Curs 14

2023/2024

Dispozitive şi circuite de microunde pentru radiocomunicații

Disciplina 2023/2024

- 2C/1L (+1), **DCMR (CDM)**
- **Minim 7 prezente (curs+laborator)**
- Curs - **conf. Radu Damian**
  - Miercuri 08(**:15**)-17, ~~Online~~/**Video (istoric)**, P5
  - E – **50%** din nota
  - **probleme** + (2p prez. curs) + (3 teste) + (bonus activitate)
    - primul test L1: 04.10.2023 (t2 si t3 neanuntate la **curs**)
    - 3pz (C) ≈ +0.5p (**2p** max)
  - **toate materialele permise**

Disciplina 2023/2024

- 2C/1L, **DCMR (CDM)**
- Laborator – **conf. Radu Damian**
  - Miercuri/Joi/Vineri, par/impar, **II.13**
  - 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

Cuprins

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

Bibliografie

- http://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

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

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

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

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]

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

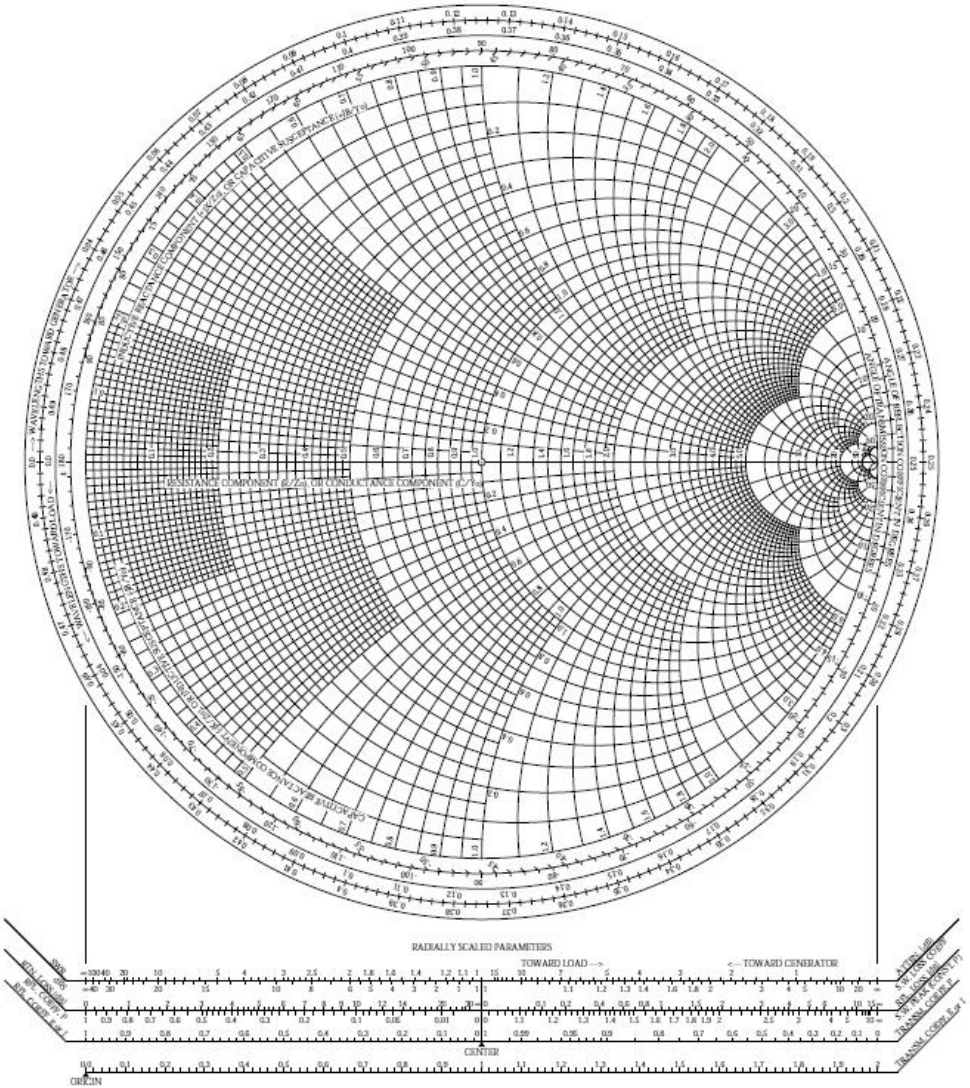


Diagrama Smith

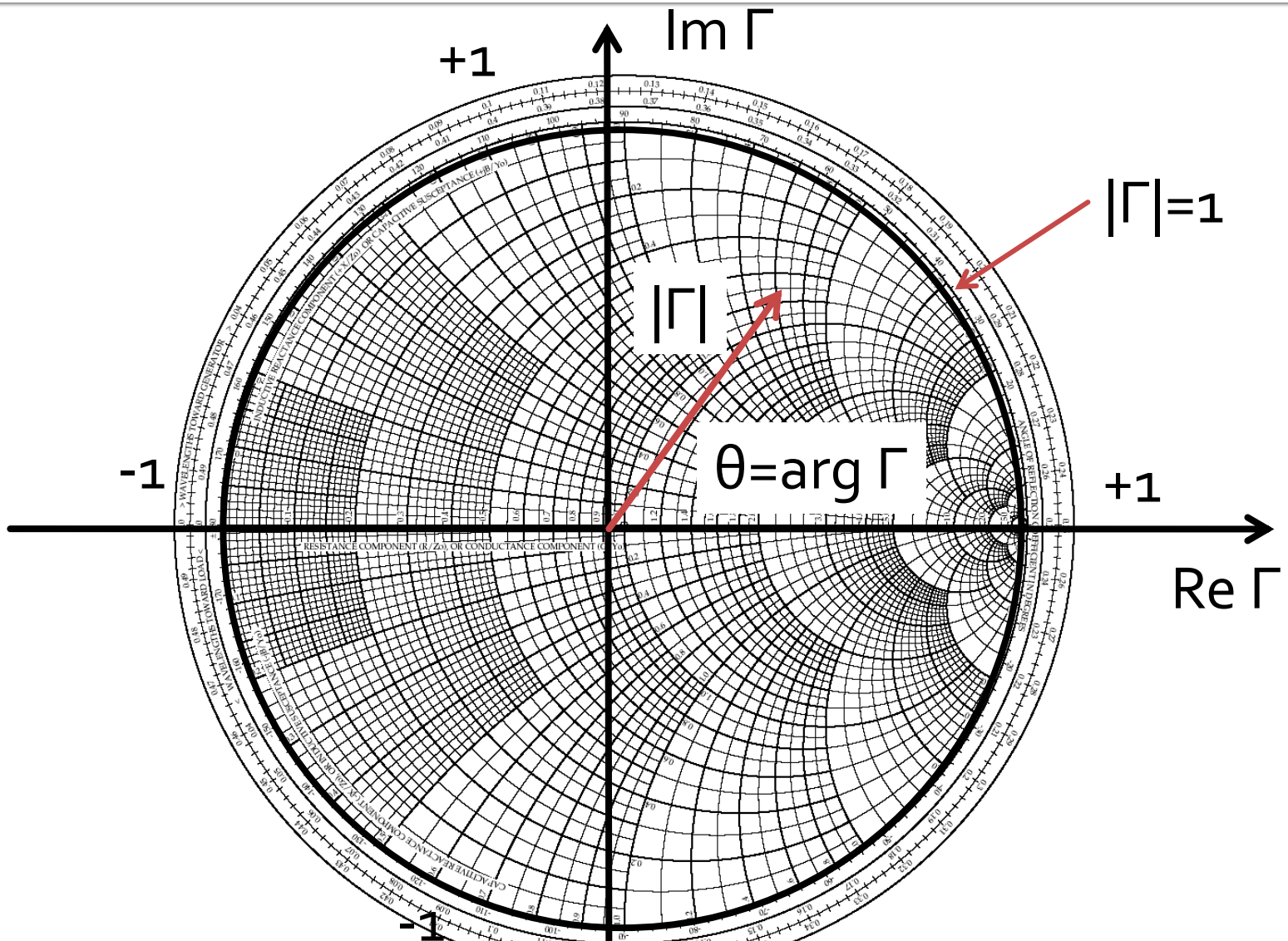
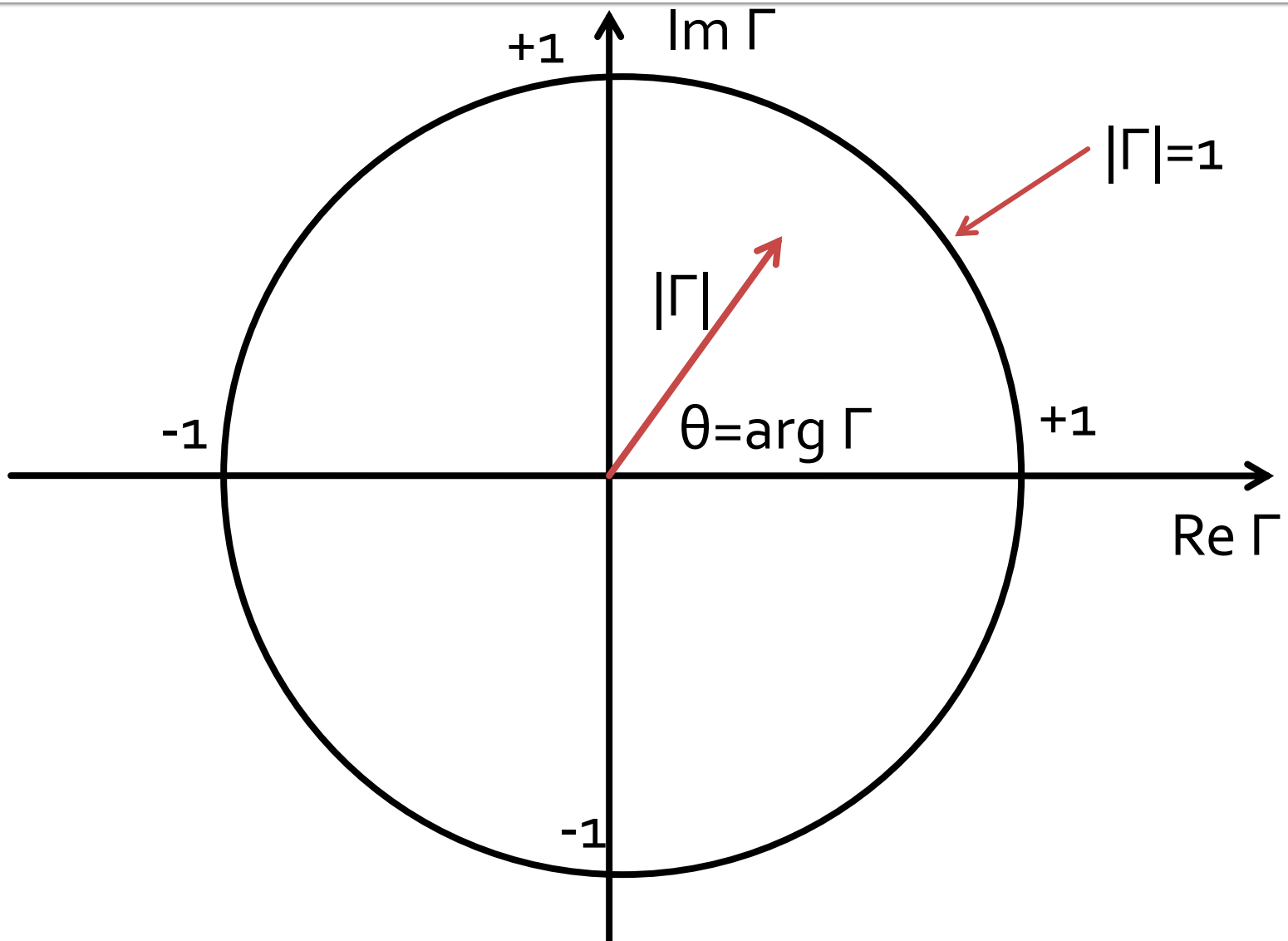


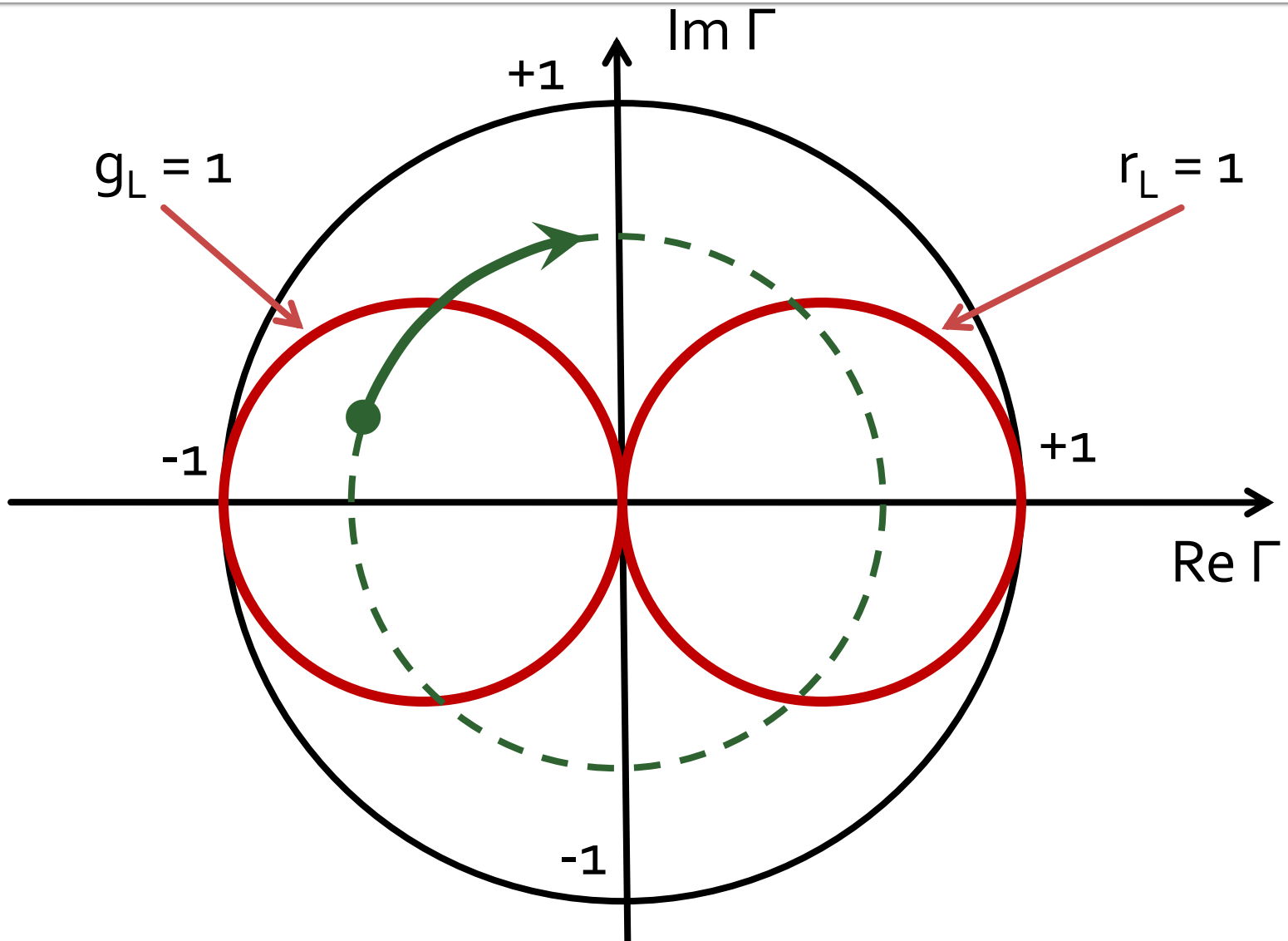
Diagrama Smith



Adaptarea cu sectiuni de linii (stub)

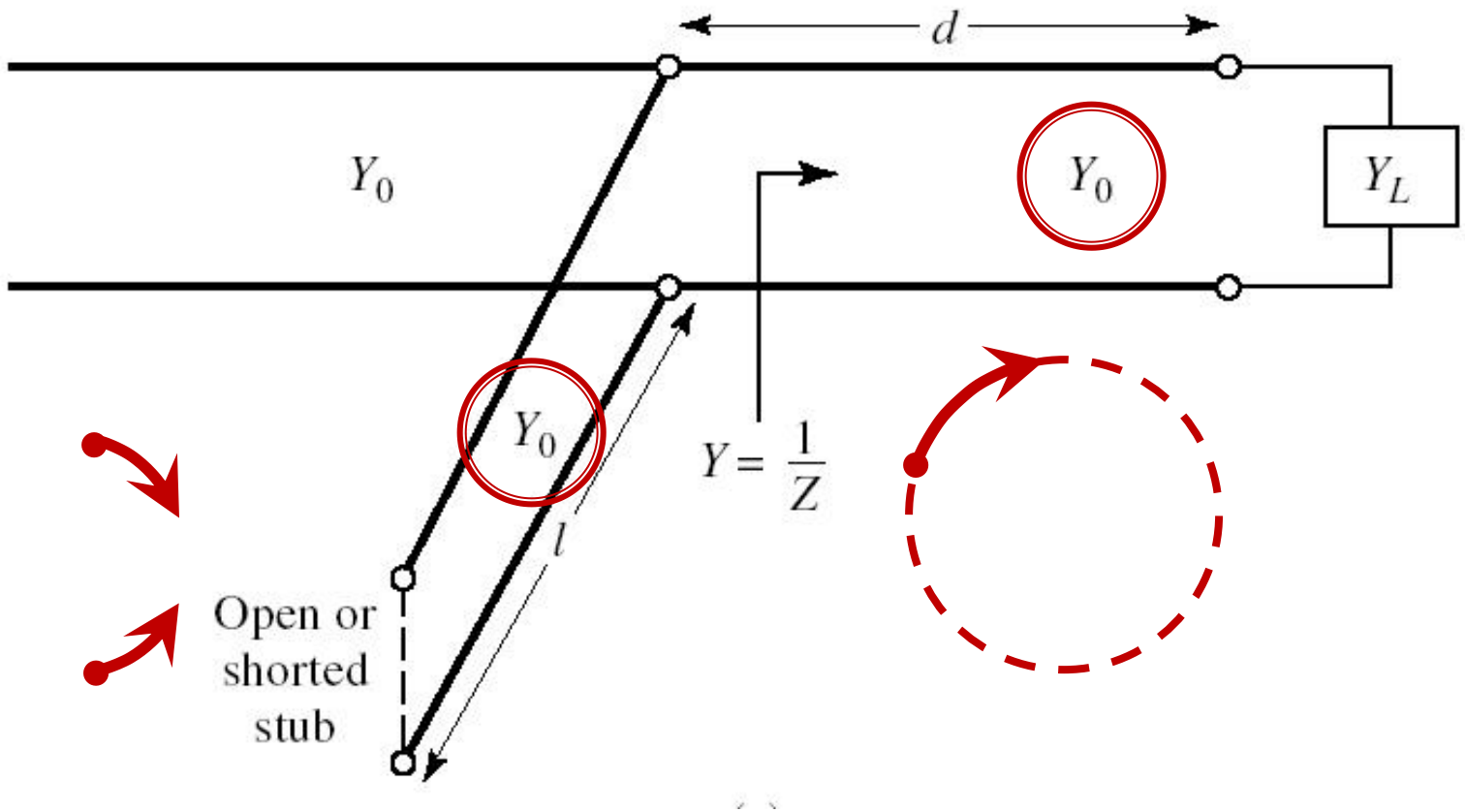
Adaptarea de impedanța

Diagrama Smith, r=1 si g=1



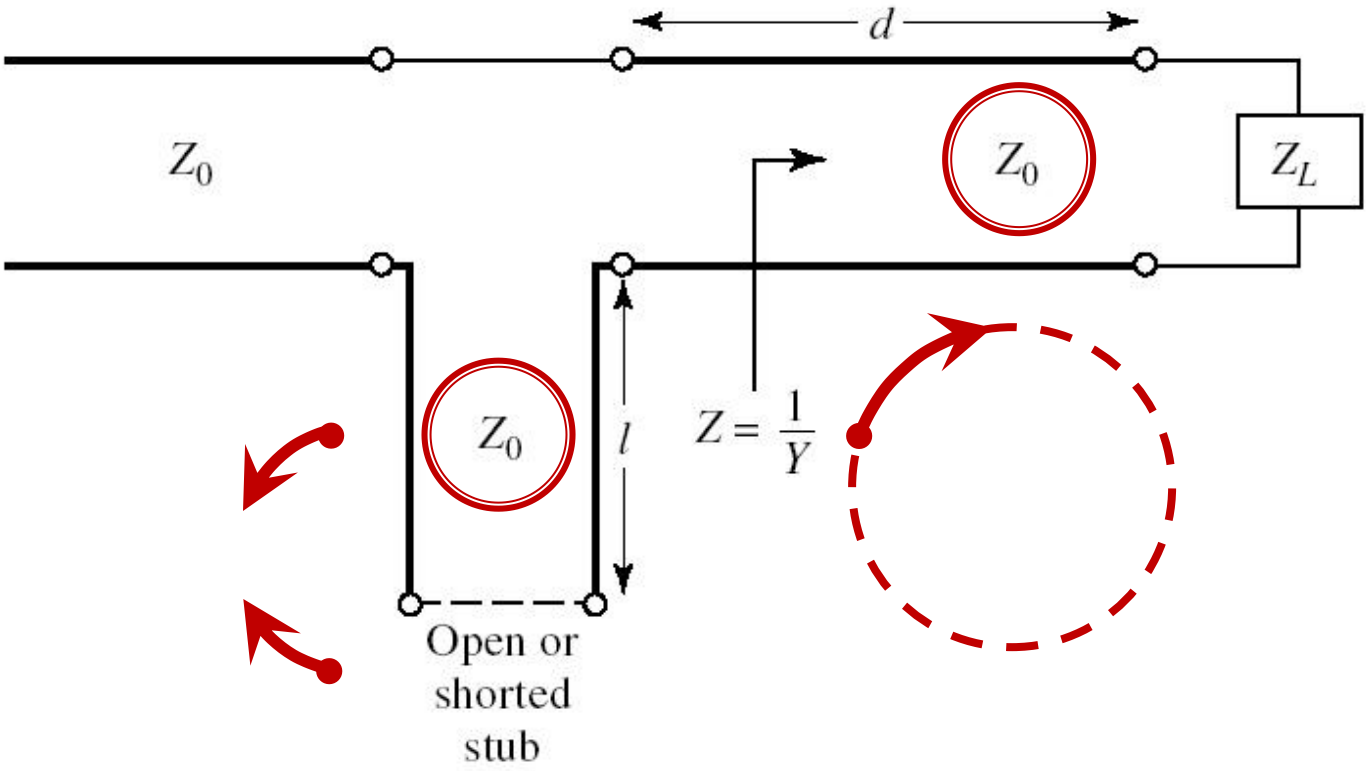
Single stub tuning

- Shunt Stub (sectiune de linie in paralel)



Single stub tuning

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

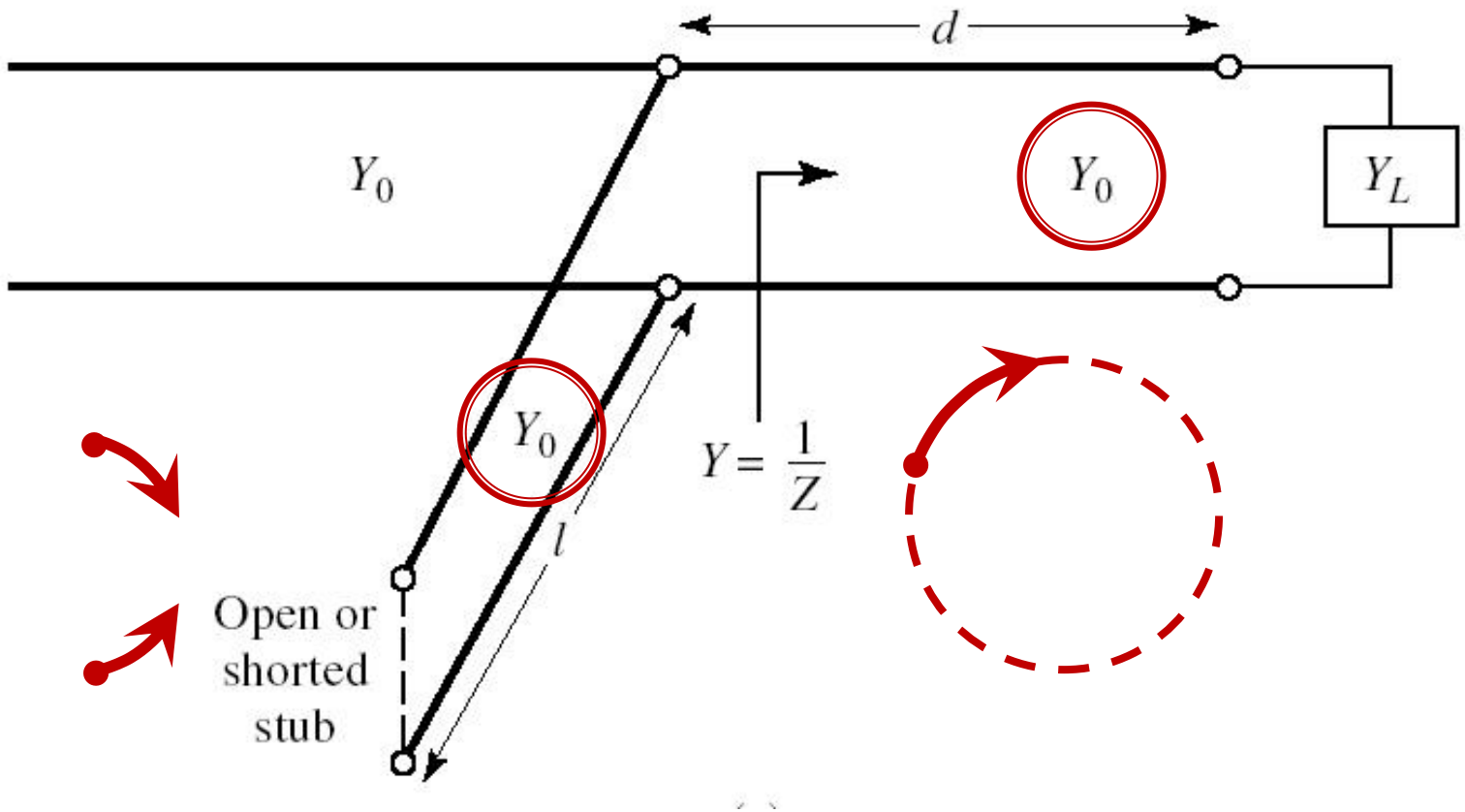


Solutii analitice

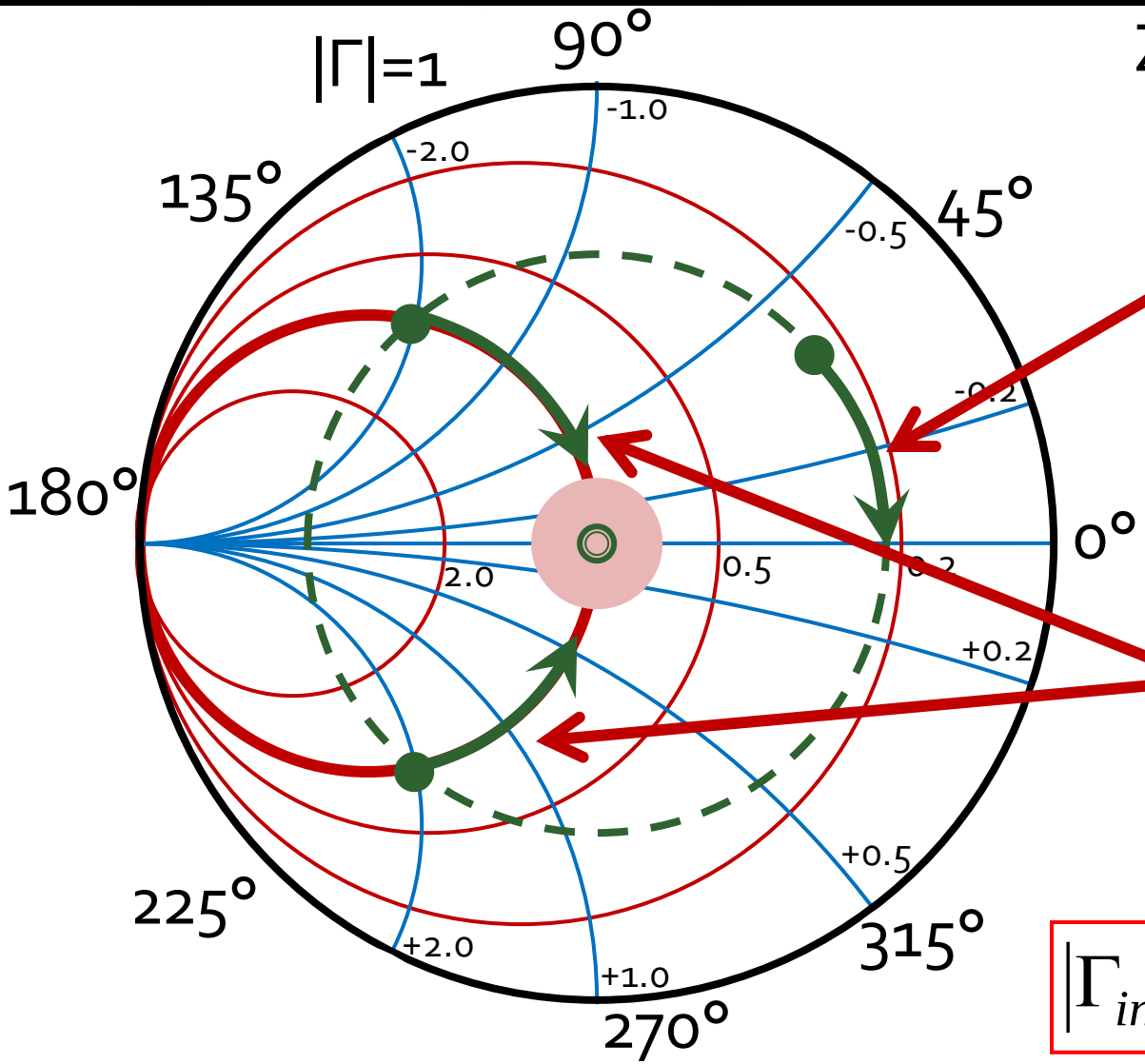
Examen / Proiect

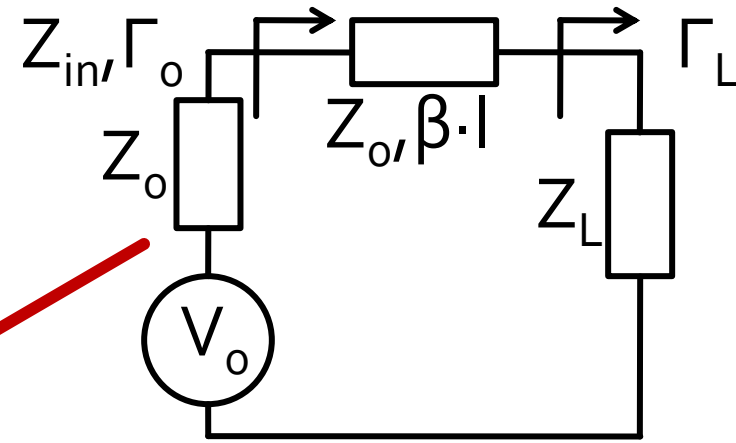
Caz 1, Shunt Stub

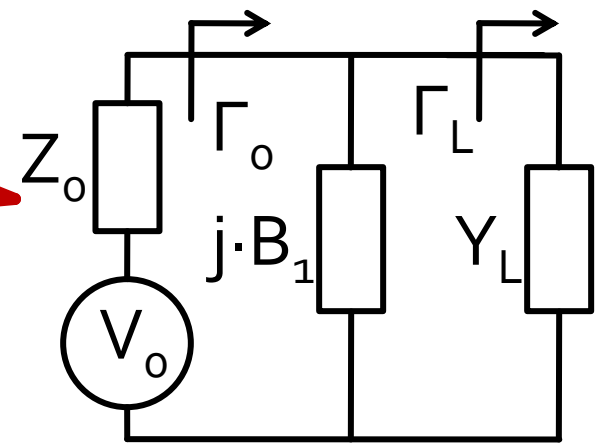
- Shunt Stub (sectiune de linie in paralel)



Adaptare, linie serie + susceptanta in paralel







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

$$\boxed{g_{in} = 1}$$

Calcul analitic (calcul efectiv)

$$\boxed{\cos(\varphi + 2\theta) = -|\Gamma_S|}$$

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

$$\Gamma_S = 0.593\angle 46.85°$$

$$|\Gamma_S| = 0.593; \quad \varphi = 46.85° \qquad \cos(\varphi + 2\theta) = -0.593 \Rightarrow \quad (\varphi + 2\theta) = \pm 126.35°$$

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

    $$(46.85° + 2\theta) = +126.35° \qquad \theta = +39.7° \qquad \operatorname{Im} y_S = \frac{-2 \cdot |\Gamma_S|}{\sqrt{1 - |\Gamma_S|^2}} = -1.472$$

    $$\theta_{sp} = \tan^{-1}(\operatorname{Im} y_S) = -55.8°\underline{(+180°)} \rightarrow \theta_{sp} = 124.2°$$

  - **solutia "cu -"**

    $$(46.85° + 2\theta) = -126.35° \qquad \theta = -86.6°\underline{(+180°)} \rightarrow \theta = 93.4°$$

    $$\operatorname{Im} y_S = \frac{+2 \cdot |\Gamma_S|}{\sqrt{1 - |\Gamma_S|^2}} = +1.472 \qquad \theta_{sp} = \tan^{-1}(\operatorname{Im} y_S) = 55.8°$$

Calcul analitic (calcul efectiv)

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

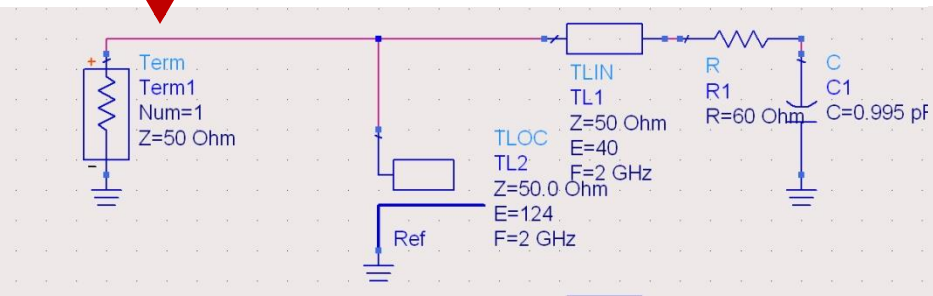
- Se alege **una** din cele doua solutii posibile
- **Semnul** (+/-) solutiei alese la **prima** ecuatie impune **semnul** solutiei utilizate la a **doua** ecuatie

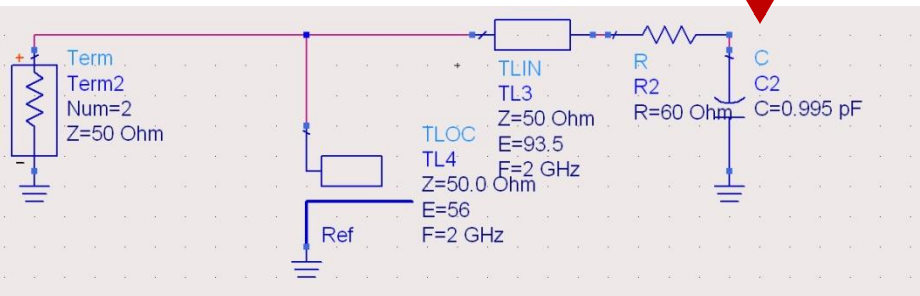
$$l_1=\frac{39.7^\circ}{360^\circ}\cdot\lambda=0.110\cdot\lambda$$

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

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

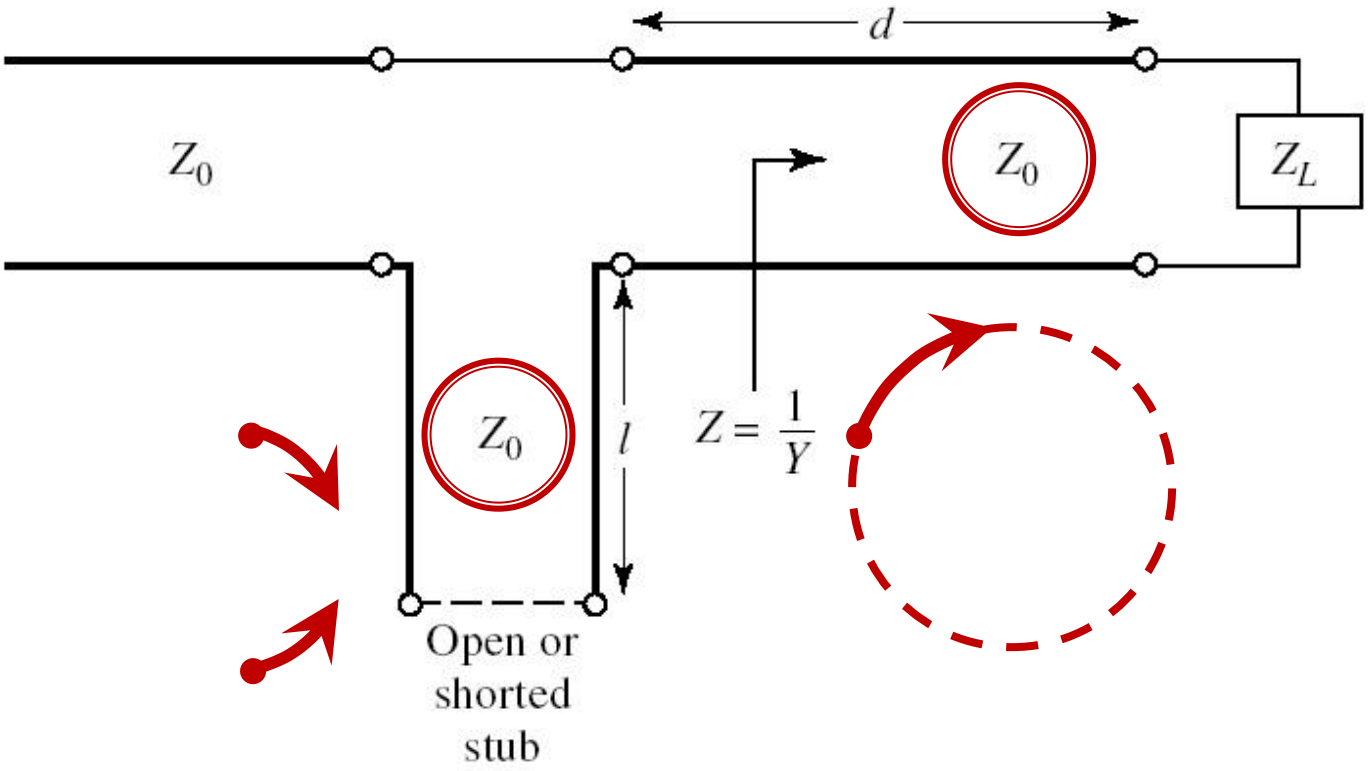
$$l_2=\frac{55.8^\circ}{360^\circ}\cdot\lambda=0.155\cdot\lambda$$



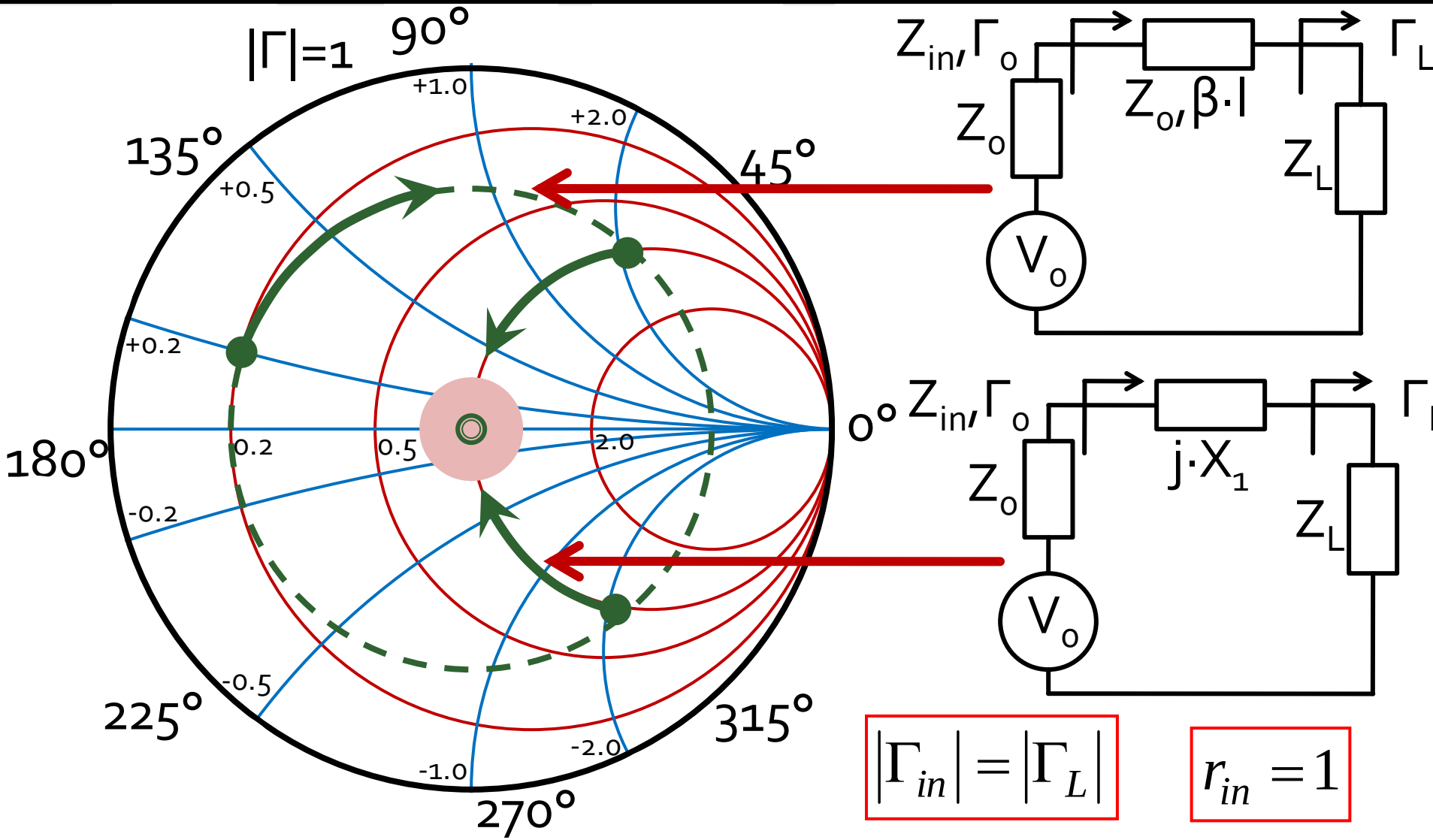


Caz 2, Series Stub

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



Adaptare, linie serie + reactanta in serie



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

$$\boxed{r_{in} = 1}$$

Calcul analitic (calcul efectiv)

$$\boxed{\cos(\varphi + 2\theta) = |\Gamma_S|}$$

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

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

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

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

$$(-29.92^\circ + 2\theta) = +56.28^\circ \qquad \theta = 43.1^\circ \qquad \operatorname{Im} z_S = \frac{+2 \cdot |\Gamma_S|}{\sqrt{1 - |\Gamma_S|^2}} = +1.335$$

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

  - **solutia "cu -"**

$$(-29.92^\circ + 2\theta) = -56.28^\circ \qquad \theta = -13.2^\circ \underline{(+180^\circ)} \rightarrow \theta = 166.8^\circ$$

$$\operatorname{Im} z_S = \frac{-2 \cdot |\Gamma_S|}{\sqrt{1 - |\Gamma_S|^2}} = -1.335 \qquad \theta_{ss} = -\cot^{-1}(\operatorname{Im} z_S) = 36.8^\circ$$

Calcul analitic (calcul efectiv)

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

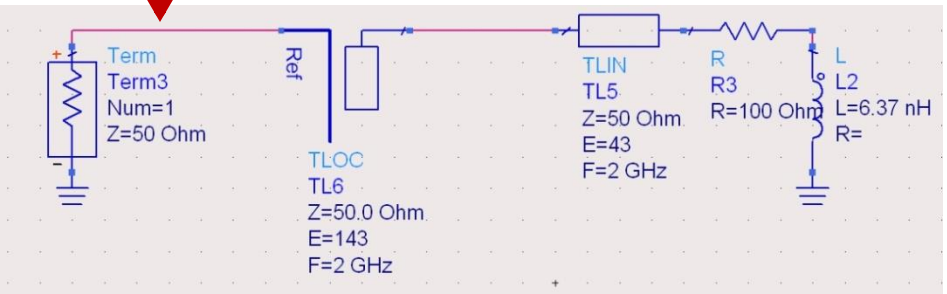
- Se alege **una** din cele doua solutii posibile
- **Semnul** (+/-) solutiei alese la **prima** ecuatie impune **semnul** solutiei utilizate la a **doua** ecuatie

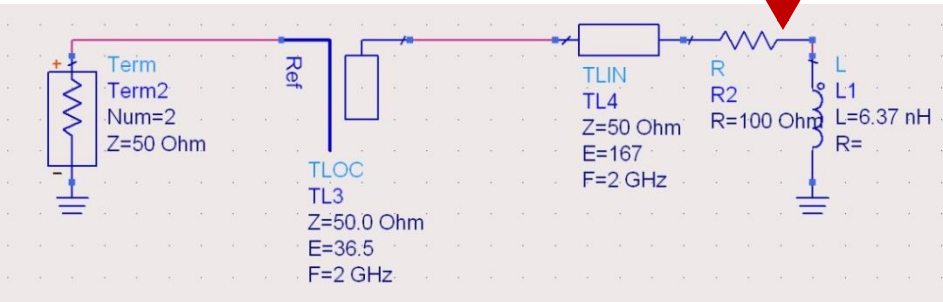
$$l_1=\frac{43.1^\circ}{360^\circ}\cdot\lambda=0.120\cdot\lambda$$

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

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

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





Stub, observatii

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

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

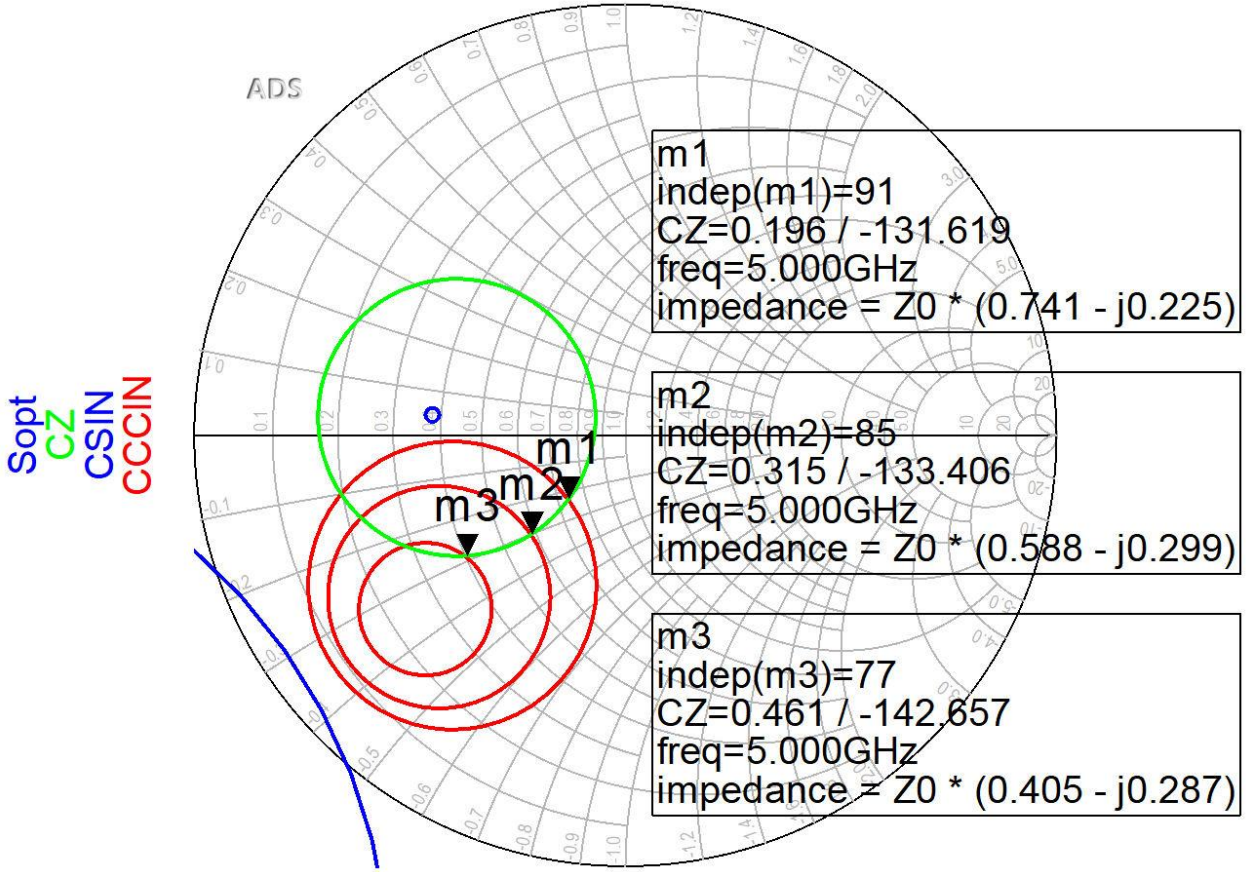
  - pentru linii de "lungime" / "lungime electrica" **negative** se adauga λ/2 / 180° pentru a avea valoare pozitiva (realizabila fizic)
- o adaugare sau scadere de **90°** (λ/4) transforma impedanta stub-ului:

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

  - pentru stub se poate adauga/scadea 90° (λ/4) simultan cu schimbare **gol** ⇔ **scurtcircuit**

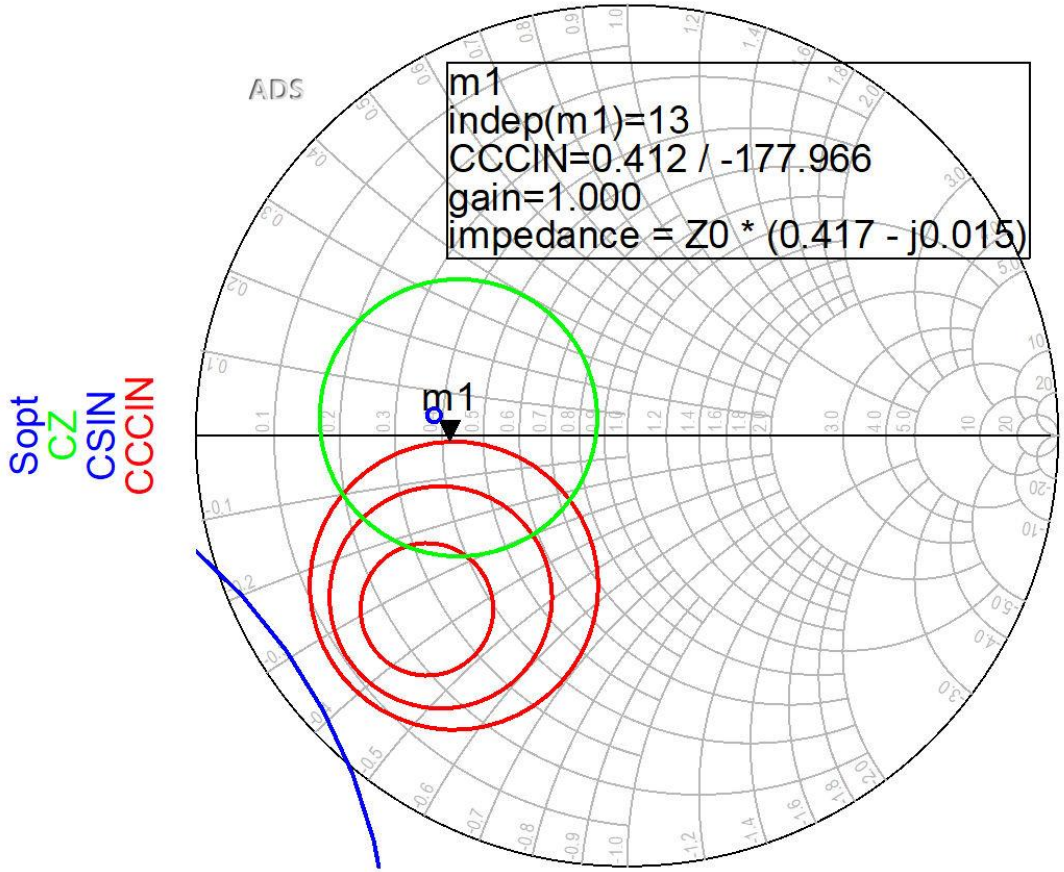
Amplificatoare de microunde

Adaptare la intrare



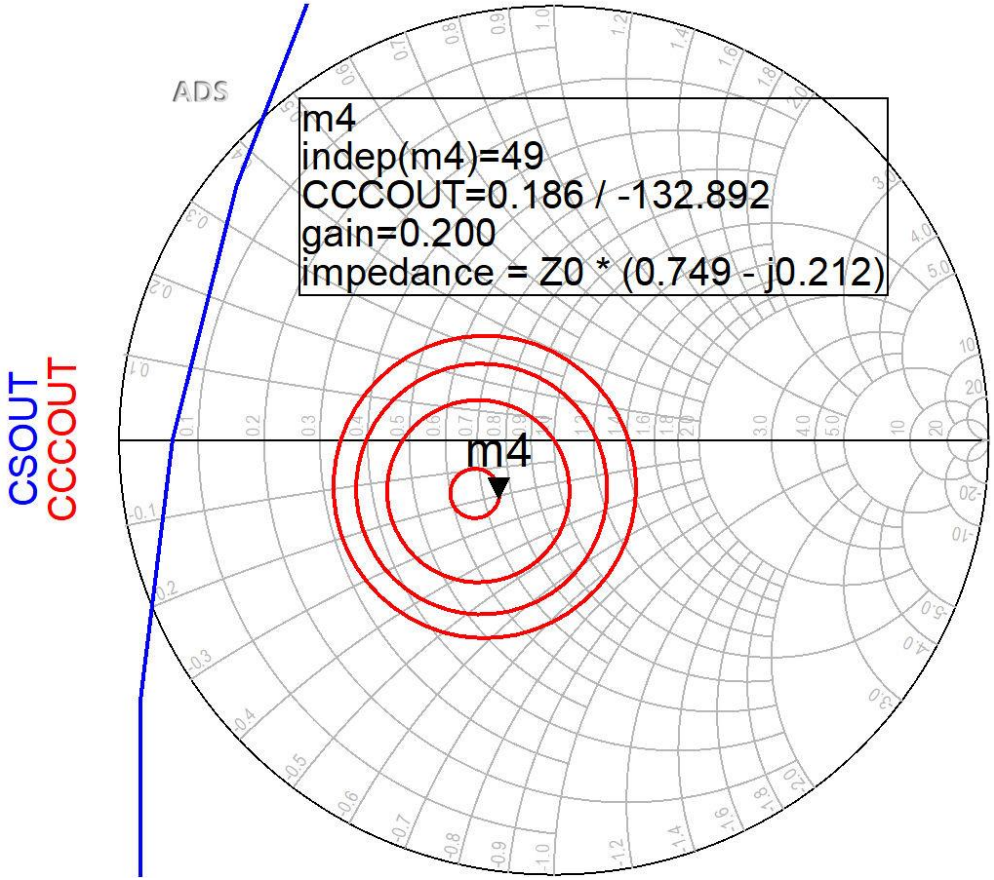
- Pentru reteaua de adaptare la intrare
  - CZ: 0.75dB
  - CCCIN: 1dB, 1.5dB, 2 dB
- Aleg (Q mic → banda larga) pozitia m1

Adaptare la intrare



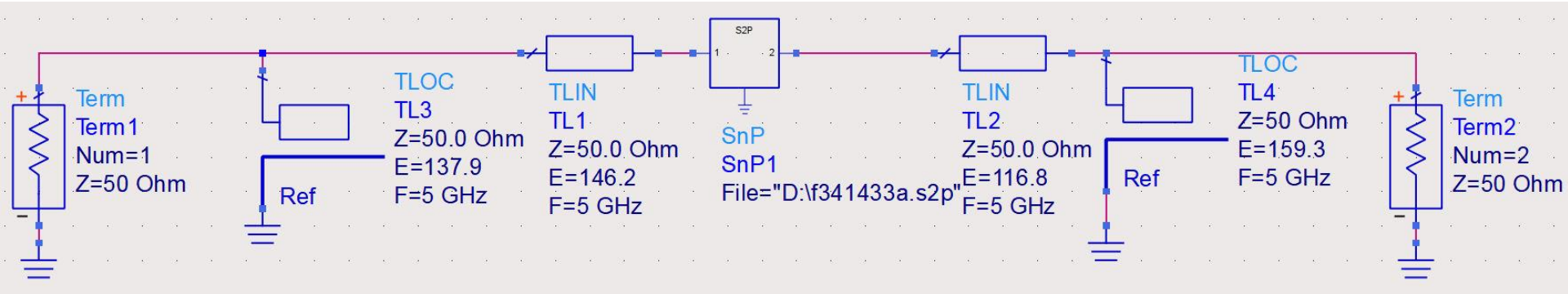
- Daca se sacrifica 1.2dB castig la intrare pentru conditii convenabile F,Q (Gs = 1 dB)
- Se prefera obtinerea unui zgomot mai mic

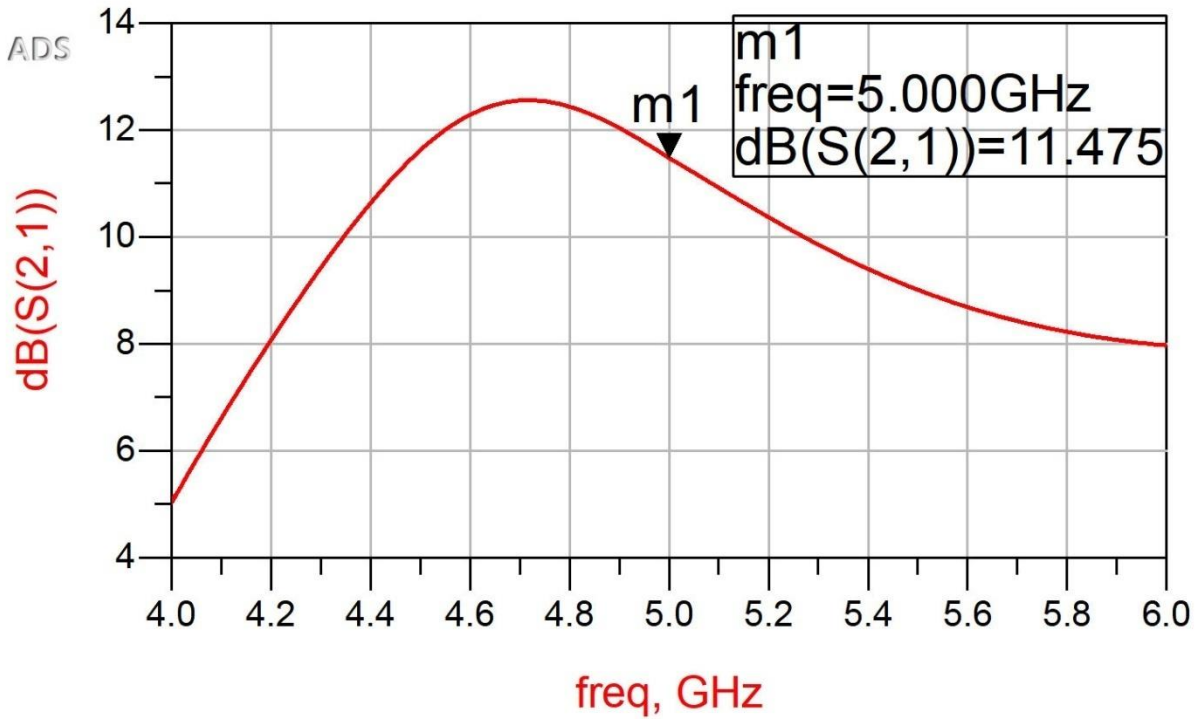
Adaptare la iesire



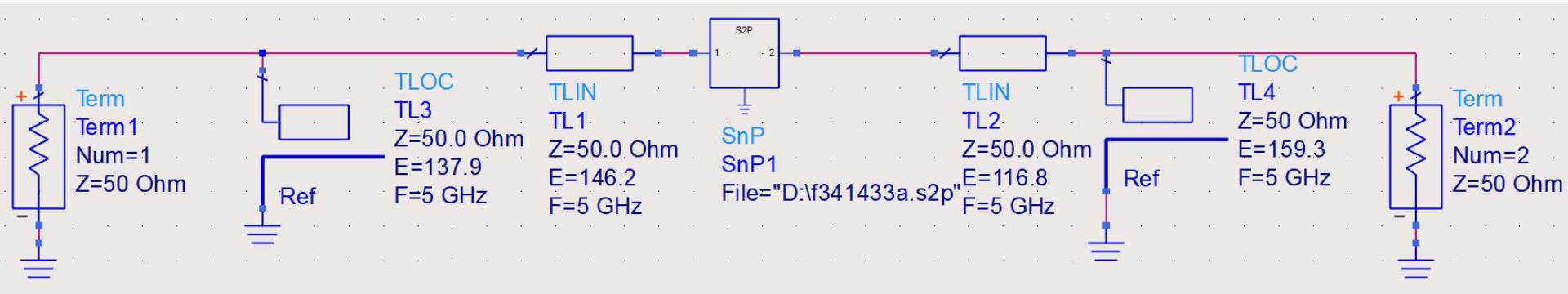
- CCCOUT: -0.4dB, -0.2dB, 0dB, +0.2dB
- Lipsa conditiilor privitoare la zgomot ofera posibilitatea obtinerii unui castig mai mare (spre maxim)

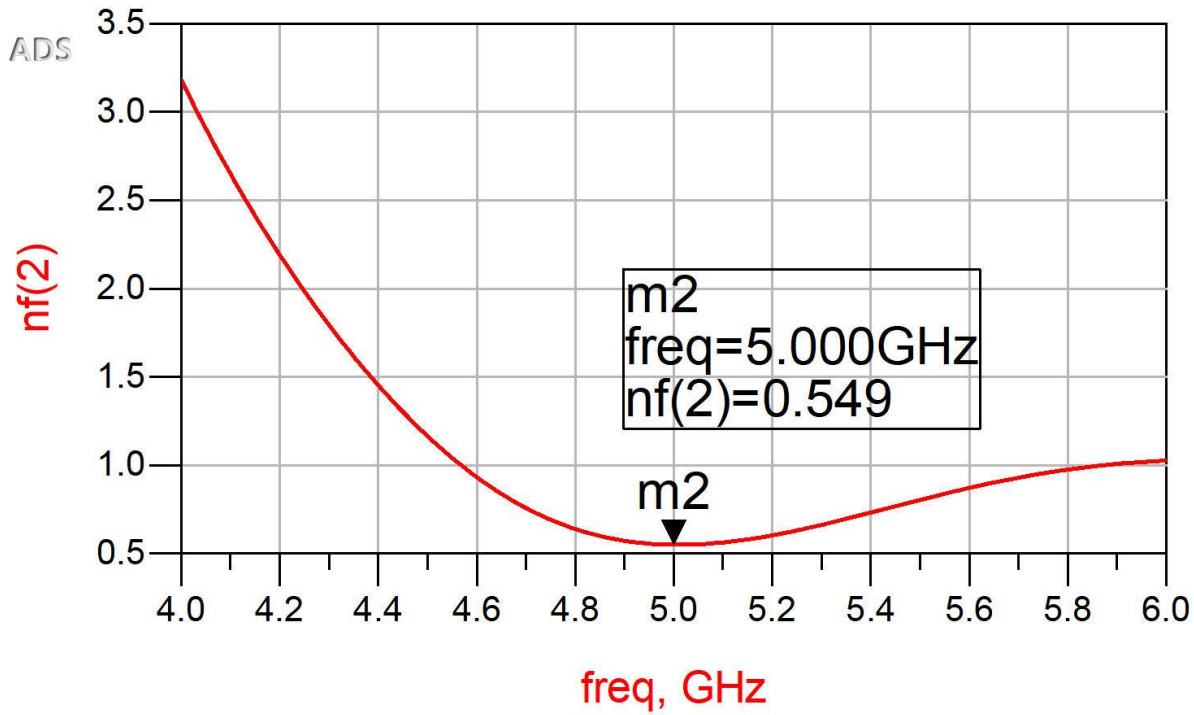
ADS


Term
Term1
Num=1
Z=50 Ohm
Ref
TLOC
TL3
Z=50.0 Ohm
E=137.9
F=5 GHz
TLIN
TL1
Z=50.0 Ohm
E=146.2
F=5 GHz
S2P
1
2
SnP
SnP1
File="D:\f341433a.s2p"
TLIN
TL2
Z=50.0 Ohm
E=116.8
F=5 GHz
Ref
TLOC
TL4
Z=50 Ohm
E=159.3
F=5 GHz
Term
Term2
Num=2
Z=50 Ohm


ADS
m1
freq=5.000GHz
dB(S(2,1))=11.475
m1
dB(S(2,1))
14
12
10
8
6
4
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0
freq, GHz

ADS


Term
Term1
Num=1
Z=50 Ohm
Ref
TLOC
TL3
Z=50.0 Ohm
E=137.9
F=5 GHz
TLIN
TL1
Z=50.0 Ohm
E=146.2
F=5 GHz
S2P
1
2
SnP
SnP1
File="D:\f341433a.s2p"
TLIN
TL2
Z=50.0 Ohm
E=116.8
F=5 GHz
Ref
TLOC
TL4
Z=50 Ohm
E=159.3
F=5 GHz
Term
Term2
Num=2
Z=50 Ohm


ADS
nf(2)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0
freq, GHz
m2
freq=5.000GHz
nf(2)=0.549
m2

Adaptare – 4

- Varianta cea mai simpla de implementare, si pentru care exista relatii analitice de calcul consta in introducerea (in ordine, de la tranzistor spre sursa Z_o):
  - o sectiune de linie serie, cu impedanta caracteristica Z_o si lungime electrica θ
  - un **s**tub **p**aralel, lasat in gol la capat, realizat dintr-o linie cu impedanta caracteristica Z_o si lungime electrica θ_{sp}

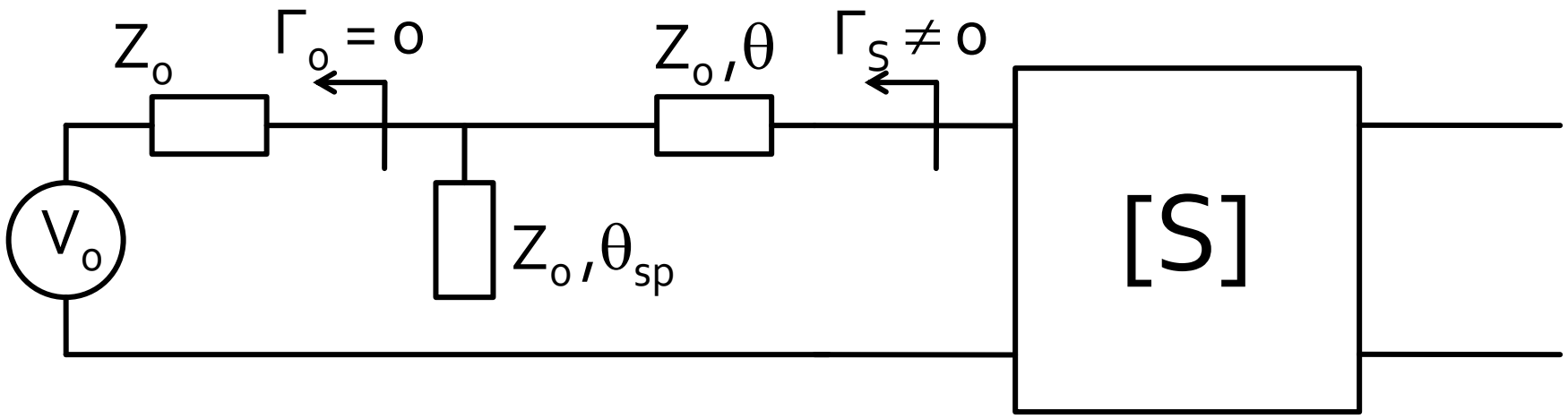


Diagrama Smith, r=1 si g=1

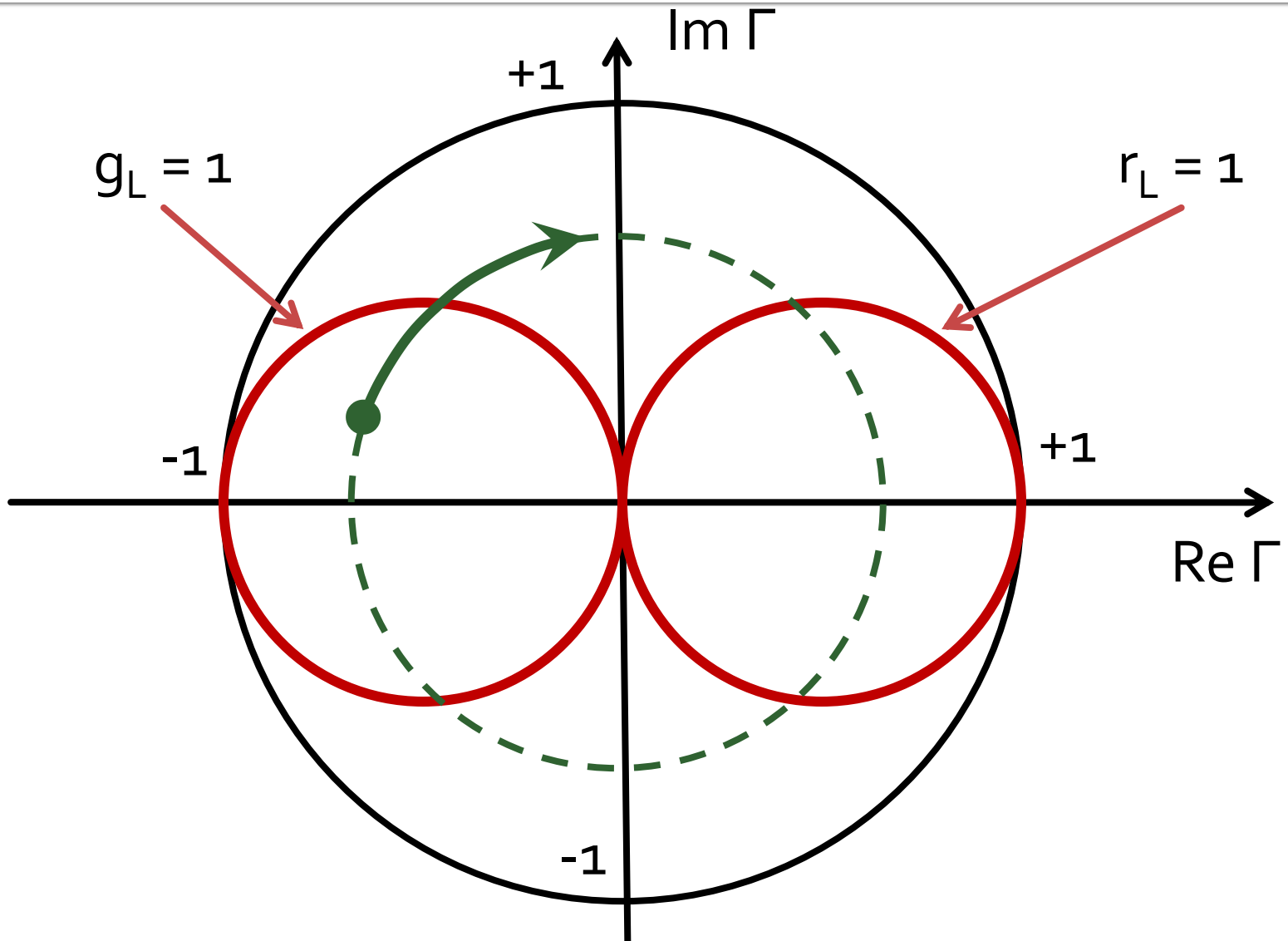
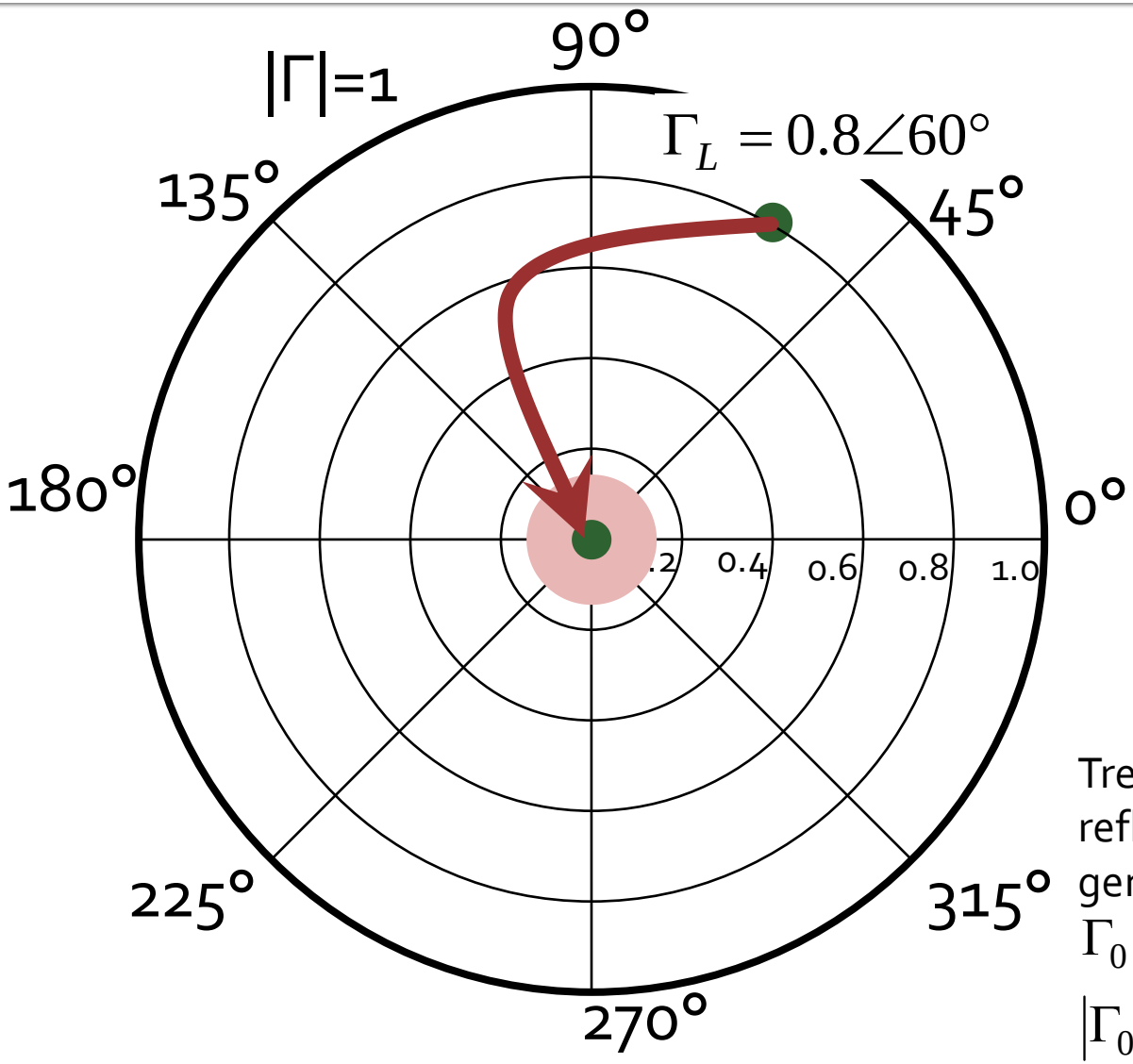
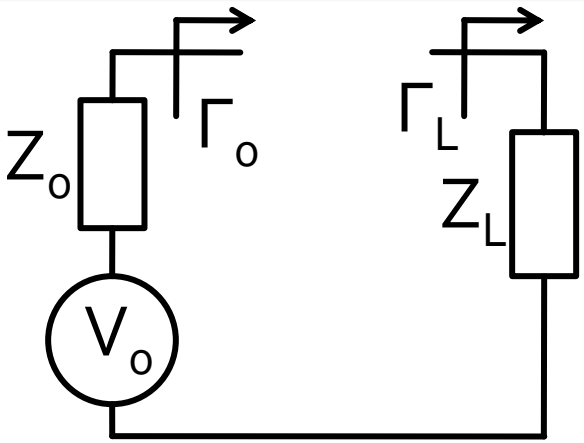


Diagrama Smith, adaptare, $Z_L \neq Z_0$





Adaptare Z_L la Z_0. Se raporteaza Z_L la Z_0

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

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

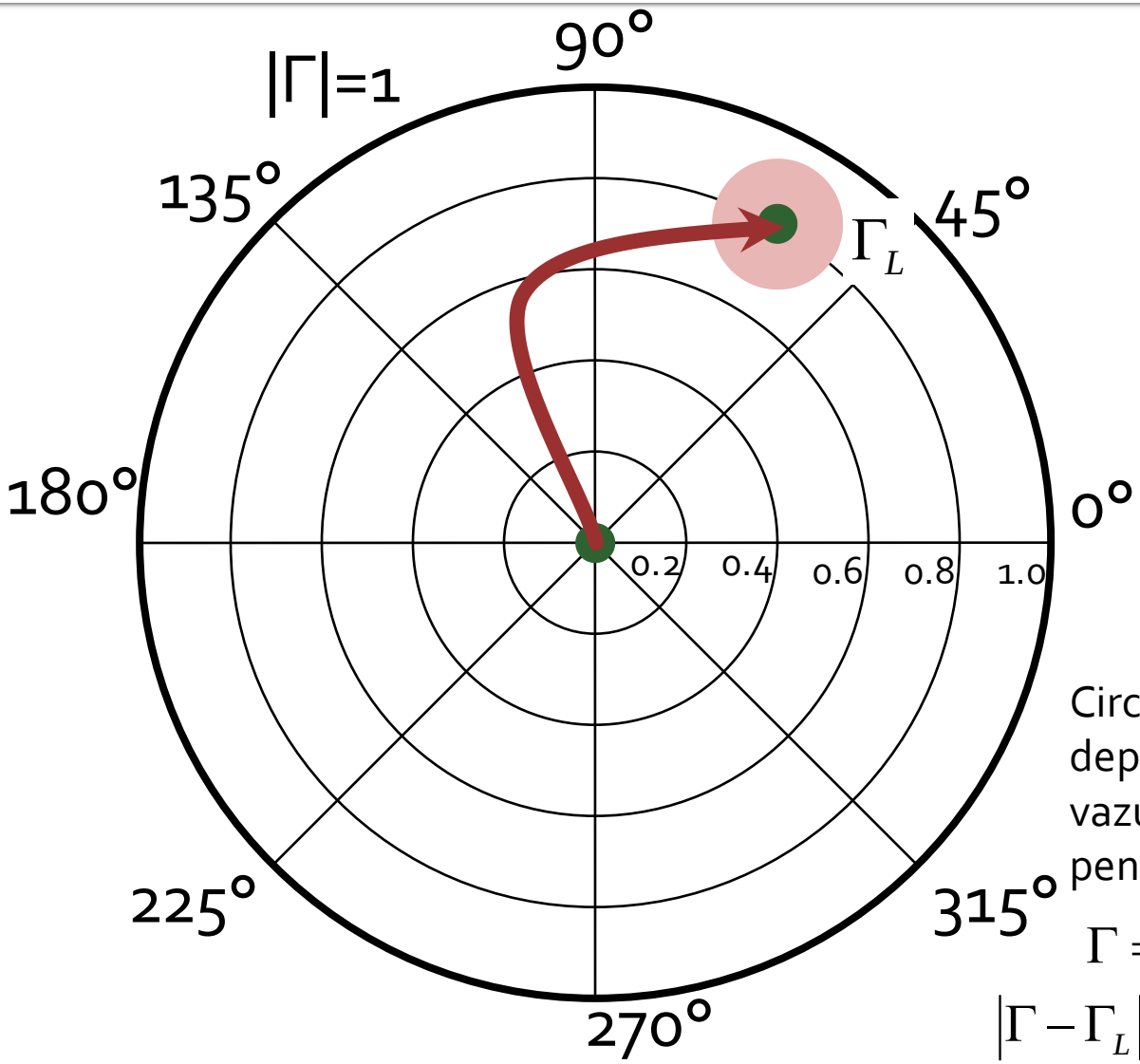
$$\Gamma_L = 0.8\angle 60°$$

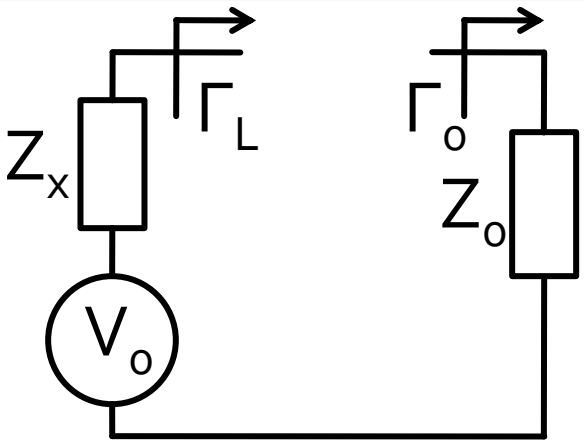
Trebuie sa deplasez coeficientul de reflexie in zona in care pentru generator cu Z_0 am:

$\Gamma_0 = 0$ adaptare perfecta

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

Diagrama Smith, adaptare, $Z_L=Z_o$





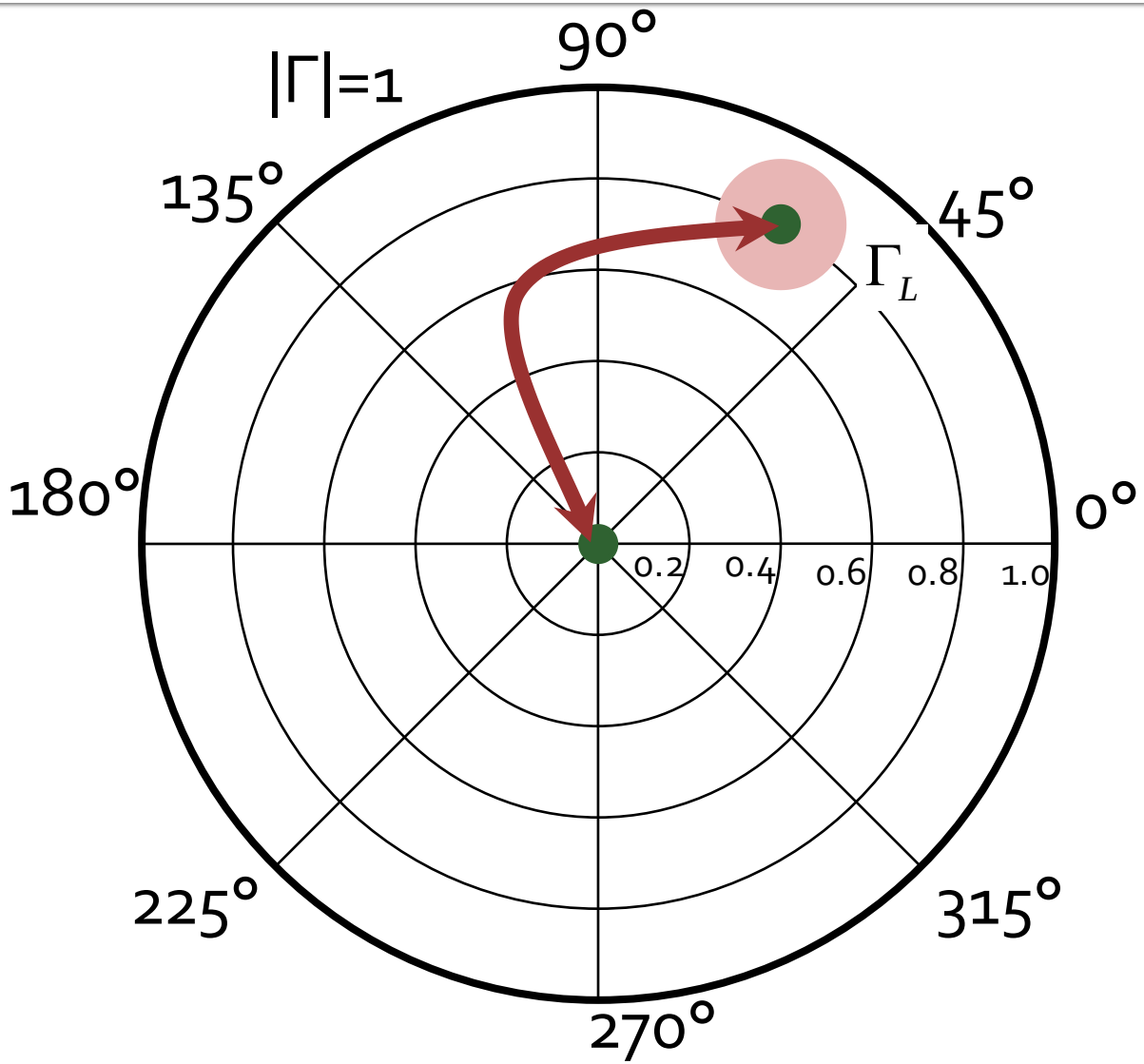
Sursa (de ex. tranzitorul) cu Z_X are nevoie de un anumit coeficient de reflexie Γ_L pentru a functiona corect

Circuitul de adaptare trebuie sa deplaseze coeficientul de reflexie vazut spre sarcina in zona in care pentru sarcina Z_o (Γ_o=0) am:

$\Gamma = \Gamma_L$ adaptare perfecta

$|\Gamma - \Gamma_L| \leq \Gamma_m$ adaptare "suficienta"

Diagrama Smith, adaptare, $Z_L=Z_0$



- Circuitele de adaptare care muta
  - Γ_L in Γ_0
  - Γ_0 in Γ_L
- sunt **identice** ca realizare. Difera doar prin **ordinea** in care se introduc elementele in circuitul de adaptare
- Ca urmare se pot folosi in proiectarea circuitelor de adaptare aceleasi:
  - **metode**
  - **relatii**

Supliment Mini Proiect

Alegere tranzistor

- Ghid de selectie

Alegere tranzistor

- Ghid de selectie
  - Low noise / LNA
  - Frecventa de lucru

Ultra-low-noise SiGe:C transistors up to 12 GHz

Product name	SP No	OPN	Electrical characteristics								Package
			V_{CEO} (max) [V]	I_C (max) [mA]	NF_{min} (typ) [dB]	G_{max} (typ) [dB]	OIP3 [dBm]	OP1dB [dBm]	f_T (typ) [GHz]	P_{tot} (max) [mW]	
BFP640ESD	SP000785482	BFP640ESDH6327XTSA1	4.1	50.0	0.65	25.0	27.0	12.0	46.0	200.0	SOT343
BFP640FESD	SP000890034	BFP640FESDH6327XTSA1	4.1	50.0	0.55	26.5	26.0	11.5	46.0	200.0	TSFP-4-1
BFP620	SP000745302	BFP620H7764XTSA1	2.3	80.0	0.7	21.5	25.5	14.5	65.0	185.0	SOT343
BFP620F	SP000745304	BFP620FH7764XTSA1	2.3	80.0	0.7	21.0	25.0	14.0	65.0	185.0	TSFP-4-1
BFP640	SP000745306	BFP640H6327XTSA1	4.0	50.0	0.65	24.0	26.5	13.0	40.0	200.0	SOT343
BFP640F	SP000750404	BFP640FH6327XTSA1	4.0	50.0	0.65	23.0	27.5	13.5	40.0	200.0	TSFP-4-1

Alegere tranzistor

- Selectare candidat
  - Ex: BFP620F

Ultra-low-noise SiGe:C transistors up to 12 GHz

Product name	SP No	OPN	Electrical characteristics								Package
			V_{CEO} (max) [V]	I_C (max) [mA]	NF_{min} (typ) [dB]	G_{max} (typ) [dB]	OIP3 [dBm]	OP1dB [dBm]	f_T (typ) [GHz]	P_{tot} (max) [mW]	
BFP640ESD	SP000785482	BFP640ESDH6327XTSA1	4.1	50.0	0.65	25.0	27.0	12.0	46.0	200.0	SOT343
BFP640FESD	SP000890034	BFP640FESDH6327XTSA1	4.1	50.0	0.55	26.5	26.0	11.5	46.0	200.0	TSFP-4-1
BFP620	SP000745302	BFP620H7764XTSA1	2.3	80.0	0.7	21.5	25.5	14.5	65.0	185.0	SOT343
BFP620F	SP000745304	BFP620FH7764XTSA1	2.3	80.0	0.7	21.0	25.0	14.0	65.0	185.0	TSFP-4-1
BFP640	SP000745306	BFP640H6327XTSA1	4.0	50.0	0.65	24.0	26.5	13.0	40.0	200.0	SOT343
BFP640F	SP000750404	BFP640FH6327XTSA1	4.0	50.0	0.65	23.0	27.5	13.5	40.0	200.0	TSFP-4-1

- Cautare model
  - verificare zip rf-opto
  - Google BFP620F s2p

Alegere transistor, model

- zip: 8064 fisiere
- BFP620F: 281 fisiere
  - diverse polarizari
  - necesar w_noise **!!**
    - **with noise**

ro	2/12/2021 10:51 AM	File folder	
test D	10/16/2020 3:45 AM	File folder	
5G.pdf	9/30/2019 2:18 PM	Adobe Acrobat Docu...	617
infineon_rft.zip	1/14/2020 9:46 AM	zip Archive	38,065
Infineon-RFTransistor-AWR_MWO_Design_Kit-S...	1/14/2020 9:43 AM	zip Archive	36,432
Infineon-RFTransistor-Keysight_ADS_Design_Kit...	1/14/2020 9:43 AM	zip Archive	39,977

BFP620F_VCE_2.3V_IC_53mA.s2p	6 853	2 802	2016-
BFP620F_VCE_2.3V_IC_55mA.s2p	6 853	2 779	2016-
BFP620F_VCE_2.3V_IC_60mA.s2p	6 853	2 788	2016-
BFP620F_VCE_2.3V_IC_65mA.s2p	6 853	2 778	2016-
BFP620F_VCE_2.3V_IC_70mA.s2p	6 853	2 778	2016-
BFP620F_VCE_2.3V_IC_75mA.s2p	6 853	2 782	2016-
BFP620F_VCE_2.3V_IC_80mA.s2p	6 853	2 775	2016-
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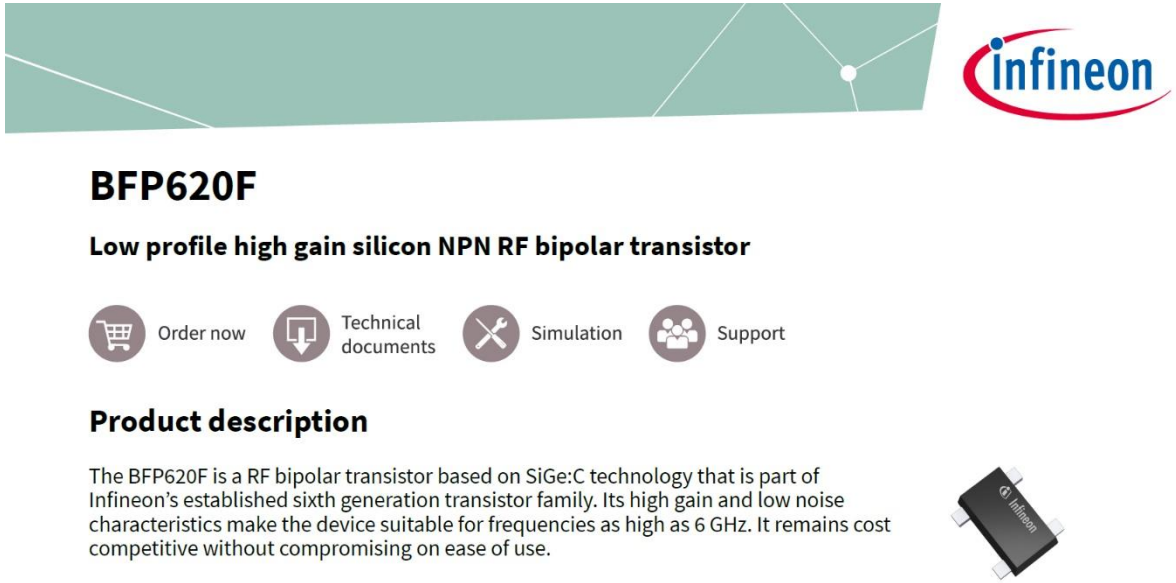
BFP620F_w_noise_VCE_0.3V_IC_3.0mA....	7 105	2 810	2016-
BFP620F_w_noise_VCE_0.3V_IC_5.0mA....	7 105	2 804	2016-
BFP620F_w_noise_VCE_0.3V_IC_7.0mA....	7 105	2 810	2016-
BFP620F_w_noise_VCE_0.3V_IC_8.0mA....	7 105	2 797	2016-
BFP620F_w_noise_VCE_0.3V_IC_10mA.s...	7 104	2 768	2016-
BFP620F_w_noise_VCE_0.3V_IC_12mA.s...	7 104	2 771	2016-
BFP620F_w_noise_VCE_0.3V_IC_13mA.s...	7 104	2 779	2016-
BFP620F_w_noise_VCE_0.3V_IC_15mA.s...	7 104	2 770	2016-
BFP620F_w_noise_VCE_0.3V_IC_17mA.s...	7 104	2 753	2016-

Alegere transistor, catalog

- Cautare Google BFP620F datasheet
- Preferabil de pe site-ul oficial (daca mai exista)



BFP620F

Low profile high gain silicon NPN RF bipolar transistor

Order now | Technical documents | Simulation | Support

Product description

The BFP620F is a RF bipolar transistor based on SiGe:C technology that is part of Infineon's established sixth generation transistor family. Its high gain and low noise characteristics make the device suitable for frequencies as high as 6 GHz. It remains cost competitive without compromising on ease of use.

Alegere transistor, catalog

- Parametrii variaza cu frecventa si polarizarea

Table 6 **AC characteristics, V_{CE} = 1.5 V, f = 1.8 GHz**

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Power gain		–		–	dB	
• Maximum power gain	G_{ms}		21			I_C = 50 mA
• Transducer gain	$\|S_{21}\|^2$		19.5			
Noise figure						
• Minimum noise figure	NF_{min}		0.7			I_C = 5 mA
Linearity					dBm	
• 3rd order intercept point at output	OIP_3		25			I_C = 50 mA, V_{CE} = 2 V,
• 1 dB gain compression point at output	OP_{1dB}		14			$Z_S = Z_L$ = 50 Ω

Table 7 **AC characteristics, V_{CE} = 1.5 V, f = 6 GHz**

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Power gain		–		–	dB	
• Maximum power gain	G_{ma}		10			I_C = 50 mA
• Transducer gain	$\|S_{21}\|^2$		9.5			
Noise figure						
• Minimum noise figure	NF_{min}		1.3			I_C = 5 mA

Alegere transistor, catalog

- Grafice cu variatia in frecventa
  - NF (f)

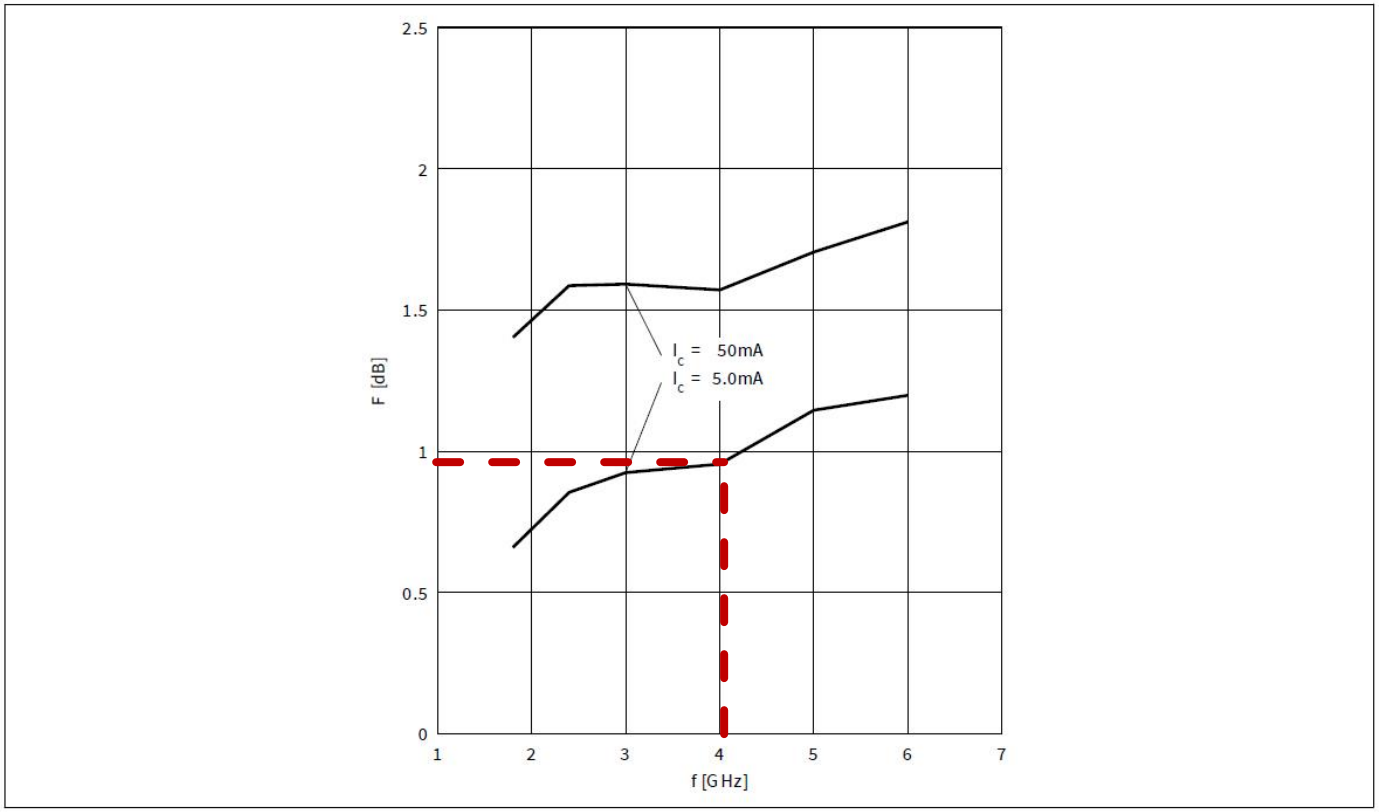


Figure 12 **Noise figure $NF_{min} = f(f)$, $Z_S = Z_{S,opt}$, $V_{CE} = 1.5$ V, $I_C = 5 / 50$ mA**

Alegere transistor, catalog

- Grafice cu variatia in frecventa
  - G (f)

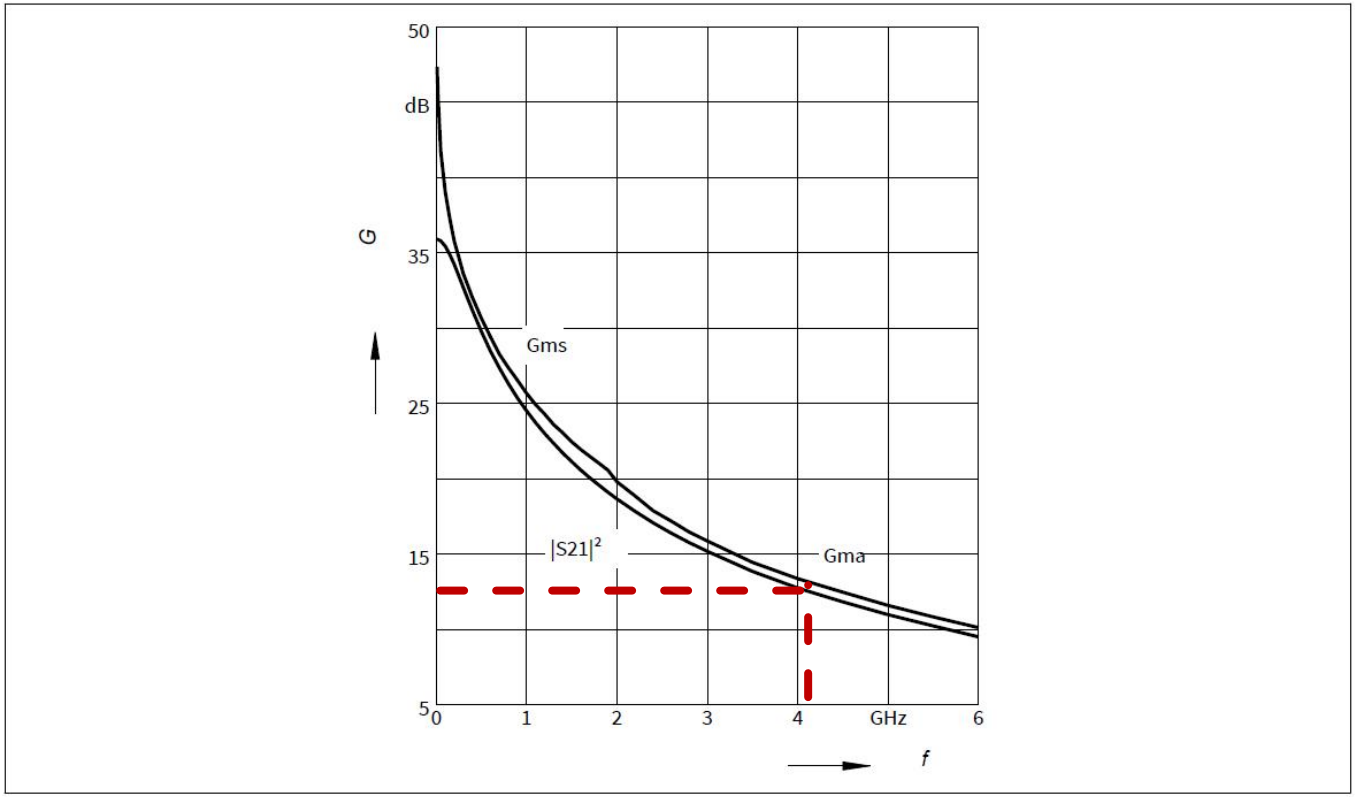


Figure 8 **Gain G_{ma}, G_{ms}, $|S_{21}|^2 = f(f)$, $V_{CE} = 1.5$ V, $I_C = 50$ mA**

Alegere transistor, catalog

- Grafice care ghideaza in alegerea polarizarii
  - NF (I_C)

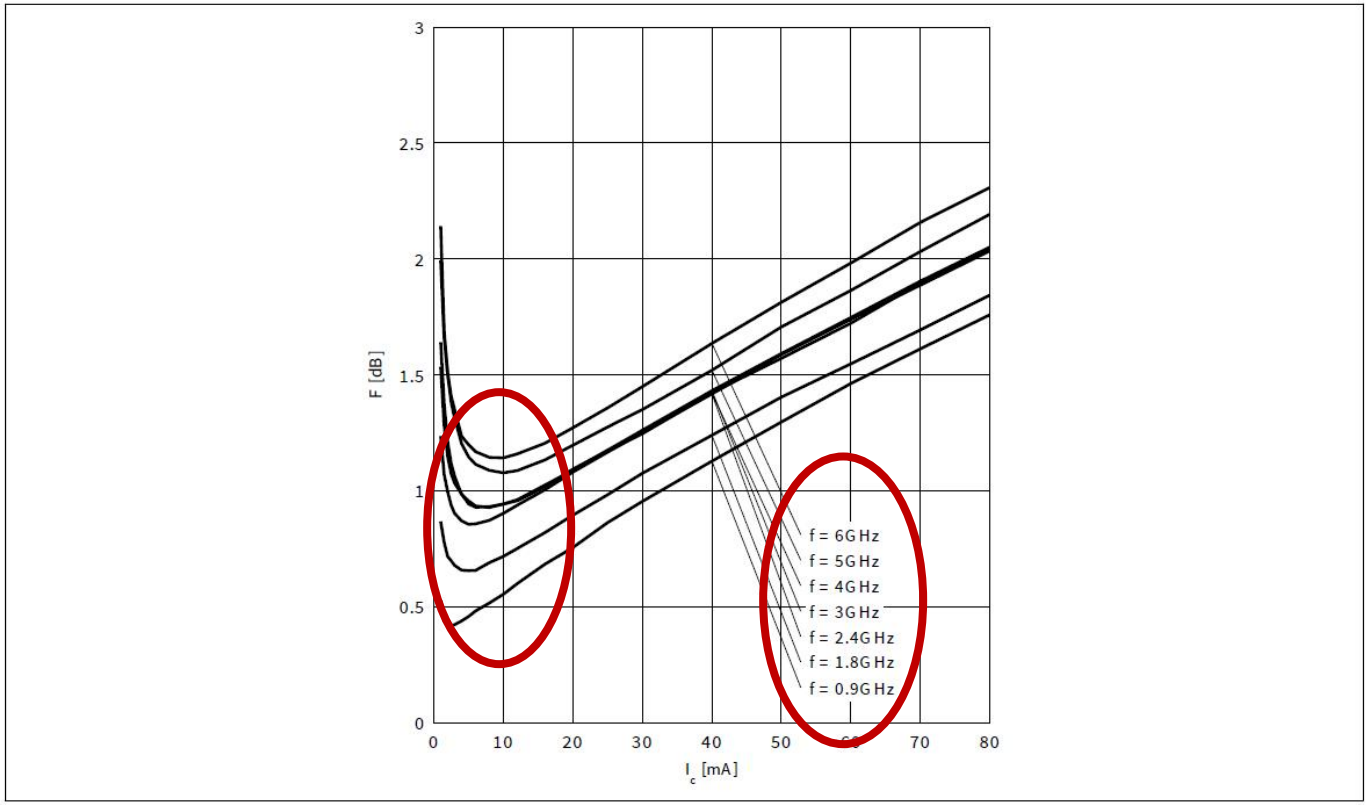


Figure 13 **Noise figure $NF_{min} = f(I_C)$, $Z_S = Z_{S,opt}$, $V_{CE} = 1.5$ V, f = parameter in GHz**

Alegere transistor, catalog

- Grafice care ghideaza in alegerea polarizarii
  - G (I_C)

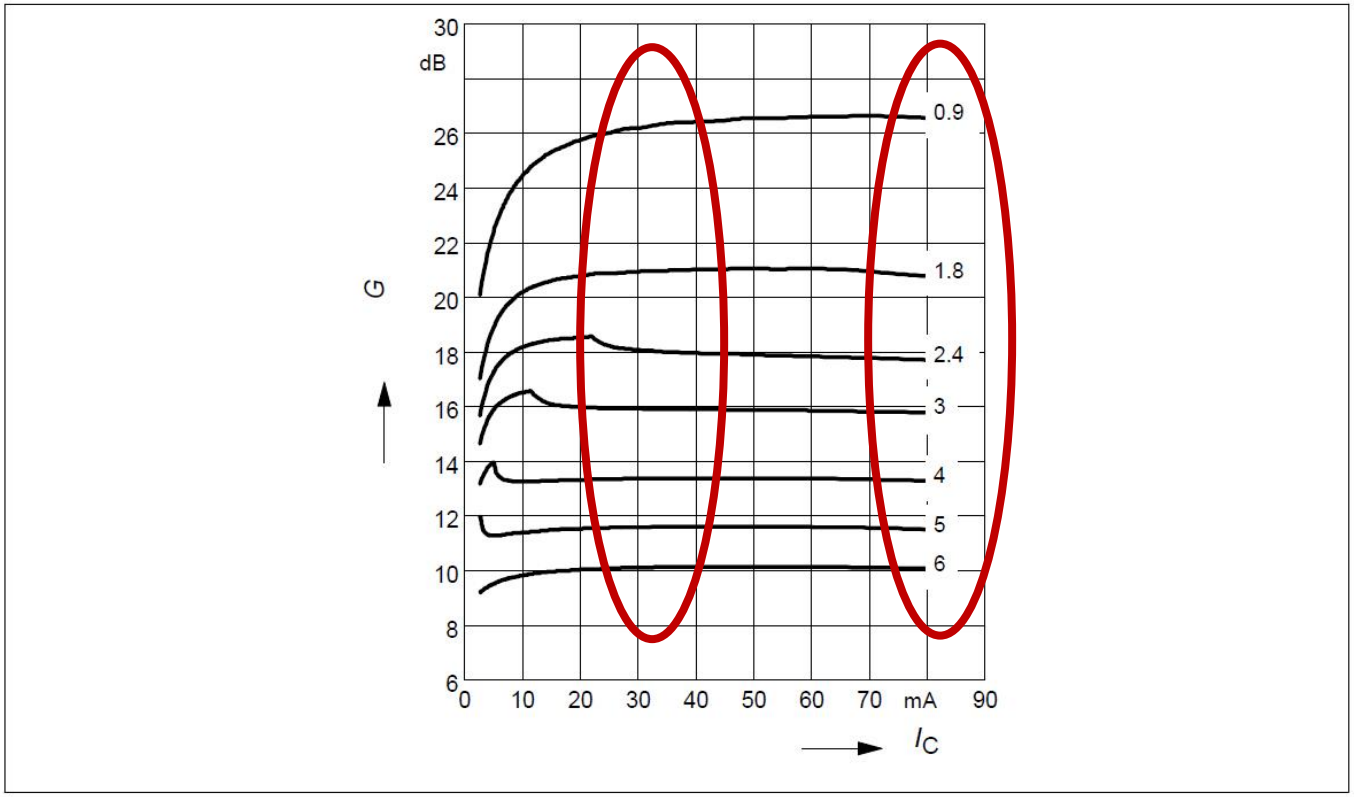


Figure 9 **Maximum power gain $G_{max} = f(I_C)$, $V_{CE} = 1.5$ V, f = parameter in GHz**

Alegere transistor, catalog

- Grafice care ghideaza in alegerea polarizarii
  - G (V_{CE})

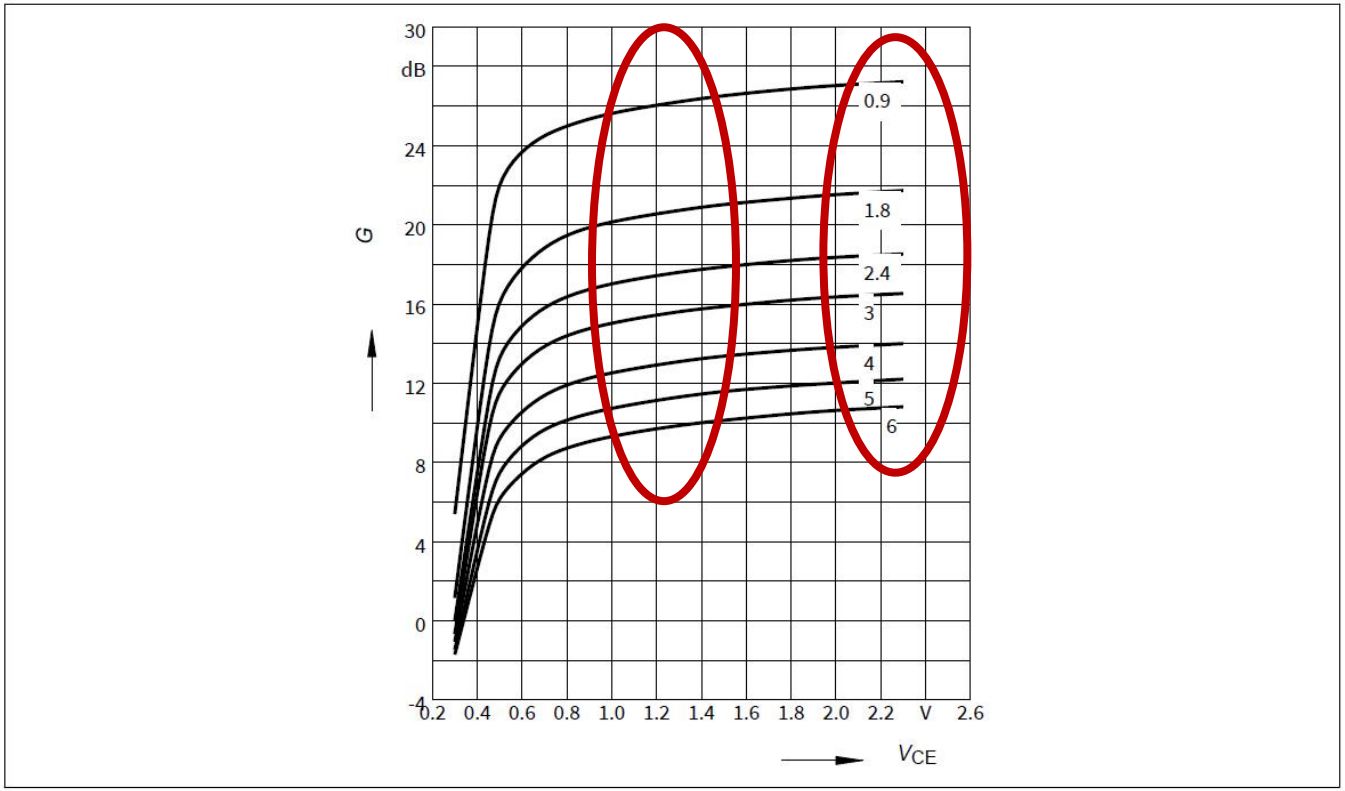


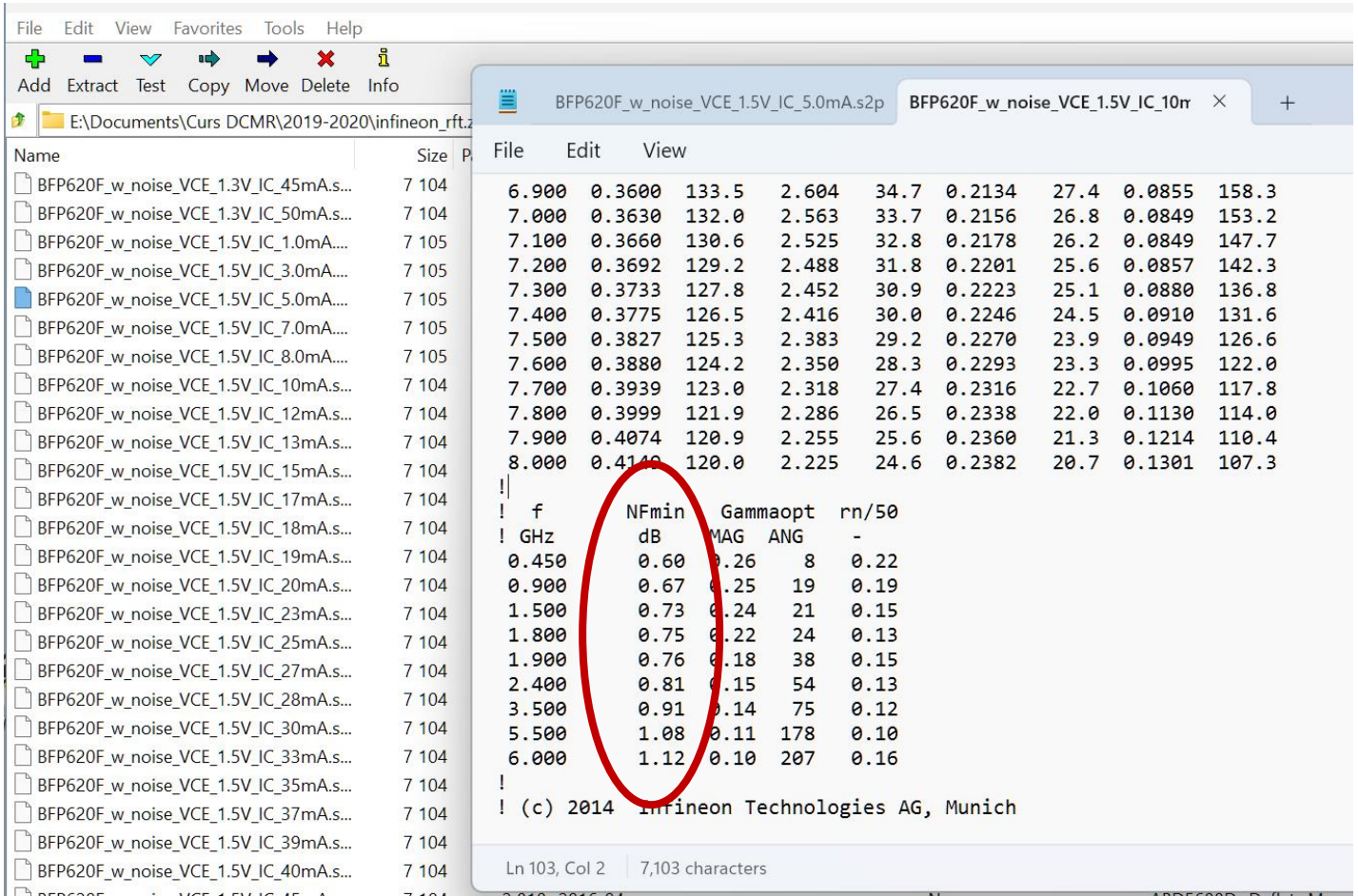
Figure 10 **Maximum power gain $G_{max} = f(V_{CE})$, $I_C = 50$ mA, f = parameter in GHz**

Alegere transistor, catalog

- De obicei:
  - polarizarile cu valori reduse (ex. BFP620F: 1.5V V_{CE}, 5÷ 10mA I_C) ofera zgomot mai mic, iar polarizarile cu valori ridicate V_{CE}, I_C ofera castig mai mare

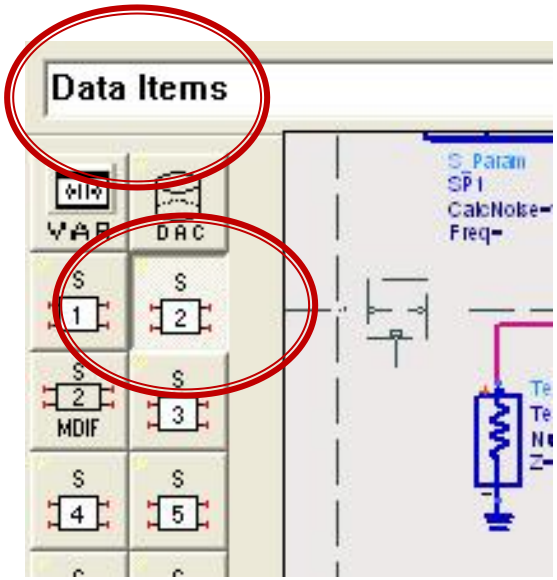
Alegere transistor, catalog

- Fisierele s2p sunt text si pot fi direct vizualizate



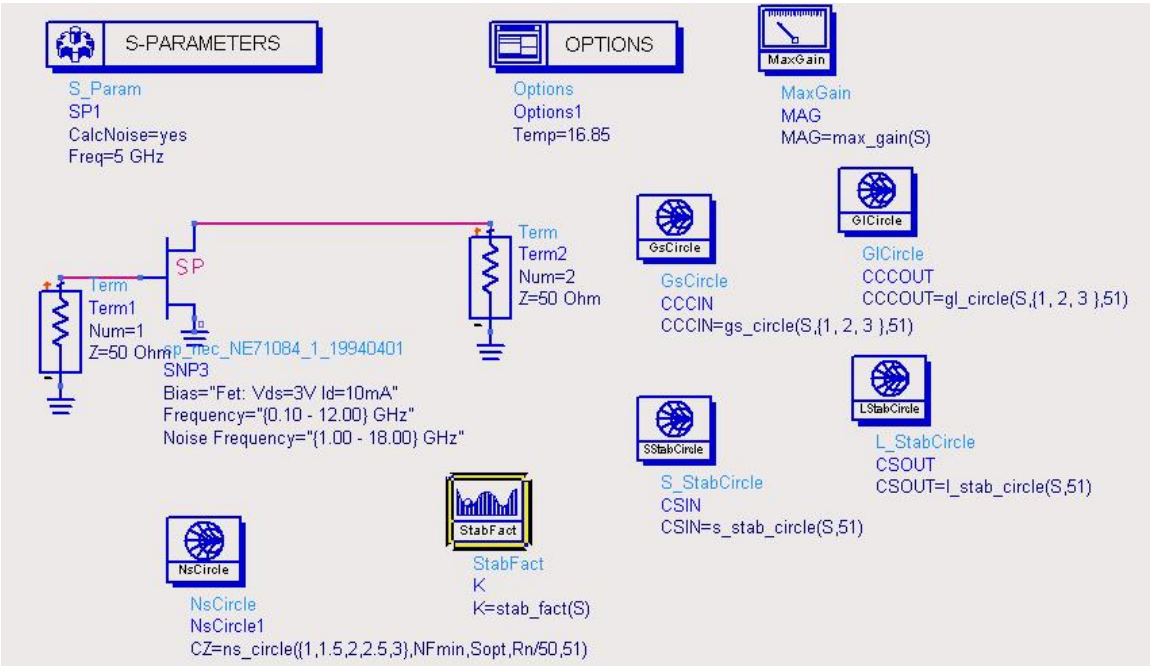
Alegere transistor, ADS

- Tranzistoare se introduc cu componente tip diport
  - se bazeaza pe un fisier s2p pe care il incarca de pe disc
  - paleta Data Items > diport (2)



Alegere transistor, ADS

- schema 1/lab 3-4
- se introduce un fisier cu parametri S si se verifica rapid prin simulare (**repetata**)

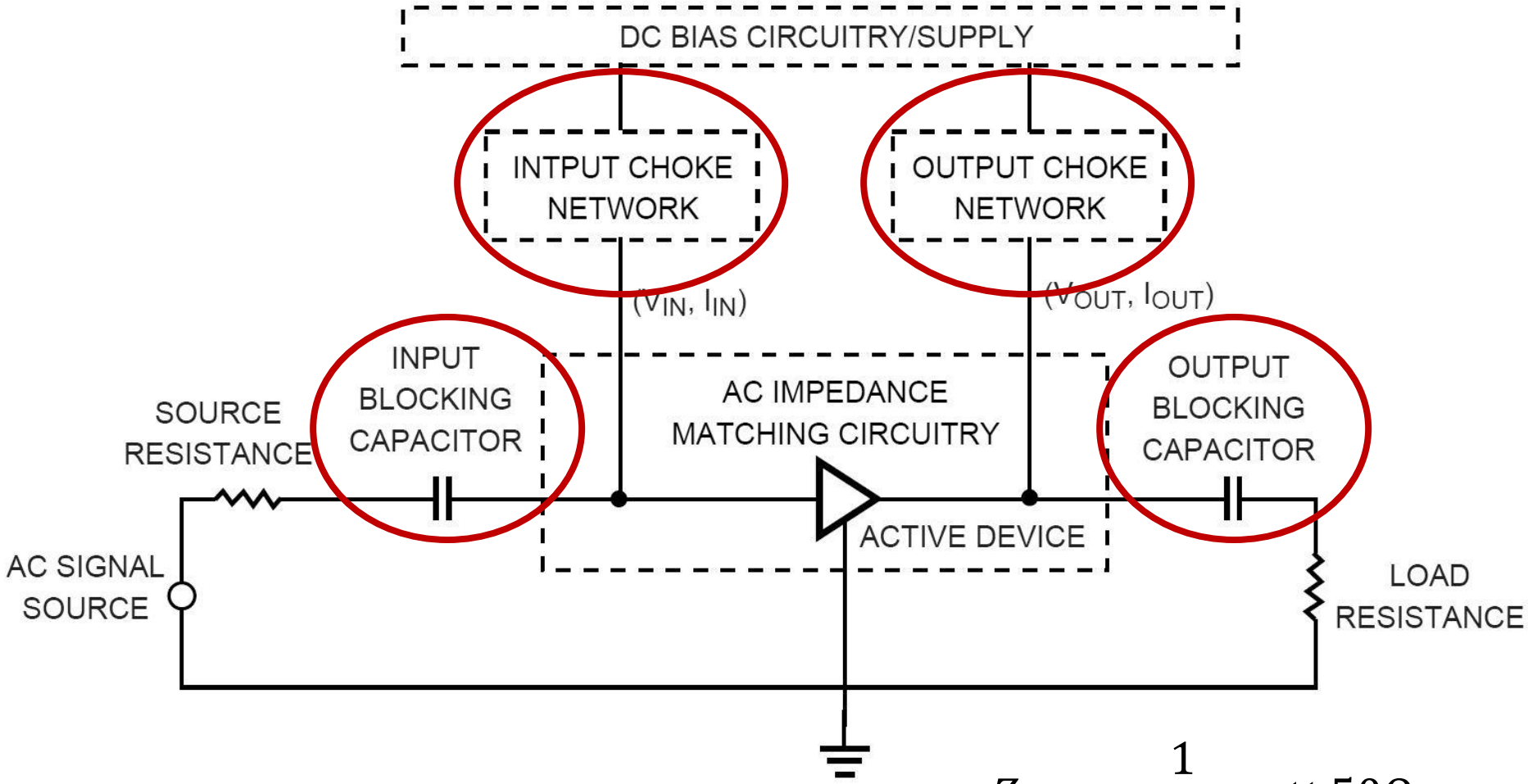


freq	K	MAG	NFmin	Sopt	Rn	G0	GLmax	GSmax
5.000 GHz	0.593	15.296	0.700	0.660 / 106....	19.500	8.974	1.634	4.249

Polarizare

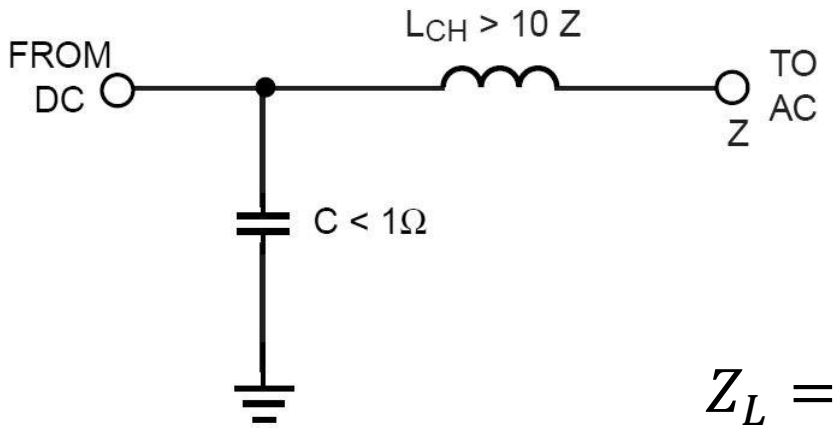
- http://rf-opto.etti.tuiasi.ro
- note de aplicatii importante Agilent
  - decuplarea circuit de semnal/circuit de polarizare
  - detalii de implementare a circuitelor de polarizare pentru tranzistoarele cu microunde
- Appcad contine instrumente pentru calculul schemelor de polarizare

Polarizare



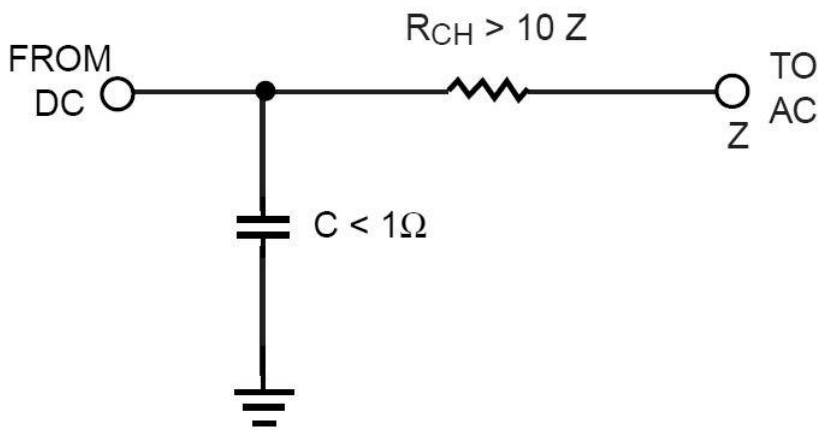
$$Z_C = \frac{1}{j \cdot \omega \cdot C} \ll 50\Omega$$

Polarizare, soc tipic



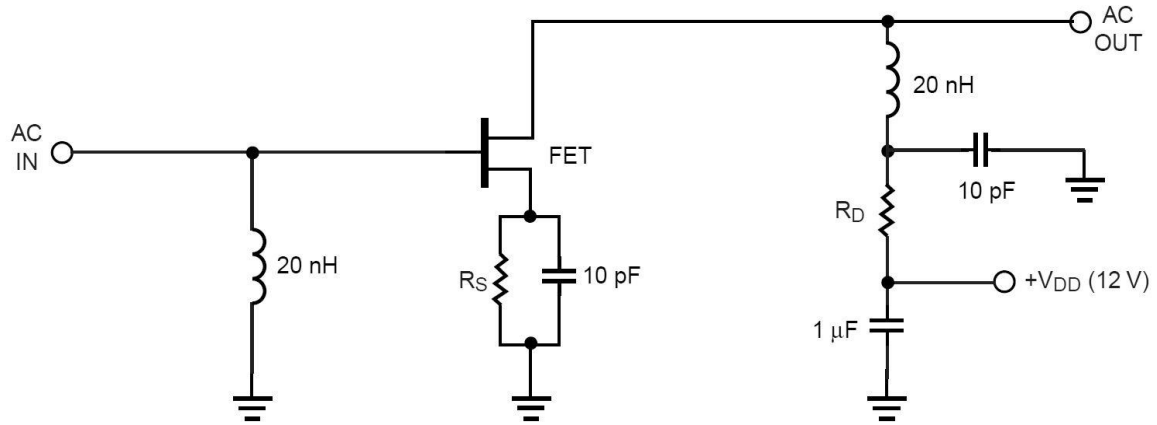
CURRENT CONTROLLED

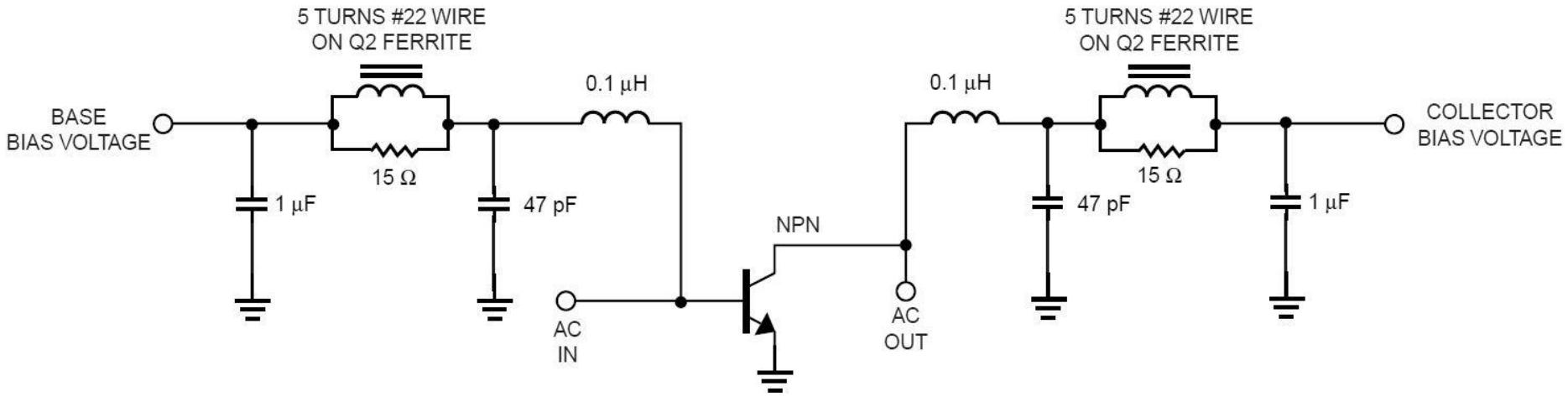
$$Z_L = j \cdot \omega \cdot L \gg 50\Omega$$



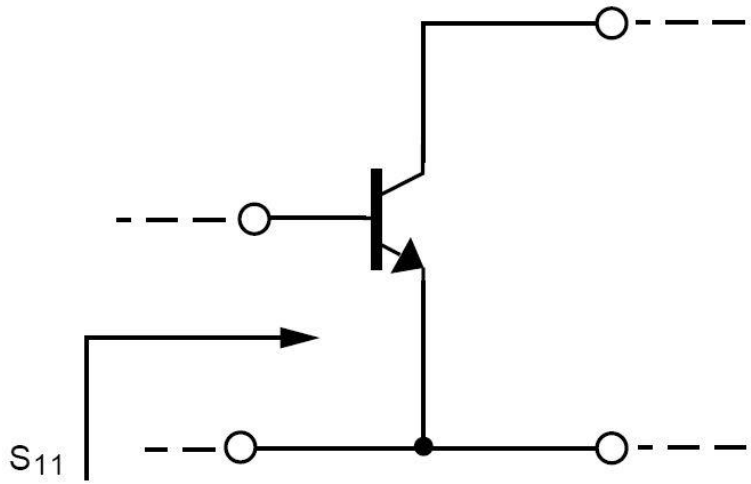
VOLTAGE CONTROLLED
(FET GATE)

Polarizare, scheme/valori tipice



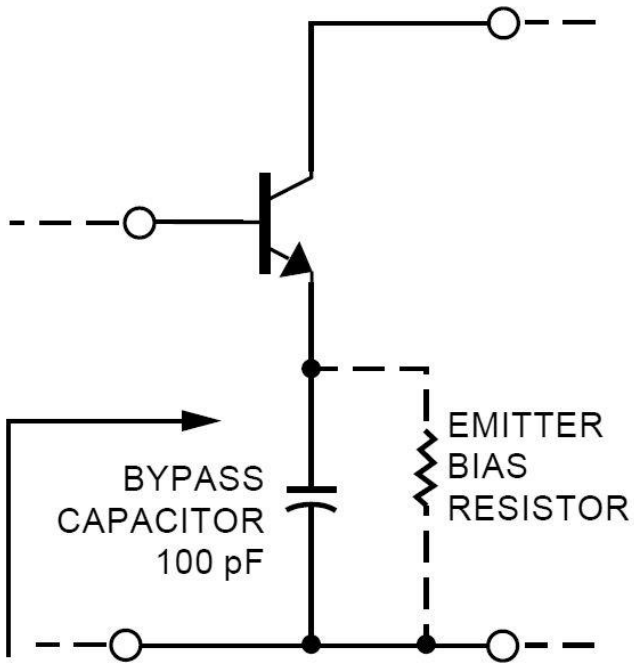


Polarizare, problema elementelor conectate in E/S



S_{11} (AT 4 GHz) = 0.52 ∠ 154°

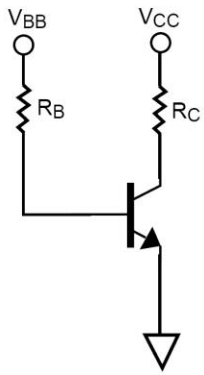
S_{11} (AT 0.1 GHz) = 0.901 ∠ –14.9°



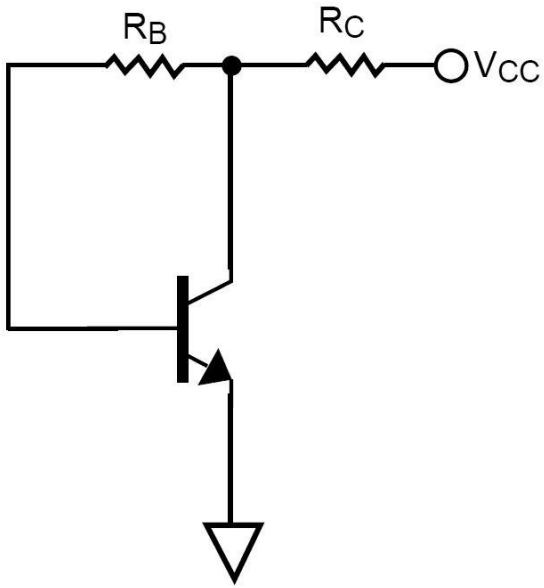
S'_{11} (AT 4 GHz) = 0.52 ∠ 154° UNCHANGED AT 4 GHz

S'_{11} (AT 0.1 GHz) = 1.066 ∠ -8.5° $|S_{11}|>1$ AT 0.1GHz

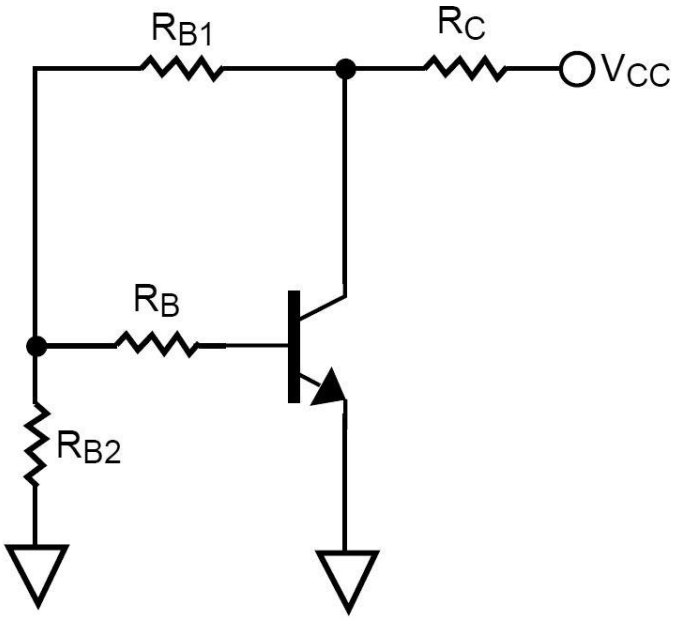
Polarizare TB scheme de polarizare



NON-STABILIZED



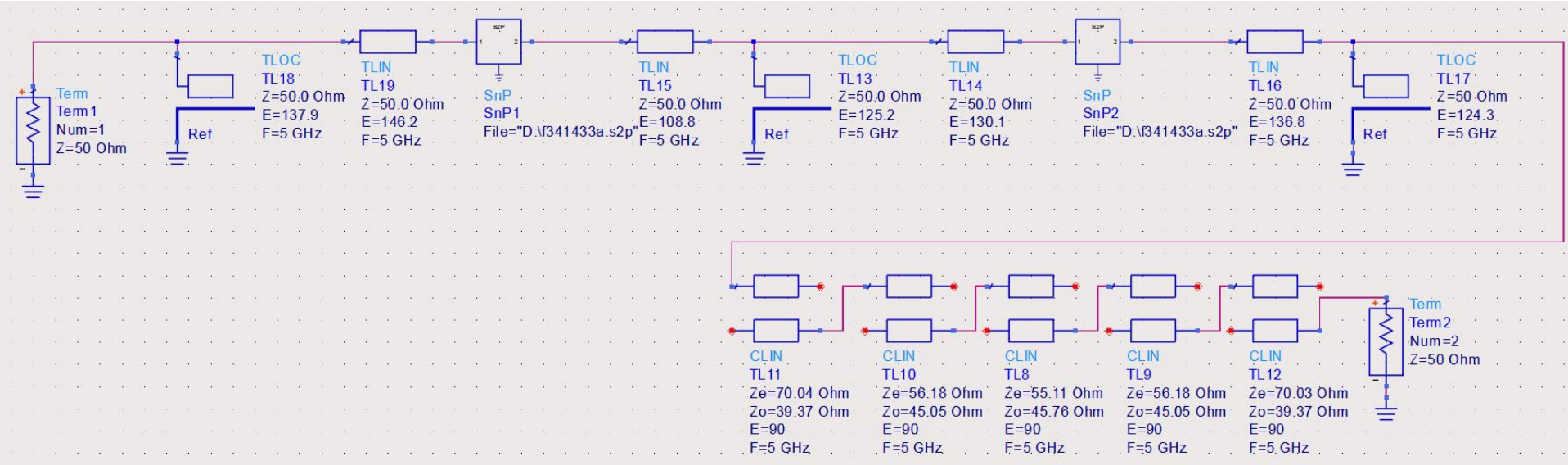
VOLTAGE FEEDBACK



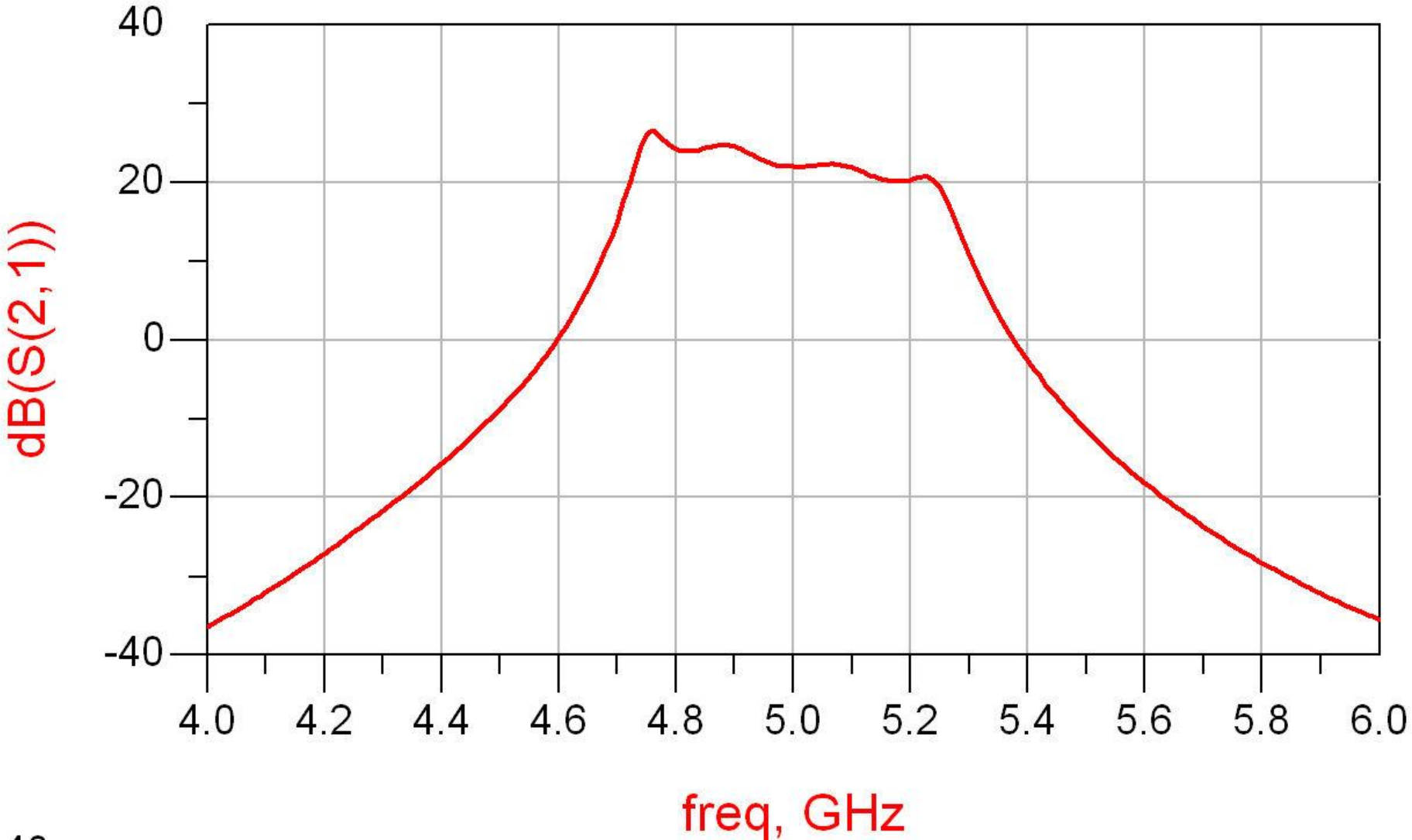
VOLTAGE FEEDBACK AND CONSTANT BASE CURRENT SOURCE

Exemplu proiect

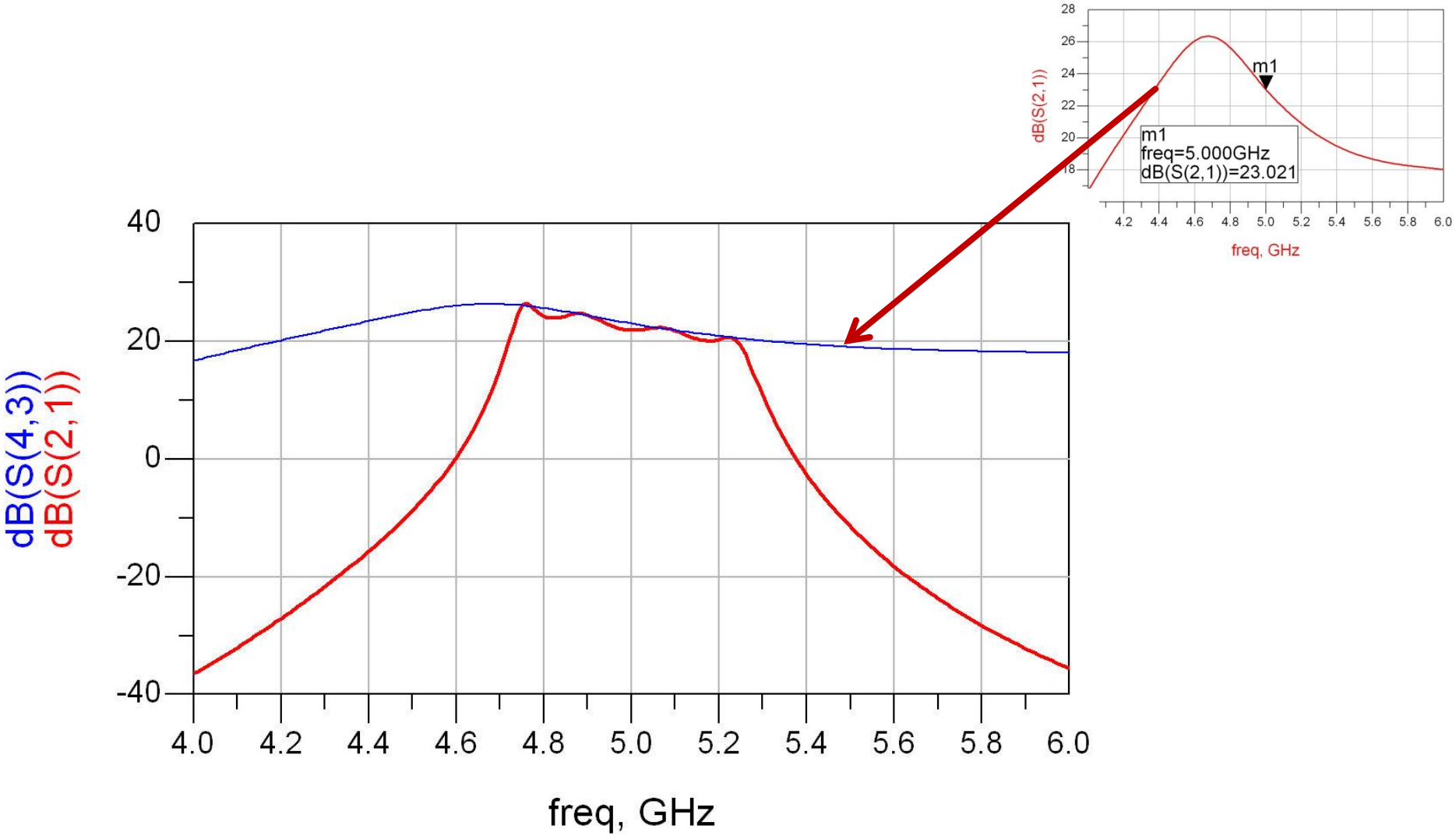
- Unirea celor doua scheme
  - C12 – amplificator
  - C13 – filtru



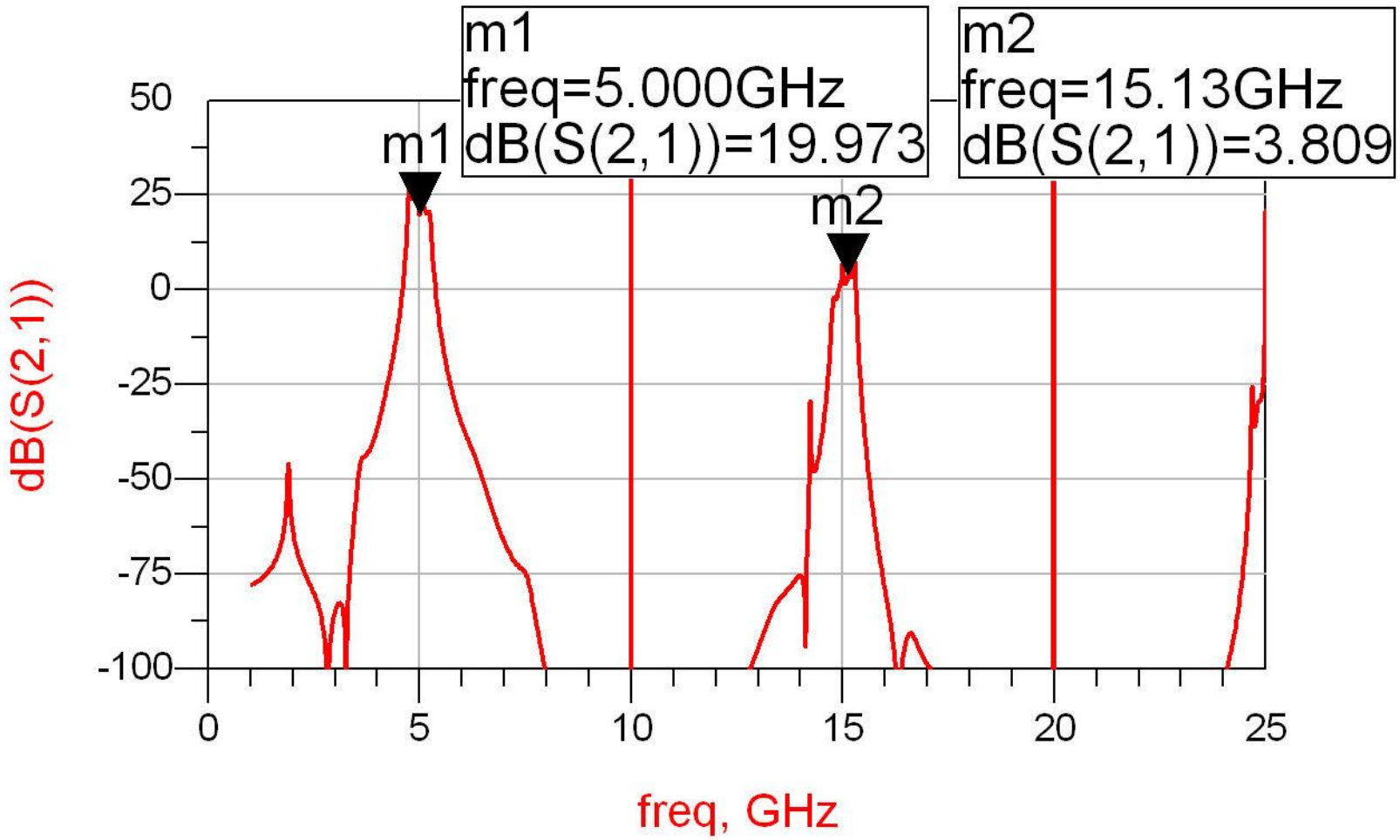
Rezultat (dezechilibrat)



Rezultat (dezechilibrat)

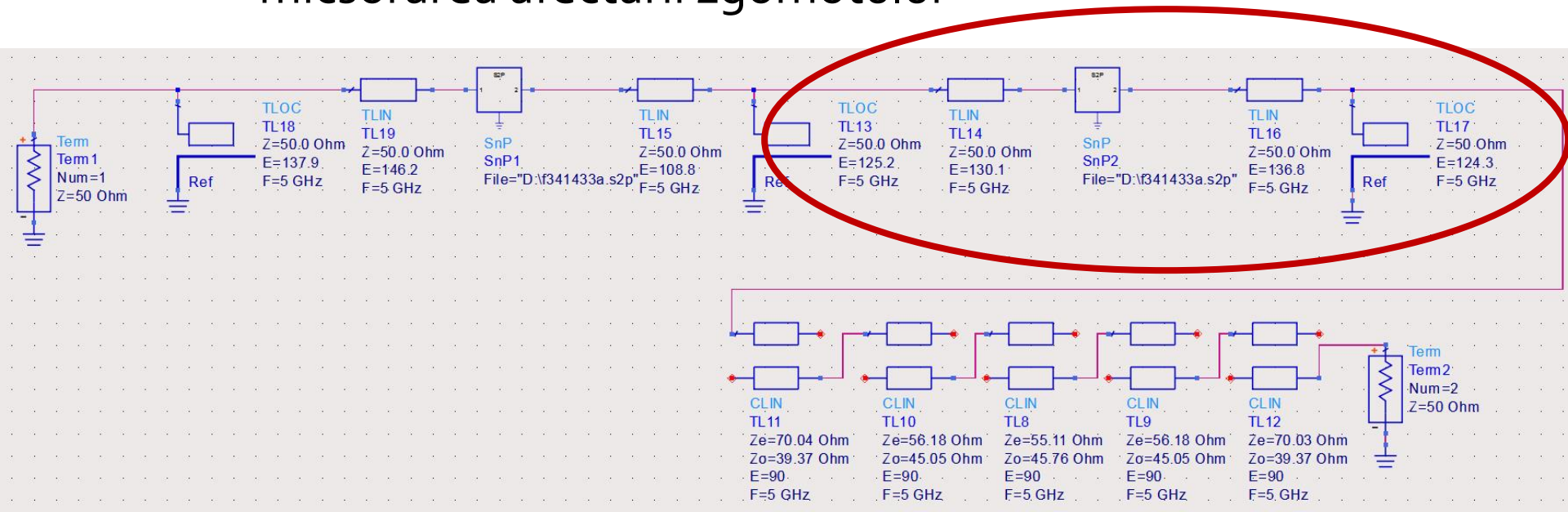


Rezultat (periodic in frecventa)

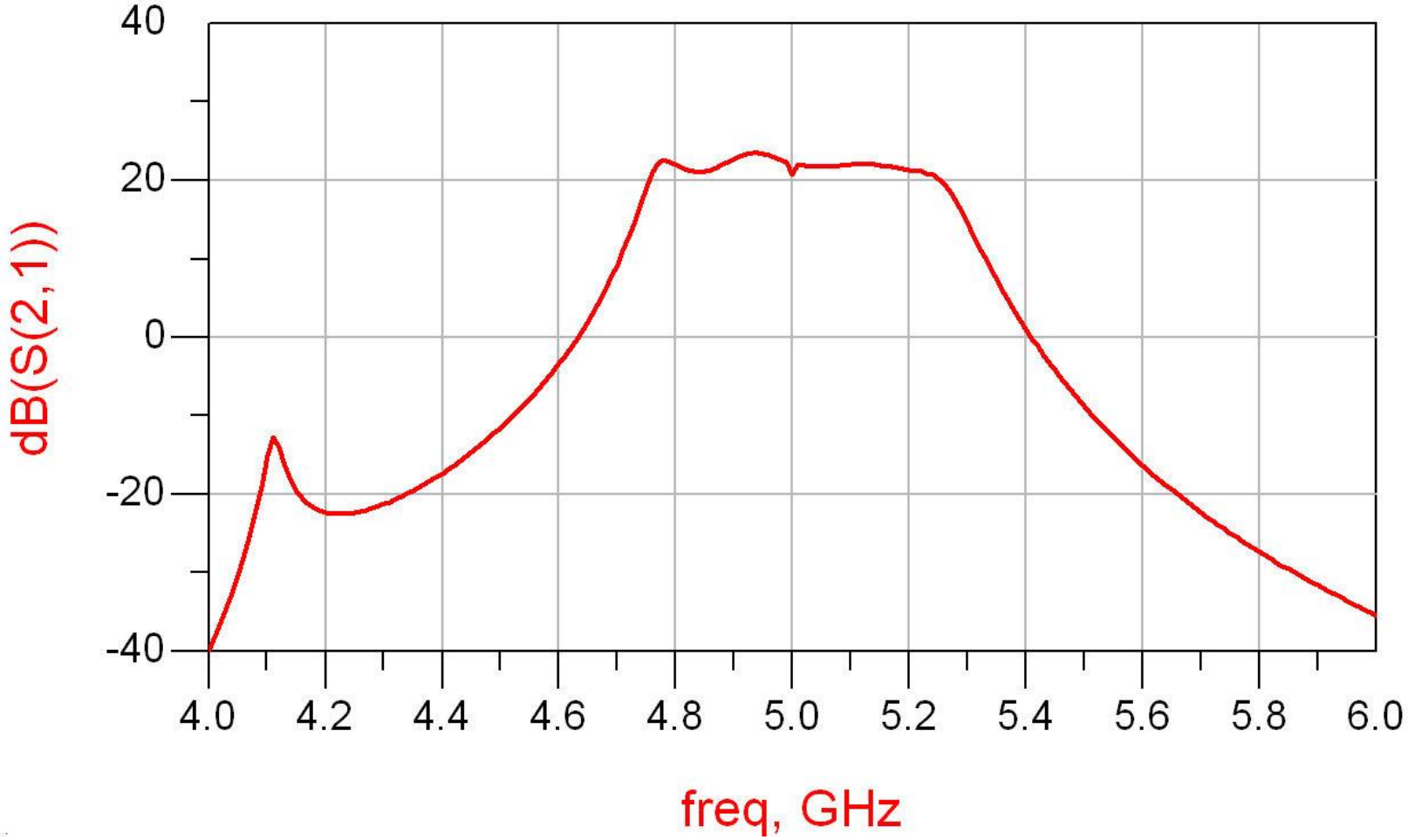


Reglaj -> echilibrare

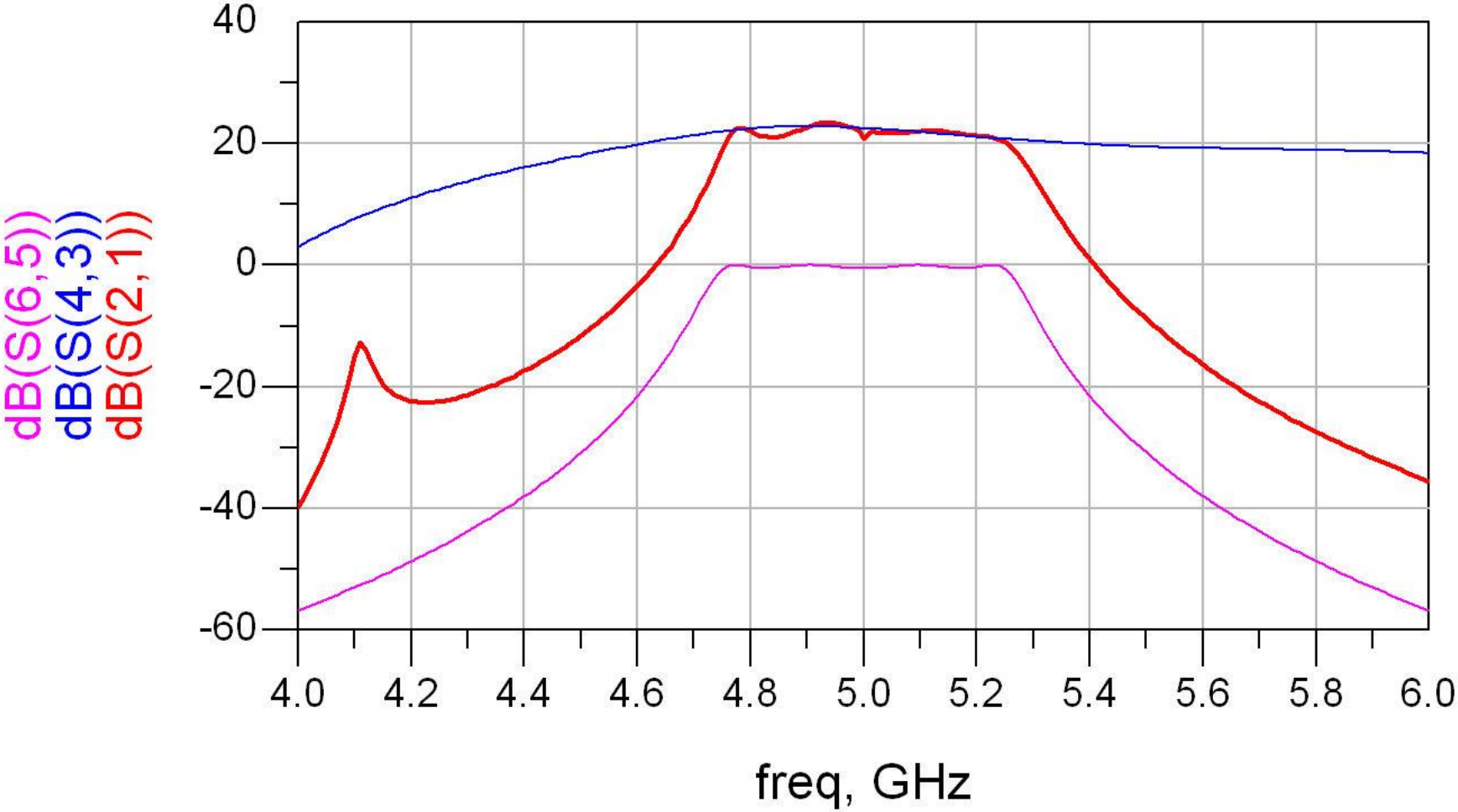
- scopul: echilibrarea caracteristicii amplificatorului (maxim la frecventa centrala)
  - se prefera reglarea lungimii liniilor de la iesirea amplificatorului
    - micsorarea afectarii zgomotului



Reglaj -> echilibrare, efect



Amplificator, Filtru, Total



Implementare cu linii microstrip

- linii microstrip
  - strat dielectric
  - metalizare totala (plan de masa)
  - trasee care fixeaza
    - impedanta caracteristica
    - lungime fizica/electrica

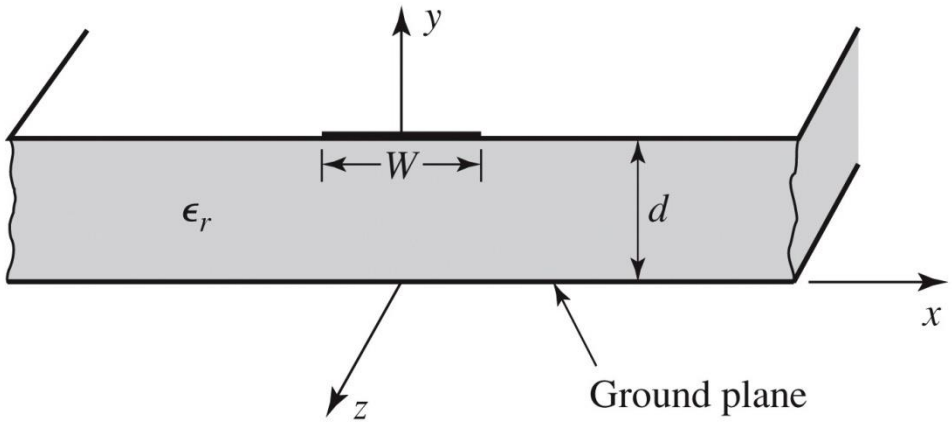


Figure 3.25a

Implementare cu linii microstrip

- Linie quasi TEM

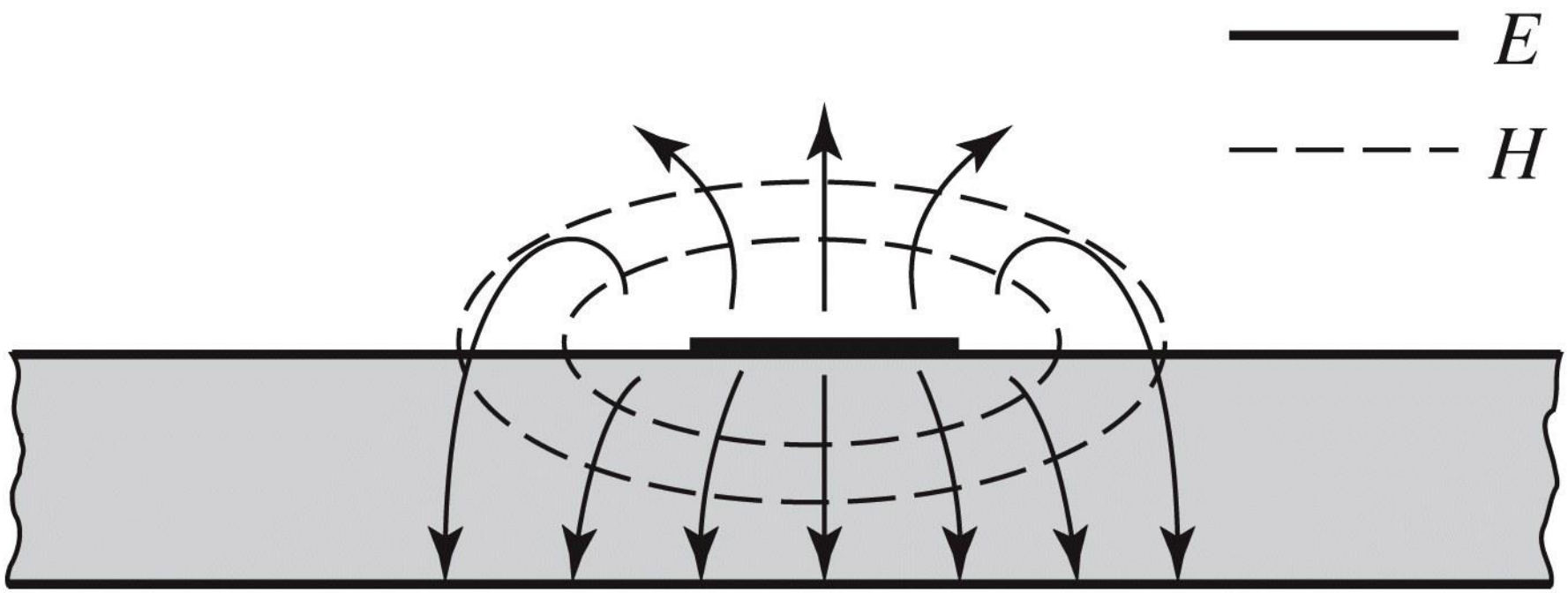
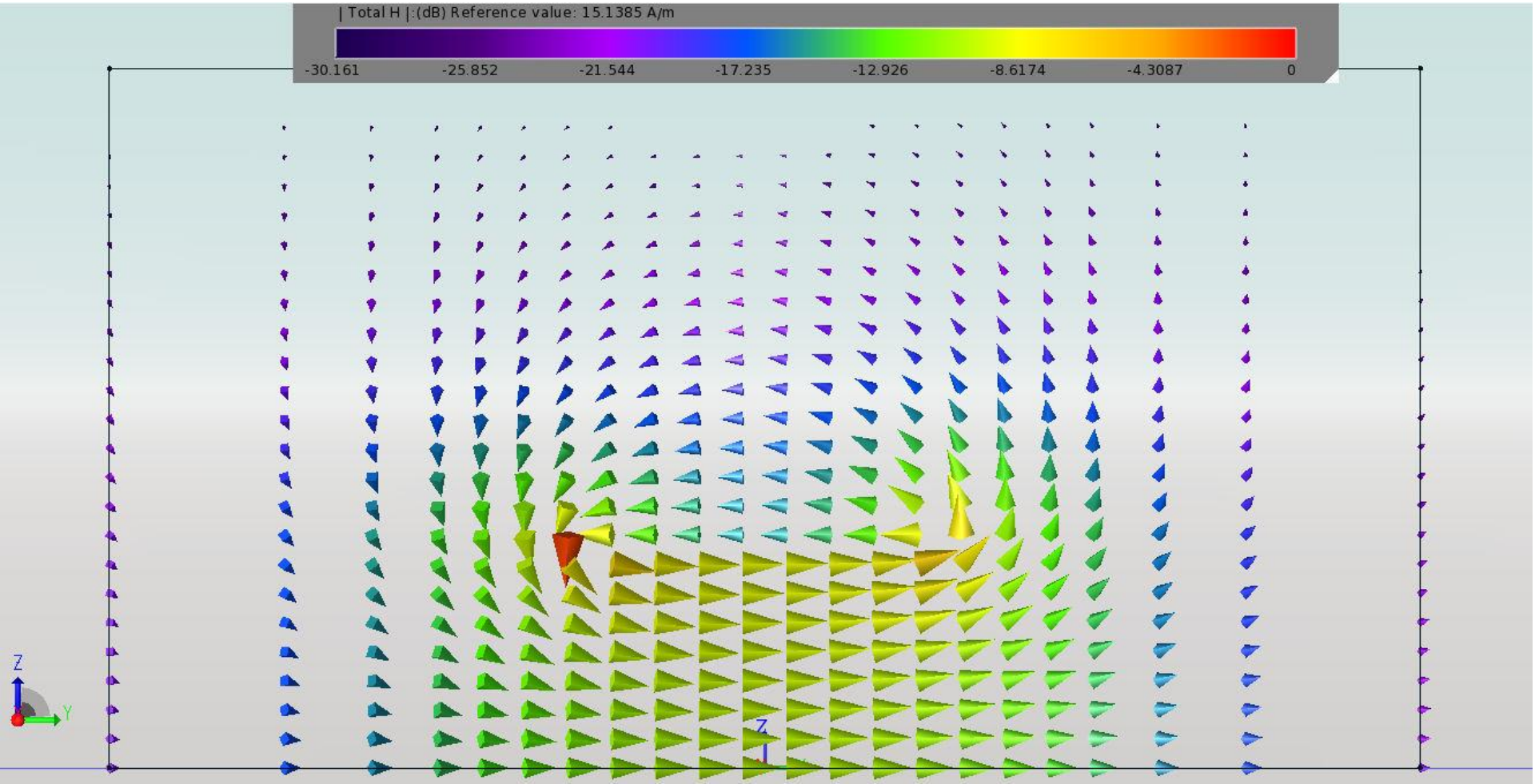


Figure 3.25b

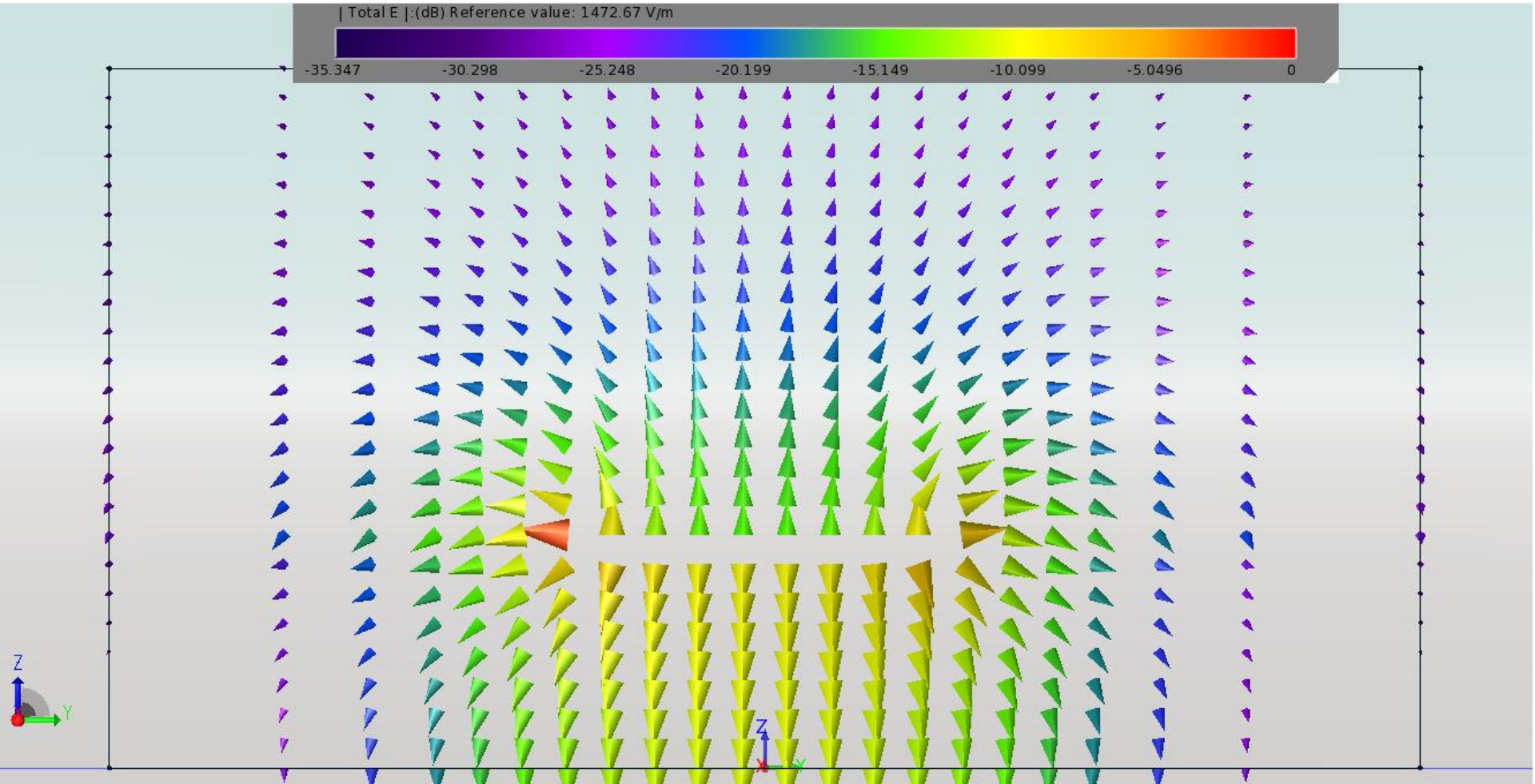
Implementare cu linii microstrip

- Linie quasi TEM, EmPro



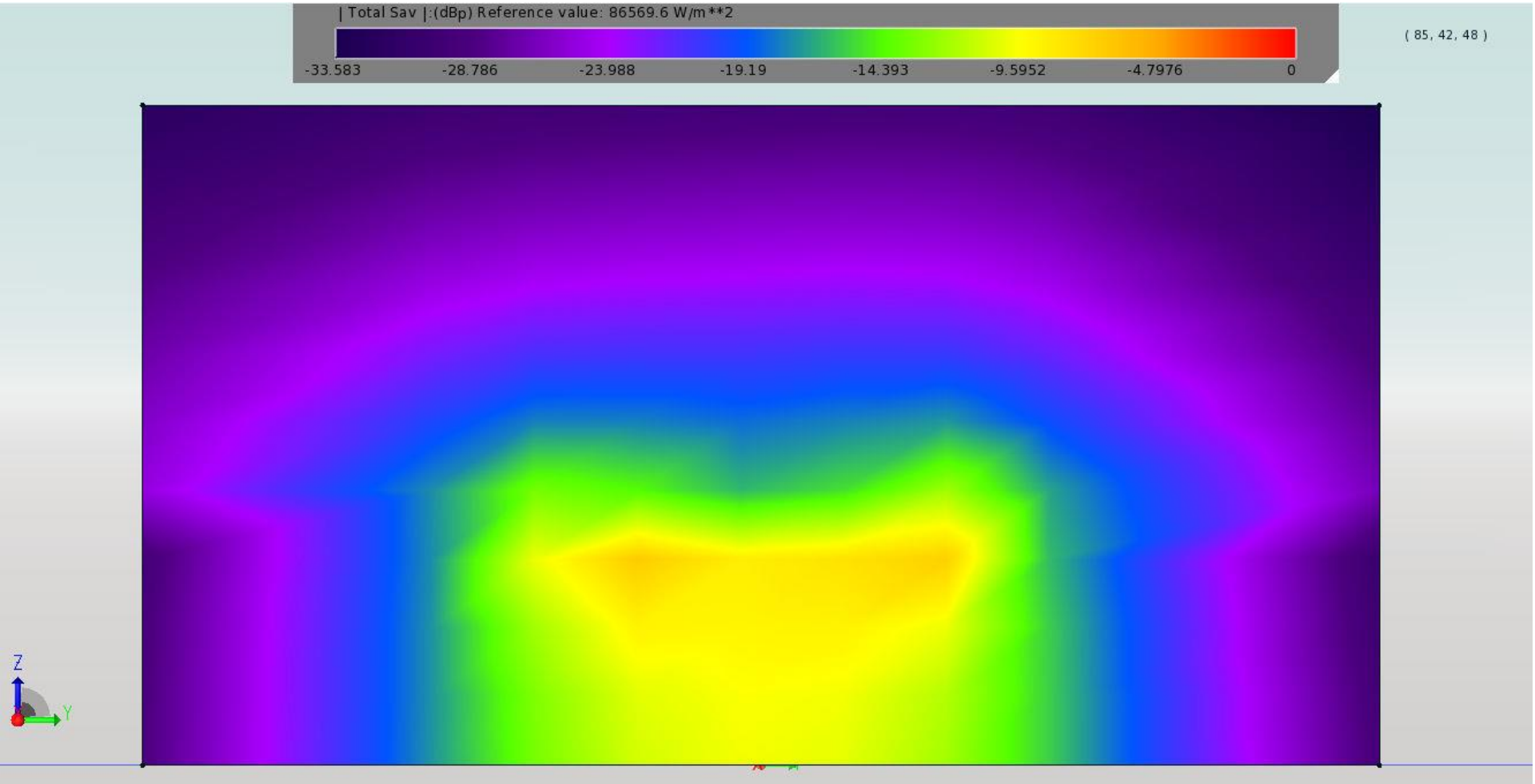
Implementare cu linii microstrip

- Linie quasi TEM, EmPro



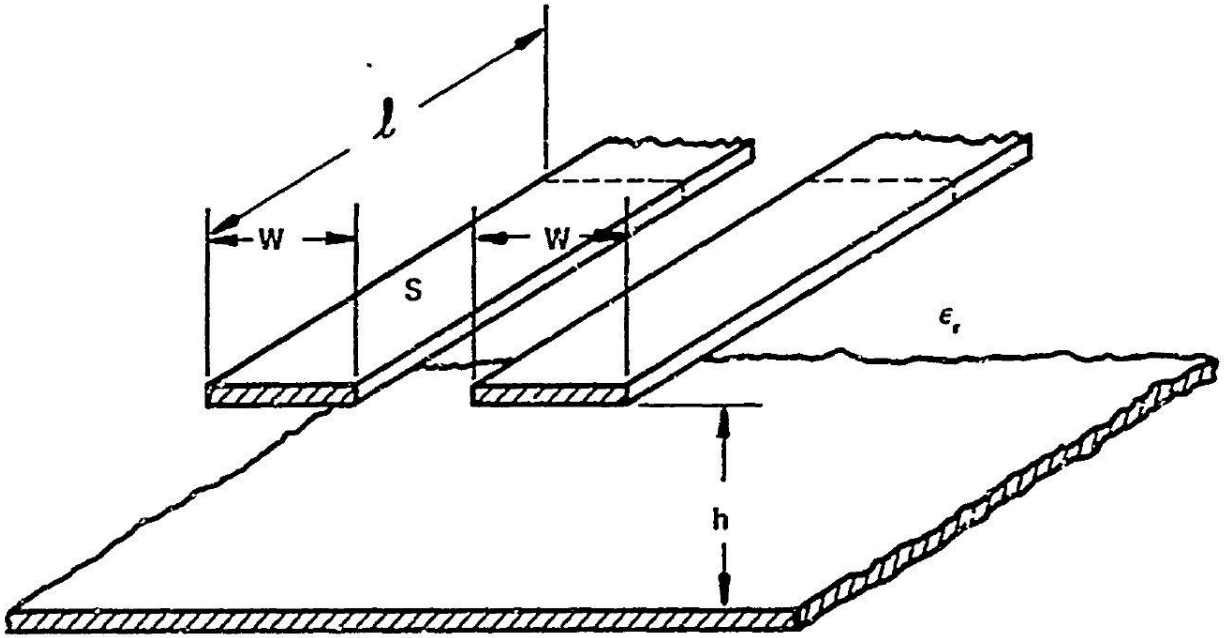
Implementare cu linii microstrip

- Linie quasi TEM, EmPro



Implementare cu linii microstrip

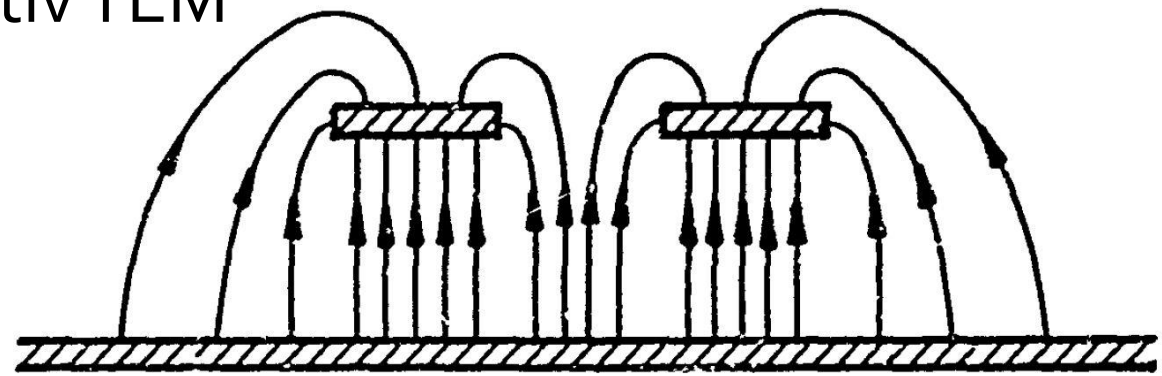
- ~ Aproximativ TEM



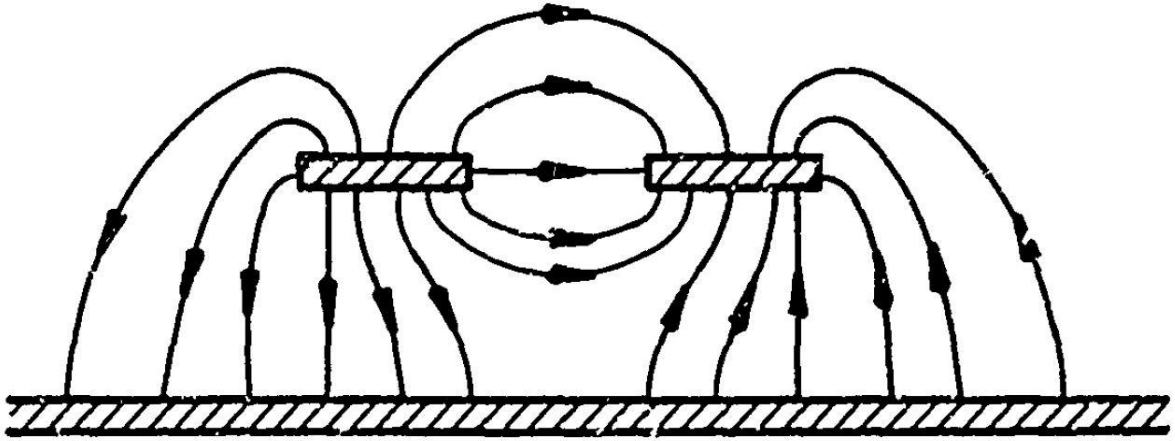
a) COUPLED STRIP GEOMETRY

Implementare cu linii microstrip

- ~ Aproximativ TEM



b) EVEN MODE ELECTRIC FIELD PATTERN (SCHEMATIC)



c) ODD MODE ELECTRIC FIELD PATTERN (SCHEMATIC)

Implementare cu linii microstrip

- Se echivaleaza linia cu o linie cu dielectric omogen echivalent

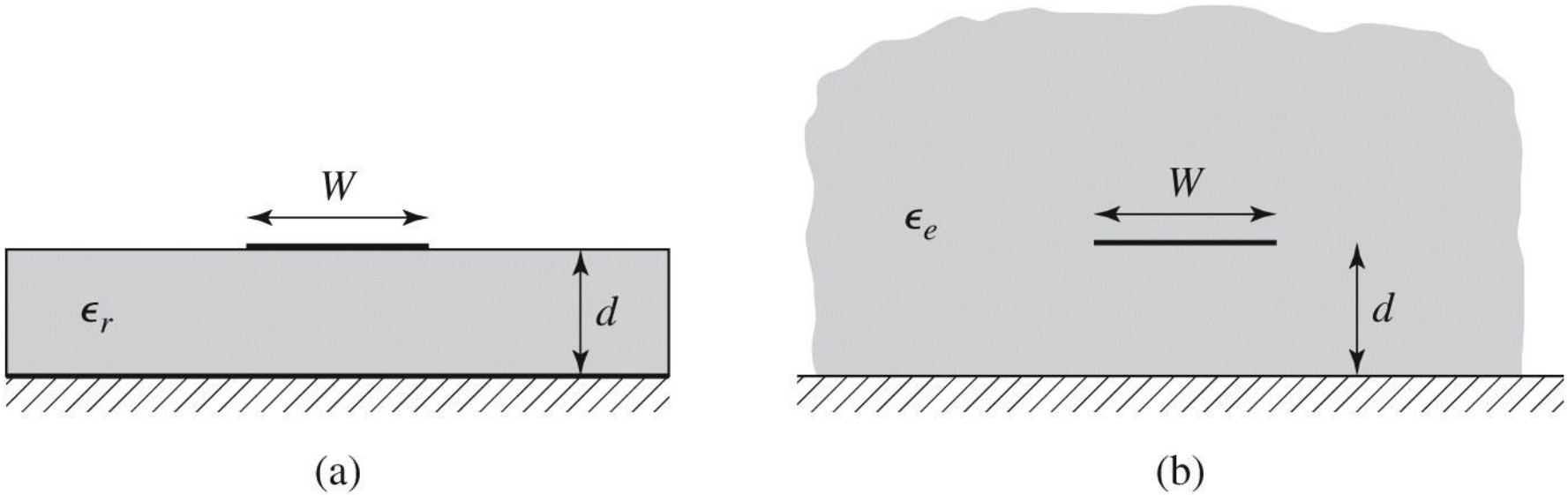


Figure 3.26

Calcul

- Calcul empiric

$$v_p = \frac{c}{\sqrt{\epsilon_e}},$$

$$\beta = k_0\sqrt{\epsilon_e},$$

$$\epsilon_e = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\frac{1}{\sqrt{1 + 12d/W}}.$$

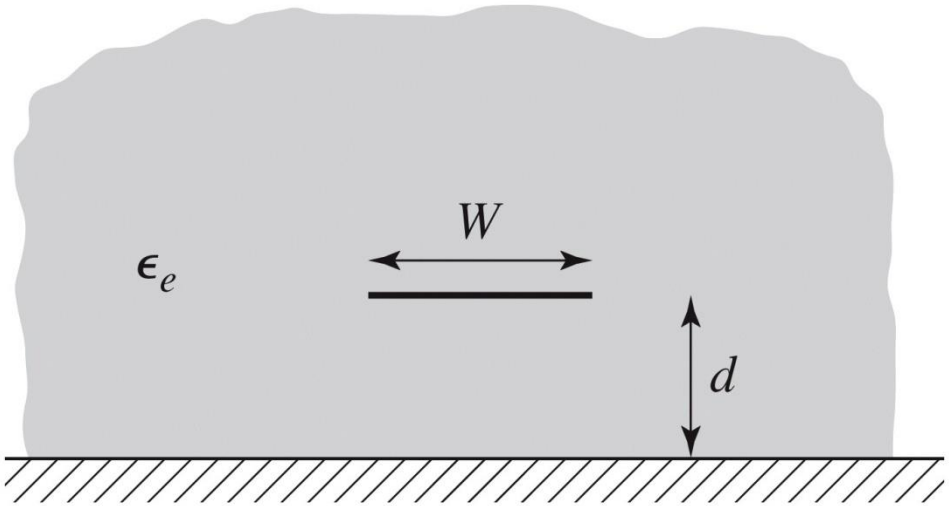


Figure 3.26b

$$Z_0 = \begin{cases} \dfrac{60}{\sqrt{\epsilon_e}} \ln\left(\dfrac{8d}{W} + \dfrac{W}{4d}\right) & \text{for } W/d \le 1 \\ \dfrac{120\pi}{\sqrt{\epsilon_e}\,[W/d + 1.393 + 0.667\ln(W/d + 1.444)]} & \text{for } W/d \ge 1. \end{cases}$$

Calcul

- Calcul empiric

$$A = \frac{Z_0}{60}\sqrt{\frac{\epsilon_r + 1}{2}} + \frac{\epsilon_r - 1}{\epsilon_r + 1}\left(0.23 + \frac{0.11}{\epsilon_r}\right)$$

$$B = \frac{377\pi}{2Z_0\sqrt{\epsilon_r}}.$$

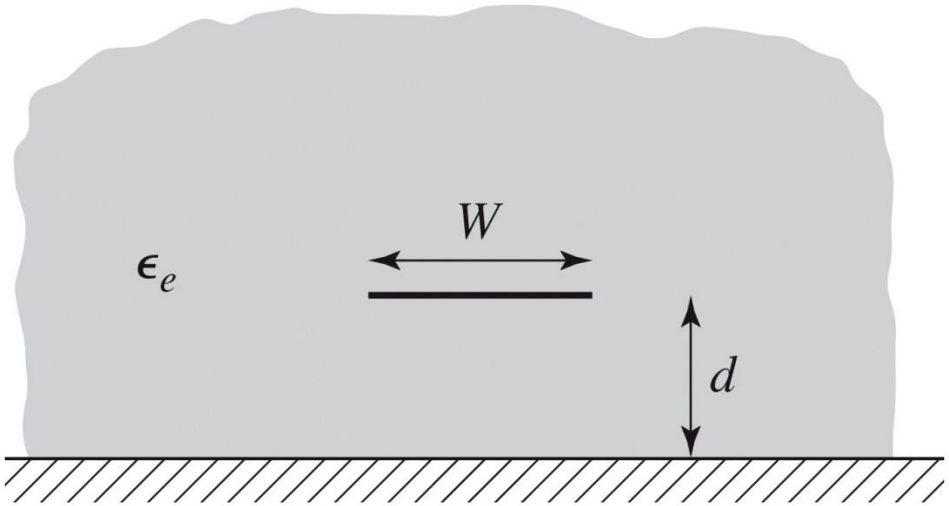
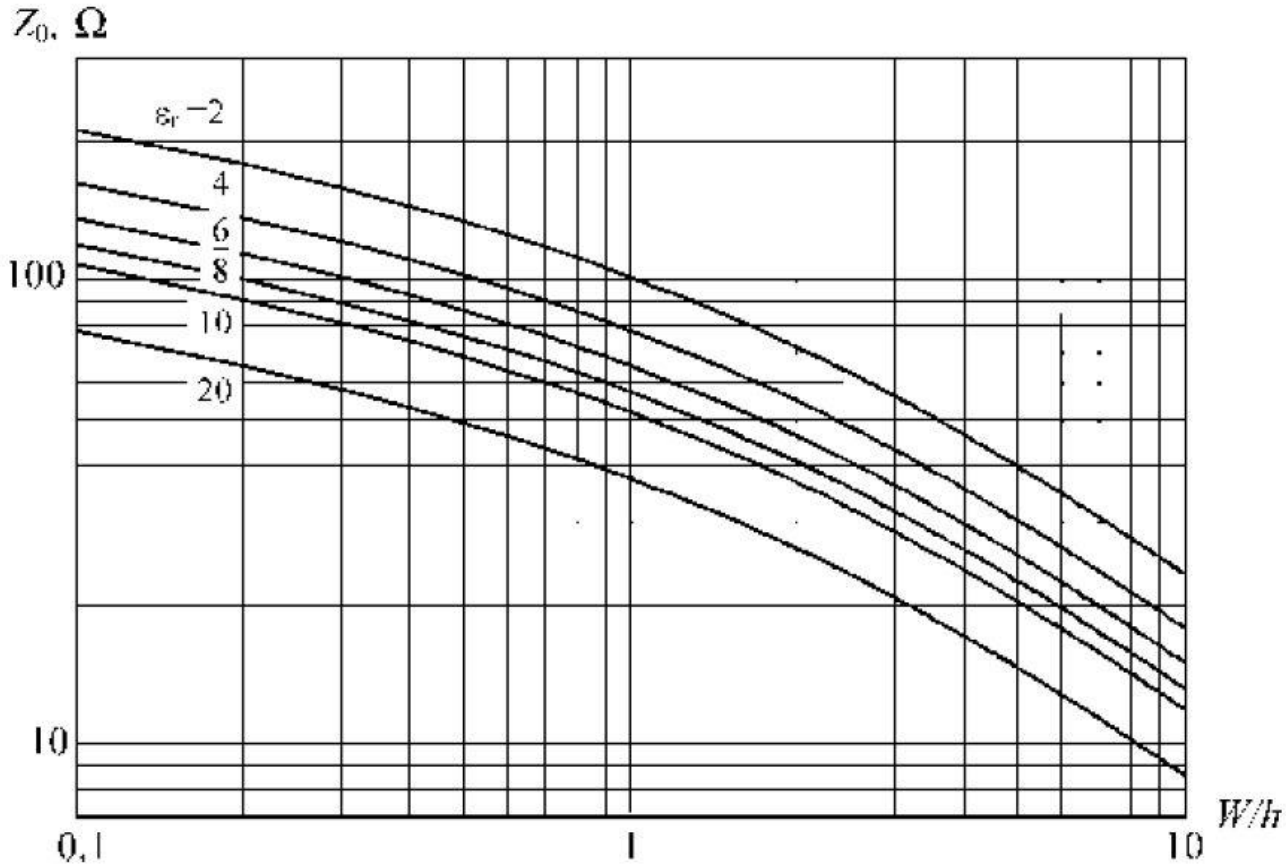


Figure 3.26b

$$\frac{W}{d} = \begin{cases} \dfrac{8e^A}{e^{2A} - 2} & \text{for } W/d < 2 \\ \dfrac{2}{\pi}\left[B - 1 - \ln(2B - 1) + \dfrac{\epsilon_r - 1}{2\epsilon_r}\left\{\ln(B - 1) + 0.39 - \dfrac{0.61}{\epsilon_r}\right\}\right] & \text{for } W/d > 2, \end{cases}$$

Impedanta caracteristica

- Pentru **impedante mari** e nevoie de **latimi mici** ale traseelor
- Pentru **impedante mici** e nevoie de **latimi mari** ale traseelor



$$k_0 = \frac{2\pi f}{c}$$

$$\beta\ell = \sqrt{\epsilon_e} k_0 \ell,$$

Microstrip standardizare

- Standardizare
  - dimensiuni in **mil**
  - 1 mil = 10^{-3} inch
  - 1 inch = 2.54 cm
- Inaltimea conductoarelor
  - in functie de greutatea cuprului
  - uncii / picioare pătrate (oz/ft^2)
  - 1oz=28.35g şi 1ft=30.48cm

Greutatea cuprului depus		Grosimea stratului	
oz/ft^2	g/ft^2	inch	mm
0.5	14.175	0.0007	0.0178
1.0	28.35	0.0014	0.0356
2.0	56.7	0.0028	0.0712

Microstrip standardizare

- Tipic inaltimea straturilor de dielectric de asemenea standardizat in mil

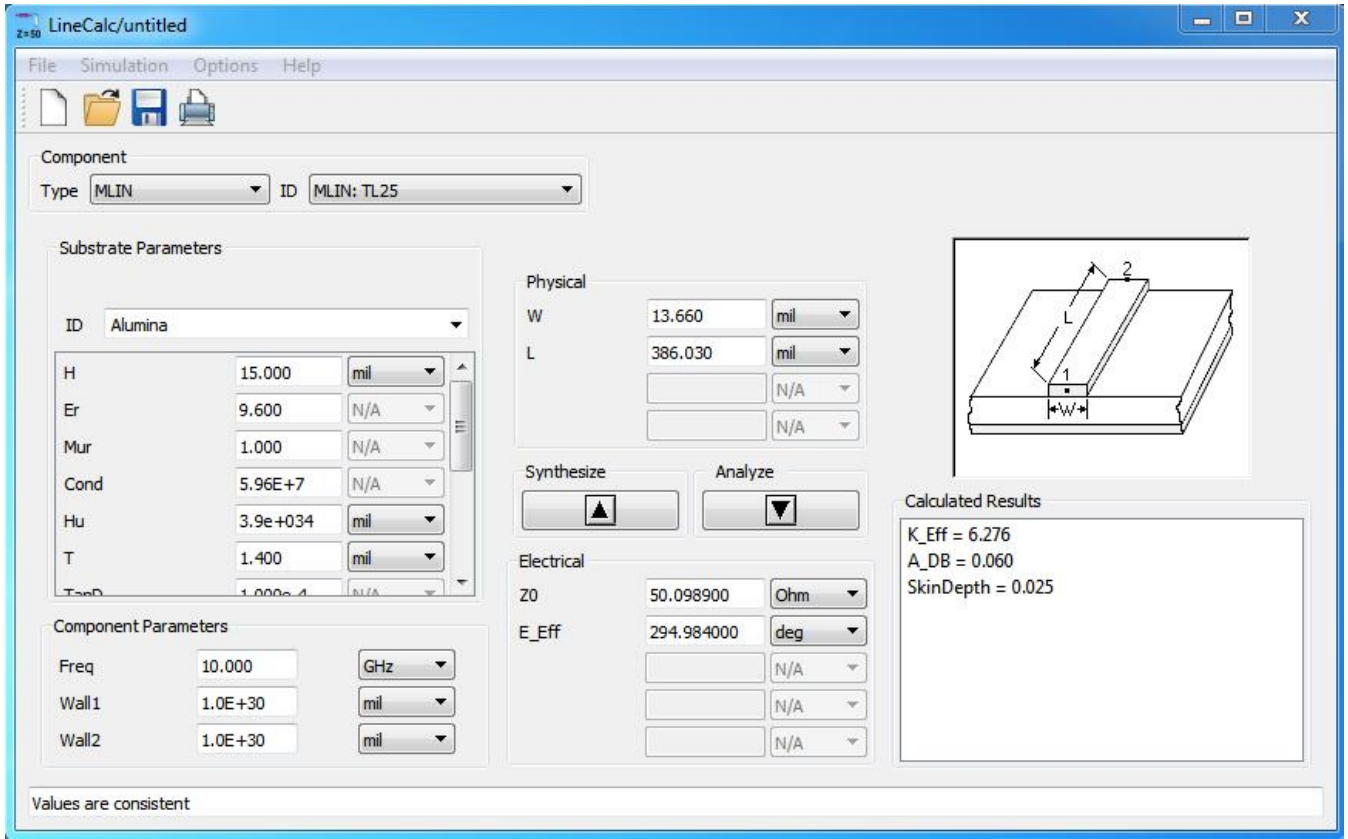
Standard Thickness
RO4003C: 0.008" (0.203mm), 0.012 (0.305mm), 0.016" (0.406mm), 0.020" (0.508mm) 0.032" (0.813mm), 0.060" (1.524mm) **RO4350B**: *0.004" (0.101mm), 0.0066" (0.168mm) 0.010" (0.254mm), 0.0133 (0.338mm), 0.0166 (0.422mm), 0.020" (0.508mm) 0.030" (0.762mm), 0.060" (1.524mm)

Microstrip, materiale substrat

	Constanta dielectrică relativă	Factorul de pierderi dielectrice	Conductivi-tate termică	Coeficient liniar de expansiune	Coeficient de temperatură a lui ε_r
Material	-	-	W/cm/K	ppm/K	ppm/K
Al_2O_3 (99.5%)	9.8	0.0001	0.37	6.3	+136
Al_2O_3 (96%)	9.4	0.001	0.35	6.4	-
Safir	9.4;11.6	0.0001	0.42	6.0	+110-+140
Sticlă quarț	3.78	0.0001	0.017	0.55	+13
Sticlă Corning 7059	5.75	0.0036	0.012	4.6	-
BeO Ceramic (98%)	6.3	0.006	2.1	6.1	+107
TiO_2	85	0.004	0.05	7.5	-575
Tetratitanat de Ba ($BaTi_4O_9$)	37	0.0005	0.02	9.4	-26
Zirconat	20-40	0.002	-	5.0	-130-+100
GaAs	12.9	0.002	0.46	5.7	-
Si	11.9	0.015	1.45	4.2	-
Ferită	9-16	0.001	-	-	-

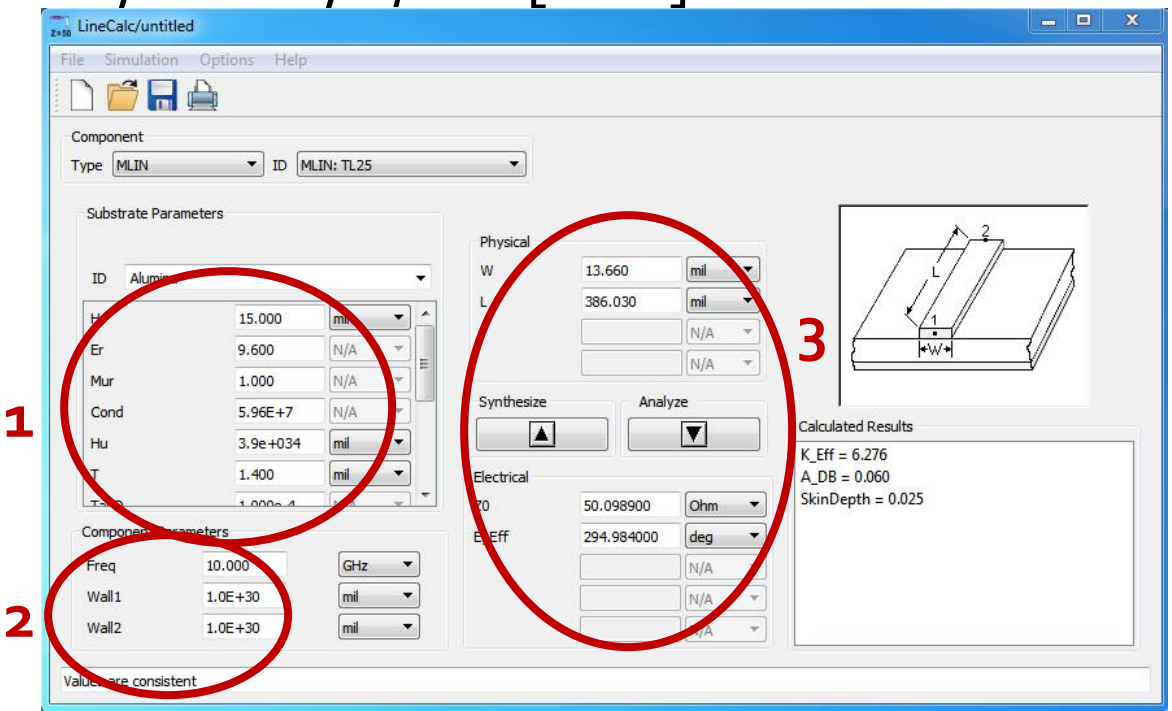
ADS linecalc

- In scheme:
  - >Tools>LineCalc>Start
  - Pentru linii Microstrip >Tools>LineCalc>Send to Linecalc



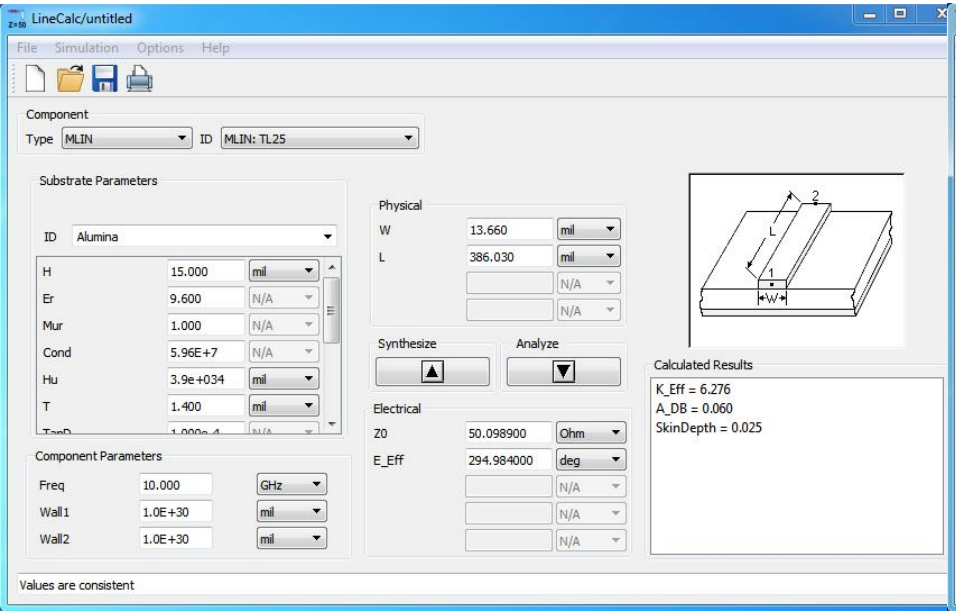
ADS linecalc

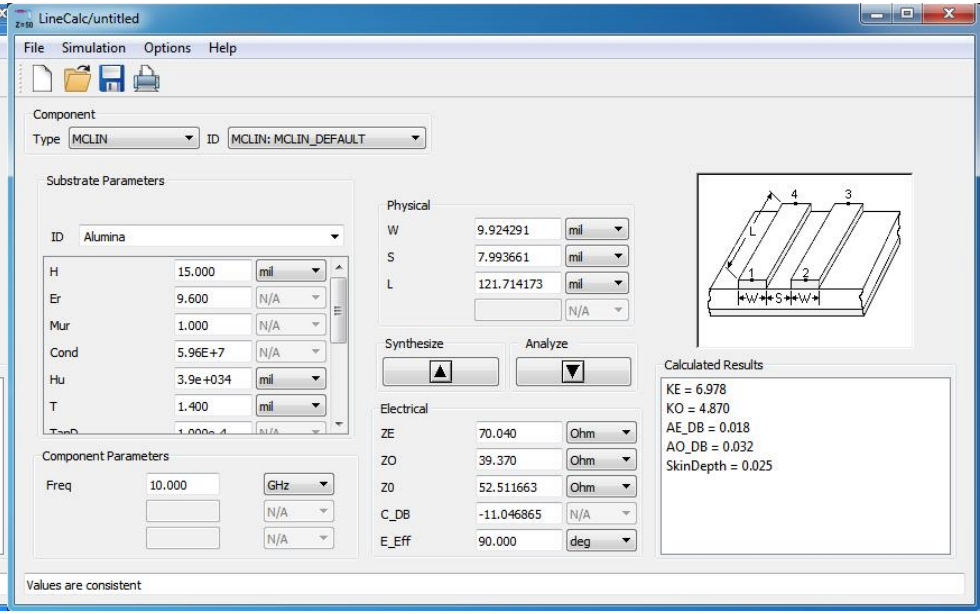
- 1. Definire (receptie din schema) substrat
- 2. Introducere frecventa
- 3. Introducere date de intrare
  - Analiza: W,L → Zo,E sau Ze,Zo,E / la f [GHz]
  - Sinteza: Zo,E → W,L / la f [GHz]



ADS linecalc

- Se poate utiliza pentru:
  - linii microstrip MLIN: W,L ⇔ Zo,E
  - linii cuplate microstrip MCLIN: W,L ⇔ Ze,Zo,E





ADS linecalc

LineCalc/untitled

File Simulation Options Help

Component

Type MCLIN ID MCLIN: MCLIN_DEFAULT

Substrate Parameters

ID Alumina

H	15.000	mil
Er	9.600	N/A
Mur	1.000	N/A
Cond	5.96E+7	N/A
Hu	3.9e+034	mil
T	1.400	mil
TanD	1.000e-4	N/A

Component Parameters

Freq	10.000	GHz
		N/A
		N/A

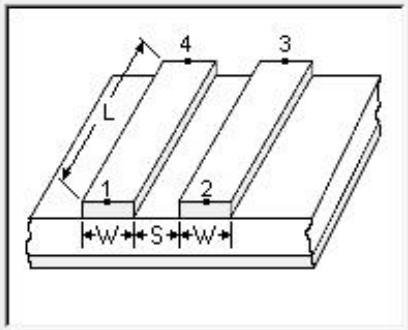
Physical

W	9.924291	mil
S	7.993661	mil
L	121.714173	mil
		N/A

Synthesize Analyze

Electrical

ZE	70.040	Ohm
ZO	39.370	Ohm
Z0	52.511603	Ohm
C_DB	-11.046865	N/A
E_Eff	90.000	deg



Calculated Results

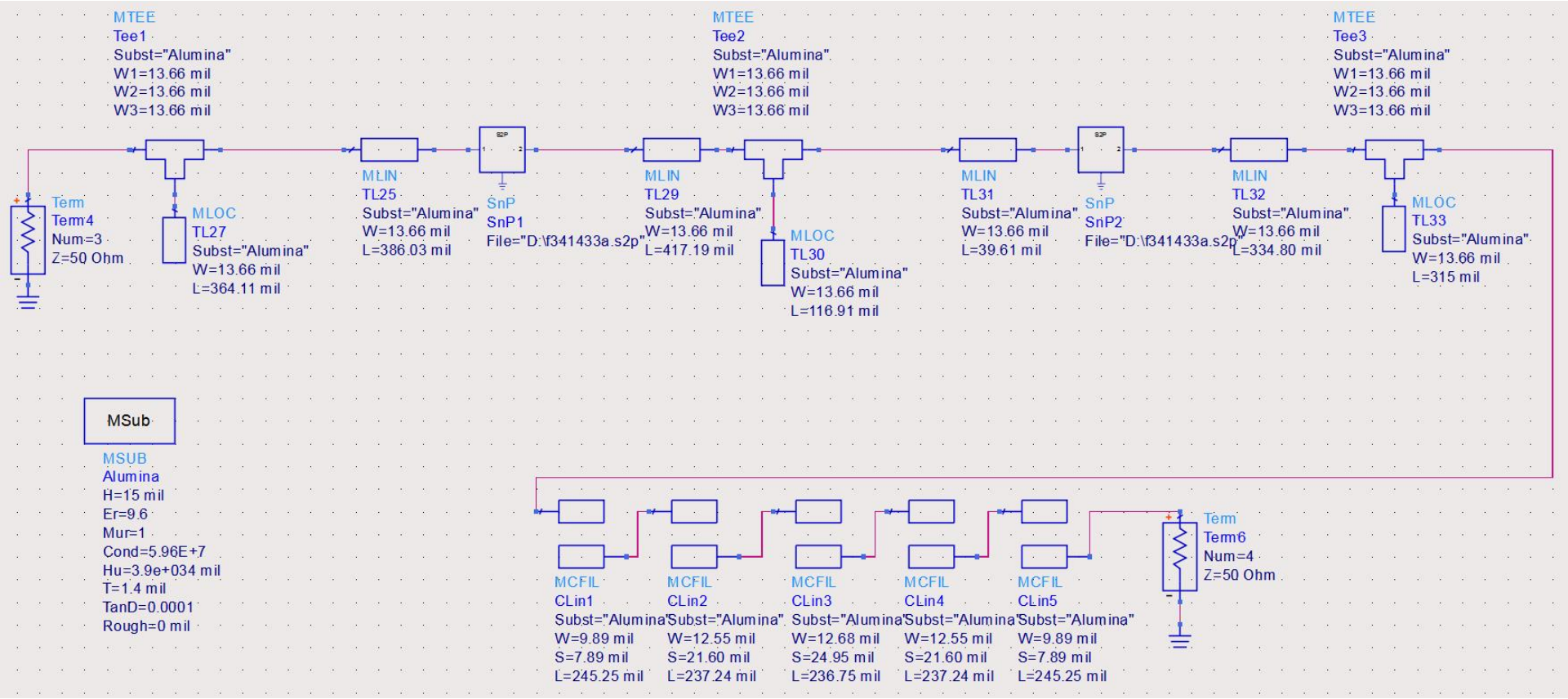
KE = 6.978
KO = 4.870
AE_DB = 0.018
AO_DB = 0.032
SkinDepth = 0.025

Values are consistent

Linii de transmisie

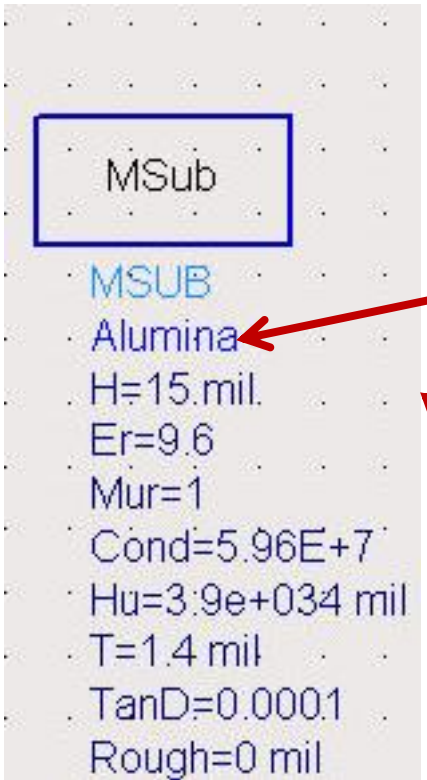
- http://rf-opto.etti.tuiasi.ro
- linii de transmisie Rogers
  - relatii dependente de
    - t, inaltimea metalizarilor
    - f, frecventa
  - relatii pentru
    - microstrip
    - strip
    - linii cuplate

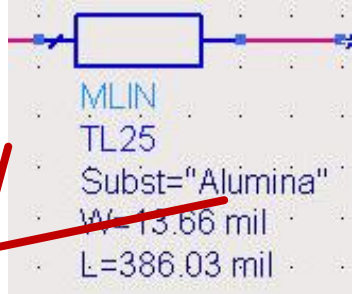
Implementare cu linii microstrip

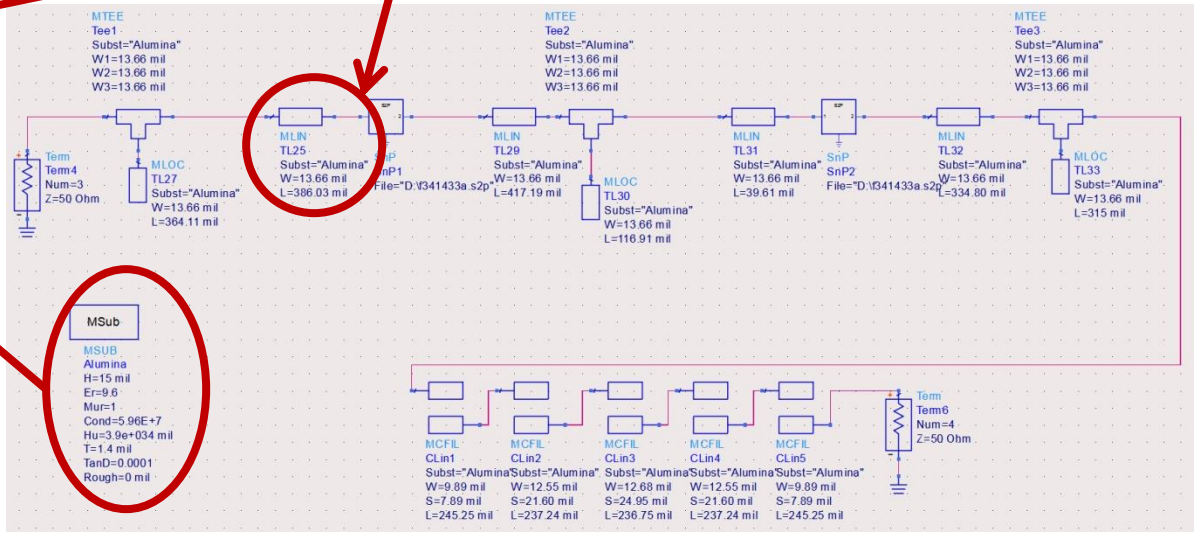


Implementare cu linii microstrip

- Se introduce modelul de substrat
- Liniile/liniile cuplate se calculeaza cu Linecalc pentru acelasi substrat





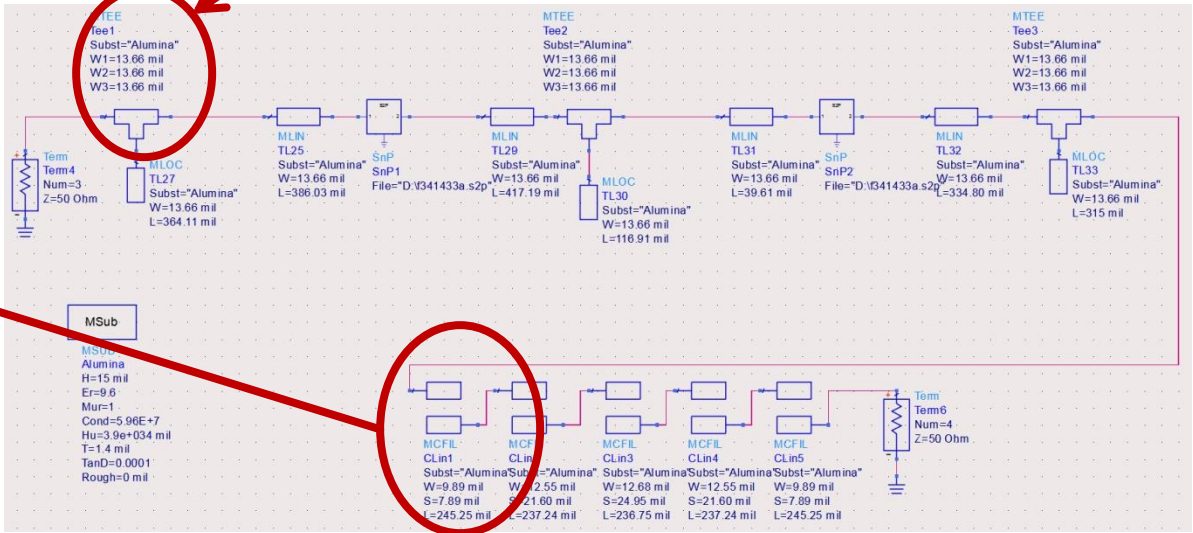


Implementare cu linii microstrip

- Se folosesc componente din paleta Transmission Lines – Microstrip
  - MSUB - substrat
  - MLIN – linie serie
  - MLOC – stub paralel in gol
  - MTEE – modelare conexiune cu stub in paralel
  - MCFIL – sectiune de filtru cu linii cuplate (alternativa mai precisa decat MCLIN – se tine cont de faptul ca doua sectiuni succesive sunt in fizic alaturate)

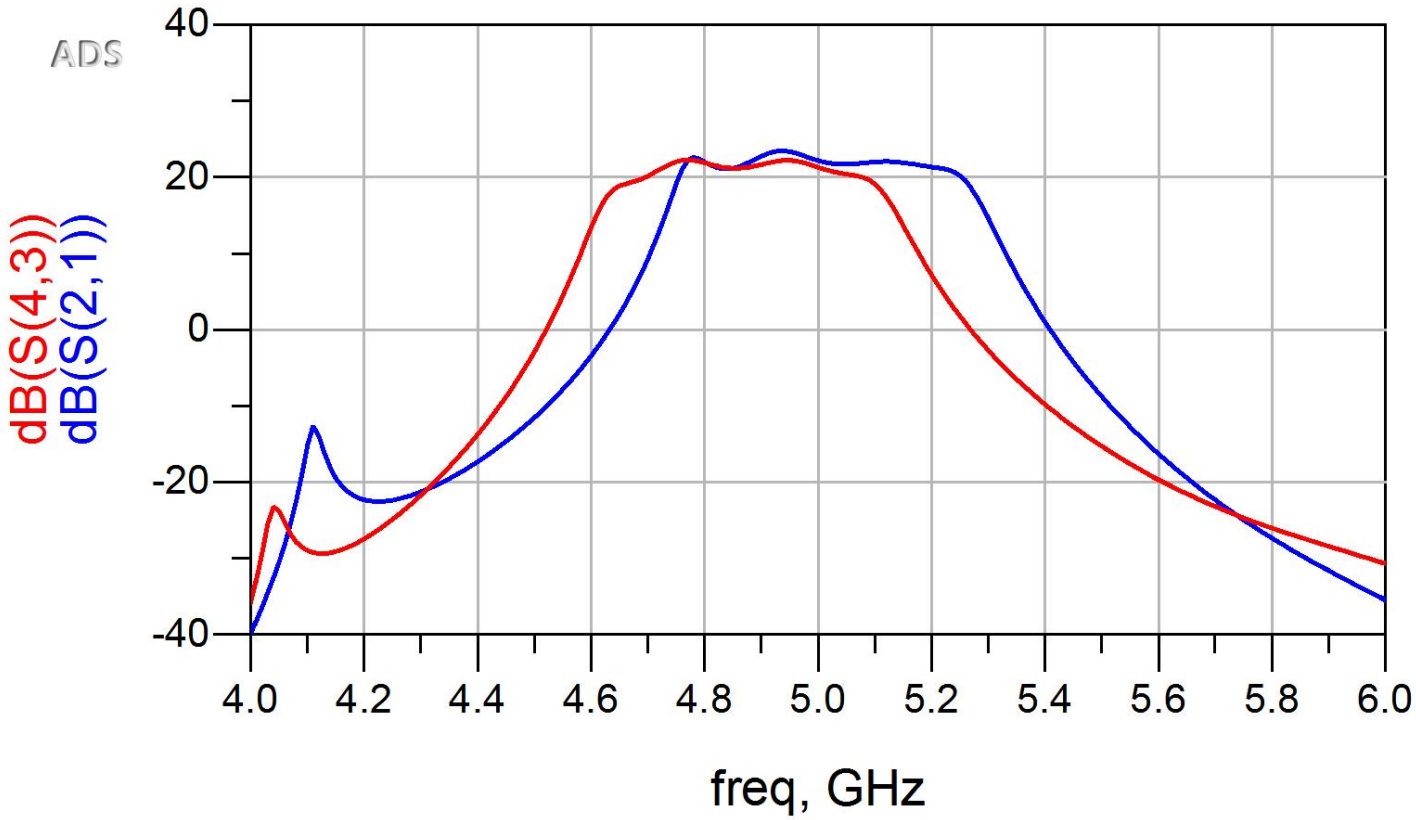
Implementare cu linii microstrip

- E necesara atentie la completarea parametrilor pentru MTEE si MCFIL prin verificarea in schema a latimii liniilor conectate la fiecare terminal



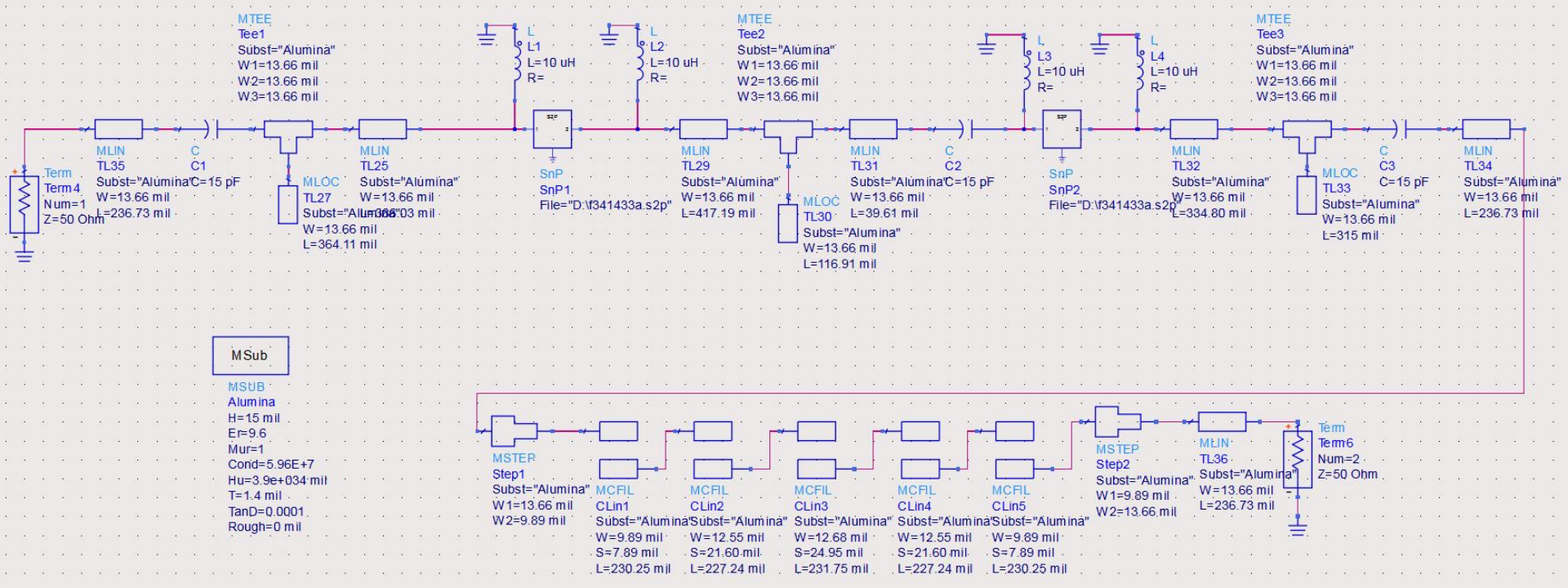
Implementare cu linii microstrip
Rezultat

- Se constata o deplasare a benzii obtinute (albastru) spre frecvente mai mici fata de modelele ideale (rosu)
  - datorat diferentei MCFIL / MCLIN

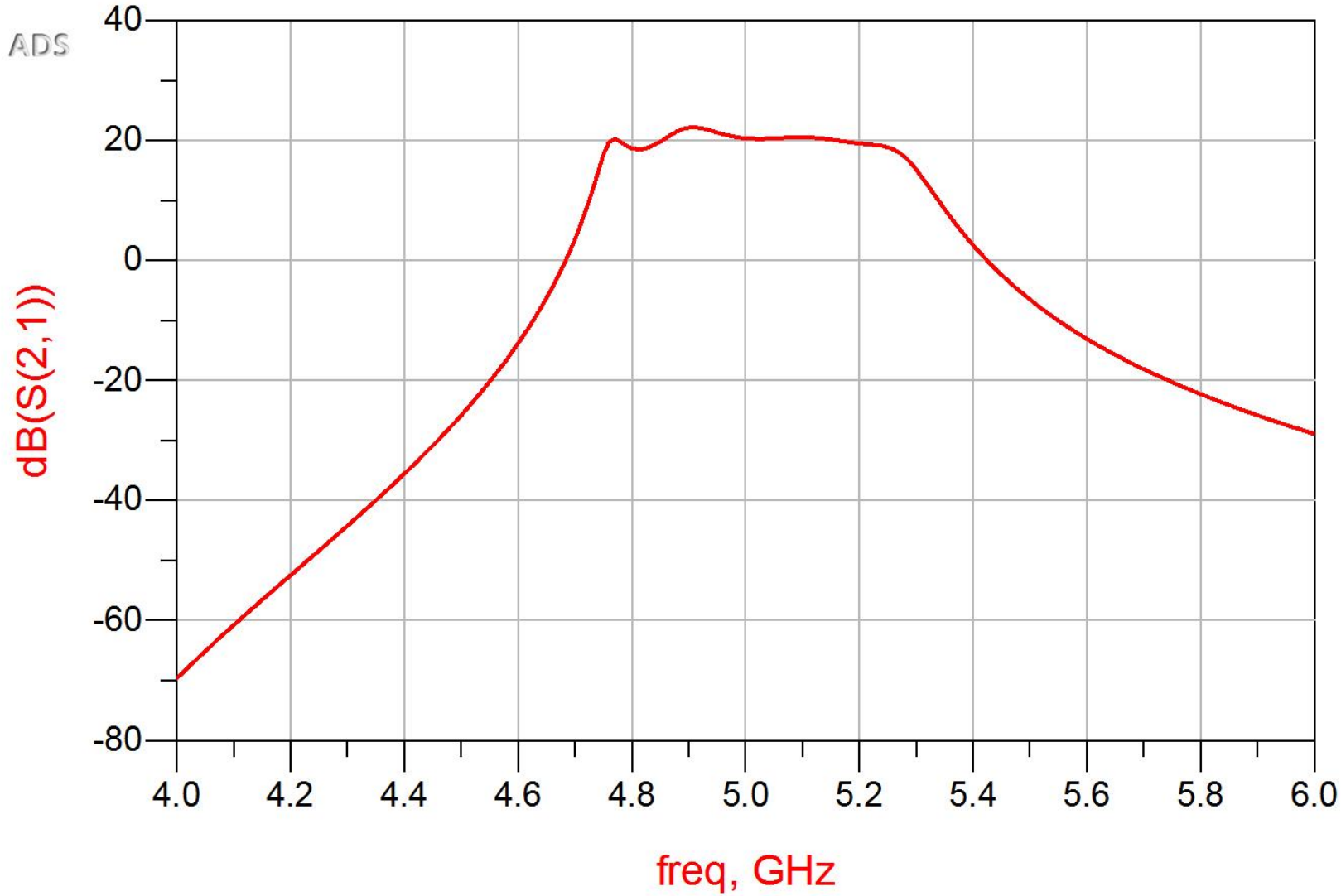


Introducere elemente de polarizare

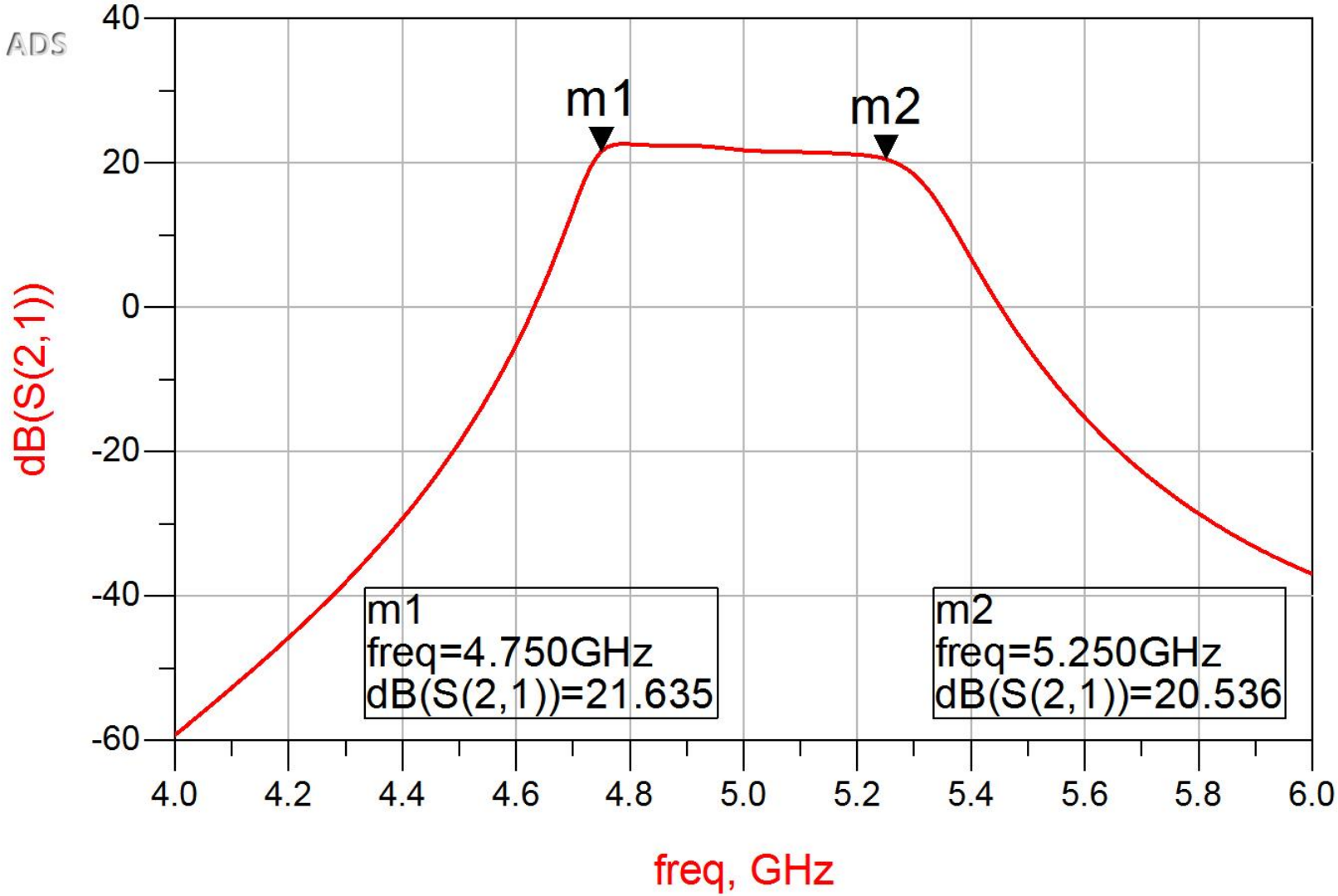
- Reglaj de lungimi la elementele filtrului pentru reglarea frecventelor in jurul fo = 5GHz
- Introducere L (soc RF) si C (decuplare)



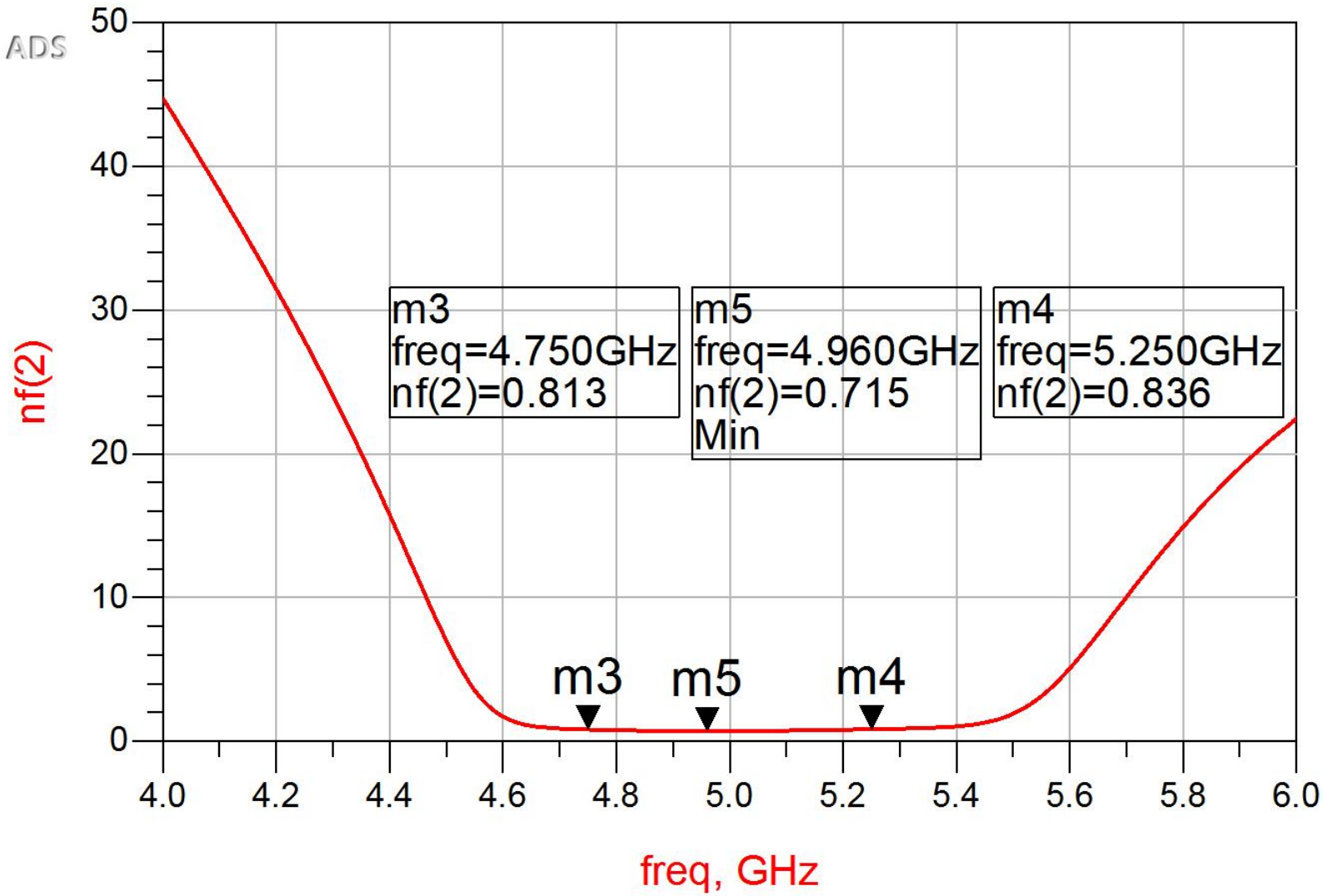
Castig -> Reglaj/Optimizare



Rezultat final (Castig)

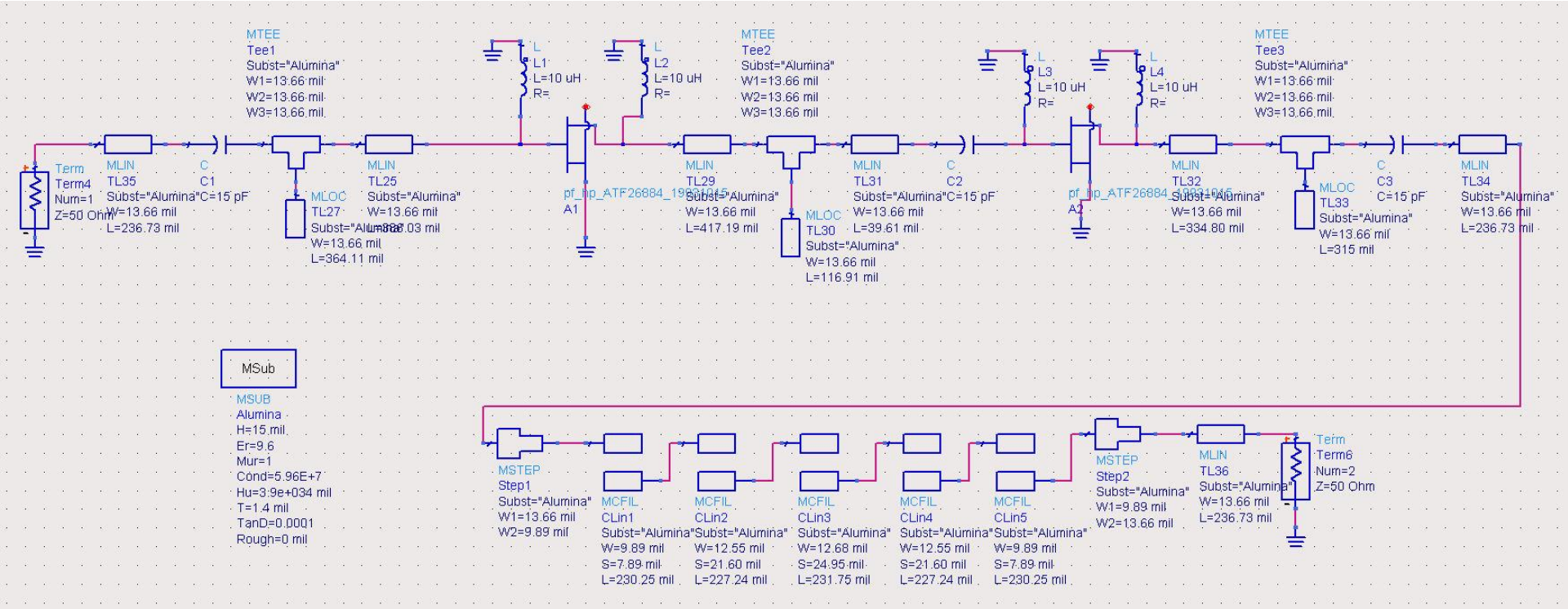


Rezultat final (Zgomot)

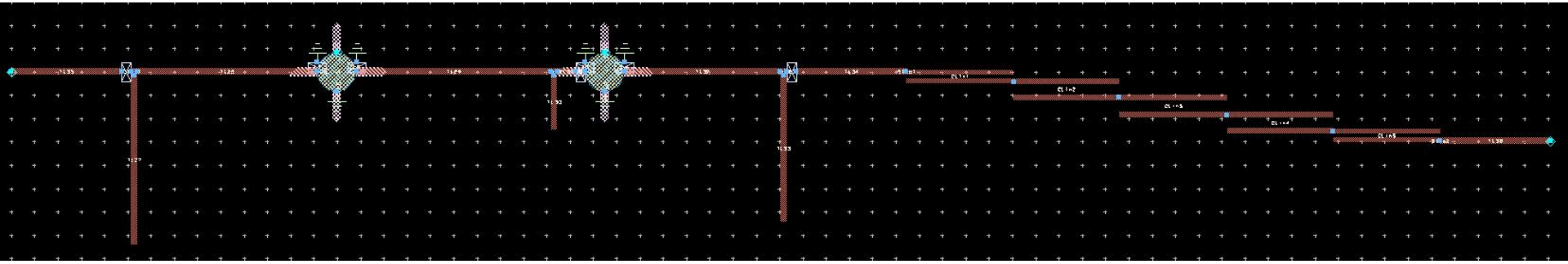


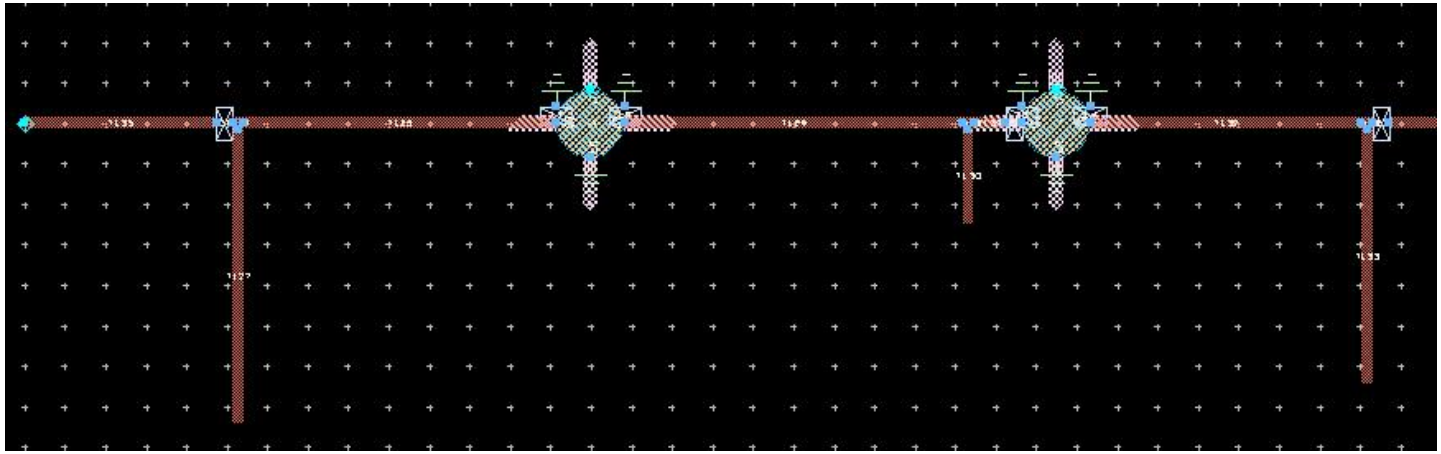
Layout (Exemplu)

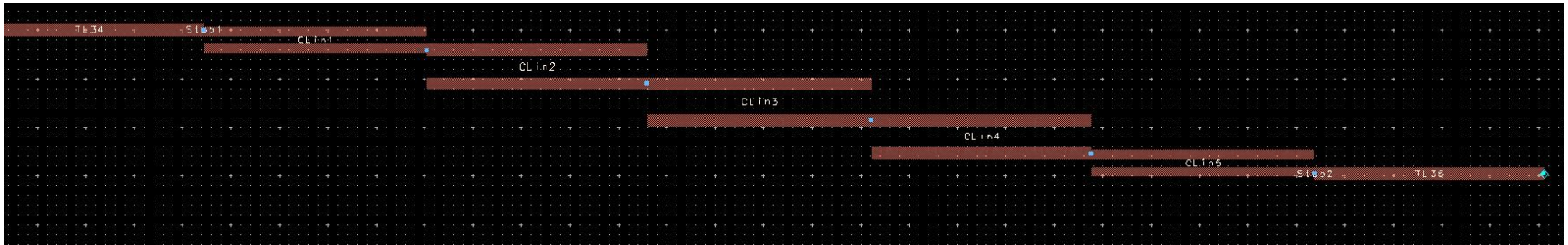
- Inlocuirea (fictiva) a tranzistoarelor si elementelor concentrate (LC) cu elemente pentru care ADS are informatii despre capsule



Layout (Exemplu)







Examen

Probleme

Istoric

Other data

Manual examen on-line (pdf, 2.65 MB, ro,)
Online Exam manual (pdf, 2.56 MB, en,)
Simulare Examen (video) (mp4, 65.12 MB, ro,)
DCMR Curs 3 Linii de transmisie (video) (mp4, 174.88 MB, ro,)
DCMR Curs 4 Adaptare de impedanta (video) (mp4, 206.99 MB, ro,)
DCMR Curs 5 Analiza de retea (video) (mp4, 196.2 MB, ro,)
DCMR Curs 6 Analiza de retea (Divizoare/Cuploare) (mp4, 214.04 MB, ro,)
DCMR Curs 7 Diagrama Smith, Adaptare de impedanta (video) (mp4, 331.63 MB, ro,)
DCMR Curs 8 Amplificatoare (video) (mp4, 460.75 MB, ro,)
DCMR Curs 10 Supliment Proiect (video) (mp4, 192.23 MB, ro,)
Exemplu Proiect 2020 (pdf, 2.49 MB, ro,)
Indicatii Proiect 1 Online (2020) (pdf, 1.82 MB, ro,)
Note de aplicatii importante - Agilent (rar, 2.36 MB, ro,)
Liniii de transmisie - Rogers (rar, 84.4 KB, ro,)

Previous years

2022-2023 | 2021-2022 | 2020-2021 | 2019-2020 | 2018-2019 | M

Server-ul "rf-opto" pastreaza istoricul materialelor pentru anii anteriori
Alegeti anul recent corespunzator pentru vizualizare sau "More years" pentru a afisa mai multi ani din istoric

Istoric 2009 - 2023

DCMR Curs 7 Diagrama Smith, Adaptare de impedanta (video) (mp4, 331.63 MB, ro,)
DCMR Curs 8 Amplificatoare (video) (mp4, 460.75 MB, ro,)
DCMR Curs 10 Supliment Proiect (video) (mp4, 192.23 MB, ro,)
Exemplu Proiect 2020 (pdf, 2.49 MB, ro,)
Indicatii Proiect 1 Online (2020) (pdf, 1.82 MB, ro,)
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Liniii de transmisie - Rogers (rar, 84.4 KB, ro,)

Previous years

2022-2023 | 2021-2022 | 2020-2021 | **2019-2020** | 2018-2019 | More years...

Microwave Devices and Circuits for Radiocommunications (English)

Course: MDCR (2019-2020)

Course Coordinator: Assoc.P. Dr. Radu-Florin Damian
Code: EDOS412T
Discipline Type: DOS; Alternative, Specialty
Credits: 4
Enrollment Year: 4, **Sem.** 7

Activities

016-2017 | 2015-2016 | 2014-2015 | 2013-2014 | 2012-2013 | 2011-2012 | **2010-2011** | 2009-201

rcuits for Radiocommunications

eek, Specialization Section, Timetable:
Hours/Week, Half Group, Timetable:

Subiecte si rezolvari

- 2009 – 2023
  - in fiecare an 1-2 seturi (~50) de probleme
  - rezolvari numerice

Selection guides 2019 (zip, 3.2 MB, en,)
Tranzistoare Infineon (zip, 37.17 MB, en,)
Colectie parametri S - 2010 (7z, 9.09 MB, en,)

Examen

Examen DCMR 2021 (pdf, 1.01 MB, ro,)
Rezolvari DCMR 2021 (pdf, 1.1 MB, ro,)
Verificare proiecte 2021 (zap, 34.3 MB, en,)
Detalii notare DCMR 2021 (L, P) (htm, 10.81 KB, ro,)

Other data

Manual examen on-line (pdf, 2.65 MB, ro,)
Simulare Examen (video) (mp4, 65.12 MB, ro,)

Problema 1

- Dacă impedanța este 50.2Ω + j·46.2Ω, calculați admitanța normalizată. **(1p)**
- Dacă impedanța este 63.1Ω + j·51.7Ω, calculați admitanța normalizată. **(1p)**
- Dacă impedanța este 66.6Ω – j·67.2Ω, calculați admitanța normalizată. **(1p)**
- Dacă impedanța este 42.5Ω + j·45.3Ω, calculați admitanța normalizată. **(1p)**

Important 1

Examen

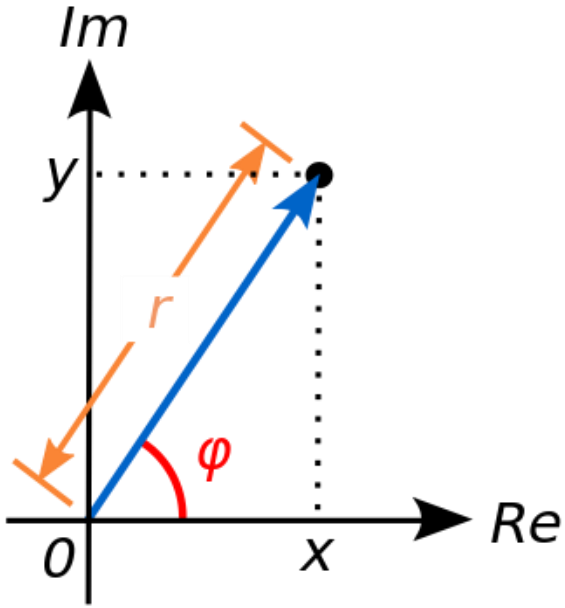
- Operatii cu numere complexe!
- $z = a + j \cdot b$; $\mathbf{j^2 = -1}$

Reprezentare polara

- Formula lui Euler

$$e^{j\cdot x} = \cos x + j\cdot \sin x; \forall x \in R$$

- Reprezentare polara



$$z = a + j\cdot b = |z|\cdot e^{j\cdot\varphi}$$

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

$$z^n = \left(|z|\cdot e^{j\cdot\varphi}\right)^n = |z|^n\cdot e^{j\cdot n\cdot\varphi} = |z|^n\cdot\left[\cos(n\cdot\varphi) + j\cdot\sin(n\cdot\varphi)\right]$$

$$\sqrt{z} = \left(|z|\cdot e^{j\cdot\varphi}\right)^{1/2} = \sqrt{|z|}\cdot e^{j\cdot\frac{\varphi}{2}} = \sqrt{|z|}\cdot\left(\cos\frac{\varphi}{2} + j\cdot\sin\frac{\varphi}{2}\right)$$

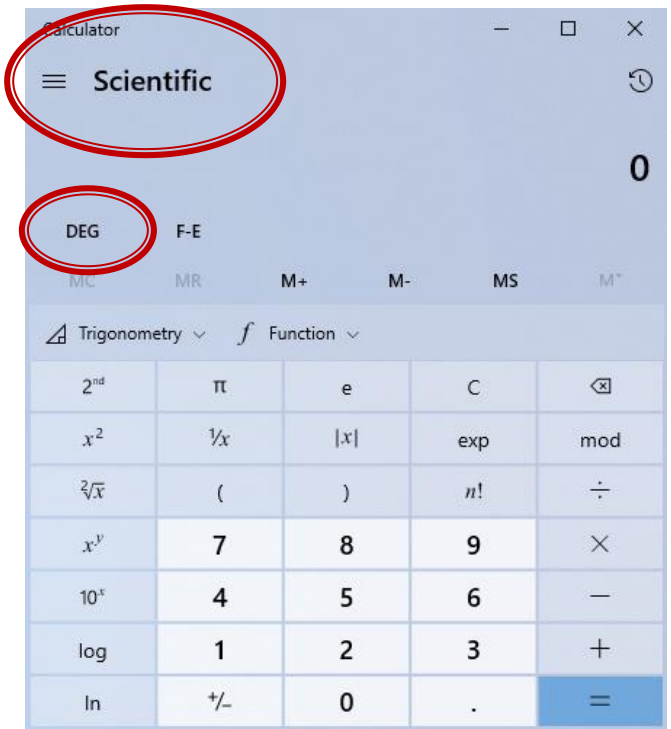
$$z\cdot w = |z|\cdot e^{j\cdot\varphi}\cdot|w|\cdot e^{j\cdot\theta} = |z|\cdot|w|\cdot e^{j\cdot(\varphi+\theta)} = |z|\cdot|w|\cdot\left[\cos(\varphi+\theta) + j\cdot\sin(\varphi+\theta)\right]$$

$$z/w = \frac{|z|\cdot e^{j\cdot\varphi}}{|w|\cdot e^{j\cdot\theta}} = \frac{|z|}{|w|}\cdot e^{j\cdot\varphi}\cdot e^{-j\cdot\theta} = \frac{|z|}{|w|}\cdot e^{j\cdot(\varphi-\theta)} = \frac{|z|}{|w|}\cdot\left[\cos(\varphi-\theta) + j\cdot\sin(\varphi-\theta)\right]$$

Reprezentare polara

- unitate de masura standard – radiani
- unitate de masura traditionala in microunde – **grade format zecimal** (55.89°)

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



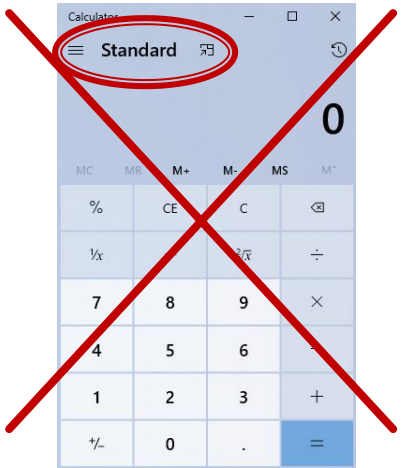
$$\varphi[°] = 180° \cdot \frac{\varphi[rad]}{\pi} \qquad \varphi[rad] = \pi \cdot \frac{\varphi[°]}{180°}$$

Reprezentare polara

- **Atentie la reprezentarea unghiurilor!!**
  - programele matematice – lucreaza standard in radiani
    - e necesara o **conversie** inainte si una dupa aplicarea unei functii trigonometrice
  - calculatoarele (stiintifice) au posibilitatea (de obicei) de a stabili unitatea de masura pentru unghiuri
    - e necesara **verificarea** unitatii de masura curente

$$\varphi[^\circ] = 180^\circ \cdot \frac{\varphi[rad]}{\pi}$$

$$\varphi[rad] = \pi \cdot \frac{\varphi[^\circ]}{180^\circ}$$



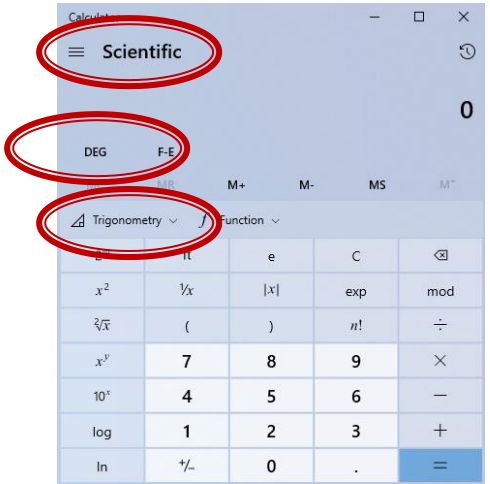


Diagrama Smith

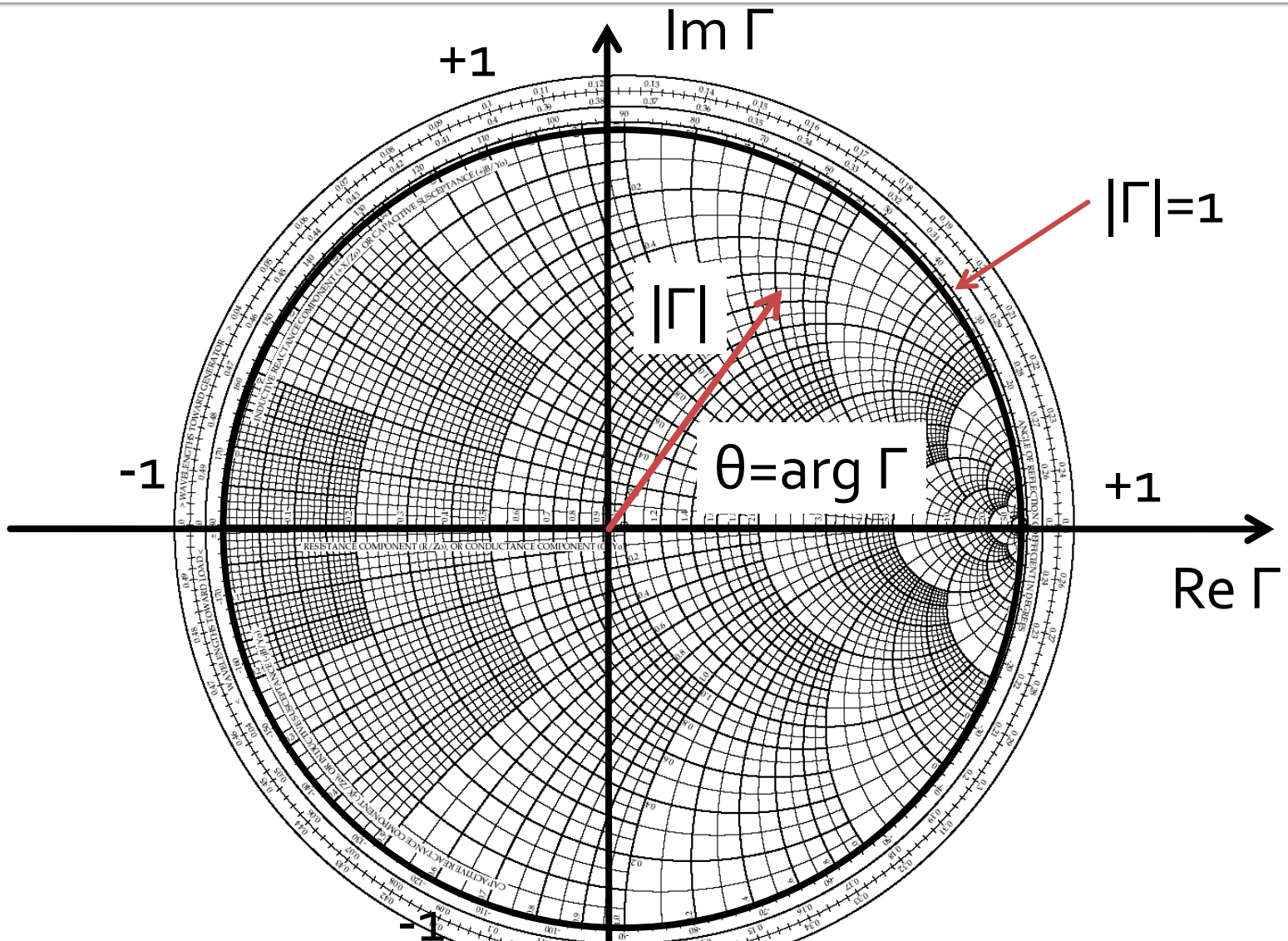
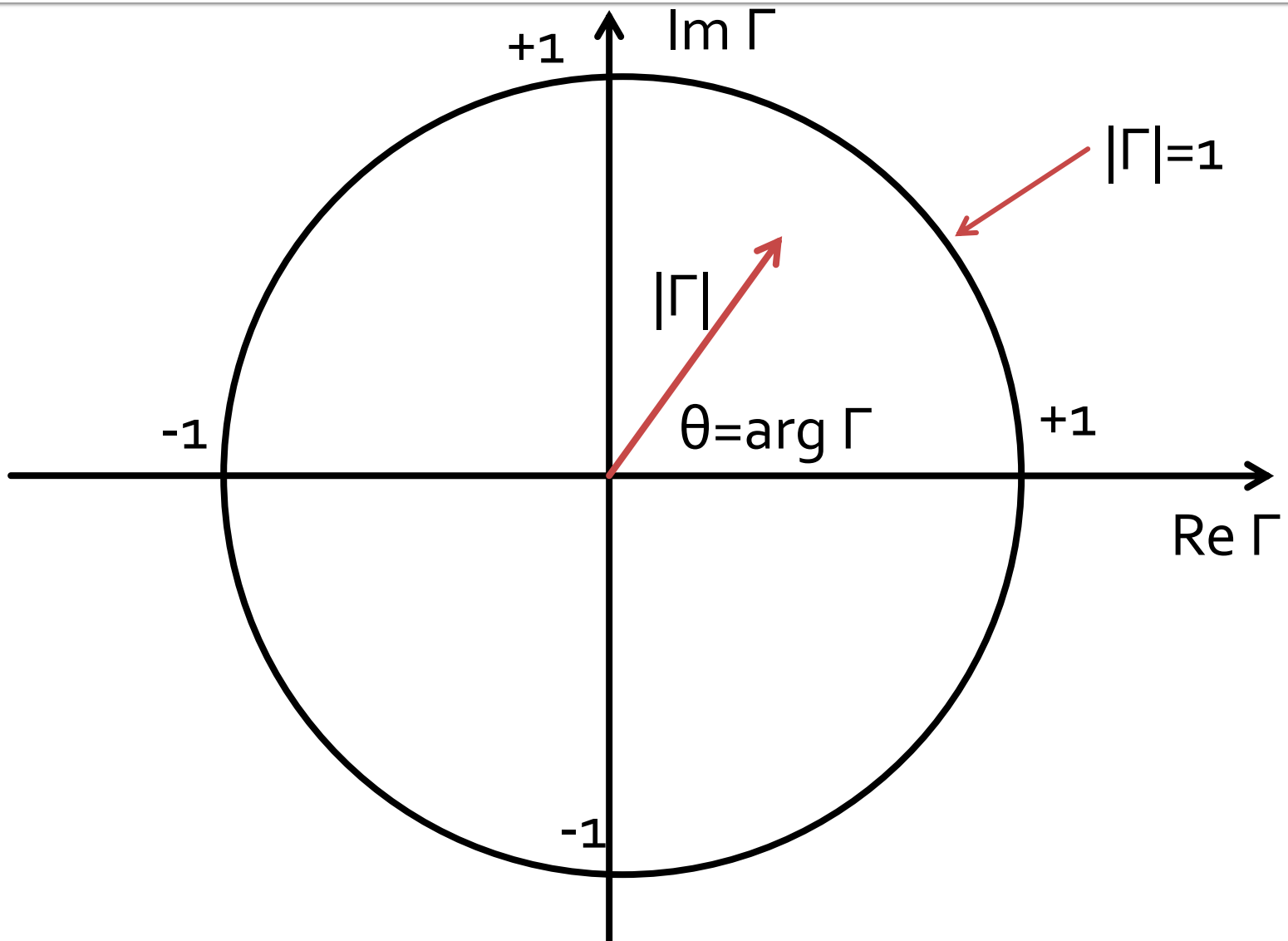


Diagrama Smith



Important 2

Reprezentare logaritmică

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

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

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

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]

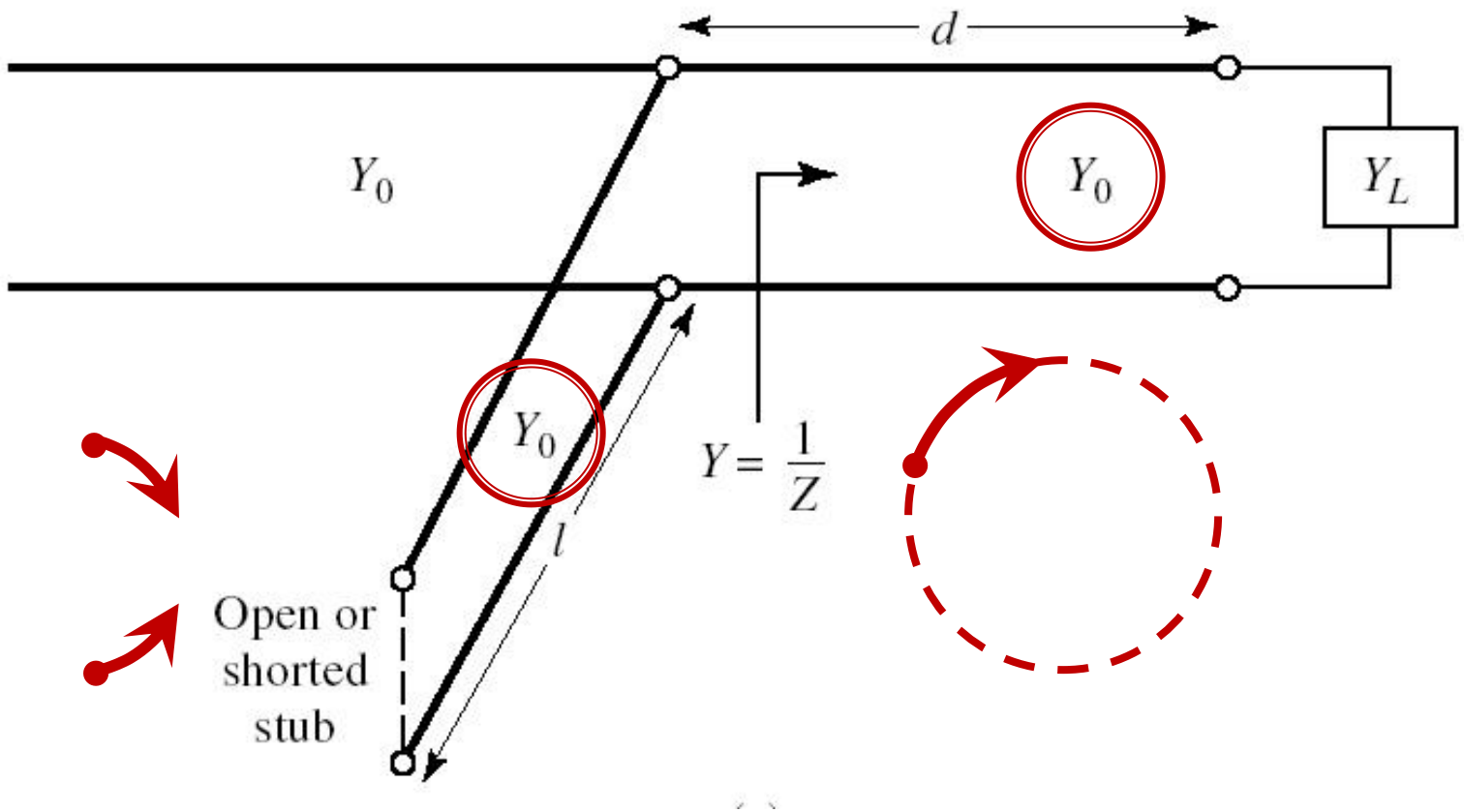
[dBm/Hz] + [dB] = [dBm/Hz]

[x] + [dB] = [x]

Important 3

Caz 1, Shunt Stub

- Shunt Stub (sectiune de linie in paralel)



Calcul analitic (calcul efectiv)

$$\boxed{\cos(\varphi + 2\theta) = -|\Gamma_S|}$$

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

$$\Gamma_S = 0.593 \angle 46.85°$$

$$|\Gamma_S| = 0.593; \quad \varphi = 46.85° \qquad \cos(\varphi + 2\theta) = -0.593 \Rightarrow \quad (\varphi + 2\theta) = \pm 126.35°$$

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

    $$(46.85° + 2\theta) = +126.35° \qquad \theta = +39.7° \qquad \operatorname{Im} y_S = \frac{-2 \cdot |\Gamma_S|}{\sqrt{1 - |\Gamma_S|^2}} = -1.472$$

    $$\theta_{sp} = \tan^{-1}(\operatorname{Im} y_S) = -55.8°(+180°) \rightarrow \theta_{sp} = 124.2°$$
  - **solutia "cu -"**

    $$(46.85° + 2\theta) = -126.35° \qquad \theta = -86.6°(+180°) \rightarrow \theta = 93.4°$$

    $$\operatorname{Im} y_S = \frac{+2 \cdot |\Gamma_S|}{\sqrt{1 - |\Gamma_S|^2}} = +1.472 \qquad \theta_{sp} = \tan^{-1}(\operatorname{Im} y_S) = 55.8°$$

Calcul analitic (calcul efectiv)

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

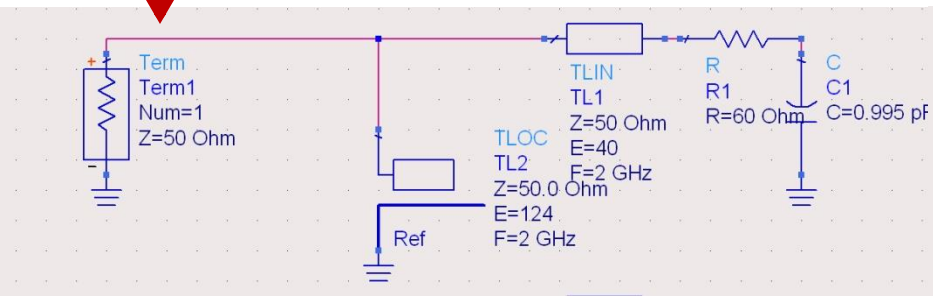
- Se alege **una** din cele doua solutii posibile
- **Semnul** (+/-) solutiei alese la **prima** ecuatie impune **semnul** solutiei utilizate la a **doua** ecuatie

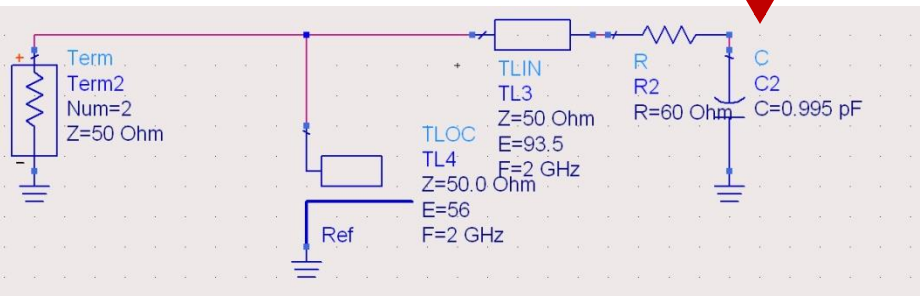
$$l_1=\frac{39.7^\circ}{360^\circ}\cdot\lambda=0.110\cdot\lambda$$

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

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

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





Important 4

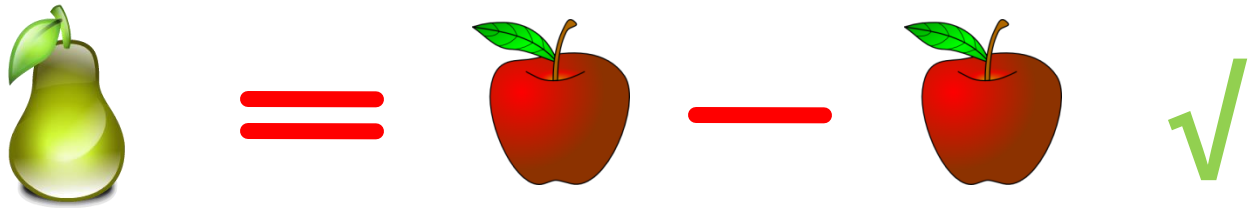
Calculul atenuarii/amplificarii

$$\text{Pierderi/Castig} = \frac{P_{out}}{P_{in}}$$

$$\text{Pierderi}[\text{dB}] = [-]10 \cdot \log_{10}\left(\frac{P_{out}}{P_{in}}\right)$$

$$\text{Pierderi}[\text{dB}] = [-]10 \cdot \log_{10}\left(\frac{P_{out}}{P_0} \cdot \frac{P_0}{P_{in}}\right) = [-]10 \cdot \left[\log_{10}\left(\frac{P_{out}}{P_0}\right) - \log_{10}\left(\frac{P_{in}}{P_0}\right)\right]$$

$$\text{Pierderi}[\text{dB}] = [-]\left(P_{out}[\text{dBm}] - P_{in}[\text{dBm}]\right)$$



Exemple

Problema 1

- Dacă admitanța normalizată este 0.705 – j·0.965, calculați impedanța. (1p)
  - **Notă**. Exceptând situațiile în care în problemă este **specificat altfel**, impedanța de referință se consideră **50Ω**.

$$Y = \frac{1}{Z} \qquad Y_0 = \frac{1}{Z_0} = \frac{1}{50\Omega} = 0.02S$$

$$z = \frac{Z}{Z_0} \qquad y = \frac{Y}{Y_0} = \frac{Z_0}{Z}$$

$$Z = \frac{Z_0}{y} = \frac{50\Omega}{0.705 - j \cdot 0.965} = 24.68\Omega + j \cdot 33.78\Omega$$

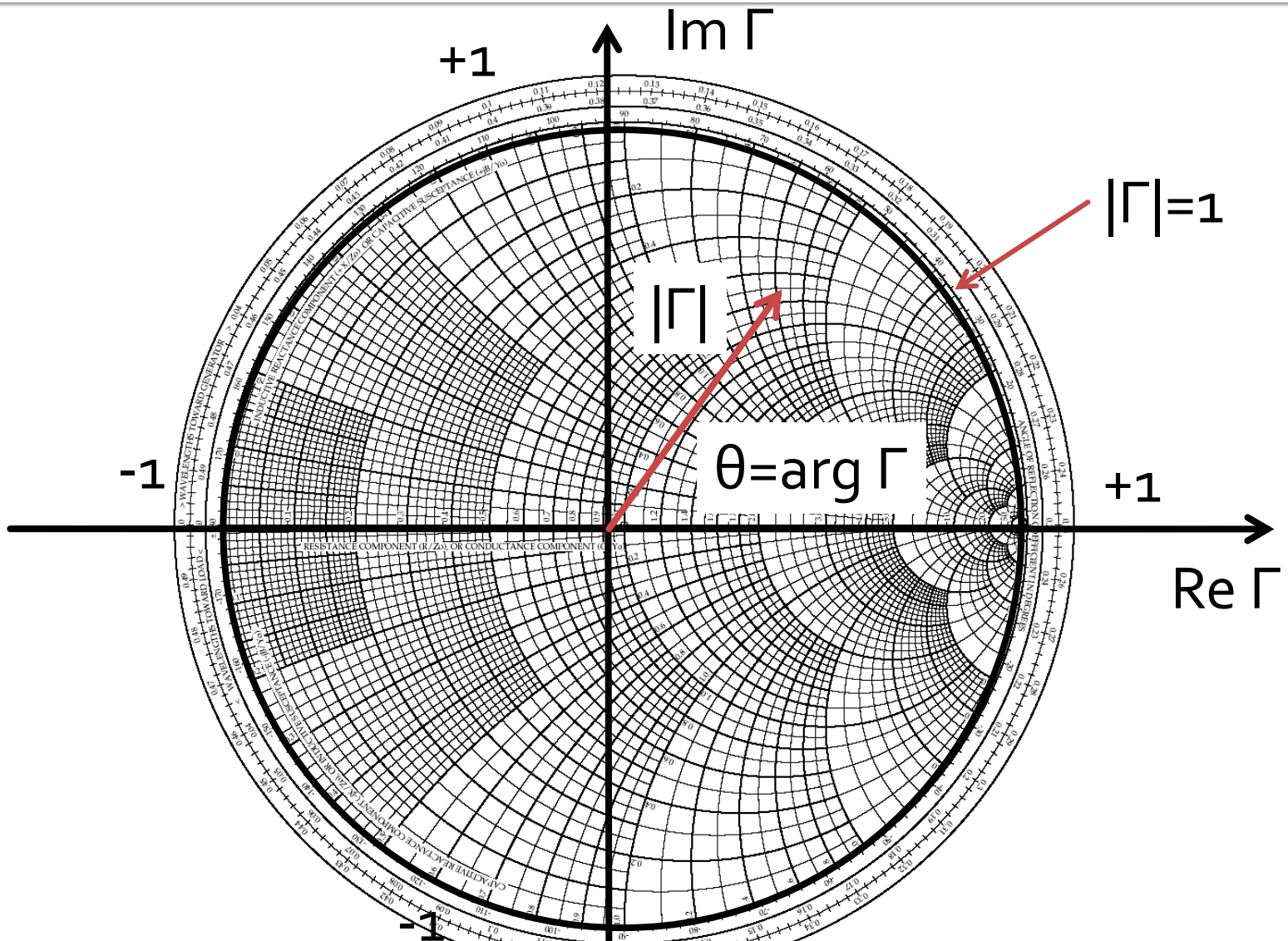
Problema 1 (seminar)

- Dacă admitanța normalizată este 0.930 + j·0.745, calculați impedanța. **(1p)**

Problema 2

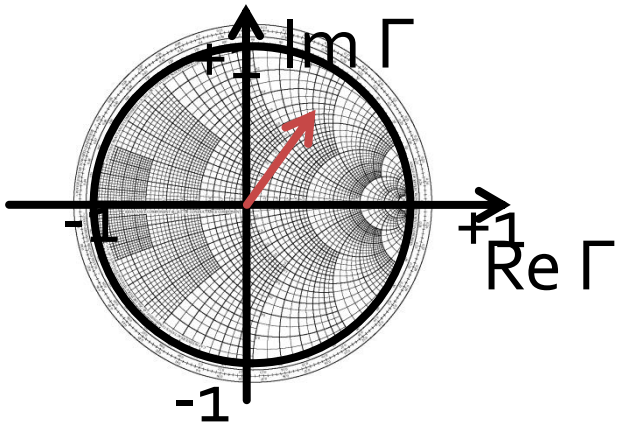
- Schițați o diagrama Smith (numai cercul exterior şi axele) şi reprezentați punctul corespunzător pentru o **impedanță de referință de 75Ω** şi:
  - o impedanță normalizată de 0.870 – j·0.975 **(1p)**
  - o rezistență de 63 Ω în serie cu o bobină de 0.84nH, la frecvența de 7.4 GHz **(1p)**

Diagrama Smith



Problema 2

- Schițați o diagrama Smith (numai cercul exterior şi axele) şi reprezentați punctul corespunzător pentru o **impedanță de referință de 75Ω** şi:
  - o impedanță normalizată de 0.870 – j·0.975 **(1p)**



Γ=?

Problema 2

- Schițați o diagrama Smith (numai cercul exterior şi axele) şi reprezentați punctul corespunzător pentru o **impedanță de referință de 75Ω** şi:
  - o impedanță normalizată de 0.870 – j·0.975 **(1p)**

$$\Gamma = \frac{Z - Z_0}{Z + Z_0} = \frac{z-1}{z+1} = \mathrm{Re}\,\Gamma + j \cdot \mathrm{Im}\,\Gamma = |\Gamma| \cdot e^{j \cdot \arg(\Gamma)}$$

$$\Gamma = \frac{z-1}{z+1} = \frac{0.870 - j \cdot 0.975 - 1}{0.870 - j \cdot 0.975 + 1} = 0.159 - j \cdot 0.438$$

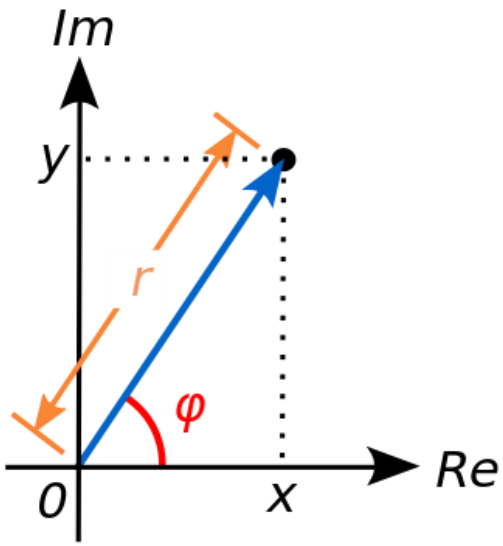
Reprezentare polara

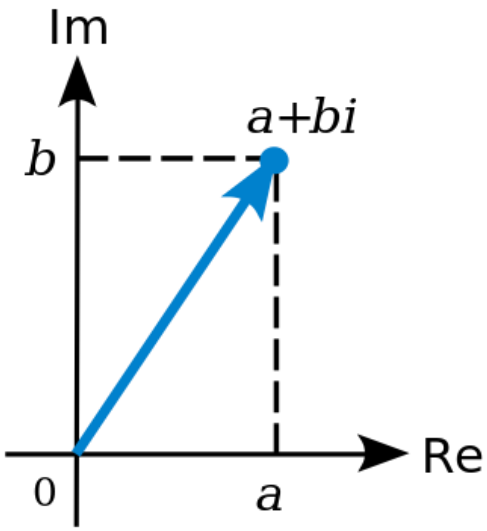
- Reprezentare polara/carteziana

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

$$|z| = z \cdot z^*$$

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





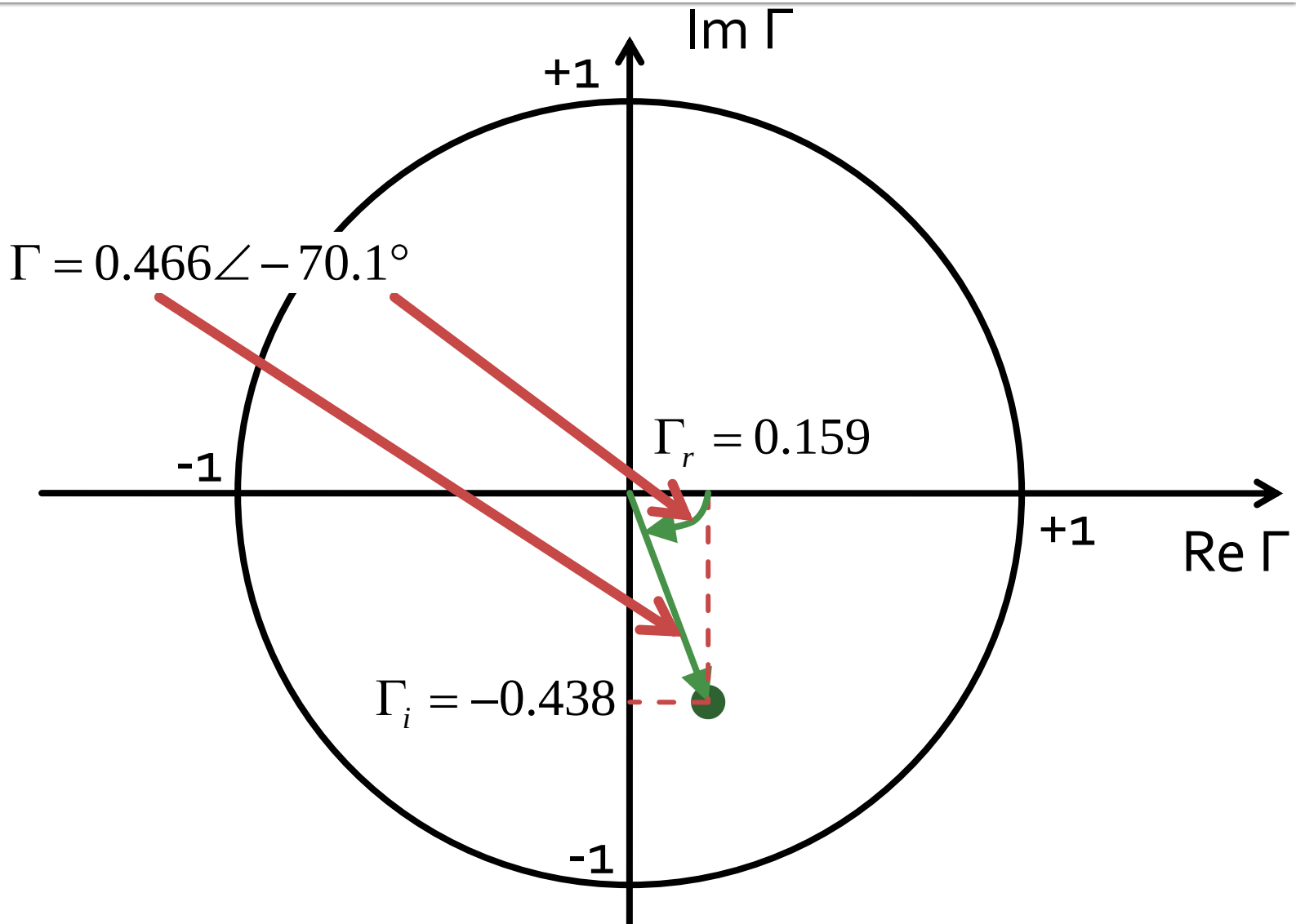
Problema 2

$$\Gamma = 0.159 - j \cdot 0.438$$

$$|\Gamma| = \sqrt{0.159^2 + 0.438^2} = 0.466$$

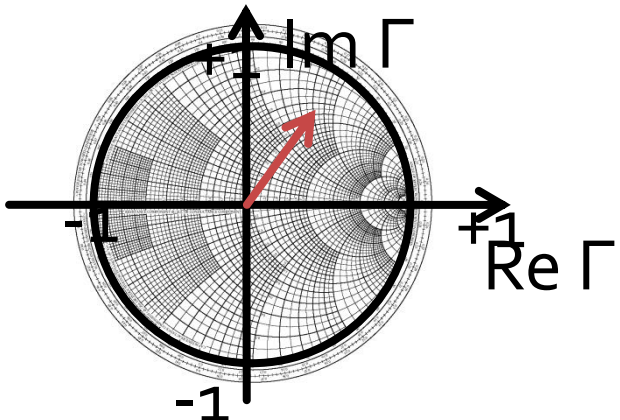
$$\arg(\Gamma) = \arctan\left(\frac{-0.438}{0.159}\right) = -1.223\, rad = -70.05°$$

Problema 2



Problema 2

- Schițați o diagrama Smith (numai cercul exterior şi axele) şi reprezentați punctul corespunzător pentru o **impedanță de referință de 75Ω** şi:
  - o rezistență de 63 Ω în serie cu o bobină de 0.84nH, la frecvența de 7.4 GHz **(1p)**



Γ=?

Problema 2

- Schițați o diagrama Smith (numai cercul exterior şi axele) şi reprezentați punctul corespunzător pentru o **impedanță de referință de 75Ω** şi:
  - o rezistență de 63 Ω în **serie** cu o bobină de 0.84nH, la frecvența de 7.4 GHz **(1p)**

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

$$Z = R + j \cdot \omega \cdot L = R + j \cdot 2\pi \cdot f \cdot L = 63\Omega + j \cdot 2\pi \cdot 7.4 \cdot 10^9 \cdot 0.84 \cdot 10^{-9}$$

$$Z = 63\Omega + j \cdot 39.20\Omega$$

Problema 2

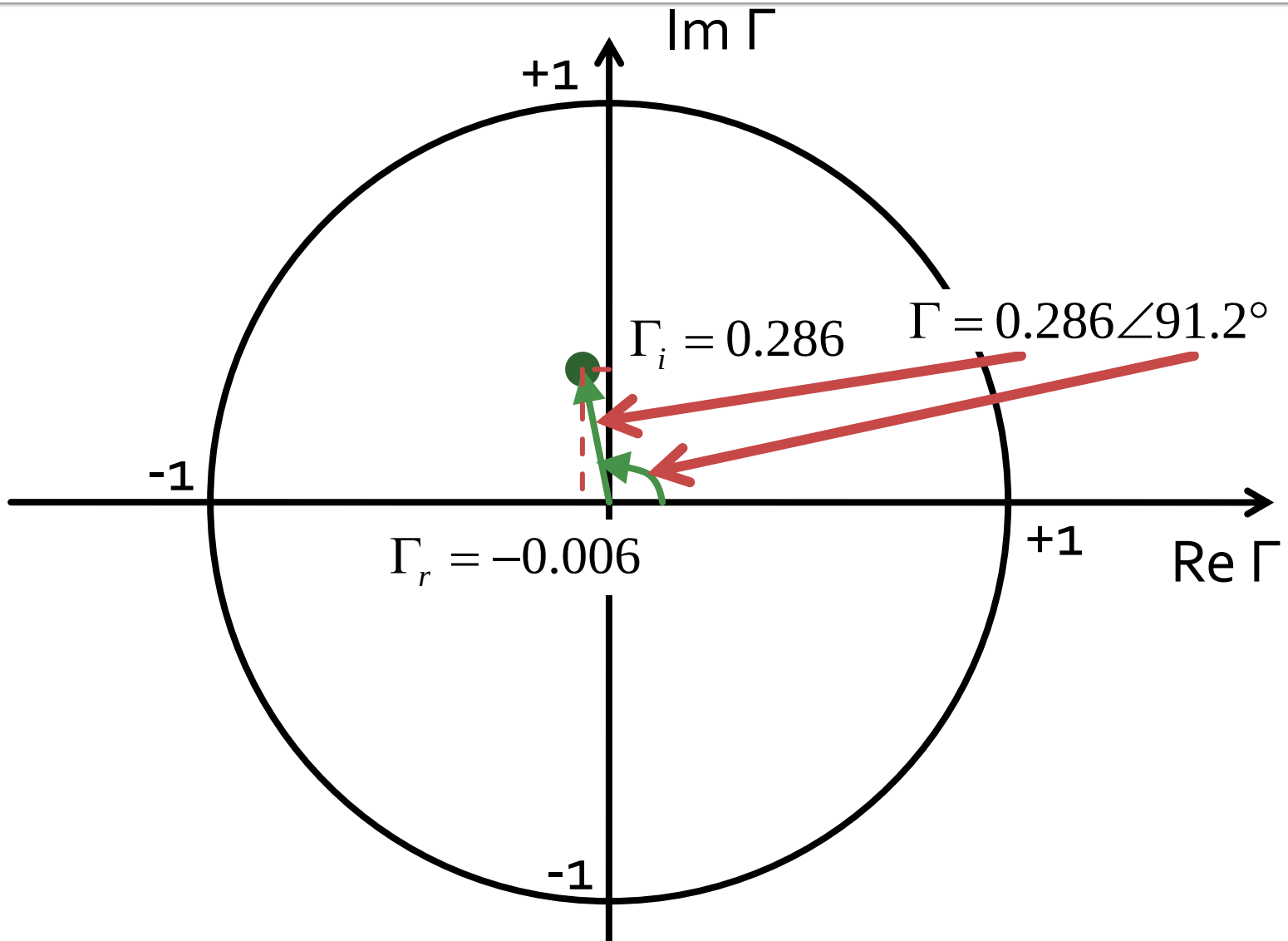
$$\Gamma = \frac{Z - Z_0}{Z + Z_0} = \frac{63\Omega + j \cdot 39.20\Omega - 75\Omega}{63\Omega + j \cdot 39.20\Omega + 75\Omega} = -0.006 + j \cdot 0.286$$

- similar:

$$|\Gamma| = \sqrt{0.006^2 + 0.286^2} = 0.286$$

$$\arg(\Gamma) = \arctan\left(\frac{0.286}{-0.006}\right) + \pi = 1.5911\, rad = 91.17°$$

Problema 2



Problema 2 (seminar)

- Schițați o diagrama Smith (numai cercul exterior şi axele) şi reprezentați punctul corespunzător pentru o impedanță de referință de 80Ω şi:
  - o impedanță normalizată de 0.710 – j·1.155 **(1p)**
  - o rezistență de 39 Ω în paralel cu o capacitate de 0.32 pF, la frecvența de 10.0 GHz **(1p)**

Problema 3

- Se aplică un semnal cu puterea de 1.75mW la intrarea unui cuplor fără pierderi caracterizat de un coeficient de cuplaj de 4.1dB şi o izolare de 23.3dB, care are la intrare VSWR = 2.465.
  - Calculați puterea de ieşire (**în dBm**) la portul de ieşire. **(1p)**
  - Proiectați un cuplor în inel ideal care să ofere acelaşi coeficient de cuplaj. **(1p)**

Cuplor directional

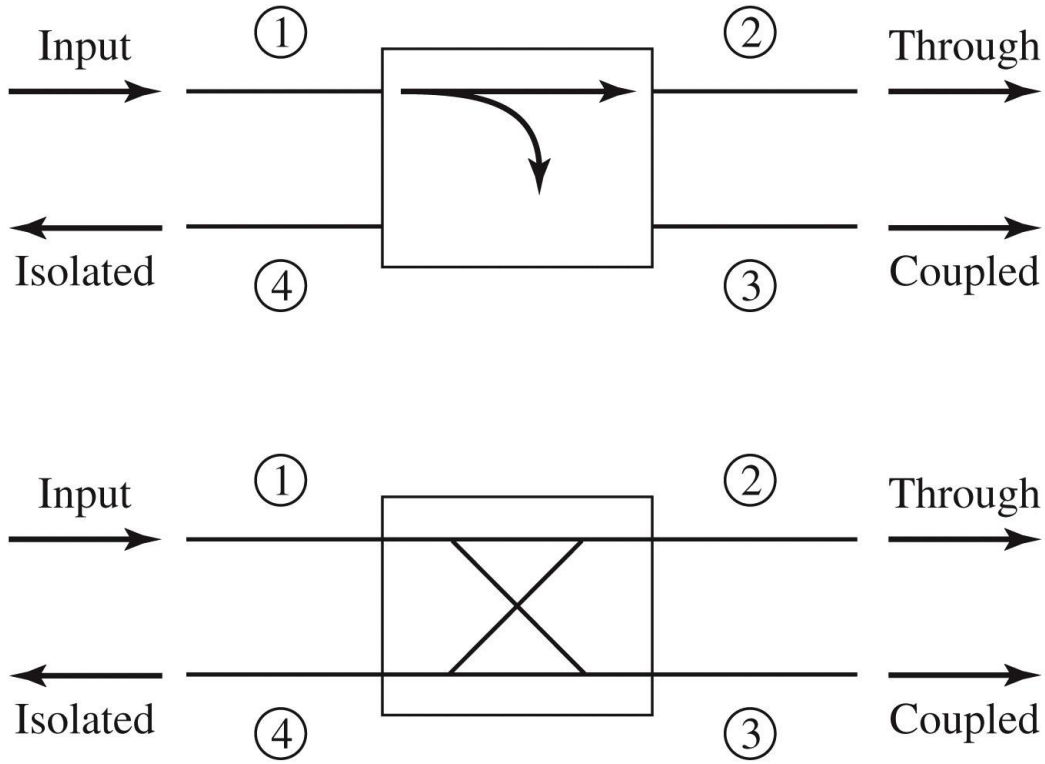


Figure 7.4

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

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

Cuplaj

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

Directivitate

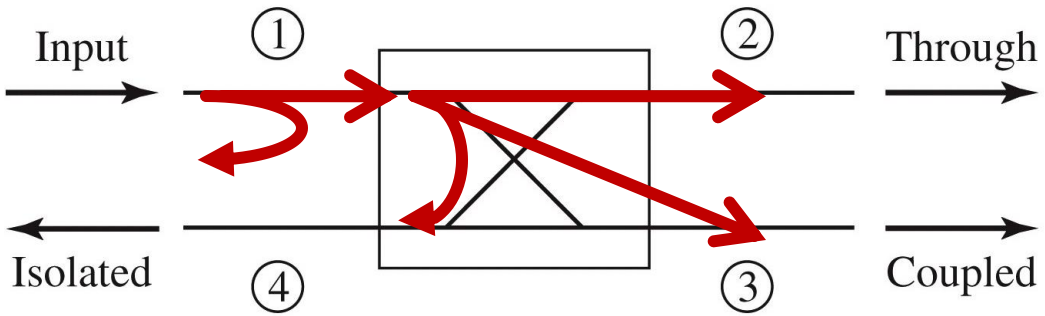
$$D = 10\log\frac{P_3}{P_4} = 20\cdot\log\left(\frac{\beta}{|S_{14}|}\right)[\mathrm{dB}]$$

Izolare

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

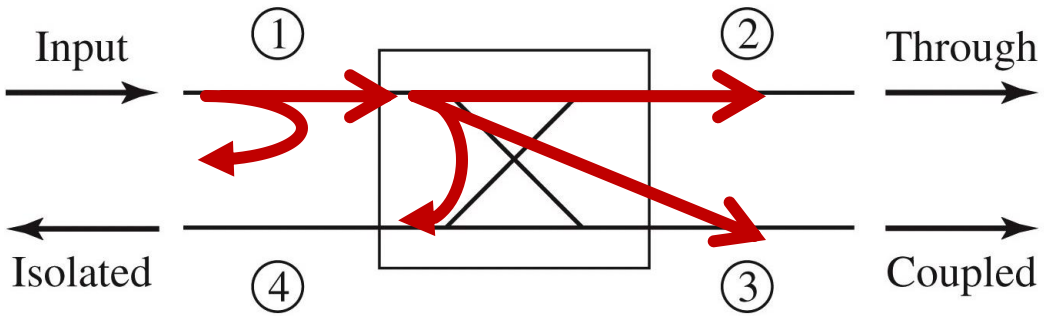
$$I = D + C\,,\ \ dB$$

Problema 3



- Cuplor fără pierderi, puterea de intrare se regăseşte în totalitate la:
  - portul de ieşire,
  - portul de cuplaj,
  - portul izolat
  - sau <u>se reflectă</u> la intrare, **inainte** de a intra in cuplor

Problema 3



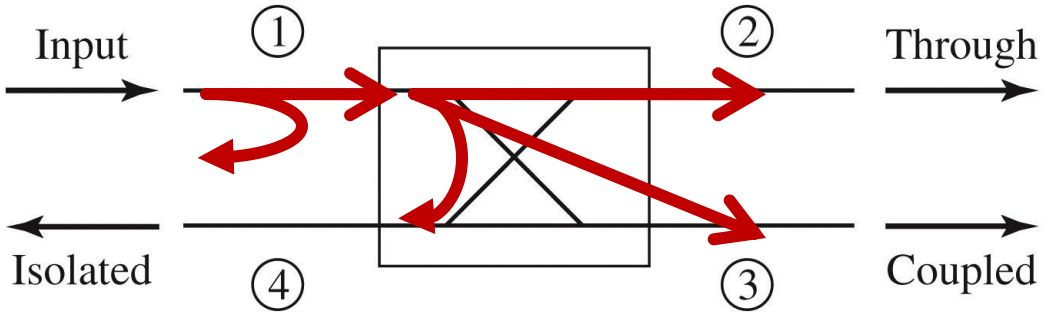
- Puterea reflectata la intrare, **inainte** de a intra in cuplor

$$VSWR = \frac{V_{\max}}{V_{\min}} = \frac{1+|\Gamma|}{1-|\Gamma|} \qquad |\Gamma_{in}| = \frac{VSWR-1}{VSWR+1} = 0.423$$

$$P_{refl} = P_{in} \cdot |\Gamma_{in}|^2 = 1.75mW \cdot 0.423^2 = 0.313mW$$

$$P_1 = P_{in} - P_{refl} = 1.75mW - 0.313mW = 1.437mW$$

Problema 3



- Puterile transferate spre:
  - portul de cuplaj
  - portul izolat

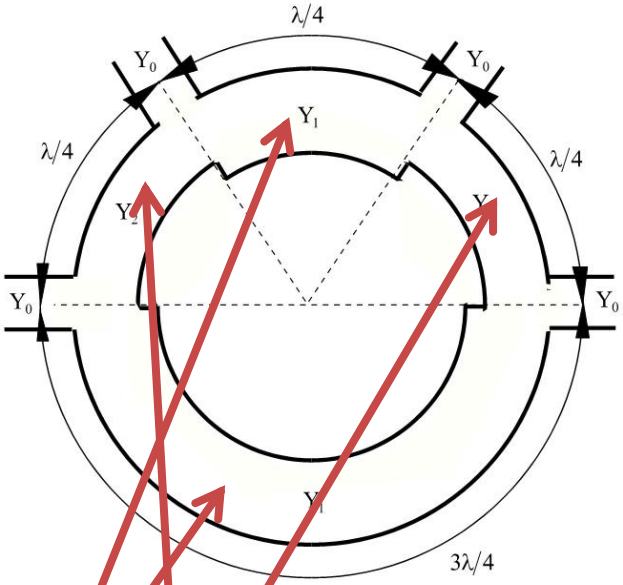
$$I = 10\log\frac{P_1}{P_4} = -20\cdot\log\left|S_{14}\right|[\text{dB}] \qquad C = 10\log\frac{P_1}{P_3} = -20\cdot\log(\beta)[\text{dB}]$$

$$P_4 = \frac{P_1}{10^{I[\text{dB}]/10}} = \frac{1.437mW}{213.8} = 0.0067mW \qquad P_3 = \frac{P_1}{10^{C[\text{dB}]/10}} = \frac{1.437mW}{2.57} = 0.559mW$$

$$P_2 = P_1 - P_3 - P_4 = 1.437mW - 0.0067mW - 0.559mW = 0.871mW$$

$$P_2[dBm] = 10\cdot\log\frac{P_2[W]}{1mW} = 10\cdot\log 0.871dBm = -0.06dBm$$

Cuplorul în inel



$$y_1^2 + y_2^2 = 1$$

$$C\,[\mathrm{dB}] = -20 \cdot \log(y_1)$$

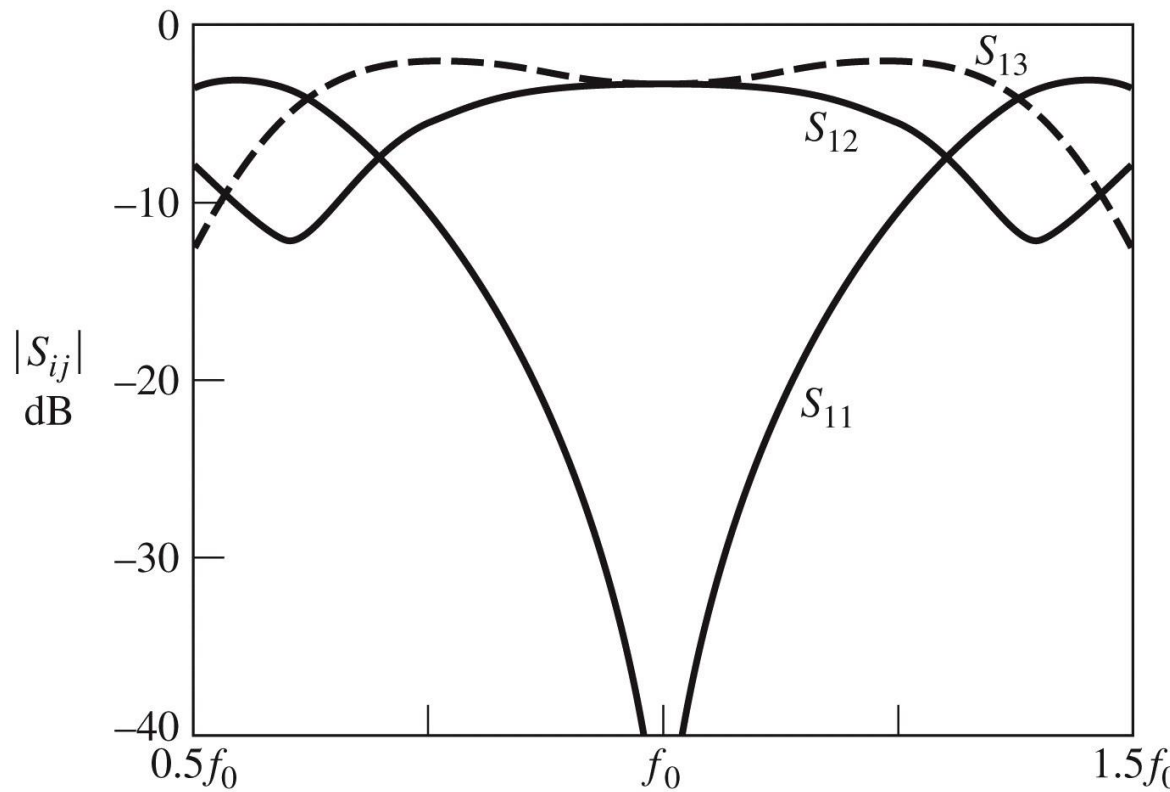
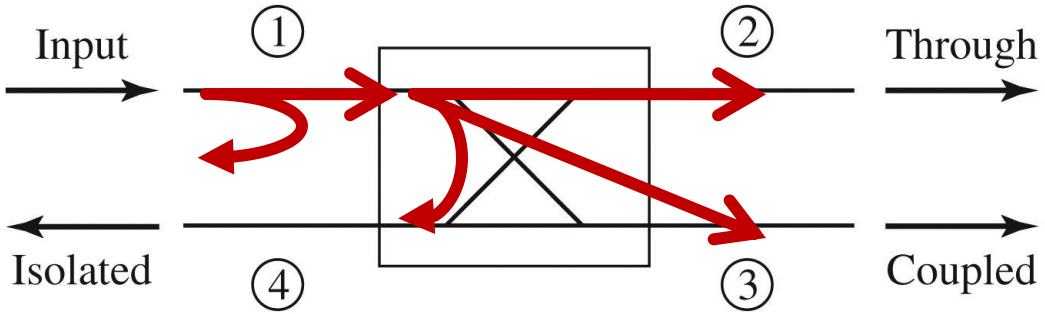
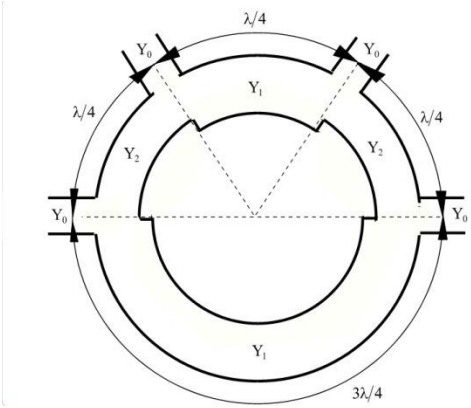


Figure 7.46

Problema 3



- Proiectarea cuplorului



$$y_1 = 10^{-C[\mathrm{dB}]/20} = 0.624$$

$$y_2 = \sqrt{1 - y_1^2} = 0.781$$

$$Z_1 = \frac{Z_0}{y_1} = 80.128\Omega$$

$$Z_2 = \frac{Z_0}{y_2} = 63.986\Omega$$

$$y_1^2 + y_2^2 = 1$$

$$C\,[\mathrm{dB}] = -20 \cdot \log(y_1)$$

Problema 3 (seminar)

- Se aplică un semnal cu puterea de 3.00mW la intrarea unui cuplor fără pierderi caracterizat de un coeficient de cuplaj de 5.2dB şi o izolare de 18.5dB, care are la intrare VSWR = 2.380.
  - Calculați puterea de ieşire (**în dBm**) la portul de ieşire. **(1p)**
  - Proiectați un cuplor în inel ideal care să ofere acelaşi coeficient de cuplaj. **(1p)**

Problema 4

- Calculați factorul de zgomot al circuitului care conține înseriate, în ordinea indicată, următoarele amplificatoare: **(2p)**
  - Amplificator 1: Factor de zgomot 2.1dB, Câştig 8.0dB ,
  - Amplificator 2: Factor de zgomot 2.1dB, Câştig 11.1dB ,
  - Amplificator 3: Factor de zgomot 3.7dB, Câştig 13.8dB .
- Formula lui Friis (**in coordonate liniare!**)

$$F_{cas} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 \cdot G_2} + \frac{F_4 - 1}{G_1 \cdot G_2 \cdot G_3} + \cdots$$

Problema 4

- Formula lui Friis (**in coordonate liniare!**)

$$F_{cas} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 \cdot G_2}$$

$$F_1 = 10^{\frac{F_1[dB]}{10}} = 10^{0.21} = 1.622 \qquad G_1 = 10^{\frac{G_1[dB]}{10}} = 10^{0.8} = 6.310$$

$$F_2 = 10^{\frac{F_2[dB]}{10}} = 10^{0.21} = 1.622 \qquad G_2 = 10^{\frac{G_2[dB]}{10}} = 10^{1.11} = 12.882$$

$$F_3 = 10^{\frac{F_3[dB]}{10}} = 10^{0.37} = 2.344$$

- Atentie la unitati de masura (**toate sunt adimensionale!**)

$$F_{cas} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 \cdot G_2} = 1.737$$

$$F_{cas}[dB] = 10 \cdot \log F_{cas} = 10 \cdot \log(1.737) = 2.398 dB$$

Problema 4 (seminar)

- Calculați factorul de zgomot al circuitului care conține înseriate, în ordinea indicată, următoarele amplificatoare: **(2p)**
  - Amplificator 1: Factor de zgomot 2.7dB, Câştig 7.3dB ,
  - Amplificator 2: Factor de zgomot 3.1dB, Câştig 11.7dB,
  - Amplificator 3: Factor de zgomot 4.5dB, Câştig 12.1dB.

Problema 5a

- 5a. Parametrii S ai unui tranzistor la frecvența de 0.9 GHz sunt dați în tabelul următor:

S_{11}		S_{12}		S_{21}		S_{22}	
Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.
0.717	-123.4°	0.049	43.9°	12.733	105.2°	0.303	-138.8°

  - Determinați cercurile de stabilitate la intrare şi ieşire. **(1.5p)**
  - Tranzistorul este necondiționat stabil la frecvența de 0.9 GHz? **(0.5p)**
  - Se obține un sistem stabil dacă la ieşire se conectează tranzistorul la 50Ω, iar la intrare sursa cu impedanța de 55Ω este conectată printr-o linie de 50Ω de lungime 0.20λ? **(1p)**
  - Cum se modifică stabilitatea sistemului dacă în urma unei defecțiuni sursa devine:
    - gol? **(0.5p)**
    - scurtcircuit? **(0.5p)**

Problema 5a

- 5a. Parametrii S ai unui tranzistor la frecvența de 0.9 GHz sunt dați în tabelul următor:

S_{11}		S_{12}		S_{21}		S_{22}	
Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.
0.717	-123.4°	0.049	43.9°	12.733	105.2°	0.303	-138.8°

  - Determinați cercurile de stabilitate la intrare şi ieşire. **(1.5p)**

$$C_S = \frac{\left(S_{11} - \Delta \cdot S_{22}^*\right)^*}{\left|S_{11}\right|^2 - \left|\Delta\right|^2} = -1.215 + 2.928 \cdot j$$

$$\left|C_S\right| = 3.170$$

$$R_S = \frac{\left|S_{12} \cdot S_{21}\right|}{\left|\left|S_{11}\right|^2 - \left|\Delta\right|^2\right|} = 2.525$$

Problema 5a

- 5a. Parametrii S ai unui tranzistor la frecvența de 0.9 GHz sunt dați în tabelul următor:

S_{11}		S_{12}		S_{21}		S_{22}	
Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.
0.717	-123.4°	0.049	43.9°	12.733	105.2°	0.303	-138.8°

  - Determinați cercurile de stabilitate la intrare şi ieşire. **(1.5p)**

$$C_L = \frac{\left(S_{22} - \Delta \cdot S_{11}^*\right)^*}{\left|S_{22}\right|^2 - \left|\Delta\right|^2} = 0.521 - 3.105 \cdot j$$

$$\left|C_L\right| = 3.149$$

$$R_L = \frac{\left|S_{12} \cdot S_{21}\right|}{\left|\left|S_{22}\right|^2 - \left|\Delta\right|^2\right|} = 3.562$$

Problema 5a

- 5a. Parametrii S ai unui tranzistor la frecvența de 0.9 GHz sunt dați în tabelul următor:

S_{11}		S_{12}		S_{21}		S_{22}	
Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.
0.717	-123.4°	0.049	43.9°	12.733	105.2°	0.303	-138.8°

  - Tranzistorul este necondiționat stabil la frecvența de 0.9 GHz? **(0.5p)**
- Doua metode
  - utilizare cercuri de stabilitate
  - utilizarea conditiilor analitice de stabilitate

Problema 5a

- 5a. Parametrii S ai unui tranzistor la frecvența de 0.9 GHz sunt dați în tabelul următor:

S_{11}		S_{12}		S_{21}		S_{22}	
Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.
0.717	-123.4°	0.049	43.9°	12.733	105.2°	0.303	-138.8°

  - Tranzistorul este necondiționat stabil la frecvența de 0.9 GHz? **(0.5p)**
- Doua metode
  - **utilizare cercuri de stabilitate**
  - utilizarea conditiilor analitice de stabilitate

$$\begin{cases} \left| |C_S| - R_S \right| = 0.645 > 1 \quad FALS \\ |S_{22}| = 0.303 < 1 \end{cases}$$

$$\begin{cases} \left| |C_L| - R_L \right| = 0.413 > 1 \quad FALS \\ |S_{11}| = 0.717 < 1 \end{cases}$$

Problema 5a

- 5a. Parametrii S ai unui tranzistor la frecvența de 0.9 GHz sunt dați în tabelul următor:

S_{11}		S_{12}		S_{21}		S_{22}	
Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.
0.717	-123.4°	0.049	43.9°	12.733	105.2°	0.303	-138.8°

  - Tranzistorul este necondiționat stabil la frecvența de 0.9 GHz? **(0.5p)**
- Doua metode
  - utilizare cercuri de stabilitate
  - **utilizarea conditiilor analitice de stabilitate**

$$|S_{11}| = 0.717 < 1 \qquad |S_{22}| = 0.303 < 1$$

$$\Delta = S_{11} \cdot S_{22} - S_{12} \cdot S_{21} \qquad |\Delta| = 0.517 < 1$$

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2 \cdot |S_{12} \cdot S_{21}|} = 0.530 > 1 \quad FALS$$

Problema 5a

- 5a. Parametrii S ai unui tranzistor la frecvența de 0.9 GHz sunt dați în tabelul următor:

S_{11}		S_{12}		S_{21}		S_{22}	
Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.
0.717	-123.4°	0.049	43.9°	12.733	105.2°	0.303	-138.8°

  - Se obține un sistem stabil dacă la ieşire se conectează tranzistorul la 50Ω, iar la intrare sursa cu impedanța de 55Ω este conectată printr-o linie de 50Ω de lungime 0.20λ? **(1p)**
- Conectare la iesire la 50Ω, coeficient de reflexie la iesire egal cu S22,

$$|S_{22}| = 0.303 < 1$$

- La iesire avem indeplinita relatia de stabilitate

Problema 5a

- 5a. Parametrii S ai unui tranzistor la frecvența de 0.9 GHz sunt dați în tabelul următor:

S_{11}		S_{12}		S_{21}		S_{22}	
Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.
0.717	-123.4°	0.049	43.9°	12.733	105.2°	0.303	-138.8°

  - Se obține un sistem stabil dacă la ieşire se conectează tranzistorul la 50Ω, iar la intrare sursa cu impedanța de 55Ω este conectată printr-o linie de 50Ω de lungime 0.20λ? **(1p)**
- Conectare la intrare, la nivelul tranzitiei sursa/linie apare dezadaptare, apare un coeficient de reflexie,

$$\Gamma_0 = \frac{Z - Z_0}{Z + Z_0} = \frac{55\Omega - 50\Omega}{55\Omega + 50\Omega} = 0.048$$

- Prin linia de lungime 0.20λ, la nivelul intrarii in tranzistor acest coeficient de reflexie devine:

$$\Gamma_s = \Gamma_0 \cdot e^{-2j\cdot\beta\cdot l} = \Gamma_0 \cdot e^{-2j\cdot\frac{2\pi}{\lambda}\cdot l}$$

Problema 5a

- 5a. Parametrii S ai unui tranzistor la frecvența de 0.9 GHz sunt dați în tabelul următor:

S_{11}		S_{12}		S_{21}		S_{22}	
Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.
0.717	-123.4°	0.049	43.9°	12.733	105.2°	0.303	-138.8°

  - Se obține un sistem stabil dacă la ieşire se conectează tranzistorul la 50Ω, iar la intrare sursa cu impedanța de 55Ω este conectată printr-o linie de 50Ω de lungime 0.20λ? **(1p)**

- Prin linia de lungime 0.20λ, la nivelul intrarii in tranzistor acest coeficient de reflexie devine:

$$\Gamma_s = \Gamma_0 \cdot e^{-2j\cdot\beta\cdot l} = \Gamma_0 \cdot e^{-2j\cdot\frac{2\pi}{\lambda}\cdot l}$$

$$\Gamma_s = \Gamma_0 \cdot e^{-2j\cdot\frac{2\pi}{\lambda}\cdot l} = 0.048\cdot\left[\cos\left(-4\pi\cdot 0.20\right) + j\cdot\sin\left(-4\pi\cdot 0.20\right)\right]$$

$$\Gamma_s = -0.039 - j\cdot 0.028$$

Problema 5a

- 5a. Parametrii S ai unui tranzistor la frecvența de 0.9 GHz sunt dați în tabelul următor:

S_{11}		S_{12}		S_{21}		S_{22}	
Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.
0.717	-123.4°	0.049	43.9°	12.733	105.2°	0.303	-138.8°

  - Se obține un sistem stabil dacă la ieşire se conectează tranzistorul la 50Ω, iar la intrare sursa cu impedanța de 55Ω este conectată printr-o linie de 50Ω de lungime 0.20λ? **(1p)**

- Distanta dintre acest punct (Γ_s) si centrul cecului de stabilitate

$$\left|\Gamma_S - C_S\right| = 3.182 > R_S = 2.525$$

  - deci punctul Γ_s este in **exteriorul** cercului de stabilitate
  - Centrul diagramei Smith este un punct de stabilitate si se gaseste in **exteriorul** cercului de stabilitate

$$\left|C_S\right| = 3.170 > R_S = 2.525$$

- Rezulta ca punctul Γ_s este **punct de stabilitate**

Problema 5a

- 5a. Parametrii S ai unui tranzistor la frecvența de 0.9 GHz sunt dați în tabelul următor:

S_{11}		S_{12}		S_{21}		S_{22}	
Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.
0.717	-123.4°	0.049	43.9°	12.733	105.2°	0.303	-138.8°

  - Cum se modifică stabilitatea sistemului dacă în urma unei defecțiuni sursa devine:
    - gol? **(0.5p)**
    - scurtcircuit? **(0.5p)**

- Cu sursa in gol sau scurtcircuit, tranzistorul este conectat cu o sectiune de linie de 50Ω la gol sau scurtcircuit, ca urmare impedanta vazuta de tranzistor la intrare este
    - gol $$Z_S = -j \cdot Z_0 \cdot \cot \beta \cdot l = -j \cdot 50\Omega \cdot \cot(2\pi \cdot 0.20)$$
    - scurtcircuit $$Z_S = j \cdot Z_0 \cdot \tan \beta \cdot l = j \cdot 50\Omega \cdot \tan(2\pi \cdot 0.20)$$

Problema 5a

- 5a. Parametrii S ai unui tranzistor la frecvența de 0.9 GHz sunt dați în tabelul următor:

S_{11}		S_{12}		S_{21}		S_{22}	
Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.
0.717	-123.4°	0.049	43.9°	12.733	105.2°	0.303	-138.8°

  - Cum se modifică stabilitatea sistemului dacă în urma unei defecțiuni sursa devine:
    - gol? **(0.5p)**
    - scurtcircuit? **(0.5p)**
- Similar cu situatia anterioara calculam coeficientul de reflexie si pozitionarea acestuia fata de cercul de stabilitate

$$\Gamma_S = \frac{Z_S - Z_0}{Z_S + Z_0}$$

  - gol $\Gamma_S = 0.809 + j \cdot 0.588$ $\quad |\Gamma_S - C_S| = 3.094 > R_S = 2.525$
  - scurtcircuit $\Gamma_S = -0.809 - j \cdot 0.588$ $\quad |\Gamma_S - C_S| = 3.539 > R_S = 2.525$

Problema 5a (seminar)

- Parametrii S ai unui tranzistor la frecvența de 0.8 GHz sunt dați în tabelul următor:

S_{11}		S_{12}		S_{21}		S_{22}	
Mag.	Ang.	Mag.	Ang.	Mag.	Ang.	Mag.	Ang.
0.732	-115.8°	0.046	45.4°	13.834	109.6°	0.302	-132.4°

  - Determinați cercurile de stabilitate la intrare şi ieşire. **(1.5p)**
  - Tranzistorul este necondiționat stabil la frecvența de 0.8 GHz? **(0.5p)**
  - Se obține un sistem stabil dacă la ieşire se conectează tranzistorul la 50Ω, iar la intrare sursa cu impedanța de 64Ω este conectată printr-o linie de 50Ω de lungime 0.10λ? **(1p)**
  - Cum se modifică stabilitatea sistemului dacă în urma unei defecțiuni sursa devine:
    - gol? **(0.5p)**
    - scurtcircuit? **(0.5p)**

Contact

- Laboratorul de microunde si optoelectronica
- http://rf-opto.etti.tuiasi.ro
- rdamian@etti.tuiasi.ro