Curs 7
2025/2026

Dispozitive şi circuite de microunde pentru radiocomunicații

Disciplina 2025/2026

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

Disciplina 2025/2026

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

Documentatie

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

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

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

English
Romana

Microwave Devices and Circuits for Radiocommunicati

Course: DCMR (2024-2025)

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

Activities

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

Evaluation

Type: **Exam**

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

Grades

Aggregate Results

Documentatie

- RF-OPTO
  - https://rf-opto.etti.tuiasi.ro ~~Moodle~~
- Fotografie
  - de trimis pe rf-opto
  - necesara la laborator/curs
  - bonus activitate 1p/0.5p (~~C4~~/C7)

Bibliografie

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

Examen: Reprezentare logaritmică

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

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

0 dB	= 1
+ 0.1 dB	= 1.023 (+2.3%)
+ 3 dB	= 2
+ 5 dB	= 3
+ 10 dB	= 10
-3 dB	= 0.5
-10 dB	= 0.1
-20 dB	= 0.01
-30 dB	= 0.001

0 dBm	= 1 mW
3 dBm	= 2 mW
5 dBm	= 3 mW
10 dBm	= 10 mW
20 dBm	= 100 mW
-3 dBm	= 0.5 mW
-10 dBm	= 100 µW
-30 dBm	= 1 µW
-60 dBm	= 1 nW

[dBm] + [dB] = [dBm]

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

[x] + [dB] = [x]

Examen

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

Linii de transmisie in mod TEM

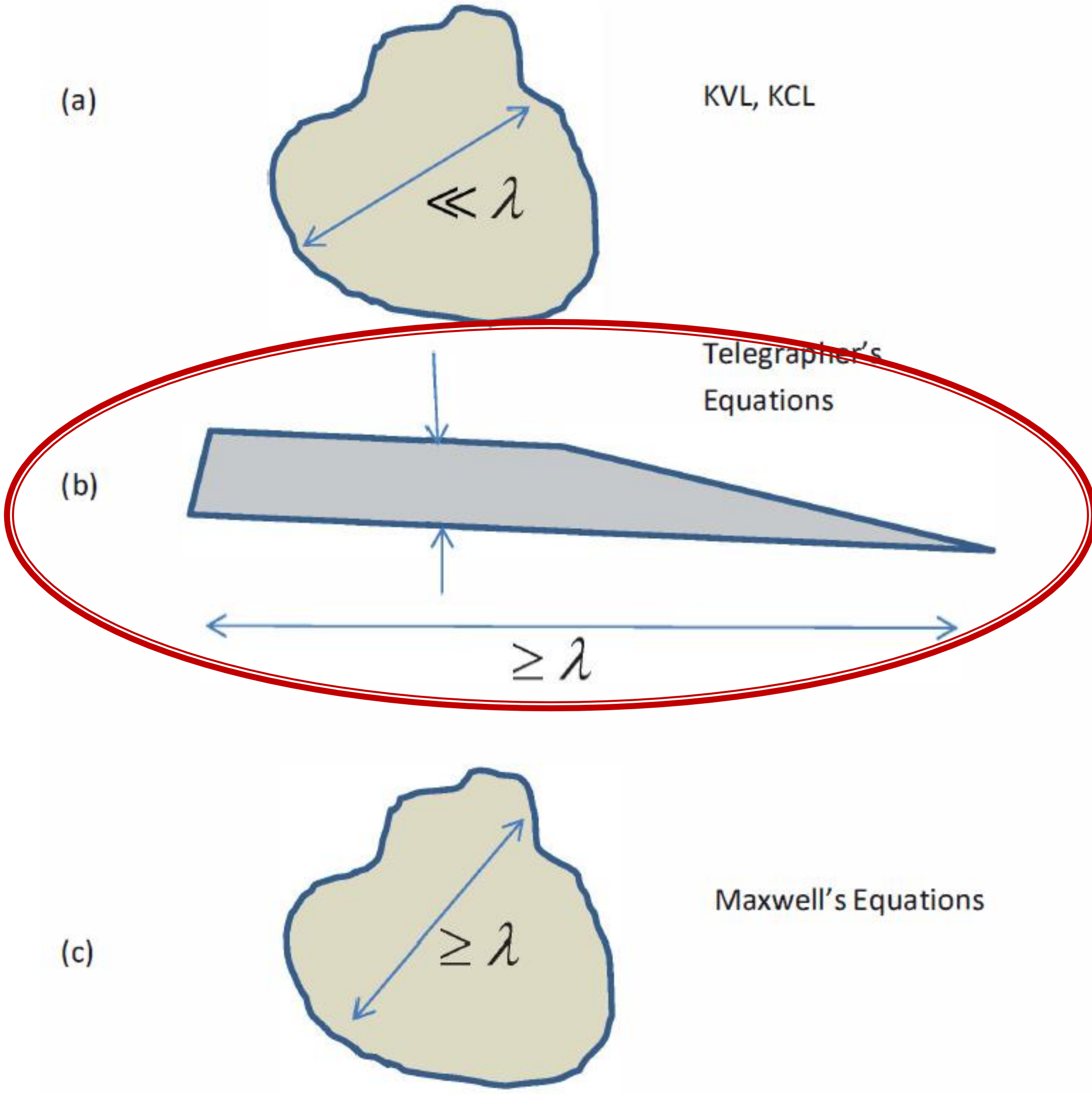
Cuprins

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

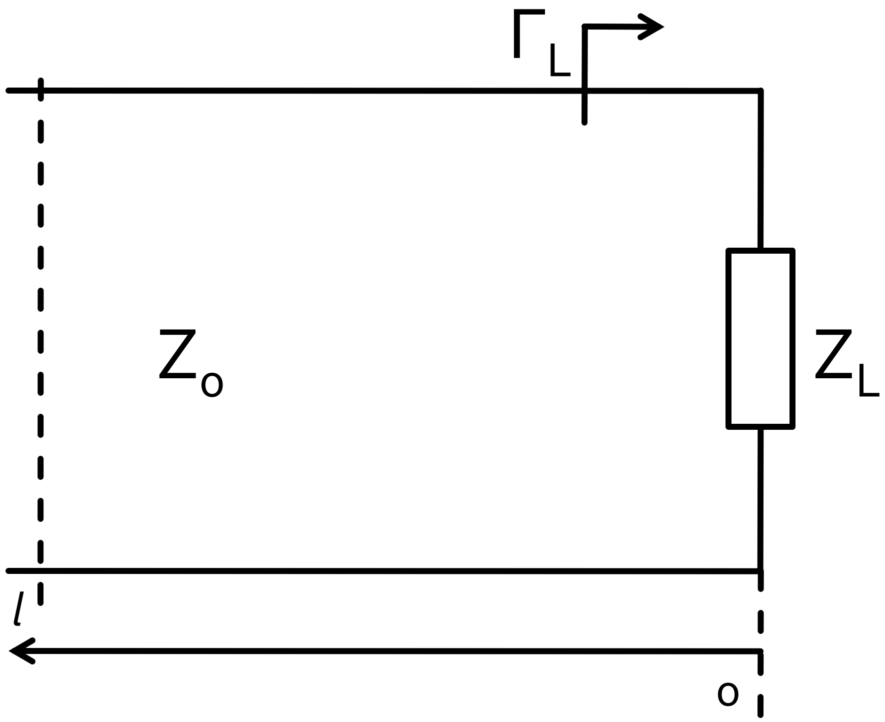
Lungime electrica

- Comportarea (descrierea) unui circuit depinde de lungimea sa electrica la frecventele de interes
  - E≈0 → Kirchhoff
  - E>0 → propagare

$$E = \beta \cdot l = \frac{2\pi}{\lambda} \cdot l = 2\pi \cdot \left(\frac{l}{\lambda} \right)$$



Linie fara pierderi



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

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

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

- coeficient de reflexie in tensiune

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

  - Z_o real

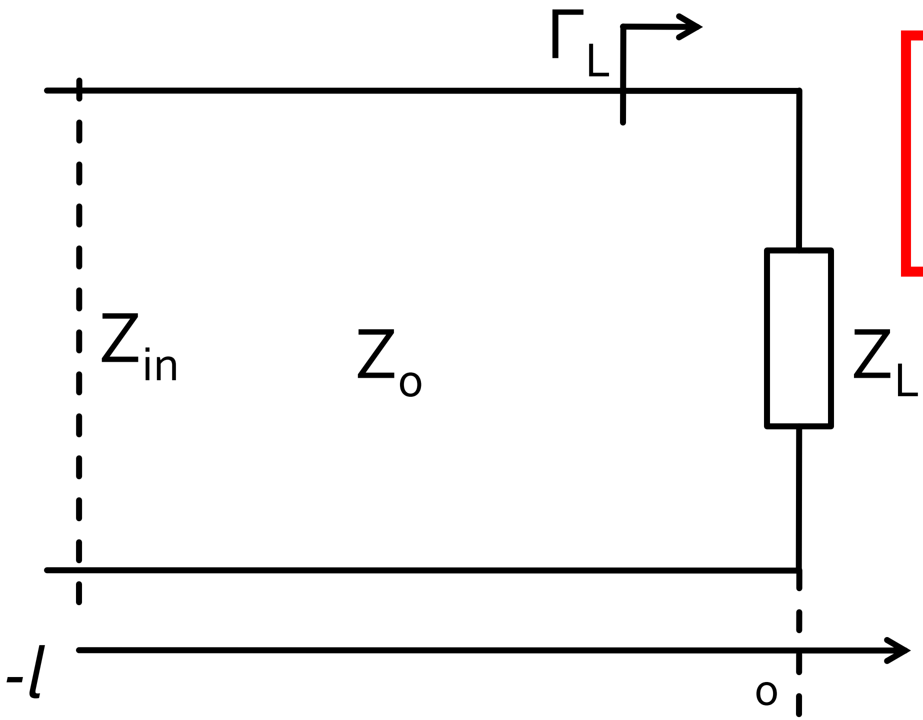
Linie fara pierderi

$$P_{avg} = \frac{1}{2} \cdot \frac{\left|V_0^+\right|^2}{Z_0} \cdot \left(1 - \left|\Gamma\right|^2\right)$$

- Puterea medie e constanta in lungul liniei
  - (**fara** $P_{avg}(\mathbf{z})$)
  - poate fi masurata
- Se utilizeaza puterea pentru a caracteriza amplitudinea semnalului
  - un punct de vedere "energetic" (fizica)
  - energie mai mare = semnal "mai mare"

Linie fara pierderi

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

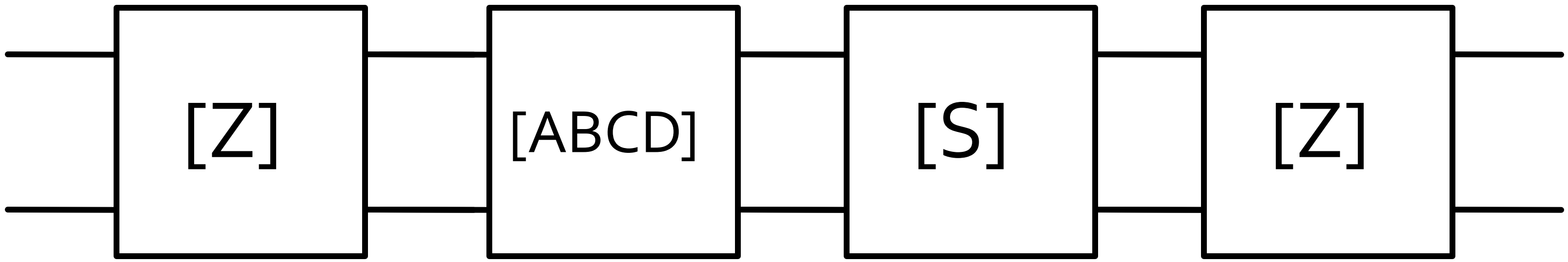


$$\boxed{Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan \beta \cdot l}{Z_0 + j \cdot Z_L \cdot \tan \beta \cdot l}}$$

Analiza la nivel de rețea a circuitelor de microunde

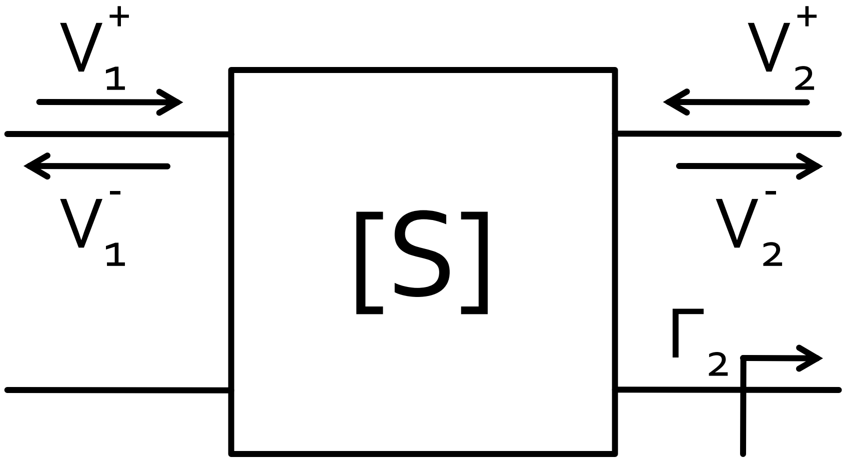
Analiza la nivel de bloc

- are ca scop separarea unui circuit complex in blocuri individuale
- acestea se analizeaza separat (decuplate de restul circuitului) si se caracterizeaza doar prin intermediul porturilor (**cutie neagra**)
- analiza la nivel de retea permite cuplarea rezultatelor individuale si obtinerea unui rezultat total pentru circuit



Matricea S (repartitie)

- Scattering parameters



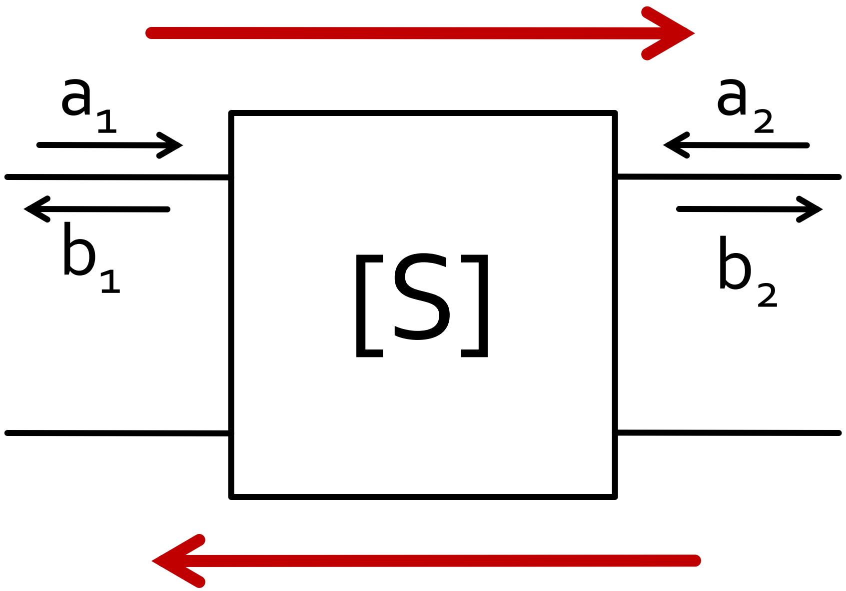
$$\begin{bmatrix} V_1^- \\ V_2^- \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \cdot \begin{bmatrix} V_1^+ \\ V_2^+ \end{bmatrix}$$

$$S_{11} = \left.\frac{V_1^-}{V_1^+}\right|_{V_2^+=0} \qquad S_{21} = \left.\frac{V_2^-}{V_1^+}\right|_{V_2^+=0}$$

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

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

Matricea S (repartitie)



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

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

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

Cuploare directionale si divizoare de putere

Cuplor directional

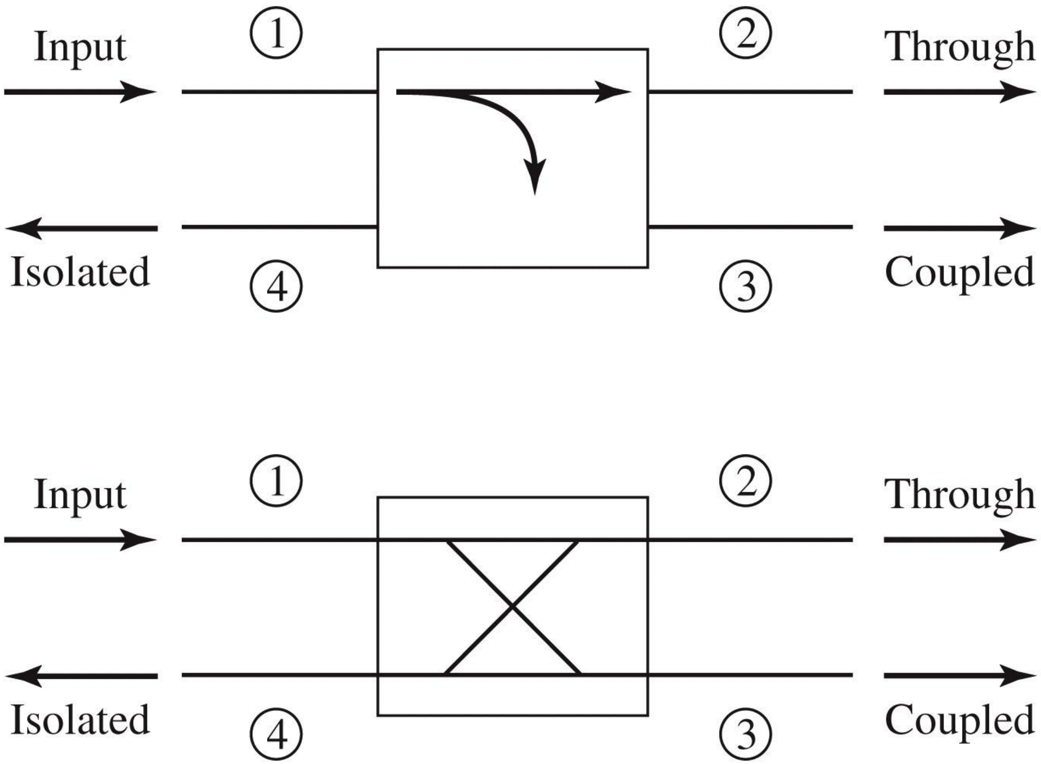


Figure 7.4

$$\left|S_{12}\right|^2 = \alpha^2 = 1 - \beta^2$$

$$\left|S_{13}\right|^2 = \beta^2$$

Cuplaj

$$C = 10\log\frac{P_1}{P_3} = -20\cdot\log(\beta)\,[\mathrm{dB}]$$

Directivitate

$$D = 10\log\frac{P_3}{P_4} = 20\cdot\log\left(\frac{\beta}{\left|S_{14}\right|}\right)[\mathrm{dB}]$$

Izolare

$$I = 10\log\frac{P_1}{P_4} = -20\cdot\log\left|S_{14}\right|\,[\mathrm{dB}]$$

$$I = D + C\,,\ \ dB$$

Continuare

Adaptarea de impedanța

Diagrama Smith

Cuprins

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

Diagrama Smith

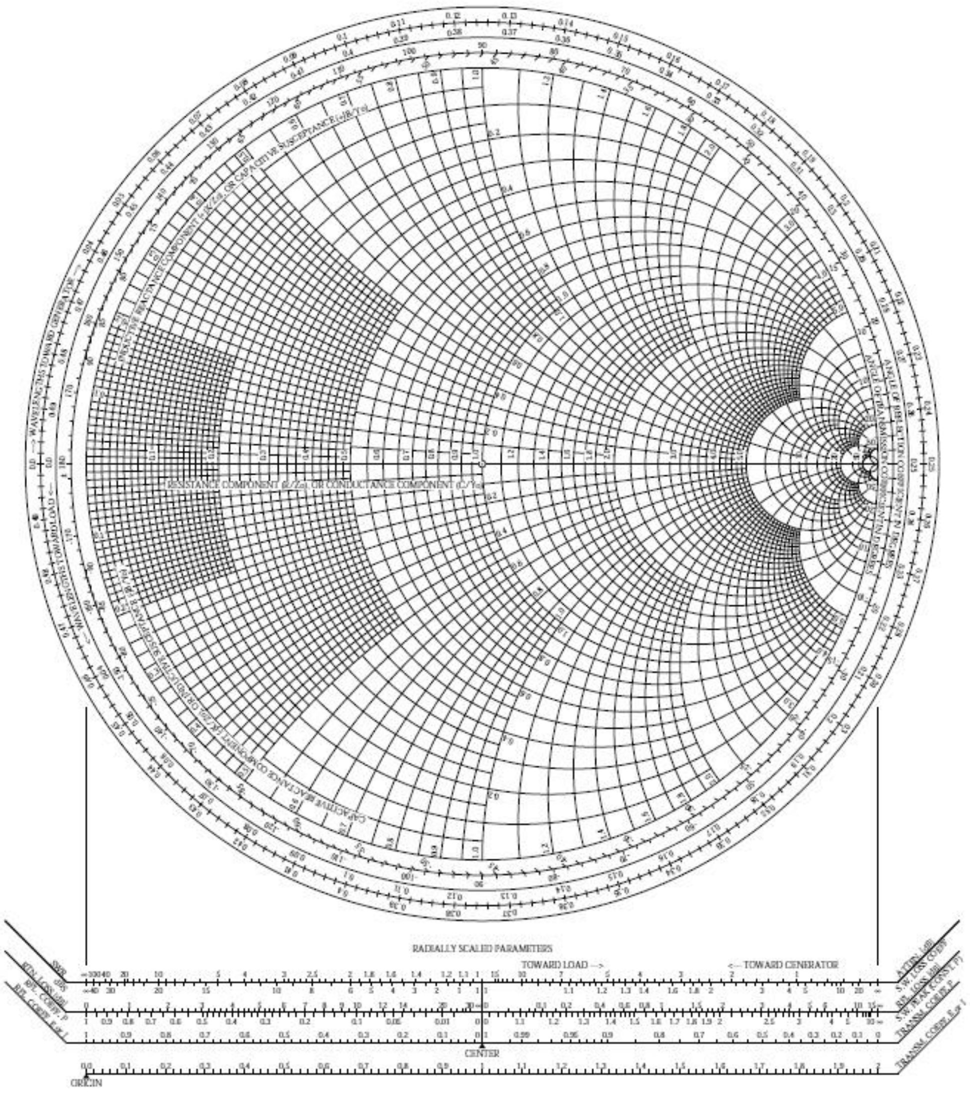


Diagrama Smith

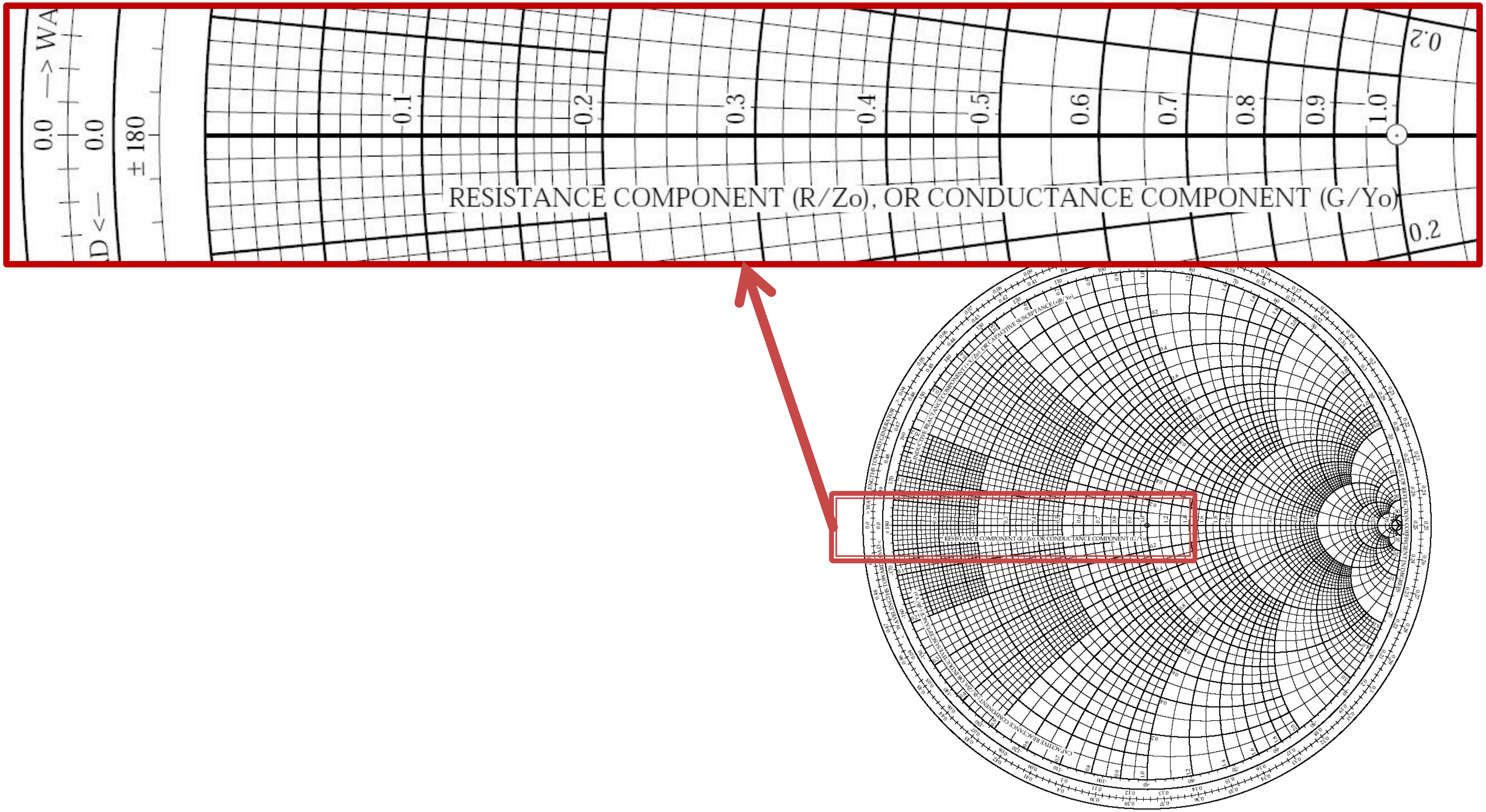


Diagrama Smith

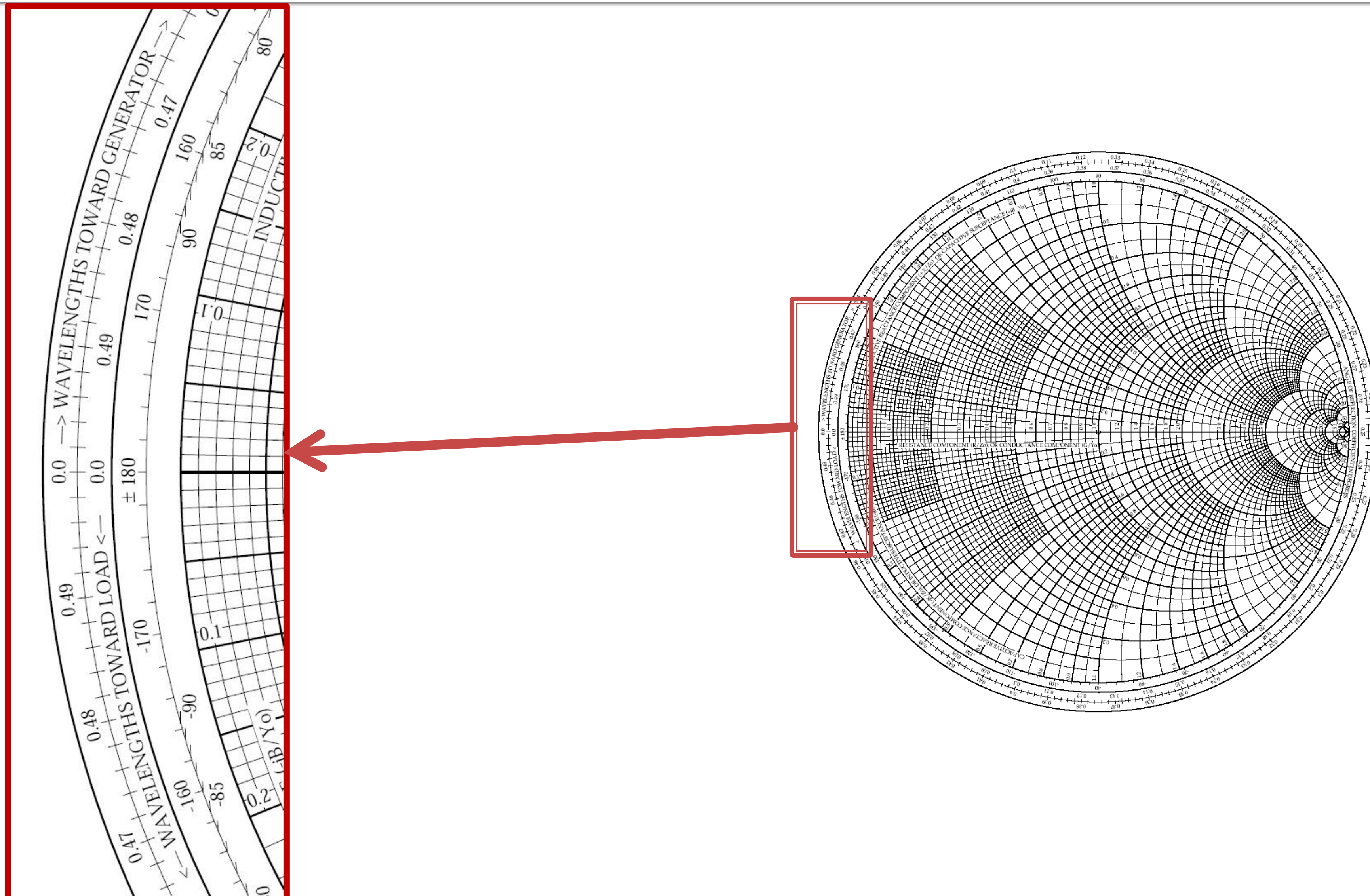


Diagrama Smith

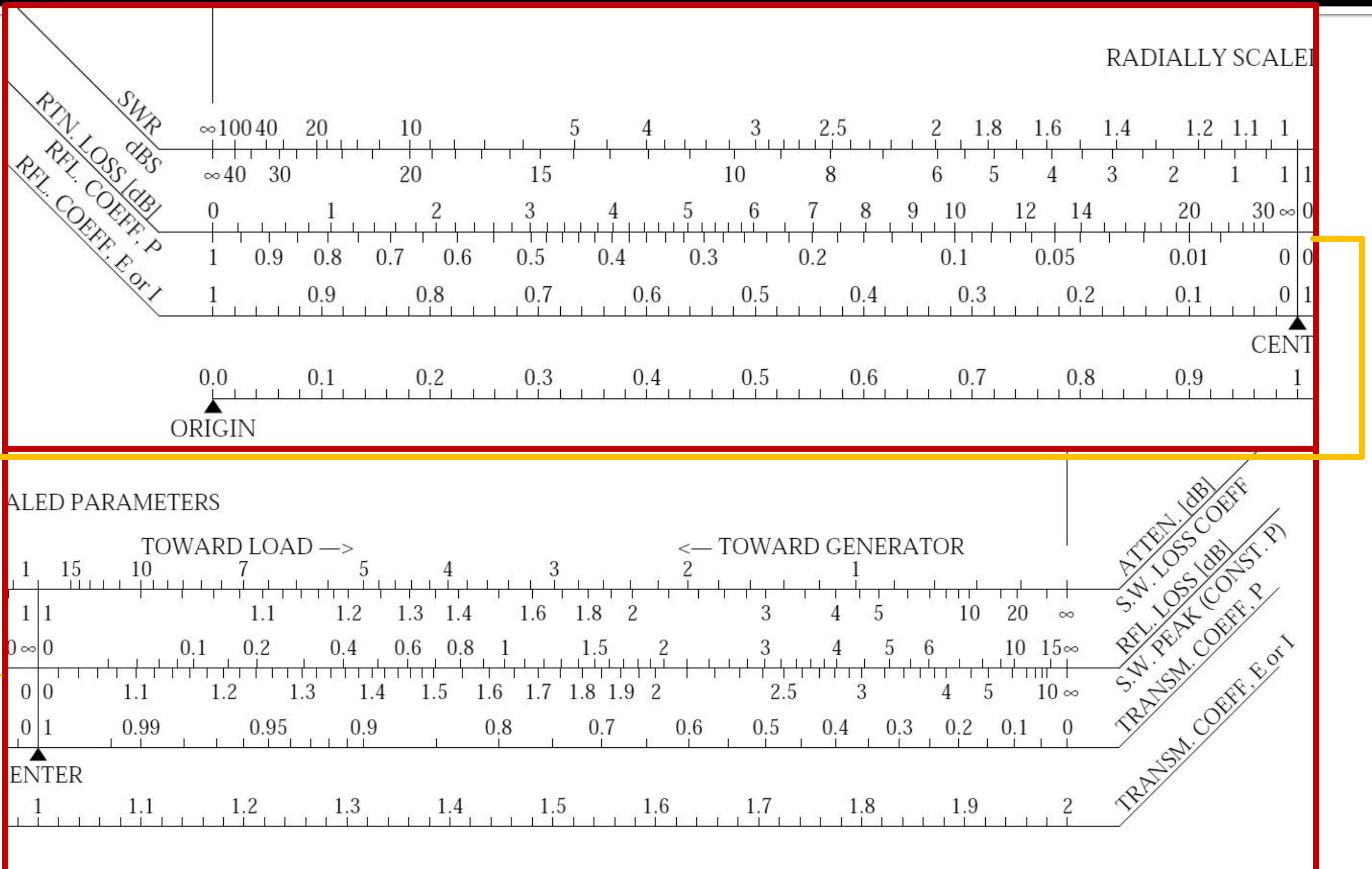
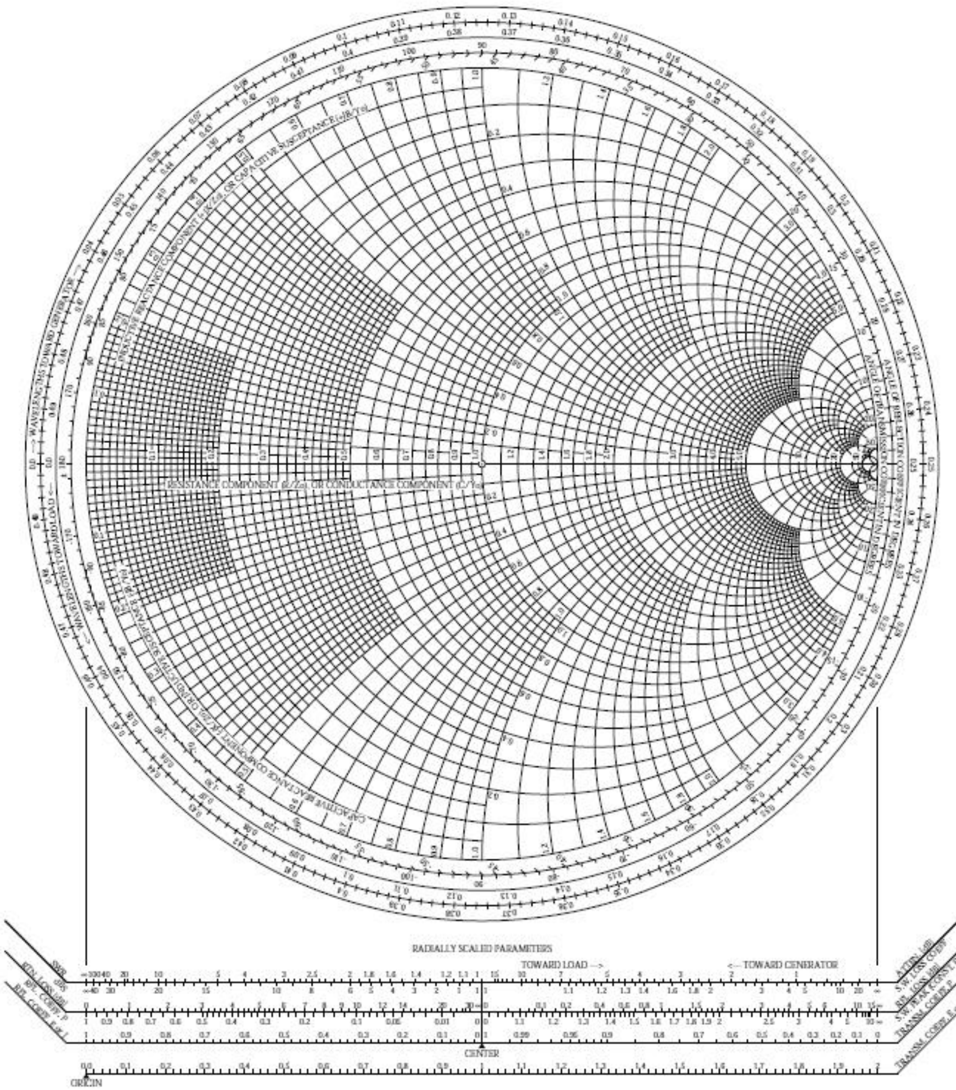


Diagrama Smith



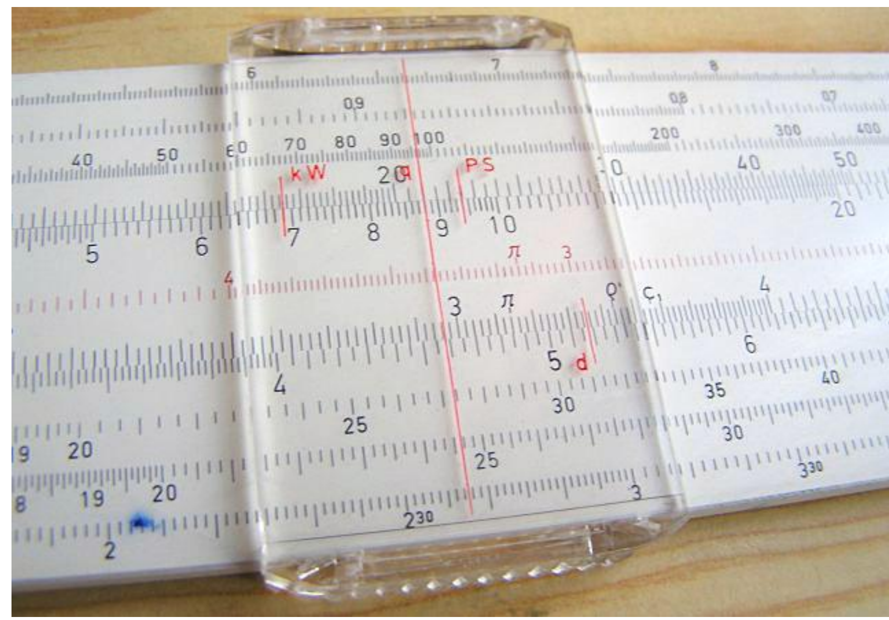
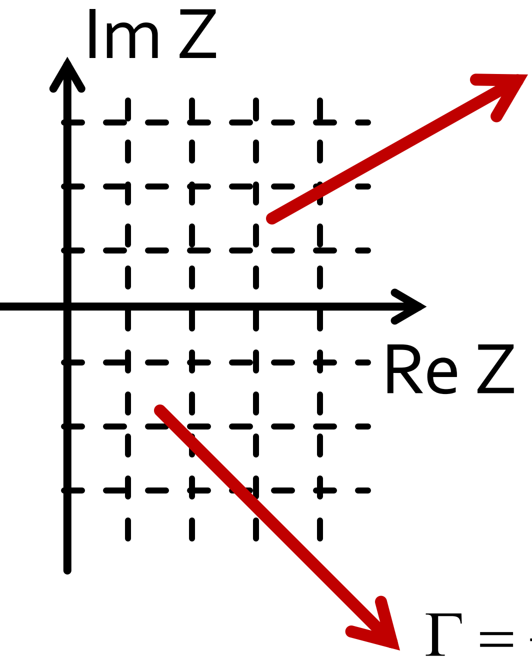
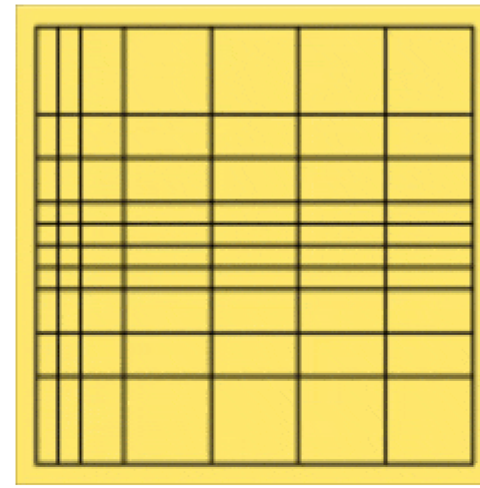


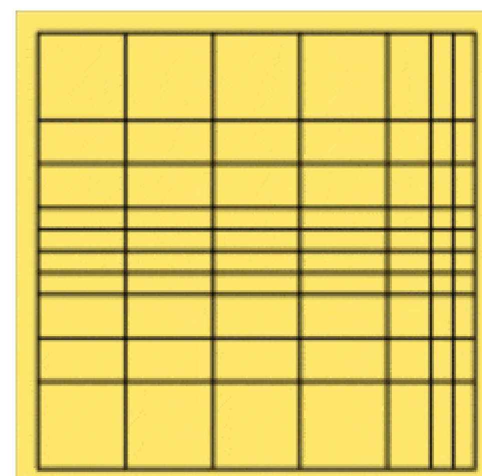
Diagrama Smith



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

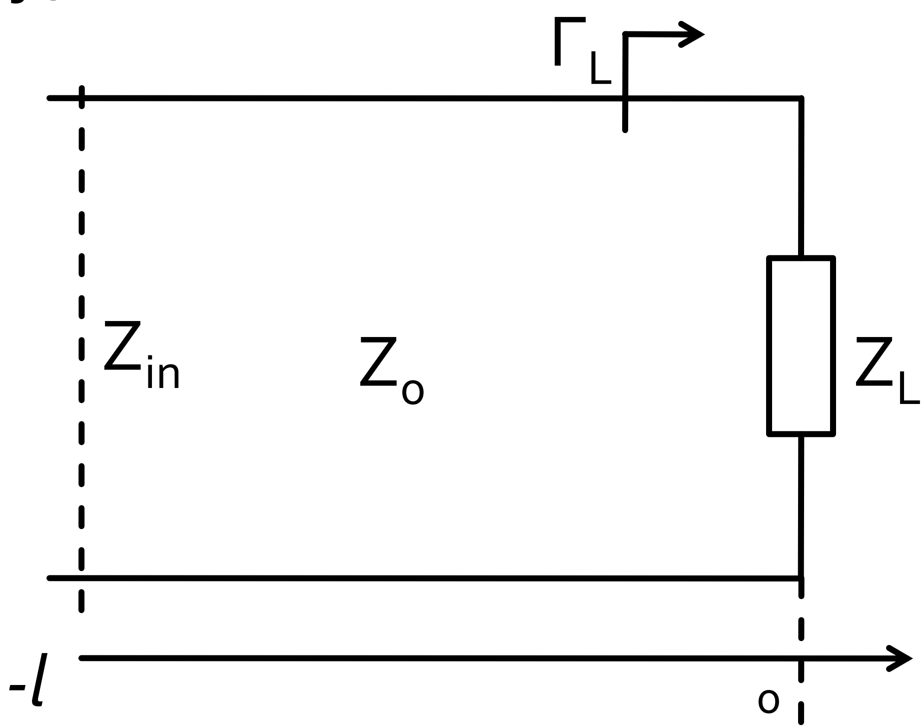


$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{Y_0 - Y_L}{Y_0 + Y_L} = \frac{1 - y_L}{1 + y_L}$$



Utilizare standard

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



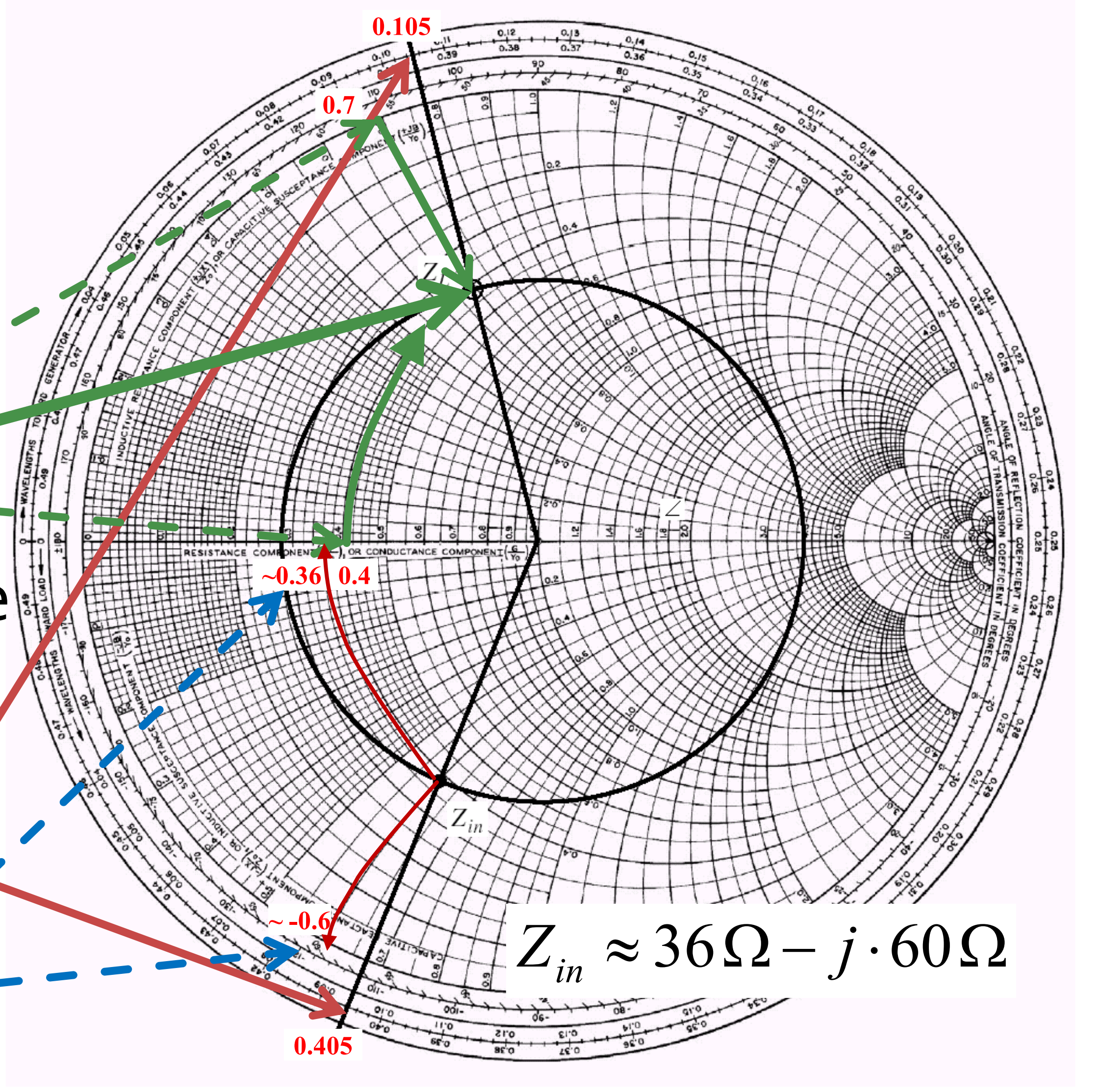
Utilizare standard

- 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)

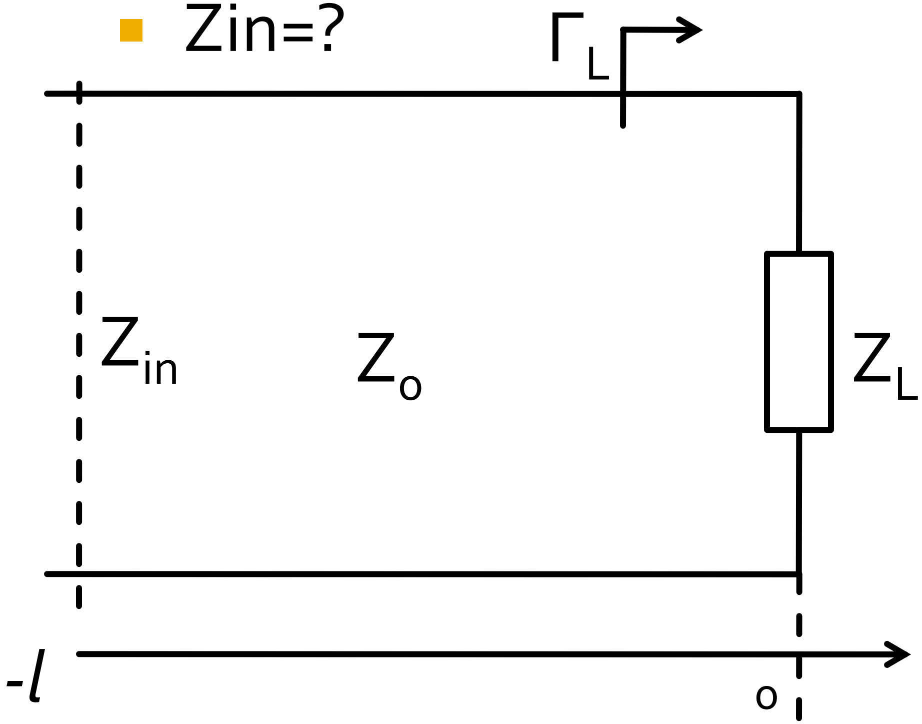
$$z_{in} \approx 0.36 - j\cdot 0.6 = \frac{Z_{in}}{Z_0}$$



$$Z_{in} \approx 36\Omega - j\cdot 60\Omega$$

Utilizare standard - calcul

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



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

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

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

Diagrama Smith

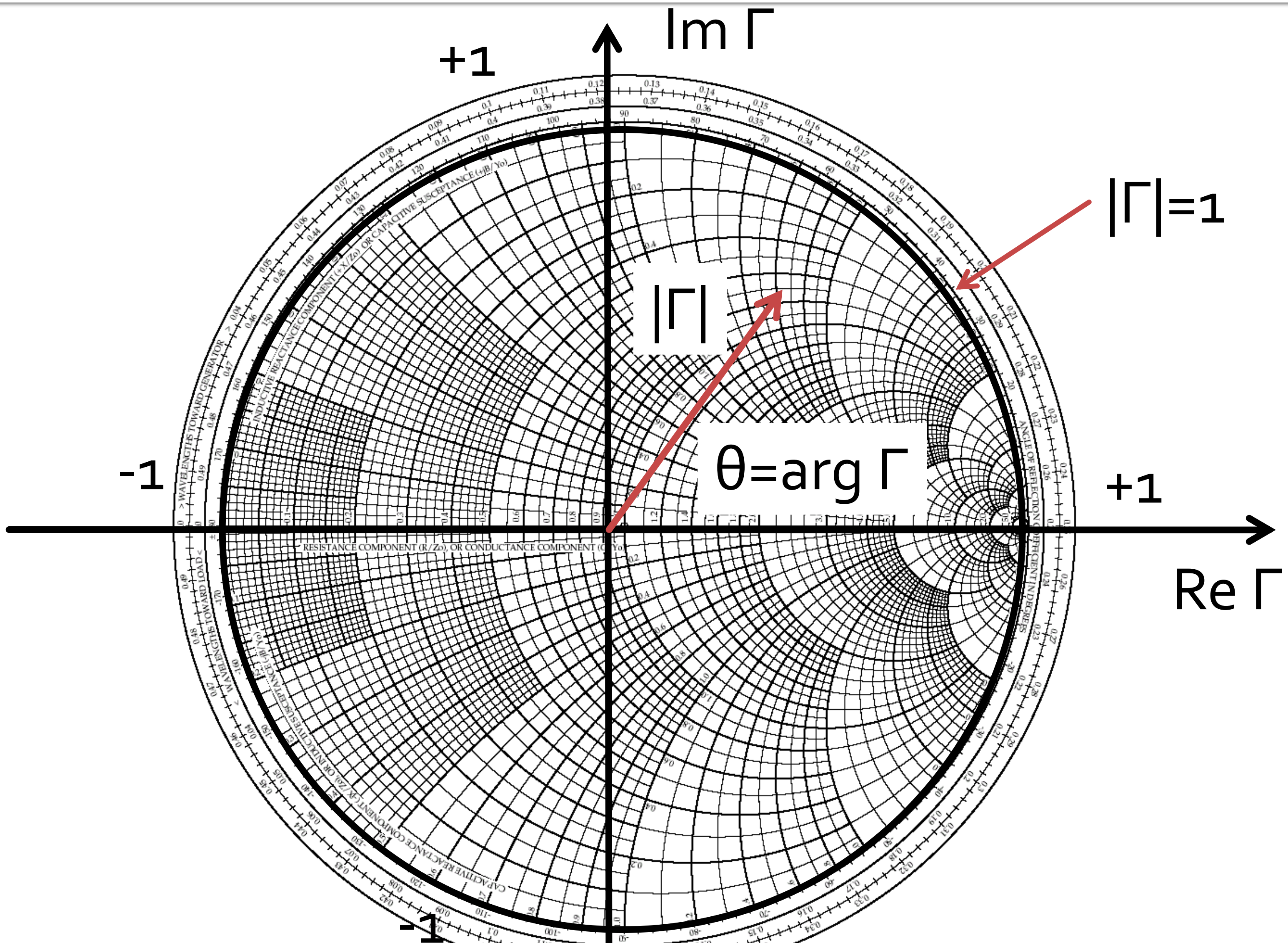


Diagrama Smith

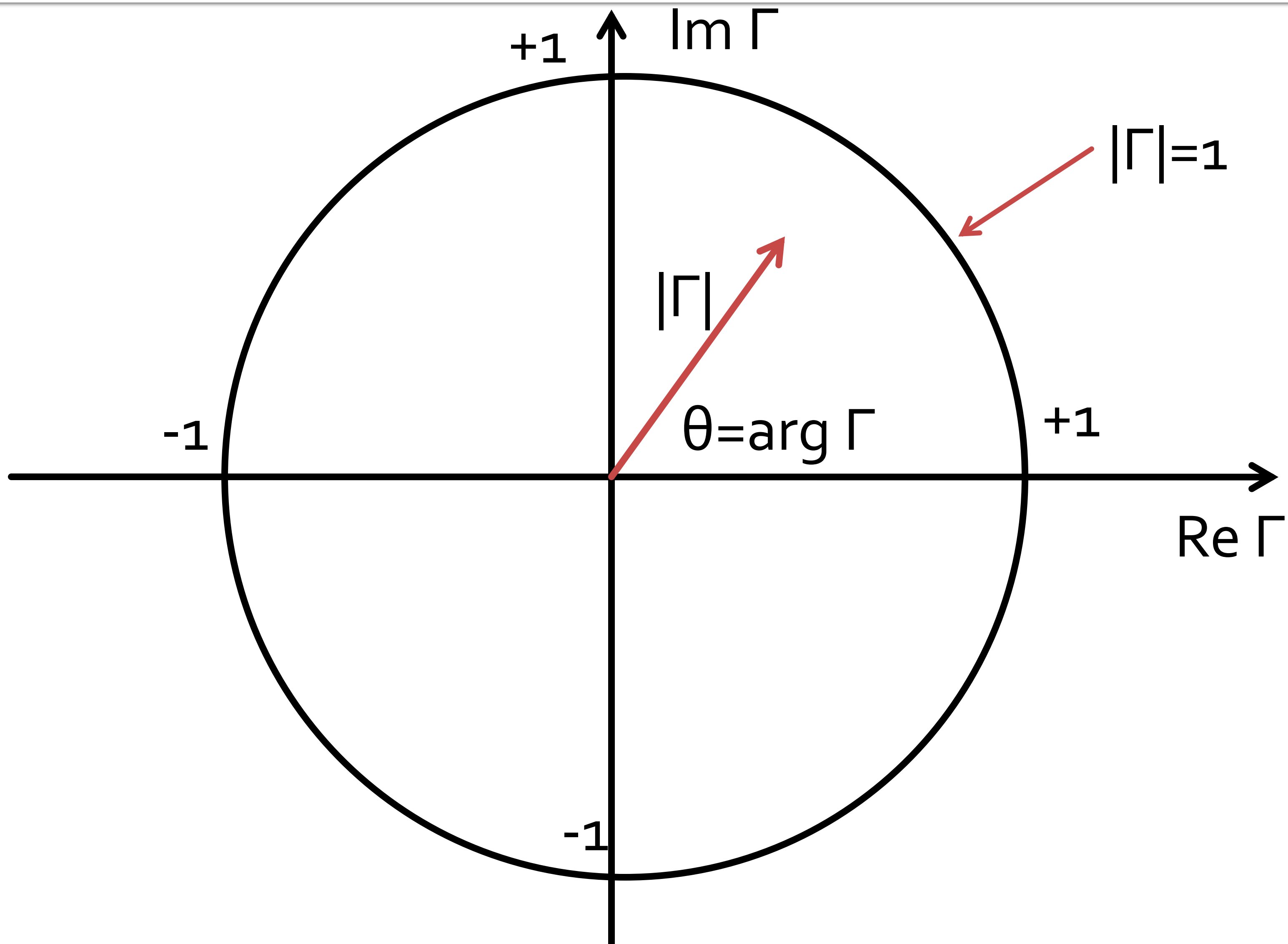
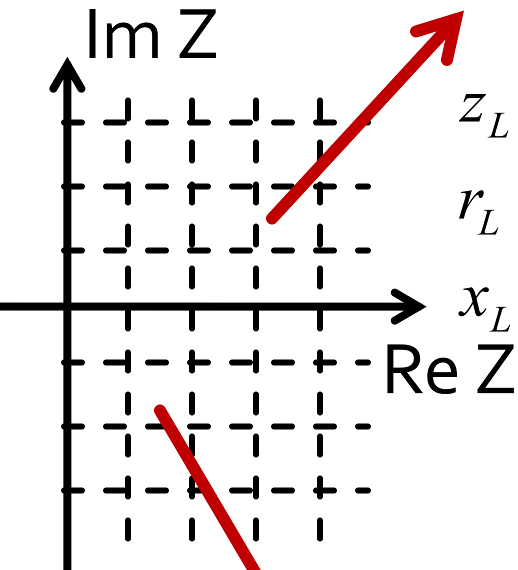


Diagrama Smith

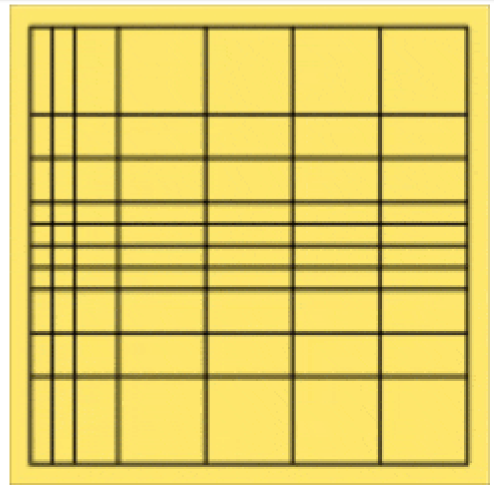
$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{z_L - 1}{z_L + 1}$$

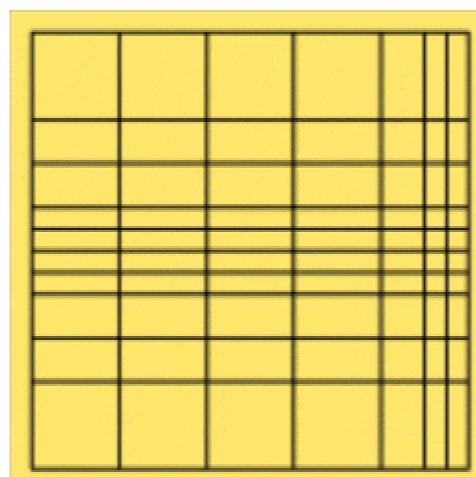


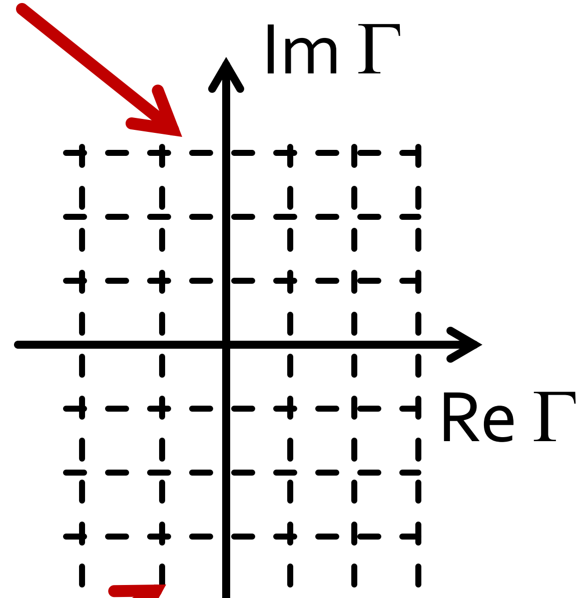
$$z_L = r_L + j \cdot x_L$$

$$r_L = ct.$$

$$x_L = ct.$$



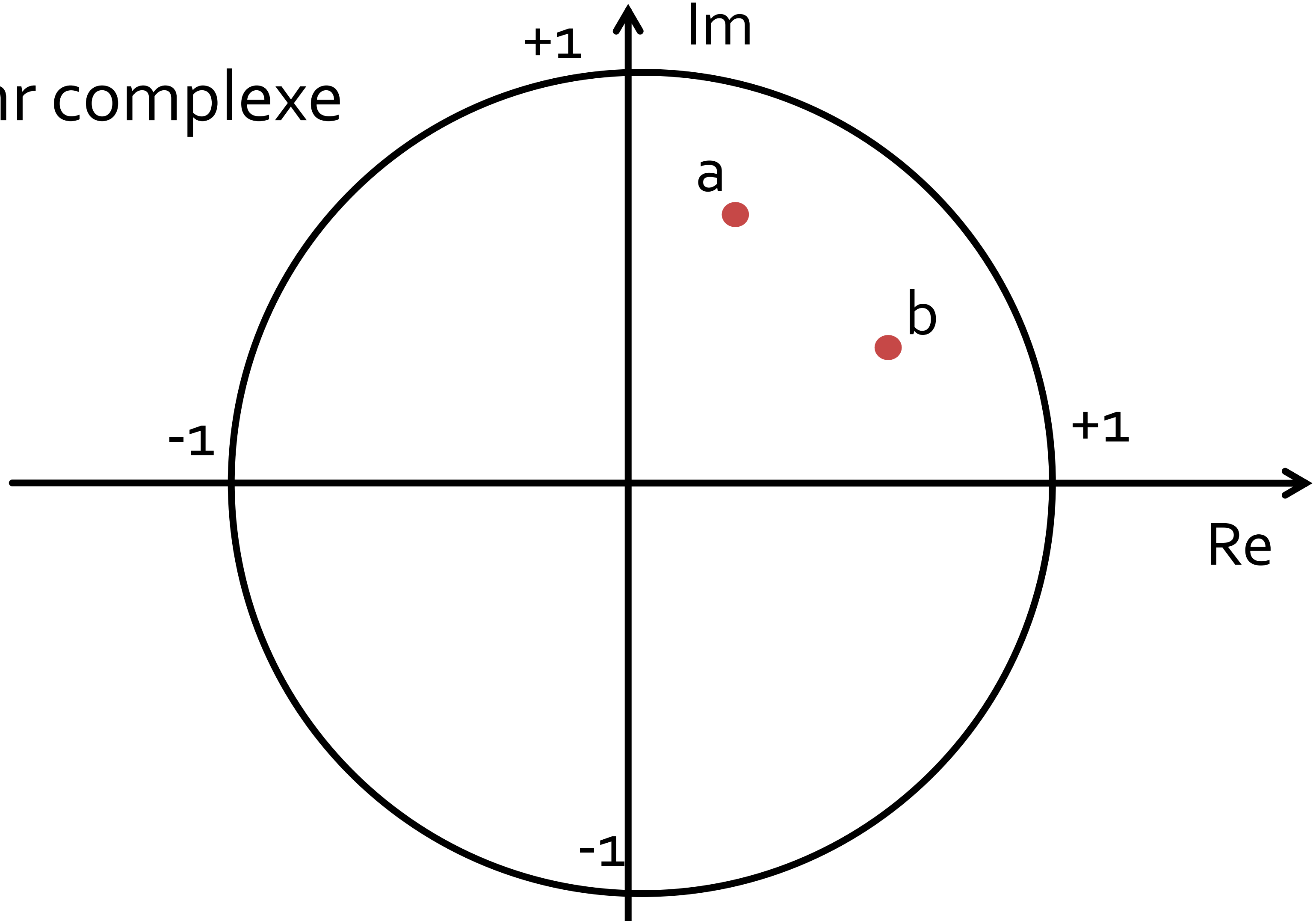




$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{Y_0 - Y_L}{Y_0 + Y_L} = \frac{1 - y_L}{1 + y_L}$$

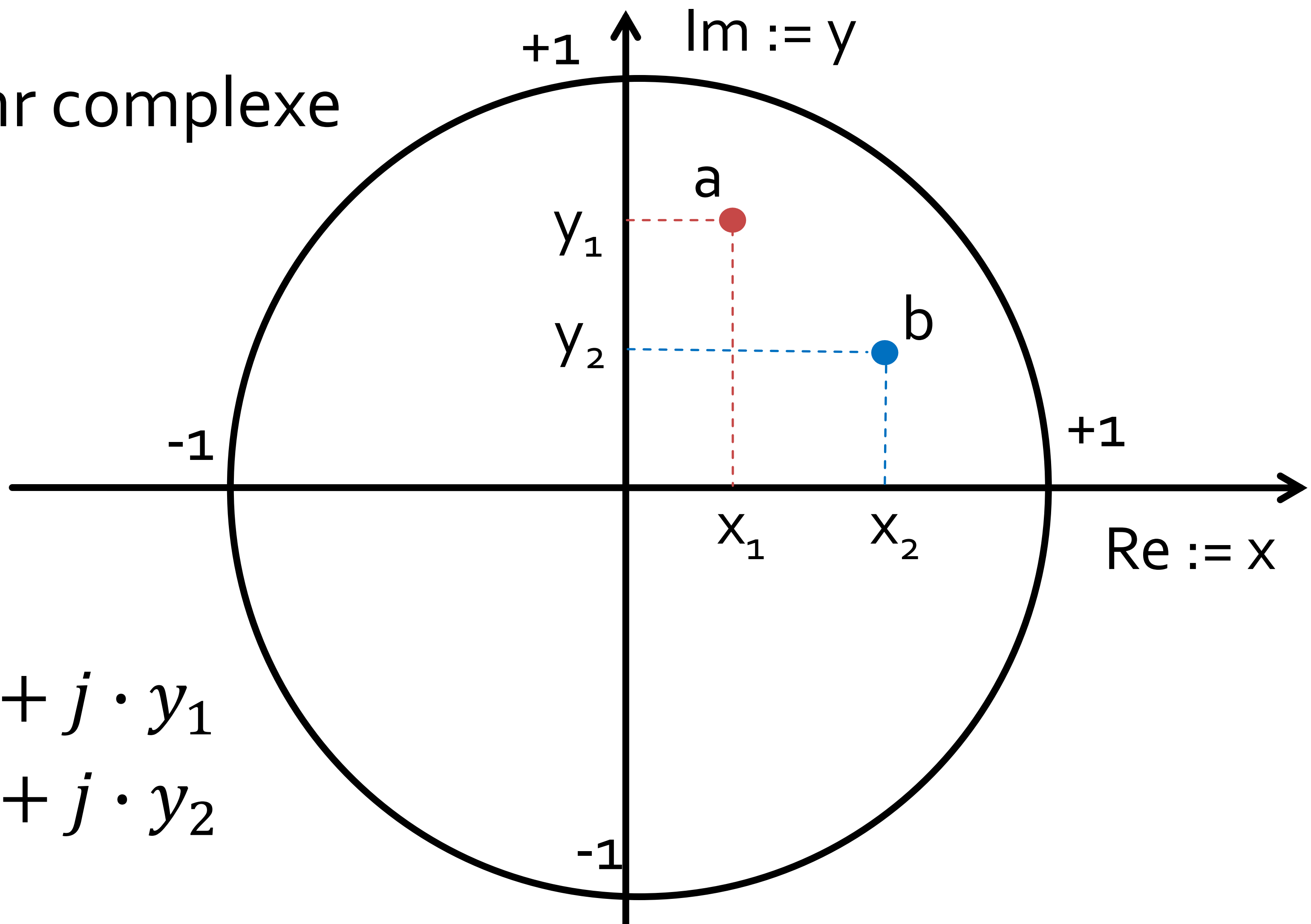
Plan complex – geometrie analitica

- 2 nr complexe



Plan complex – geometrie analitica

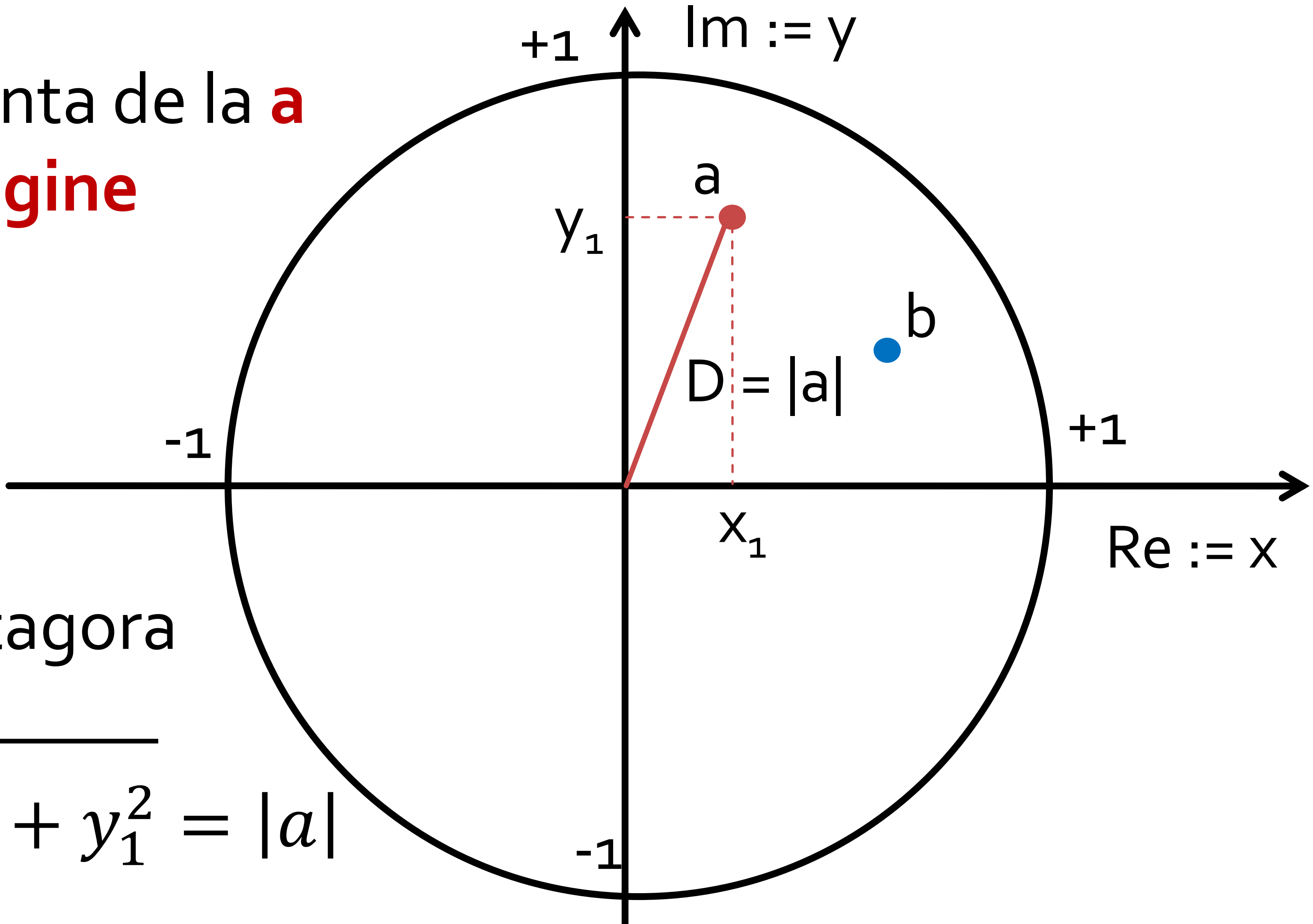
- 2 nr complexe



$$a = x_1 + j \cdot y_1$$
$$b = x_2 + j \cdot y_2$$

Plan complex – geometrie analitica

- distanta de la **a** la **origine**

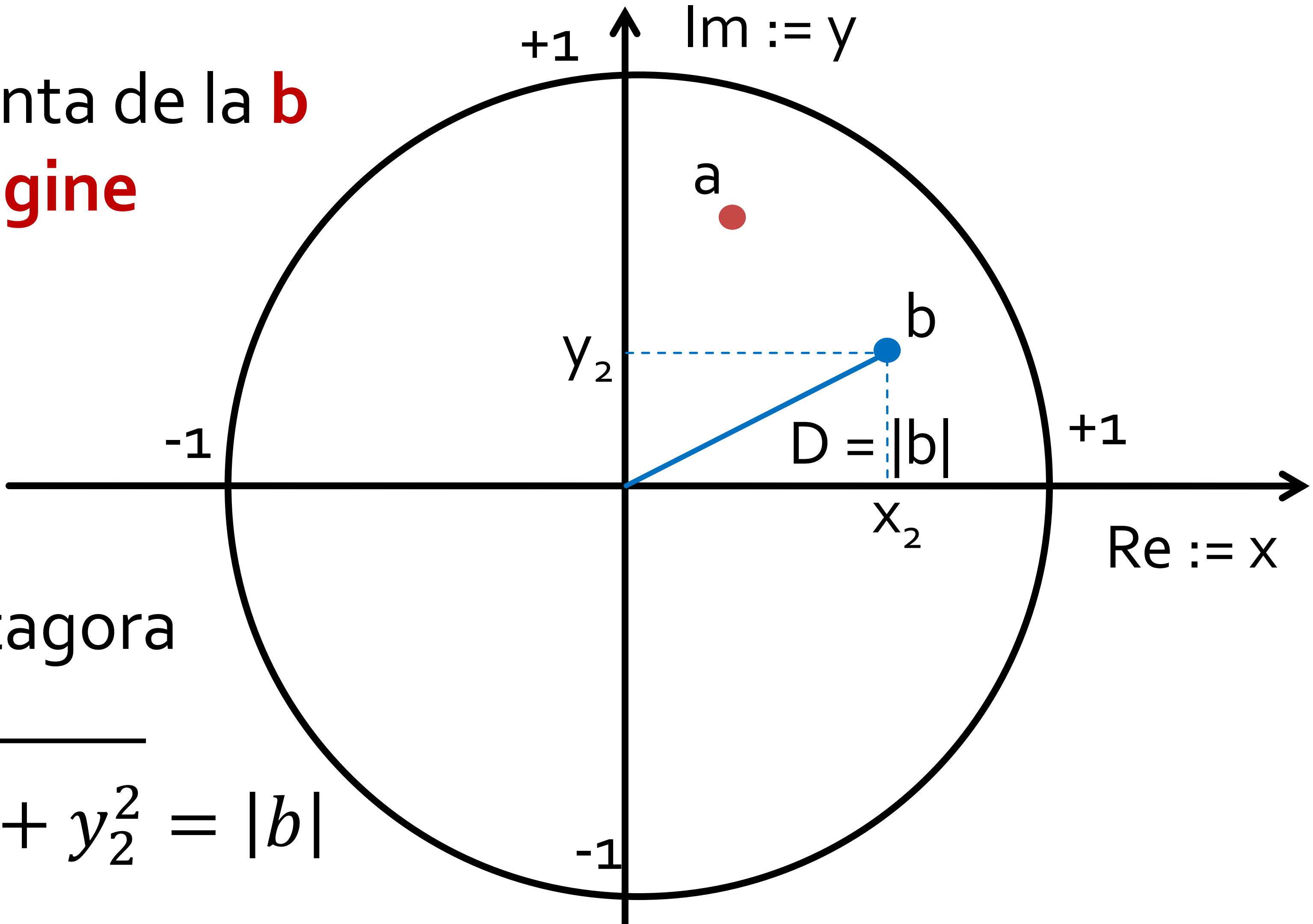


- T. Pitagora

$$D = \sqrt{x_1^2 + y_1^2} = |a|$$

Plan complex – geometrie analitica

- distanta de la **b** la **origine**



- T. Pitagora

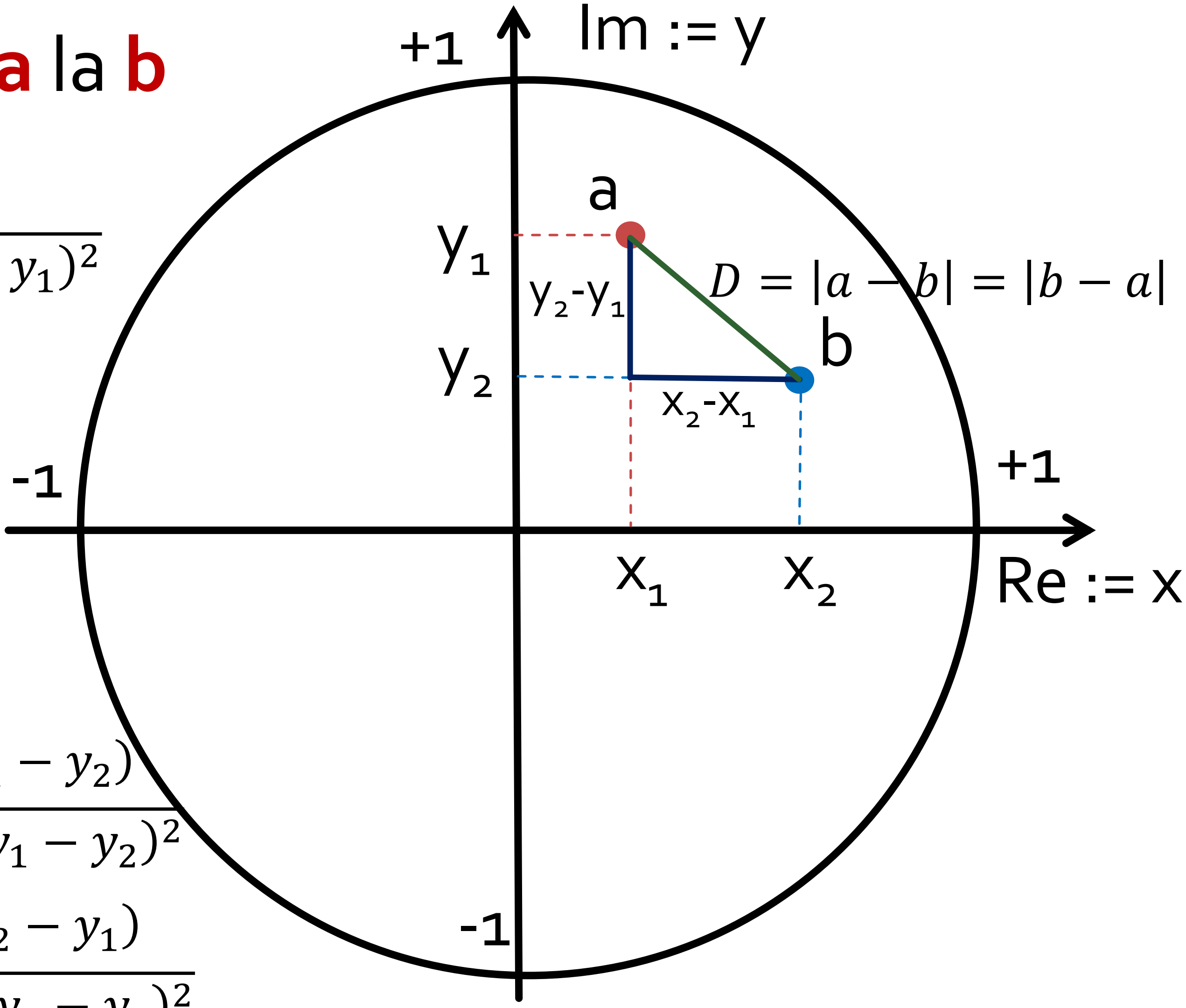
$$D = \sqrt{x_2^2 + y_2^2} = |b|$$

Plan complex – geometrie analitica

- distanta de la **a** la **b**
- T. Pitagora

$$D=\sqrt{(x_2-x_1)^2+(y_2-y_1)^2}$$

$$D=|a-b|=|b-a|$$



$$a-b=(x_1-x_2)+j\cdot(y_1-y_2)$$

$$|a-b|=\sqrt{(x_1-x_2)^2+(y_1-y_2)^2}$$

$$b-a=(x_2-x_1)+j\cdot(y_2-y_1)$$

$$|b-a|=\sqrt{(x_2-x_1)^2+(y_2-y_1)^2}$$

Plan complex – geometrie analitica

- Ecuatie, **x y** necunoscute

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

- 1 ecuatie, 2 necunoscute o infinitate de solutii

Plan complex – geometrie analitica

- distanta de la **a** la **b**

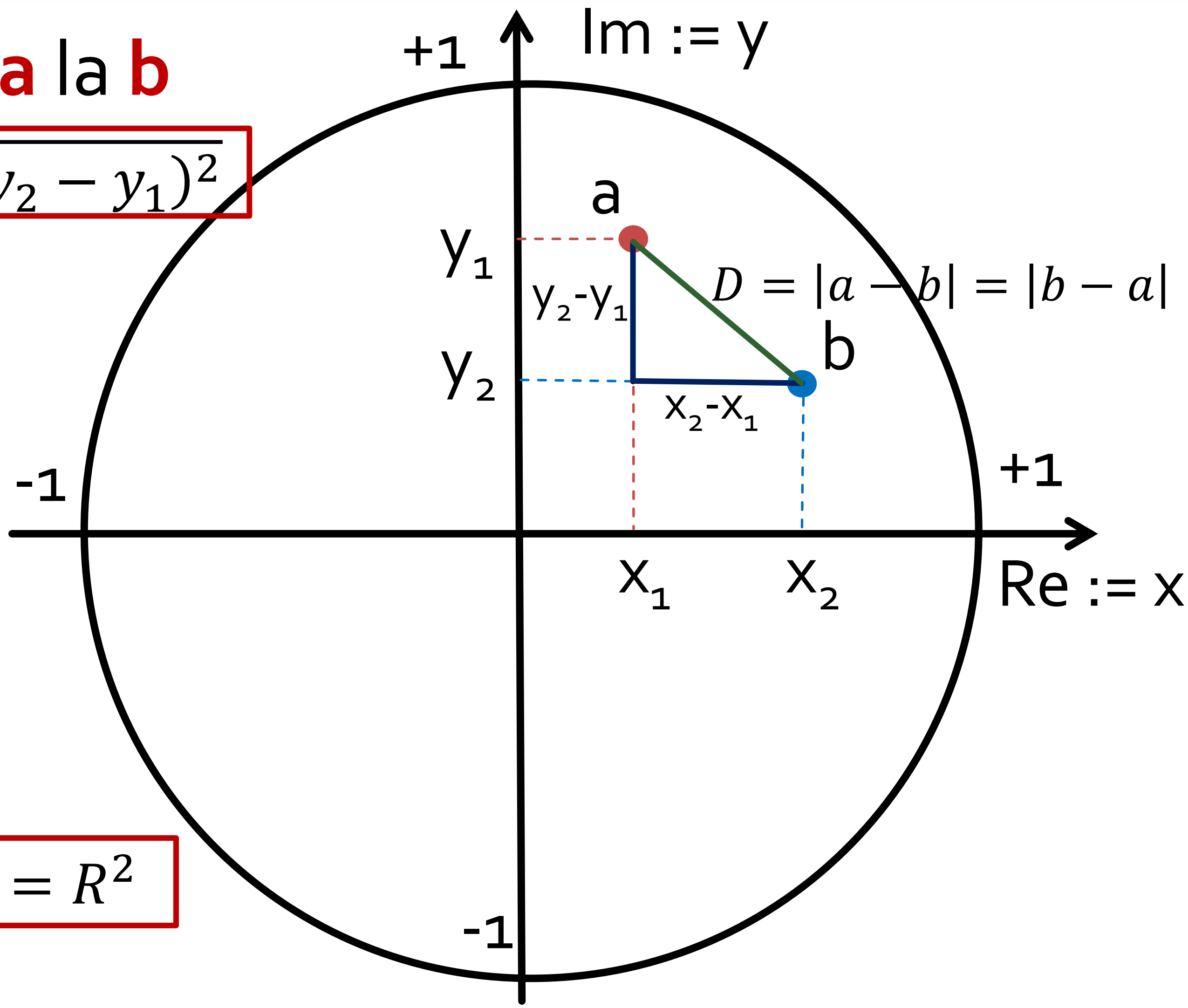
$$\boxed{D = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}}$$

$$D = |a - b| = |b - a|$$

$$a = x_1 + j \cdot y_1$$

$$b = x_2 + j \cdot y_2$$

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



Plan complex – geometrie analitica

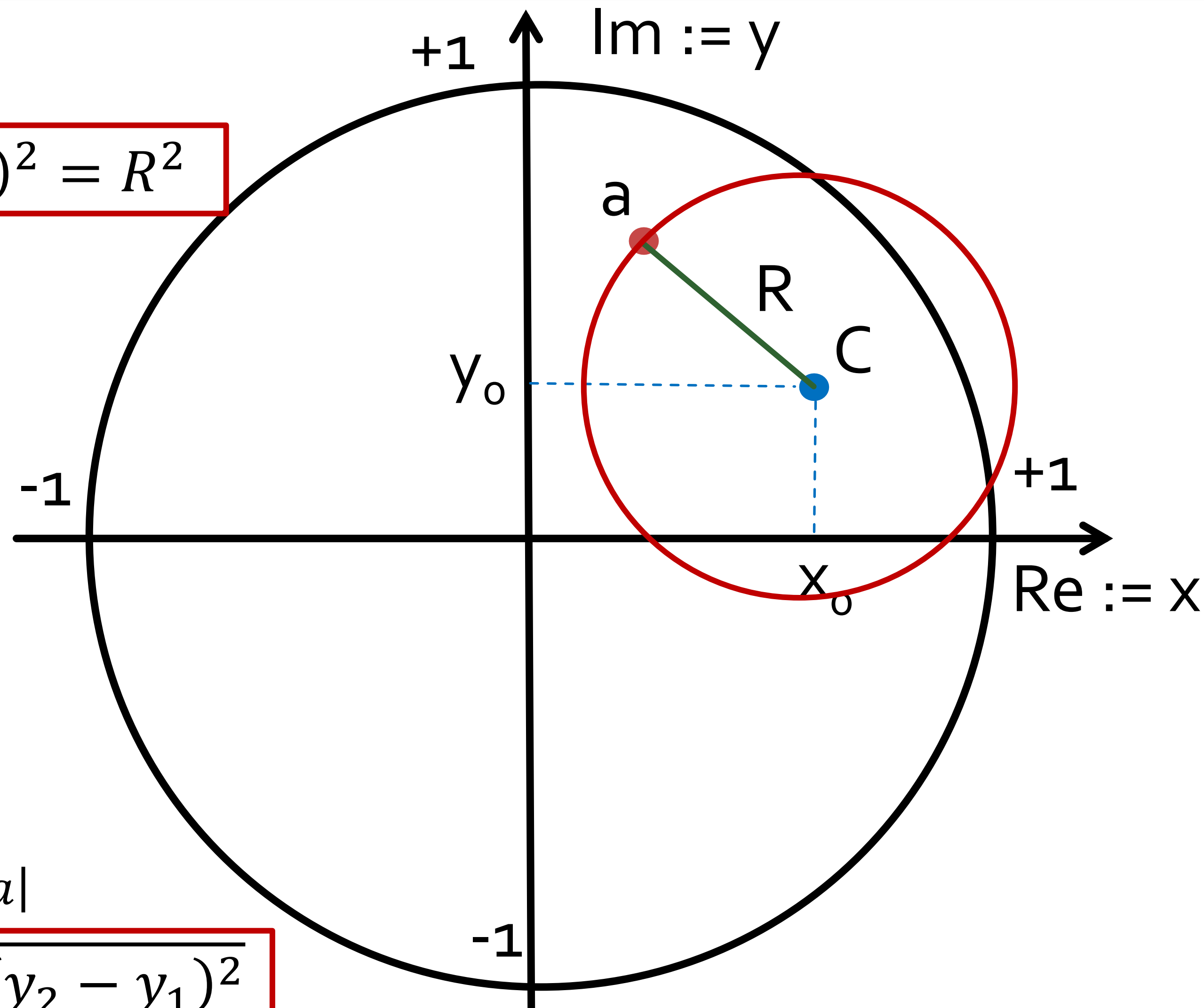
- solutii

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

$$a = x + j \cdot y$$

$$C = x_0 + j \cdot y_0$$

$$D(a, C) = |a - C| = R$$



$$a = x_1 + j \cdot y_1$$

$$b = x_2 + j \cdot y_2$$

$$D(a, b) = |a - b| = |b - a|$$

$$\boxed{D = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}}$$

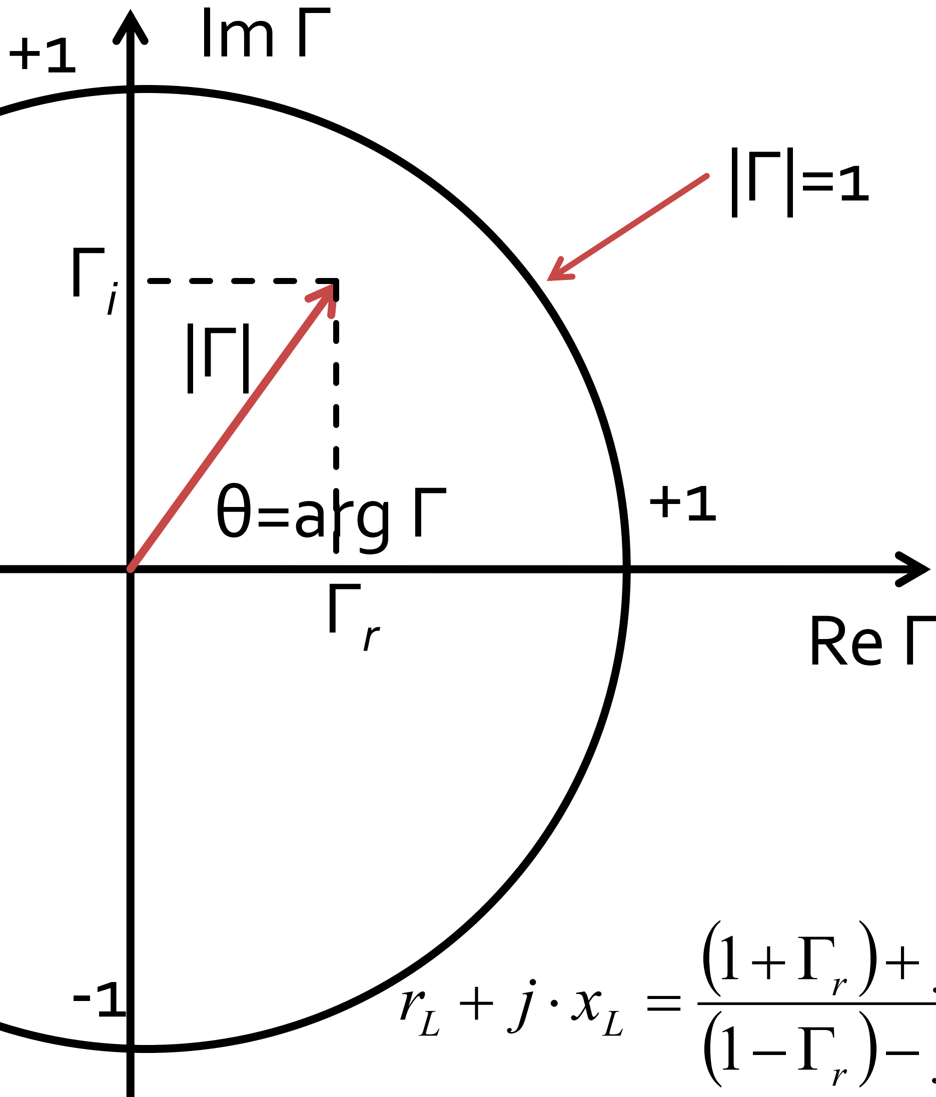
Plan complex – geometrie analitica

- Ecuatie, **x y** necunoscute

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

- 1 ecuatie, 2 necunoscute o infinitate de solutii
- Locul geometric in plan al solutiilor este un **cerc** de raza **R** in jurul punctului **C(x_o,y_o)**

Diagrama Smith



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

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

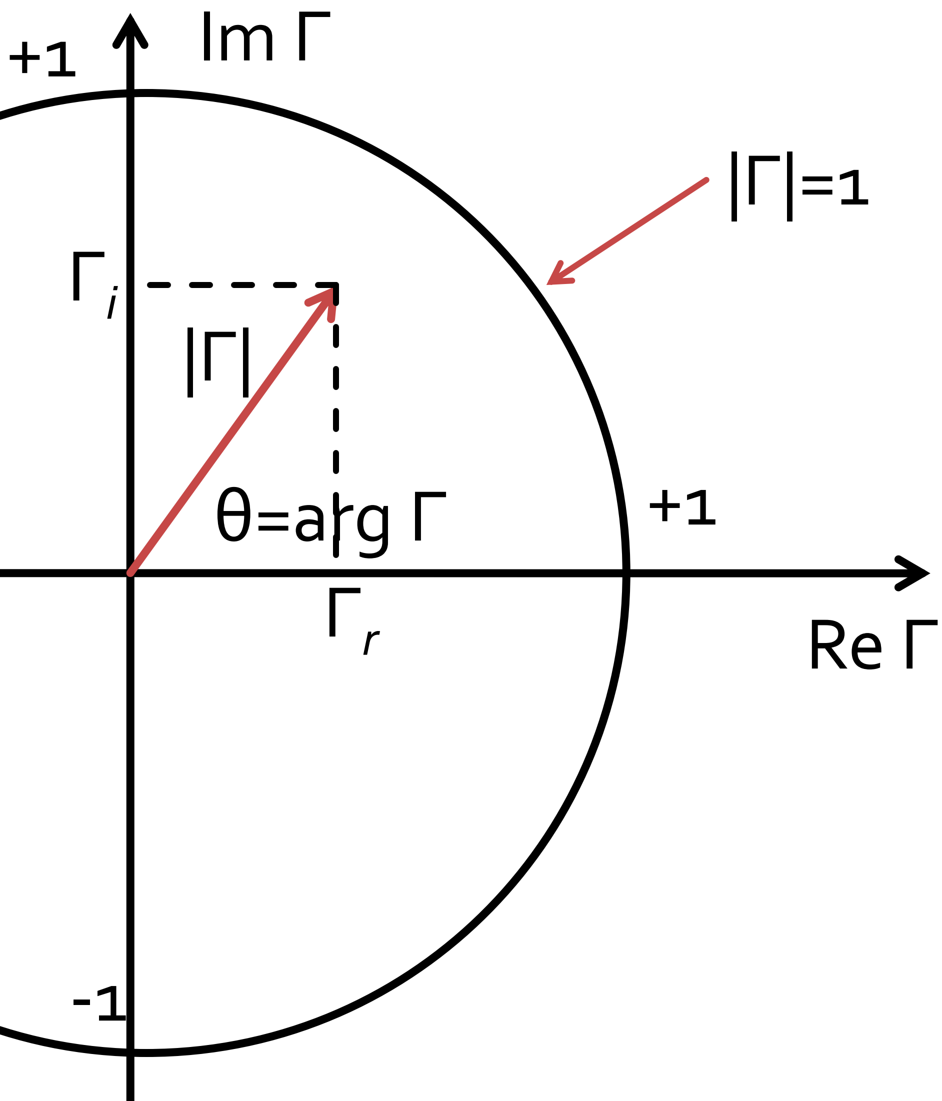
Raportarea $Z_L \rightarrow z_L$ permite utilizarea aceleiasi diagrame pentru oricare impedanta de referinta Z_o (face reprezentarea independenta de valoarea aleasa pentru Z_o)

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

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

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

Diagrama 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

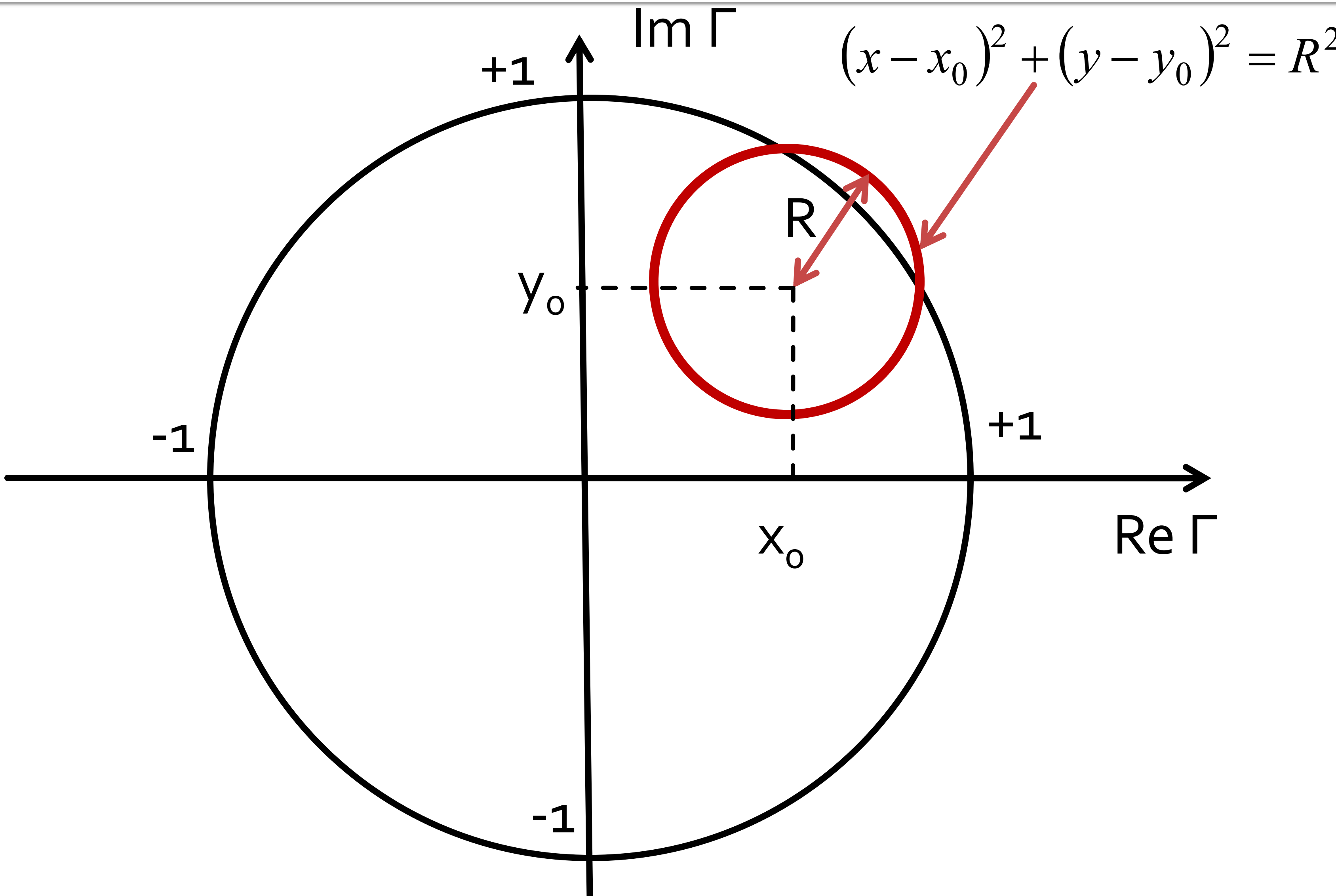
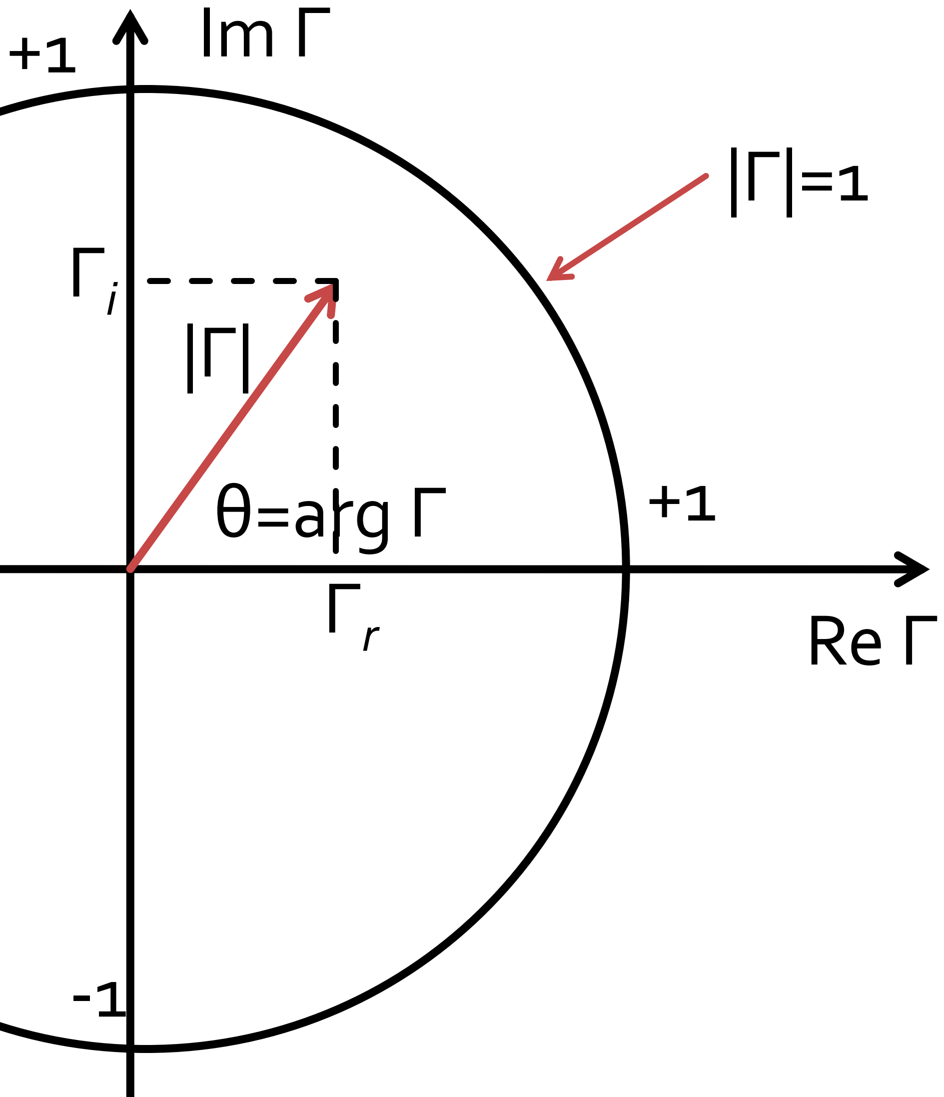


Diagrama Smith



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

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

- Cercuri in planul complex

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

Diagrama Smith, rezistenta

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

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

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

- Locul geometric al punctelor care pot fi ocupate de impedantele cu rezistenta r_L este un cerc:
  - Cu **centrul pe axa reala** (y_0=0)
  - trece prin punctul **x=1,y=0** oricare x_0,r_L
  - 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**
  - pentru orice r_L **pozitiv** raza este **<1**

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

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

Diagrama Smith, rezistenta

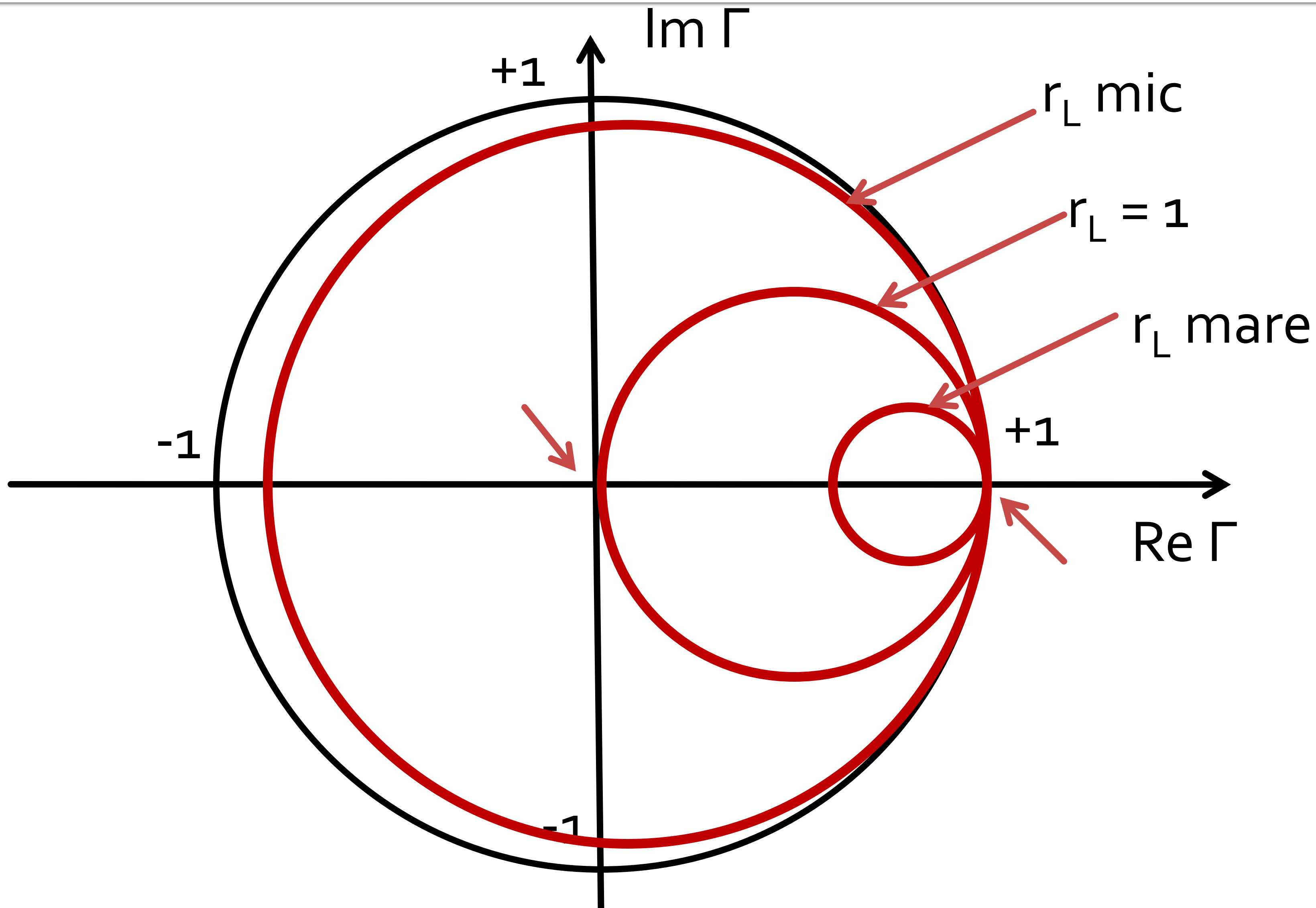


Diagrama Smith, reactanta

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

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

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

- 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

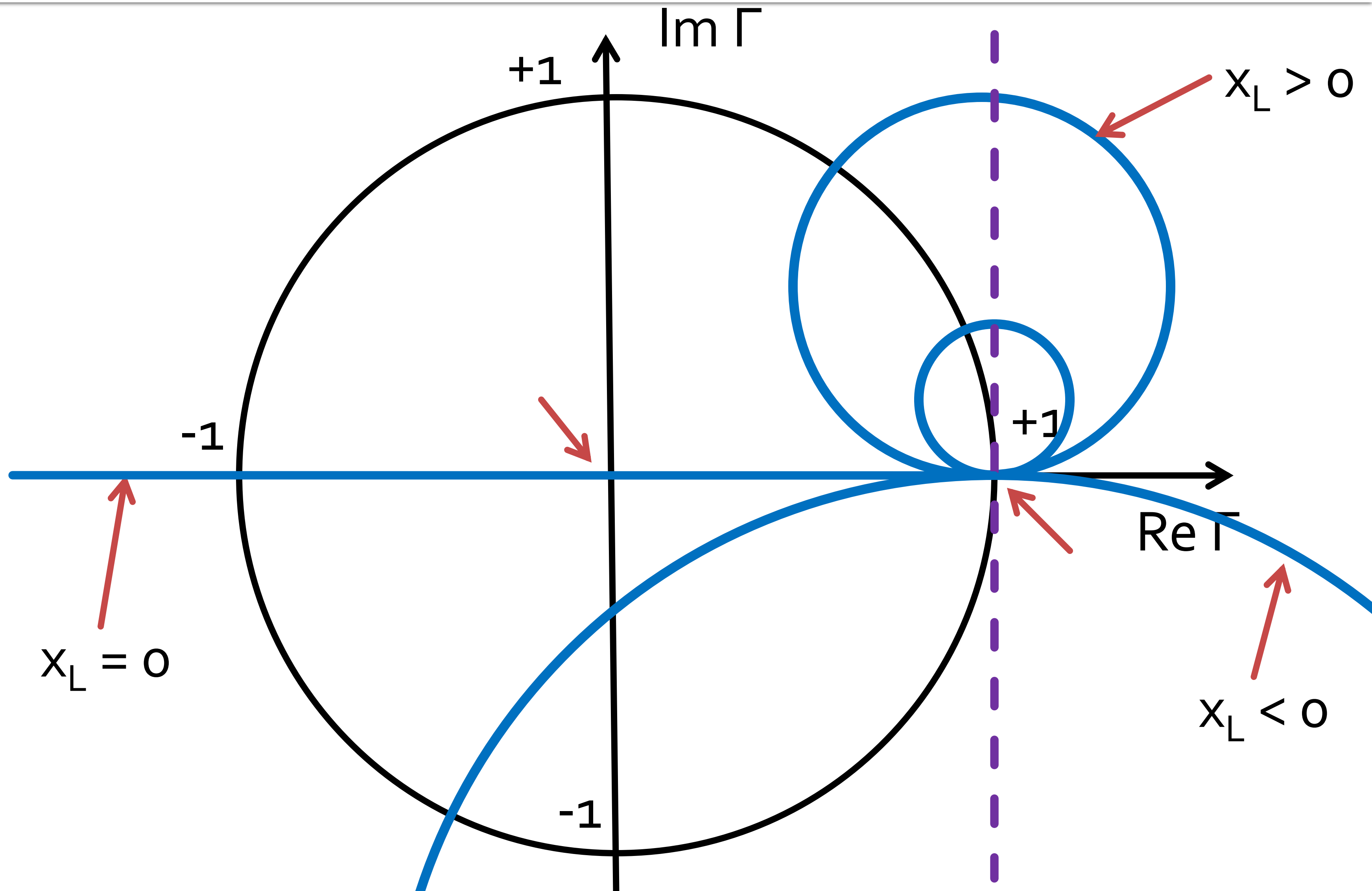


Diagrama Smith, impedanta

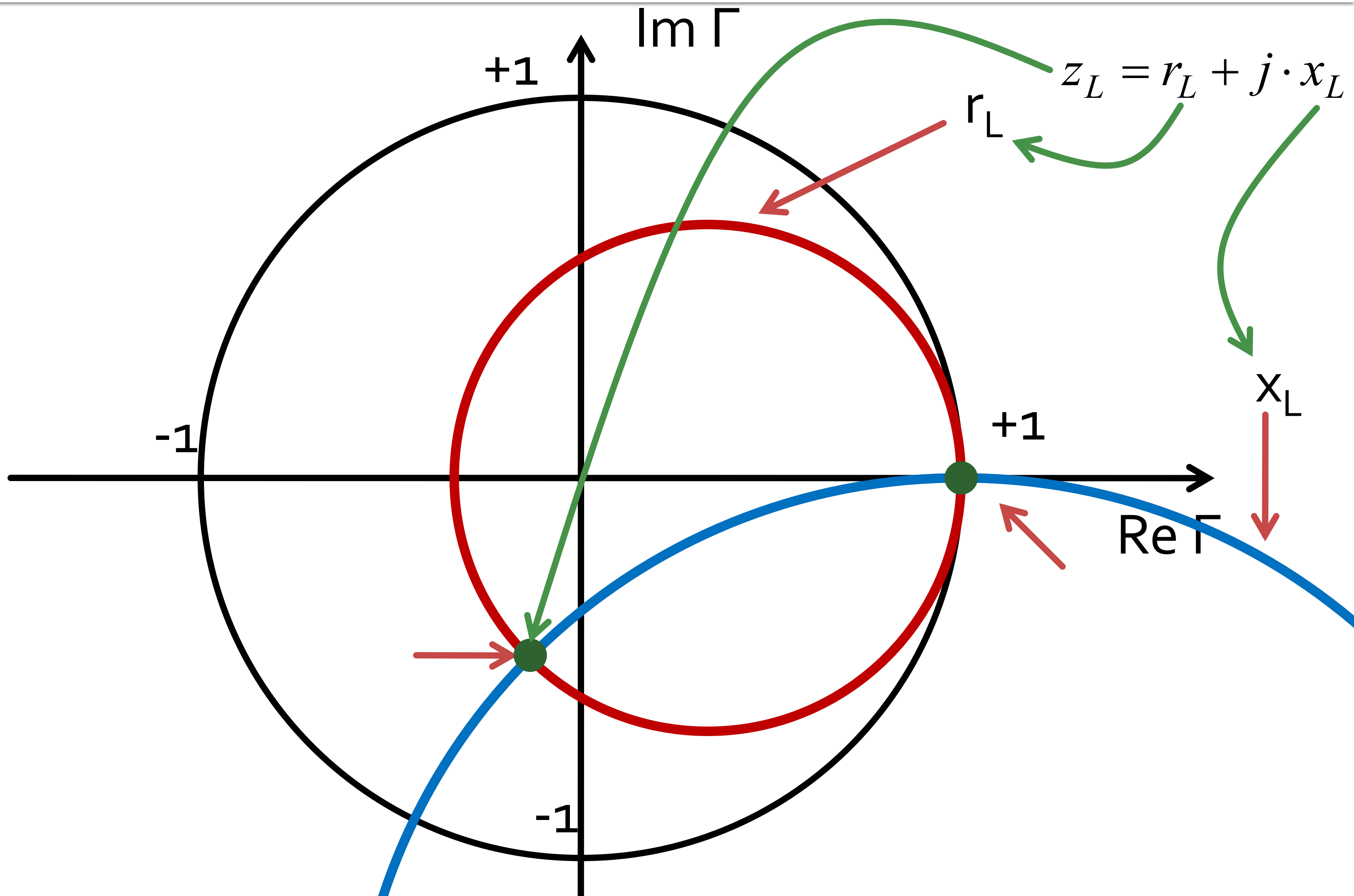
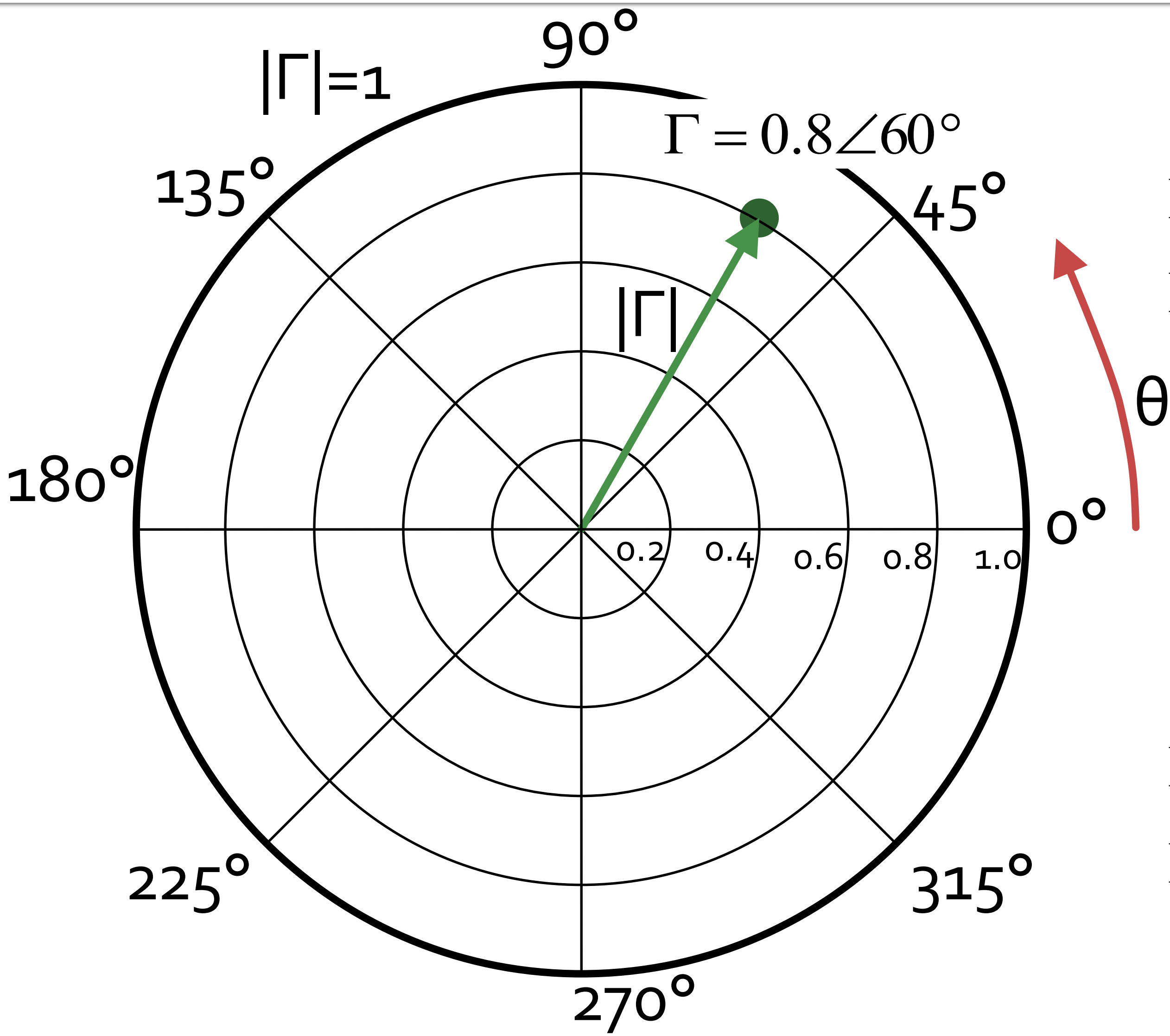


Diagrama Smith, coeficient de reflexie, coordonate polare



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

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

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

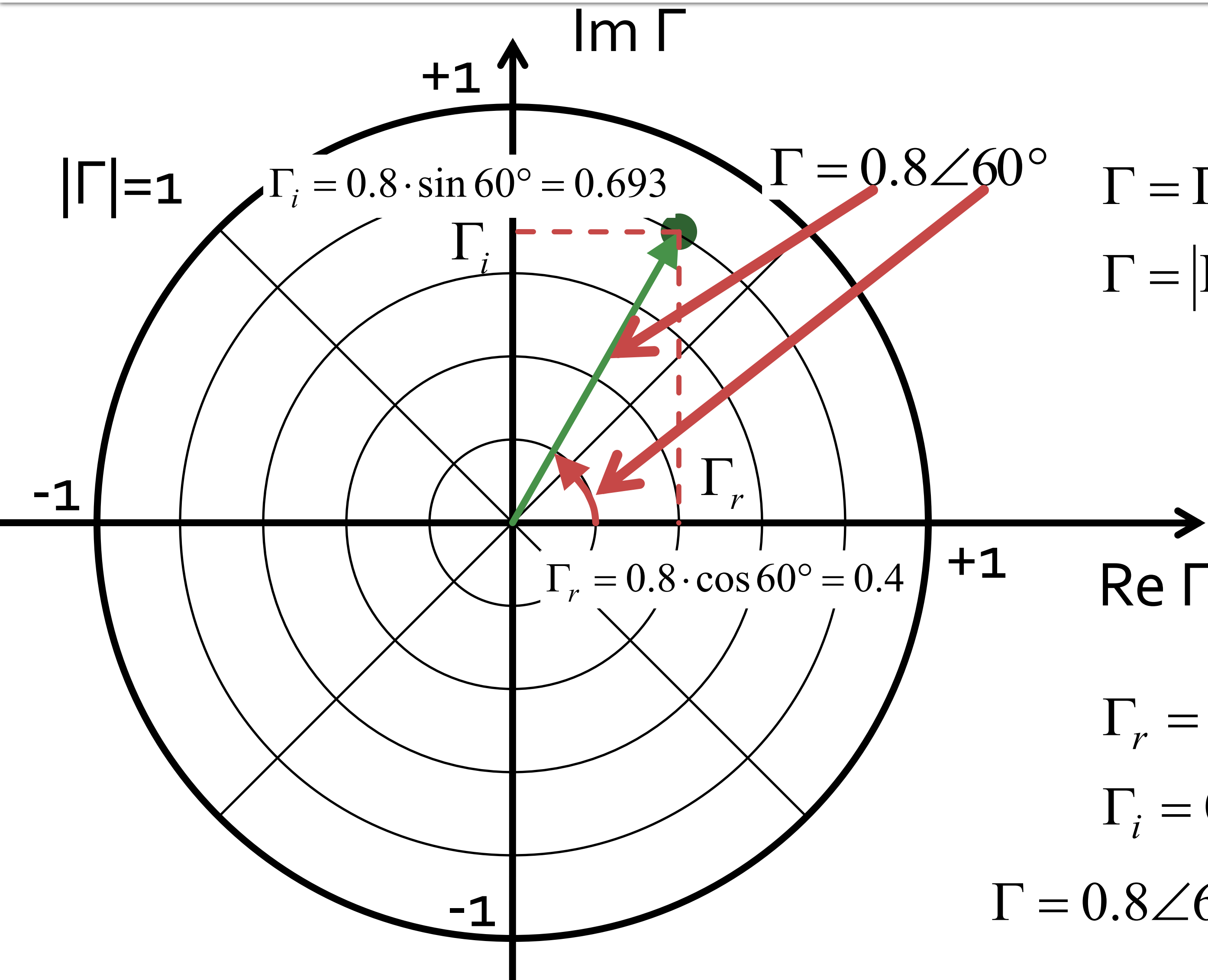
$$\Gamma = |\Gamma| \angle \theta°$$

$$\Gamma = 0.8 \angle 60°$$

$$\Gamma_r = 0.8 \cdot \cos 60° = 0.4$$

$$\Gamma_i = 0.8 \cdot \sin 60° = 0.693$$

Diagrama Smith, coeficient de reflexie, coordonate rectangulare



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

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

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

$$\Gamma = |\Gamma|\angle\theta°$$

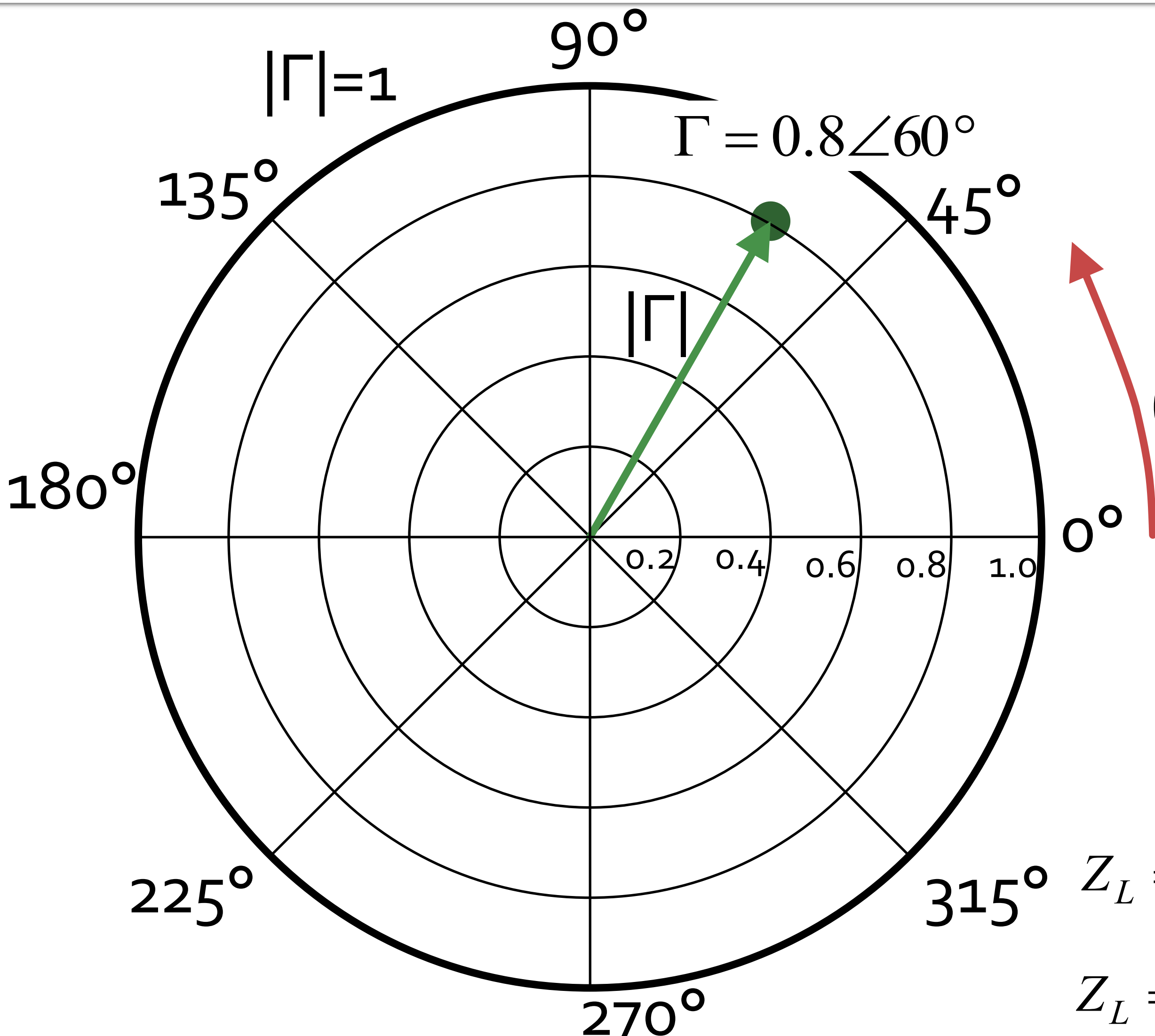
$$\Gamma = 0.8\angle 60°$$

$$\Gamma_r = 0.8 \cdot \cos 60° = 0.4$$

$$\Gamma_i = 0.8 \cdot \sin 60° = 0.693$$

$$\Gamma = 0.8\angle 60° = 0.4 + j \cdot 0.693$$

Diagrama Smith, coeficient de reflexie, impedanta



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

$$\Gamma = |\Gamma| \angle \theta°$$

$$\Gamma = 0.8\angle 60°$$

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

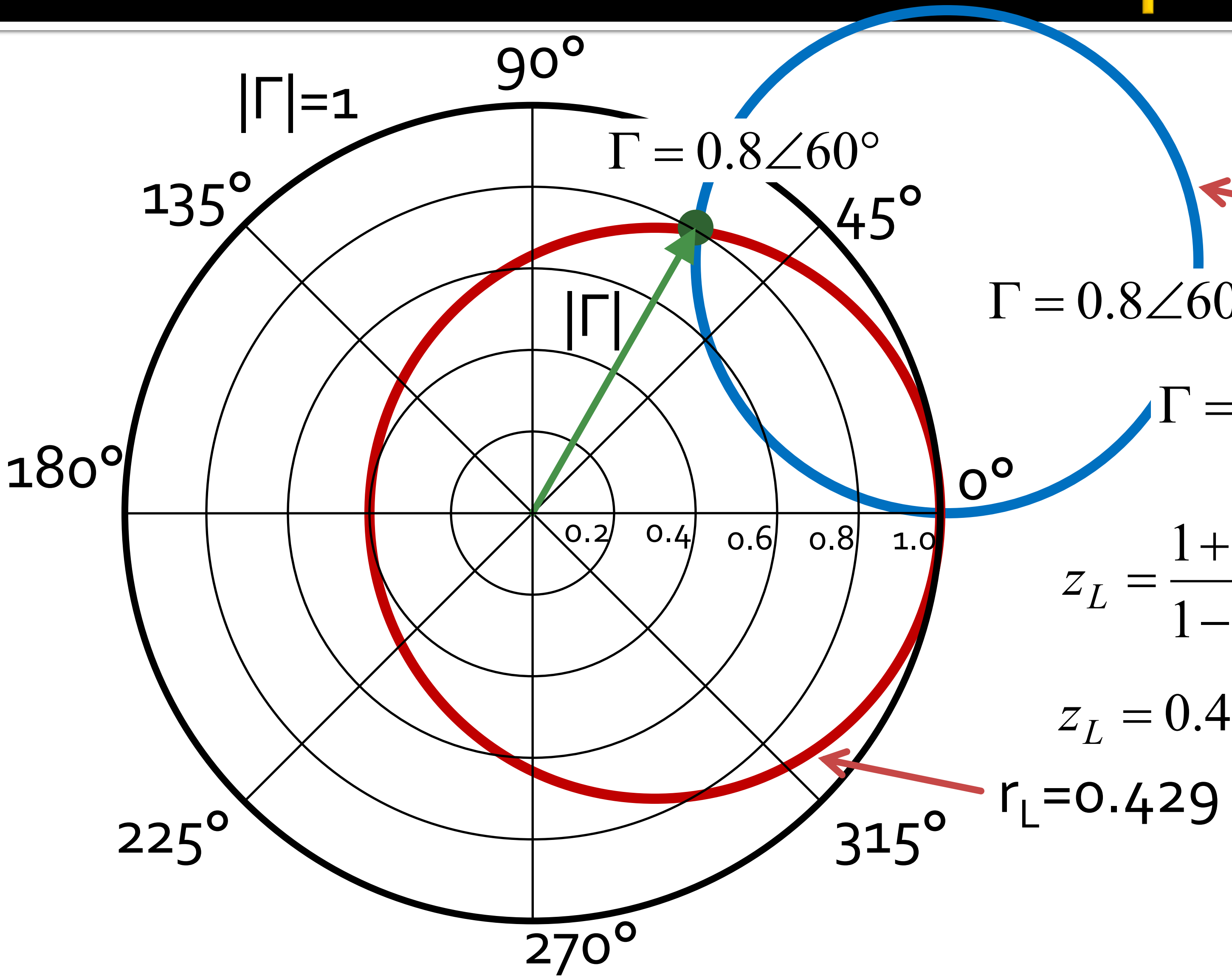
$$z_L = \frac{1+\Gamma}{1-\Gamma} = \frac{1+0.8\angle 60°}{1-0.8\angle 60°}$$

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

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

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

Echivalenta coeficient de reflexie ⇔ impedanta



$$\Gamma = 0.8\angle 60° = 0.4 + j\cdot 0.693$$

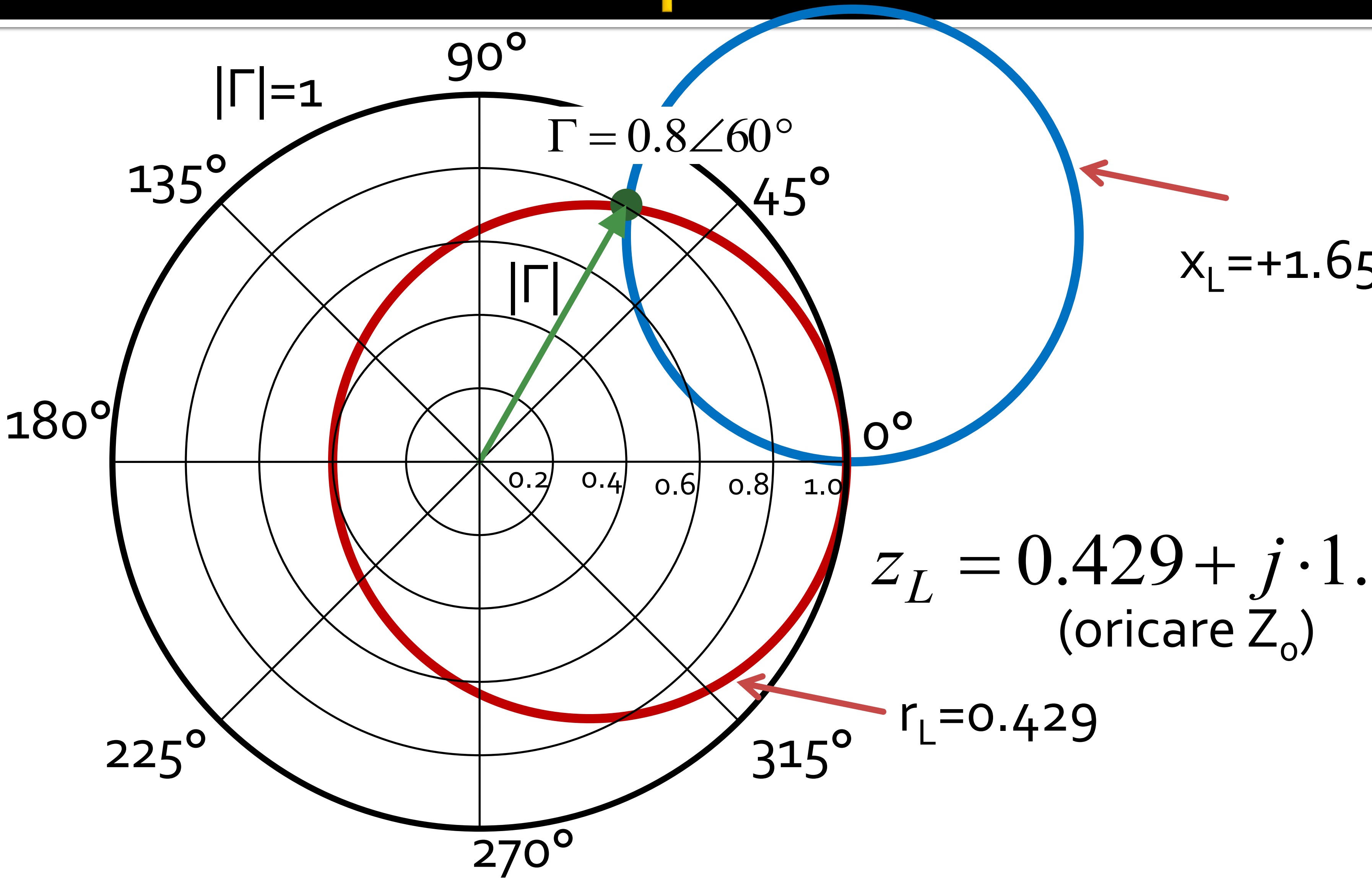
$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{z_L - 1}{z_L + 1}$$

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

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

(oricare Z_o)

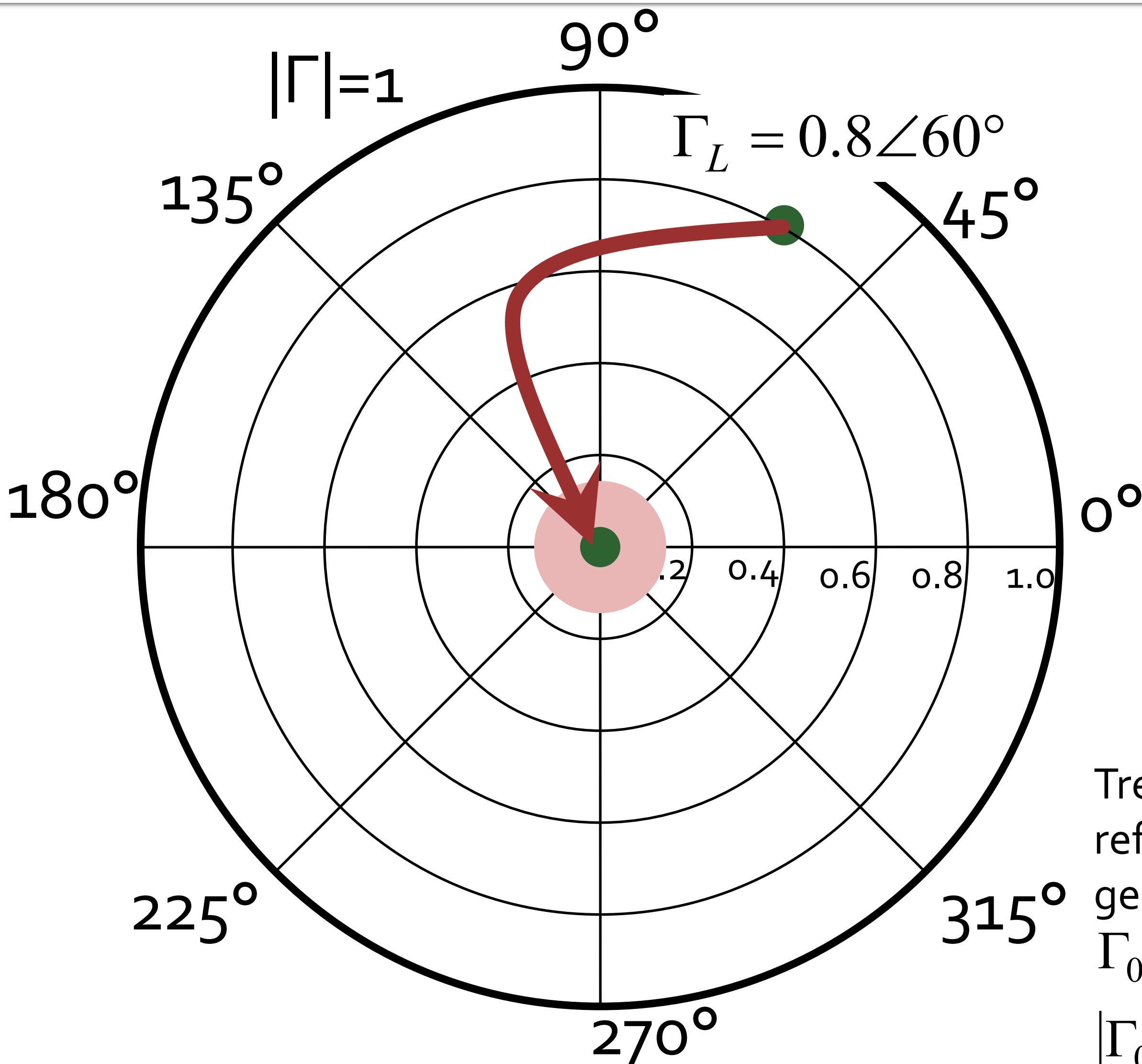
Diagrama Smith, coeficient de reflexie ←→ impedanta

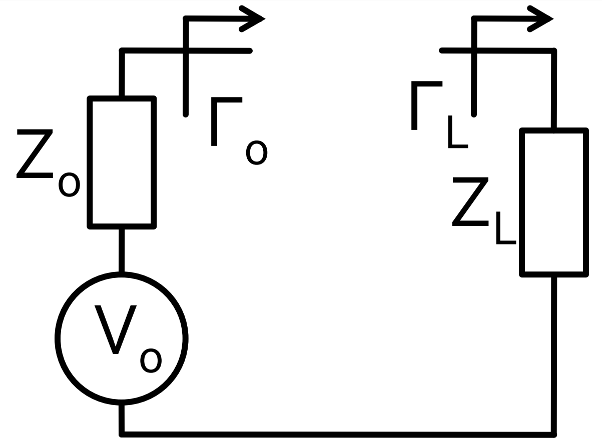


$$z_L = 0.429 + j \cdot 1.65$$

(oricare Z_0)

Diagrama Smith, coeficient de reflexie, adaptare





Adaptare Z_L la Z_o. Se raporteaza Z_L la Z_o

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

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

$$\Gamma_L = 0.8\angle 60°$$

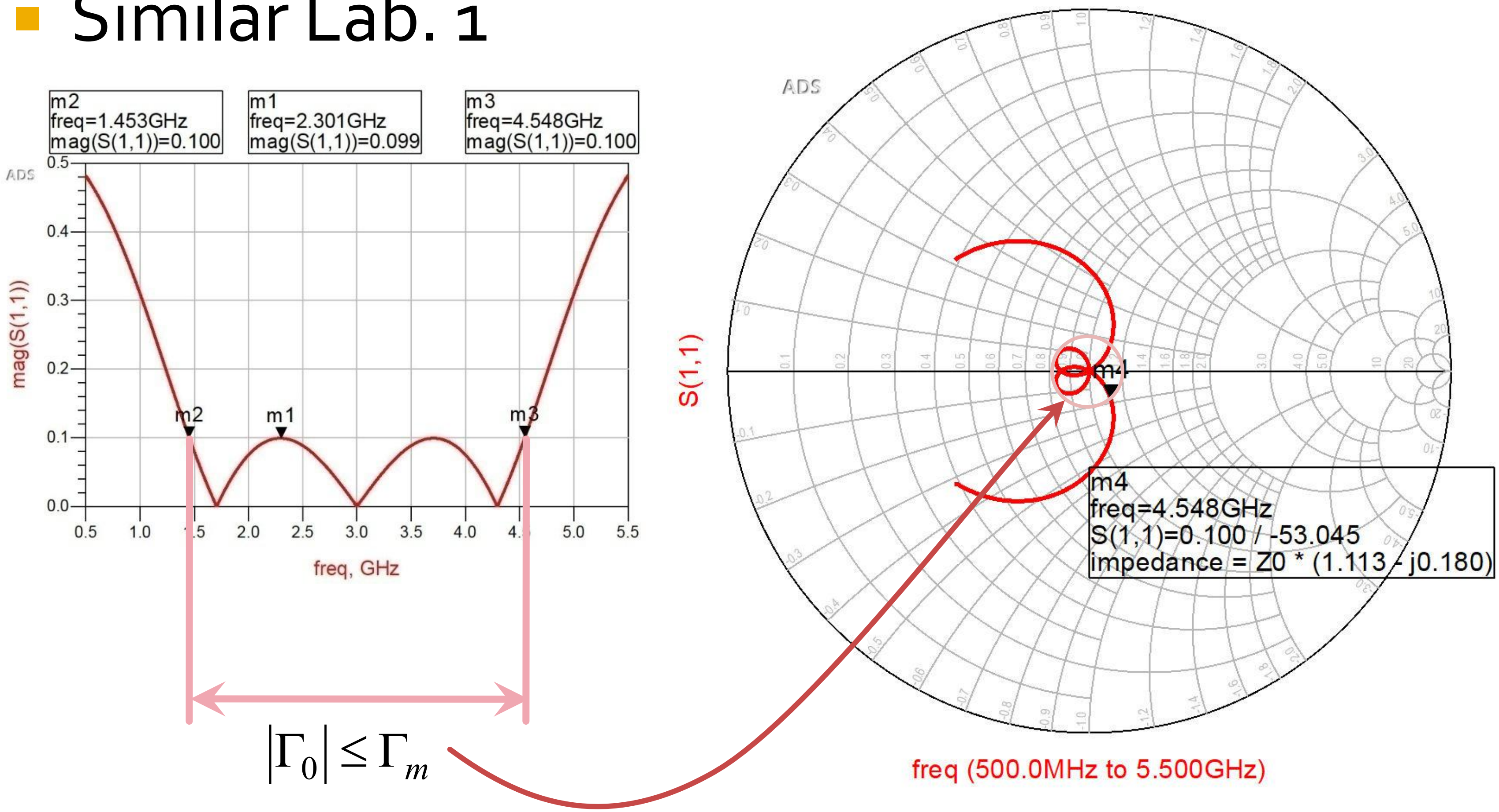
Trebuie sa deplasez coeficientul de reflexie in zona in care pentru generator cu Z_o am:

$\Gamma_0 = 0$ adaptare perfecta

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

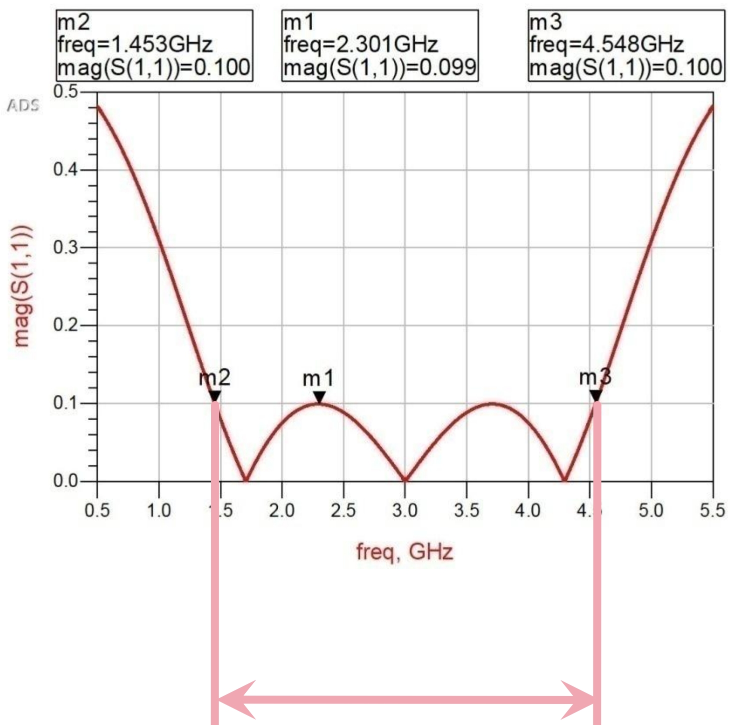
Simulare

- Similar Lab. 1



Simulare

- Similar Lab. 1



$$\left|\Gamma_0\right| \le \Gamma_m$$

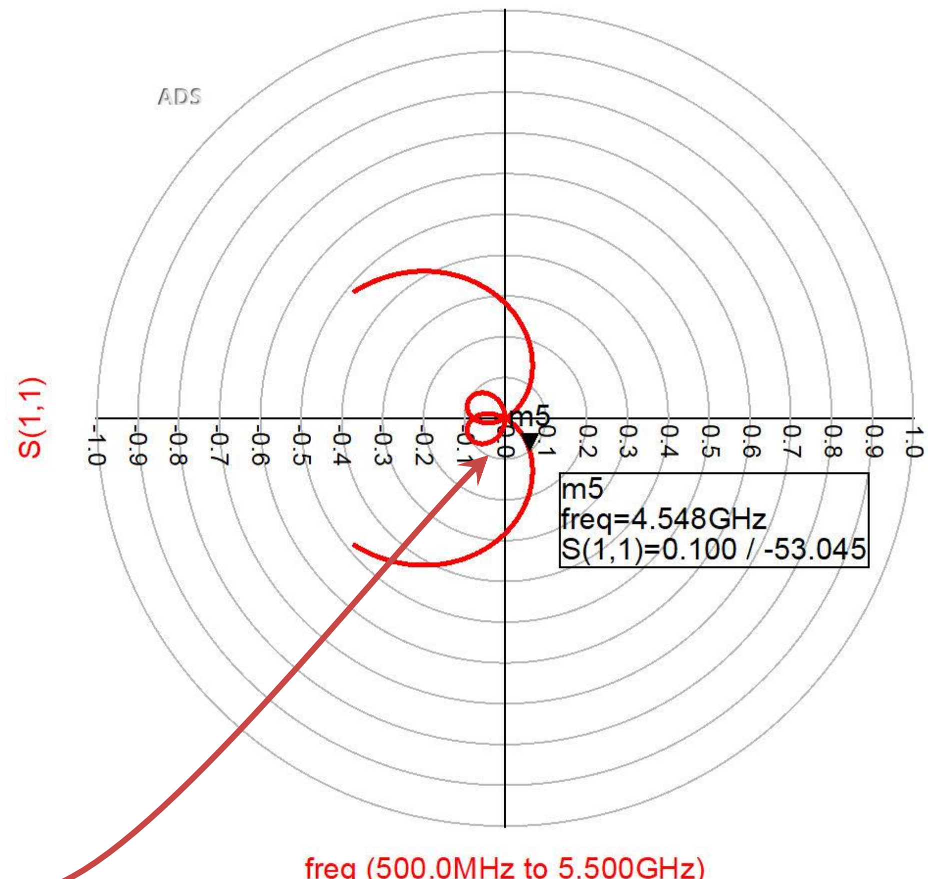
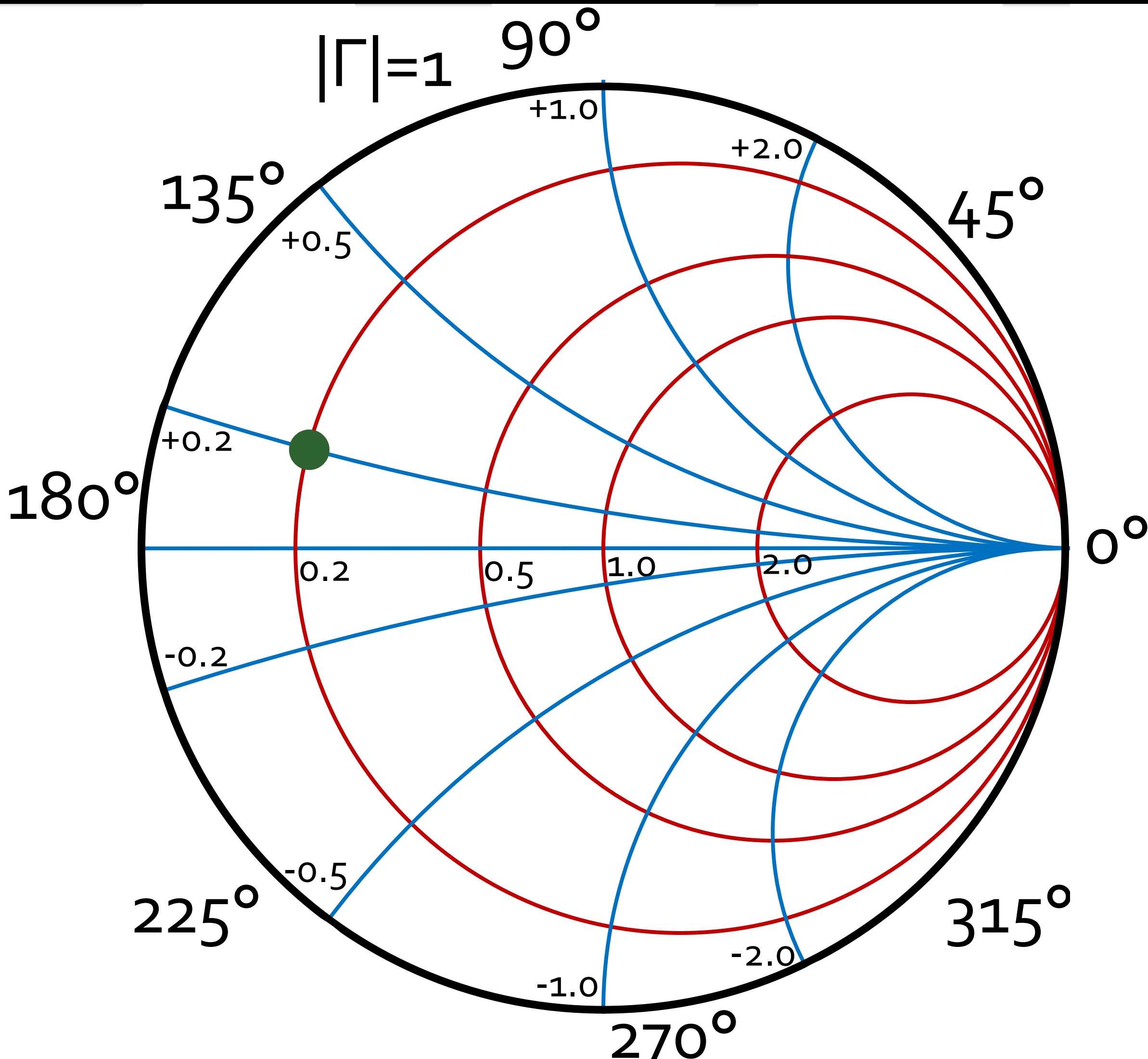
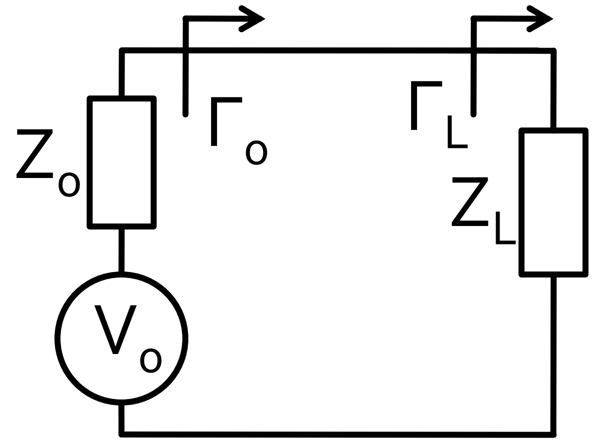


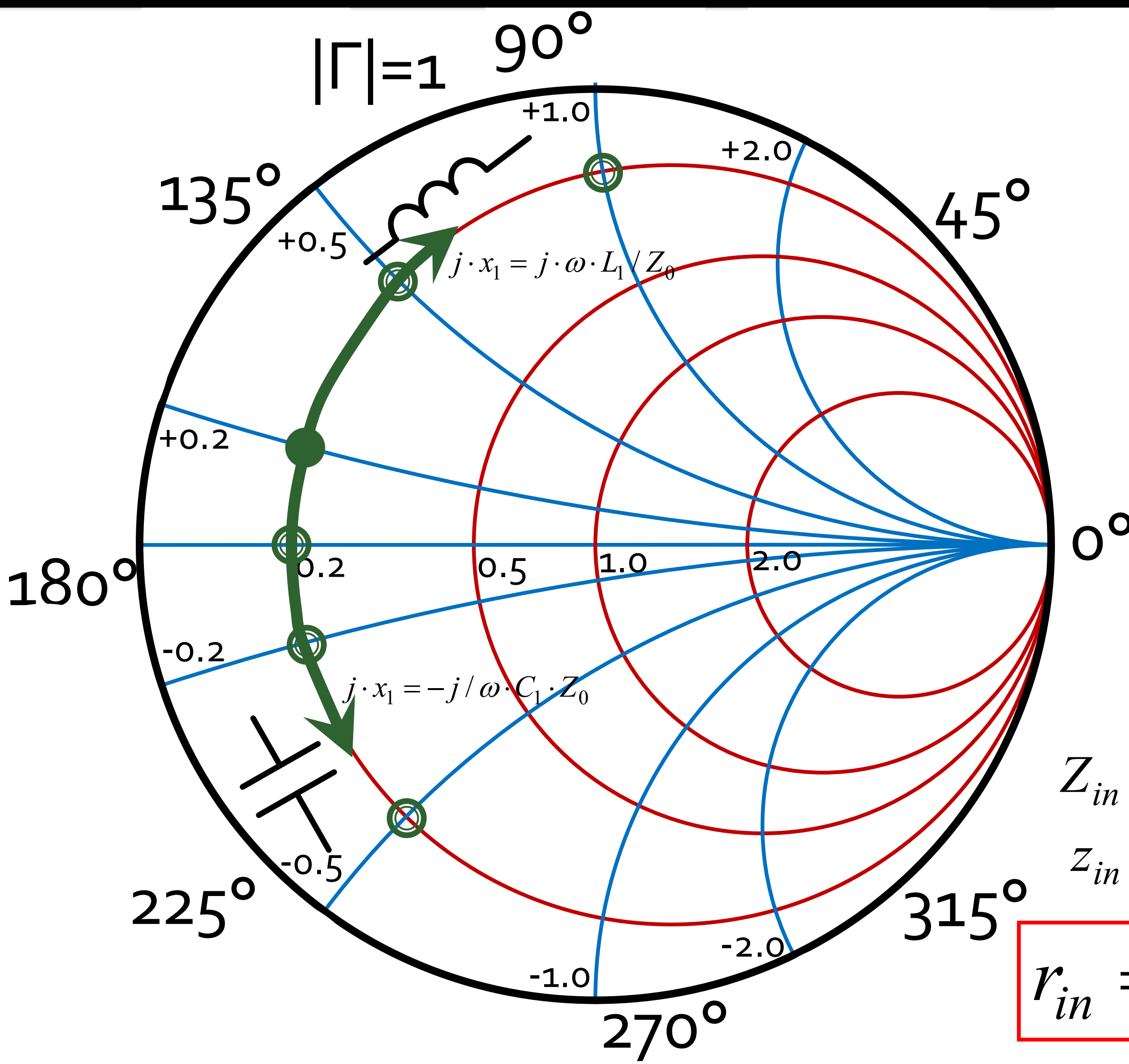
Diagrama Smith, coeficient de reflexie

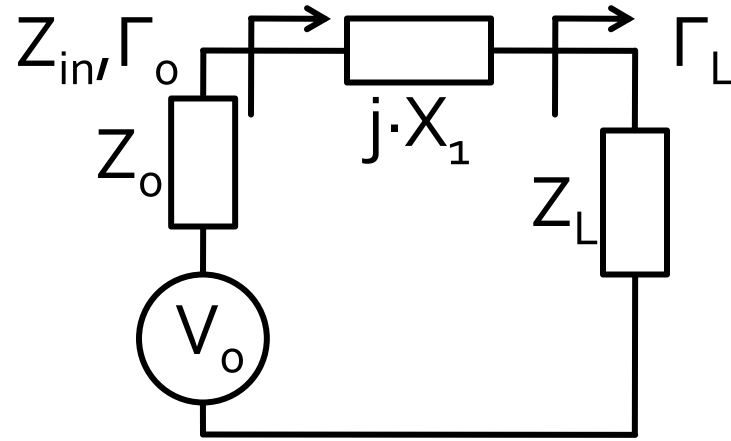




$$Z_0 = 50\Omega$$
$$Z_L = 10\Omega + j \cdot 10\Omega$$
$$z_L = 0.2 + j \cdot 0.2$$
$$\Gamma_L = \Gamma_0 = 0.678\angle 156.5$$

Diagrama Smith, coeficient de reflexie, reactanta in serie





$$Z_0 = 50\Omega$$

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

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

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

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

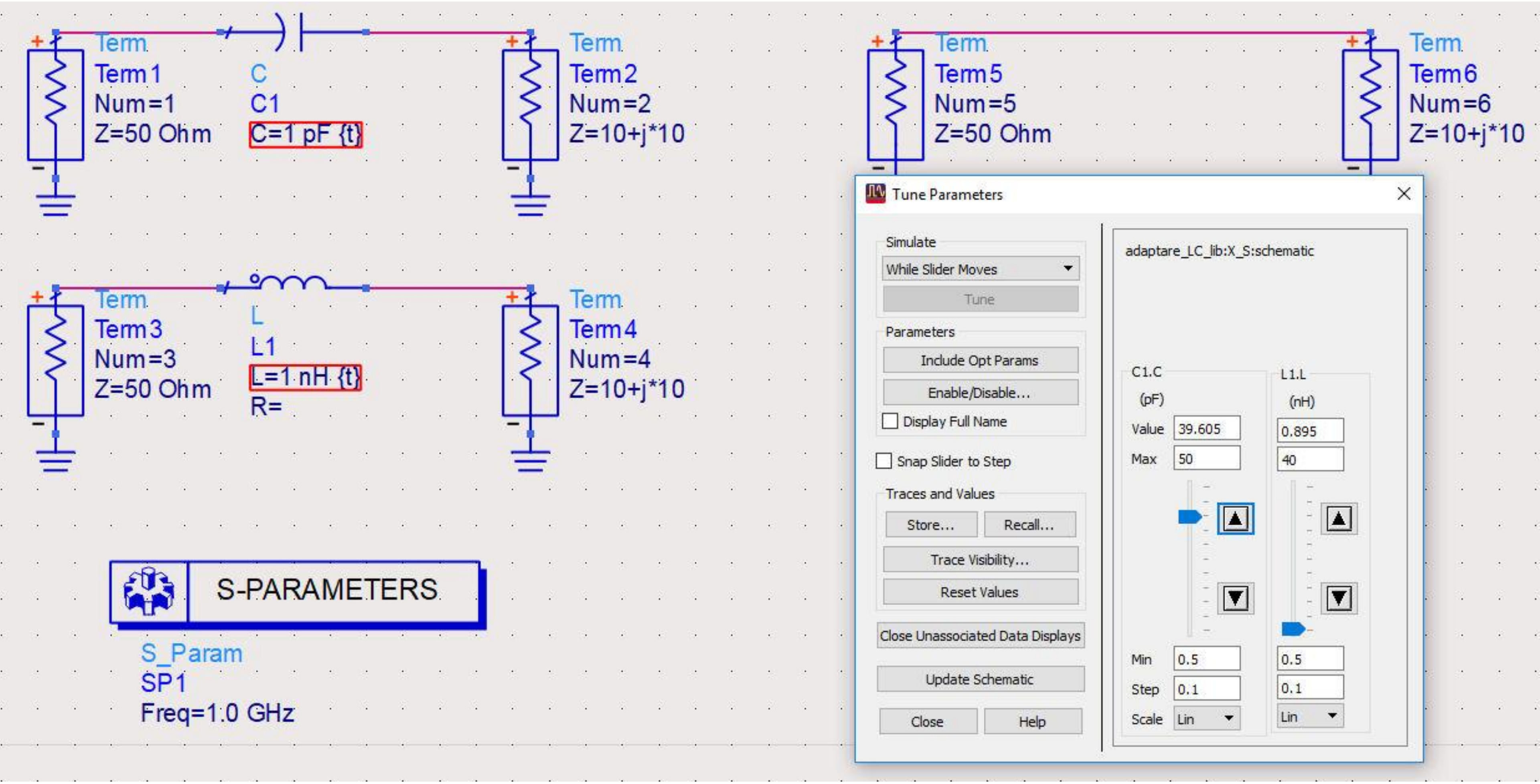
$$z_{in} = r_L + j \cdot \left(x_L + x_1\right)$$

$$\boxed{r_{in} = r_L}$$

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

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

ADS, Diagrama Smith, reactanta in serie



ADS, Diagrama Smith, reactanta in serie

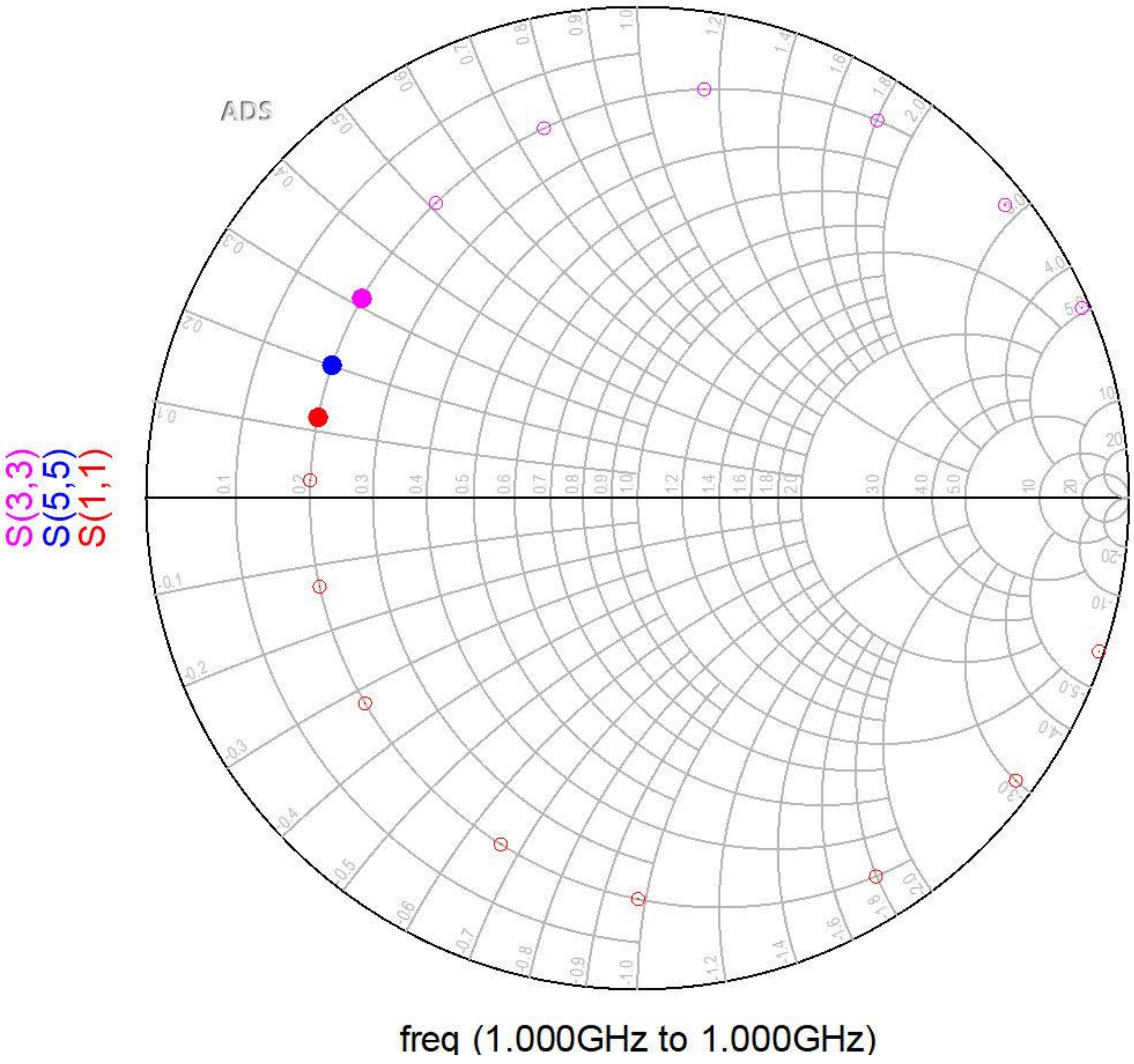
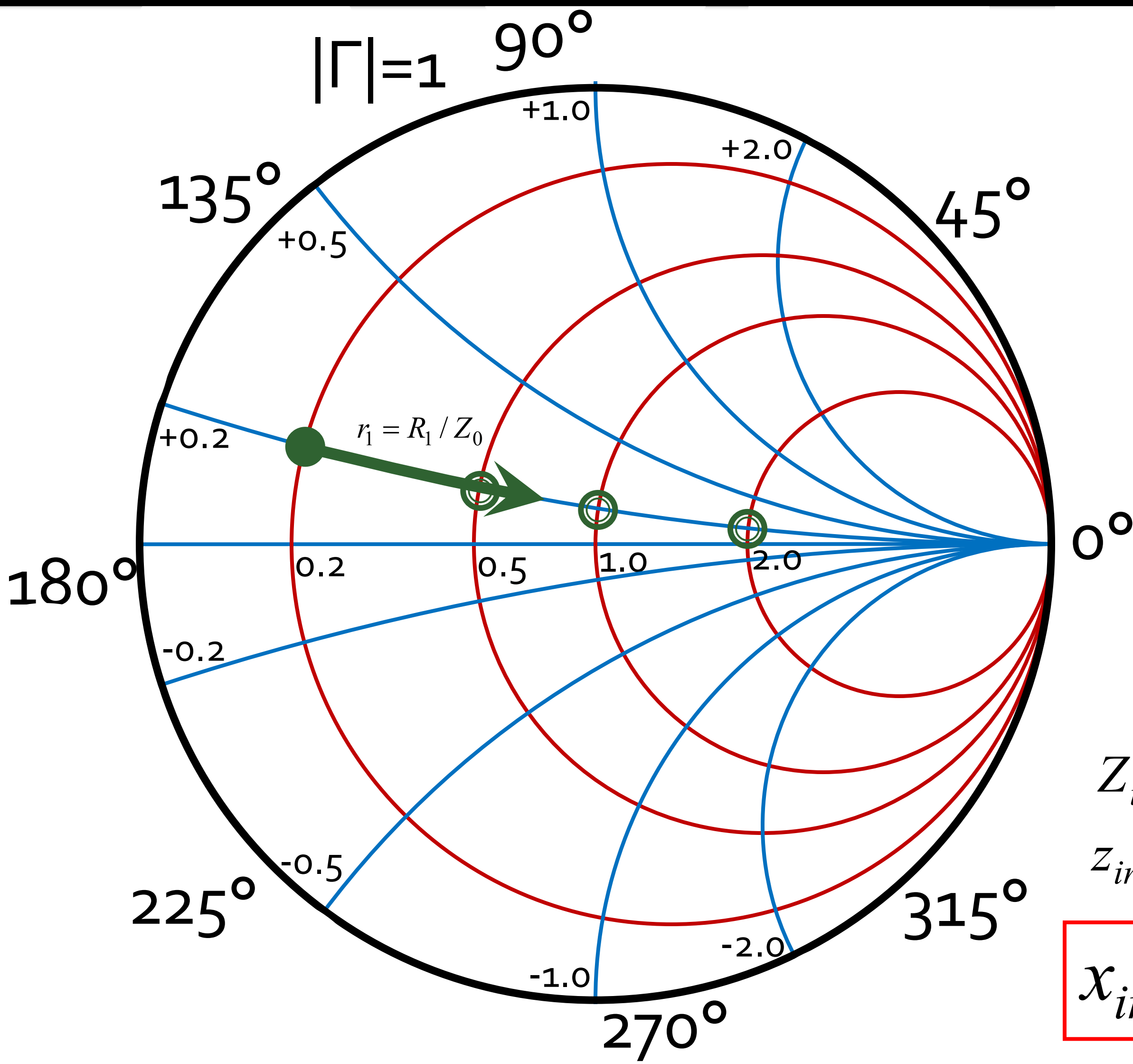
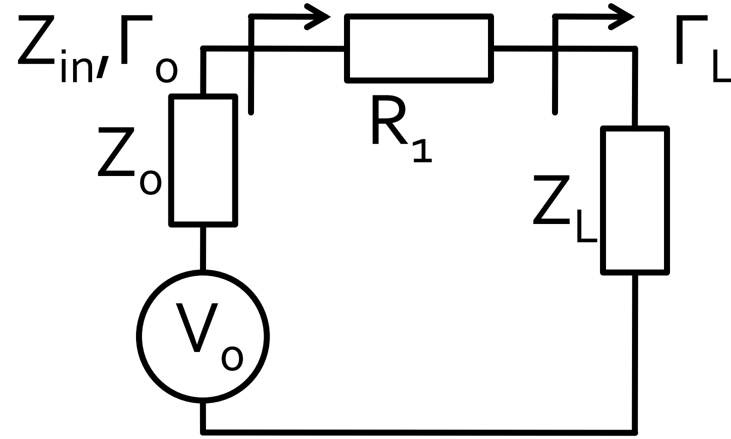


Diagrama Smith, coeficient de reflexie, rezistenta in serie





$$Z_0 = 50\Omega$$

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

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

$$\Gamma_L = 0.678\angle 156.5°$$

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

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

$$\boxed{x_{in} = x_L} \qquad r_{in} = r_L + R_1 / Z_0$$

ADS, Diagrama Smith, rezistenta in serie

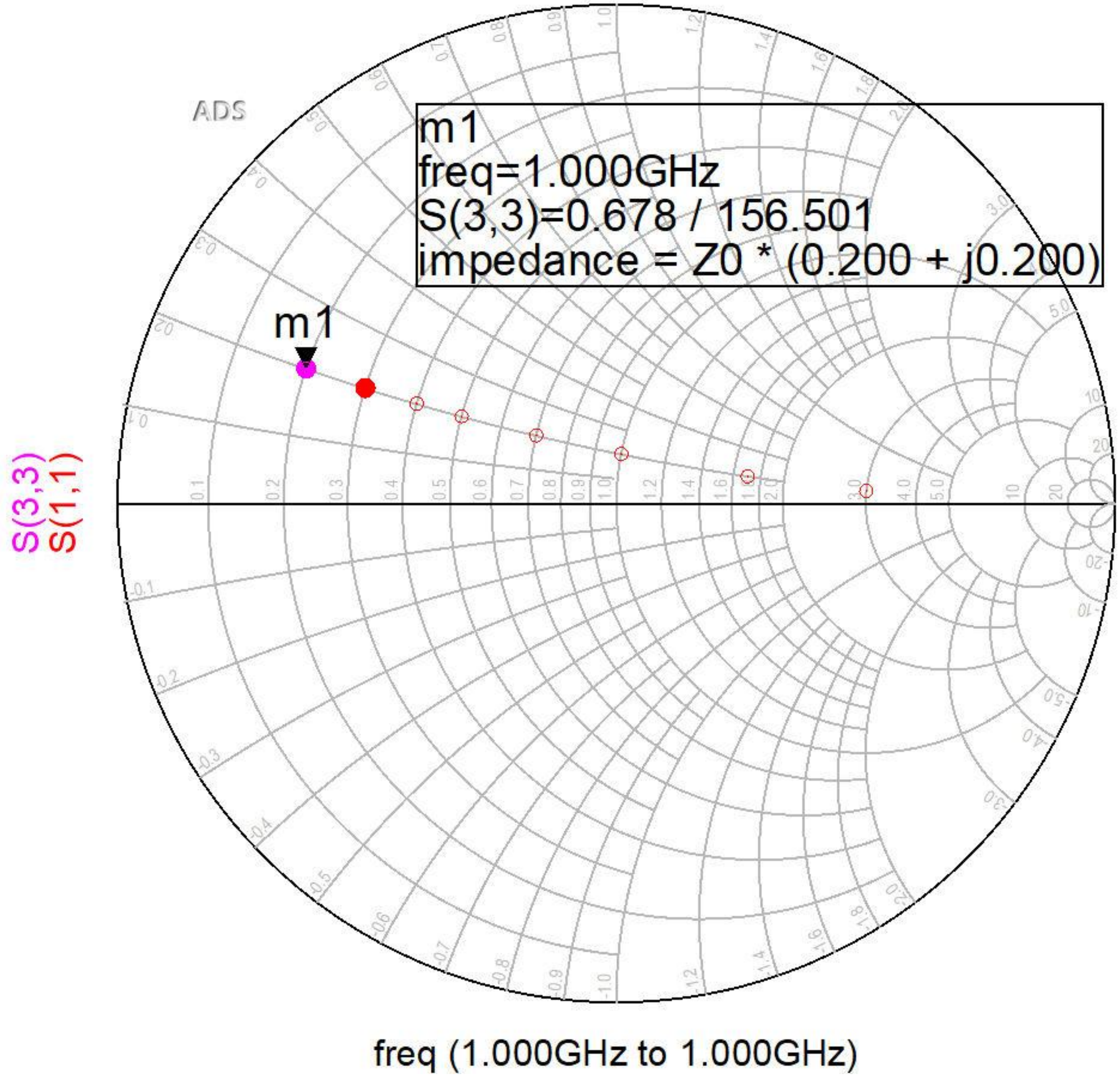
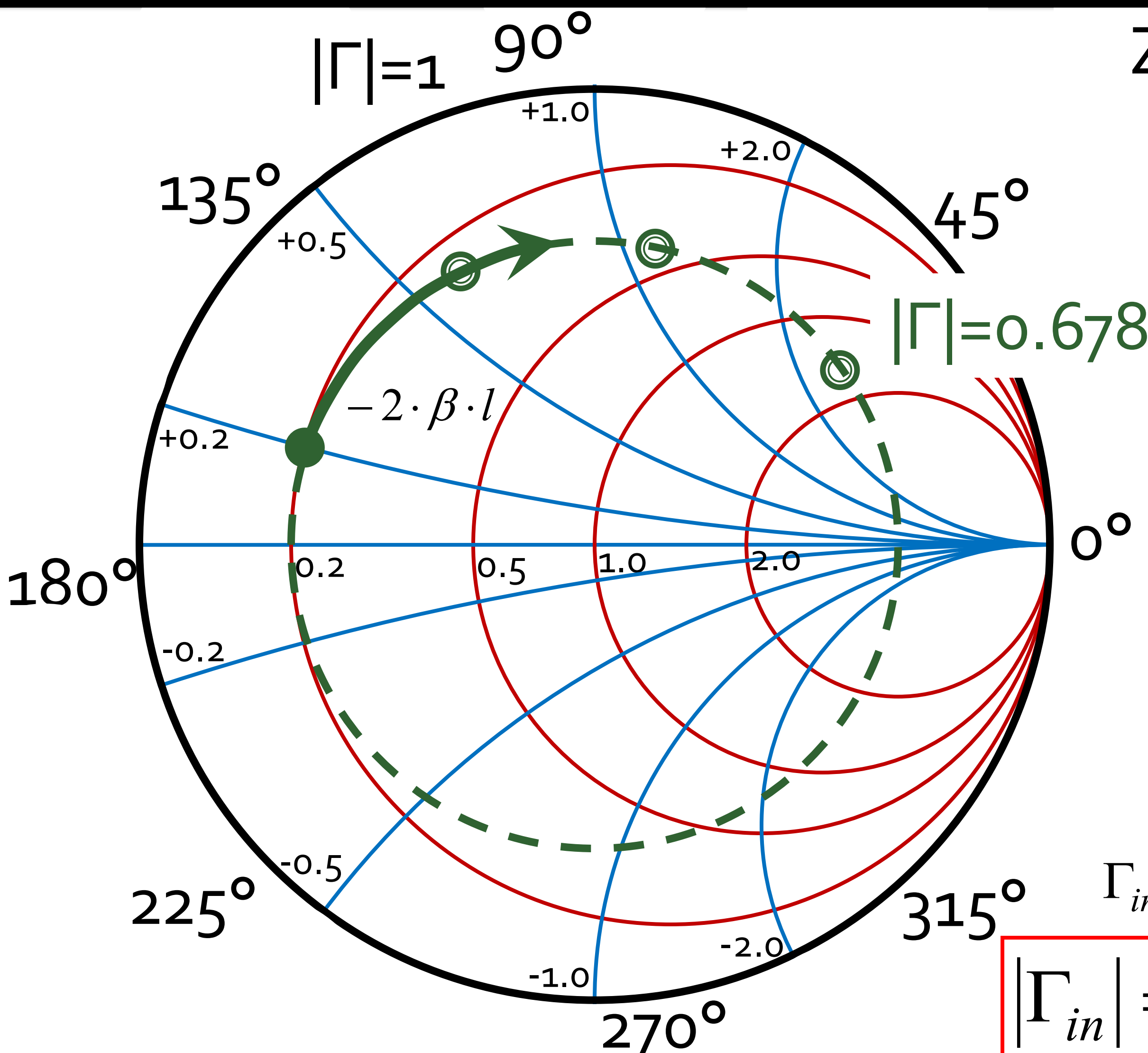
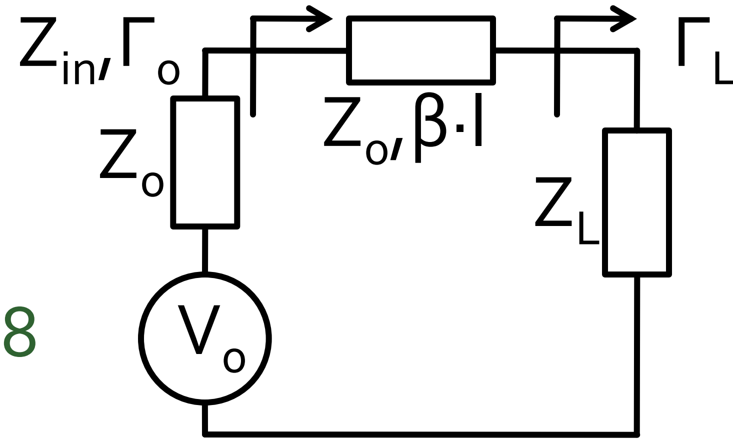


Diagrama Smith, coeficient de reflexie, linie de transmisie in serie





$$Z_0 = 50\Omega$$

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

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

$$\Gamma_L = 0.678\angle 156.5°$$

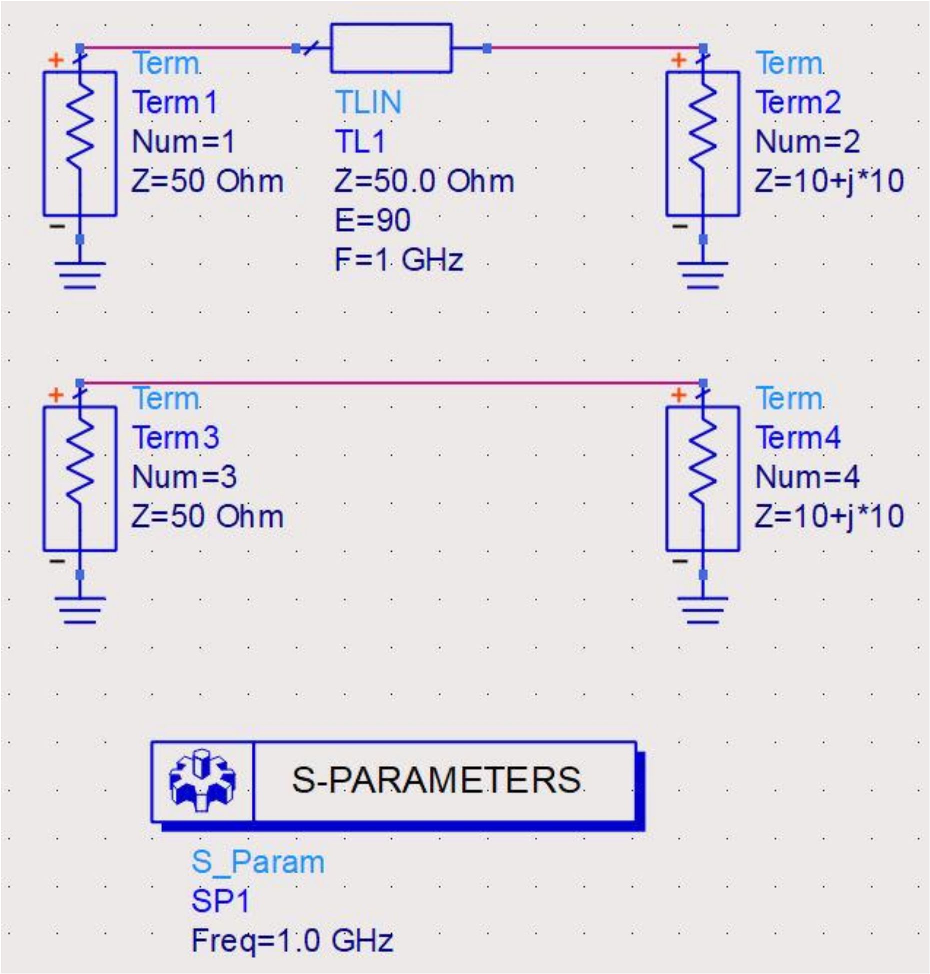
$$Z_{in} = Z_0 \cdot \frac{1+\Gamma_L\cdot e^{-2j\cdot\beta\cdot l}}{1-\Gamma_L\cdot e^{-2j\cdot\beta\cdot l}}$$

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

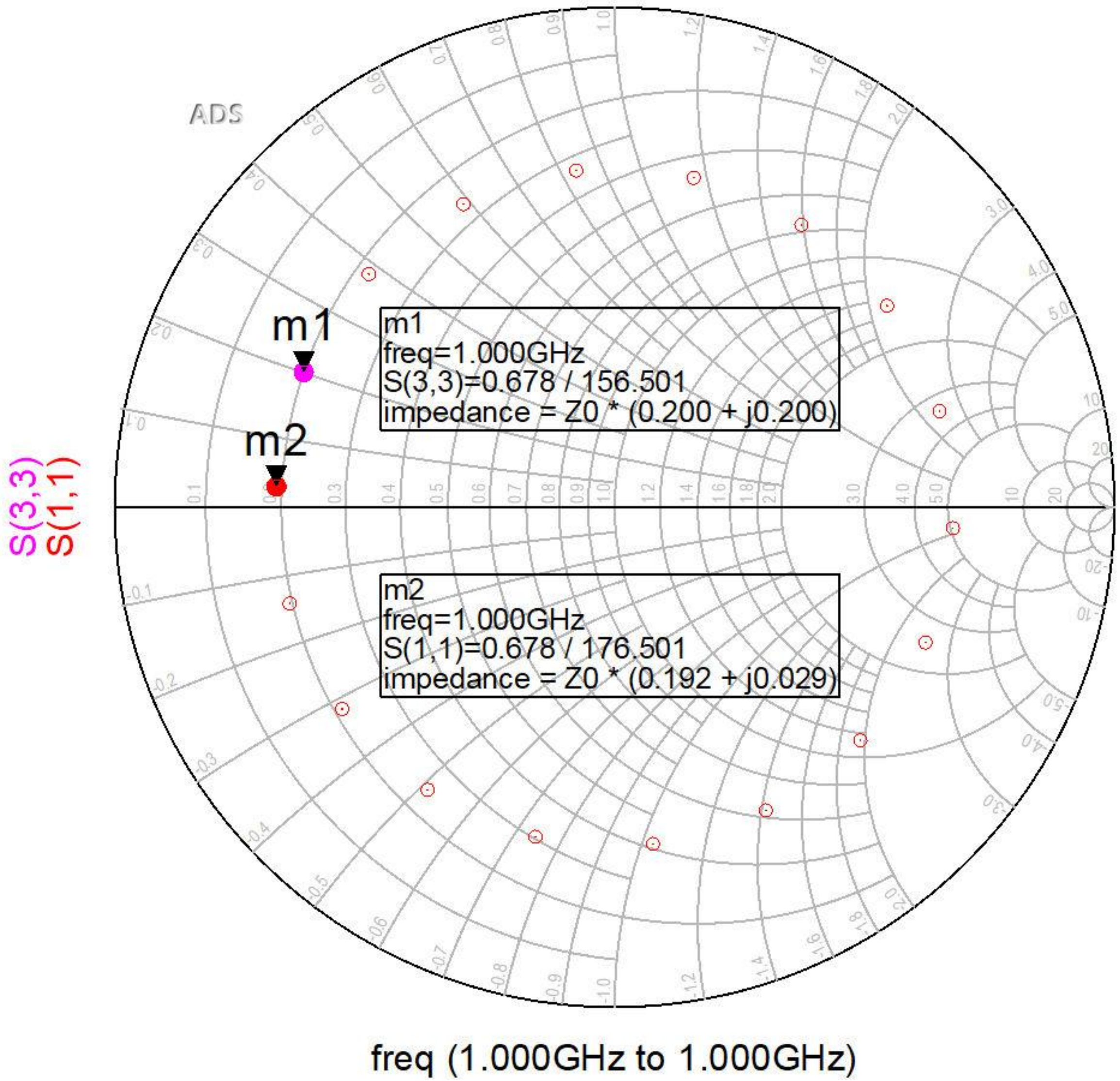
$$\boxed{\left|\Gamma_{in}\right| = \left|\Gamma_L\right|}$$

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

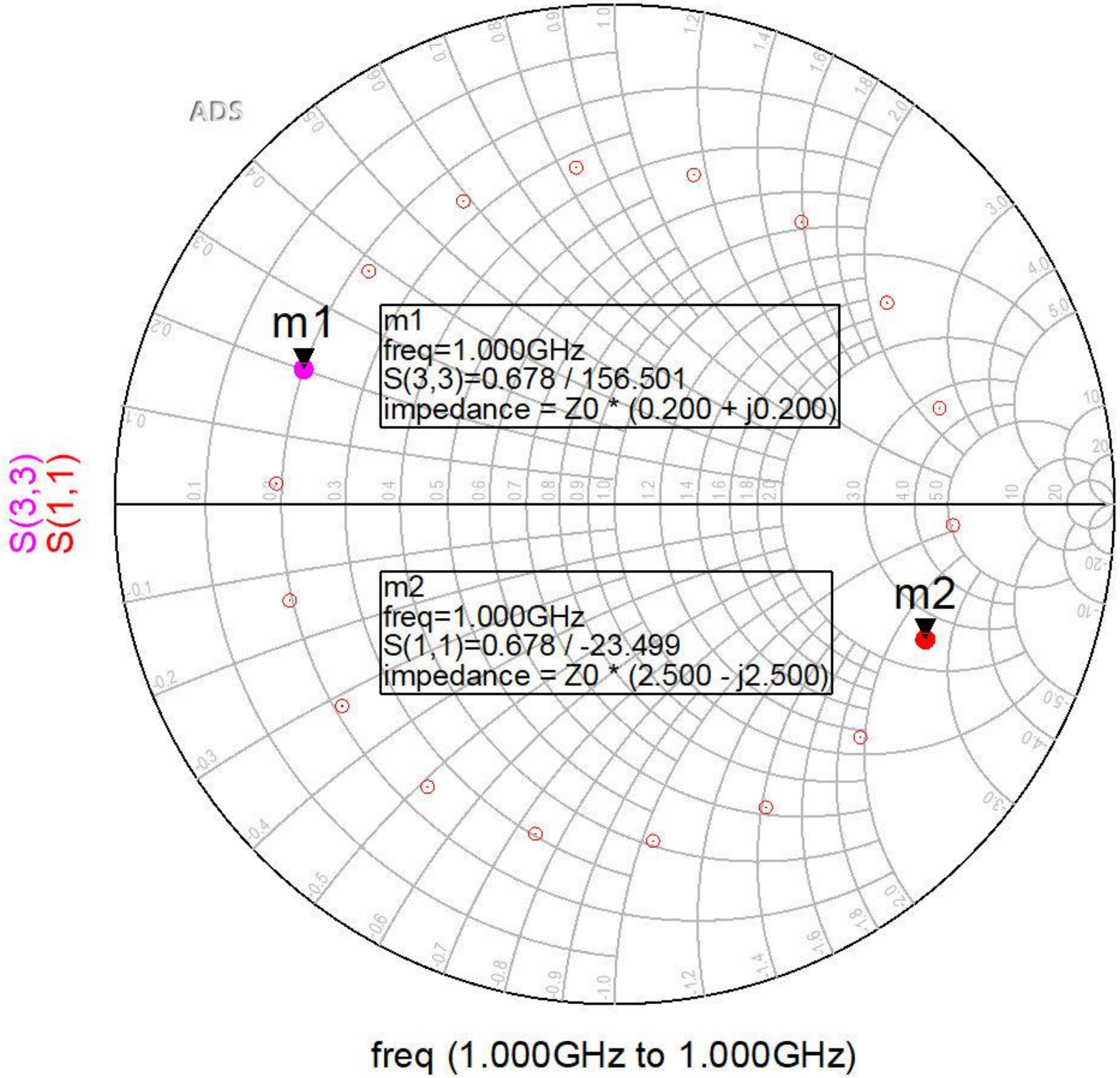
ADS, Diagrama Smith, linie de transmisie in serie



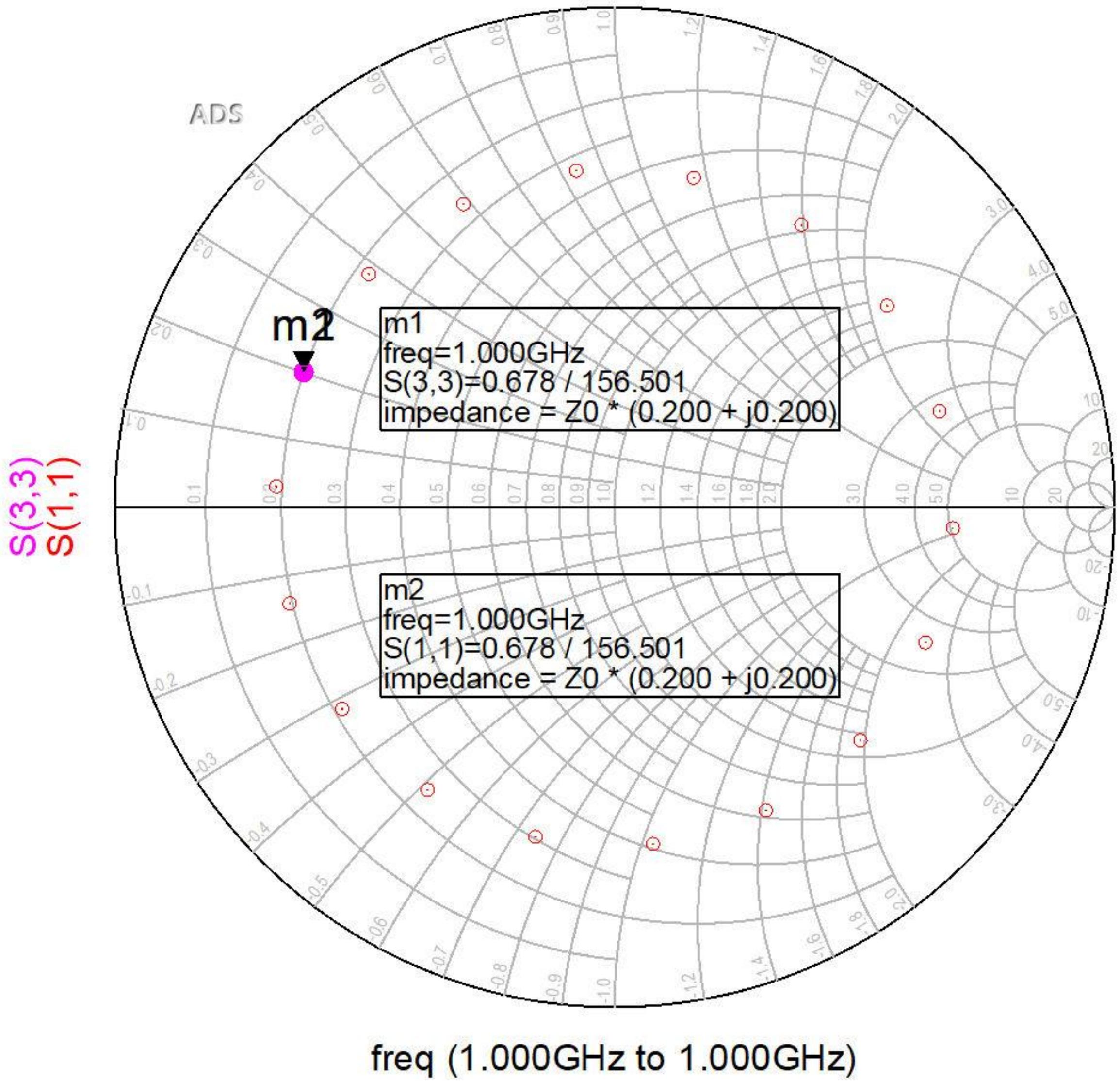
ADS, Diagrama Smith, linie de transmisie in serie



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=25Ω≠Zo

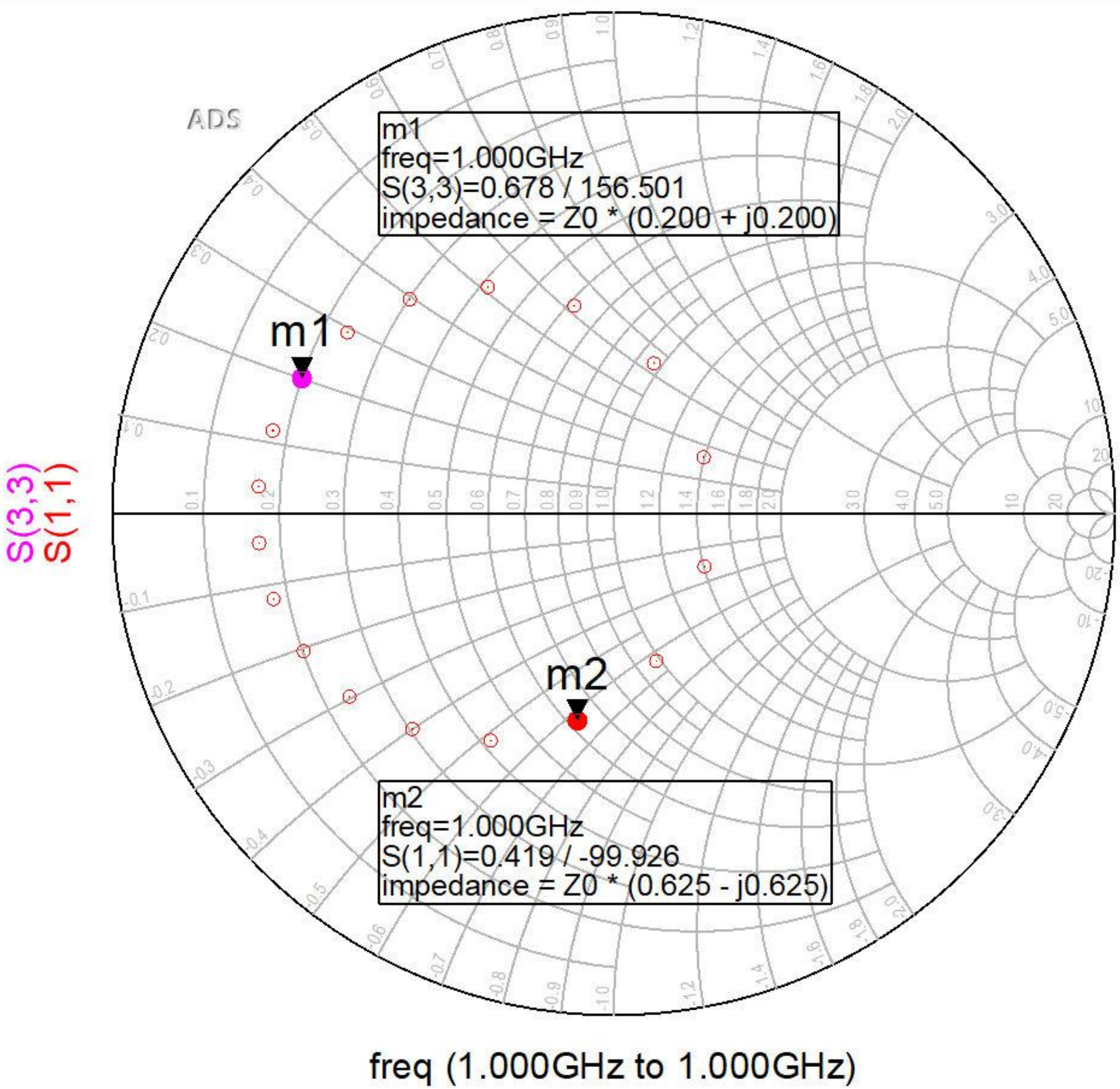
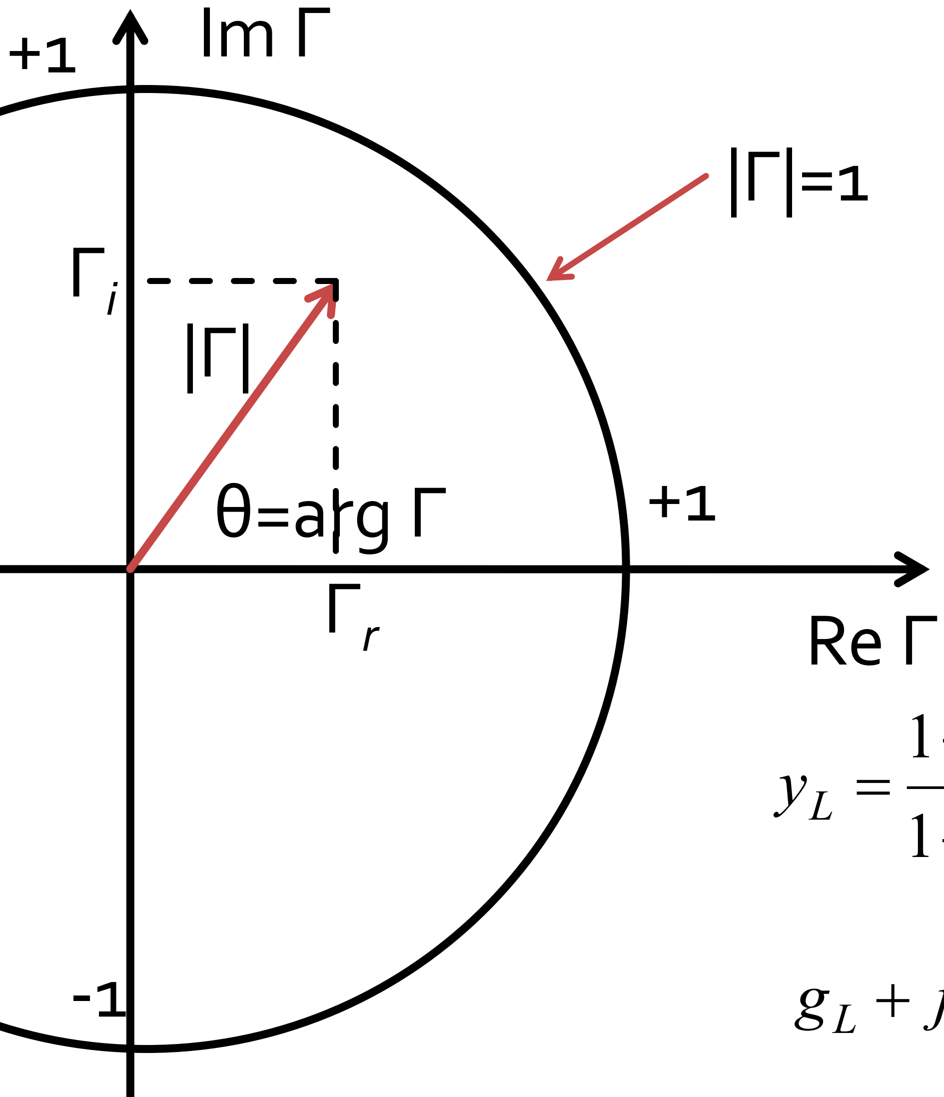


Diagrama Smith, admitante



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

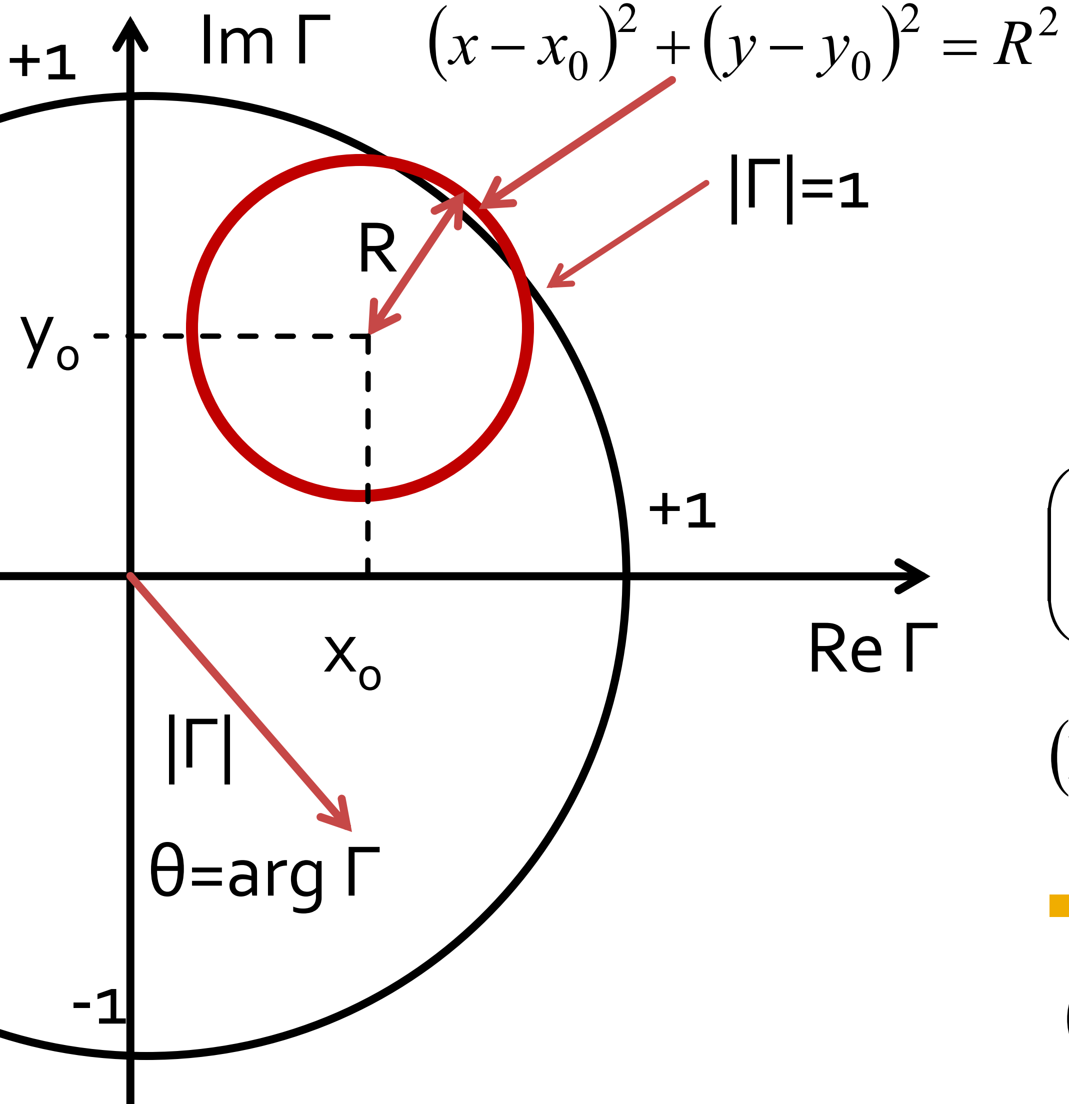
$$\Gamma = \Gamma_r + j \cdot \Gamma_i$$

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

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

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

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

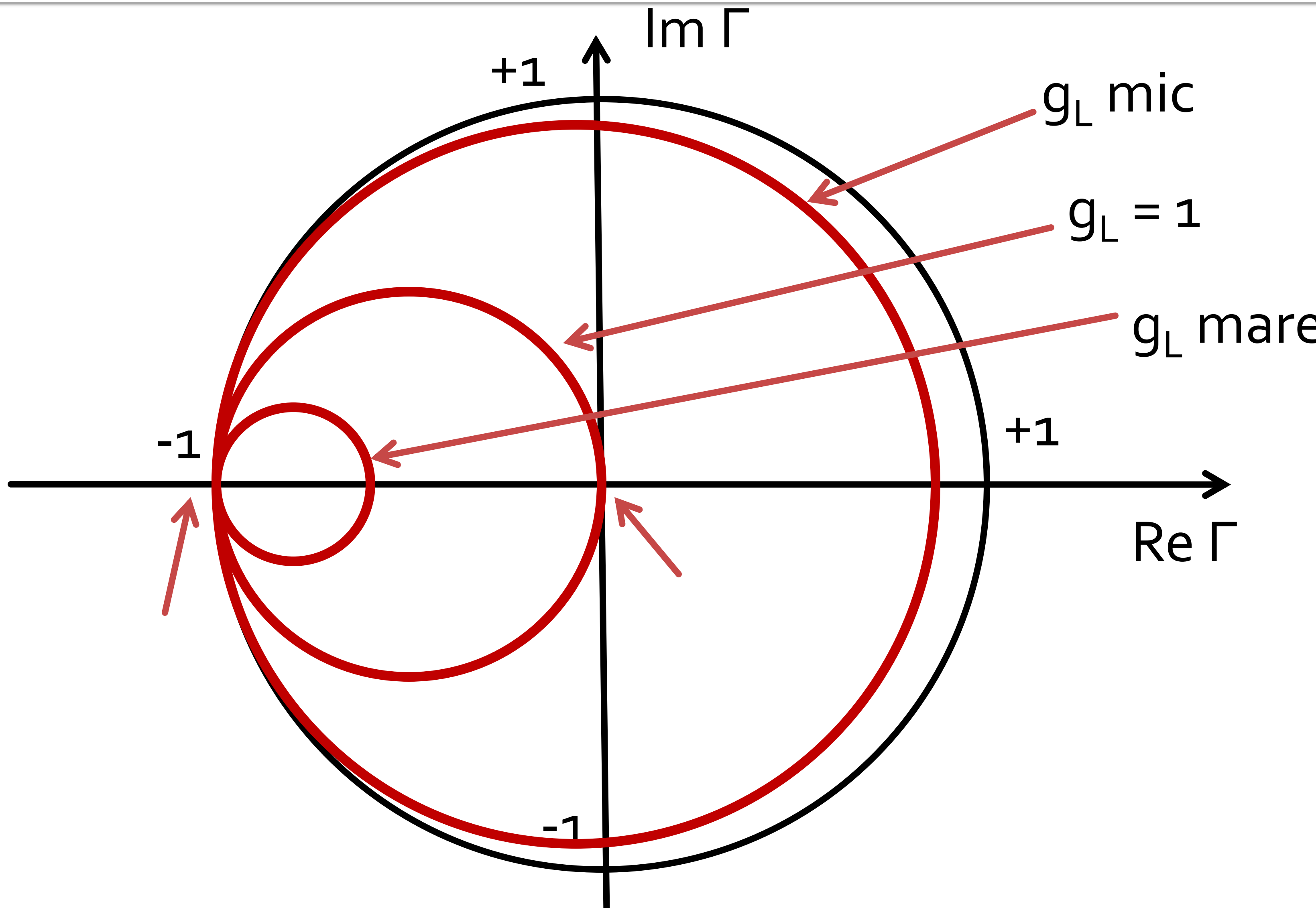


Diagrama Smith, susceptanta

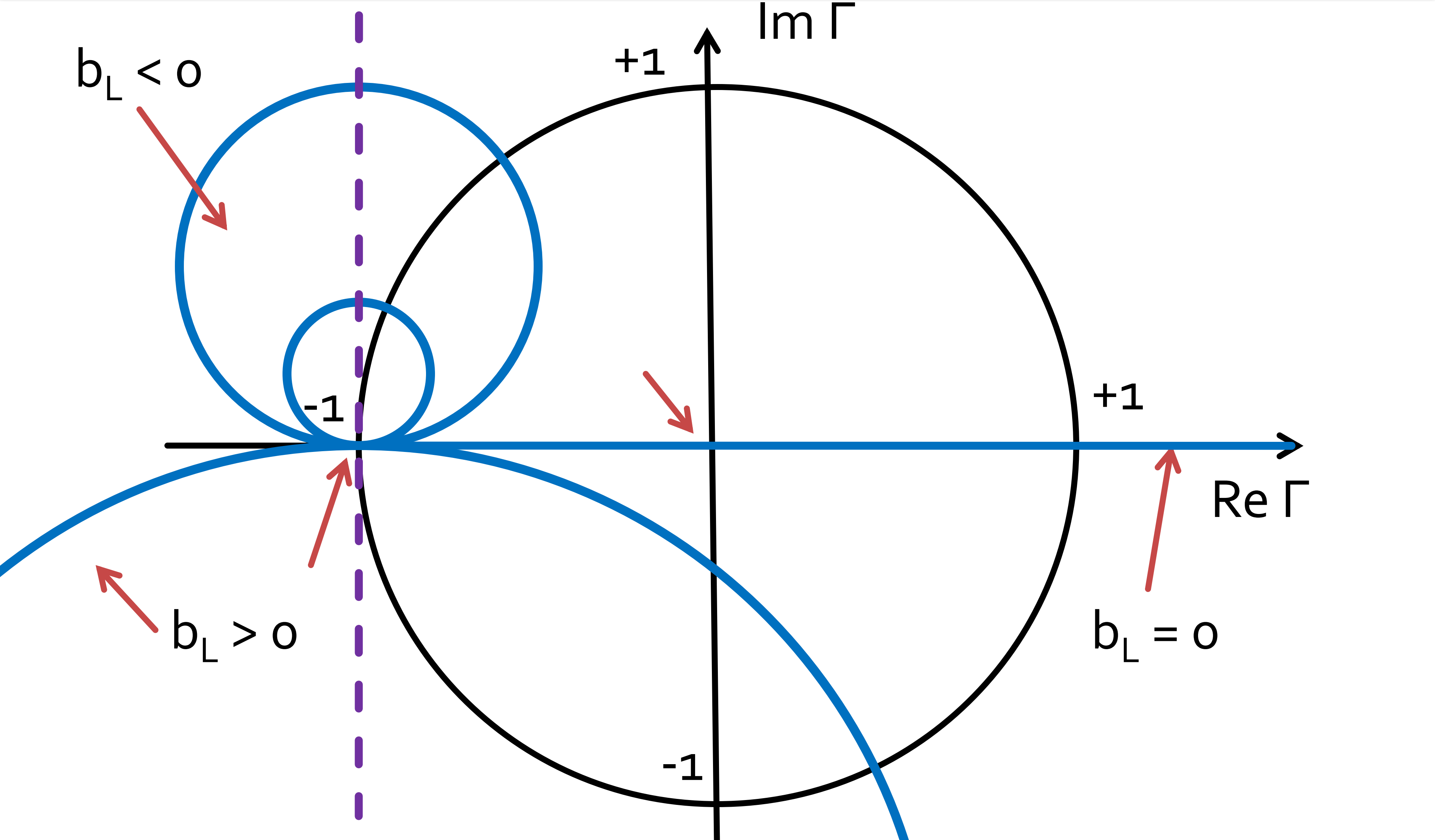
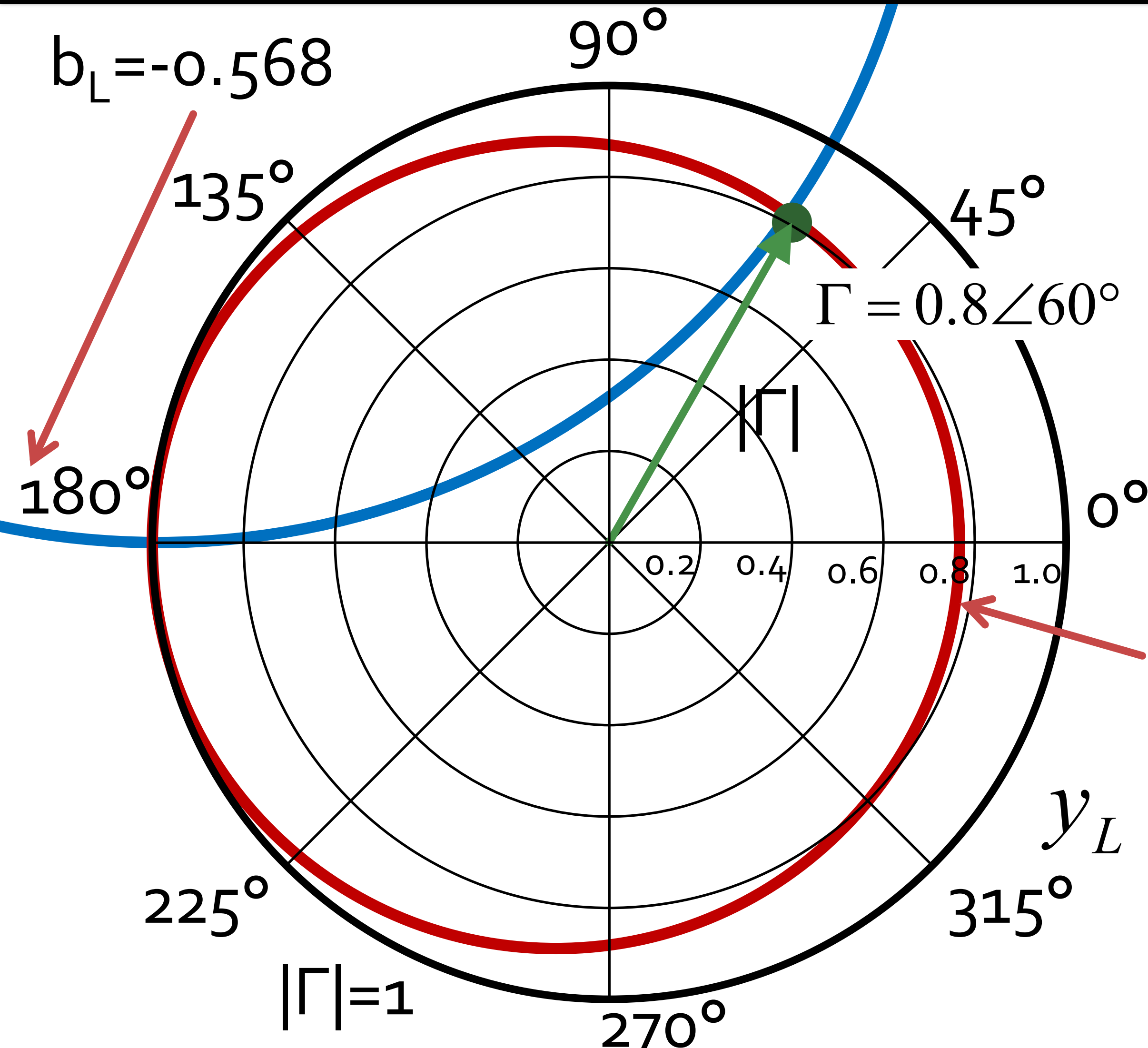


Diagrama Smith, coeficient de reflexie ⇔ admitanta



$$\Gamma = 0.8\angle 60°$$

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

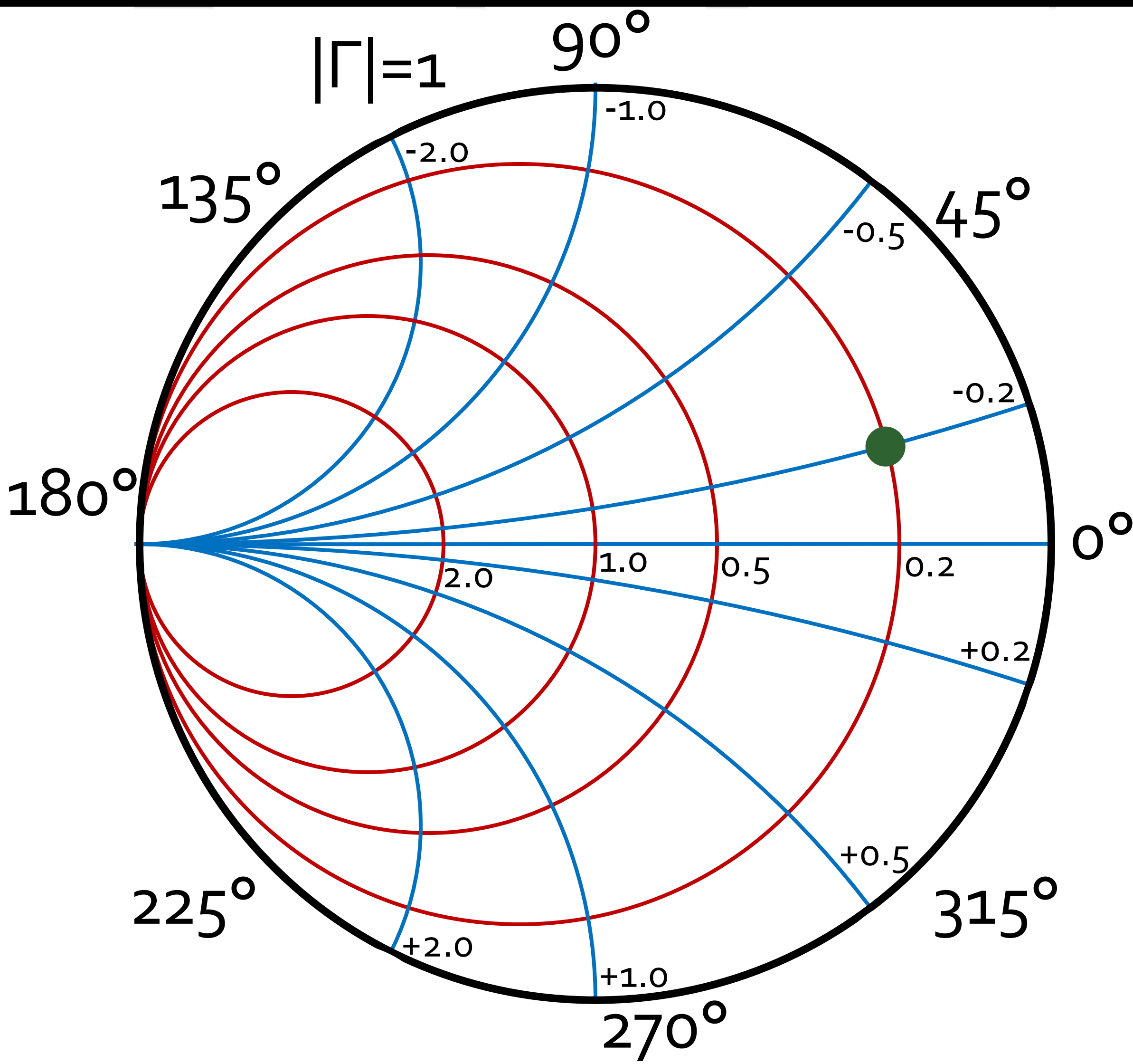
$$z_L = 0.429 + j\cdot 1.65$$

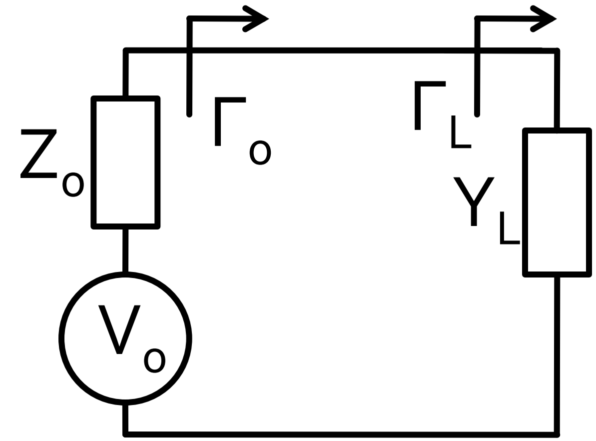
$$y_L = \frac{1}{z_L} = 0.148 - j\cdot 0.568$$

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

(oricare Z_0)

Diagrama Smith, coeficient de reflexie, admitanta





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

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

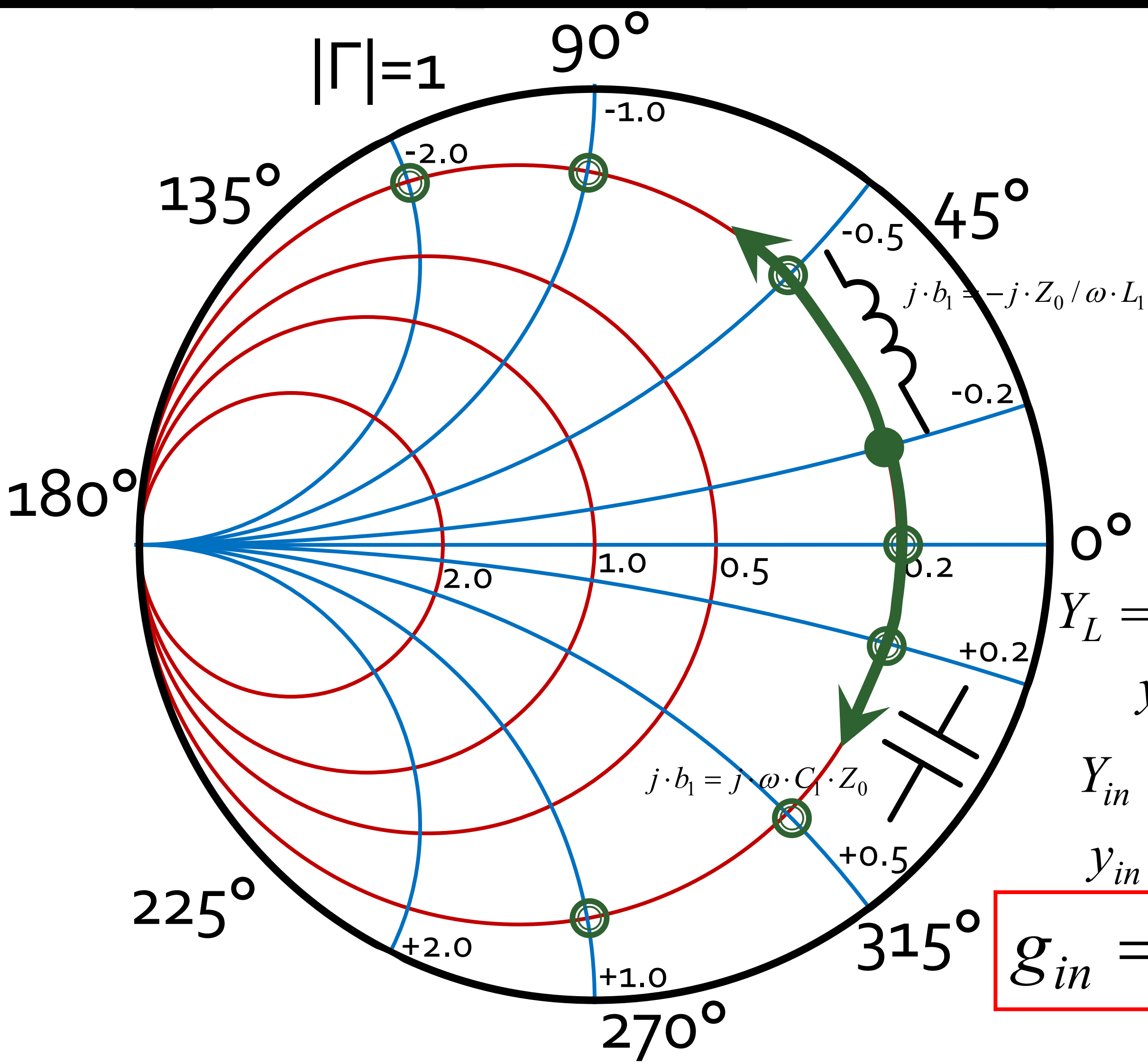
$$z_L = 2.5 + j \cdot 2.5$$

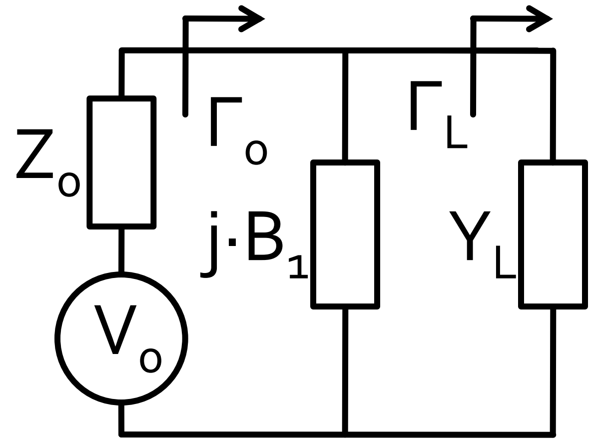
$$\Gamma_L = \Gamma_0 = 0.678\angle 23.5°$$

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

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

Diagrama Smith, coeficient de reflexie, susceptanta in paralel





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

$$\Gamma_L = 0.678\angle 23.5°$$

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

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

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

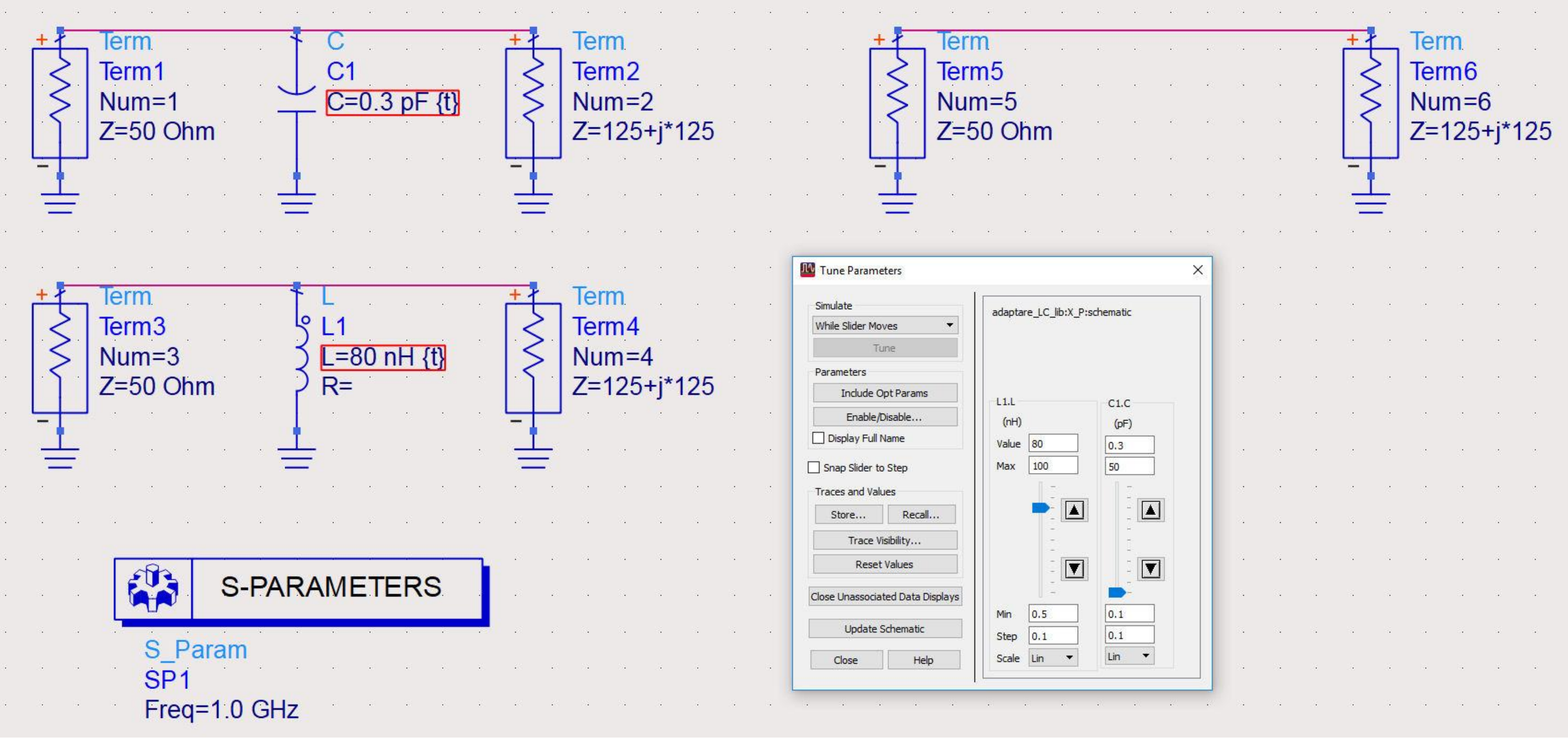
$$y_{in} = g_L + j \cdot (b_L + b_1)$$

$$\boxed{g_{in} = g_L}$$

$$j \cdot b_1 = j \cdot \omega \cdot C_1 \cdot Z_0 > 0$$

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

ADS, Diagrama Smith, susceptanta in paralel



ADS, Diagrama Smith, susceptanta in paralel

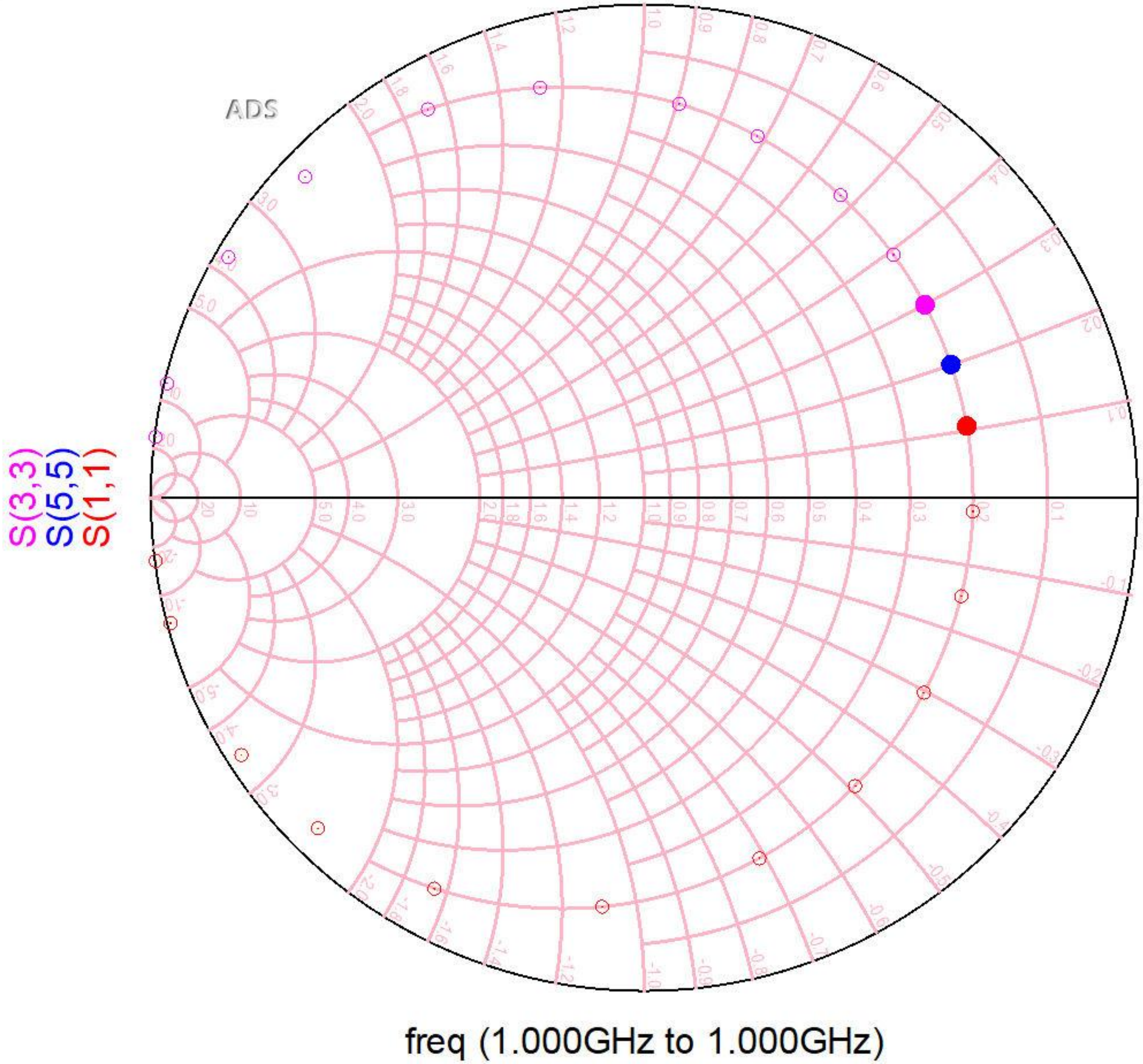
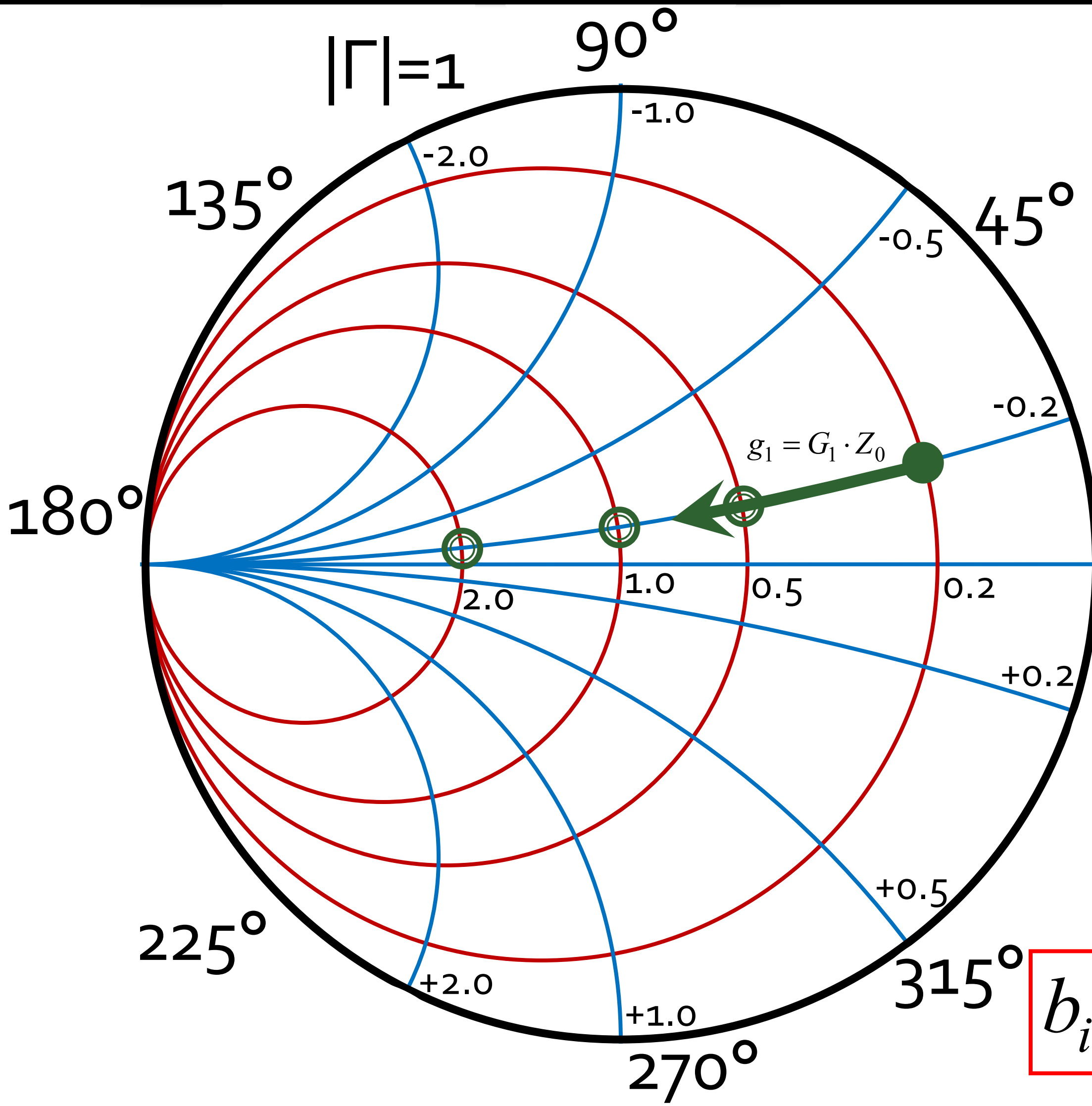
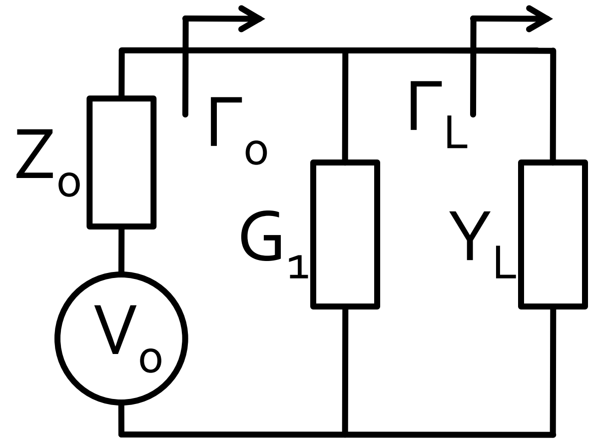


Diagrama Smith, coeficient de reflexie, conductanta in paralel





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

$$\Gamma_L = 0.678\angle 23.5°$$

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

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

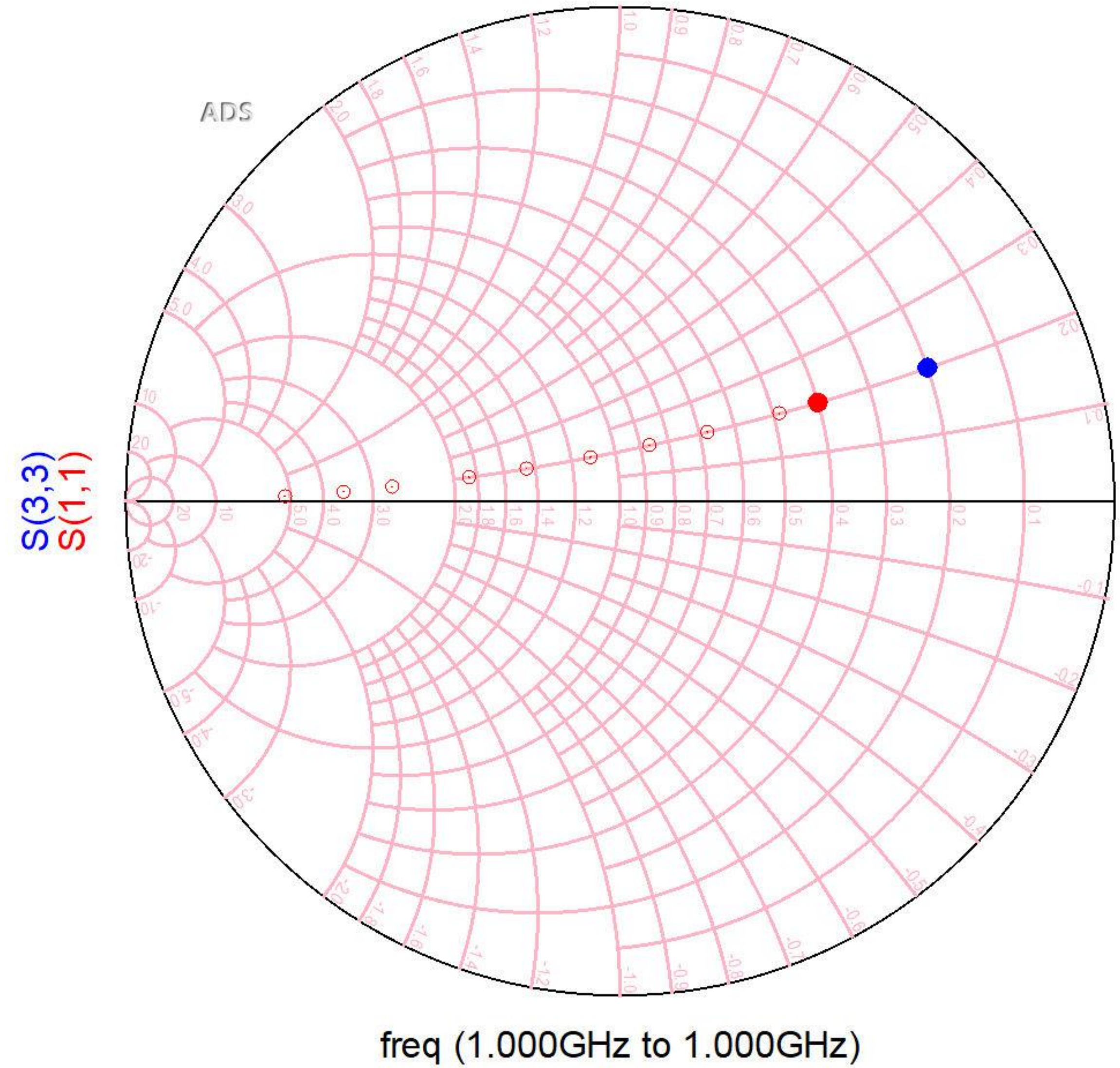
$$Y_{in} = Y_L + G_1 = (G_L + G_1) + j \cdot B_L$$

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

$$\boxed{b_{in} = b_L}$$

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

ADS, Diagrama Smith, conductanta in paralel



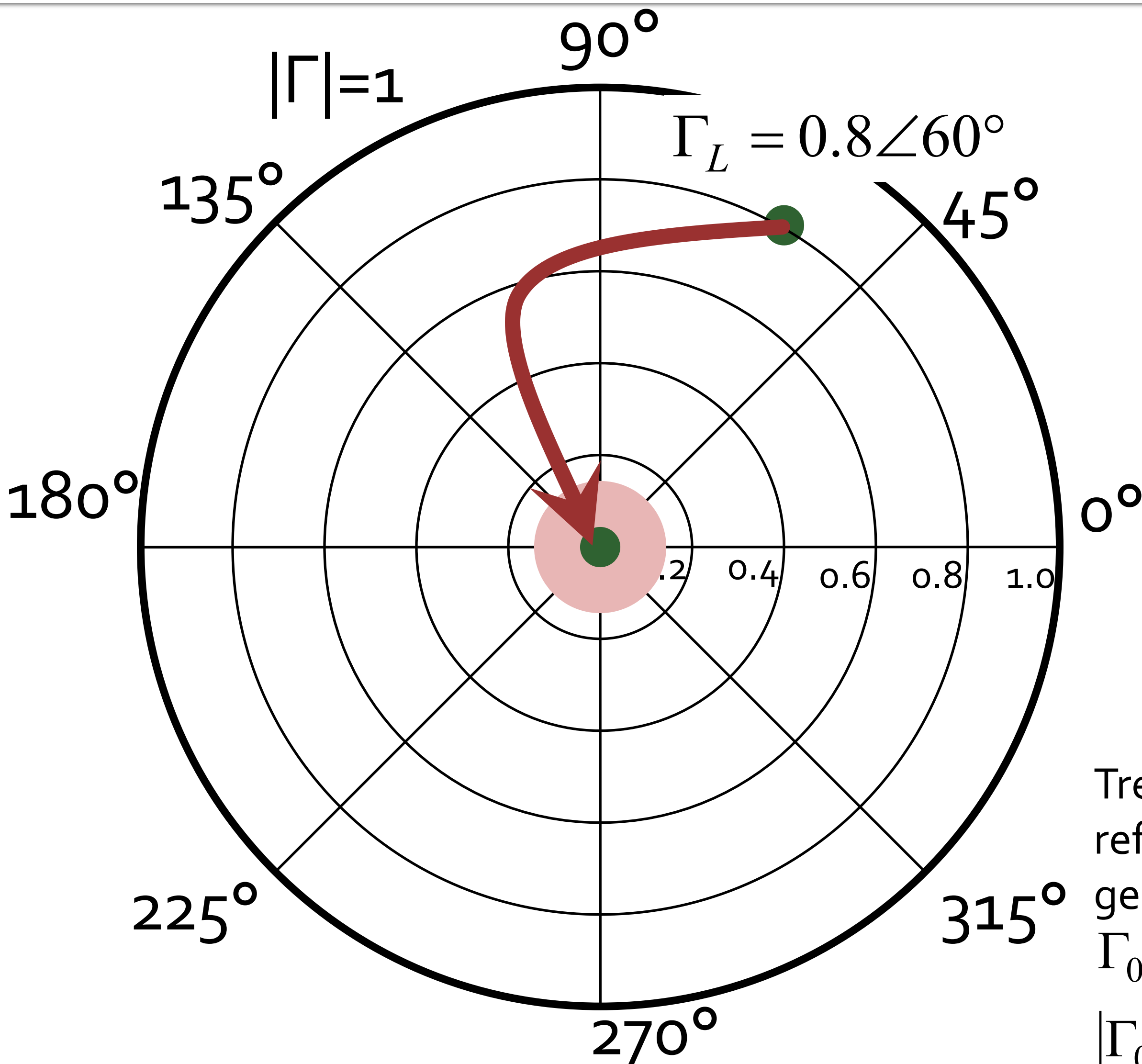
Adaptarea de impedanța

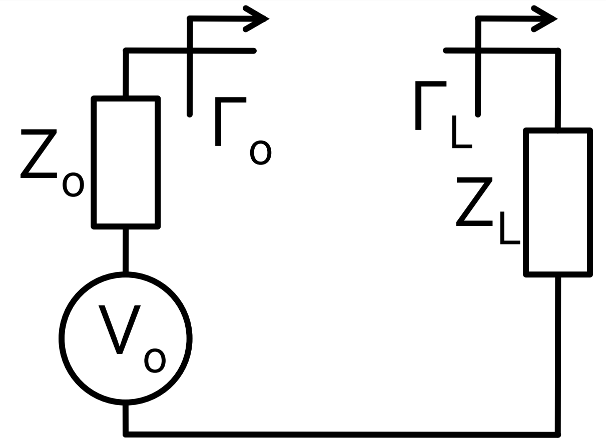
Adaptarea cu elemente concentrate (Retele in L)

Cuprins

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

Diagrama Smith, adaptare





Adaptare Z_L la Z_o. Se raporteaza Z_L la Z_o

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

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

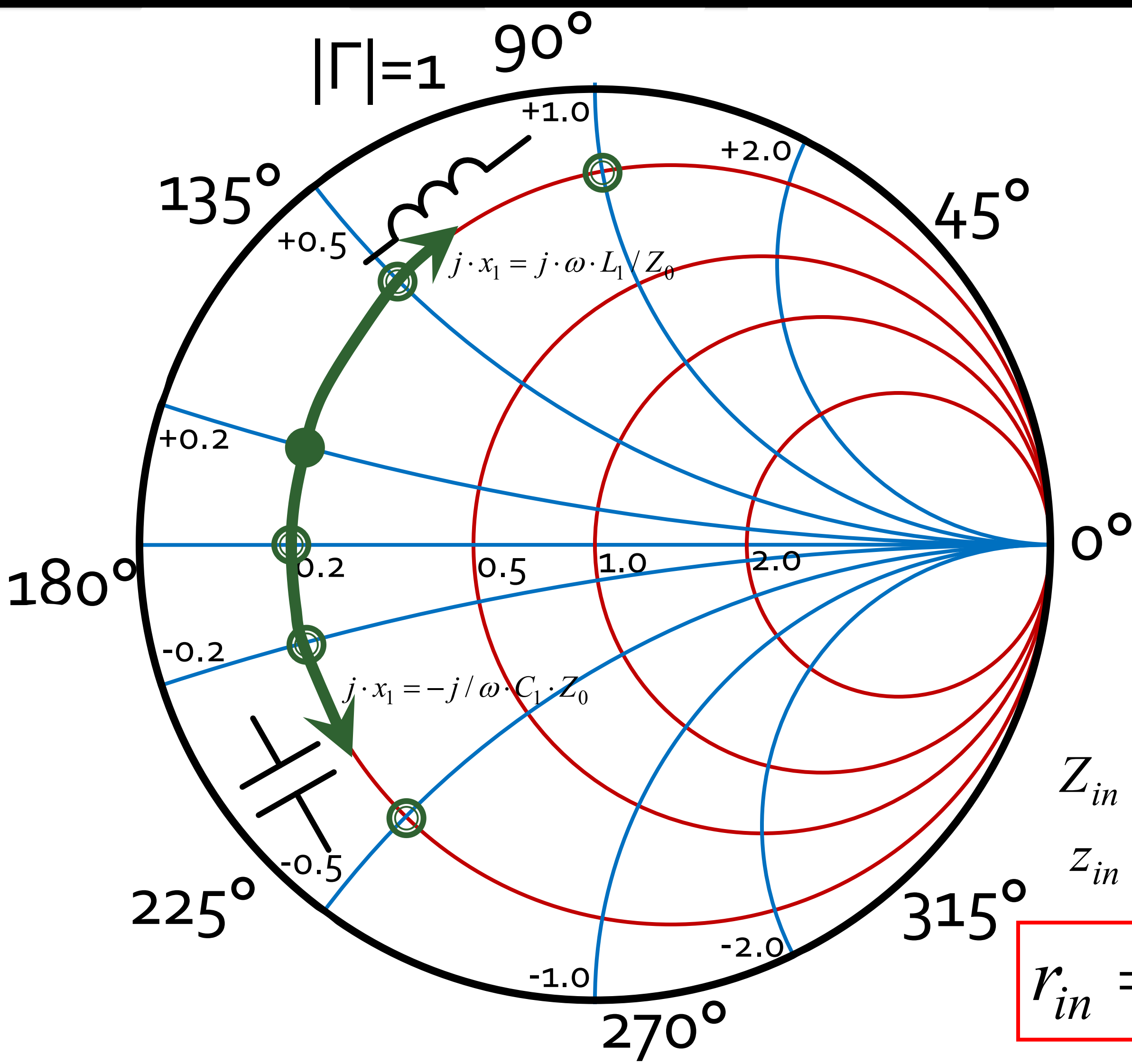
$$\Gamma_L = 0.8\angle 60°$$

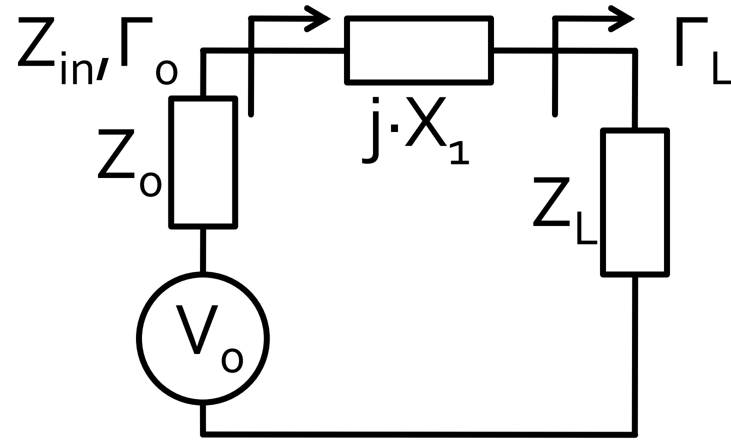
Trebuie sa deplasez coeficientul de reflexie in zona in care pentru generator cu Z_o am:

$\Gamma_0 = 0$ adaptare perfecta

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

Diagrama Smith, coeficient de reflexie, reactanta in serie





$$Z_0 = 50\Omega$$

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

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

$$\Gamma_L = 0.678\angle 156.5°$$

$$Z_{in} = Z_L + j\cdot X_1 = R_L + j\cdot\left(X_L + X_1\right.$$

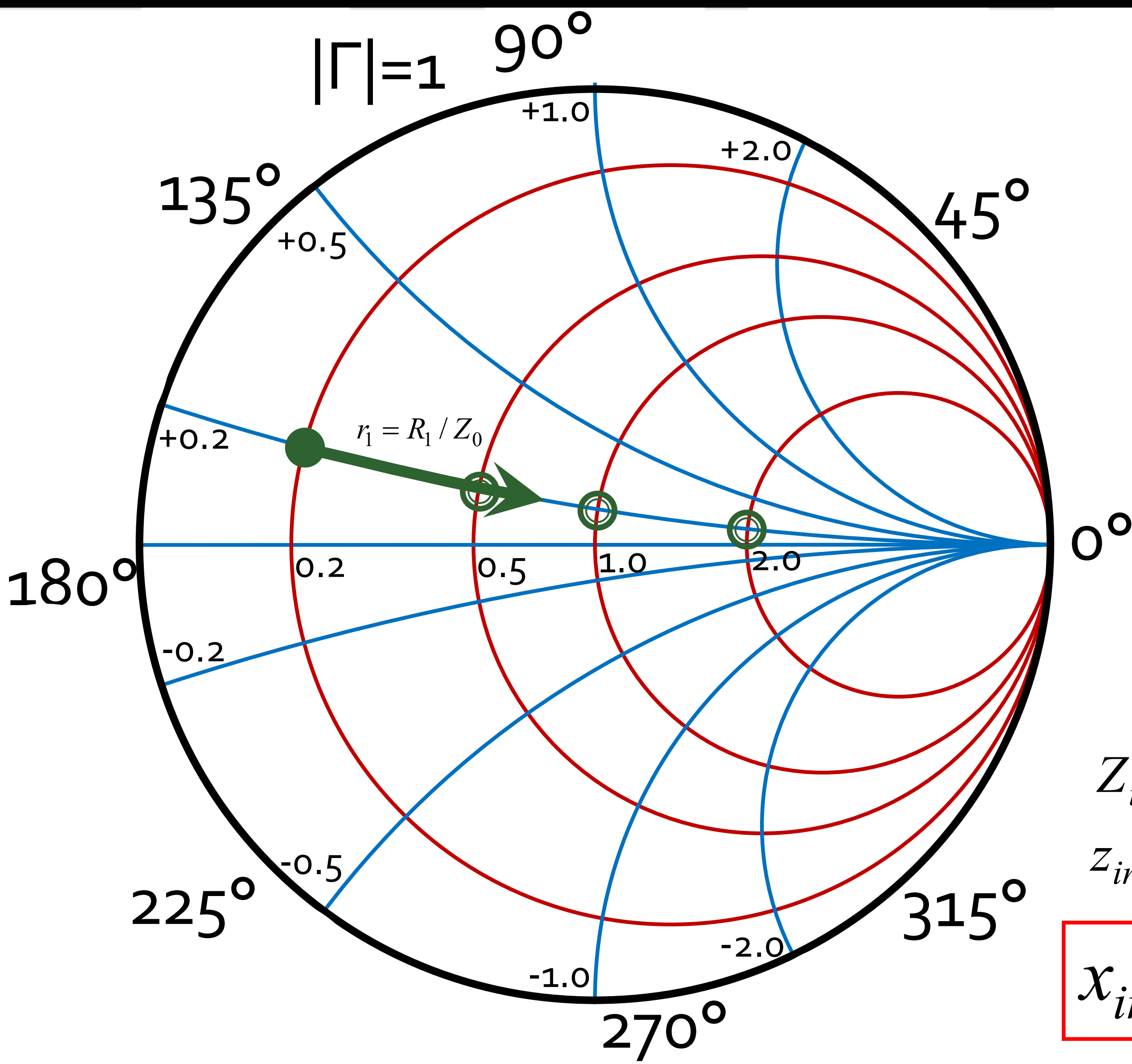
$$z_{in} = r_L + j\cdot\left(x_L + x_1\right)$$

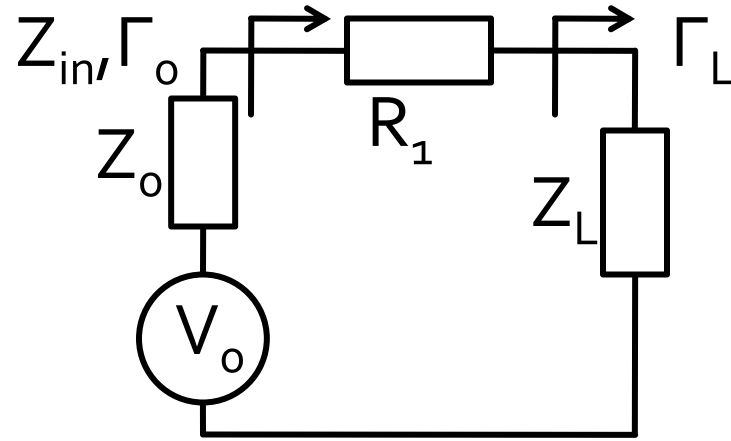
$$\boxed{r_{in} = r_L}$$

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

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

Diagrama Smith, coeficient de reflexie, rezistenta in serie





$$Z_0 = 50\Omega$$

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

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

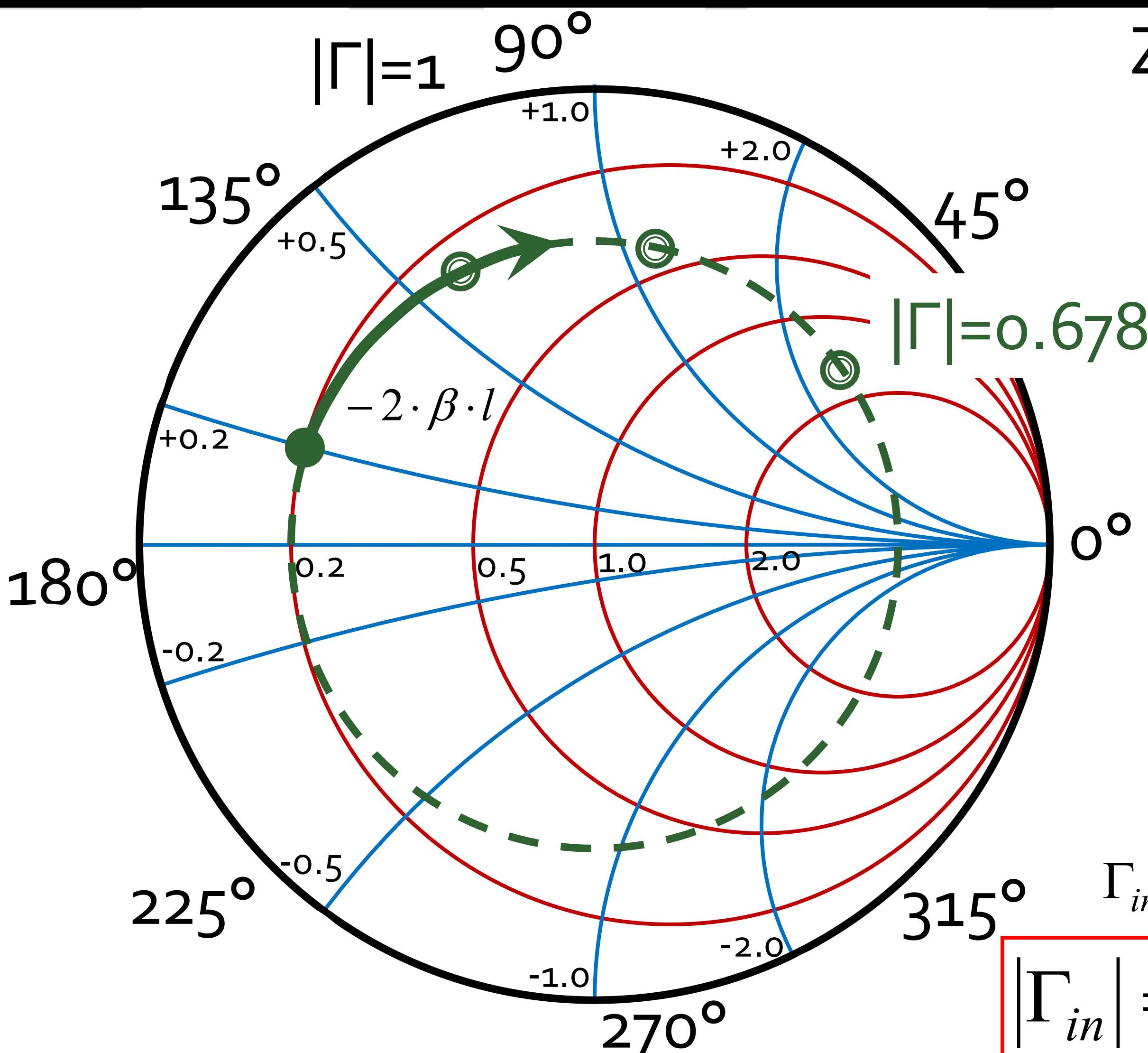
$$\Gamma_L = 0.678\angle 156.5°$$

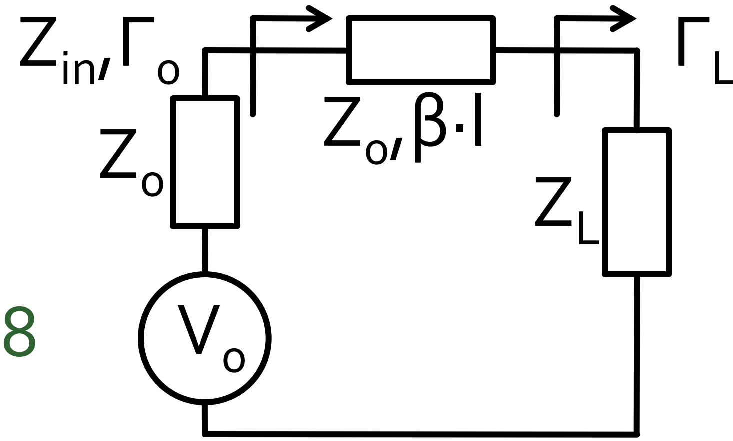
$$Z_{in} = Z_L + R_1 = (R_L + R_1) + j \cdot X_L$$

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

$$\boxed{x_{in} = x_L} \qquad r_{in} = r_L + R_1 / Z_0$$

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





$$Z_0 = 50\Omega$$

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

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

$$\Gamma_L = 0.678\angle 156.5°$$

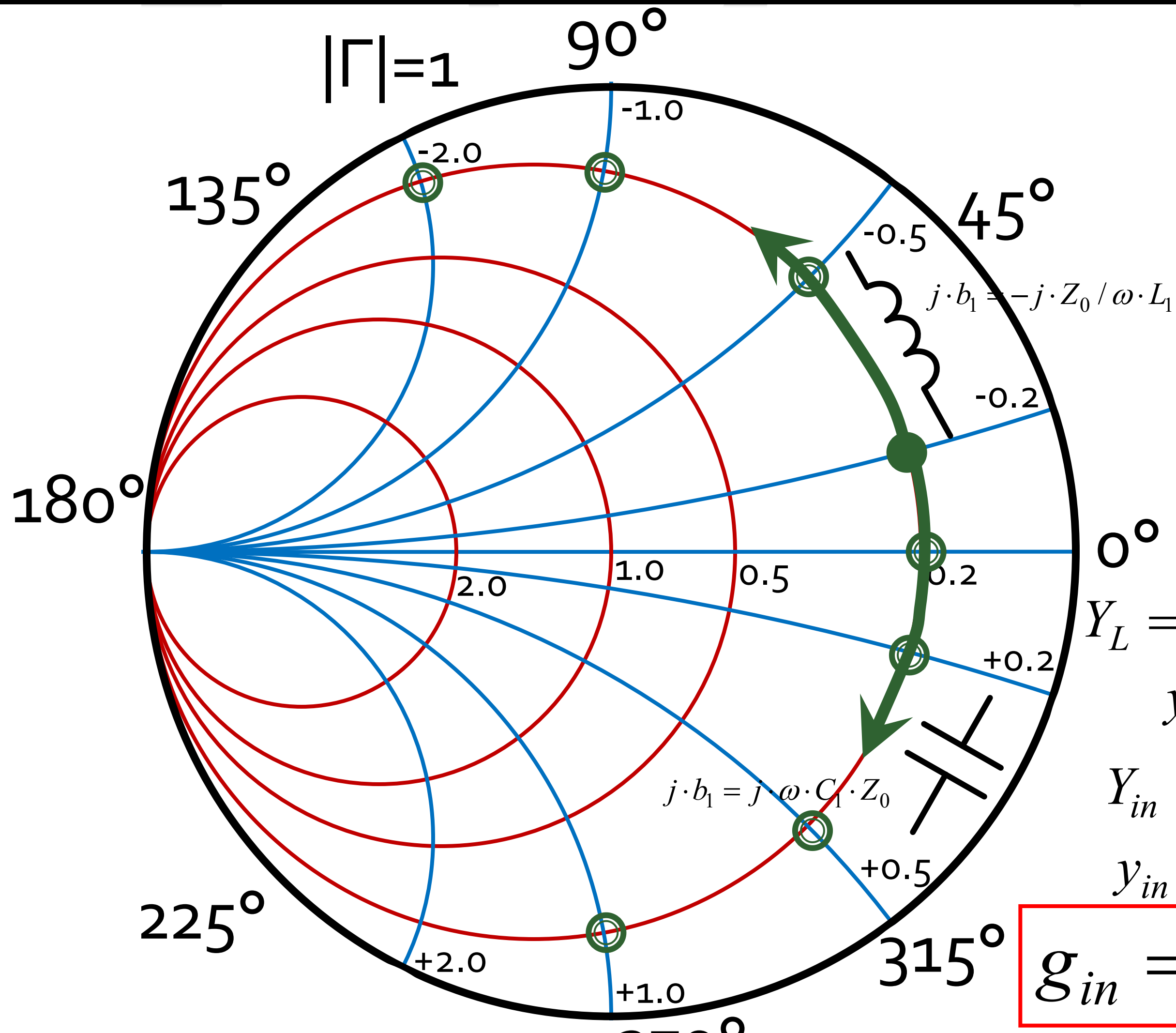
$$Z_{in} = Z_0 \cdot \frac{1+\Gamma_L\cdot e^{-2j\cdot\beta\cdot l}}{1-\Gamma_L\cdot e^{-2j\cdot\beta\cdot l}}$$

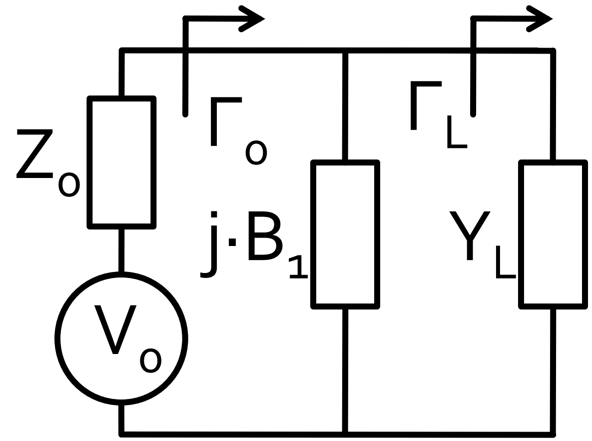
$$\Gamma_{in} = \Gamma_L \cdot e^{-2j\cdot\beta\cdot l}$$

$$\boxed{\left|\Gamma_{in}\right| = \left|\Gamma_L\right|}$$

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

Diagrama Smith, coeficient de reflexie, susceptanta in paralel





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

$$\Gamma_L = 0.678\angle 23.5°$$

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

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

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

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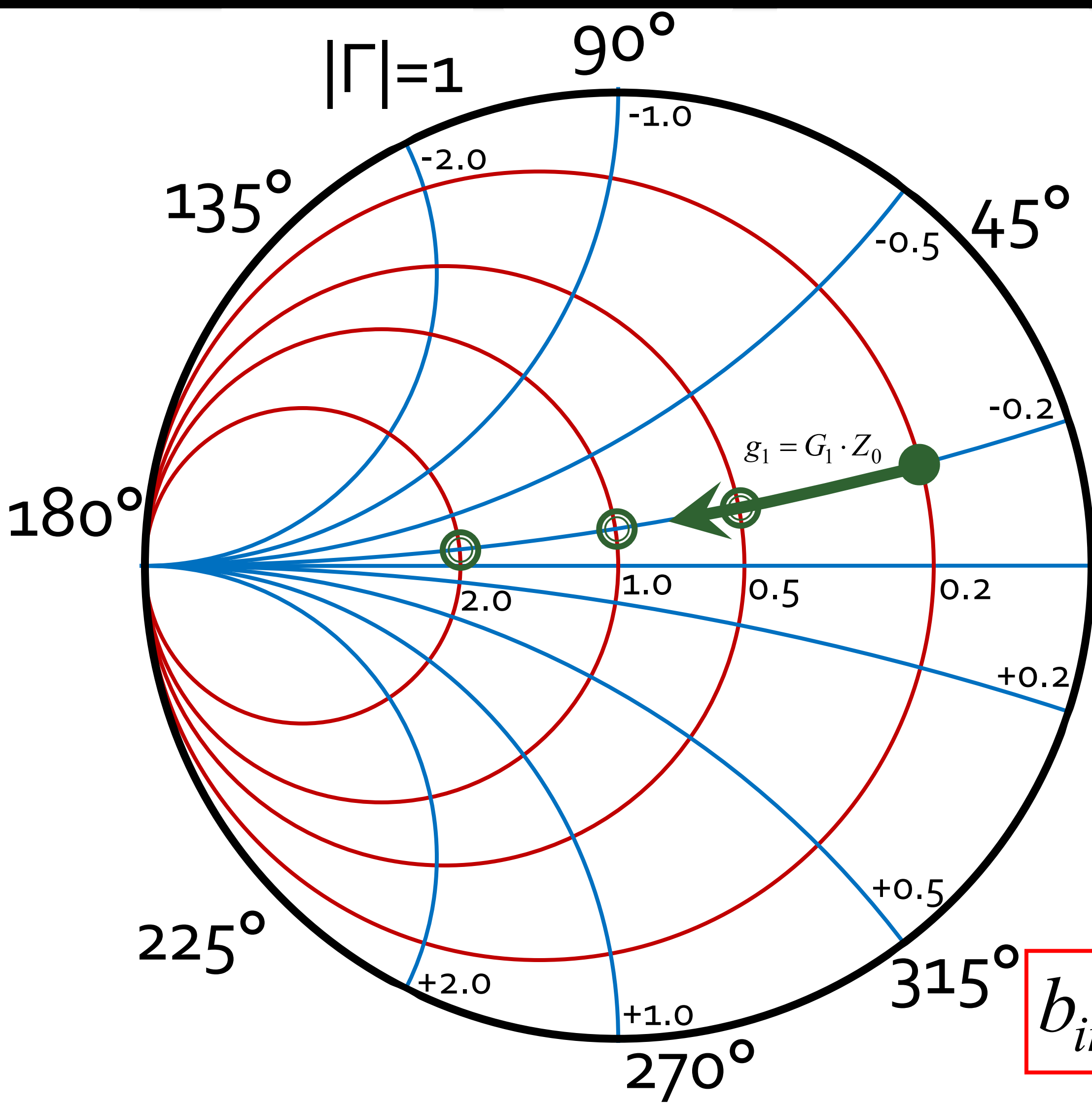
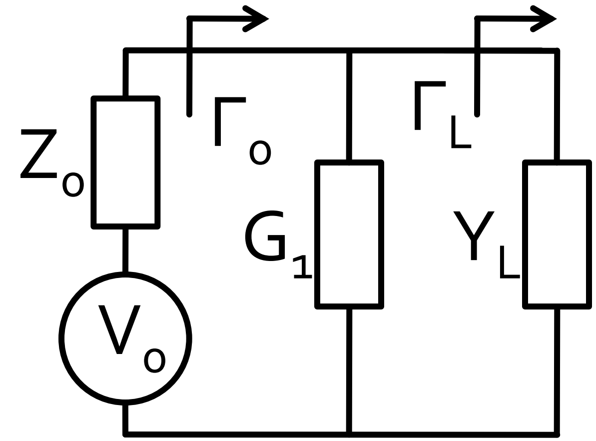
$$j \cdot b_1 = j \cdot \omega \cdot C_1 \cdot Z_0 > 0$$

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

Diagrama Smith, coeficient de reflexie, conductanta in paralel





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

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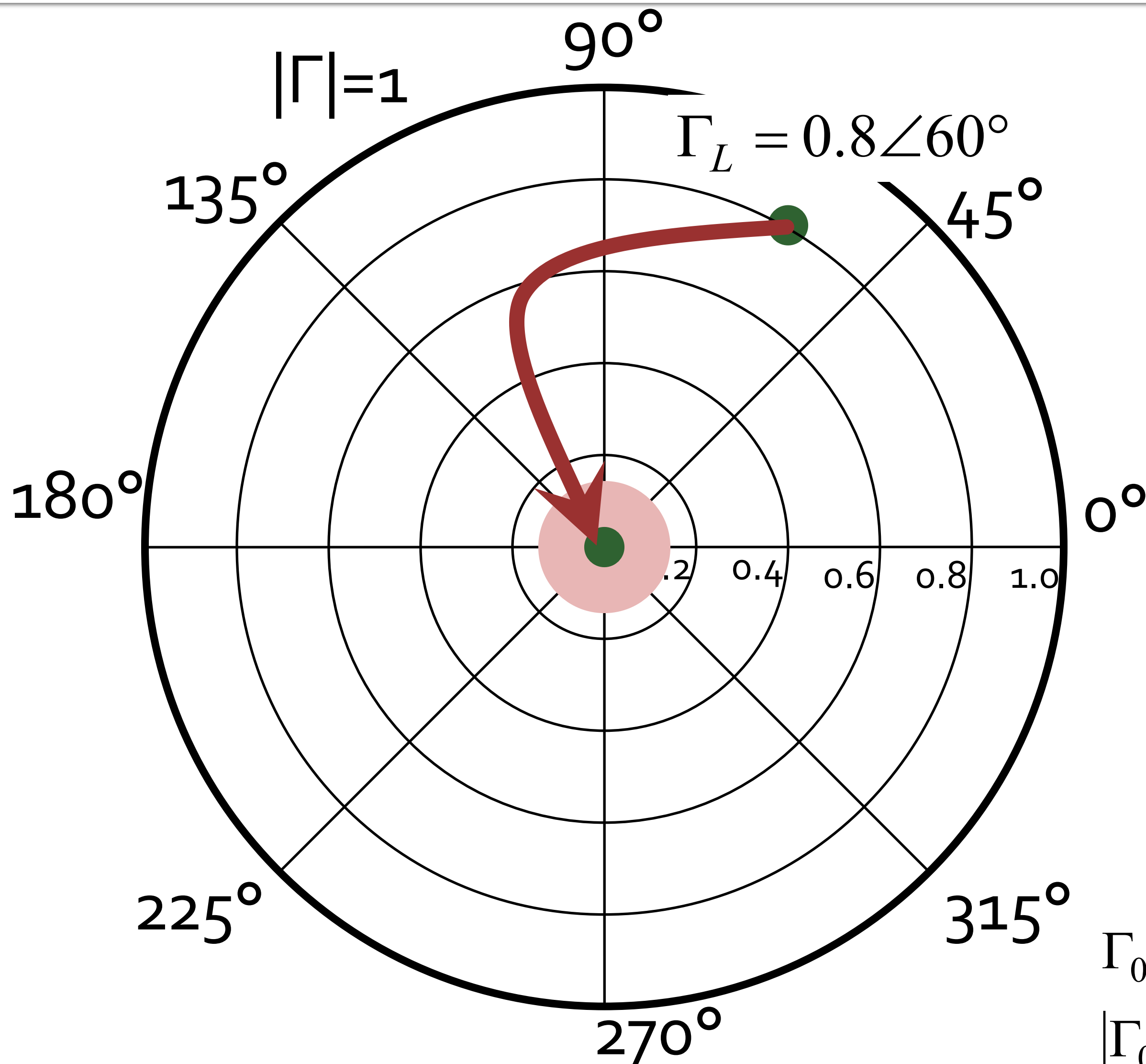
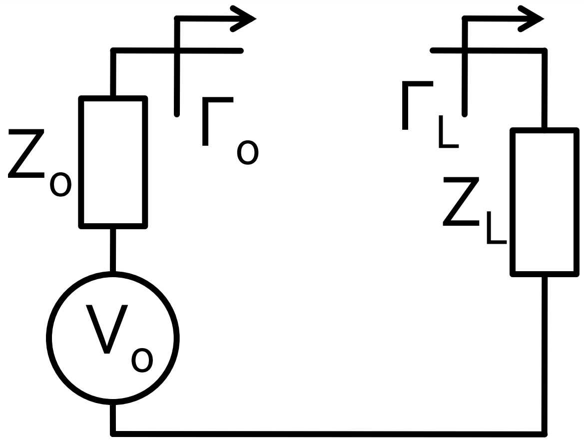
$$y_{in} = (g_L + g_1) + j\cdot b_L$$

$$\boxed{b_{in} = b_L}$$

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

Adaptare de impedanța



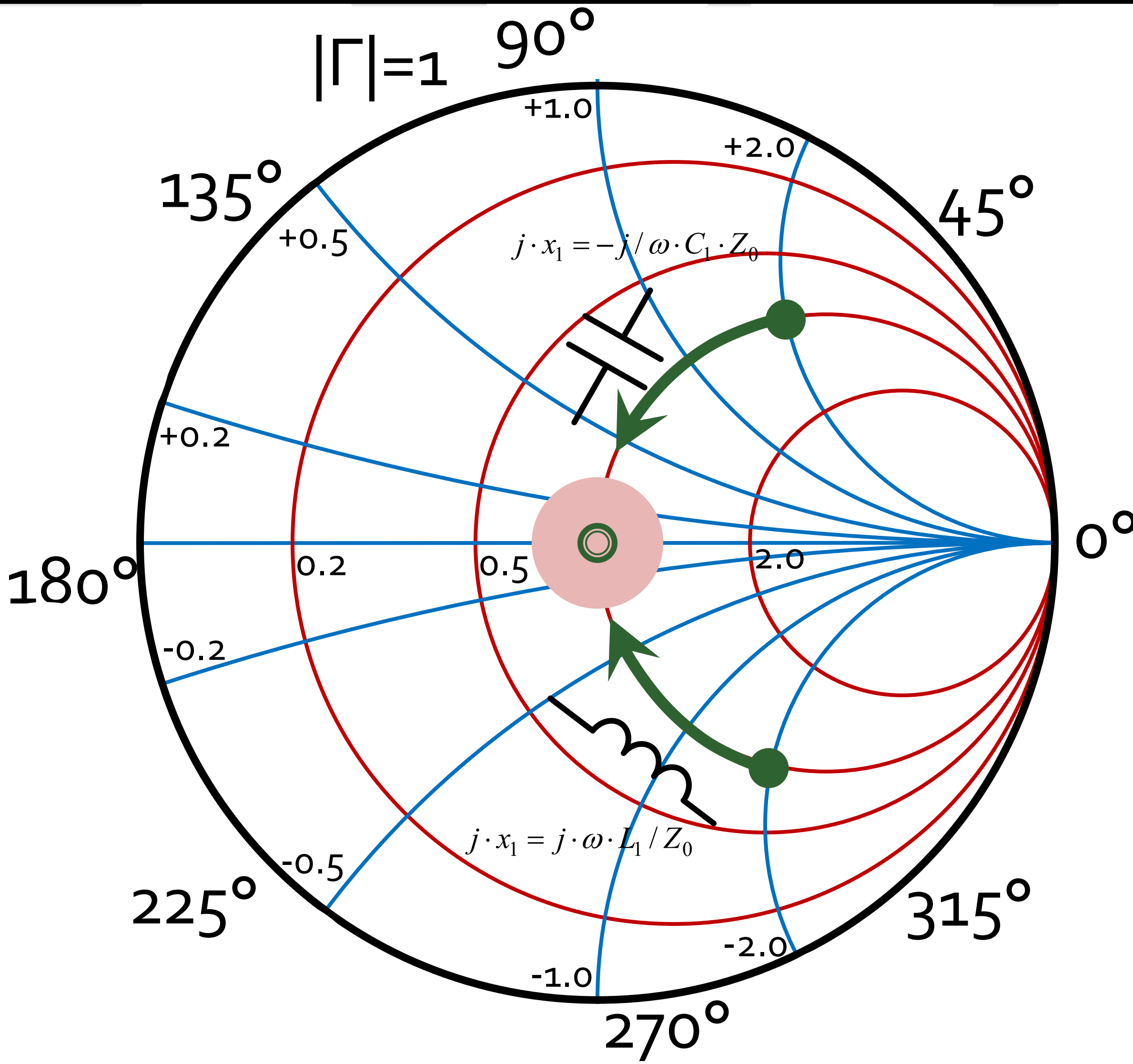


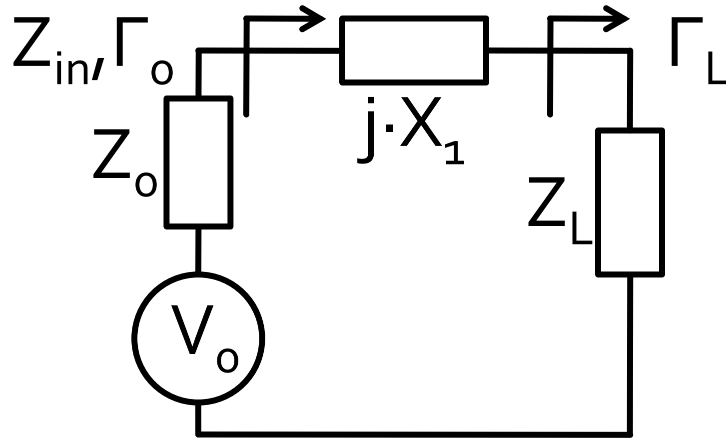
Cum?

$\Gamma_0 = 0$ adaptare perfecta

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

Adaptare, reactanta in serie





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

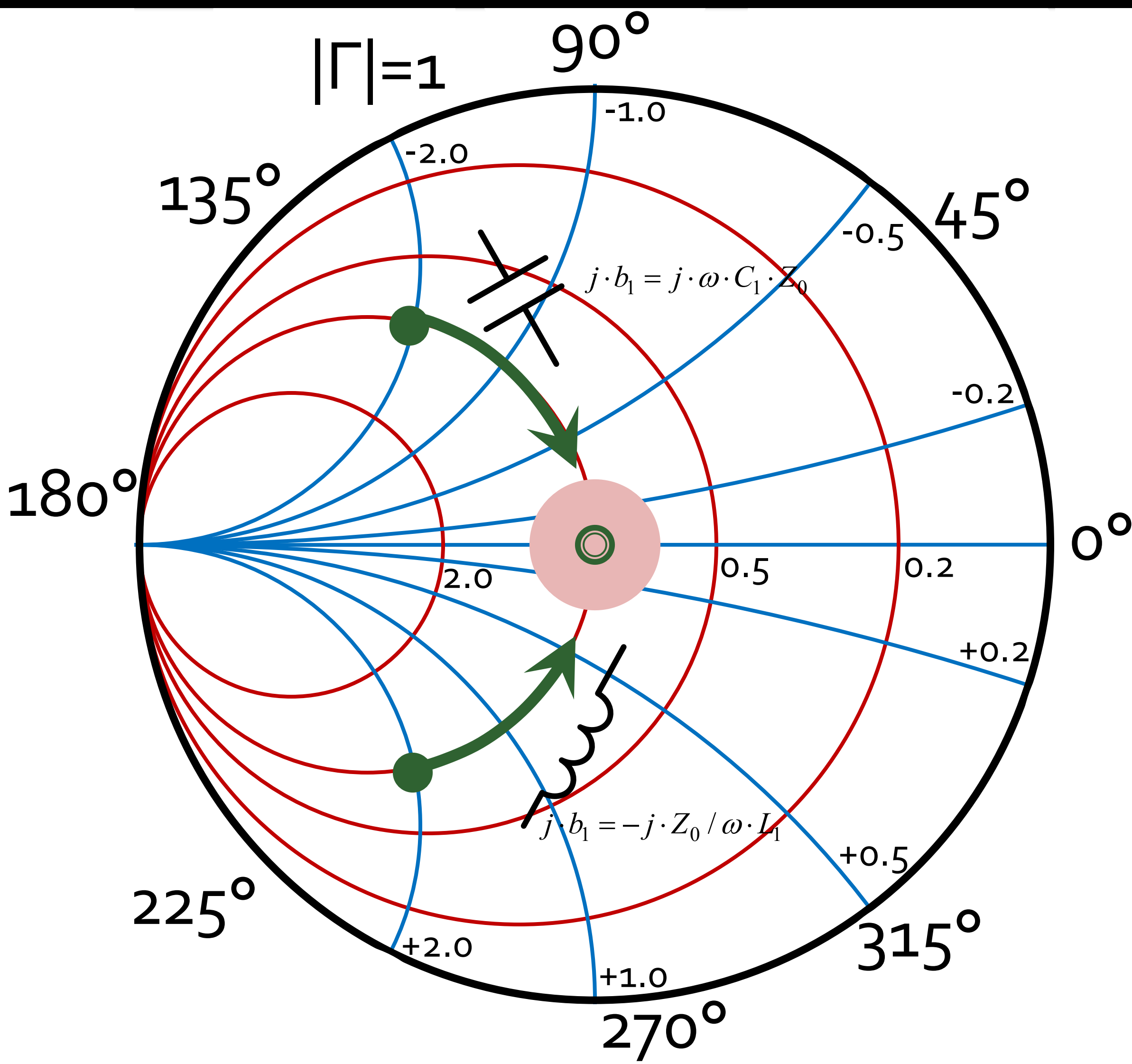
$$z_{in} = r_L + j \cdot (x_L + x_1)$$

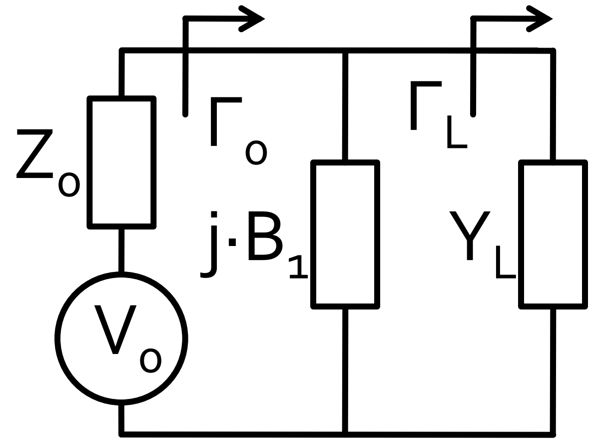
$$\boxed{r_{in} = r_L}$$

- 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





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

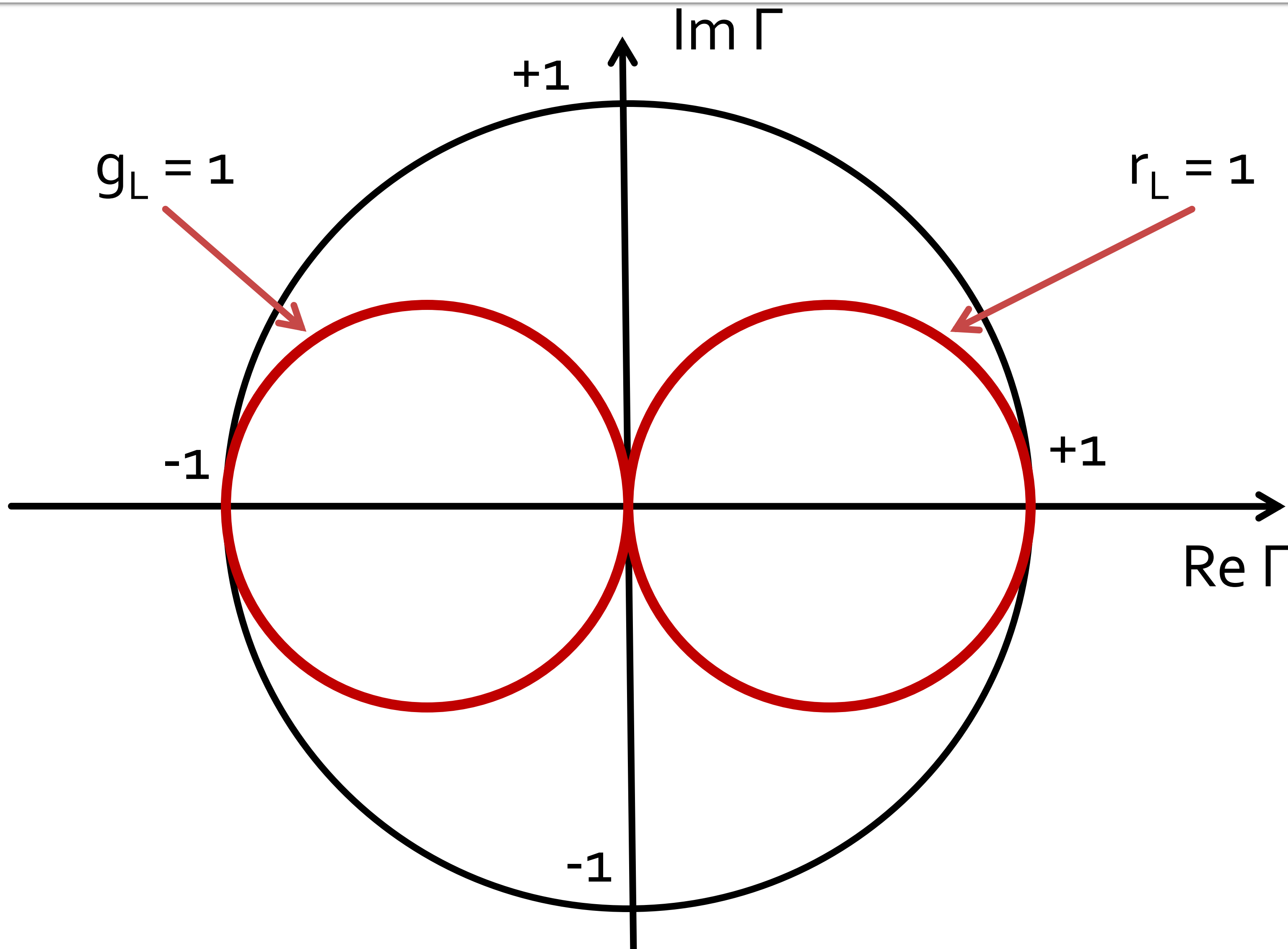
$$y_{in} = g_L + j\cdot(b_L + b_1)$$

$$\boxed{g_{in} = g_L}$$

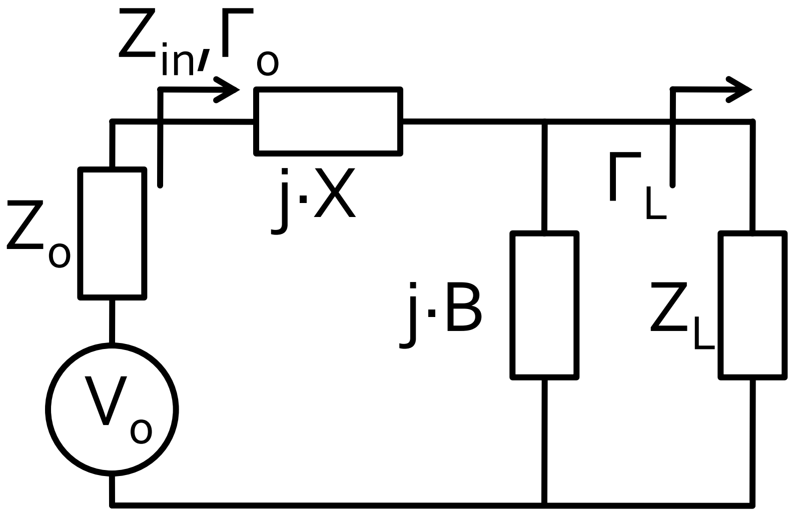
- Adaptarea se poate realiza **numai daca** $g_L = 1$
- se realizeaza compensarea partii reactive a sarcinii

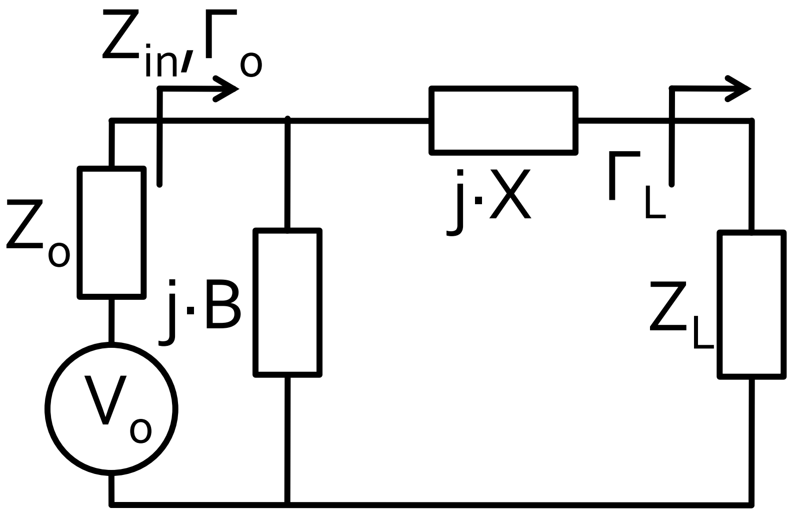
$$j\cdot b_1 = -j\cdot b_L$$

Diagrama Smith, r=1 si g=1



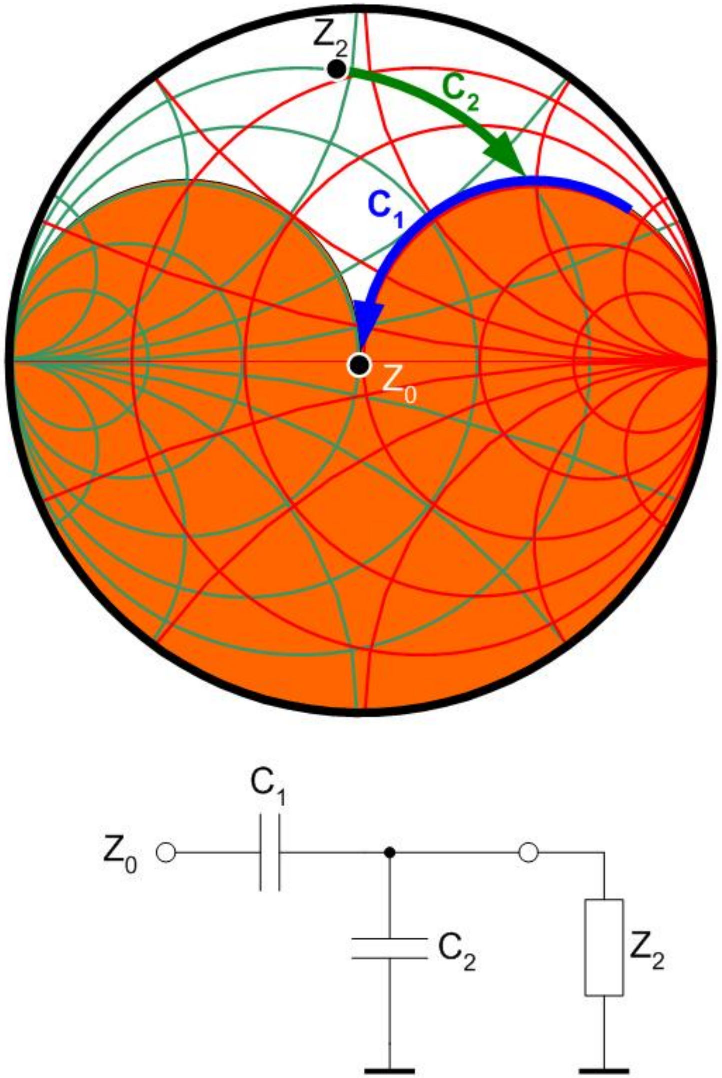
Adaptare cu doua elemente reactive (retele in L)

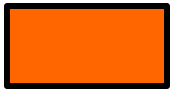




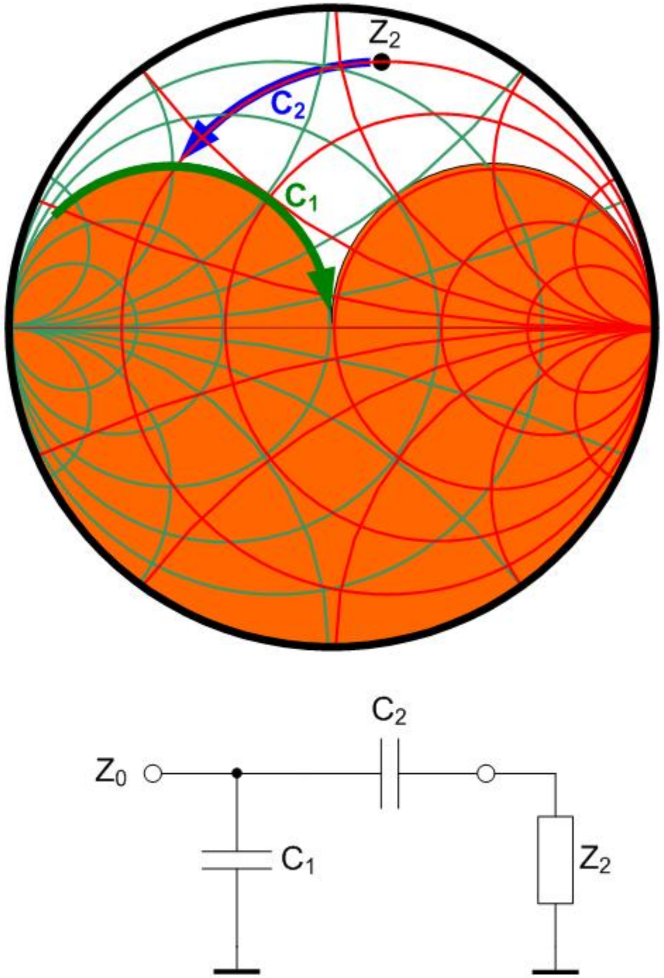
- Adaptare in **doi** pasi
  - un prim element muta coeficientul de reflexie **pe cercul** $r_L = 1/g_L = 1$
  - al doilea element realizeaza adaptarea

C serie, C paralel / C paralel, C serie

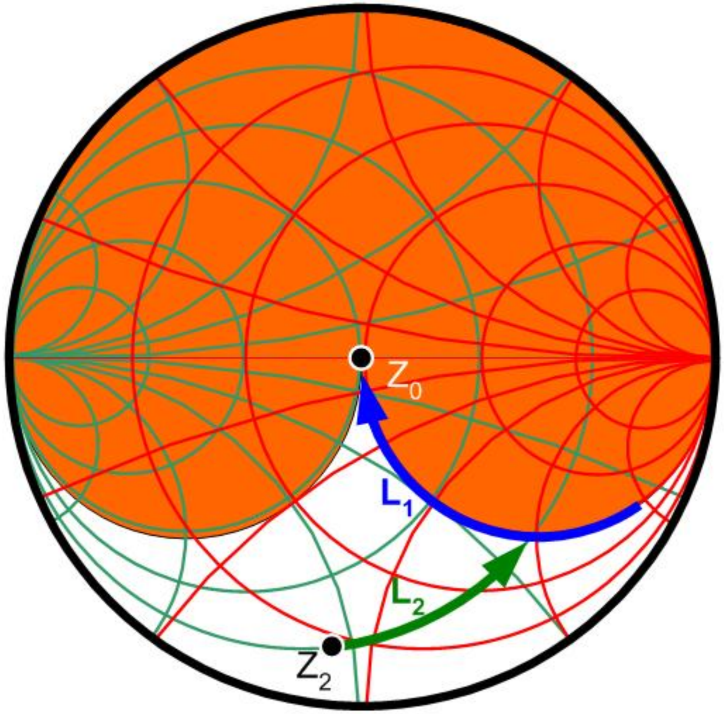


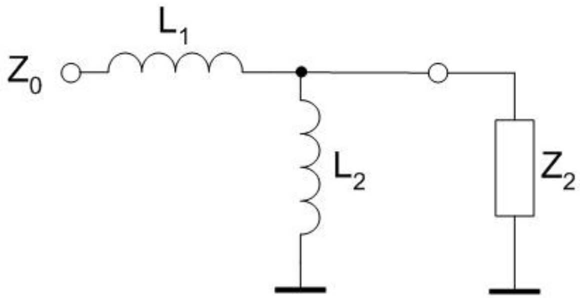


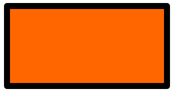
Zona interzisa cu schema curenta



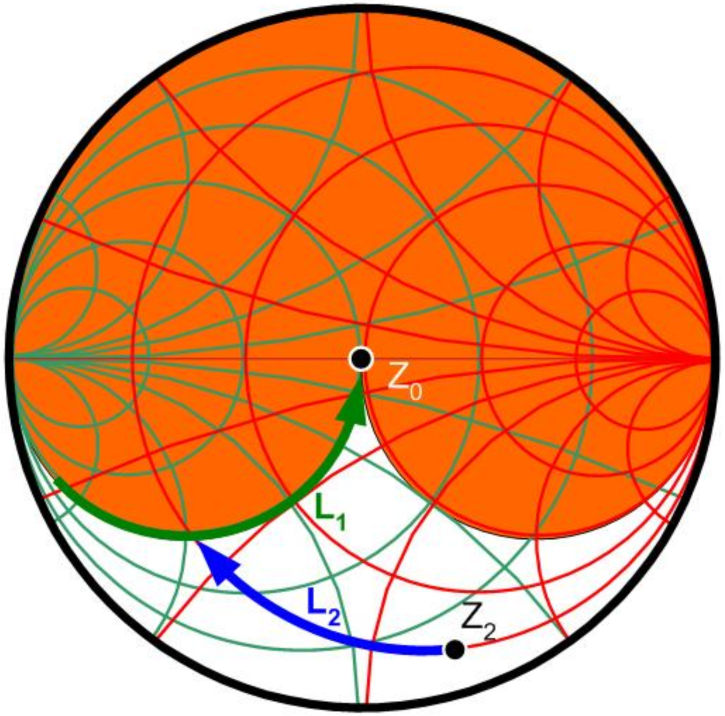
L serie, L paralel / L paralel, L serie

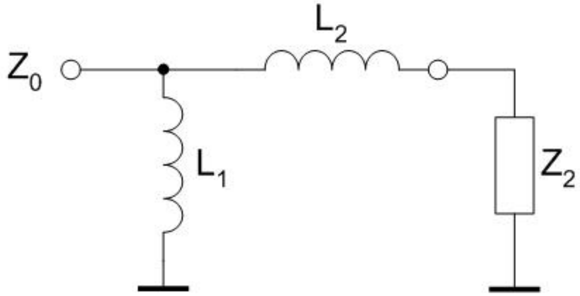




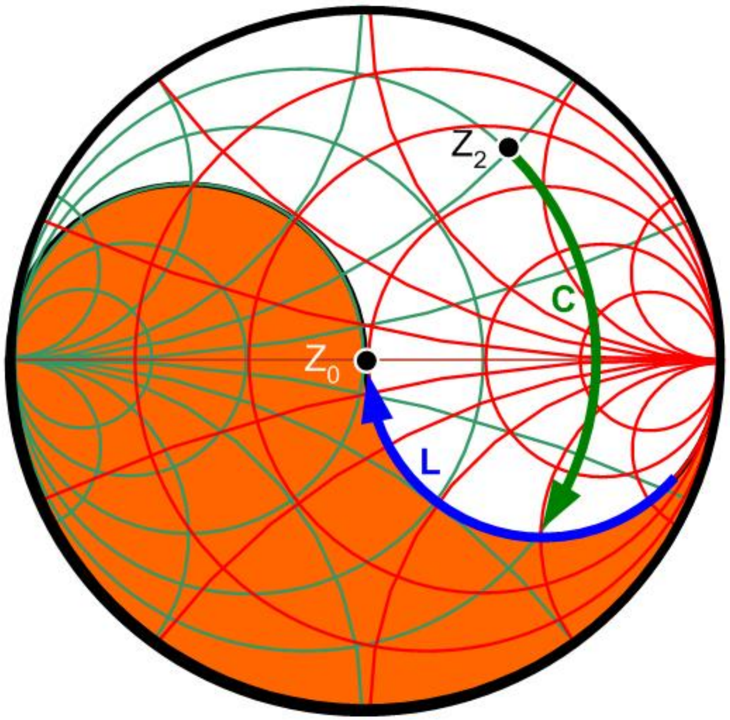


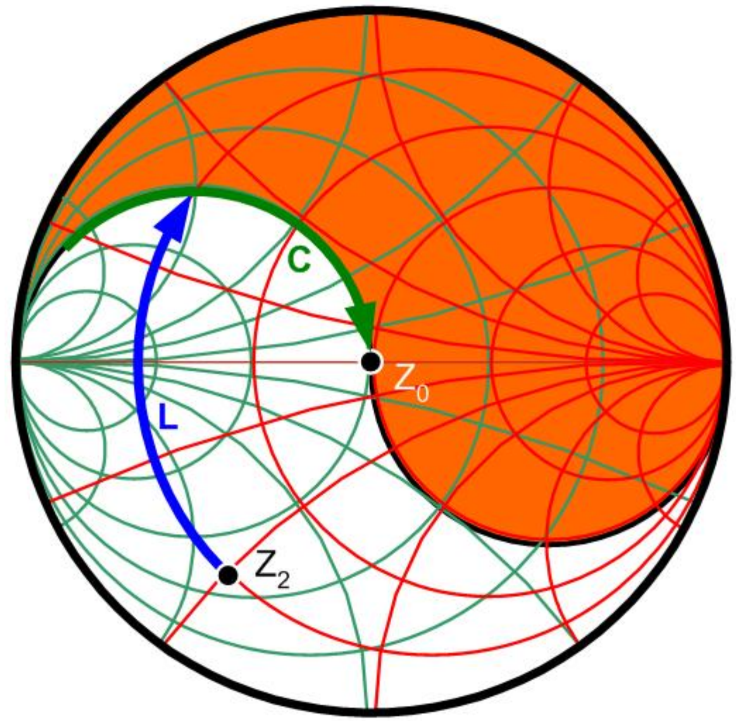
Zona interzisa cu schema curenta



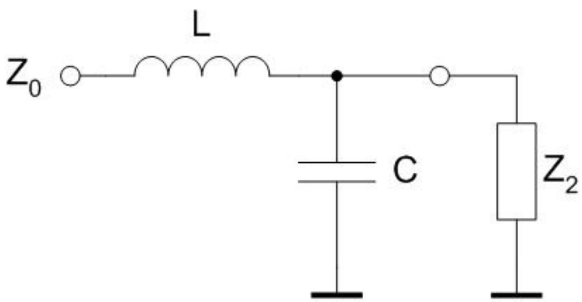


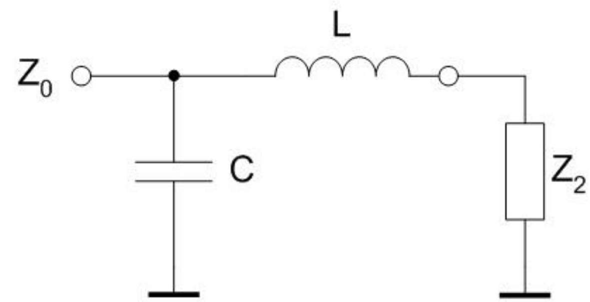
L serie, C paralel / C paralel, L serie



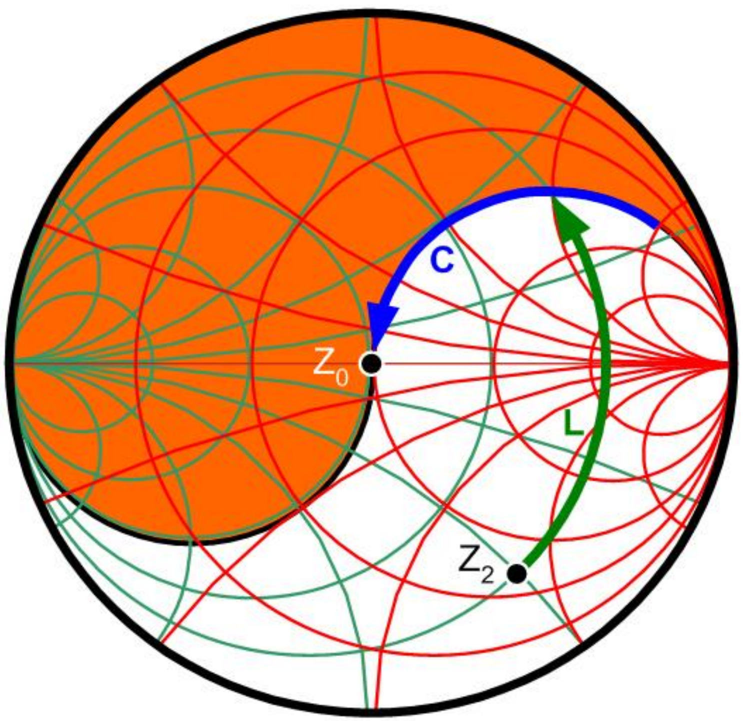


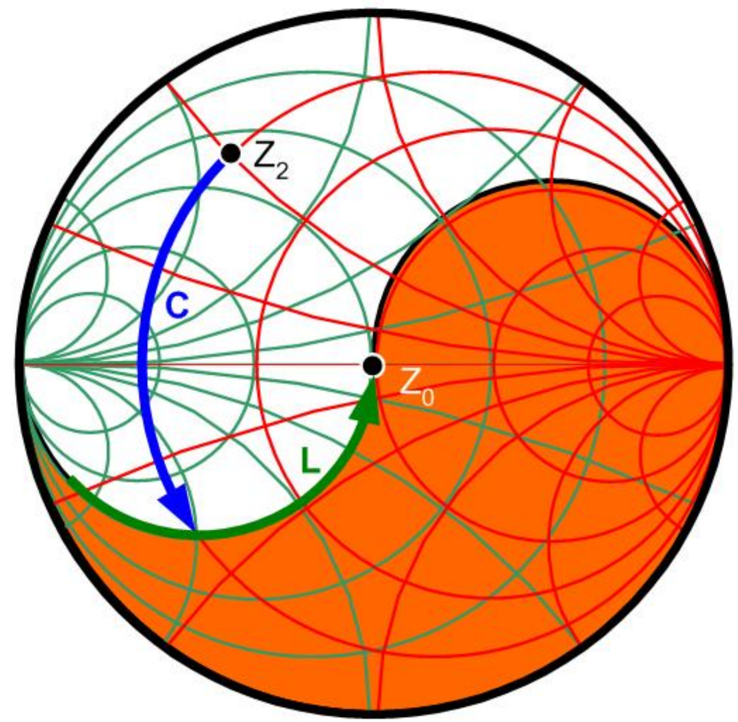
Zona interzisa cu schema curenta

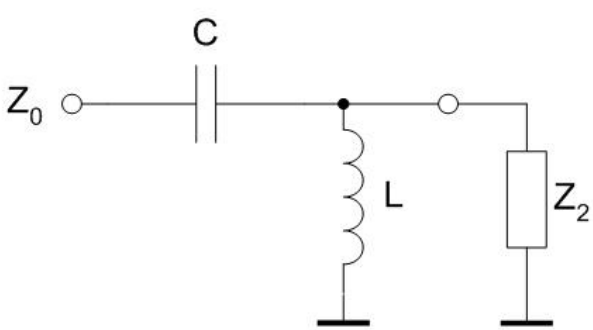




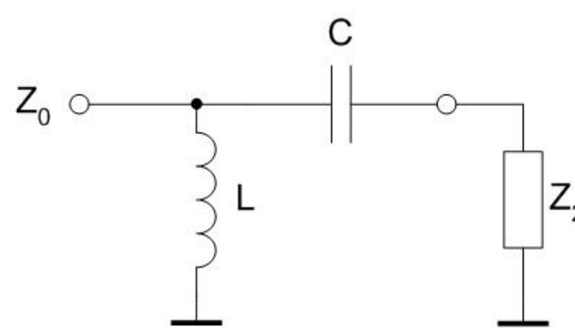
C serie, L paralel / L paralel, C serie



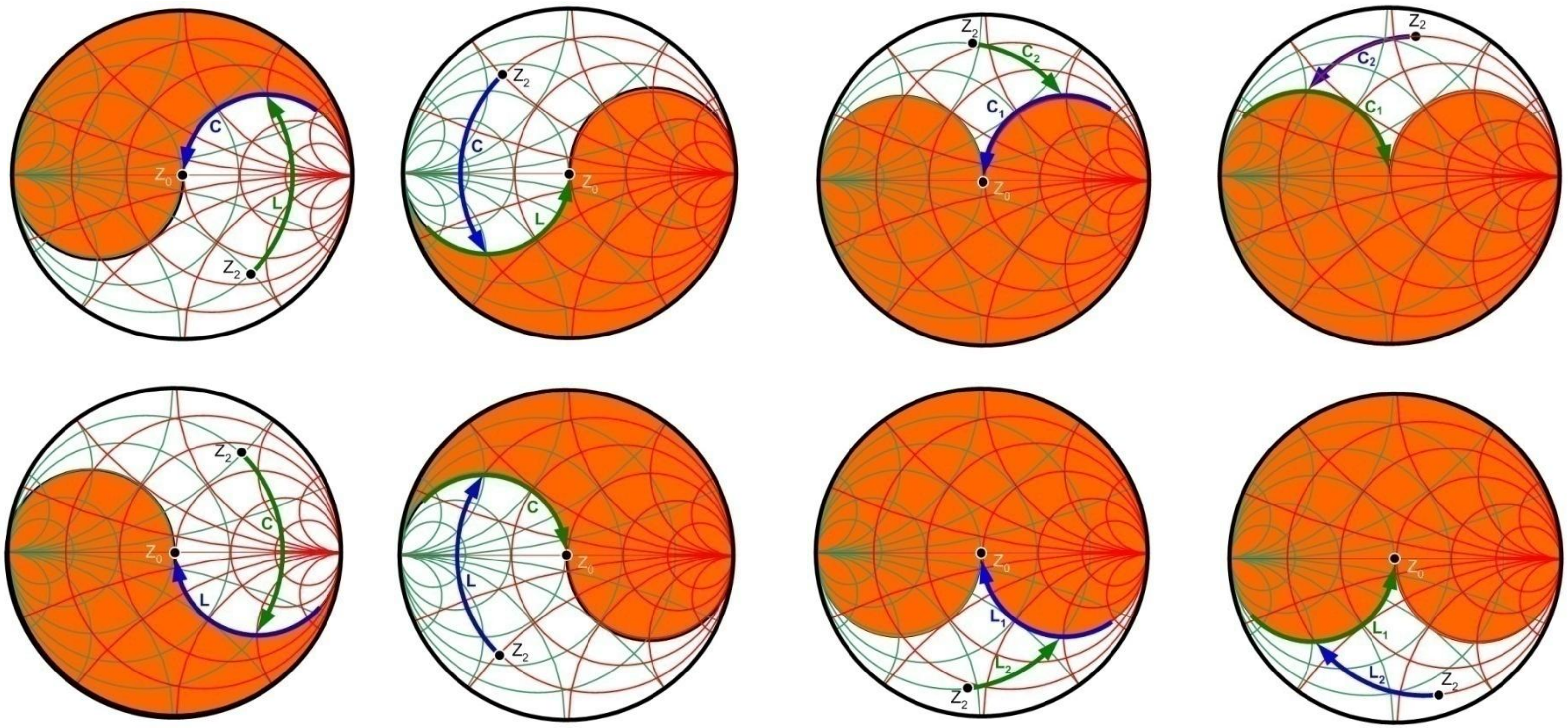




Zona interzisa cu schema curenta



Adaptare cu doua elemente reactive (retele in L)



Zona interzisa cu schema curenta

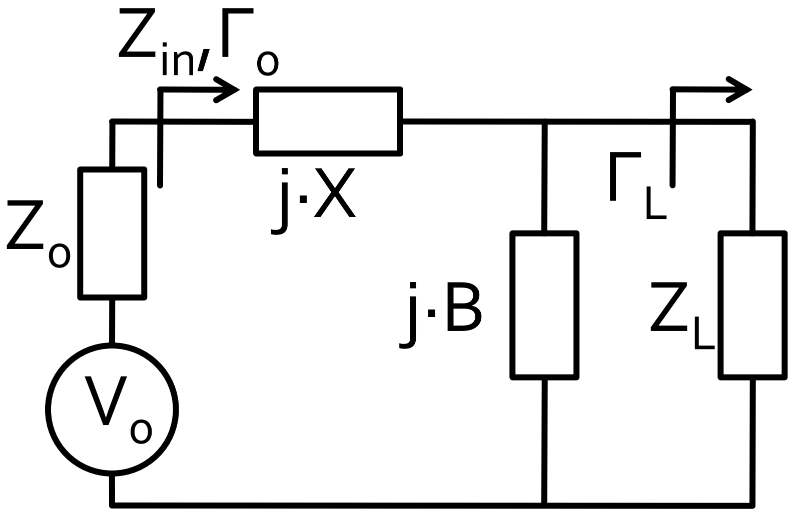
Adaptare cu doua elemente reactive (retele in L)

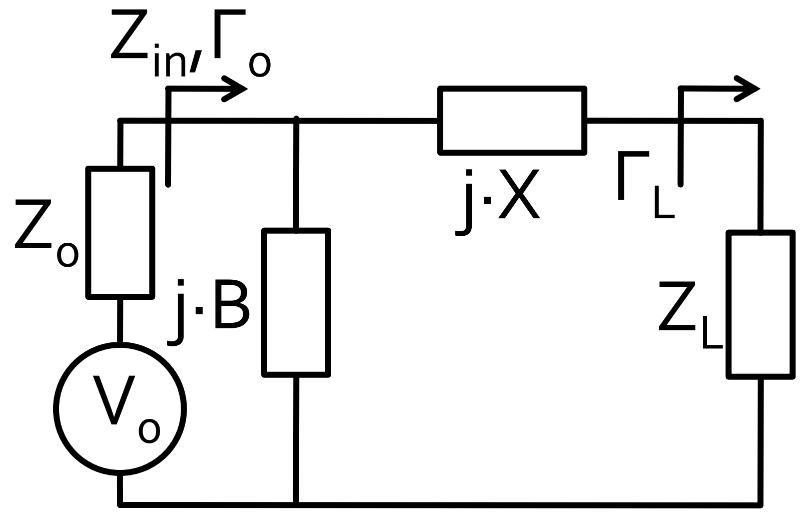
- Pentru orice Γ_L exista **cel putin 2 retele in L** de adaptare posibile (L+C)
- Pentru **anumite** zone de start de pe diagrama Smith exista 4 posibilitati (+2 retele C+C/L+L)
- Se alege reteaua care necesita componente de valori realizabile
- Prin adaugarea elementelor rezistive se pot suplimenta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

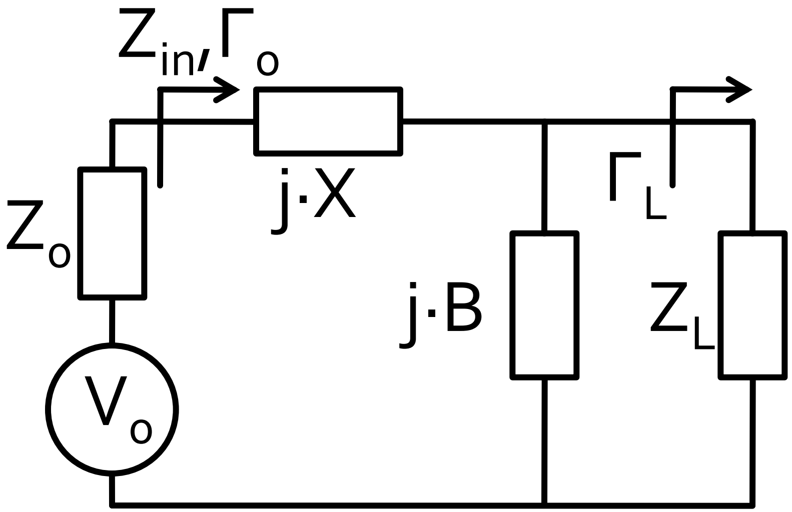
Adaptare cu doua elemente reactive (retele in L)





- 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)



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

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

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

$$B = \frac{X_L \pm \sqrt{R_L/Z_0} \cdot \sqrt{R_L^2 + X_L^2 - Z_0 \cdot R_L}}{R_L^2 + X_L^2} \qquad X = \frac{1}{B} + \frac{X_L \cdot Z_0}{R_L} - \frac{Z_0}{B \cdot R_L}$$

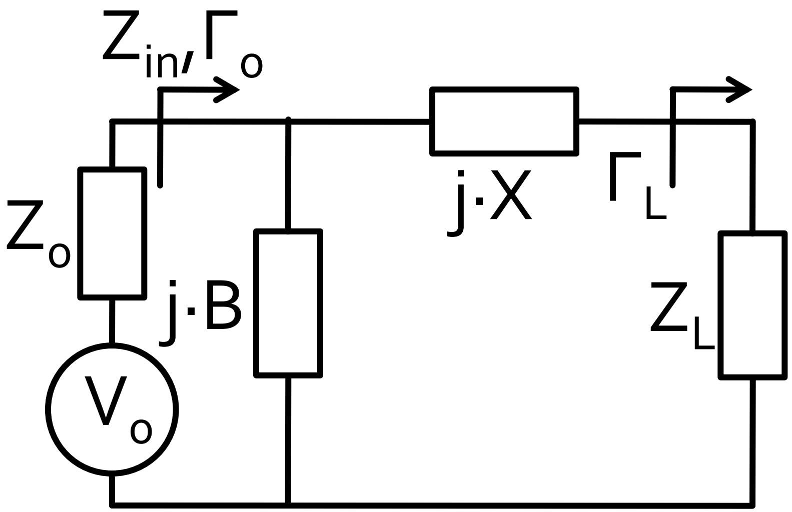
- valoarea de sub radical e intotdeauna pozitiva pentru

$$R_L > Z_0$$

- se obtin doua solutii realizabile

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

Adaptare cu doua elemente reactive (retele in L)



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

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

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

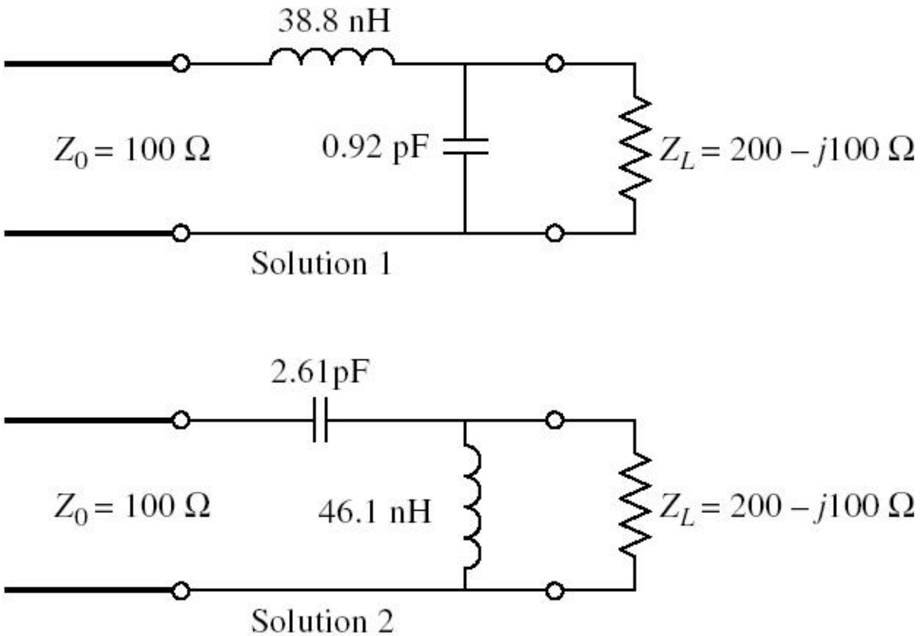
$$X = \pm\sqrt{R_L \cdot (Z_0 - R_L)} - X_L \qquad B = \pm\frac{\sqrt{(Z_0 - R_L)/R_L}}{Z_0}$$

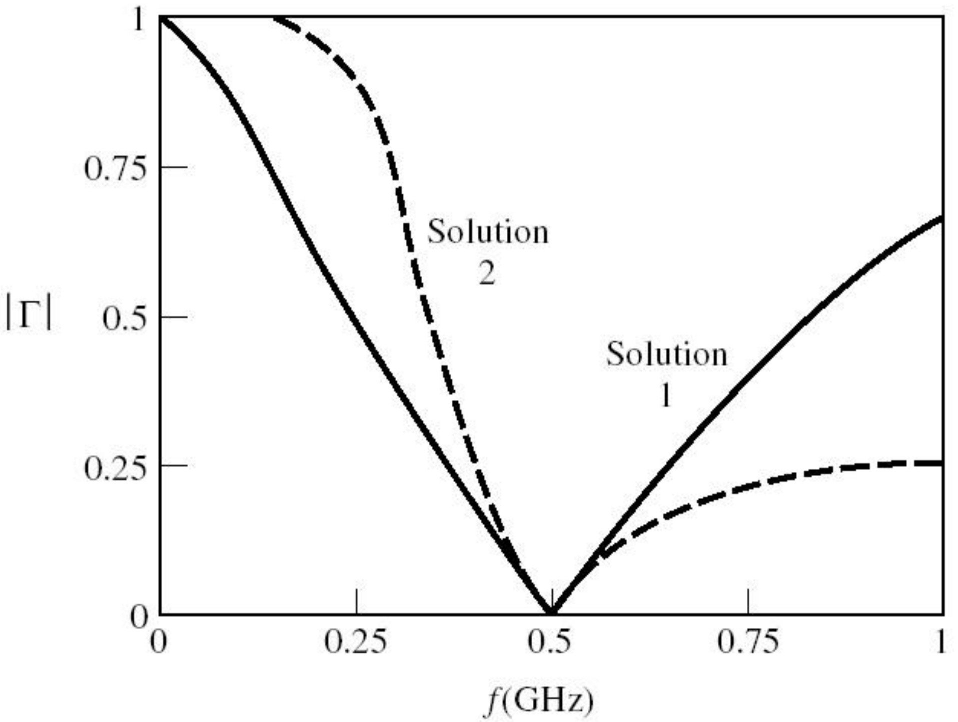
- valoarea de sub radical e intotdeauna pozitiva pentru

$$R_L < Z_0$$

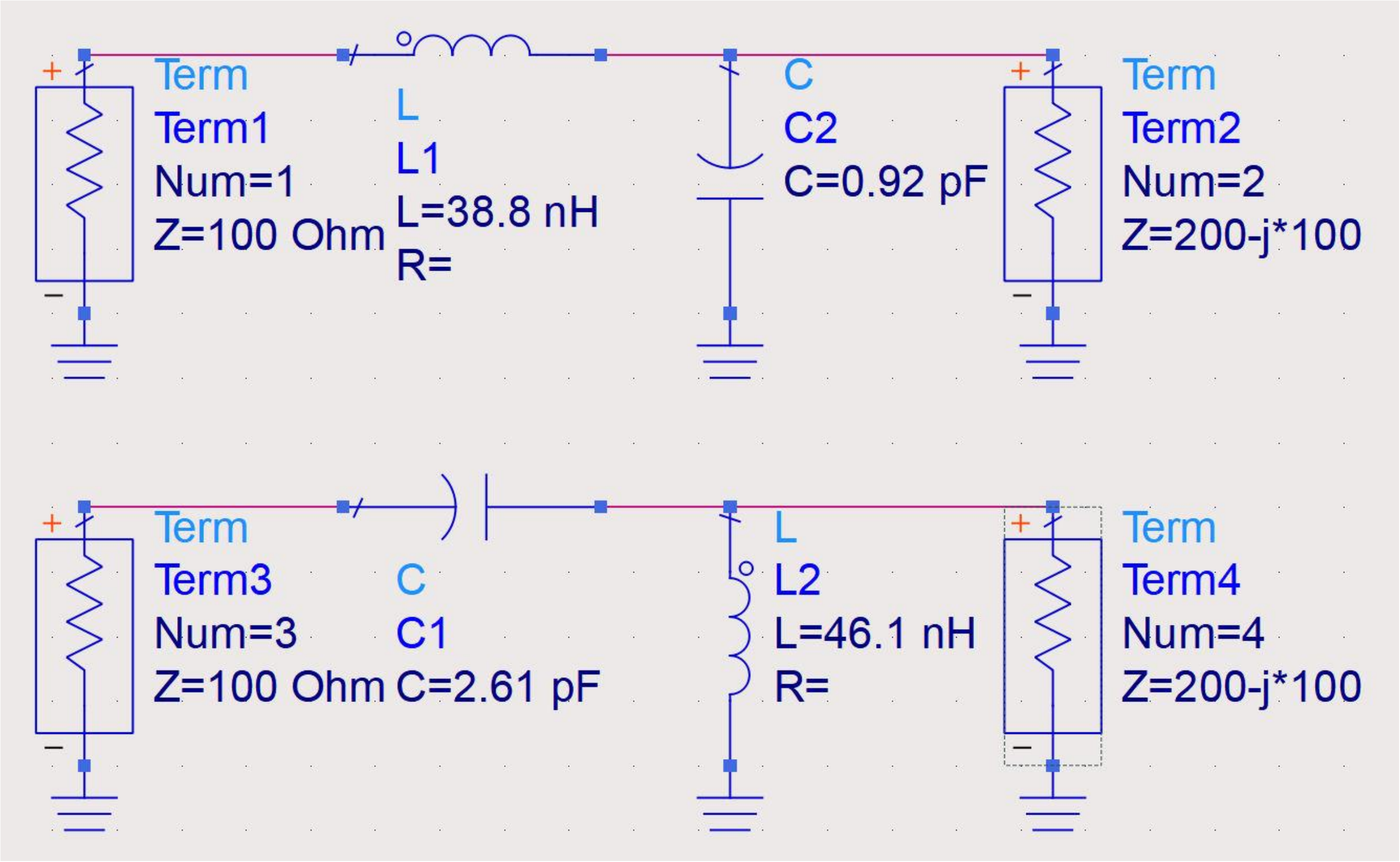
- se obtin doua solutii realizabile $X = \begin{cases} \omega \cdot L \\ -\dfrac{1}{\omega \cdot C} \end{cases} \qquad B = \begin{cases} \omega \cdot C \\ -\dfrac{1}{\omega \cdot L} \end{cases}$

Exemplu


38.8 nH
$Z_0 = 100\ \Omega$
0.92 pF
$Z_L = 200 - j100\ \Omega$
Solution 1
2.61pF
$Z_0 = 100\ \Omega$
46.1 nH
$Z_L = 200 - j100\ \Omega$
Solution 2

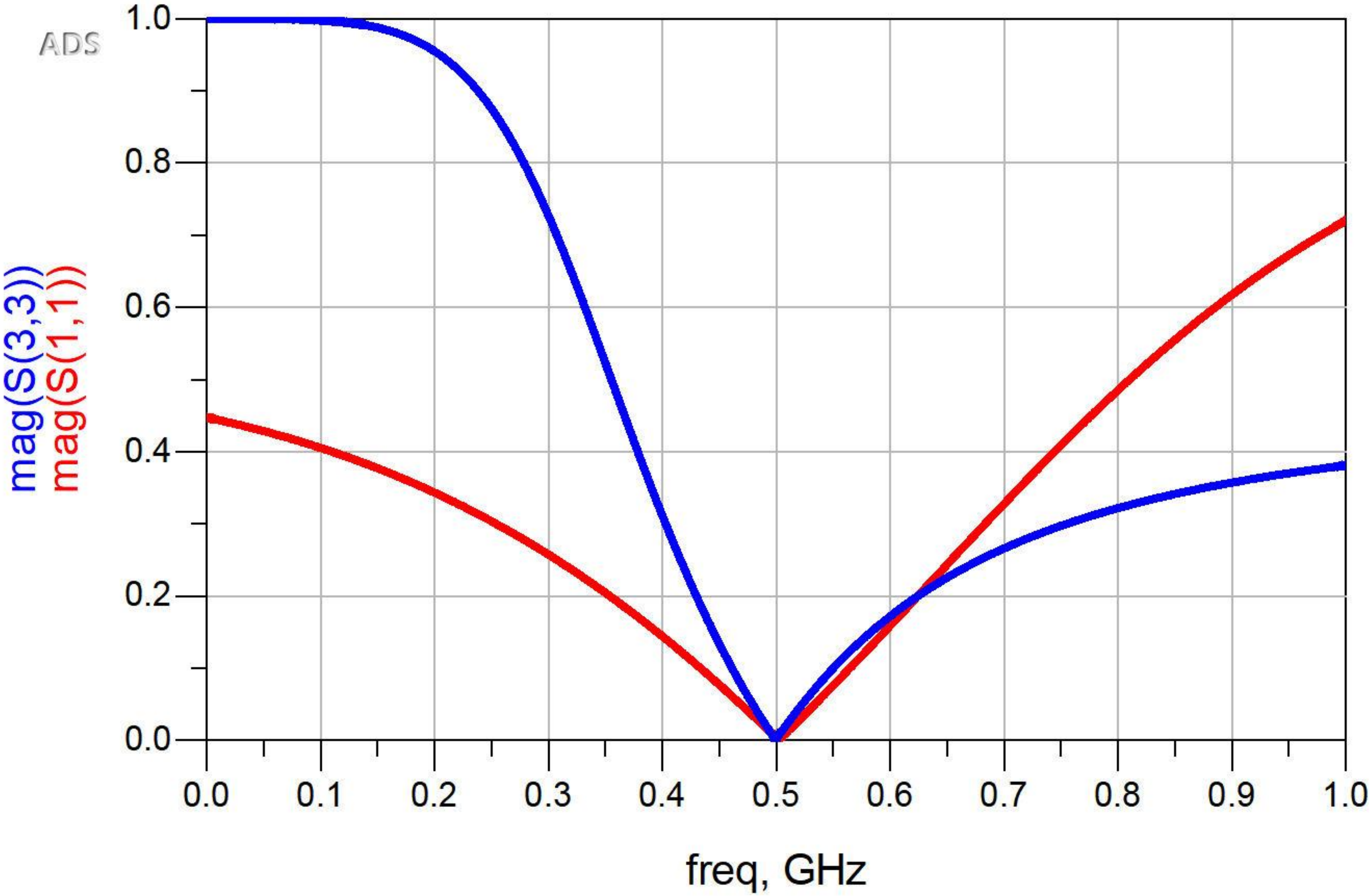

1
0.75
0.5
0.25
0
$|\Gamma|$
Solution 2
Solution 1
0
0.25
0.5
0.75
1
f(GHz)

Exemplu ADS



Term
Term1
Num=1
Z=100 Ohm
L
L1
L=38.8 nH
R=
C
C2
C=0.92 pF
Term
Term2
Num=2
Z=200-j*100
Term
Term3
Num=3
Z=100 Ohm
C
C1
C=2.61 pF
L
L2
L=46.1 nH
R=
Term
Term4
Num=4
Z=200-j*100

Exemplu ADS

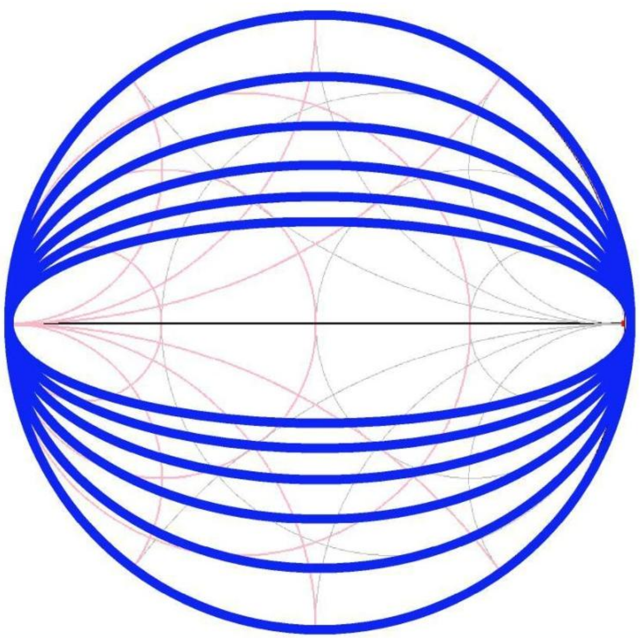


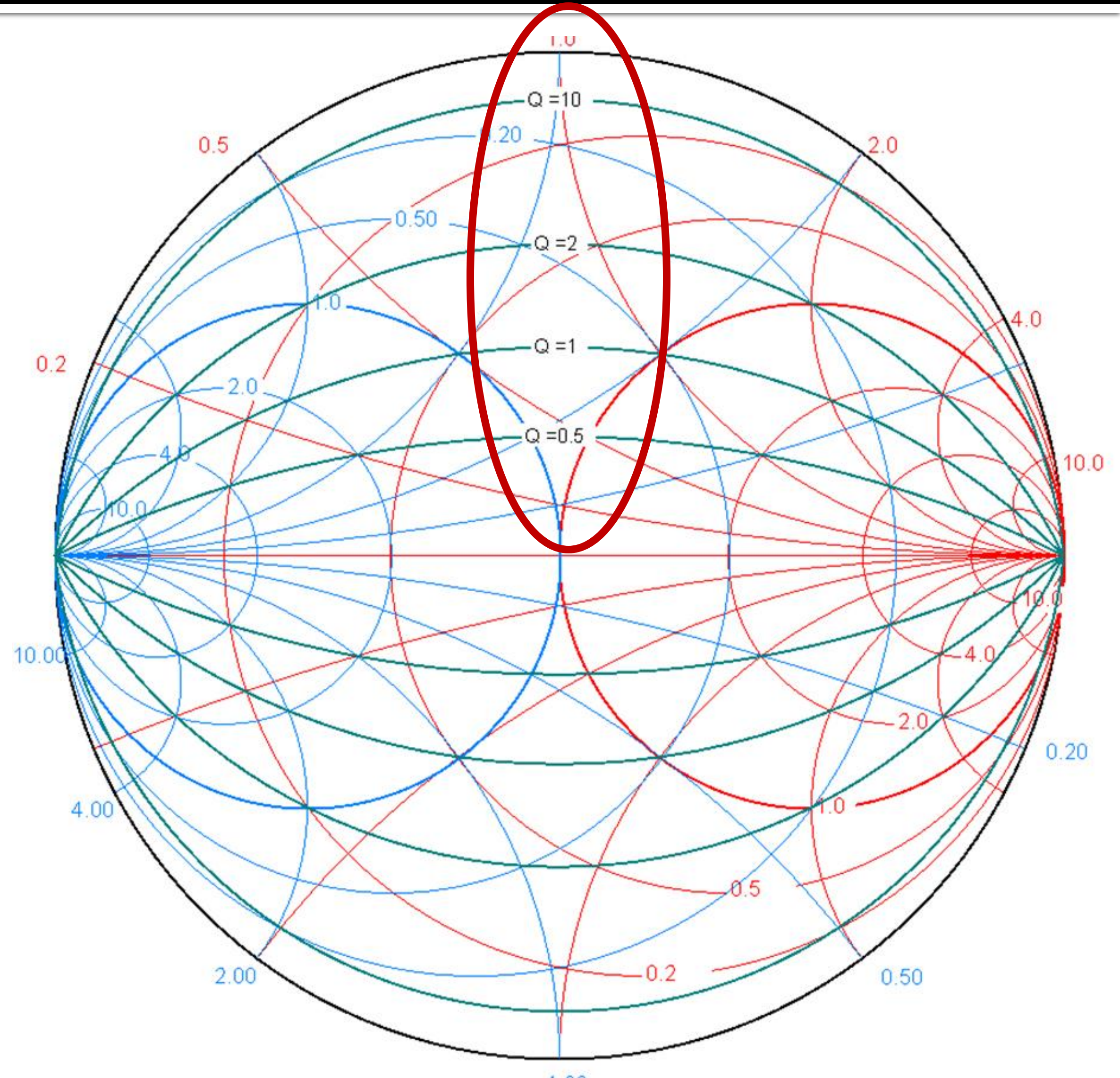
ADS
1.0
0.8
0.6
0.4
0.2
0.0
mag(S(3,3))
mag(S(1,1))
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
freq, GHz

Cercuri de factor de calitate constant

- Diagrama Smith

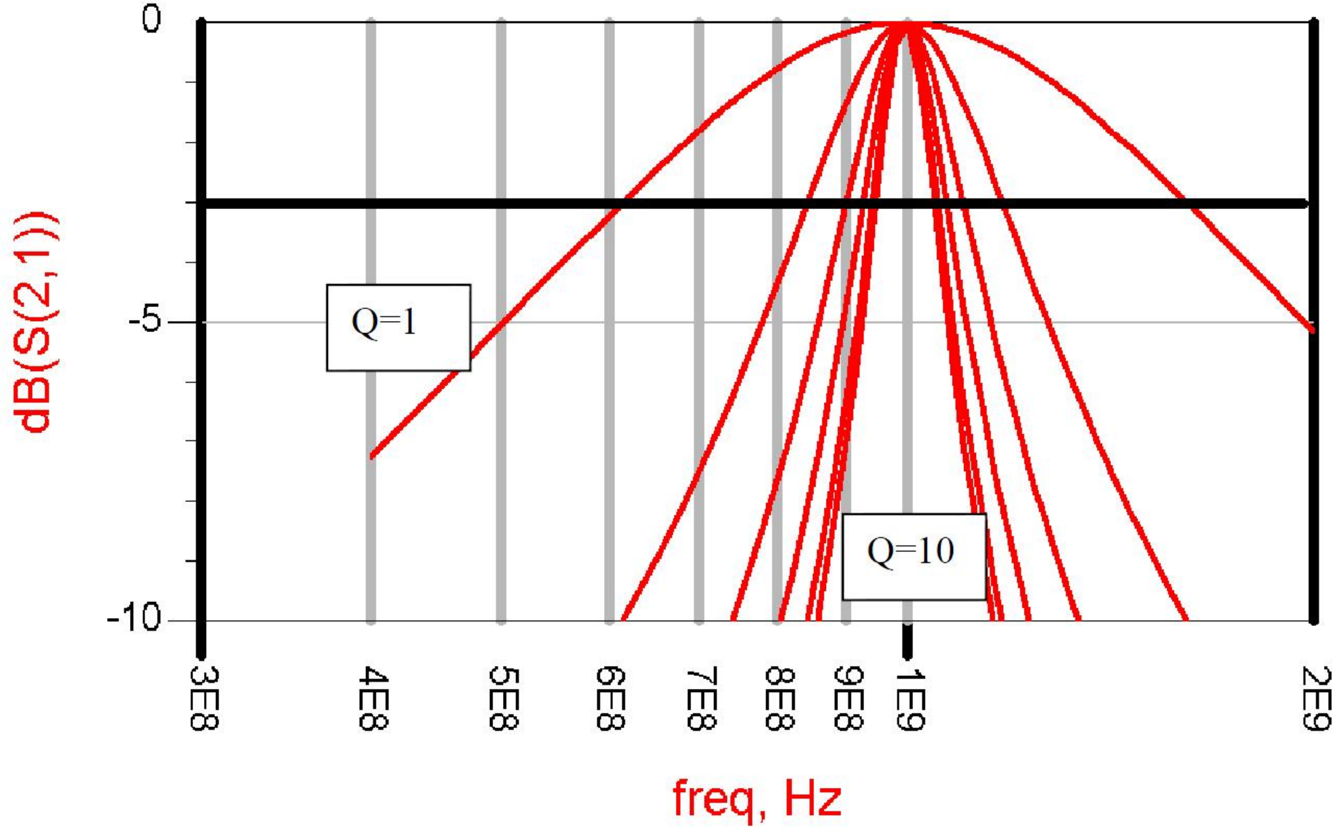
$$Q = \frac{X}{R} = \frac{G}{B} = const$$



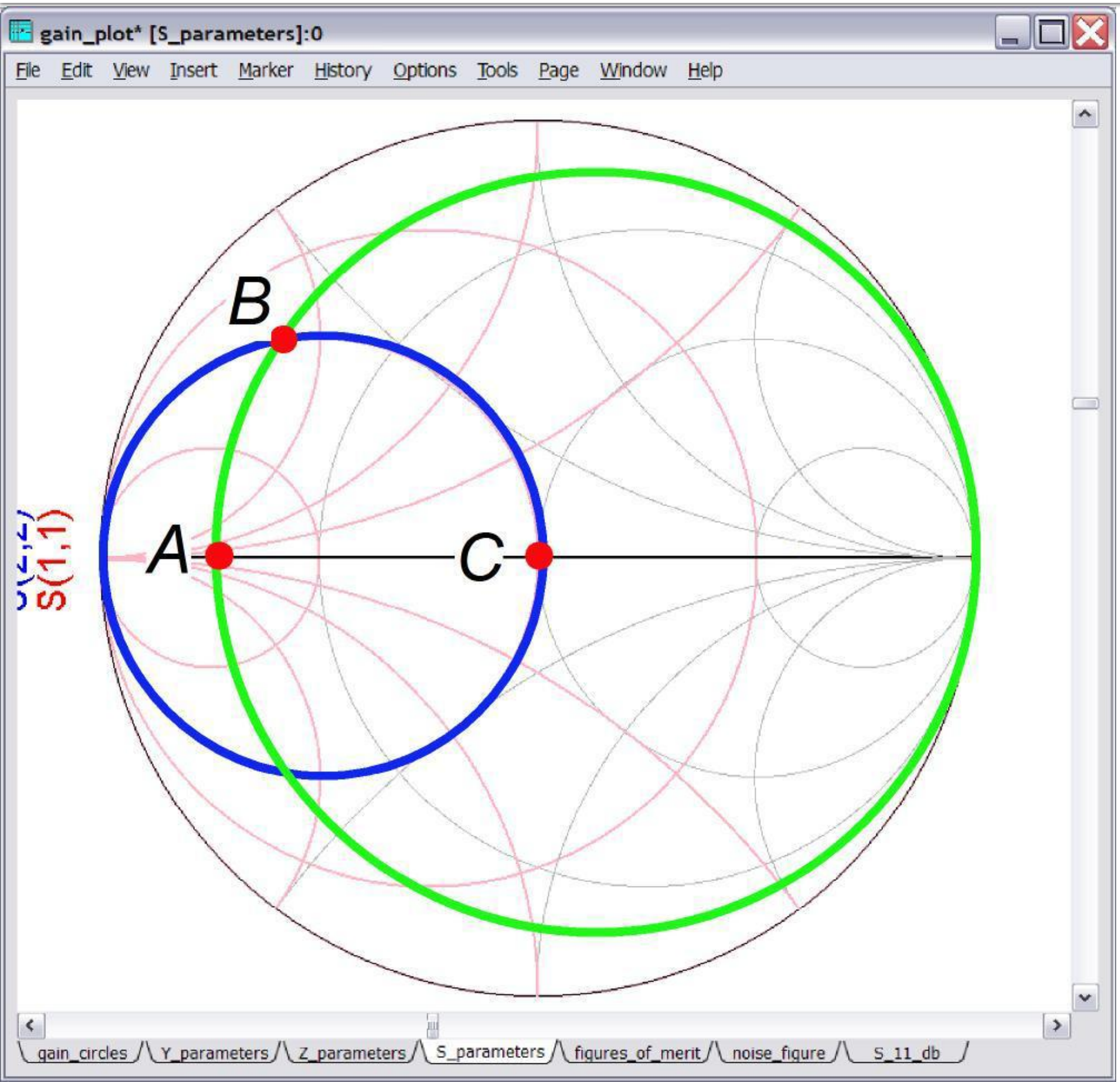


Factor de calitate - banda

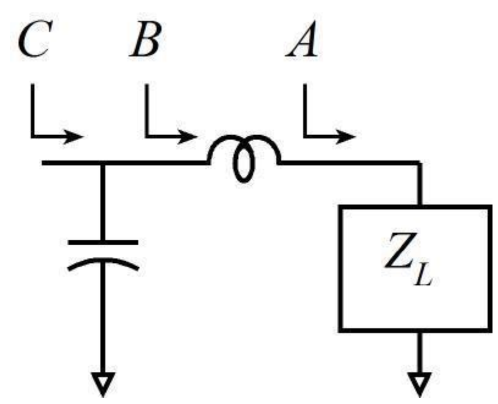
- Factor de calitate ridicat echivalent cu banda ingusta



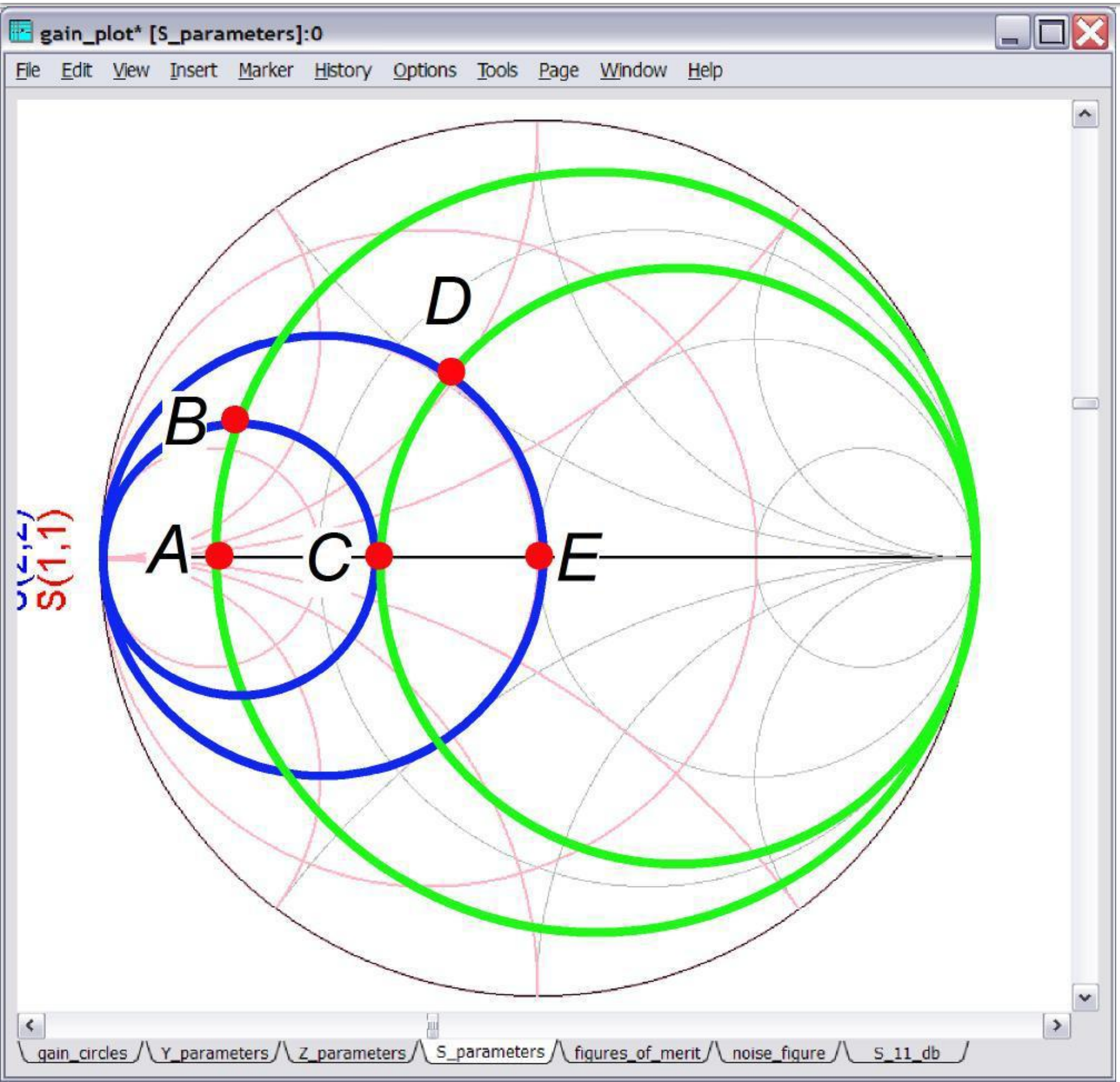
Adaptare - banda



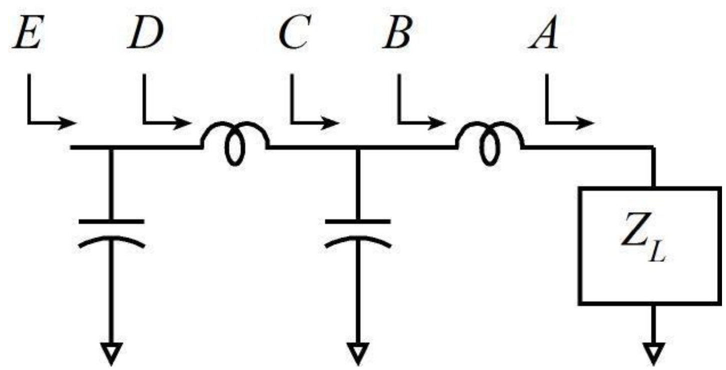
- Pozitia punctului intermediar (B) atins de Γ corespunzatoare celui mai ridicat factor de calitate impune largimea de banda a adaptarii



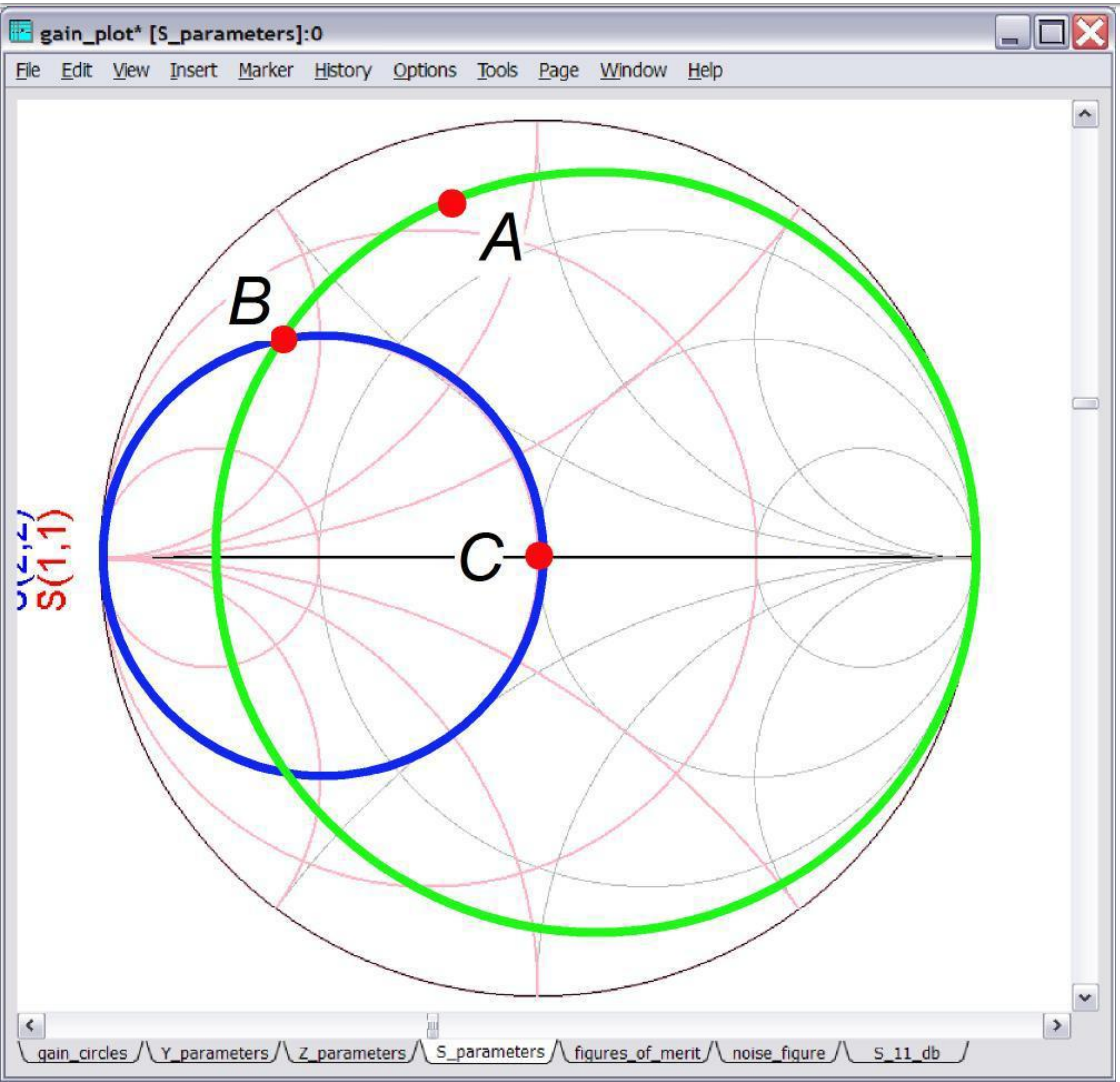
Adaptare - banda



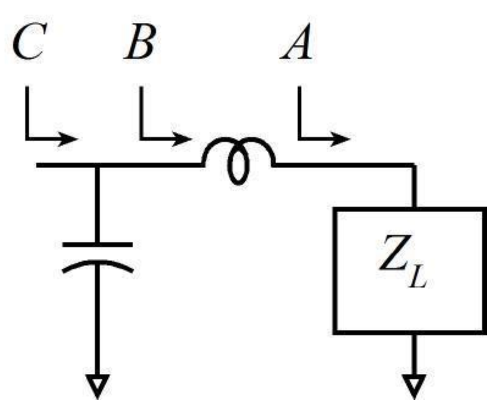
- Adaptare in banda mai larga poate fi obtinuta prin realizarea unor retele in L multiple, fiecare pentru variatii mai mici ale lui Γ, astfel incat toti coeficientii de reflexie intermediari (B, D) sa ocupe pozitii care corespund unui factor de calitate mai mic



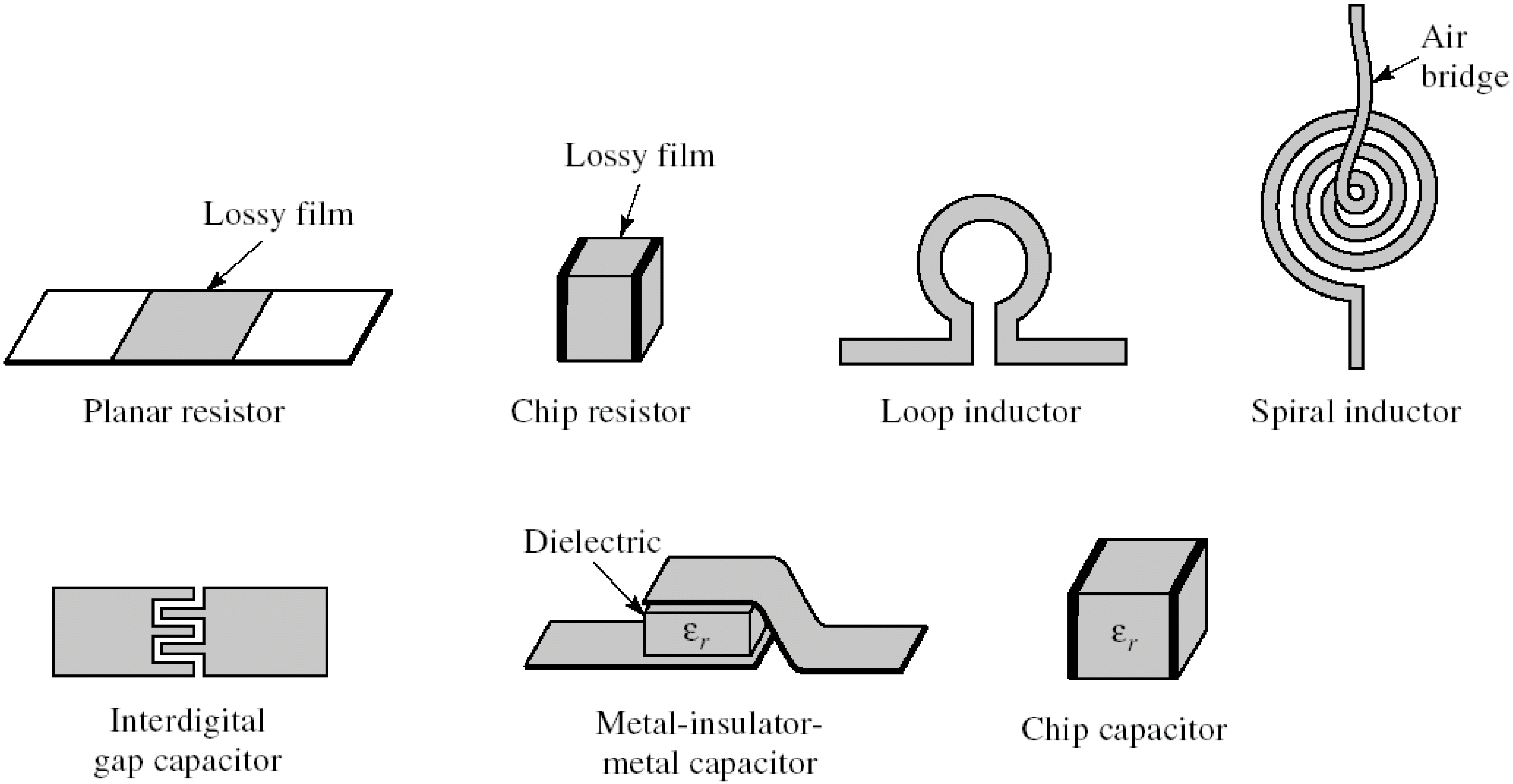
Adaptare - banda



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



Realizare elemente concentrate



Contact

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