

Curs 7

2021/2022

Dispozitive și circuite de microunde pentru radiocomunicații

Disciplina 2021/2022

- 2C/1L, DCMR (CDM)
- Minim 7 prezente (curs+laborator)
- Curs - **conf. Radu Damian**
 - Marti 8-10, Online/**Video**, Microsoft Teams
 - E – **50%** din nota
 - probleme + (2p prez. curs) + (3 teste) + (bonus activitate)
 - primul test C2: 12.10.2020 (t2 si t3 neanuntate)
 - 3pz (C) ≈ +0.5p (**2p** max)
 - toate materialele permise

Online

- acces la **examene** necesita **parola** primita prin email

English | Romana |

Start Didactic Master Colectiv Cercetare **Studenti**

Note Lista Studenti Examene Fotografii

POPESCU GOPO ION

Fotografia nu exista

Date:

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

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

Note obtinute

Inca nu a fost notat.

Start Didactic Master Colectiv C

Note **Lista Studenti** Examene Fotografii

Identificare

Introduceti numele si adresa de email utilizata la inscriere

Nume
POPESCU GOPO

E-mail/Parola

Introduceti codul afisat mai jos

4db4457

Trimite

Cuprins

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

Bibliografie

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

Examen: Reprezentare logaritmică

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

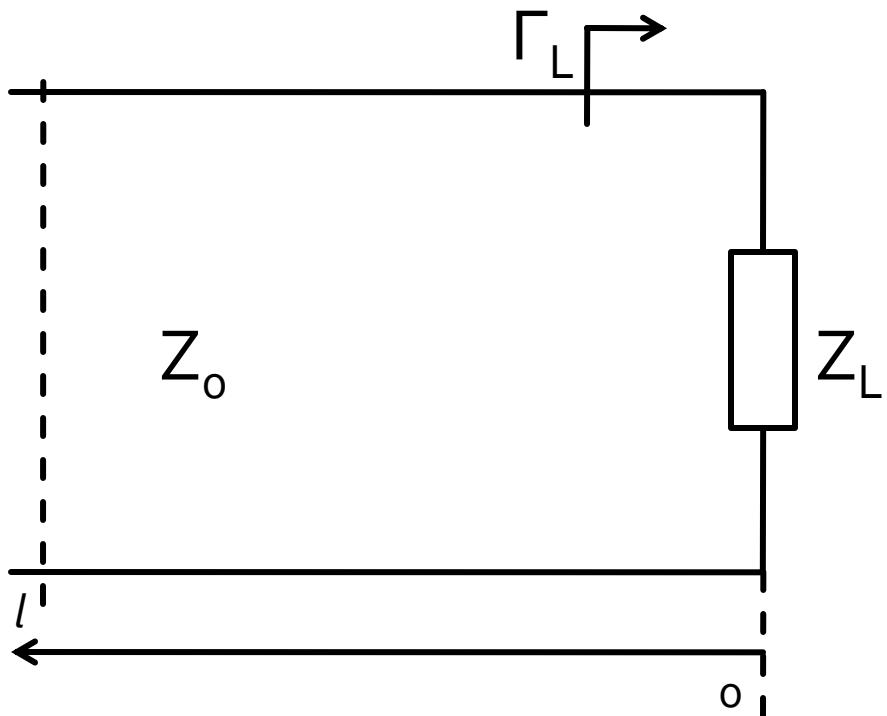
Examen: numere complexe

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

Cuprins

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

Linie fara pierderi



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

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

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

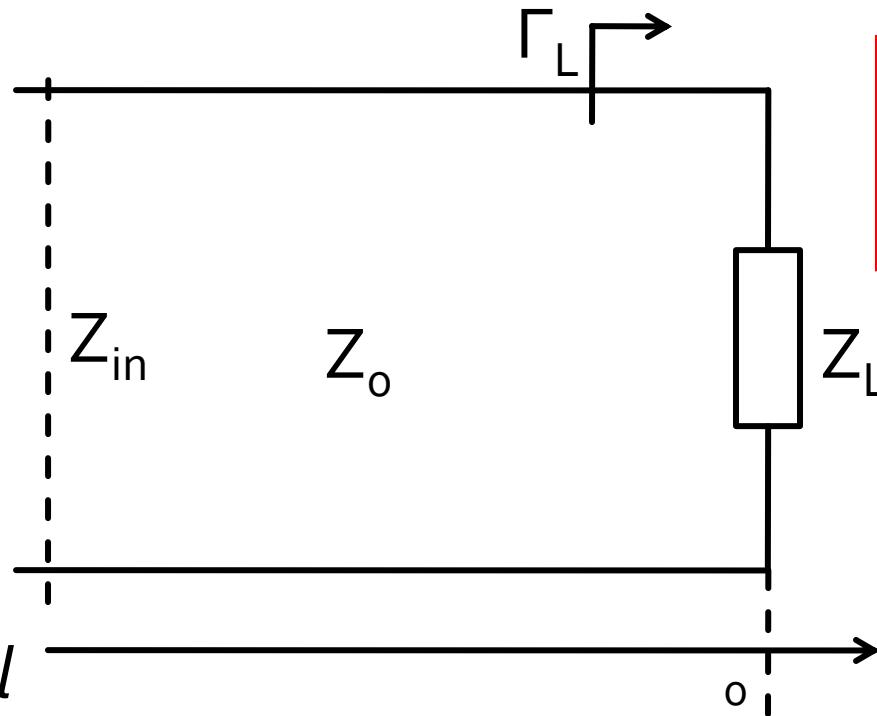
- coeficient de reflexie in tensiune

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

- Z_0 real

Linie fara pierderi

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



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

Cuprins

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

Adaptare dpdv al puterii

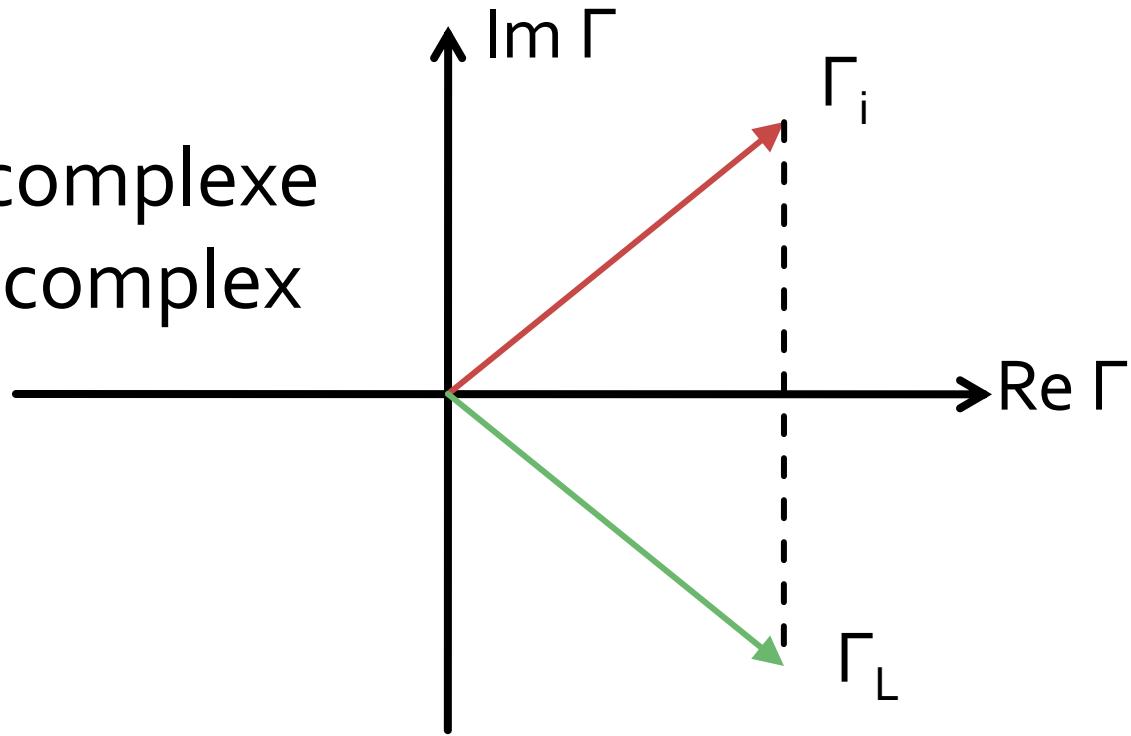
$$Z_L = Z_i^*$$

Daca se alege un Z_0 real

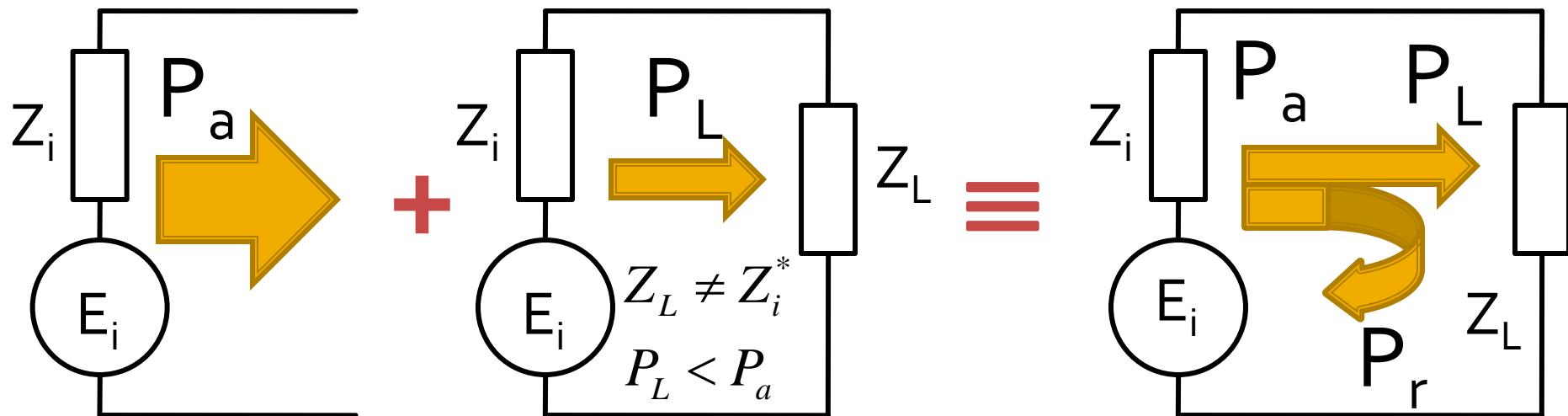
$$\Gamma = \frac{Z - Z_0}{Z + Z_0}$$

$$\Gamma_L = \Gamma_i^*$$

- numere complexe
- in planul complex

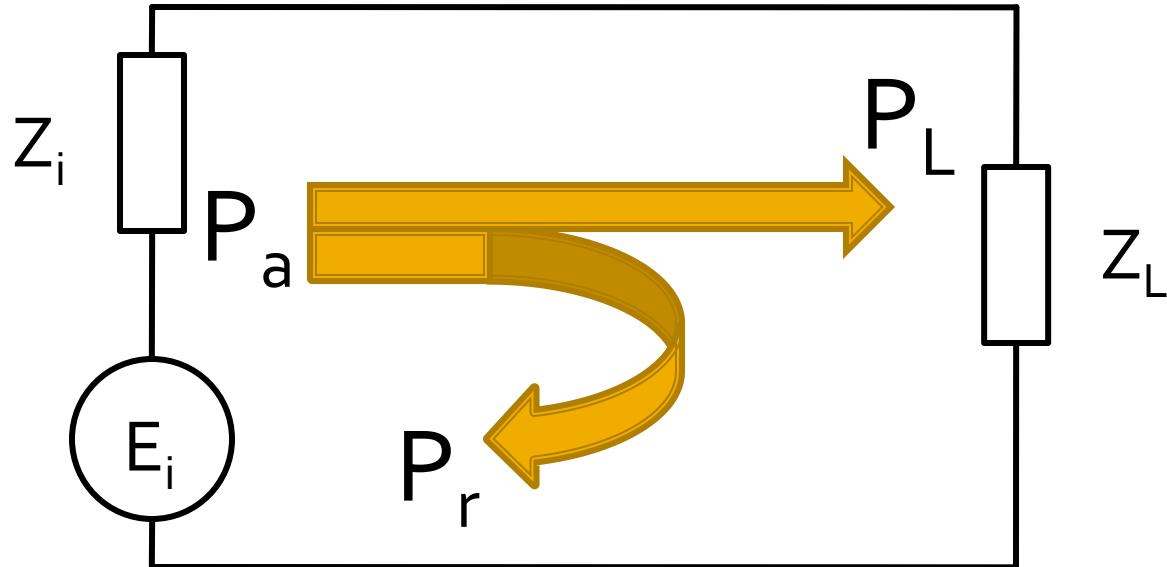


Reflexie de putere / Model



- Generatorul are posibilitatea de a oferi o anumita putere maxima de semnal P_a
- Pentru o sarcina oarecare, acesteia i se ofera o putere de semnal mai mica $P_L < P_a$
- Se intampla **“ca si cum”** (model) o parte din putere se reflecta $P_r = P_a - P_L$
- Puterea este o marime **scalara!**

Reflexie de putere / Model



$$P_a = \frac{|E_i|^2}{4R_i}$$

$$P_L = \frac{R_L \cdot |E_i|^2}{(R_i + R_L)^2 + (X_i + X_L)^2}$$

$$P_r = P_a - P_L = \frac{|E_i|^2}{4R_i} - \frac{R_L \cdot |E_i|^2}{(R_i + R_L)^2 + (X_i + X_L)^2} = \frac{|E_i|^2}{4R_i} \cdot \left[1 - \frac{4R_L \cdot R_i}{(R_i + R_L)^2 + (X_i + X_L)^2} \right]$$

$$P_r = \frac{|E_i|^2}{4R_i} \cdot \left[\frac{(R_i - R_L)^2 + (X_i + X_L)^2}{(R_i + R_L)^2 + (X_i + X_L)^2} \right] = P_a \cdot |\Gamma|^2$$

- $|\Gamma|^2$ este un coeficient de reflexie in putere

**Cuploare directionale si
divizoare de putere**

Cuprins

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

Cuploare/Divizoare

- Funcționalitatea dorită:
 - divizarea
 - combinarea
- puterii semnalului

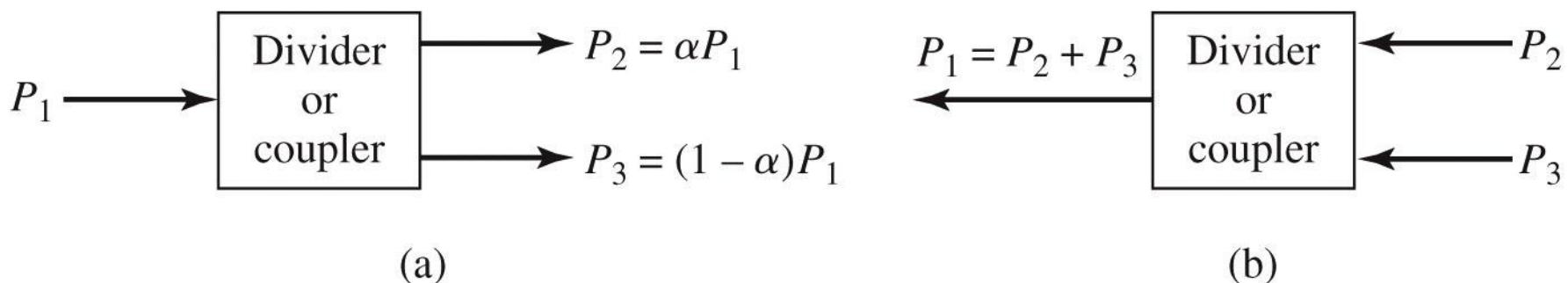


Figure 7.1
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Adaptarea de impedanță

Diagrama Smith

Diagrama Smith

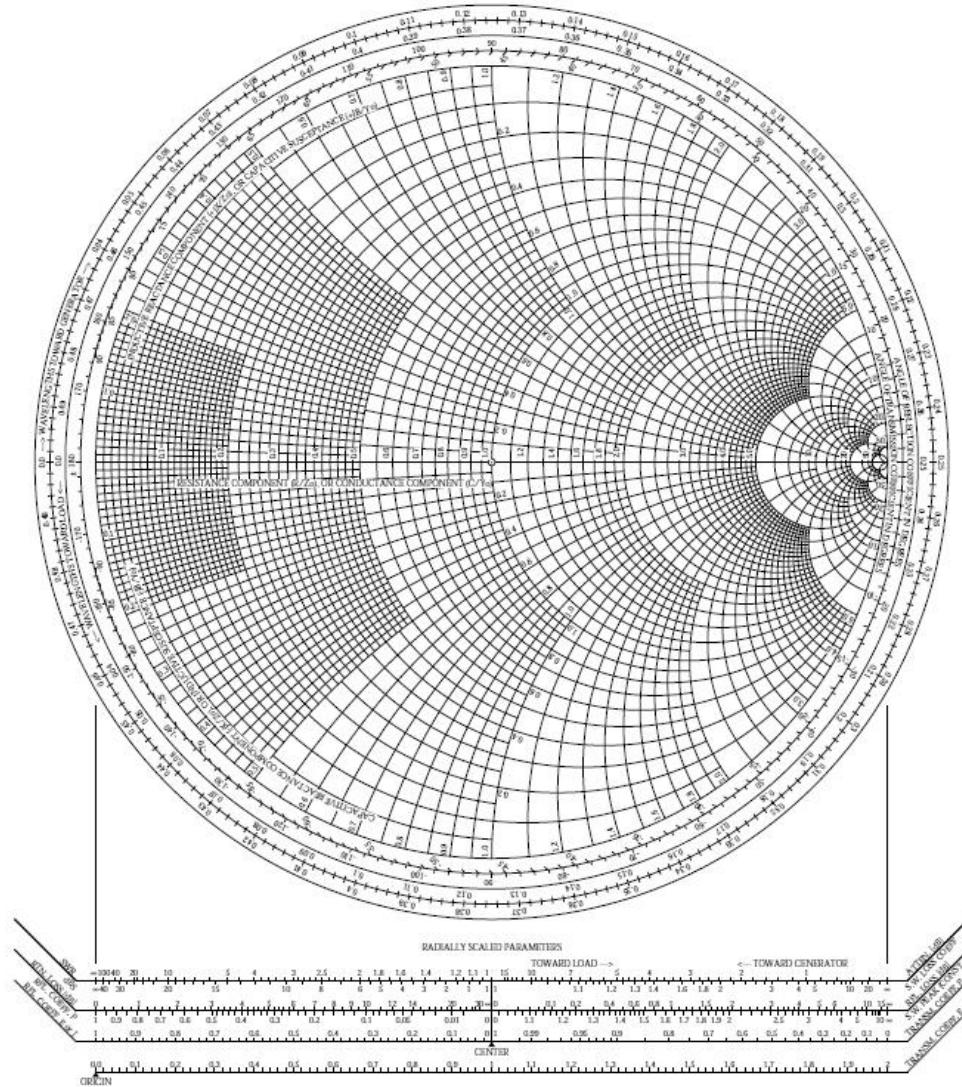


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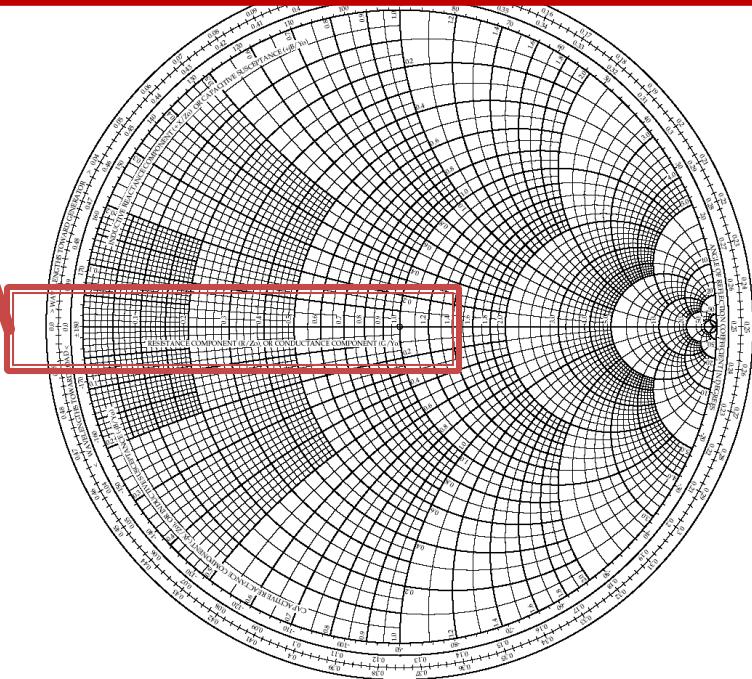
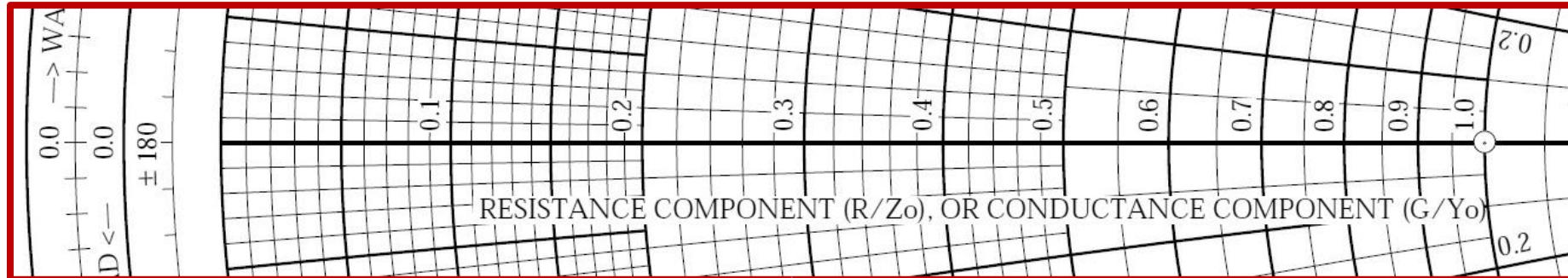


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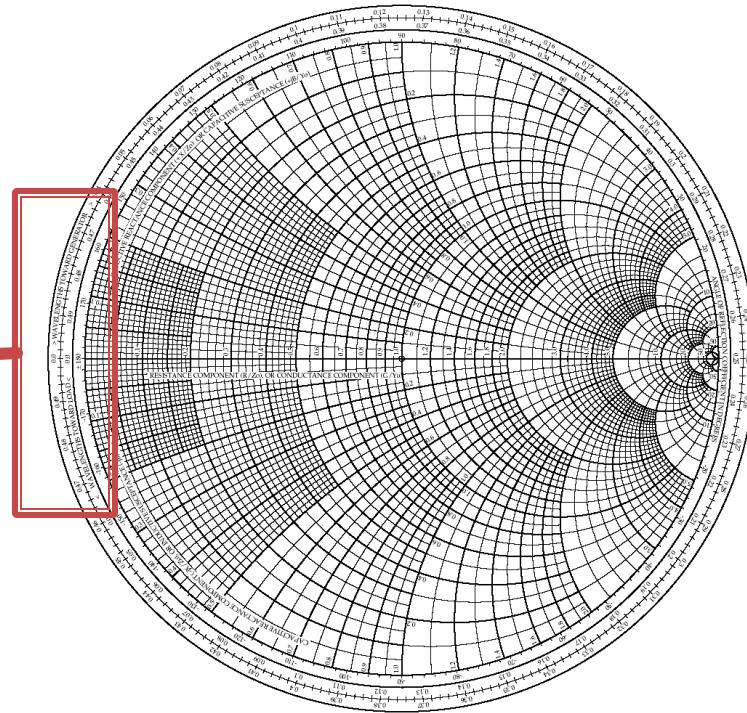
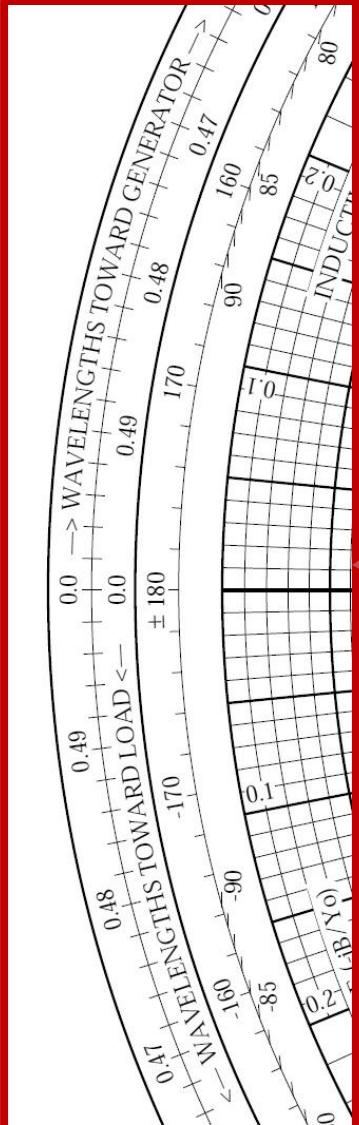
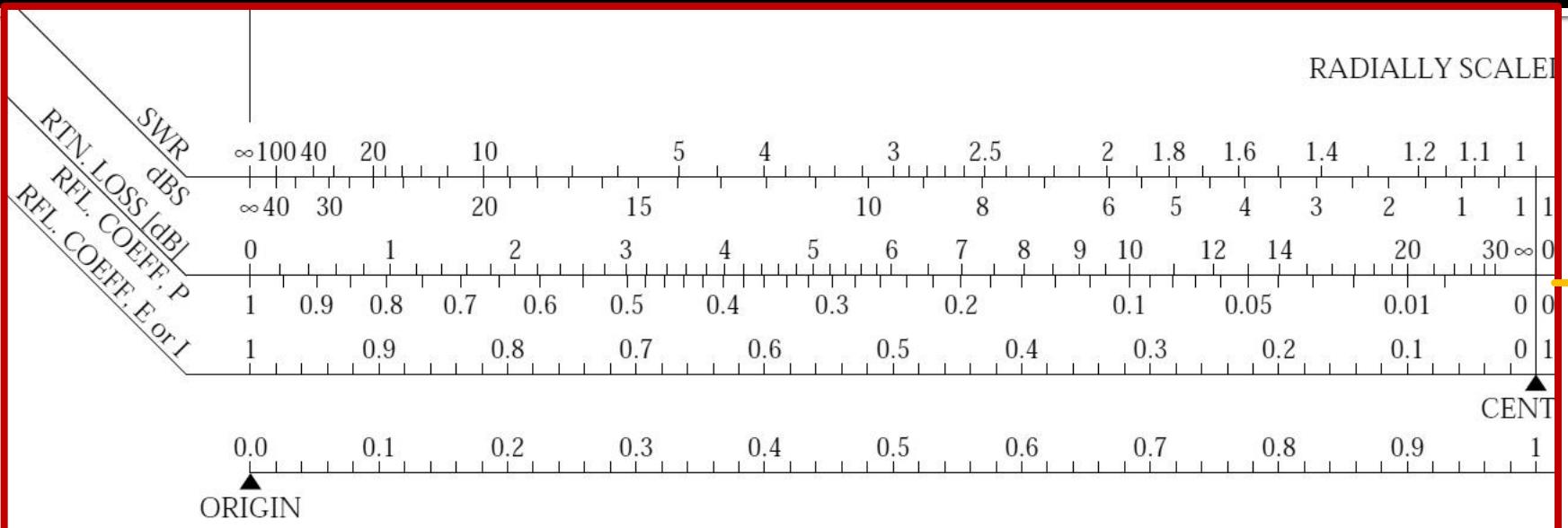


Diagrama Smith



Scaled Parameters

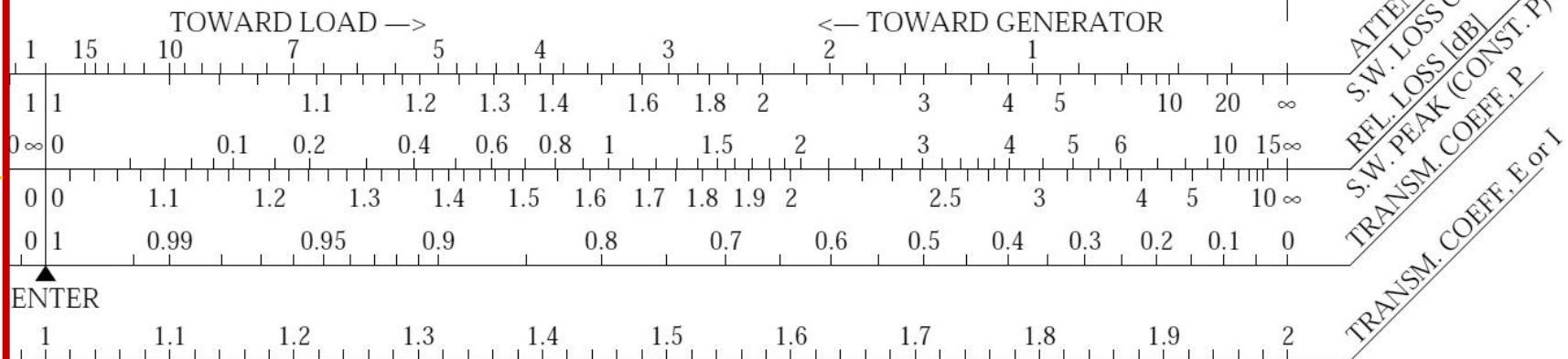


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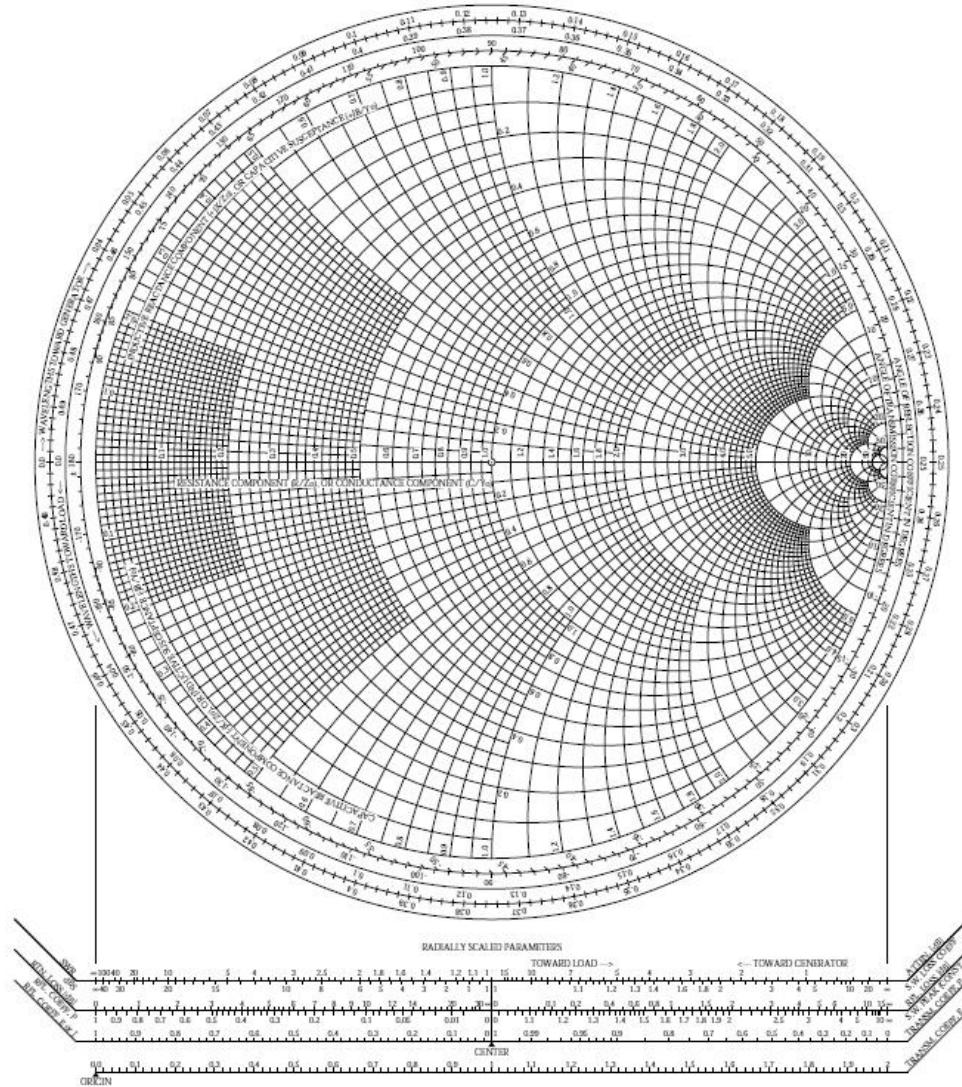
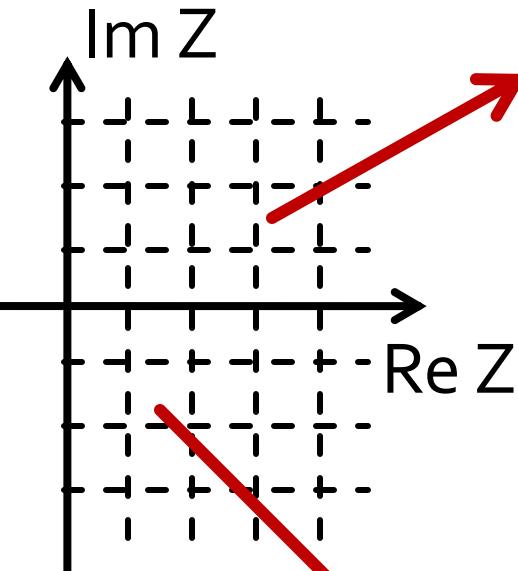
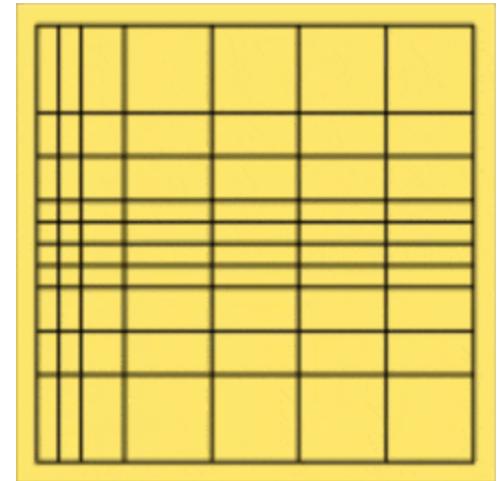


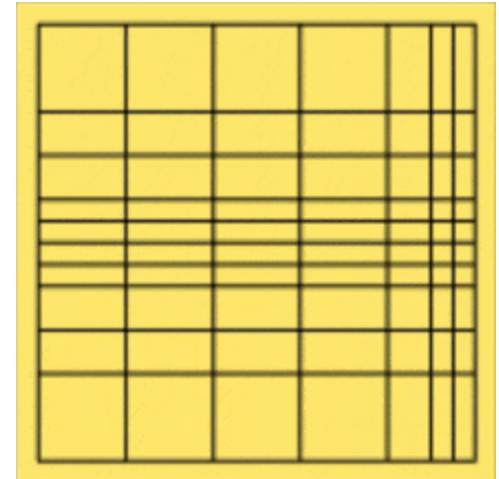
Diagrama Smith



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

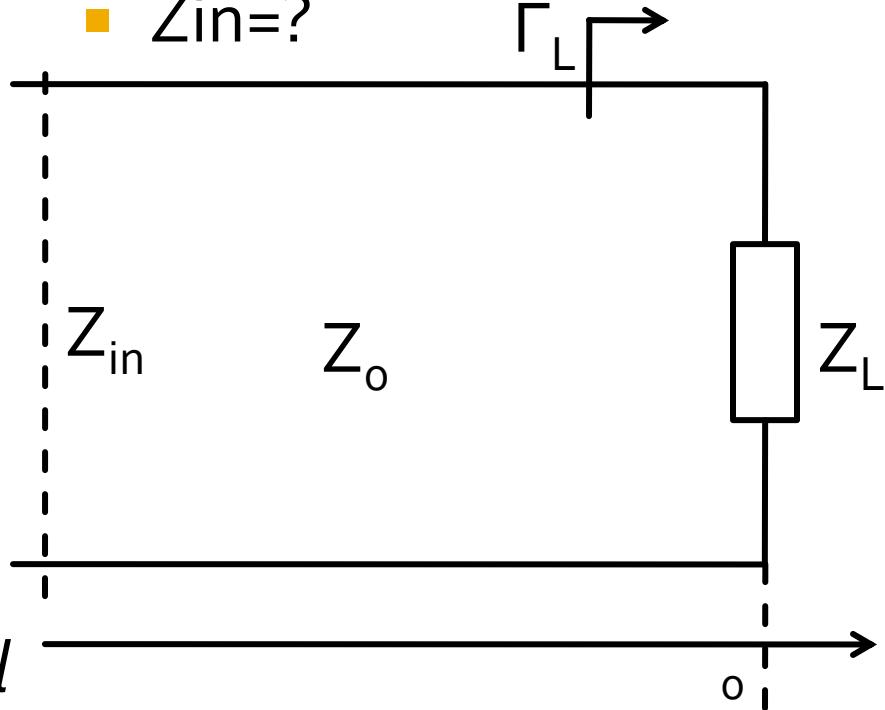


$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{Y_0 - Y_L}{Y_0 + Y_L} = \frac{1 - y_L}{1 + y_L}$$



Utilizare standard

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



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

$$Z_{in} = 100\Omega \cdot \frac{(40 + j \cdot 70) + j \cdot 100 \cdot \tan(2\pi/\lambda \cdot 0.3\lambda)}{100 + j \cdot (40 + j \cdot 70) \cdot \tan(2\pi/\lambda \cdot 0.3\lambda)}$$

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

Utilizare standard

- linie de transmisie

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

- raportare la $Z_0 = 100\Omega$

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

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

- Plecand din z_L (0.105λ)
- Pana la z_{in} (0.405λ)

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

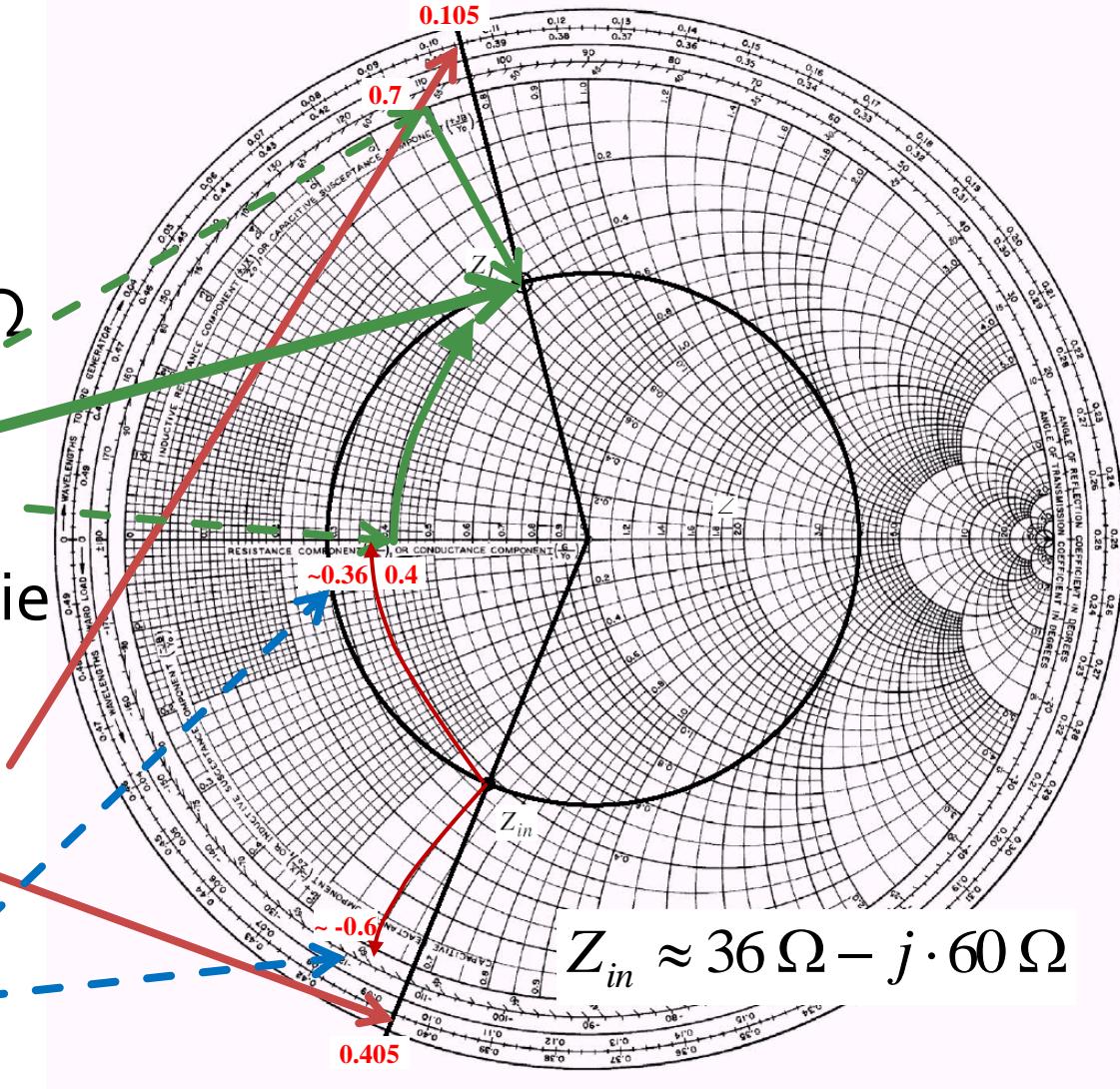


Diagrama Smith

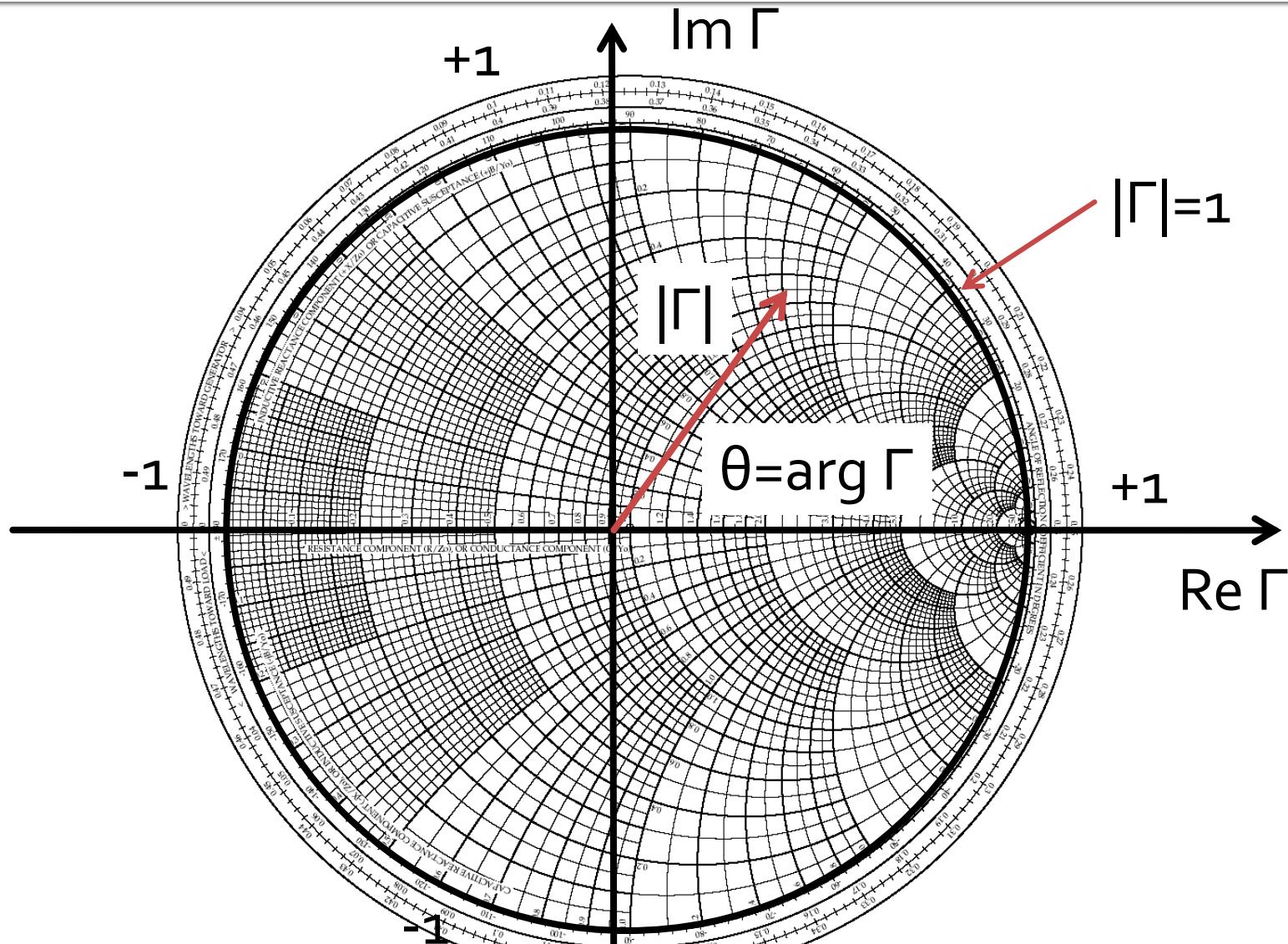


Diagrama Smith

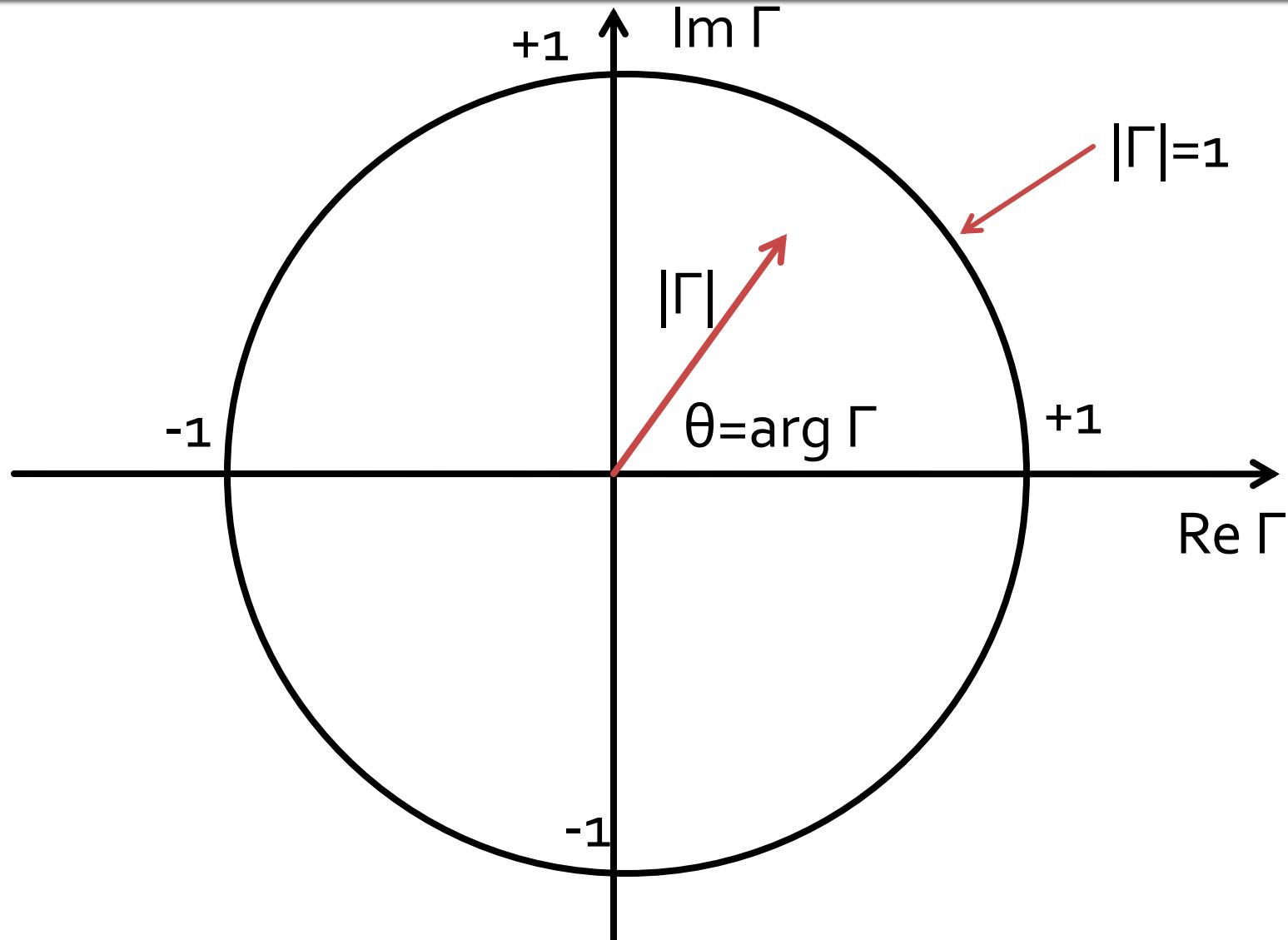
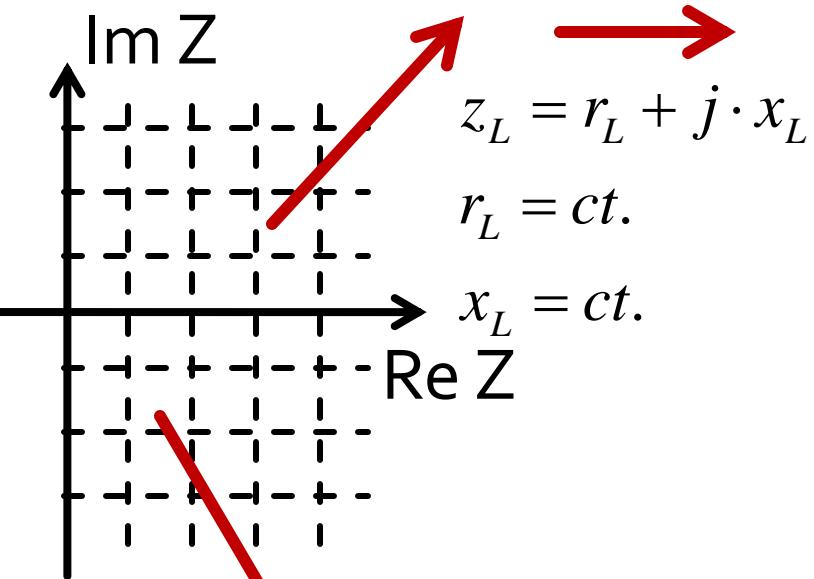


Diagrama Smith

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



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

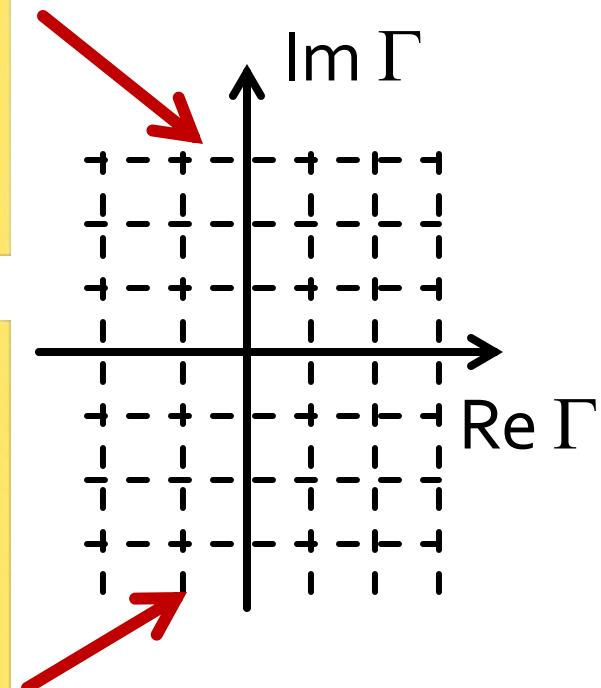
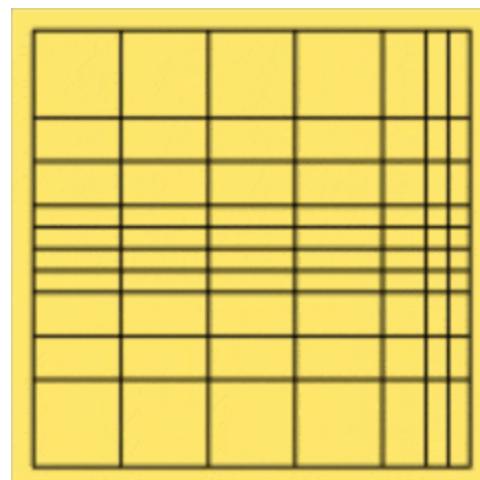
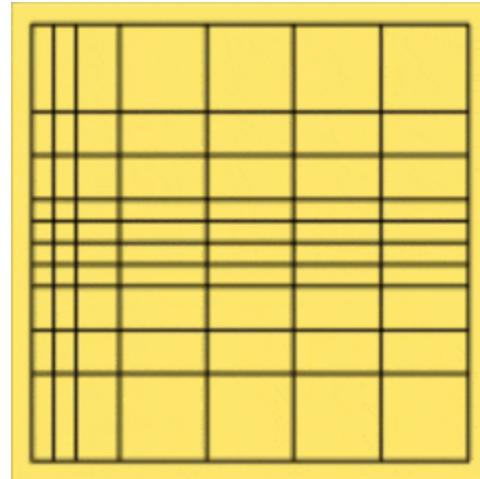
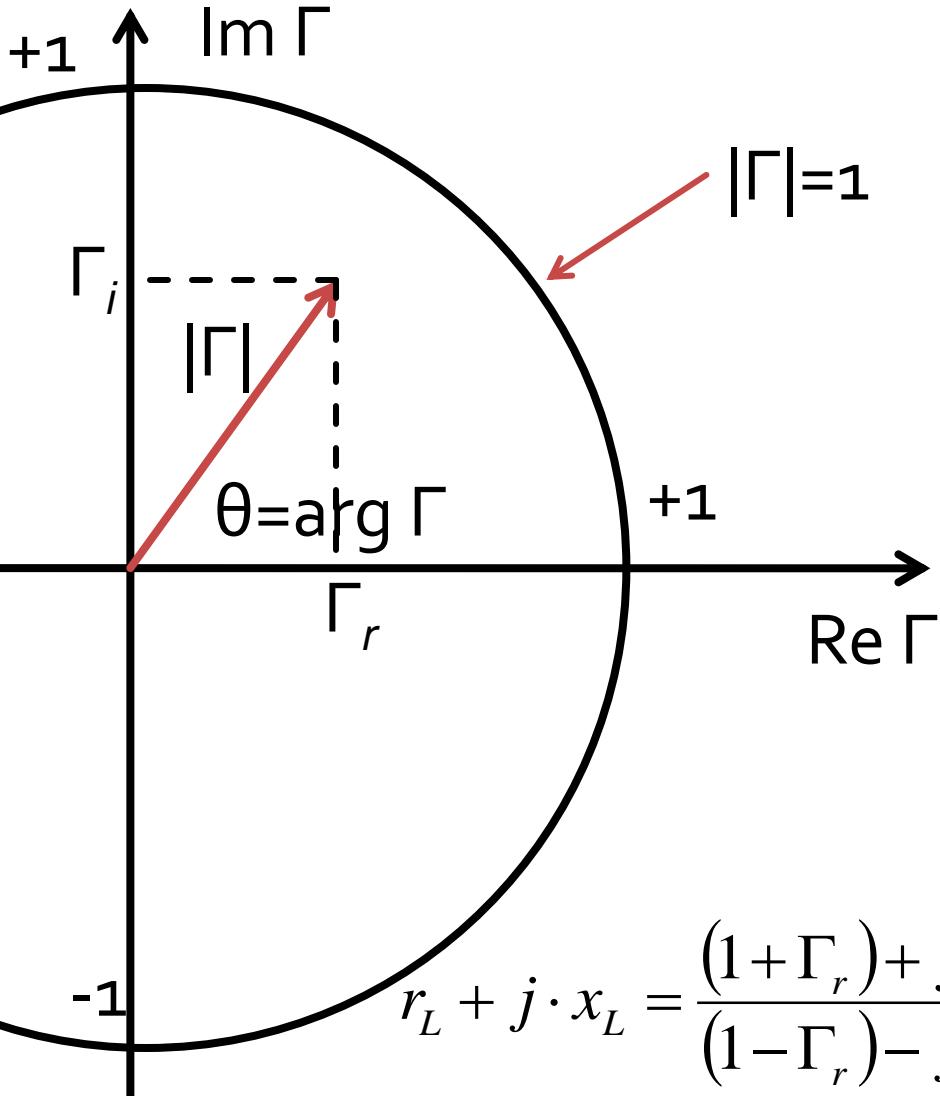


Diagrama Smith



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

$$z_L = \frac{Z_L}{Z_0} \quad y_L = \frac{Y_L}{Y_0} = \frac{Z_0}{Z_L}$$

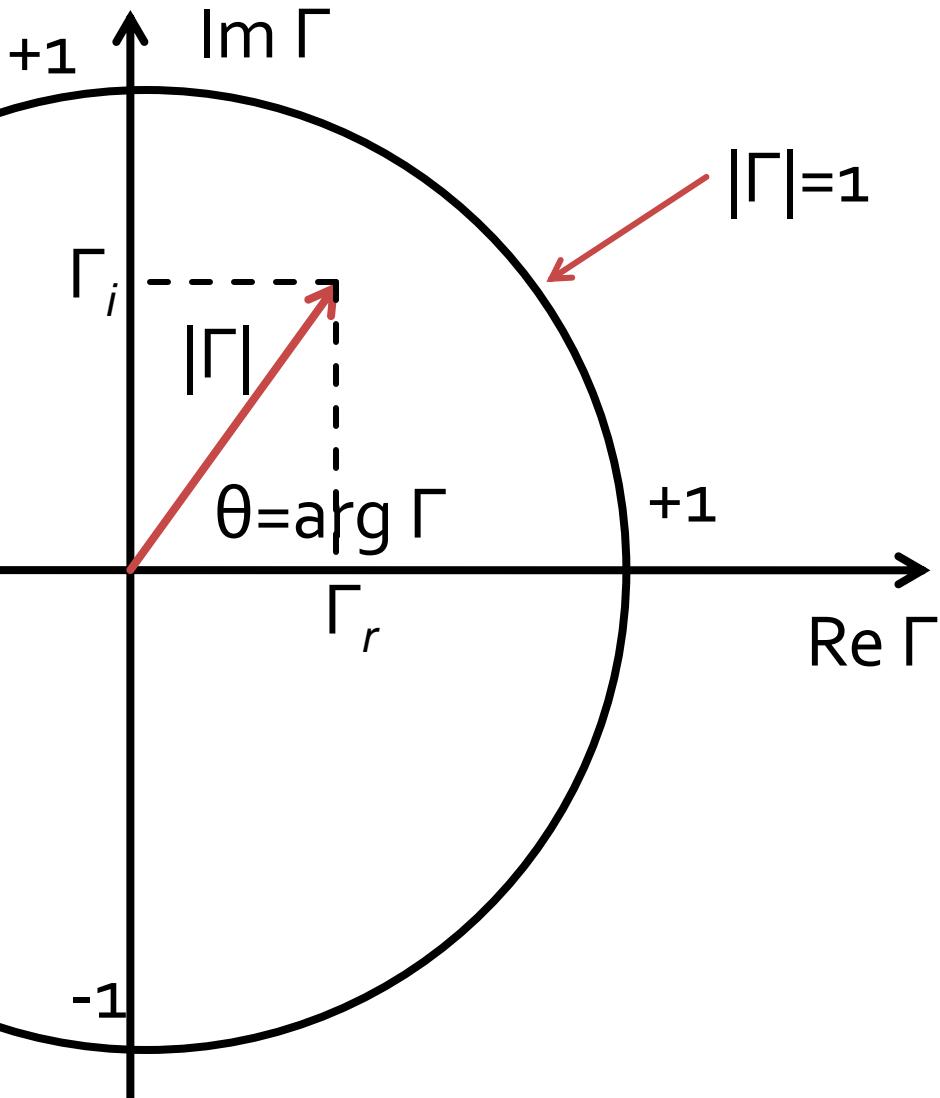
Raportarea $Z_L \rightarrow z_L$ permite utilizarea aceleiasi diagrame pentru oricare impedanta de referinta Z_0 (face reprezentarea independenta de valoarea aleasa pentru Z_0)

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

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

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

Diagramma Smith



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

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

■ Rearajate

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

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

Diagrama Smith

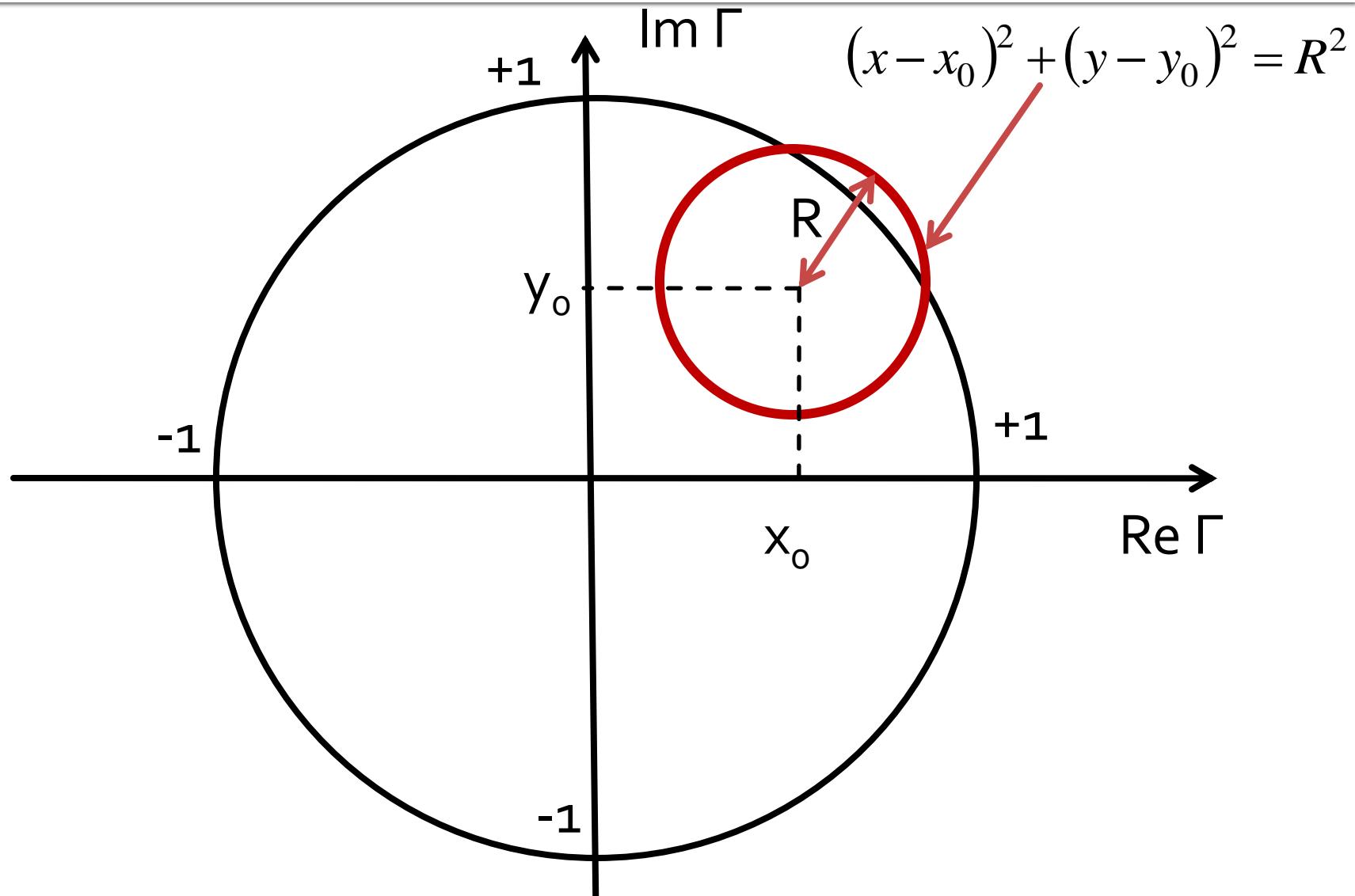
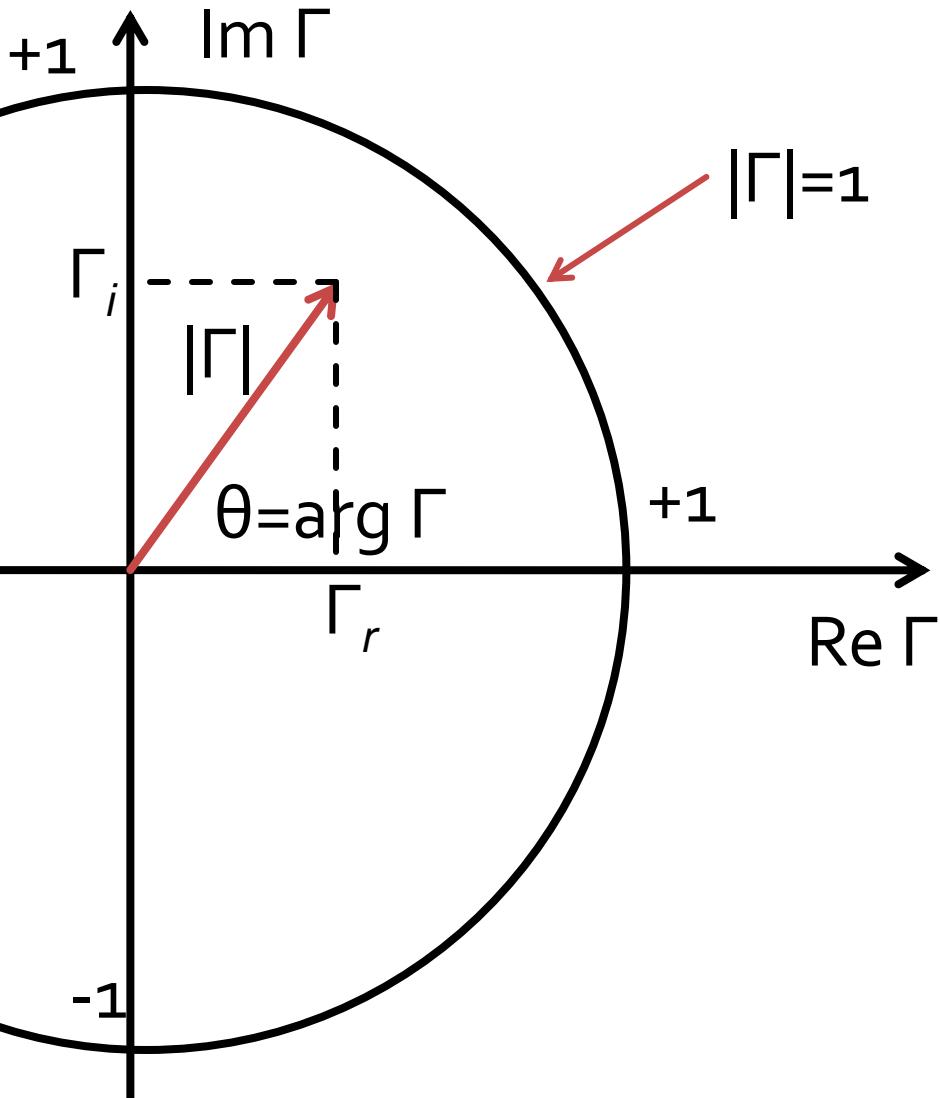


Diagrama Smith



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

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

- Cercuri in planul complex

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

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

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

- 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**

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

- pentru orice r_L **pozitiv** raza este **<1**

Diagrama Smith, rezistenta

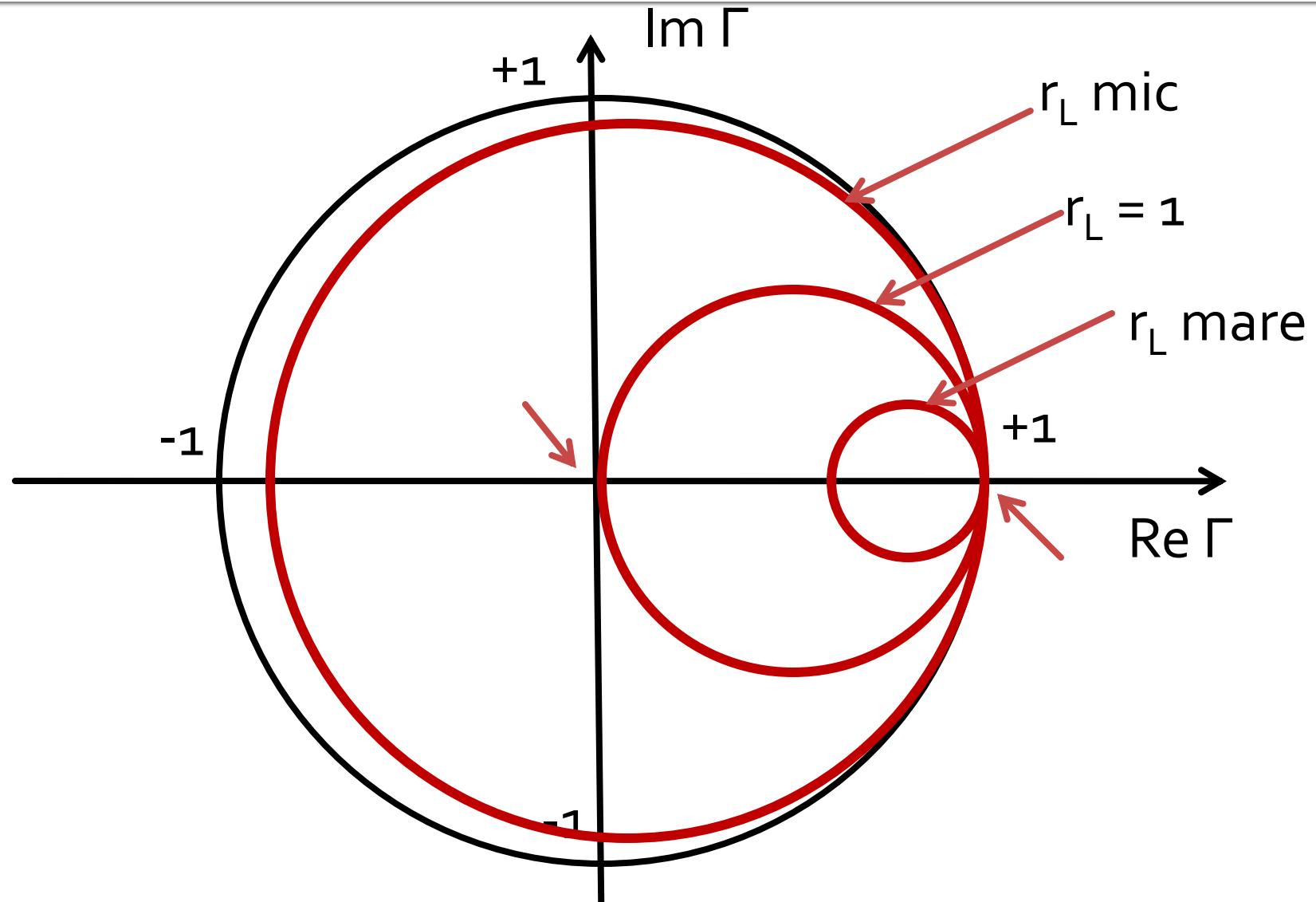


Diagrama Smith, reactanta

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

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

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

- 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 ∞
 - tinzand spre 0 cand $|x_L|$ este mare
 - tinzand spre ∞ 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

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

Diagrama Smith, reactanta

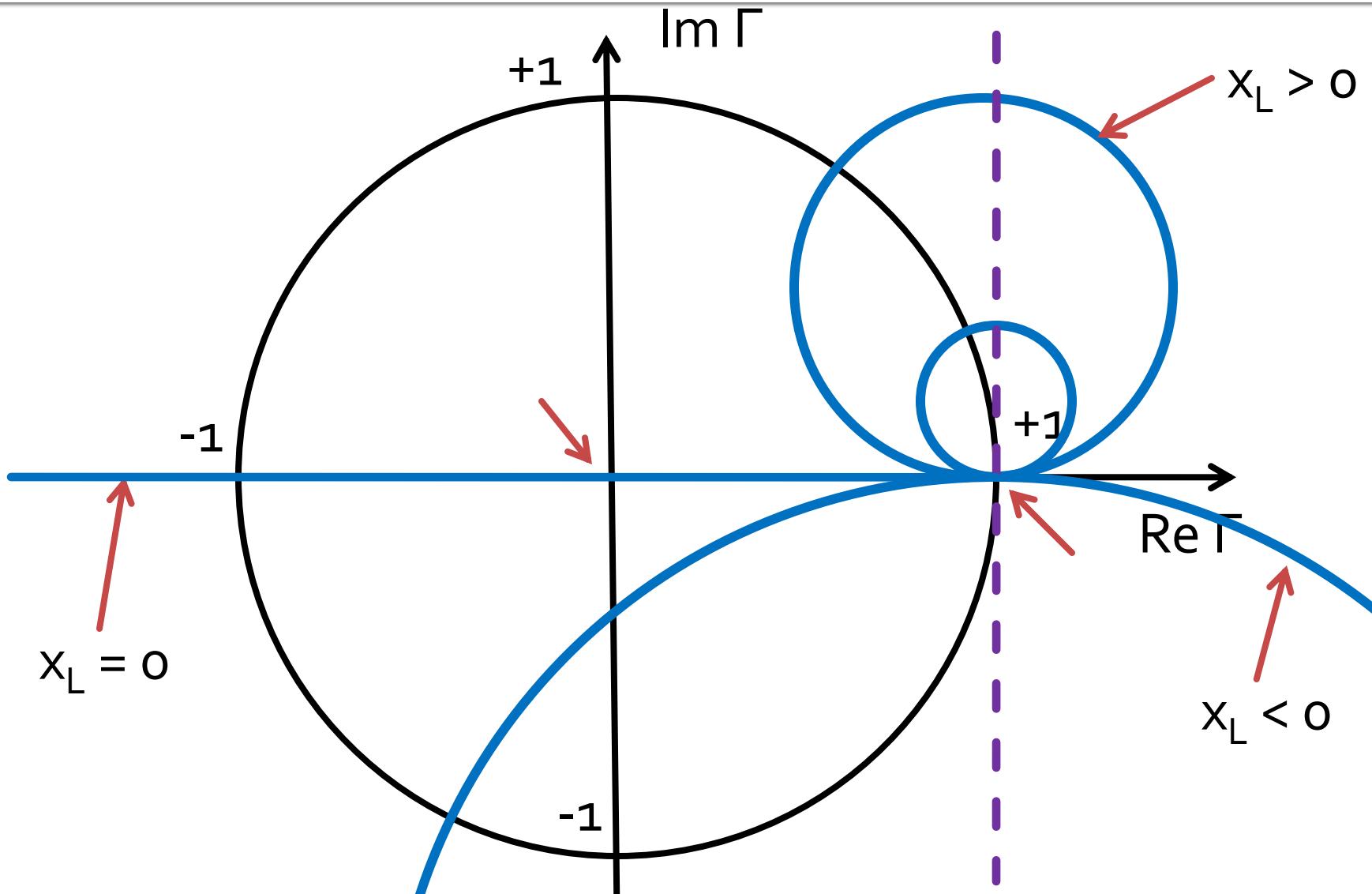


Diagrama Smith, impedanta

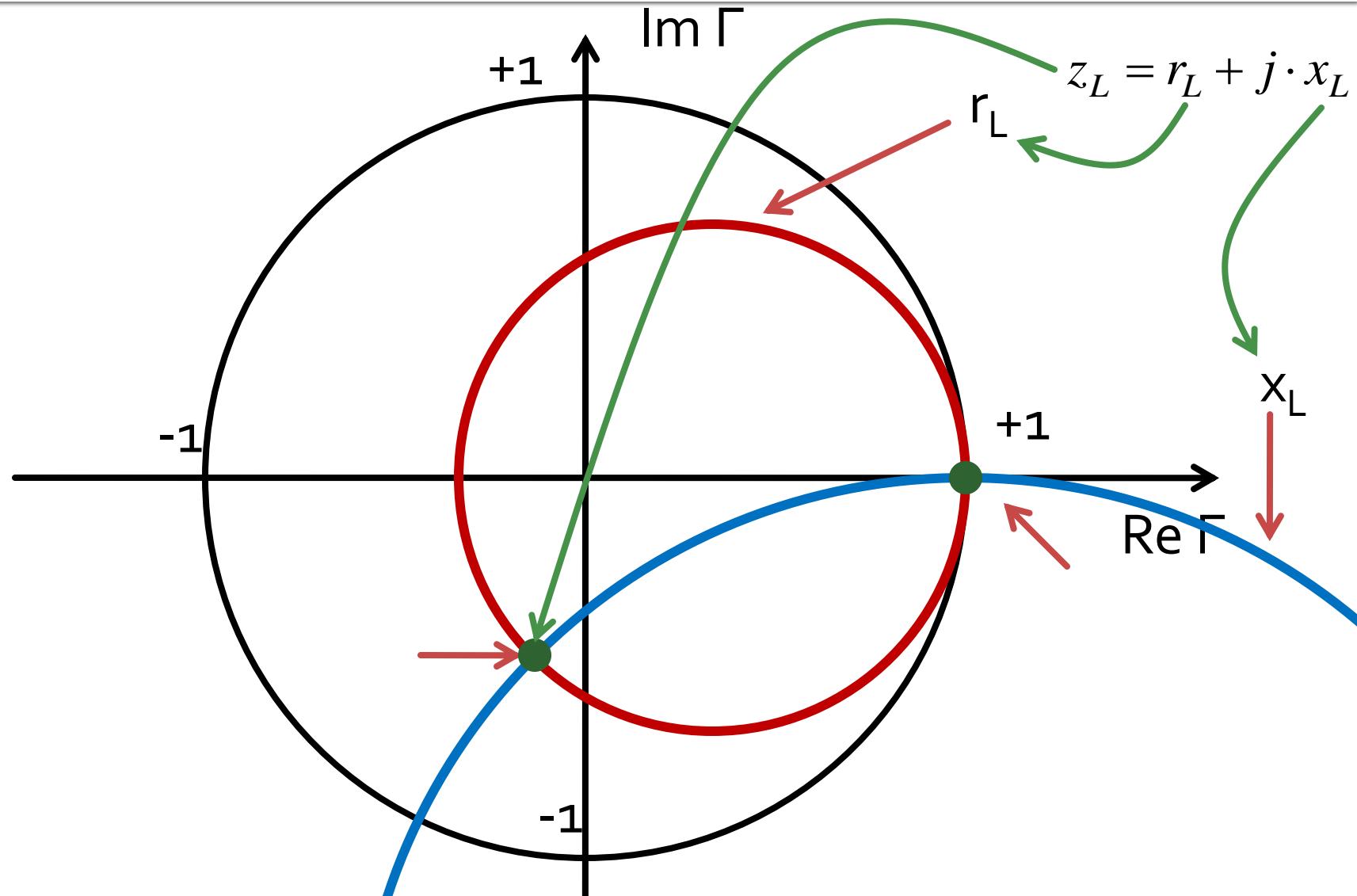


Diagrama Smith, coeficient de reflexie, coordonate rectangulare

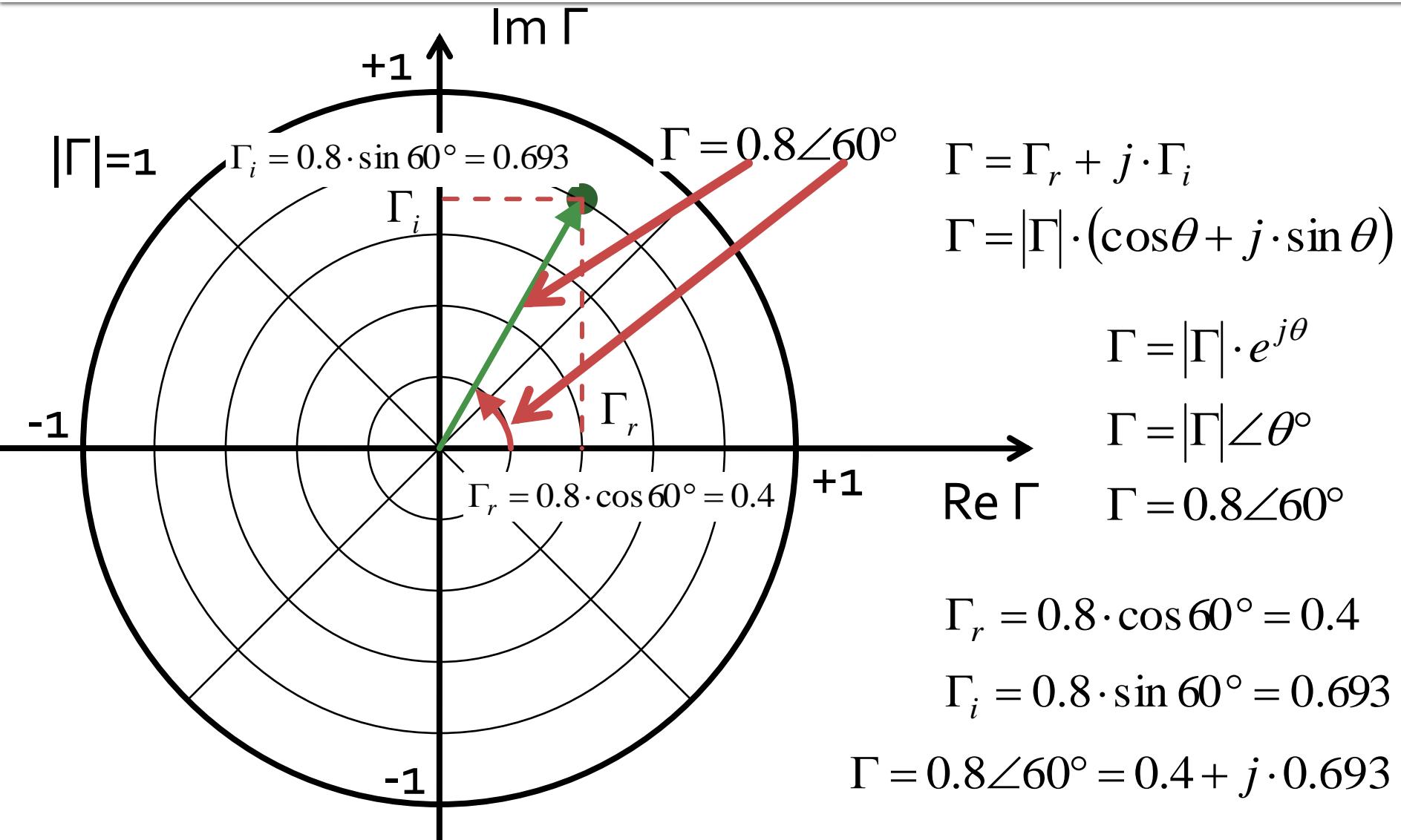
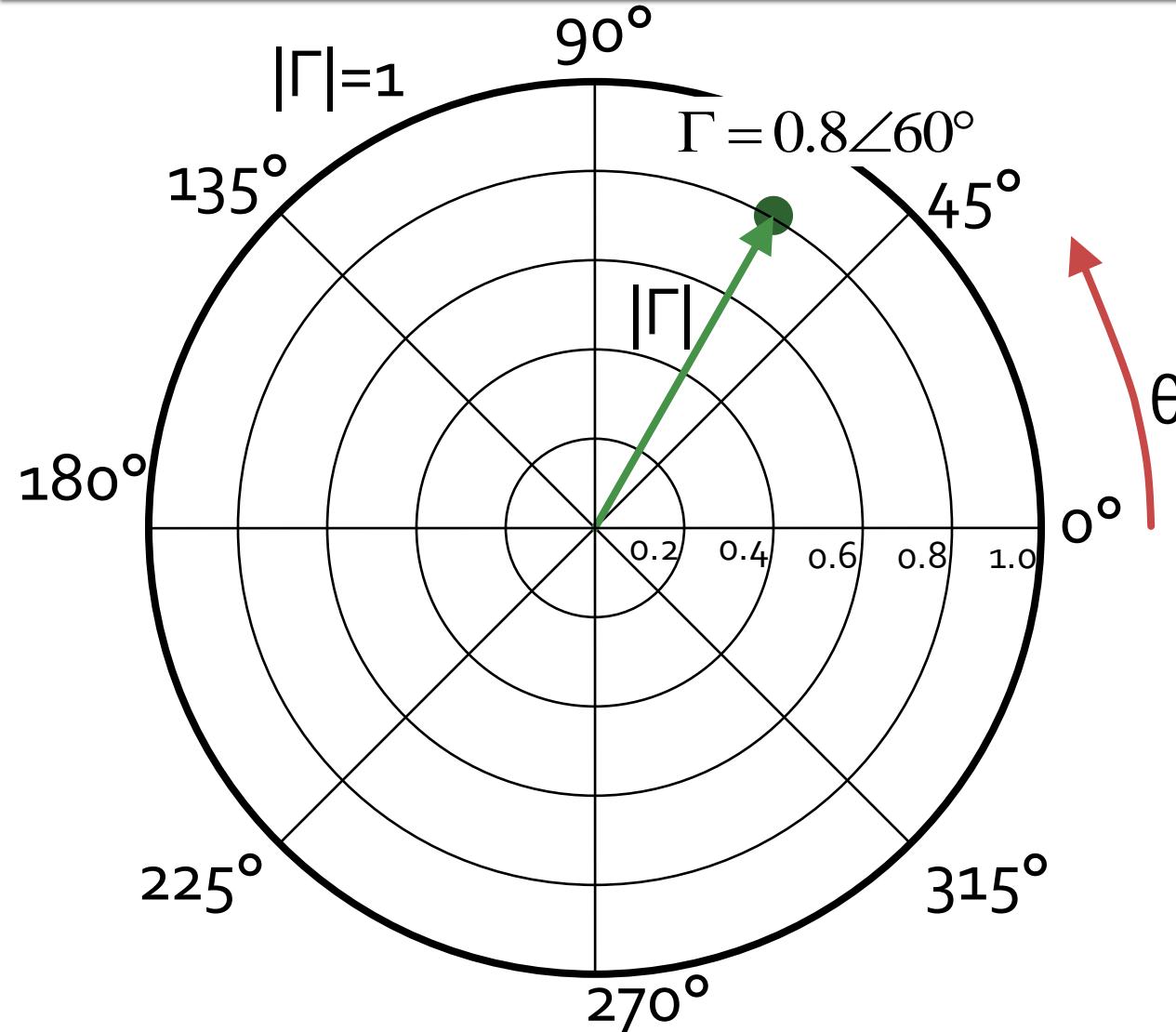


Diagrama Smith, coeficient de reflexie, coordonate polare



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

$$\Gamma = |\Gamma| \cdot (\cos \theta + j \cdot \sin \theta)$$

$$\Gamma = |\Gamma| \cdot e^{j\theta}$$

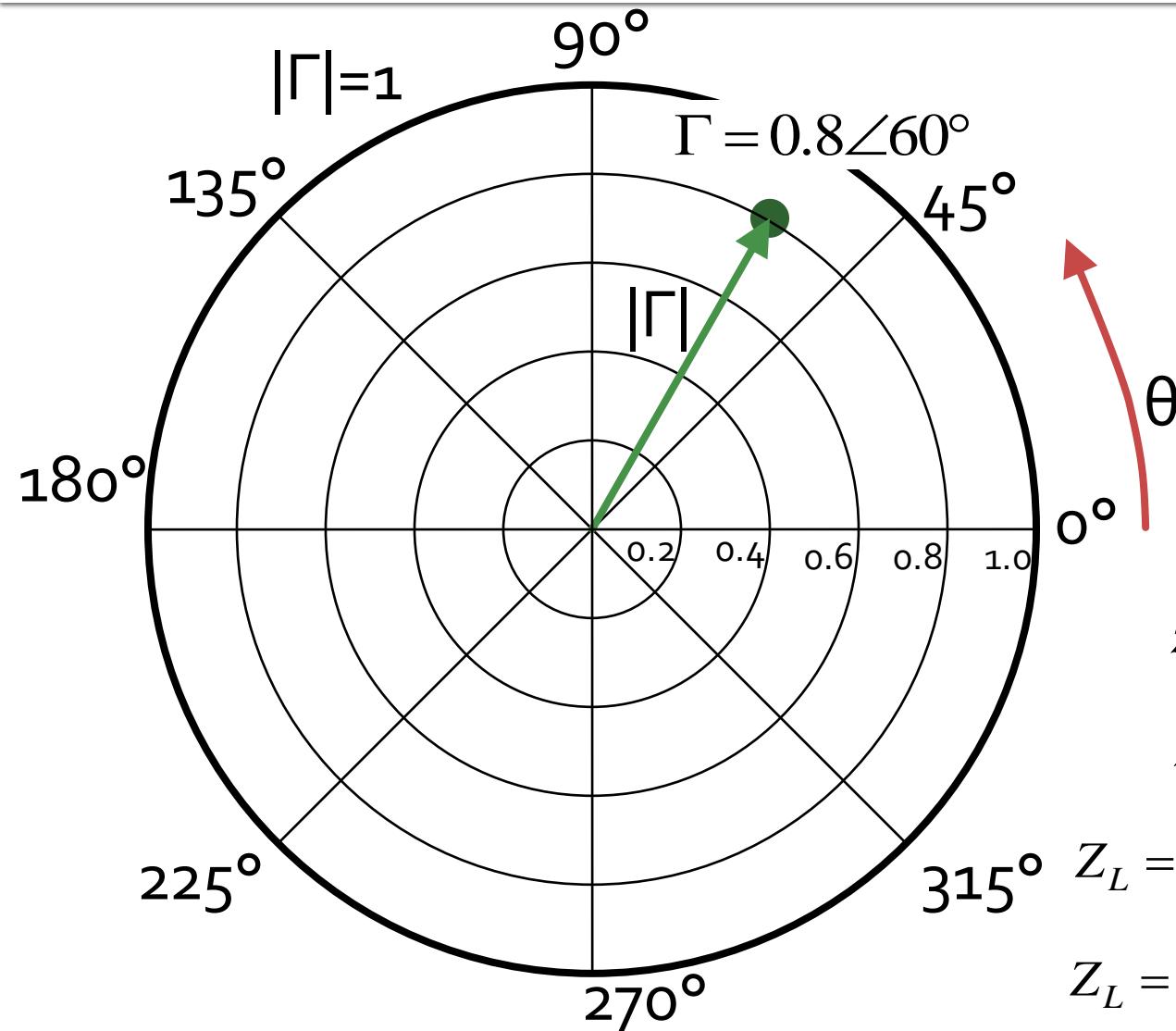
$$\Gamma = |\Gamma| \angle \theta^\circ$$

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

$$\Gamma_r = 0.8 \cdot \cos 60^\circ = 0.4$$

$$\Gamma_i = 0.8 \cdot \sin 60^\circ = 0.693$$

Diagrama Smith, coeficient de reflexie, impedanta



$$\Gamma = |\Gamma| \cdot e^{j\theta}$$

$$\Gamma = |\Gamma| \angle \theta^\circ$$

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

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

$$z_L = \frac{1 + \Gamma}{1 - \Gamma} = \frac{1 + 0.8 \angle 60^\circ}{1 - 0.8 \angle 60^\circ}$$

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

$$Z_L = Z_0 \cdot \frac{1 + \Gamma}{1 - \Gamma} = 50\Omega \cdot \frac{1 + 0.8 \angle 60^\circ}{1 - 0.8 \angle 60^\circ}$$

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

Echivalenta coeficient de reflexie \Leftrightarrow impedanta

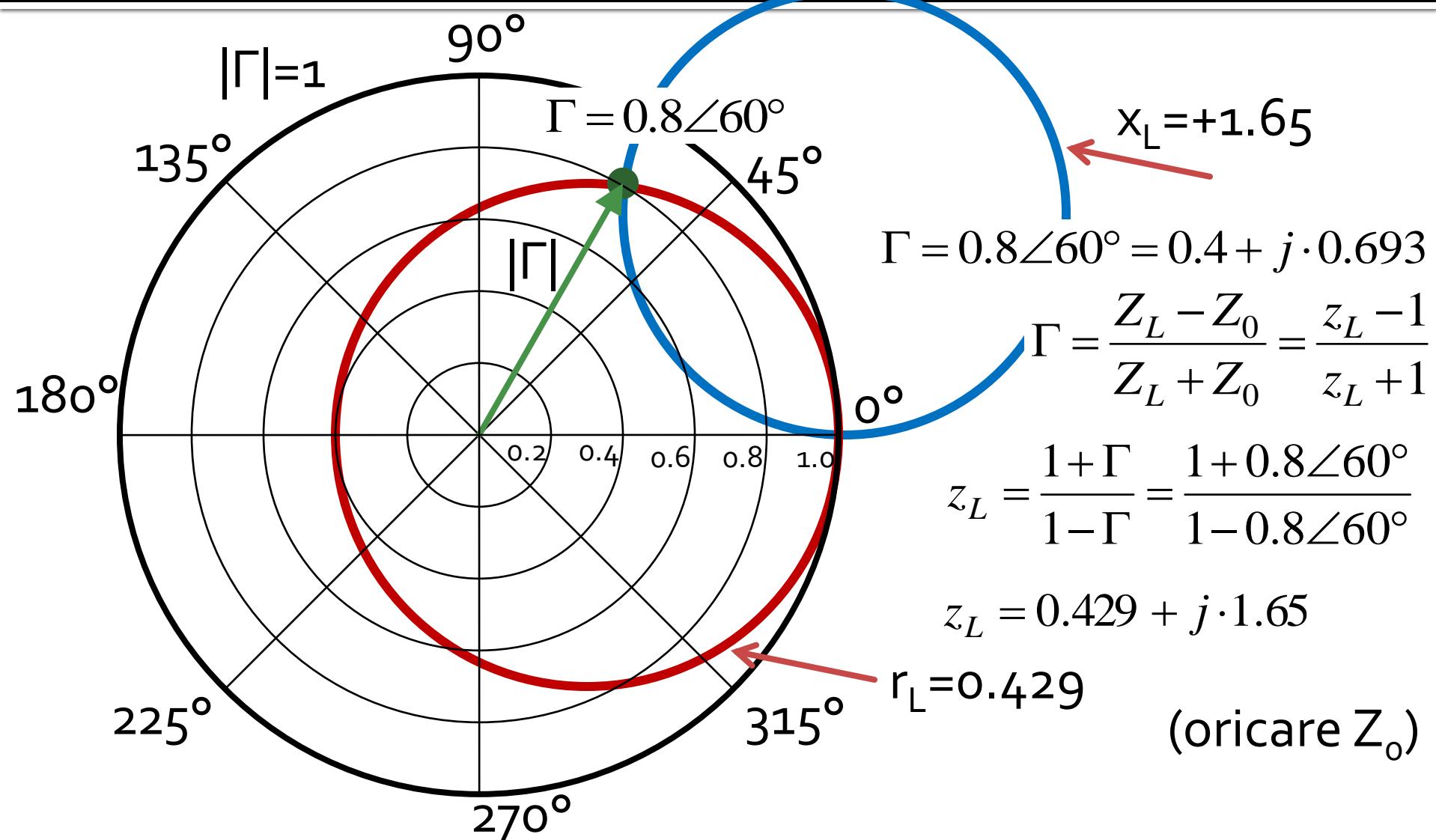


Diagrama Smith, coeficient de reflexie \leftrightarrow impedanta

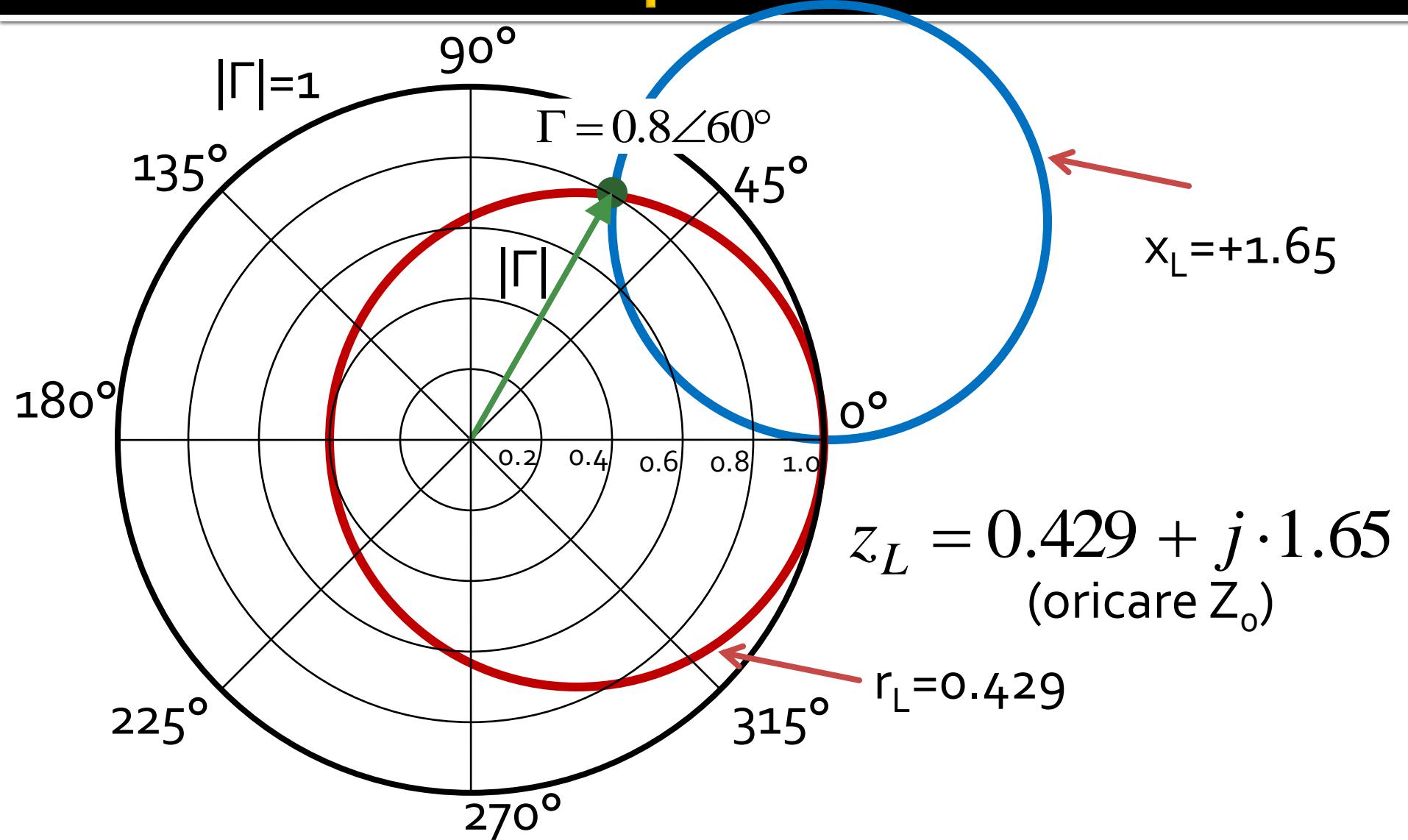
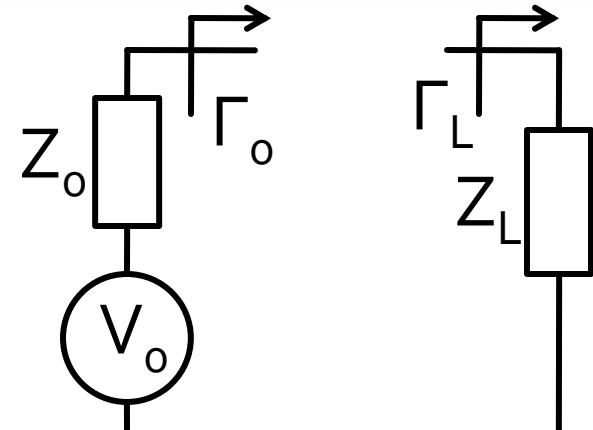
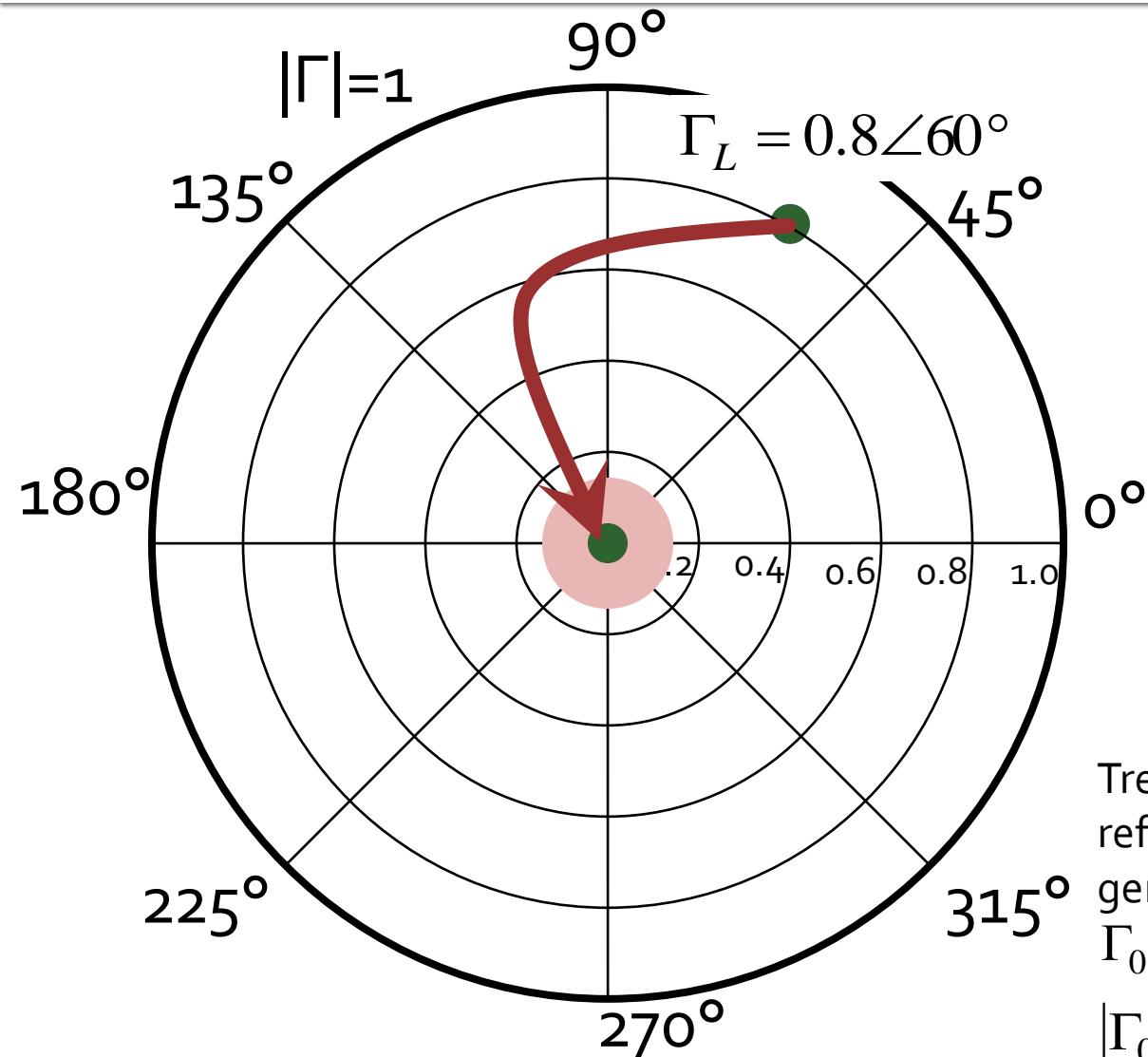


Diagrama Smith, coeficient de reflexie, adaptare



Adaptare Z_L la Z_0 . Se raporteaza Z_L la Z_0

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

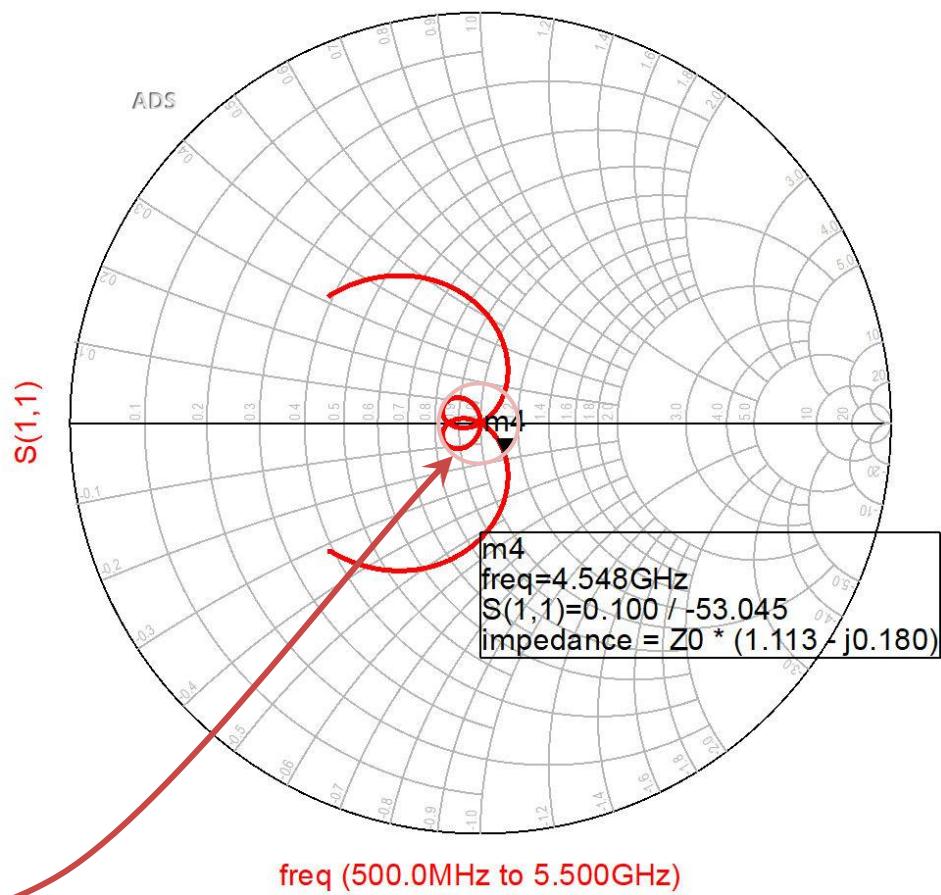
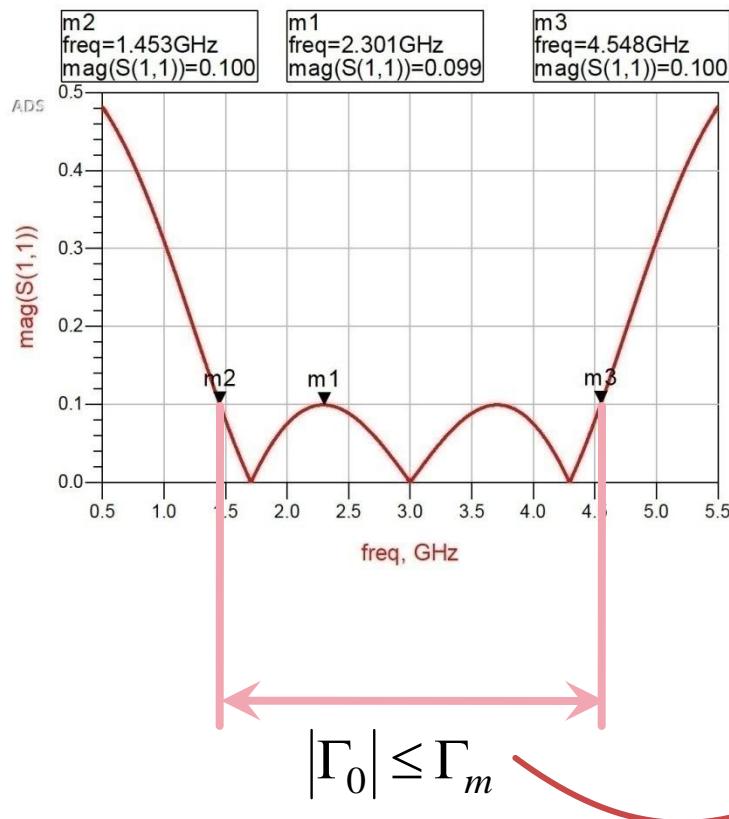
Trebuie sa deplasez coeficientul de reflexie in zona in care pentru generator cu Z_0 am:

$\Gamma_0 = 0$ adaptare perfecta

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

Simulare

■ Similar Lab. 1



Simulare

■ Similar Lab. 1

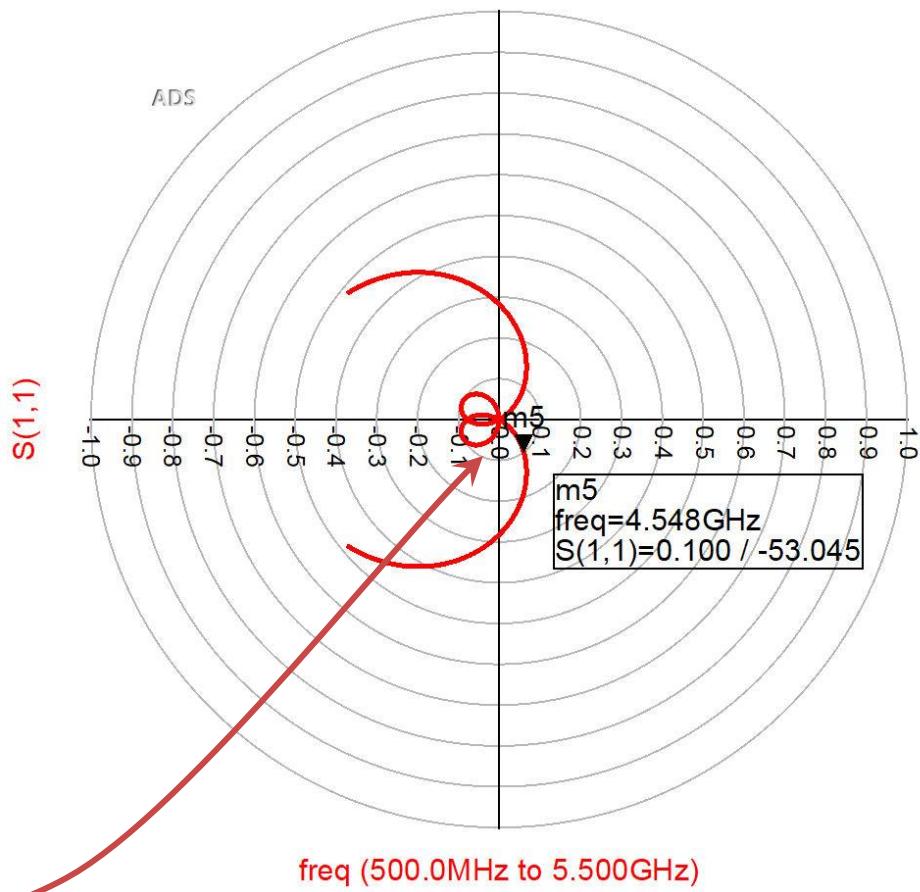
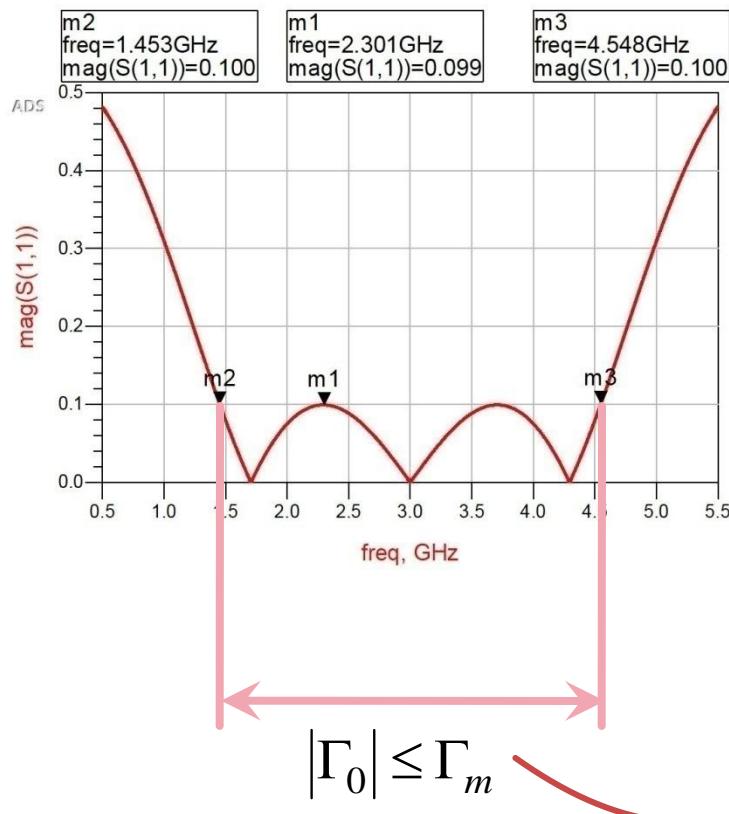
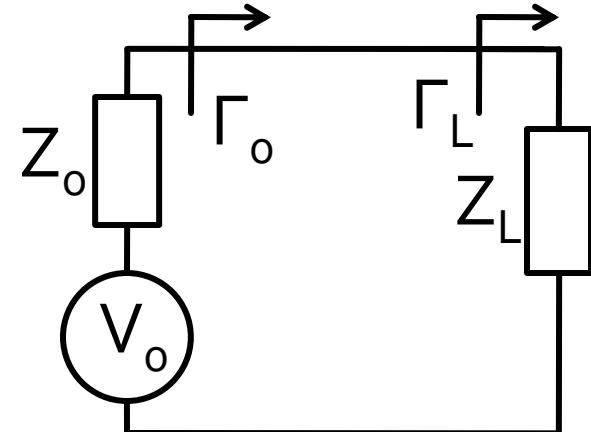
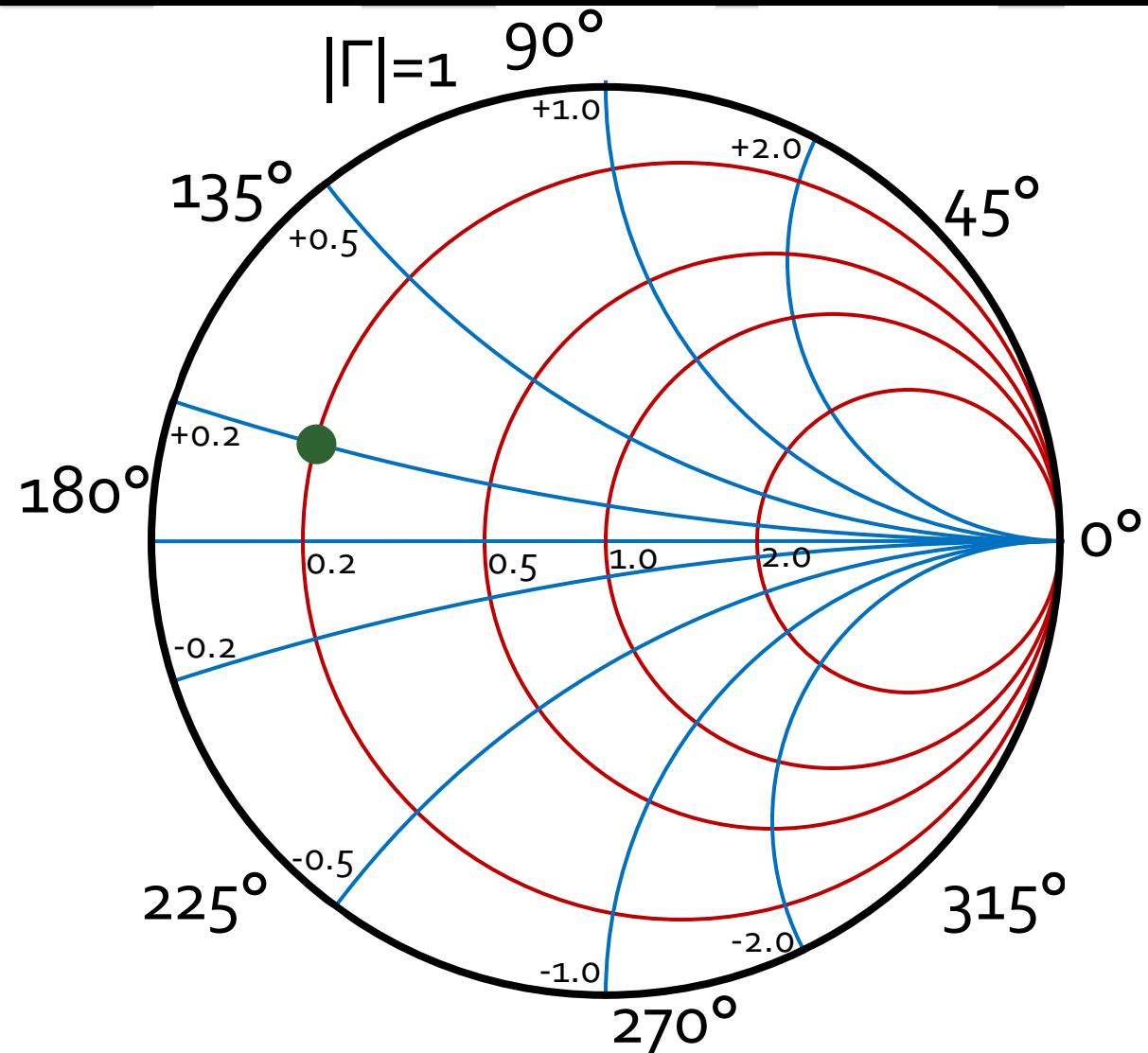


Diagrama Smith, coeficient de reflexie



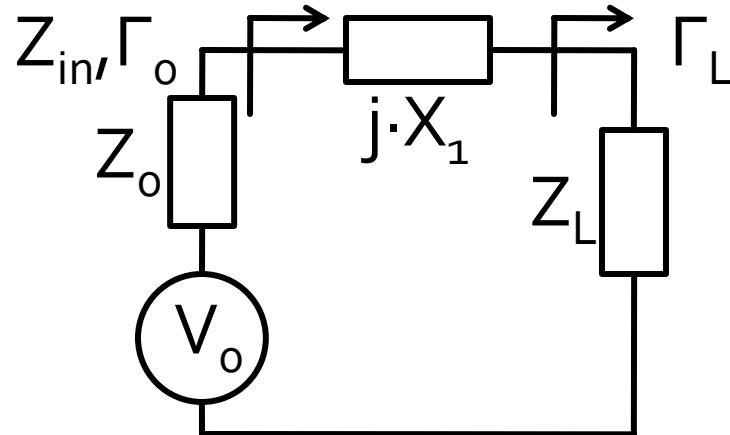
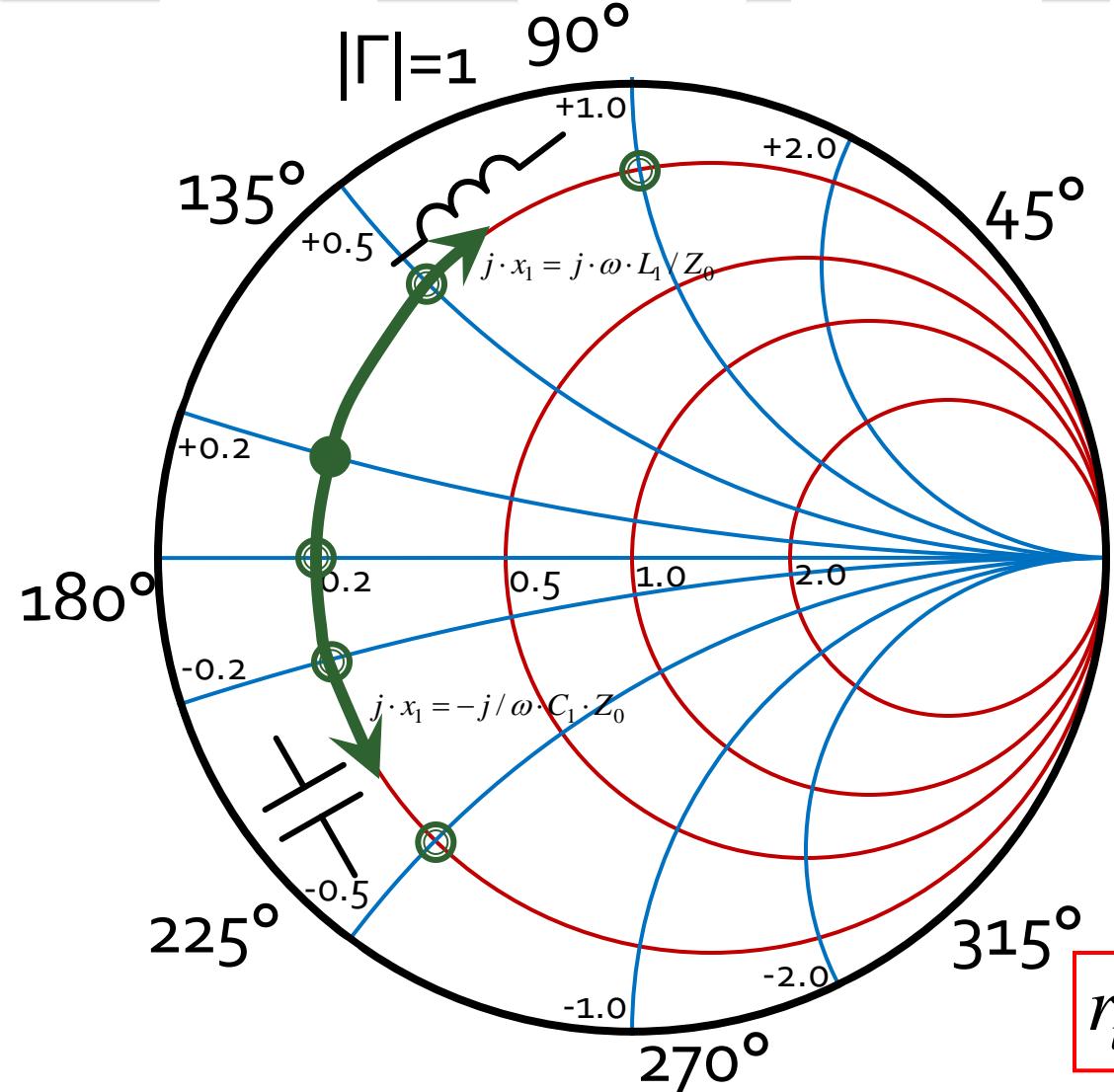
$$Z_0 = 50\Omega$$

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

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

$$\Gamma_L = \Gamma_0 = 0.678 \angle 156.5^\circ$$

Diagrama Smith, coeficient de reflexie, reactanta in serie



$$Z_0 = 50\Omega$$

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

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

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

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

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

$$r_{in} = r_L \quad j \cdot x_1 = j \cdot \omega \cdot L_1 / Z_0 > 0$$

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

ADS, Diagrama Smith, reactanta in serie

The screenshot shows the Advanced Design System (ADS) interface. On the left, a schematic diagram of a series RLC circuit is displayed. The circuit consists of two resistors (Term1, Term3), one capacitor (C1), and one inductor (L1). The component values are labeled as terms:

- Term1: Num=1, Z=50 Ohm
- Term3: Num=3, Z=50 Ohm
- C1: C=1 pF {t}
- L1: L=1 nH {t}
- Term2: Num=2, Z=10+j*10
- Term4: Num=4, Z=10+j*10
- Term5: Num=5, Z=50 Ohm
- Term6: Num=6, Z=10+j*10

Below the schematic, an "S-PARAMETERS" button is visible, along with the text "S_Param SP1 Freq=1.0 GHz".

On the right, a "Tune Parameters" dialog box is open, showing the parameters for components C1.C and L1.L. The dialog box includes fields for Value, Max, Min, Step, and Scale.

Parameter	Value	Max	Min	Step	Scale
C1.C (pF)	39.605	50	0.5	0.1	Lin
L1.L (nH)	0.895	40	0.5	0.1	Lin

ADS, Diagramma Smith, reactanta in serie

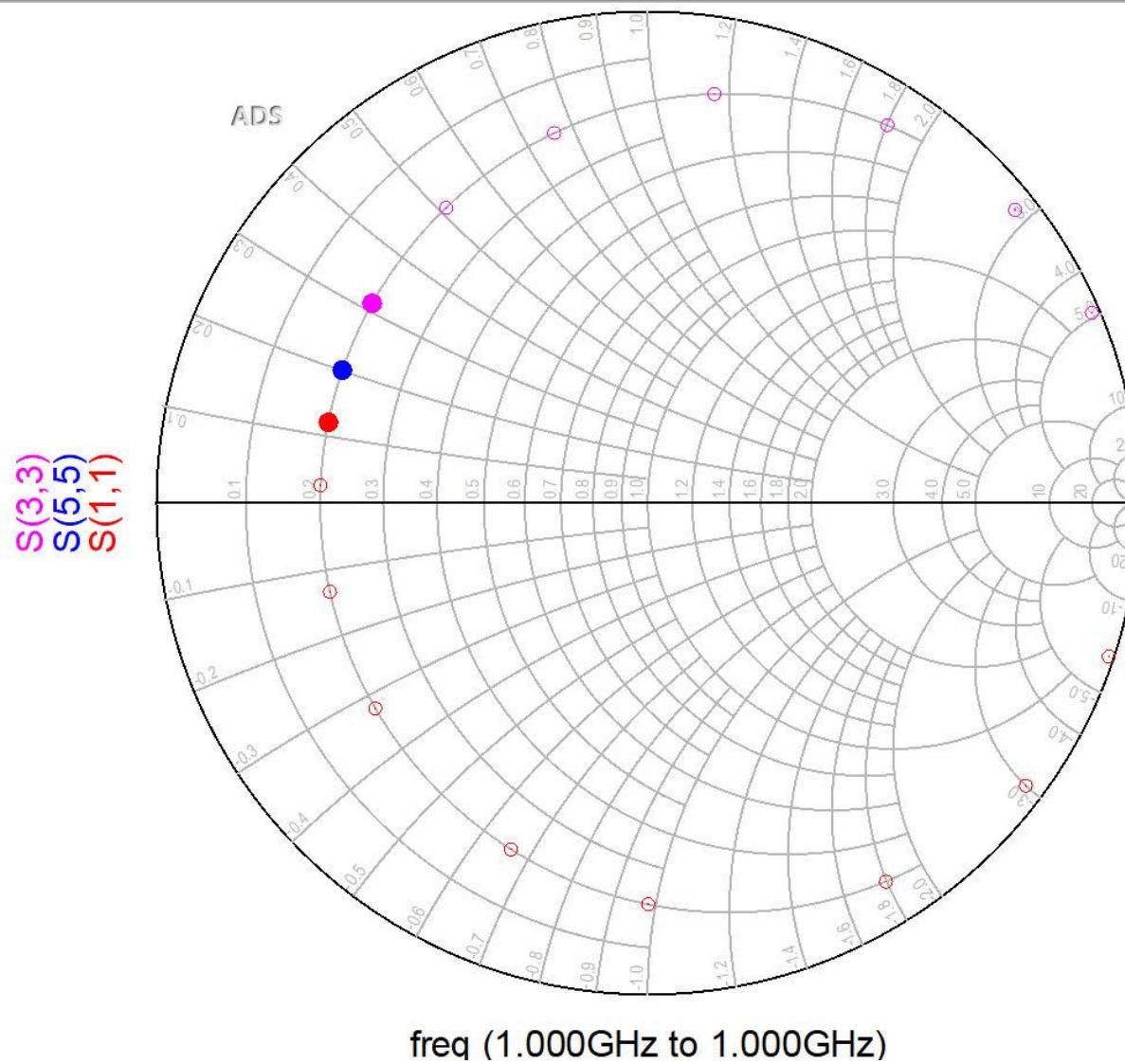
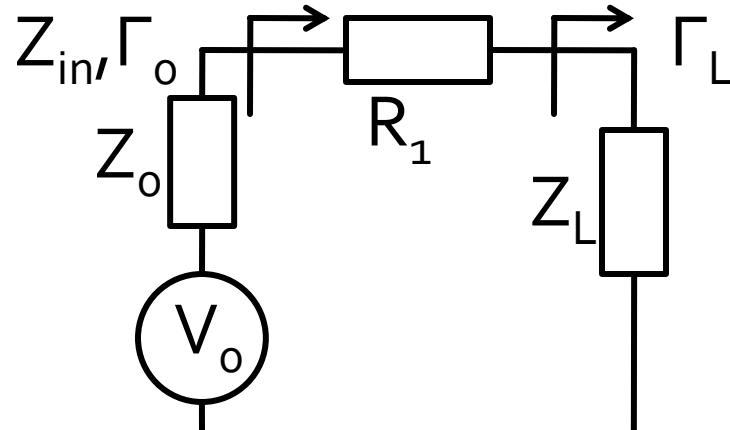
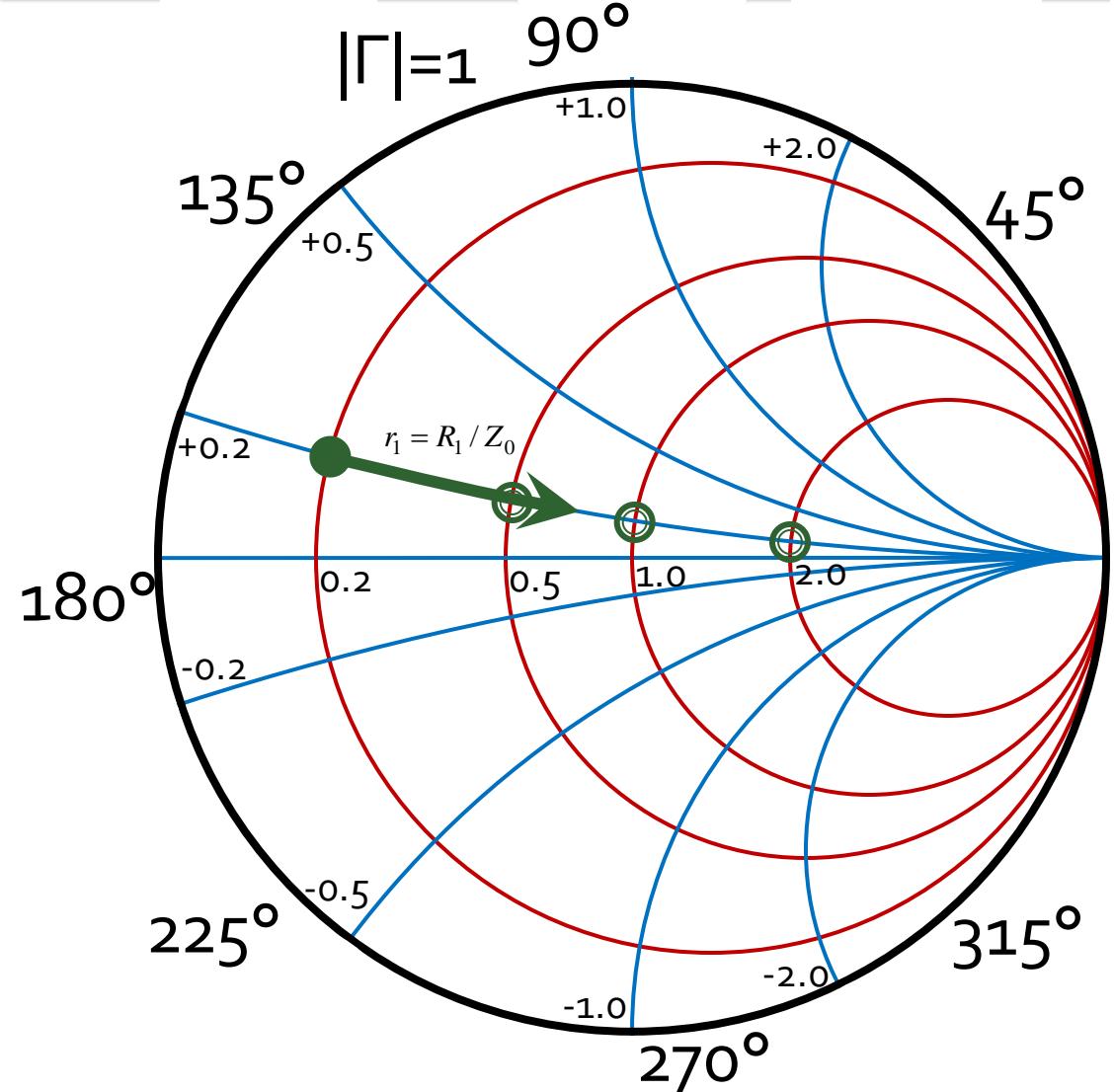


Diagrama Smith, coeficient de reflexie, rezistenta in serie



$$Z_0 = 50\Omega$$

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

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

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

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

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

$x_{in} = x_L$

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

ADS, Diagramma Smith, rezistenza in serie

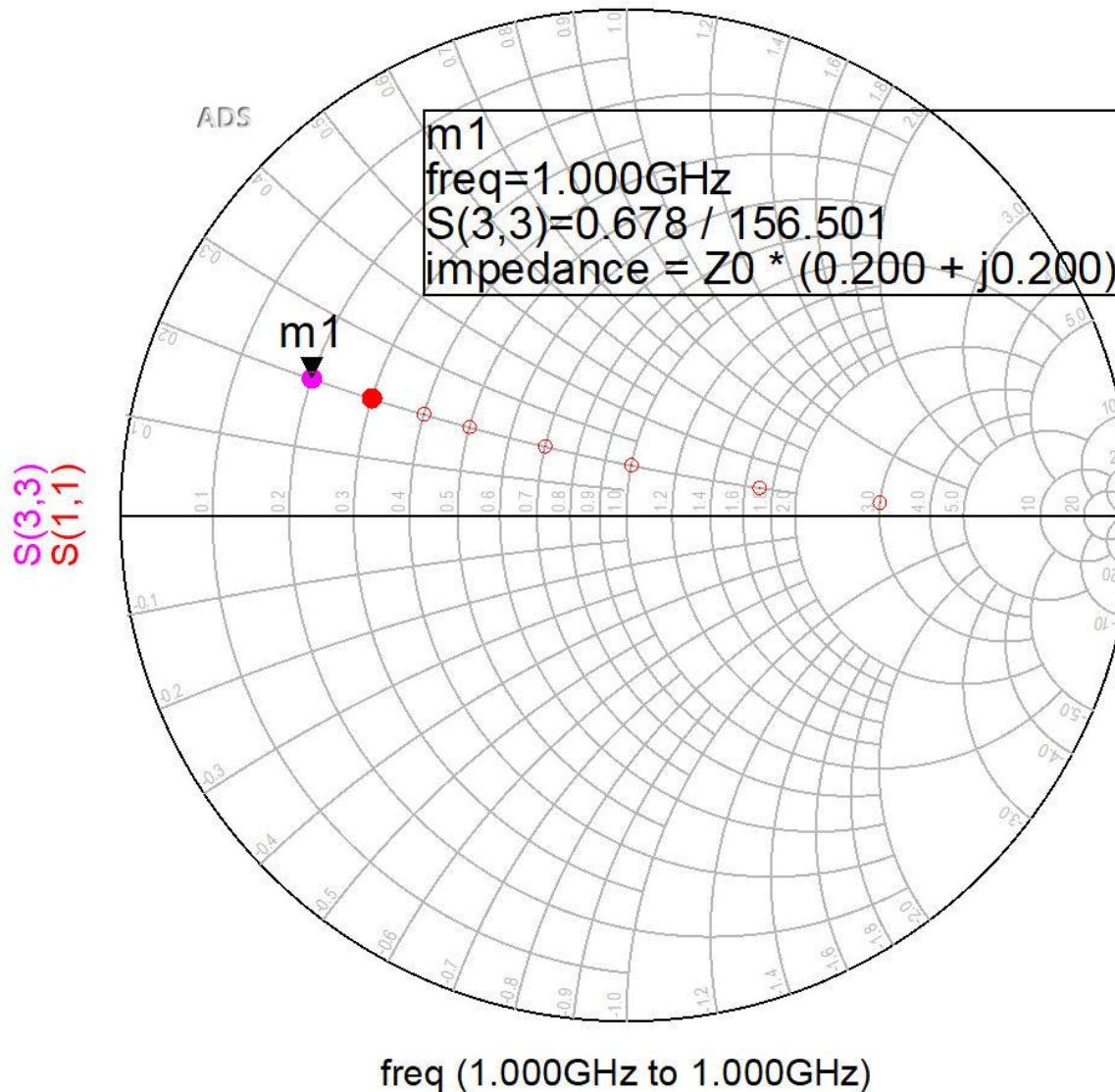
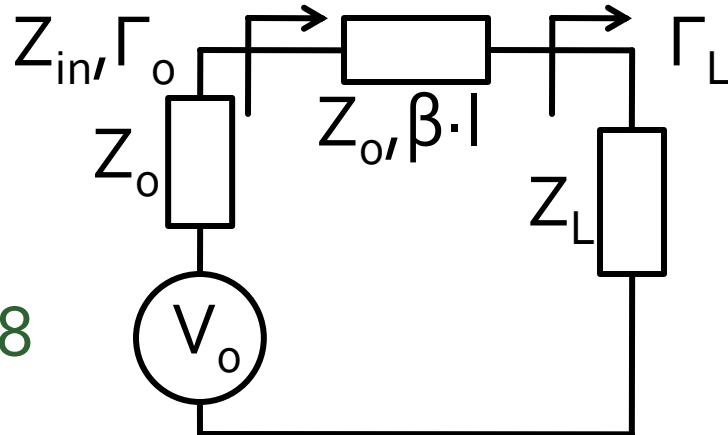
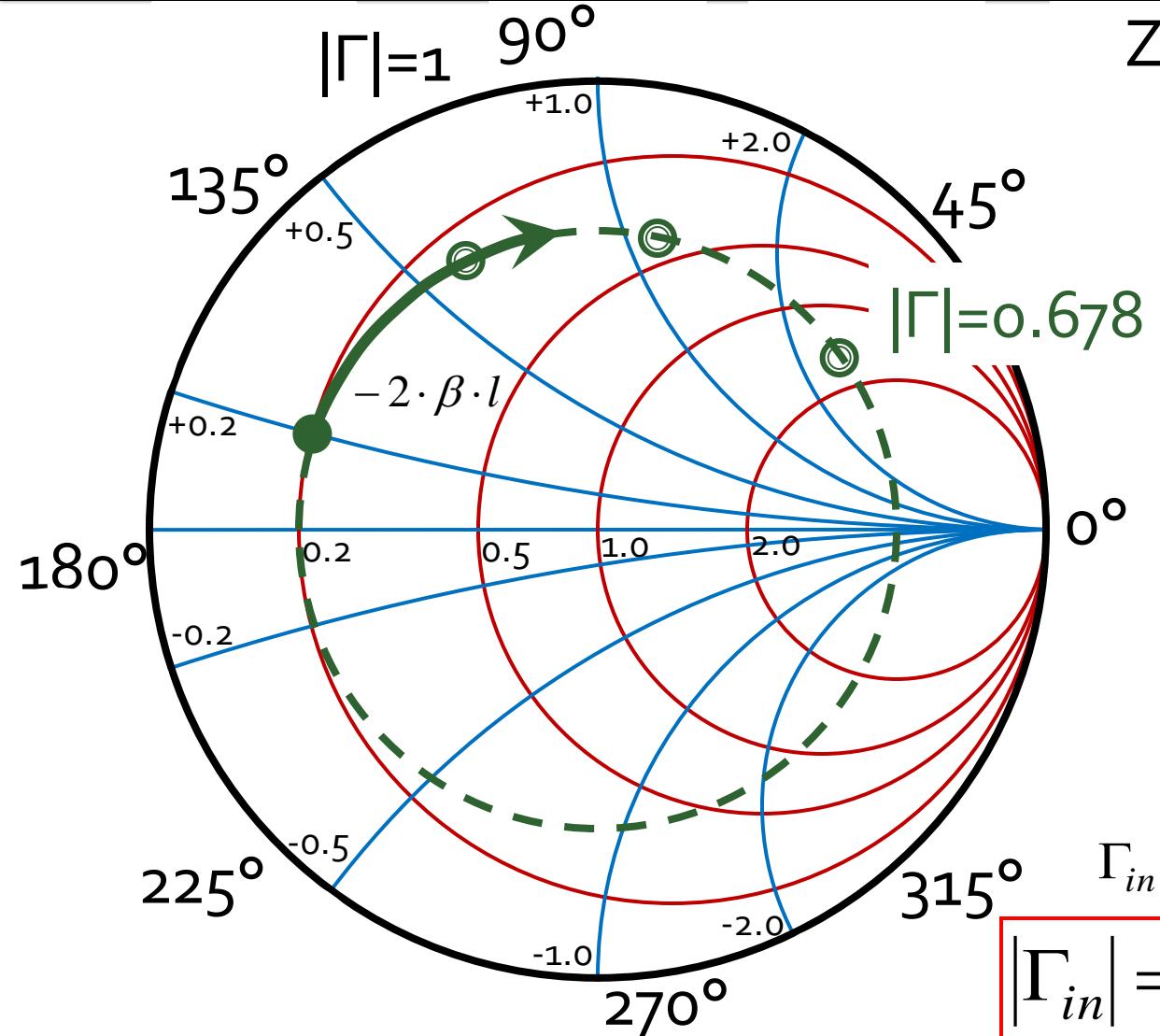


Diagrama Smith, coeficient de reflexie, linie de transmisie in serie



$$Z_0 = 50\Omega$$

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

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

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

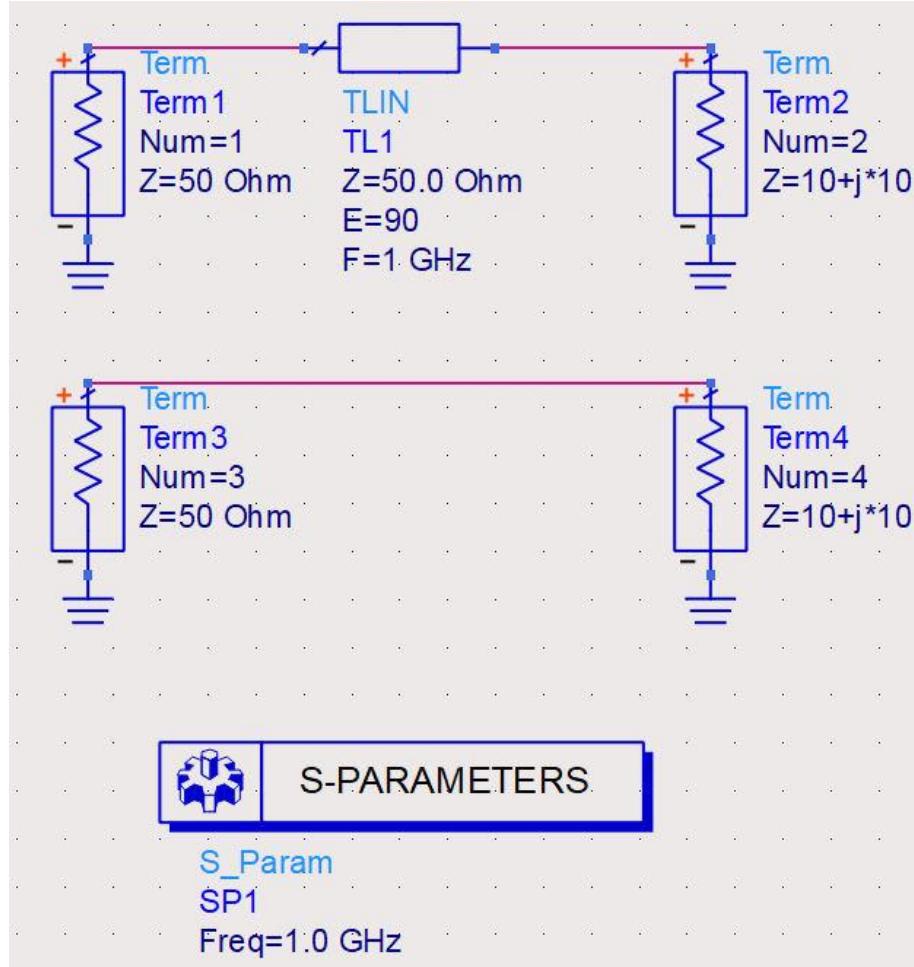
$$Z_{in} = Z_0 \cdot \frac{1 + \Gamma_L \cdot e^{-2j \cdot \beta \cdot l}}{1 - \Gamma_L \cdot e^{-2j \cdot \beta \cdot l}}$$

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

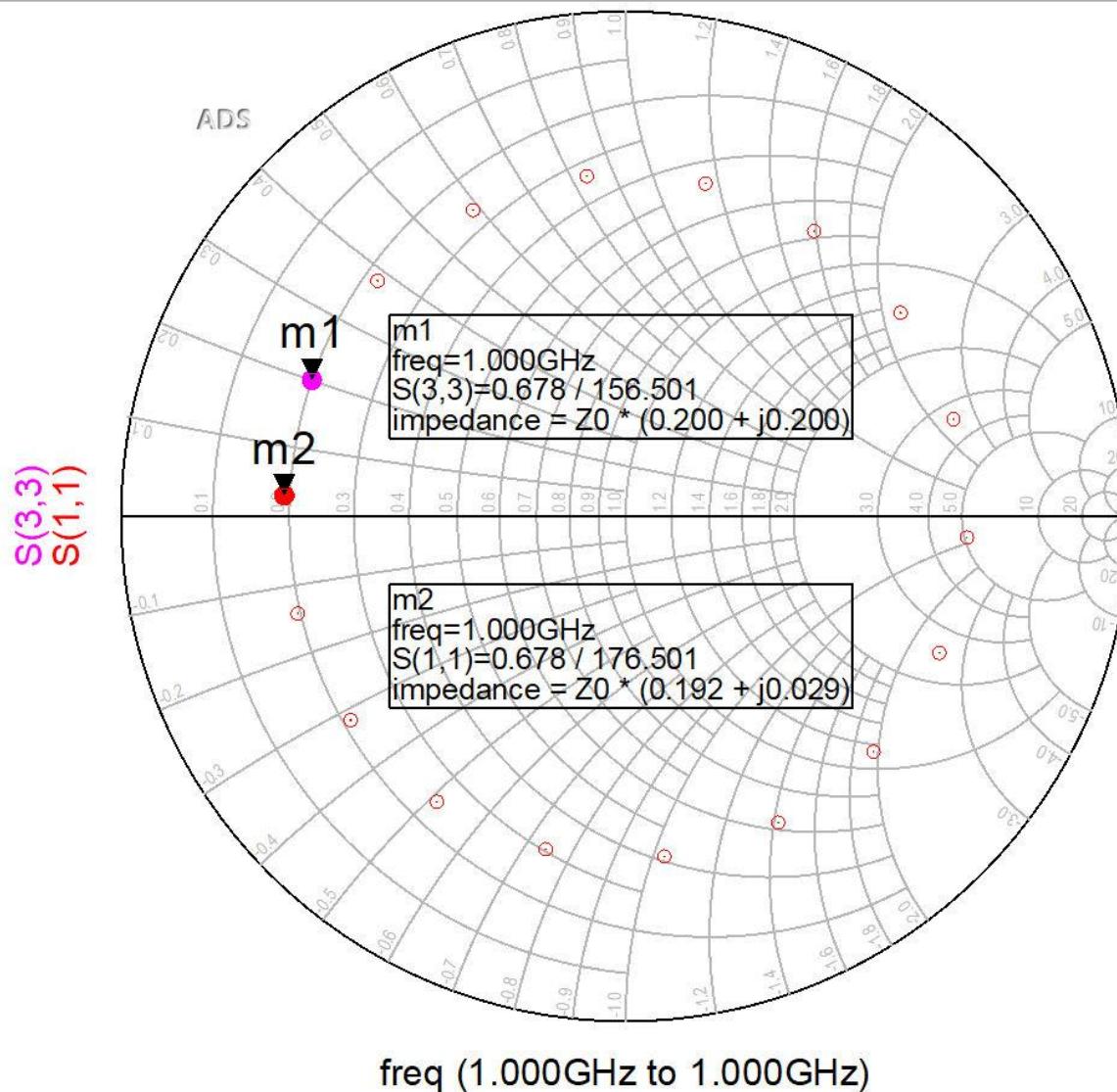
$$|\Gamma_{in}| = |\Gamma_L|$$

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

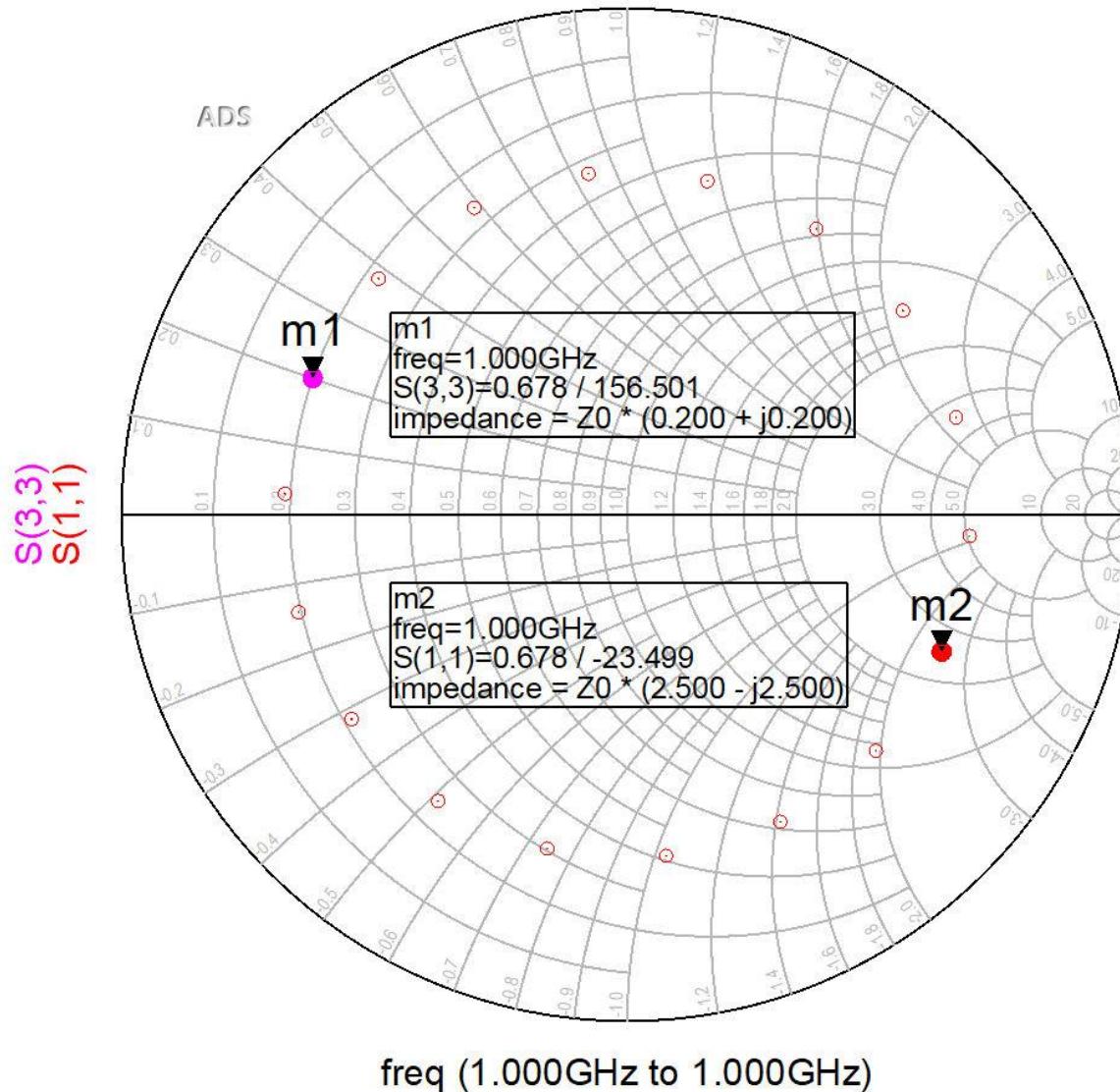
ADS, Diagrama Smith, linie de transmisie in serie



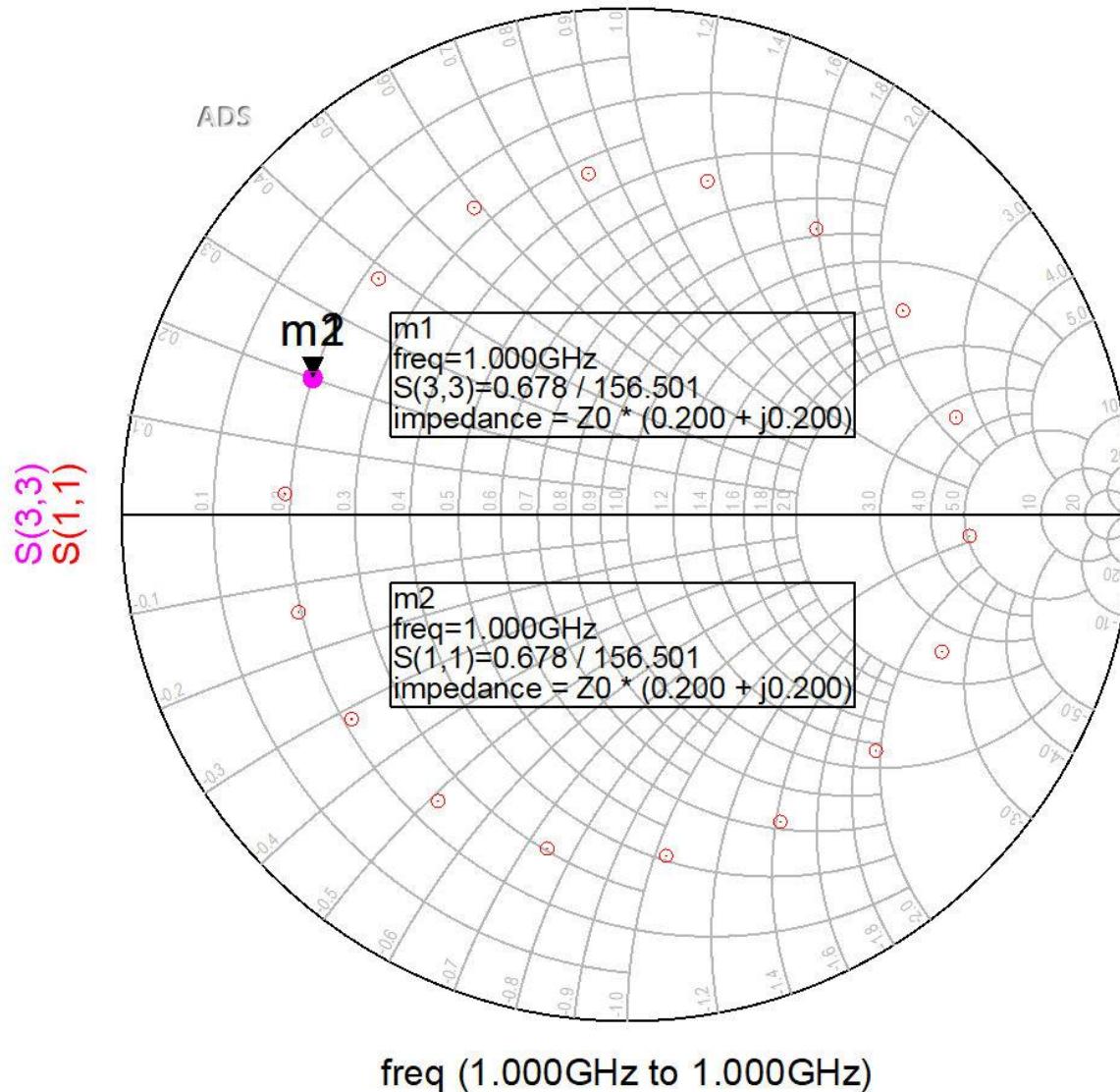
ADS, Diagrama Smith, linie de transmisie in serie



ADS, Diagrama Smith, linie de transmisie in serie, 90°



ADS, Diagrama Smith, linie de transmisie in serie, 180°



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

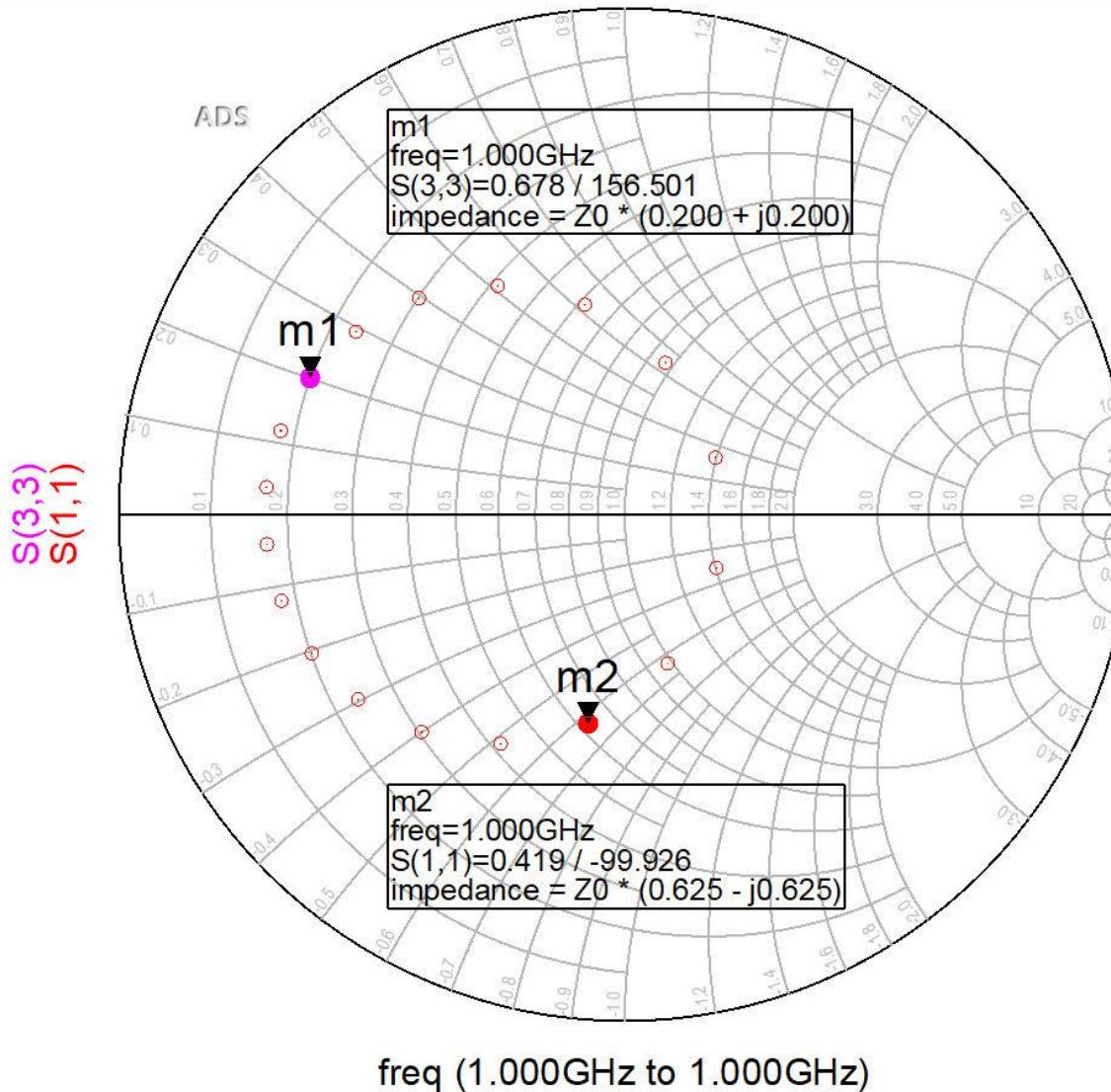
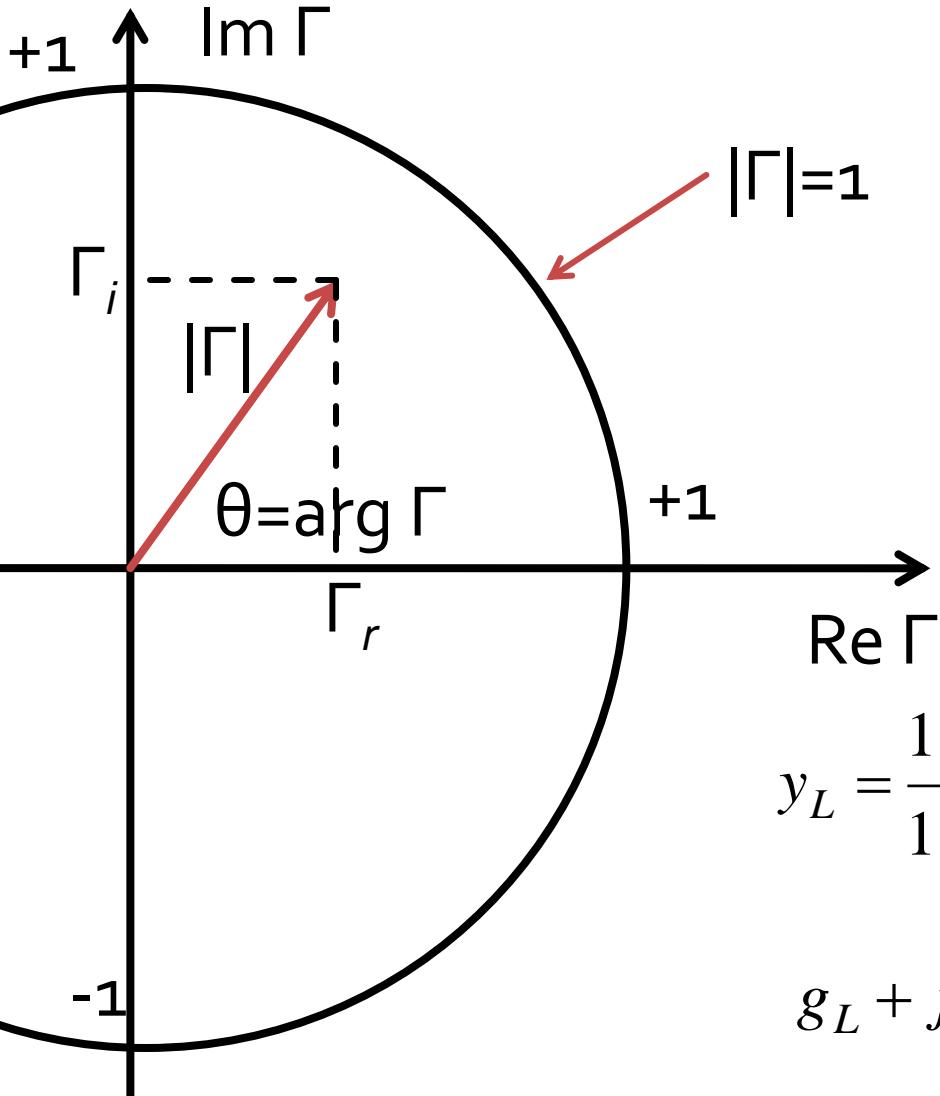


Diagramma Smith, admitante



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

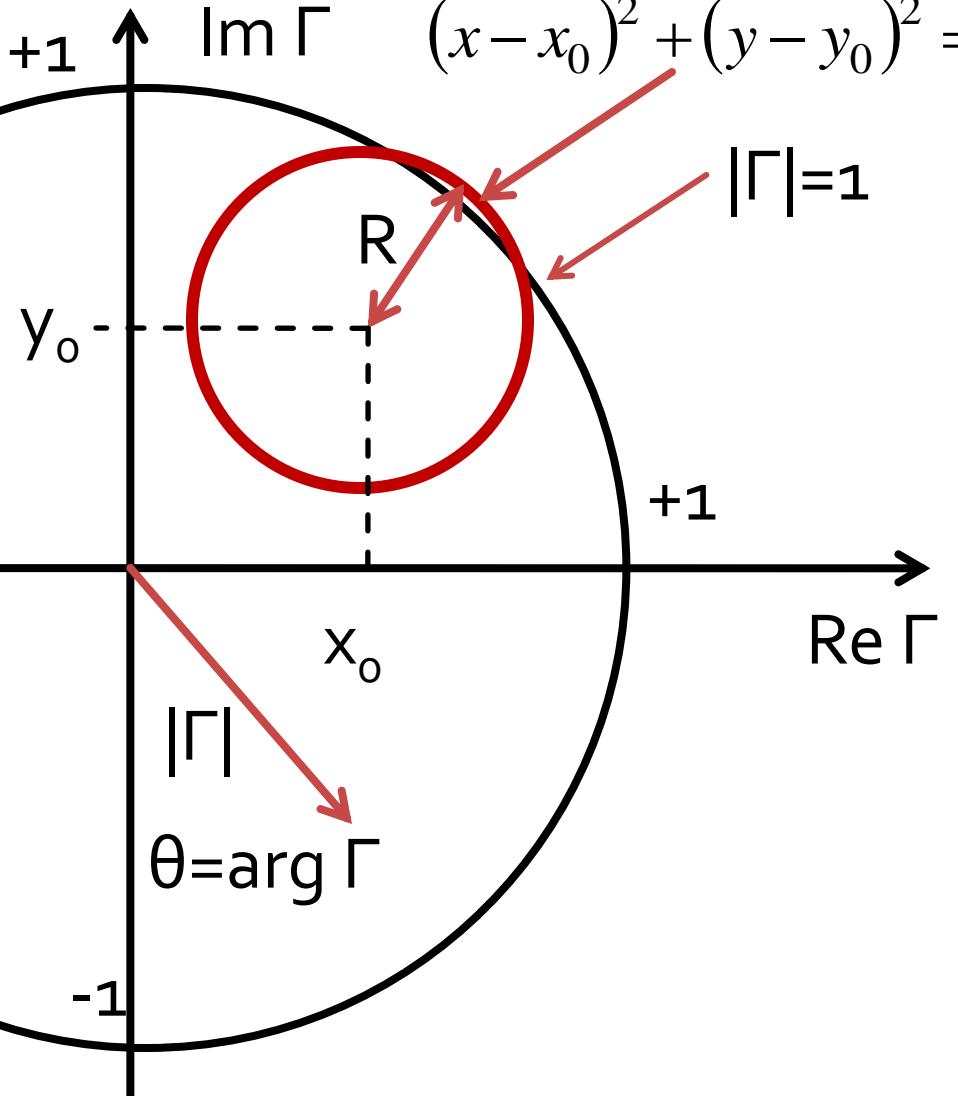
$$\Gamma = \Gamma_r + j \cdot \Gamma_i$$

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

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

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

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

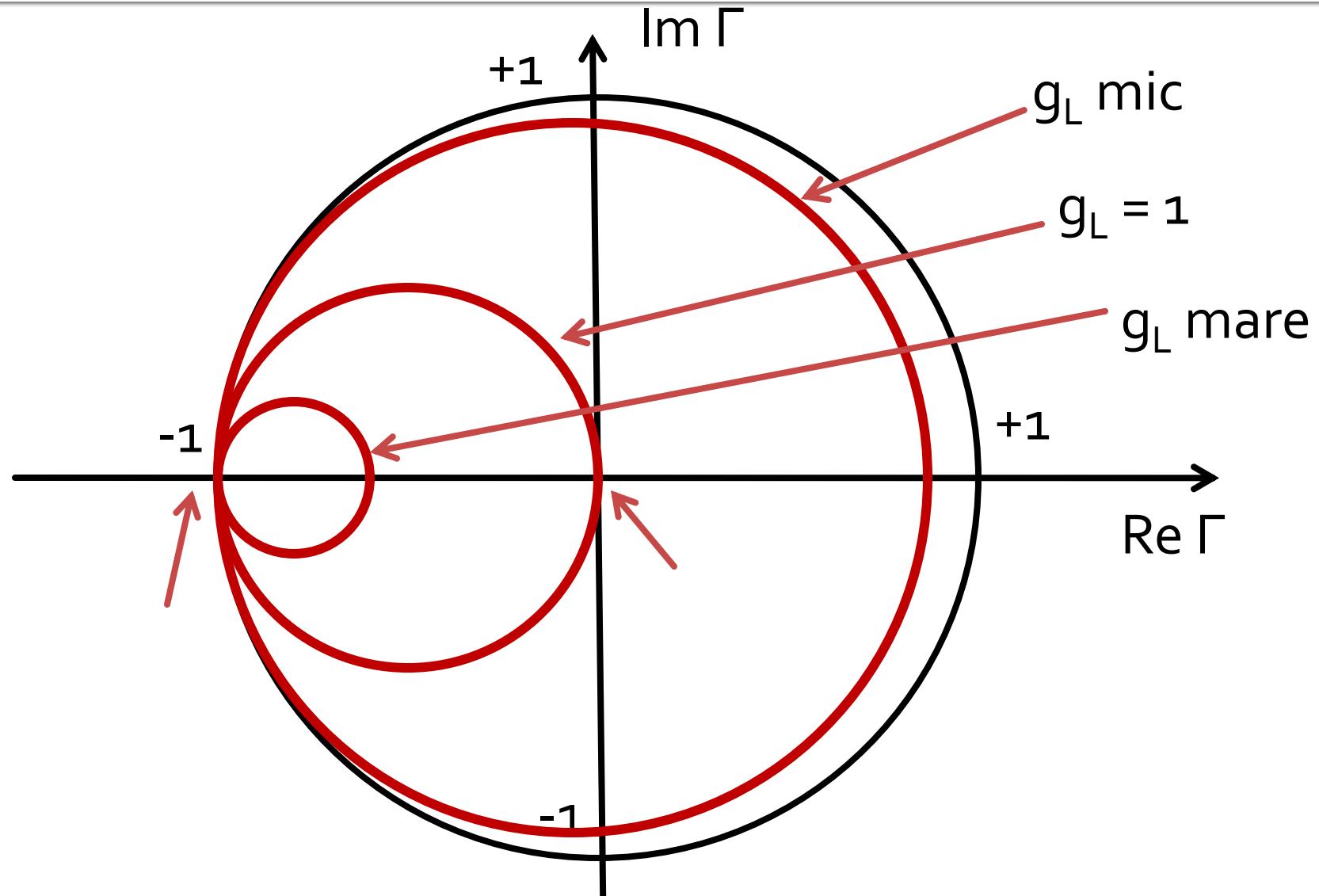


Diagrama Smith, susceptanta

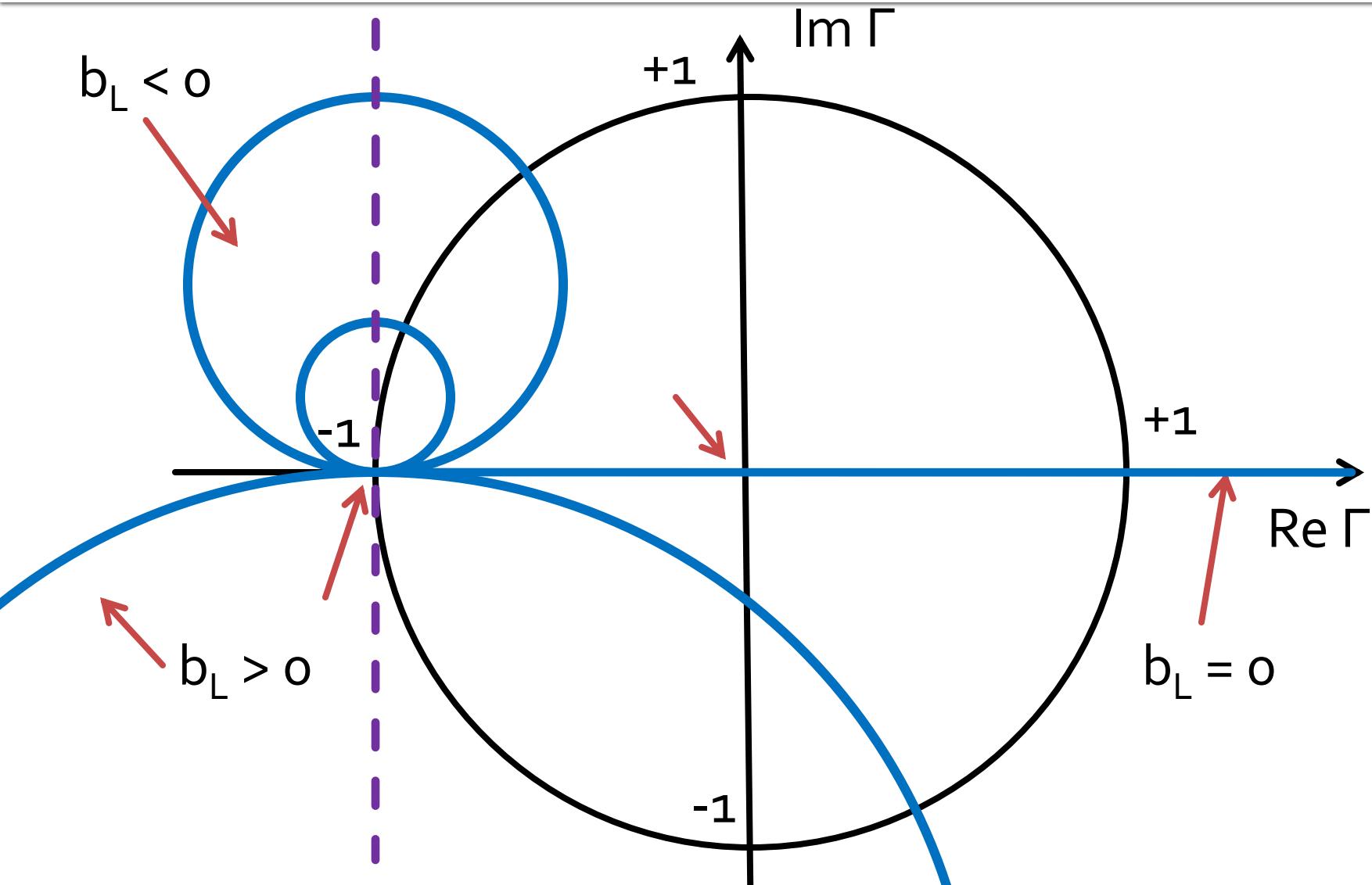
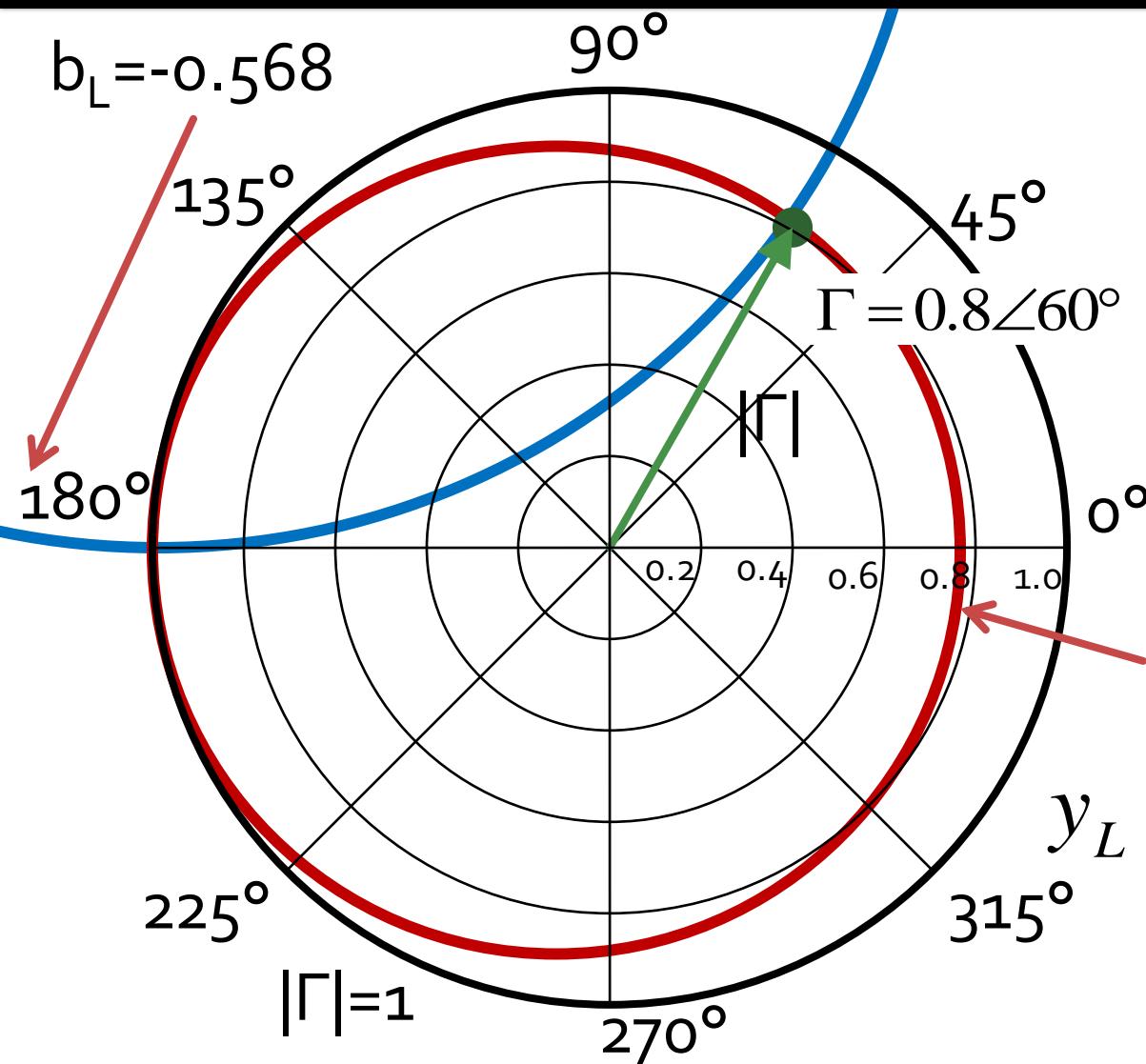


Diagrama Smith, coeficient de reflexie \Leftrightarrow admitanta



$$\Gamma = 0.8∠60^\circ$$

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

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

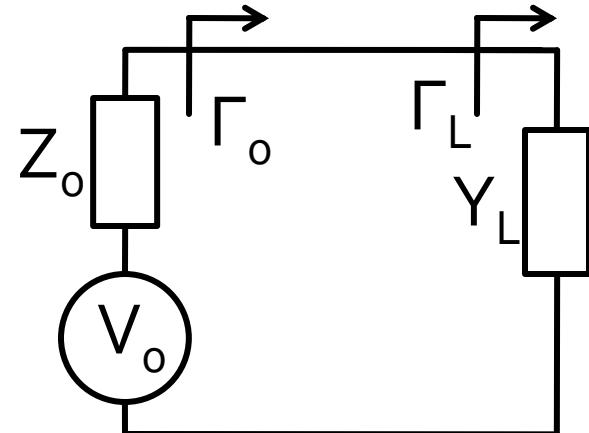
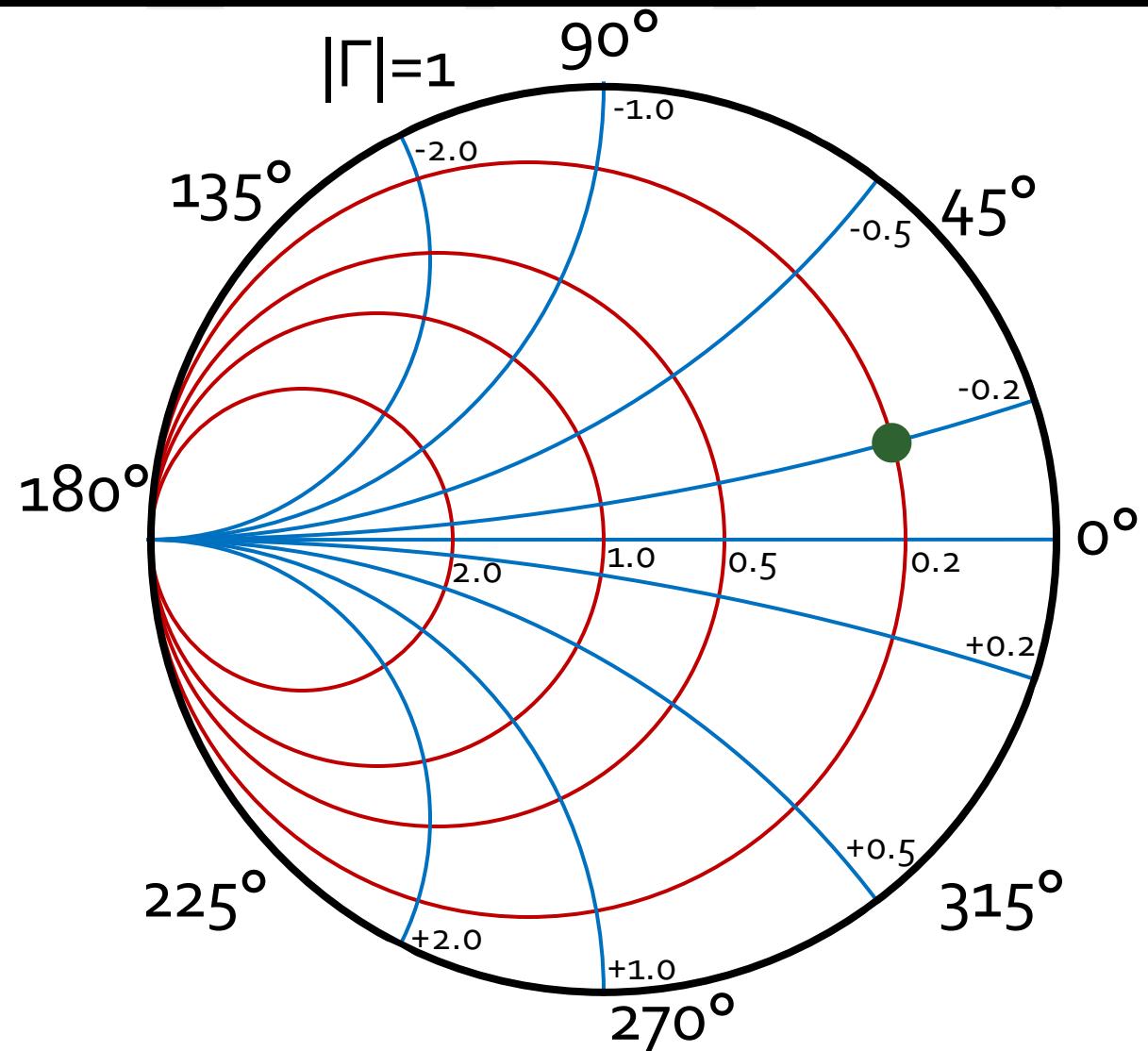
$$y_L = \frac{1}{z_L} = 0.148 - j \cdot 0.568$$

$$g_L = 0.148$$

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

(oricare Z_0)

Diagrama Smith, coeficient de reflexie, admitanta



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

$$Z_L = 125\Omega + j \cdot 125\Omega$$

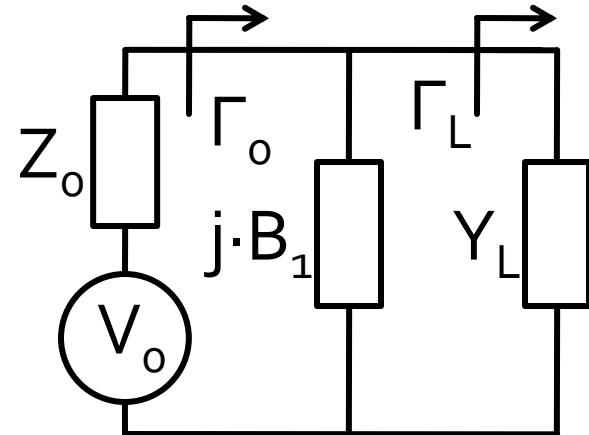
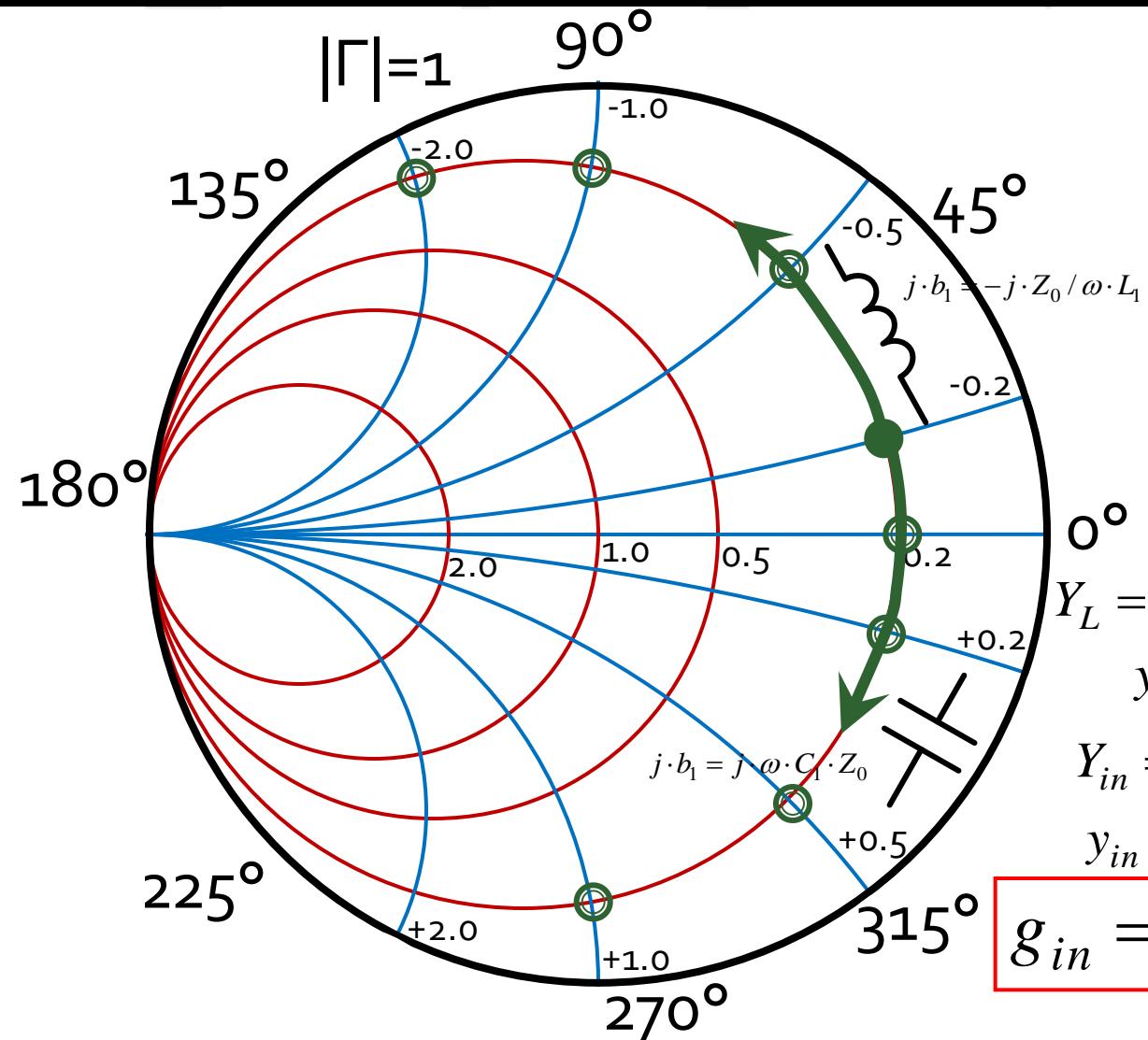
$$z_L = 2.5 + j \cdot 2.5$$

$$\Gamma_L = \Gamma_0 = 0.678 \angle 23.5^\circ$$

$$Y_L = \frac{1}{Z_L} = 0.004S - j \cdot 0.004S$$

$$y_L = \frac{1}{z_L} = \frac{Y_L}{Y_0} = 0.2 - j \cdot 0.2$$

Diagrama Smith, coeficient de reflexie, susceptanta in paralel



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

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

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

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

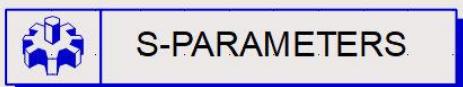
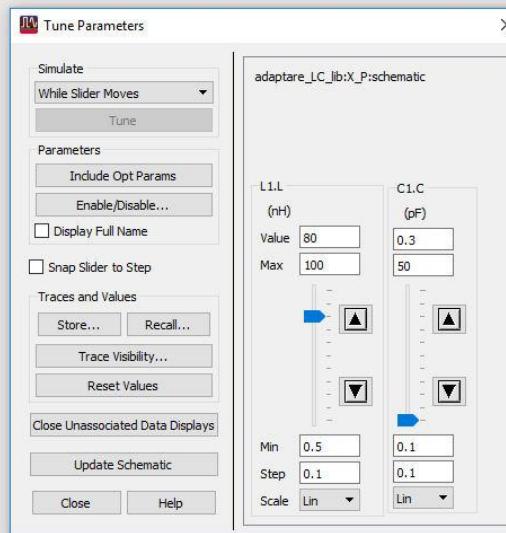
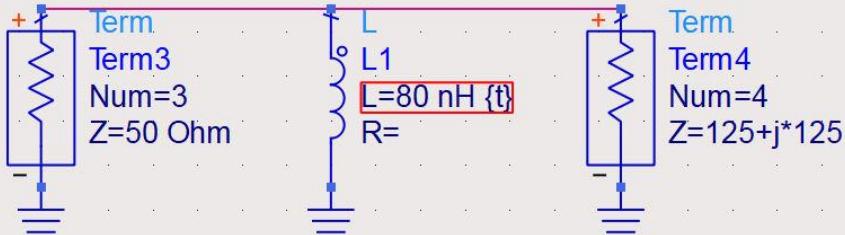
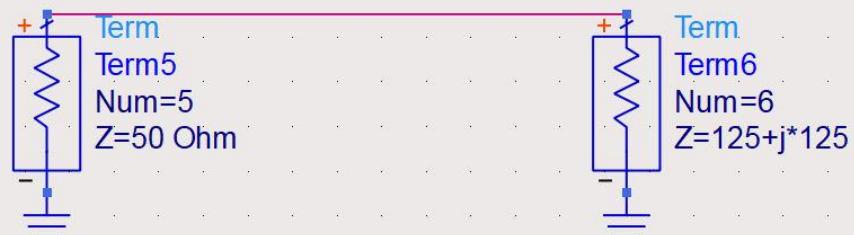
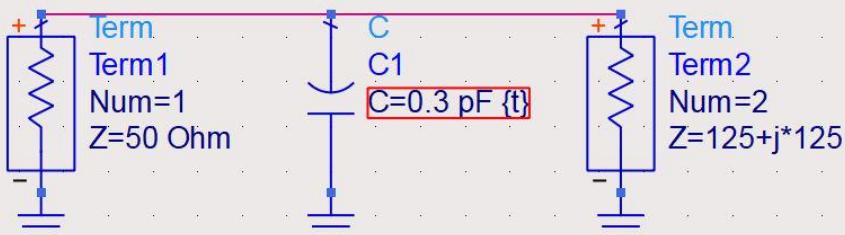
$$Y_{in} = Y_L + j \cdot B_1 = G_L + j \cdot (B_L + B_1)$$

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

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

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

ADS, Diagrama Smith, susceptanta in paralel



S_Param
SP1
Freq=1.0 GHz

ADS, Diagrama Smith, susceptanta in paralel

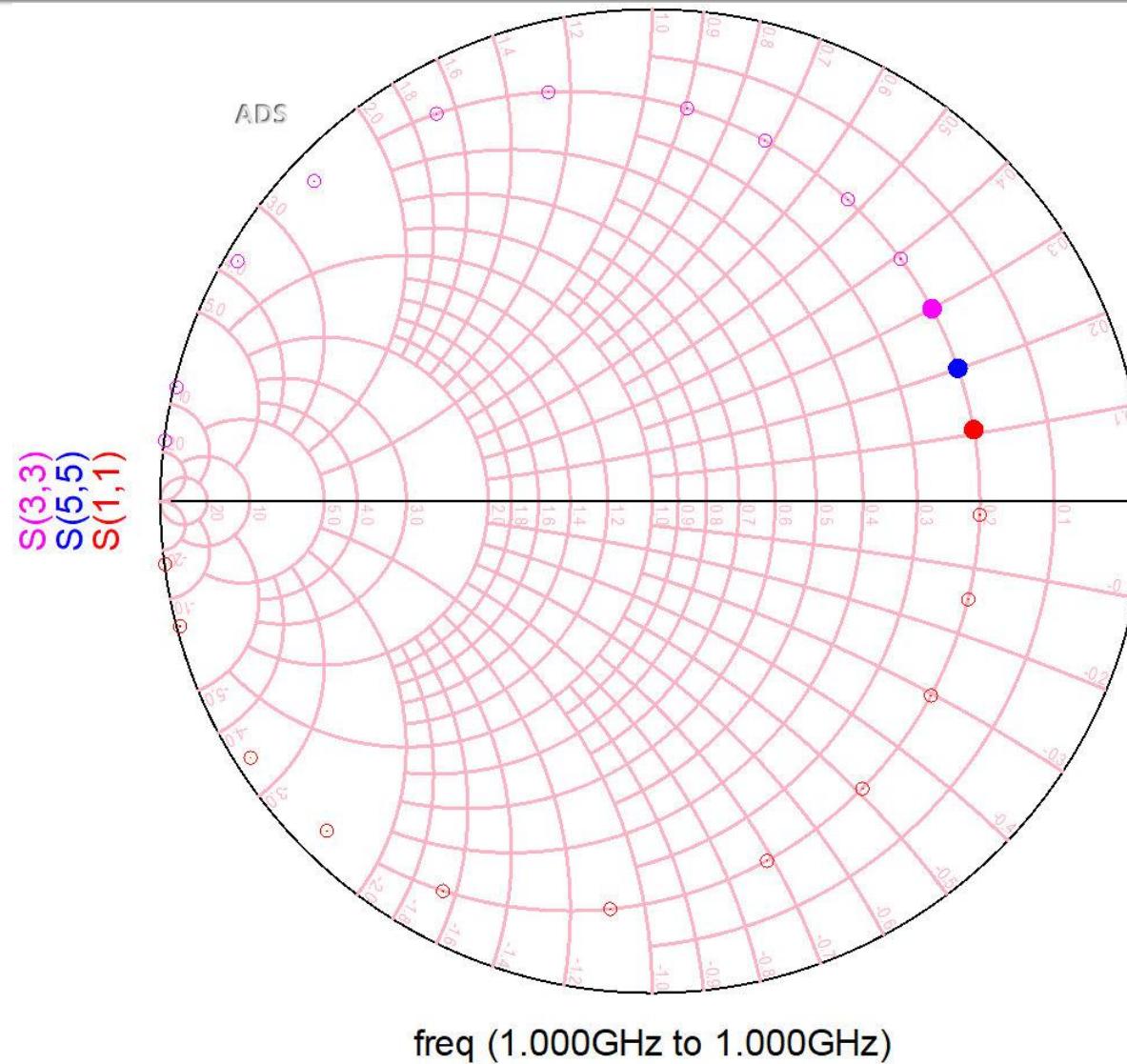
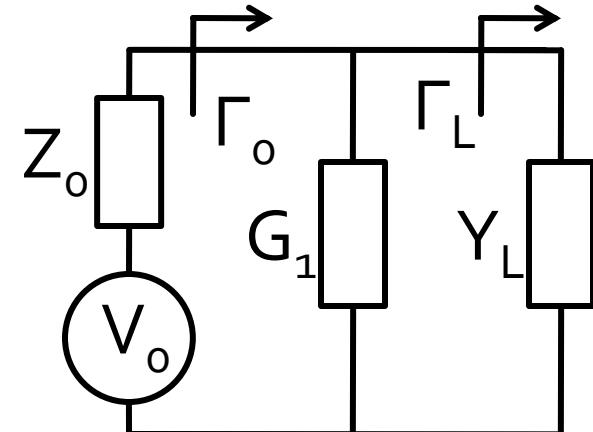
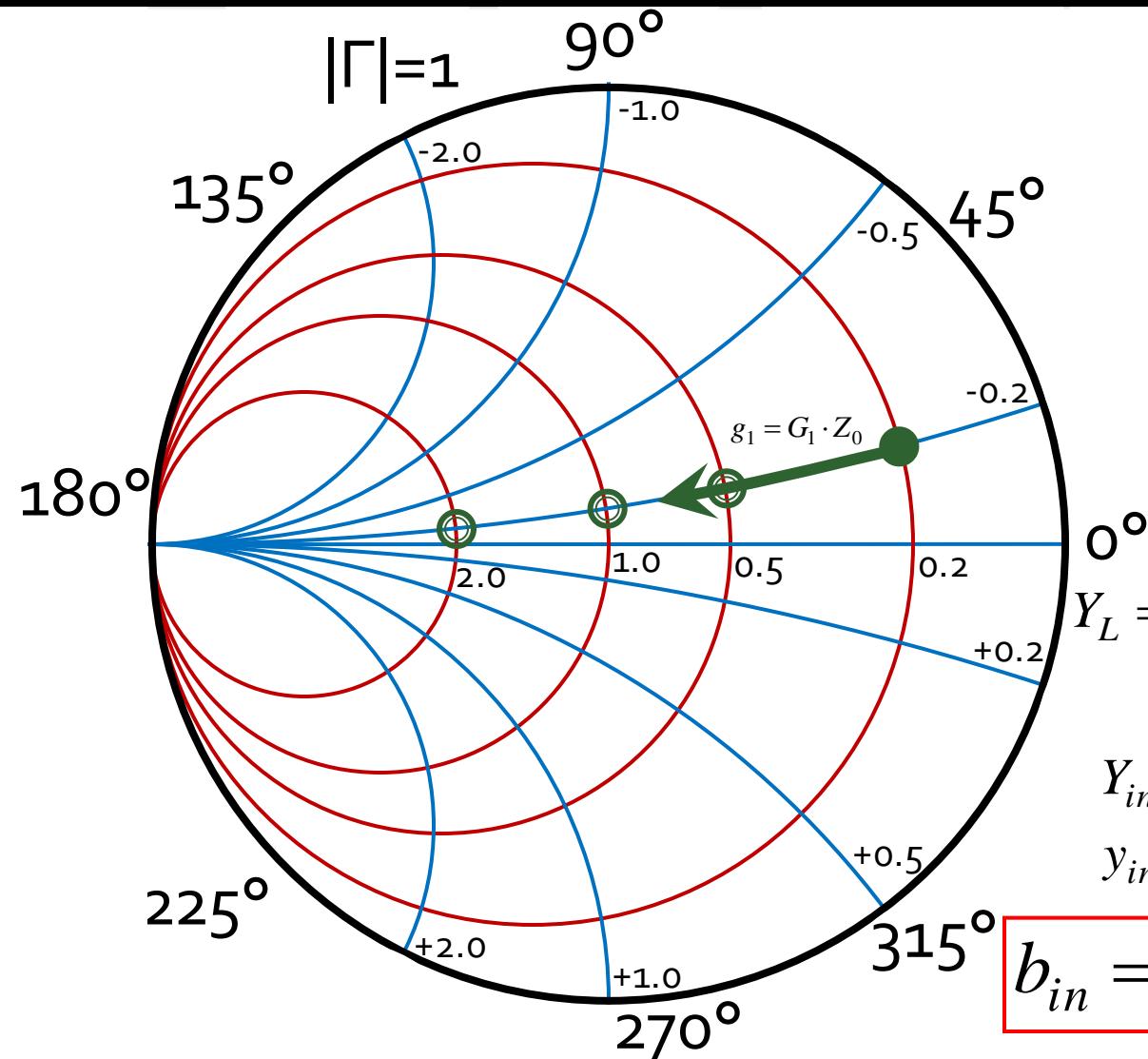


Diagrama Smith, coeficient de reflexie, conductanta in paralel



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

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

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

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

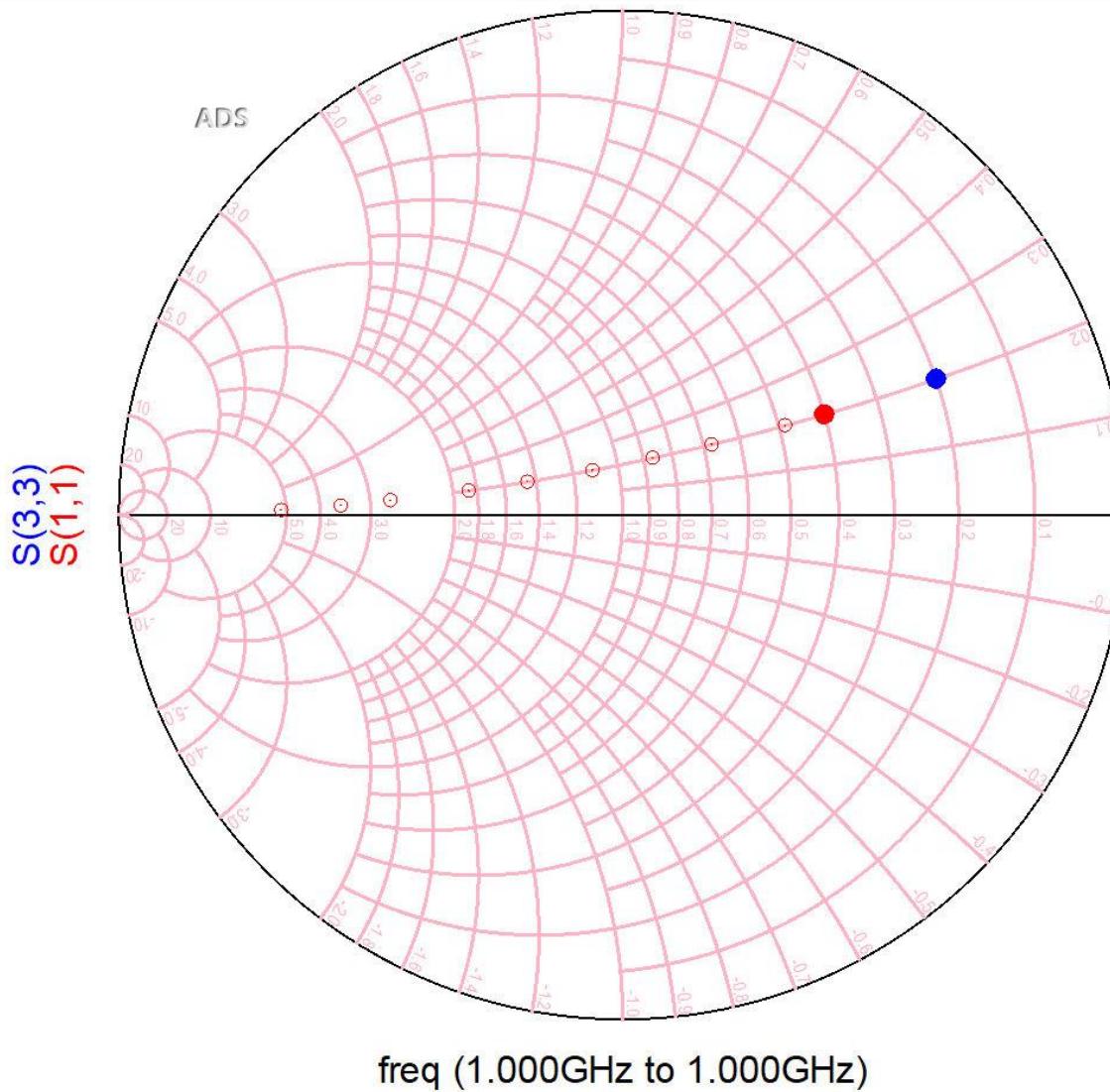
$$Y_{in} = Y_L + G_1 = (G_L + G_1) + j \cdot B_L$$

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

$$b_{in} = b_L$$

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

ADS, Diagrama Smith, conductanta in paralel



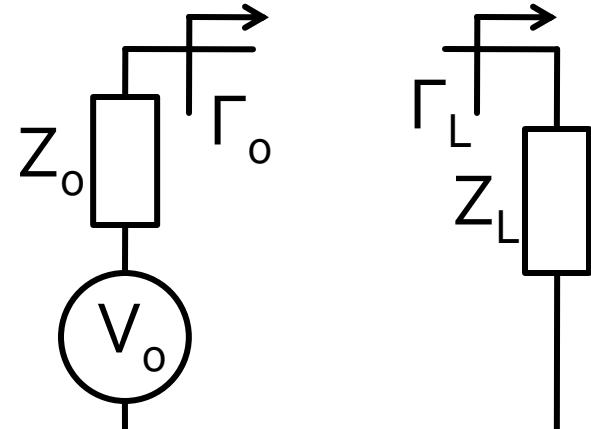
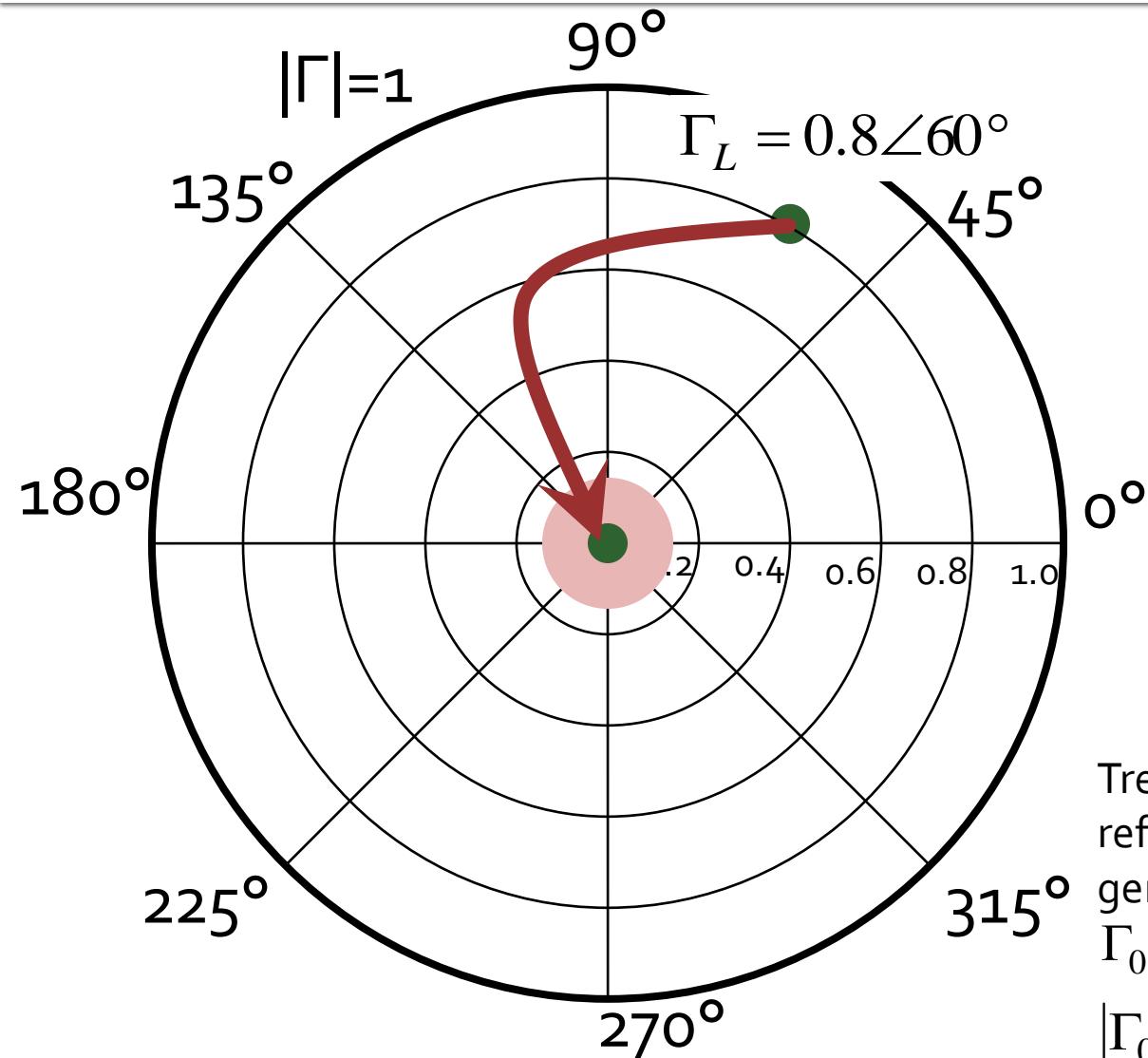
Adaptarea de impedanță

Adaptarea cu elemente concentrate (Retele in L)

Cuprins

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

Diagrama Smith, adaptare



Adaptare Z_L la Z_0 . Se raporteaza Z_L la Z_0

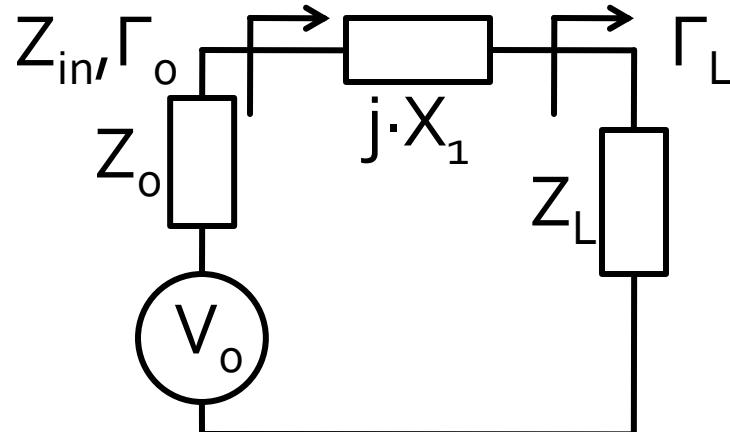
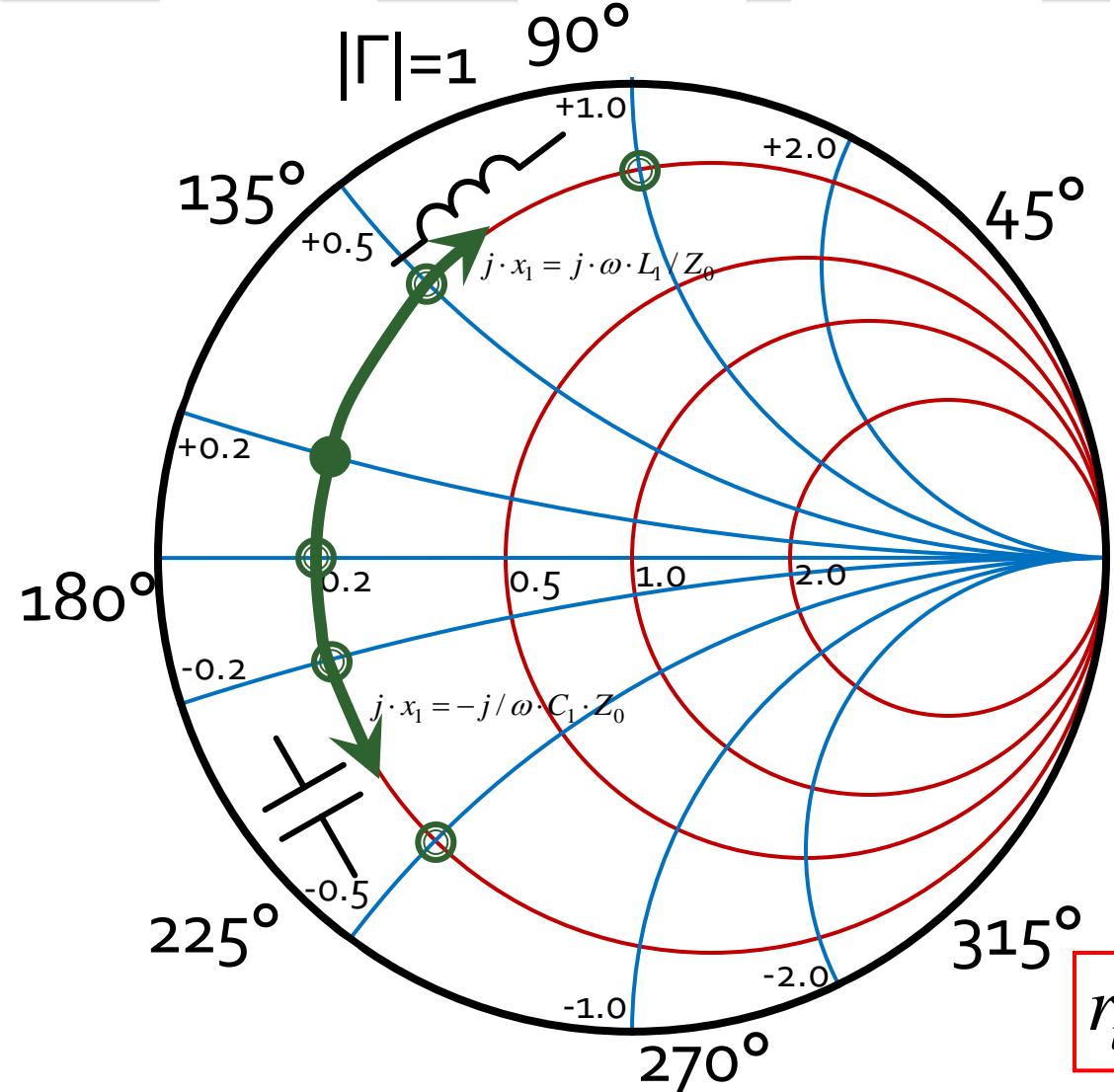
$$Z_L = 21.429 \Omega + j \cdot 82.479 \Omega$$
$$z_L = 0.429 + j \cdot 1.65$$
$$\Gamma_L = 0.8 \angle 60^\circ$$

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"

Diagrama Smith, coeficient de reflexie, reactanta in serie



$$Z_0 = 50\Omega$$

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

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

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

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

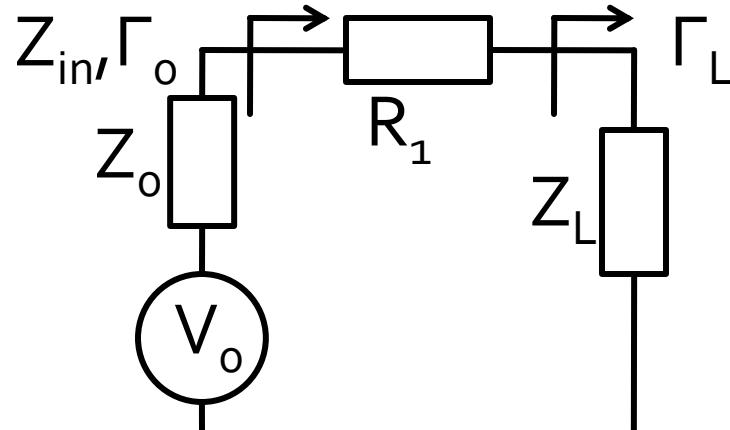
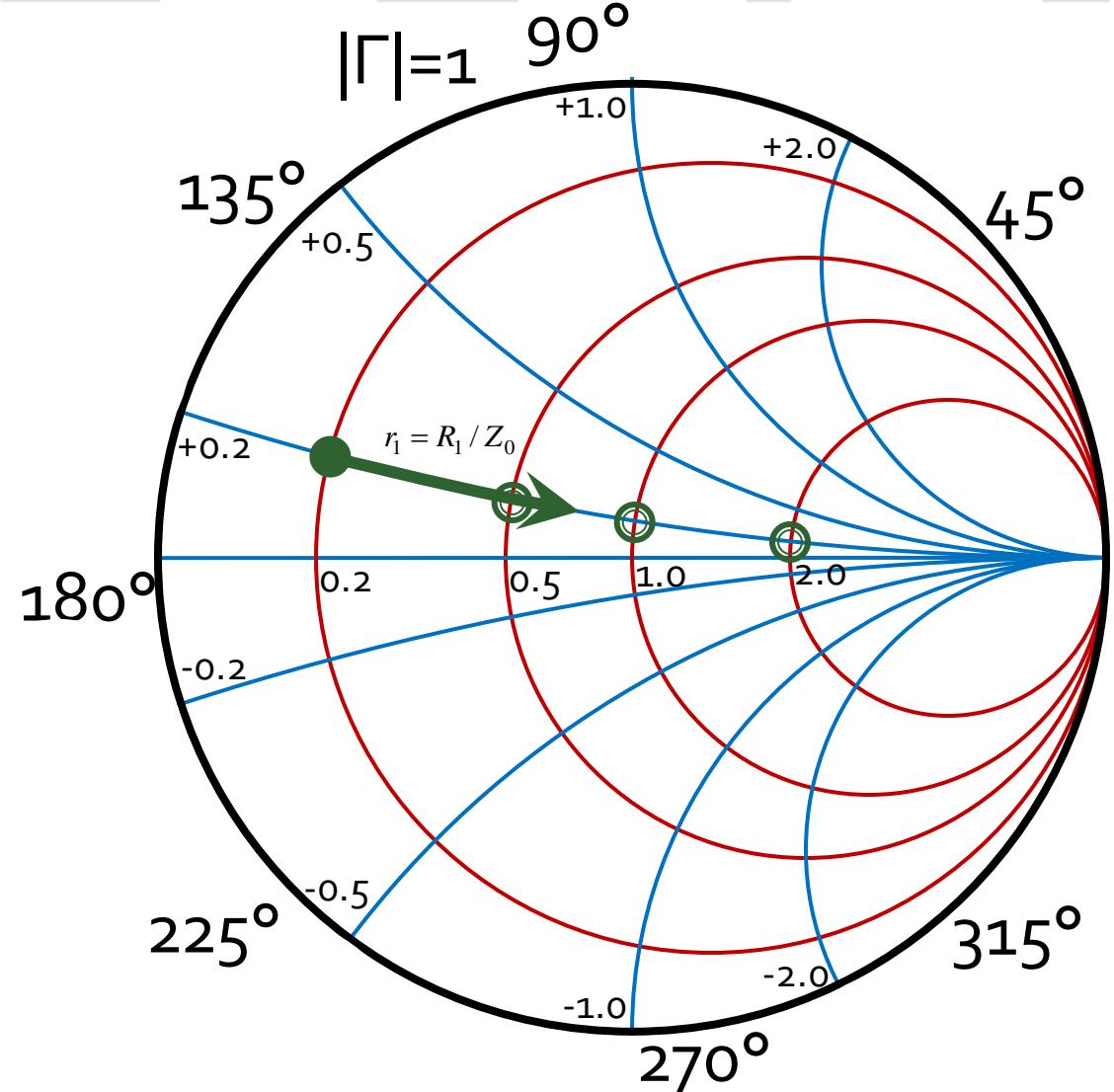
$$z_{in} = r_L + j \cdot (x_L + x_1)$$

$$r_{in} = r_L$$

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

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

Diagrama Smith, coeficient de reflexie, rezistenta in serie



$$Z_0 = 50\Omega$$

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

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

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

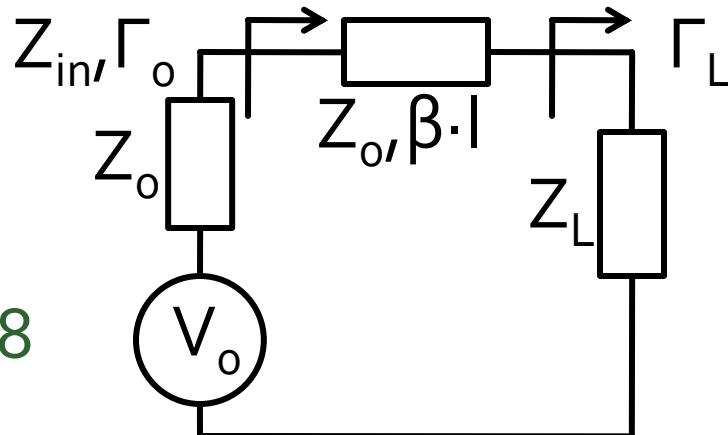
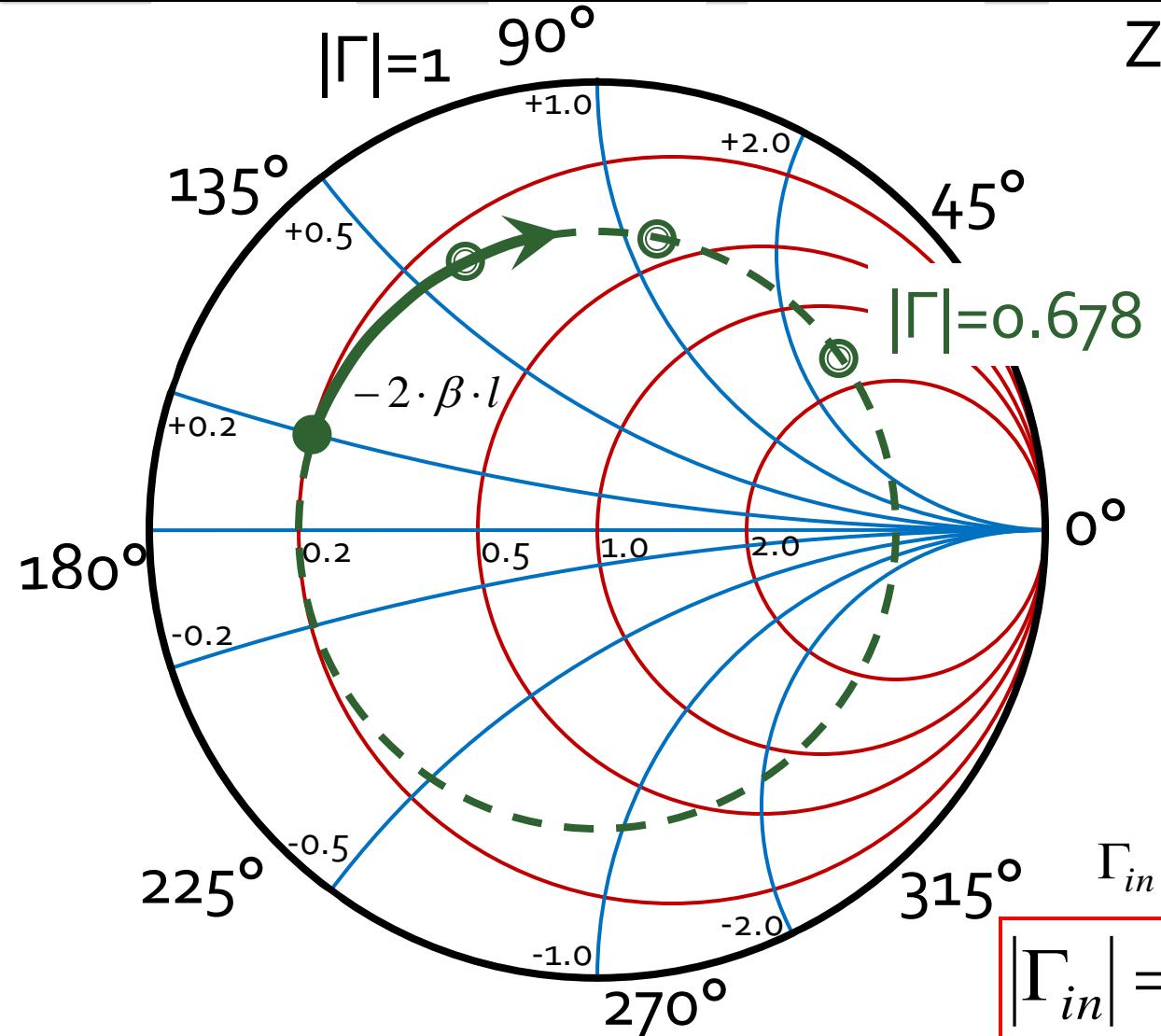
$$Z_{in} = Z_L + R_1 = (R_L + R_1) + j \cdot X_L$$

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

$x_{in} = x_L$

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

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



$$Z_0 = 50\Omega$$

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

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

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

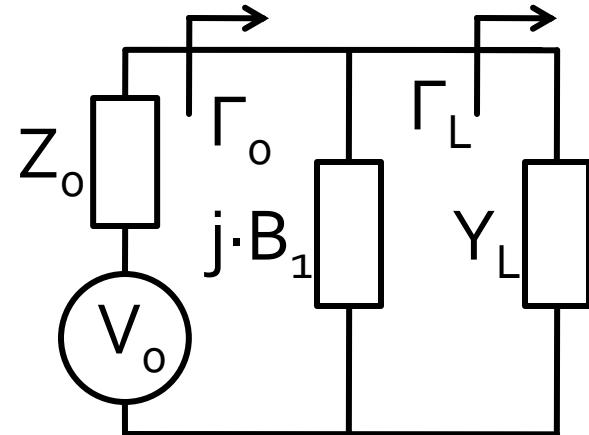
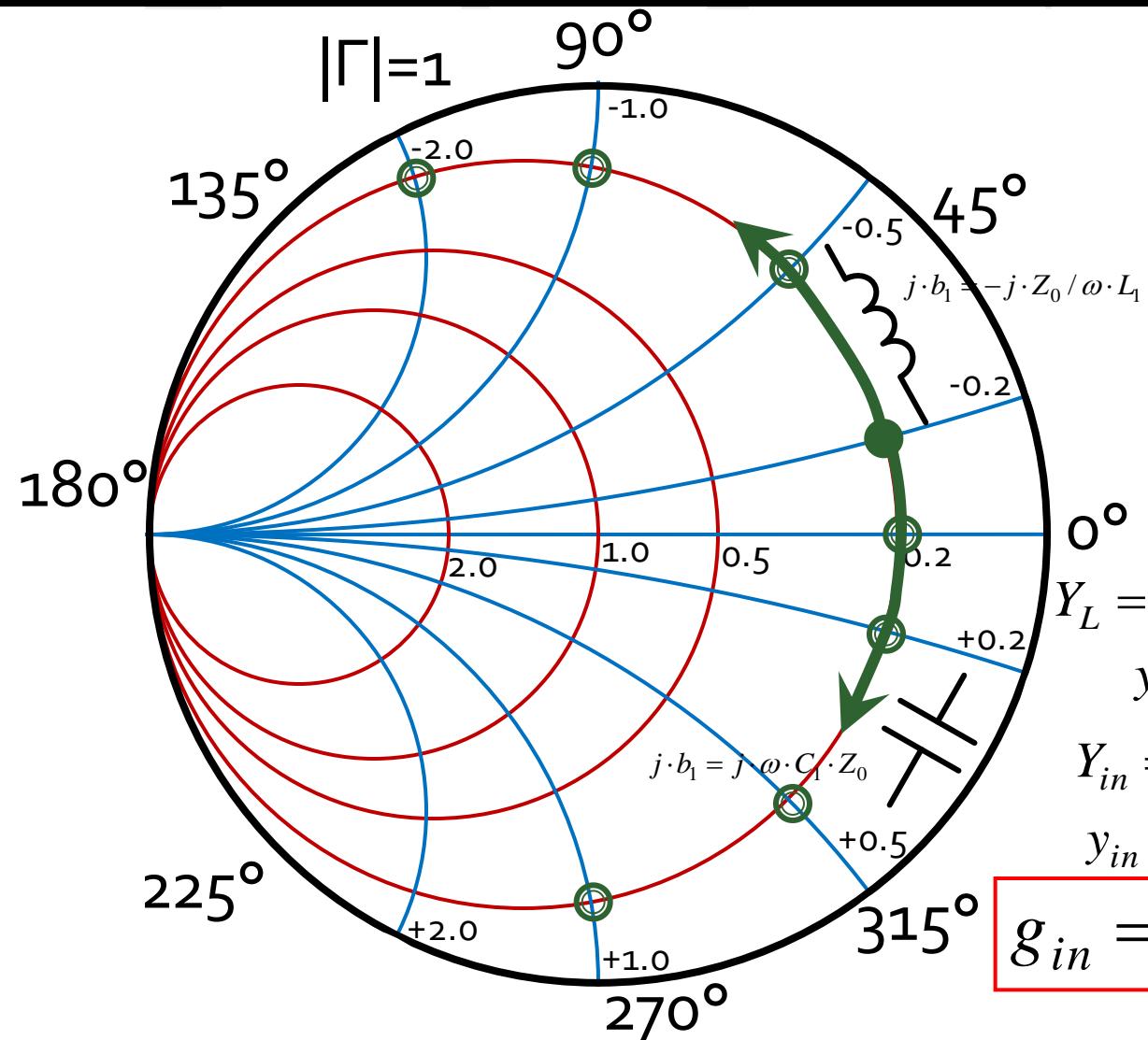
$$Z_{in} = Z_0 \cdot \frac{1 + \Gamma_L \cdot e^{-2j\beta l}}{1 - \Gamma_L \cdot e^{-2j\beta l}}$$

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

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

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

Diagrama Smith, coeficient de reflexie, susceptanta in paralel



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

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

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

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

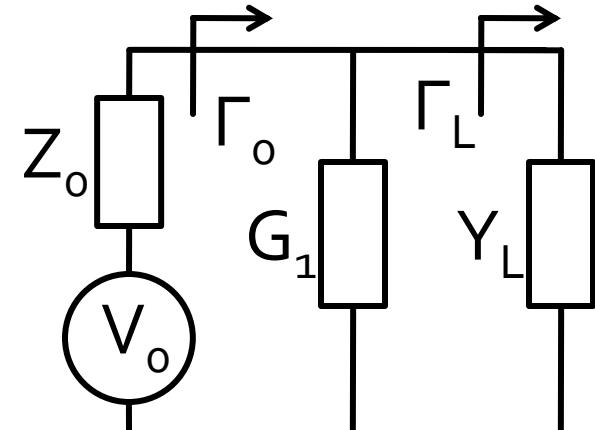
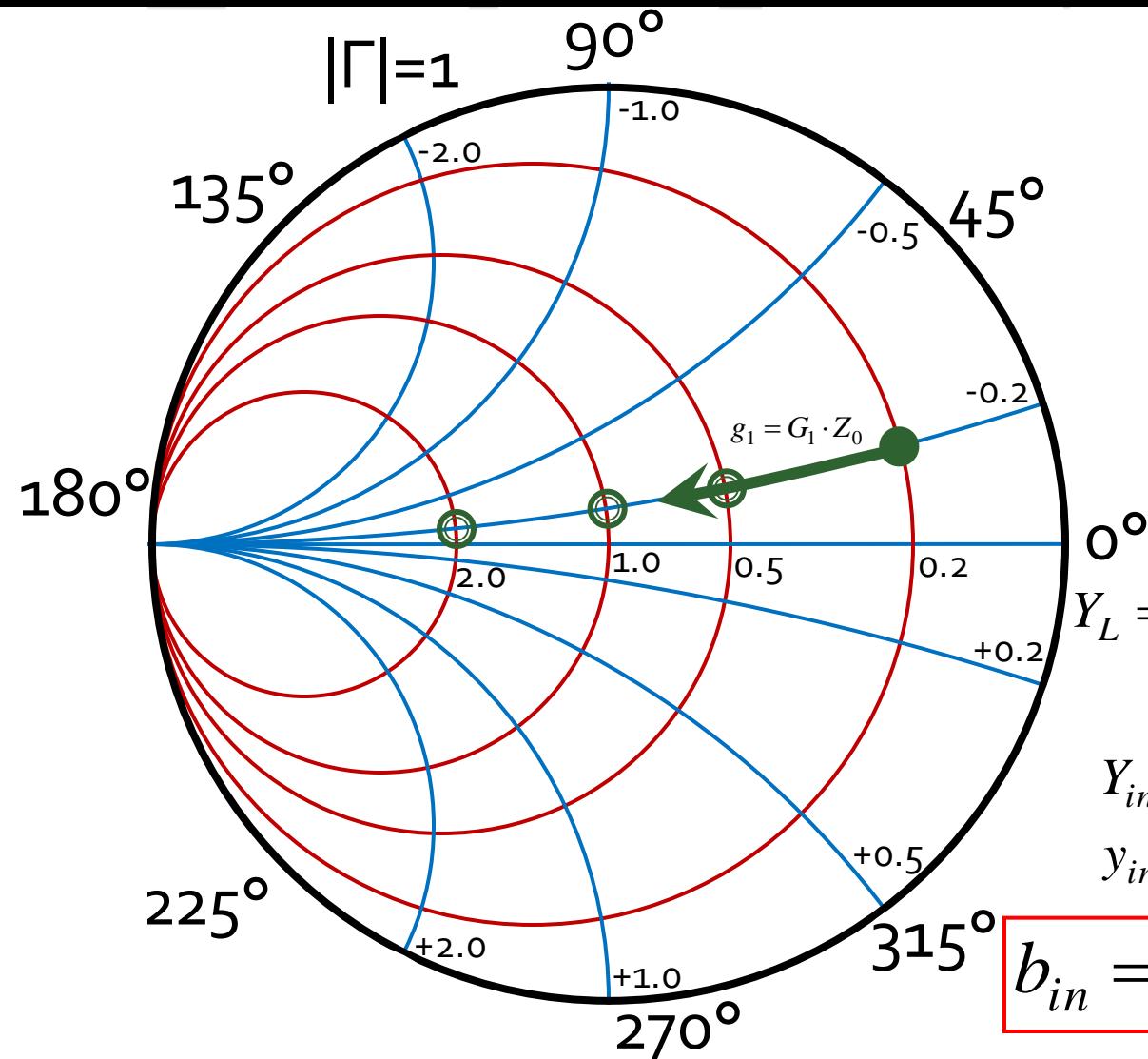
$$Y_{in} = Y_L + j \cdot B_1 = G_L + j \cdot (B_L + B_1)$$

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

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

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

Diagrama Smith, coeficient de reflexie, conductanta in paralel



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

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

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

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

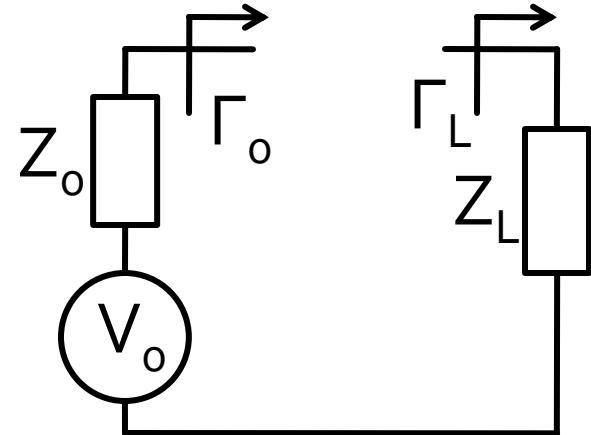
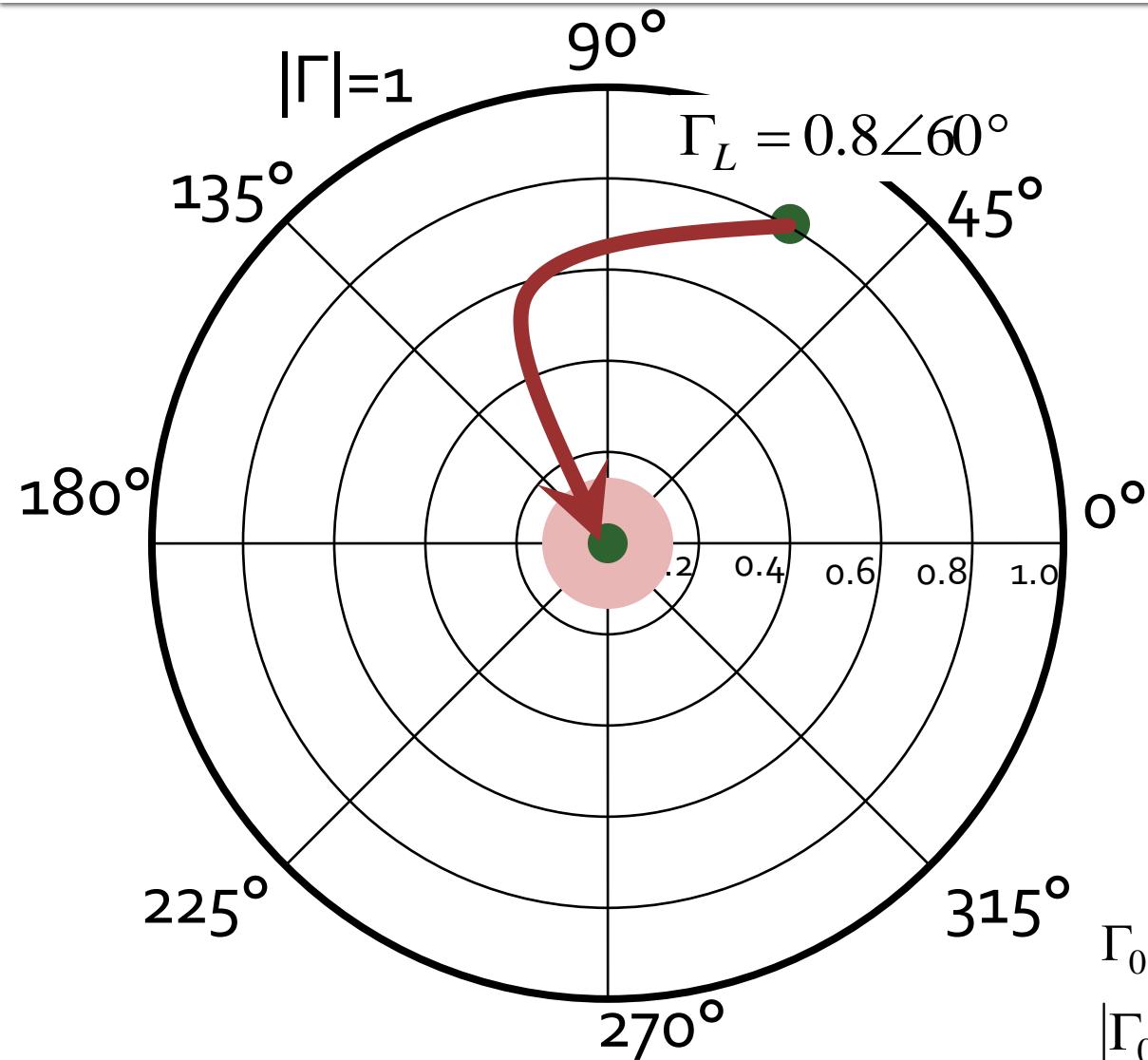
$$Y_{in} = Y_L + G_1 = (G_L + G_1) + j \cdot B_L$$

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

$$b_{in} = b_L$$

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

Adaptare de impedanță

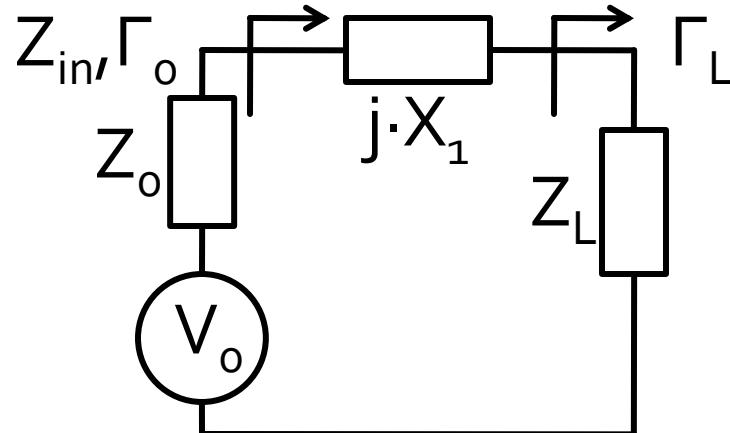
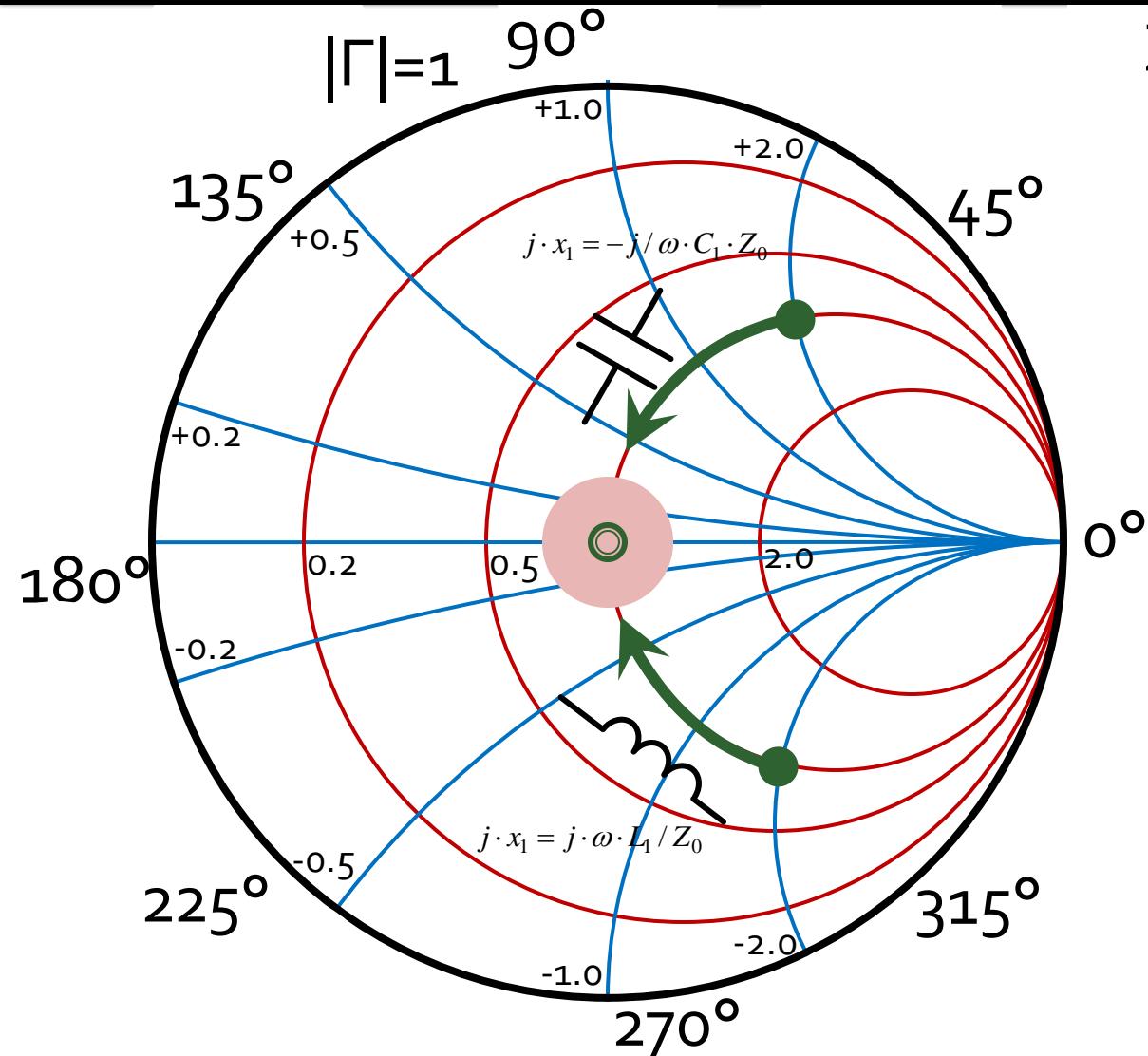


Cum?

$\Gamma_0 = 0$ adaptare perfectă ●

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

Adaptare, reactanta in serie



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

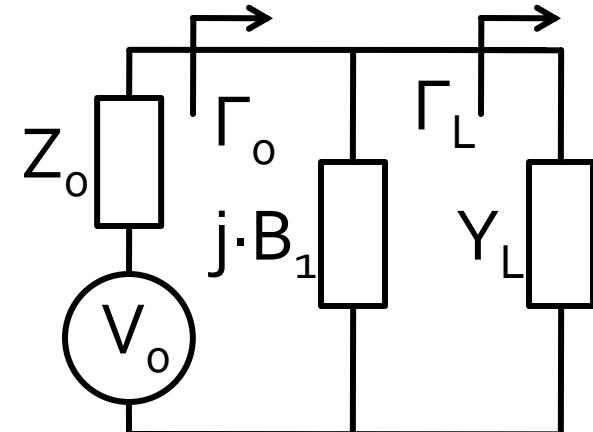
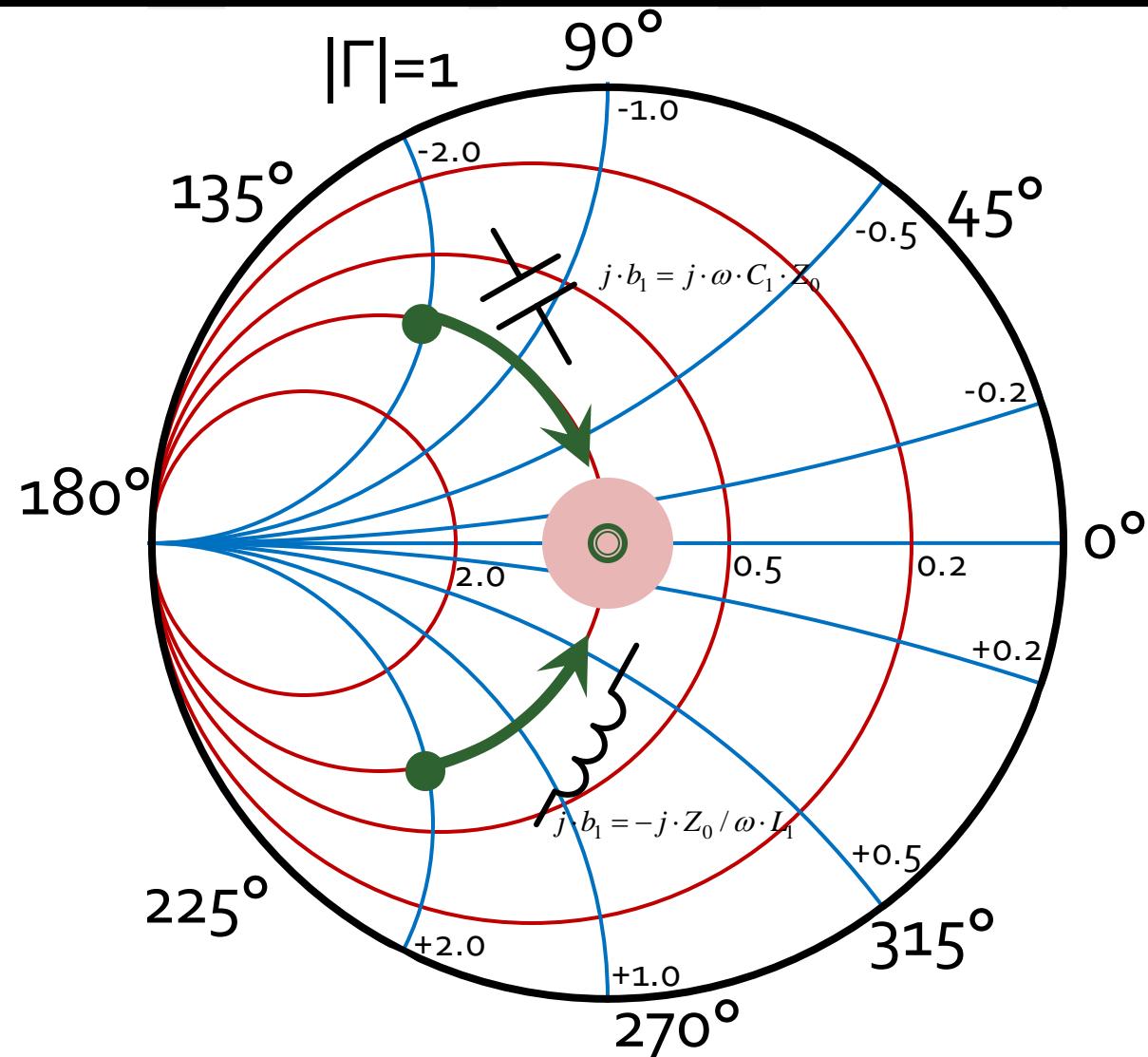
$$z_{in} = r_L + j \cdot (x_L + x_1)$$

$$r_{in} = r_L$$

- 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



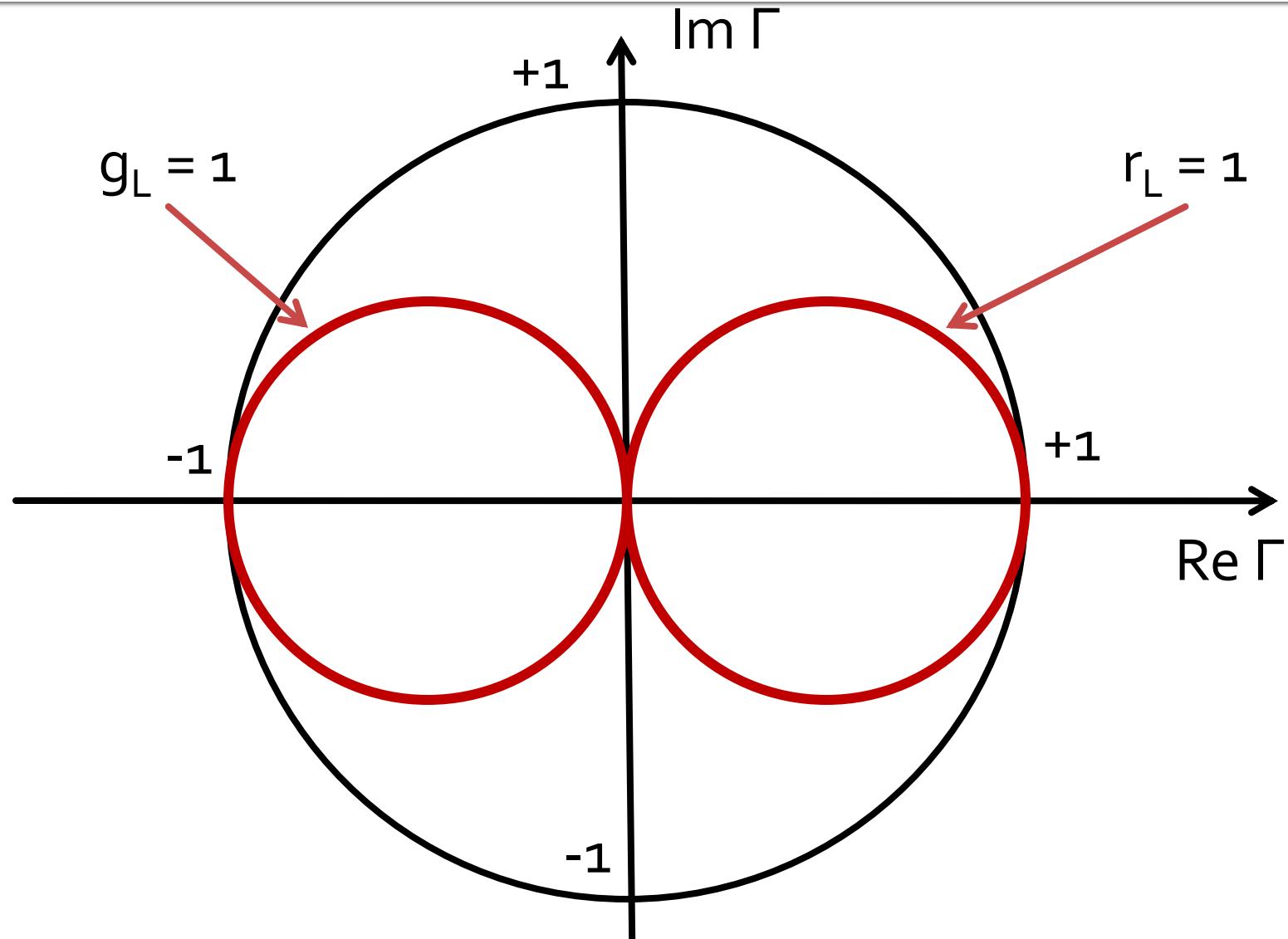
$$y_L = g_L + j \cdot b_L$$

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

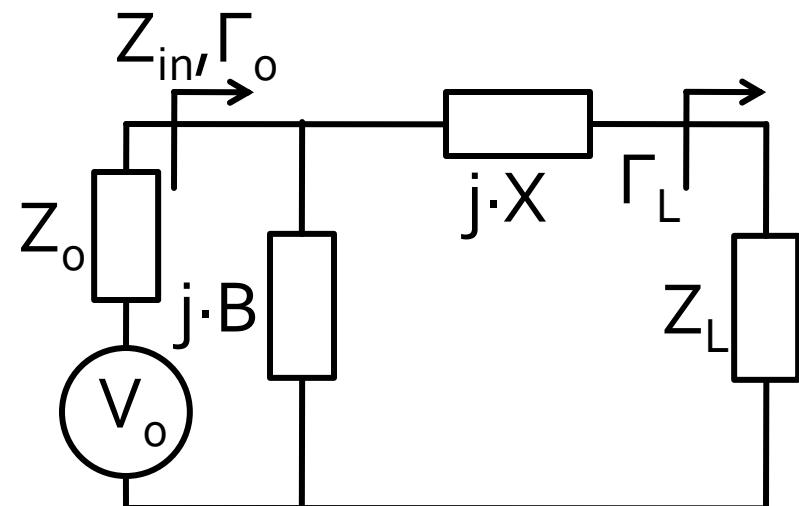
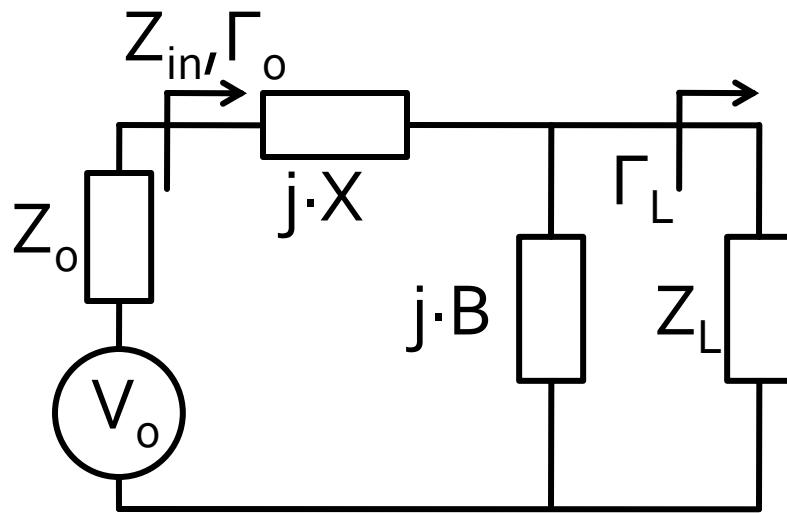
$$g_{in} = g_L$$

- 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 $g=1$

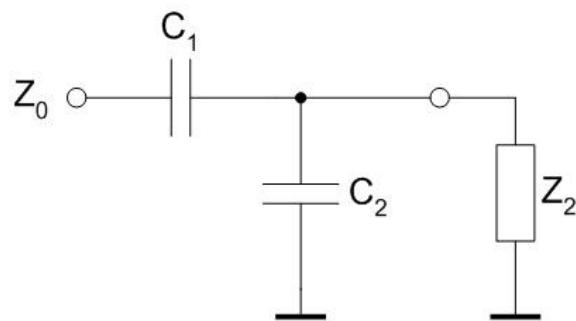
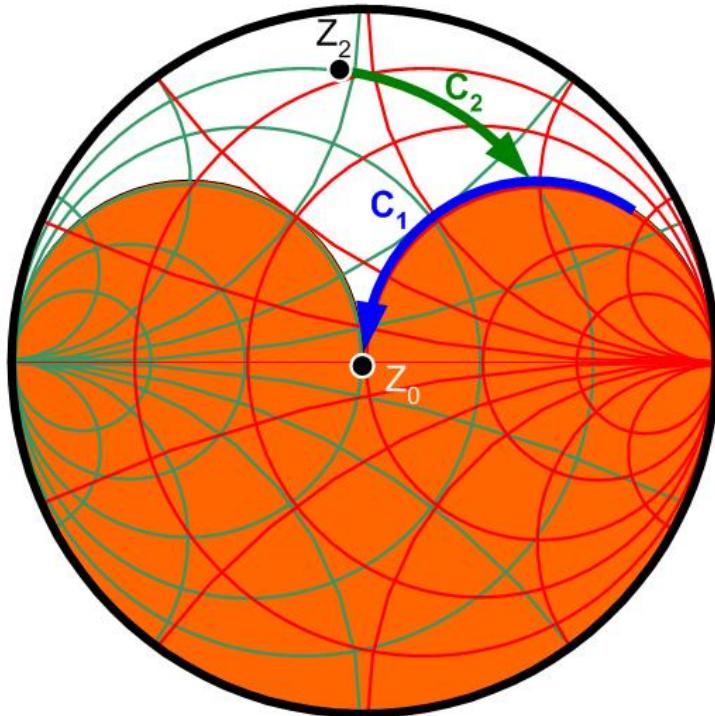


Adaptare cu două elemente reactive (retele in L)

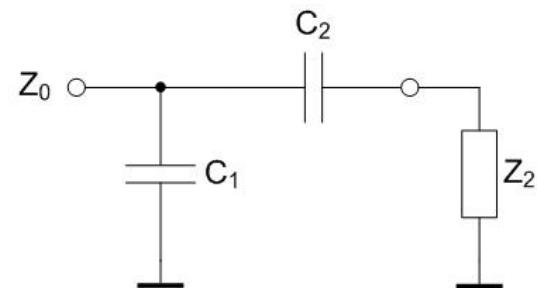
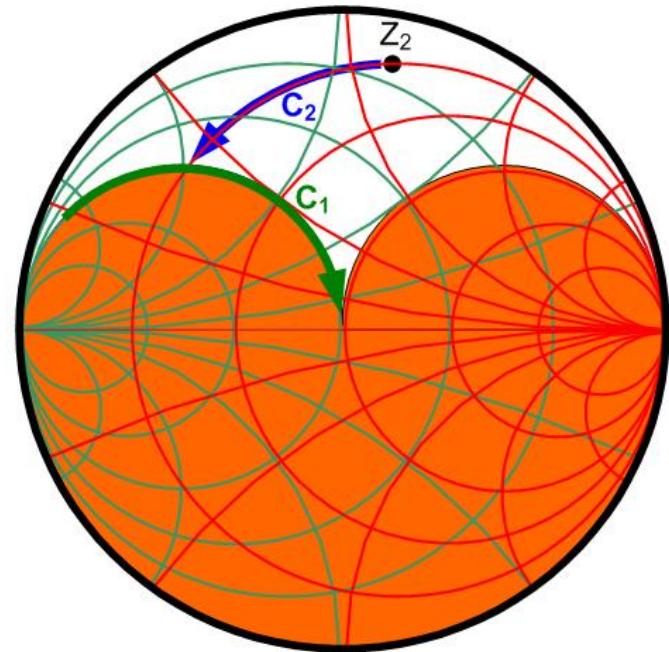


- Adaptare in **doi** pasi
 - un prim element muta coeficientul de reflexie **pe cercul** $r_L = 1/g_L = 1$
 - al doilea element realizeaza adaptarea

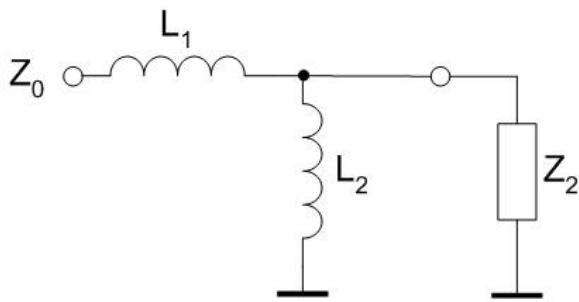
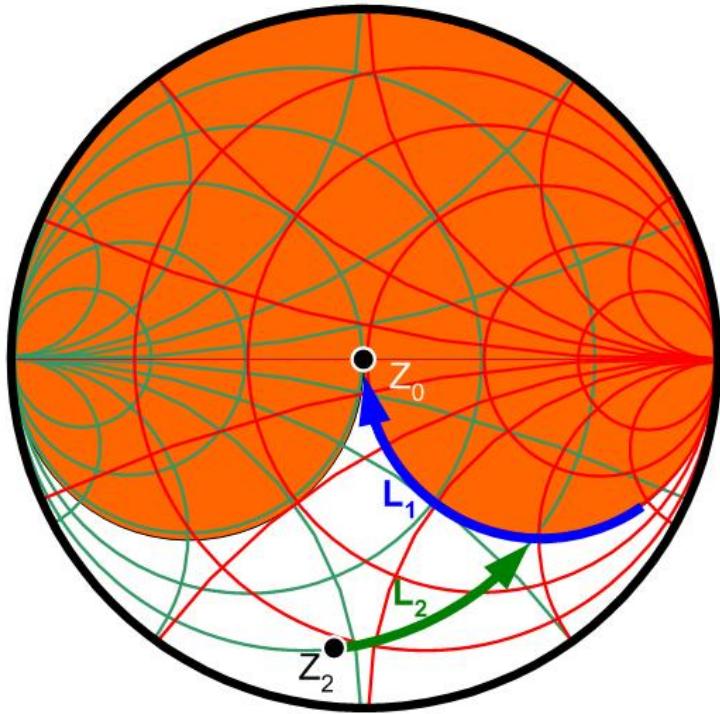
C serie, C paralel / C paralel, C serie



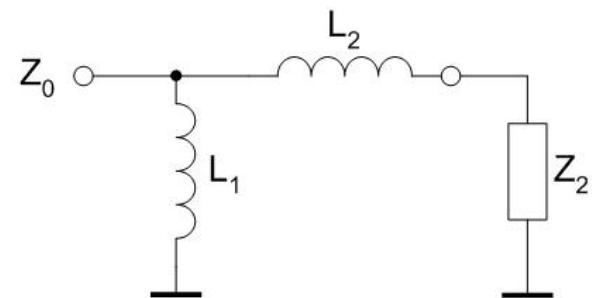
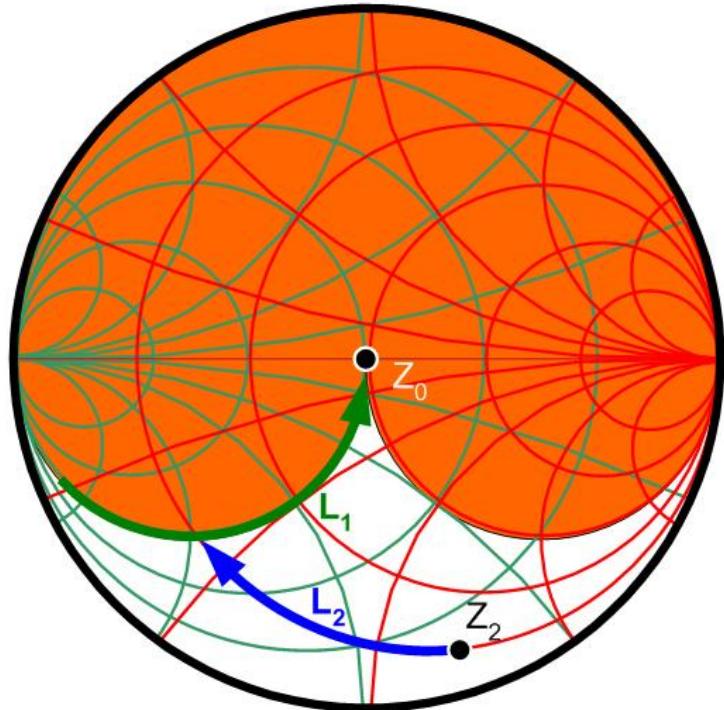
Zona interzisa cu
schema curenta



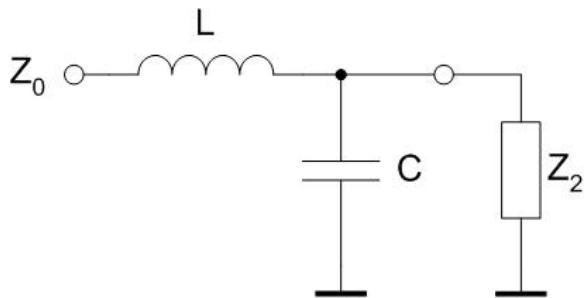
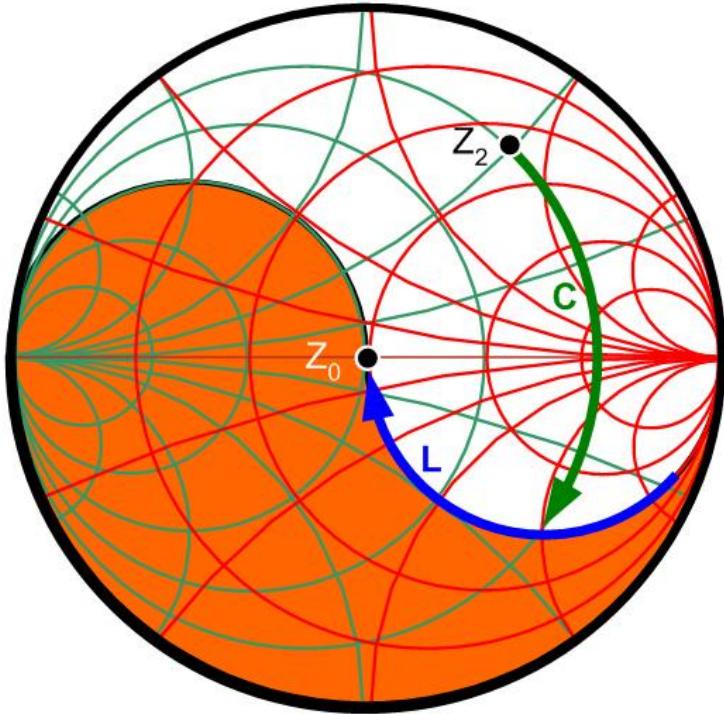
L serie, L paralel / L paralel, L serie



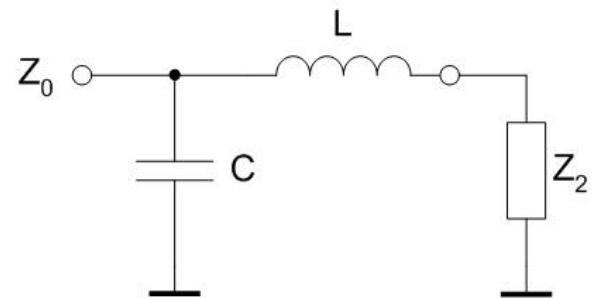
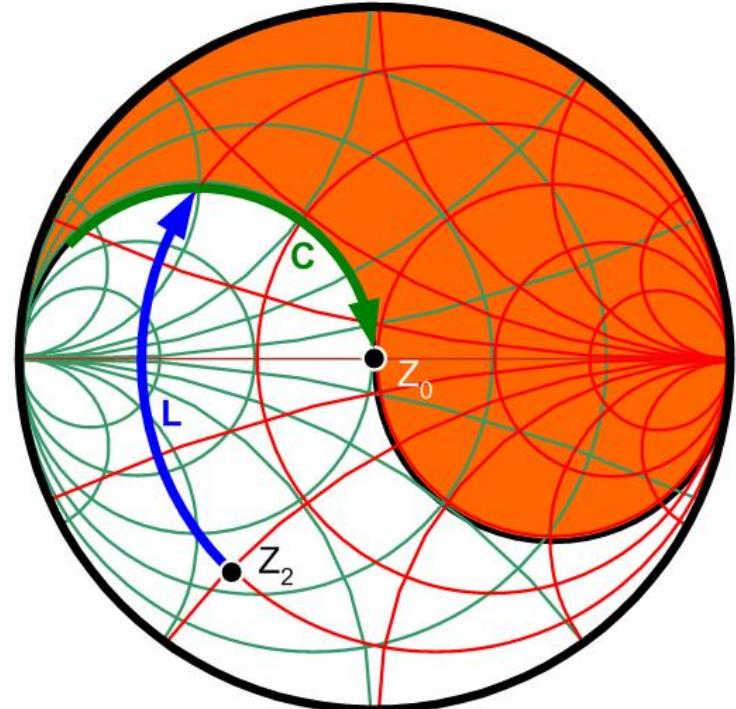
Zona interzisa cu
schema curenta



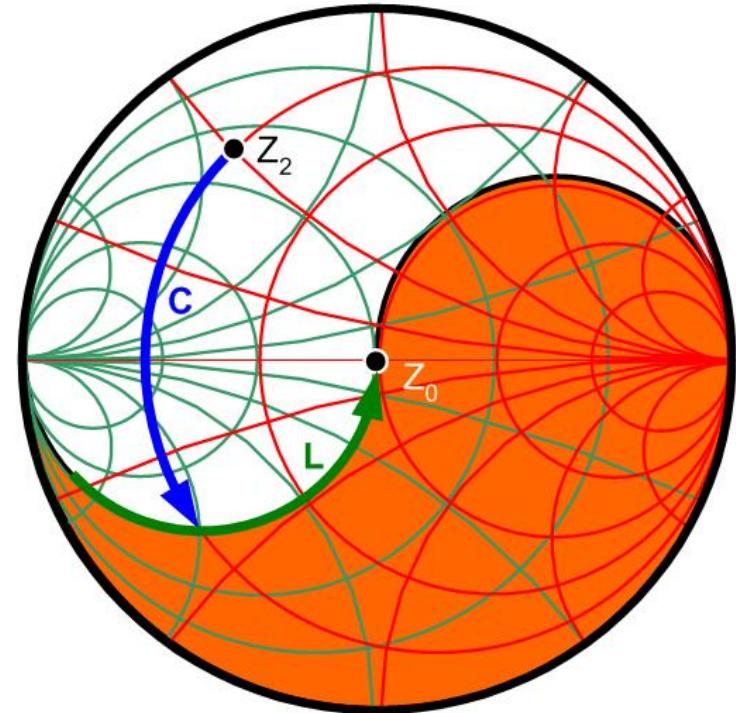
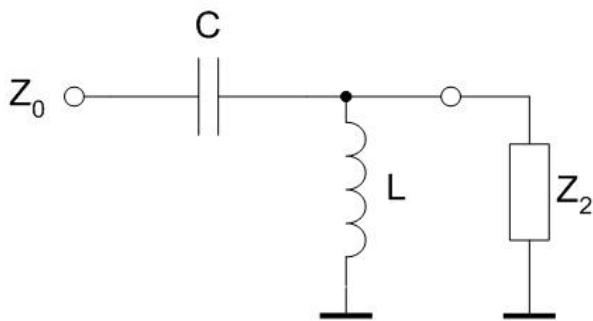
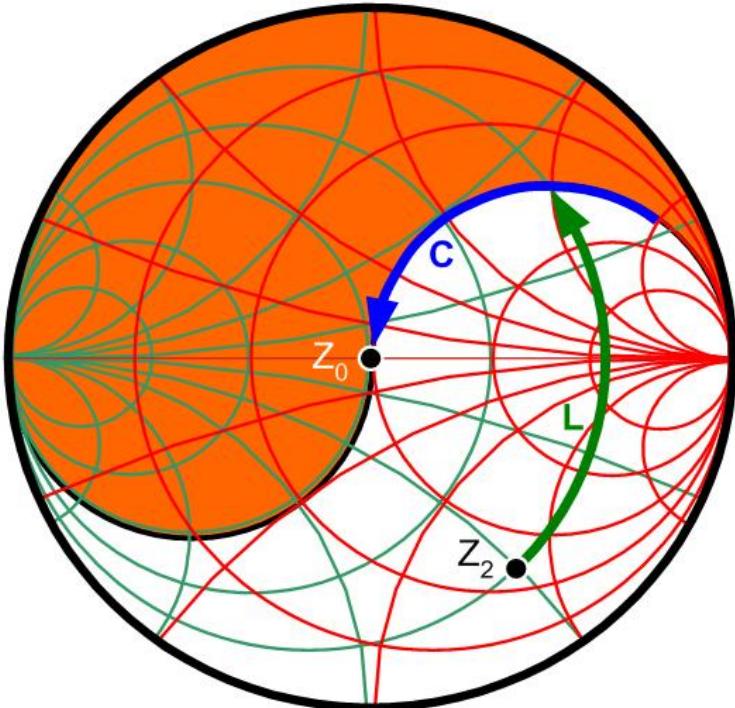
L serie, C paralel / C paralel, L serie



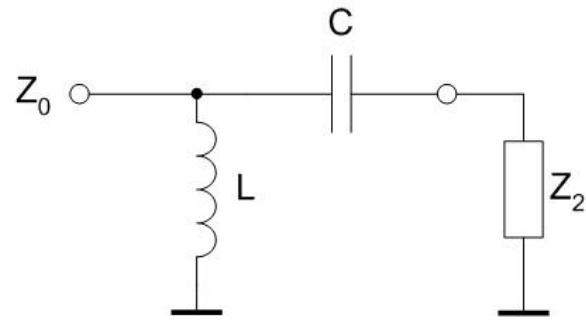
Zona interzisa cu
schema curenta



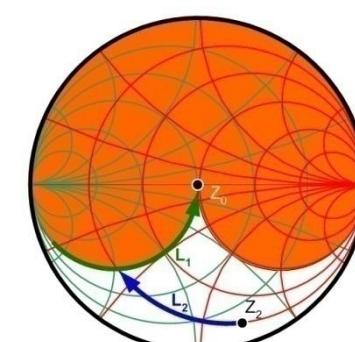
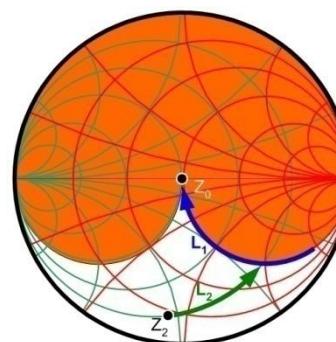
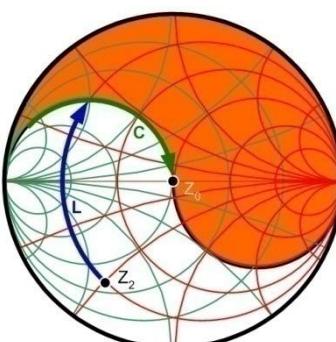
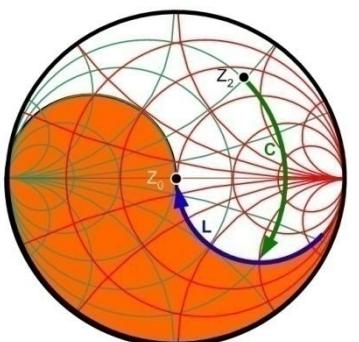
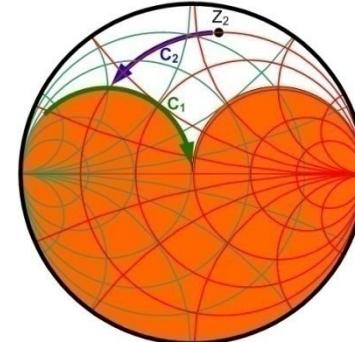
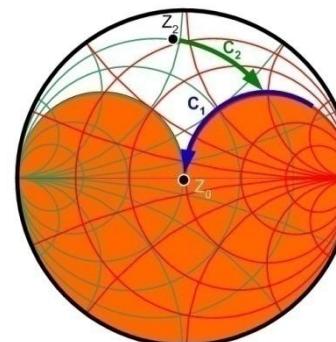
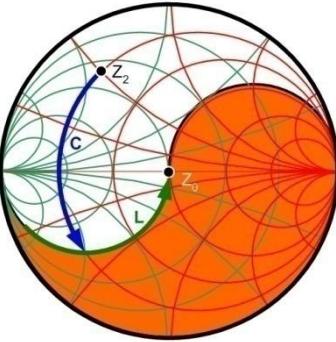
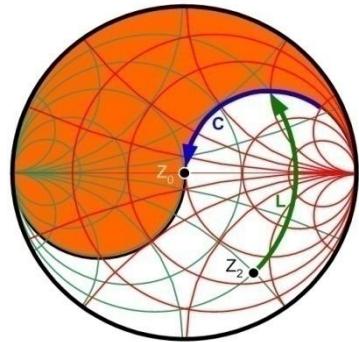
C serie, L paralel / L paralel, C serie



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)

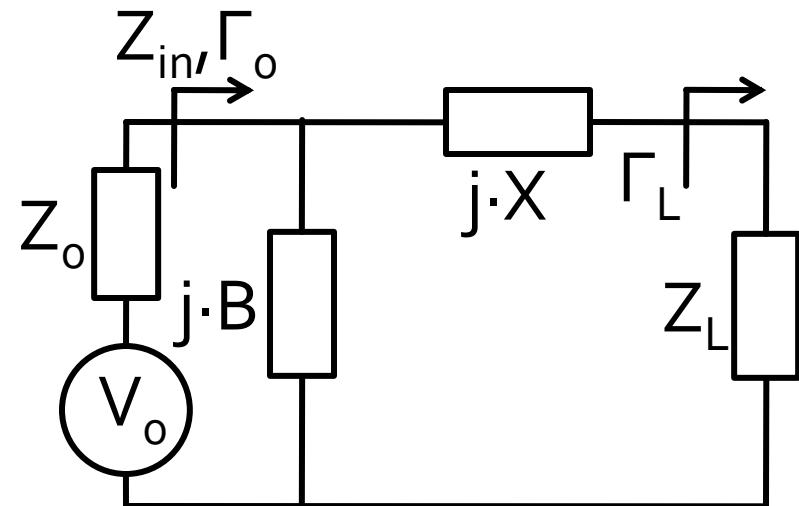
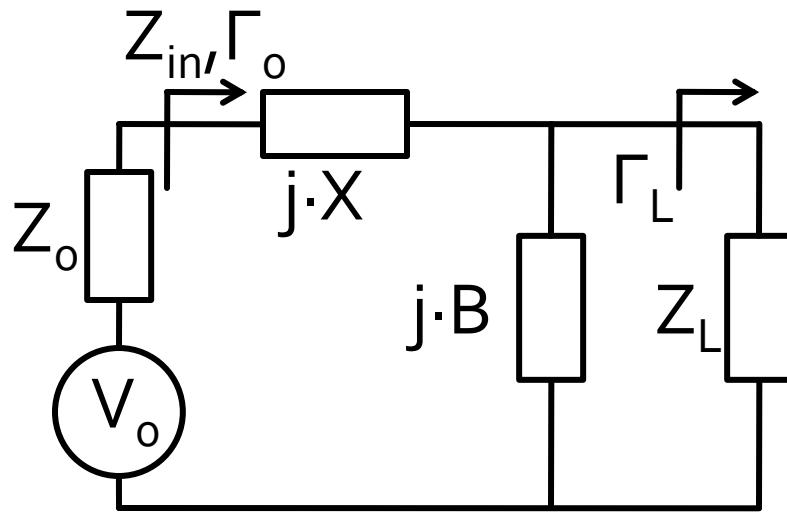
- Pentru orice Γ_L există **cel putin 2 retele in L** de adaptare posibile (L+C)
- Pentru **anumite** zone de start de pe diagrama Smith există 4 posibilități (+2 retele C+C/L+L)
- Se alege reteaua care necesită componente de valori realizabile
- Prin adăugarea elementelor rezistive se pot suplimenta 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



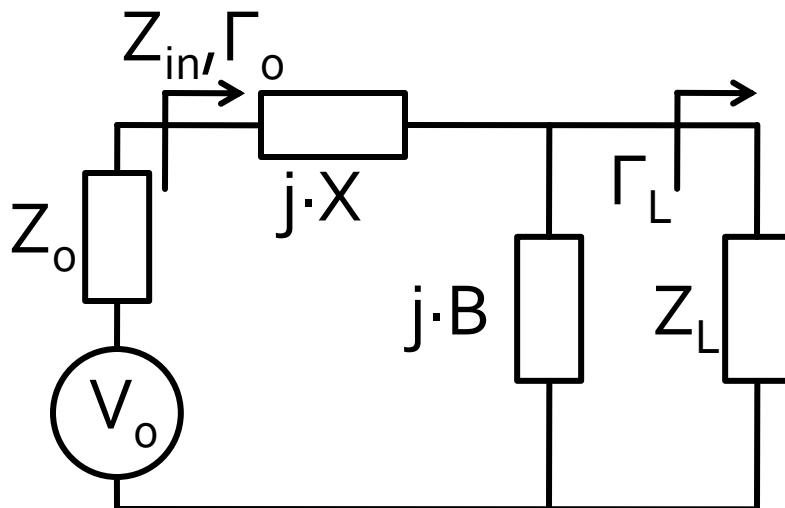
Adaptare cu doua elemente reactive (retele in L)



■ 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)



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

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

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

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

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

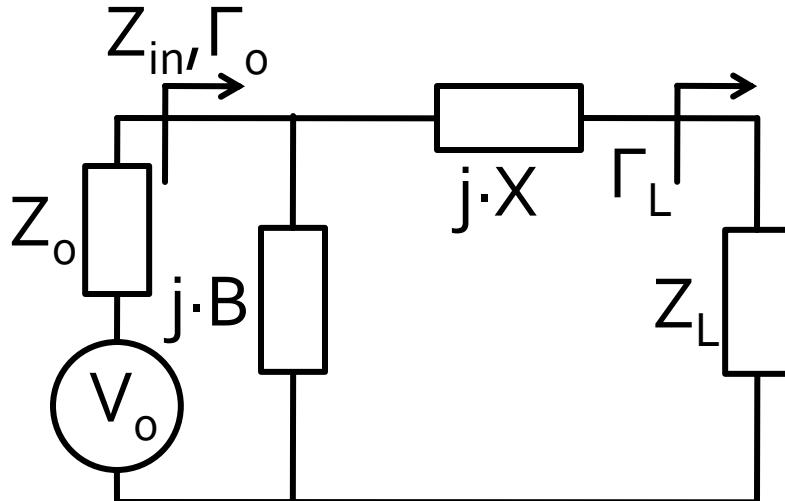
- valoarea de sub radical e intotdeauna pozitiva pentru

$$R_L > Z_0$$

- se obtin doua solutii realizabile

$$X = \begin{cases} \omega \cdot L \\ -\frac{1}{\omega \cdot C} \end{cases} \quad B = \begin{cases} \omega \cdot C \\ -\frac{1}{\omega \cdot L} \end{cases}$$

Adaptare cu doua elemente reactive (retele in L)



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

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

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

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

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

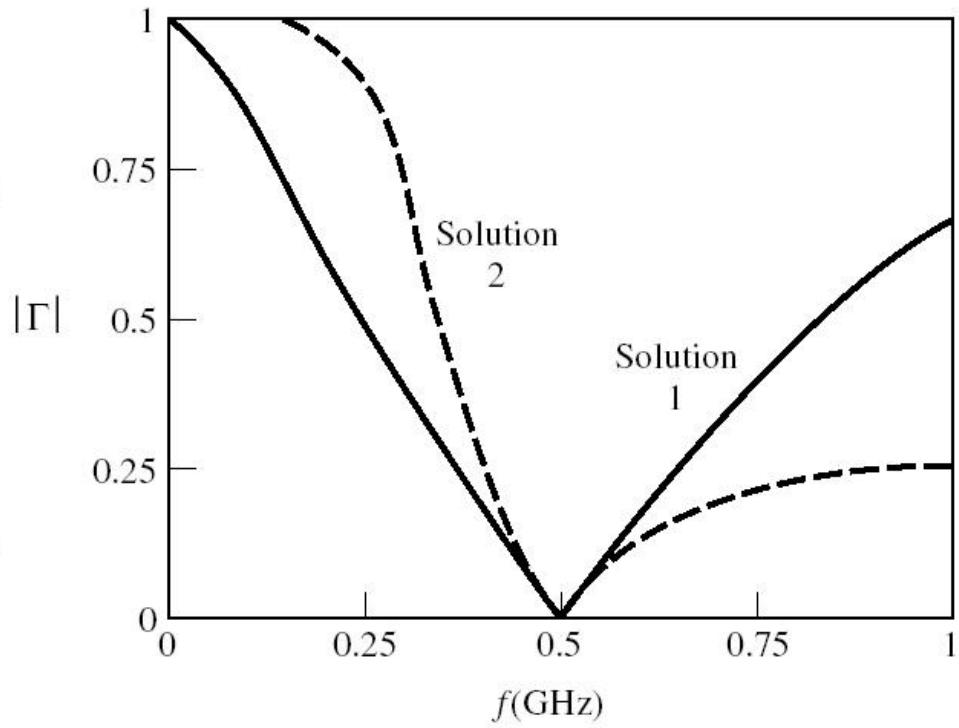
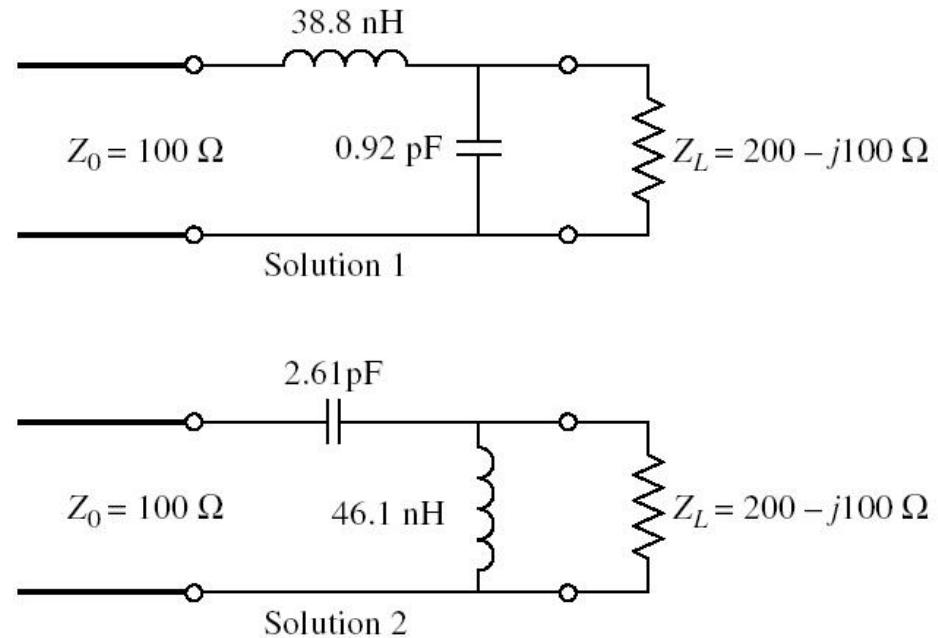
- valoarea de sub radical e intotdeauna pozitiva pentru

$$R_L < Z_0$$

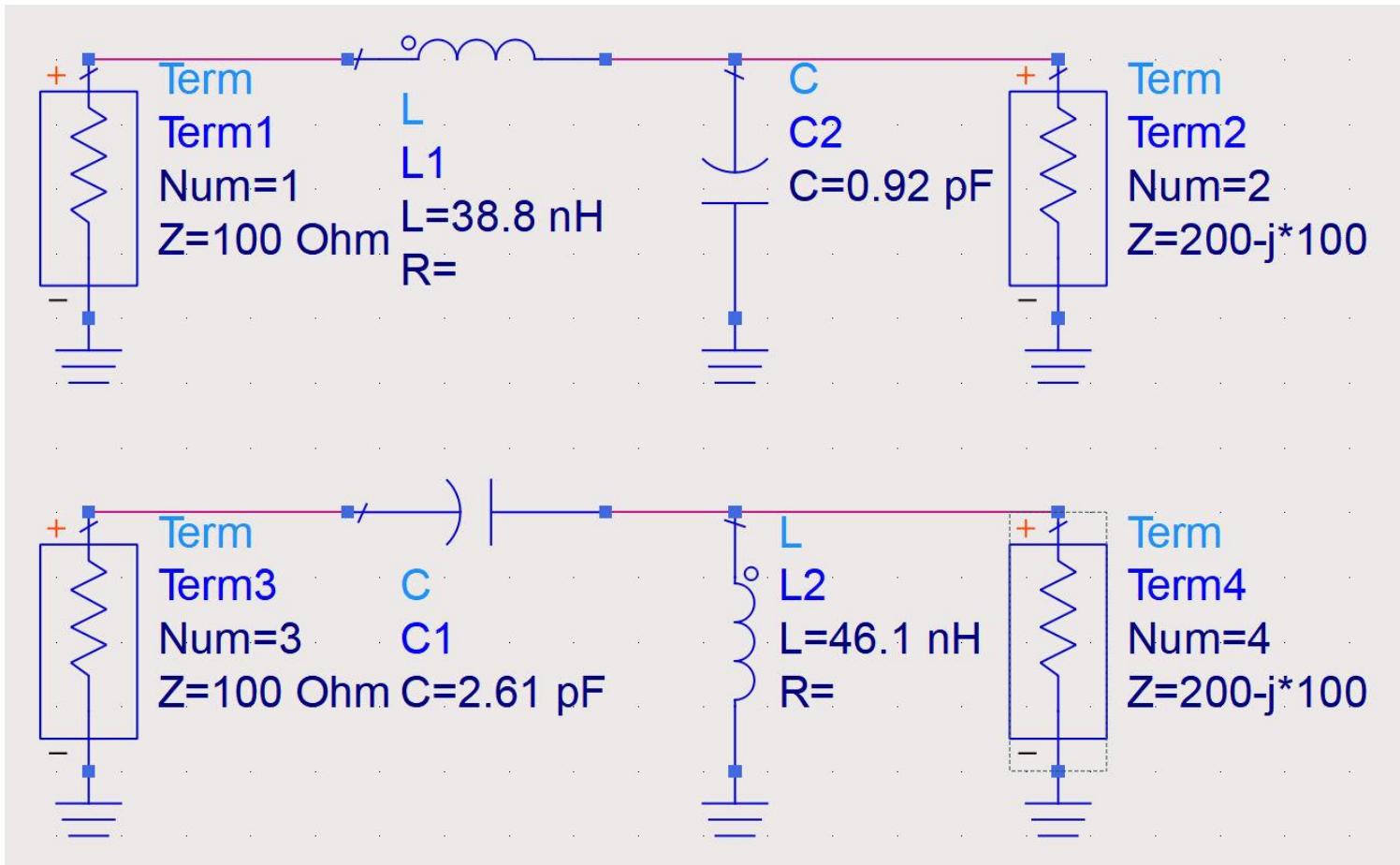
- se obtin doua solutii realizabile

$$X = \begin{cases} \omega \cdot L \\ -\frac{1}{\omega \cdot C} \end{cases} \quad B = \begin{cases} \omega \cdot C \\ -\frac{1}{\omega \cdot L} \end{cases}$$

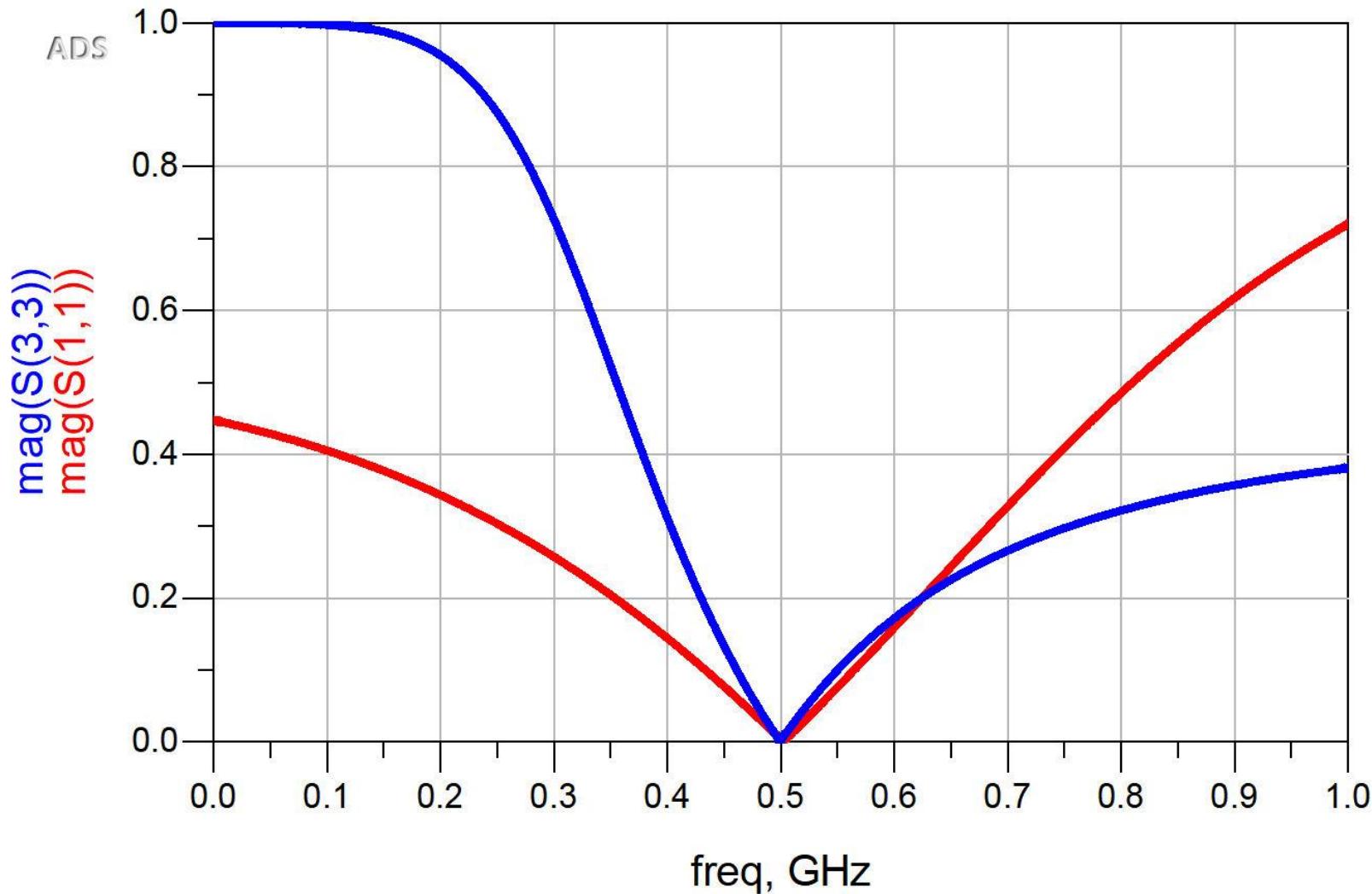
Exemplu



Exemplu



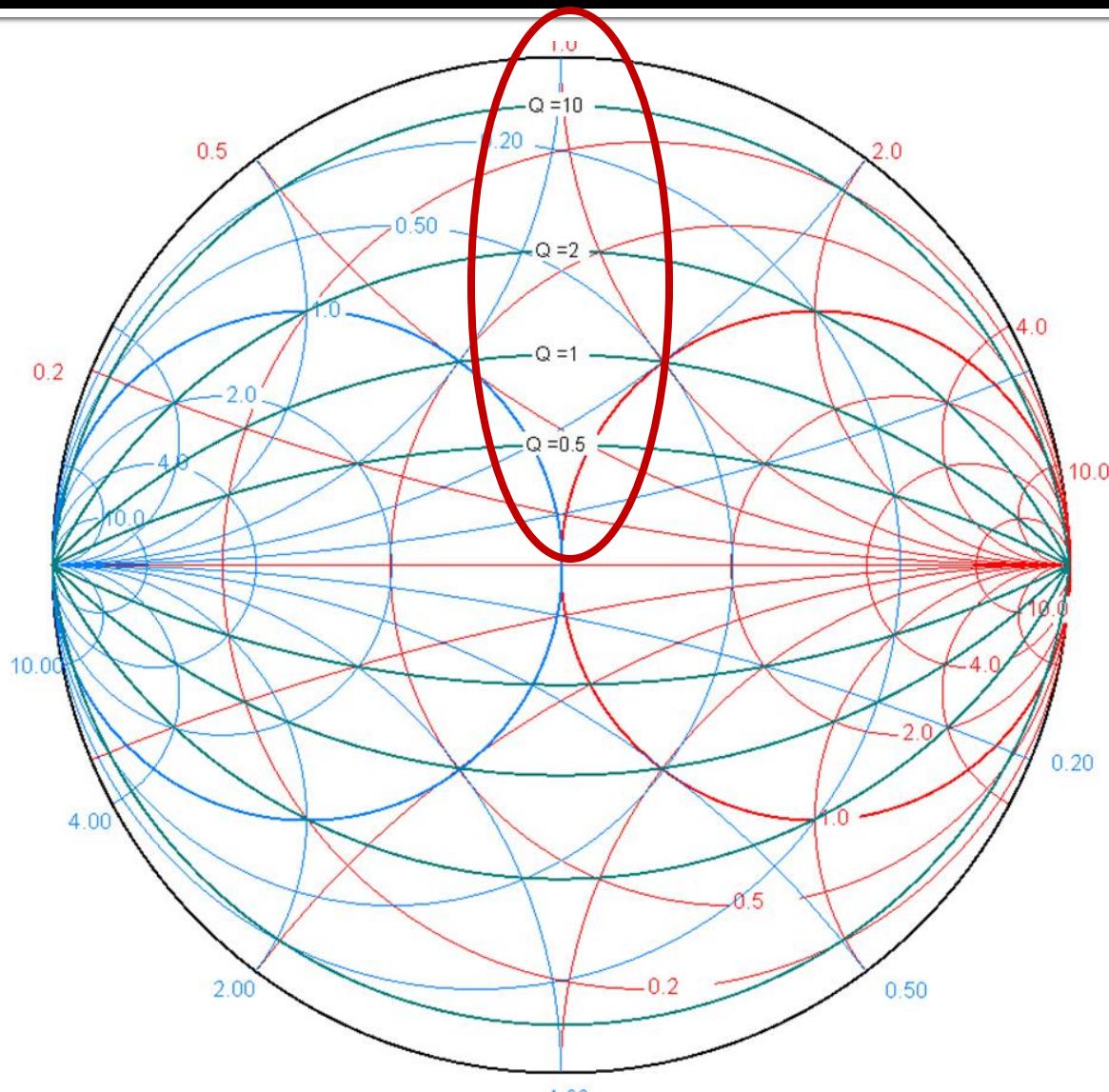
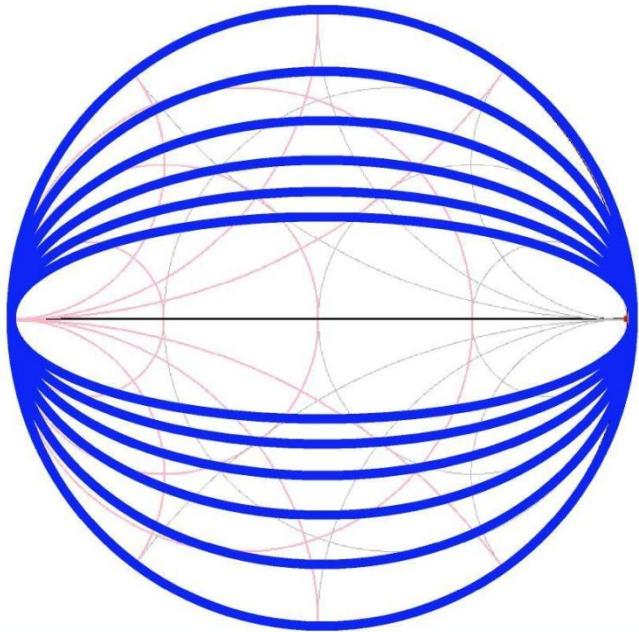
Exemplu



Cercuri de factor de calitate constant

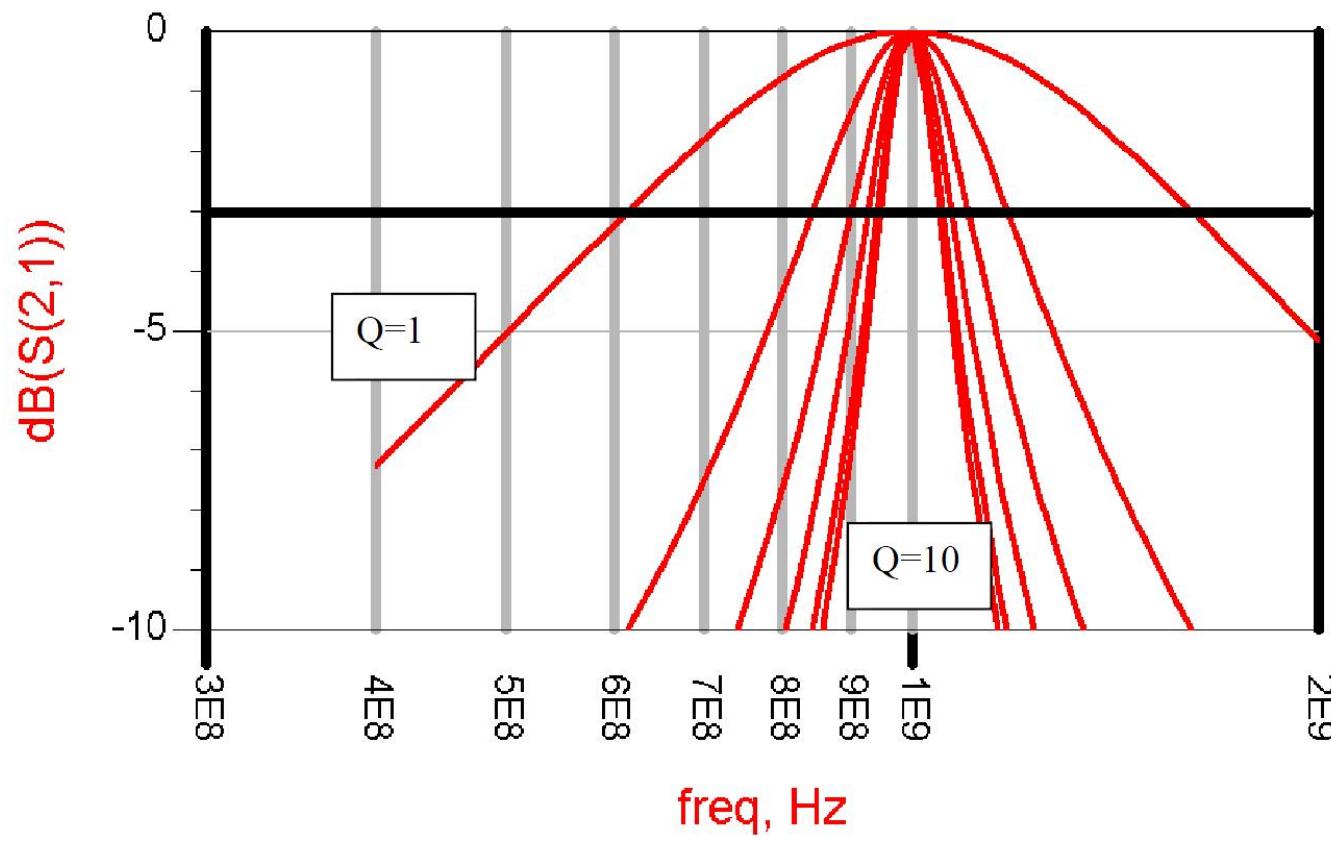
- Diagrama Smith

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

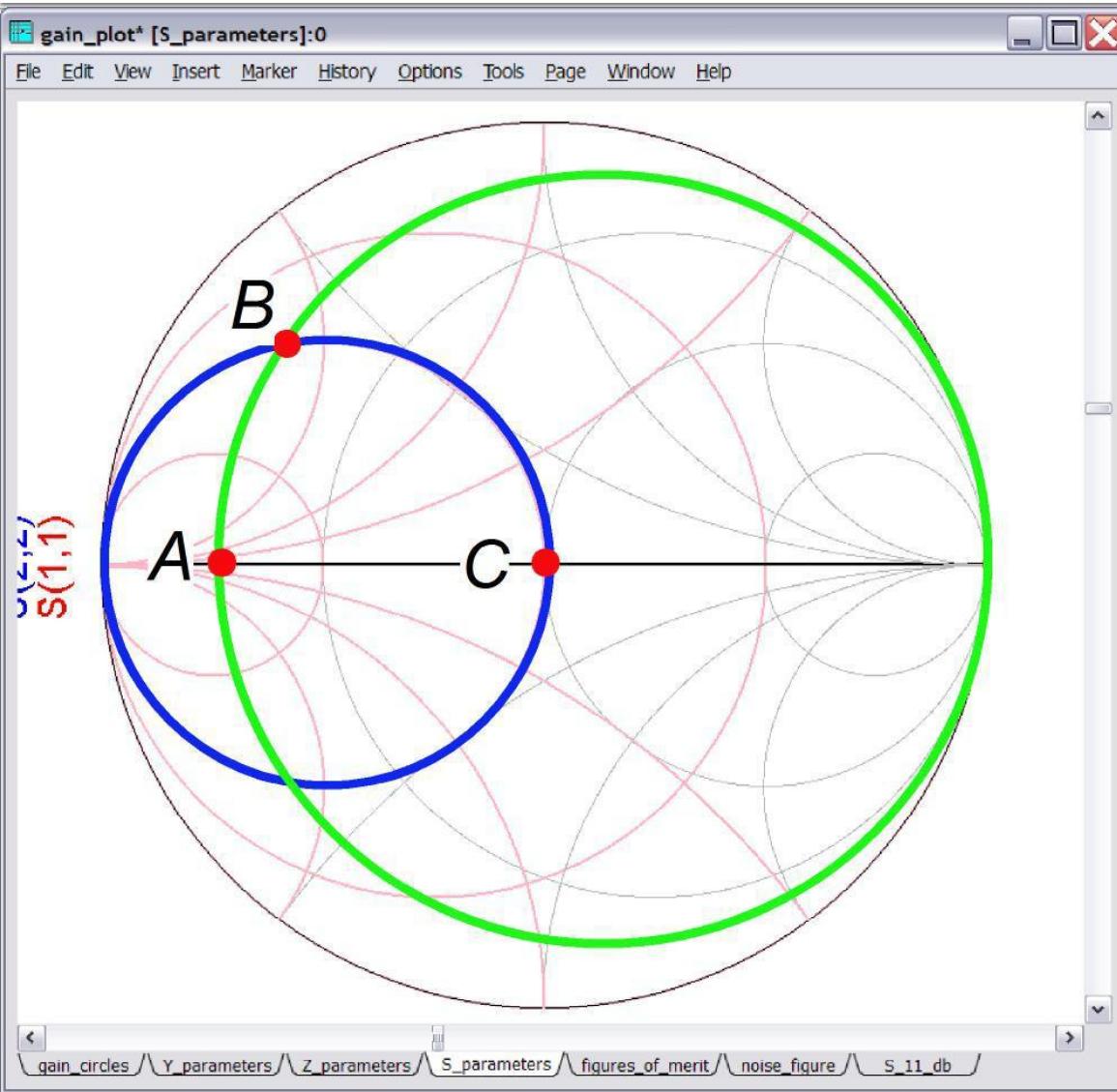


Factor de calitate - banda

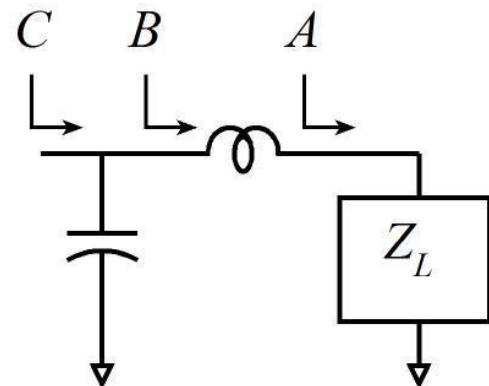
- Factor de calitate ridicat echivalent cu banda ingusta



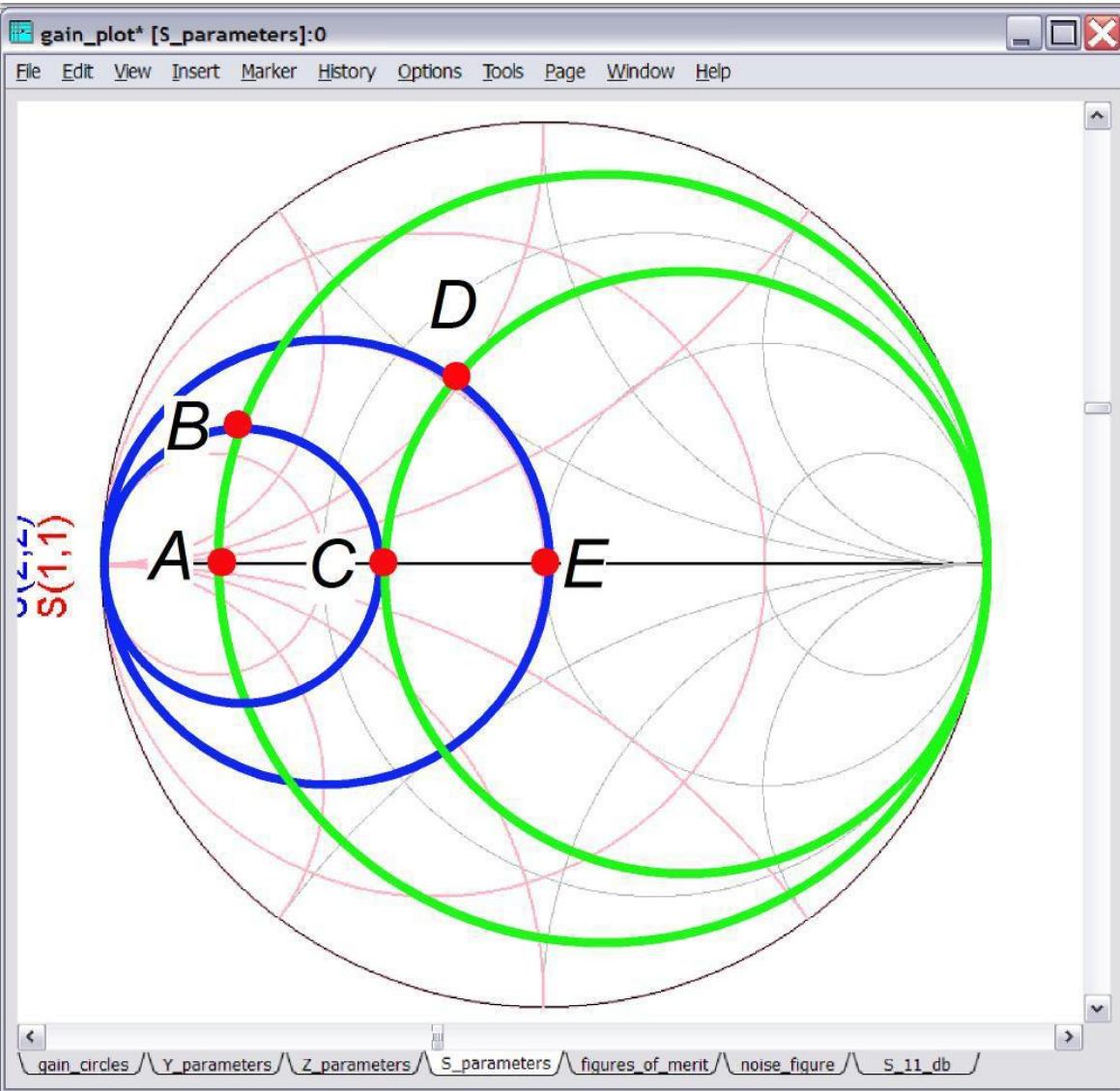
Adaptare - banda



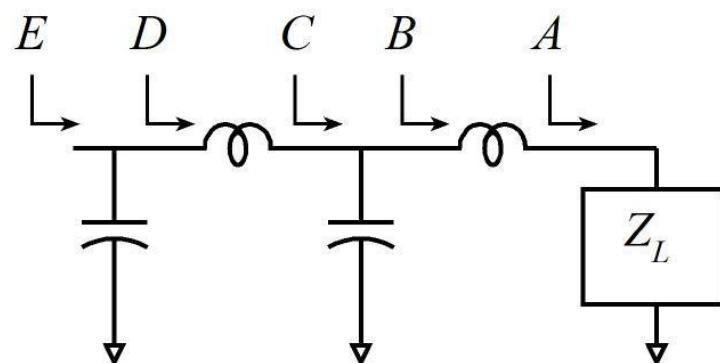
- Pozitia punctului intermediar (B) atins de Γ corespunzatoare celui mai ridicat factor de calitate impune largimea de banda a adaptarii



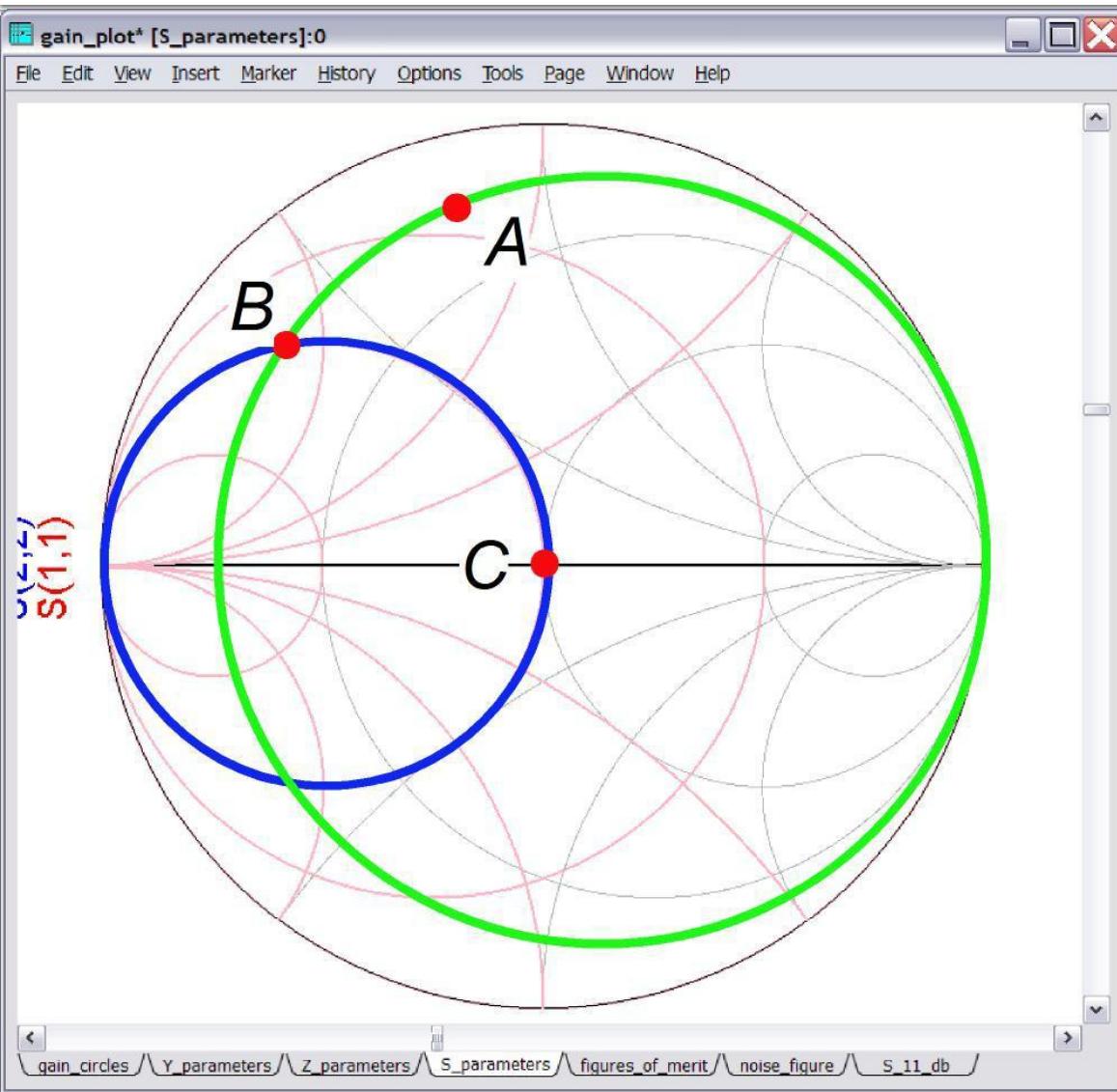
Adaptare - banda



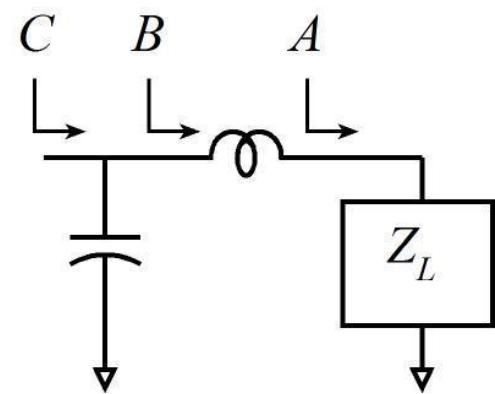
- Adaptare in banda mai larga poate fi obtinuta prin realizarea unor retele in L multiple, fiecare pentru variatii mai mici ale lui Γ , astfel incat toti coeficientii de reflexie intermediari (B, D) sa ocupe pozitii care corespund unui factor de calitate mai mic



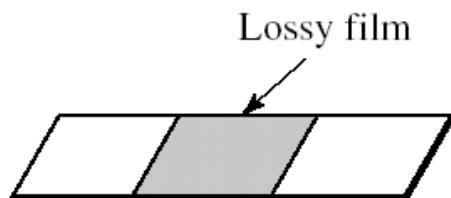
Adaptare - banda



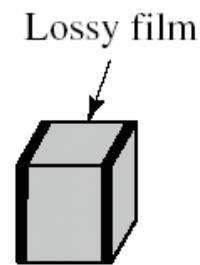
- Pentru pozitii initiale (determinate de sarcina) corespunzatoare unui factor de calitate ridicat (A) banda ingusta a adaptarii este inevitabila



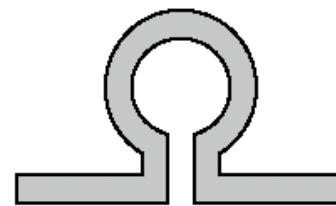
Realizare elemente concentrate



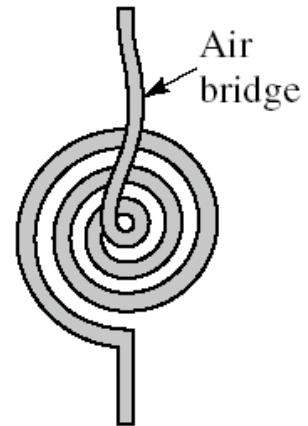
Planar resistor



Chip resistor



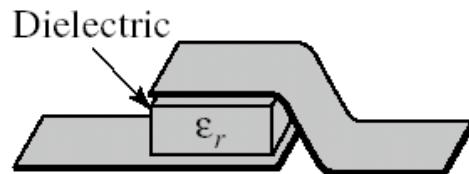
Loop inductor



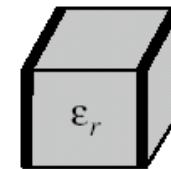
Spiral inductor



Interdigital
gap capacitor



Metal-insulator-
metal capacitor



Chip capacitor

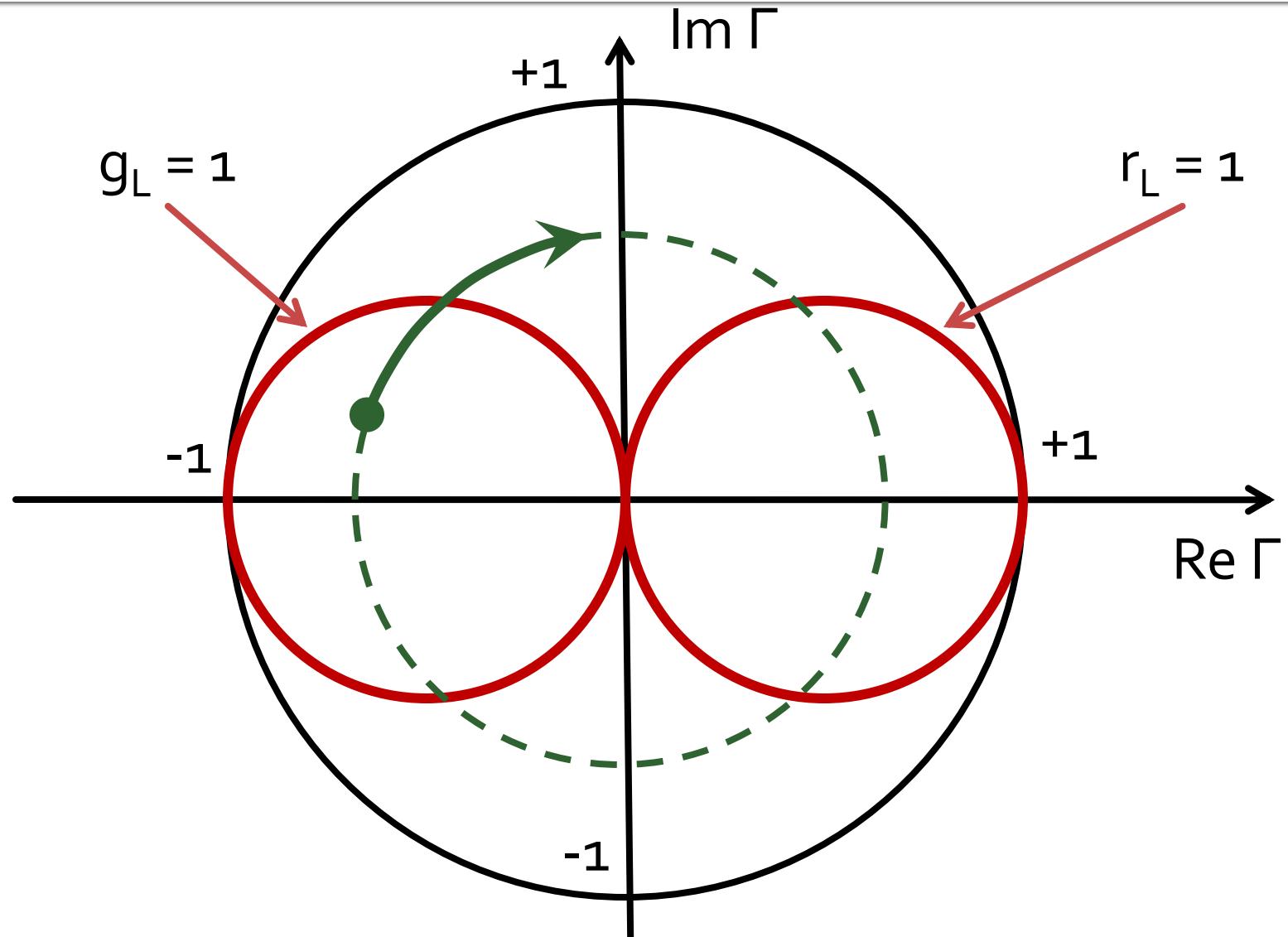
Adaptarea cu sectiuni de linii (stub)

Adaptarea de impedanță

Stub

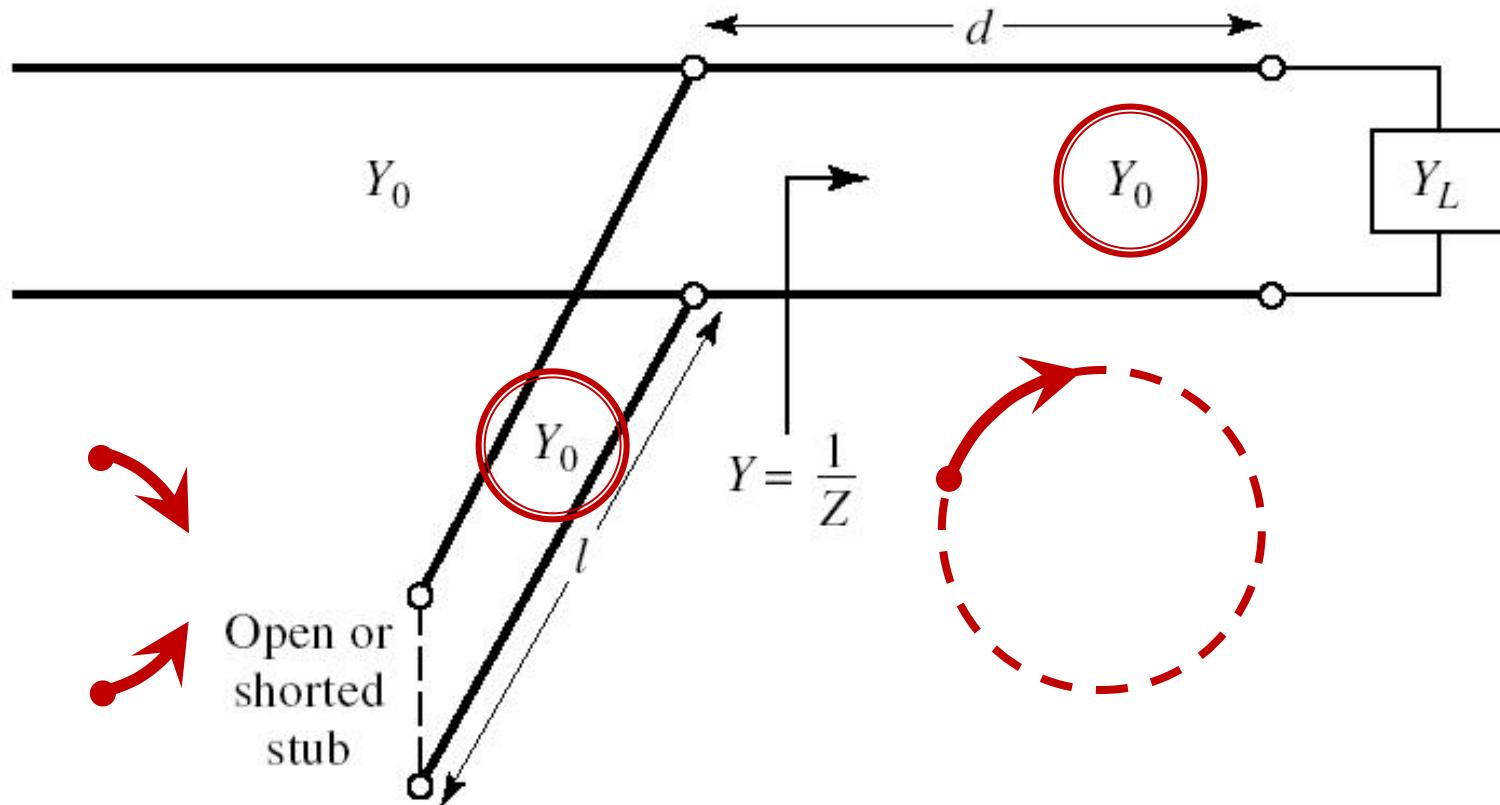
- Stub=rest, ciot, cotor, capăt
- Se evita utilizarea elementelor concentrate
- Se realizeaza (foarte precis) utilizând liniile de transmisie uzuale ale circuitului
- Se utilizeaza secțiuni de linie (stub-uri) in serie sau paralel care pot fi:
 - in gol
 - scurtcircuitate
- De obicei liniile in gol sunt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

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



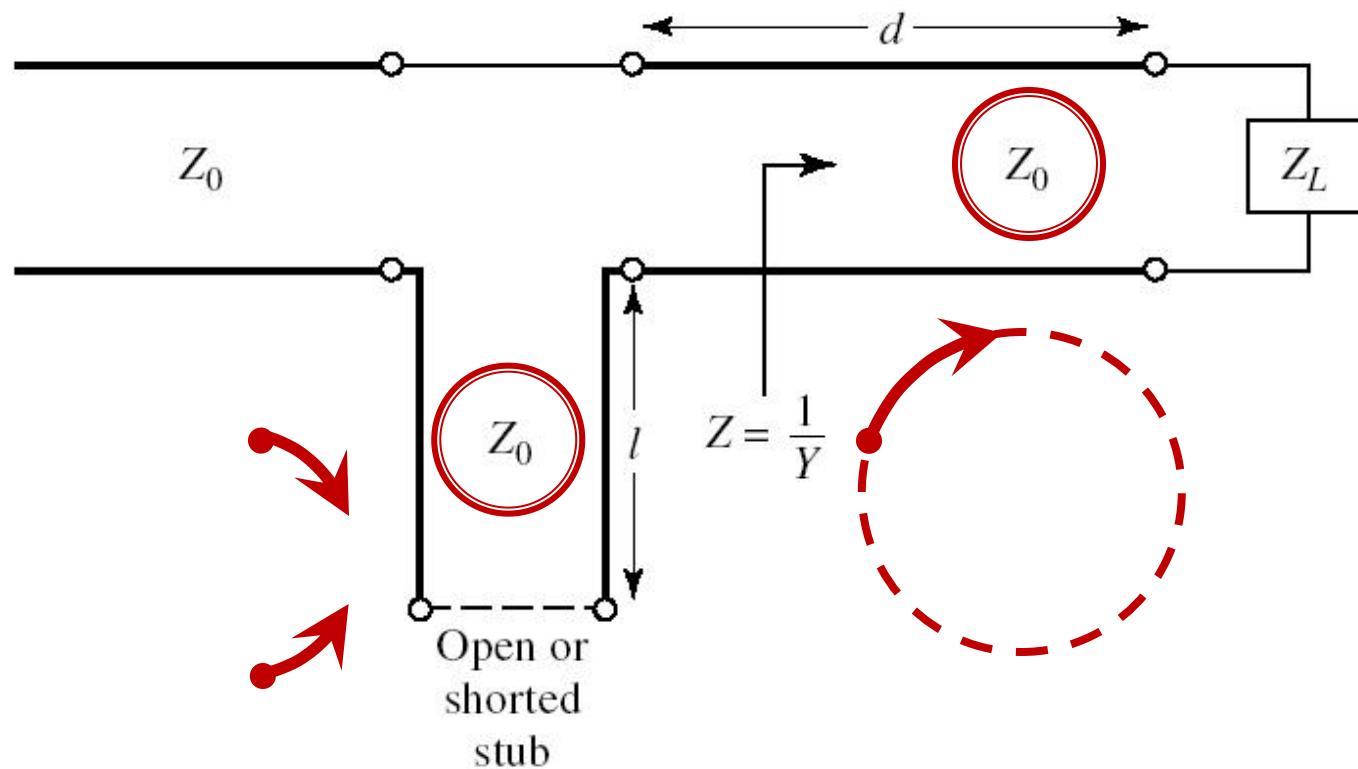
Single stub tuning

- Shunt Stub (secțiune de linie în paralel)

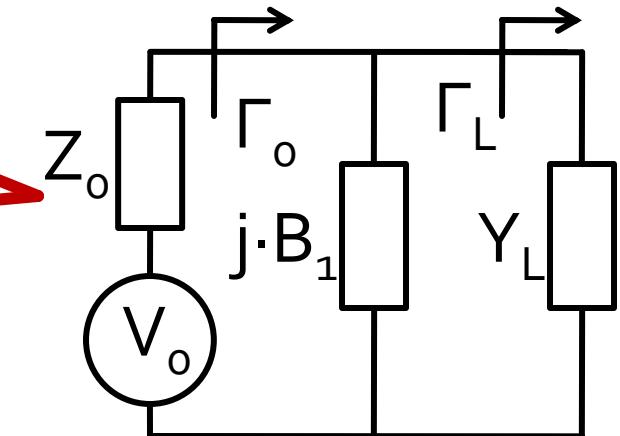
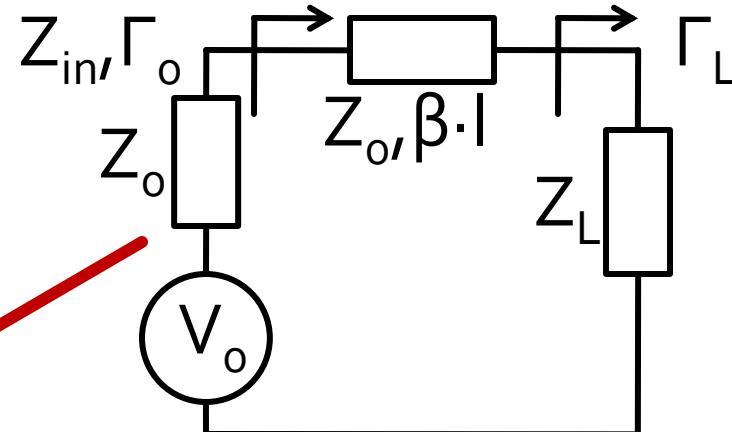
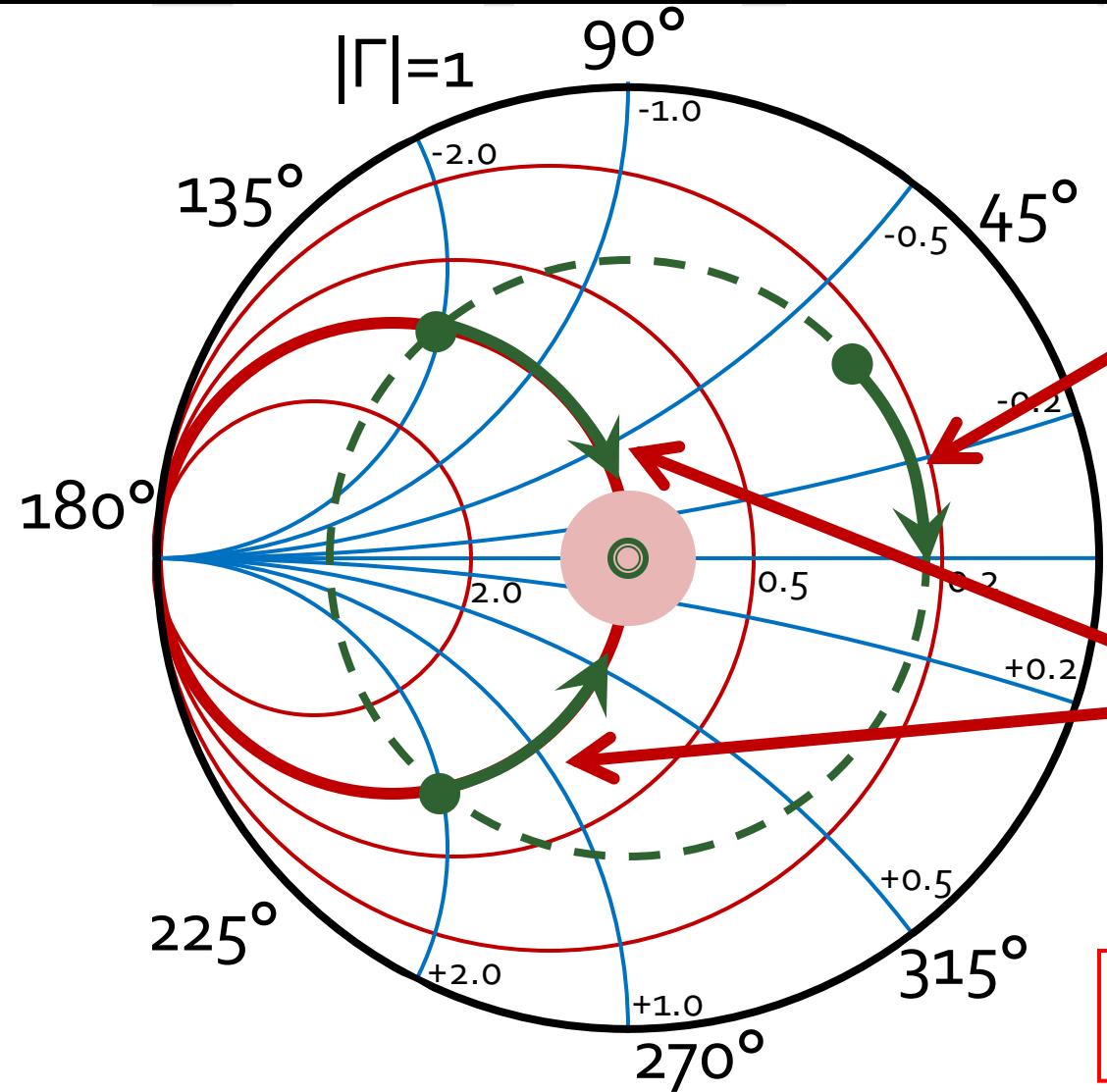


Single stub tuning

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



Adaptare, linie serie + susceptanta in paralel



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

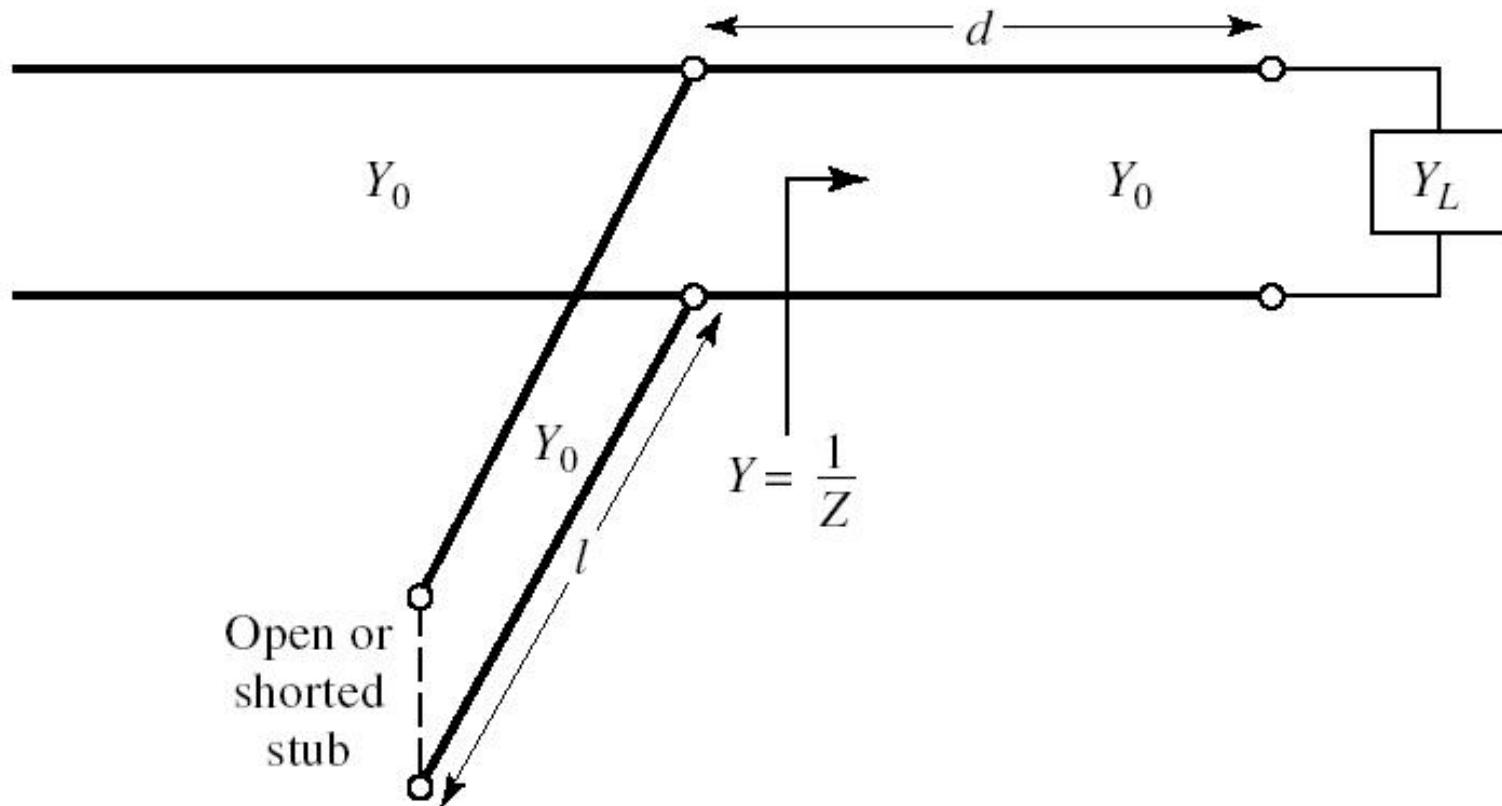
$$g_{in} = 1$$

Shunt Stub

Sectiune de linie paralel

Caz 1, Shunt Stub

- Shunt Stub (secțiune de linie în paralel)



Caz 1, Shunt Stub

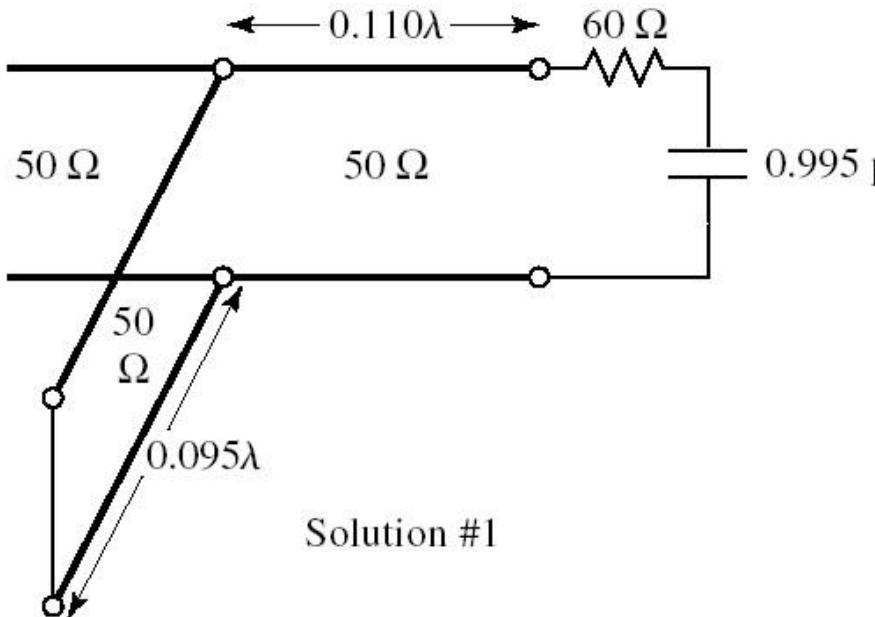
- Se utilizeaza o linie de transmisie serie pentru a muta coeficientul de reflexie pe cercul $g_L = 1$
- Se introduce o reactanta in paralel pentru a realiza adaptarea
- Aceasta reactanta se realizeaza cu o linie de transmisie care poate fi dupa nevoie:
 - in gol
 - in scurtcircuit

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

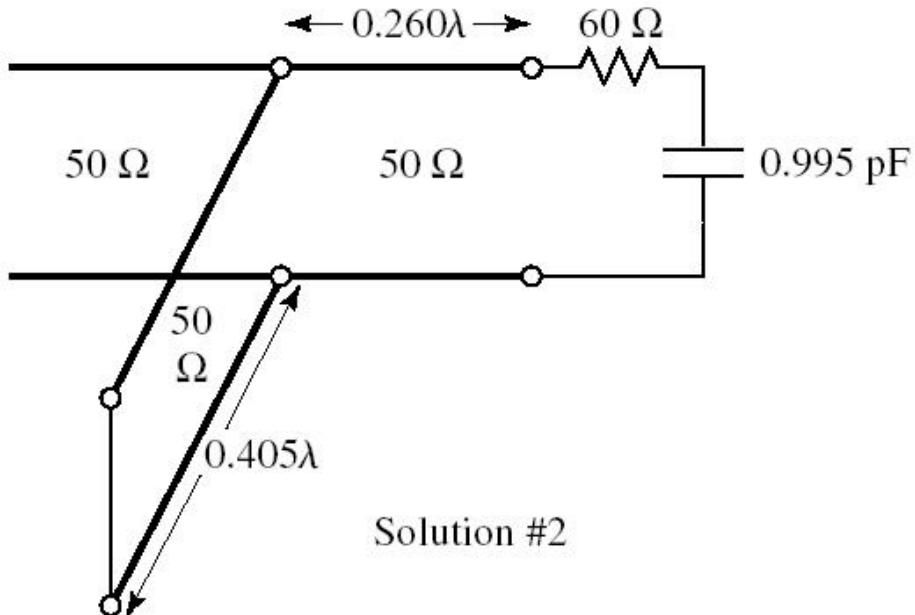
$$Z_{in,sc} = j \cdot Z_0 \cdot \tan \beta \cdot l \qquad \qquad Z_{in,g} = -j \cdot Z_0 \cdot \cot \beta \cdot l$$

Exemplu, Shunt Stub, sc

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

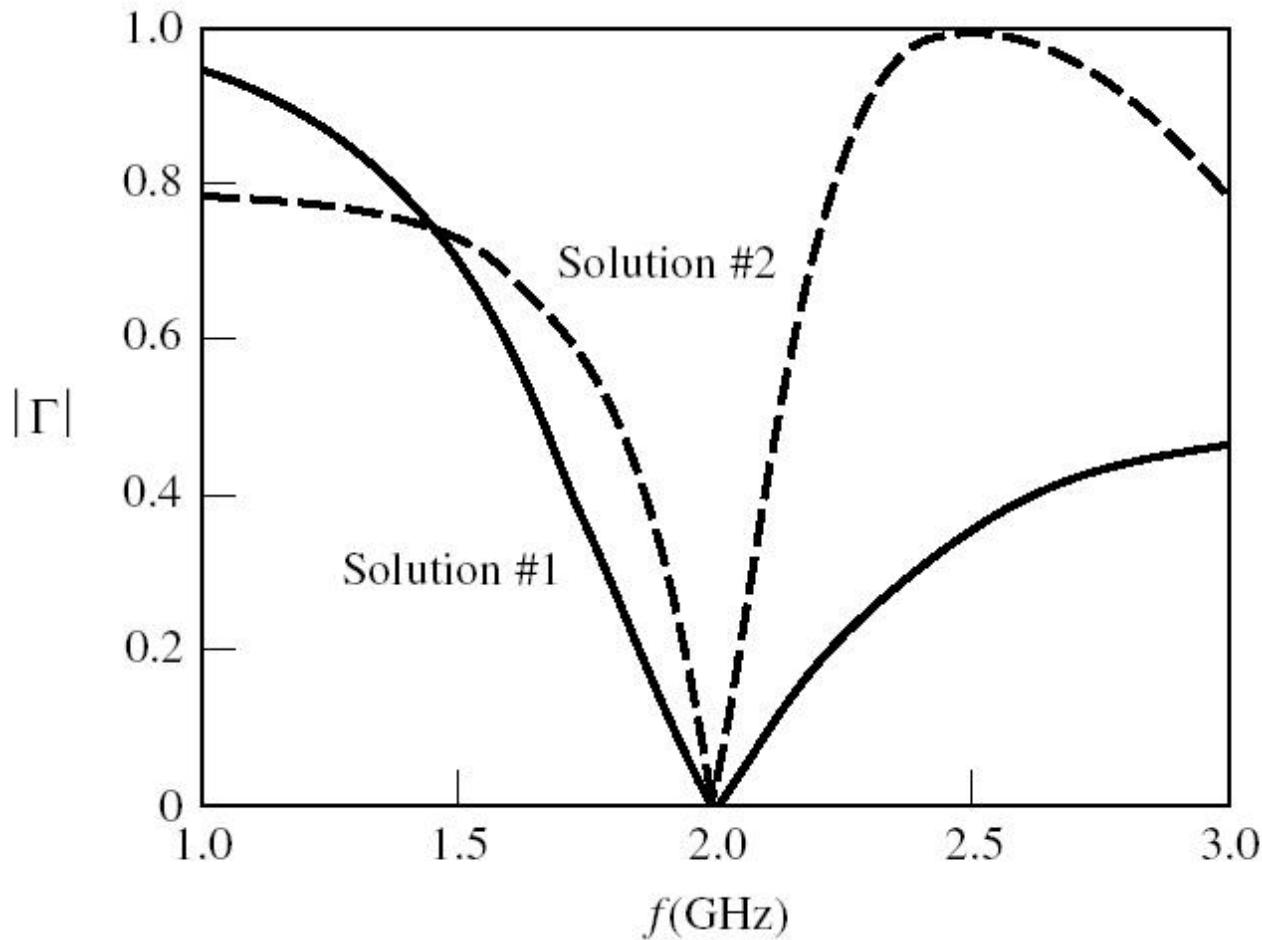


Solution #1

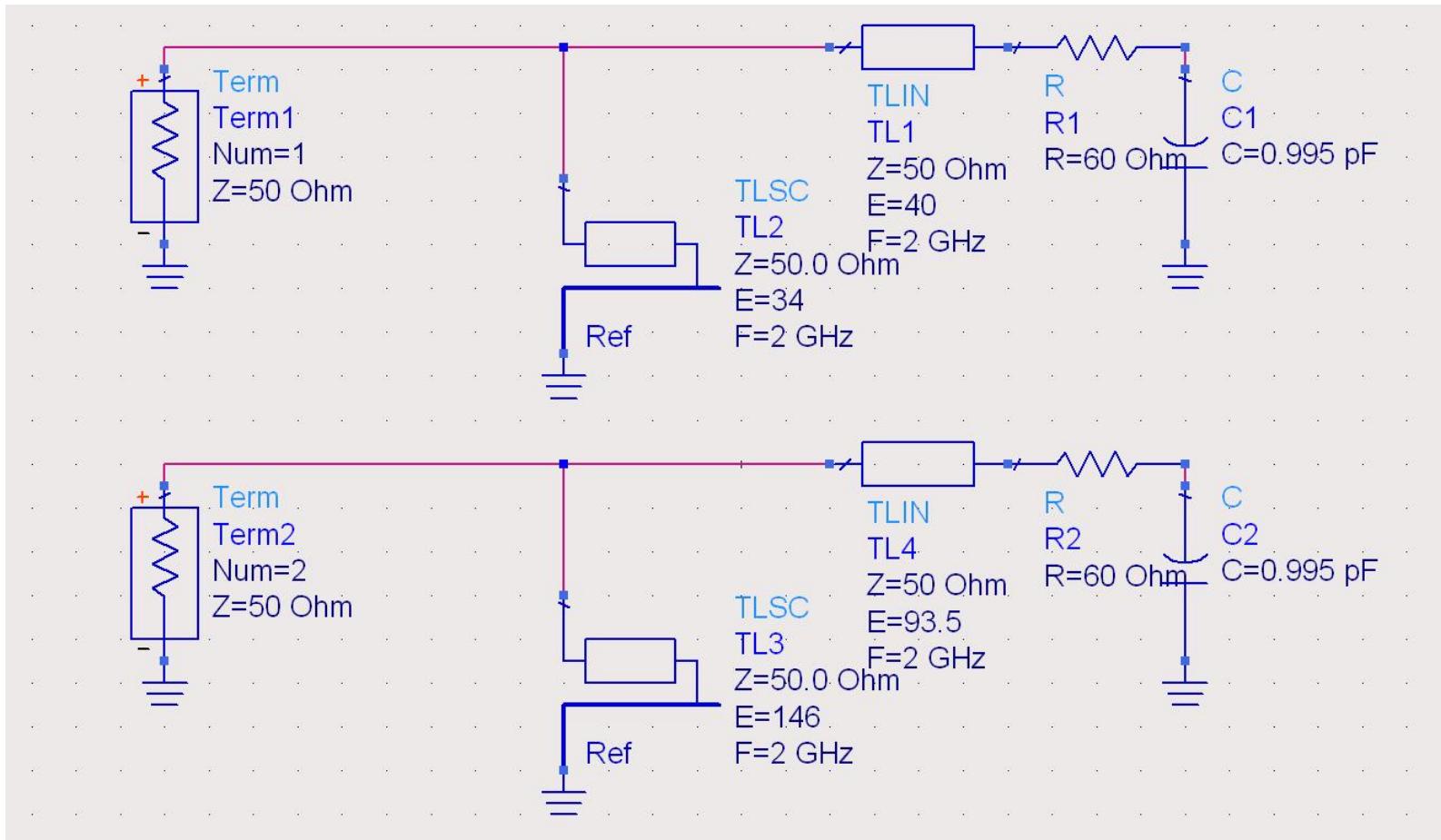


Solution #2

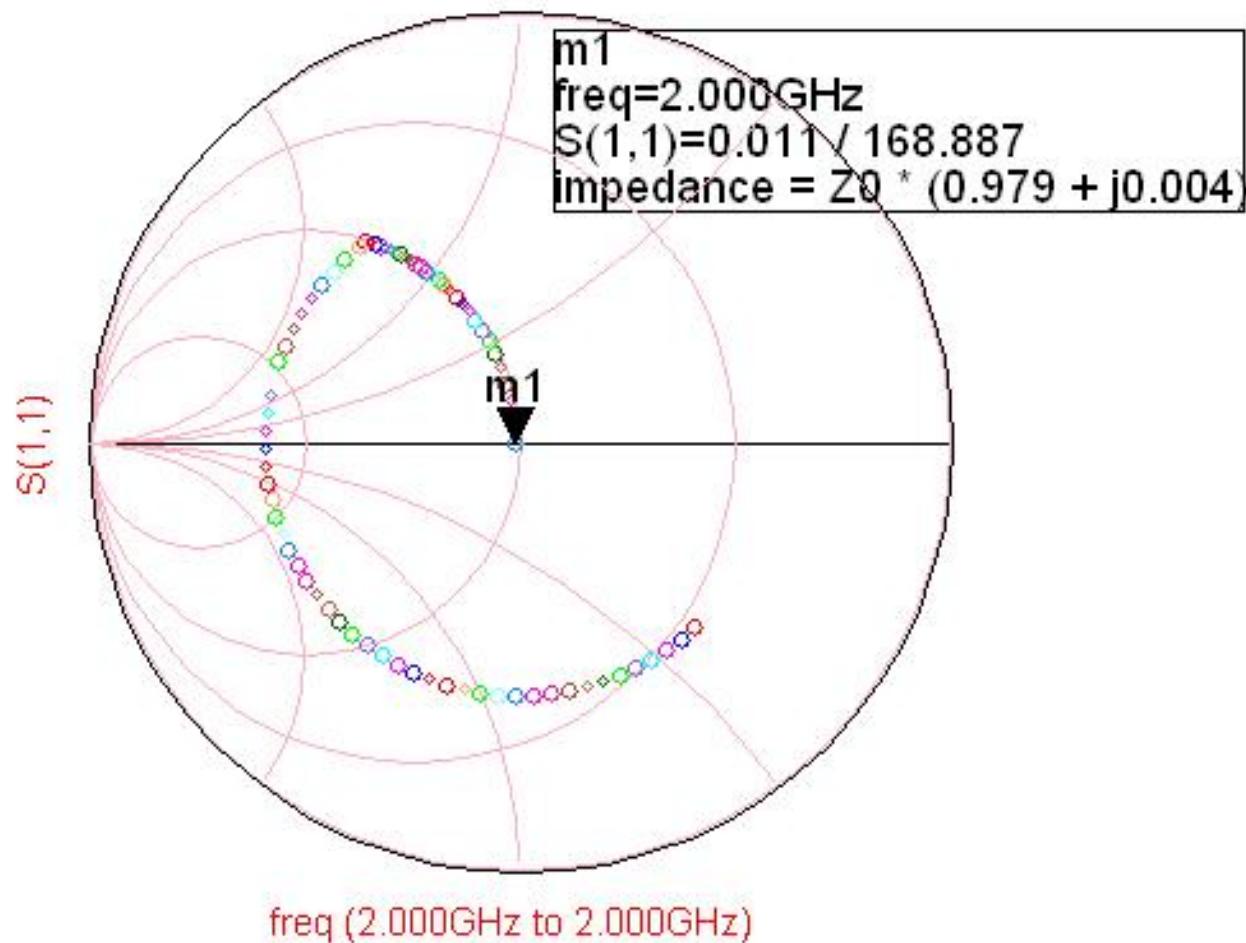
Exemplu, Shunt Stub, sc



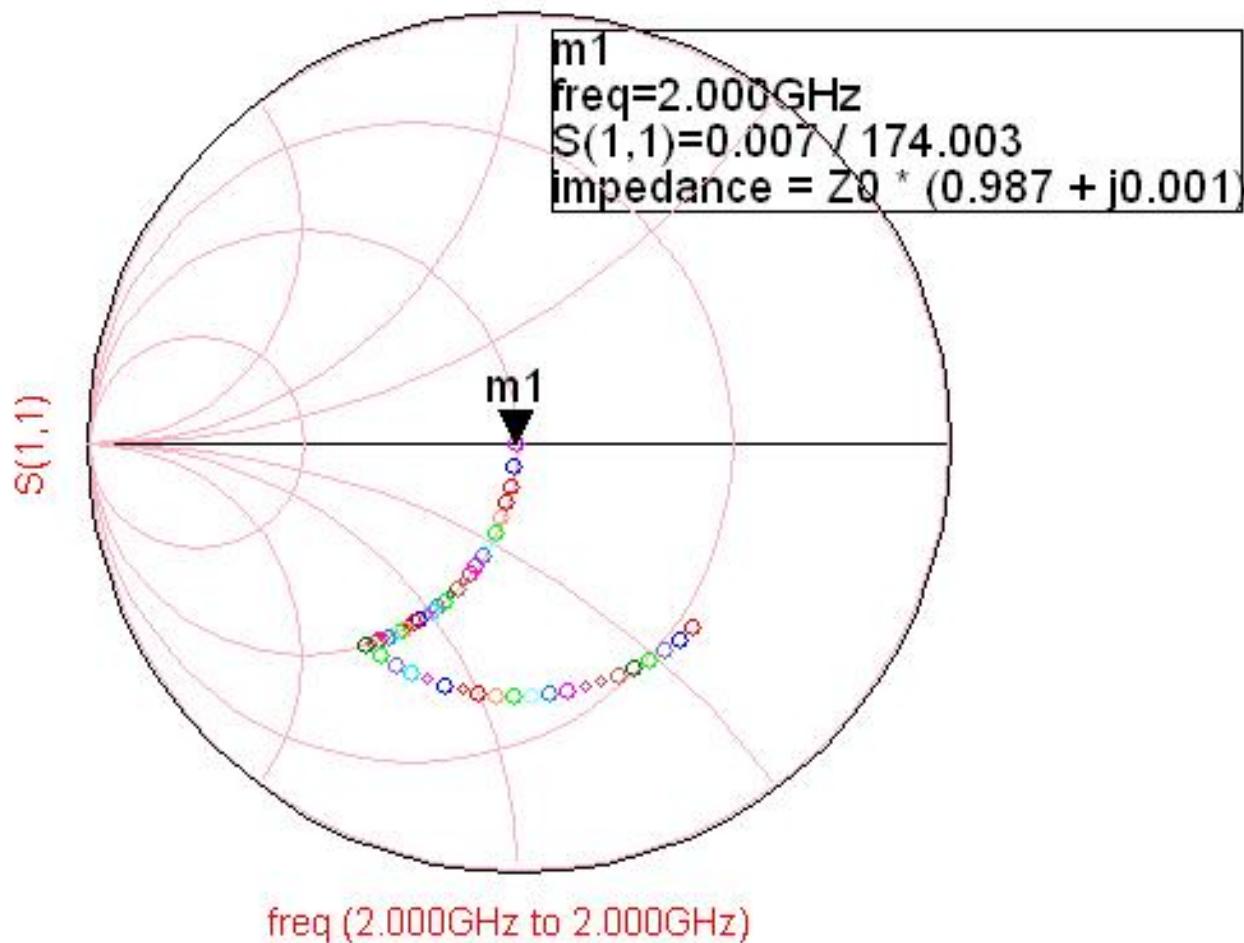
Exemplu, Shunt Stub, sc



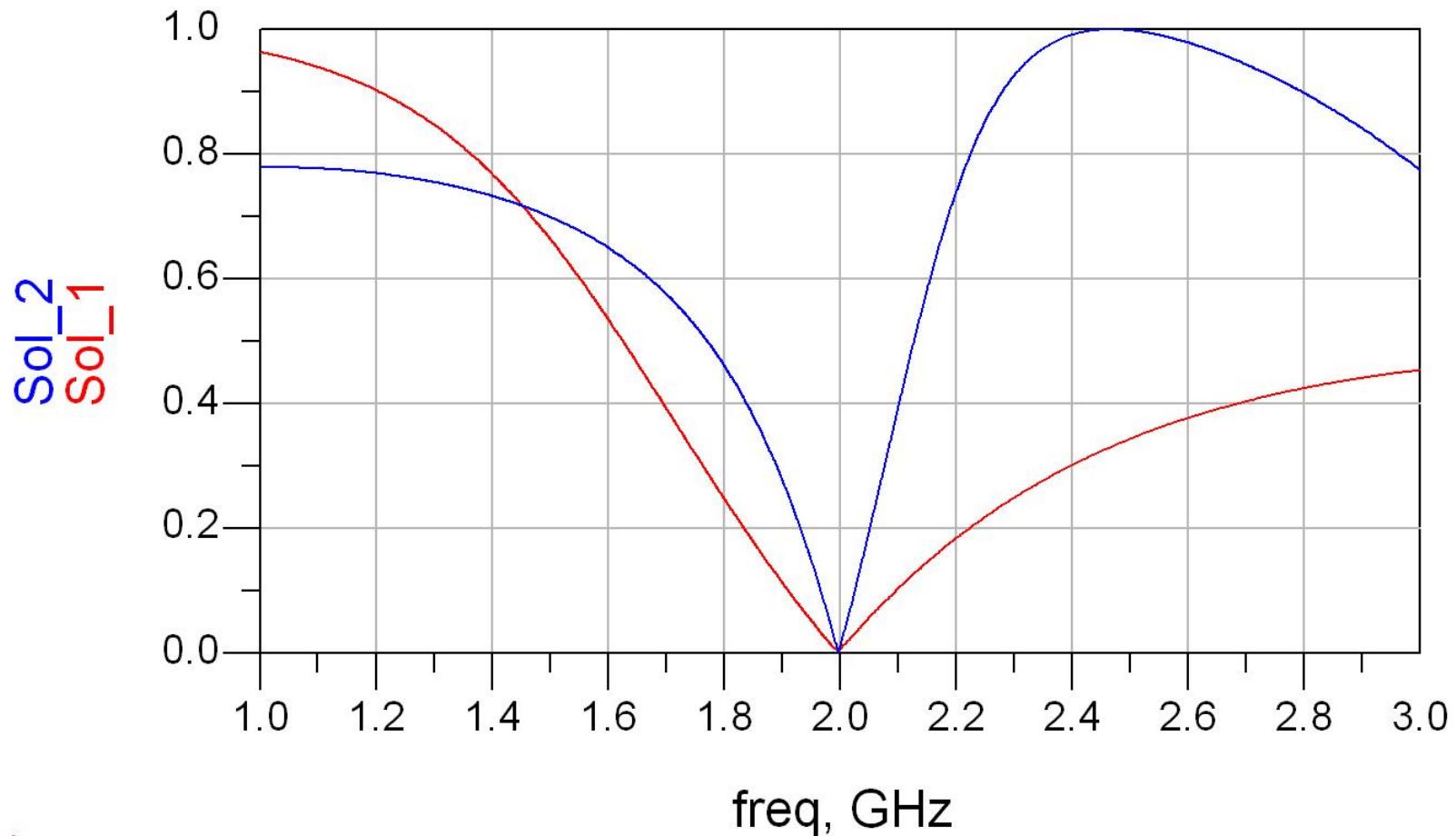
Exemplu, Shunt Stub, sc



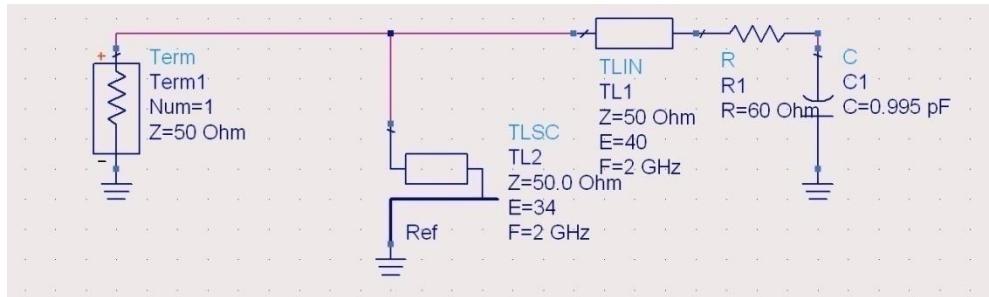
Exemplu, Shunt Stub, sc



Exemplu, Shunt Stub, sc



Exemplu, Shunt Stub, sc

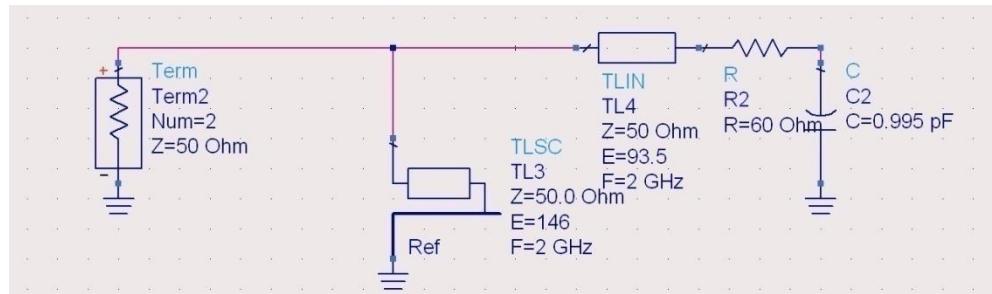


$$l_1 = \frac{40^\circ}{360^\circ} \cdot \lambda = 0.111 \cdot \lambda$$

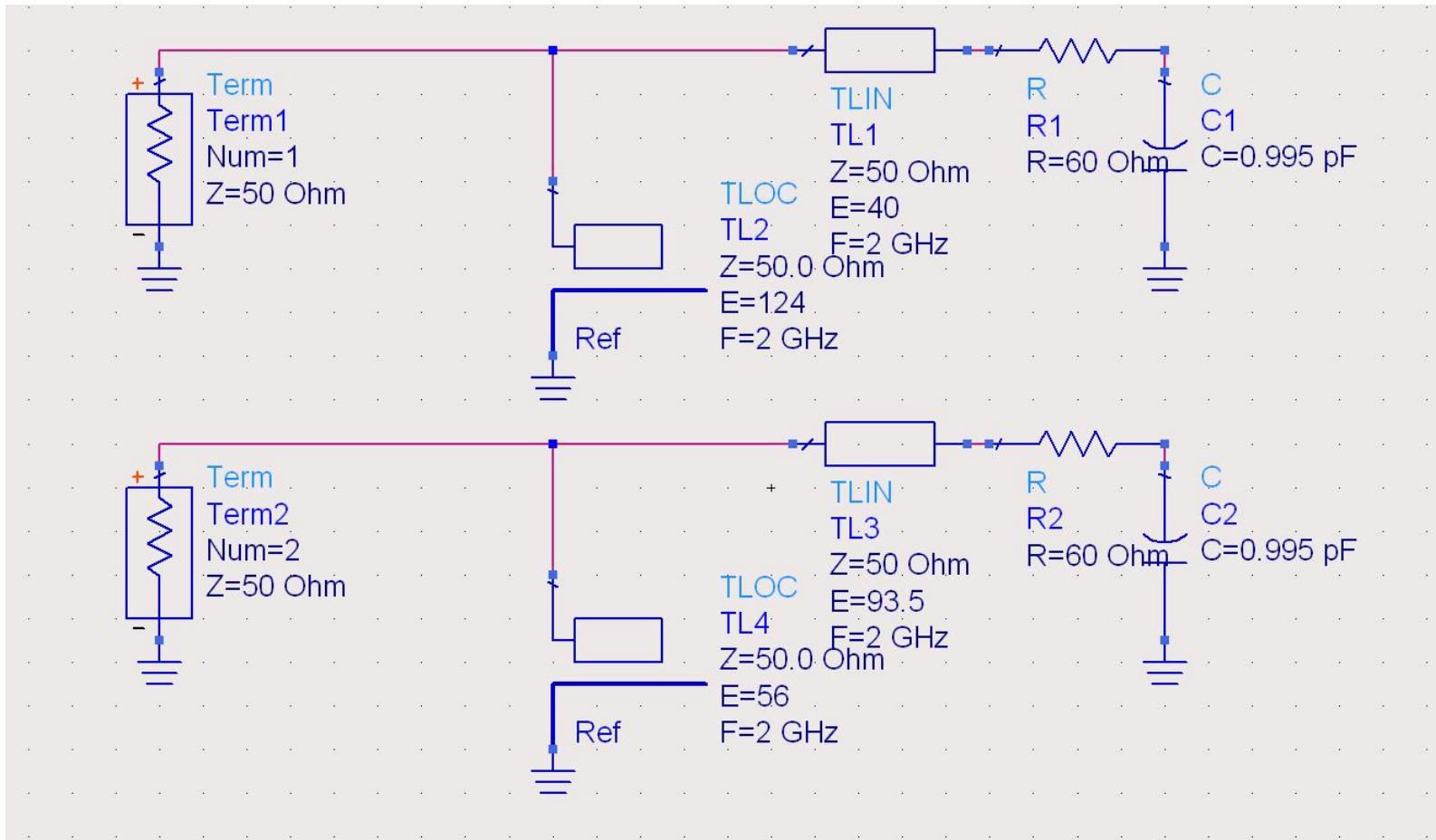
$$l_2 = \frac{34^\circ}{360^\circ} \cdot \lambda = 0.094 \cdot \lambda$$

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

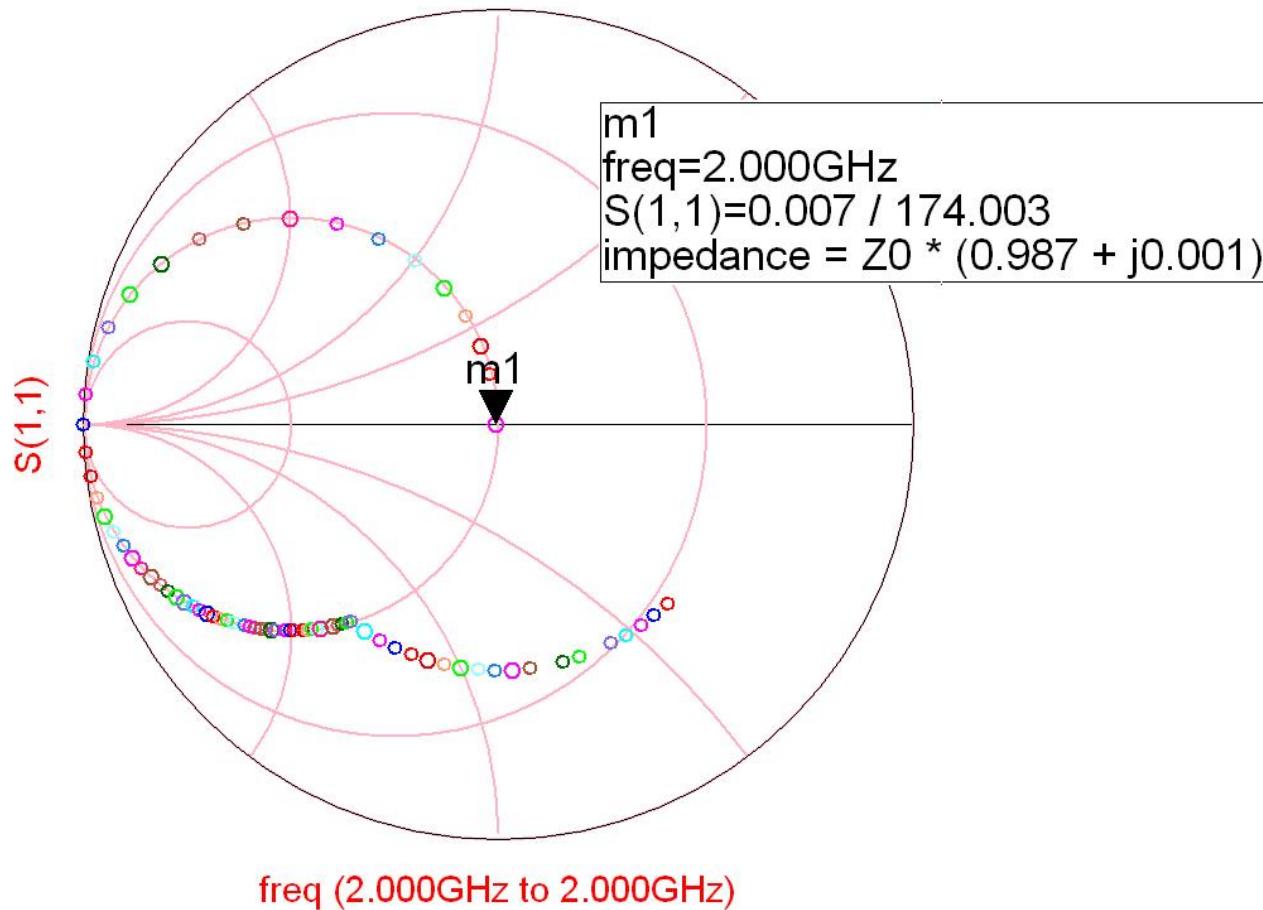
$$l_2 = \frac{146^\circ}{360^\circ} \cdot \lambda = 0.406 \cdot \lambda$$



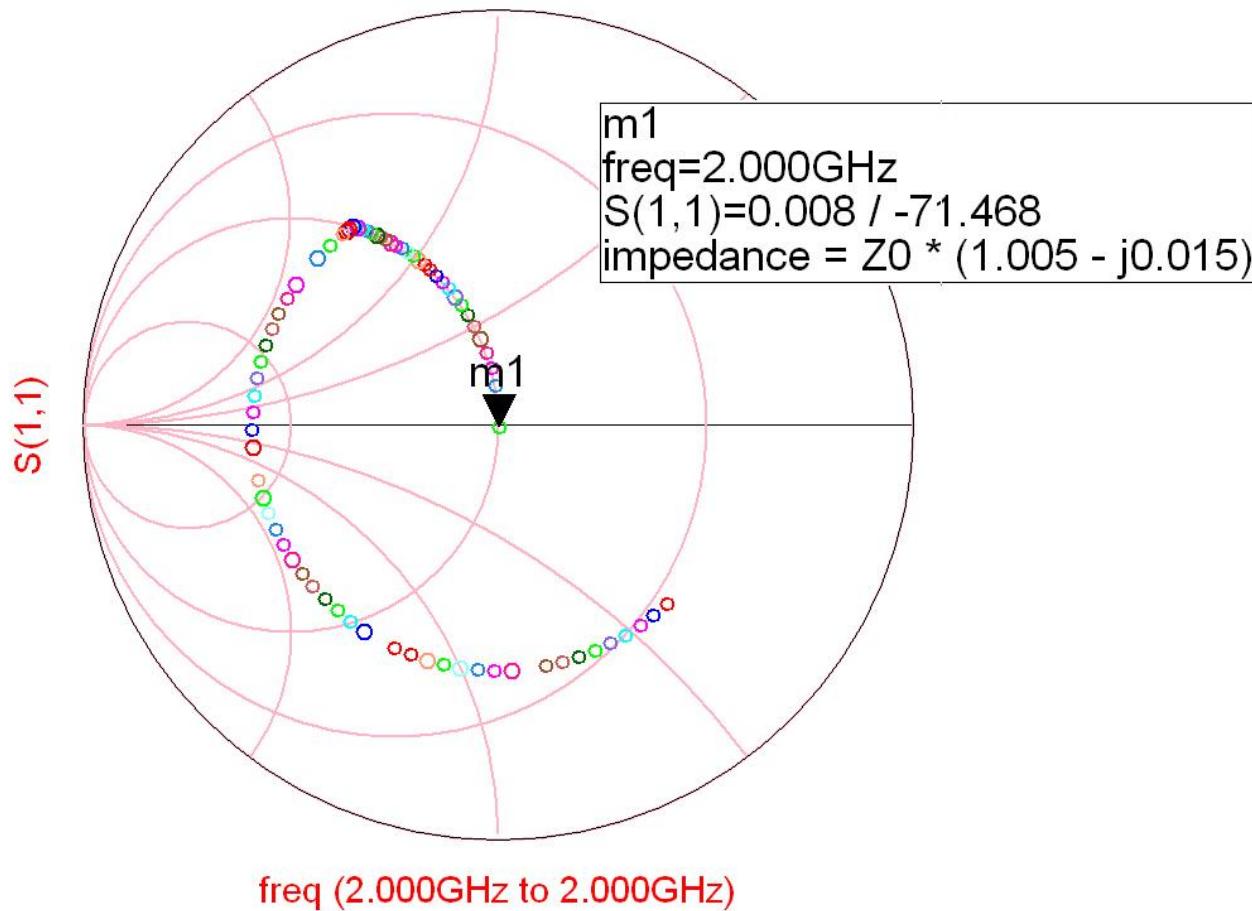
Exemplu, Shunt Stub, gol



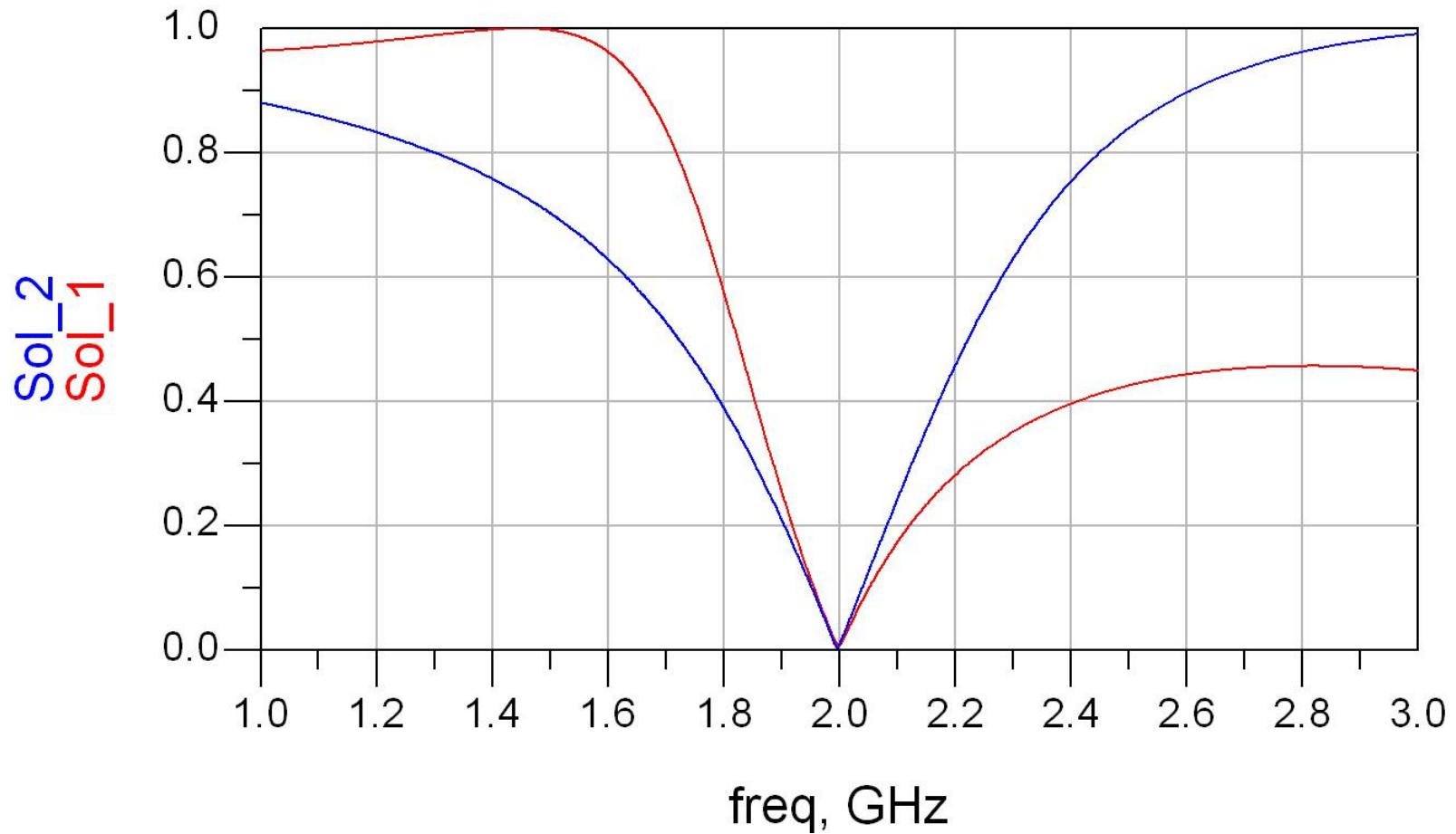
Exemplu, Shunt Stub, gol



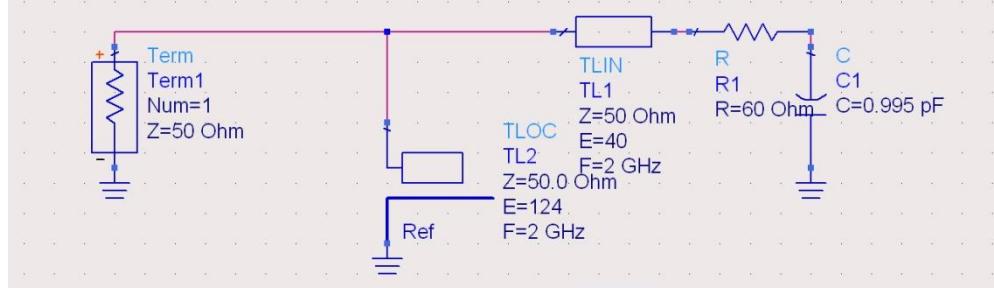
Exemplu, Shunt Stub, gol



Exemplu, Shunt Stub, gol



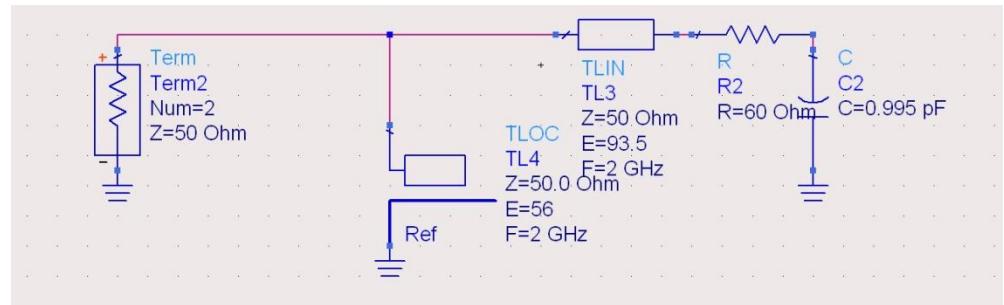
Exemplu, Shunt Stub, gol



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

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

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



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



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:

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

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:

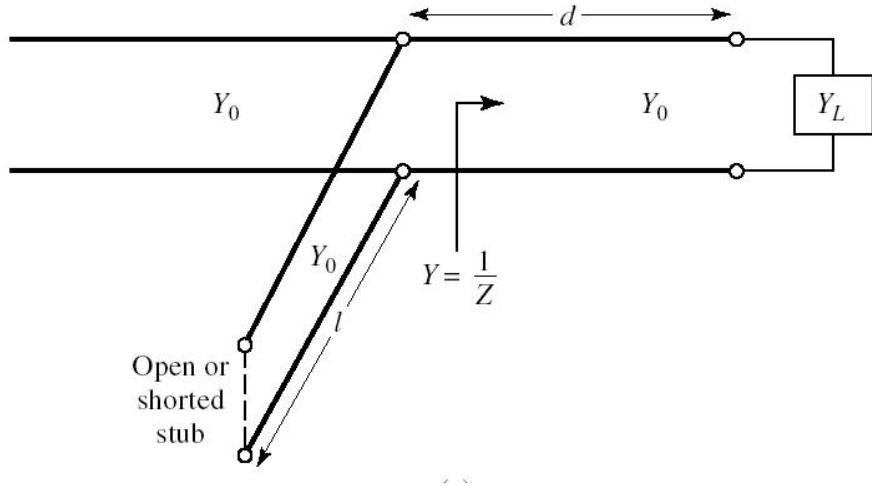
$$Z_{in,sc} = j \cdot Z_0 \cdot \tan \beta \cdot l \quad Z_{in,g} = -j \cdot Z_0 \cdot \cot \beta \cdot l$$

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

Solutie analitica

Shunt Stub

Solutie analitica, impedante



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

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

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

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

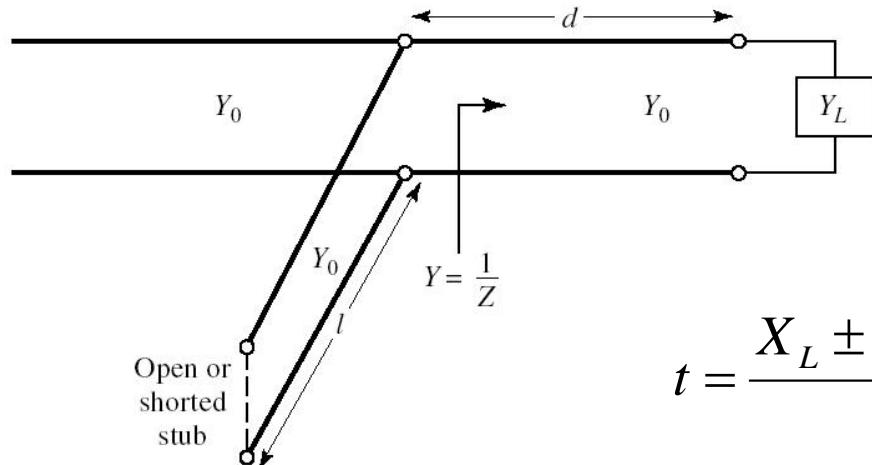
$$B = \frac{R_L^2 \cdot t - (Z_0 - X_L \cdot t) \cdot (X_L + Z_0 \cdot t)}{Z_0 \cdot [R_L^2 + (X_L + Z_0 \cdot t)^2]}$$

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

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

- d este ales astfel incat

Solutie analitica



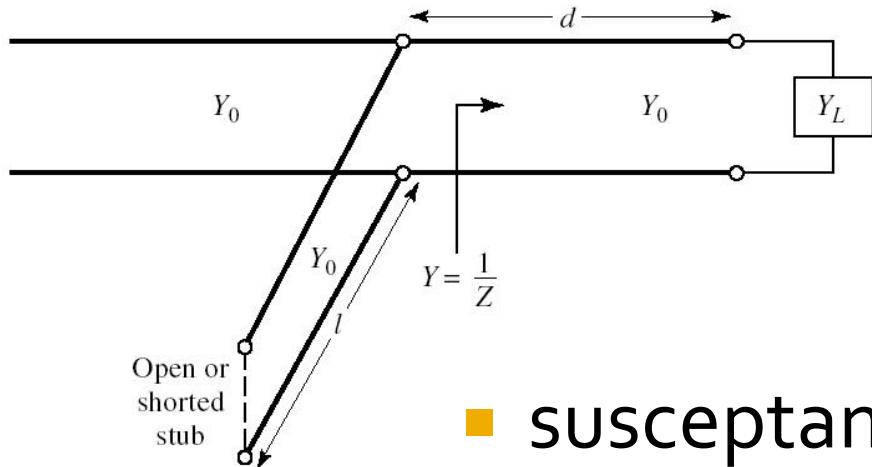
$$t = -\frac{X_L}{2 \cdot Z_0}, \quad R_L = Z_0$$

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

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

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

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

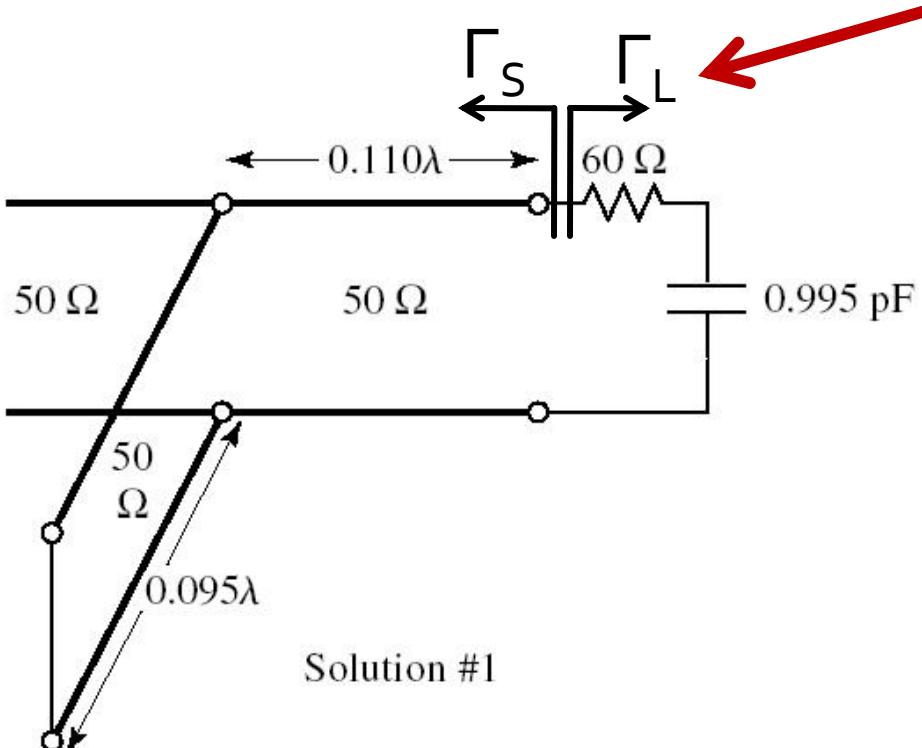
$$\frac{l_{gol}}{\lambda} = \frac{1}{2\pi} \cdot \arctan \left(\frac{B_S}{Y_0} \right) = \frac{-1}{2\pi} \cdot \arctan \left(\frac{B}{Y_0} \right)$$

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

■ 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

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

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

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

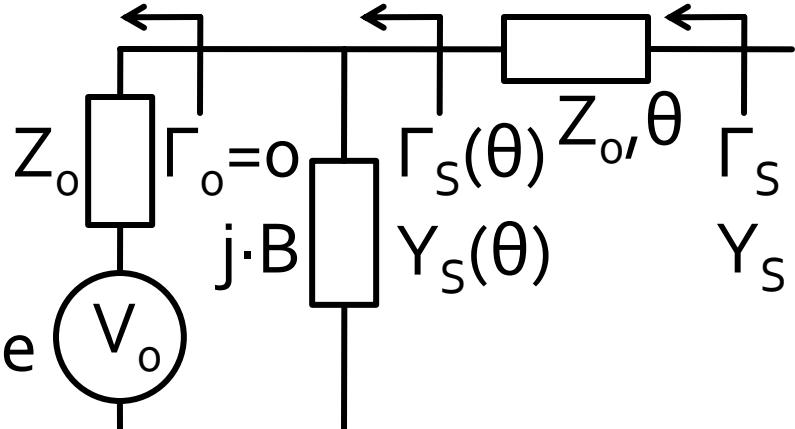
Calcul analitic, coeficienti de reflexie

■ 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}

$$\operatorname{Re}[y_s(\theta)] = 1 \quad \cos(\varphi + 2\theta) = -|\Gamma_S| \quad \operatorname{Im}[y_s(\theta)] = \frac{1}{2j} \cdot [y_s(\theta) - y_s^*(\theta)]$$

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

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

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

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

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)

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

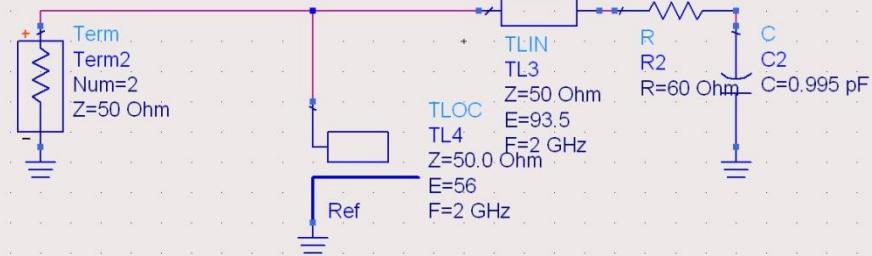
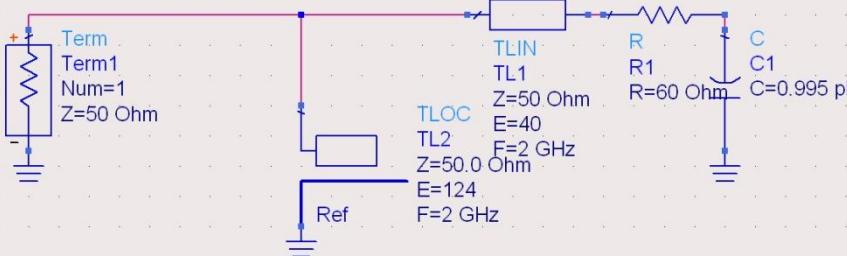
- Se alege **una** din cele doua solutii posibile
- **Semnul (+/-)** solutiei alese la **prima** ecuatie impune **semnul** solutiei utilizate la a **doua** ecuatie

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

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

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

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

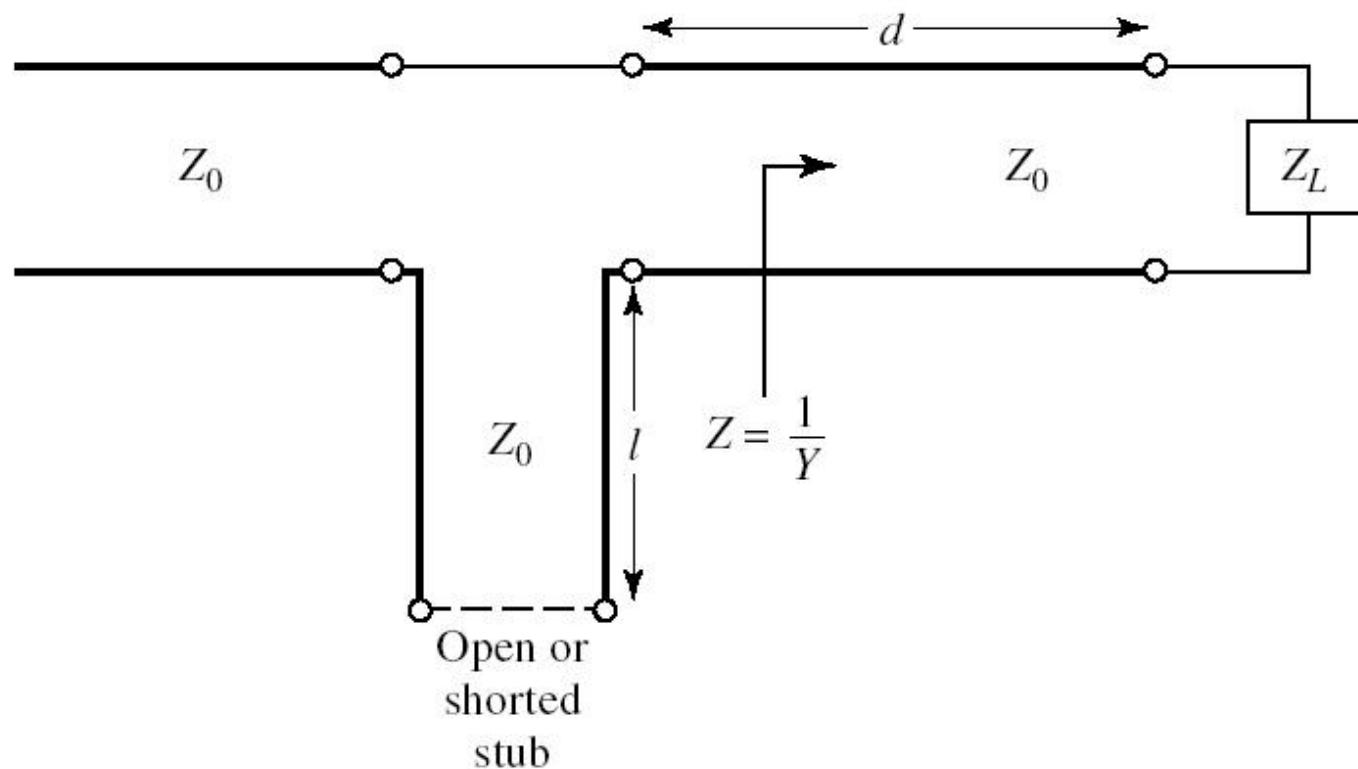


Series Stub

Sectiune de linie serie

Caz 2, Series Stub

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



Caz 2, Series Stub

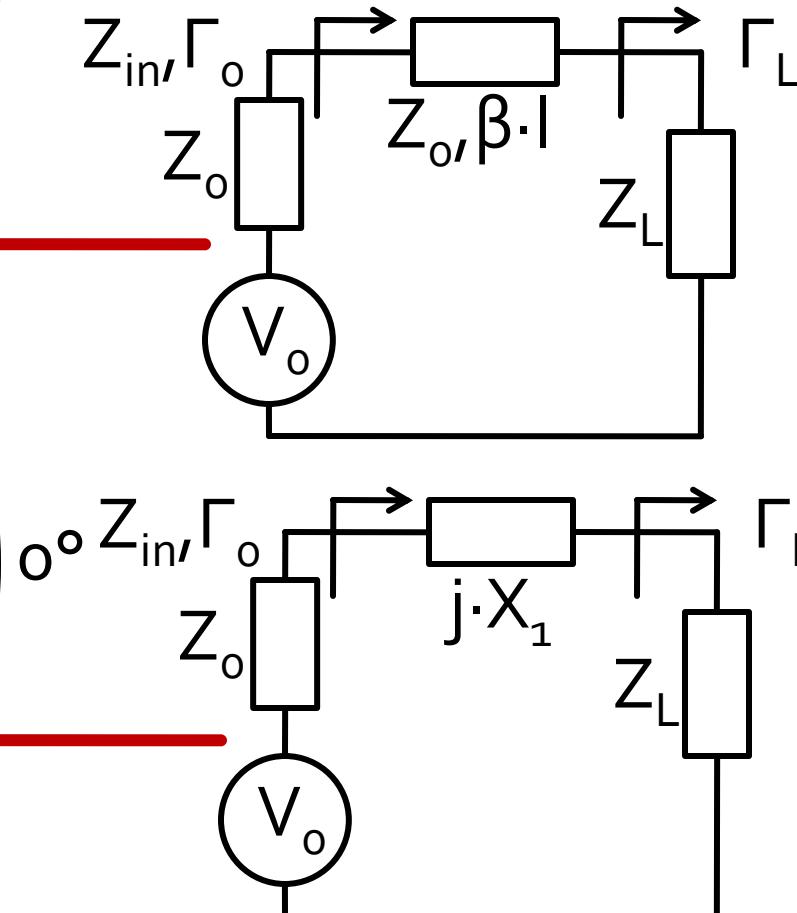
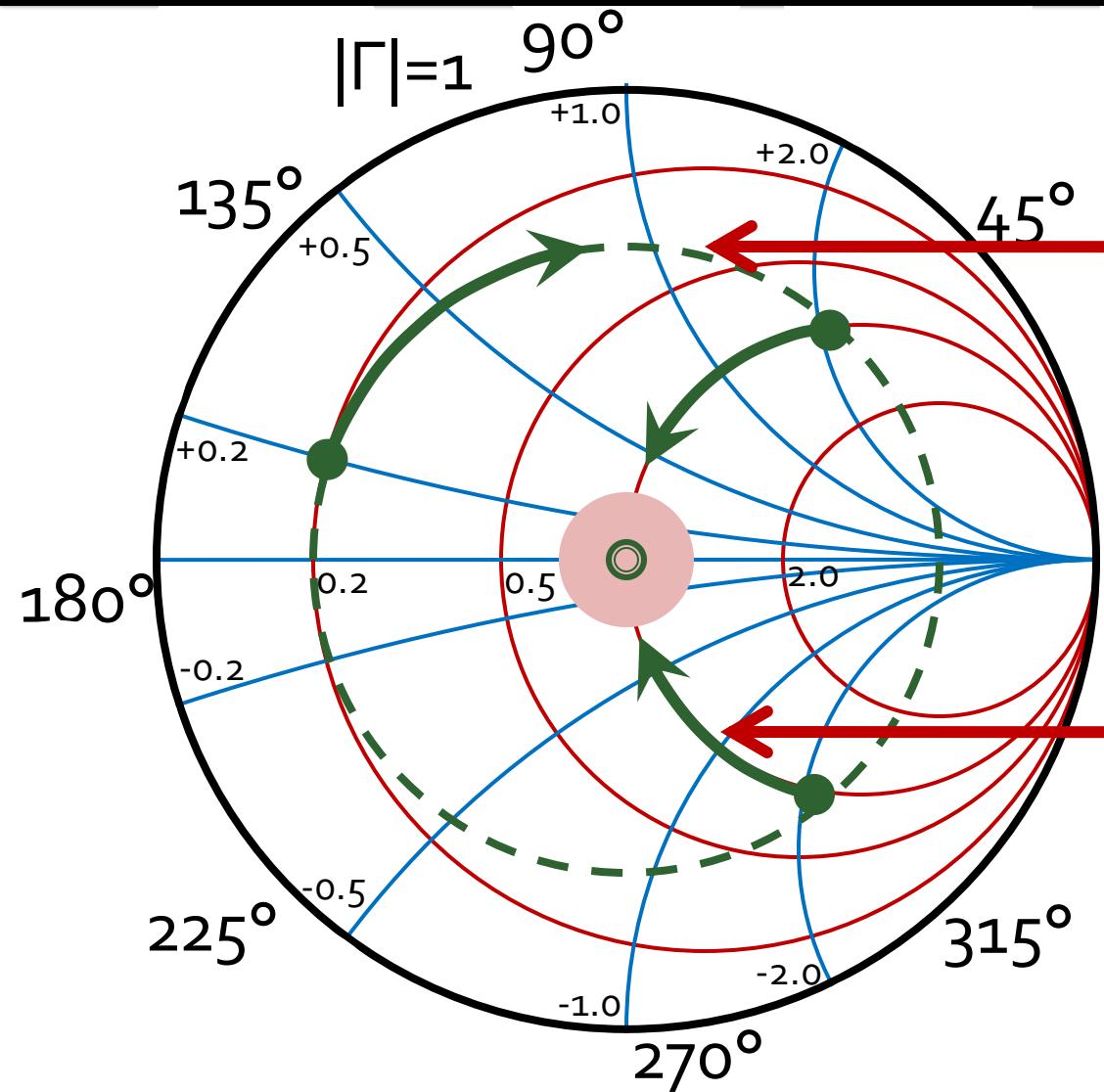
- Se utilizeaza o linie de transmisie serie pentru a muta coeficientul de reflexie pe cercul $r_L = 1$
- Se introduce o reactanta in serie pentru a realiza adaptarea
- Aceasta reactanta se realizeaza cu o linie de transmisie care poate fi dupa nevoie:
 - in gol
 - in scurtcircuit

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

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

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

Adaptare, linie serie + reactanta in serie

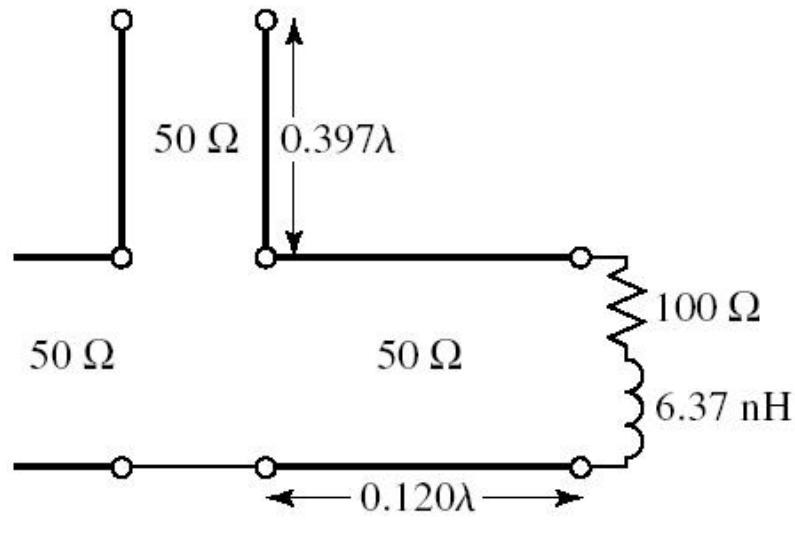


$$|\Gamma_{in}| = |\Gamma_L|$$

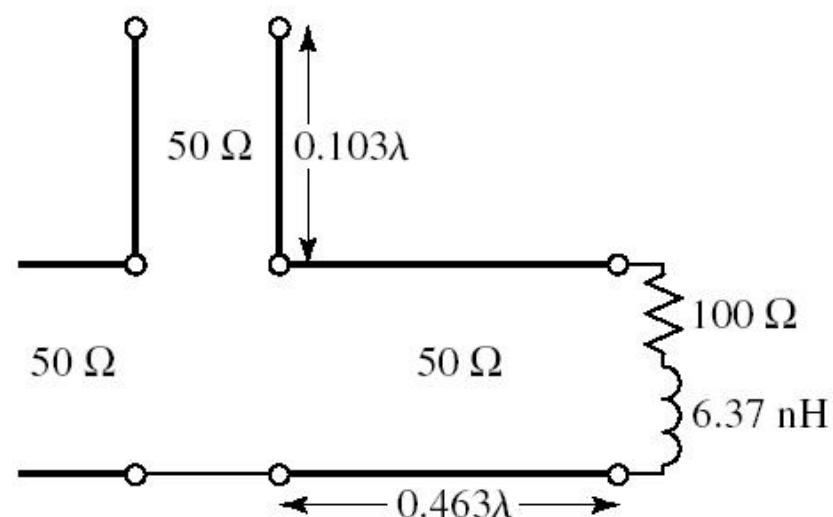
$$r_{in} = 1$$

Exemplu, Series Stub, gol

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

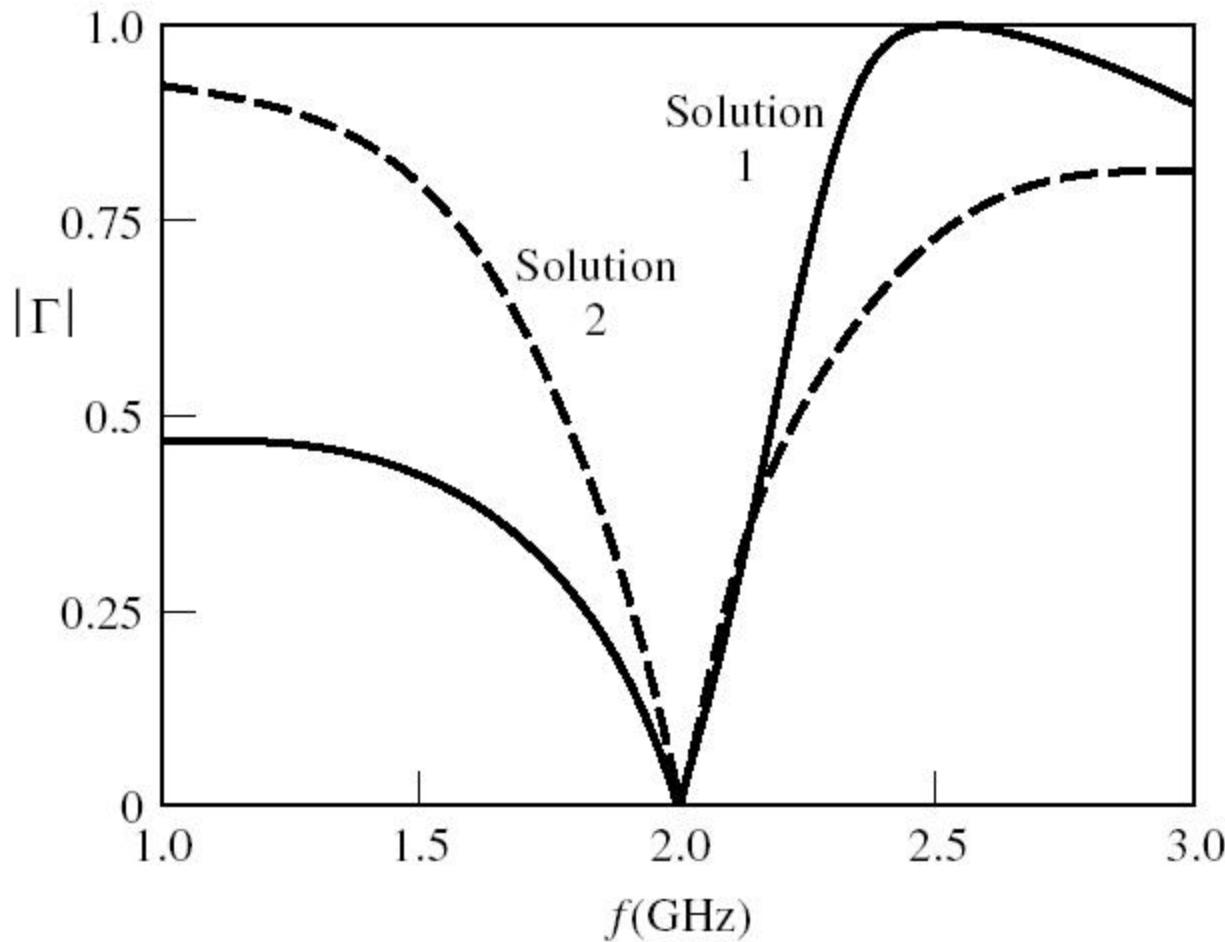


Solution 1

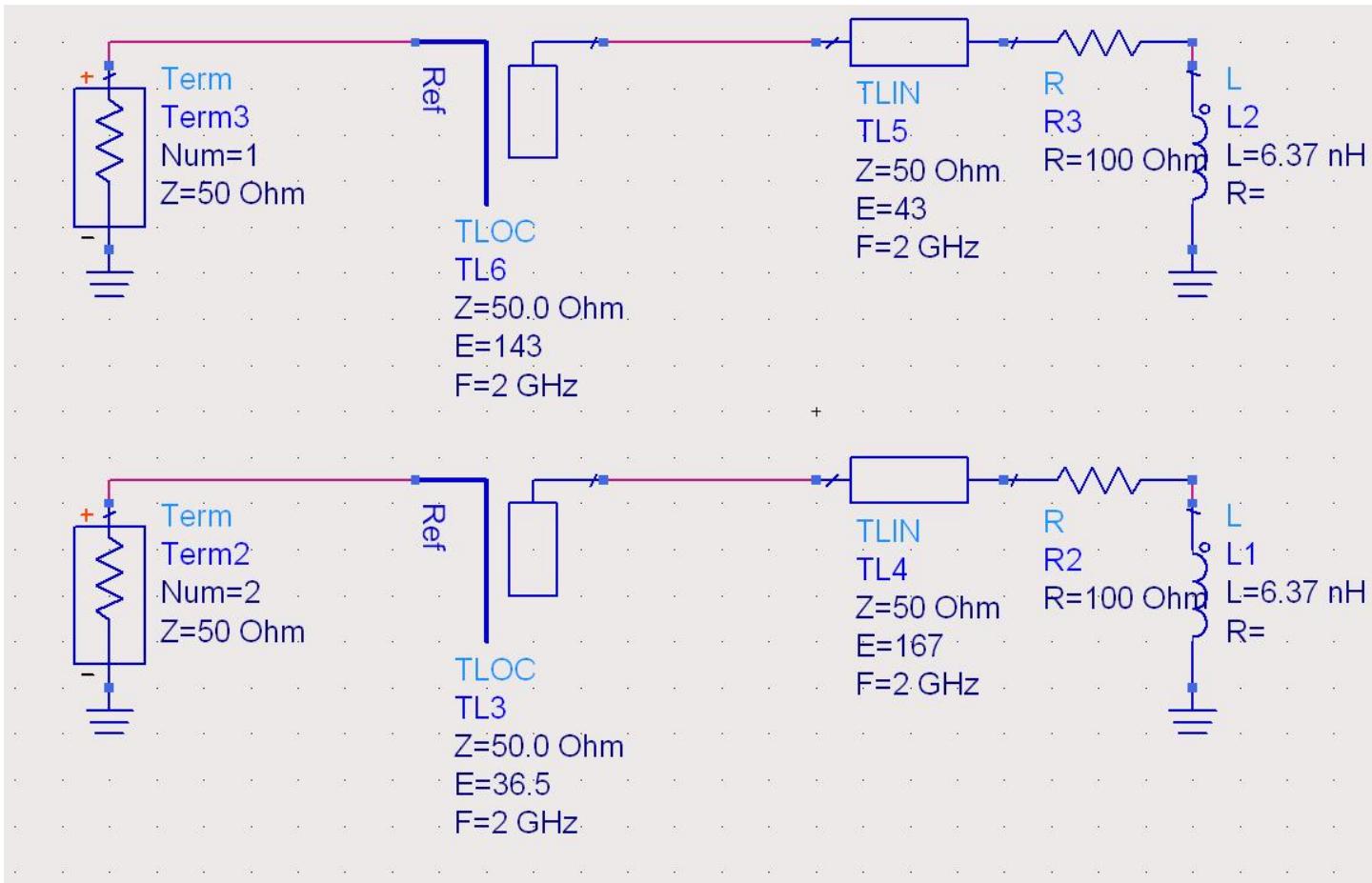


Solution 2

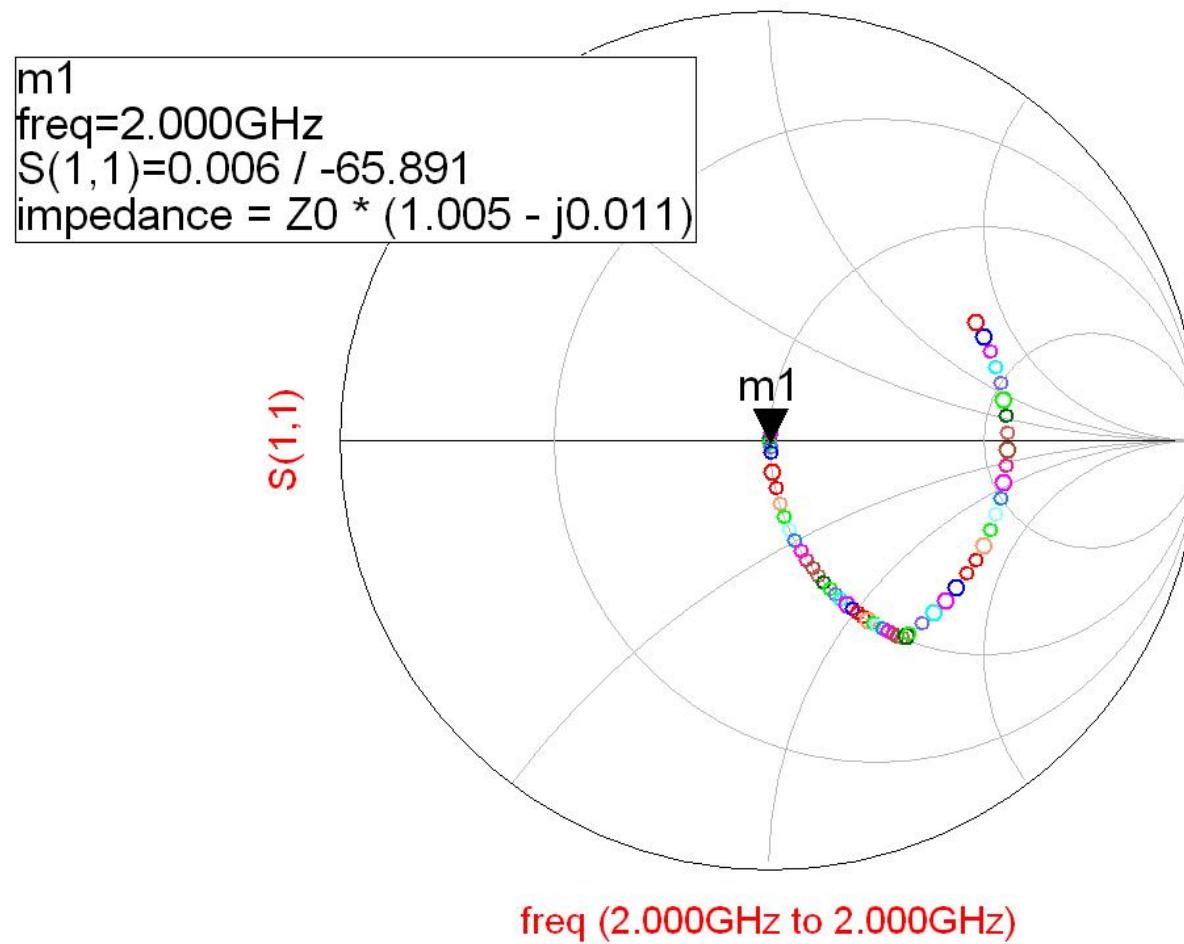
Exemplu, Series Stub, gol



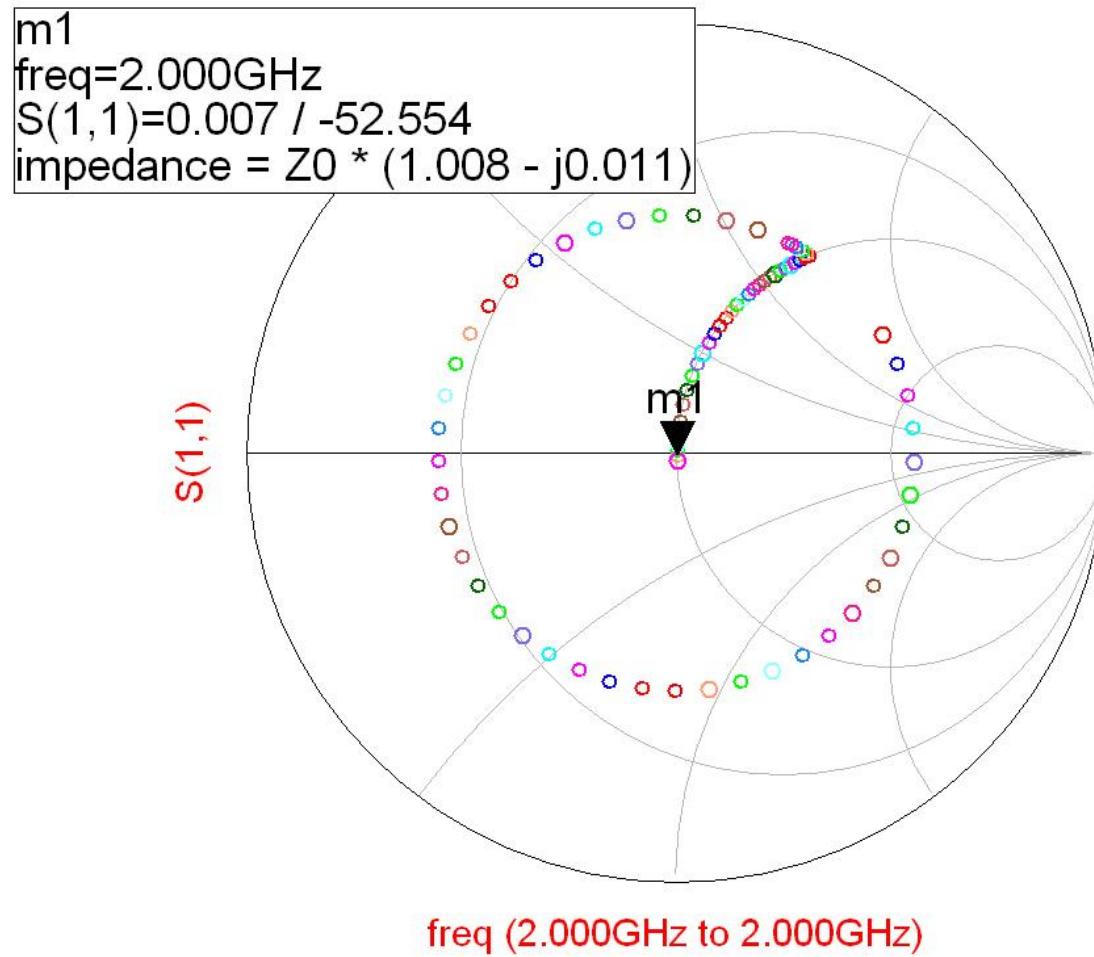
Exemplu, Series Stub, gol



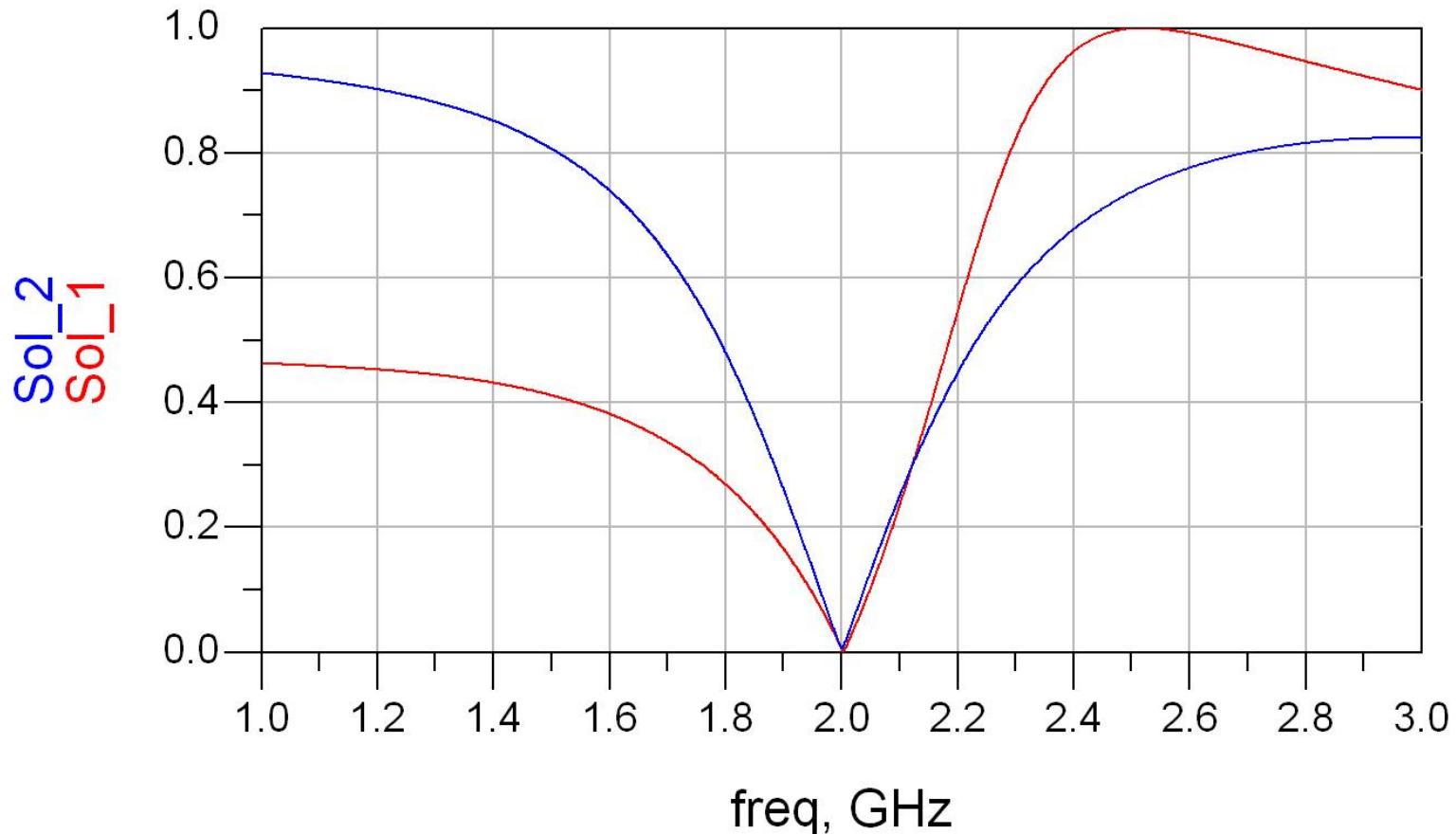
Exemplu, Series Stub, gol



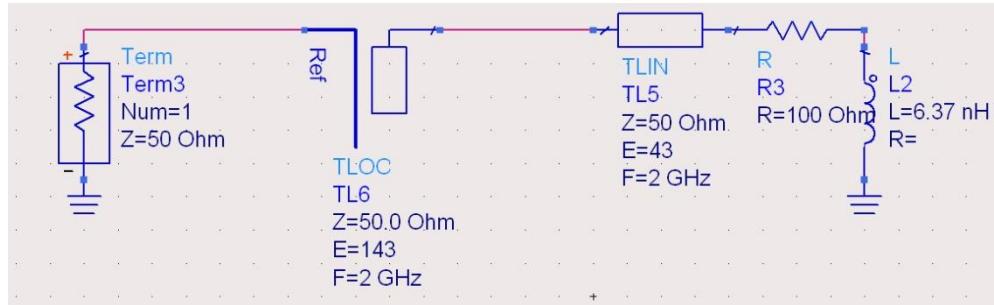
Exemplu, Series Stub, gol



Exemplu, Series Stub, gol



Exemplu, Series Stub, gol

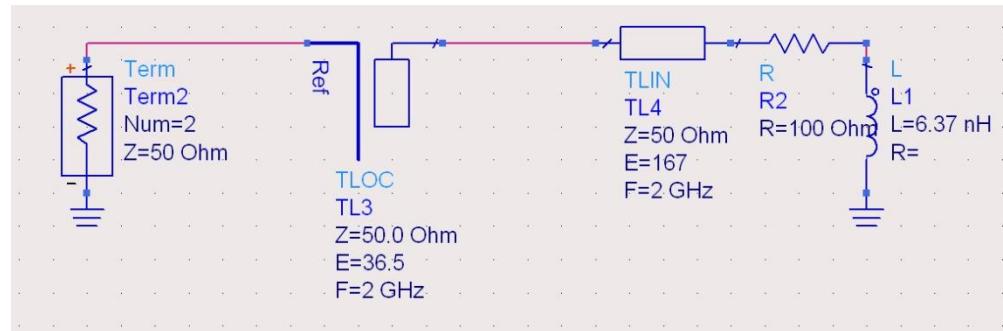


$$l_1 = \frac{43^\circ}{360^\circ} \cdot \lambda = 0.119 \cdot \lambda$$

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

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

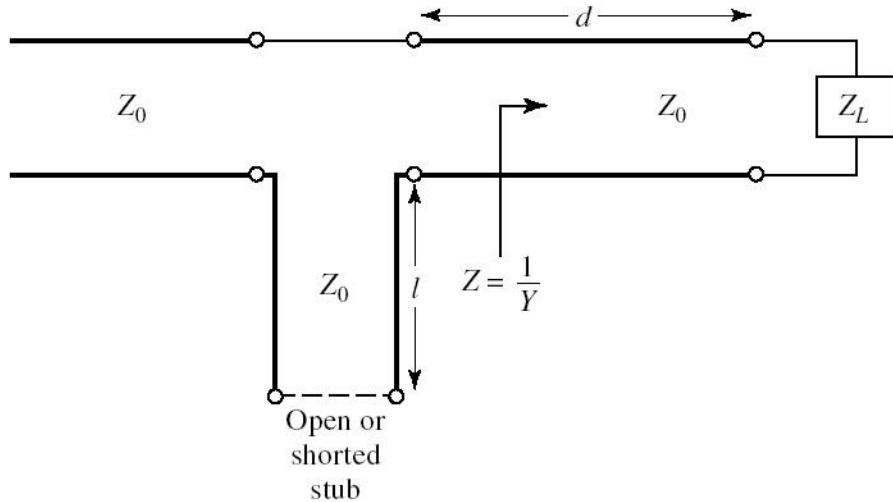
$$l_2 = \frac{36.5^\circ}{360^\circ} \cdot \lambda = 0.101 \cdot \lambda$$



Solutie analitica

Series Stub

Solutie analitica, impedante



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

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

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

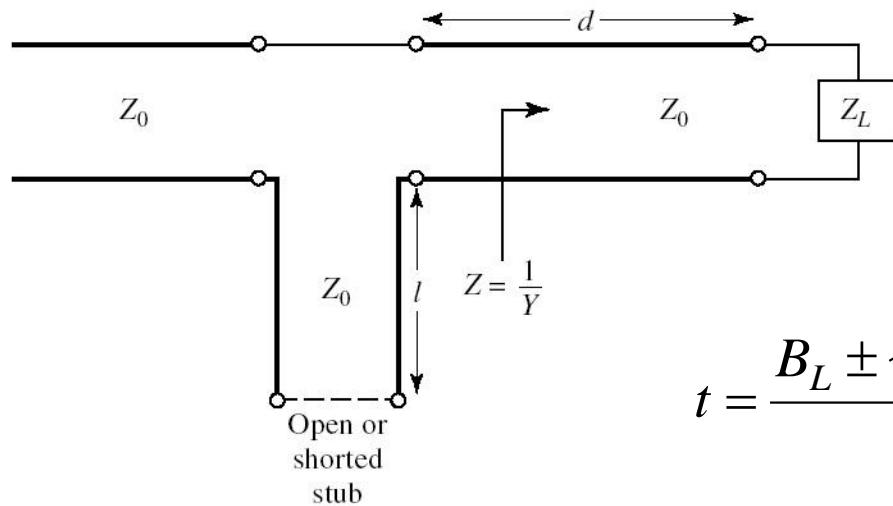
$$t = \tan \beta \cdot d \quad Z = R + j \cdot X = \frac{1}{Y}$$

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

- 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



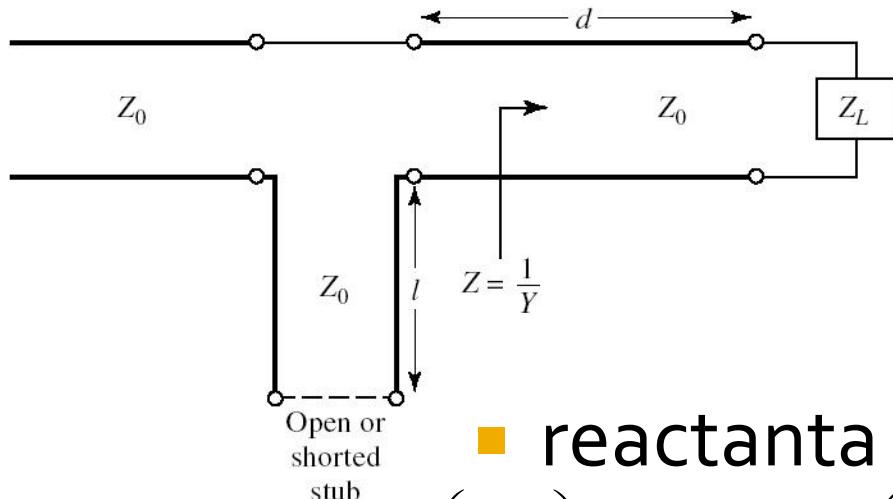
$$t = \frac{-B_L}{2 \cdot Y_0}, \quad G_L = Y_0$$

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

- 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:

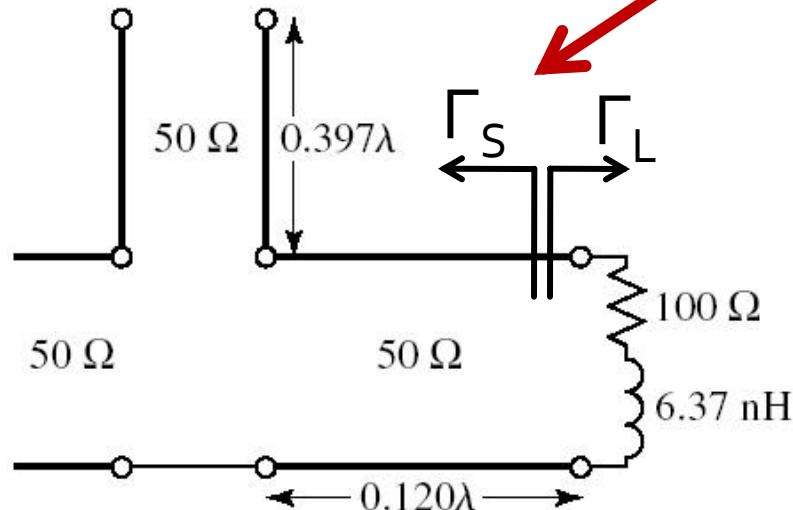
$$\frac{l_{sc}}{\lambda} = \frac{1}{2\pi} \cdot \arctan \left(\frac{X_S}{Z_0} \right) = \frac{-1}{2\pi} \cdot \arctan \left(\frac{X}{Z_0} \right)$$

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

■ 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

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

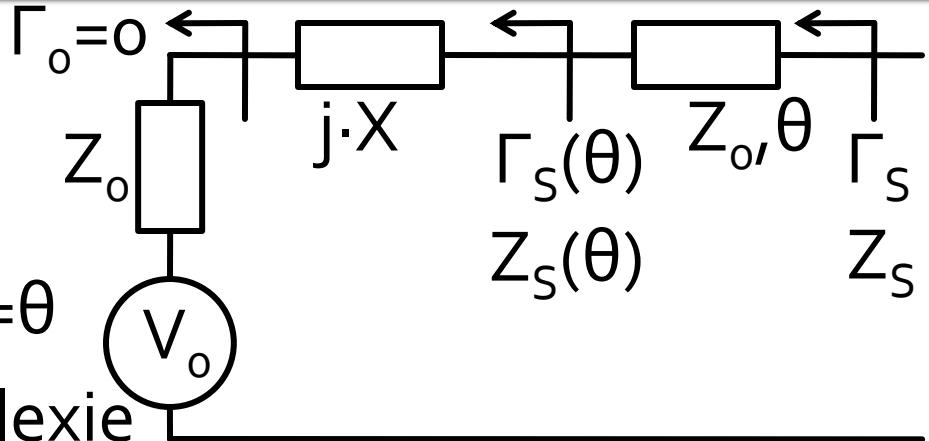
$$\Gamma_s = 0.555 \angle -29.92^\circ$$

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

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 :

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

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

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

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

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

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

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

Calcul analitic, linie serie (calcul)

- Ecuatia pentru calcularea 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} :

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

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

- 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 $j \cdot X$

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

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

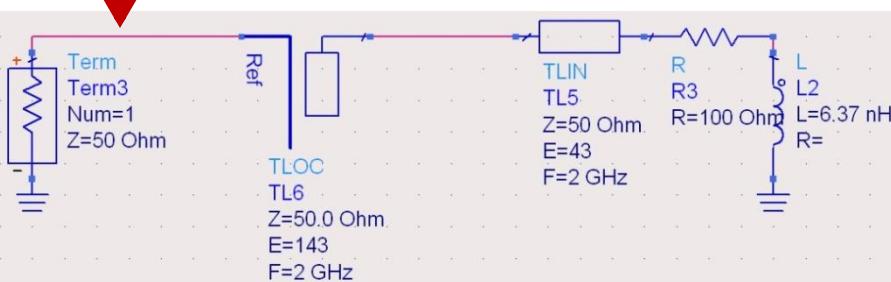
Calcul analitic (calcul efectiv)

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

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

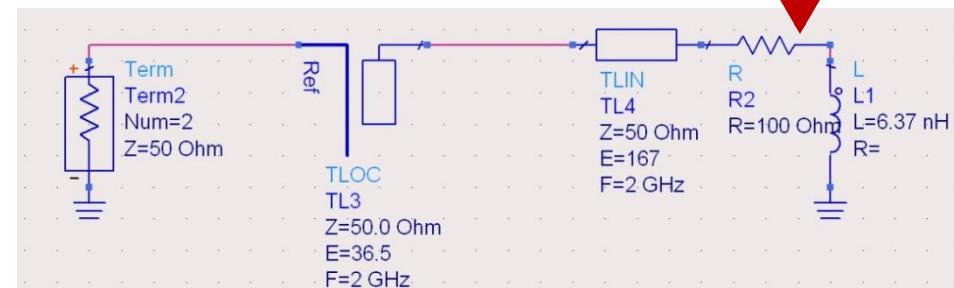
$$l_1 = \frac{43.1^\circ}{360^\circ} \cdot \lambda = 0.120 \cdot \lambda$$

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



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

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

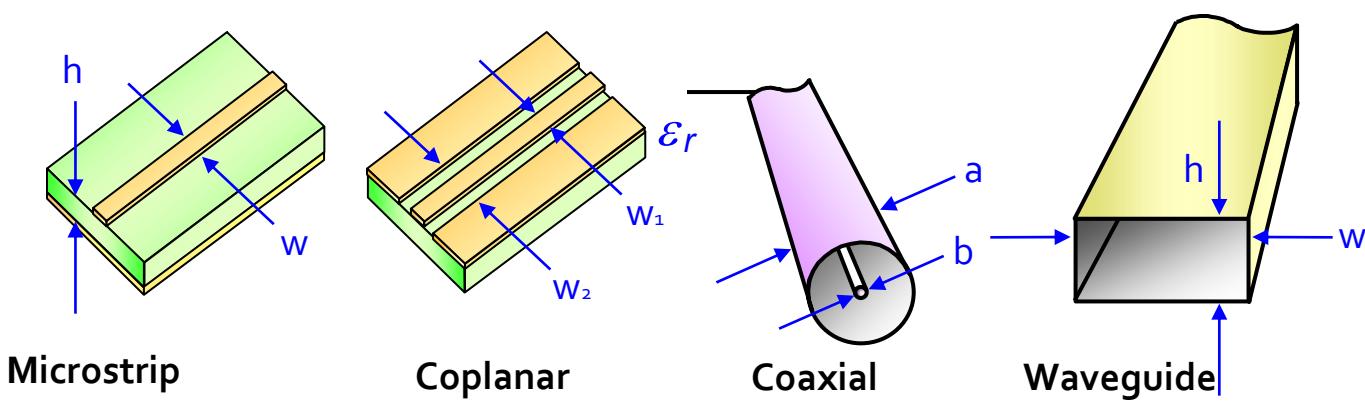


Adaptarea cu sectiuni de linii (stub)

- 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)



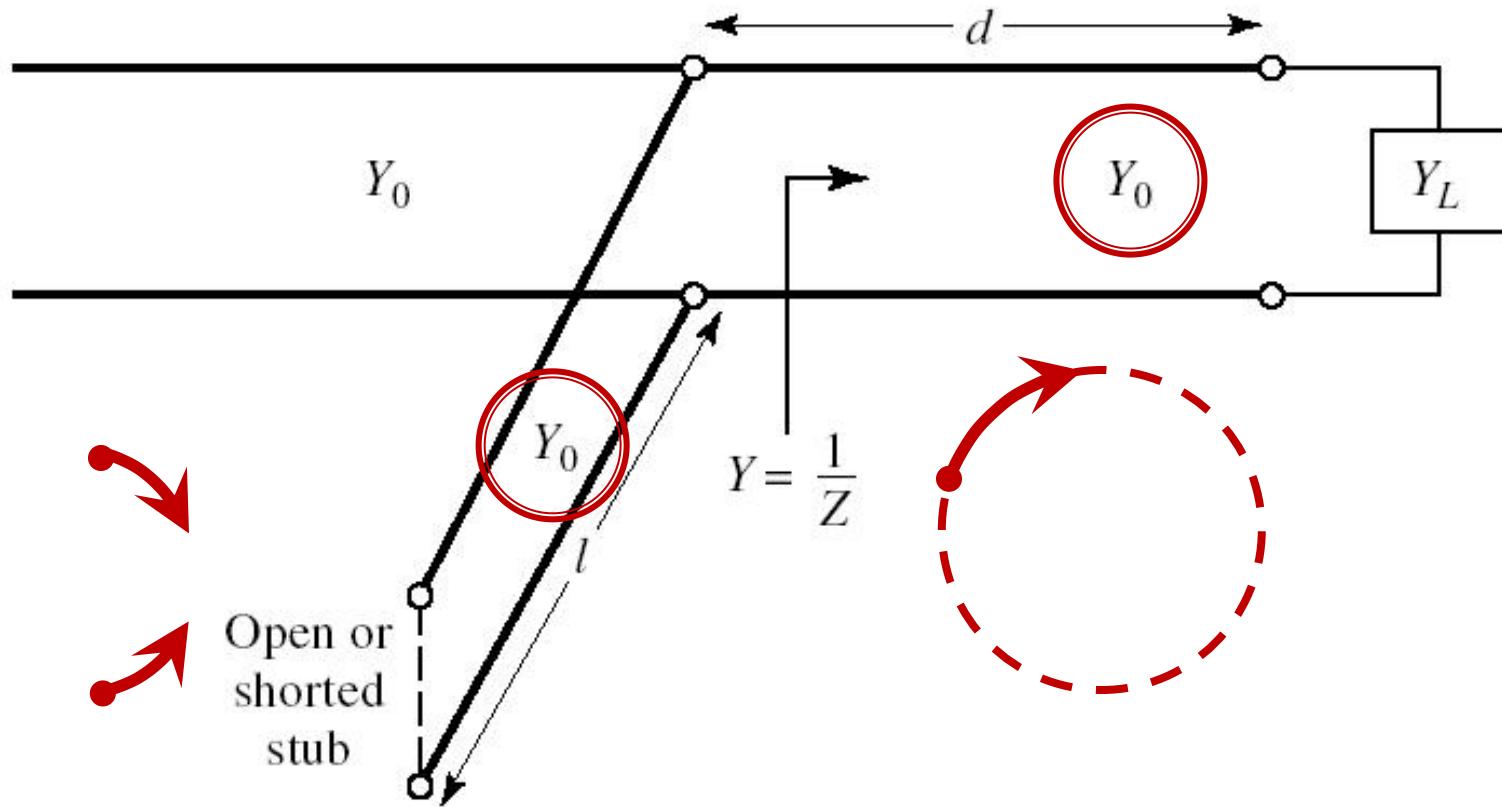
- Dezavantaj:
 - lungimea sectiunii de linie serie e variabila

Solutii analitice

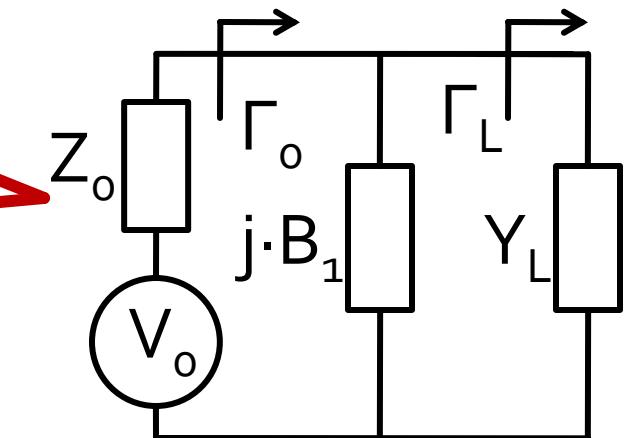
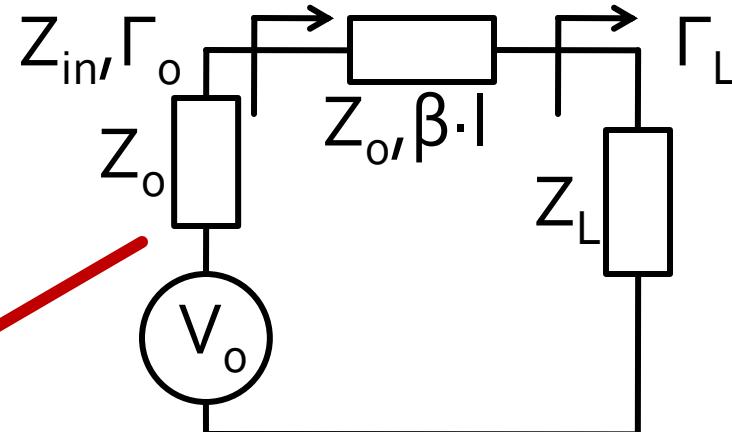
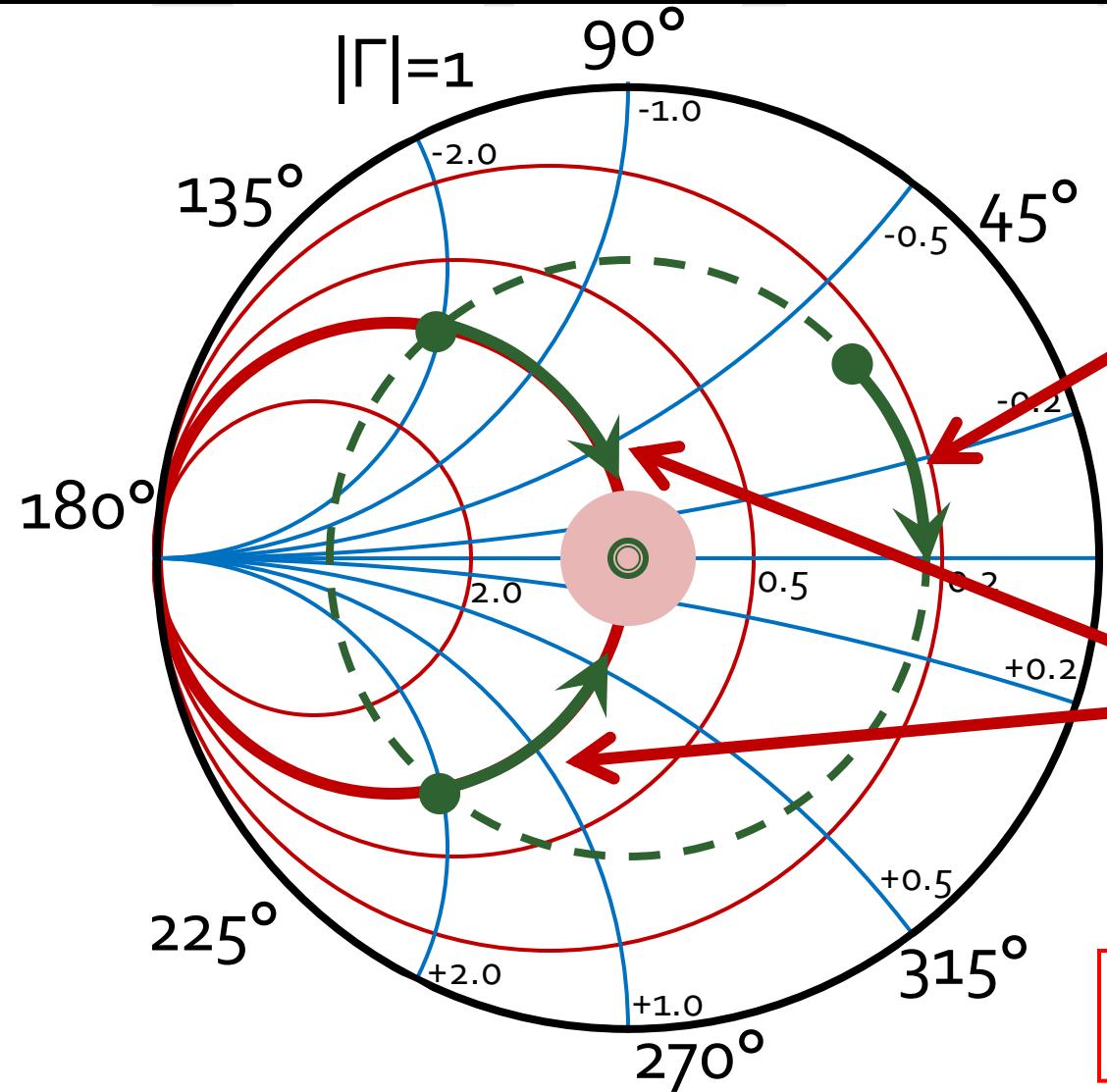
Examen / Proiect

Caz 1, Shunt Stub

- Shunt Stub (secțiune de linie în paralel)



Adaptare, linie serie + susceptanta in paralel



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

$$g_{in} = 1$$

Calcul analitic (calcul efectiv)

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

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

$$|\Gamma_s| = 0.593; \quad \varphi = 46.85^\circ \quad \cos(\varphi + 2\theta) = -0.593 \Rightarrow (\varphi + 2\theta) = \pm 126.35^\circ$$

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

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

- **solutia "cu +"** 

$$(46.85^\circ + 2\theta) = +126.35^\circ \quad \theta = +39.7^\circ \quad \text{Im } y_s = \frac{-2 \cdot |\Gamma_s|}{\sqrt{1 - |\Gamma_s|^2}} = -1.472$$

$$\theta_{sp} = \tan^{-1}(\text{Im } y_s) = -55.8^\circ (+180^\circ) \rightarrow \theta_{sp} = 124.2^\circ$$

- **solutia "cu -"** 

$$(46.85^\circ + 2\theta) = -126.35^\circ \quad \theta = -86.6^\circ (+180^\circ) \rightarrow \theta = 93.4^\circ$$

$$\text{Im } y_s = \frac{+2 \cdot |\Gamma_s|}{\sqrt{1 - |\Gamma_s|^2}} = +1.472 \quad \theta_{sp} = \tan^{-1}(\text{Im } y_s) = 55.8^\circ$$

Calcul analitic (calcul efectiv)

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

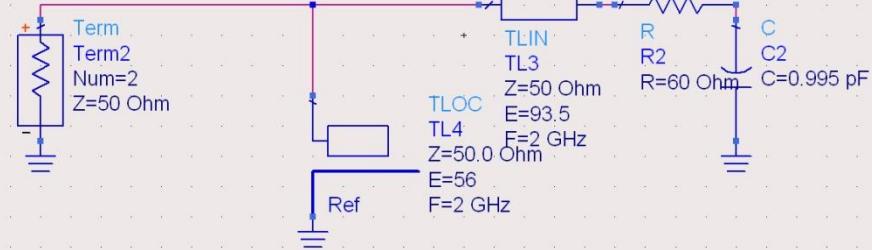
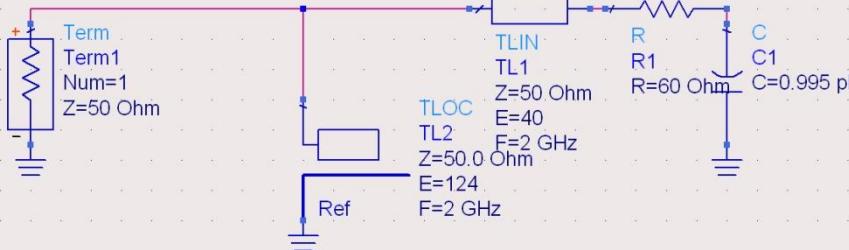
- Se alege **una** din cele doua solutii posibile
- **Semnul (+/-)** solutiei alese la **prima** ecuatie impune **semnul** solutiei utilizate la a **doua** ecuatie

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

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

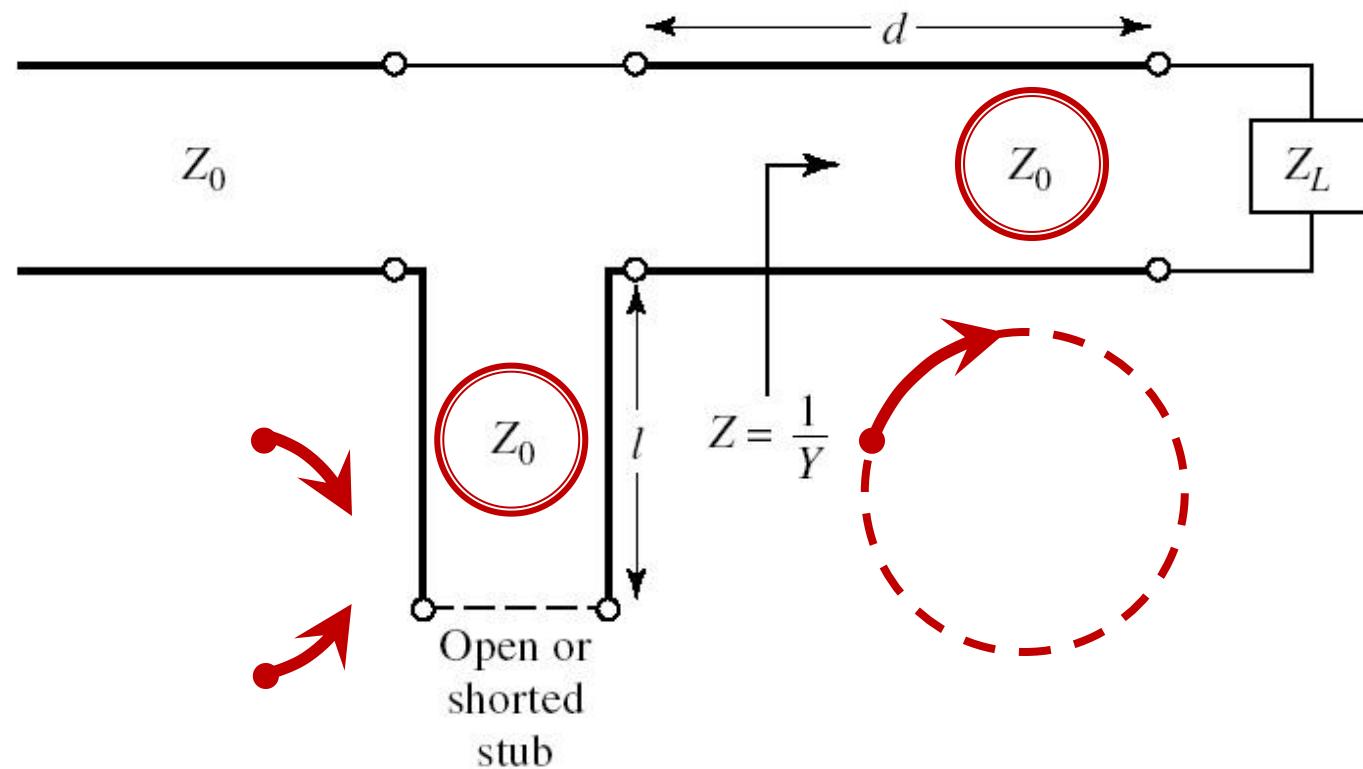
$$l_1 = \frac{93.4^\circ}{360^\circ} \cdot \lambda = 0.259 \cdot \lambda$$

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

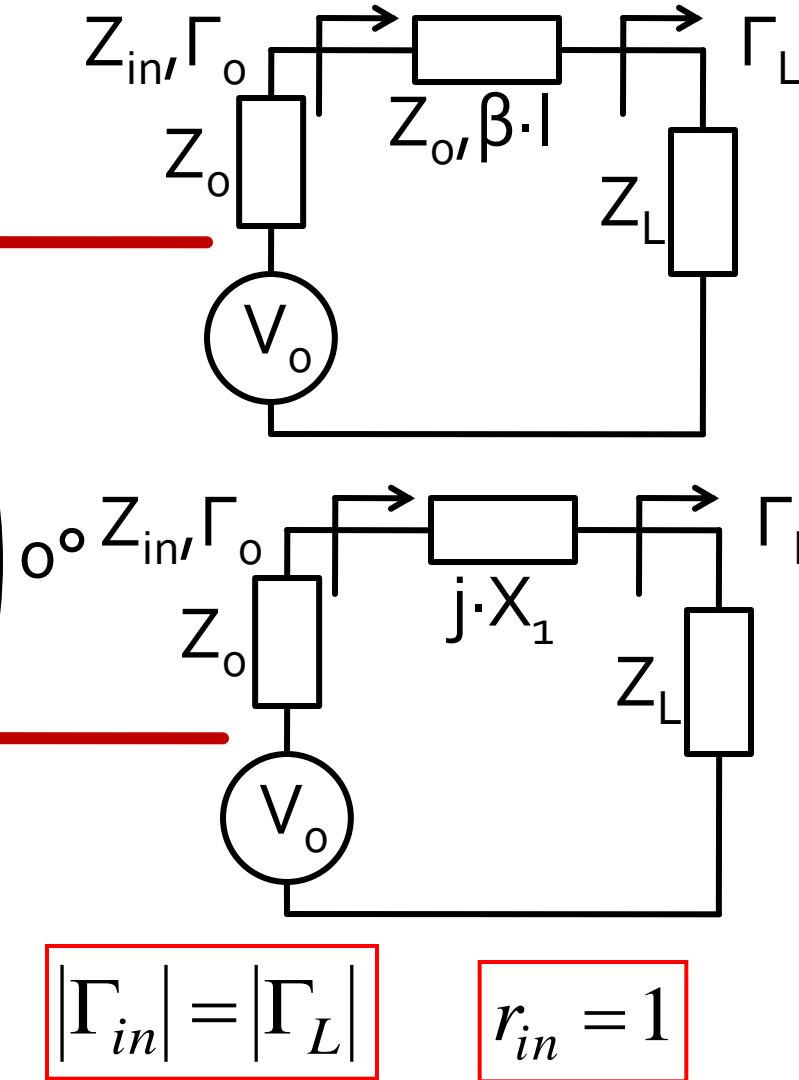
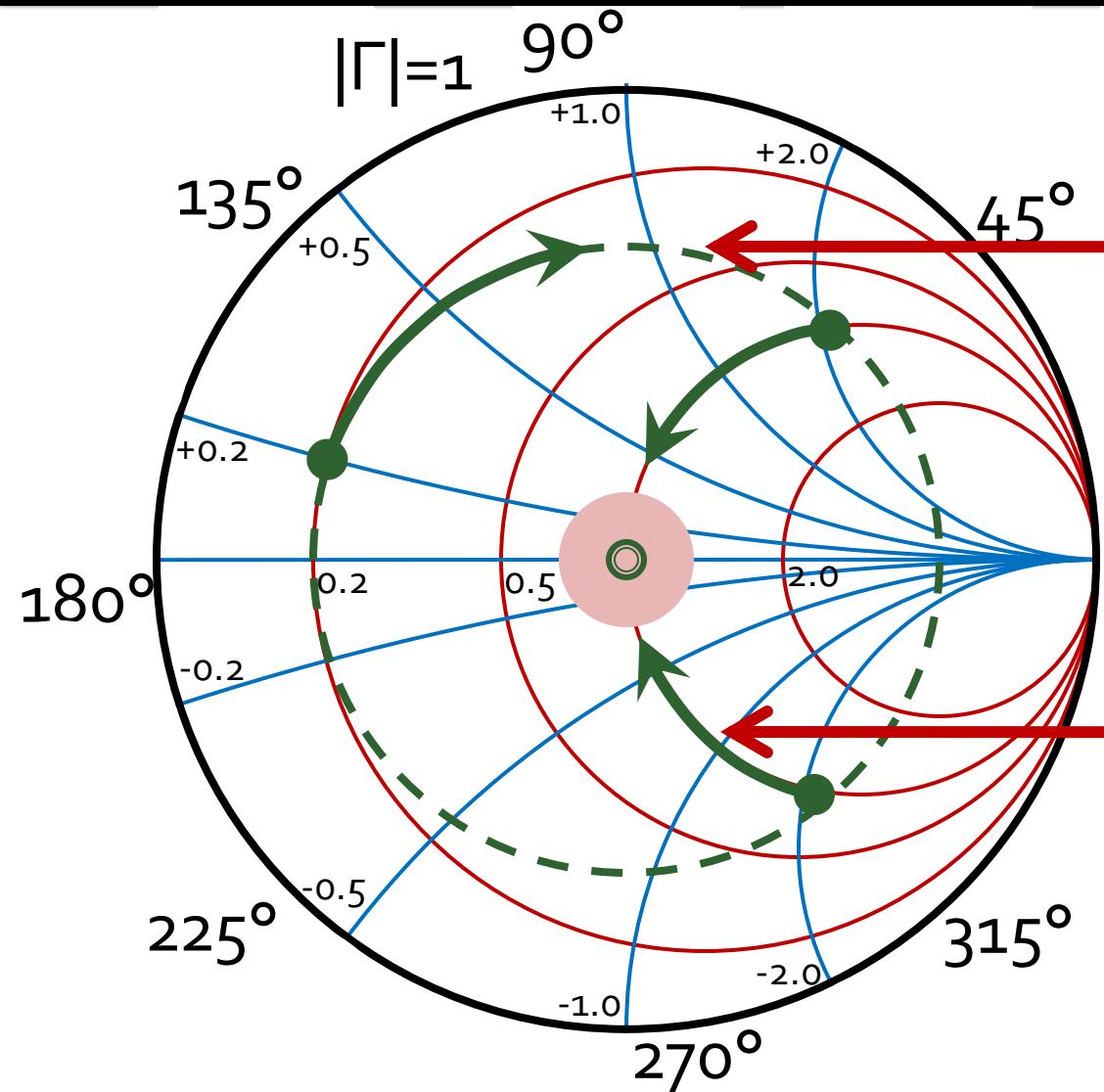


Caz 2, Series Stub

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



Adaptare, linie serie + reactanta in serie



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

$$r_{in} = 1$$

Calcul analitic (calcul efectiv)

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

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

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

$$|\Gamma_s| = 0.555; \quad \varphi = -29.92^\circ \quad \cos(\varphi + 2\theta) = 0.555 \Rightarrow (\varphi + 2\theta) = \pm 56.28^\circ$$

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

- **solutia "cu +"**

$$(-29.92^\circ + 2\theta) = +56.28^\circ$$

$$\theta = 43.1^\circ$$

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

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

- **solutia "cu -"**

$$(-29.92^\circ + 2\theta) = -56.28^\circ$$

$$\theta = -13.2^\circ (+180^\circ) \rightarrow \theta = 166.8^\circ$$

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

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

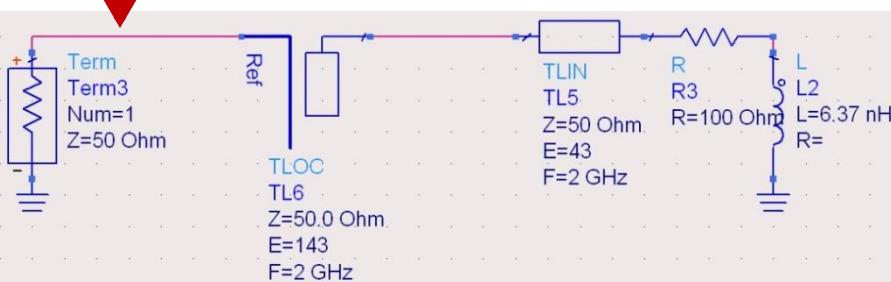
Calcul analitic (calcul efectiv)

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

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

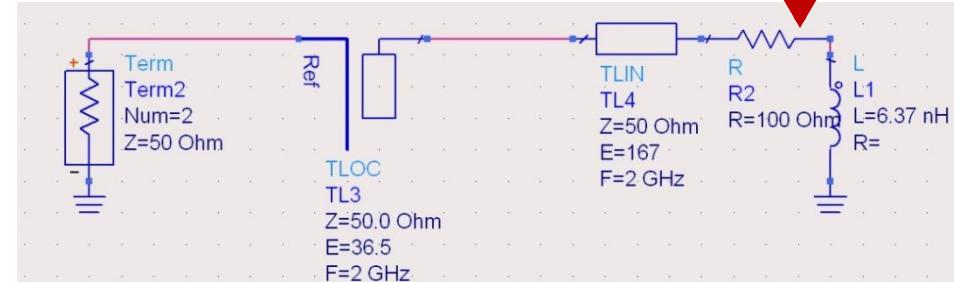
$$l_1 = \frac{43.1^\circ}{360^\circ} \cdot \lambda = 0.120 \cdot \lambda$$

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



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

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



Stub, observatii

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

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

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

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

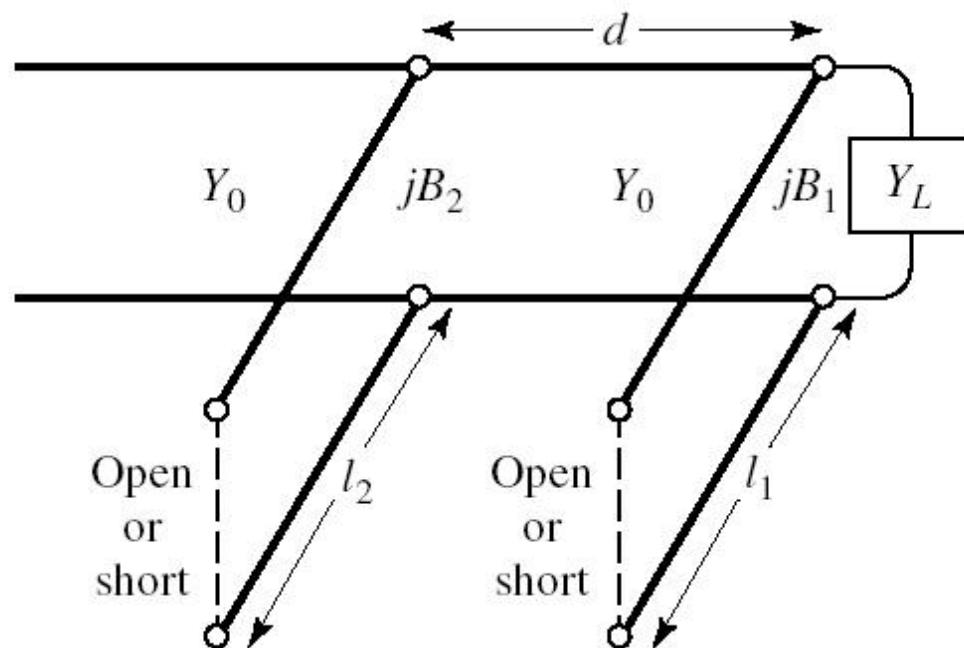
- pentru stub se poate adauga/scadea 90° ($\lambda/4$) simultan cu schimbare **gol** \Leftrightarrow **scurtcircuit**

Double stub tuning

Adaptarea cu două secțiuni de linie

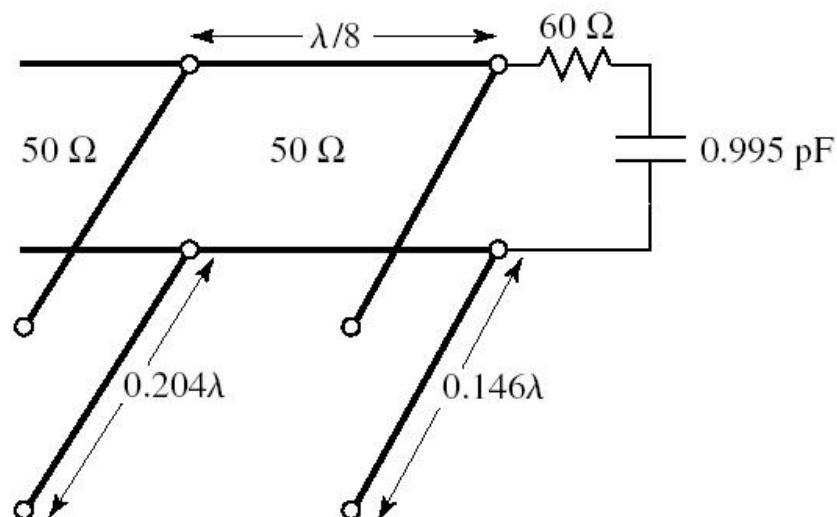
Adaptarea cu două secțiuni de linie

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

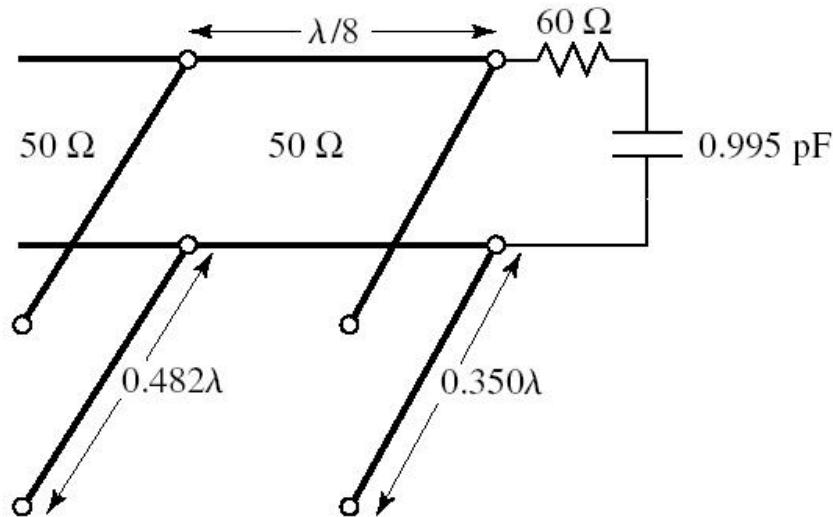


Adaptarea cu două secțiuni de linie

- Două soluții posibile



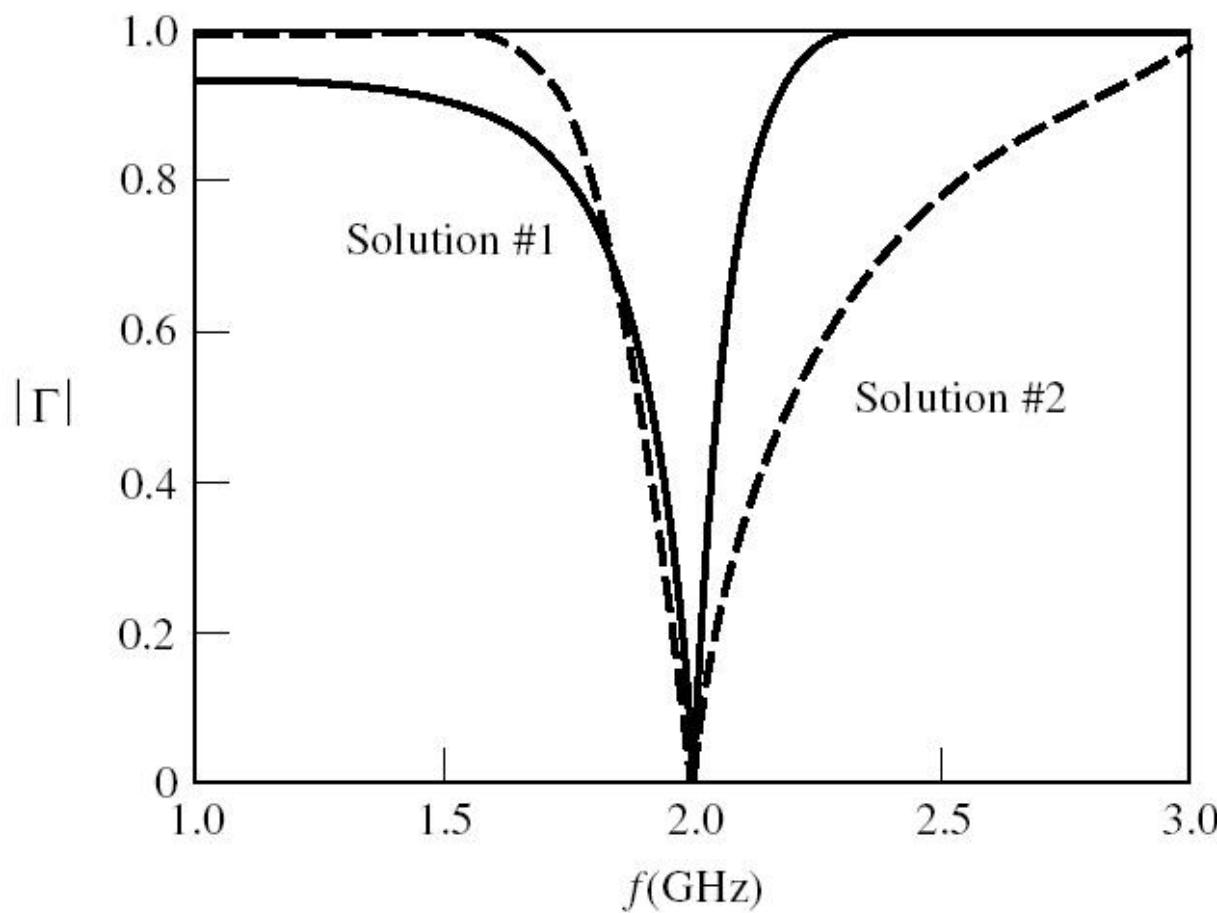
Solution 1



Solution 2

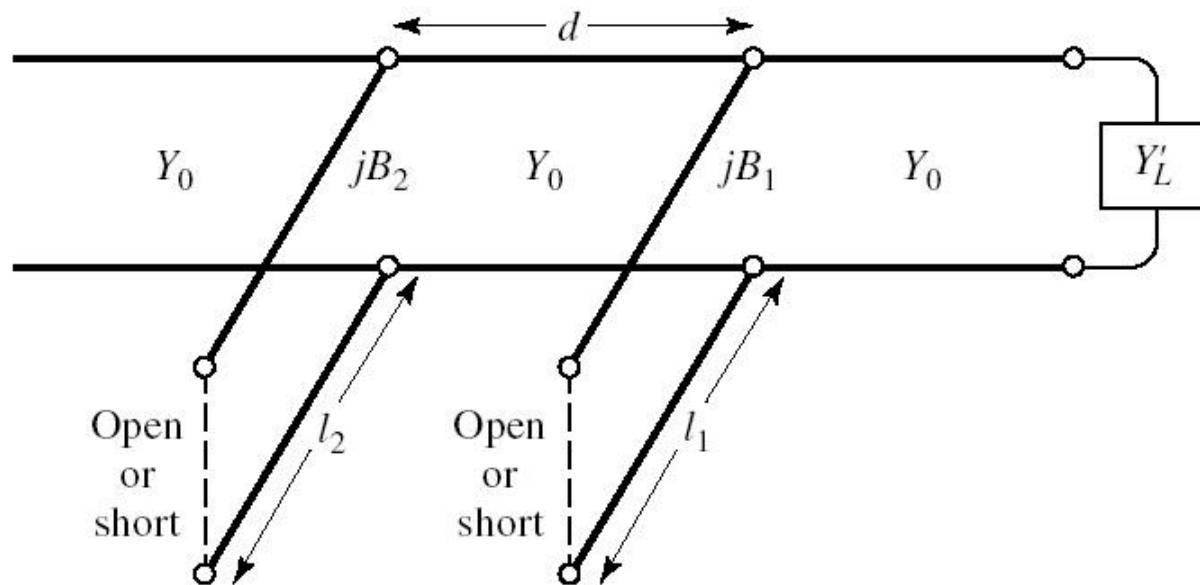
Adaptarea cu două sectiuni de linie

- Două solutii posibile

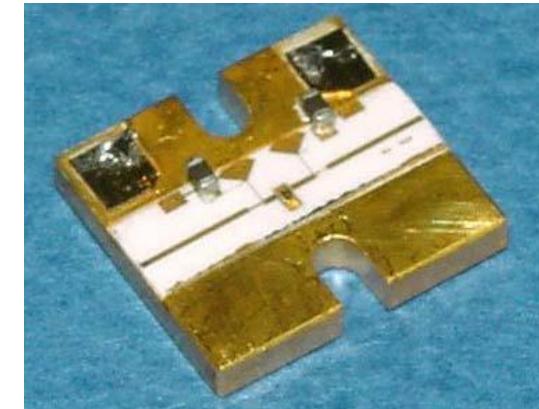
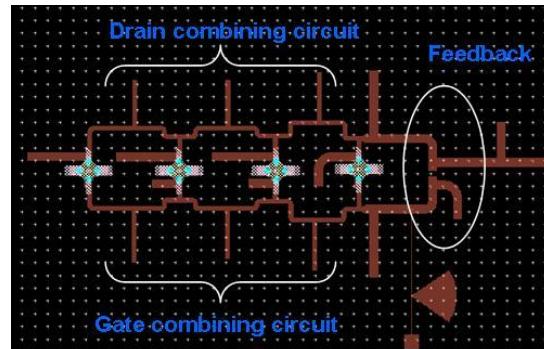
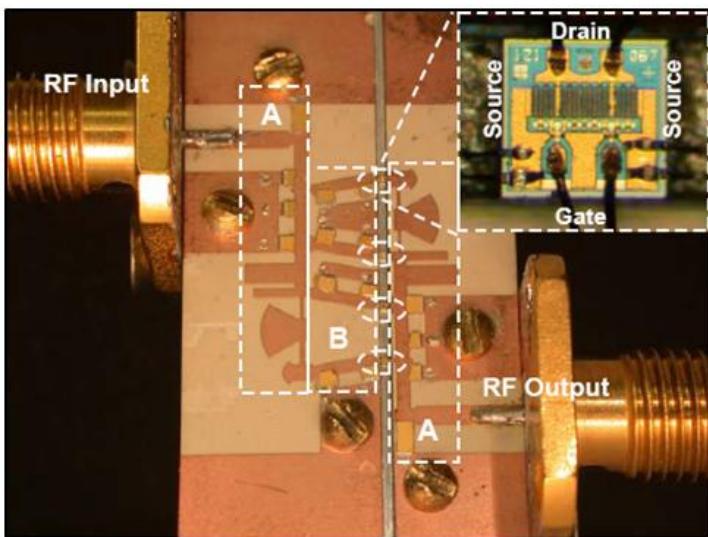
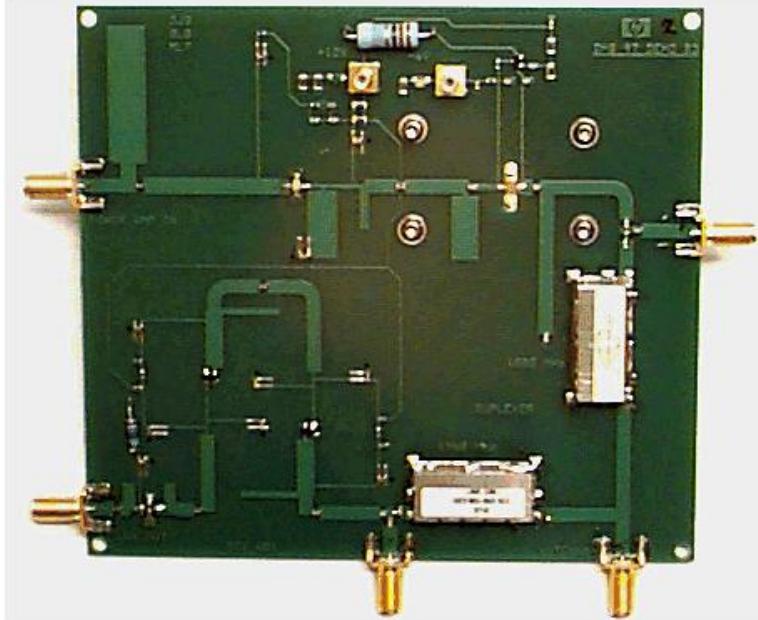
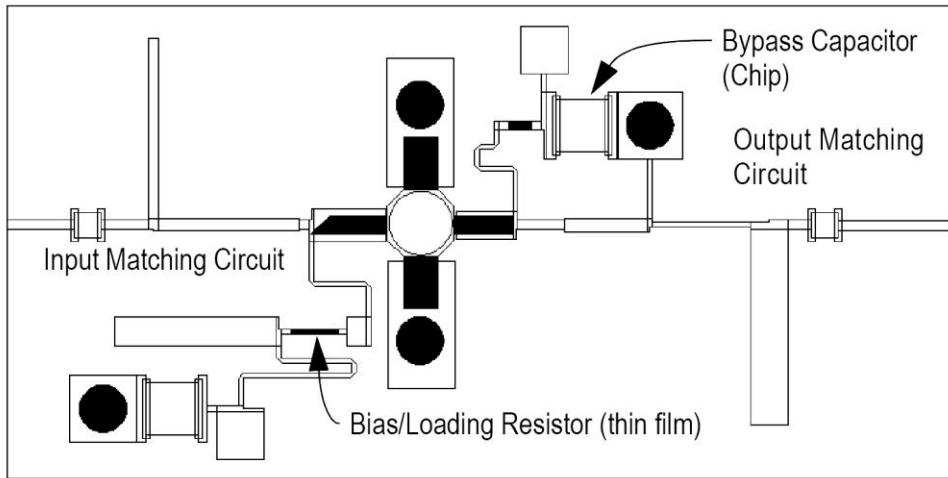


Adaptarea cu două secțiuni de linie

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



Adaptarea cu sectiuni de linie



Contact

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