

Curs 6

2017/2018

# Dispozitive și circuite de microunde pentru radiocomunicații

# Documentatie

- RF-OPTO
  - <http://rf-opto.eti.tuiasi.ro>
- Fotografie
  - de trimis prin email: [rdamian@etti.tuiasi.ro](mailto:rdamian@etti.tuiasi.ro)
  - necesara la laborator/curs

# Software

- ADS 2016
- EmPro 2015
- pe baza de IP din exterior

Date:

Grupa	5601 (2017/2018)
Specializarea	Master Retele de Comunicatii
Marca	857

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

**Note obtinute**

Disciplina	Tip	Data	Descriere	Nota	Puncte	Obs.
TMPAW	Tehnici moderne de proiectare a aplicatiilor web	N	29/05/2017	Nota finala	10	-

Nume  
MOOROUN

Email

Cod de verificare  
344bd9f

Trimite

# Software

Advanced Design System  
Premier High-Frequency and High Speed Design Platform  
2016.01

KEYSIGHT TECHNOLOGIES

© Keysight Technologies 1985-2016

JW License Setup Wizard for Advanced Design System 2016.01

Specify Remote License Server  
Enter the name of the network license server you wish to add or replace.

Advanced Design System 2016.01  
Enter the ne

Network li  Examining your license server...  
(e.g. 27001)

What is a ne  
How do I know which network license server to use?  
How do I specify a network license server name?  
Can I find out the network license server name from the license file?

Details < Back Next > Exit

Update Availability Legend: License available License in use or not available << Hide D

**ADS Inclusive**

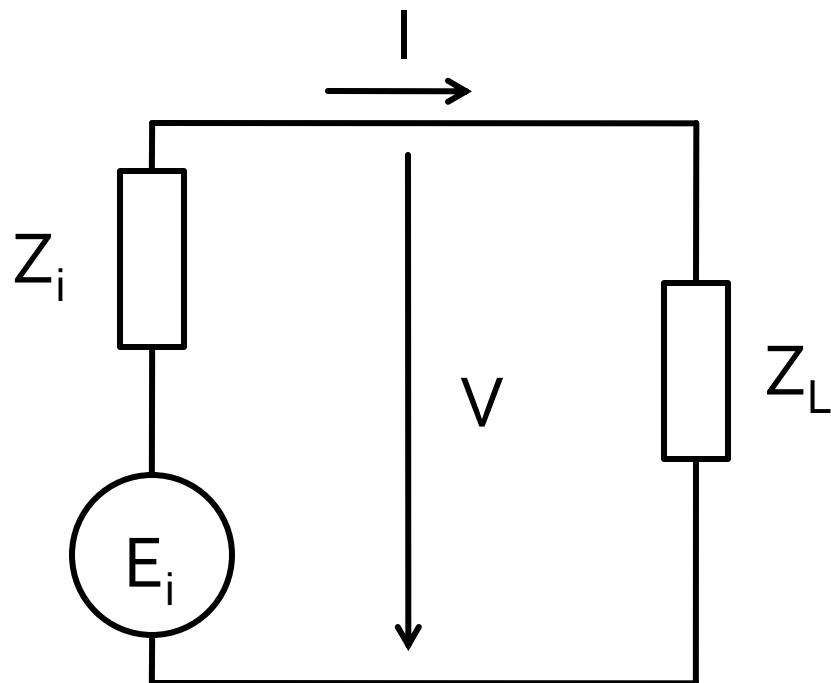
License is available

Number of licenses:  Used:  Version:  Expires:

b\_ads\_i

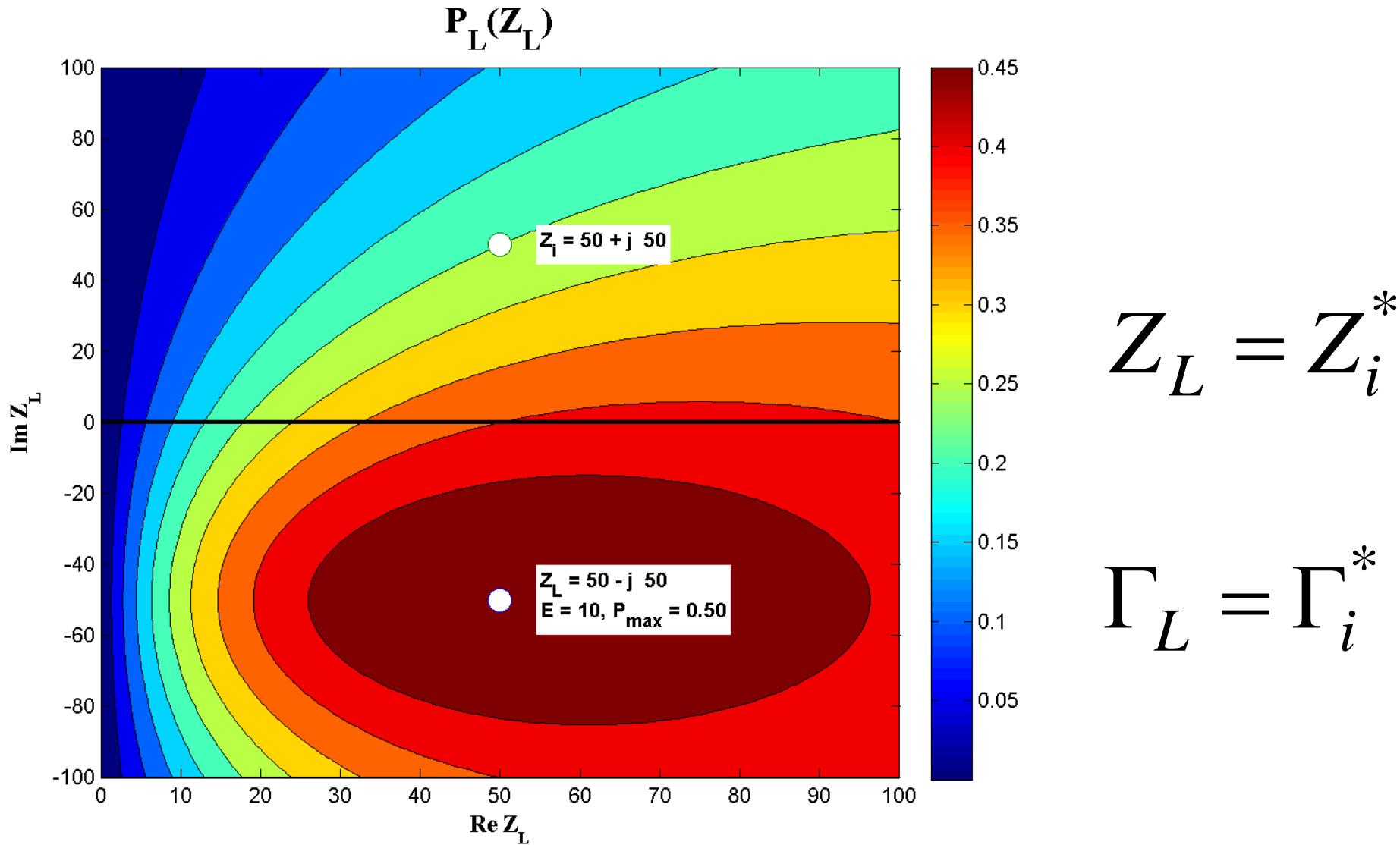
# Adaptare

- Generator adaptat la sarcina ?

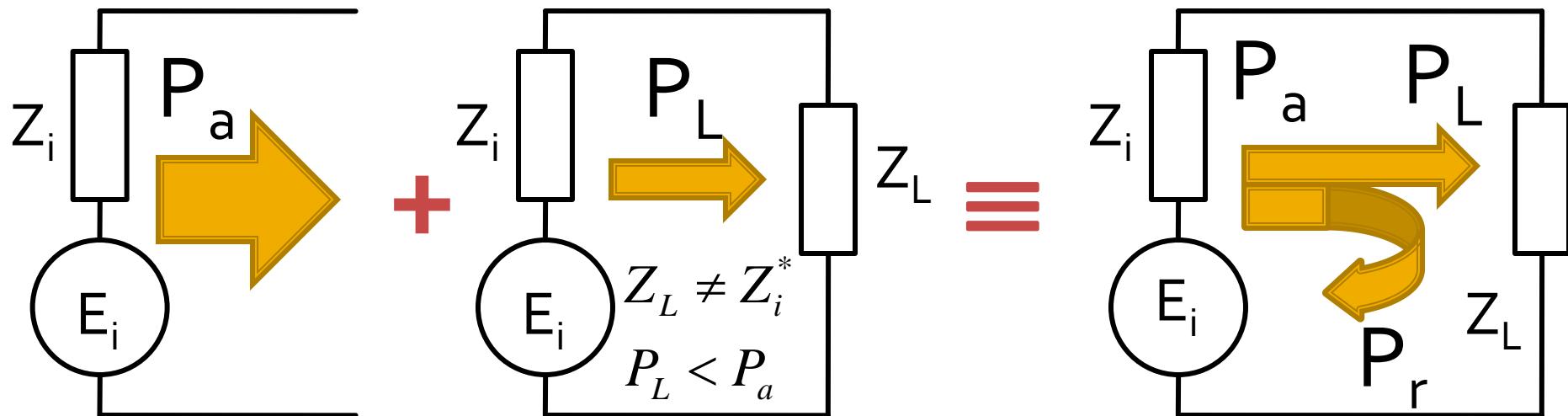


- valori impedanta ?
- reflexii ?

# Adaptare, exemplu



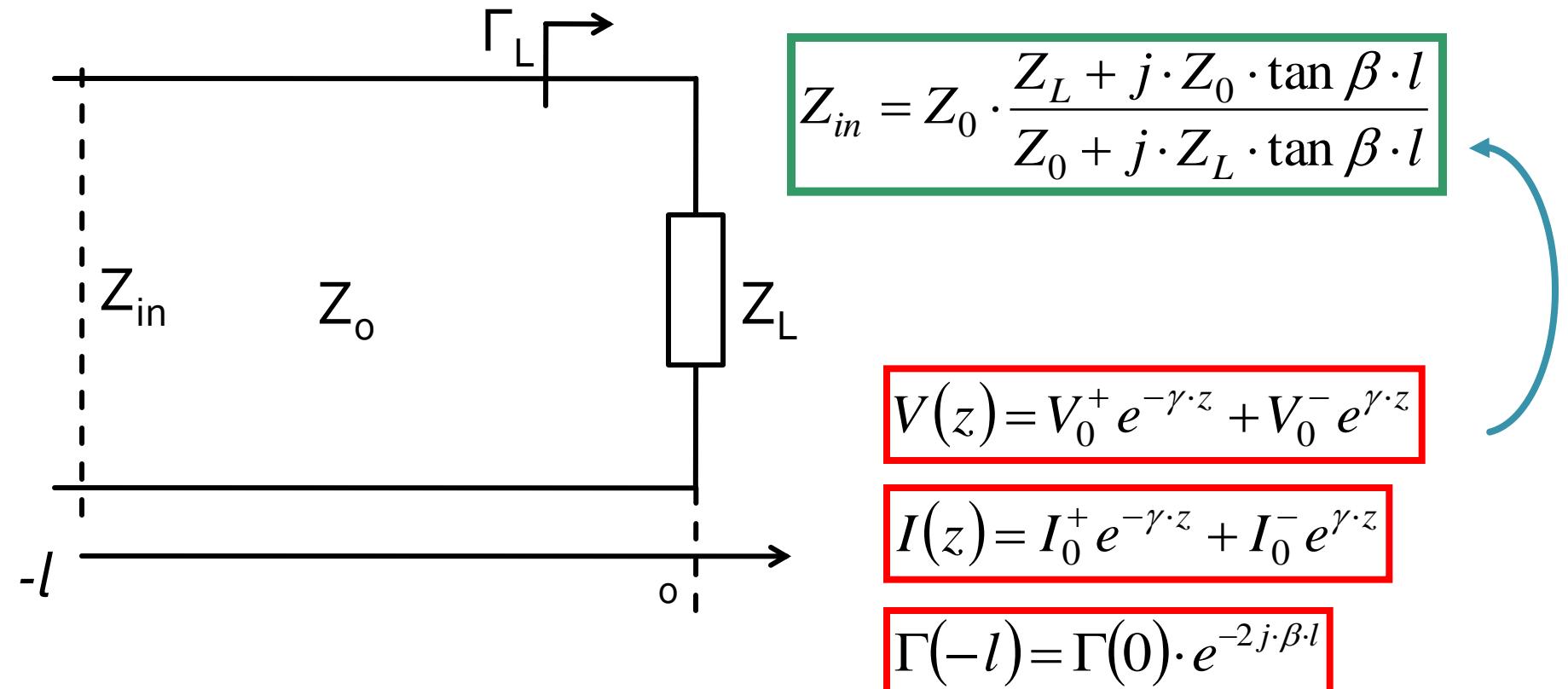
# Reflexie de putere / Model



- 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!**

# **Linii de transmisie in mod TEM**

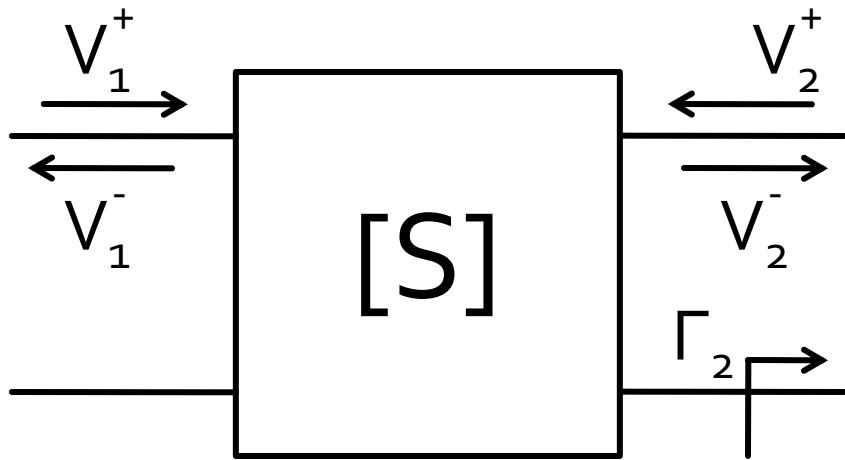
# Linie fara pierderi +/-



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

# Matricea S (repartitie)

- Scattering parameters



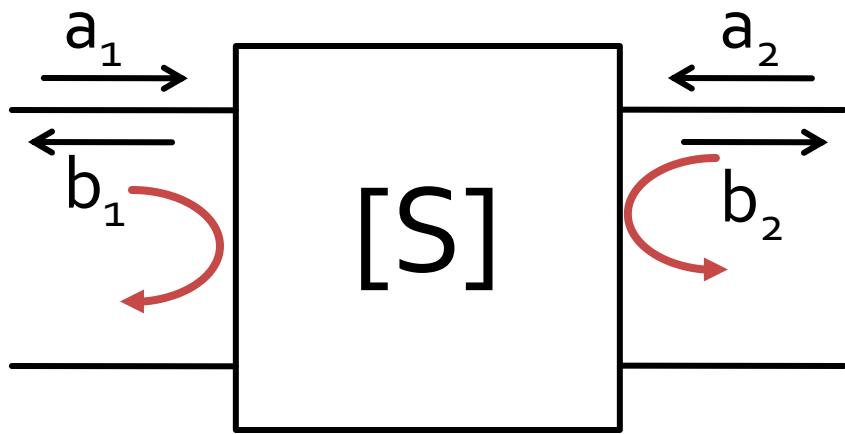
$$\begin{bmatrix} V_1^- \\ V_2^- \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} V_1^+ \\ V_2^+ \end{bmatrix}$$

$$S_{11} = \frac{V_1^-}{V_1^+} \Big|_{V_1^+=0} \quad S_{21} = \frac{V_2^-}{V_1^+} \Big|_{V_2^+=0}$$

- $V_2^+ = 0$  are semnificatia: la portul 2 este conectata impedanta care realizeaza conditia de adaptare (complex conjugat)

$$\Gamma_2 = 0 \rightarrow V_2^+ = 0$$

# Matricea S (repartitie)

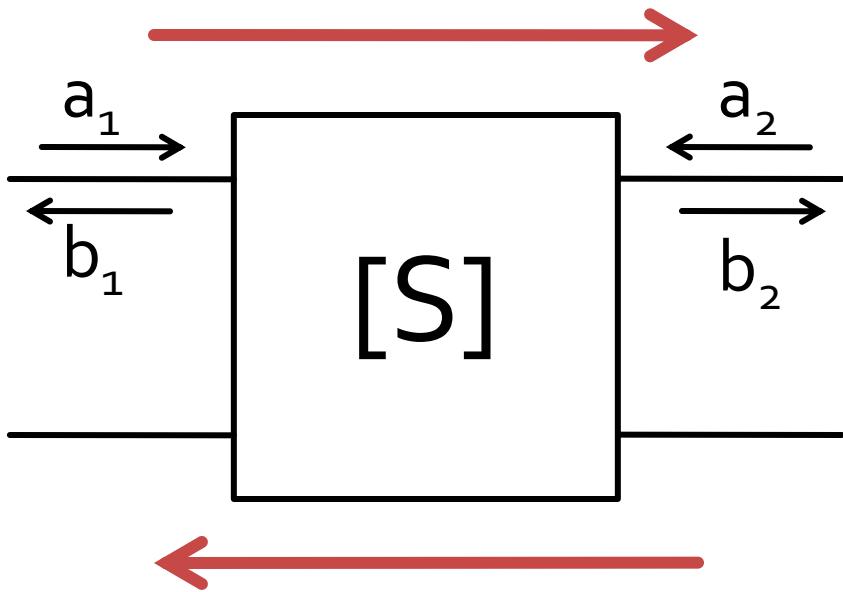


$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

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

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

# Matricea S (repartitie)



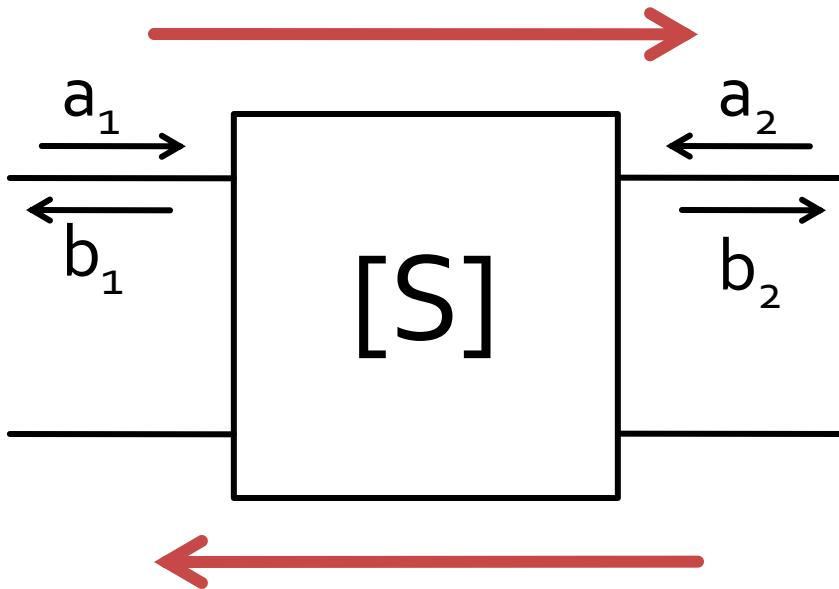
$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

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

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

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

# Matricea S (repartitie)



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

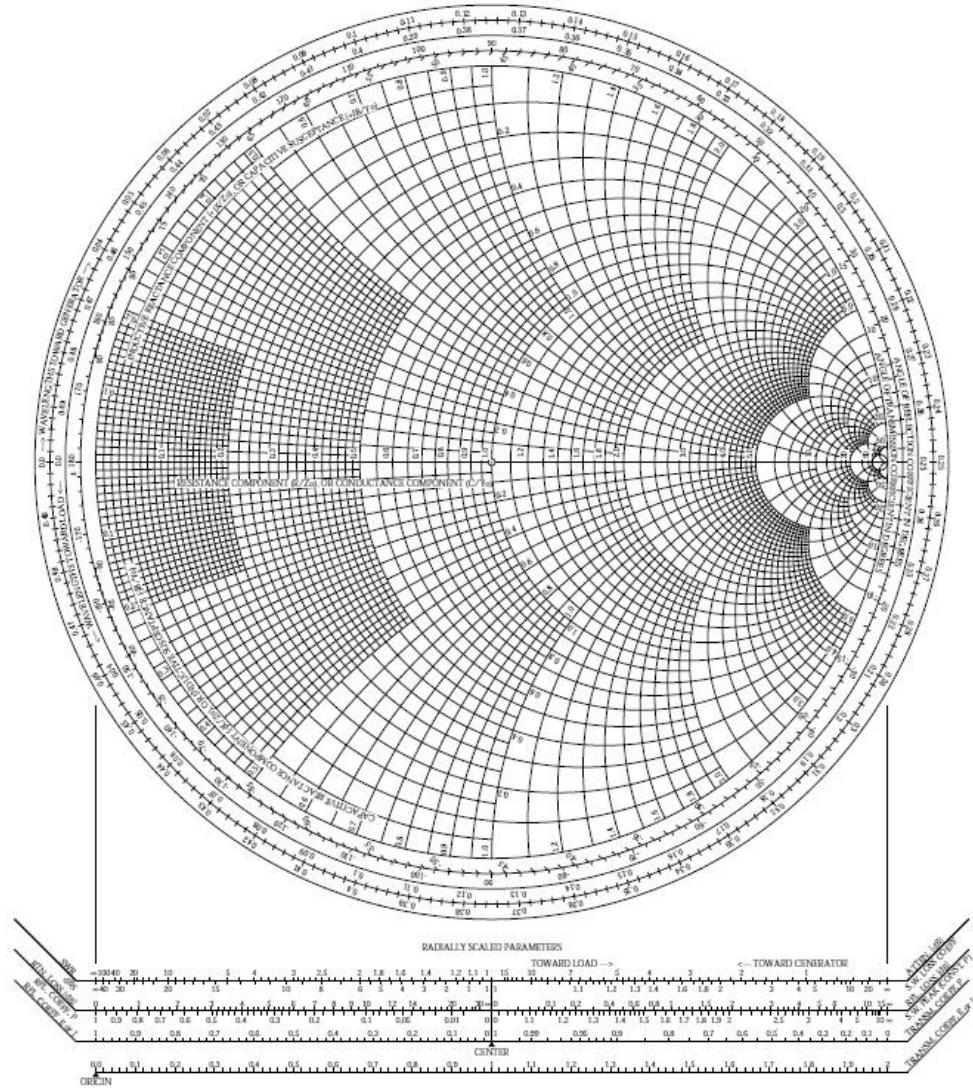
$$|S_{21}|^2 = \frac{\text{Putere sarcina } Z_0}{\text{Putere sursa } Z_0}$$

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

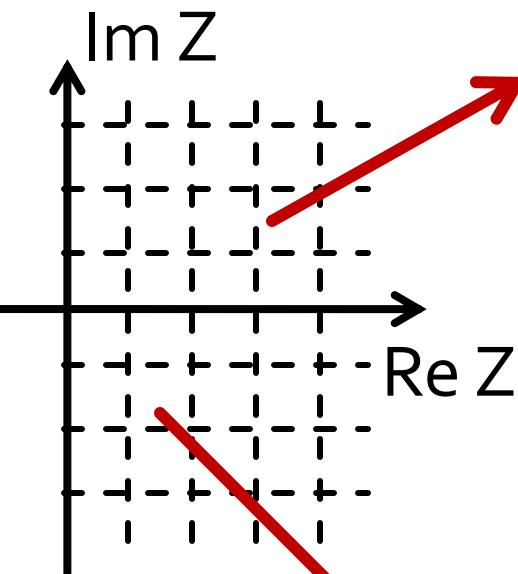
Adaptarea de impedanță

# Diagrama Smith

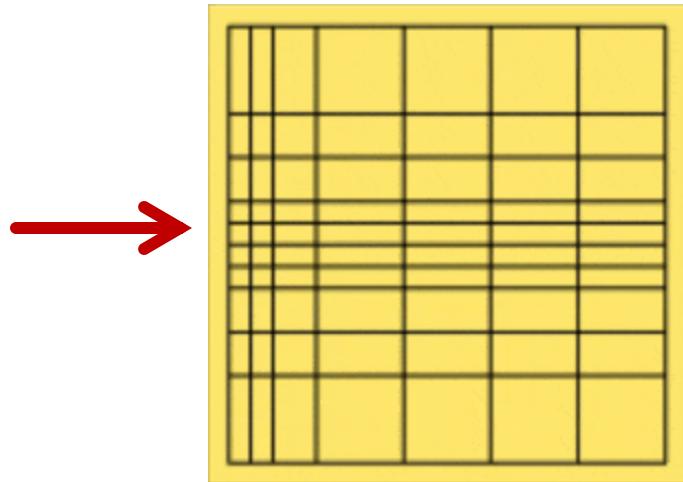
# Diagrama Smith



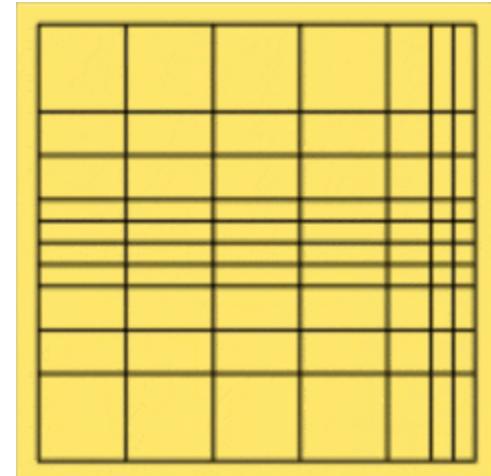
# Diagrama Smith



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

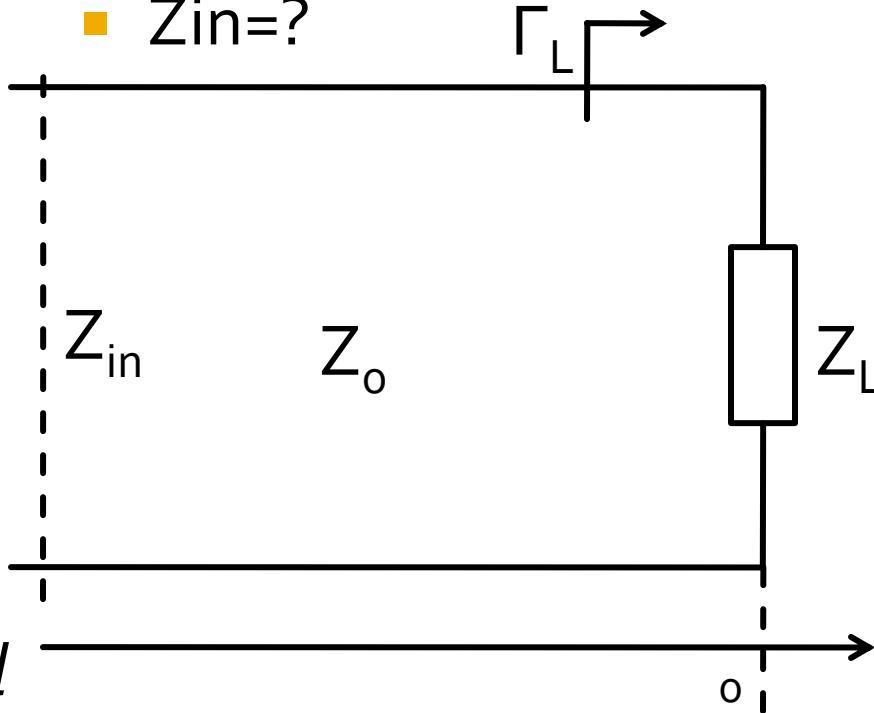


$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{Y_0 - Y_L}{Y_0 + Y_L} = \frac{1 - y_L}{1 + y_L}$$



# Exemplu

- linie de transmisie
  - $100\Omega$  impedanta caracteristica
  - $0.3\lambda$  lungime
  - $Z_L = 40\Omega + j \cdot 70\Omega$
- $Z_{in}=?$



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

$$Z_{in} = 36.5340\Omega - j \cdot 61.1190\Omega$$

# Utilizare standard

- linie de transmisie

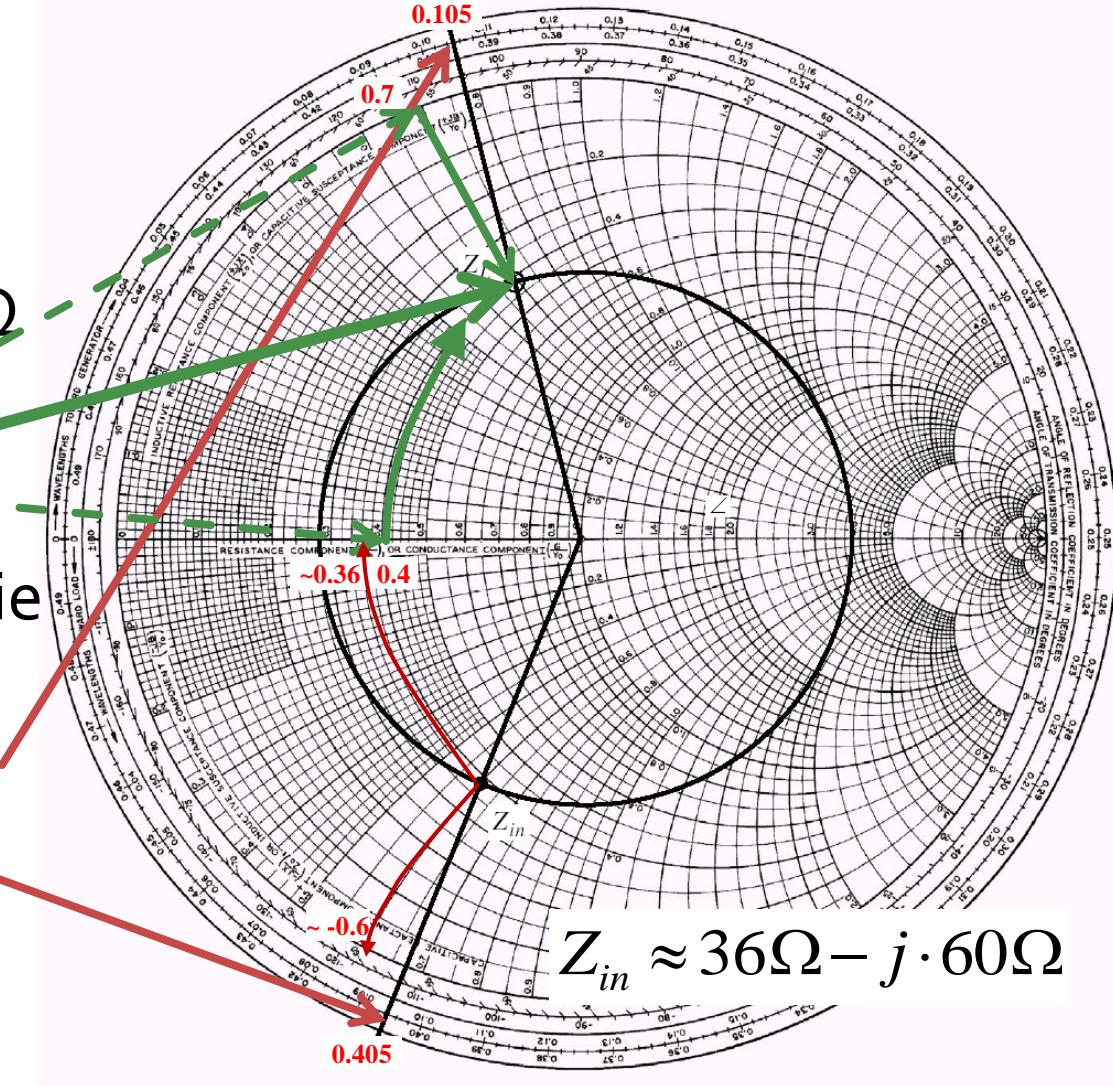
- $100\Omega$
- $0.3\lambda$  lungime
- $Z_L = 40\Omega + j \cdot 70\Omega$

$$z_L = \frac{Z_L}{Z_0} = 0.4 + j \cdot 0.7$$

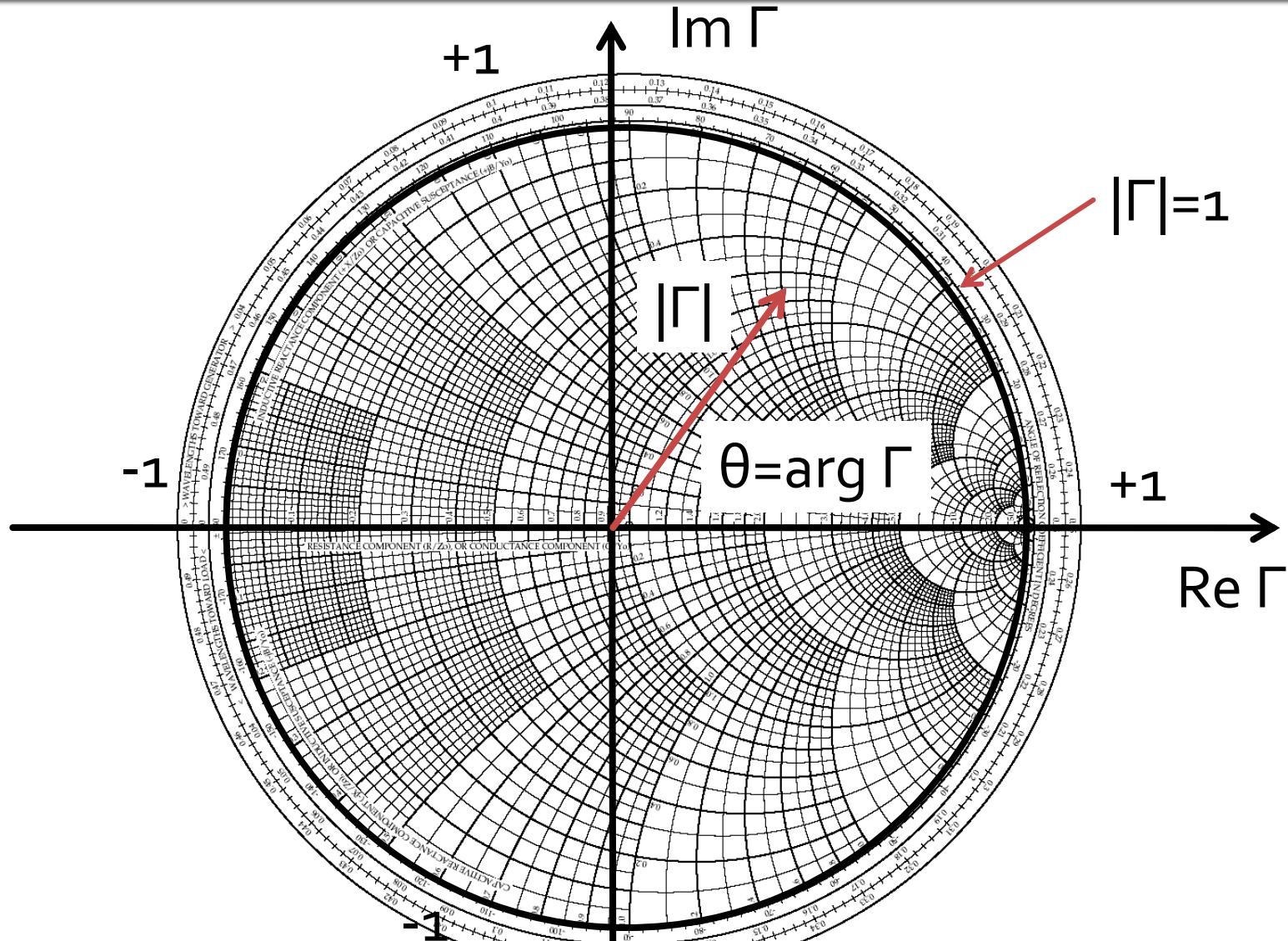
- deplasare  $0.3\lambda$  pe o linie cu  $Z_0 = 100\Omega$  (cerc)

- Plecand din  $z_L$  ( $0.105\lambda$ )
- Pana la  $z_{in}$  ( $0.405\lambda$ )

$$z_{in} \approx 0.36 - j \cdot 0.6 = \frac{Z_{in}}{Z_0}$$

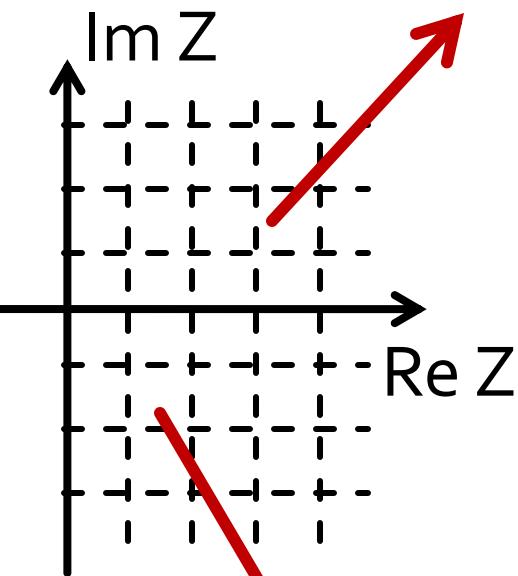


# Diagrama Smith

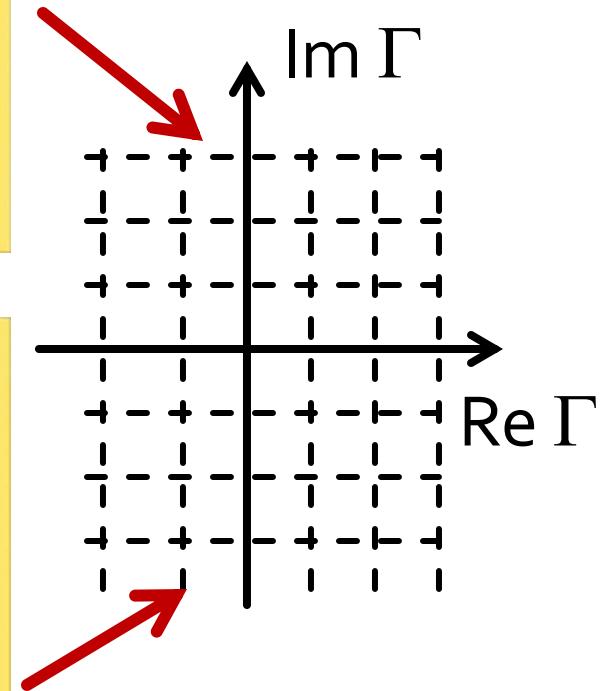
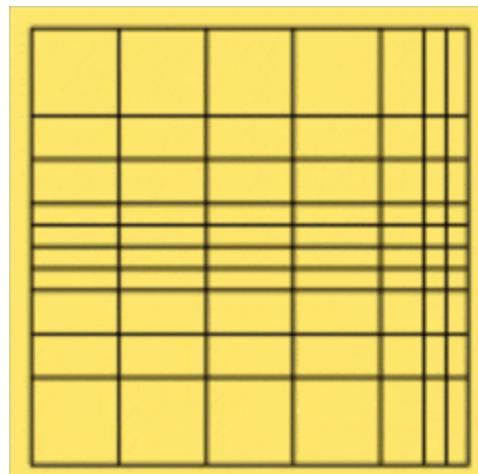
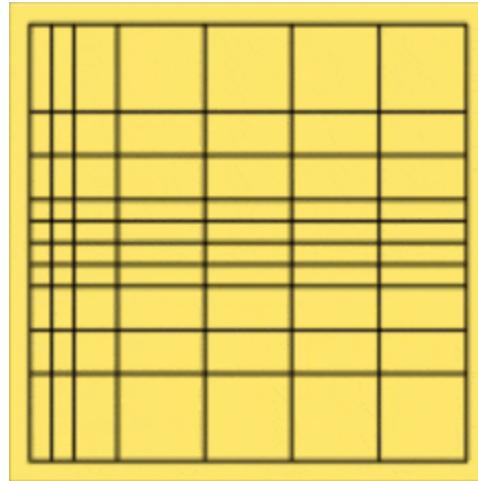


# Diagrama Smith

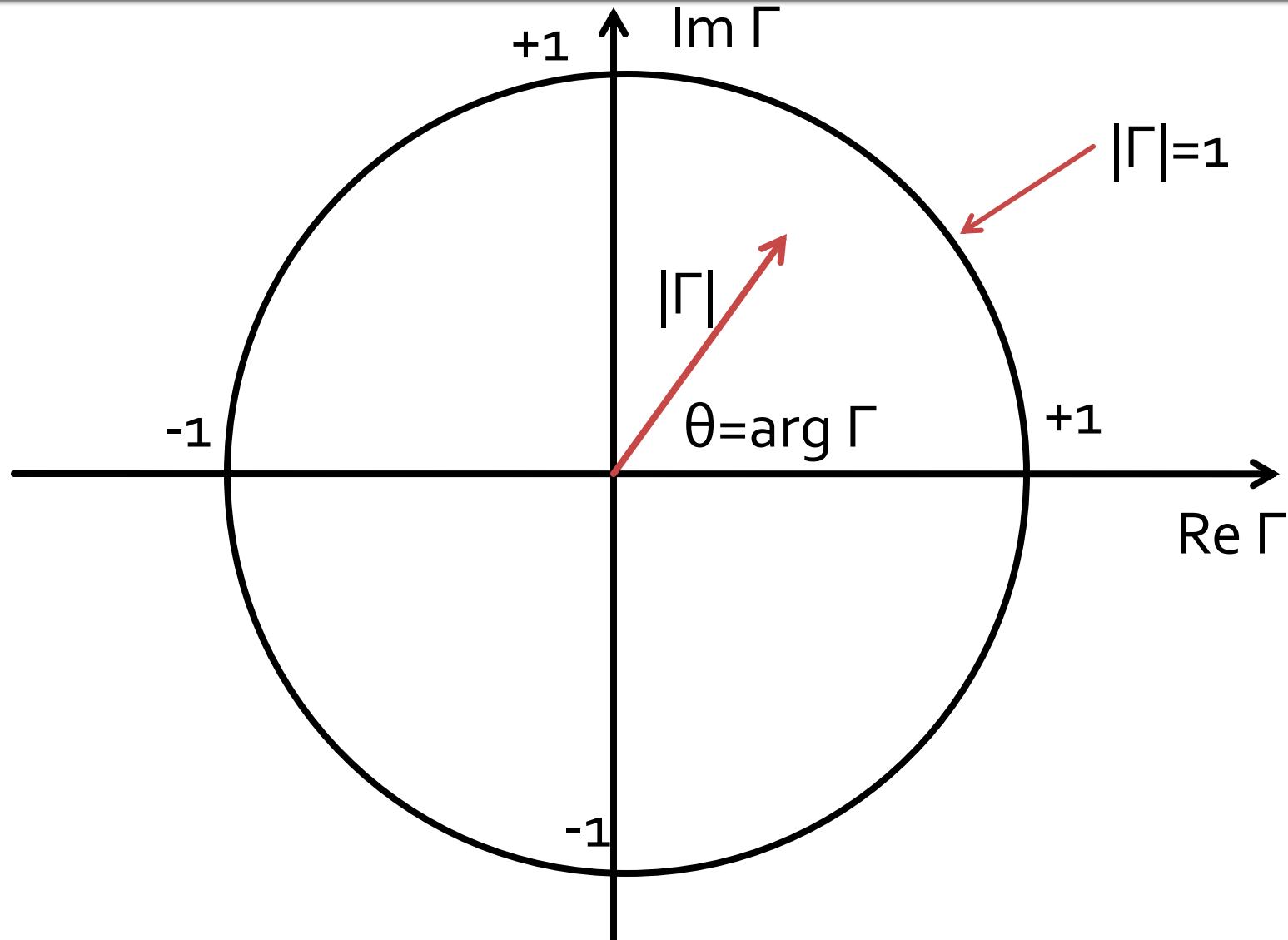
$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{z_L - 1}{z_L + 1}$$



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



# Diagrama Smith

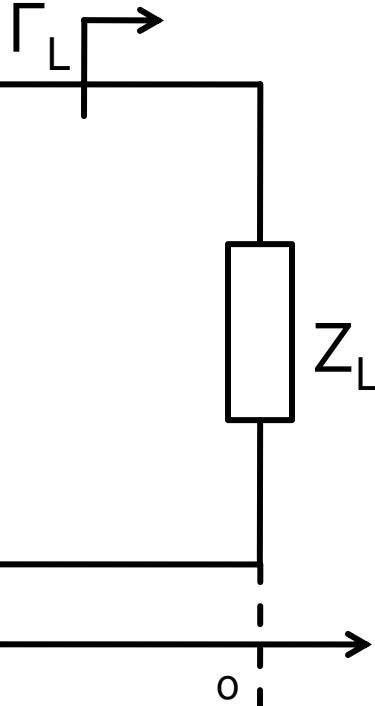


# Utilizare coeficienti de reflexie

- linie de transmisie

- $100\Omega$  impedanta caracteristica
- $0.3\lambda$  lungime
- $Z_L = 40\Omega + j \cdot 70\Omega$

■  $Z_{in}=?$



$$z_L = \frac{Z_L}{Z_0} = 0.4 + j \cdot 0.7$$

$$\Gamma_L = \frac{z_L - 1}{z_L + 1} = -0.143 + j \cdot 0.571$$

$$\Gamma_{in} = \Gamma_L \cdot e^{-2j \cdot \beta \cdot l} = \Gamma_L \cdot e^{-2j \cdot \frac{2\pi}{\lambda} \cdot 0.3\lambda} = \Gamma_L \cdot e^{-1.2j \cdot \pi}$$

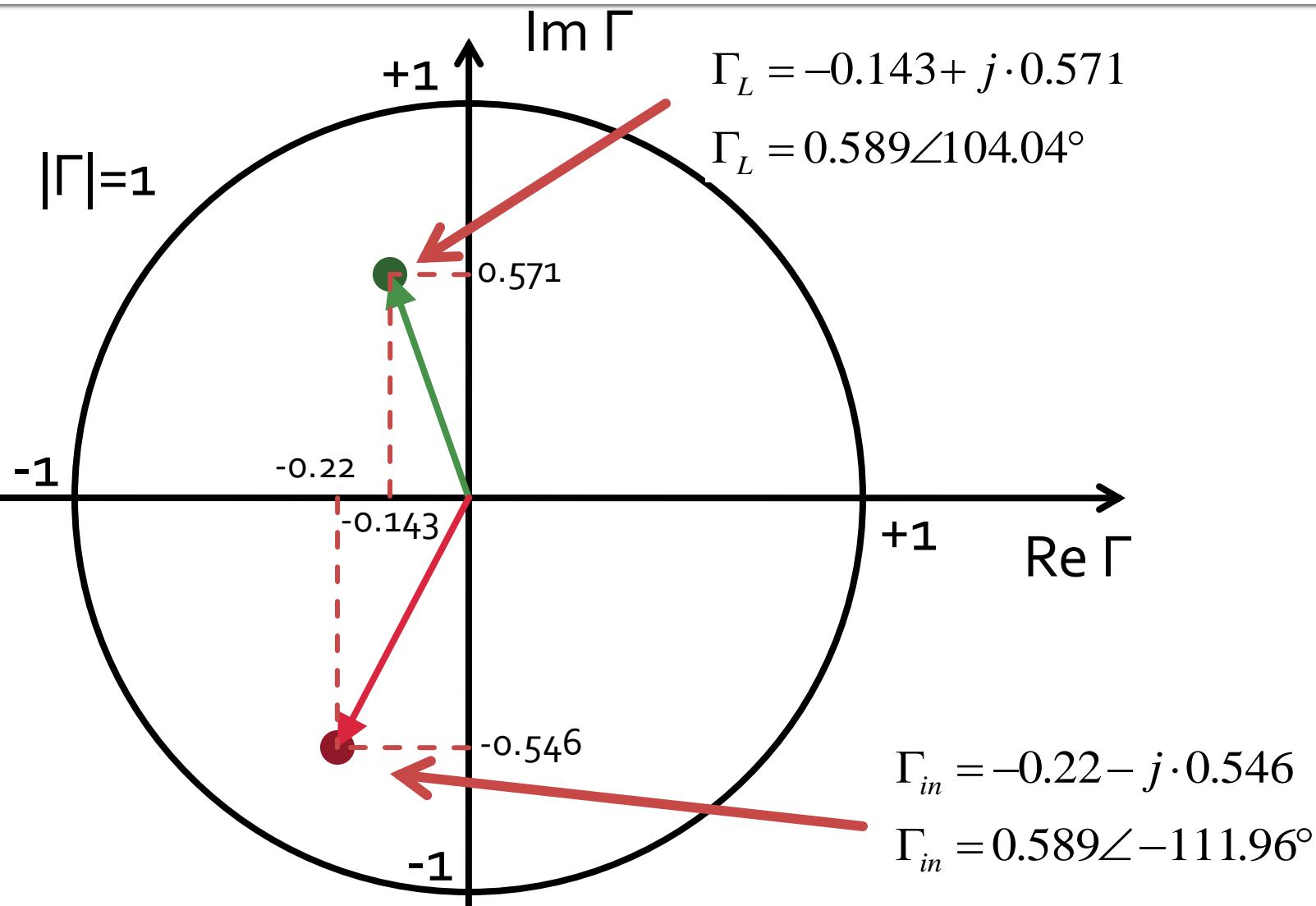
$$\theta = -1.2 \cdot \pi = -216^\circ$$

$$\begin{aligned} \Gamma_{in} &= \Gamma_L \cdot (\cos 216^\circ - j \cdot \sin 216^\circ) = \\ &= -0.22 - j \cdot 0.546 \end{aligned}$$

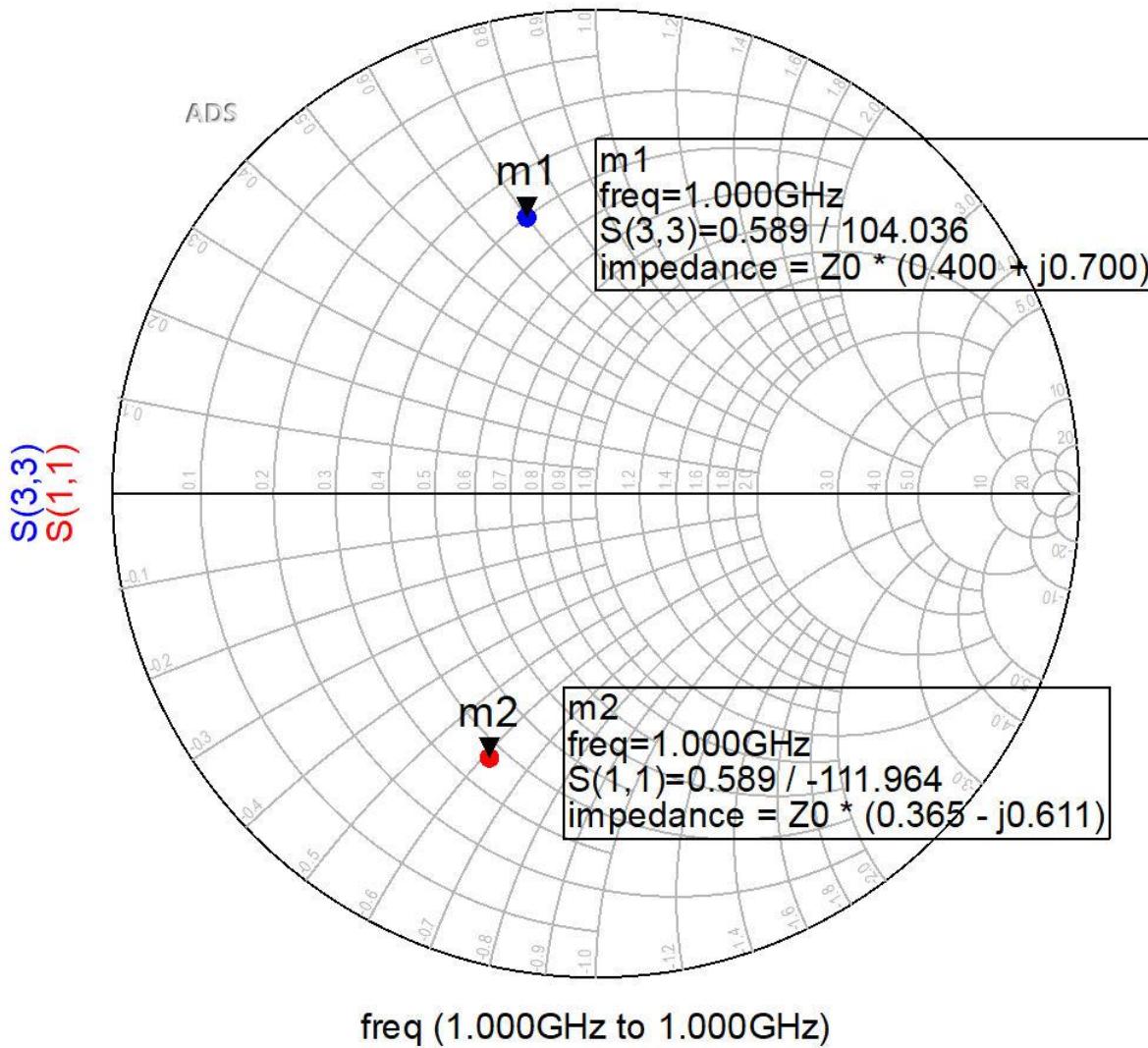
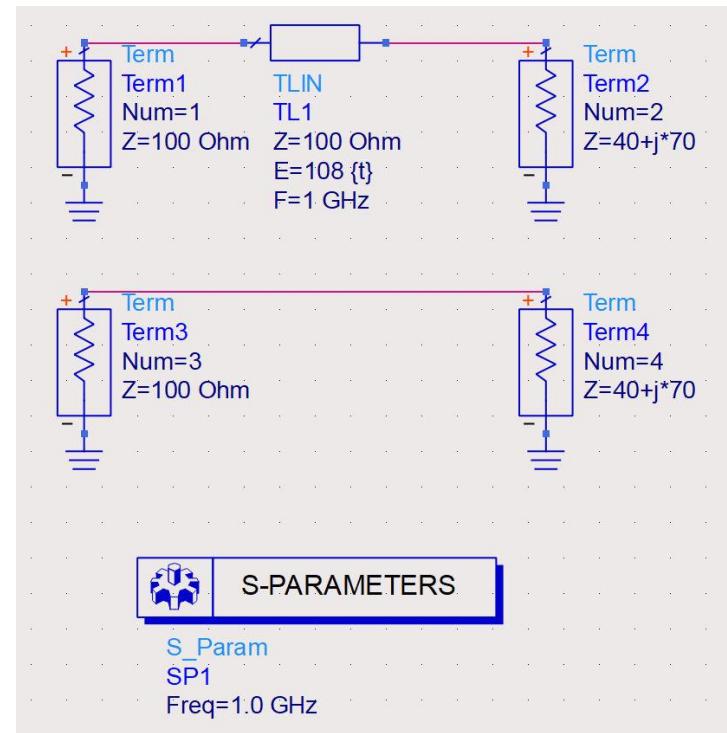
$$z_{in} = \frac{1 + \Gamma_{in}}{1 - \Gamma_{in}} = 0.365 - j \cdot 0.611$$

$$Z_{in} = z_{in} \cdot Z_0 = 36.534\Omega - j \cdot 61.119\Omega$$

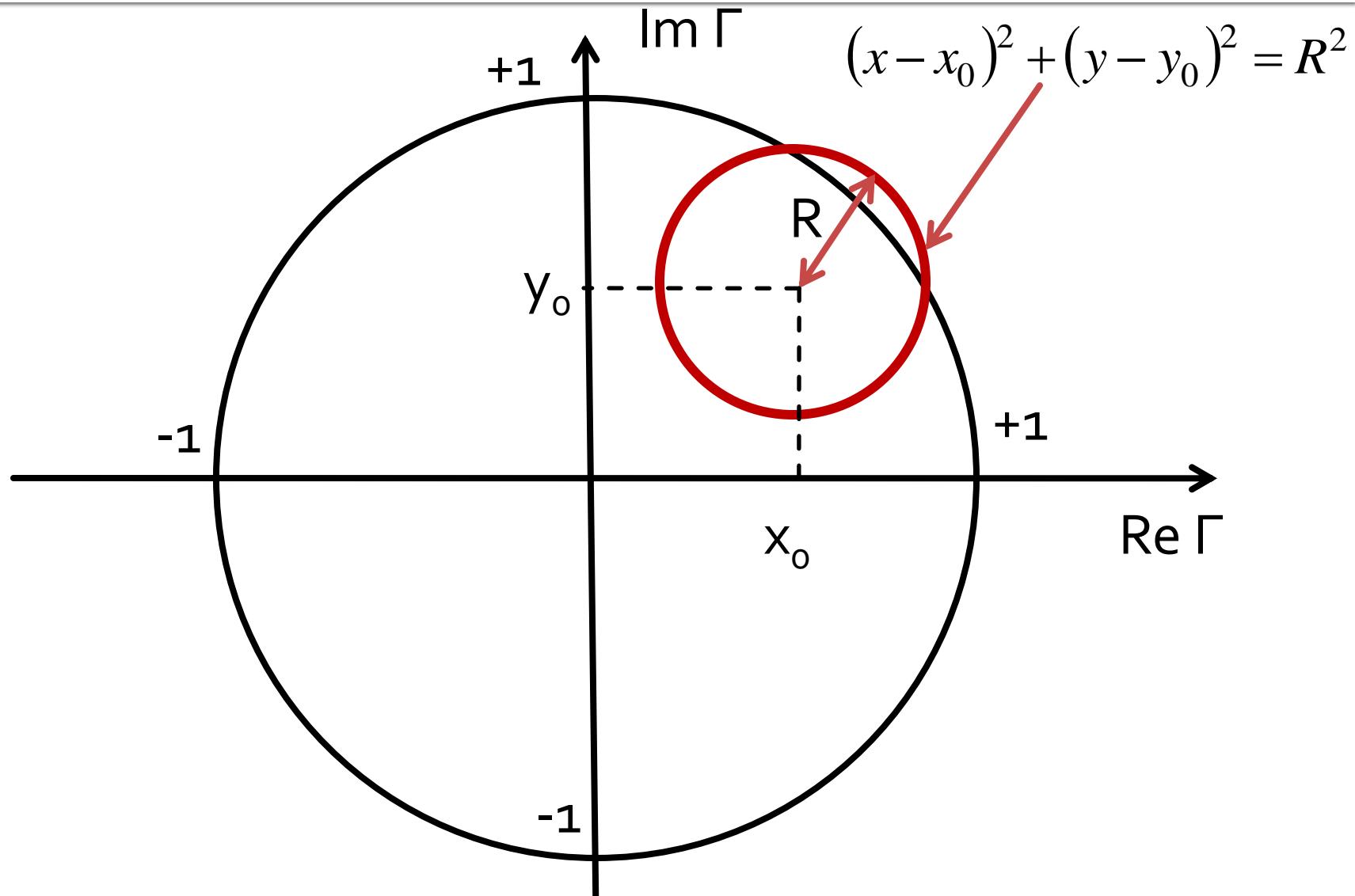
# Utilizare coeficienti de reflexie



# ADS, simulare



# Diagrama Smith



# Diagrama Smith, rezistenta


$$\left( \Gamma_r - \frac{r_L}{1+r_L} \right)^2 + \Gamma_i^2 = \left( \frac{1}{1+r_L} \right)^2$$
$$(x-x_0)^2 + (y-y_0)^2 = R^2$$

$$\begin{cases} x_0 = \frac{r_L}{1+r_L} \\ y_0 = 0 \\ R = \frac{1}{1+r_L} \end{cases}$$

- Locul geometric al punctelor care pot fi ocupate de impedantele cu rezistenta  $r_L$  este un cerc:

- Cu **centrul pe axa reală** ( $y_0=0$ )

- trece prin punctul  **$x=1, y=0$**  oricare  $x_0, r_L$   $\left(1 - \frac{r_L}{1+r_L}\right)^2 + 0 = \left(\frac{1}{1+r_L}\right)^2$

- are raza intre 0 si 1

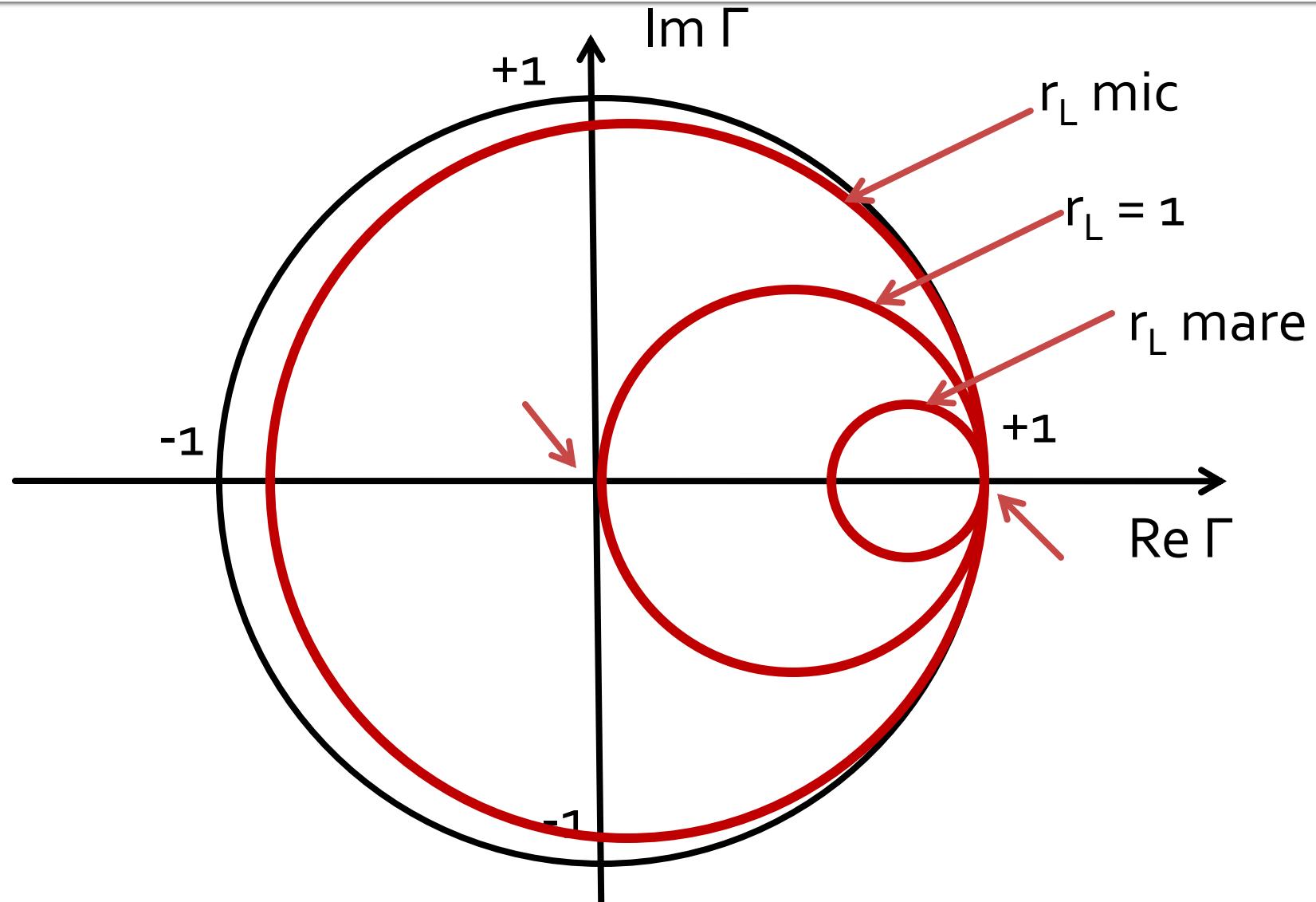
- tinzand spre 0 cand  $r_L$  este mare

- tinzand spre 1 cand  $r_L$  este mic

- cand  $r_L$  este **1** trece si prin **origine**

$$\left(0 - \frac{r_L}{1+r_L}\right)^2 = \left(\frac{1}{1+r_L}\right)^2 \Leftrightarrow r_L = 1$$

# Diagrama Smith, rezistenta



# Diagrama Smith, reactanta

$$\text{Circumlocution: } (\Gamma_r - 1)^2 + \left( \Gamma_i - \frac{1}{x_L} \right)^2 = \left( \frac{1}{x_L} \right)^2$$

$$\text{Circumlocution: } (x - x_0)^2 + (y - y_0)^2 = R^2$$

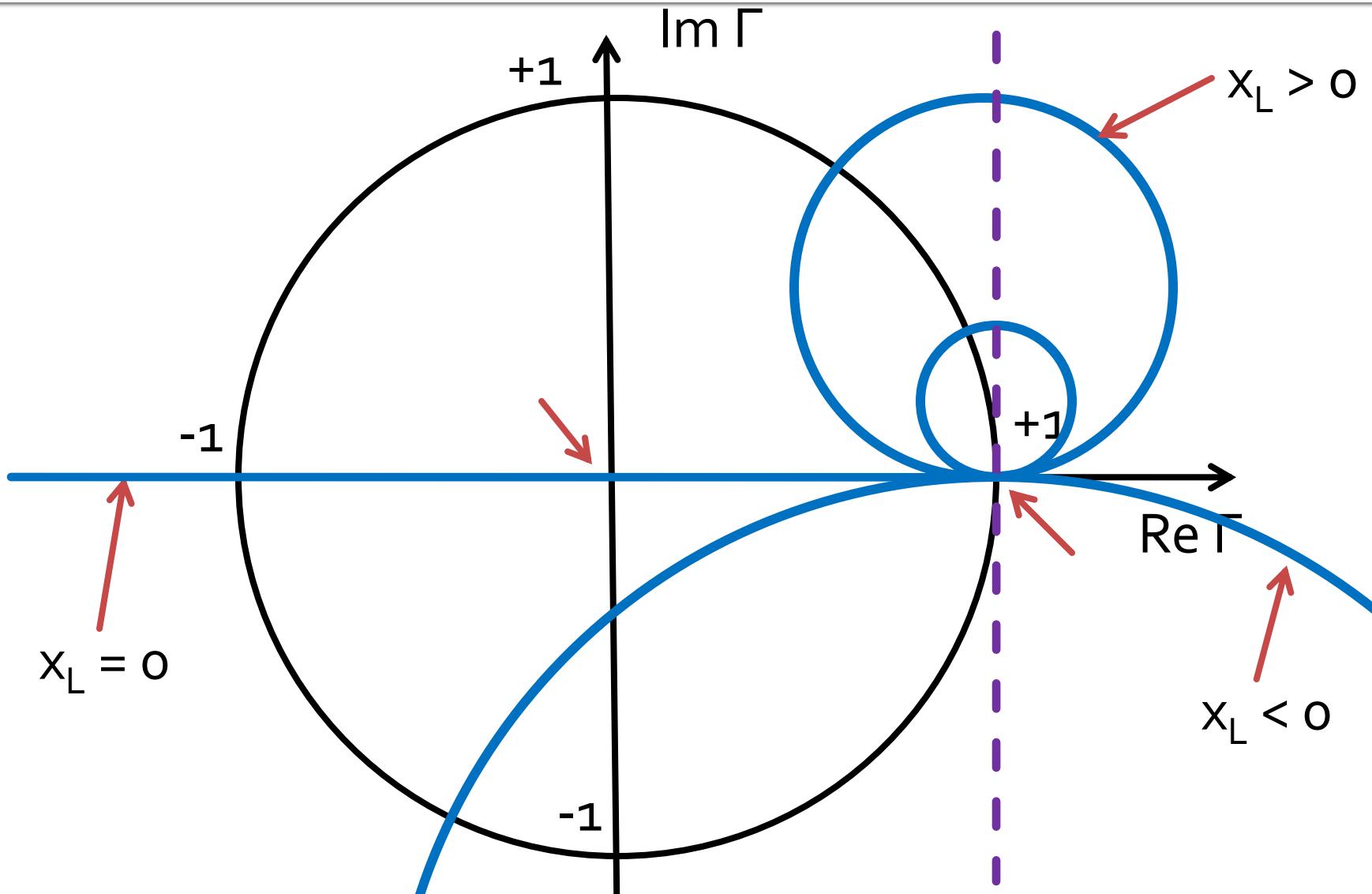
$$\begin{cases} x_0 = 1 \\ y_0 = \frac{1}{x_L} \\ R = \frac{1}{x_L} \end{cases}$$

- Locul geometric al punctelor care pot fi ocupate de impedantele cu reactanta  $x_L$  este un cerc:

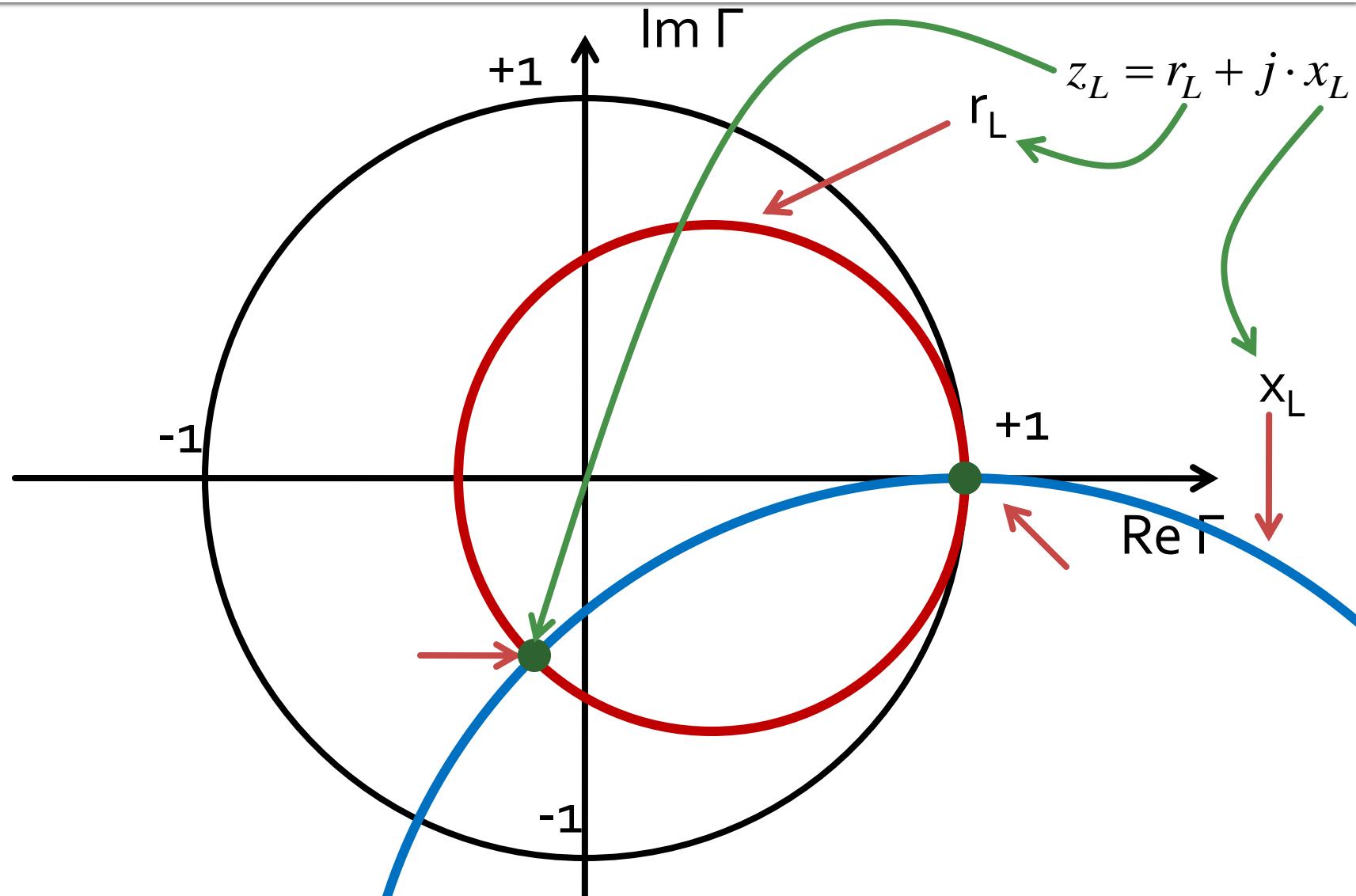
- Cu **centrul pe o dreapta paralela cu axa imaginara** ( $x_0=1$ )
- trece prin punctul  **$x=1, y=0$**  oricare  $x_0, x_L$
- are raza intre 0 si  $\infty$ 
  - tinzand spre 0 cand  $|x_L|$  este mare
  - tinzand spre  $\infty$  cand  $|x_L|$  este mic
- cand  $x_L$  este **0**, la limita se transforma in **axa reala**
- daca  $x_L > 0$  cercul e deasupra axei reale, altfel e sub axa reala

$$0 + \left( 0 - \frac{1}{x_L} \right)^2 = \left( \frac{1}{x_L} \right)^2$$

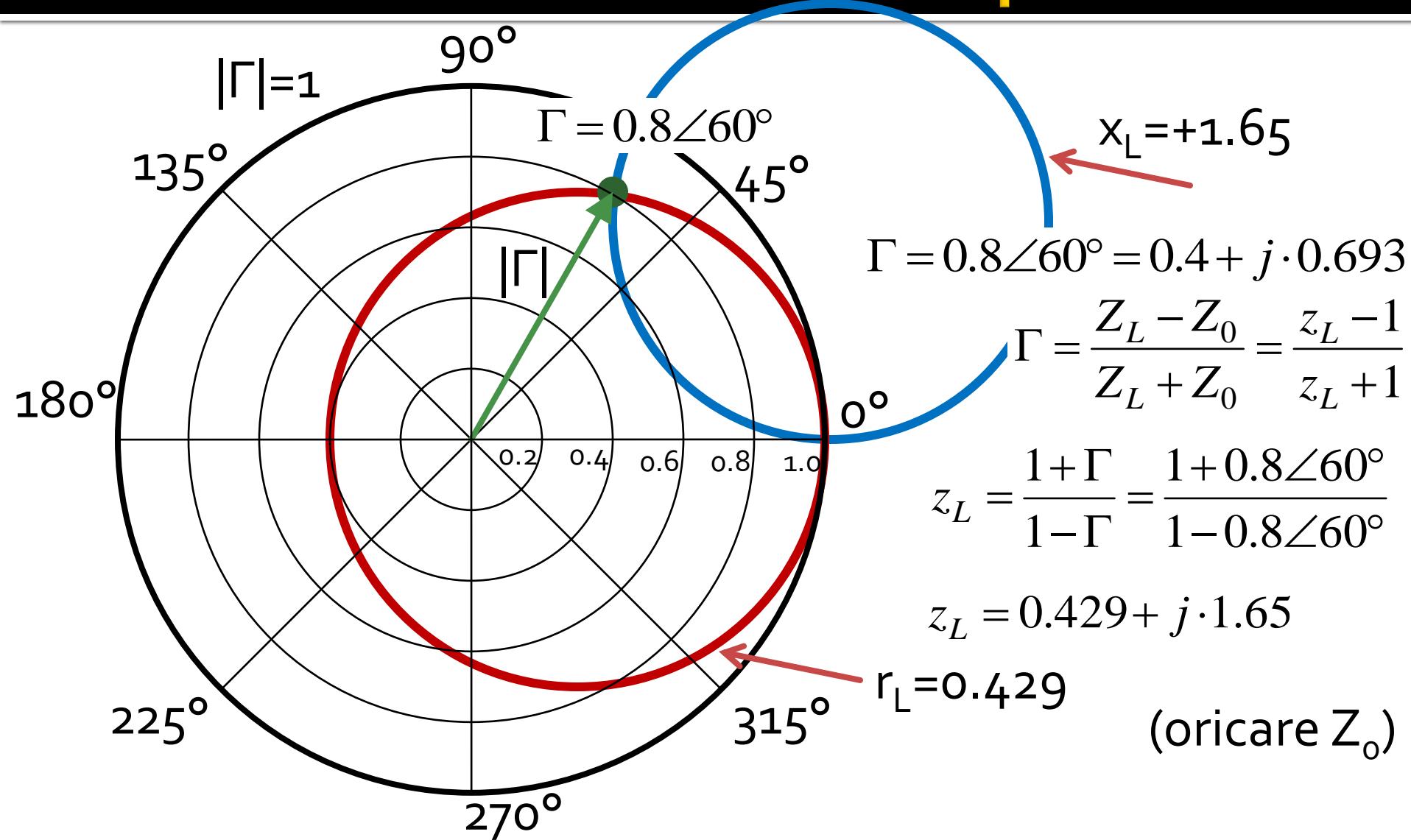
# Diagrama Smith, reactanta



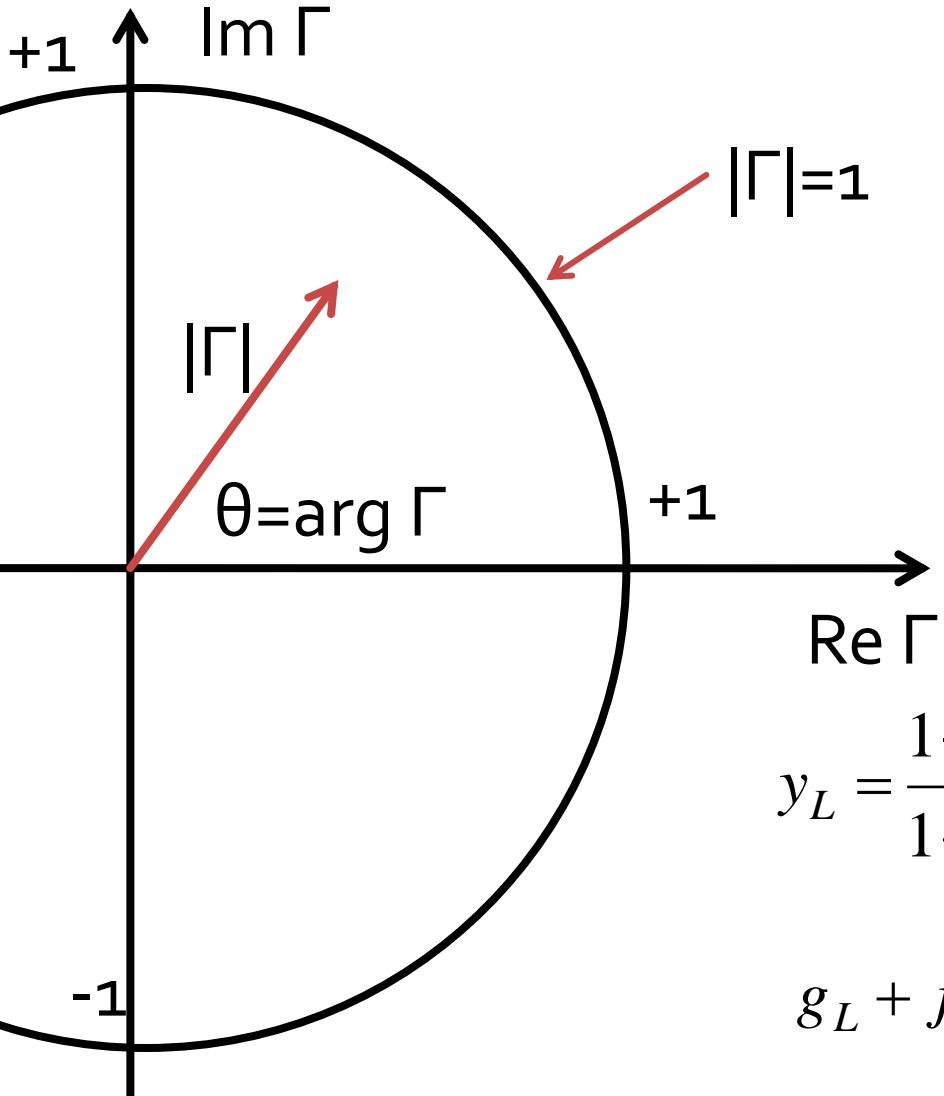
# Diagrama Smith, impedanta



# Echivalenta coeficient de reflexie $\Leftrightarrow$ impedanta



# Diagramma Smith, admitante



$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{z_L - 1}{z_L + 1} = |\Gamma| \cdot e^{j\theta}$$

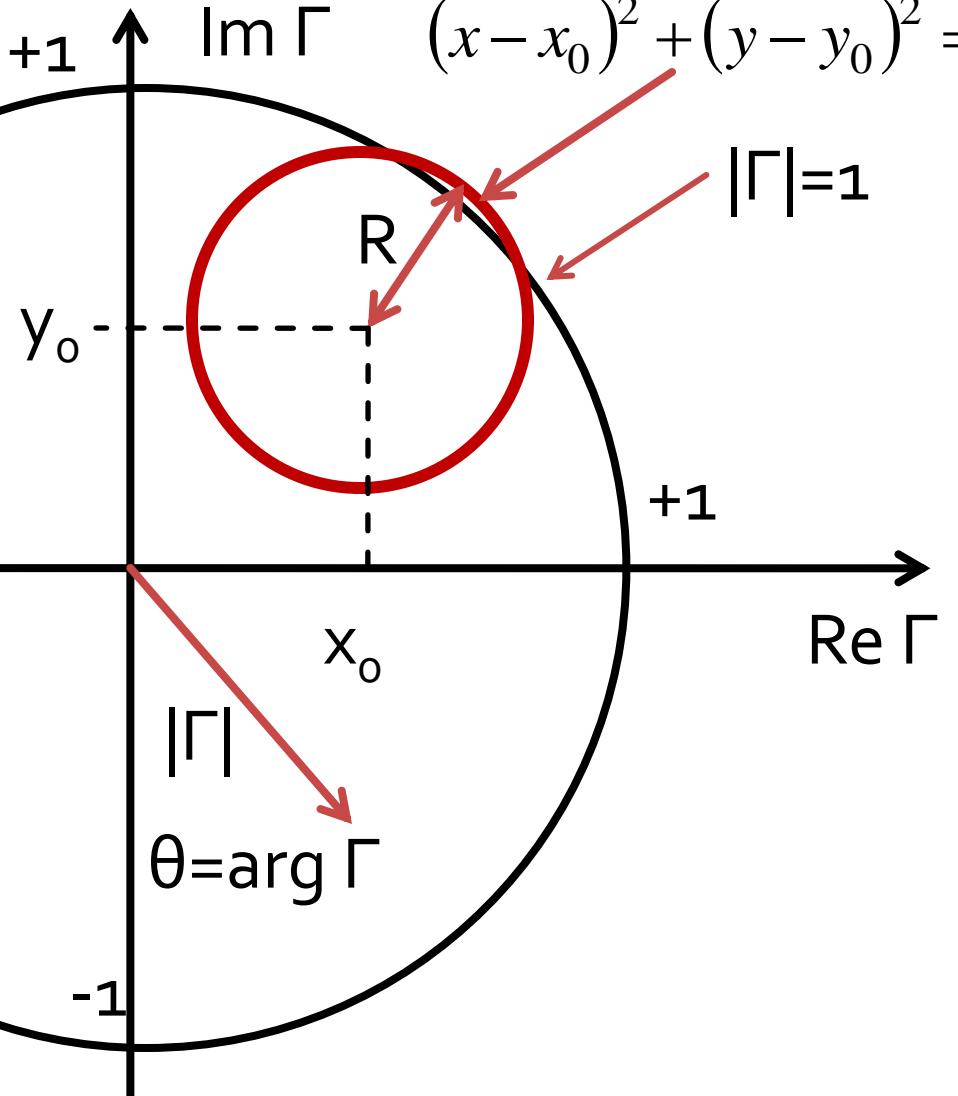
$$\Gamma = \Gamma_r + j \cdot \Gamma_i$$

$$z_L = \frac{1 + |\Gamma| \cdot e^{j\theta}}{1 - |\Gamma| \cdot e^{j\theta}} = r_L + j \cdot x_L$$

$$y_L = \frac{1 - |\Gamma| \cdot e^{j\theta}}{1 + |\Gamma| \cdot e^{j\theta}} = \frac{1}{r_L + j \cdot x_L} = g_L + j \cdot b_L$$

$$g_L + j \cdot b_L = \frac{(1 - \Gamma_r) - j \cdot \Gamma_i}{(1 + \Gamma_r) + j \cdot \Gamma_i}$$

# Diagrama Smith, admitante



$$g_L = \frac{1 - \Gamma_r^2 - \Gamma_i^2}{(1 + \Gamma_r)^2 + \Gamma_i^2}$$

$$b_L = \frac{-2 \cdot \Gamma_i}{(1 + \Gamma_r)^2 + \Gamma_i^2}$$

- Rearajate

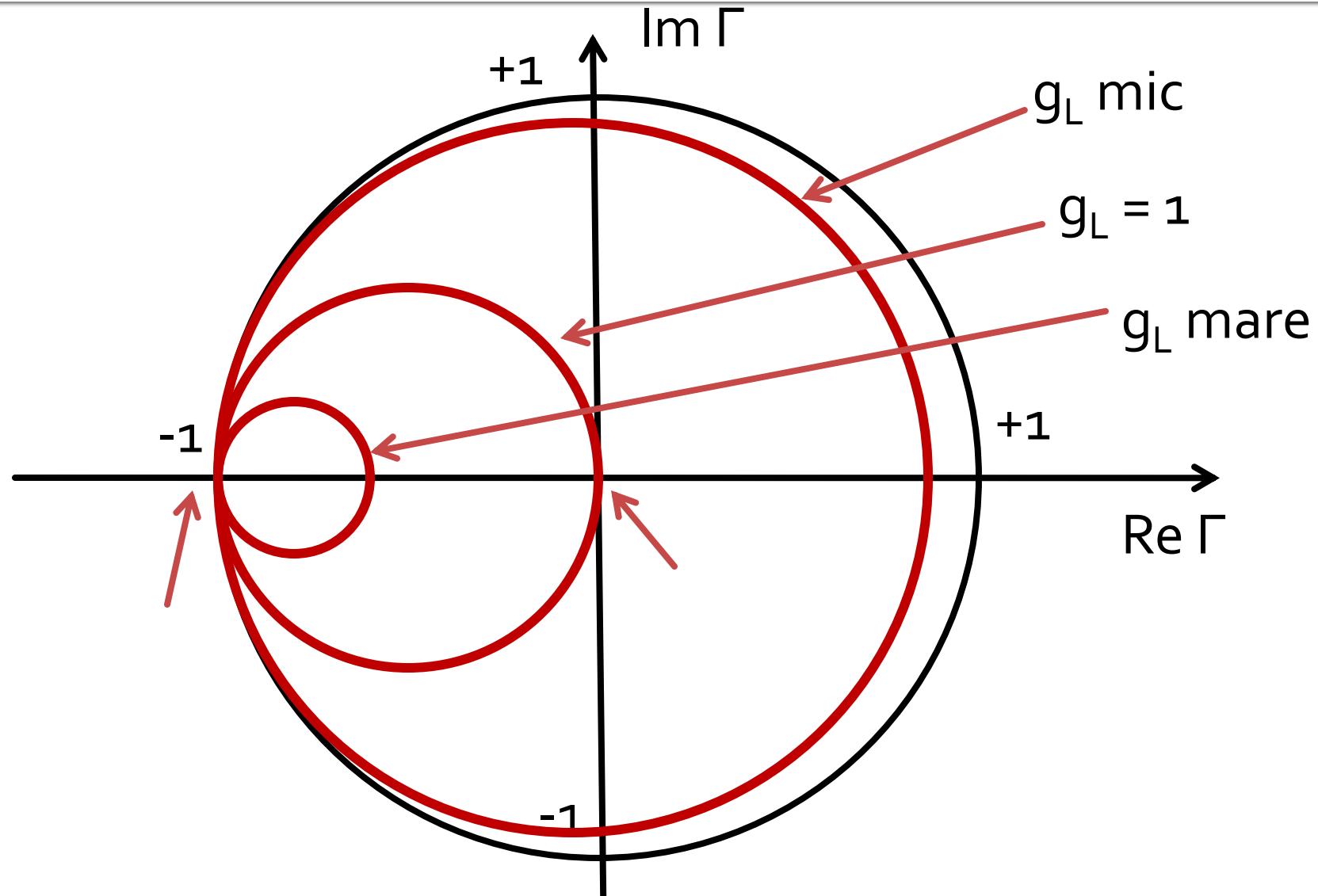
$$\left( \Gamma_r + \frac{g_L}{1 + g_L} \right)^2 + \Gamma_i^2 = \left( \frac{1}{1 + g_L} \right)^2$$

$$(\Gamma_r + 1)^2 + \left( \Gamma_i + \frac{1}{b_L} \right)^2 = \left( \frac{1}{b_L} \right)^2$$

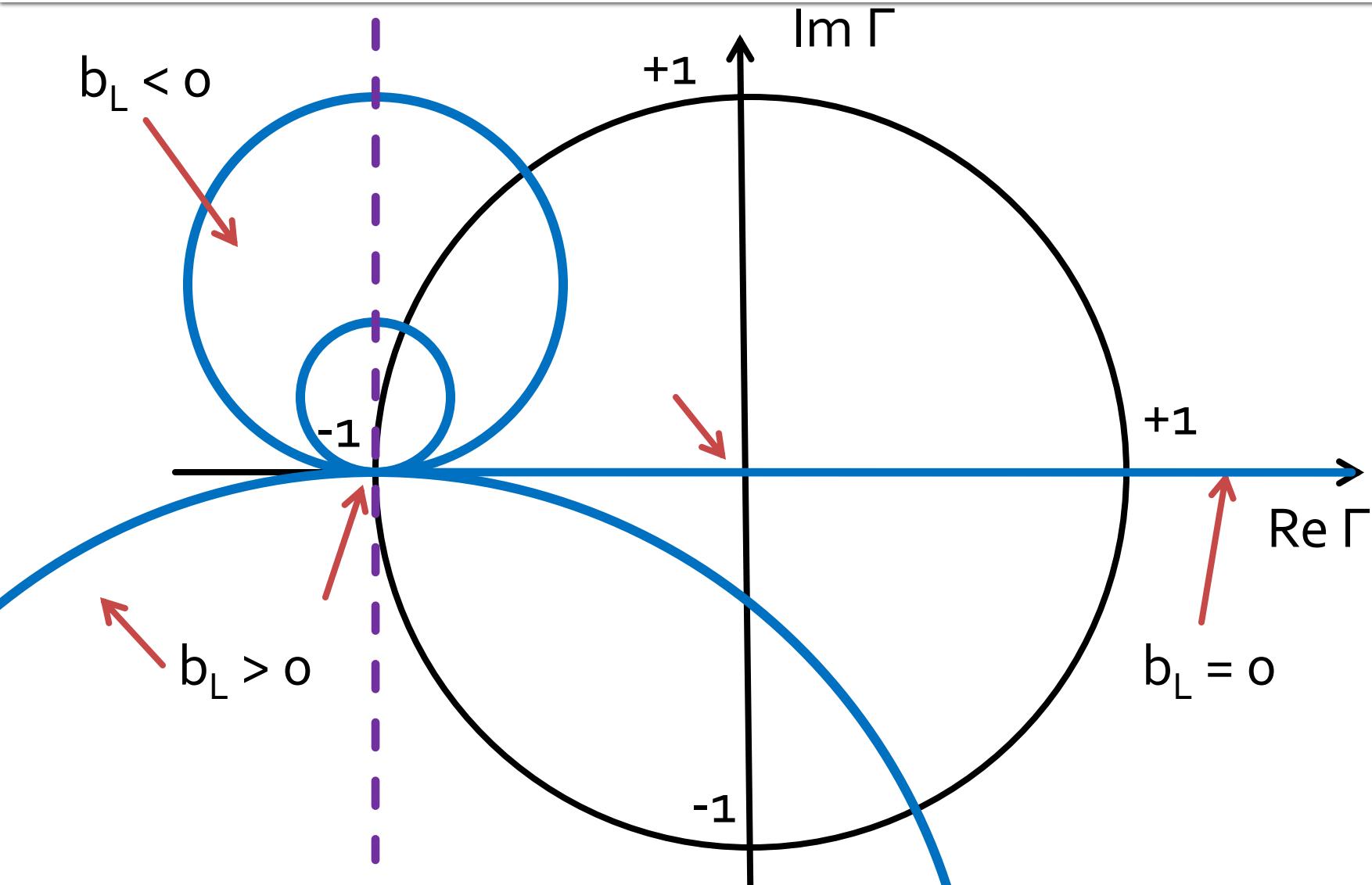
- Cercuri in planul complex

$$(x - x_0)^2 + (y - y_0)^2 = R^2$$

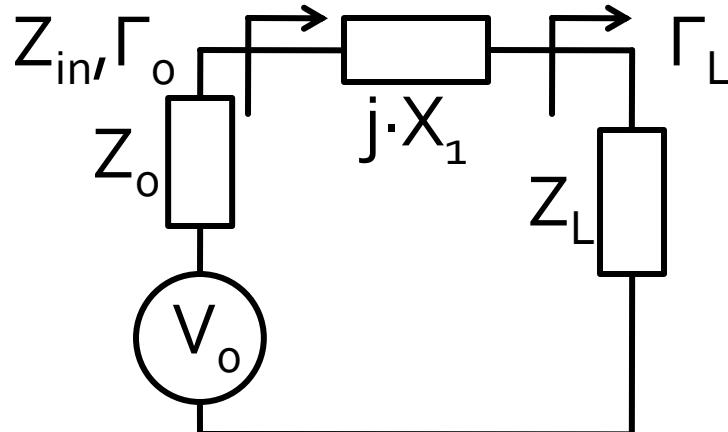
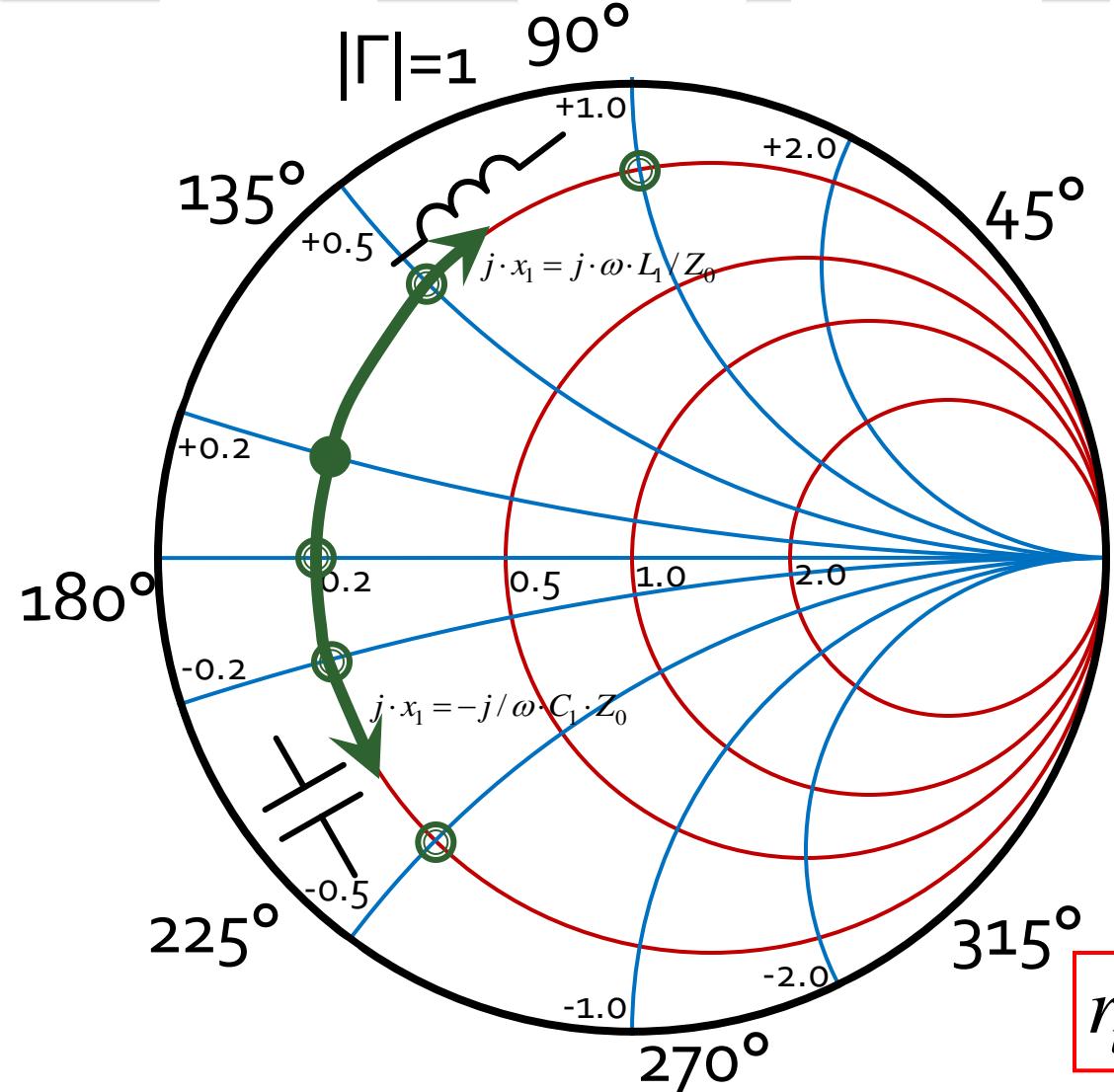
# Diagrama Smith, conductanta



# Diagrama Smith, susceptanta



# Diagrama Smith, coeficient de reflexie, reactanta in serie



$$Z_0 = 50\Omega$$

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

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

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

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

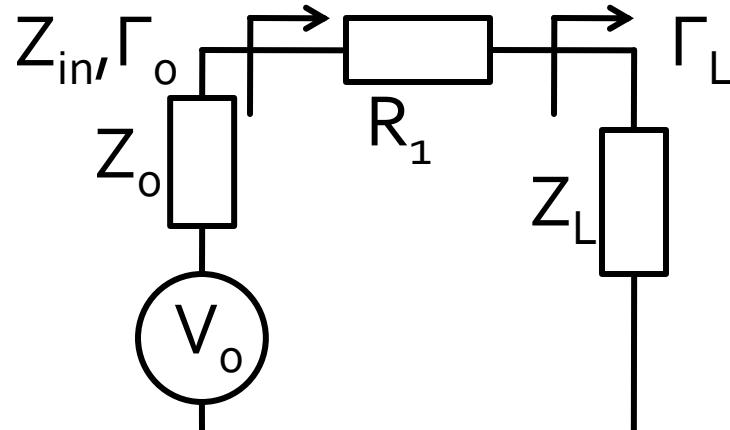
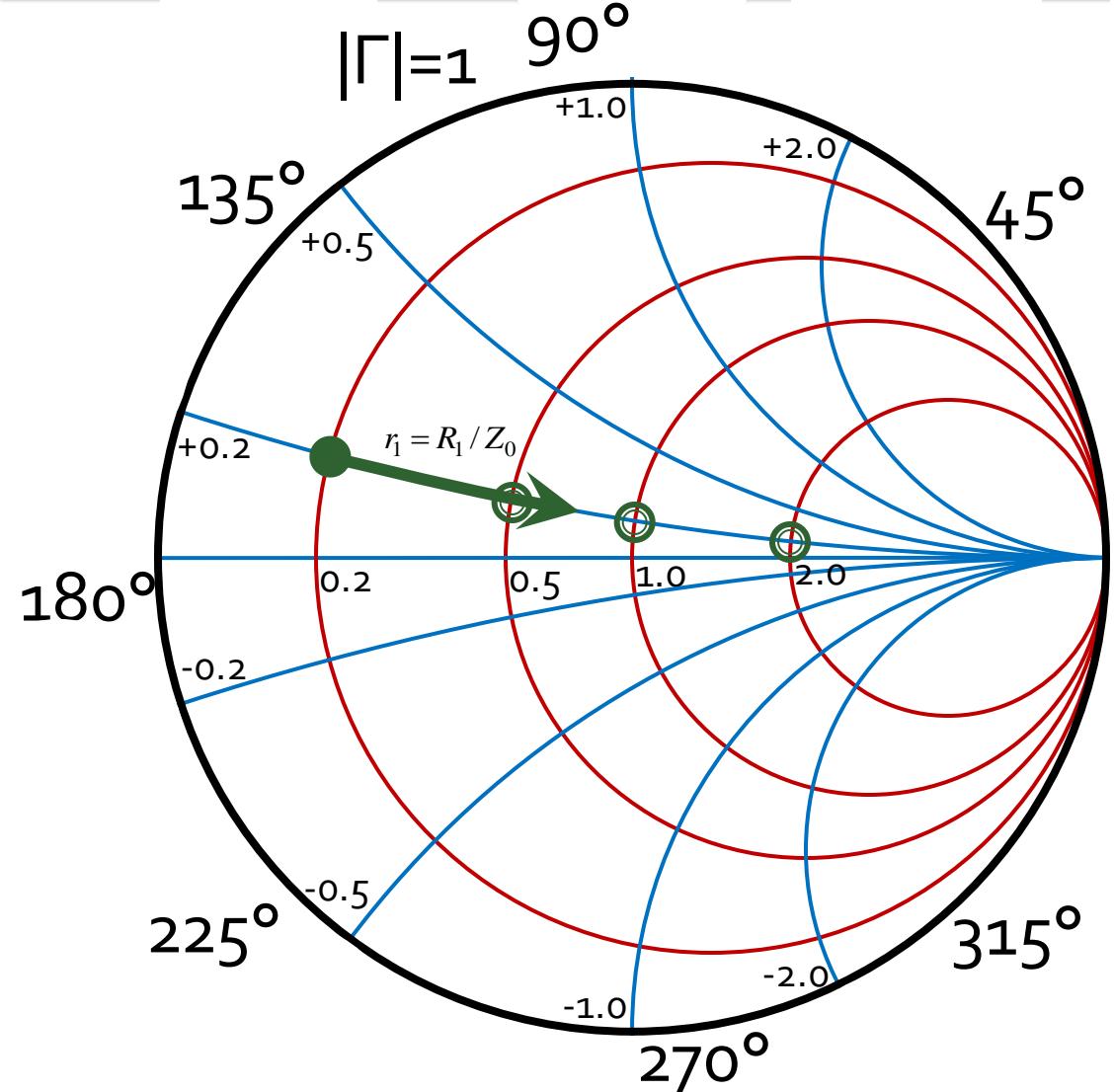
$$z_{in} = r_L + j \cdot (x_L + x_1)$$

$$r_{in} = r_L$$

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

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

# Diagrama Smith, coeficient de reflexie, rezistenta in serie



$$Z_0 = 50\Omega$$

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

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

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

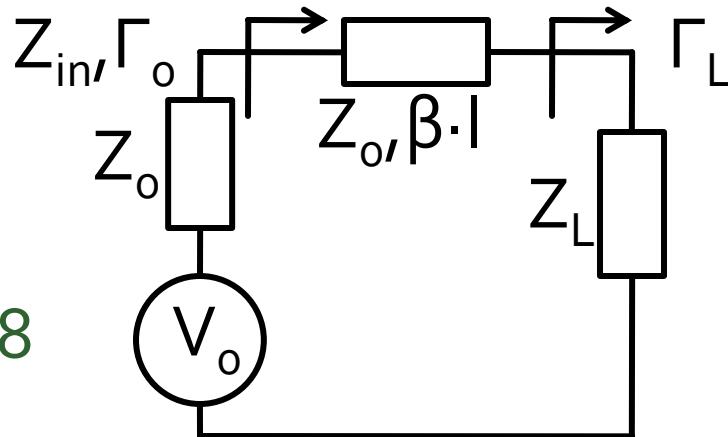
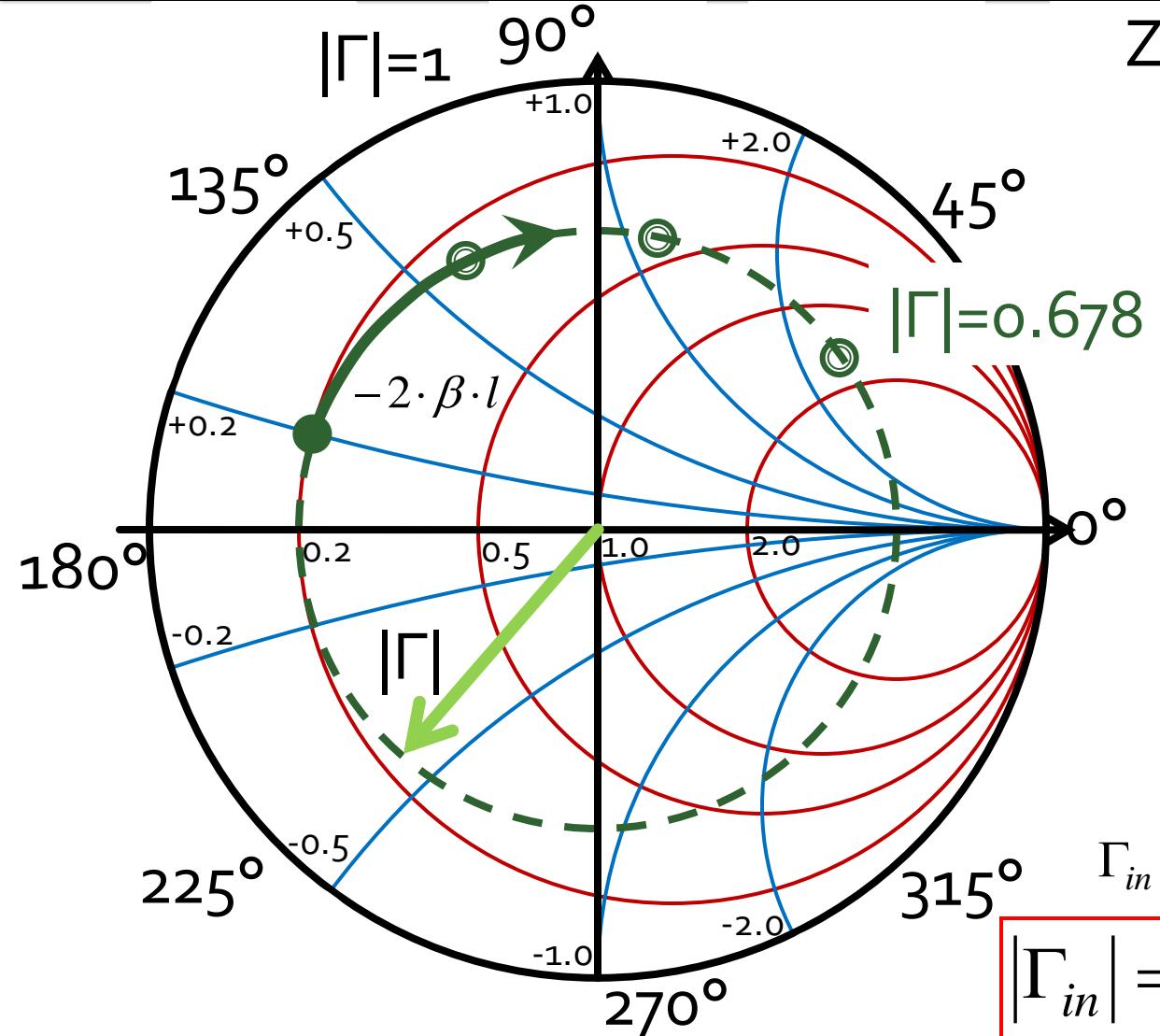
$$Z_{in} = Z_L + R_1 = (R_L + R_1) + j \cdot X_L$$

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

$x_{in} = x_L$

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

# Diagrama Smith, coeficient de reflexie, linie de transmisie in serie



$$Z_0 = 50\Omega$$

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

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

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

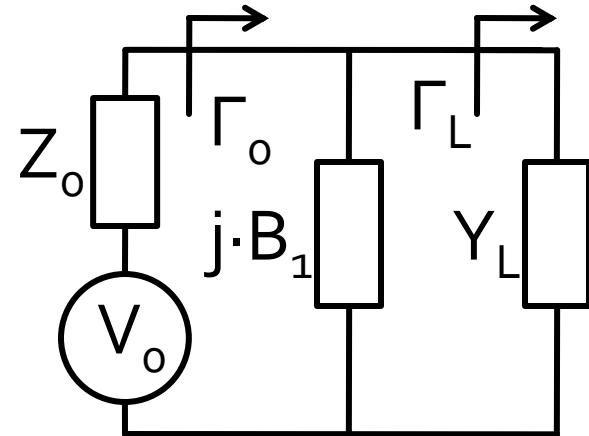
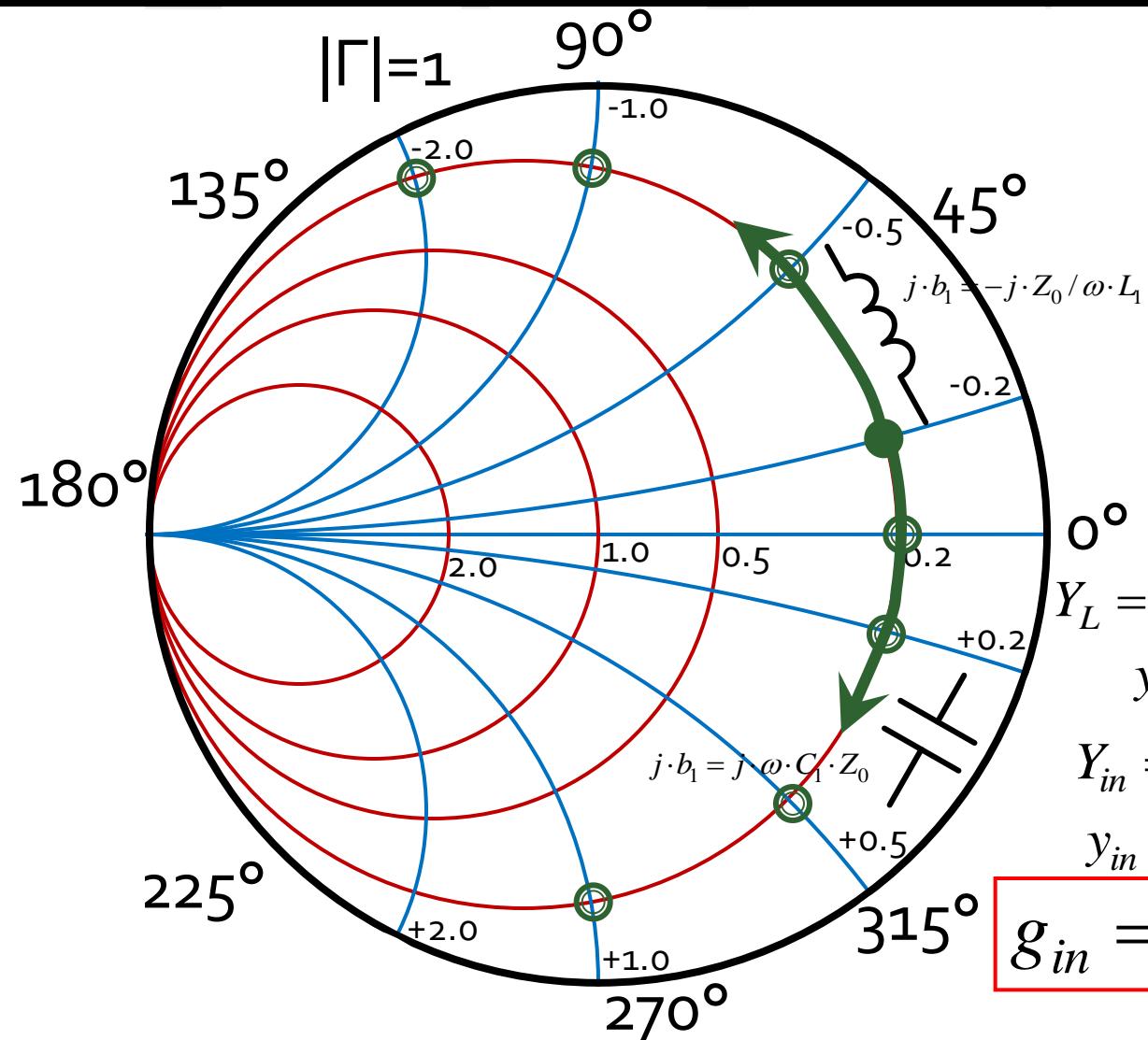
$$Z_{in} = Z_0 \cdot \frac{1 + \Gamma_L \cdot e^{-2j\beta \cdot l}}{1 - \Gamma_L \cdot e^{-2j\beta \cdot l}}$$

$$\Gamma_{in} = \Gamma_L \cdot e^{-2j\beta \cdot l}$$

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

$$\arg(\Gamma_{in}) = \arg(\Gamma_L) - 2 \cdot \beta \cdot l$$

# Diagrama Smith, coeficient de reflexie, susceptanta in paralel



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

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

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

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

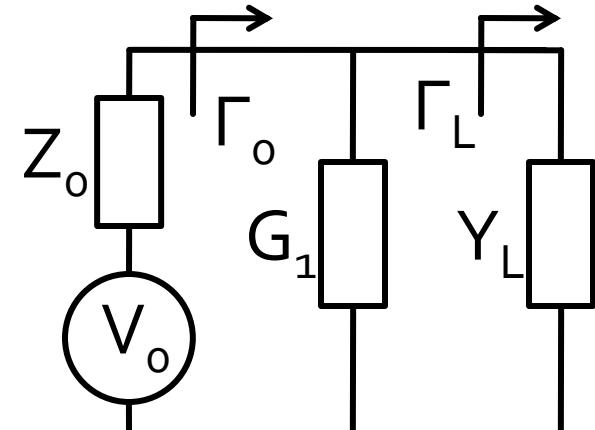
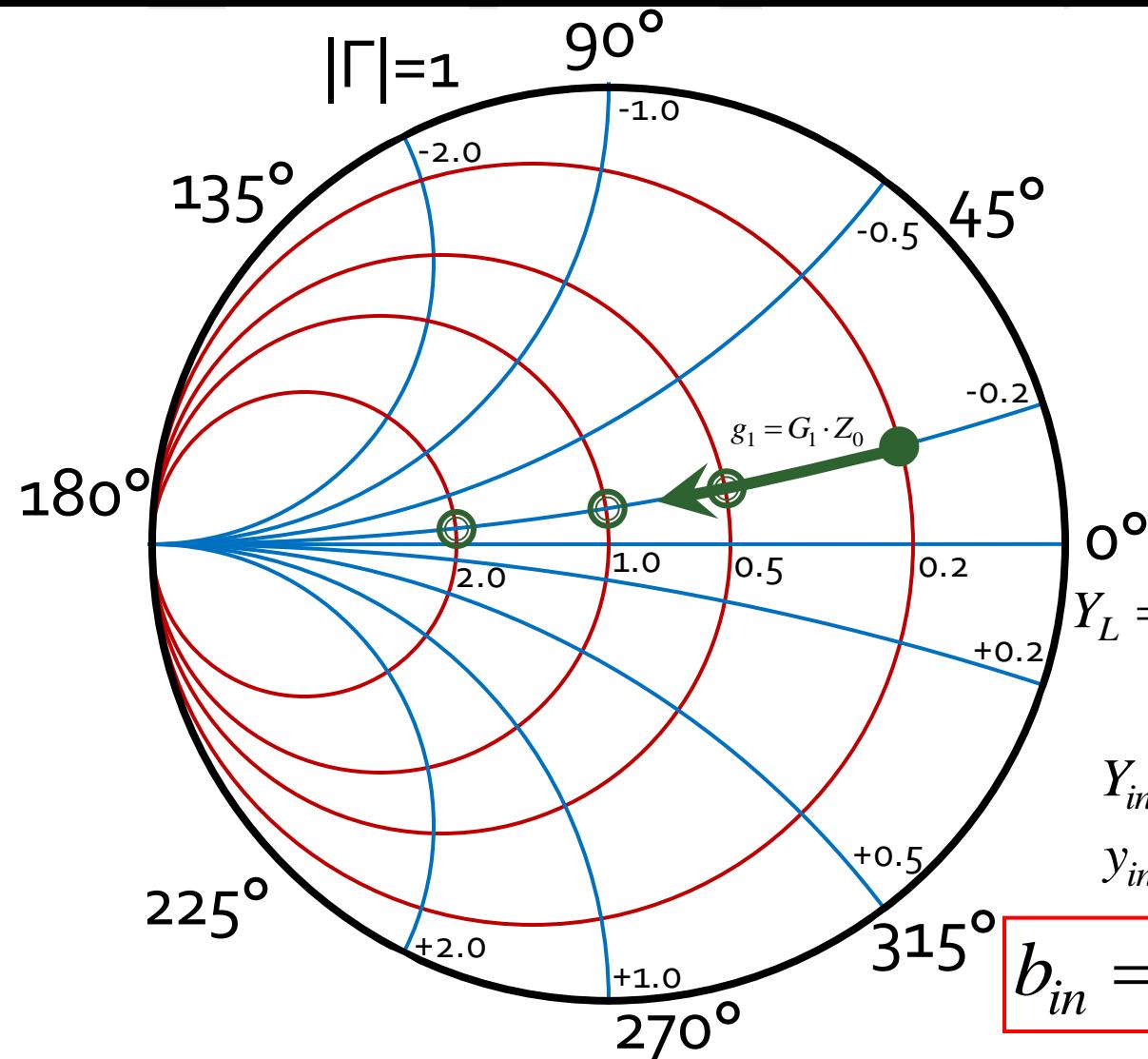
$$Y_{in} = Y_L + j \cdot B_1 = G_L + j \cdot (B_L + B_1)$$

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

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

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

# Diagrama Smith, coeficient de reflexie, conductanta in paralel



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

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

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

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

$$Y_{in} = Y_L + G_1 = (G_L + G_1) + j \cdot B_L$$

$$y_{in} = (g_L + g_1) + j \cdot b_L$$

$$b_{in} = b_L$$

$$g_{in} = g_L + G_1 \cdot Z_0$$

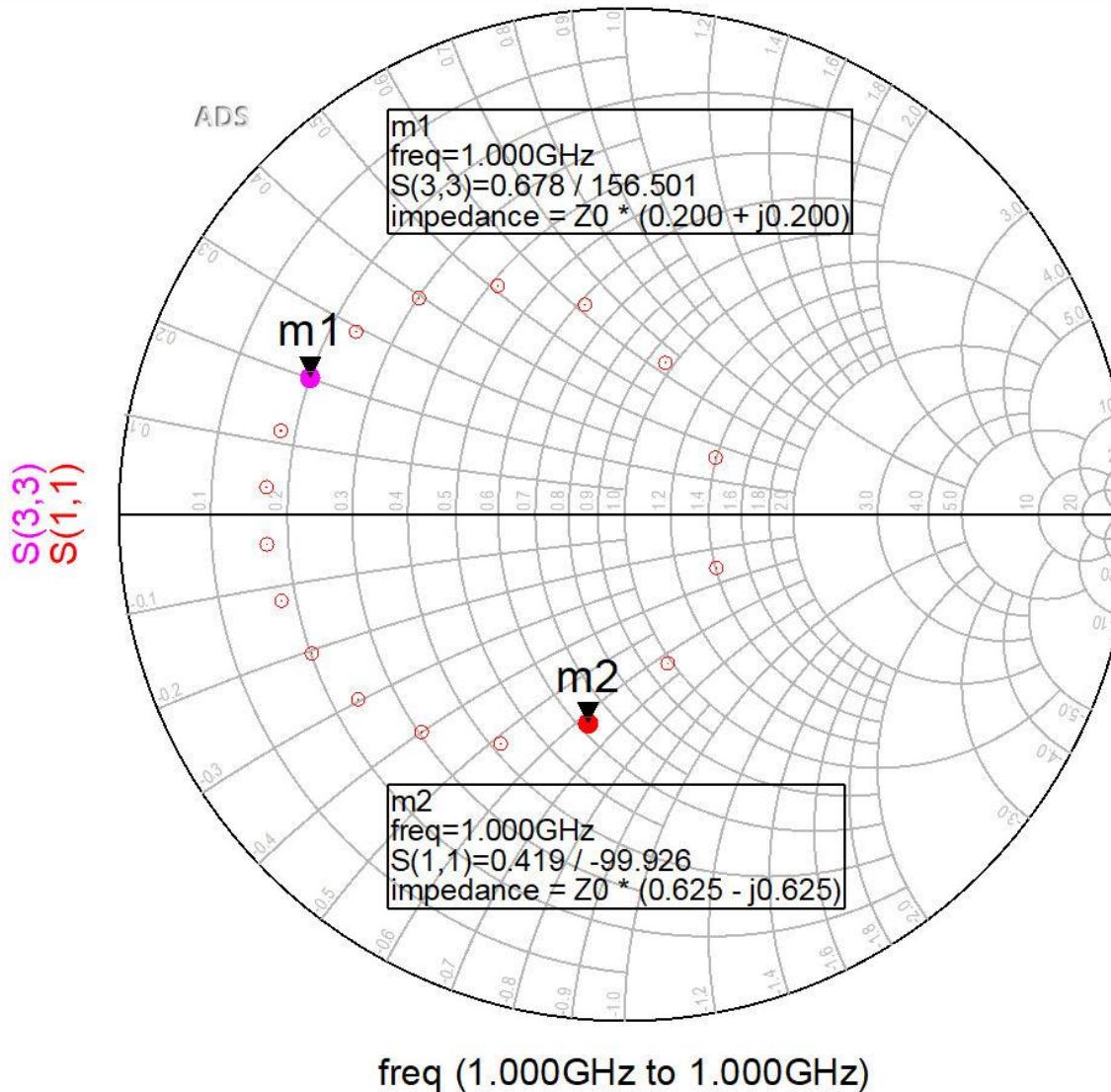
Adaptarea cu transformatoare de impedanta (Lab. 1)

# **Adaptarea de impedanță**

# Transformatoare de impedanta

- Pentru adaptarea intre doua impedante **reale**
- Se realizeaza in functie de banda necesara cu una sau mai multe sectiuni de linie cu lungimea egala cu  $\lambda/4$  la frecventa centrala:
  - Transformatorul in sfert de lungime de unda
  - Transformatorul binomial
  - Transformatorul Cebîşev

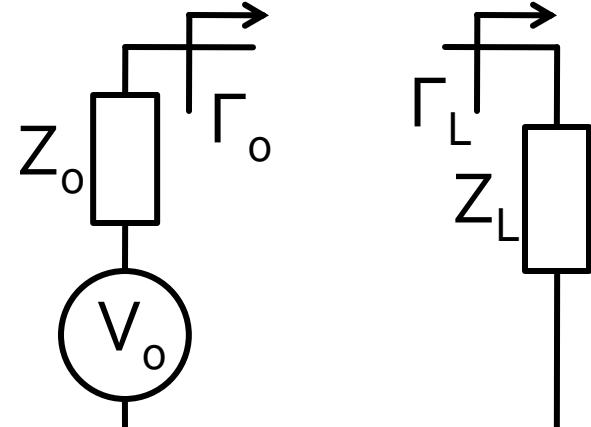
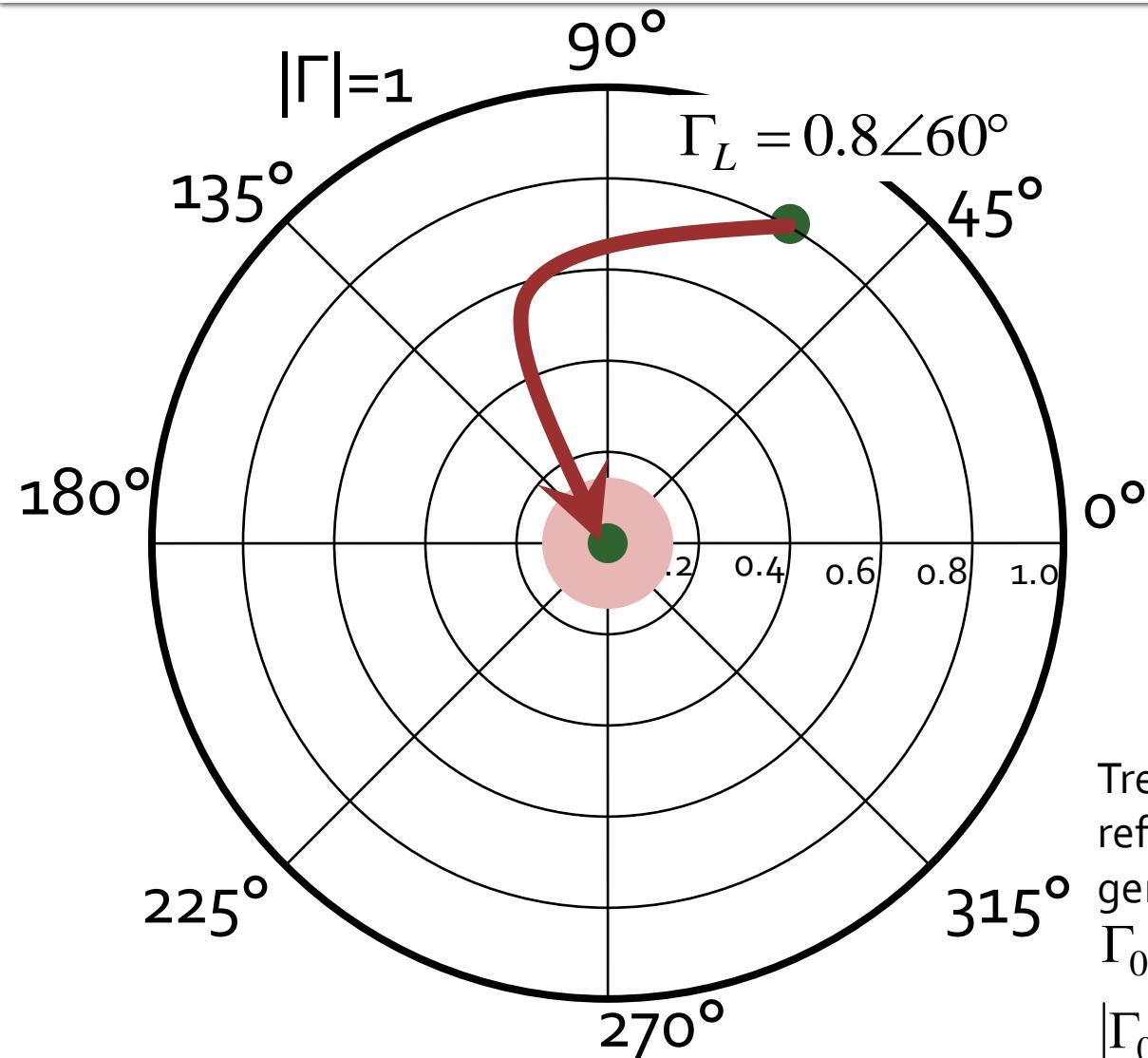
# ADS, Diagrama Smith, linie de transmisie in serie, $Z=25\Omega \neq Z_0$



Adaptarea cu elemente concentrate (Retele in L)

# **Adaptarea de impedanță**

# Diagrama Smith, adaptare



Adaptare  $Z_L$  la  $Z_0$ . Se raporteaza  $Z_L$  la  $Z_0$

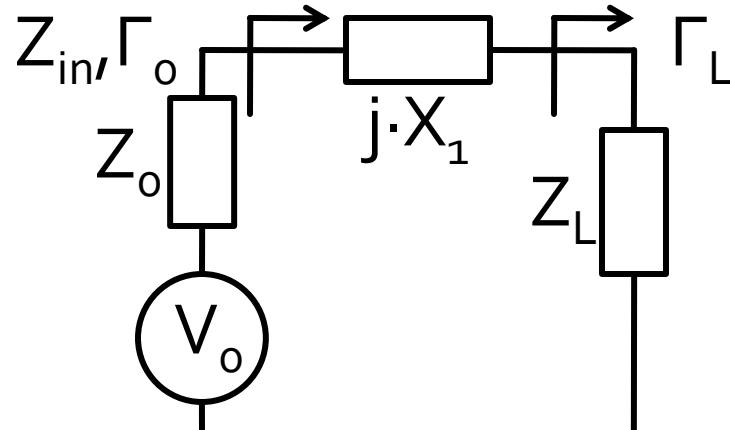
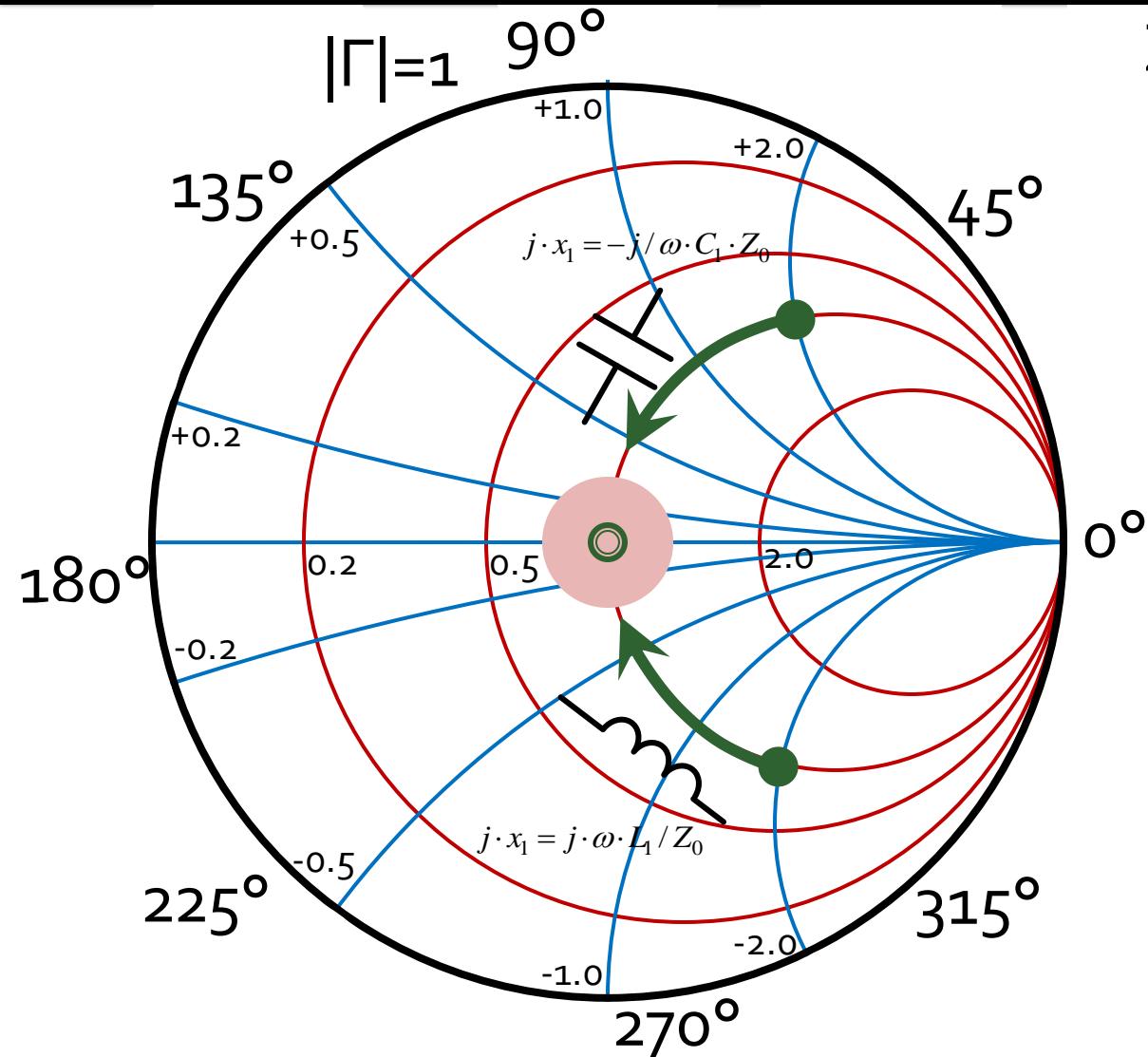
$$Z_L = 21.429\Omega + j \cdot 82.479\Omega$$
$$z_L = 0.429 + j \cdot 1.65$$
$$\Gamma_L = 0.8 \angle 60^\circ$$

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



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

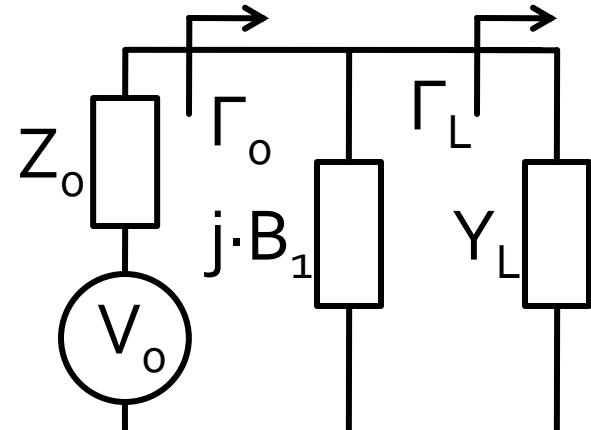
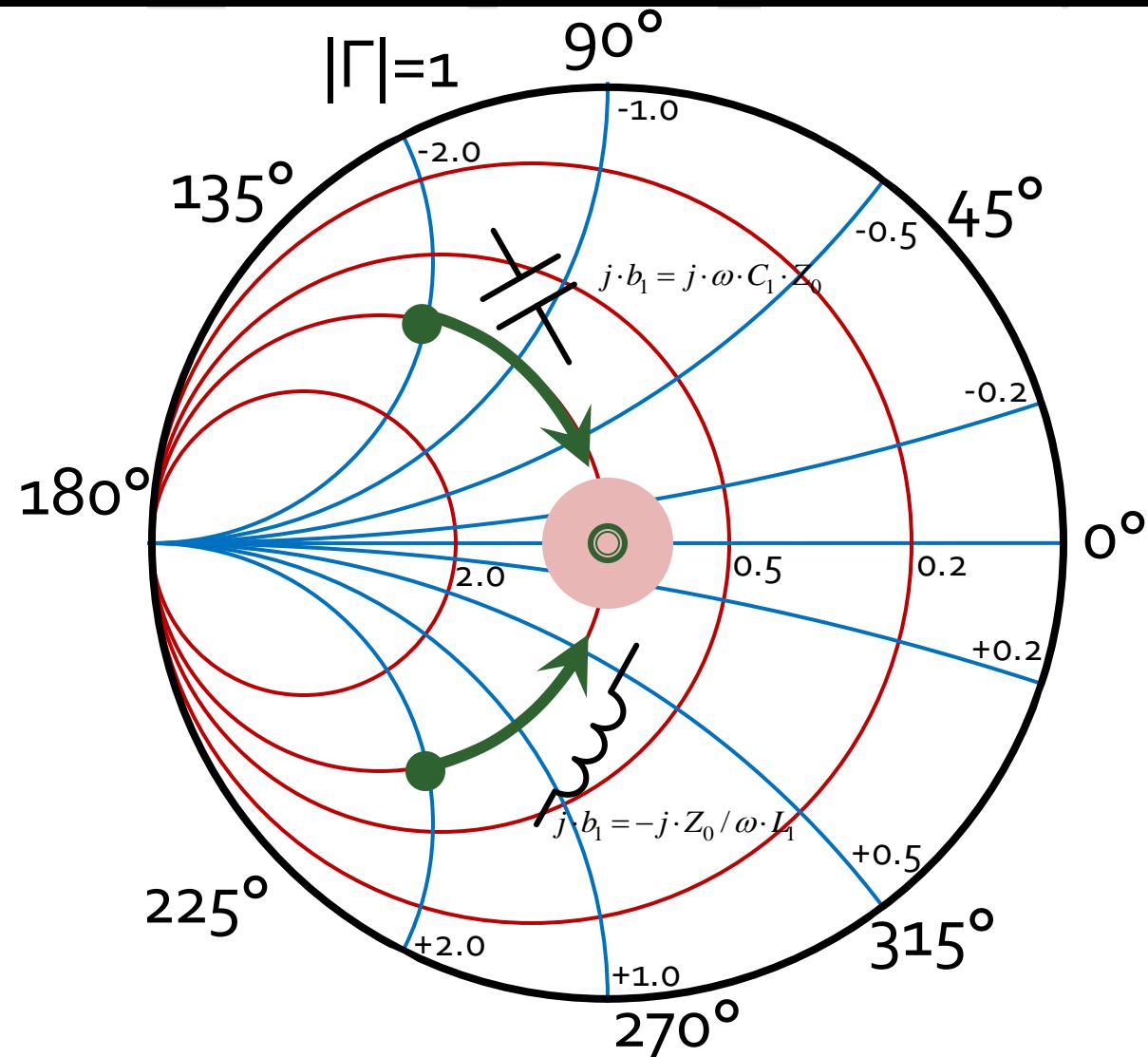
$$z_{in} = r_L + j \cdot (x_L + x_1)$$

$$r_{in} = r_L$$

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

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

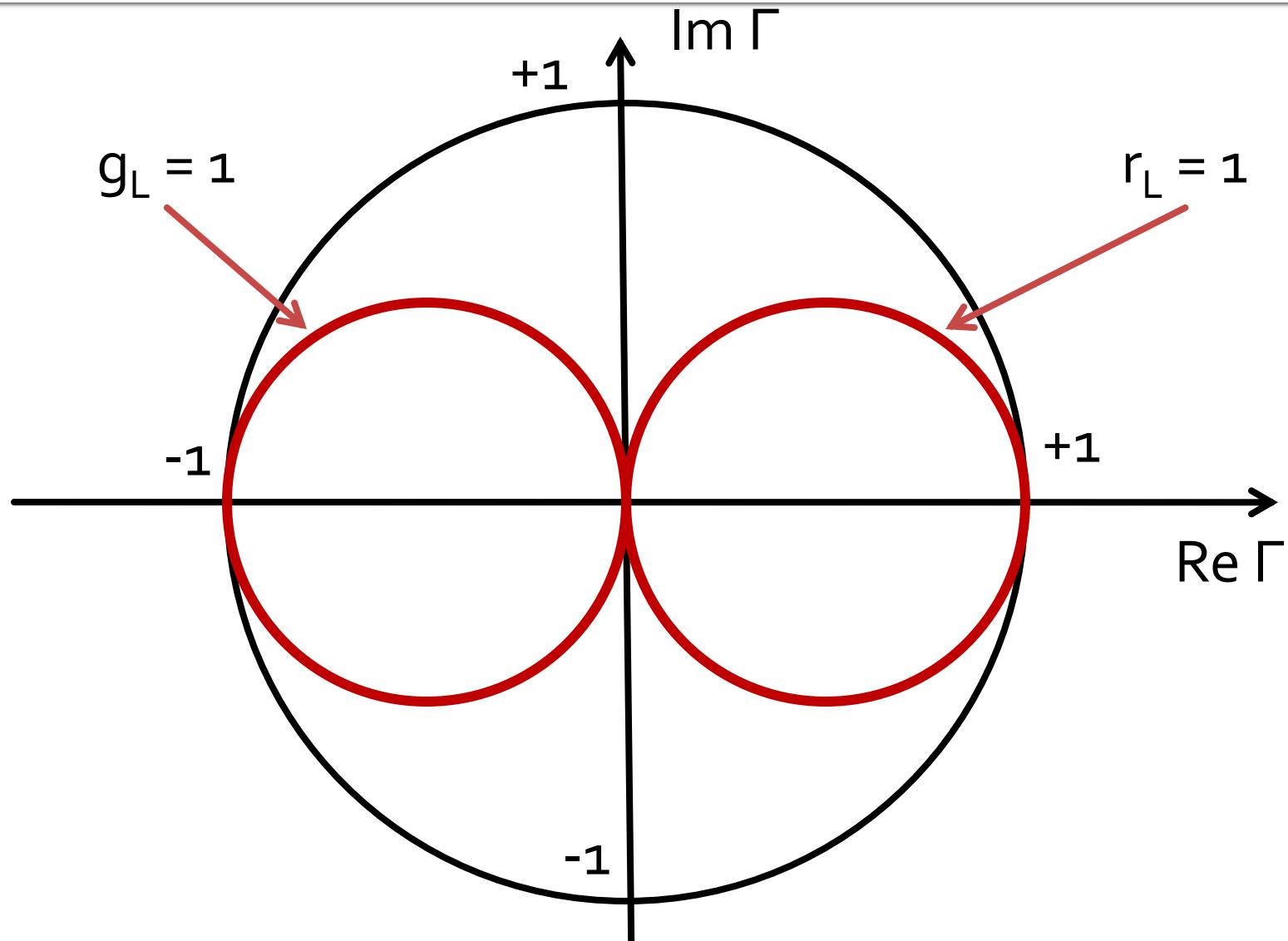
# Adaptare, susceptanta in paralel



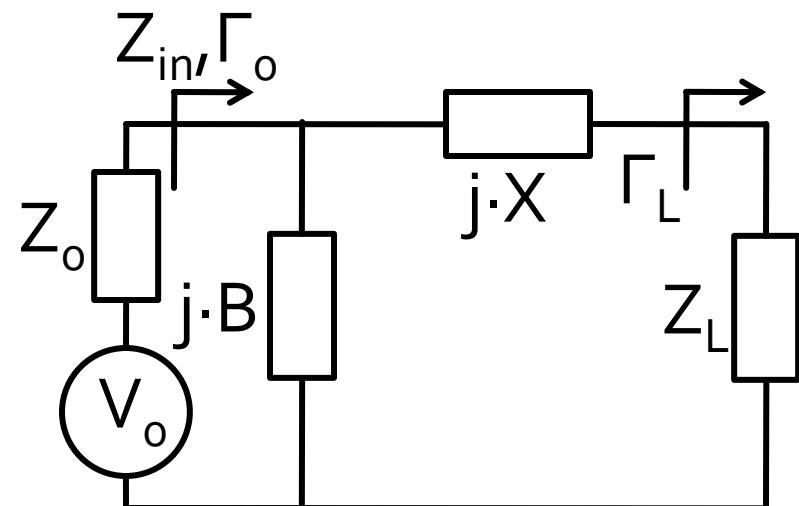
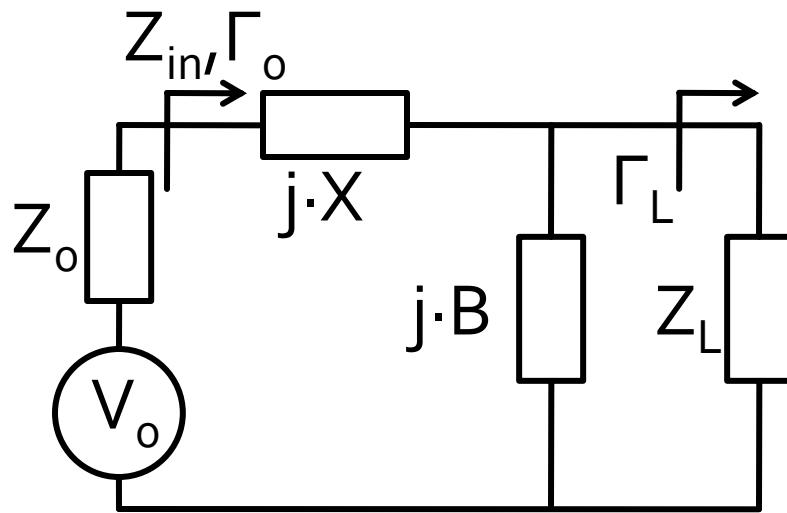
$$g_{in} = g_L$$

- 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

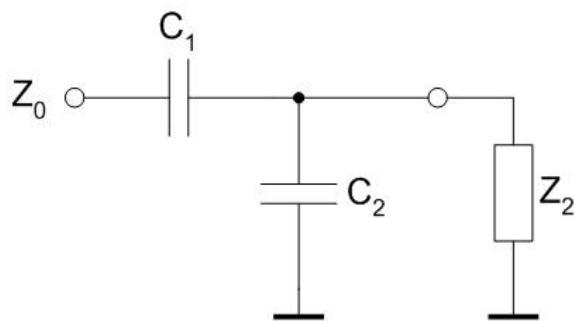
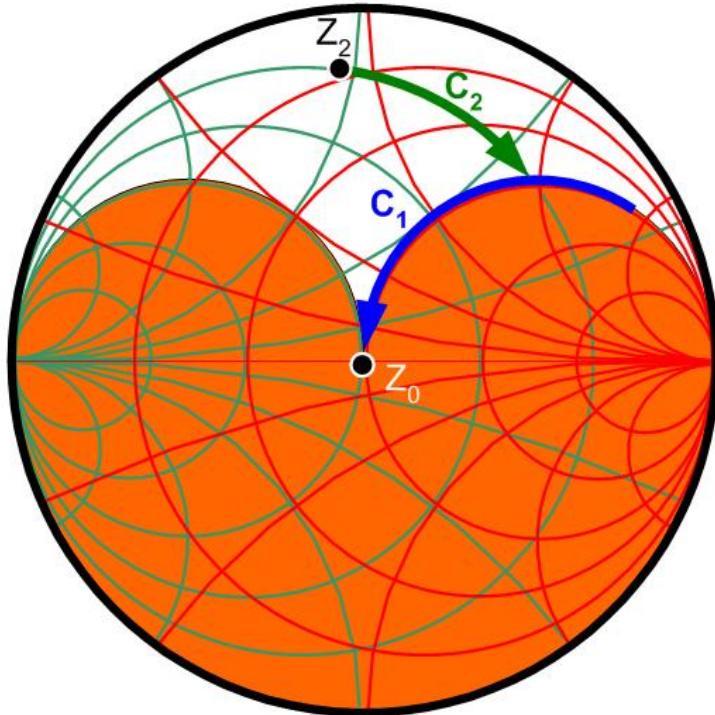


# Adaptare cu două elemente reactive (retele in L)

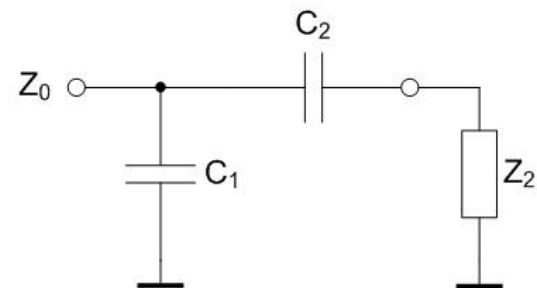
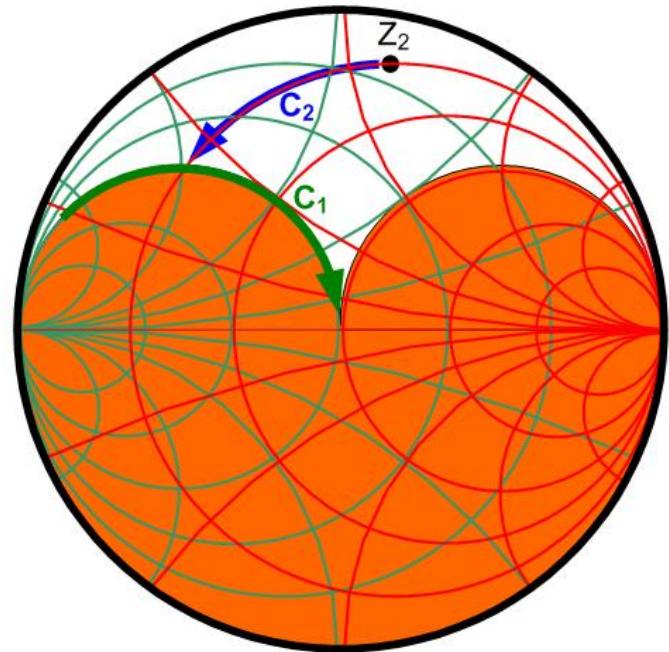


- Adaptare in doi pasi
  - un prim element muta coeficientul de reflexie **pe cercul**  $r_L = 1/g_L = 1$
  - al doilea element realizeaza adaptarea

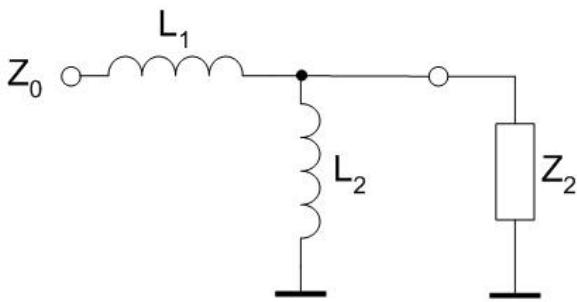
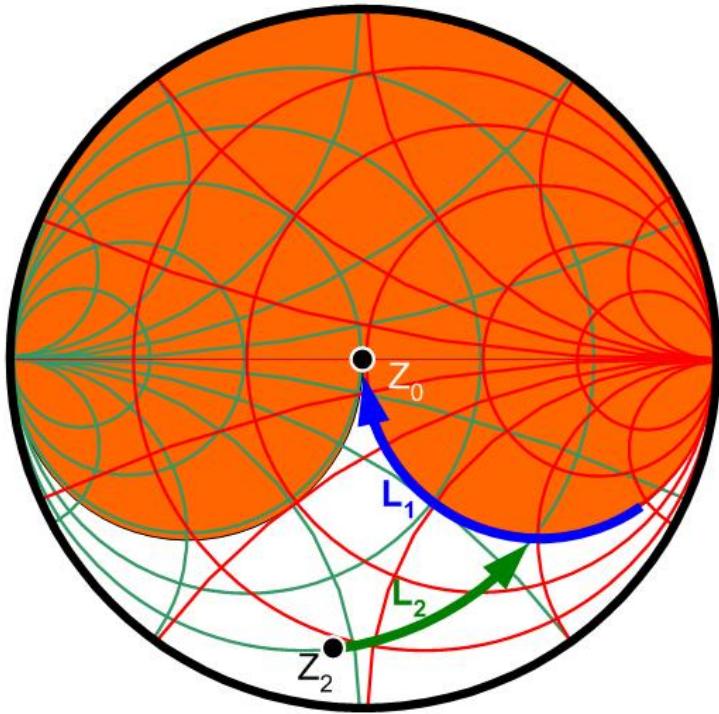
# C serie, C paralel / C paralel, C serie



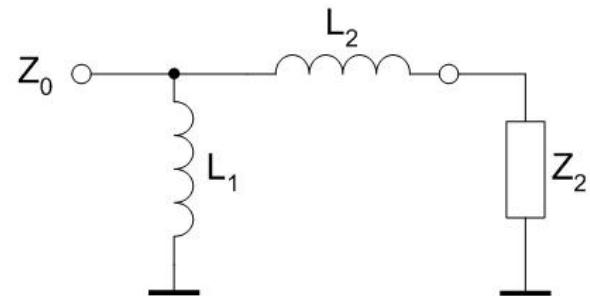
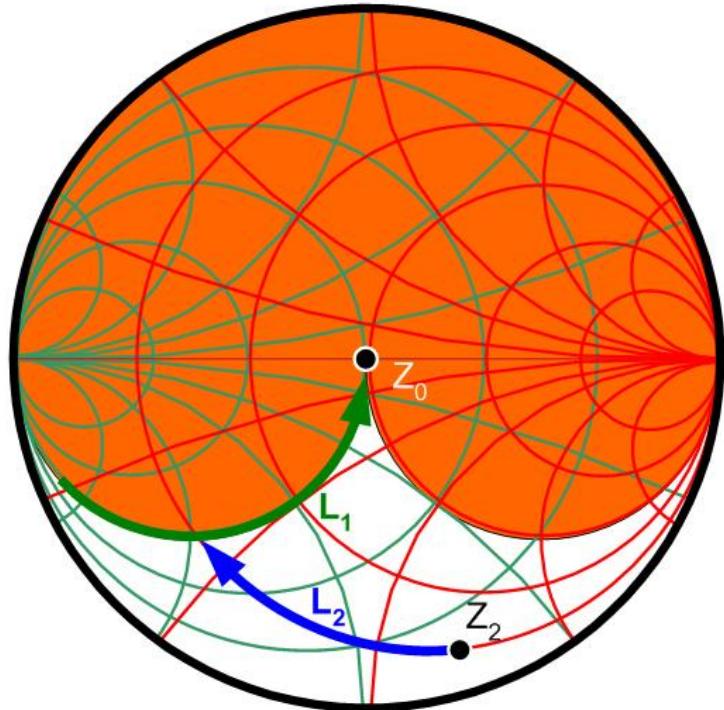
Zona interzisa cu  
schema curenta



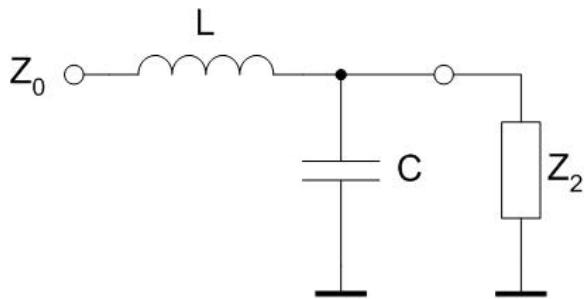
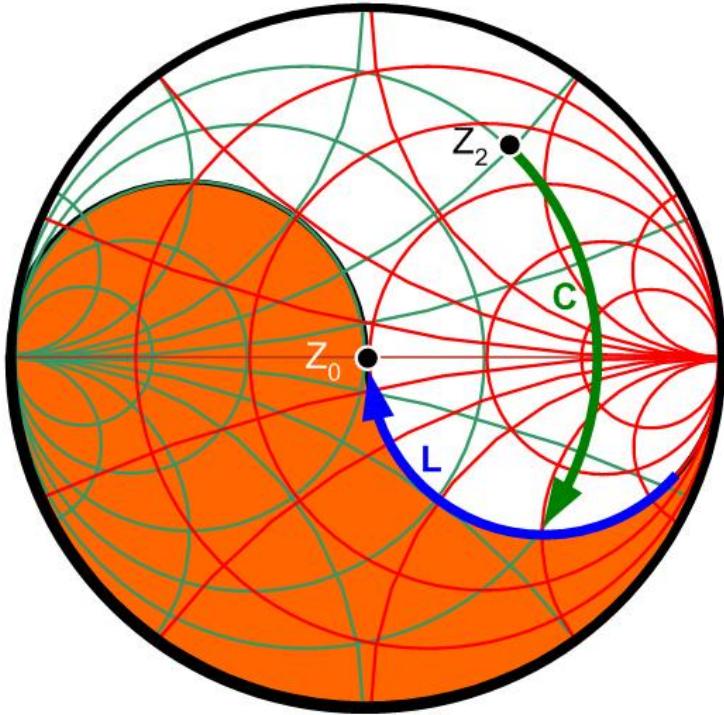
# L serie, L paralel / L paralel, L serie



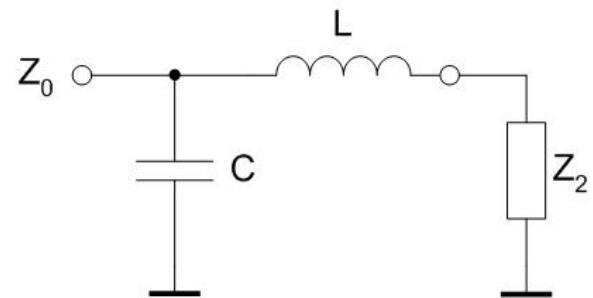
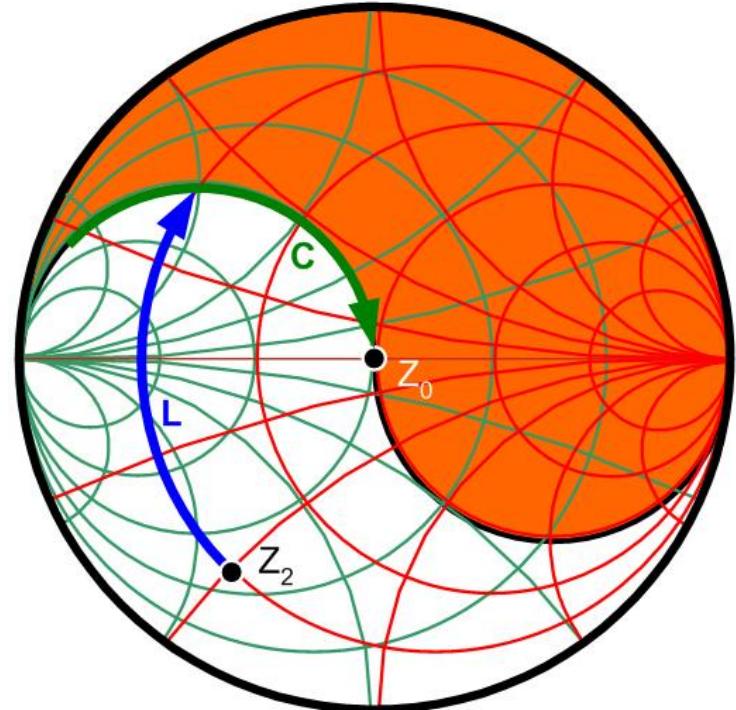
Zona interzisa cu  
schema curenta



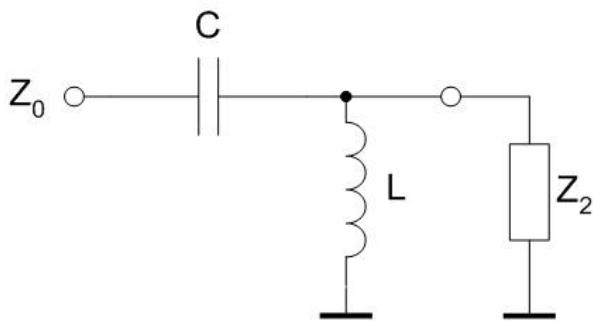
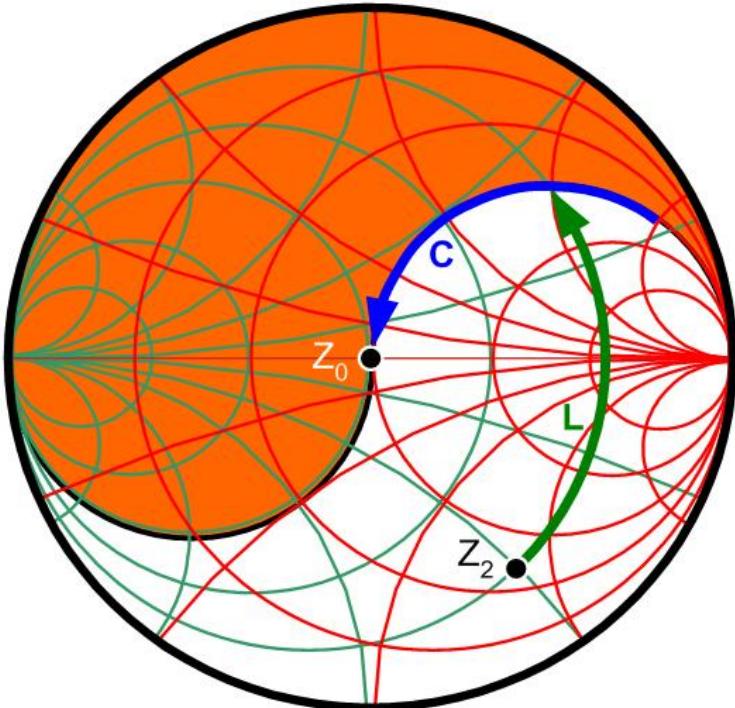
# L serie, C paralel / C paralel, L serie



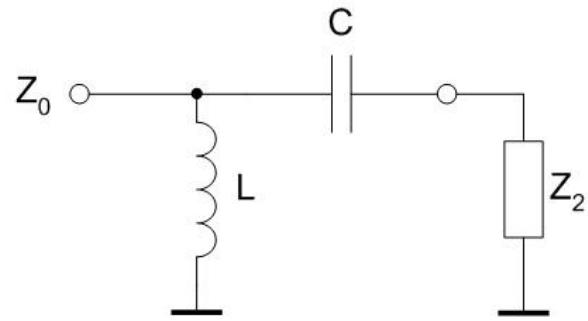
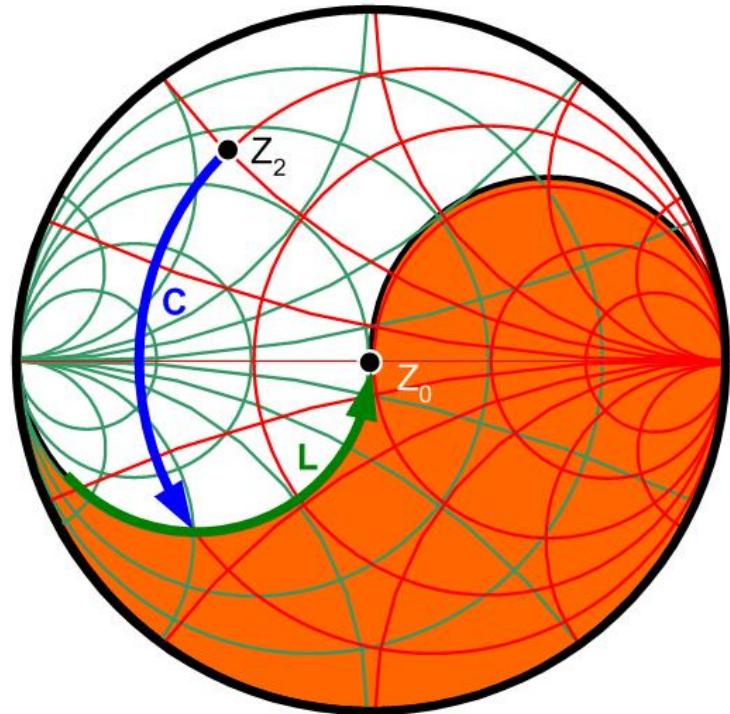
Zona interzisa cu  
schema curenta



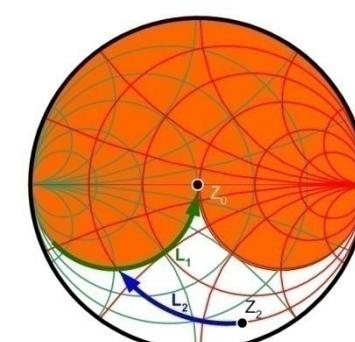
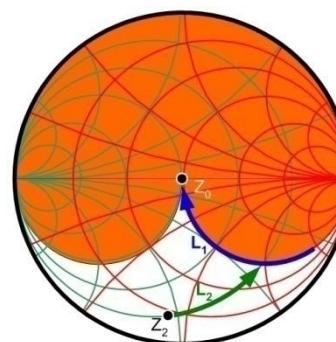
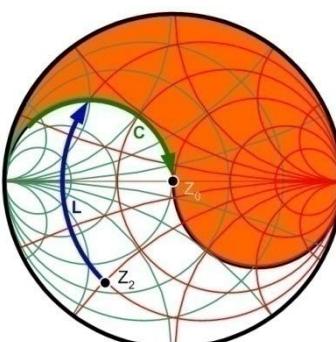
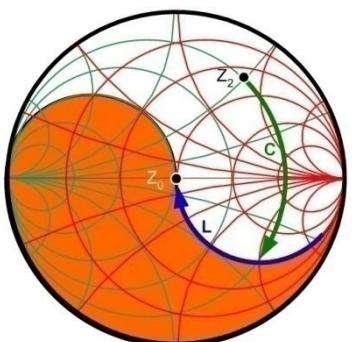
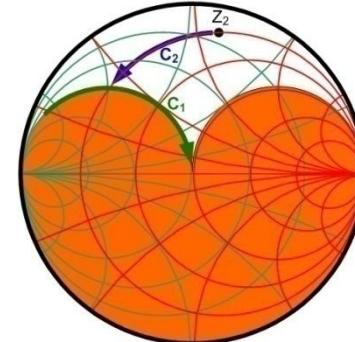
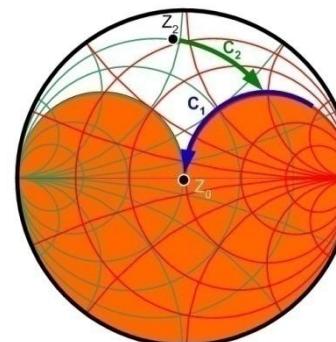
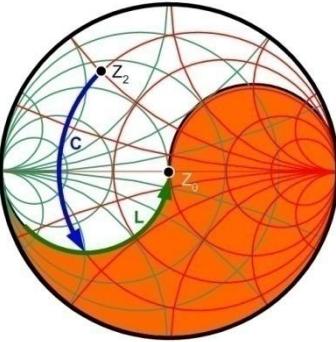
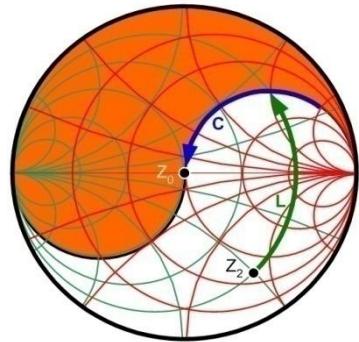
# C serie, L paralel / L paralel, C serie



Zona interzisa cu  
schema curenta



# Adaptare cu două elemente reactive (retele in L)



Zona interzisa cu  
schema curenta

# Adaptare cu doua elemente reactive (retele in L)

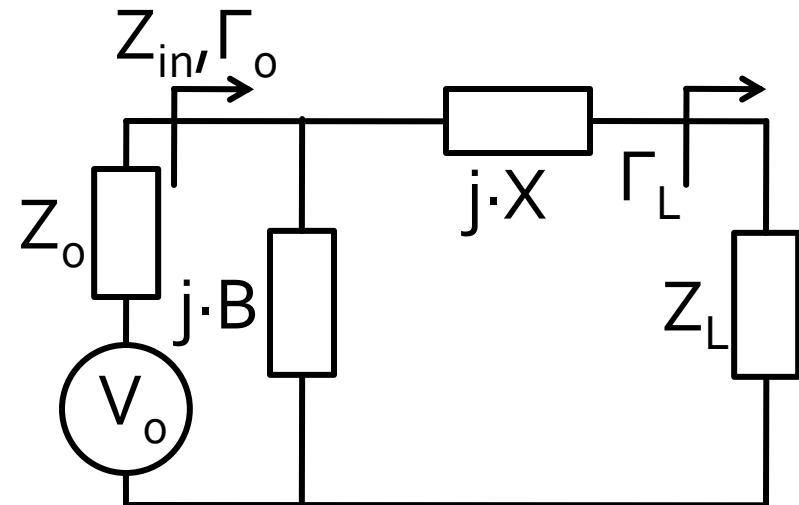
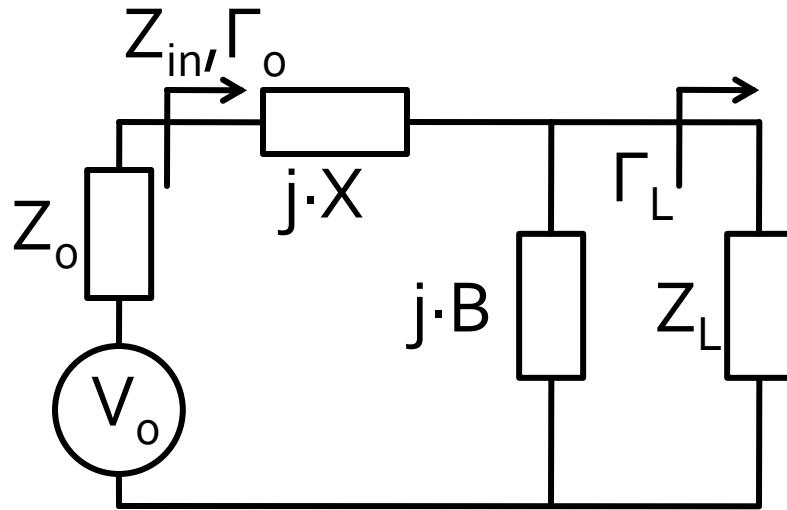
- Pentru orice  $\Gamma_L$  există cel puțin 2 retele în L de adaptare posibile (L+C)
- Pentru anumite zone de start de pe diagrama Smith există 4 posibilități (+2 retele C+C/L+L)
- Se alege reteaua care necesită componente de valori realizabile
- Prin adăugarea elementelor rezistive se pot suplimenta retelele posibile cu **pierdere de putere (nerecomandat)**

# Adaptare cu elemente rezistive

- Circuitele active lucreaza in zona frecventei unitare
- Orice "risipa" de putere este **nerecomandata**
- Exista situatii in care este **necesara** o astfel de actiune pentru asigurarea stabilitatii



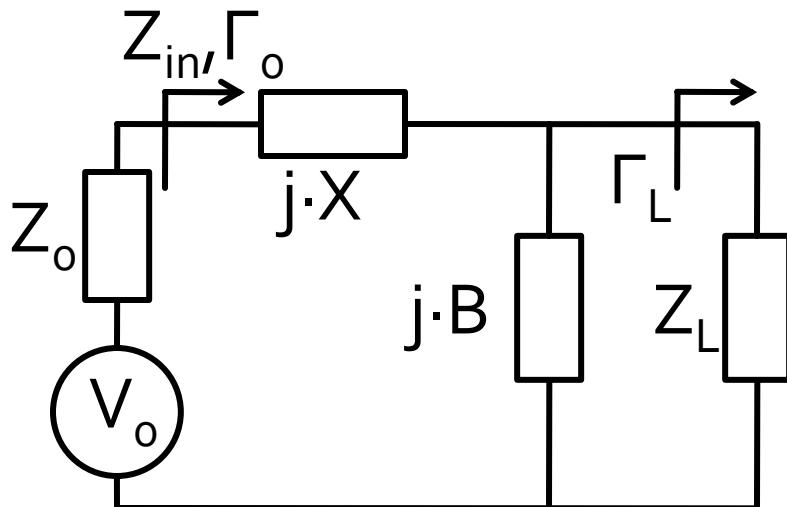
# Adaptare cu doua elemente reactive (retele in L)



## ■ Adaptare in doi pasi

- pentru elementele situate in interiorul cercului  $r_L = 1$  se utilizeaza prima schema
- pentru elementele situate in exteriorul cercului  $r_L = 1$  se utilizeaza a doua schema

# Adaptare cu doua elemente reactive (retele in L)



$$Z_L = R_L + j \cdot X_L \quad R_L > Z_0 \quad Z_{in} = Z_0$$

$$Z_0 = j \cdot X + \frac{1}{j \cdot B + 1/(R_L + j \cdot X_L)}$$

$$\begin{cases} B \cdot (X \cdot R_L - X_L \cdot Z_0) = R_L - Z_0 \\ X \cdot (1 - B \cdot X_L) = B \cdot Z_0 \cdot R_L - X_L \end{cases}$$

$$B = \frac{X_L \pm \sqrt{R_L/Z_0} \cdot \sqrt{R_L^2 + X_L^2 - Z_0 \cdot R_L}}{R_L^2 + X_L^2}$$

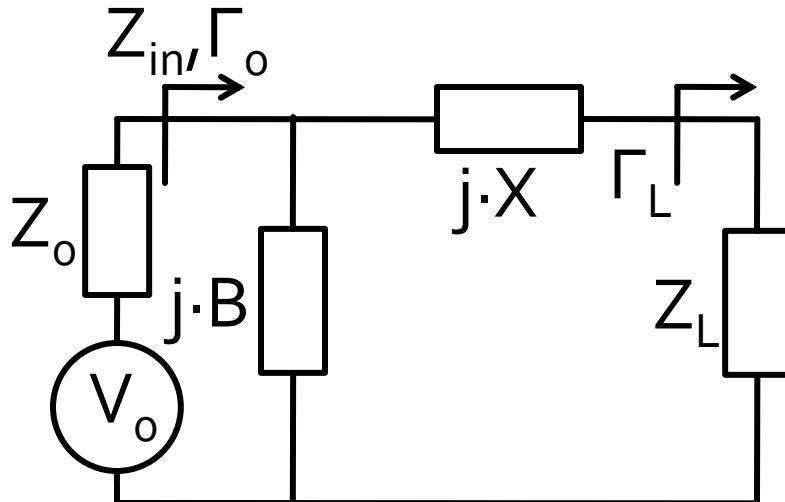
$$X = \frac{1}{B} + \frac{X_L \cdot Z_0}{R_L} - \frac{Z_0}{B \cdot R_L}$$

- valoarea de sub radical e intotdeauna pozitiva pentru

$$R_L > Z_0$$

- se obtin doua solutii realizabile

# Adaptare cu două elemente reactive (retele în L)



$$Z_L = R_L + j \cdot X_L \quad R_L < Z_0 \quad Y_{in} = Y_0 = \frac{1}{Z_0}$$

$$\frac{1}{Z_0} = j \cdot B + \frac{1}{R_L + j \cdot (X + j \cdot X_L)}$$

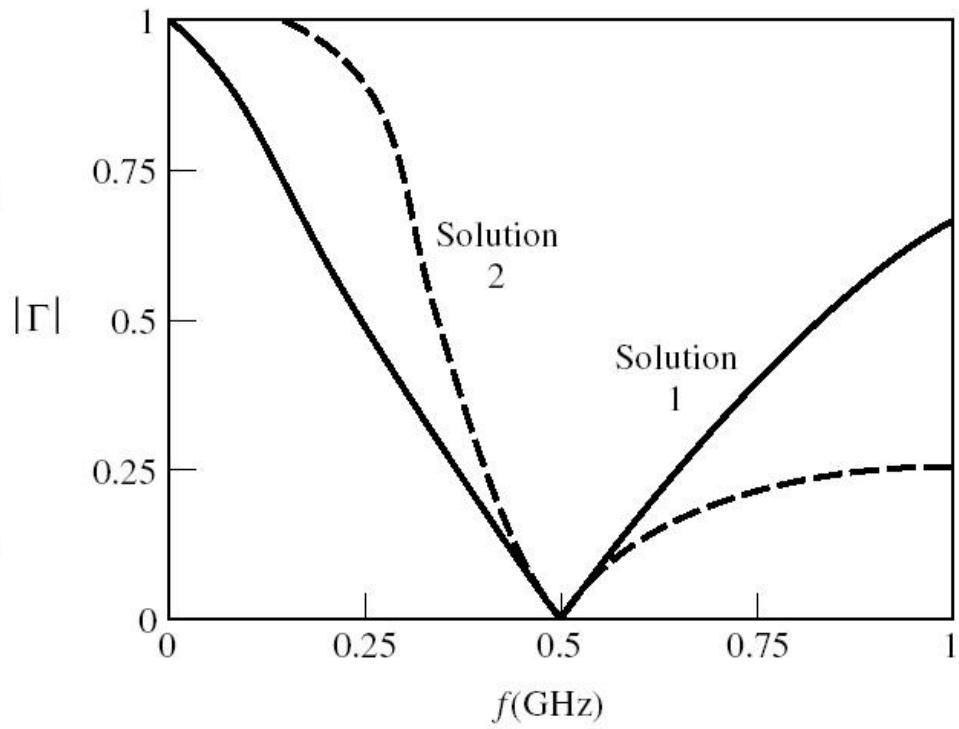
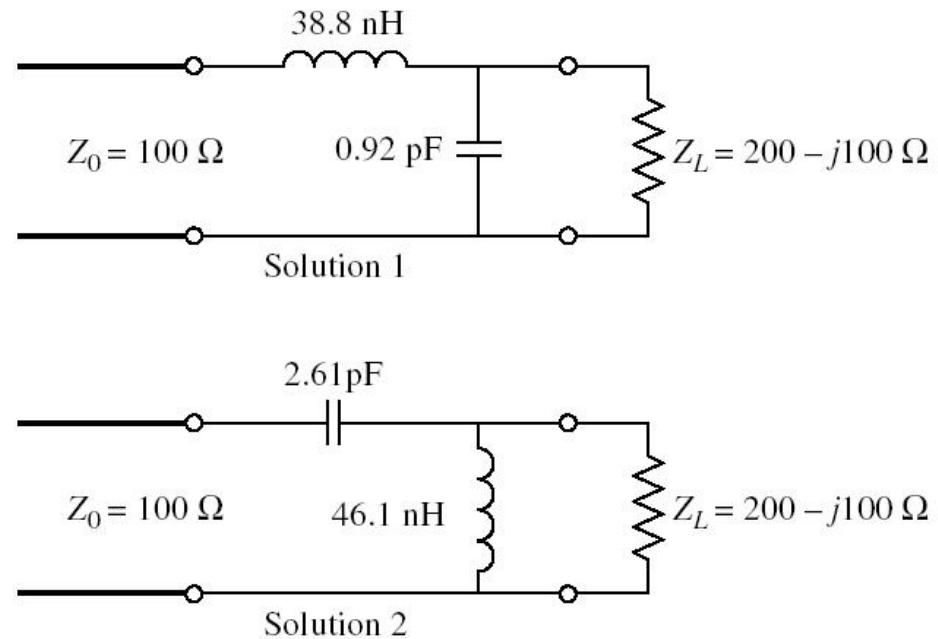
$$\begin{cases} B \cdot Z_0 \cdot (X + X_L) = Z_0 - R_L \\ (X + X_L) = B \cdot Z_0 \cdot R_L \end{cases}$$

$$X = \pm \sqrt{R_L \cdot (Z_0 - R_L)} - X_L$$

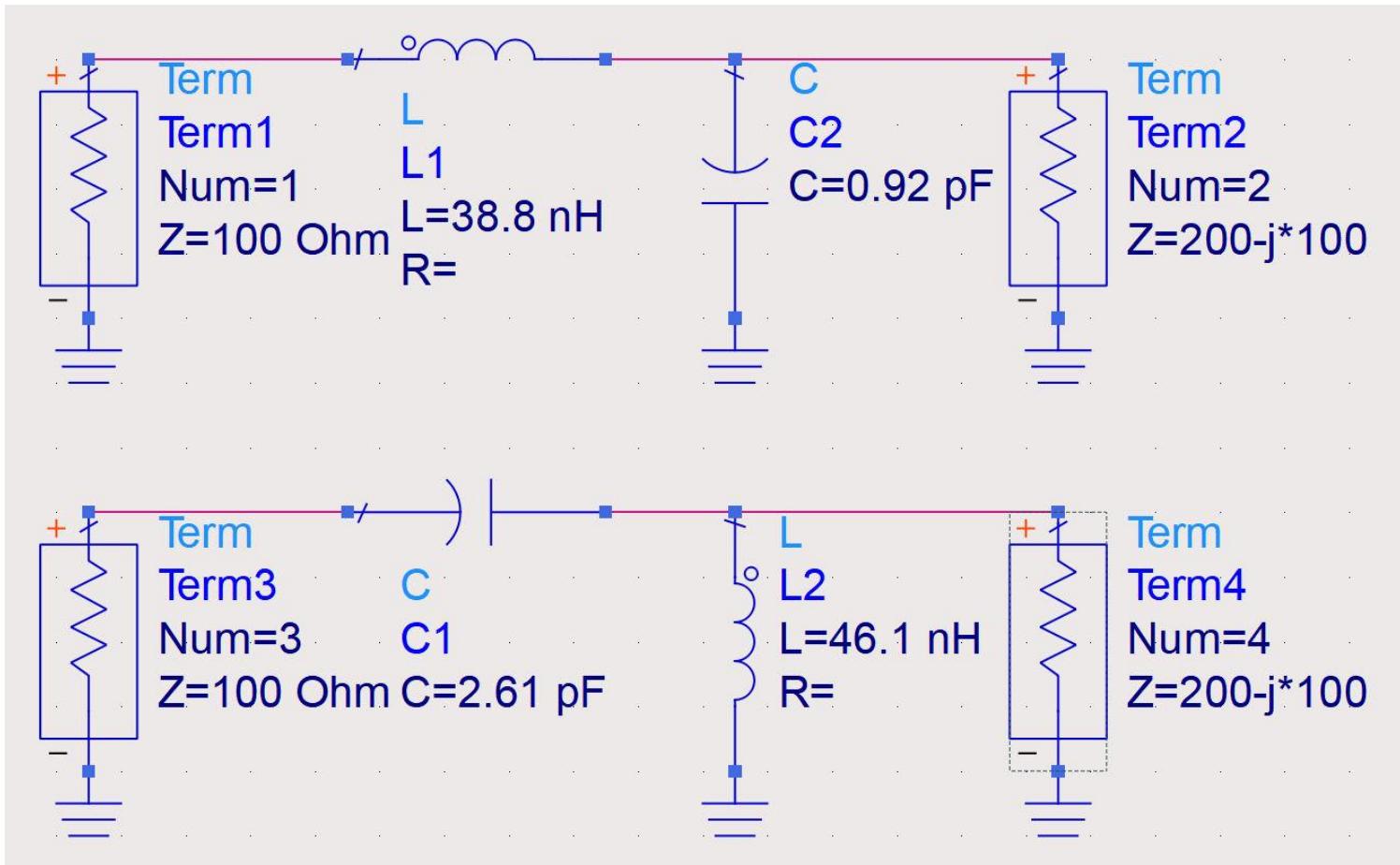
$$B = \pm \frac{\sqrt{(Z_0 - R_L)/R_L}}{Z_0}$$

- valoarea de sub radical e întotdeauna pozitiva pentru  $R_L < Z_0$
- se obțin două soluții realizabile

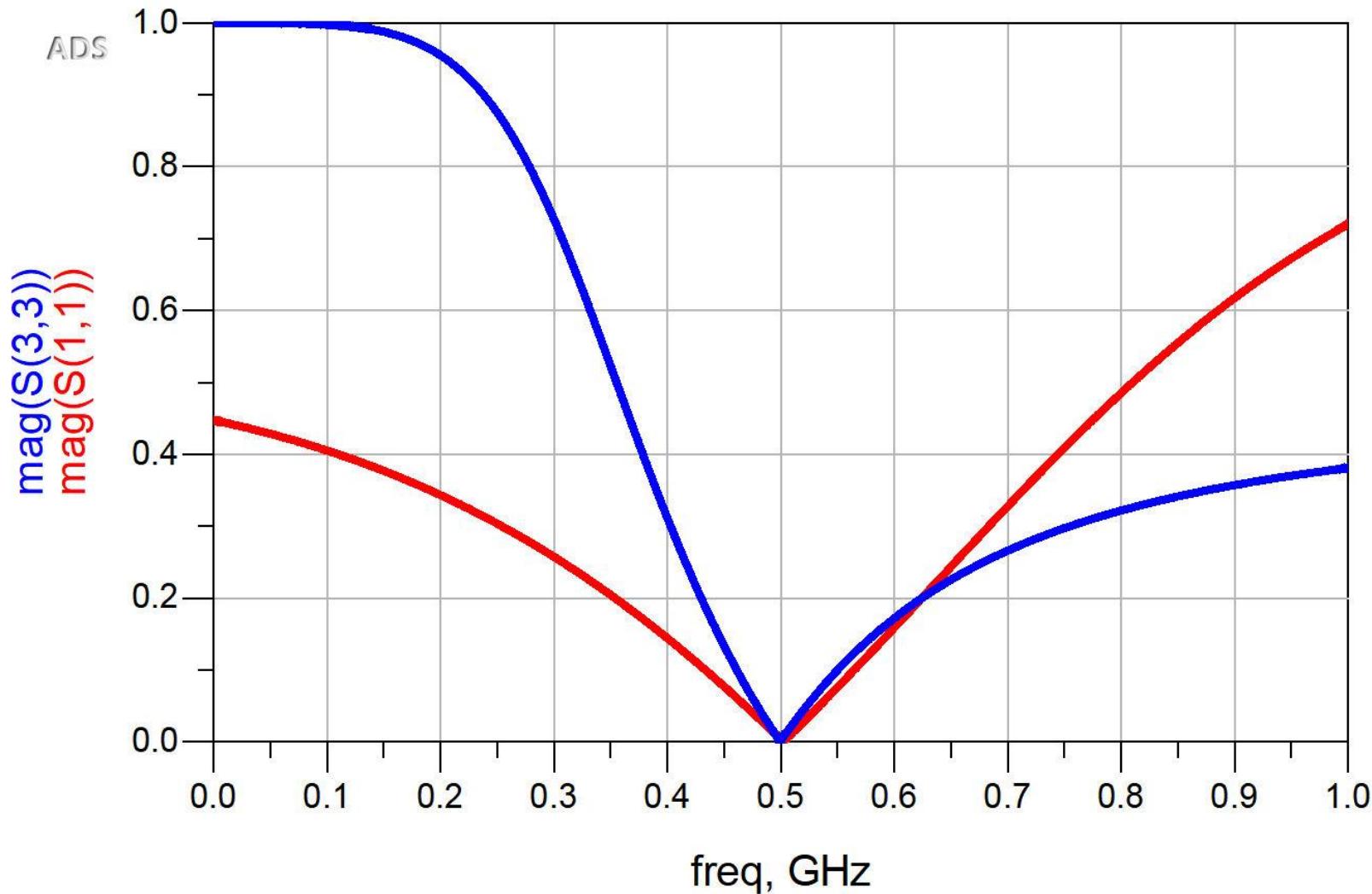
# Exemplu



# Exemplu



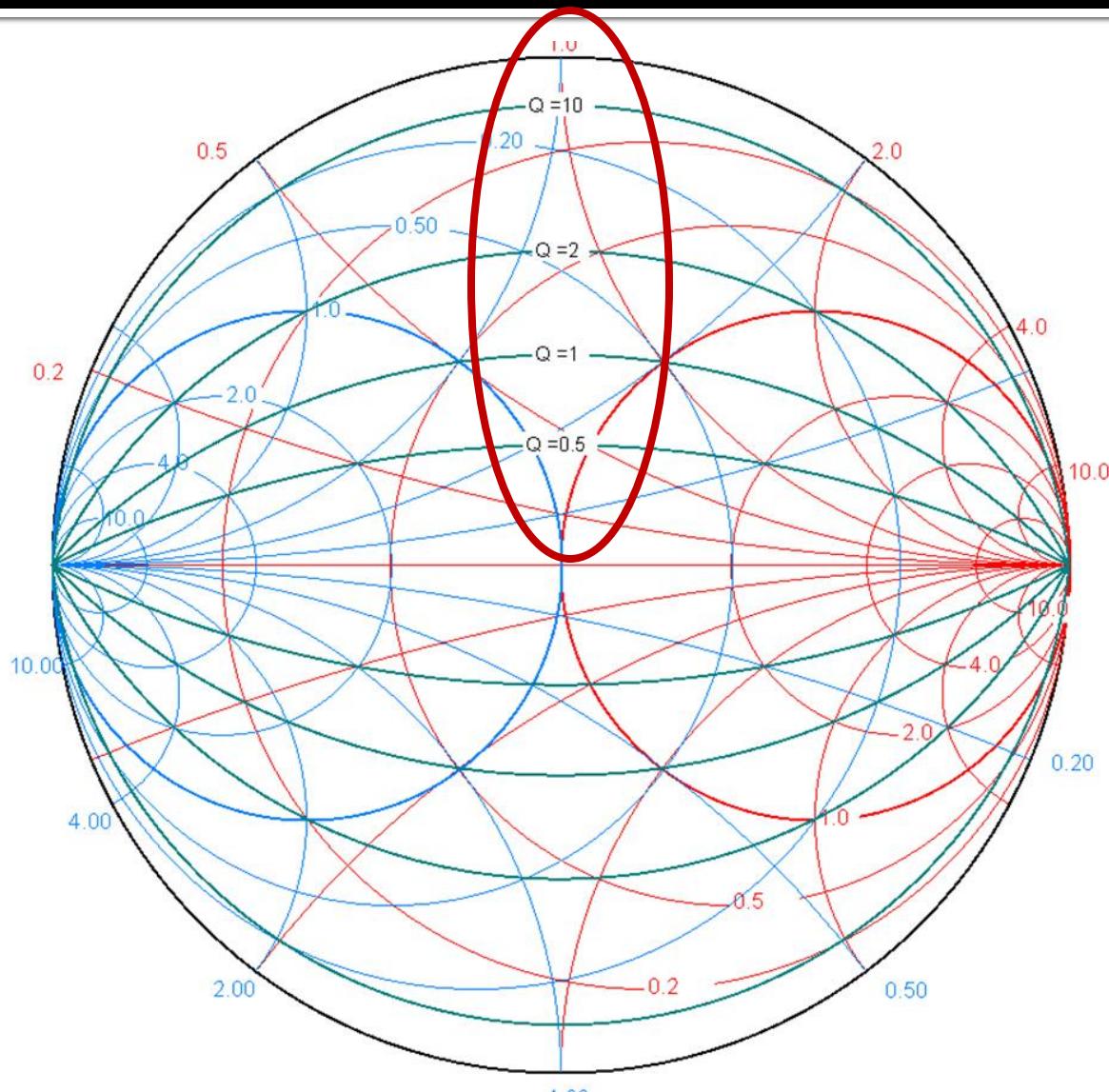
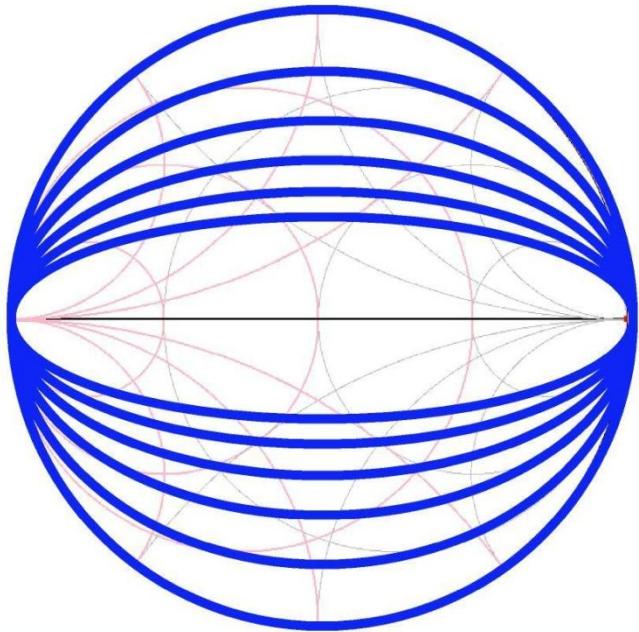
# Exemplu



# Cercuri de factor de calitate constant

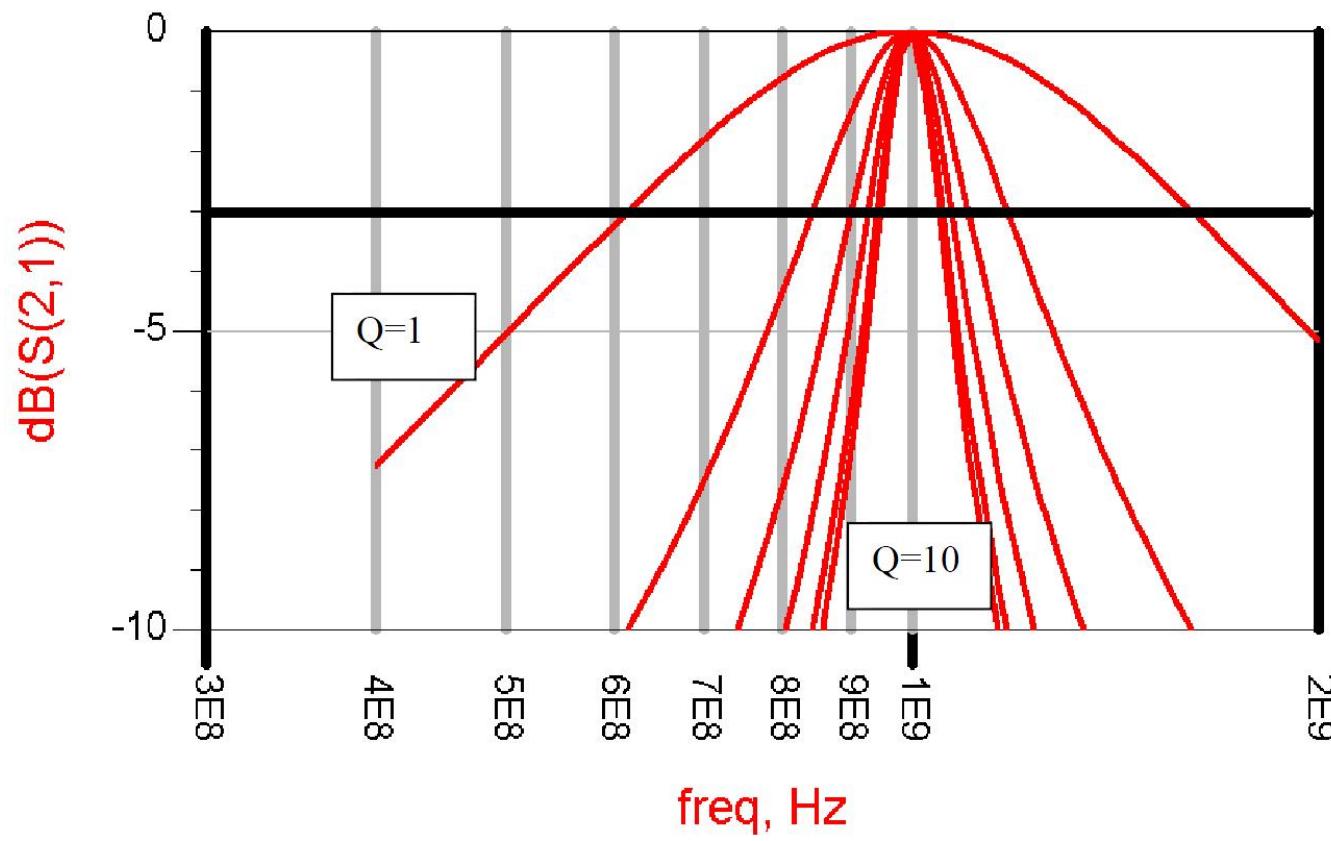
- Diagrama Smith

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

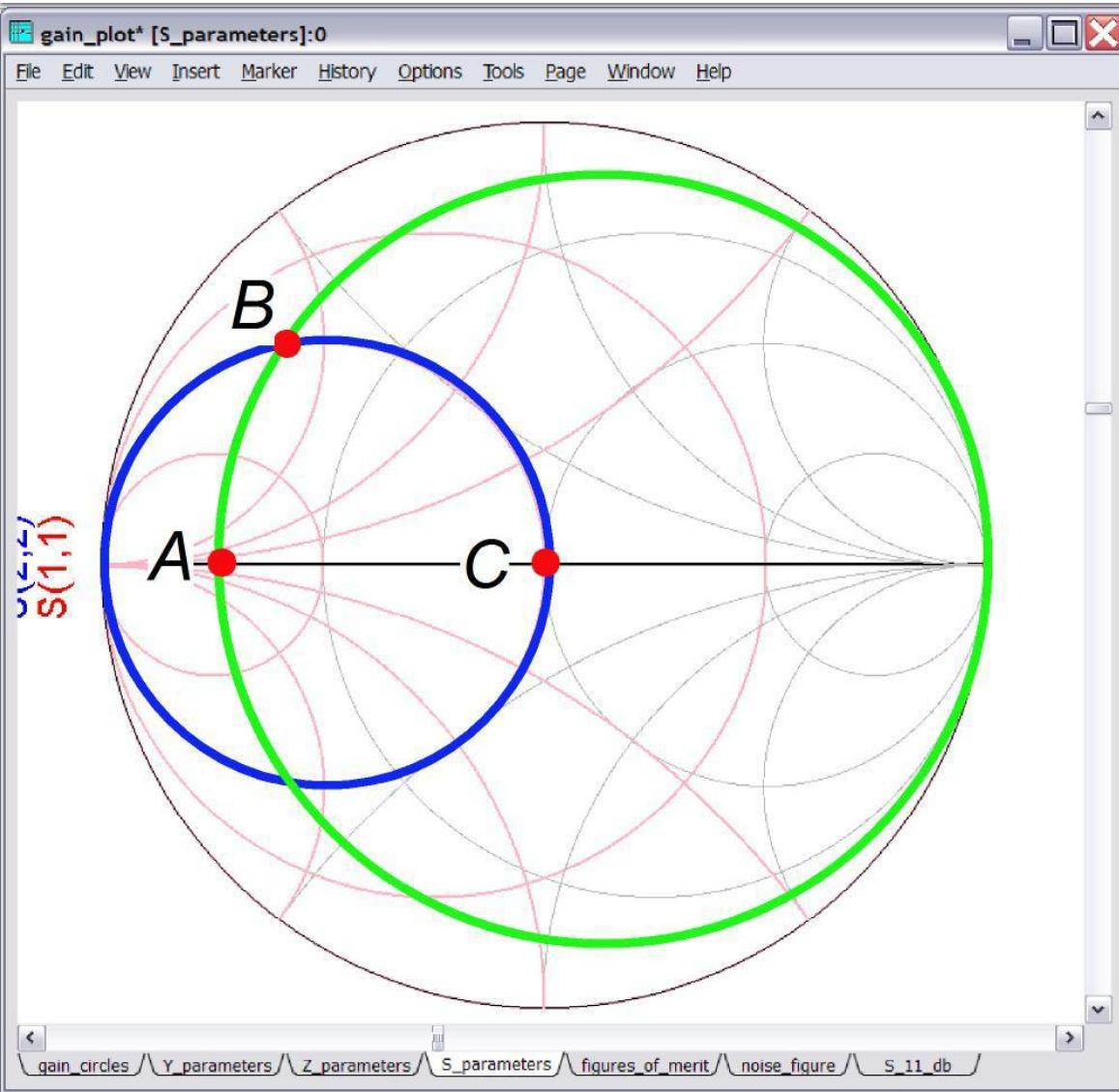


# Factor de calitate - banda

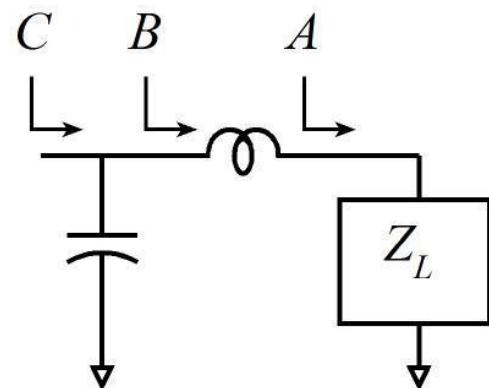
- Factor de calitate ridicat echivalent cu banda ingusta



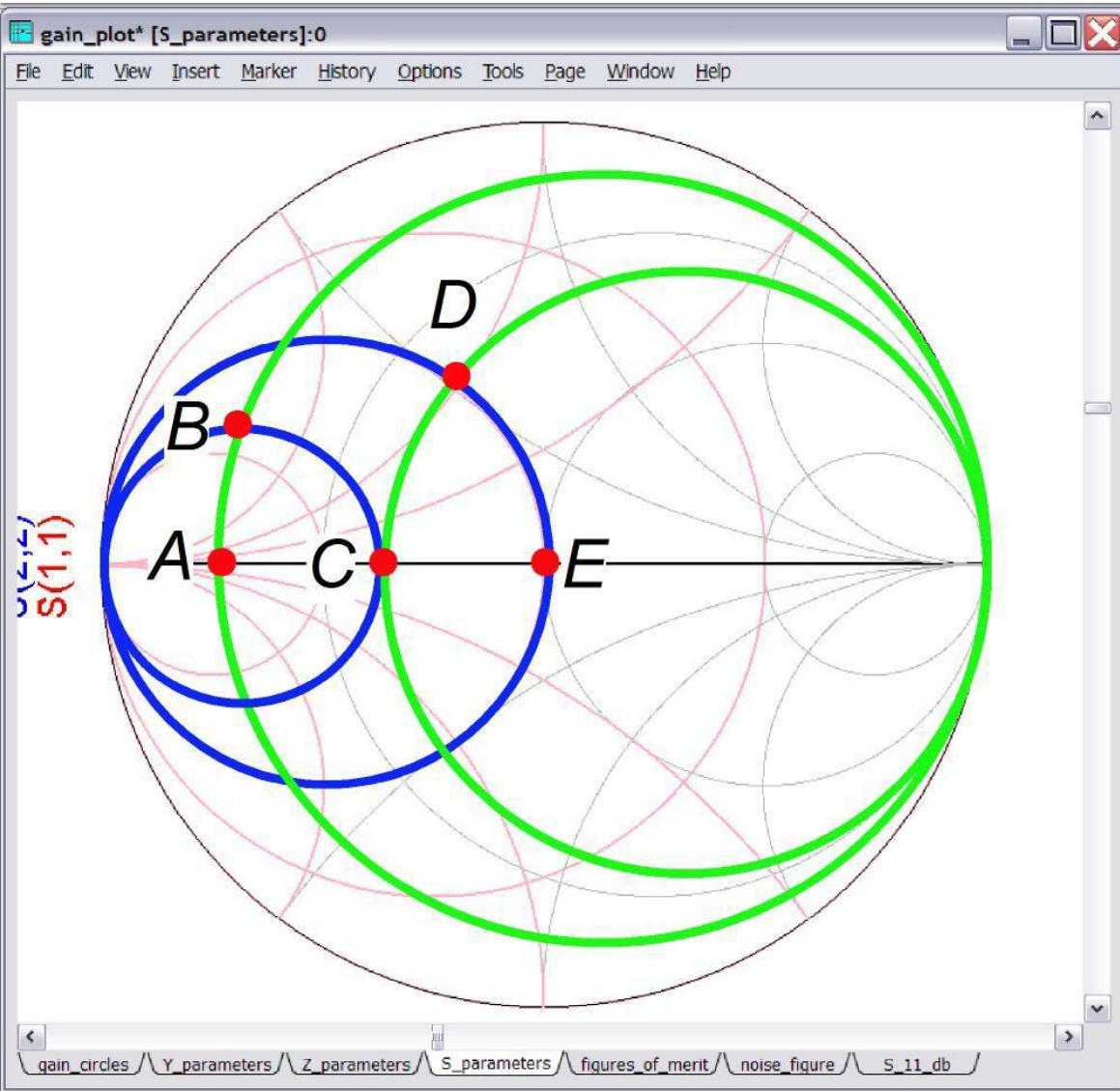
# Adaptare - banda



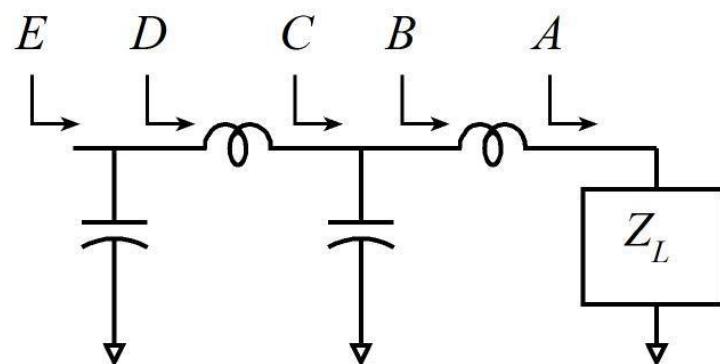
- Pozitia punctului intermediar (B) atins de  $\Gamma$  corespunzatoare celui mai ridicat factor de calitate impune largimea de banda a adaptarii



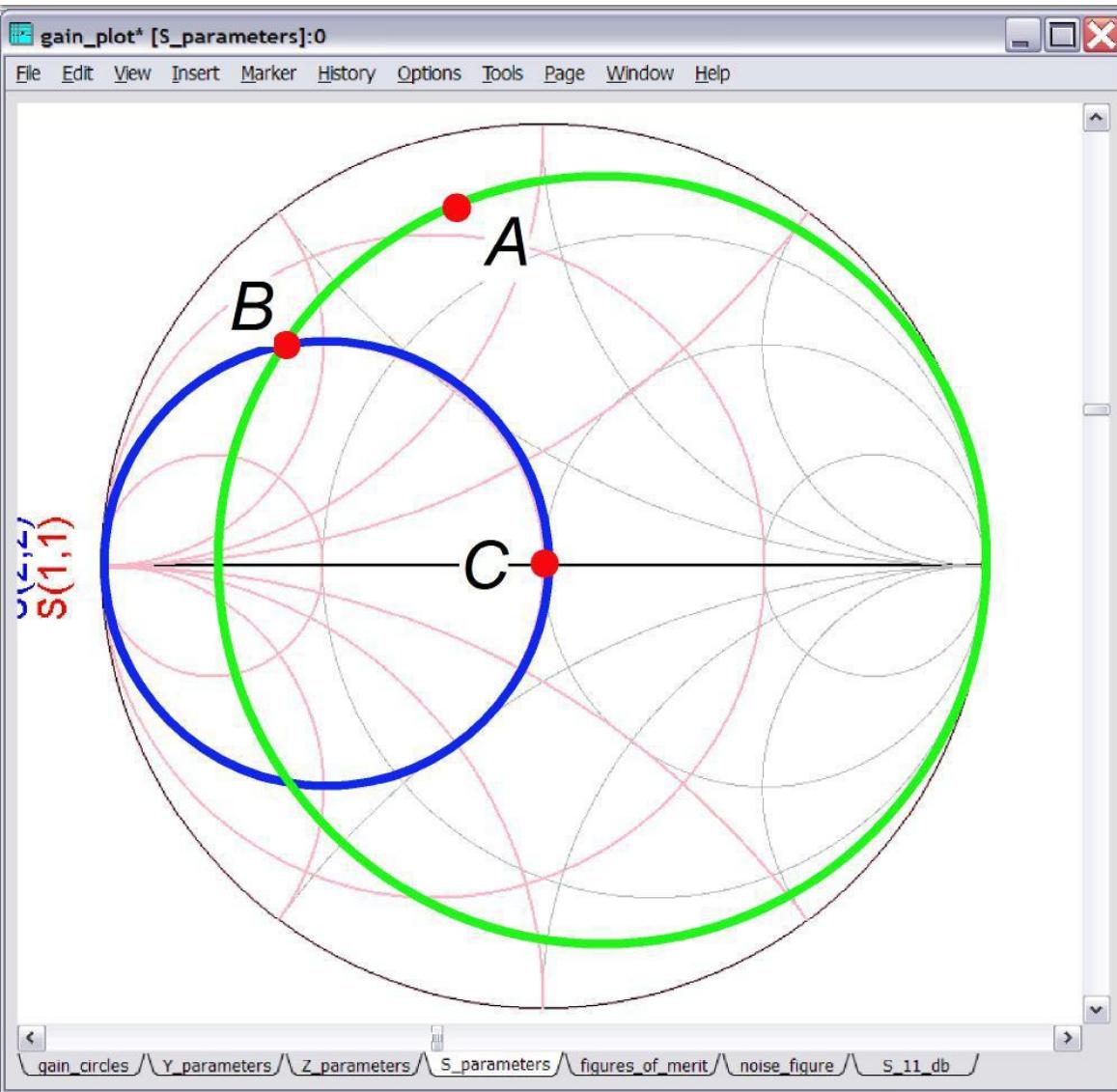
# Adaptare - banda



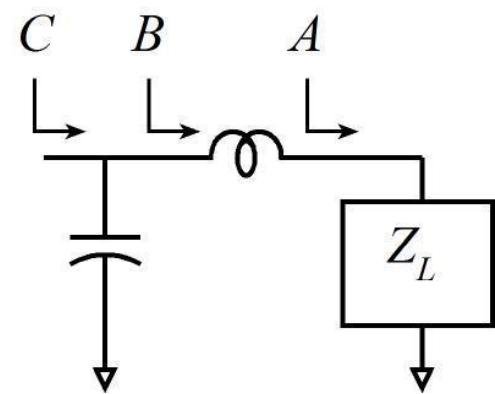
- Adaptare in banda mai larga poate fi obtinuta prin realizarea unor retele in L multiple, fiecare pentru variatii mai mici ale lui  $\Gamma$ , astfel incat toti coeficientii de reflexie intermediari (B, D) sa ocupe pozitii care corespund unui factor de calitate mai mic



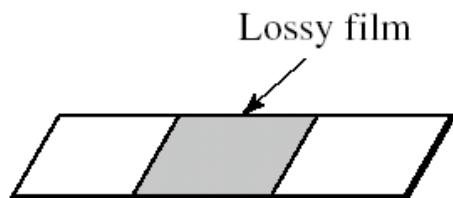
# Adaptare - banda



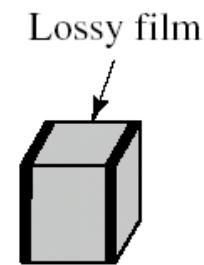
- Pentru pozitii initiale (determinate de sarcina) corespunzatoare unui factor de calitate ridicat (A) banda ingusta a adaptarii este inevitabila



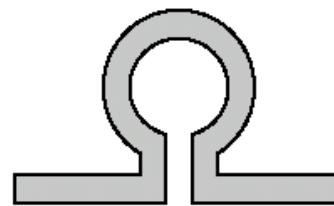
# Realizare elemente concentrate



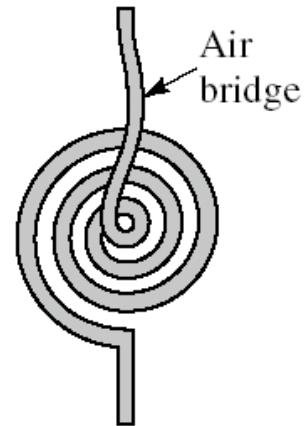
Planar resistor



Chip resistor



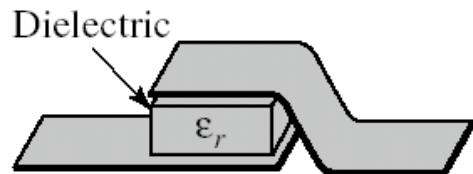
Loop inductor



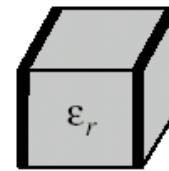
Spiral inductor



Interdigital  
gap capacitor



Metal-insulator-  
metal capacitor



Chip capacitor

Adaptarea cu sectiuni de linii (stub)

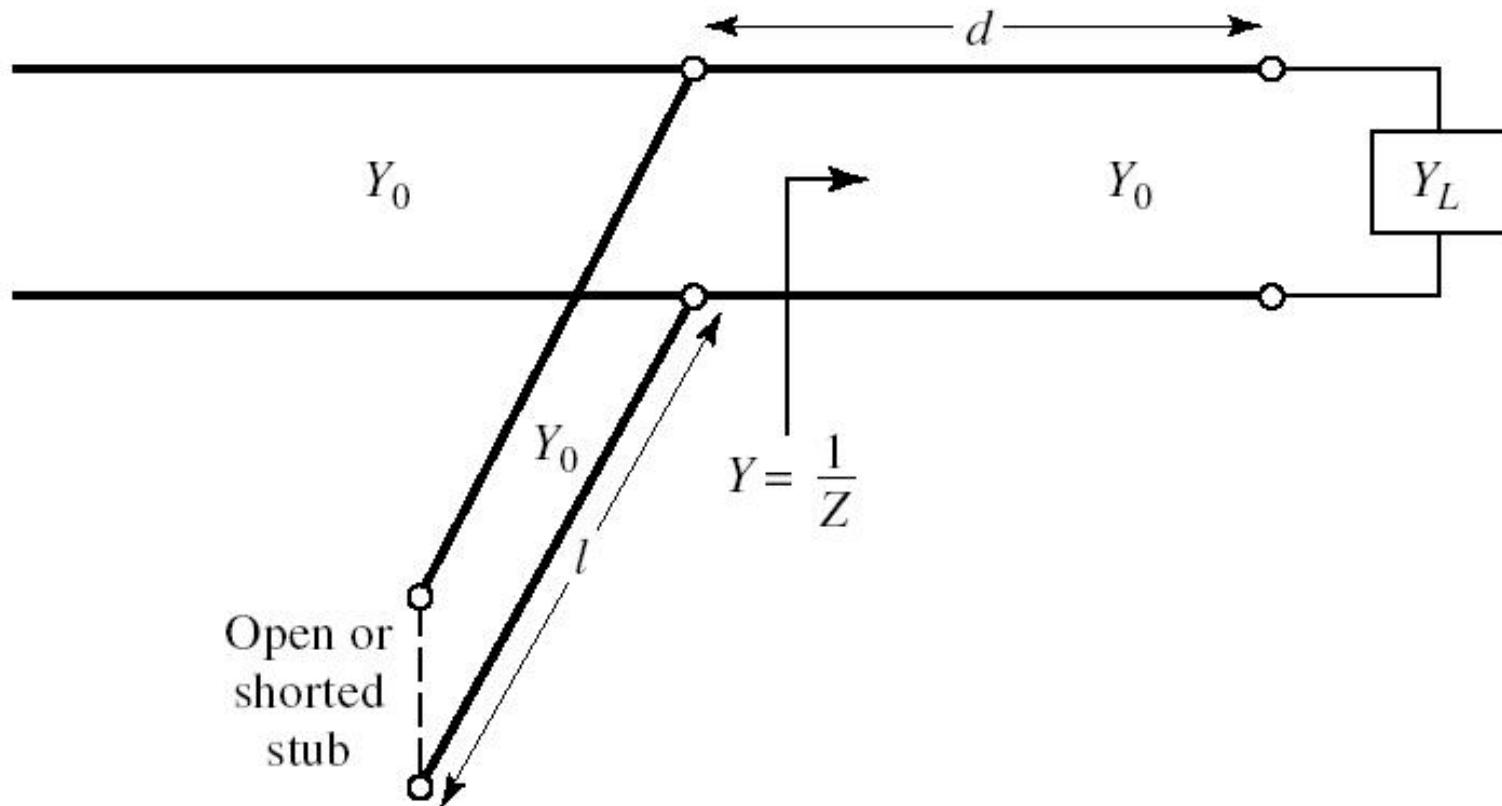
# **Adaptarea de impedanță**

# Stub

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

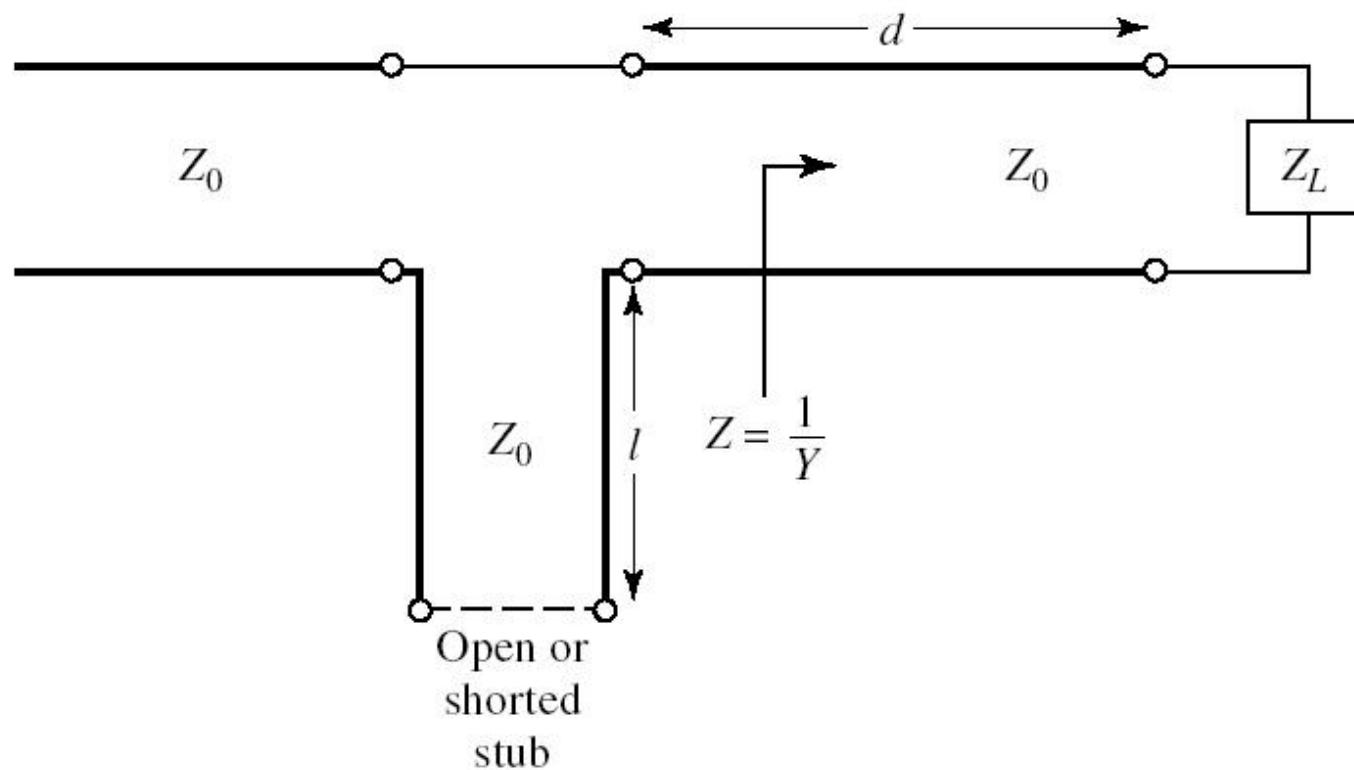
# Single stub tuning

- Shunt Stub (secțiune de linie în paralel)

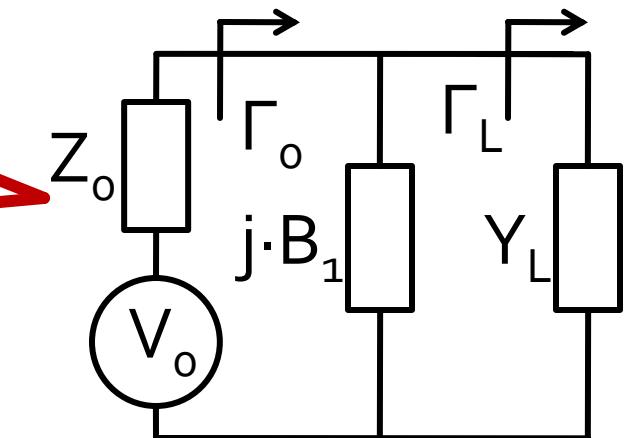
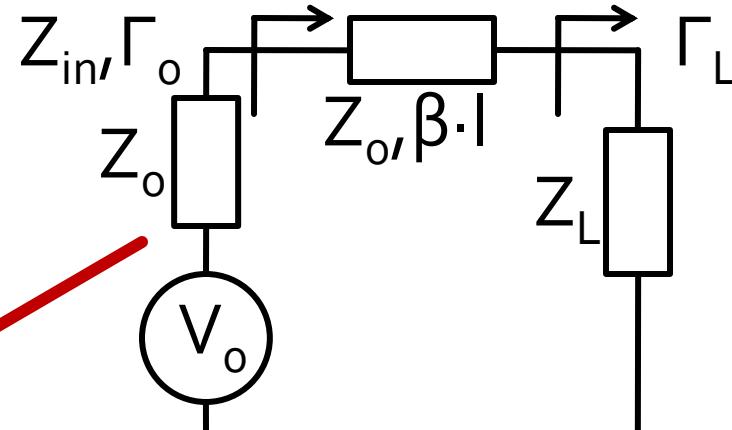
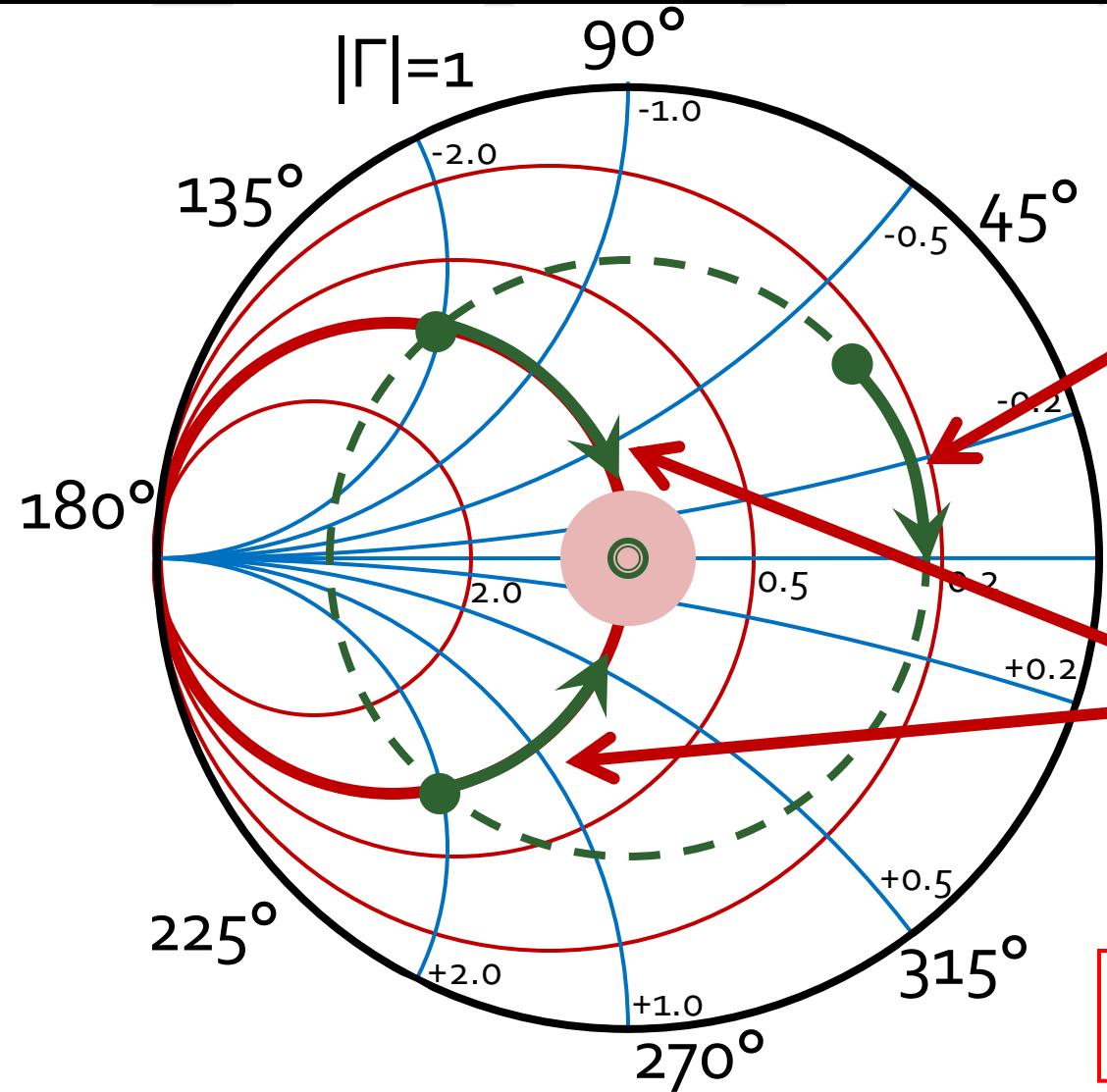


# Single stub tuning

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



# Adaptare, linie serie + susceptanta in paralel

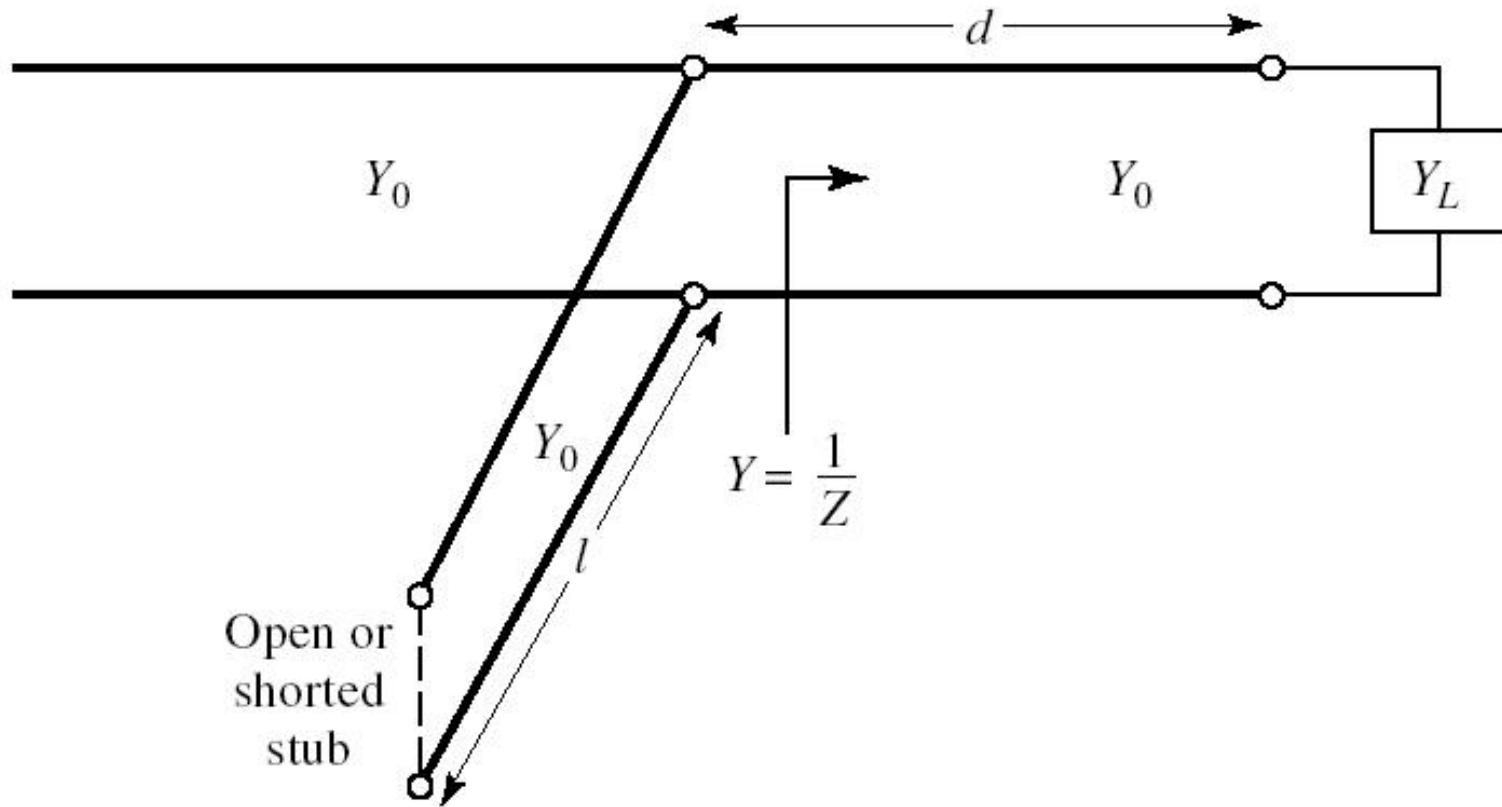


$$|\Gamma_{in}| = |\Gamma_L|$$

$$g_{in} = 1$$

# 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

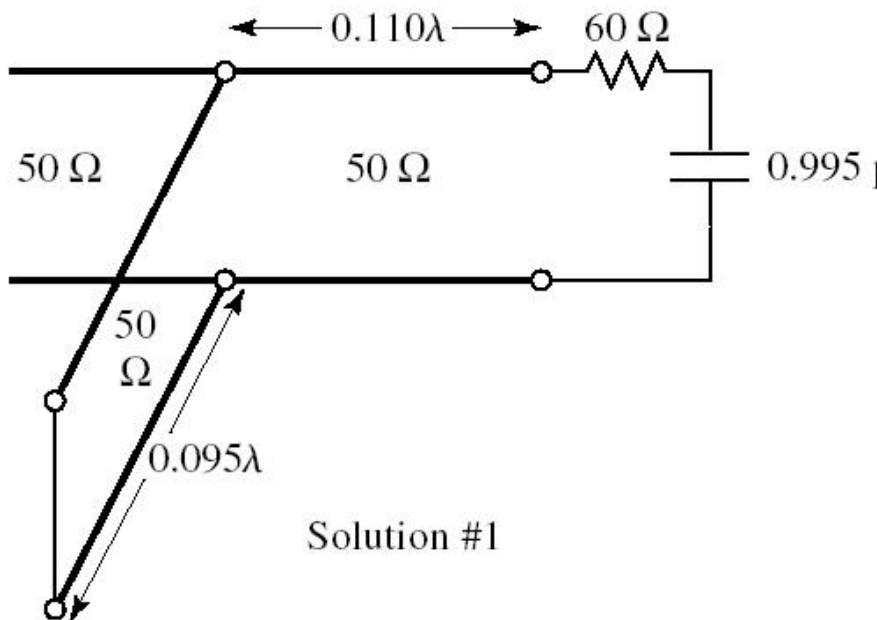
$$Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan \beta \cdot l}{Z_0 + j \cdot Z_L \cdot \tan \beta \cdot l}$$

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

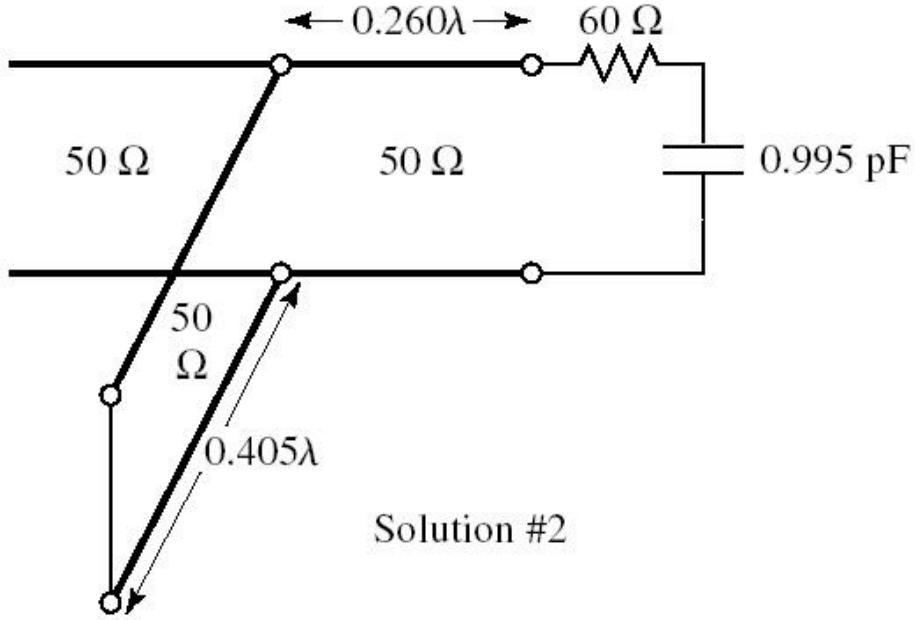
$$Z_{in,g} = -j \cdot Z_0 \cdot \cot \beta \cdot l$$

# Exemplu, Shunt Stub, sc

- sarcina:  $60 \Omega$  serie  $0.995 \text{ pF}$  la  $2\text{GHz}$
- doua solutii posibile

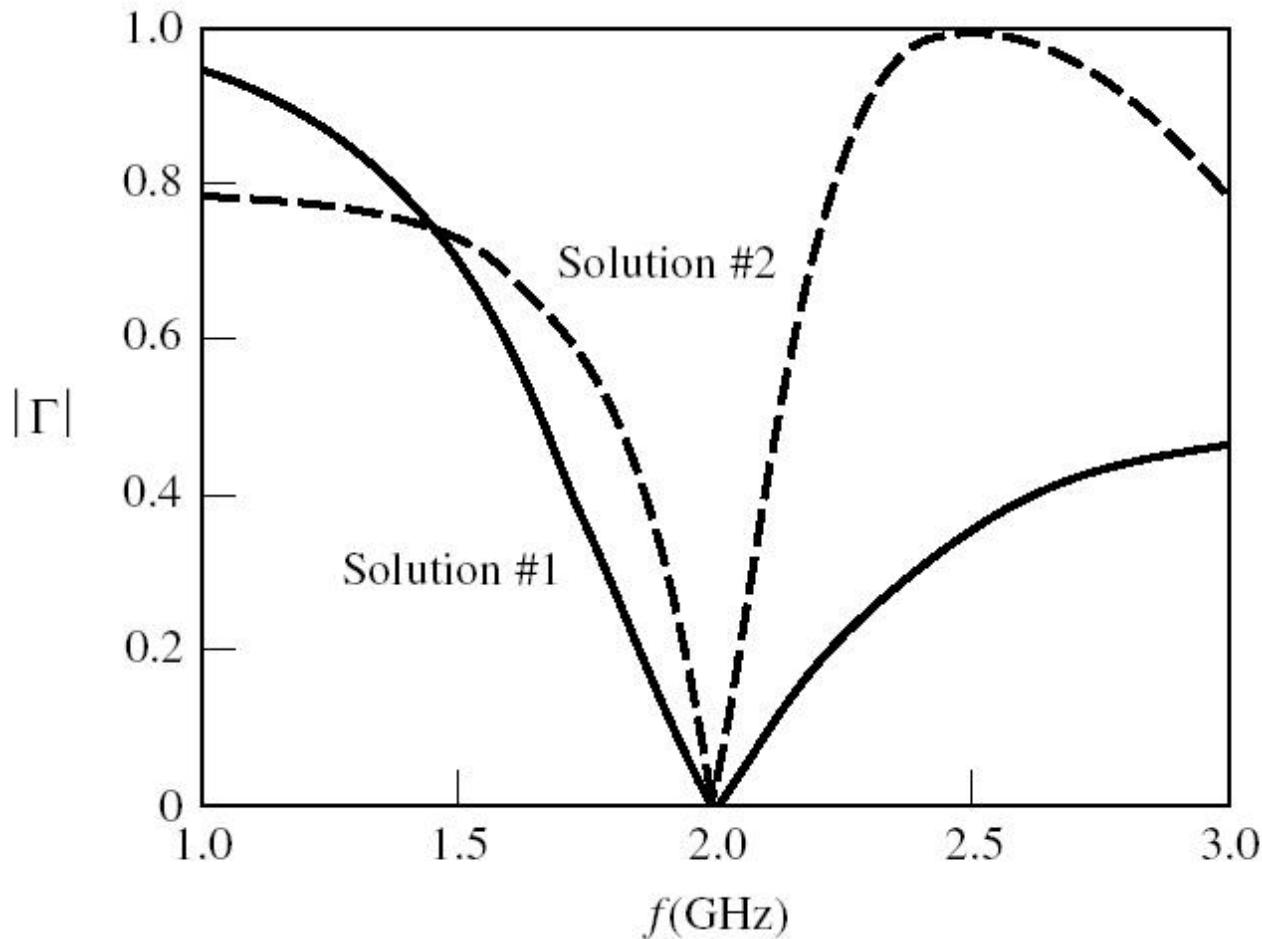


Solution #1

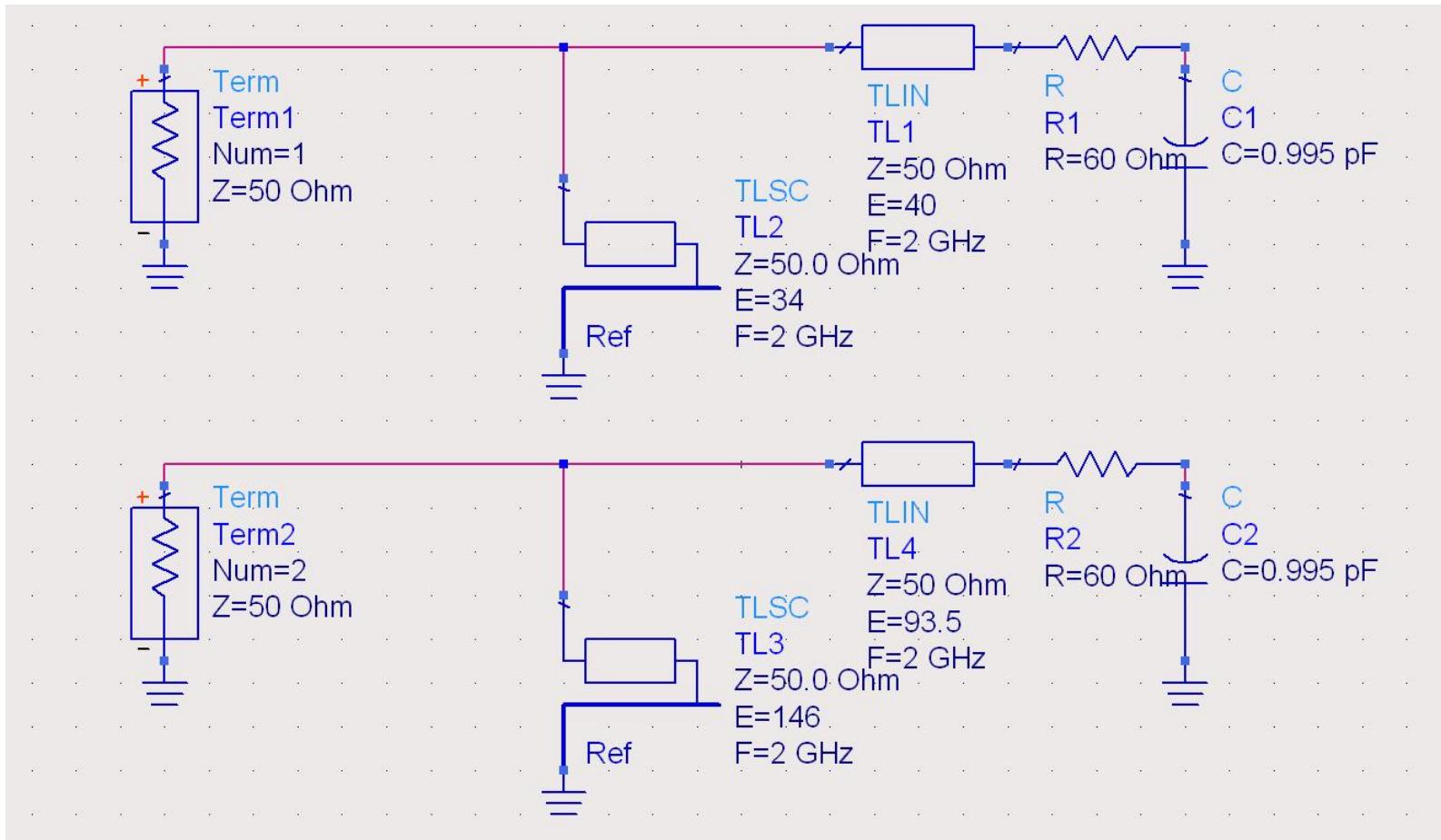


Solution #2

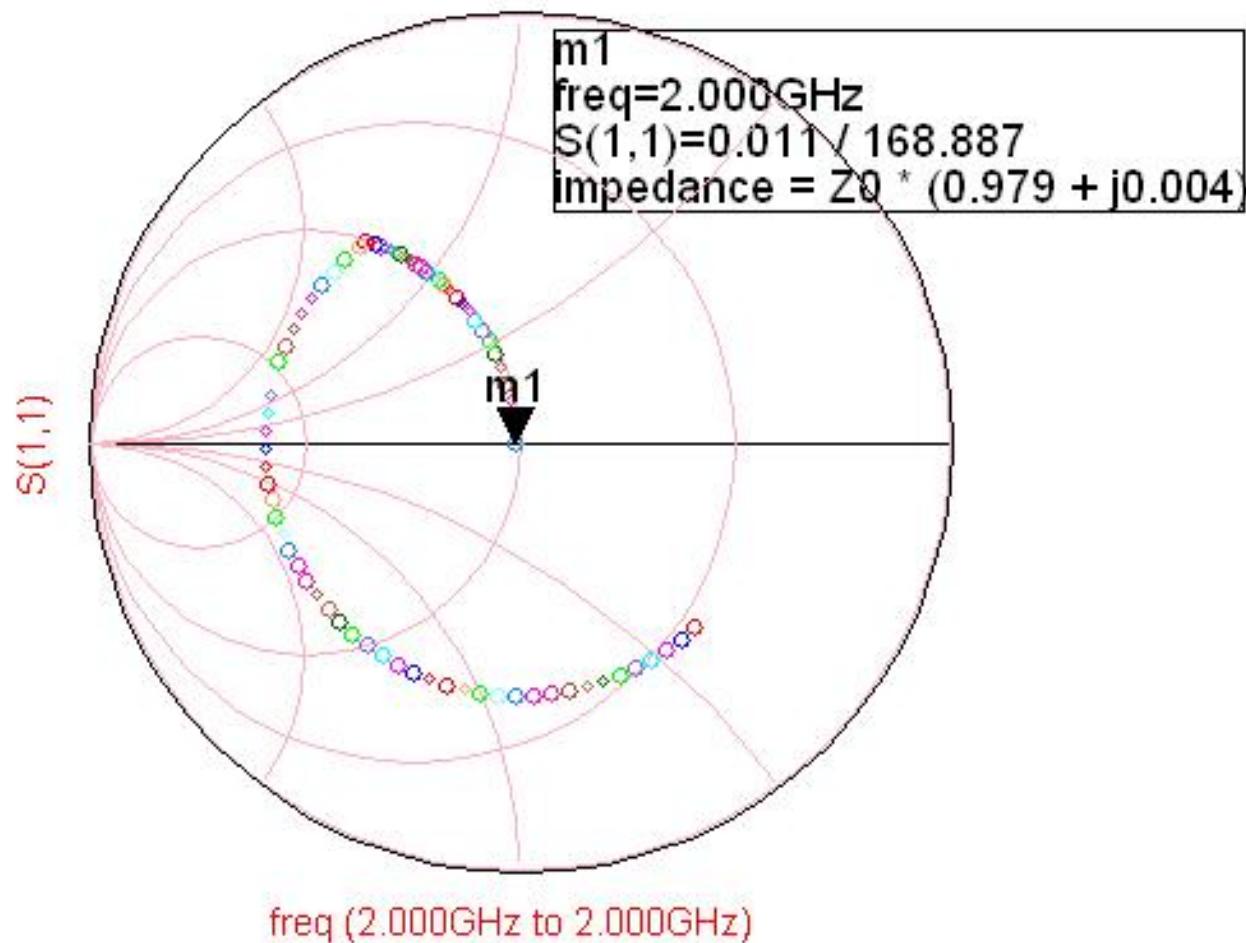
# Exemplu, Shunt Stub, sc



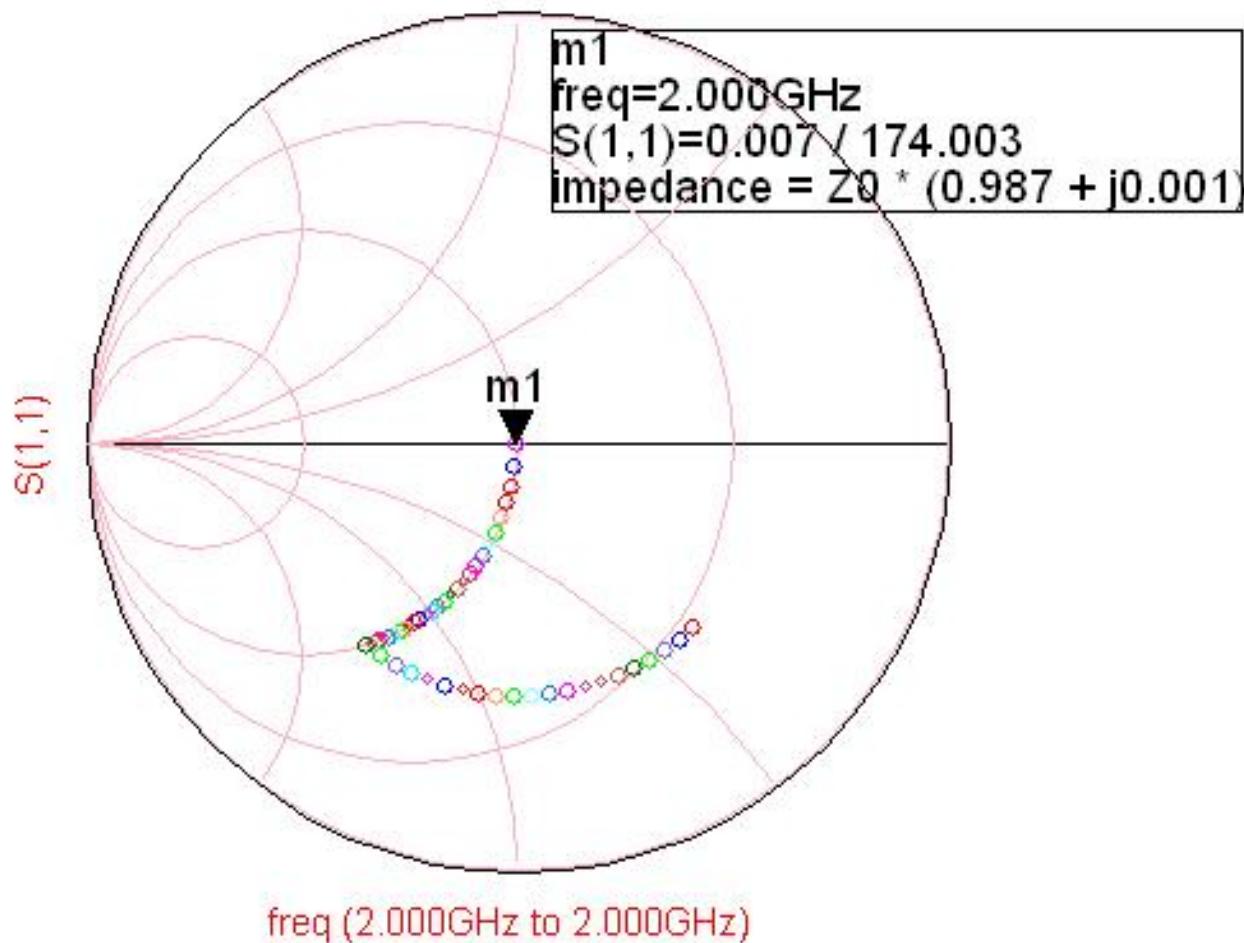
# Exemplu, Shunt Stub, sc



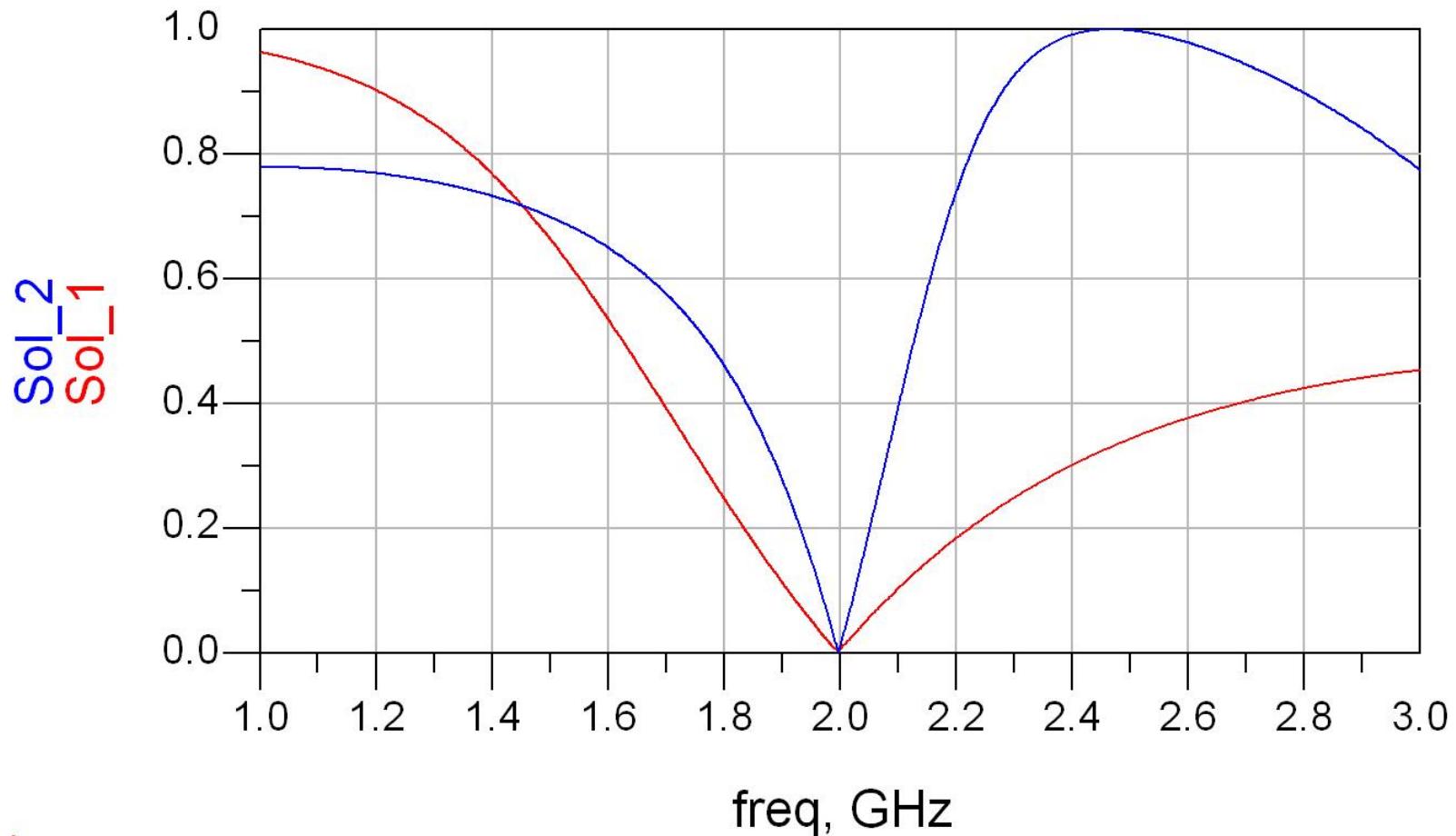
# Exemplu, Shunt Stub, sc



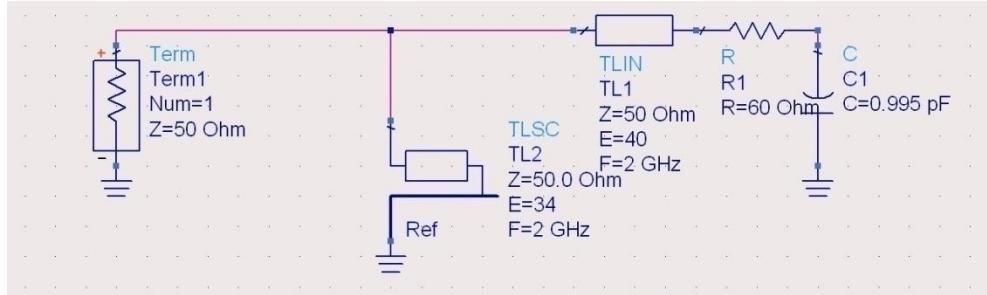
# Exemplu, Shunt Stub, sc



# Exemplu, Shunt Stub, sc



# Exemplu, Shunt Stub, sc

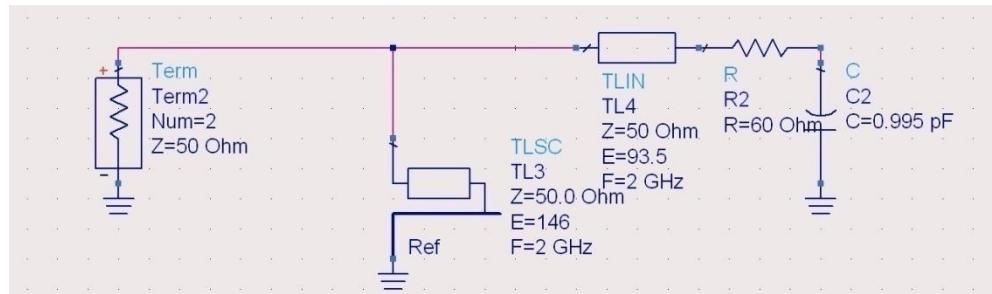


$$l_1 = \frac{40^\circ}{360^\circ} \cdot \lambda = 0.111 \cdot \lambda$$

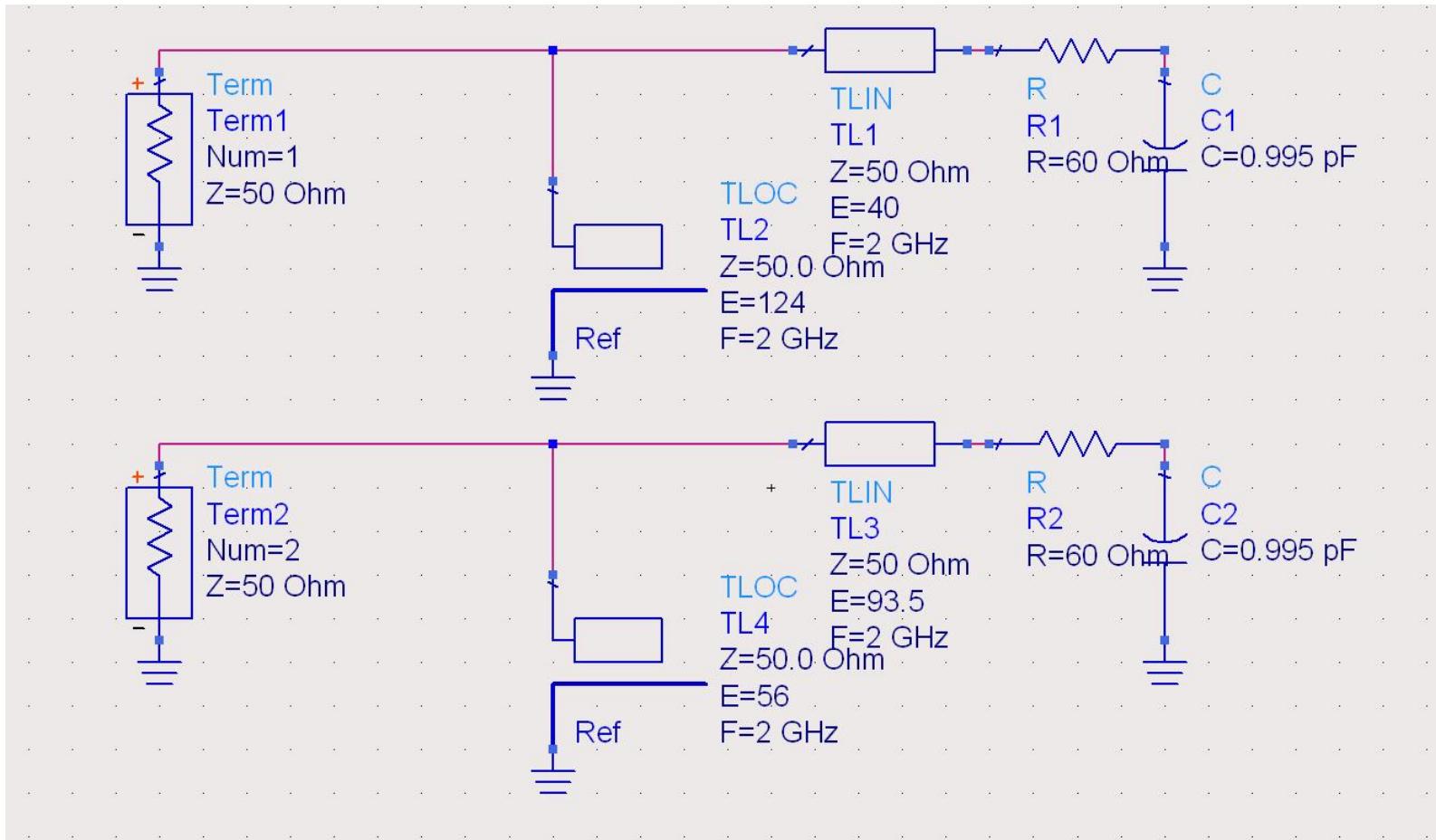
$$l_2 = \frac{34^\circ}{360^\circ} \cdot \lambda = 0.094 \cdot \lambda$$

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

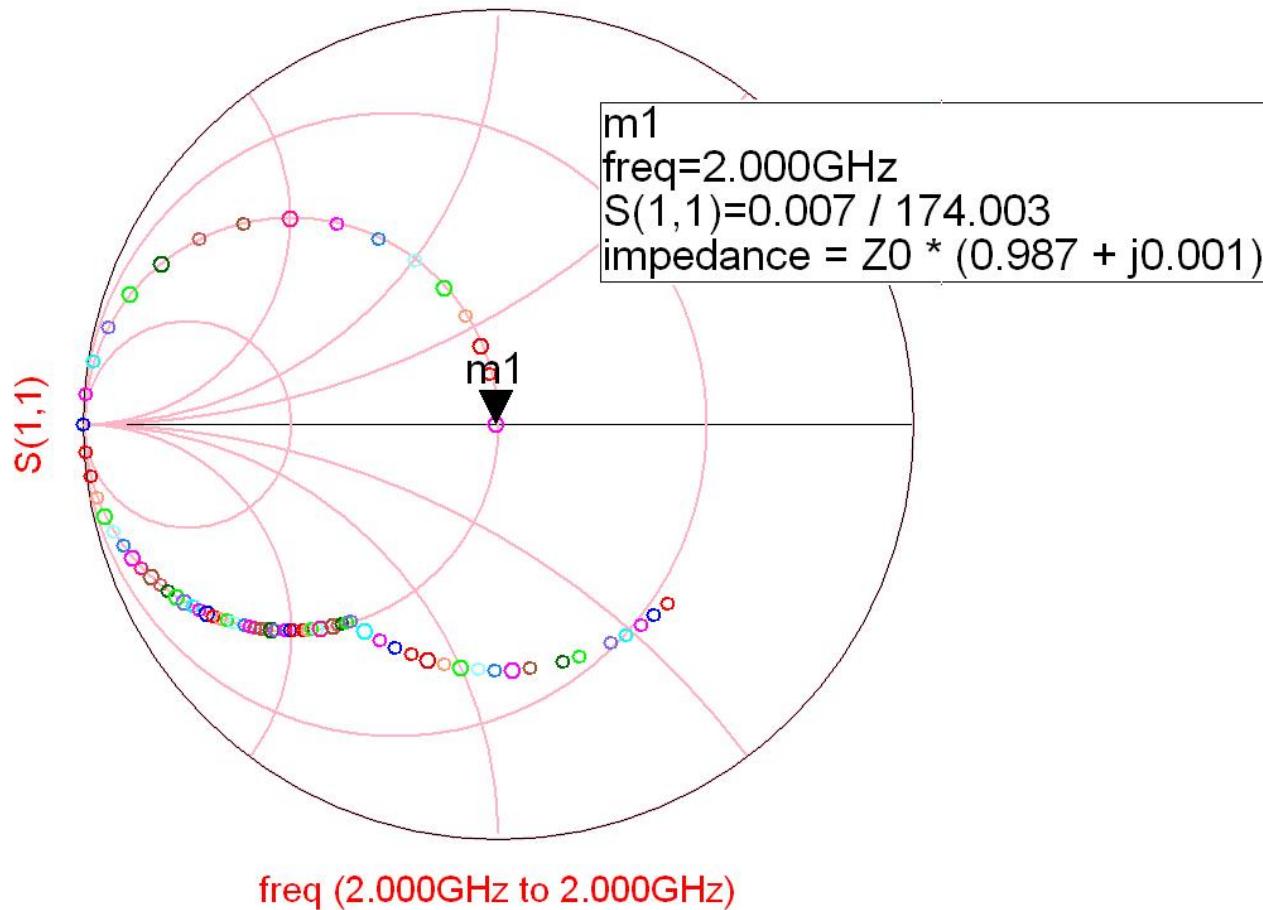
$$l_2 = \frac{146^\circ}{360^\circ} \cdot \lambda = 0.406 \cdot \lambda$$



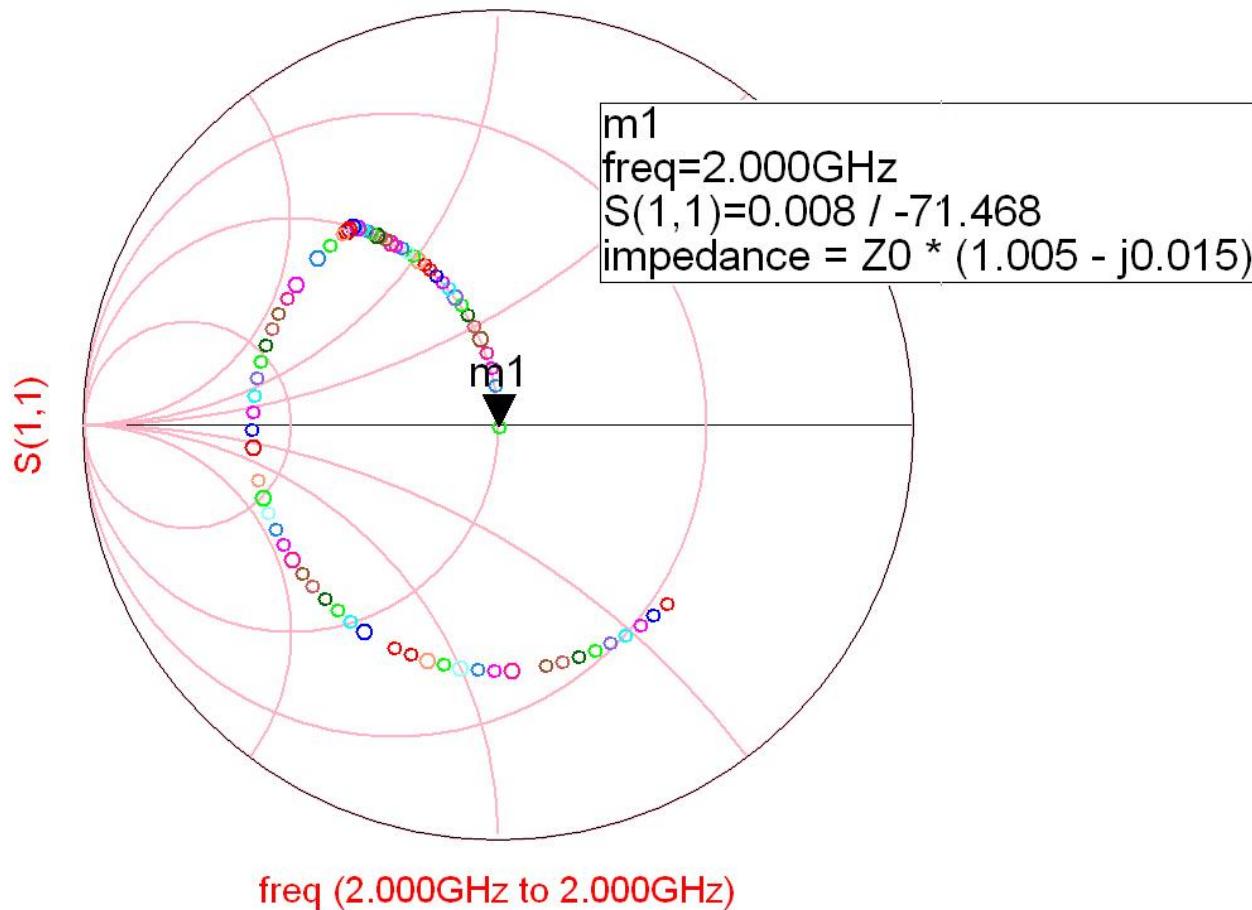
# Exemplu, Shunt Stub, gol



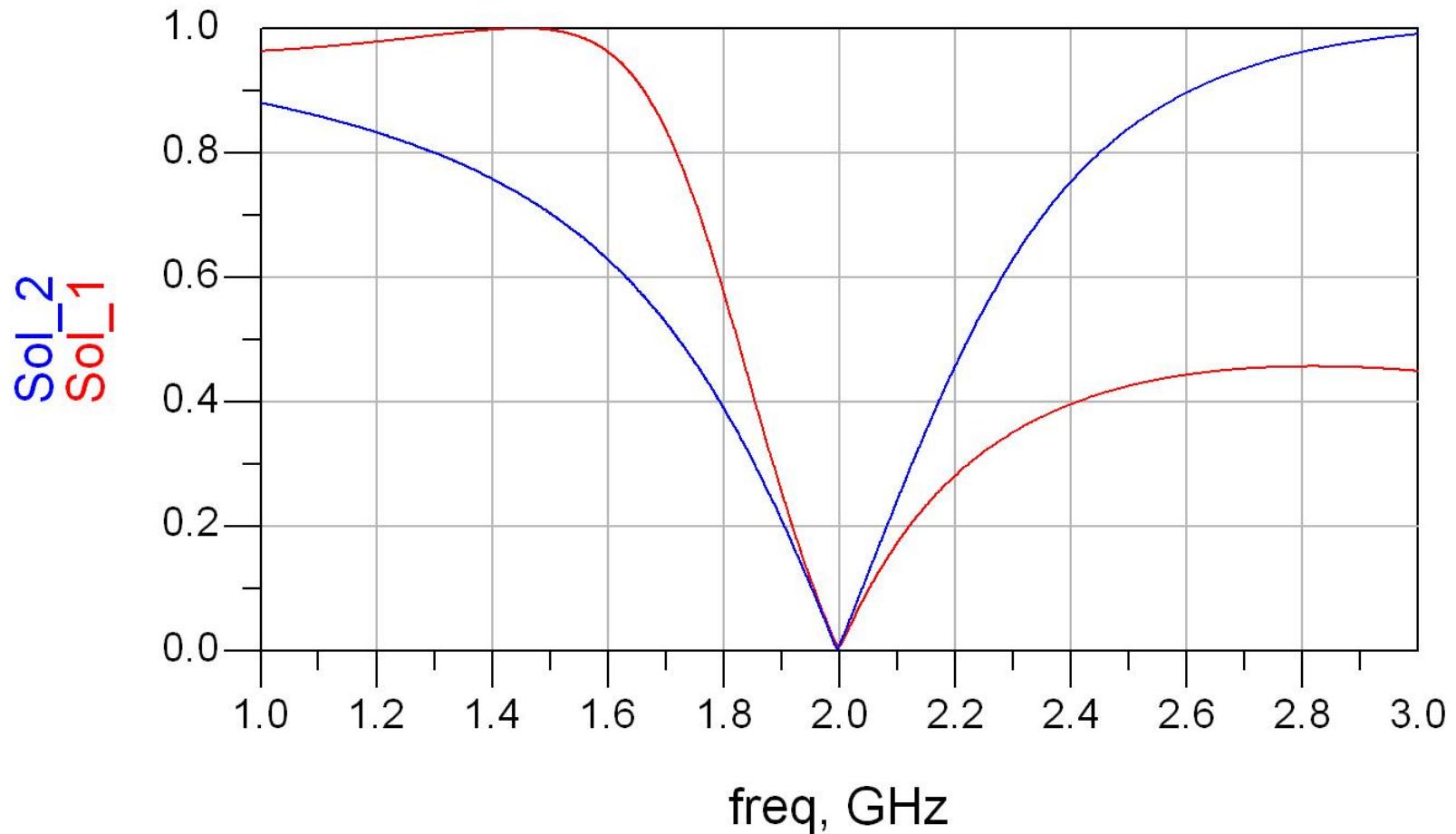
# Exemplu, Shunt Stub, gol



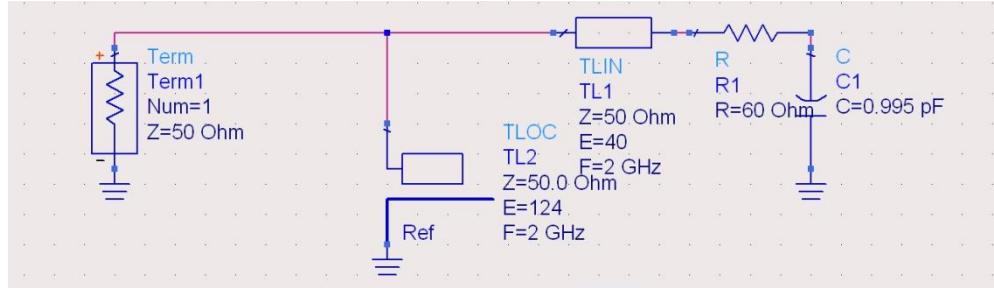
# Exemplu, Shunt Stub, gol



# Exemplu, Shunt Stub, gol



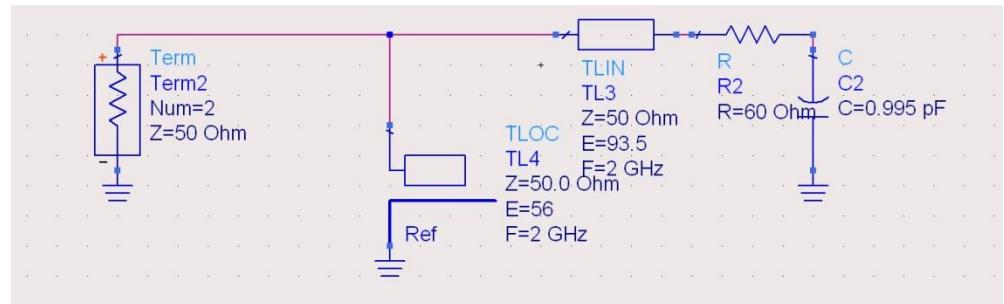
# Exemplu, Shunt Stub, gol



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

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

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



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



# 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:

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

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

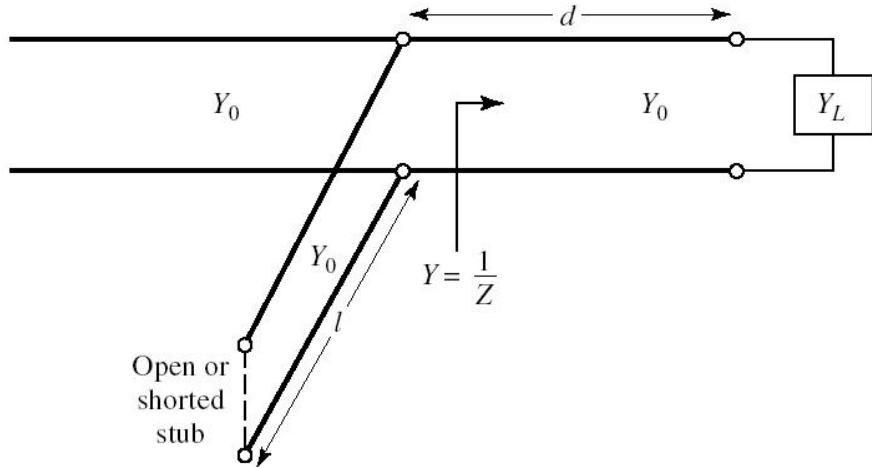
# Stub, observatii

- 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



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

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

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

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

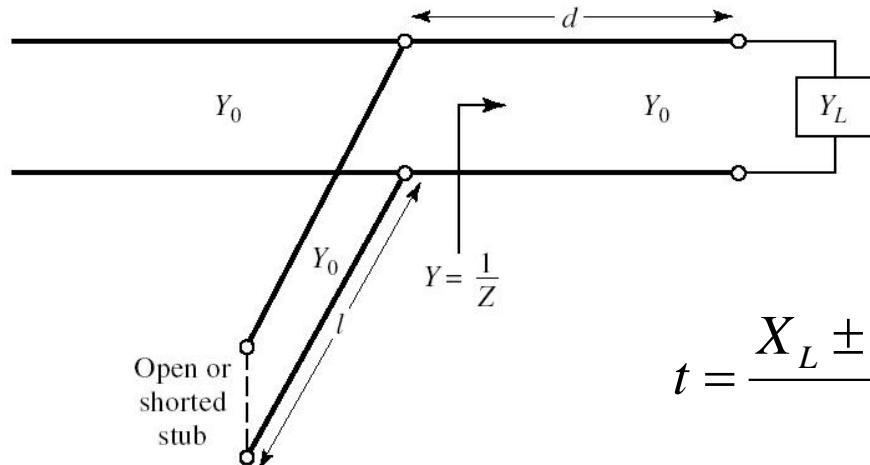
$$B = \frac{R_L^2 \cdot t - (Z_0 - X_L \cdot t) \cdot (X_L + Z_0 \cdot t)}{Z_0 \cdot [R_L^2 + (X_L + Z_0 \cdot t)^2]}$$

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

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

- $d$  este ales astfel incat

# Solutie analitica



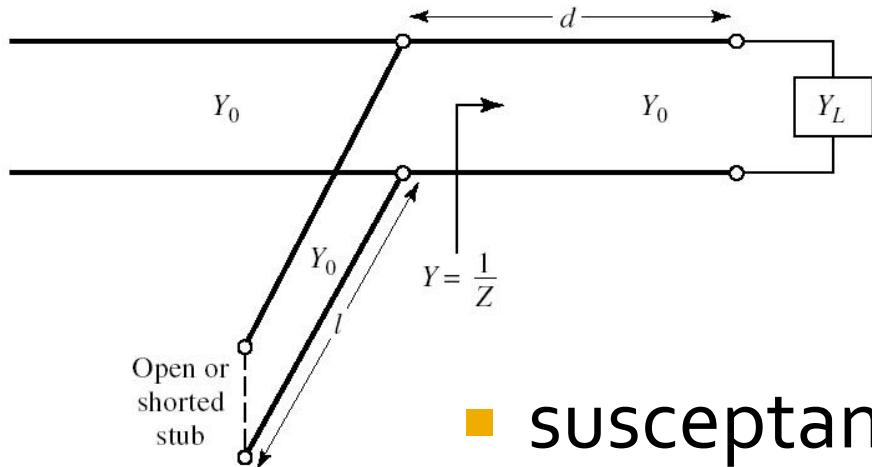
$$t = -\frac{X_L}{2 \cdot Z_0}, \quad R_L = Z_0$$

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

- 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

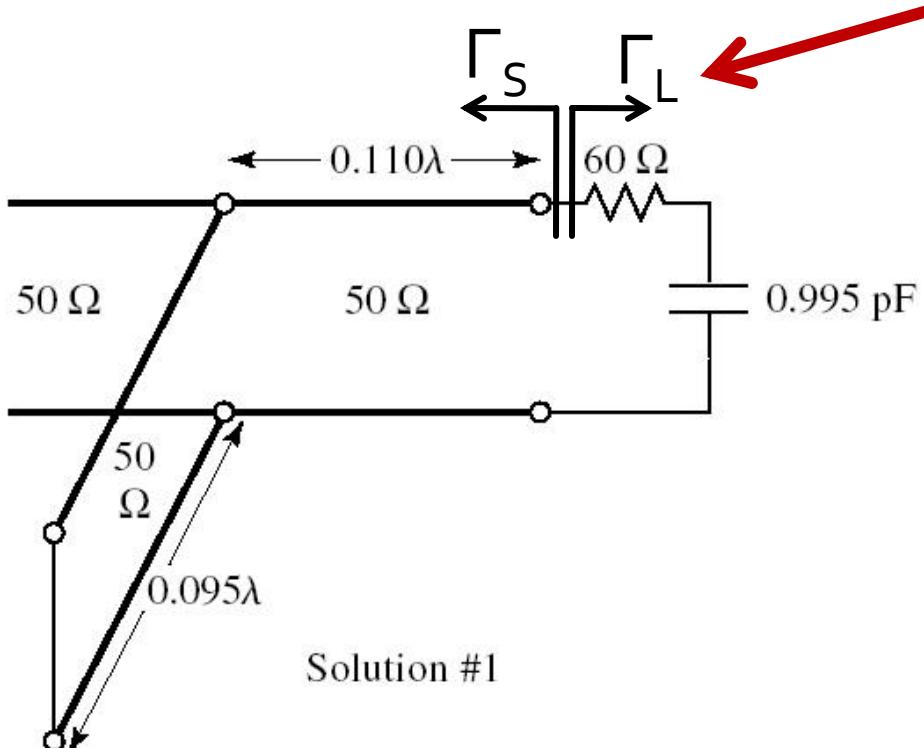
$$\frac{l_{gol}}{\lambda} = \frac{1}{2\pi} \cdot \arctan \left( \frac{B_S}{Y_0} \right) = \frac{-1}{2\pi} \cdot \arctan \left( \frac{B}{Y_0} \right)$$

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

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

# Calcul analitic, coeficienti de reflexie

- sarcina:  $60 \Omega$  serie  $0.995 \text{ pF}$  la  $2\text{GHz}$



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

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

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

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

- 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

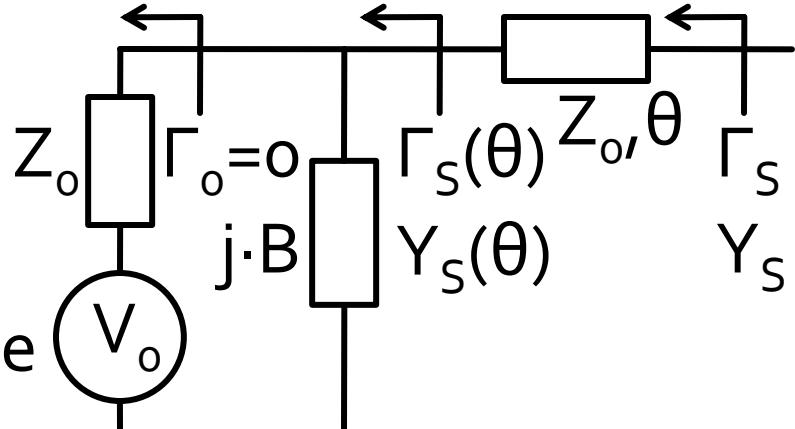
## ■ linie serie

- 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  $\theta$

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

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

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

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

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

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

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

# Calcul analitic, linie serie (calcul)

- Ecuatia pentru calcularea  $\theta$  (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  $\lambda/2$  ( $180^\circ$ ) dupa nevoie

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

$$\cos(\varphi + 2\theta) = -0.593 \Rightarrow (\varphi + 2\theta) = \pm 126.35^\circ \quad \forall k \in N$$

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

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

# Calcul analitic, stub paralel (dem.)

- Ecuatia pentru calcularea stub-ului paralel  $\theta_{sp}$

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

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

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

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

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

# 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)

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

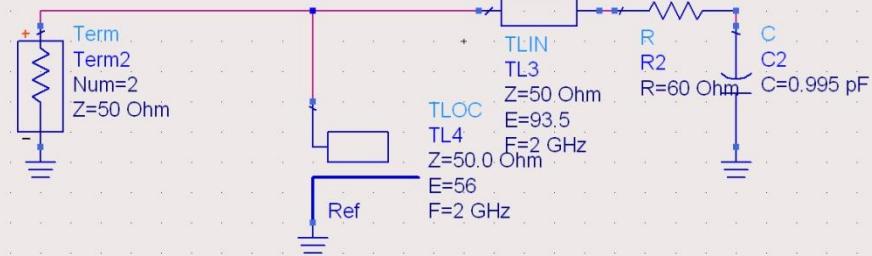
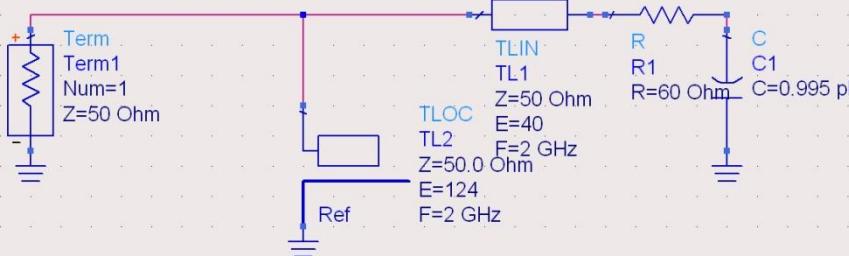
- Se alege **una** din cele doua solutii posibile
- **Semnul (+/-)** solutiei alese la **prima** ecuatie impune **semnul** solutiei utilizate la a **doua** ecuatie

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

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

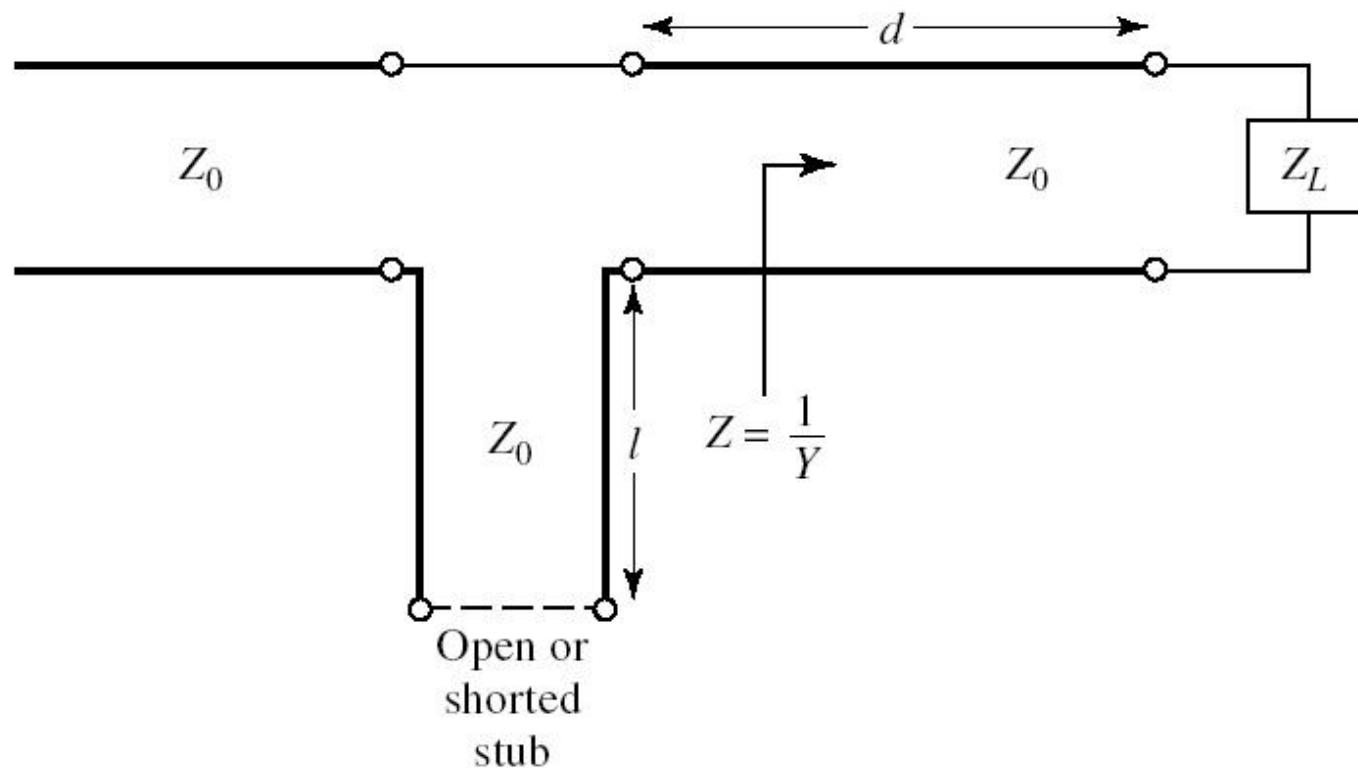
$$l_1 = \frac{93.4^\circ}{360^\circ} \cdot \lambda = 0.259 \cdot \lambda$$

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



# Caz 2, Series Stub

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



# Caz 2, Series Stub

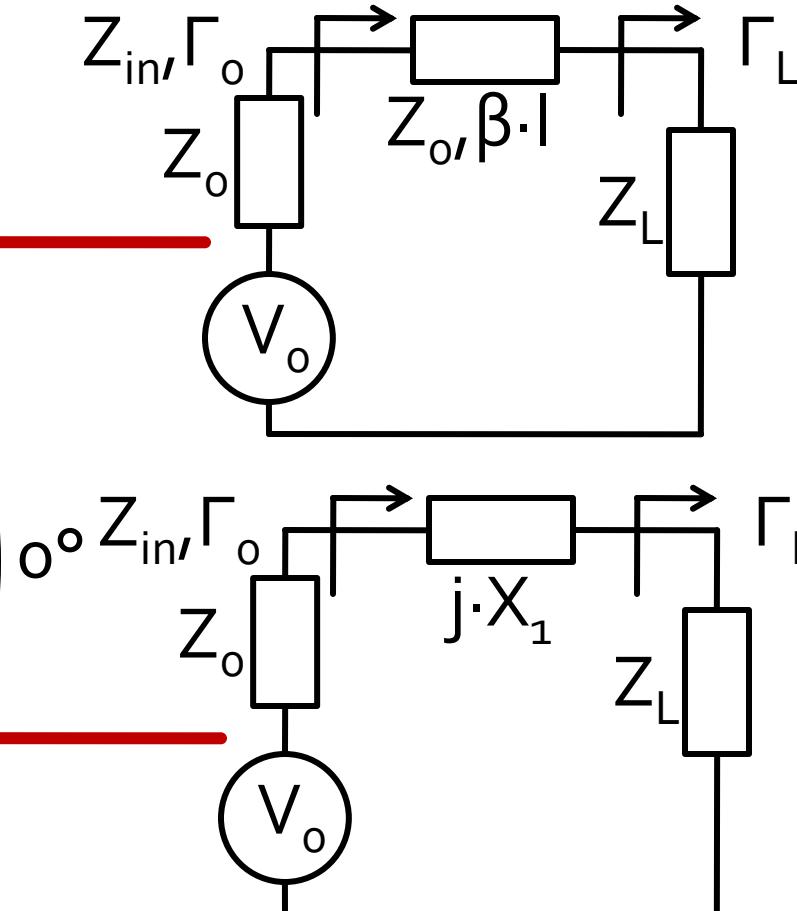
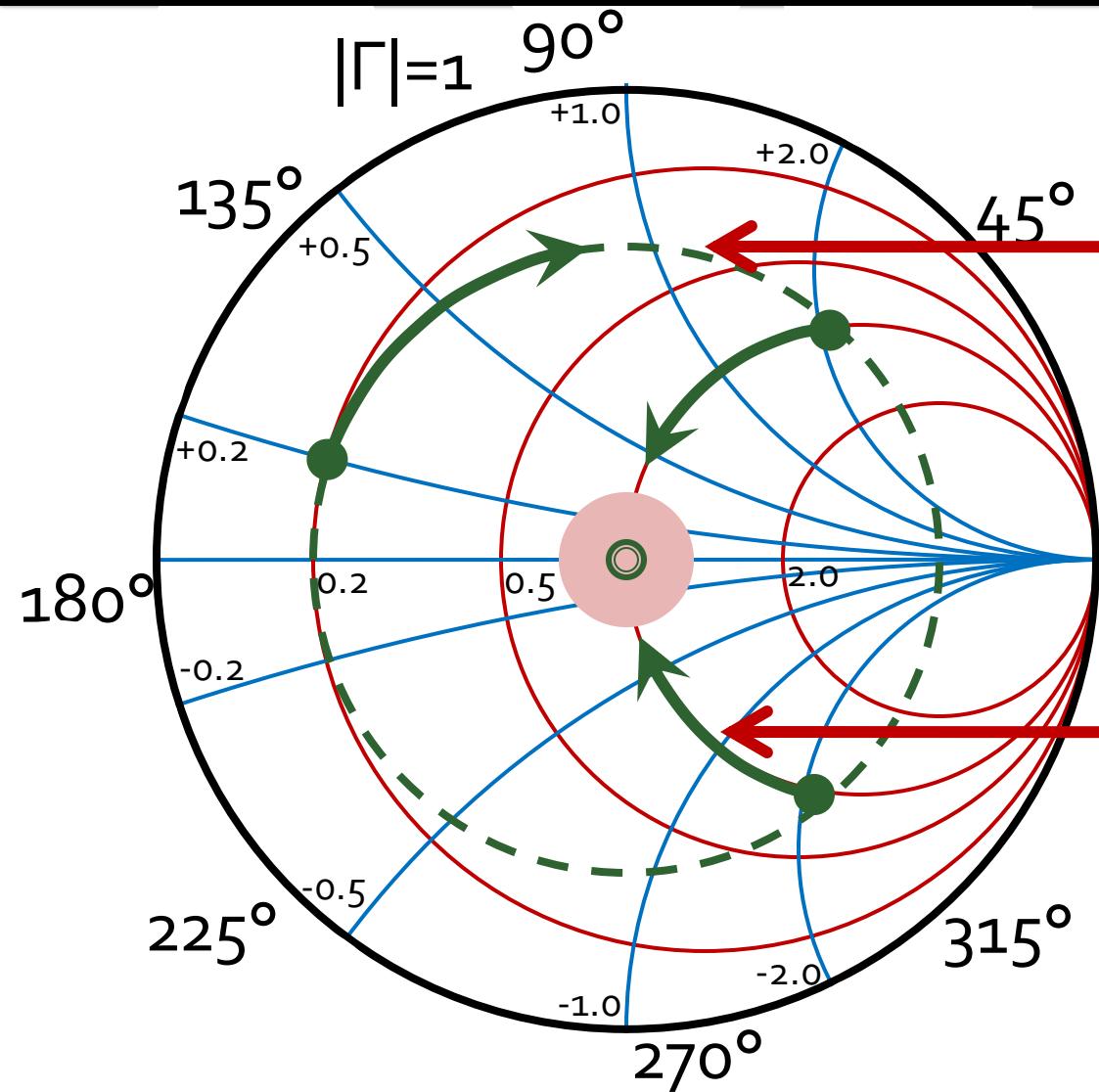
- Se utilizeaza o linie de transmisie serie pentru a muta coeficientul de reflexie pe cercul  $r_L = 1$
- Se introduce o reactanta in serie pentru a realiza adaptarea
- Aceasta reactanta se realizeaza cu o linie de transmisie care poate fi dupa nevoie:
  - in gol
  - in scurtcircuit

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

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

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

# Adaptare, linie serie + reactanta in serie

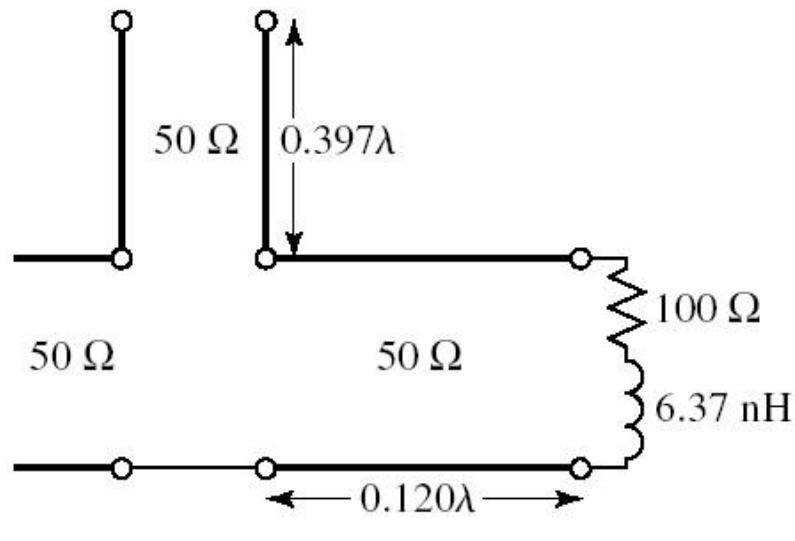


$$|\Gamma_{in}| = |\Gamma_L|$$

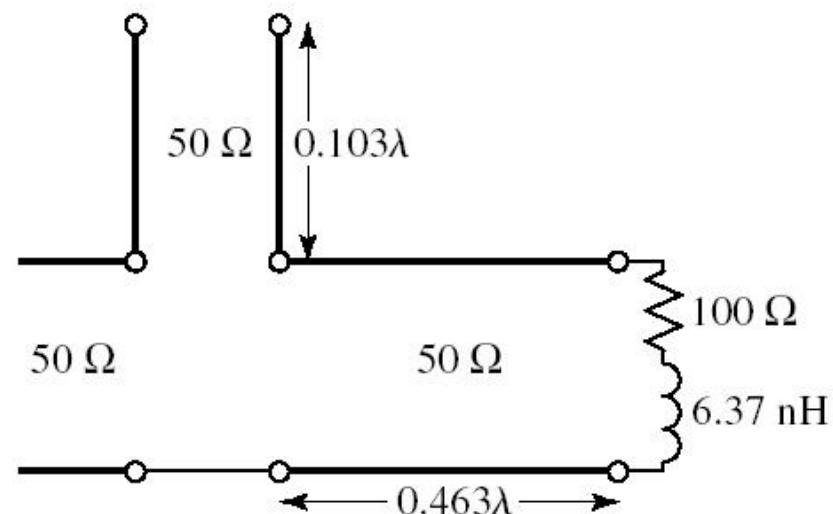
$$r_{in} = 1$$

# Exemplu, Series Stub, gol

- sarcina:  $100 \Omega$  serie  $6.37 \text{ nH}$  la  $2\text{GHz}$
- doua solutii posibile

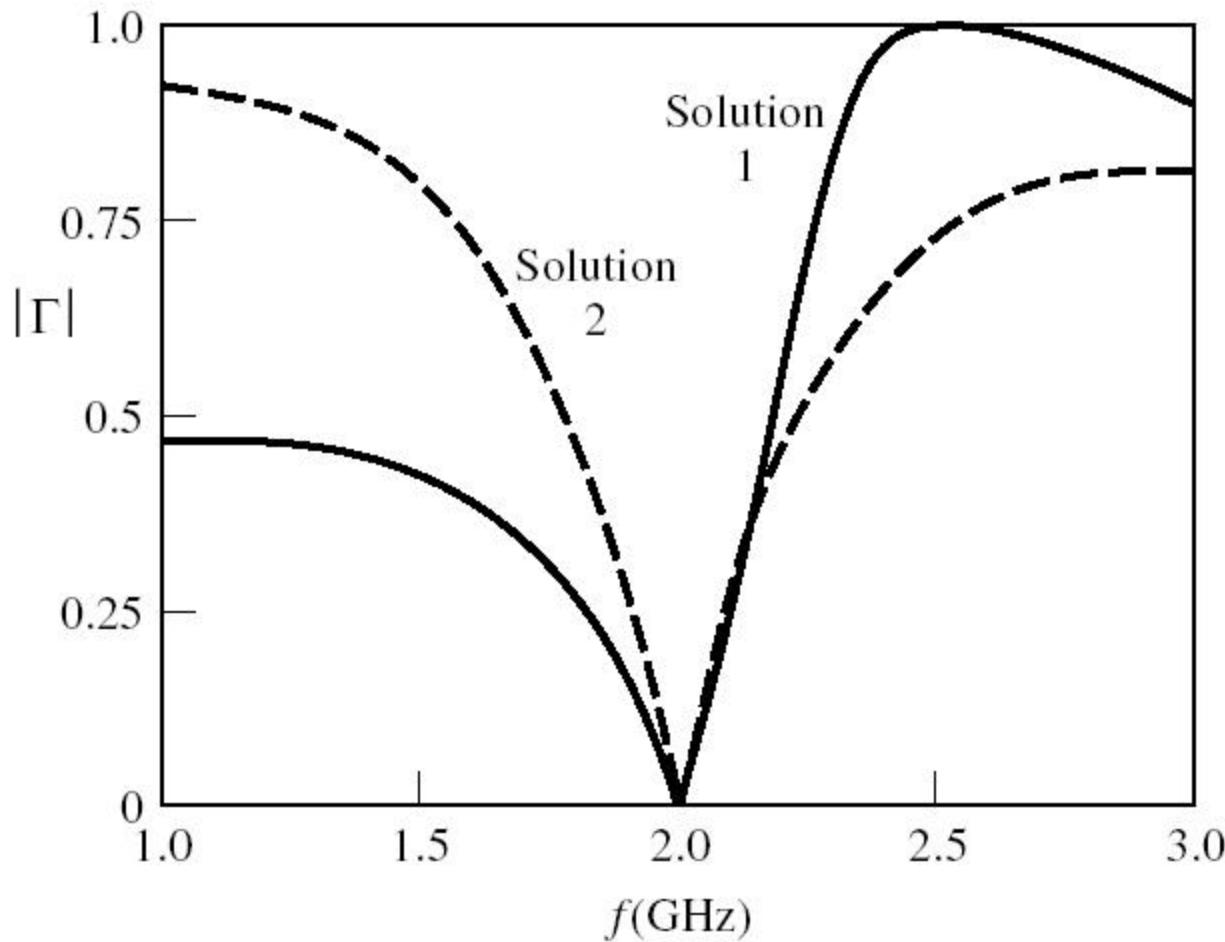


Solution 1

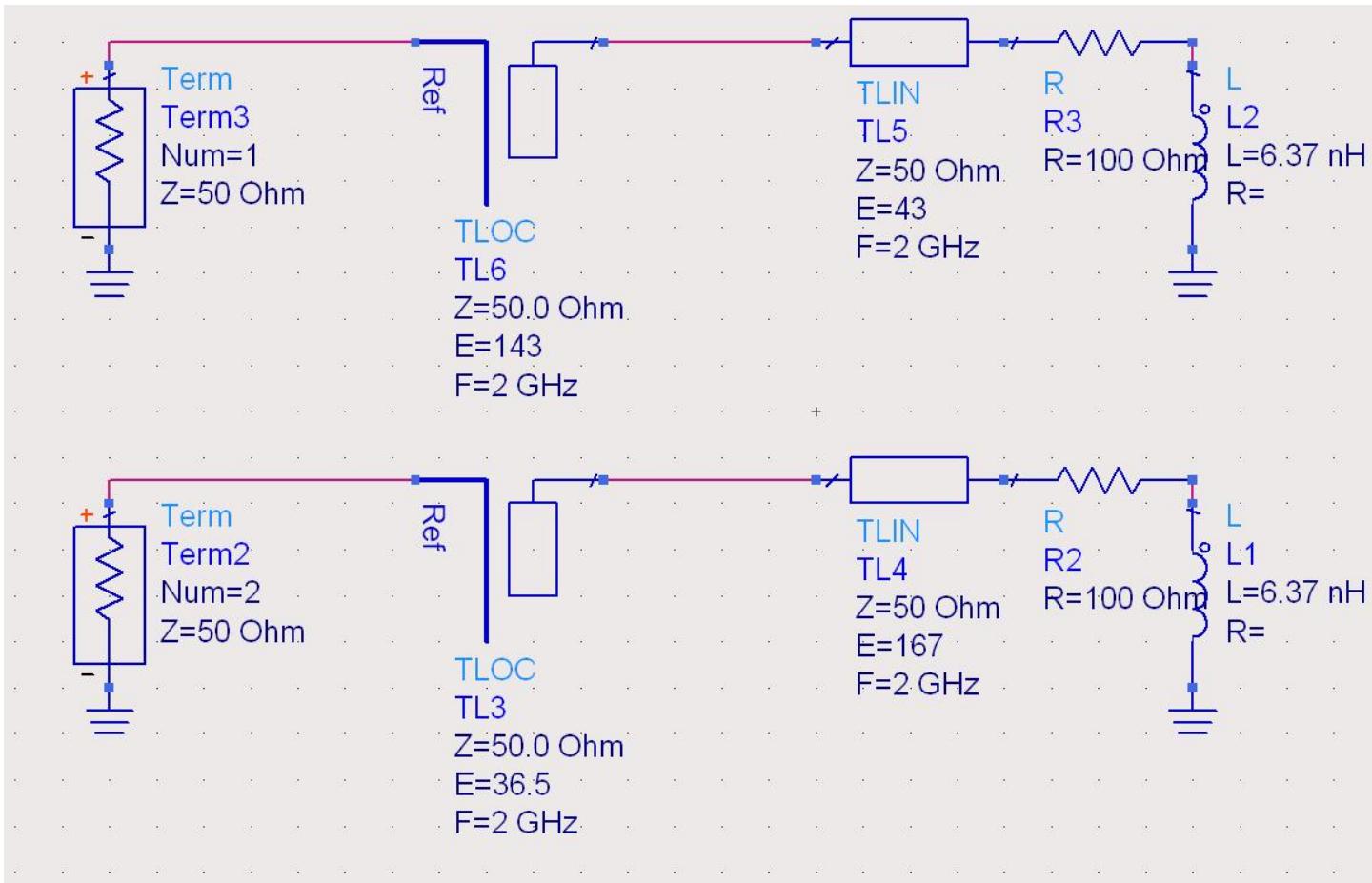


Solution 2

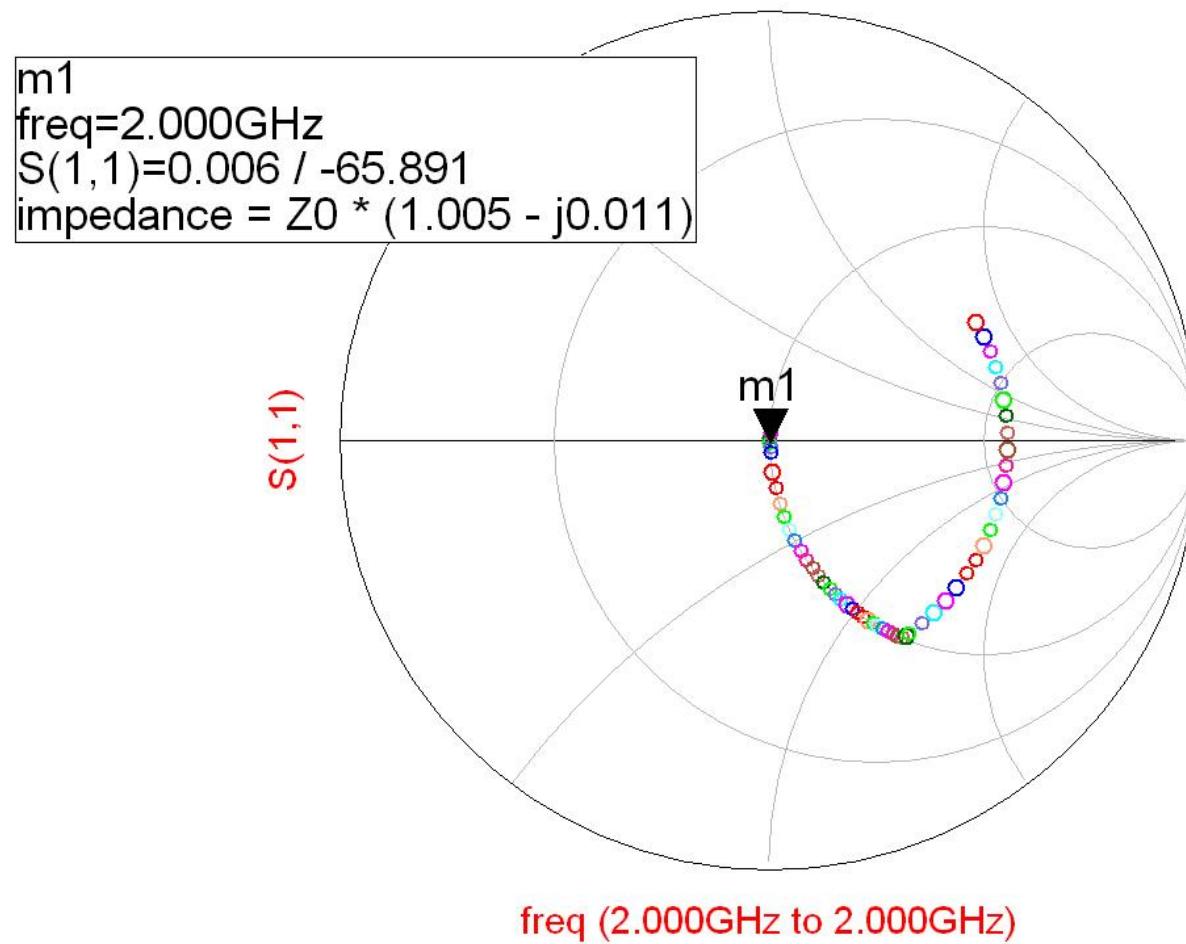
# Exemplu, Series Stub, gol



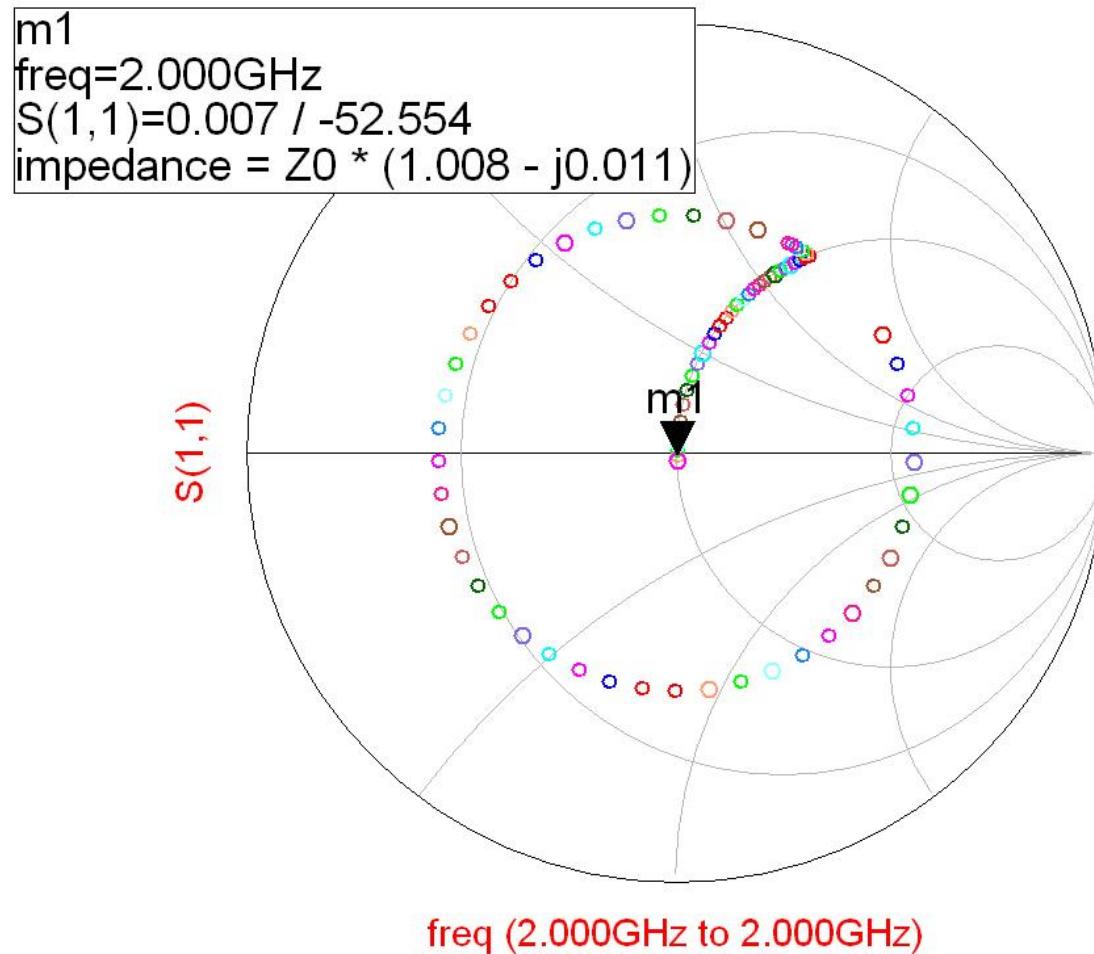
# Exemplu, Series Stub, gol



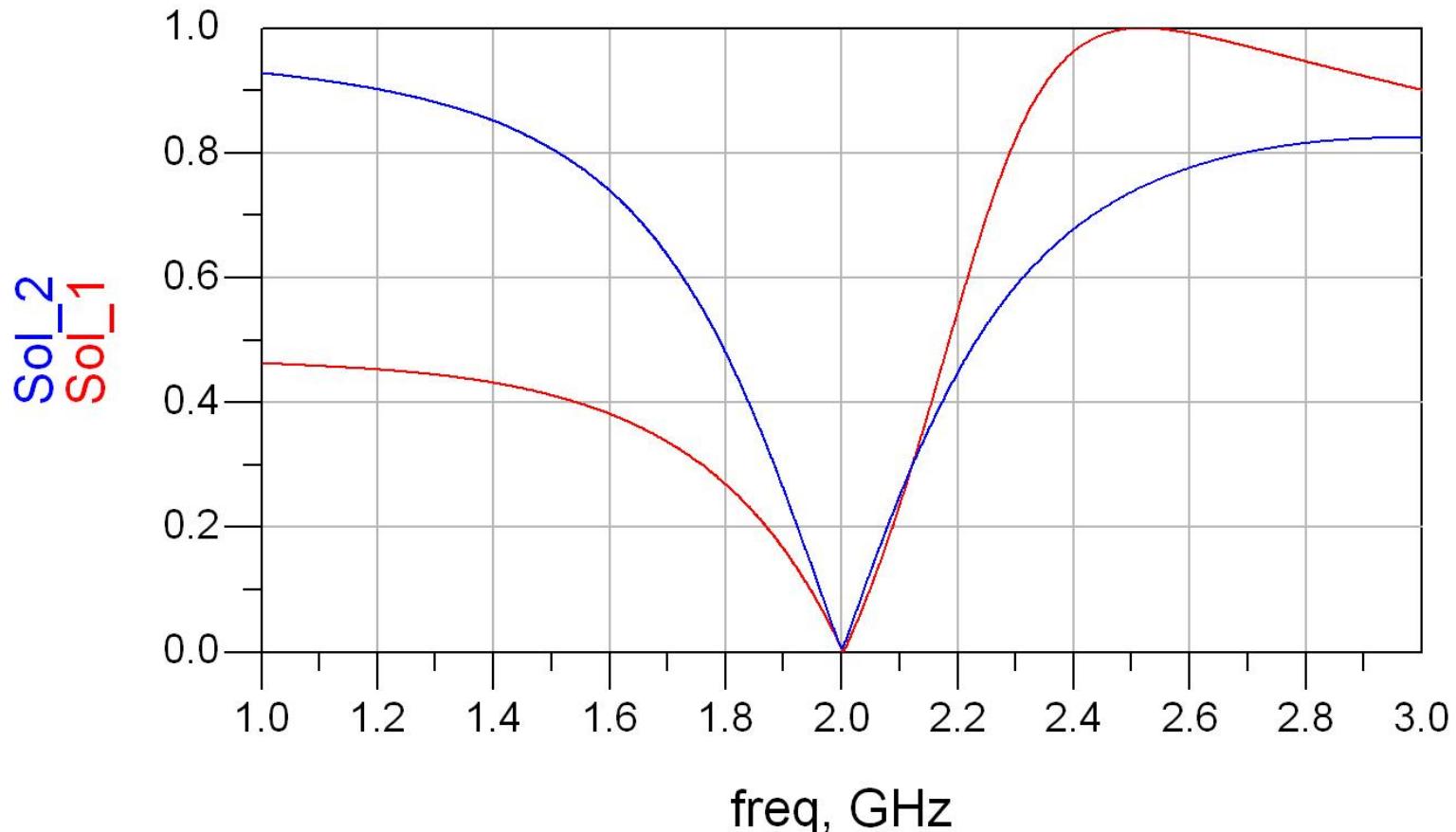
# Exemplu, Series Stub, gol



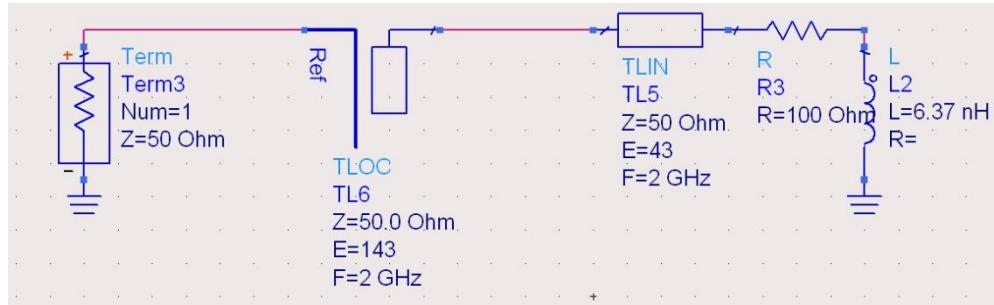
# Exemplu, Series Stub, gol



# Exemplu, Series Stub, gol



# Exemplu, Series Stub, gol

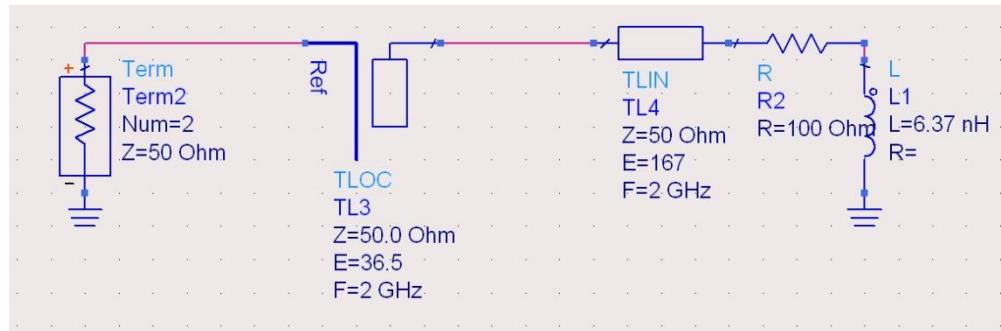


$$l_1 = \frac{43^\circ}{360^\circ} \cdot \lambda = 0.119 \cdot \lambda$$

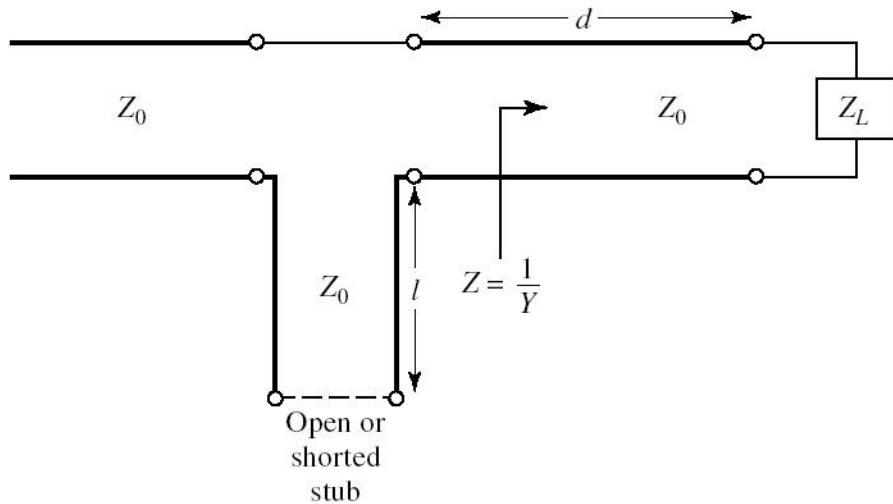
$$l_2 = \frac{143^\circ}{360^\circ} \cdot \lambda = 0.397 \cdot \lambda$$

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

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



# Solutie analitica



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

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

*not*

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

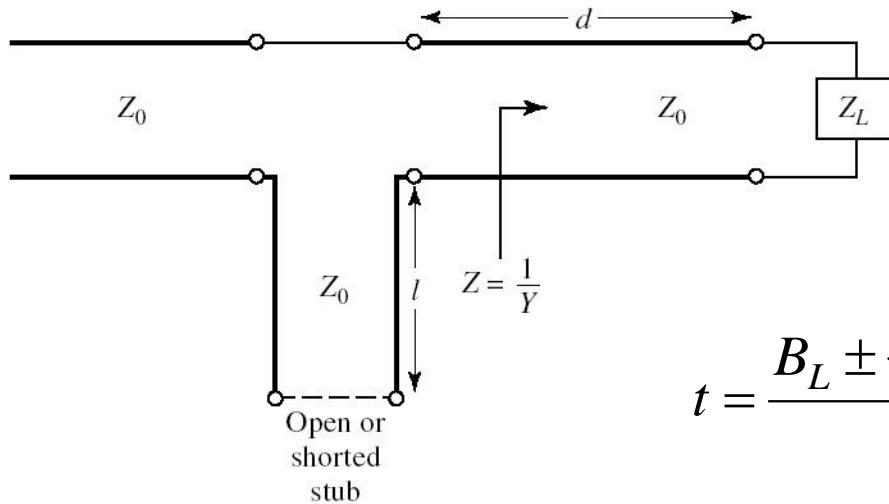
$$R = \frac{G_L \cdot (1 + t^2)}{G_L^2 + (G_L + Y_0 \cdot t)^2}$$

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

- $d$  (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



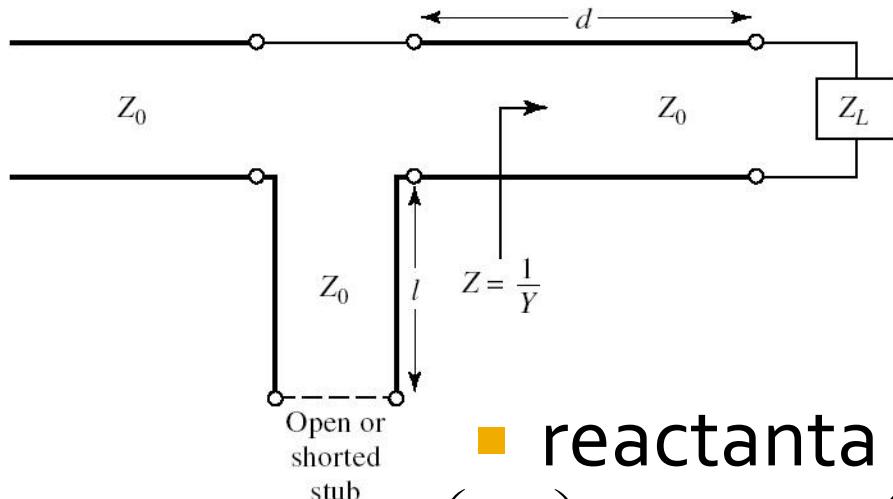
$$t = \frac{-B_L}{2 \cdot Y_0}, \quad G_L = Y_0$$

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

- 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:

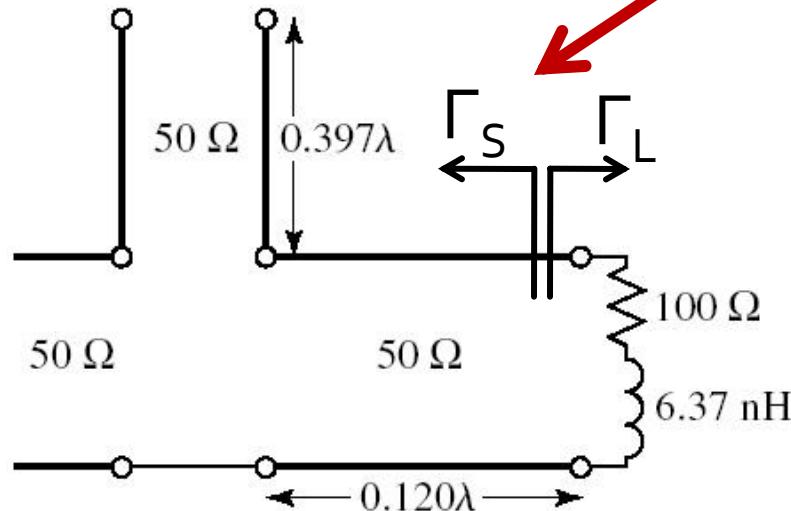
$$\frac{l_{sc}}{\lambda} = \frac{1}{2\pi} \cdot \arctan \left( \frac{X_S}{Z_0} \right) = \frac{-1}{2\pi} \cdot \arctan \left( \frac{X}{Z_0} \right)$$

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

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

# Calcul analitic, coeficienti de reflexie

- sarcina:  $100 \Omega$  serie  $6.37 \text{ nH}$  la  $2\text{GHz}$



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  $\Gamma$  complex conjugat

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

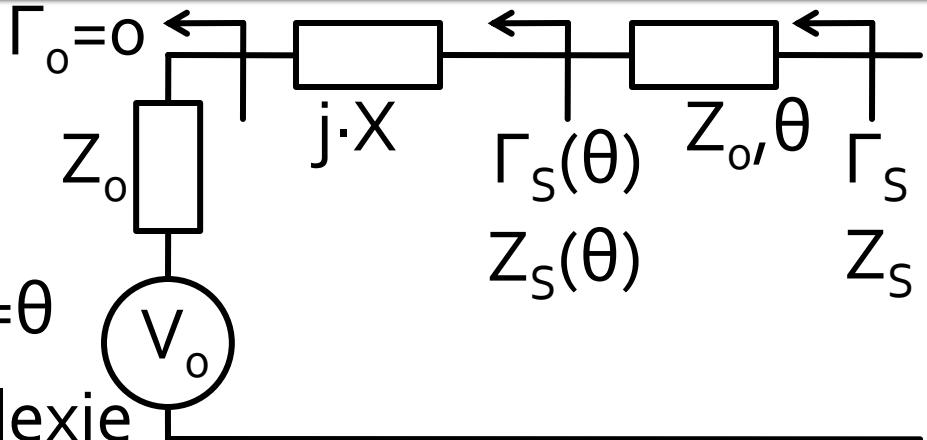
$$\Gamma_s = 0.555 \angle -29.92^\circ$$

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

# 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 ( $\Gamma_0 = 0$ )

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

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

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

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

# Calcul analitic, linie serie (dem.)

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

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

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

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

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

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

# Calcul analitic, linie serie (calcul)

- Ecuatia pentru calcularea  $\theta$  (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  $\lambda/2$  ( $180^\circ$ ) 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  $\theta_{ss}$ :

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

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

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

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

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

# Calcul analitic, stub serie (dem.)

- Ecuatia pentru calcularea stub-ului serie  $\theta_{ss}$ :

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

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

- doua situatii

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

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

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

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

- 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  $j \cdot X$

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

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

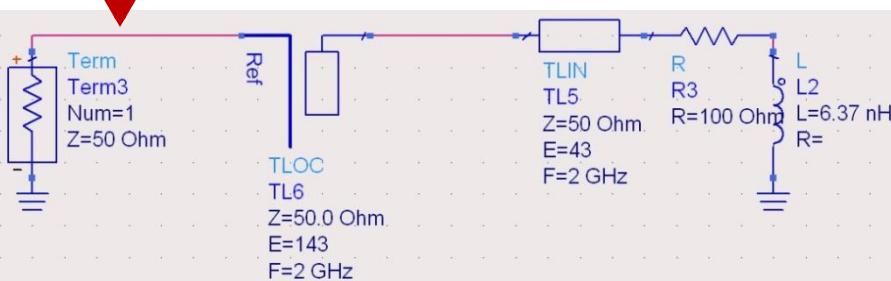
# Calcul analitic (calcul efectiv)

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

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

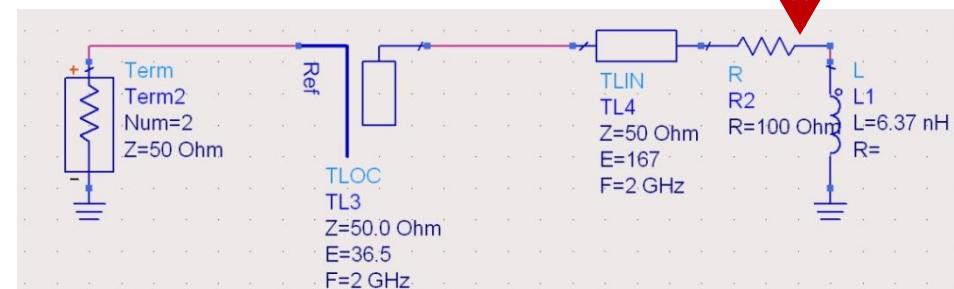
$$l_1 = \frac{43.1^\circ}{360^\circ} \cdot \lambda = 0.120 \cdot \lambda$$

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



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

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

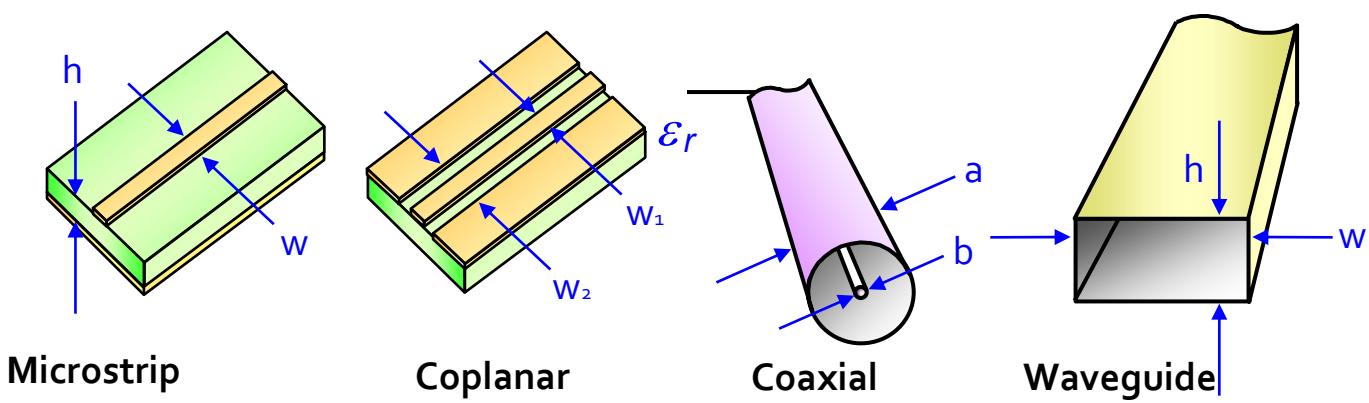


# Adaptarea cu sectiuni de linii (stub)

- 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)

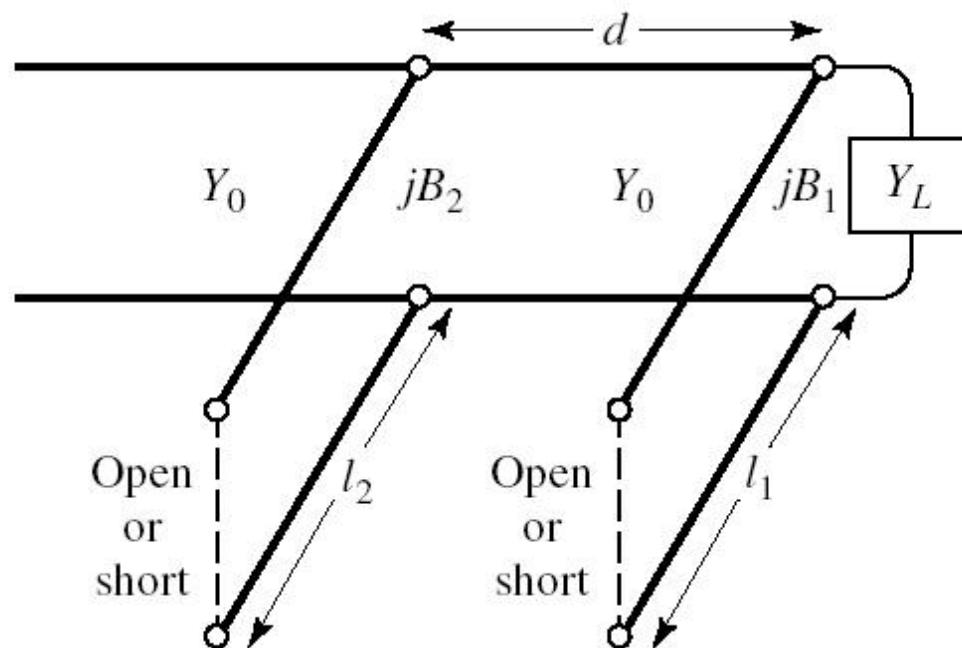
- Se alege una din cele 8 solutii posibile convenabila tinand cont de:
  - realizabilitate fizica (conform tehnologiei de linie utilizata)



- Dezavantaj:
  - lungimea sectiunii de linie serie e variabila

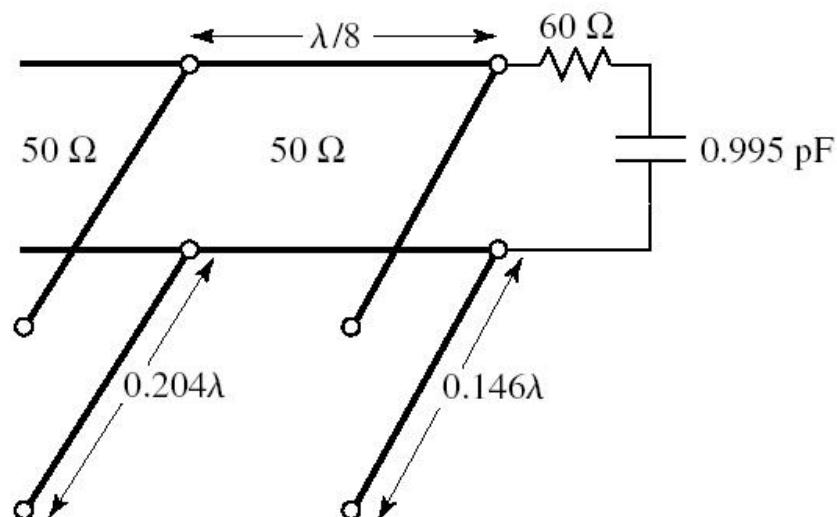
# Adaptarea cu două secțiuni de linie

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

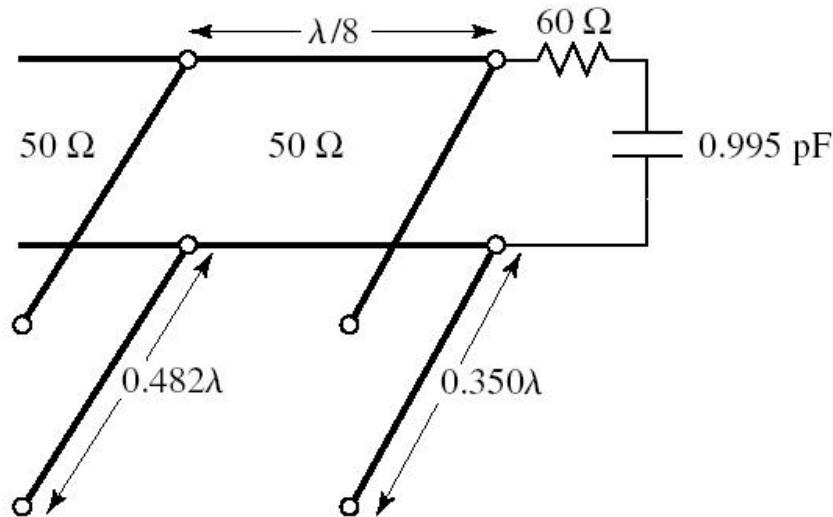


# Adaptarea cu două secțiuni de linie

- Două soluții posibile



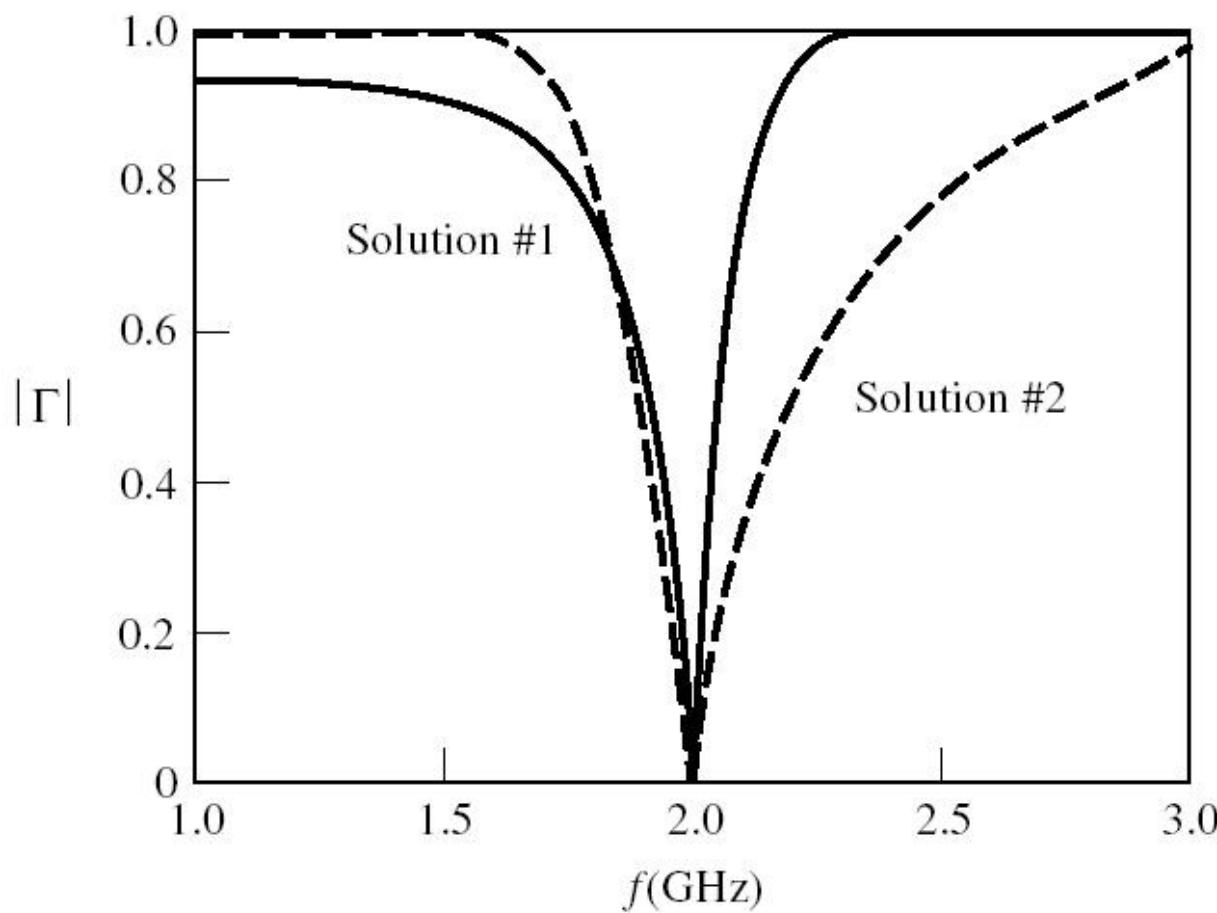
Solution 1



Solution 2

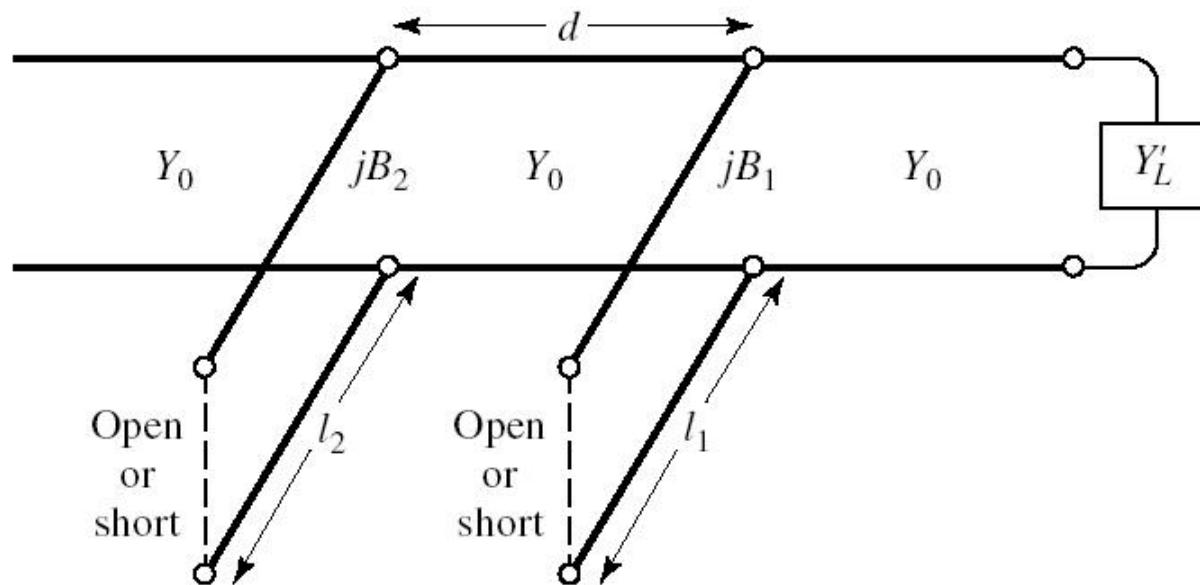
# Adaptarea cu două sectiuni de linie

- Două solutii posibile

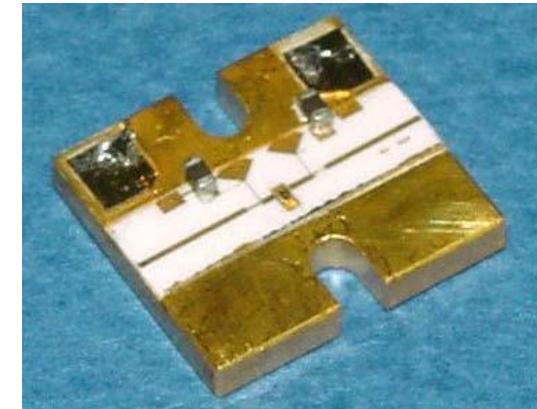
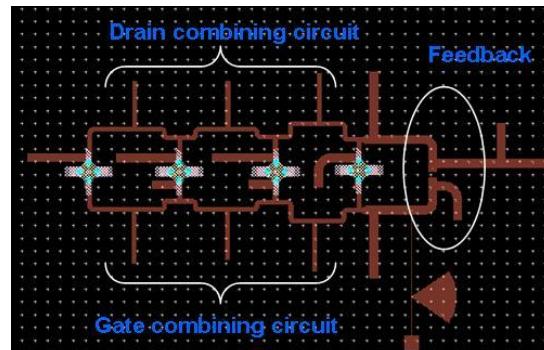
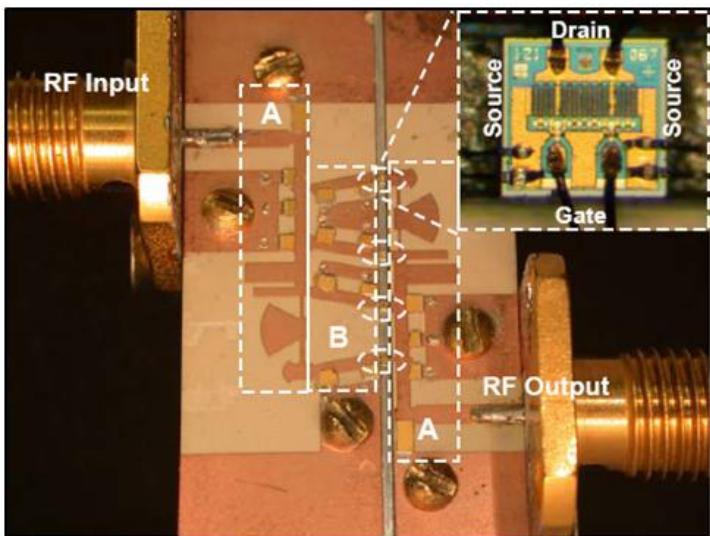
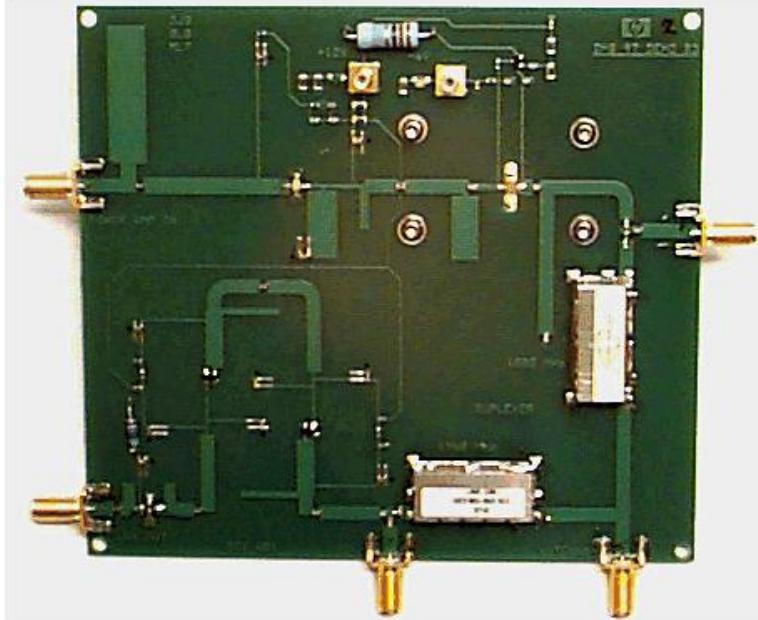
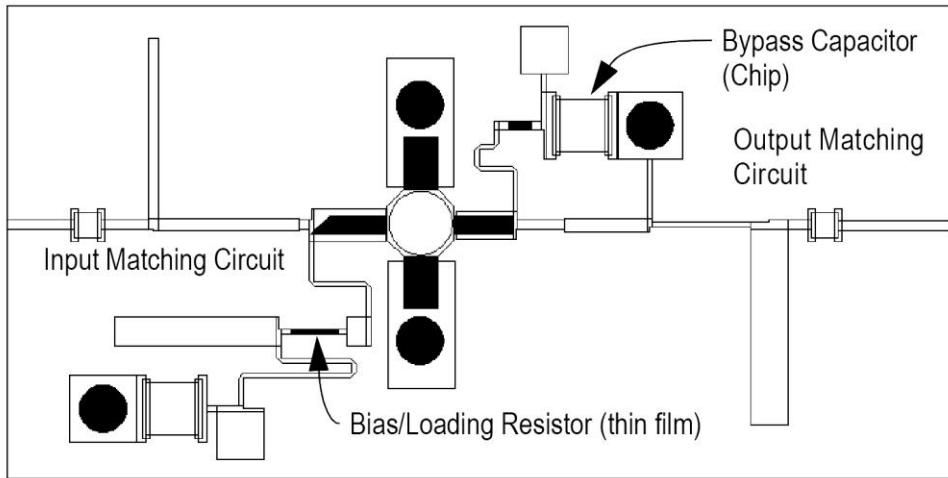


# Adaptarea cu doua sectiuni de linie

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



# Adaptarea cu sectiuni de linie



# Contact

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