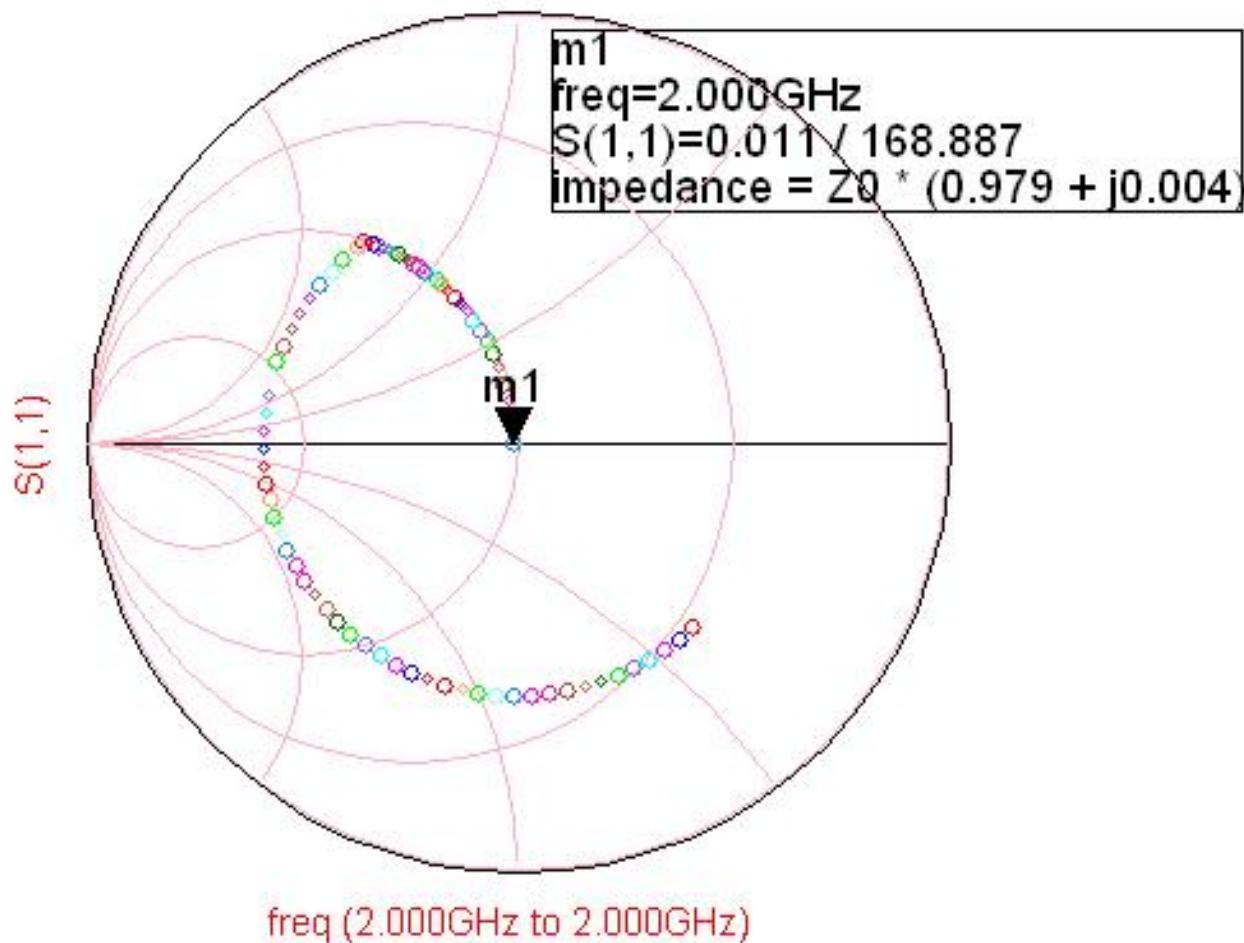
Exemplu, Shunt Stub, sc



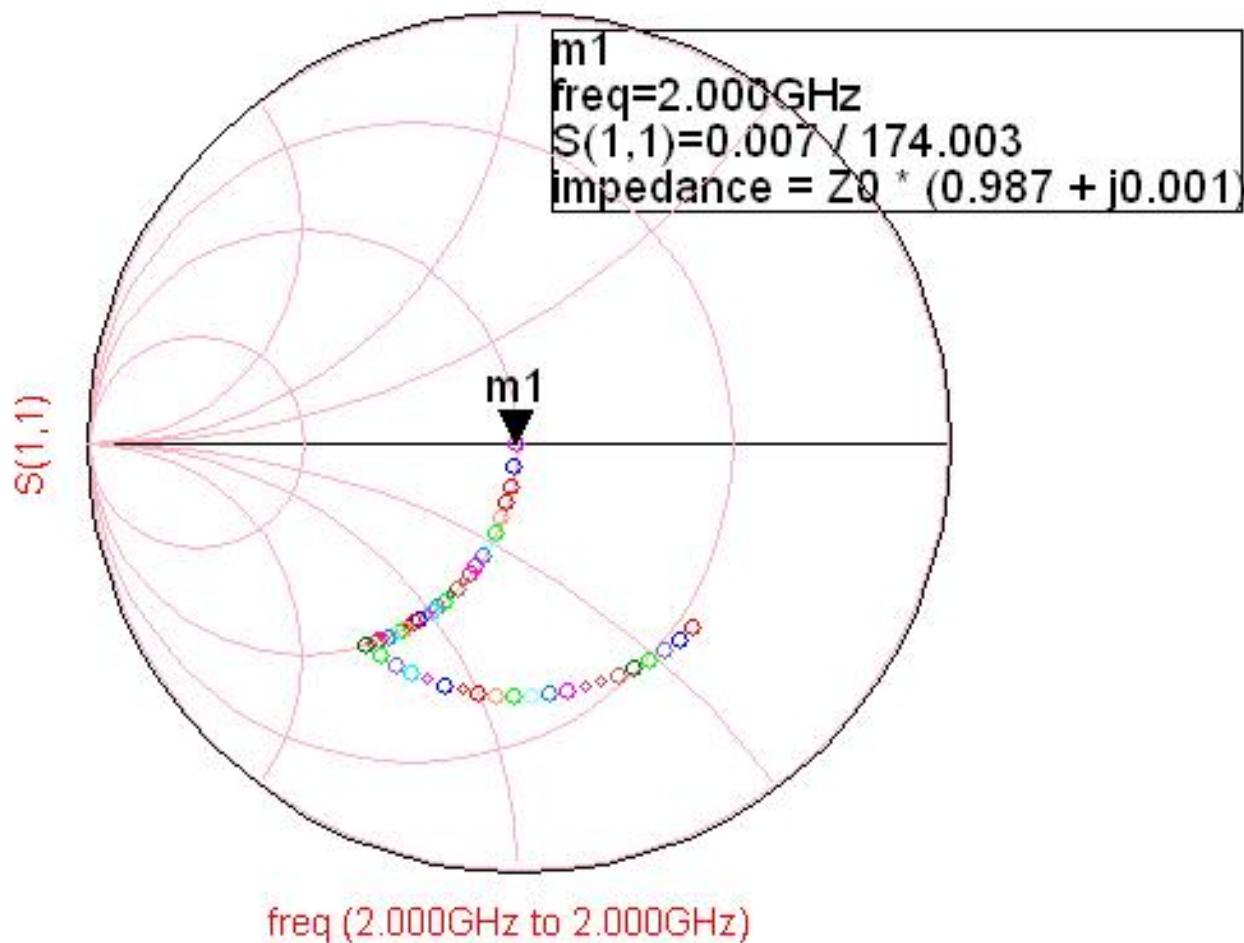
Exemplu, Shunt Stub, sc



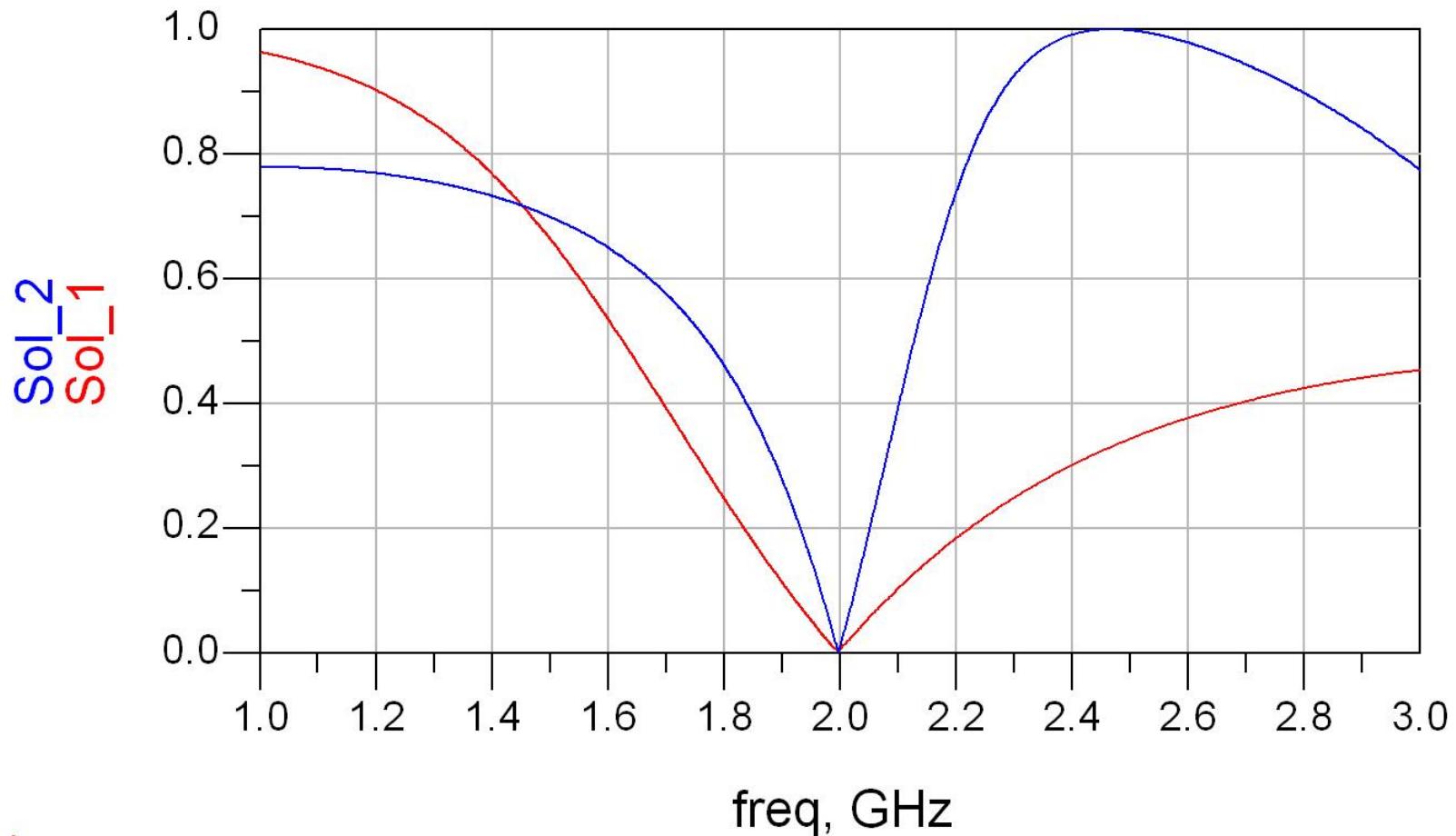
Exemplu, Shunt Stub, sc



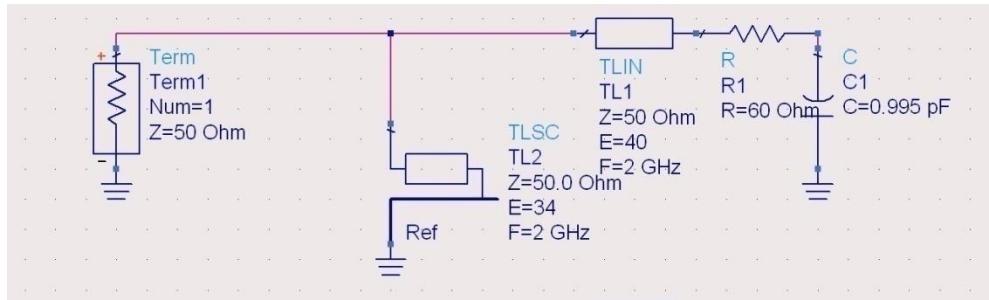
Exemplu, Shunt Stub, sc



Exemplu, Shunt Stub, sc



Exemplu, Shunt Stub, sc

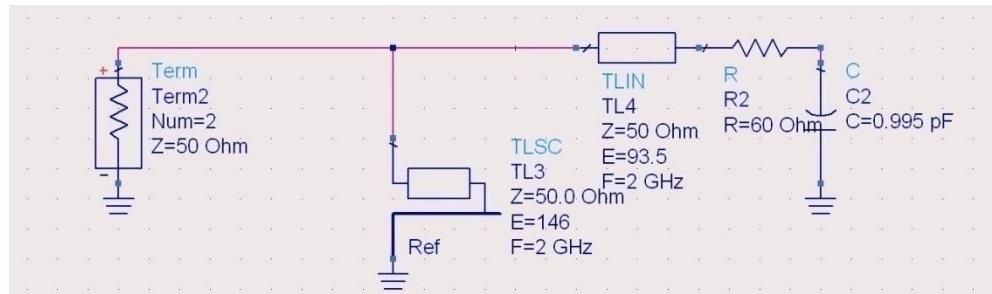


$$l_1 = \frac{40^\circ}{360^\circ} \cdot \lambda = 0.111 \cdot \lambda$$

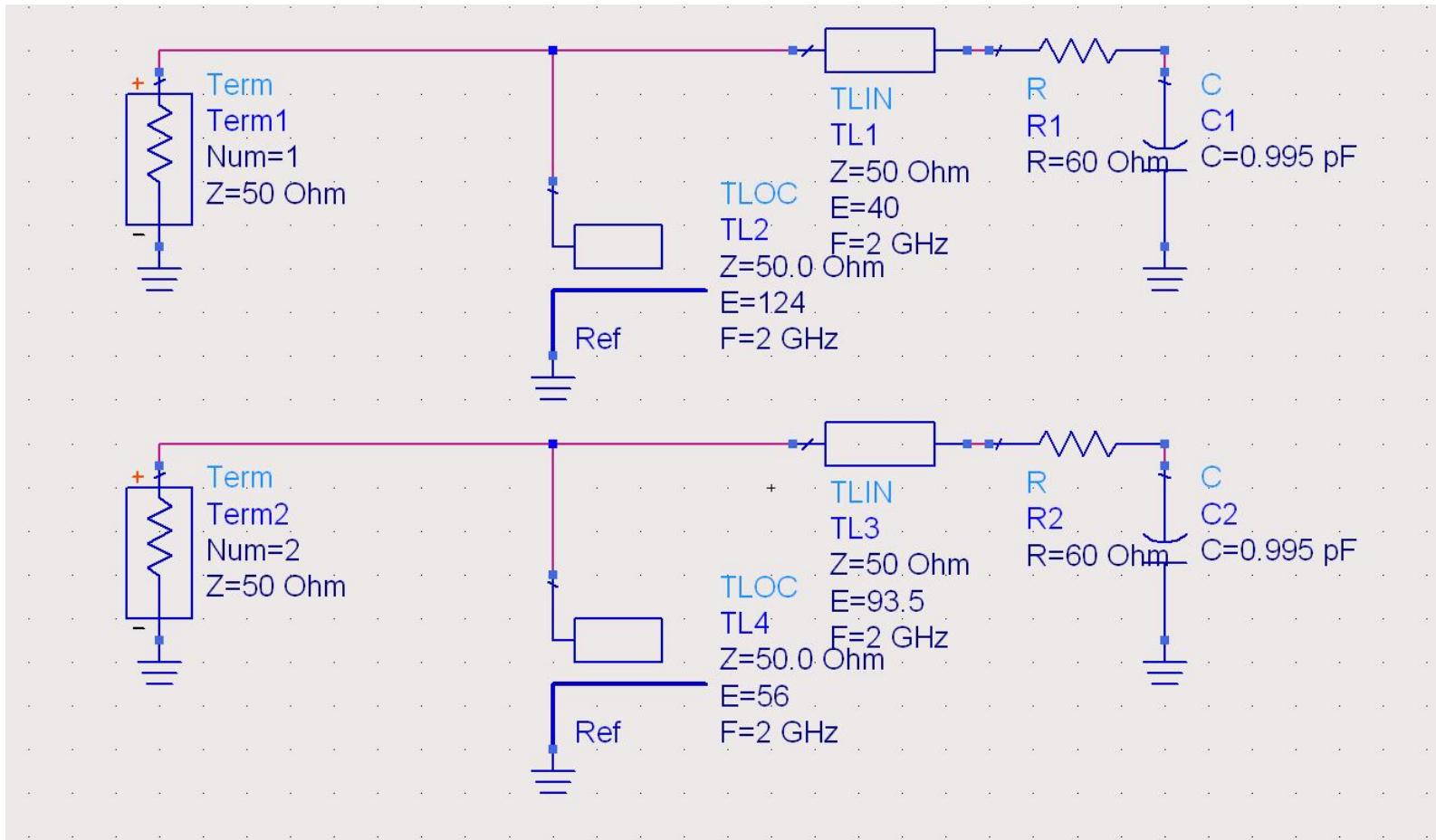
$$l_2 = \frac{34^\circ}{360^\circ} \cdot \lambda = 0.094 \cdot \lambda$$

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

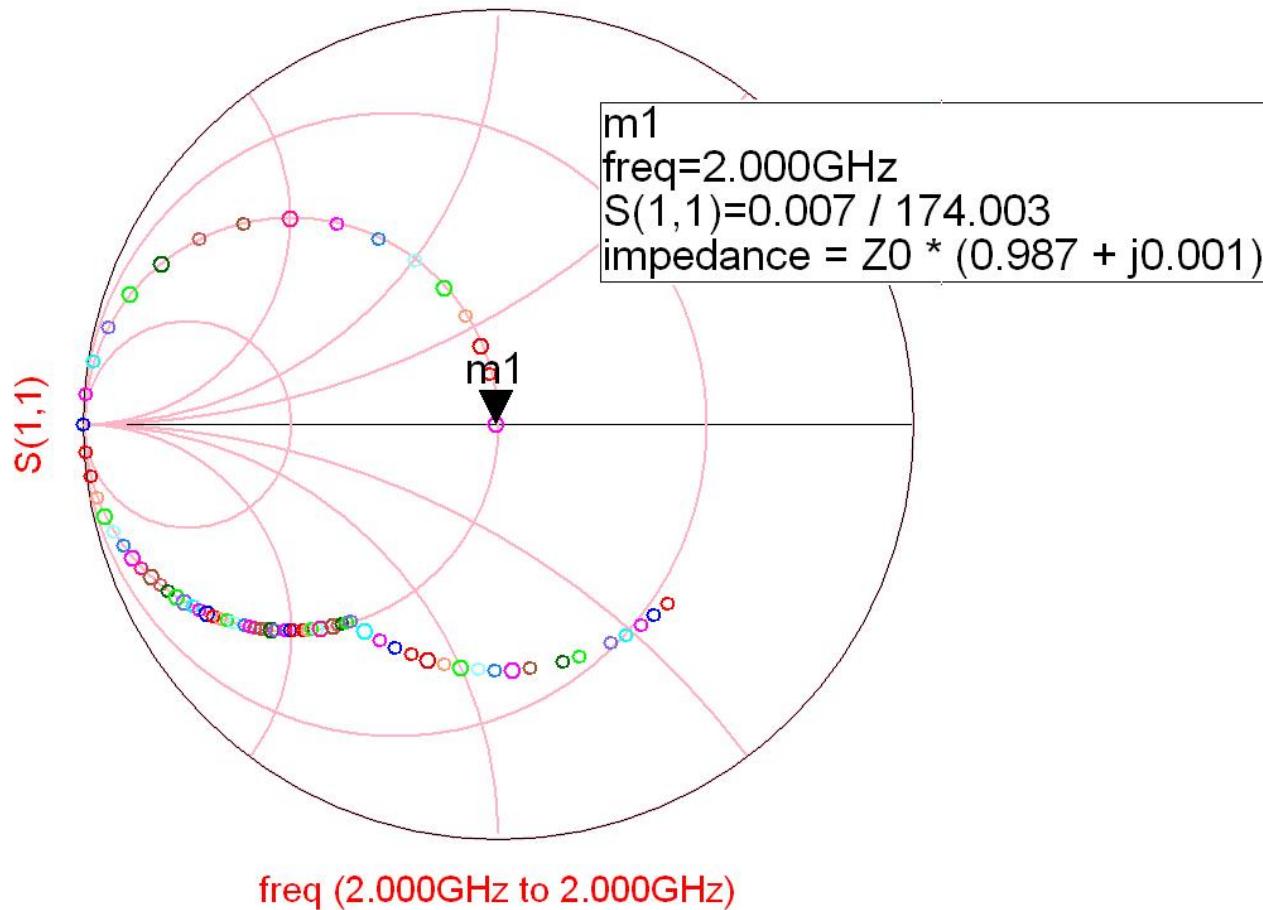
$$l_2 = \frac{146^\circ}{360^\circ} \cdot \lambda = 0.406 \cdot \lambda$$



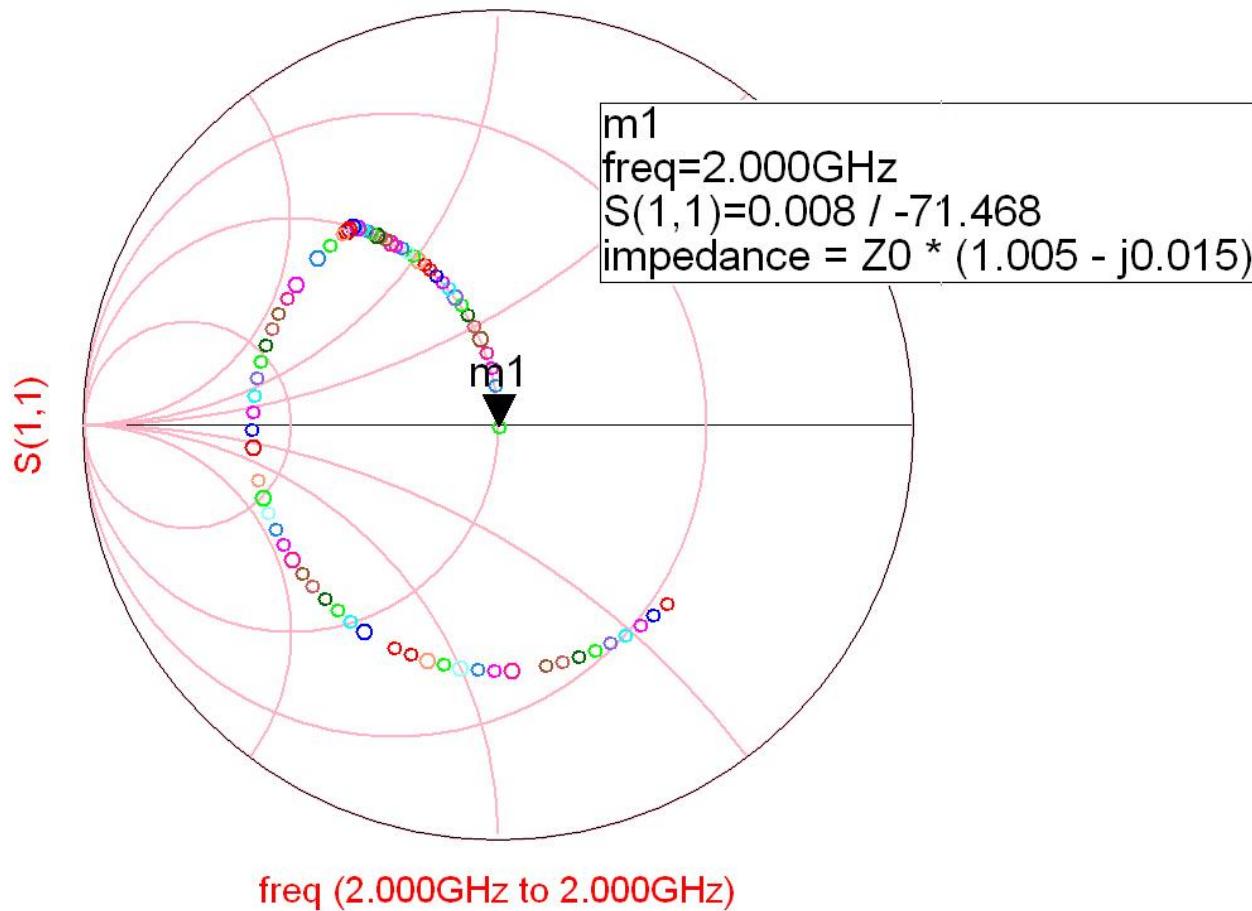
Exemplu, Shunt Stub, gol



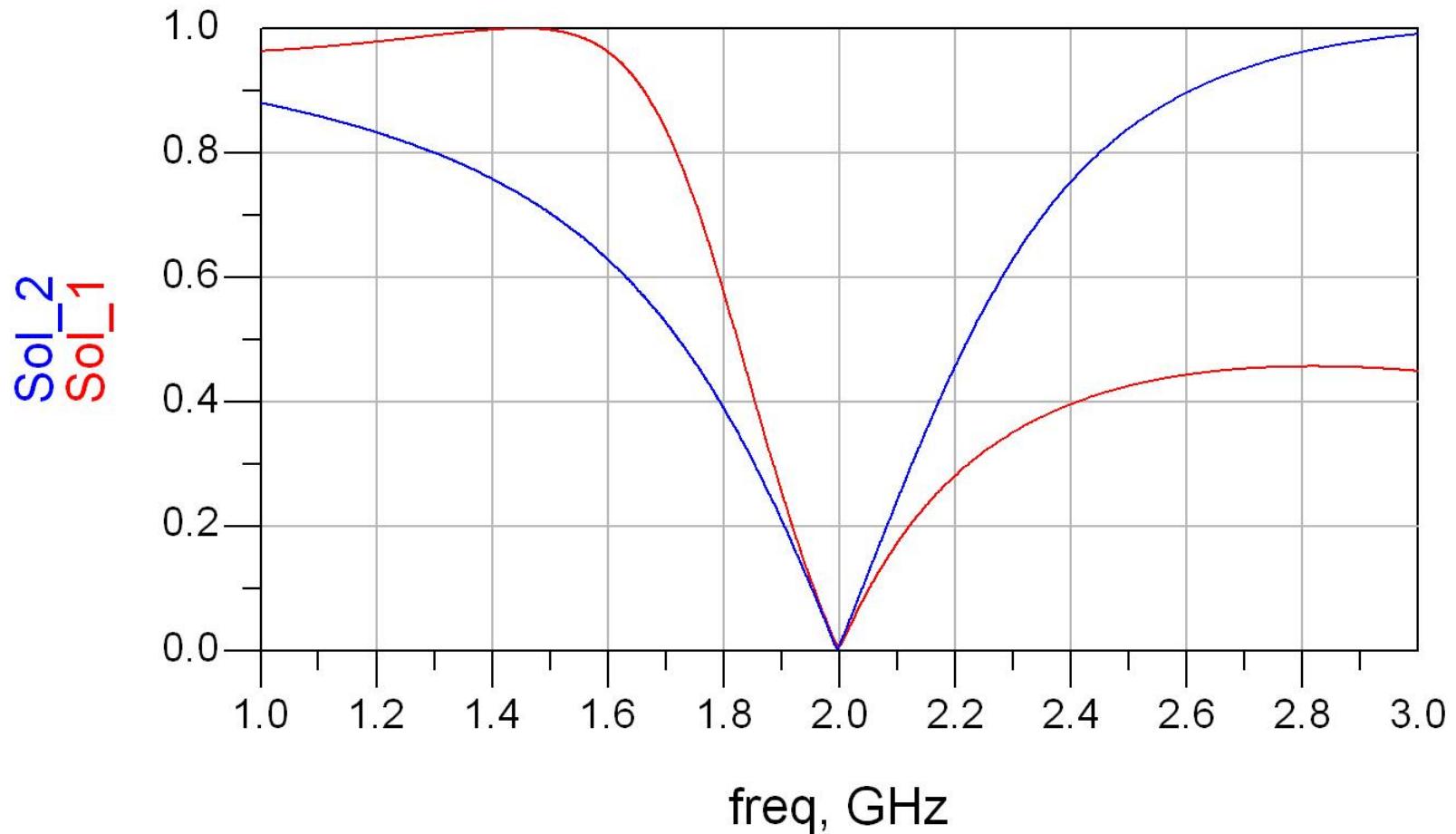
Exemplu, Shunt Stub, gol



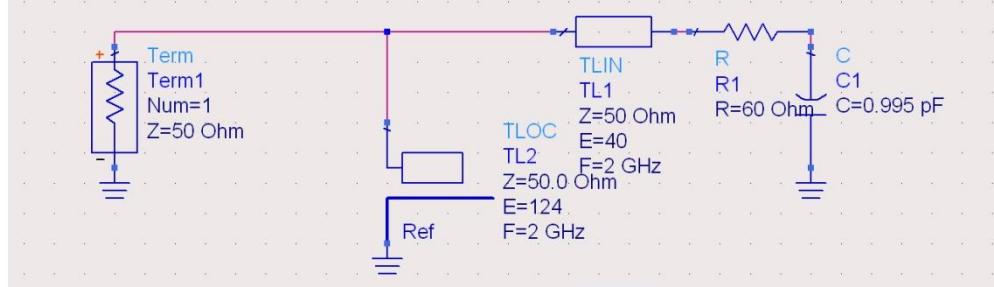
Exemplu, Shunt Stub, gol



Exemplu, Shunt Stub, gol



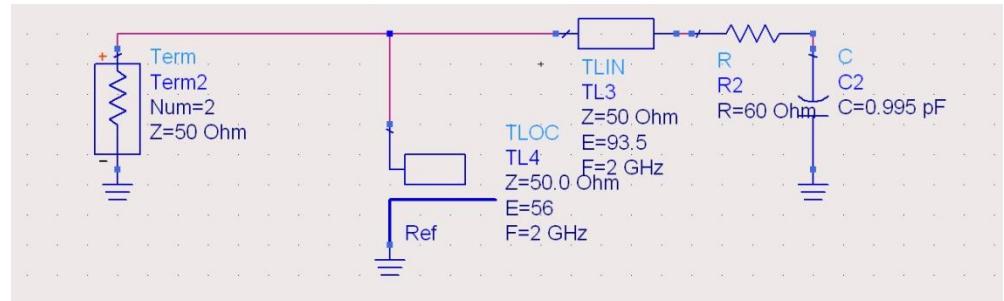
Exemplu, Shunt Stub, gol



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

$$l_2 = \frac{124^\circ}{360^\circ} \cdot \lambda = 0.344 \cdot \lambda = 0.094 \cdot \lambda + \frac{\lambda}{4}$$

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



$$l_2 = \frac{56^\circ}{360^\circ} \cdot \lambda = 0.156 \cdot \lambda = 0.406 \cdot \lambda - \frac{\lambda}{4}$$



Stub, observatii

- functiile care ofera impedanta de intrare intr-un stub sunt periodice in functie de lungime (l), functii tip tg/ctg

$$Z_{in,sc} = j \cdot Z_0 \cdot \tan \beta \cdot l$$

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

- adunarea si scadere de:

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

nu schimba rezultatul (rotatie completa in jurul diagramei – de aici provine gradatia 0.5 lungimi de unda a circumferintei diagramei)

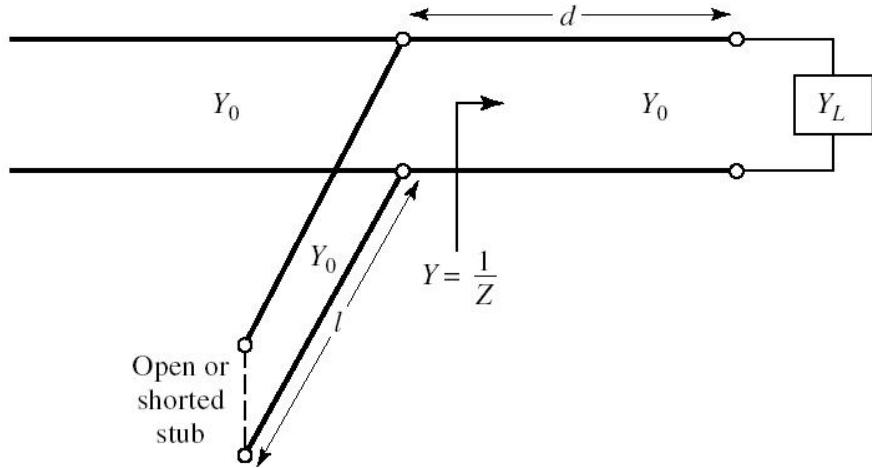
Stub, observatii

- pentru reglaj in vederea adaptarii este preferabila pornirea din punctul neutru (valoarea lungimii liniei care nu influenteaza circuitul)
 - linia in serie: $E = \beta \cdot l = 0$
 - stub: $Z_{in} \rightarrow \infty$, $\tan \beta \cdot l / \cot \beta \cdot l \rightarrow \infty$, $E = 90^\circ / 0^\circ$
- o adaugare sau scadere de sfert de lungime de unda transforma impedanta:

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

$$\tan \beta \cdot \left(l + \frac{\lambda}{4} \right) = \tan \left(\beta \cdot l + \frac{\pi}{2} \right) = \frac{\sin(\beta \cdot l + \pi/2)}{\cos(\beta \cdot l + \pi/2)} = \frac{\cos \beta \cdot l}{-\sin \beta \cdot l} = -\cot \beta \cdot l$$

Solutie analitica, impedante



$$Z_L = \frac{1}{Y_L} = R_L + j \cdot X_L$$

$$Z = Z_0 \cdot \frac{(R_L + j \cdot X_L) + j \cdot Z_0 \cdot t}{Z_0 + j \cdot (R_L + j \cdot X_L) \cdot t}$$

$$t = \tan \beta \cdot d \quad Y = G + j \cdot B = \frac{1}{Z}$$

$$G = \frac{R_L \cdot (1 + t^2)}{R_L^2 + (X_L + Z_0 \cdot t)^2}$$

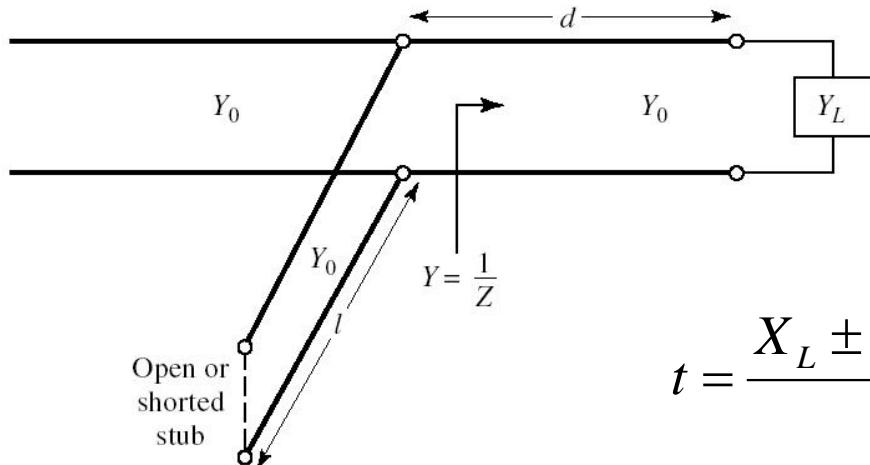
$$B = \frac{R_L^2 \cdot t - (Z_0 - X_L \cdot t) \cdot (X_L + Z_0 \cdot t)}{Z_0 \cdot [R_L^2 + (X_L + Z_0 \cdot t)^2]}$$

$$G = Y_0 = \frac{1}{Z_0}$$

$$Z_0 \cdot (R_L - Z_0) \cdot t^2 - 2 \cdot X_L \cdot Z_0 \cdot t + (R_L \cdot Z_0 - R_L^2 - X_L^2) = 0$$

- d este ales astfel incat

Solutie analitica



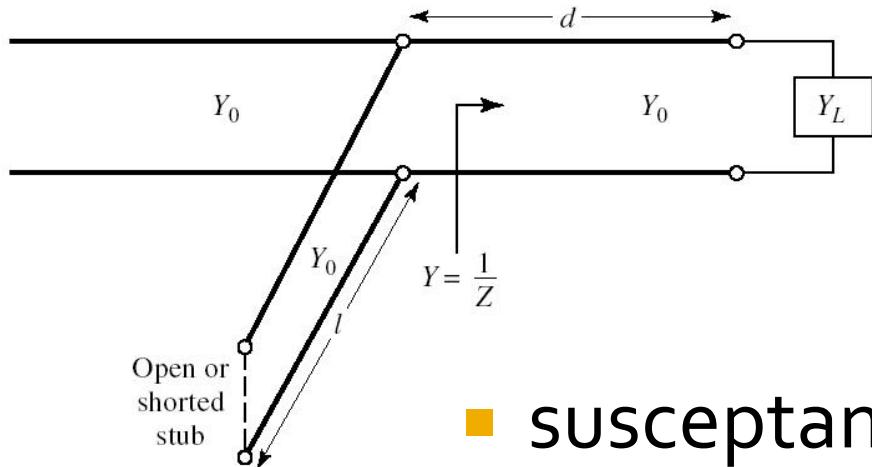
$$t = -\frac{X_L}{2 \cdot Z_0}, \quad R_L = Z_0$$

$$t = \frac{X_L \pm \sqrt{R_L \cdot [(Z_0 - R_L)^2 + X_L^2] / Z_0}}{R_L - Z_0} \quad R_L \neq Z_0$$

- ecuatie de gradul 2, 2 solutii posibile
- d este ales astfel incat

$$\frac{d}{\lambda} = \begin{cases} \frac{1}{2\pi} \cdot \arctan t & t \geq 0 \\ \frac{1}{2\pi} \cdot (\pi + \arctan t) & t < 0 \end{cases}$$

Solutie analitica



$$B_S = -B$$

$$B = \frac{R_L^2 \cdot t - (Z_0 - X_L \cdot t) \cdot (X_L + Z_0 \cdot t)}{Z_0 \cdot [R_L^2 + (X_L + Z_0 \cdot t)^2]}$$

■ susceptanta de anulare se obtine

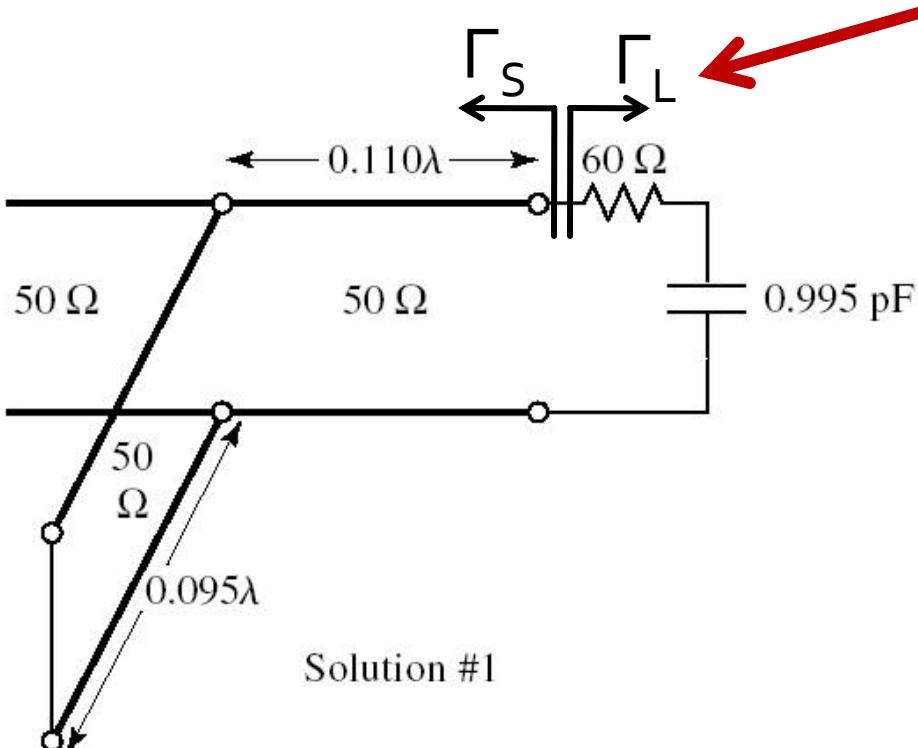
$$\frac{l_{gol}}{\lambda} = \frac{1}{2\pi} \cdot \arctan \left(\frac{B_S}{Y_0} \right) = \frac{-1}{2\pi} \cdot \arctan \left(\frac{B}{Y_0} \right)$$

$$\frac{l_{sc}}{\lambda} = \frac{-1}{2\pi} \cdot \arctan \left(\frac{Y_0}{B_S} \right) = \frac{1}{2\pi} \cdot \arctan \left(\frac{Y_0}{B} \right)$$

■ pentru **lungimi negative** se adauga $\lambda/2$

Calcul analitic, coeficienti de reflexie

- sarcina: 60Ω serie 0.995 pF la 2GHz



$$Z_L = R_L + \frac{1}{j \cdot \omega \cdot C_L} = 60\Omega - j \cdot 79.977\Omega$$

$$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0} = 0.405 - j \cdot 0.432$$

$$Y_L = \frac{1}{Z_L} = 0.006S + j \cdot 0.008S$$

$$y_L = \frac{Y_L}{Y_0} = 0.3 + j \cdot 0.4$$

- adaptare necesita complex conjugat

$$\Gamma_s = \Gamma_L^* = 0.405 + j \cdot 0.432$$

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

$$|\Gamma_s| = 0.593; \quad \varphi = 46.85^\circ$$

Calcul analitic, coeficienti de reflexie

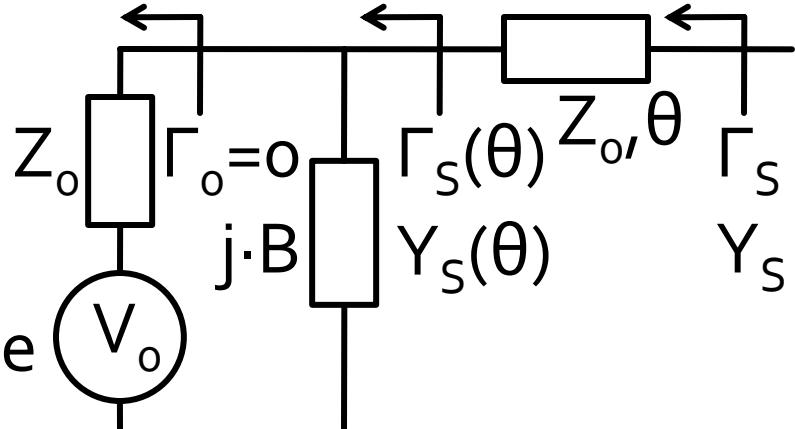
■ linie serie

- lungime electrica $E = \beta \cdot l = \theta$

- mută coeficientul de reflexie pe cercul $g=1$

■ stub paralel:

- lungime electrica $E = \beta \cdot l_{sp} = \theta_{sp}$
- mută coeficientul de reflexie în centrul diagramei Smith ($\Gamma_o=0$)



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

$$y_s = \frac{1 - \Gamma_s}{1 + \Gamma_s} = 0.3 - j \cdot 0.4$$

$$\Gamma_s(\theta) = [\Gamma_L(\theta)]^* = [\Gamma_L \cdot e^{-2j\theta}]^*$$

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

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

Calcul analitic, linie serie (dem.)

- Dupa sectiunea de linie cu lungimea electrica θ

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

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

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

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

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

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

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

Calcul analitic, linie serie (calcul)

- Ecuatia pentru calcularea θ (linie serie)

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

$$\Gamma_s = |\Gamma_s| \cdot e^{j\varphi} \quad \Gamma_s = 0.593 \angle 46.85^\circ \quad |\Gamma_s| = 0.593; \quad \varphi = 46.85^\circ$$

- doua solutii posibile, normate la intervalul $0^\circ \div 180^\circ$
 - se adauga $\lambda/2$ (180°) dupa nevoie

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

$$\cos(\varphi + 2\theta) = -0.593 \Rightarrow (\varphi + 2\theta) = \pm 126.35^\circ$$

$$(46.85^\circ + 2\theta) = \begin{cases} +126.35^\circ \\ -126.35^\circ \end{cases}$$

$$\theta = \begin{cases} +39.7^\circ \\ -86.6^\circ + 180^\circ = +93.4^\circ \end{cases}$$

Calcul analitic, stub paralel (dem.)

- Ecuatia pentru calcularea stub-ului paralel θ_{sp}

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

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

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

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

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

Calcul analitic, stub paralel (dem.)

- Ecuatia pentru calcularea stub-ului paralel

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

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

- doua situatii

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

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

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

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

- Semnul** (+/-) solutiei alese la **prima** ecuatie impune **semnul** solutiei utilizate la a **doua** ecuatie

Calcul analitic, stub paralel (dem.)

- Se prefera (pentru microstrip) stub in gol

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

- Susceptanta raportata introdusa pentru adaptare
 - $Y(\theta)$ este admitanta vazuta **inspre** sursa, Z_0 in paralel cu $j \cdot B$

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

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

Calcul analitic (calcul efectiv)

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

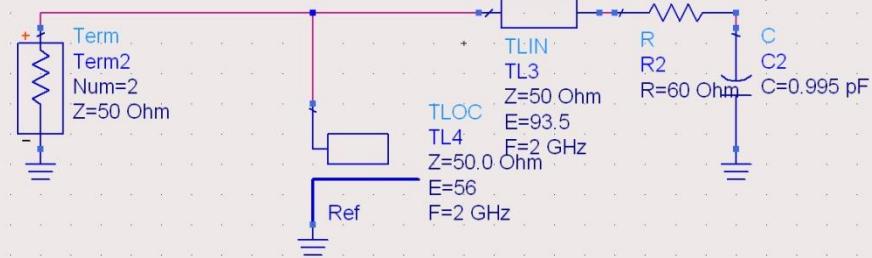
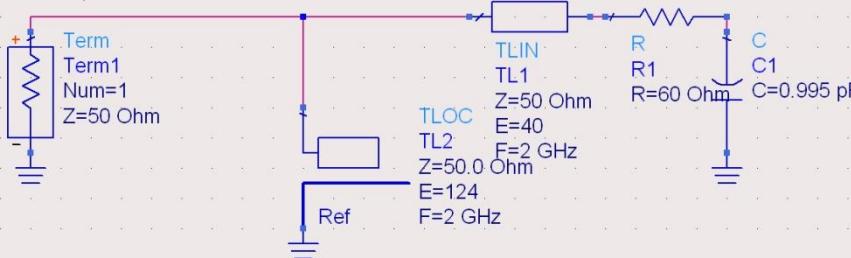
- Se alege **una** din cele doua solutii posibile
- **Semnul (+/-)** solutiei alese la **prima** ecuatie impune **semnul** solutiei utilizate la a **doua** ecuatie

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

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

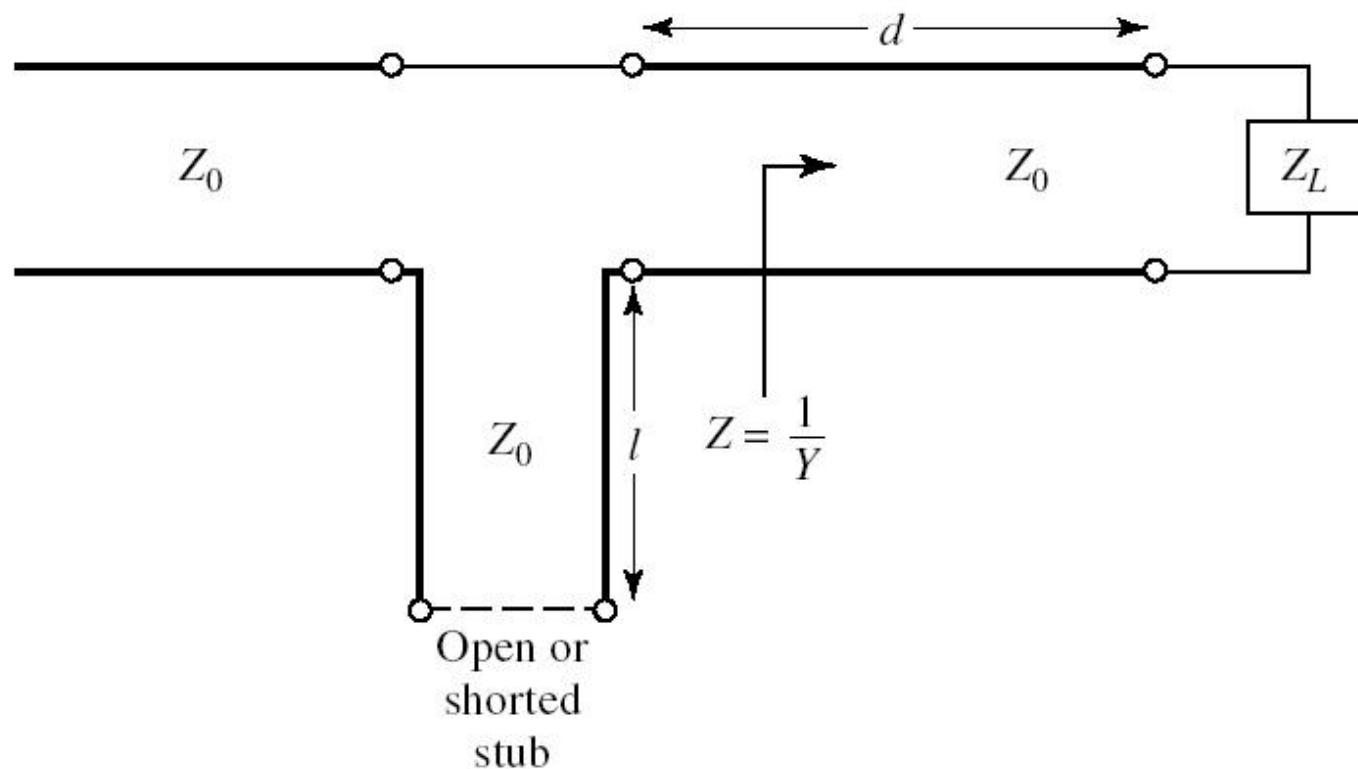
$$l_1 = \frac{93.4^\circ}{360^\circ} \cdot \lambda = 0.259 \cdot \lambda$$

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



Caz 2, Series Stub

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



Caz 2, Series Stub

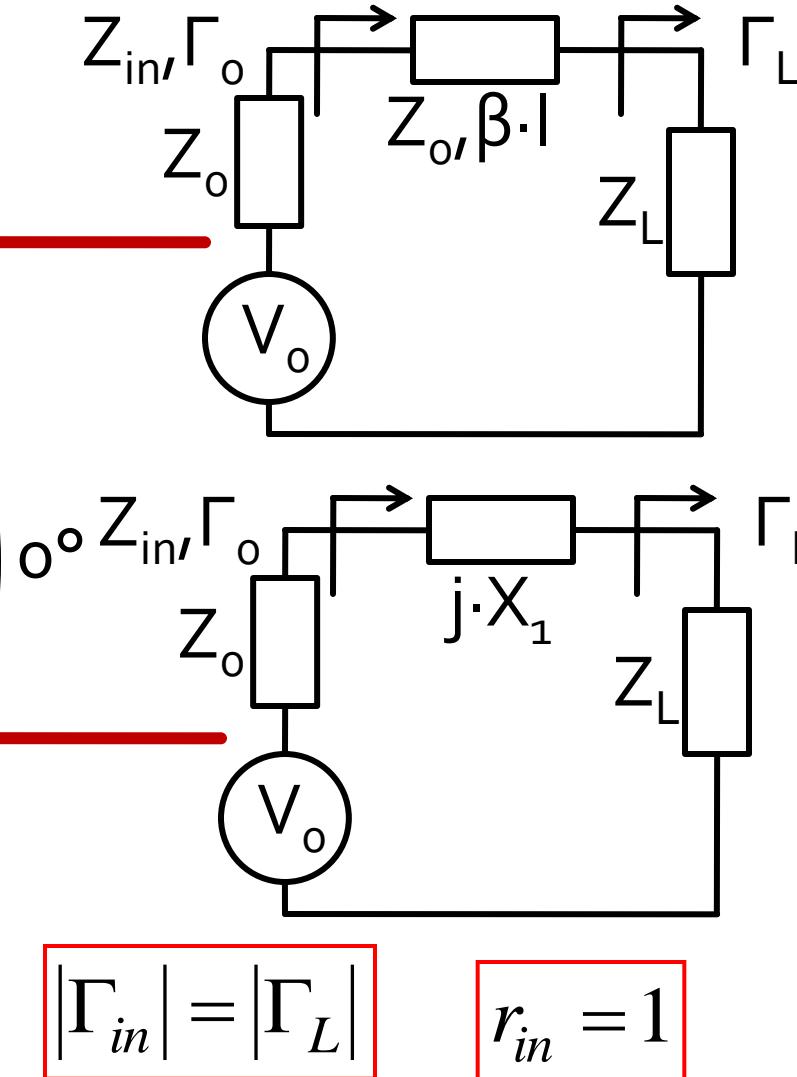
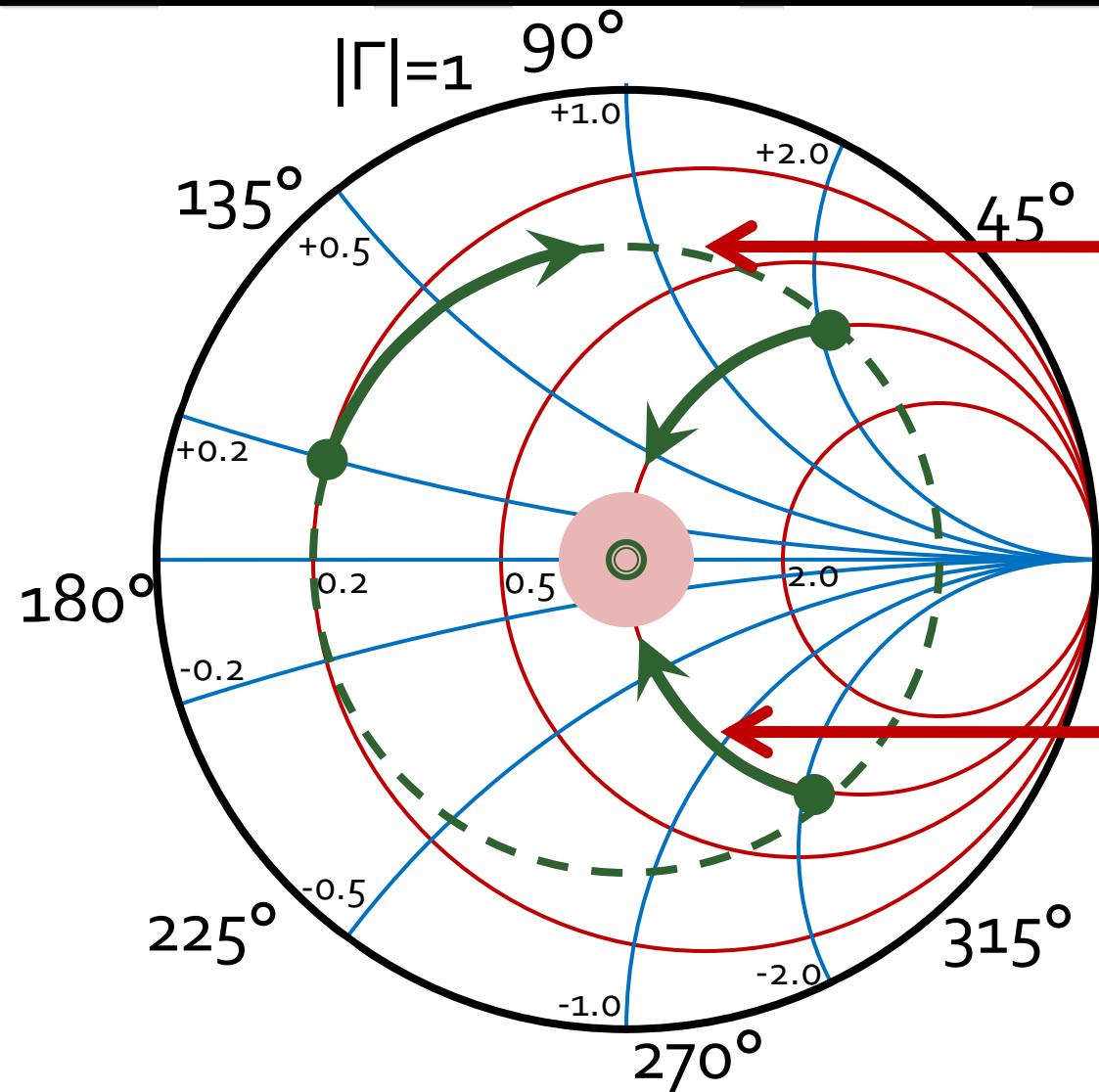
- Se utilizeaza o linie de transmisie serie pentru a muta coeficientul de reflexie pe cercul $r_L = 1$
- Se introduce o reactanta in serie pentru a realiza adaptarea
- Aceasta reactanta se realizeaza cu o linie de transmisie care poate fi dupa nevoie:
 - in gol
 - in scurtcircuit

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

$$Z_{in,sc} = j \cdot Z_0 \cdot \tan \beta \cdot l$$

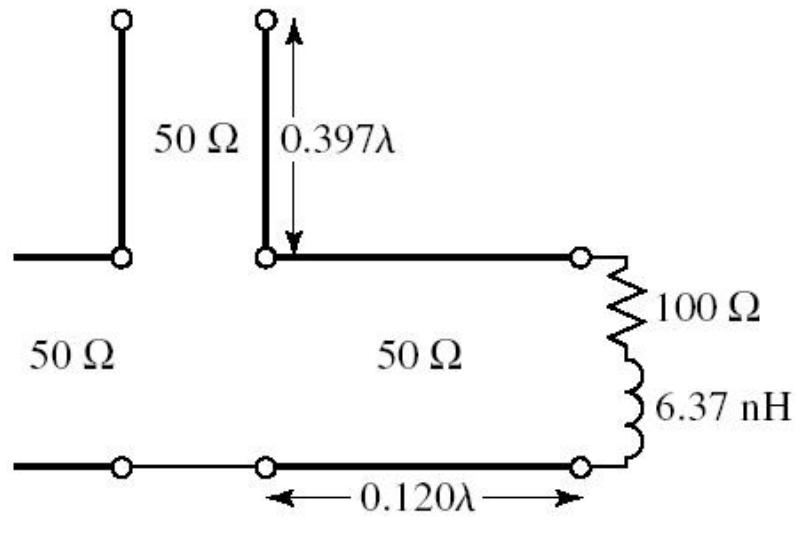
$$Z_{in,g} = -j \cdot Z_0 \cdot \cot \beta \cdot l$$

Adaptare, linie serie + reactanta in serie

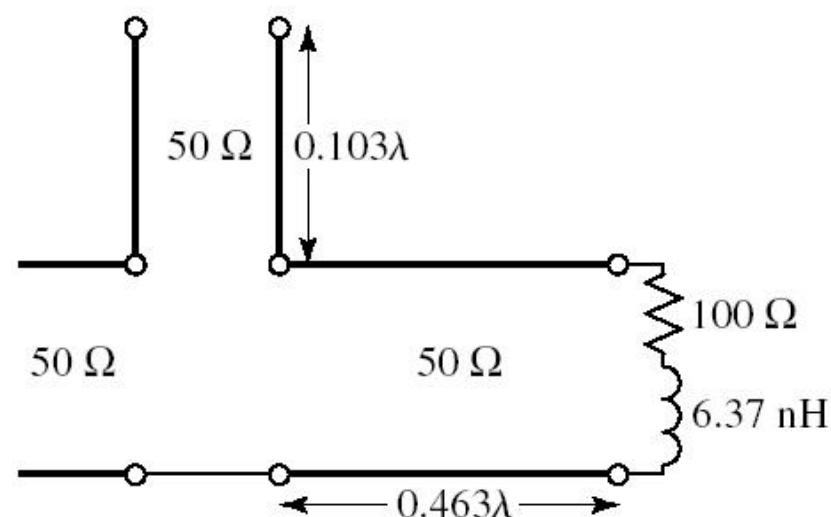


Exemplu, Series Stub, gol

- sarcina: 100Ω serie 6.37 nH la 2GHz
- doua solutii posibile

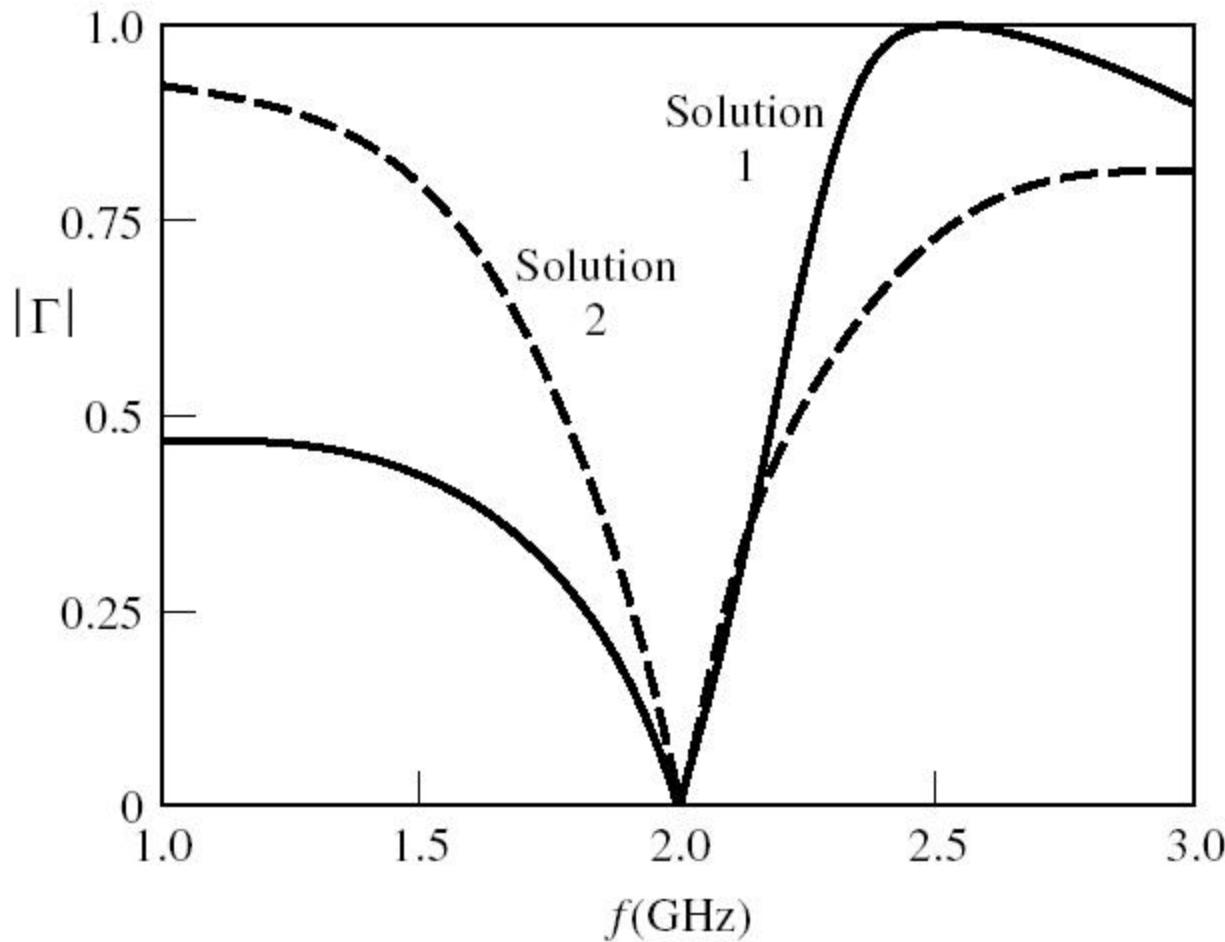


Solution 1

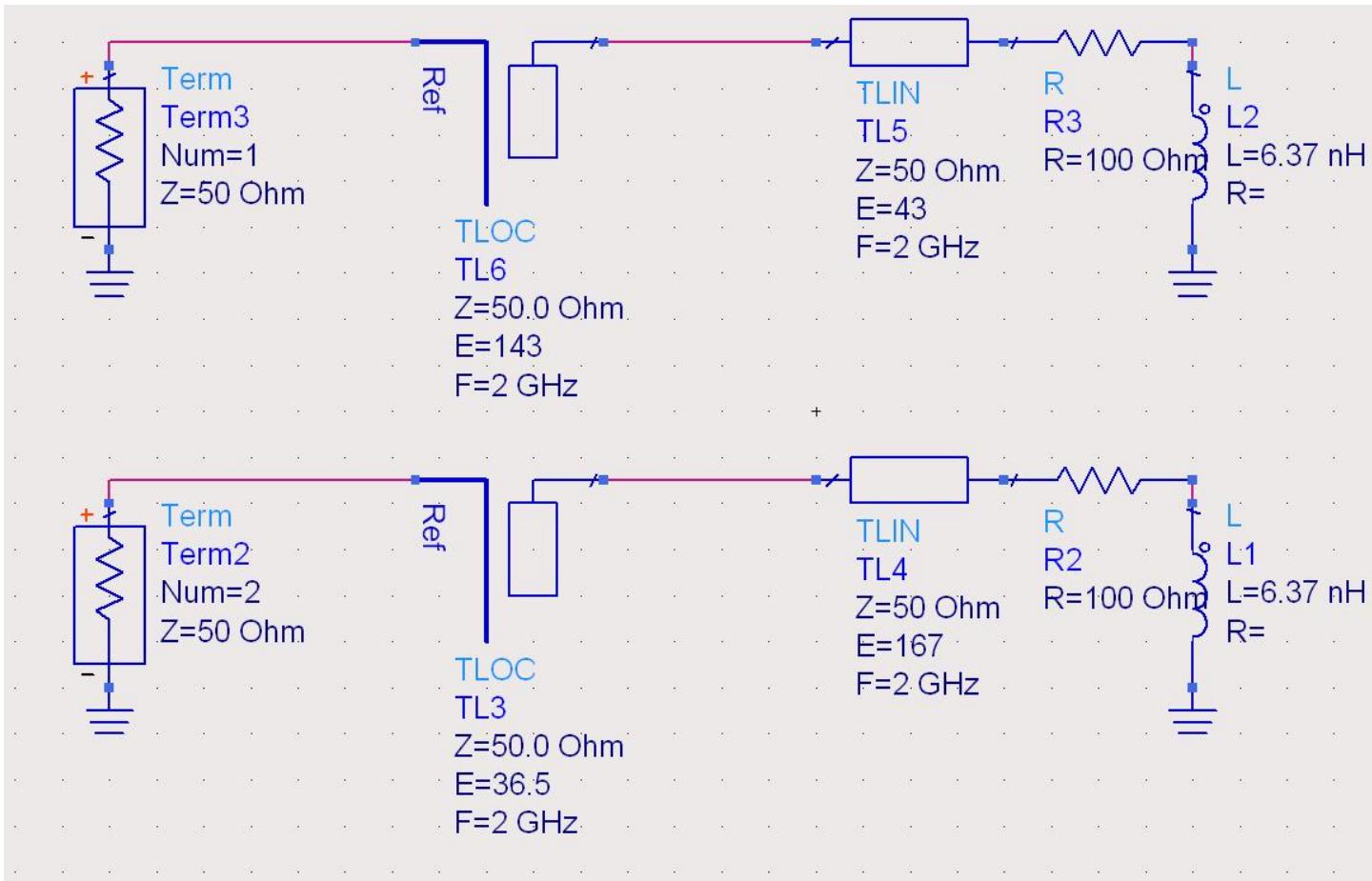


Solution 2

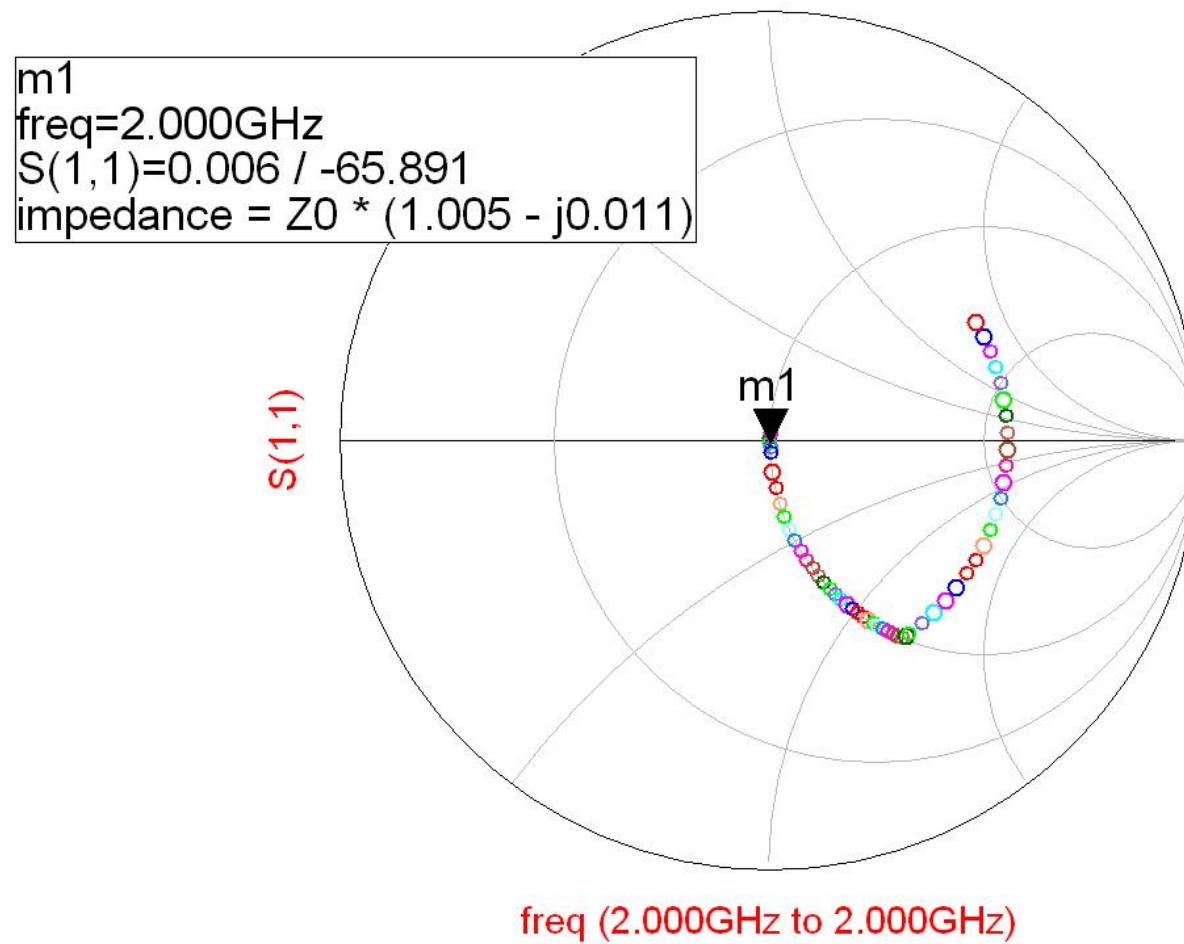
Exemplu, Series Stub, gol



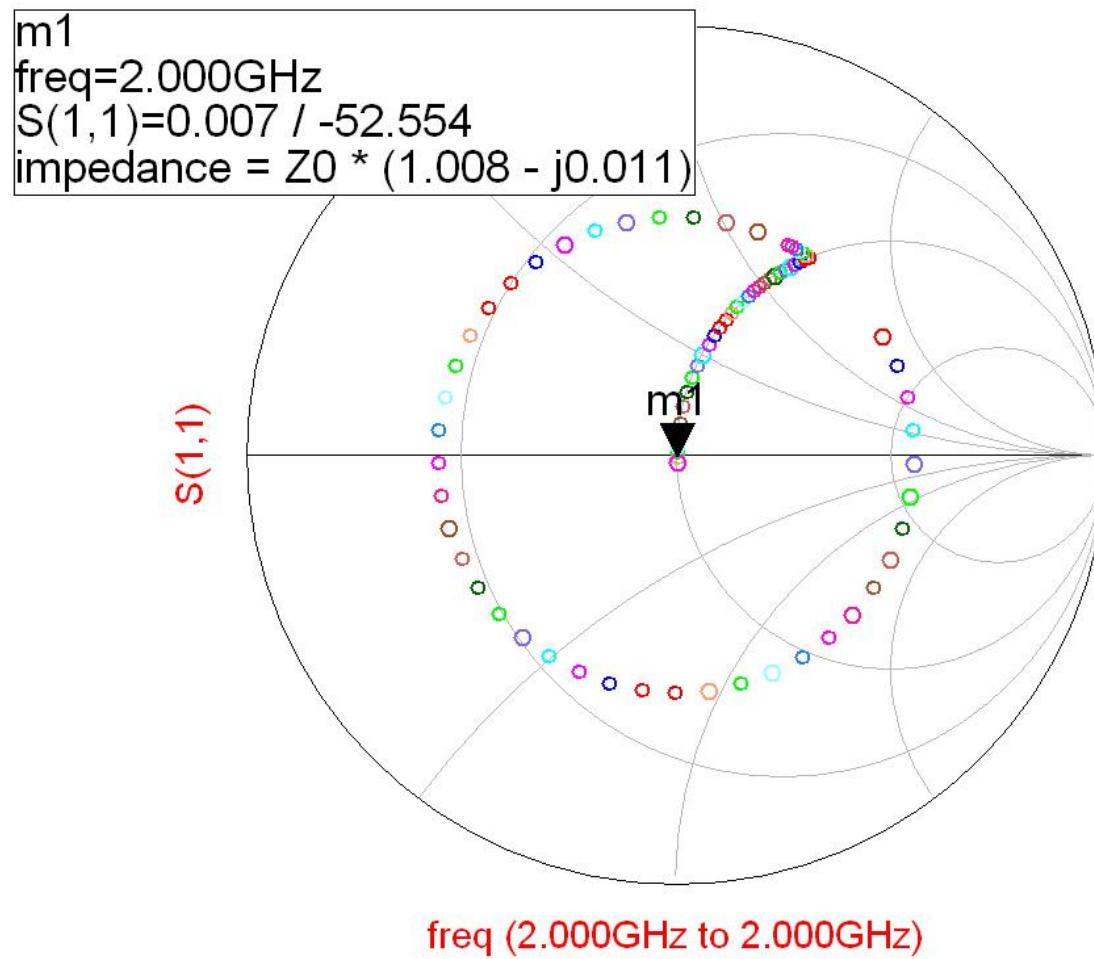
Exemplu, Series Stub, gol



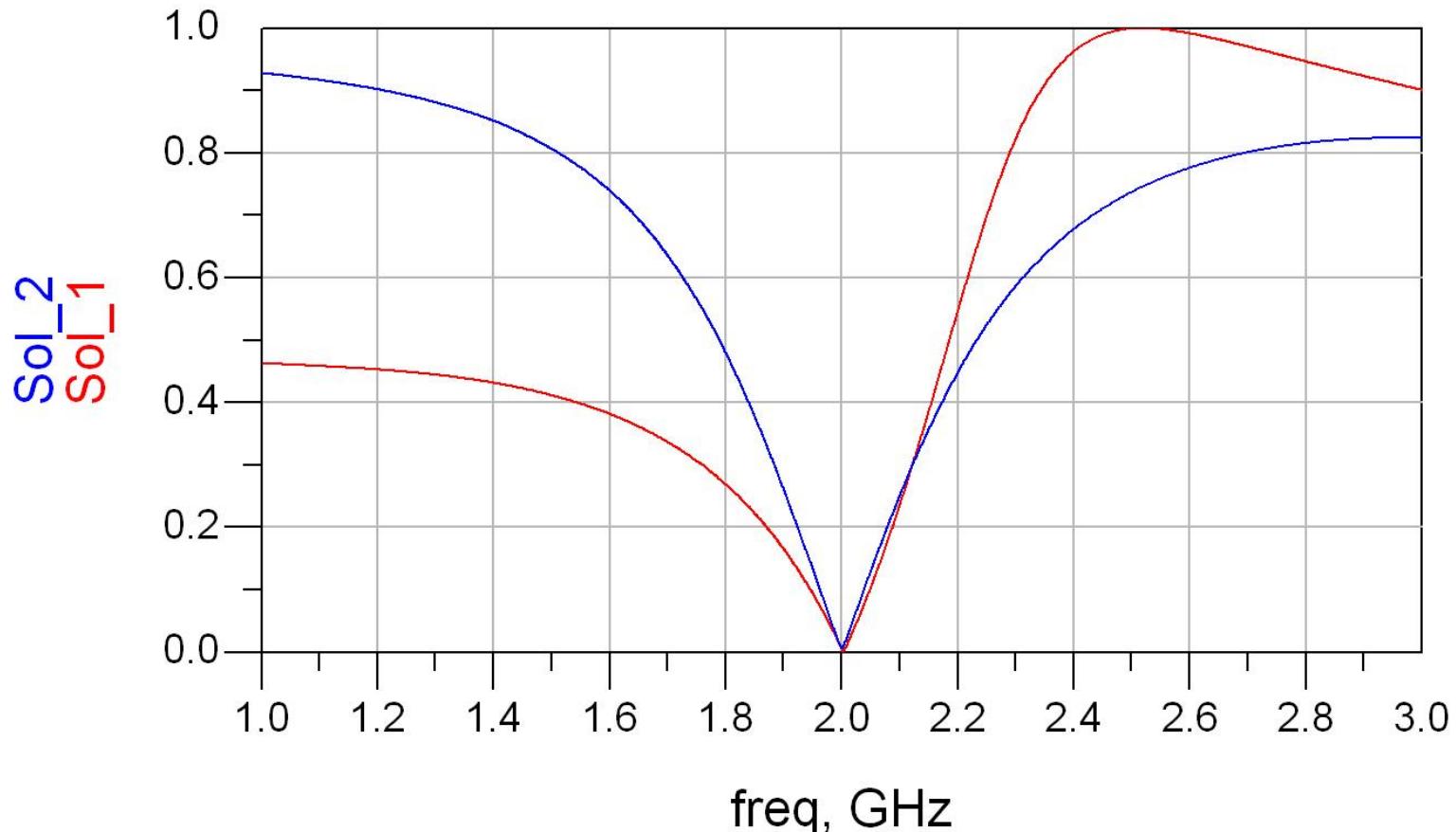
Exemplu, Series Stub, gol



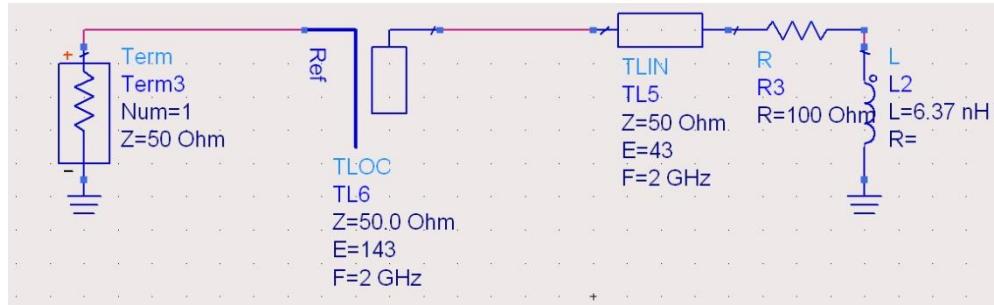
Exemplu, Series Stub, gol



Exemplu, Series Stub, gol



Exemplu, Series Stub, gol

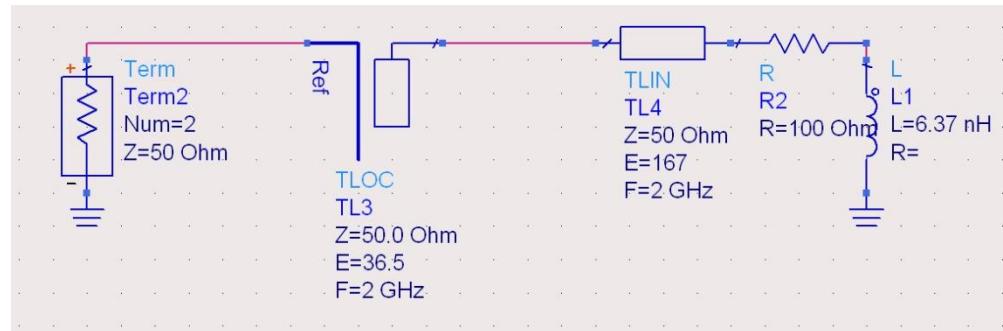


$$l_1 = \frac{43^\circ}{360^\circ} \cdot \lambda = 0.119 \cdot \lambda$$

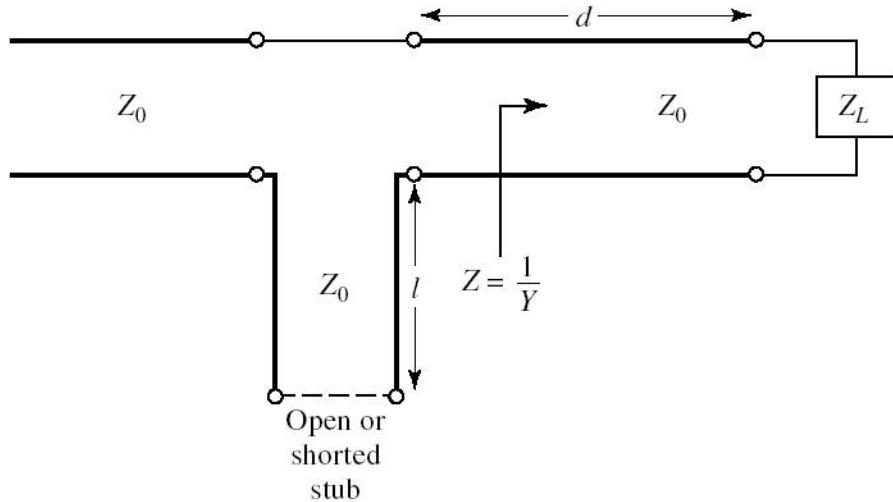
$$l_2 = \frac{143^\circ}{360^\circ} \cdot \lambda = 0.397 \cdot \lambda$$

$$l_1 = \frac{167^\circ}{360^\circ} \cdot \lambda = 0.464 \cdot \lambda$$

$$l_2 = \frac{36.5^\circ}{360^\circ} \cdot \lambda = 0.101 \cdot \lambda$$



Solutie analitica, impedante



$$Y_L = \frac{1}{Z_L} = G_L + j \cdot B_L$$

$$Y = Y_0 \cdot \frac{(G_L + j \cdot B_L) + j \cdot Y_0 \cdot t}{Y_0 + j \cdot (G_L + j \cdot B_L) \cdot t}$$

$$t = \tan \beta \cdot d \quad Z = R + j \cdot X = \frac{1}{Y}$$

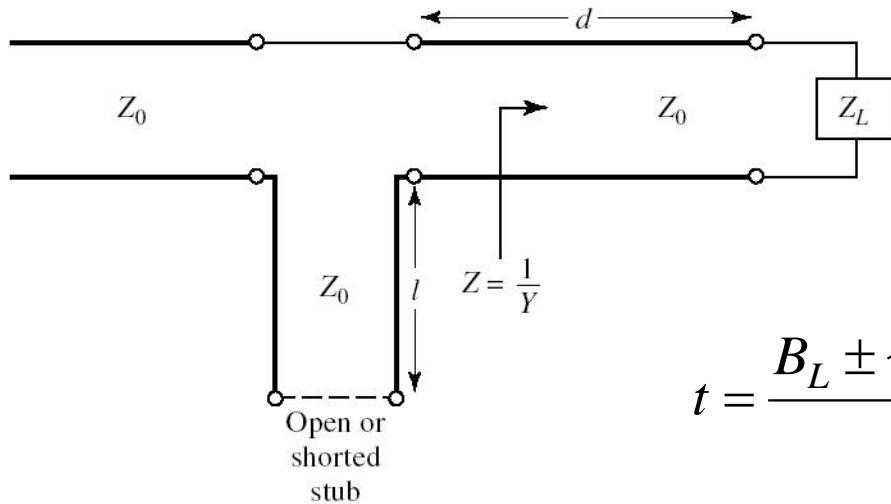
$$R = \frac{G_L \cdot (1 + t^2)}{G_L^2 + (G_L + Y_0 \cdot t)^2}$$

$$X = \frac{G_L^2 \cdot t - (Y_0 - B_L \cdot t) \cdot (B_L + Y_0 \cdot t)}{Y_0 \cdot [G_L^2 + (B_L + Y_0 \cdot t)^2]}$$

- d (deci si t) este ales astfel incat: $R = Z_0 = \frac{1}{Y_0}$

$$Y_0 \cdot (G_L - Y_0) \cdot t^2 - 2 \cdot B_L \cdot Y_0 \cdot t + (G_L \cdot Y_0 - G_L^2 - B_L^2) = 0$$

Solutie analitica



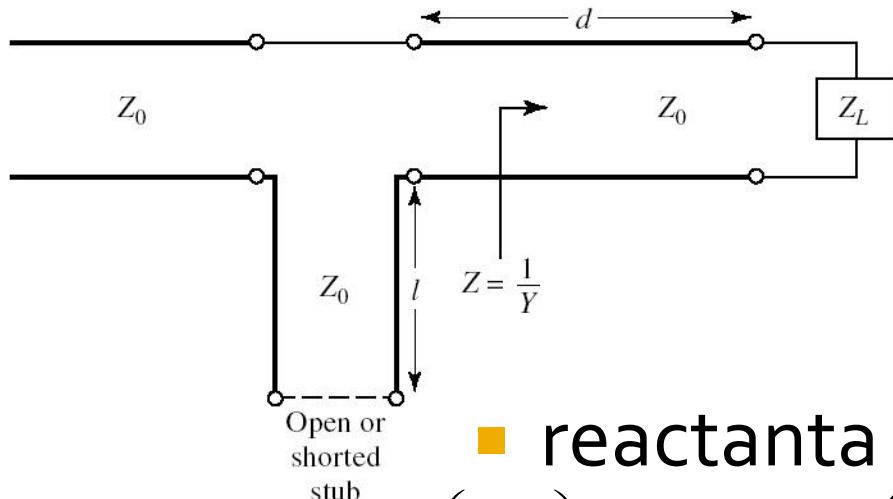
$$t = \frac{-B_L}{2 \cdot Y_0}, \quad G_L = Y_0$$

$$t = \frac{B_L \pm \sqrt{G_L \cdot [(Y_0 - G_L)^2 + B_L^2] / Y_0}}{G_L - Y_0} \quad G_L \neq Y_0$$

- ecuatie de gradul 2, 2 solutii posibile
- d (din t determinat):

$$\frac{d}{\lambda} = \begin{cases} \frac{1}{2\pi} \cdot \arctan t & t \geq 0 \\ \frac{1}{2\pi} \cdot (\pi + \arctan t) & t < 0 \end{cases}$$

Solutie analitica



$$X_S = -X$$

$$X = \frac{G_L^2 \cdot t - (Y_0 - B_L \cdot t) \cdot (B_L + Y_0 \cdot t)}{Y_0 \cdot [G_L^2 + (B_L + Y_0 \cdot t)^2]}$$

■ reactanta de anulare se obtine cu:

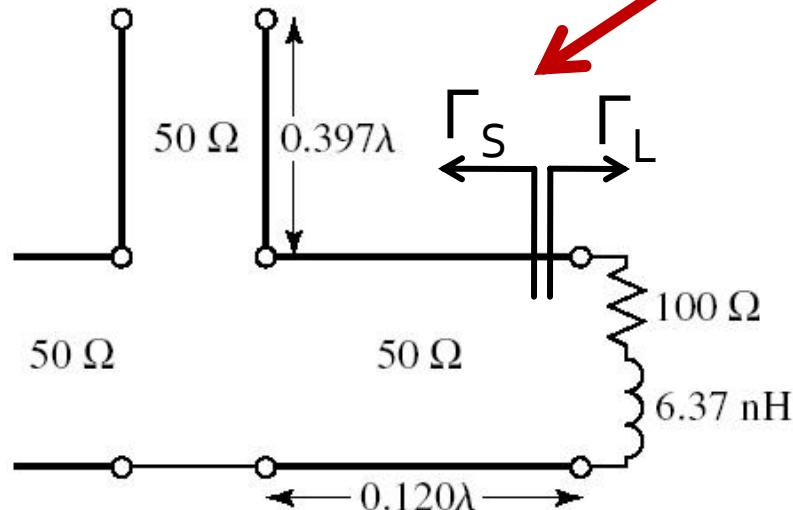
$$\frac{l_{sc}}{\lambda} = \frac{1}{2\pi} \cdot \arctan \left(\frac{X_S}{Z_0} \right) = \frac{-1}{2\pi} \cdot \arctan \left(\frac{X}{Z_0} \right)$$

$$\frac{l_{gol}}{\lambda} = \frac{-1}{2\pi} \cdot \arctan \left(\frac{Z_0}{X_S} \right) = \frac{1}{2\pi} \cdot \arctan \left(\frac{Z_0}{X} \right)$$

■ pentru **lungimi negative** se adauga $\lambda/2$

Calcul analitic, coeficienti de reflexie

- sarcina: 100Ω serie 6.37 nH la 2GHz



Solution 1

$$Z_L = R_L + \frac{1}{j \cdot \omega \cdot C_L} = 100\Omega + j \cdot 80.05\Omega$$

$$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0} = 0.481 + j \cdot 0.277$$

$$z_L = \frac{Z_L}{Z_0} = 2 + j \cdot 1.6$$

- adaptare necesita Γ complex conjugat

$$\Gamma_s = \Gamma_L^* = 0.481 - j \cdot 0.277$$

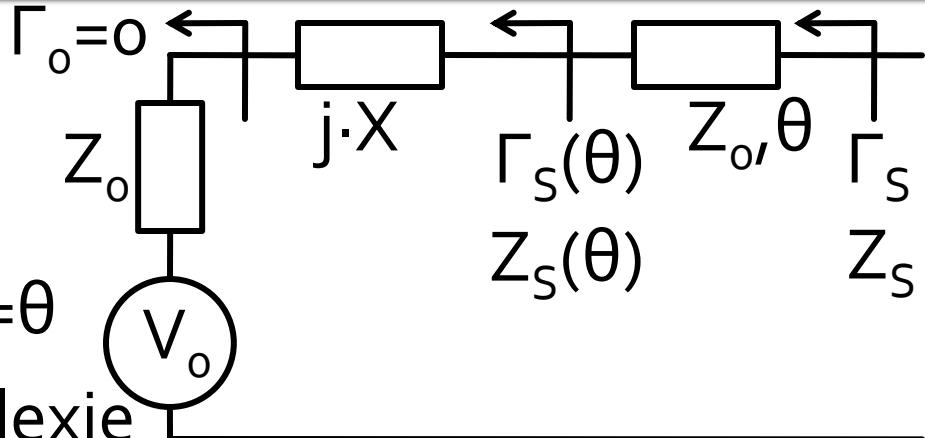
$$\Gamma_s = 0.555 \angle -29.92^\circ$$

$$|\Gamma_s| = 0.555; \quad \varphi = -29.92^\circ$$

Calcul analitic, coeficienti de reflexie

■ linie serie

- lungime electrica $E = \beta \cdot l = \theta$
- mută coeficientul de reflexie pe cercul $r=1$



■ stub serie

- lungime electrica $E = \beta \cdot l_{ss} = \theta_{ss}$
- mută coeficientul de reflexie în centrul diagramei Smith ($\Gamma_o = 0$)

$$z_s = \frac{Z_s}{Z_0} = \frac{Z_s}{50\Omega}$$

$$z_s = \frac{1 + \Gamma_s}{1 - \Gamma_s} = 2 - j \cdot 1.6$$

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

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

Calcul analitic, linie serie (dem.)

- Dupa sectiunea de linie cu lungimea electrica θ :

$$\operatorname{Re}[z_s(\theta)] = 1 \quad \operatorname{Im}[z_s(\theta)] = X$$

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

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

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

$$\operatorname{Re}[z_s(\theta)] = \frac{1}{2} \cdot \left[\frac{2 - 2 \cdot |\Gamma_s|^2}{1 + |\Gamma_s|^2 - 2 \cdot |\Gamma_s| \cdot \cos(\varphi + 2\theta)} \right] = 1 \quad \Rightarrow \quad \boxed{\cos(\varphi + 2\theta) = |\Gamma_s|}$$

Calcul analitic, linie serie (calcul)

- Ecuatia pentru calcularea θ (linie serie)

$$\operatorname{Re}[z_s(\theta)] = 1 \Rightarrow \cos(\varphi + 2\theta) = |\Gamma_s|$$

$$\Gamma_s = |\Gamma_s| \cdot e^{j\varphi} \quad \Gamma_s = 0.555 \angle -29.92^\circ \quad |\Gamma_s| = 0.555; \quad \varphi = -29.92^\circ$$

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

- se adauga $\lambda/2$ (180°) dupa nevoie

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

$$\cos(\varphi + 2\theta) = 0.555 \Rightarrow (\varphi + 2\theta) = \pm 56.28^\circ \quad \forall k \in N$$

$$(-29.92^\circ + 2\theta) = \begin{cases} +56.28^\circ \\ -56.28^\circ \end{cases} \quad \theta = \begin{cases} +43.1^\circ \\ -13.2^\circ + 180^\circ = +166.8^\circ \end{cases}$$

Calcul analitic, stub serie (dem.)

- Ecuatia pentru calcularea stub-ului serie θ_{ss} :

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

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

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

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

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

Calcul analitic, stub serie (dem.)

- Ecuatia pentru calcularea stub-ului serie θ_{ss} :

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

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

- doua situatii

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

$$\begin{cases} \sin(\varphi + 2\theta) = \sqrt{1 - |\Gamma_s|^2} \\ \operatorname{Im}[z_s(\theta)] = \frac{2 \cdot |\Gamma_s|}{\sqrt{1 - |\Gamma_s|^2}} \end{cases}$$

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

$$\begin{cases} \sin(\varphi + 2\theta) = -\sqrt{1 - |\Gamma_s|^2} \\ \operatorname{Im}[z_s(\theta)] = \frac{-2 \cdot |\Gamma_s|}{\sqrt{1 - |\Gamma_s|^2}} \end{cases}$$

- Semnul** (+/-) solutiei alese la **prima** ecuatie impune **semnul** solutiei utilizate la a **doua** ecuatie

Calcul analitic, stub serie (dem.)

- Se prefera (pentru microstrip) stub in gol

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

- Reactanta raportata introdusa pentru adaptare
 - $Z(\theta)$ este impedanta vazuta **inspre** sursa, Z_0 in serie cu $j \cdot X$

$$x = \operatorname{Im} \left[\frac{Z_{in,oc}}{Z_0} \right] = -\cot \beta \cdot l = \operatorname{Im}[z_s(\theta)]$$

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

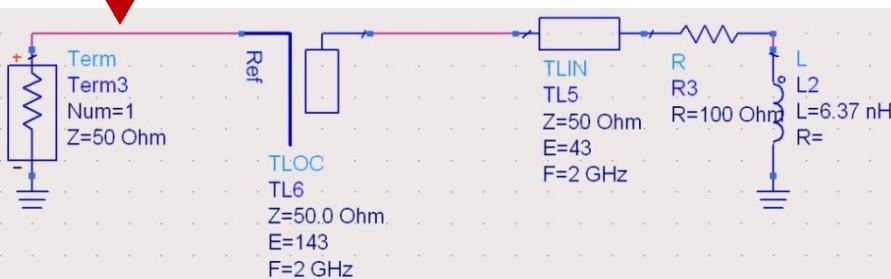
Calcul analitic (calcul efectiv)

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

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

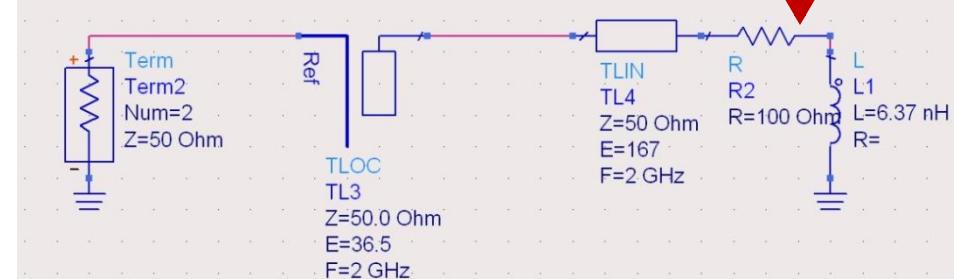
$$l_1 = \frac{43.1^\circ}{360^\circ} \cdot \lambda = 0.120 \cdot \lambda$$

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



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

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

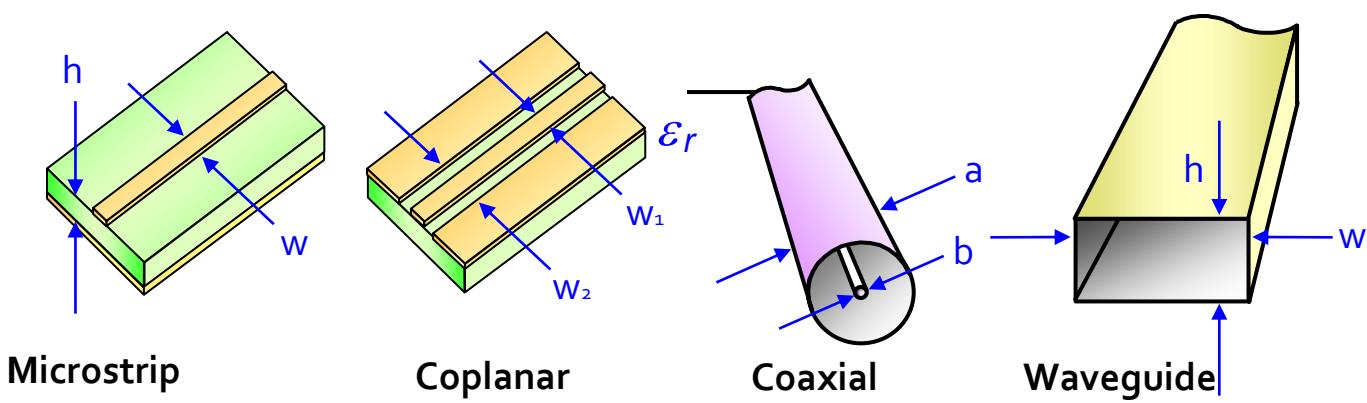


Adaptarea cu sectiuni de linii (stub)

- Se alege una din cele 8 solutii posibile convenabila tinand cont de:
 - dimensiuni fizice (suprafata ocupata pe chip/placa)
 - sensibilitatea adaptarii la variația parametrilor fizici ai liniilor ($\Delta\Gamma/\Delta E$, $\Delta\Gamma/\Delta I$)
 - caracteristica de frecvență convenabilă

Adaptarea cu sectiuni de linii (stub)

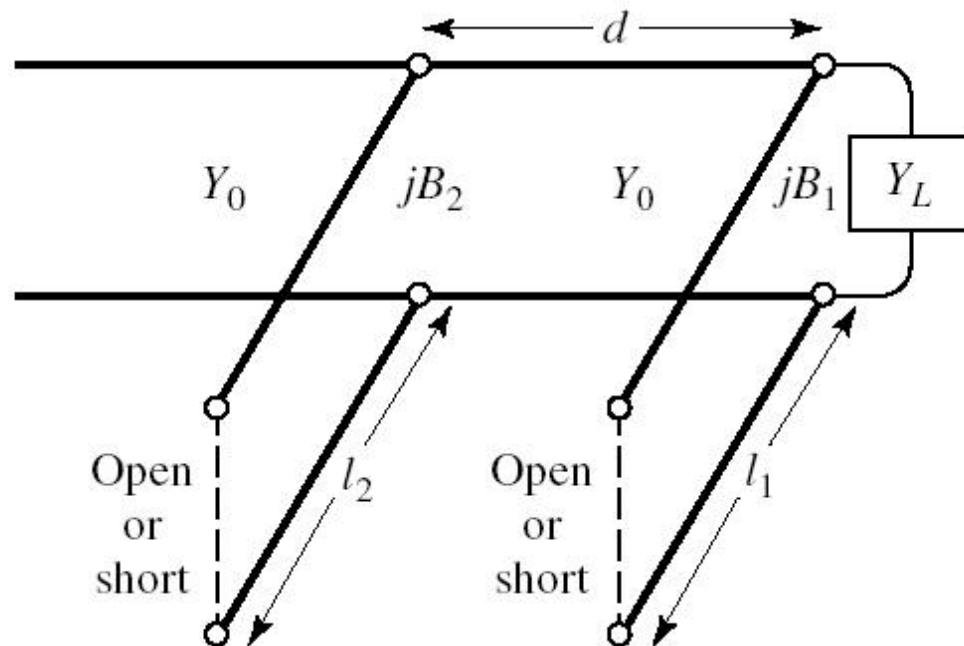
- Se alege una din cele 8 solutii posibile convenabila tinand cont de:
 - realizabilitate fizica (conform tehnologiei de linie utilizata)



- Dezavantaj:
 - lungimea sectiunii de linie serie e variabila

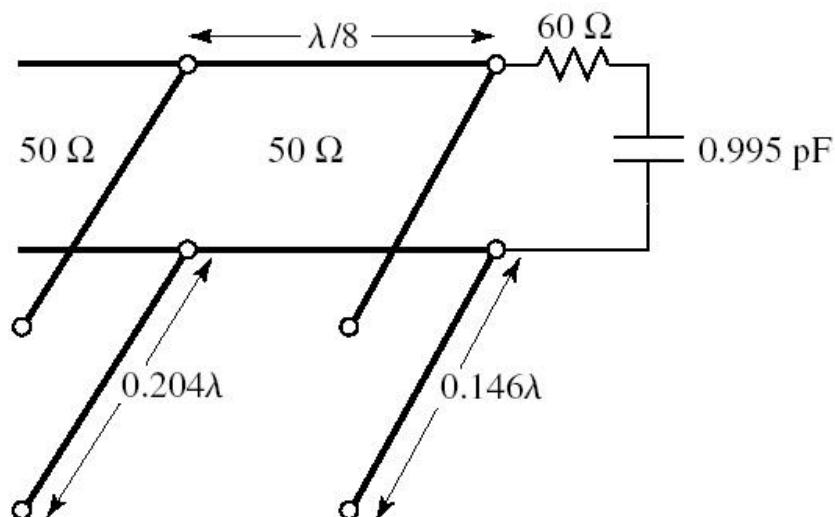
Adaptarea cu două secțiuni de linie

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

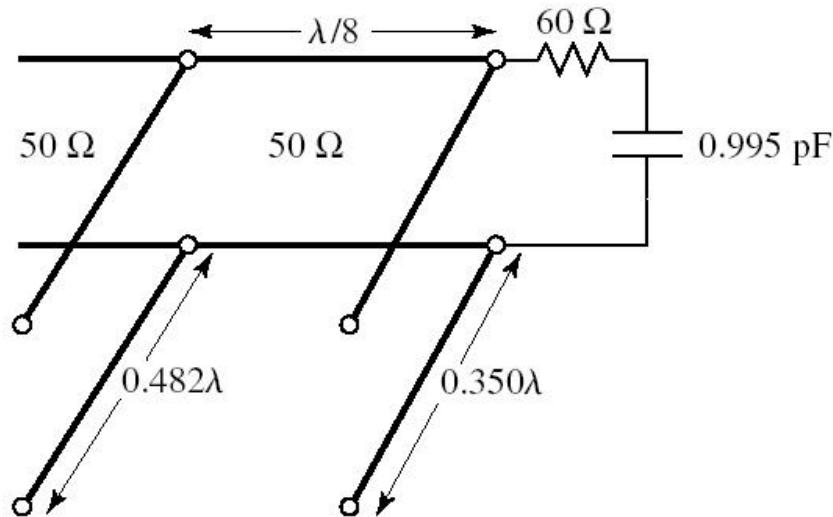


Adaptarea cu două secțiuni de linie

- Două soluții posibile



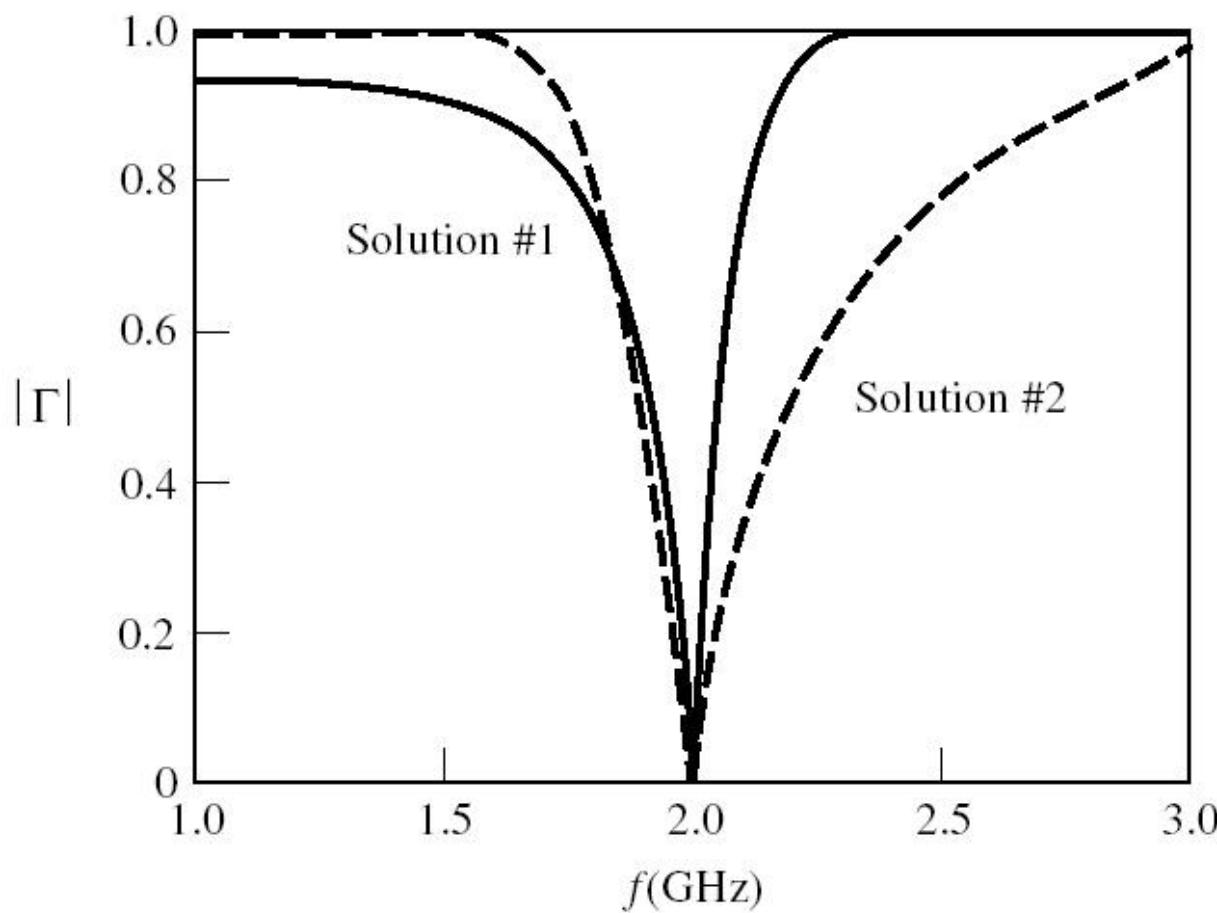
Solution 1



Solution 2

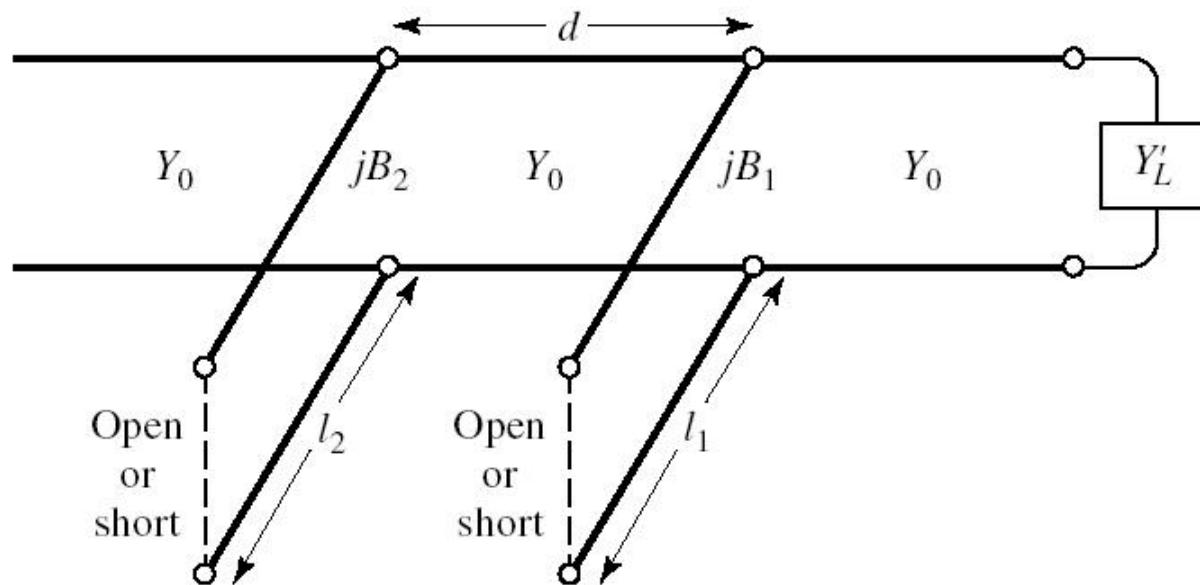
Adaptarea cu două sectiuni de linie

- Două solutii posibile

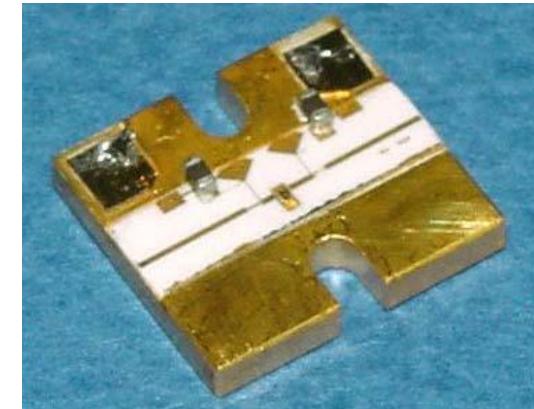
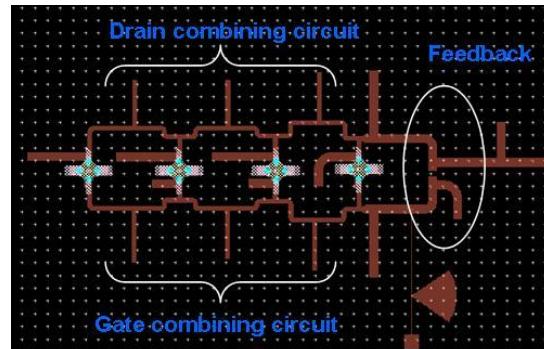
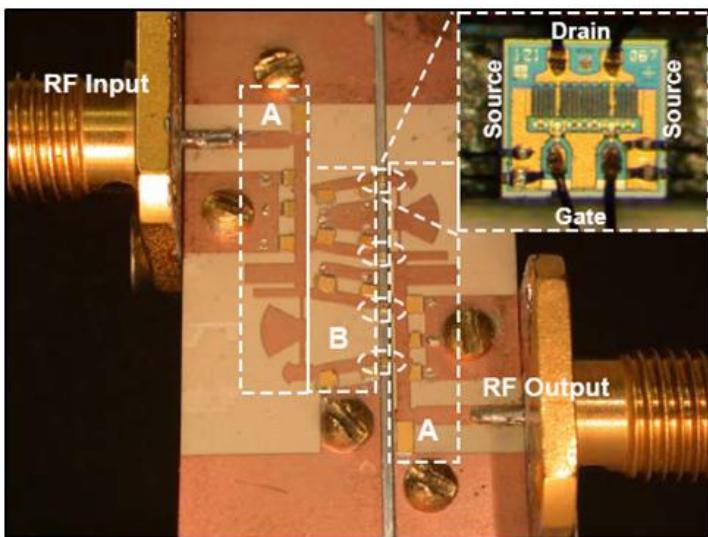
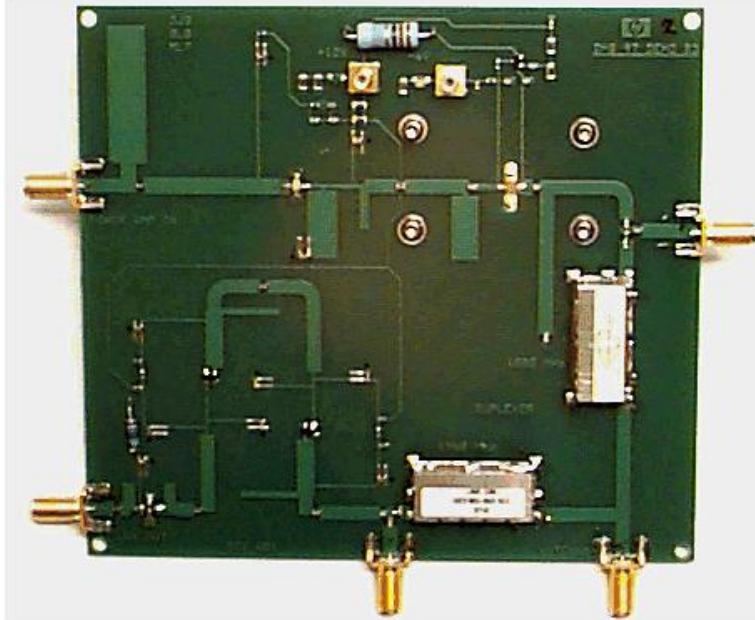
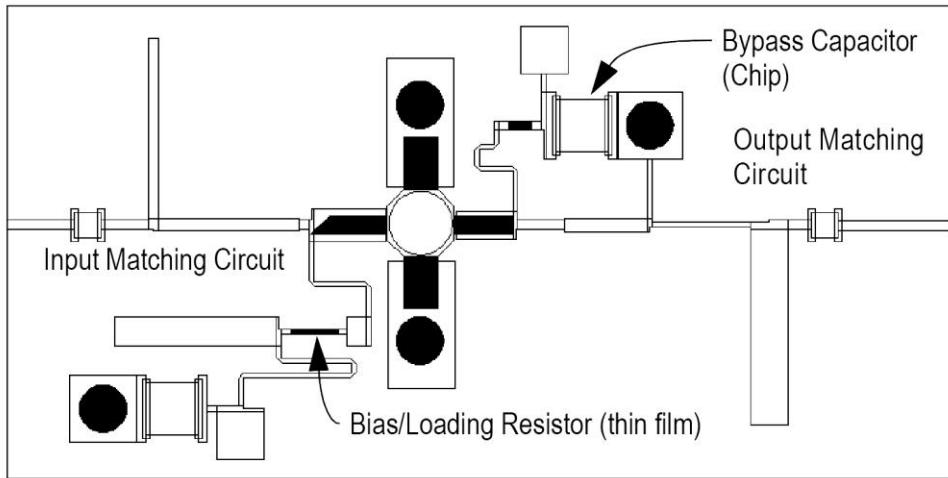


Adaptarea cu două secțiuni de linie

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



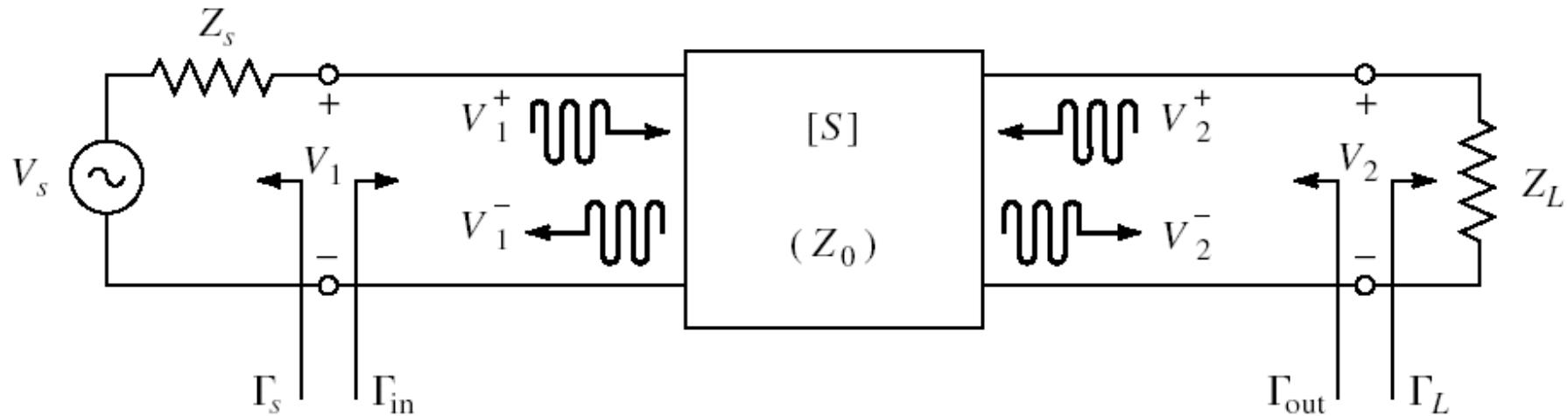
Adaptarea cu sectiuni de linie



Preview (pentru laborator 3-4)

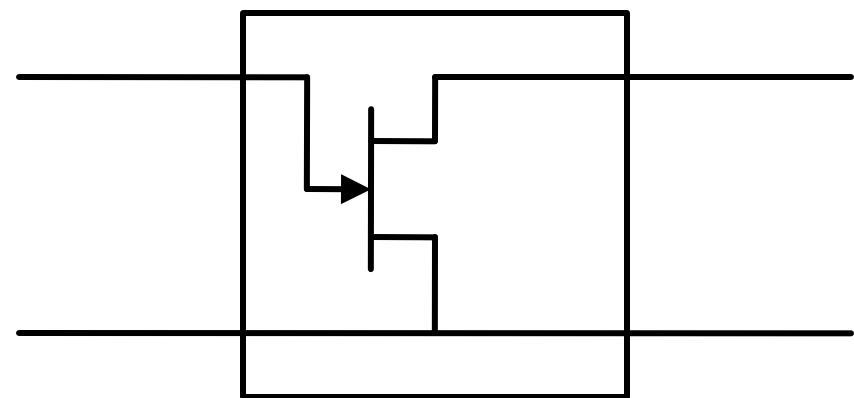
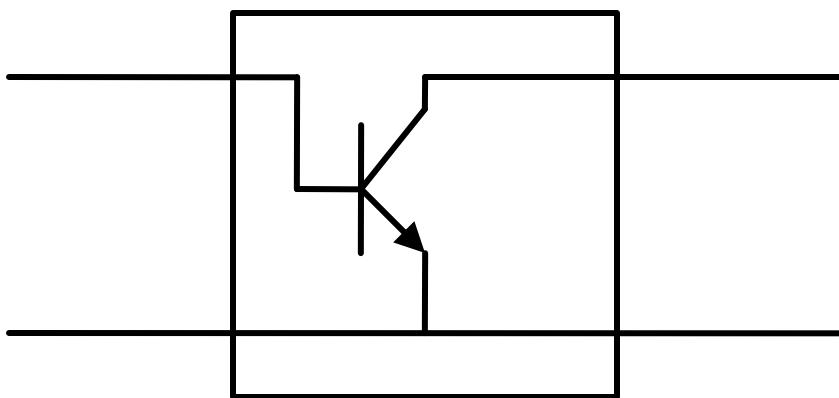
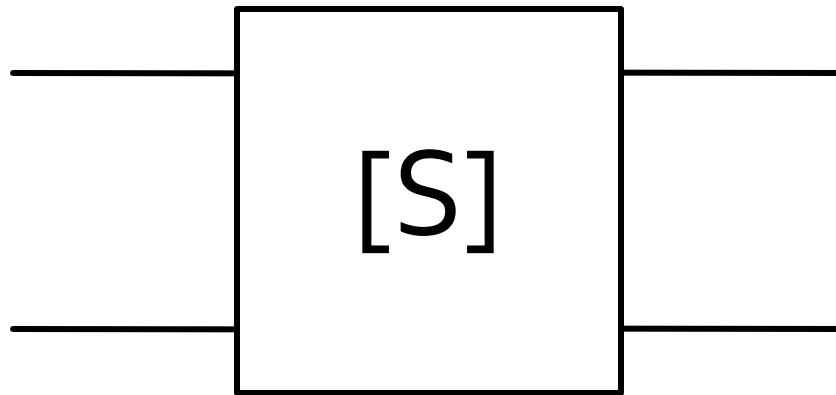
Amplificatoare de microunde

Cuadripol Amplificator (diport)



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

Parametri S

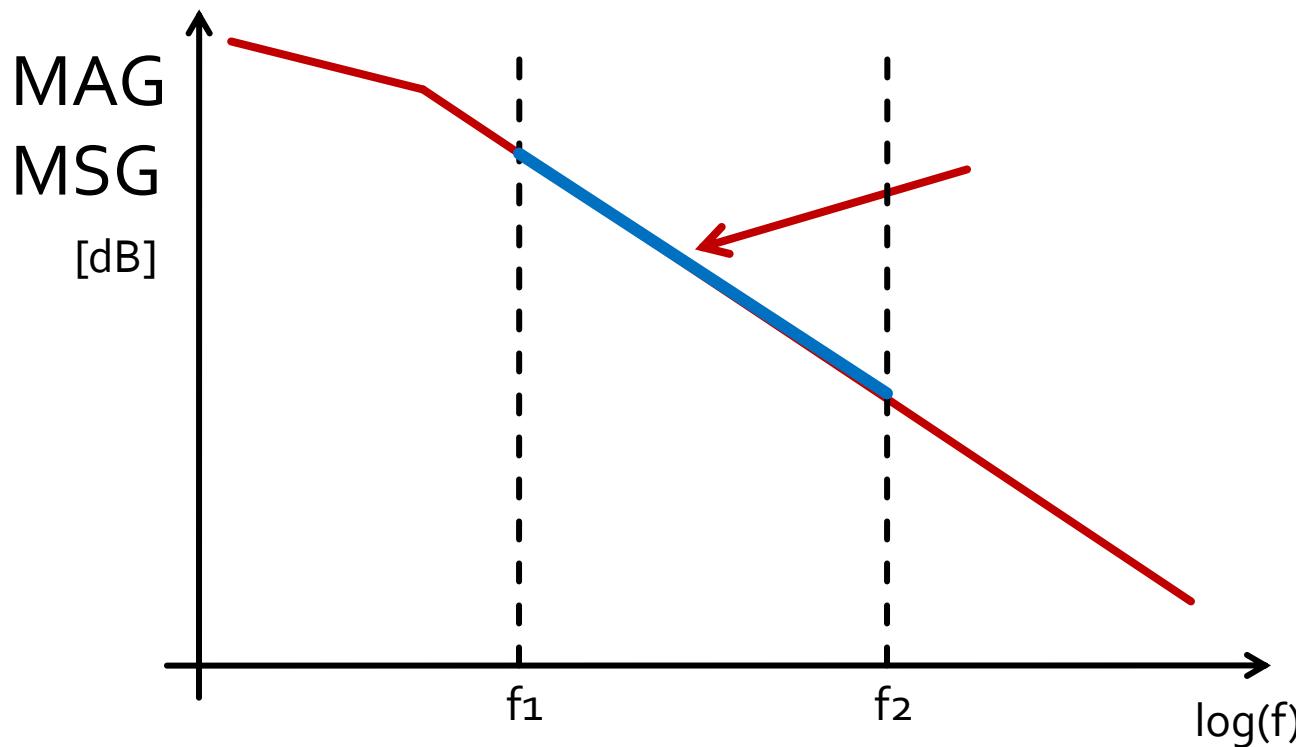


Proiectare pentru castig impus

- 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)
 - conditii de stabilitate mai bune
 - obtinerea unui VSWR mai mic
 - controlul performantelor la mai multe frecvente
 - banda de functionare a amplificatorului

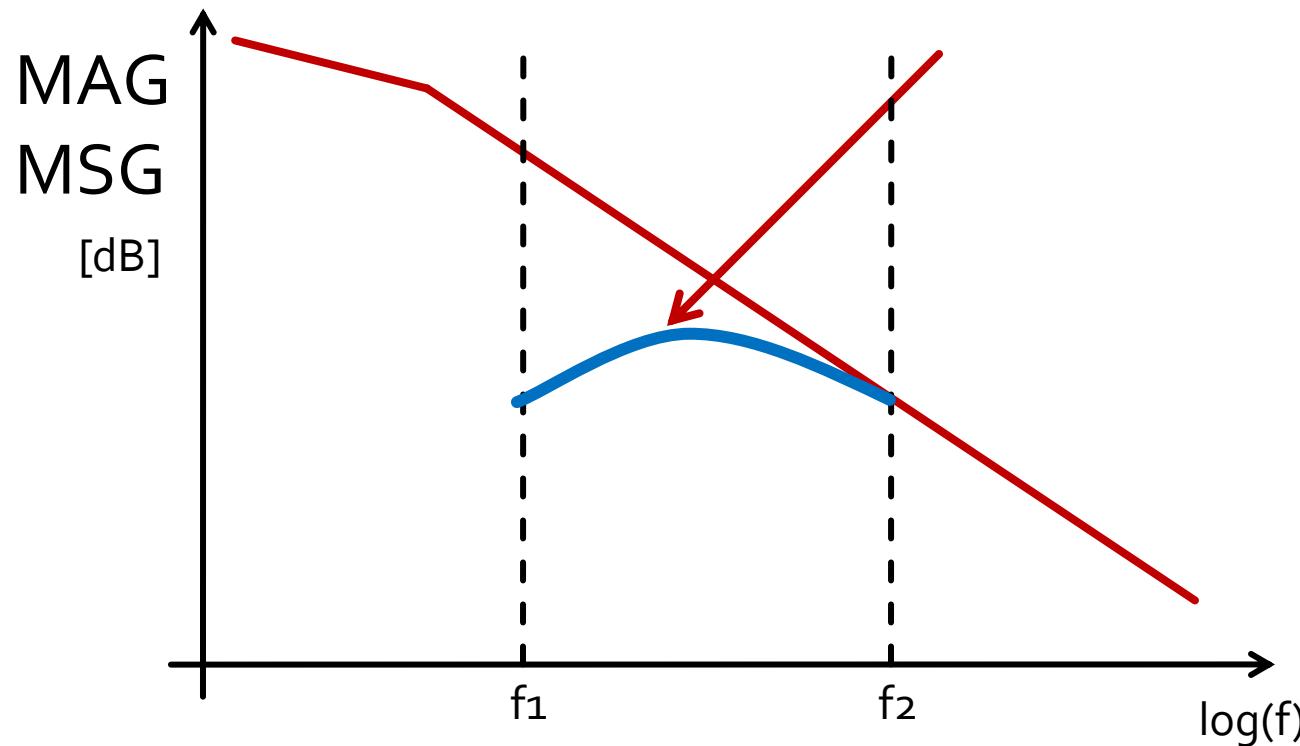
Amplificator de banda largă

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

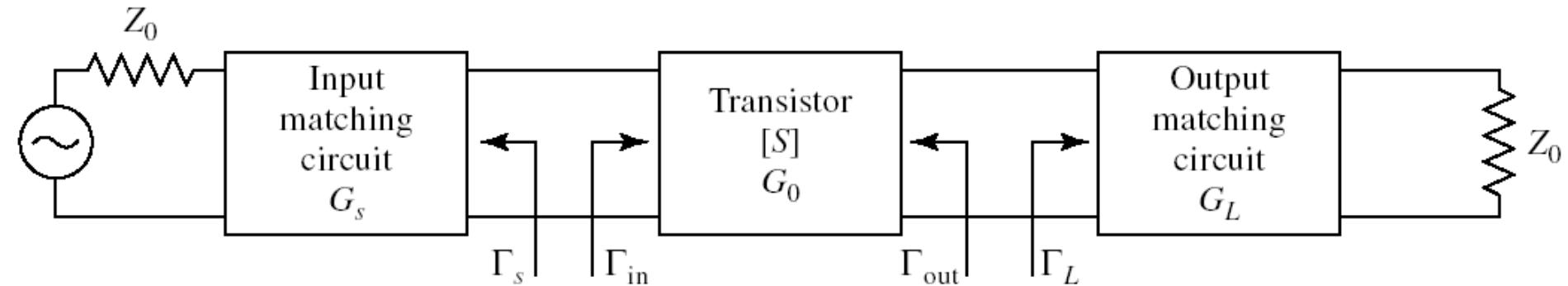


Amplificator de banda largă

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



Proiectare pentru castig impus



- Daca ipoteza tranzistorului unilateral este justificata:

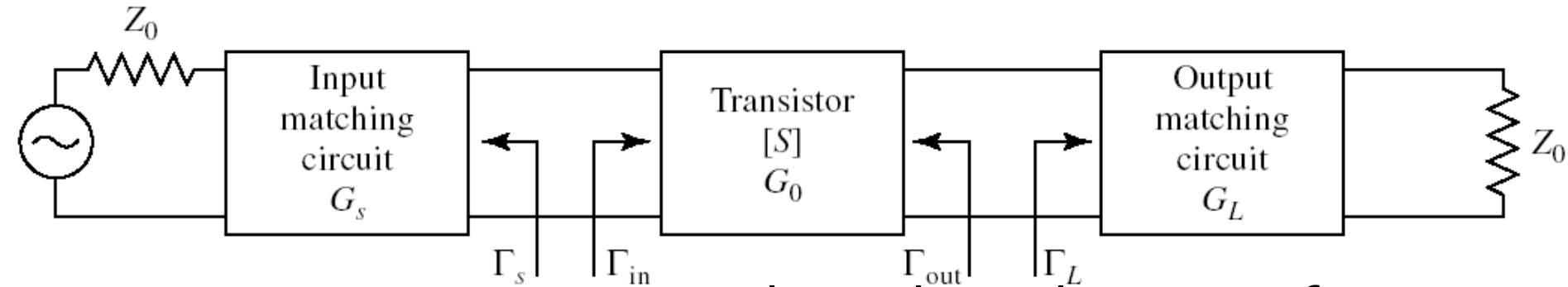
$$G_{TU} = |S_{21}|^2 \cdot \frac{1 - |\Gamma_s|^2}{|1 - S_{11} \cdot \Gamma_s|^2} \cdot \frac{1 - |\Gamma_L|^2}{|1 - S_{22} \cdot \Gamma_L|^2}$$

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

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

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

Proiectare pentru castig impus

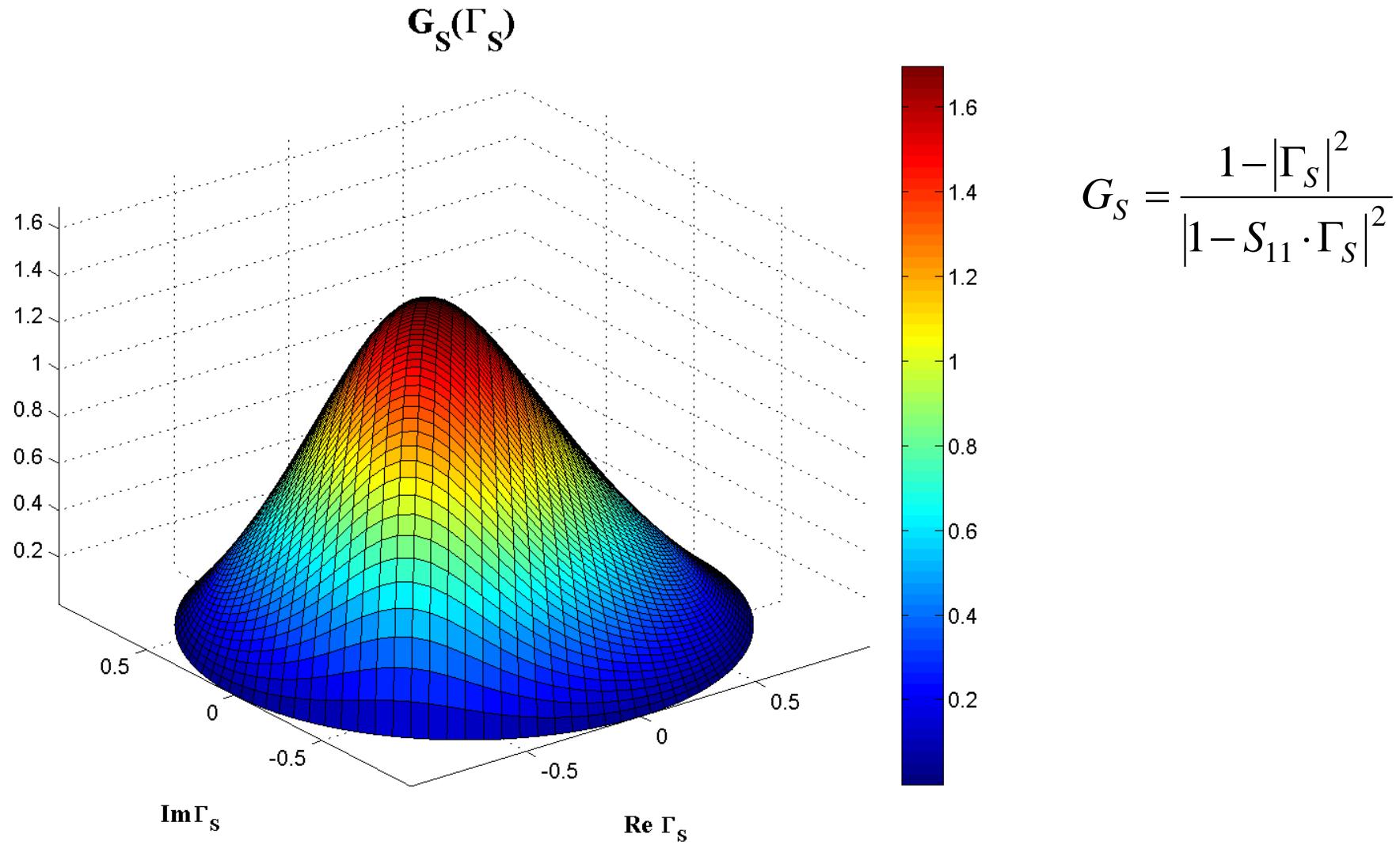


- Daca ipoteza tranzistorului unilateral este justificata:
 - castigul adaugat prin adaptare mai buna la intrare **nu** depinde de adaptarea la iesire
 - castigul adaugat prin adaptare mai buna la iesire **nu** depinde de adaptarea la intrare
- Adaptarile la intrare/iesire pot fi tratate independent
 - Se pot impune cerinte diferite intrare/iesire
 - se tine cont de compunerea castigurilor generate

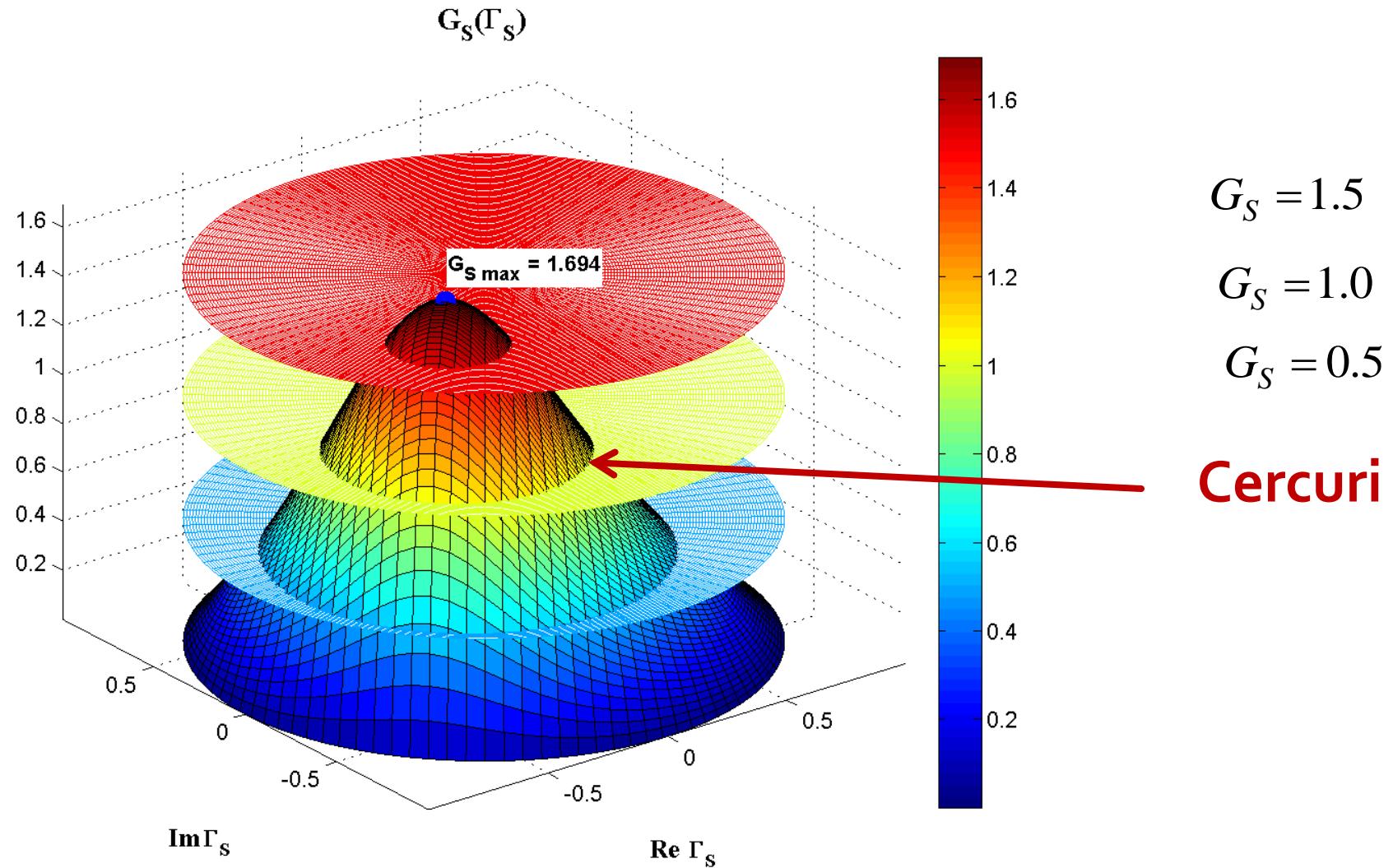
$$G_T = G_s \cdot G_0 \cdot G_L$$

$$G_T [dB] = G_s [dB] + G_0 [dB] + G_L [dB]$$

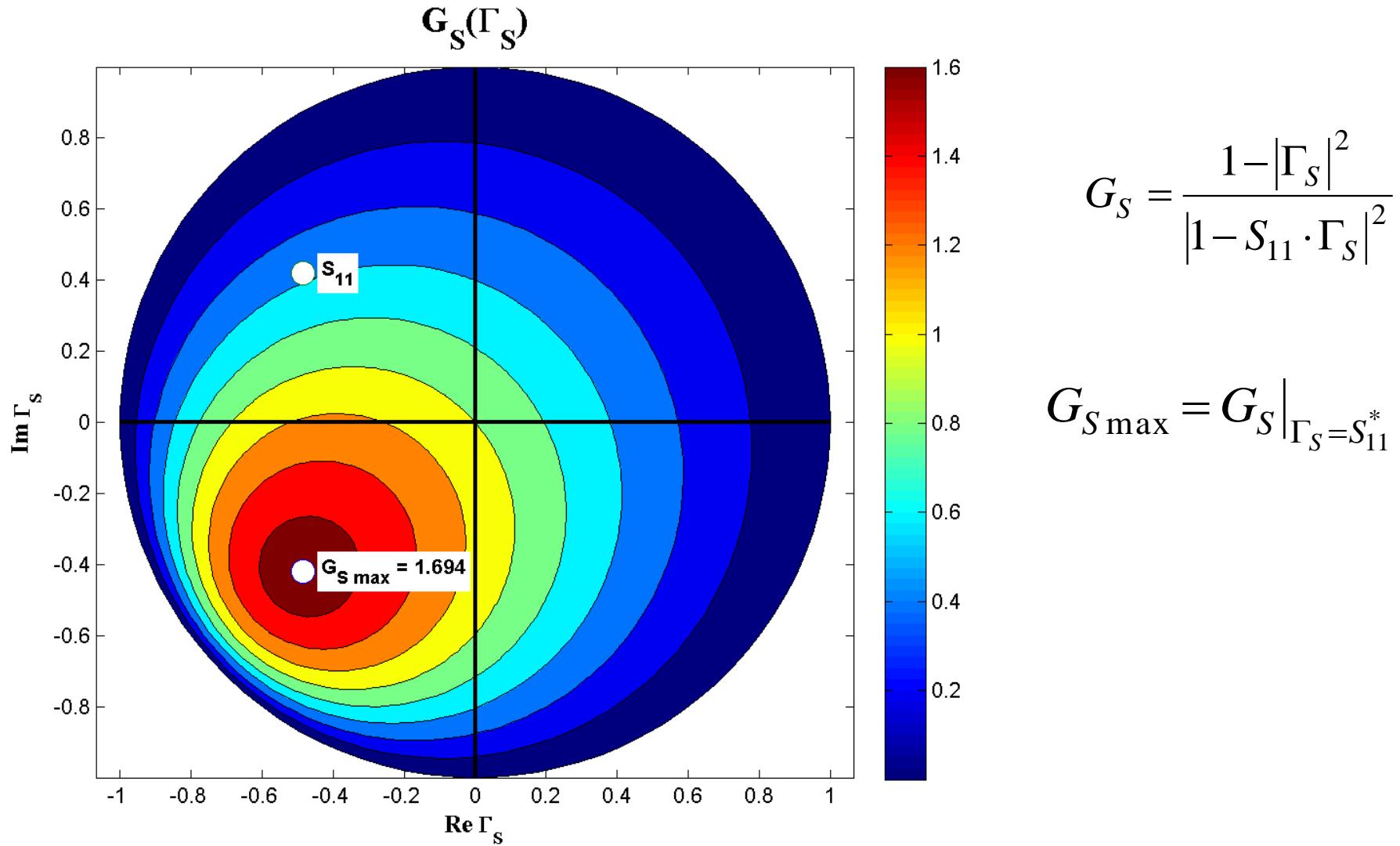
$\mathbf{G}_S(\Gamma_S)$



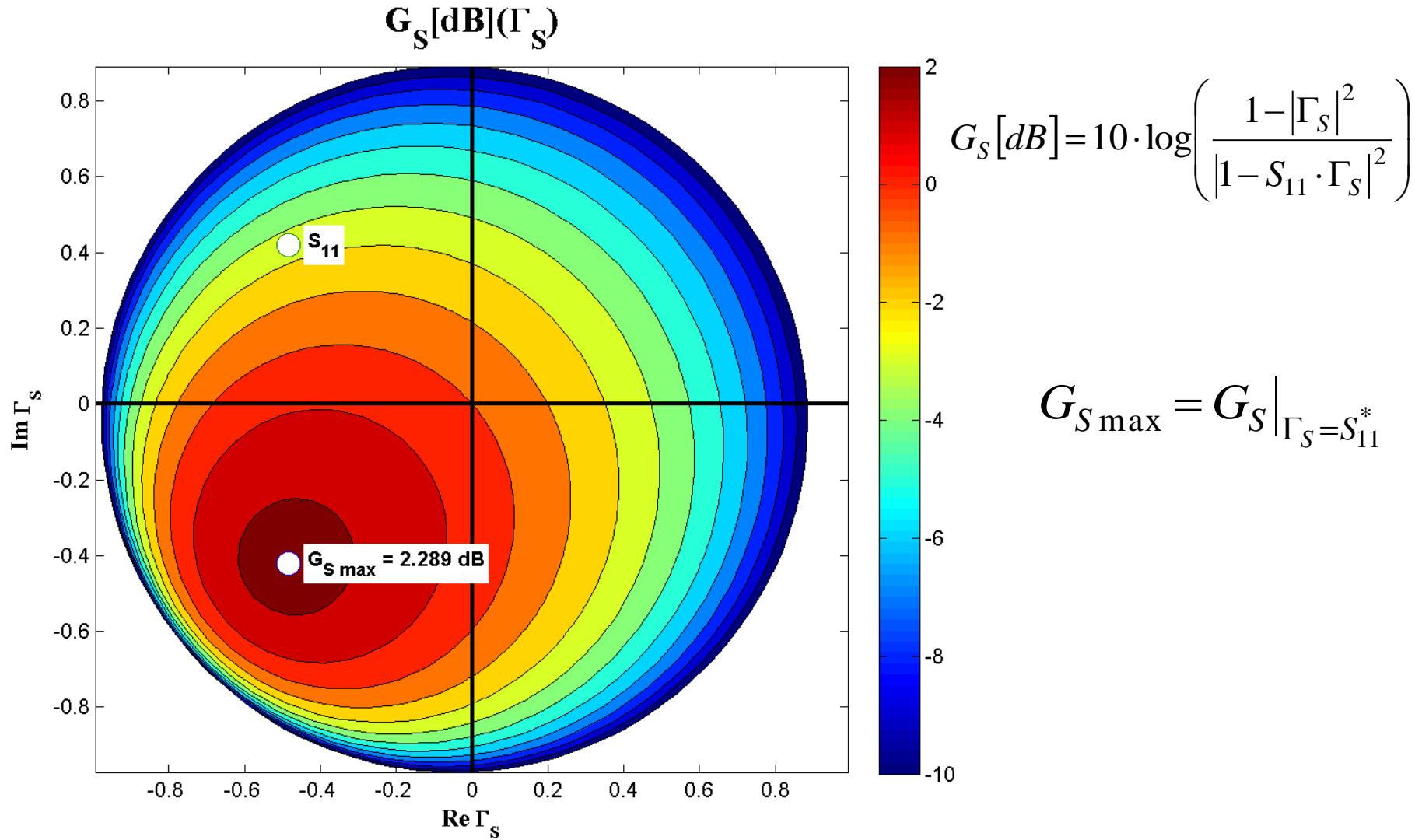
$G_S(\Gamma_S)$, nivel constant



$G_S(\Gamma_S)$, diagrama de nível



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

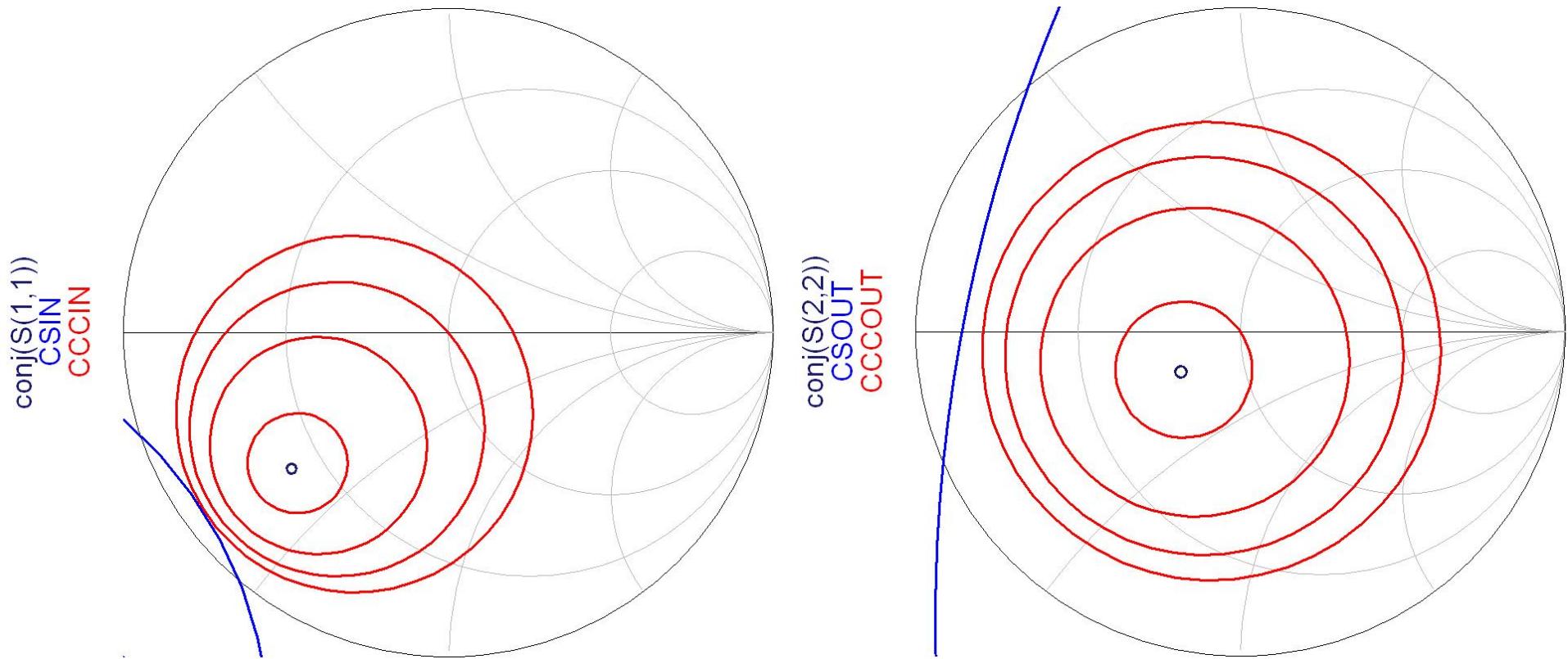


Cercuri de castig constant la intrare

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

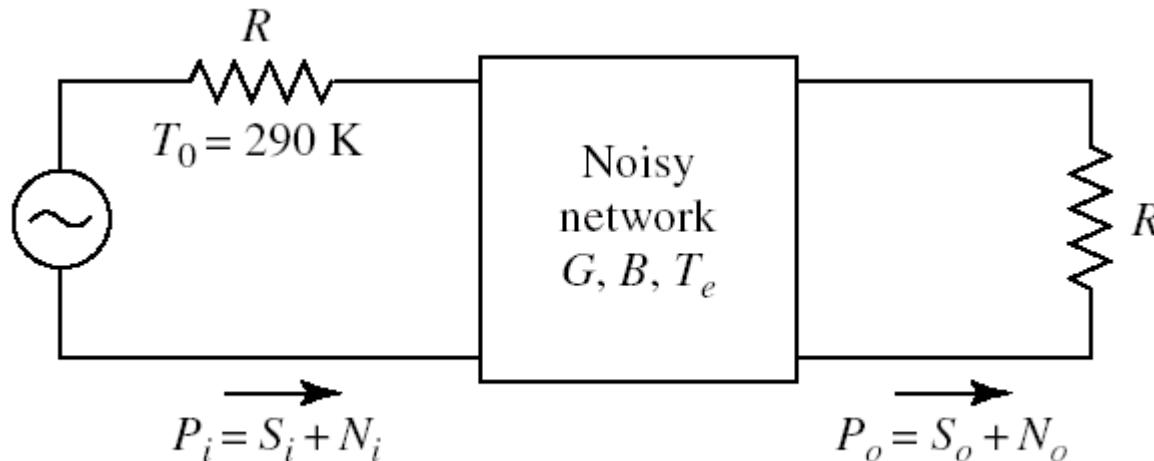
- Ecuatia unui cerc in planul complex in care reprezint Γ_S
- **Interpretare:** Orice punct Γ_S care reprezentat in planul complex se gaseste **pe** cercul desenat pentru $g_{\text{cerc}} = G_{\text{cerc}} / G_{\text{Smax}}$ va conduce la obtinerea castigului $G_S = G_{\text{cerc}}$
 - Orice punct **in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

CCCIN, CCCOUT



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

Factor de zgomot

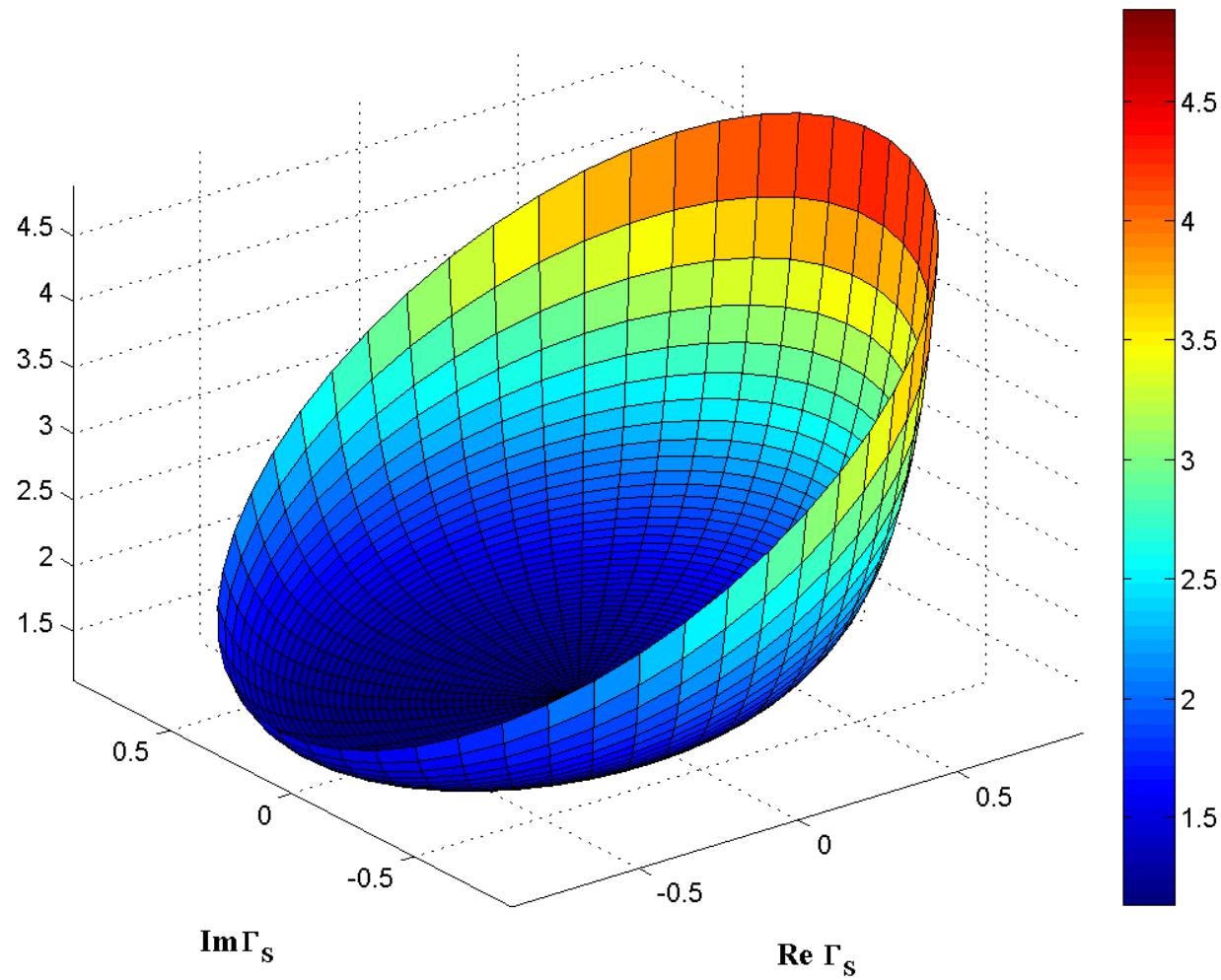


- Factorul de zgomot F caracterizeaza degradarea raportului semnal/zgomot intre intrarea si iesirea unei componente

$$F = \frac{S_i/N_i}{S_o/N_o}$$

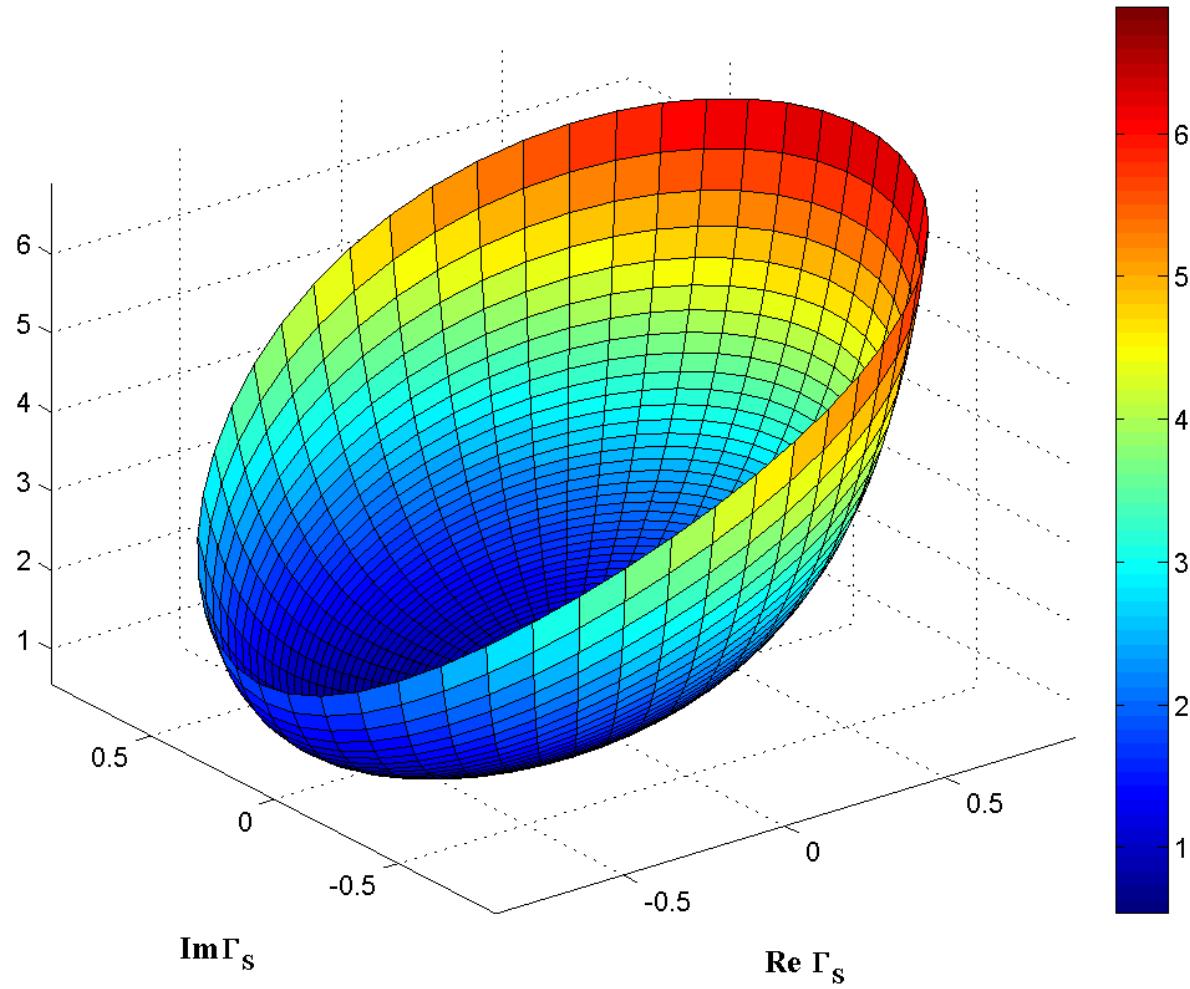
$F(\Gamma_s)$

$F(\Gamma_s)$

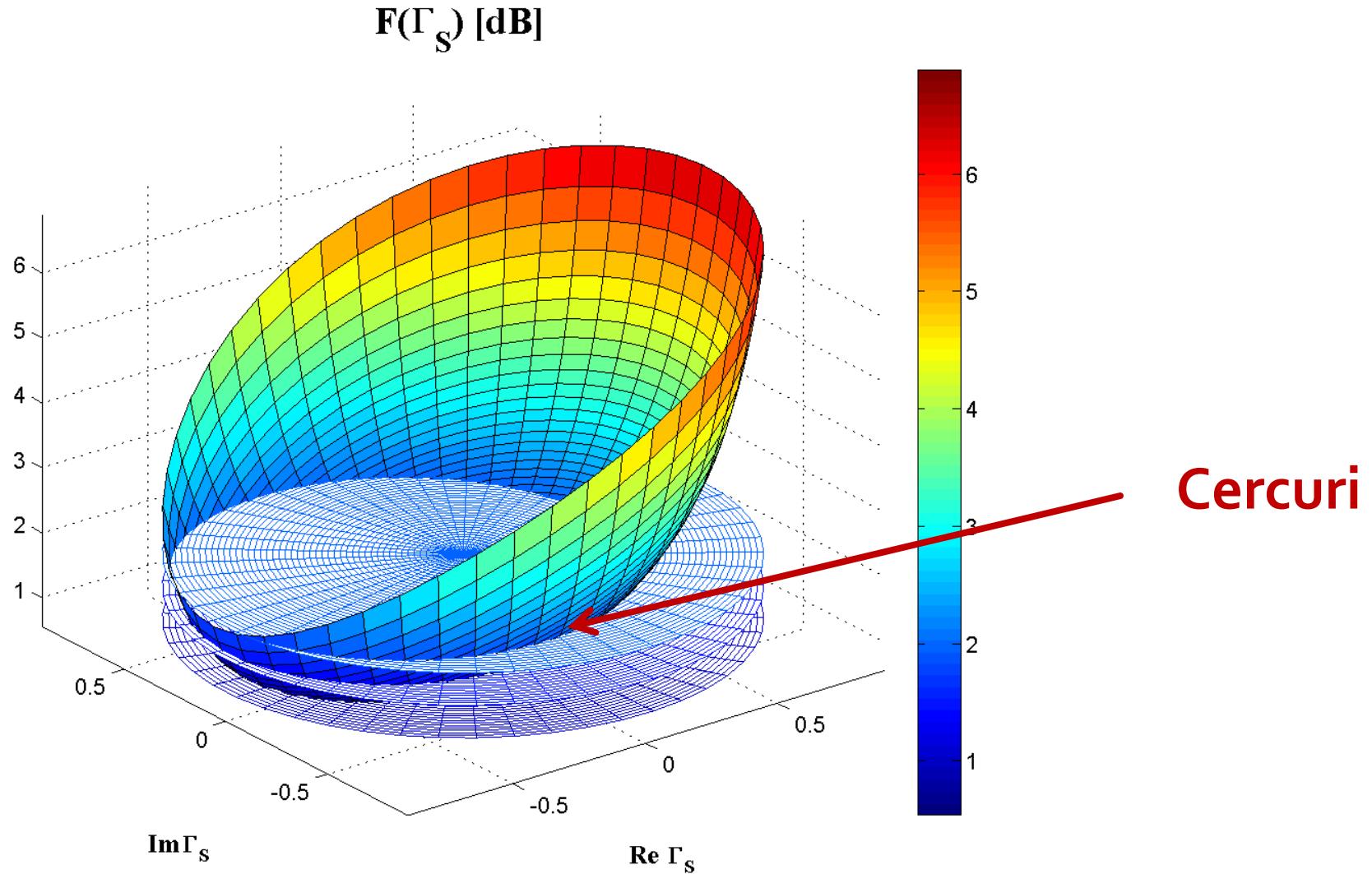


$F[dB](\Gamma_S)$

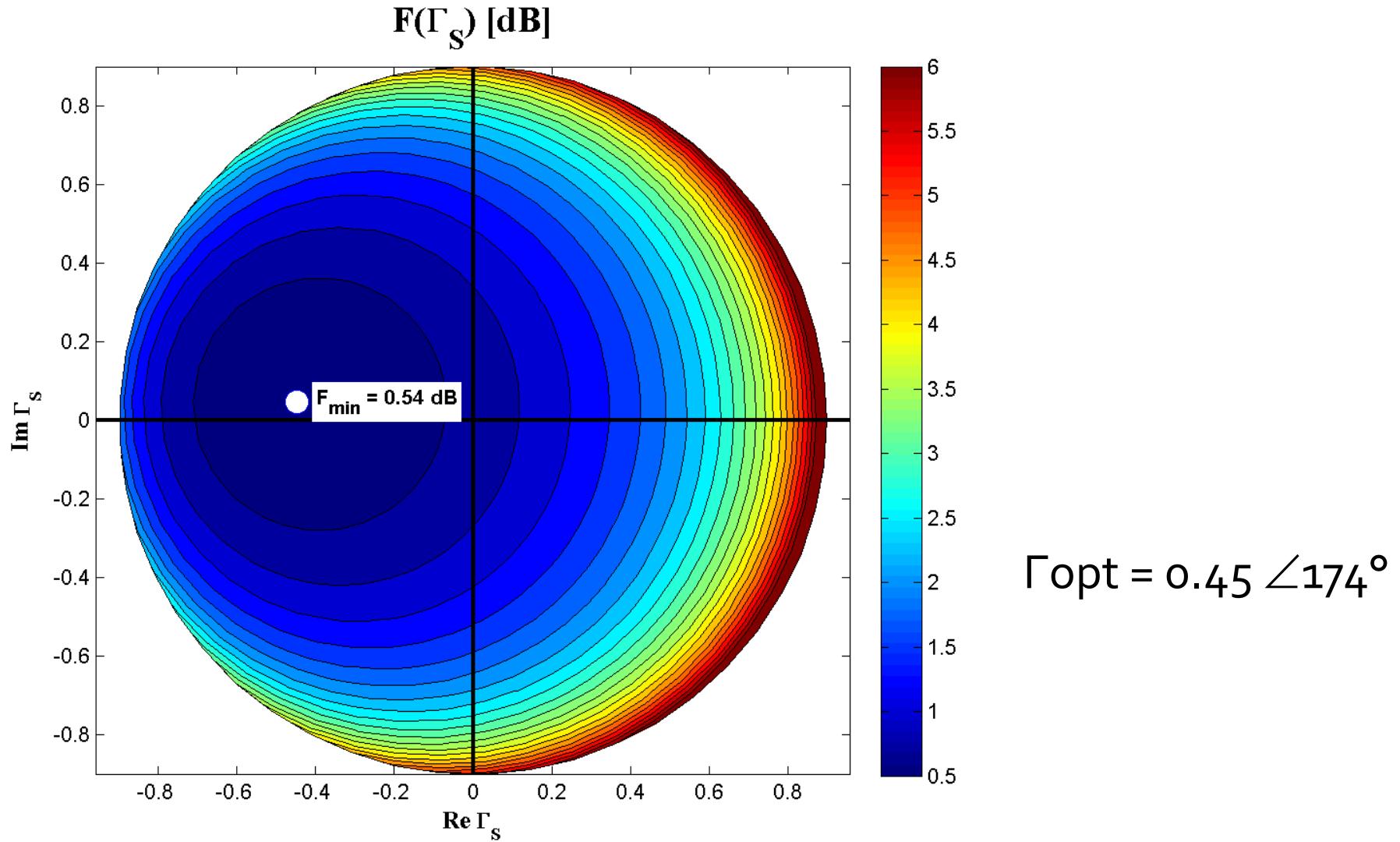
$F(\Gamma_S) [dB]$



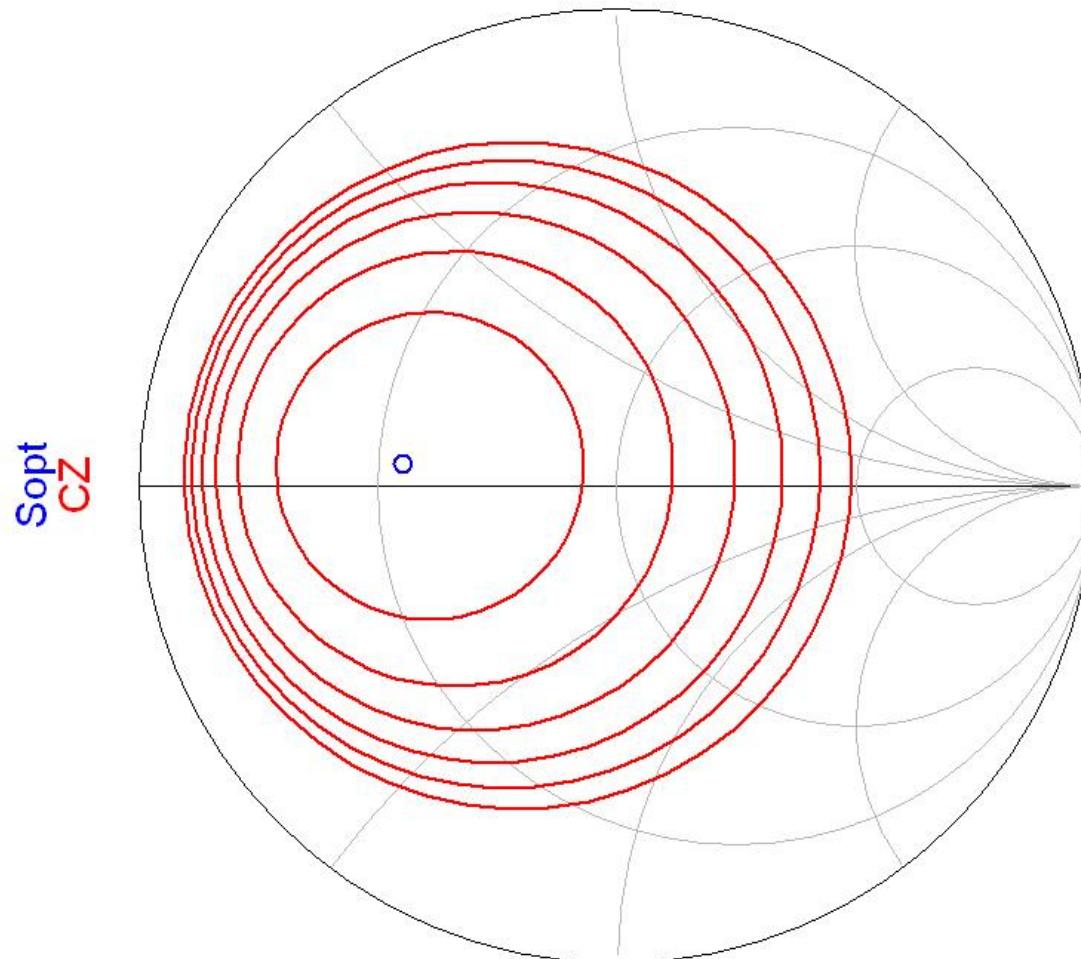
$F[dB](\Gamma_s)$, diagrama de nivel



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



CZ – numai la intrare !



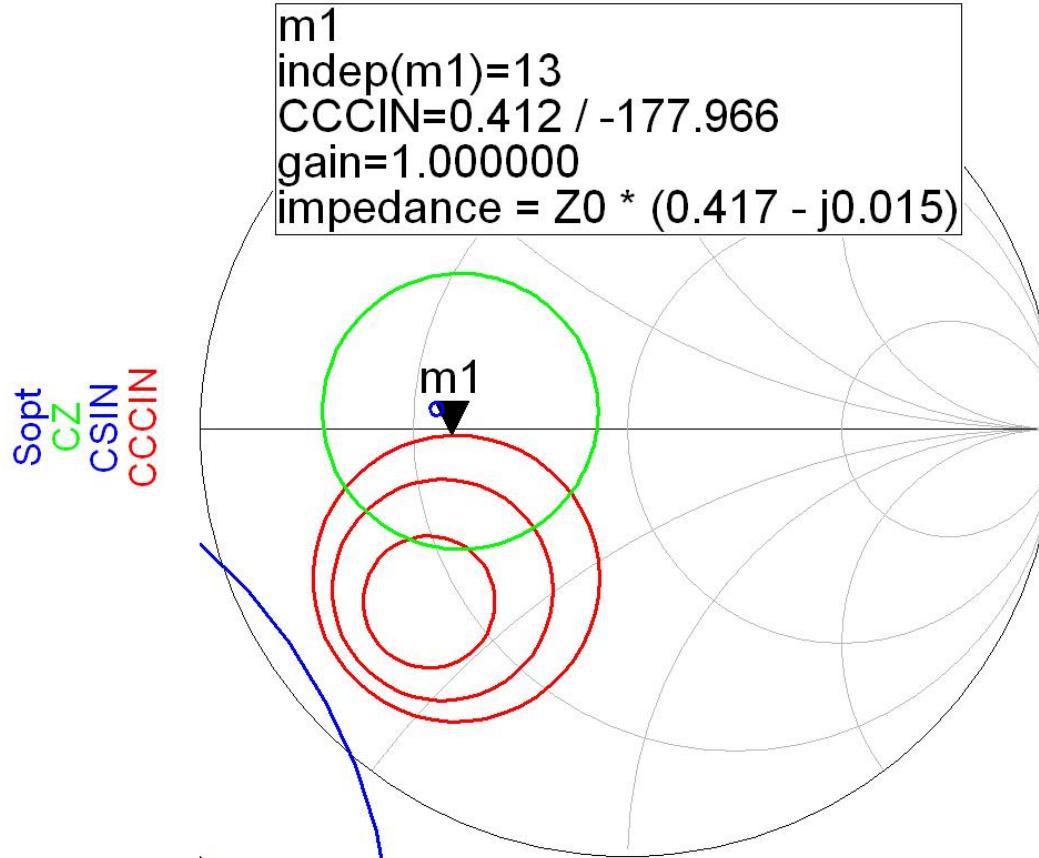
S_{CZ}^{opt}

cir_pts (0.000 to 51.000)
freq (5.000GHz to 5.000GHz)

Exemplu, LNA @ 5 GHz

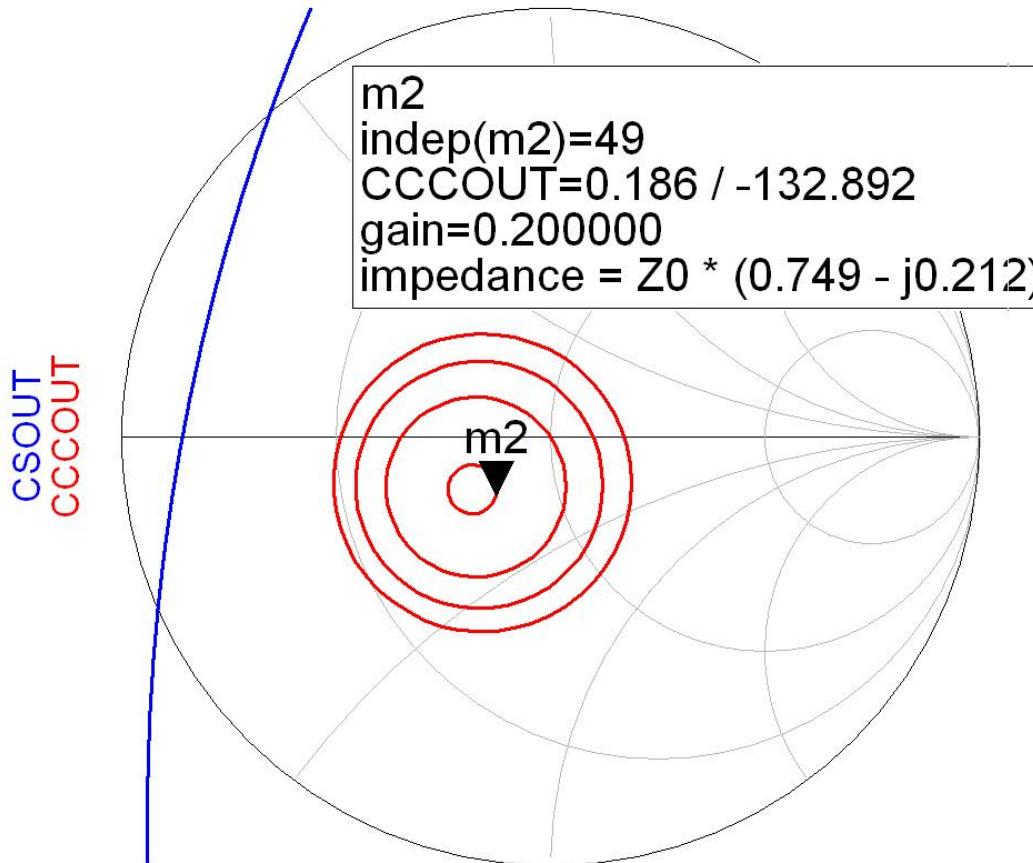
- Amplificator de zgomot redus
- La intrare e necesar un compromis intre
 - zgomot (cerc de zgomot constant ~~la intrare~~)
 - castig (cerc de castig constant la intrare)
 - stabilitate (cerc de stabilitate la intrare)
- La iesire zgomotul **nu intervine** (nu exista influenta). Compromis intre:
 - castig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

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

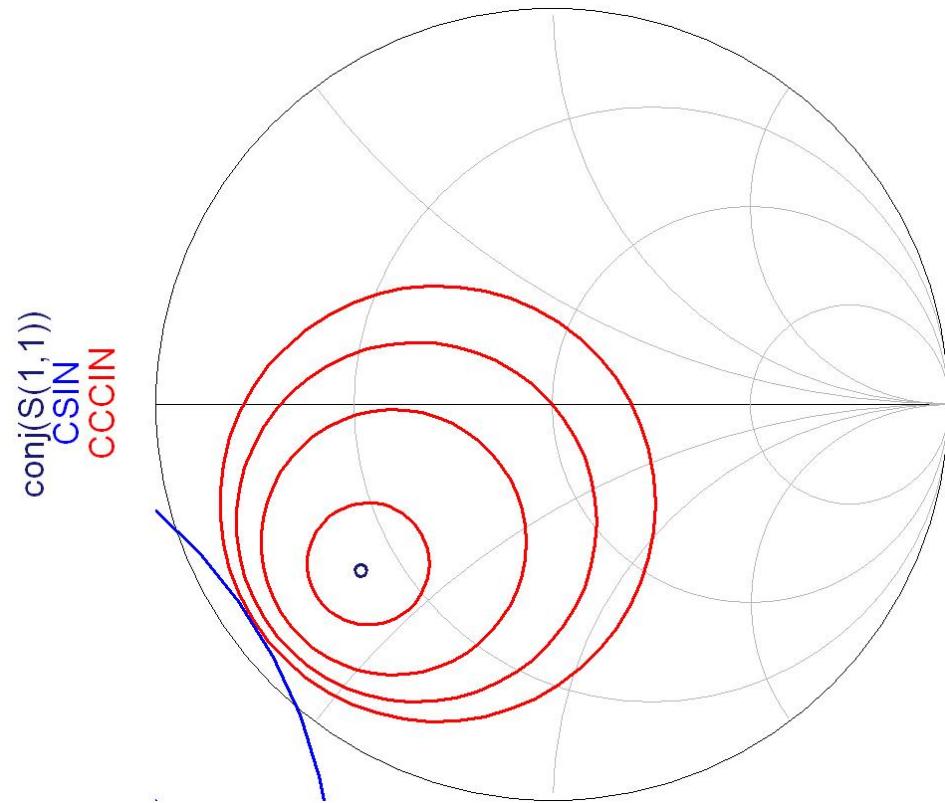
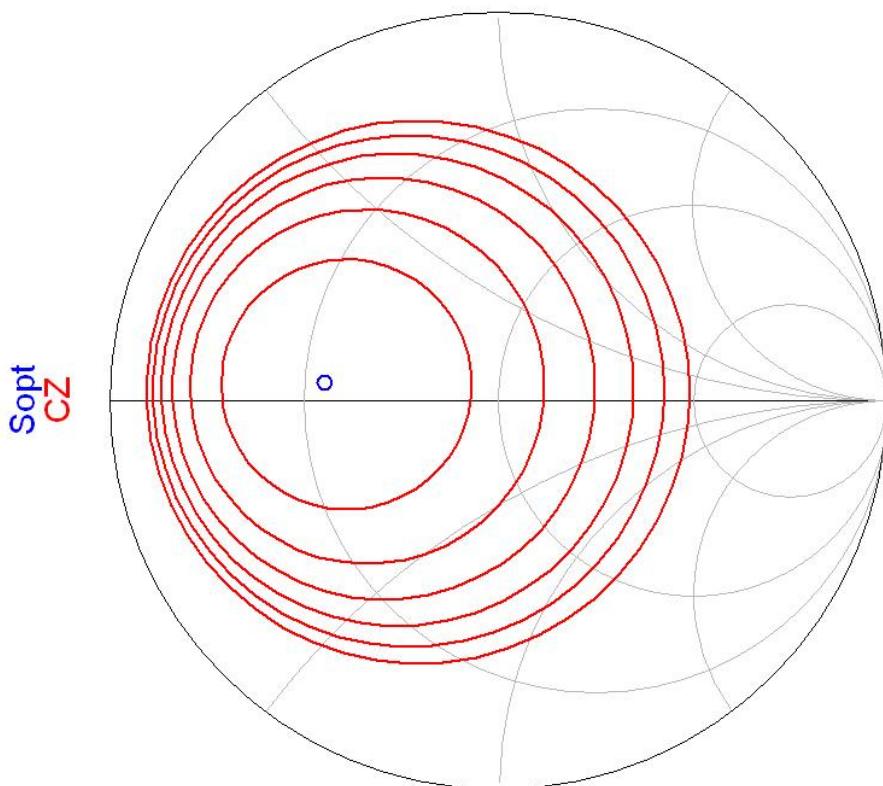
Adaptare la ieșire



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

LNA

- 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



Contact

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