

**Curs 4**  
2014/2015

# **Dispozitive și circuite de microunde pentru radiocomunicații**

# Fotografii

## FLORESCU DAN-CONSTANȚĂ



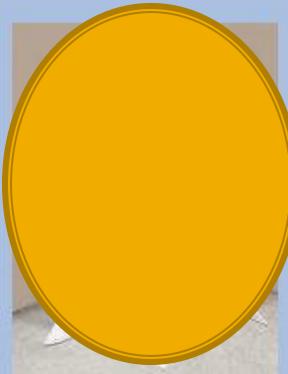
Date:

Grupa	5405 (2008)
Specializarea	Tehnologii si sisteme
Marca	3275

### Note obtinute

Disciplina	Tip	Data	Descriere	Nota	Obiectiv
<b>DCMR Dispozitive si circuite de microunde pentru radiocomunicații</b>					
	Nota	19/06/2009	Nota finală	10	
	Exam	19/06/2009	Examen DCMR	9	
	Tema	05/06/2009	Proiect DCMR	10	

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### Detalii

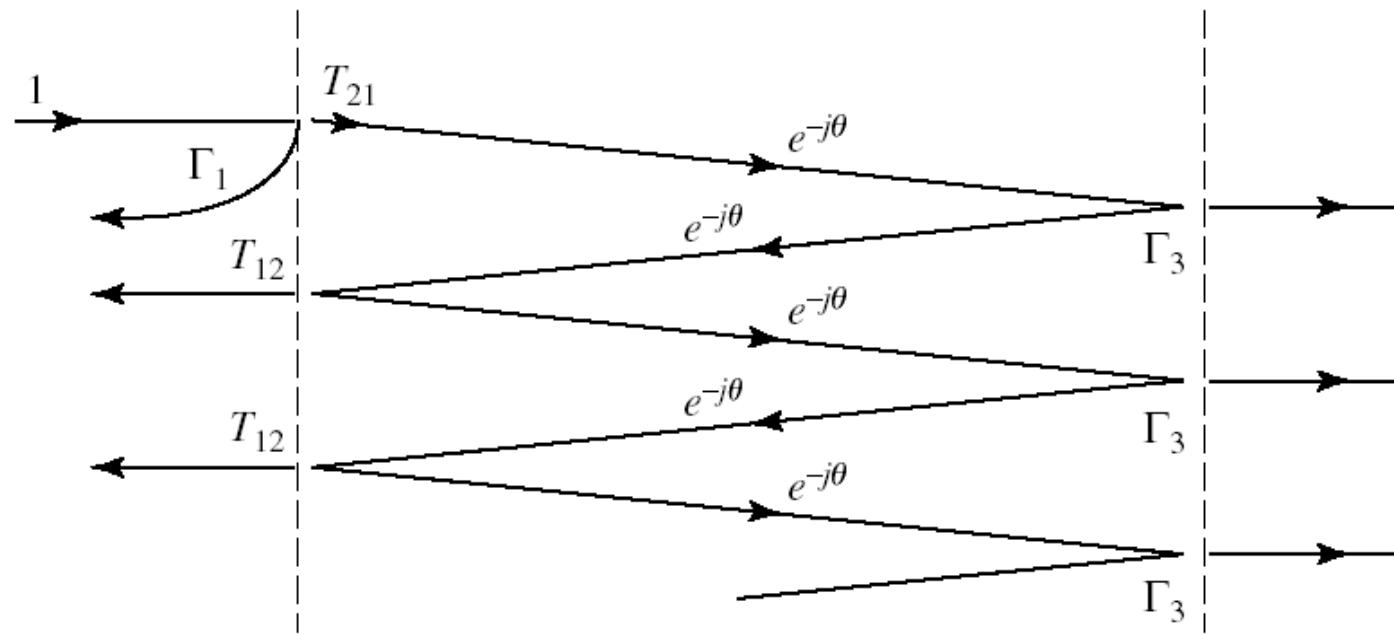
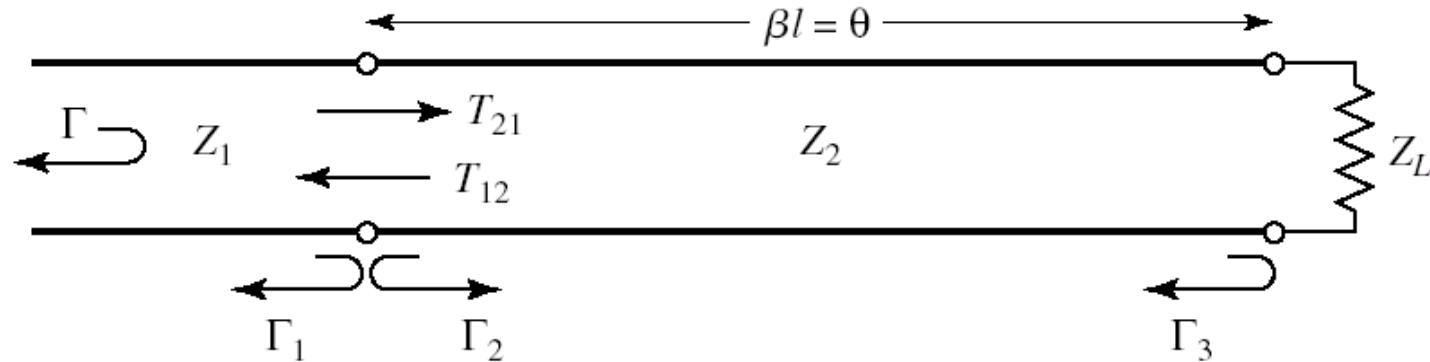
Finanțare	Buget
Bursa	Bursa de Studii
Domiciliu	Iasi, judet Iasi
Promovare	Promovare Integrala
Credite	60
Media	8.86

# **Adaptarea de impedanță**

# Transformatoare de impedanta multisectiune

- Transformatorul in sfert de lungime de unda permite adaptarea oricarei impedante reale cu orice impedanta a fiderului (liniei).
- Daca banda necesara este mai mare decat cea oferita de transformatorul in sfert de lungime de unda se folosesc transformatoare multisectiune
  - caracteristica binomiala
  - tip Cebîşev

# Teoria reflexiilor mici



# Teoria reflexiilor mici

$$\Gamma_1 = \frac{Z_2 - Z_1}{Z_2 + Z_1}$$

$$\Gamma_2 = -\Gamma_1$$

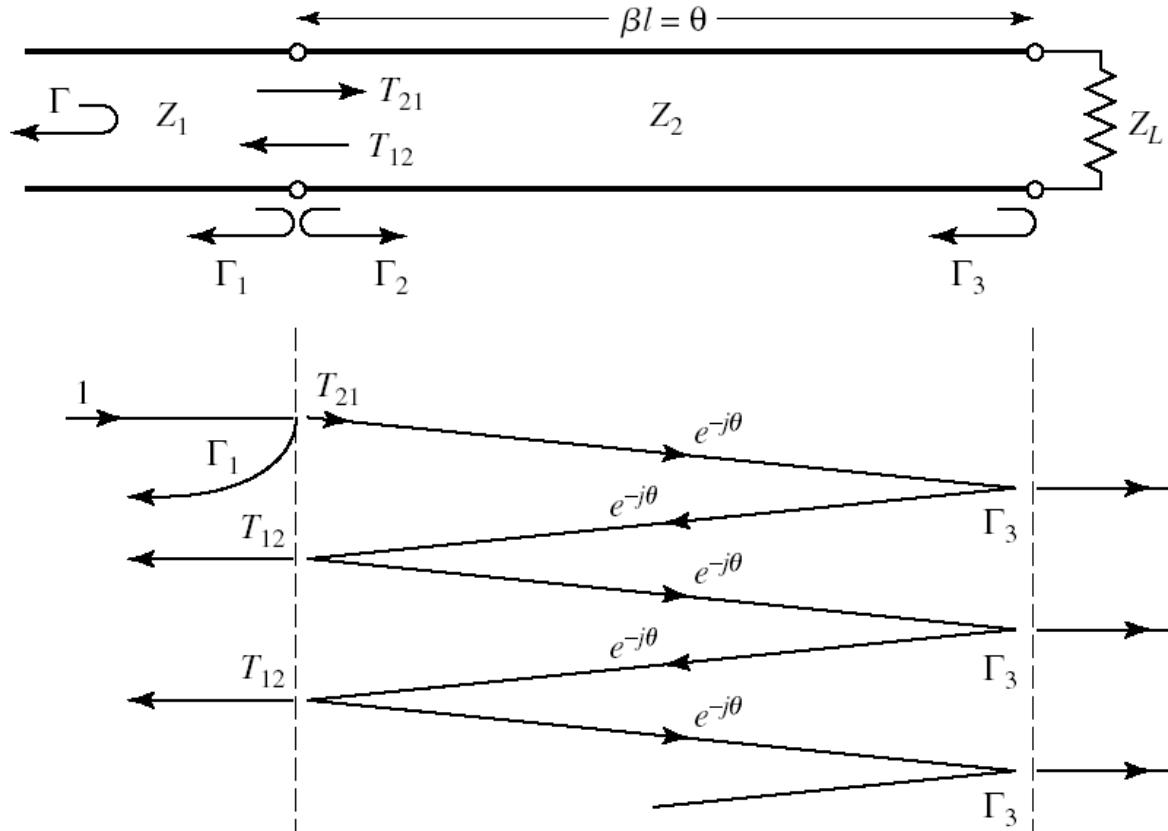
$$\Gamma_3 = \frac{Z_L - Z_2}{Z_L + Z_2}$$

$$T_{21} = 1 + \Gamma_1 = \frac{2 \cdot Z_2}{Z_1 + Z_2}$$

$$T_{12} = 1 + \Gamma_2 = \frac{2 \cdot Z_1}{Z_1 + Z_2}$$

$$\Gamma = \Gamma_1 + T_{12} \cdot T_{21} \cdot \Gamma_3 \cdot e^{-2j\theta} + T_{12} \cdot T_{21} \cdot \Gamma_3^2 \cdot \Gamma_2 \cdot e^{-4j\theta} + T_{12} \cdot T_{21} \cdot \Gamma_3^3 \cdot \Gamma_2^2 \cdot e^{-6j\theta} + \dots$$

$$\Gamma = \Gamma_1 + T_{12} \cdot T_{21} \cdot \Gamma_3 \cdot e^{-2j\theta} \sum_{n=0}^{\infty} \Gamma_3^n \cdot \Gamma_2^n \cdot e^{-2jn\theta}$$



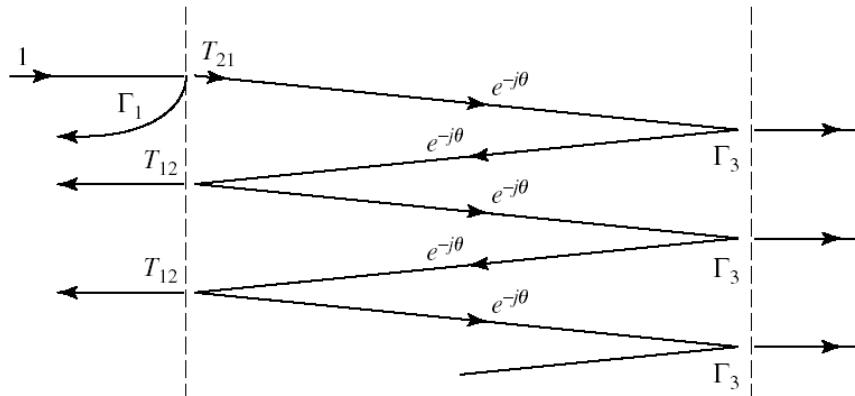
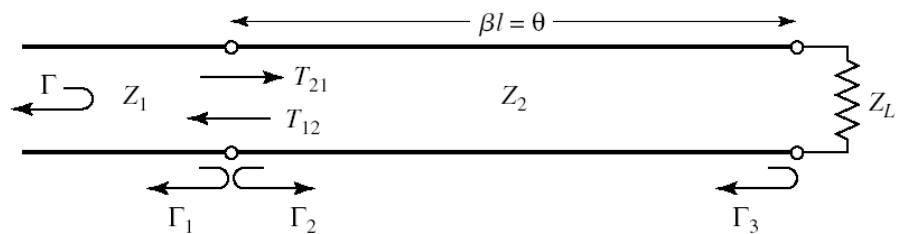
# Teoria reflexiilor mici

$$\Gamma = \Gamma_1 + T_{12} \cdot T_{21} \cdot \Gamma_3 \cdot e^{-2j\theta} \sum_{n=0}^{\infty} \Gamma_3^n \cdot \Gamma_2^n \cdot e^{-2jn\theta}$$

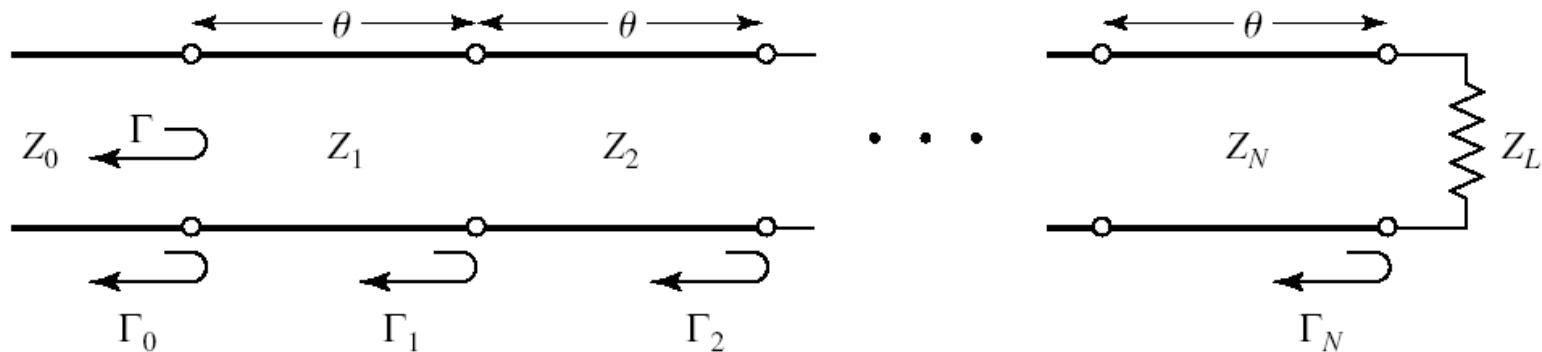
$$\sum_{n=0}^{\infty} x^n = \frac{1}{1-x} \quad |x| < 1$$

$$\Gamma = \frac{\Gamma_1 + \Gamma_3 \cdot e^{-2j\theta}}{1 + \Gamma_1 \cdot \Gamma_3 \cdot e^{-2j\theta}}$$

$$\Gamma \cong \Gamma_1 + \Gamma_3 \cdot e^{-2j\theta}$$



# Transformatoare cu mai multe sectiuni



- Presupunem ca toate impedantele **cresc sau descresc uniform**
- Toti coeficientii de reflexie vor fi reali si de acelasi semn
- Anterior  $\Gamma \cong \Gamma_1 + \Gamma_3 \cdot e^{-2j\theta} \Rightarrow$   
$$\Gamma(\theta) = \Gamma_0 + \Gamma_1 \cdot e^{-2j\theta} + \Gamma_2 \cdot e^{-4j\theta} + \dots + \Gamma_N \cdot e^{-2jN\theta}$$

$$\Gamma_1 = \frac{Z_1 - Z_0}{Z_1 + Z_0}$$

$$\Gamma_n = \frac{Z_{n+1} - Z_n}{Z_{n+1} + Z_n}$$

$$n = \overline{1, N-1}$$

$$\Gamma_N = \frac{Z_L - Z_N}{Z_L + Z_N}$$

# Transformatoare cu mai multe sectiuni

- Realizez transformatorul **simetric**
- Aceasta **nu** implica faptul ca impedantele sunt egale

$$\Gamma_0 = \Gamma_N, \Gamma_1 = \Gamma_{N-1}, \Gamma_2 = \Gamma_{N-2} \dots$$

$$\Gamma(\theta) = \Gamma_0 + \Gamma_1 \cdot e^{-2j\theta} + \Gamma_2 \cdot e^{-4j\theta} + \dots + \Gamma_N \cdot e^{-2jN\theta}$$

$$\Gamma(\theta) = e^{-jN\theta} \cdot [\Gamma_0 \cdot (e^{jN\theta} + e^{-jN\theta}) + \Gamma_1 \cdot (e^{j(N-2)\theta} + e^{-j(N-2)\theta}) + \Gamma_2 \cdot (e^{j(N-4)\theta} + e^{-j(N-4)\theta}) + \dots]$$

$$\Gamma(\theta) = 2e^{-jN\theta} \cdot [\Gamma_0 \cdot \cos N\theta + \Gamma_1 \cdot \cos(N-2)\theta + \dots + \Gamma_n \cdot \cos(N-2n)\theta + \dots]$$

$$\dots - \frac{1}{2} \cdot \Gamma_{N/2} \quad n \text{ par}$$

ultimul termen:

$$\dots + \Gamma_{(N-1)/2} \cdot \cos \theta \quad n \text{ impar}$$

# Transformatoare cu mai multe sectiuni

- Coeficient de reflexie

$$\Gamma(\theta) = \Gamma_0 + \Gamma_1 \cdot e^{-2j\theta} + \Gamma_2 \cdot e^{-4j\theta} + \cdots + \Gamma_N \cdot e^{-2jN\theta}$$

$$e^{-2j\theta} \equiv x$$

$$f(x) = a_0 + a_1 \cdot x + a_2 \cdot x^2 + \cdots + a_N \cdot x^N$$

- aleg coeficientii astfel incat sa obtin o variatie dorita (a polinomului)

# Transformatoare cu mai multe sectiuni cu caracteristica binomiala

- Raspunsul acestui transformator este de tip maxim plat in jurul frecventei de adaptare
- Pentru N sectiuni se anuleaza primele N-1 derivate ale functiei  $|\Gamma(\theta)|$

$$f(x) = A \cdot (1+x)^N$$

$$\Gamma(\theta) = A \cdot (1 + e^{-2j\theta})^N$$

$$|\Gamma(\theta)| = |A| \cdot |e^{-j\theta}|^N \cdot |e^{j\theta} + e^{-j\theta}|^N = 2^N \cdot |A| \cdot |\cos \theta|^N$$

$$\left| \Gamma\left(\frac{\pi}{2}\right) \right| = 0; \quad \frac{d^n}{d\theta^n} |\Gamma(\theta)| \Big|_{\theta=\frac{\pi}{2}} = 0 \quad n = \overline{1, N-1} \quad l = \frac{\lambda}{4} \Rightarrow \theta = \beta \cdot l = \frac{\pi}{2}$$

# Transformatoare cu mai multe sectiuni cu caracteristica binomiala

- $A, \theta \rightarrow 0$ , liniile de lungime o, dispar

$$\Gamma(0) = 2^N \cdot A = \frac{Z_L - Z_0}{Z_L + Z_0} \quad A = 2^{-N} \cdot \frac{Z_L - Z_0}{Z_L + Z_0}$$

- dezvoltarea binomului

$$f(x) = (1+x)^N = C_N^0 + C_N^1 \cdot x + \cdots + C_N^n \cdot x^n + \cdots + C_N^N \cdot x^N$$

$$C_N^n = \frac{N!}{(N-n)!n!}$$

- Coeficientii de reflexie

$$\Gamma(\theta) = A \cdot (1 + e^{-2j\theta})^N \quad \Gamma(\theta) = \Gamma_0 + \Gamma_1 \cdot e^{-2j\theta} + \Gamma_2 \cdot e^{-4j\theta} + \cdots + \Gamma_N \cdot e^{-2jN\theta}$$

$$\Gamma_n = A \cdot C_N^n$$

# Transformatoare cu mai multe sectiuni cu caracteristica binomiala

## ■ Proiectare

$$\Gamma_n = A \cdot C_N^n$$

$$\Gamma_n = \frac{Z_{n+1} - Z_n}{Z_{n+1} + Z_n} \cong \frac{1}{2} \ln \frac{Z_{n+1}}{Z_n} \quad \ln x \cong 2 \cdot \frac{x-1}{x+1} \quad x \cong 1$$

$$\ln \frac{Z_{n+1}}{Z_n} \cong 2 \cdot \Gamma_n = 2 \cdot A \cdot C_N^n = 2 \cdot 2^{-N} \cdot \frac{Z_L - Z_0}{Z_L + Z_0} \cong 2^{-N} \cdot C_N^n \cdot \ln \frac{Z_L}{Z_0}$$

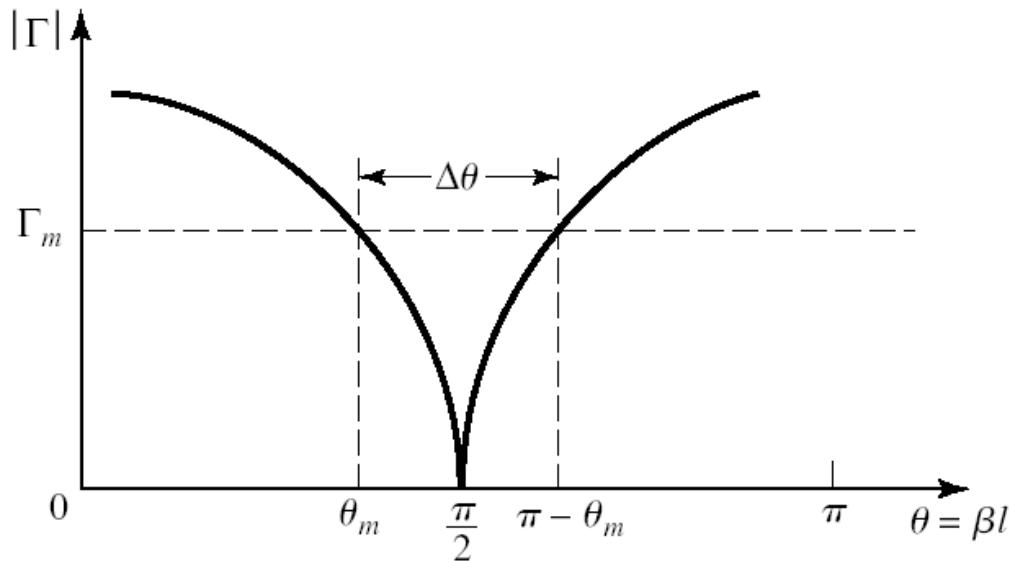
$$\ln Z_{n+1} \cong \ln Z_n + 2^{-N} \cdot C_N^n \cdot \ln \frac{Z_L}{Z_0}$$

# Transformatoare cu mai multe sectiuni cu caracteristica binomiala

- Banda,  $\Gamma_m$  maxim tolerat

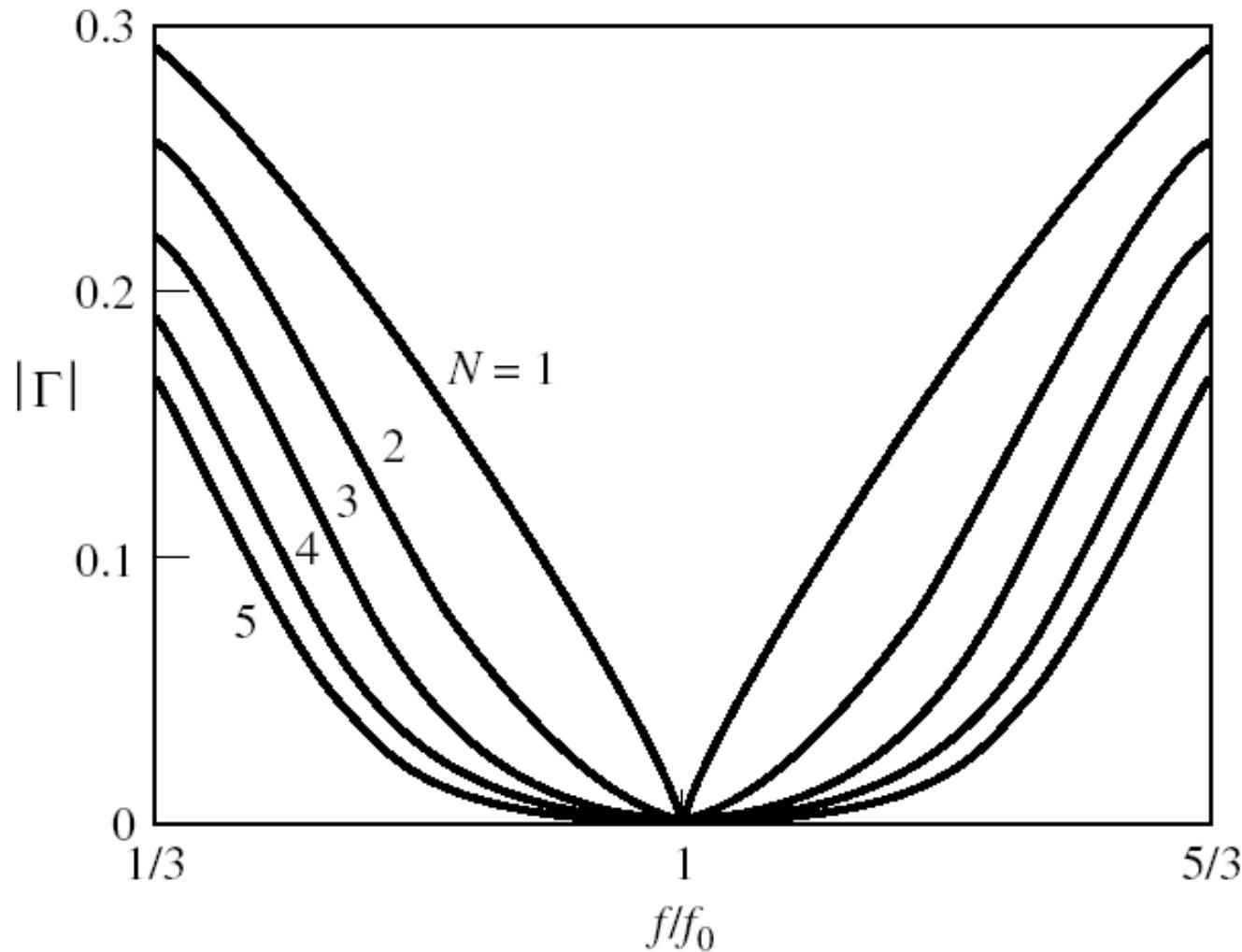
$$\Gamma_m = |\Gamma(\theta_m)| = 2^N \cdot |A| \cdot |\cos \theta_m|^N$$

$$\theta_m = \cos^{-1} \left[ \frac{1}{2} \left( \frac{\Gamma_m}{|A|} \right)^{\frac{1}{N}} \right]$$



$$\frac{\Delta f}{f_0} = \frac{2(f_0 - f_m)}{f_0} = 2 - \frac{4\theta_m}{\pi} = 2 - \frac{4}{\pi} \cdot \cos^{-1} \left[ \frac{1}{2} \left( \frac{\Gamma_m}{|A|} \right)^{\frac{1}{N}} \right]$$

# Banda



# Transformatoare cu mai multe sectiuni cu caracteristica binomiala rezultate exacte

$Z_L/Z_0$	$N = 2$		$N = 3$			$N = 4$					
	$Z_1/Z_0$	$Z_2/Z_0$	$Z_1/Z_0$	$Z_2/Z_0$	$Z_3/Z_0$	$Z_1/Z_0$	$Z_2/Z_0$	$Z_3/Z_0$	$Z_4/Z_0$		
1.0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000		
1.5	1.1067	1.3554	1.0520	1.2247	1.4259	1.0257	1.1351	1.3215	1.4624		
2.0	1.1892	1.6818	1.0907	1.4142	1.8337	1.0444	1.2421	1.6102	1.9150		
3.0	1.3161	2.2795	1.1479	1.7321	2.6135	1.0718	1.4105	2.1269	2.7990		
4.0	1.4142	2.8285	1.1907	2.0000	3.3594	1.0919	1.5442	2.5903	3.6633		
6.0	1.5651	3.8336	1.2544	2.4495	4.7832	1.1215	1.7553	3.4182	5.3500		
8.0	1.6818	4.7568	1.3022	2.8284	6.1434	1.1436	1.9232	4.1597	6.9955		
10.0	1.7783	5.6233	1.3409	3.1623	7.4577	1.1613	2.0651	4.8424	8.6110		
$Z_L/Z_0$	$N = 5$					$N = 6$					
	$Z_1/Z_0$	$Z_2/Z_0$	$Z_3/Z_0$	$Z_4/Z_0$	$Z_5/Z_0$	$Z_1/Z_0$	$Z_2/Z_0$	$Z_3/Z_0$	$Z_4/Z_0$	$Z_5/Z_0$	$Z_6/Z_0$
1.0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.5	1.0128	1.0790	1.2247	1.3902	1.4810	1.0064	1.0454	1.1496	1.3048	1.4349	1.4905
2.0	1.0220	1.1391	1.4142	1.7558	1.9569	1.0110	1.0790	1.2693	1.5757	1.8536	1.9782
3.0	1.0354	1.2300	1.7321	2.4390	2.8974	1.0176	1.1288	1.4599	2.0549	2.6577	2.9481
4.0	1.0452	1.2995	2.0000	3.0781	3.8270	1.0225	1.1661	1.6129	2.4800	3.4302	3.9120
6.0	1.0596	1.4055	2.4495	4.2689	5.6625	1.0296	1.2219	1.8573	3.2305	4.9104	5.8275
8.0	1.0703	1.4870	2.8284	5.3800	7.4745	1.0349	1.2640	2.0539	3.8950	6.3291	7.7302
10.0	1.0789	1.5541	3.1623	6.4346	9.2687	1.0392	1.2982	2.2215	4.5015	7.7030	9.6228

# Exemplu

- Transformator de adaptare cu 3 sectiuni pentru a adapta o sarcina de  $30\Omega$  la o linie de  $100\Omega$  la frecventa  $f_o=3\text{GHz}$ ,  $\Gamma_m=0.1$ 
  - $N = 3$

$$Z_L = 30\Omega \quad Z_0 = 100\Omega$$

$$A = 2^{-N} \frac{Z_L - Z_0}{Z_L + Z_0} \approx \frac{1}{2^{N+1}} \ln \frac{Z_L}{Z_0} = -0.07525$$

$$C_3^0 = \frac{3!}{3!0!} = 1 \qquad C_3^1 = \frac{3!}{2!1!} = 3 \qquad C_3^2 = \frac{3!}{1!2!} = 3$$

# Exemplu

$n = 0$

$$\ln Z_1 = \ln Z_0 + 2^{-N} C_3^0 \ln \frac{Z_L}{Z_0} = \ln 100 + 2^{-3} \cdot 1 \cdot \ln \frac{30}{100} = 4.455$$

$$Z_1 = 86.03\Omega$$

$n = 1$

$$\ln Z_2 = \ln Z_1 + 2^{-N} C_3^1 \ln \frac{Z_L}{Z_0} = \ln 86.03 + 2^{-3} \cdot 3 \cdot \ln \frac{30}{100} = 4.003$$

$$Z_2 = 54.77\Omega$$

$n = 2$

$$\ln Z_3 = \ln Z_2 + 2^{-N} C_3^2 \ln \frac{Z_L}{Z_0} = \ln 54.77 + 2^{-3} \cdot 3 \cdot \ln \frac{30}{100} = 3.552$$

$$Z_3 = 34.87\Omega$$

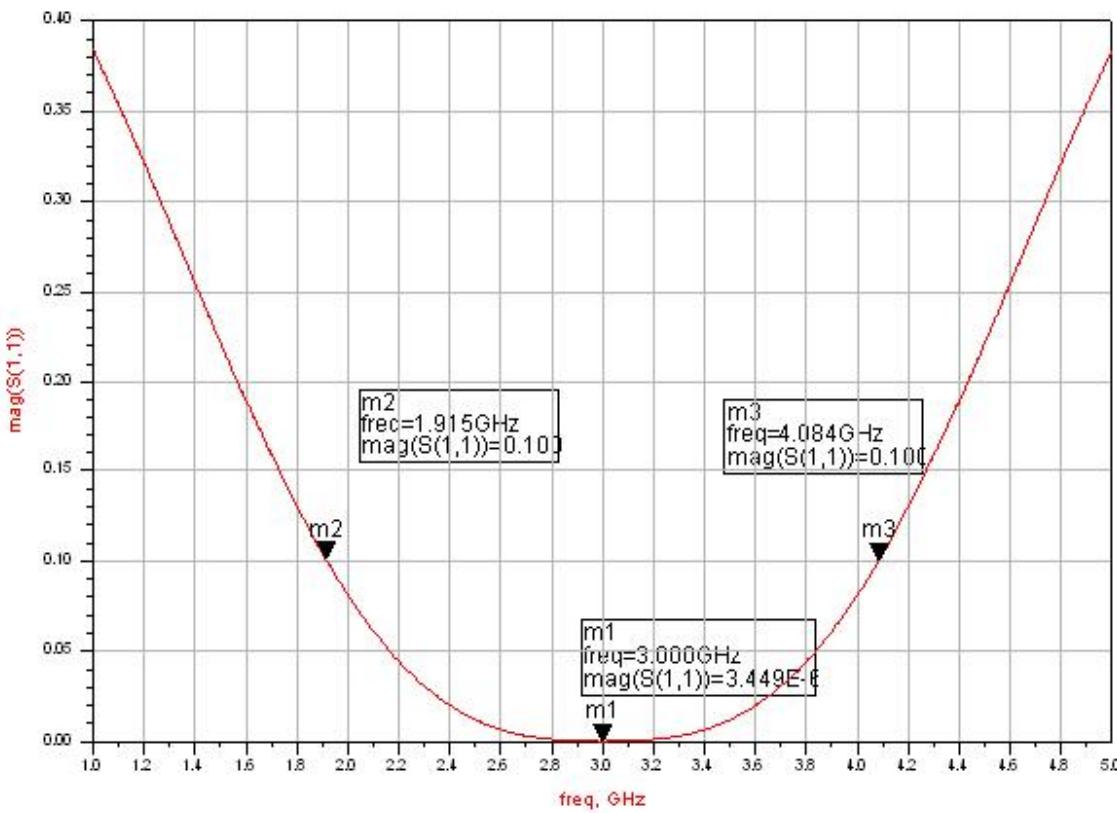
# Exemplu

$$\frac{\Delta f}{f_0} = 2 - \frac{4}{\pi} \arccos \left[ \frac{1}{2} \left( \frac{\Gamma_m}{|A|} \right)^{1/N} \right] = 2 - \frac{4}{\pi} \arccos \left[ \frac{1}{2} \left( \frac{0.1}{0.07525} \right)^{1/3} \right] = 0.74$$

$$\Delta f = 2.22 \text{GHz}$$

# Simulare

## ■ Similar Lab. 1



$$\Delta f = 2.169 \text{ GHz}$$

$$|\Gamma(3 \text{ GHz})| = 3.5 \cdot 10^{-6}$$

# Transformatoare cu mai multe sectiuni de tip Cebîșev

- Raspunsul acestui transformator este de tip echiriplu in jurul frecventei de adaptare
- mareste banda in detrimentul riplului in banda de adaptare
- Se egaleaza functia  $\Gamma(\theta)$  cu un polinom Cebîșev

# Polinoame Cebîşev

$$T_1(x) = x$$

$$T_2(x) = 2x^2 - 1$$

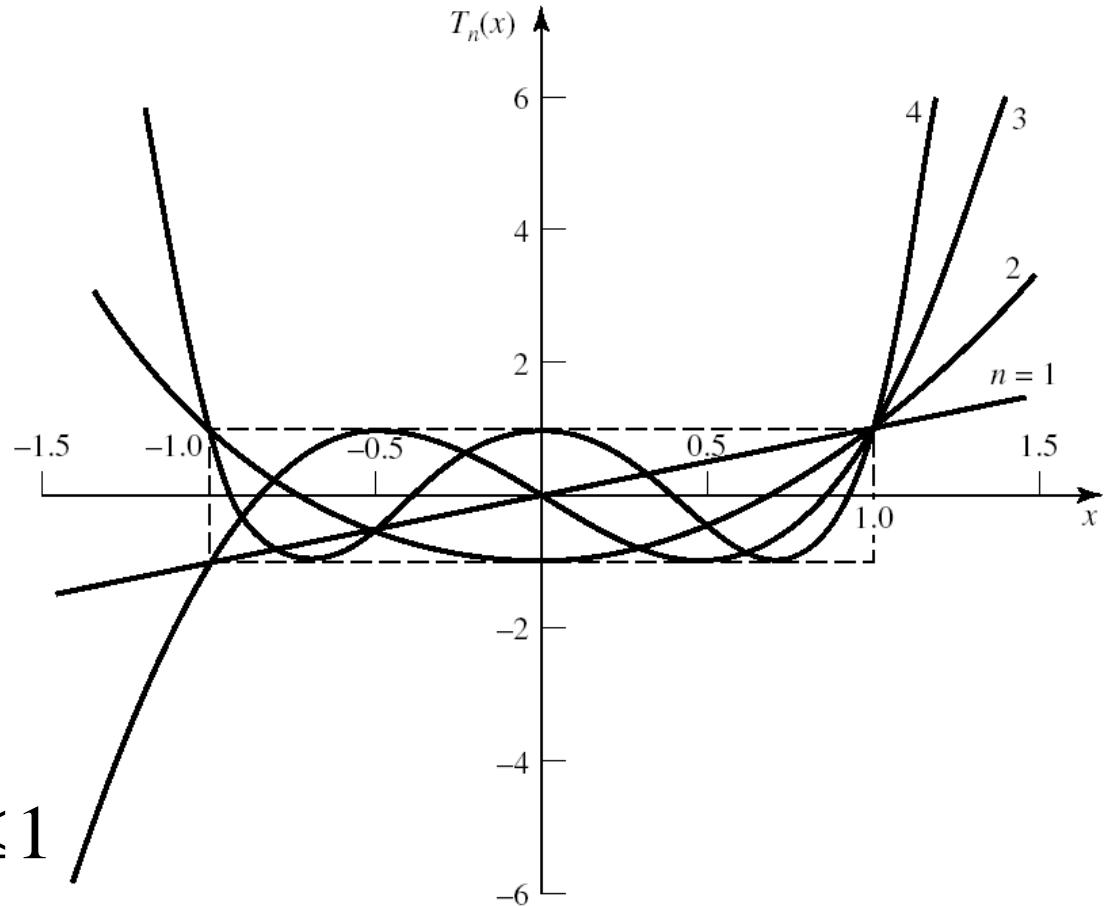
$$T_3(x) = 4x^3 - 3x$$

$$T_4(x) = 8x^4 - 8x^2 + 1$$

■ Echiriplu

$$-1 \leq x \leq 1 \Rightarrow |T_n(x)| \leq 1$$

$$T_n(x) = 2xT_{n-1}(x) - T_{n-2}(x)$$



# Polinoame Cebîşev

$$\Gamma(\theta) = \Gamma_0 + \Gamma_1 \cdot e^{-2j\theta} + \Gamma_2 \cdot e^{-4j\theta} + \cdots + \Gamma_N \cdot e^{-2jN\theta}$$

$$e^{-2j\theta} \equiv x$$

$$f(x) = a_0 + a_1 \cdot x + a_2 \cdot x^2 + \cdots + a_N \cdot x^N$$

$$\Gamma(\theta) = 2e^{-jN\theta} \cdot [\Gamma_0 \cdot \cos N\theta + \Gamma_1 \cdot \cos(N-2)\theta + \cdots + \Gamma_n \cdot \cos(N-2n)\theta + \cdots]$$

$$\cdots \frac{1}{2} \cdot \Gamma_{N/2} \quad n \text{ par}$$

ultimul termen:

$$\cdots \Gamma_{(N-1)/2} \cdot \cos \theta \quad n \text{ impar}$$

$$x = \cos \theta \quad T_n(\cos \theta) = \cos(n\theta)$$

$$T_n(x) = \cos(n \arccos(x)) \quad |x| < 1 \quad T_n(x) = \cosh(n \cosh^{-1}(x)) \quad |x| > 1$$

# Transformatoare cu mai multe sectiuni de tip Cebîșev

- Schimbare de variabila

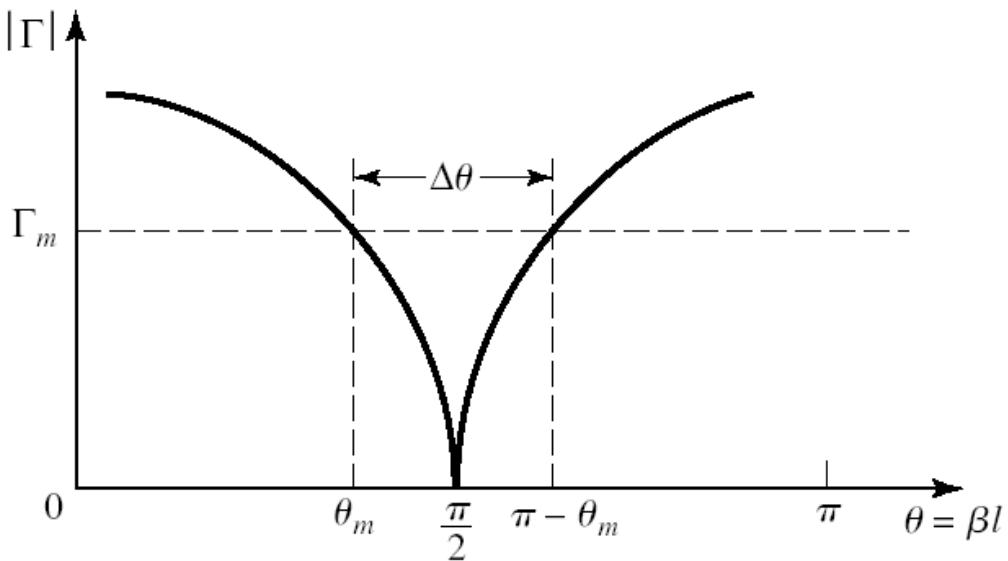
$$\theta = \theta_m \rightarrow x = 1$$

$$\theta = \pi - \theta_m \rightarrow x = -1$$

$$x \equiv \frac{\cos \theta}{\cos \theta_m}$$

$$\sec \theta = \frac{1}{\cos \theta}$$

$$x = \sec \theta_m \cos \theta$$



# Transformatoare cu mai multe sectiuni de tip Cebîșev

$$T_1(\sec \theta_m \cos \theta) = \sec \theta_m \cos \theta$$

$$T_2(\sec \theta_m \cos \theta) = \sec^2 \theta_m (1 + \cos 2\theta) - 1$$

$$T_3(\sec \theta_m \cos \theta) = \sec^3 \theta_m (\cos 3\theta + 3\cos \theta) - 3\sec \theta_m \cos \theta$$

$$T_4(\sec \theta_m \cos \theta) = \sec^4 \theta_m (\cos 4\theta + 4\cos 2\theta + 3) - 4\sec^2 \theta_m (\cos 2\theta + 1) + 1$$

- Cautam coeficientii pentru a obtine un polinom Cebîșev

$$\Gamma(\theta) = 2e^{-jN\theta} \cdot [\Gamma_0 \cdot \cos N\theta + \Gamma_1 \cdot \cos(N-2)\theta + \dots + \Gamma_n \cdot \cos(N-2n)\theta + \dots]$$

$$\Gamma(\theta) = A \cdot e^{-jN\theta} \cdot T_N(\sec \theta_m \cos \theta)$$

ultimul termen:  $\dots \frac{1}{2} \cdot \Gamma_{N/2} \quad n \text{ par}$

$$\dots \Gamma_{(N-1)/2} \cdot \cos \theta \quad n \text{ impar}$$

# Transformatoare cu mai multe sectiuni de tip Cebîșev

- A,  $\theta \rightarrow 0$ , liniile de lungime o, dispar

$$\Gamma(0) = \frac{Z_L - Z_0}{Z_L + Z_0} = A \cdot T_N(\sec \theta_m) \quad A = \frac{Z_L - Z_0}{Z_L + Z_0} \cdot \frac{1}{T_N(\sec \theta_m)} \quad \Gamma_m = |A|$$

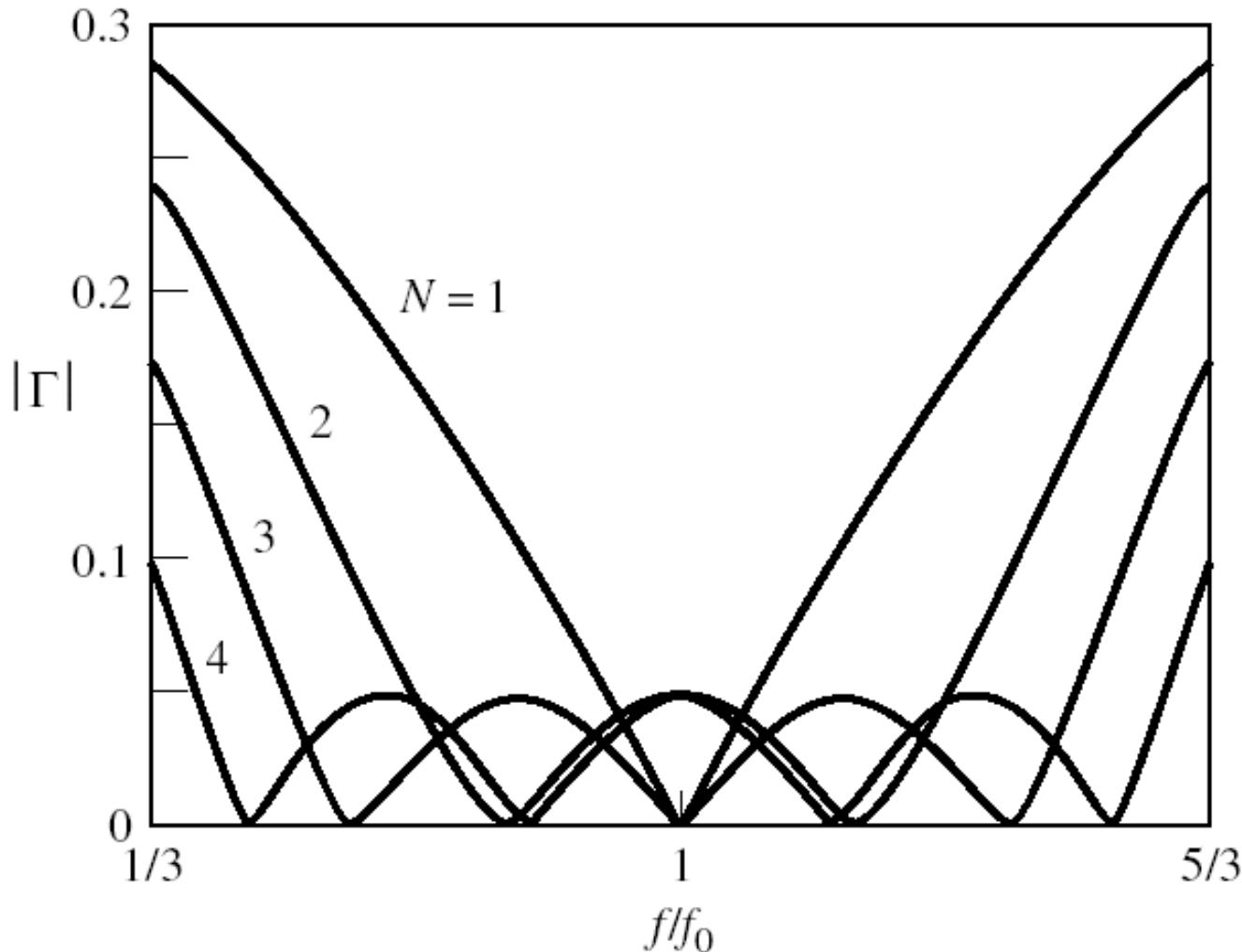
$$T_N(\sec \theta_m) = \frac{1}{\Gamma_m} \left| \frac{Z_L - Z_0}{Z_L + Z_0} \right| \cong \frac{1}{2\Gamma_m} \left| \ln \frac{Z_L}{Z_0} \right|$$

$$T_n(x) = \cosh(n \cosh^{-1}(x))$$

$$\sec \theta_m = \cosh \left[ \frac{1}{N} \cosh^{-1} \left( \frac{1}{\Gamma_m} \left| \frac{Z_L - Z_0}{Z_L + Z_0} \right| \right) \right] \cong \cosh \left[ \frac{1}{N} \cosh^{-1} \left( \left| \frac{\ln(Z_L/Z_0)}{2\Gamma_m} \right| \right) \right]$$

$$\frac{\Delta f}{f_0} = \frac{2(f_0 - f_m)}{f_0} = 2 - \frac{4\theta_m}{\pi}$$

# Transformatoare cu mai multe sectiuni de tip Cebîșev



# Transformatoare cu mai multe sectiuni de tip Cebîșev

$Z_L/Z_0$	$N = 2$				$N = 3$					
	$\Gamma_m = 0.05$		$\Gamma_m = 0.20$		$\Gamma_m = 0.05$			$\Gamma_m = 0.20$		
	$Z_1/Z_0$	$Z_2/Z_0$	$Z_1/Z_0$	$Z_2/Z_0$	$Z_1/Z_0$	$Z_2/Z_0$	$Z_3/Z_0$	$Z_1/Z_0$	$Z_2/Z_0$	$Z_3/Z_0$
1.0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.5	1.1347	1.3219	1.2247	1.2247	1.1029	1.2247	1.3601	1.2247	1.2247	1.2247
2.0	1.2193	1.6402	1.3161	1.5197	1.1475	1.4142	1.7429	1.2855	1.4142	1.5558
3.0	1.3494	2.2232	1.4565	2.0598	1.2171	1.7321	2.4649	1.3743	1.7321	2.1829
4.0	1.4500	2.7585	1.5651	2.5558	1.2662	2.0000	3.1591	1.4333	2.0000	2.7908
6.0	1.6047	3.7389	1.7321	3.4641	1.3383	2.4495	4.4833	1.5193	2.4495	3.9492
8.0	1.7244	4.6393	1.8612	4.2983	1.3944	2.8284	5.7372	1.5766	2.8284	5.0742
10.0	1.8233	5.4845	1.9680	5.0813	1.4385	3.1623	6.9517	1.6415	3.1623	6.0920
$N = 4$										
$Z_L/Z_0$	$\Gamma_m = 0.05$				$\Gamma_m = 0.20$					
	$Z_1/Z_0$	$Z_2/Z_0$	$Z_3/Z_0$	$Z_4/Z_0$	$Z_1/Z_0$	$Z_2/Z_0$	$Z_3/Z_0$	$Z_4/Z_0$		
1.0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000		
1.5	1.0892	1.1742	1.2775	1.3772	1.2247	1.2247	1.2247	1.2247		
2.0	1.1201	1.2979	1.5409	1.7855	1.2727	1.3634	1.4669	1.5715		
3.0	1.1586	1.4876	2.0167	2.5893	1.4879	1.5819	1.8965	2.0163		
4.0	1.1906	1.6414	2.4369	3.3597	1.3692	1.7490	2.2870	2.9214		
6.0	1.2290	1.8773	3.1961	4.8820	1.4415	2.0231	2.9657	4.1623		
8.0	1.2583	2.0657	3.8728	6.3578	1.4914	2.2428	3.5670	5.3641		
10.0	1.2832	2.2268	4.4907	7.7930	1.5163	2.4210	4.1305	6.5950		

# Exemplu

- Transformator de adaptare cu 3 sectiuni pentru a adapta o sarcina de  $30\Omega$  la o linie de  $100\Omega$  la frecventa  $f_o=3\text{GHz}$ ,  $\Gamma_m=0.1$ 
  - $N = 3 \quad Z_L = 30\Omega \quad Z_0 = 100\Omega$

$$\Gamma(\theta) = 2e^{-j3\theta} [\Gamma_0 \cos 3\theta + \Gamma_1 \cos \theta] = Ae^{-j3\theta} T_3(\sec \theta_m \cos \theta)$$

$$|A| = \Gamma_m = 0.1 \quad A = \frac{Z_L - Z_0}{Z_L + Z_0} \cdot \frac{1}{T_N(\sec \theta_m)} \quad Z_L < Z_0 \rightarrow A < 0 \quad A = -0.1$$

$$\sec \theta_m = \cosh \left[ \frac{1}{N} \cdot \cosh^{-1} \left( \left| \frac{\ln Z_L/Z_0}{2\Gamma_m} \right| \right) \right] = \cosh \left[ \frac{1}{3} \cdot \cosh^{-1} \left( \left| \frac{\ln(30/100)}{2 \cdot 0.1} \right| \right) \right] = 1.362$$

$$\theta_m = \arccos \left( \frac{1}{\sec \theta_m} \right) = 0.746 \text{ rad} = 42.76^\circ$$

# Exemplu

$$2[\Gamma_0 \cos 3\theta + \Gamma_1 \cos \theta] = A \sec^3 \theta_m (\cos 3\theta + 3 \cos \theta) - 3A \sec \theta_m \cos \theta$$

$$\cos 3\theta \quad 2\Gamma_0 = A \sec^3 \theta_m \quad \Gamma_0 = -0.1263$$

$$\cos \theta \quad 2\Gamma_1 = 3A(\sec^3 \theta_m - \sec \theta_m) \quad \Gamma_1 = -0.1747$$

simetrie:  $\Gamma_3 = \Gamma_0; \quad \Gamma_2 = \Gamma_1$

# Exemplu

$$n = 0$$

$$\ln Z_1 = \ln Z_0 + 2 \cdot \Gamma_0 = \ln 100 - 2 \cdot 0.1263 = 4.353 \quad \Gamma_0 = -0.1263$$

$$Z_1 = 77.68\Omega \quad \Gamma_1 = -0.1747$$

$$n = 1$$

$$\ln Z_2 = \ln Z_1 + 2 \cdot \Gamma_1 = \ln 77.68 - 2 \cdot 0.1747 = 4.003$$

$$Z_2 = 54.77\Omega$$

$$n = 2$$

$$\ln Z_3 = \ln Z_2 + 2 \cdot \Gamma_2 = \ln 54.77 - 2 \cdot 0.1747 = 3.654$$

$$Z_3 = 38.62\Omega$$

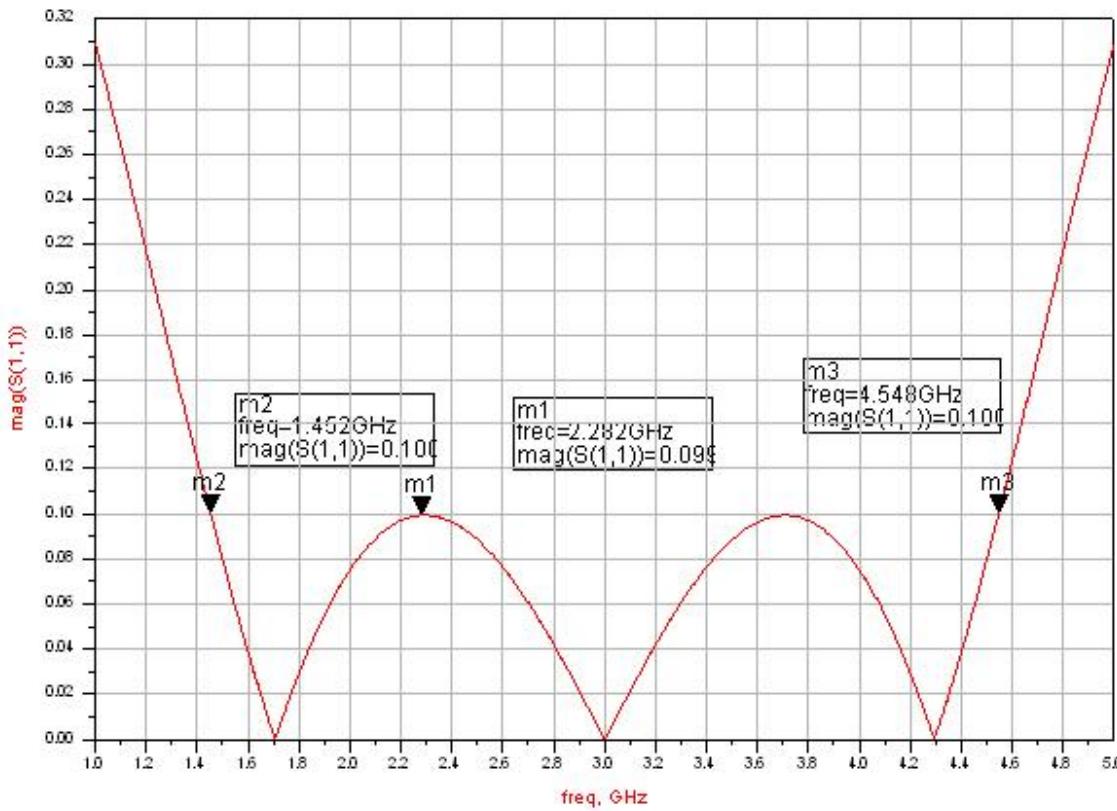
# Exemplu

$$\frac{\Delta f}{f_0} = \frac{2(f_0 - f_m)}{f_0} = 2 - \frac{4\theta_m}{\pi} = 2 - \frac{4 \cdot 42.76^\circ}{180^\circ} = 1.045$$

$$\Delta f = 3.15 GHz$$

# Simulare

## ■ Similar Lab. 1

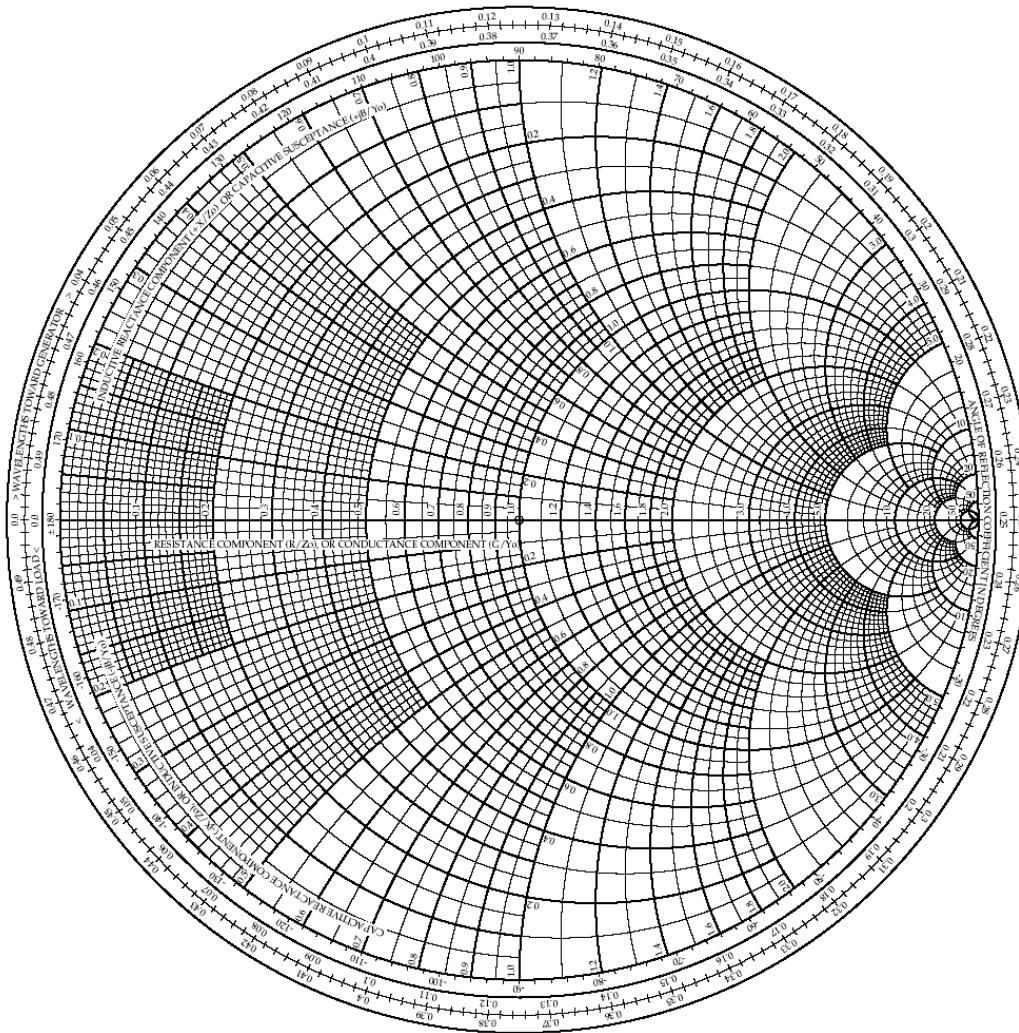


$$\Delta f = 3.096 \text{ GHz}$$

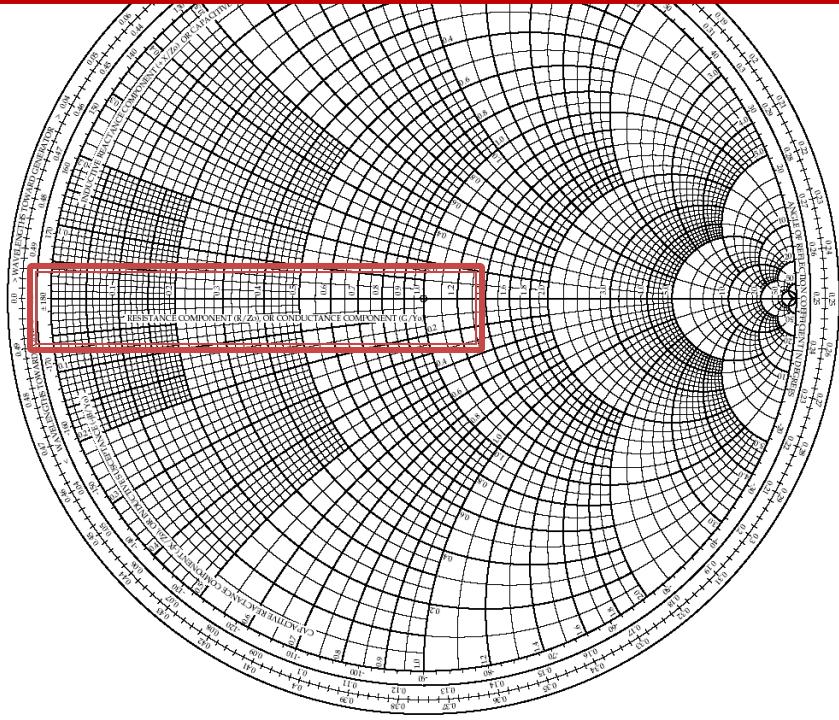
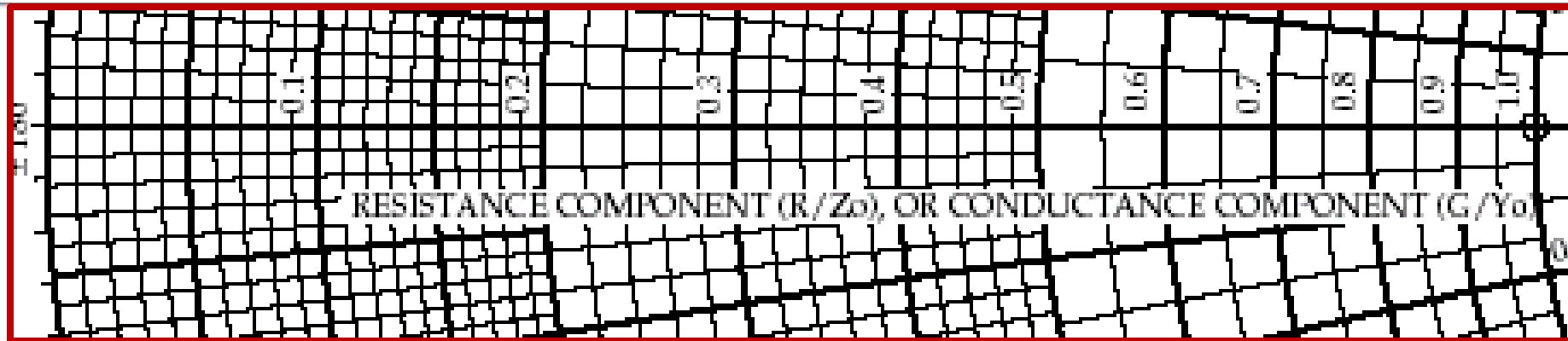
$$|\Gamma(3 \text{ GHz})| = 4.17 \cdot 10^{-5}$$

$$|\Gamma(2.282 \text{ GHz})| = 0.09925$$

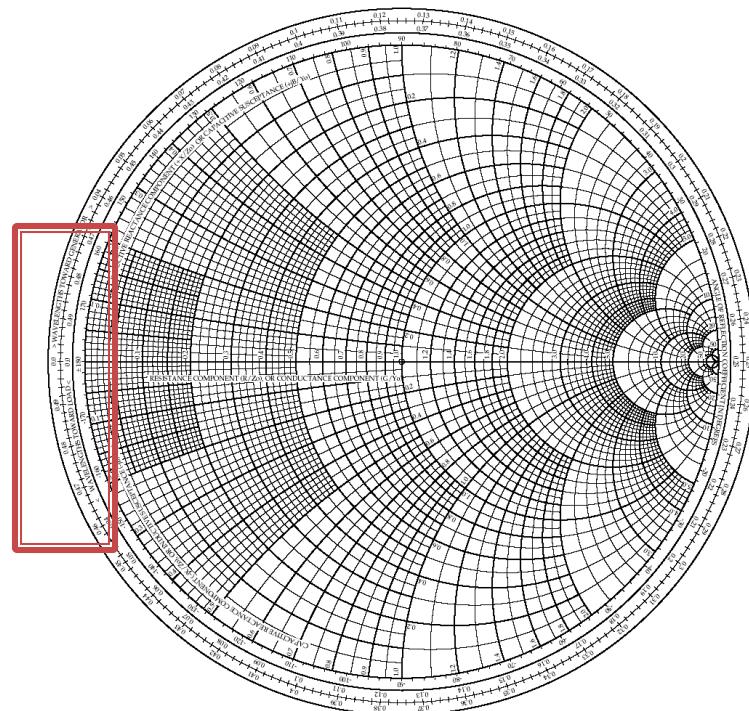
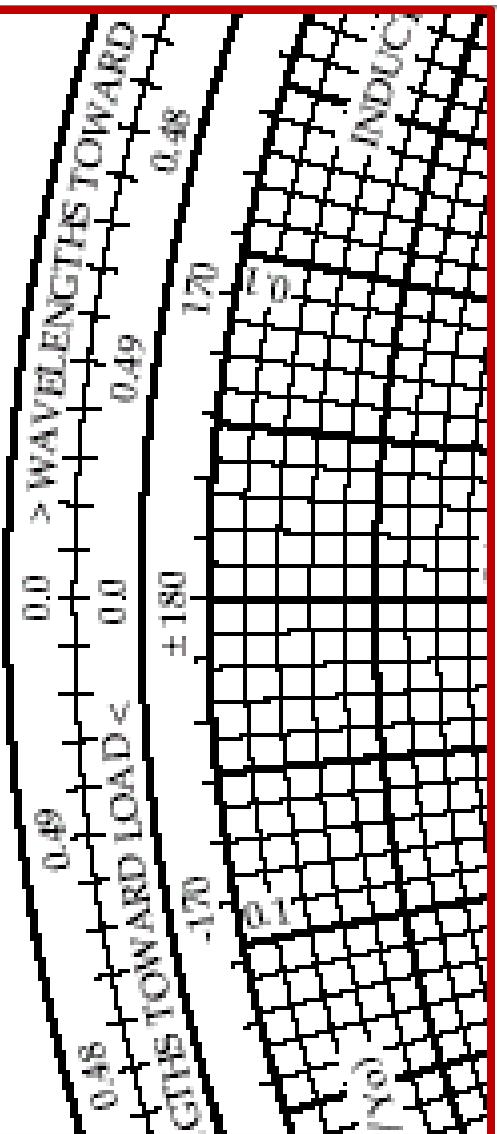
# Diagrama Smith



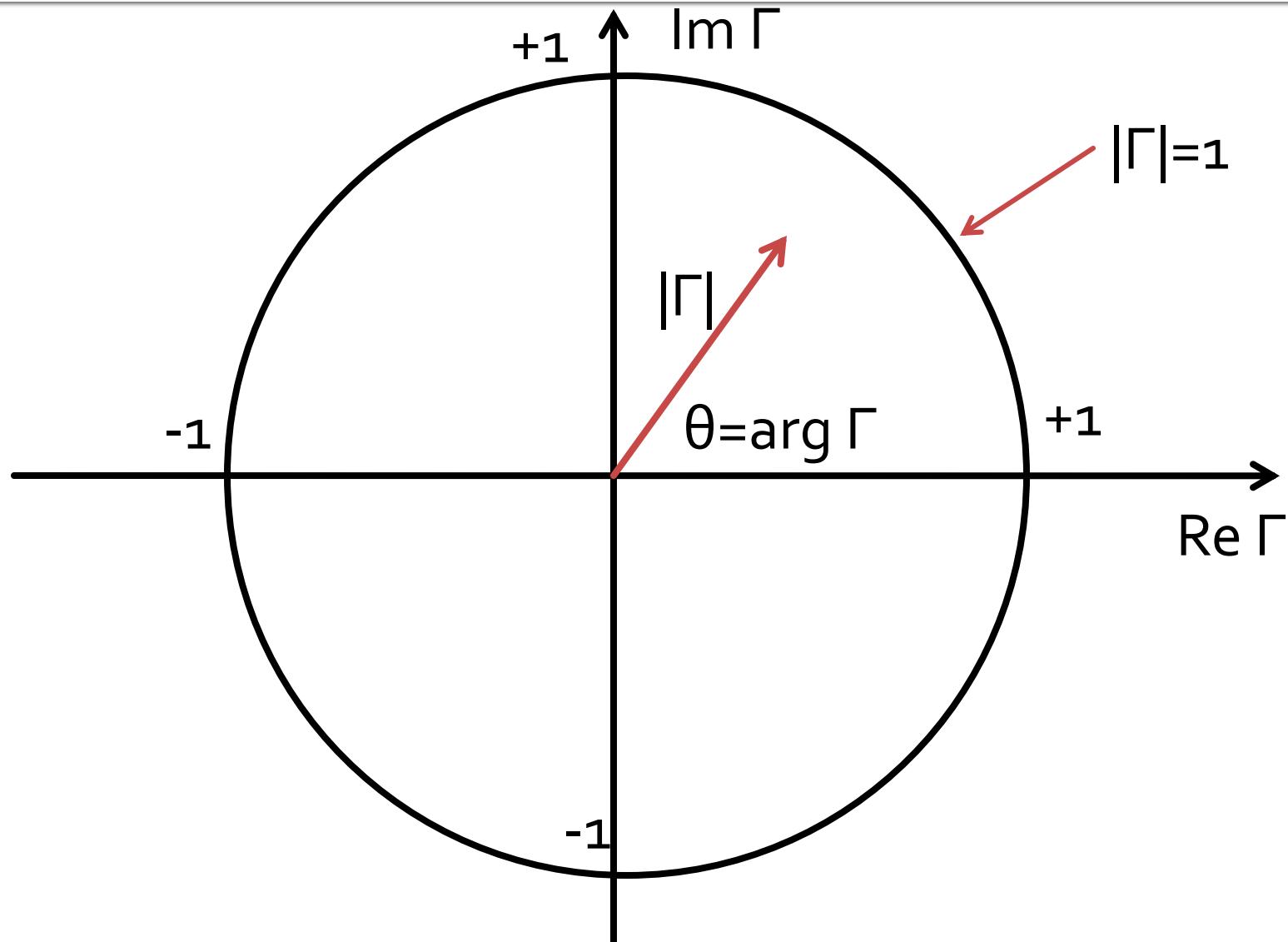
# Diagrama Smith



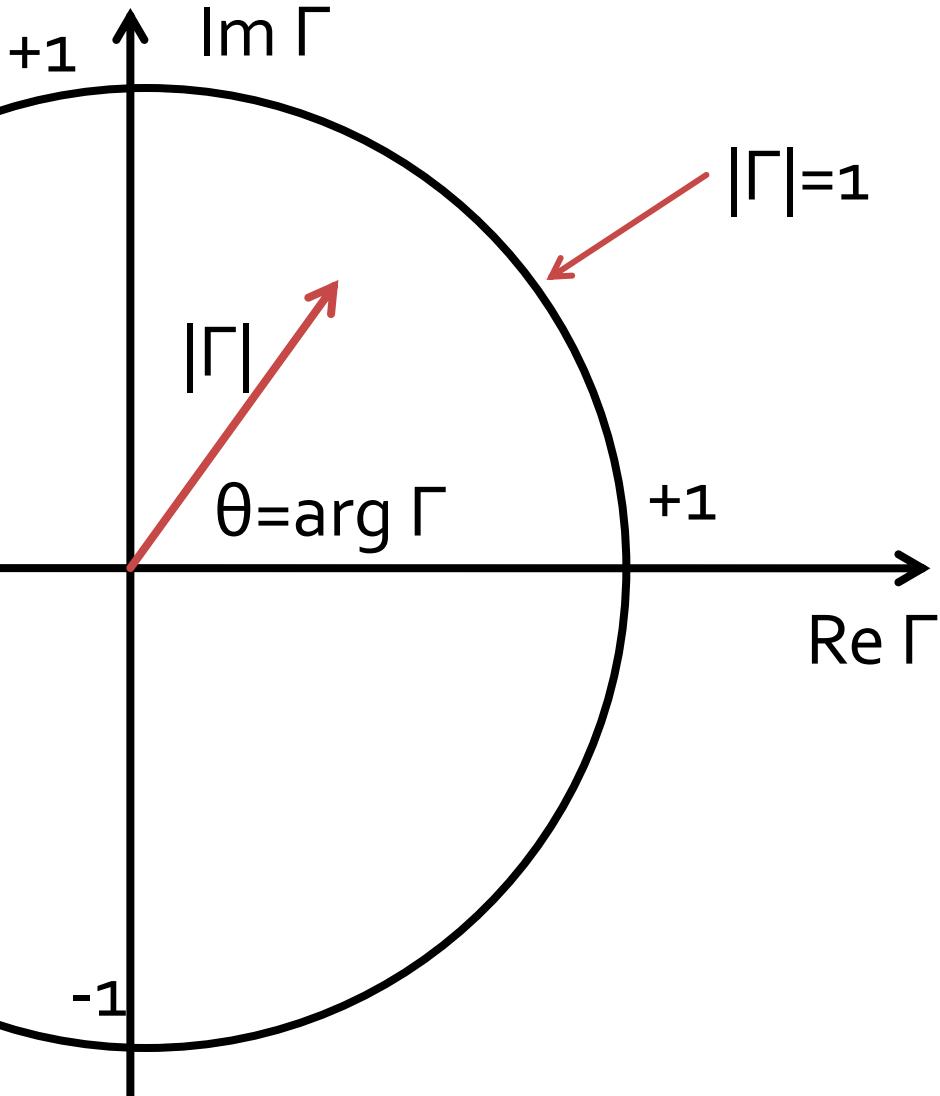
# Diagrama Smith



# Diagrama Smith



# Diagramma Smith



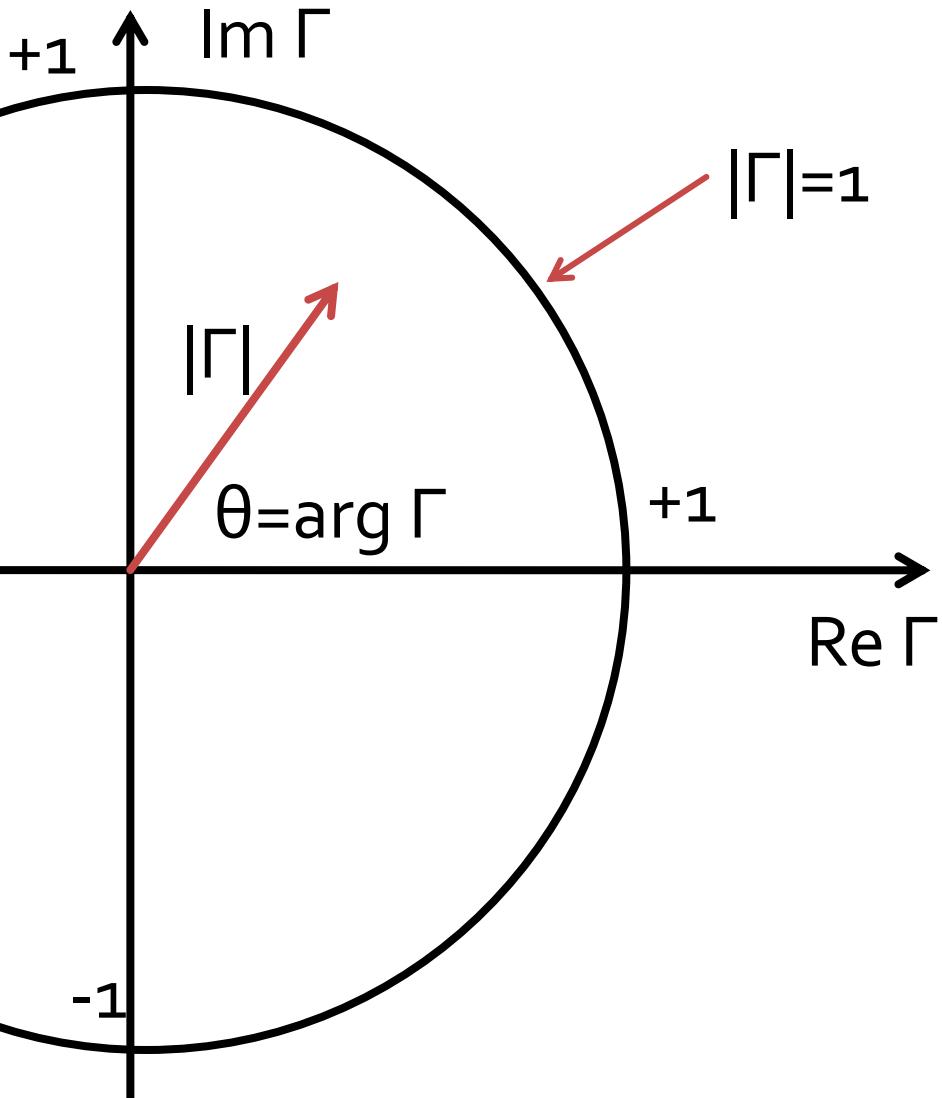
$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{z_L - 1}{z_L + 1} = |\Gamma| \cdot e^{j\theta}$$

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

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

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

# Diagramma Smith



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

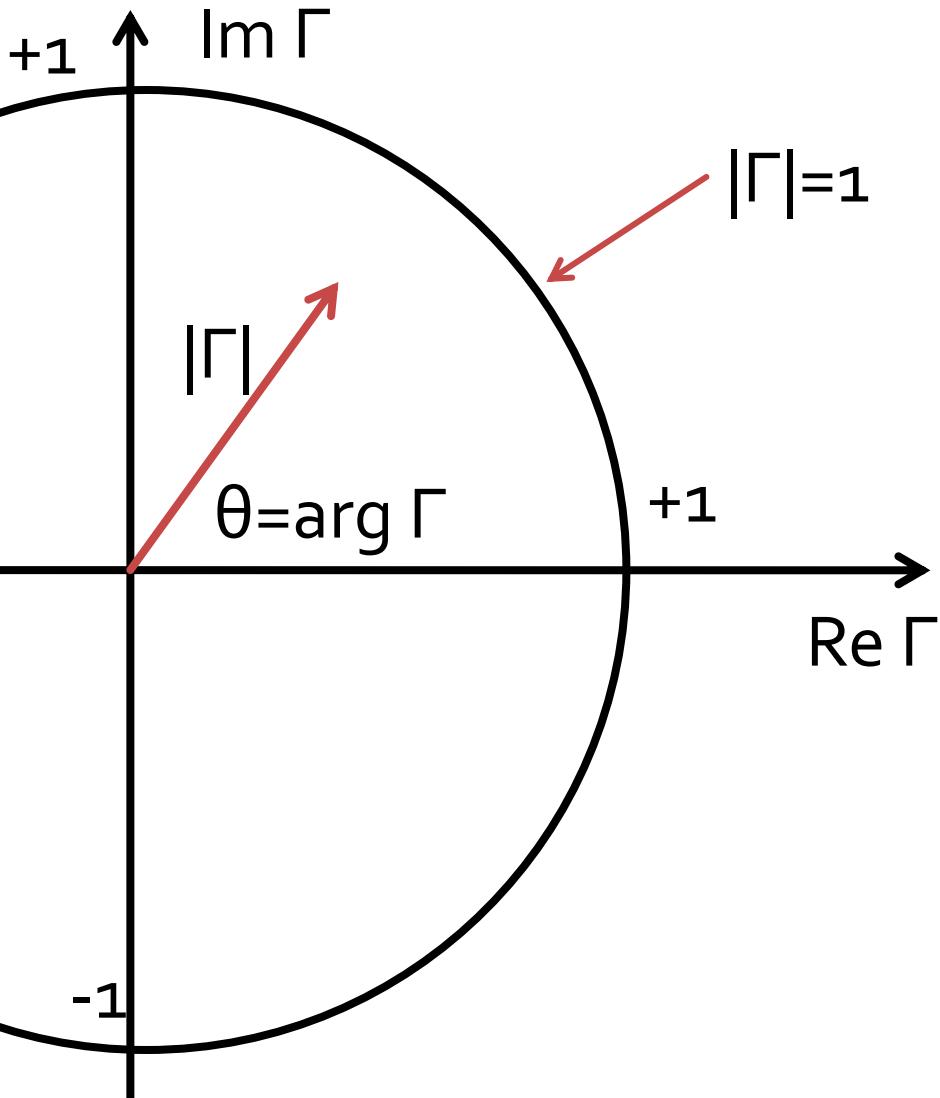
$$x_L = \frac{2 \cdot \Gamma_i}{(1 - \Gamma_r)^2 + \Gamma_i^2}$$

■ 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



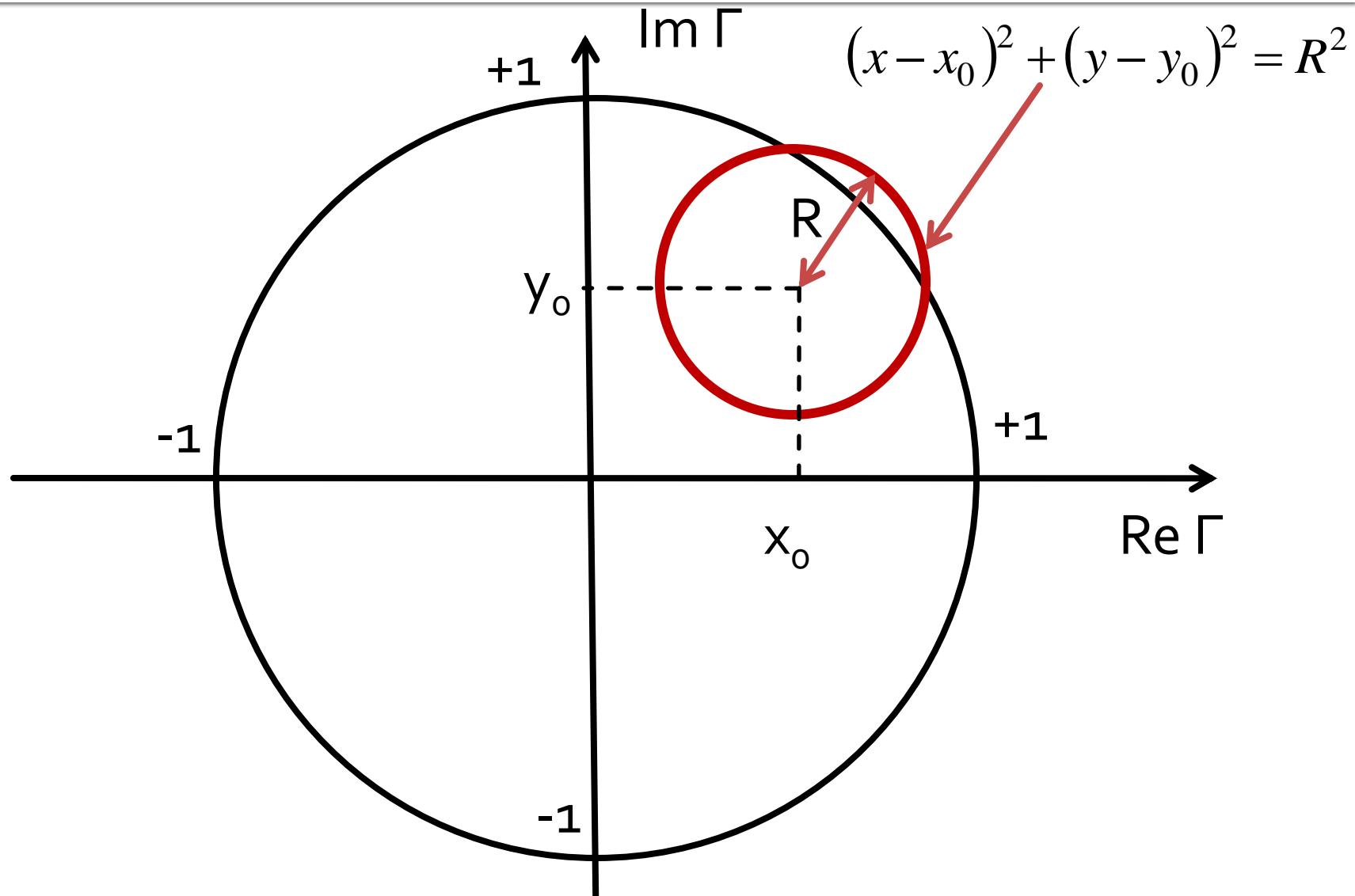
$$\left( \Gamma_r - \frac{r_L}{1+r_L} \right)^2 + \Gamma_i^2 = \left( \frac{1}{1+r_L} \right)^2$$

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

- Cercuri in planul complex

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

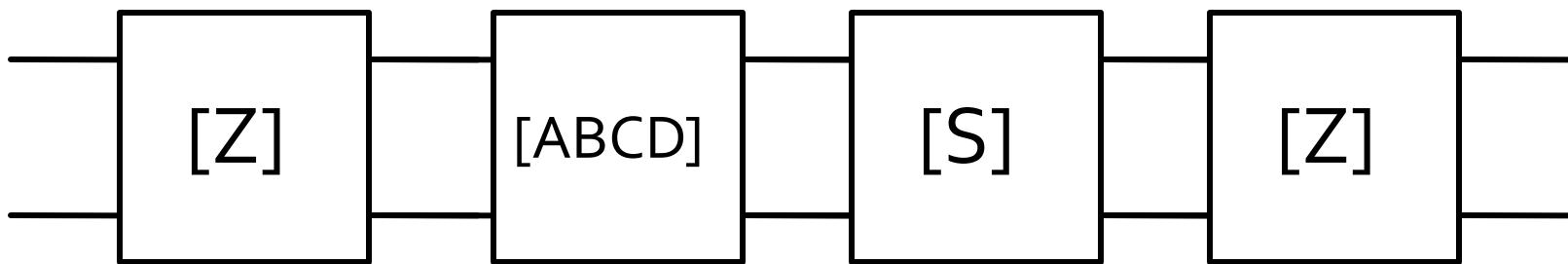
# Diagrama Smith



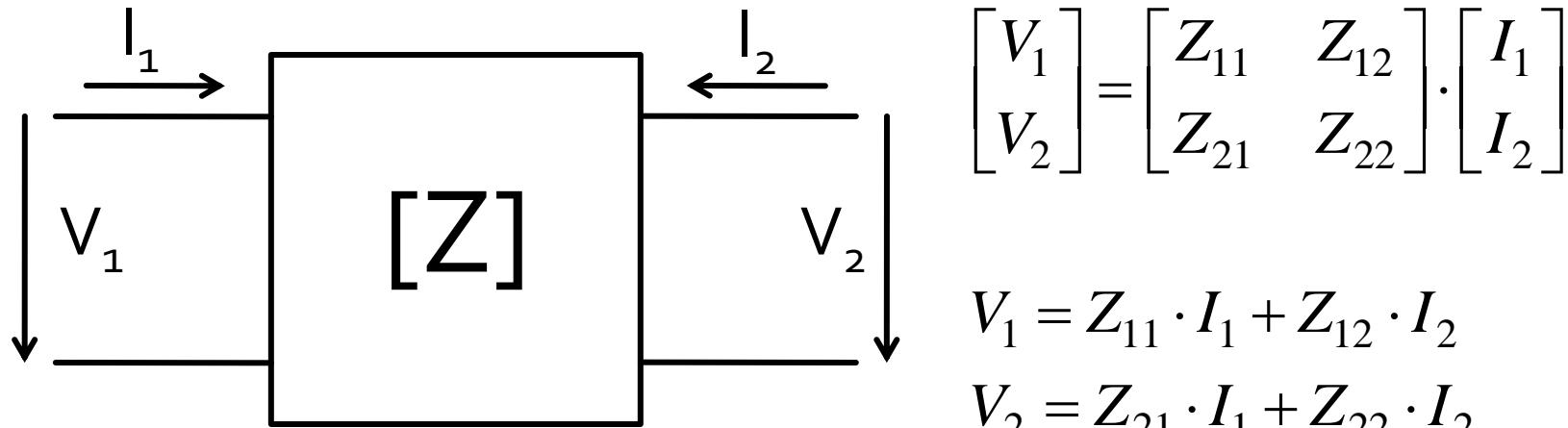
**Analiza la nivel de rețea a  
circuitelor de microunde**

# Analiza la nivel de bloc

- are ca scop separarea unui circuit complex în blocuri individuale
- acestea se analizează separat (decuplate de restul circuitului) și se caracterizează doar prin intermediul porturilor (**cutie neagră**)
- analiza la nivel de rețea permite cuplarea rezultatelor individuale și obținerea unui rezultat total pentru circuit



# Matricea impedanta



$$V_1 = Z_{11} \cdot I_1 \Big|_{I_2=0} \quad Z_{11} = \frac{V_1}{I_1} \Big|_{I_2=0}$$

- $Z_{11}$  – impedanta de intrare cu iesirea in gol

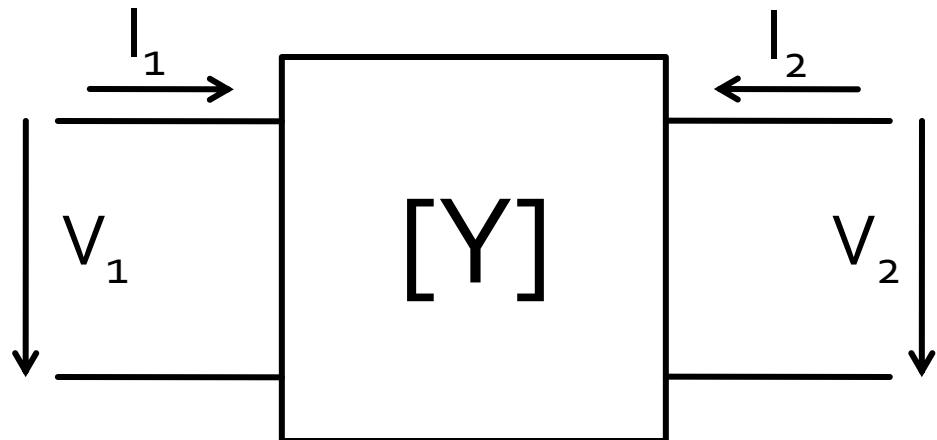
$$Z_{11} = \frac{V_1}{I_1} \Big|_{I_2=0}$$

$$Z_{12} = \frac{V_1}{I_2} \Big|_{I_1=0}$$

$$Z_{21} = \frac{V_2}{I_1} \Big|_{I_2=0}$$

$$Z_{22} = \frac{V_2}{I_2} \Big|_{I_1=0}$$

# Matricea admitanta



$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} \cdot \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

$$I_1 = Y_{11} \cdot V_1 + Y_{12} \cdot V_2$$

$$I_2 = Y_{21} \cdot V_1 + Y_{22} \cdot V_2$$

$$I_1 = Y_{11} \cdot V_1 \Big|_{V_2=0} \quad Y_{11} = \frac{I_1}{V_1} \Big|_{V_2=0}$$

- **Y<sub>11</sub>** – admitanta de intrare cu ieșirea în scurtcircuit

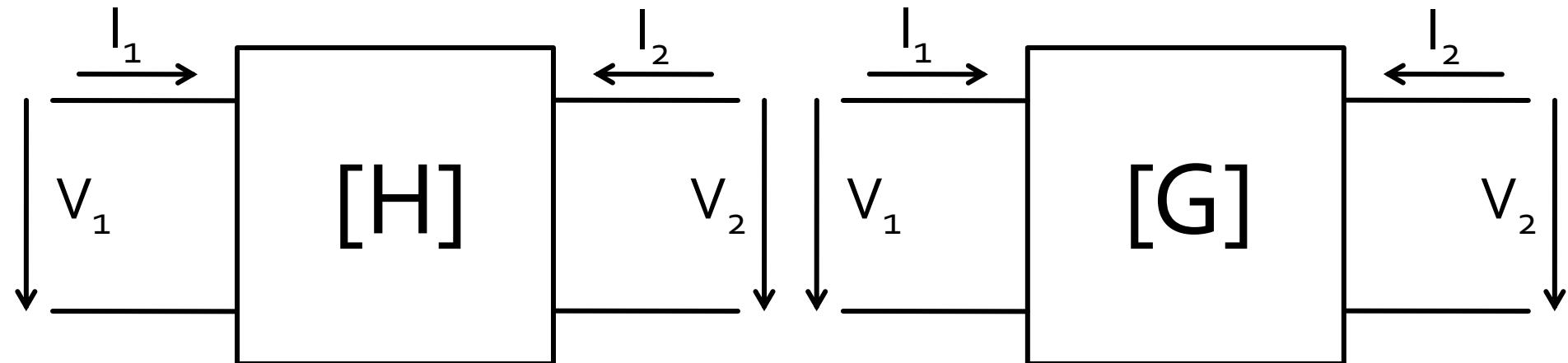
$$Y_{11} = \frac{I_1}{V_1} \Big|_{V_2=0}$$

$$Y_{12} = \frac{I_1}{V_2} \Big|_{V_1=0}$$

$$Y_{21} = \frac{I_2}{V_1} \Big|_{V_2=0}$$

$$Y_{22} = \frac{I_2}{V_2} \Big|_{V_1=0}$$

# Matrici hibride



$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{bmatrix} \cdot \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$

$$\begin{bmatrix} I_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} G_{11} & G_{12} \\ G_{21} & G_{22} \end{bmatrix} \cdot \begin{bmatrix} V_1 \\ I_2 \end{bmatrix}$$

$$H_{21} = \frac{I_2}{I_1} \Bigg|_{V_2=0 \text{ sau } H_{22} \rightarrow \infty}$$

- $h_{21E}$  utilizat la TB, conexiune Emitor comun ( $\beta, h_{22}$  este foarte mare)

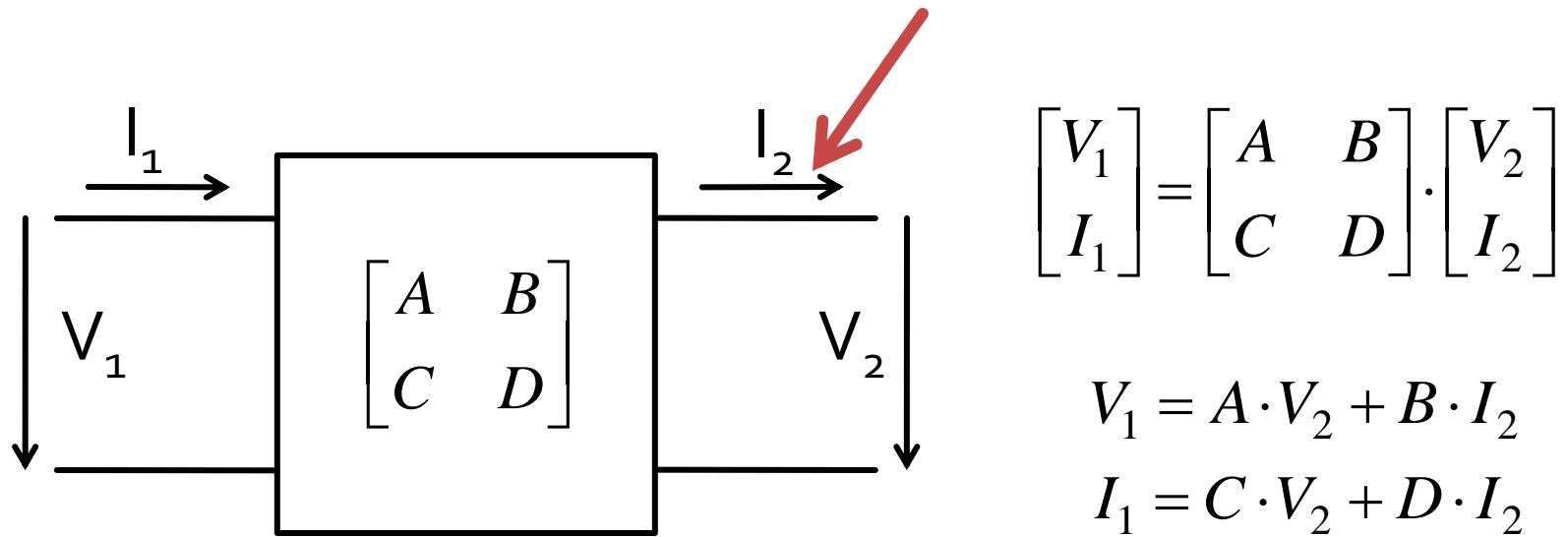
# Analiza la nivel de bloc

- fiecare matrice este potrivita pentru un anumit mod de excitare a porturilor ( $V, I$ )
  - matricea  $H$  in conexiune emitor comun pentru TB:  $I_B, V_{CE}$
  - matricile ofera marimile asociate in functie de marimile de "atac"
- traditional parametrii  $Z, Y, G, H$  sunt notati cu litera mica ( $z, y, g, h$ )
- In microunde se prefera notatia cu litera mare pentru a nu exista confuzie cu parametrii raportati la o valoare de referinta

$$z = \frac{Z}{Z_0} \quad y = \frac{Y}{Y_0} = \frac{1/Z}{1/Z_0} = \frac{Z_0}{Z} = Z_0 \cdot Y$$

$$z_{11} = \frac{Z_{11}}{Z_0} \quad y_{11} = \frac{Y_{11}}{Y_0} = Z_0 \cdot Y_{11}$$

# Matricea ABCD – de transmisie

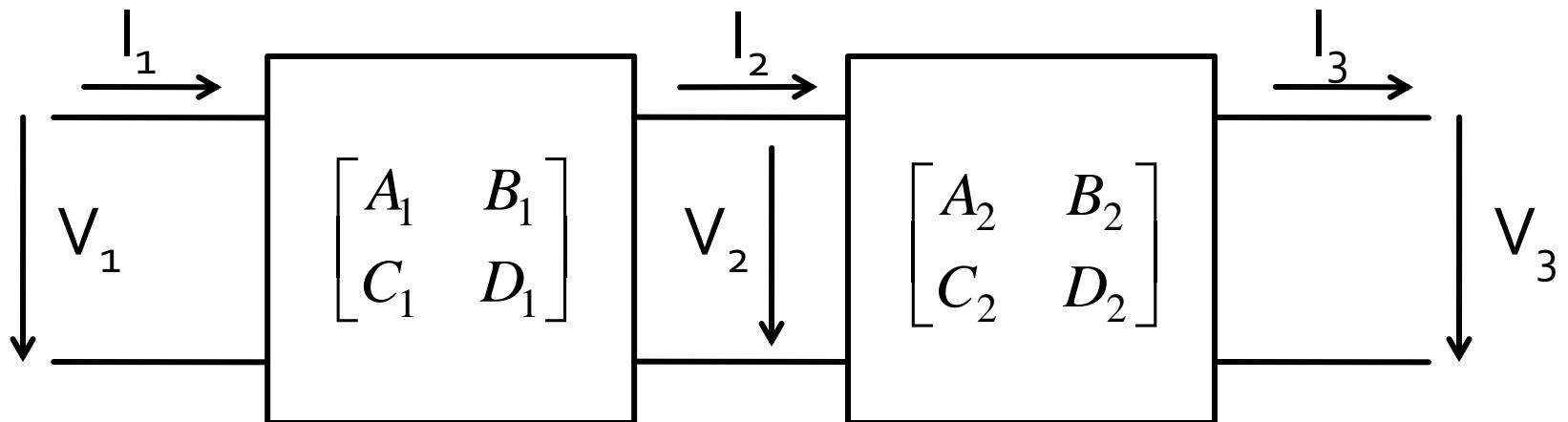


$$V_1 = A \cdot V_2 \Big|_{I_2=0} \quad A = \frac{V_1}{V_2} \Big|_{I_2=0}$$

$$A = \frac{V_1}{V_2} \Big|_{I_2=0} \quad B = \frac{V_1}{I_2} \Big|_{V_2=0} \quad C = \frac{I_1}{V_2} \Big|_{I_2=0} \quad D = \frac{I_1}{I_2} \Big|_{V_2=0}$$

# Matricea ABCD – de transmisie

- introduce o legatura intre "intrare" si "iesire"
- permite inlatuirea usoara intre mai multe blocuri



$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \cdot \begin{bmatrix} V_2 \\ I_2 \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \cdot \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \cdot \begin{bmatrix} V_3 \\ I_3 \end{bmatrix}$$

# Contact

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- [rdamian@etti.tuiasi.ro](mailto:rdamian@etti.tuiasi.ro)