

Curs 14

2022/2023

Dispozitive și circuite de microunde pentru radiocomunicații

Disciplina 2022/2023

- 2C/1L, **DCMR (CDM)**
- Minim 7 prezente (curs+laborator)
- Curs - **conf. Radu Damian**
 - Marti 15-17, ~~Online~~/**Video (istoric)**, P2
 - E – **50%** din nota
 - probleme + (2p prez. curs) + (3 teste) + (bonus activitate)
 - primul test L1: 05.10.2022 (t2 si t3 neanuntate la **curs**)
 - 3pz (C) \approx +0.5p (**2p** max)
 - toate materialele permise

Disciplina 2022/2023

- 2C/1L, **DCMR (CDM)**
- Laborator – **conf. Radu Damian**
 - Miercuri/Joi, 12/14 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

Laborator

- 5409 – 21.12.2022, 12-14
- online
 - **fara** prezenta (proiect)
 - prezenta necesara (**minim 7**)
 - curs
 - alta grupa

Documentatie

■ <http://rf-opto.etti.tuiasi.ro>

Laboratorul de Microunde si Opti

Not secure | rf-opto.etti.tuiasi.ro/microwave_cd.php?chg_lang=1



English | Romana

Start **Didactic** Master Colectiv Cercetare Studenti

Microunde Comunicatii Optice Optoelectronica Internet Antene Tehnologie/Zgomote Practica Soft didactic

Dispozitive si circuite de microunde pentru radiocomunicatii

Disciplina: DCMR (2021-2022)

Coordonator Disciplina: conf. dr. Radu-Florin Damian
Cod: DOS412T
Tip Disciplina: DOS; Disciplina Optionala, Disciplina de Specialitate
Credite: 4
An de Studiu: 4, Sem. 7

Activitati

Curs: Cadru Didactic: conf. dr. Radu-Florin Damian, 2 Ore/Saptamana, Sectie Specializare, Orar:
Laborator: Cadru Didactic: conf. dr. Radu-Florin Damian, 1 Ore/Saptamana, Grupa, Orar:

Evaluare

Tip: Examen

A: 50%, (Examen/Colocviu)
B: 25%, (Activitate Seminar/Laborator/Proiect)
D: 25%, (Teme de casa/Lucrari de specialitate)

Note

[Rezultate totale](#)

Prezenta


[Curs](#)
[Laborator](#)


Liste


[Studenti care nu pot intra in examen \(final\)](#)
[Bonus-uri acumulate \(final\)](#)

Istoric

Alte informatii

[Online Exam manual](#) (pdf, 2.56 MB, en, )

[Exam Simulation \(video\)](#) (mp4, 41.96 MB, en, )

[Important Agilent Application Notes](#) (rar, 2.36 MB, ro, )

Ani anteriori

2020-2021

2019-2020

2018-2019

2017-2018

2016-2017

Mai mult...

Dispozitive si circuite de microunde pentru radiocomunicatii

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Laborator: Cadru Didactic: conf. dr. Radu-Florin Damian, 1 Ore/Saptamana, Grupa, Orar:

Acces

■ Personalizat



Date:

Grupa	5304 (2015/2016)
Specializarea	Tehnologii si sisteme de telecomunicatii
Marca	5184

[Acceseaza ca acest student](#)

Note obtinute

Disciplina	Tip	Data	Descriere	Nota	Puncte	Obs.
TW	Tehnologii Web					
	N	17/01/2014	Nota finala	10	-	
	A	17/01/2014	Colocviu Tehnologii Web 2013/2014	10	7.55	
	B	17/01/2014	Laborator Tehnologii Web 2013/2014	9	-	
	D	17/01/2014	Tema Tehnologii Web 2013/2014	9	-	

Nume

Email

Cod de verificare

Trimite

Online

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

English | **Romana**

Start Didactic Master Colectiv Cercetare **Stu**

Note Lista Studenti Examene Fotografii

POPESCU GOPO ION

Fotografia nu exista

Date:

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

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

Note obtinute

Inca nu a fost notat.

Start Didactic Master Colectiv C

Note **Lista Studenti** Examene Fotografii

Identificare

Introduceti numele si adresa de email utilizata la inscriere

Nume
POPESCU GOPO

E-mail/Parola

Introduceti codul afisat mai jos

4db4457

Trimite

Online

- acces email/parola

[Start](#) [Didactic](#) [Master](#) [Colectiv](#)

[Note](#) [Lista Studenti](#) [Examene](#) [Fotografii](#)

POPESCU GOPO ION

Fotografia
nu exista

Date:

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

Se acceseaza site-ul **ca acest student!**

[Start](#) [Didactic](#) [Master](#) [Colectiv](#) [C](#)

[Note](#) [Lista Studenti](#) [Examene](#) [Fotografii](#)

POPESCU GOPO ION

Fotografia
nu exista

Date:

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

Se acceseaza site-ul **ca acest student (inclusiv examene)!**

Parola

■ primita prin email

Important message from RF-OPTO

Inbox x



Radu-Florin Damian

to me, POPESCU



Romanian

> English

[Translate message](#)



Laboratorul de Microunde si Optoelectronica
Facultatea de Electronica, Telecomunicatii si Tehnologia Informatiei
Universitatea Tehnica "Gh. Asachi" Iasi

In atentie: POPESCU GOPO ION

Parola pentru a accesa examenele pe server-ul **rf-opto** este

Parola: [REDACTED]

Identificati-va pe [server](#), cu parola, cat mai rapid, pentru confirmare.

Memorati acest mesaj intr-un loc sigur, pentru utilizare ulterioara

Attention: POPESCU GOPO ION

The password to access the exams on the **rf-opto** server is

Password: [REDACTED]

Login to the [server](#), with this password, as soon as possible, for confirmation.

Save this message in a safe place for later use

Reply

Reply all

Forward

	Subject	Correspondents
★	Important message from RF-OPTO	POPESCU GOPO ION
★	Validation of MD/CR exam from 02/05/2020	[REDACTED]
★	[REDACTED]	[REDACTED]

From: Me <rdamian@etti.tuiasi.ro> ★

Subject: Important message from RF-OPTO

To: [REDACTED]

Cc: Me <rdamian@etti.tuiasi.ro> ★



Laboratorul de Microunde si Optoelectronica
Facultatea de Electronica, Telecomunicatii si Tehnologia Informatiei
Universitatea Tehnica "Gh. Asachi" Iasi

In atentie: POPESCU GOPO ION

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Save this message in a safe place for later use


Manual examen online

- Aplicatia de examen online utilizata intens la:
 - ~~curs (prezentat)~~
 - **laborator (rezultate)**
 - **proiect (predare)**
 - ~~examen~~

Materials

Other data

[Manual examen on-line](#) (pdf, 2.65 MB, ro, )

[Simulare Examen](#) (video) (mp4, 65.12 MB, ro, )

Microwave Devices and Circuits (Englis

Examen online

- intotdeauna **contratimp**
 - **perioada lunga** (rezultate laborator)
 - perioada scurta (teste: 15min, examen: 2h)

Start Didactic Master Colectiv Cercetare **Studenti**

Note Lista Studenti **Examene** Fotografii

Anunț
17:28 (29/04/2020)

Material suport
17:30 (29/04/2020)

Subiecte
17:32 (29/04/2020)

Rezultate
17:35 (29/04/2020)

Finalizare
17:45 (29/04/2020)

Confirmare
17:45 (30/04/2020)

urmatorul interval de timp in:
01 m 08 s
[Reincarca acum](#)

Anunț

In acest examen se verifica diverse actiuni ale studentilor pentru examen

Ora pe server

Toate examenele sunt bazate pe fusul orar al server-ului (ar putea sa fie diferit de timpul local). Pentru referinta ora pe server este acum:

29/04/2020 17:28:51

Cuprins

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

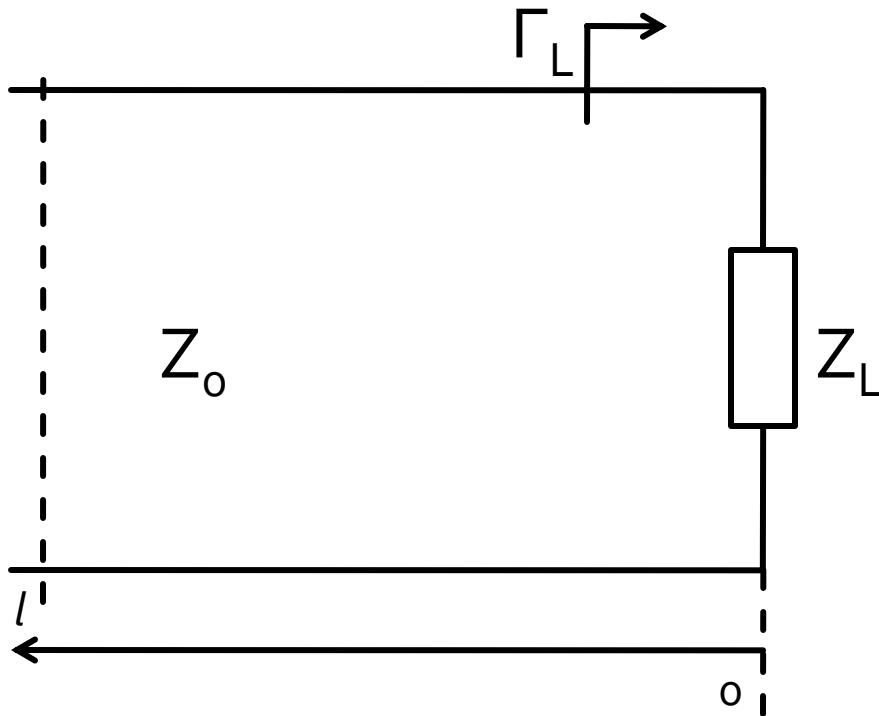
Bibliografie

- <http://rf-opto.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)**

Cuprins

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

Linie fara pierderi



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

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

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

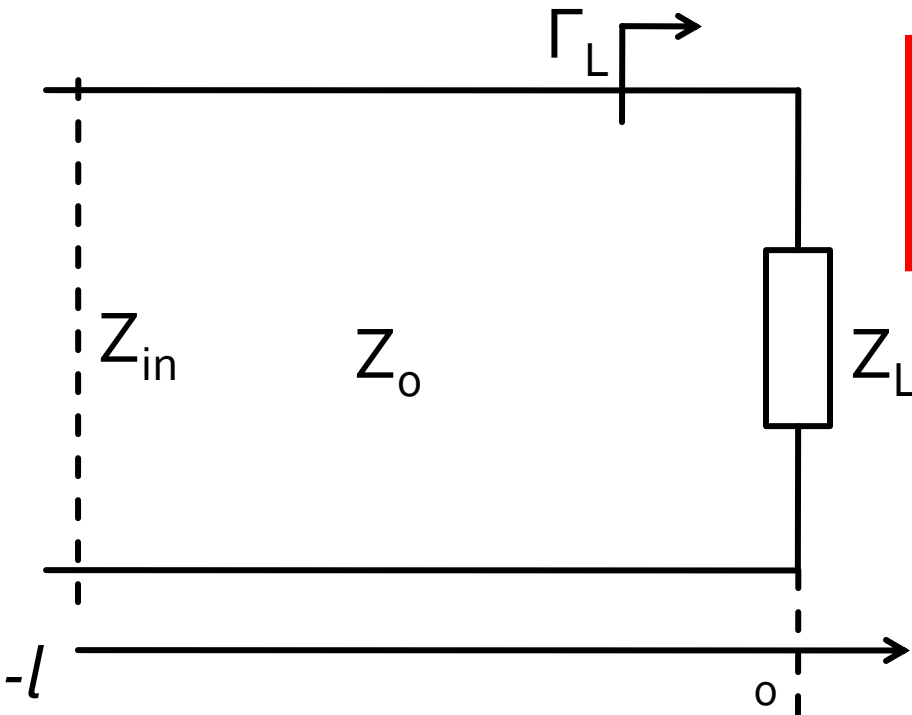
- coeficient de reflexie in tensiune

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

- Z_0 real

Linie fara pierderi

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



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

Cuprins

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

Adaptare dpdv al puterii

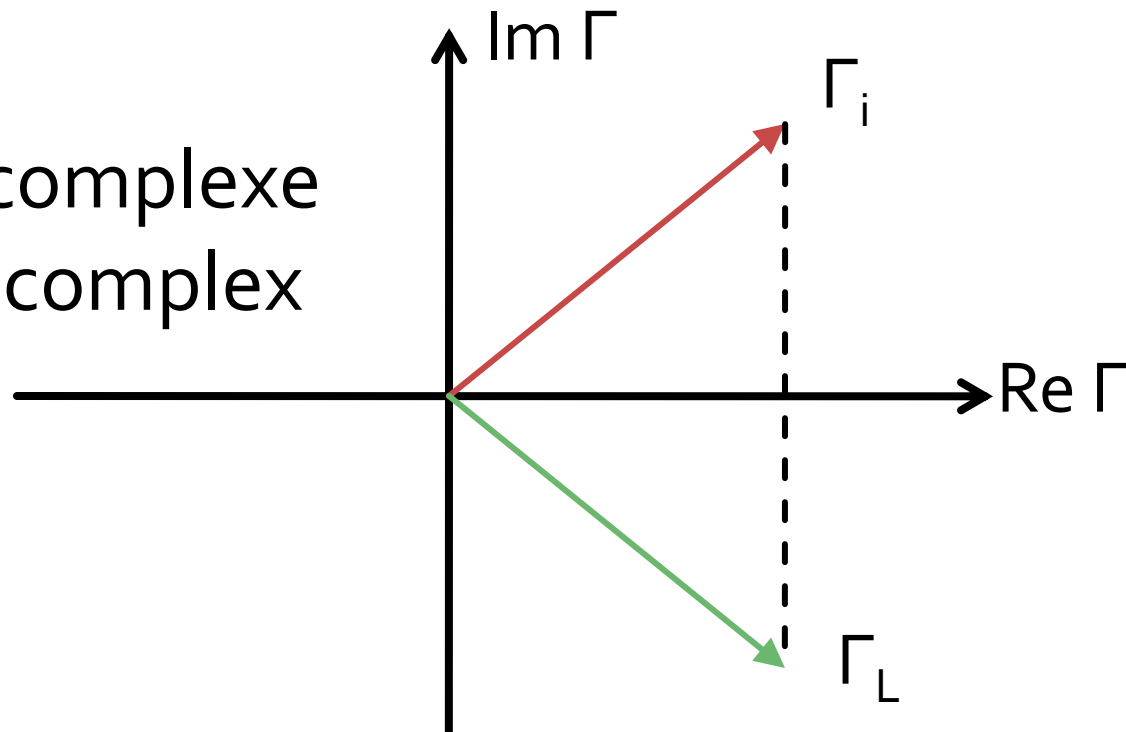
Daca se alege un Z_0 real

$$Z_L = Z_i^*$$

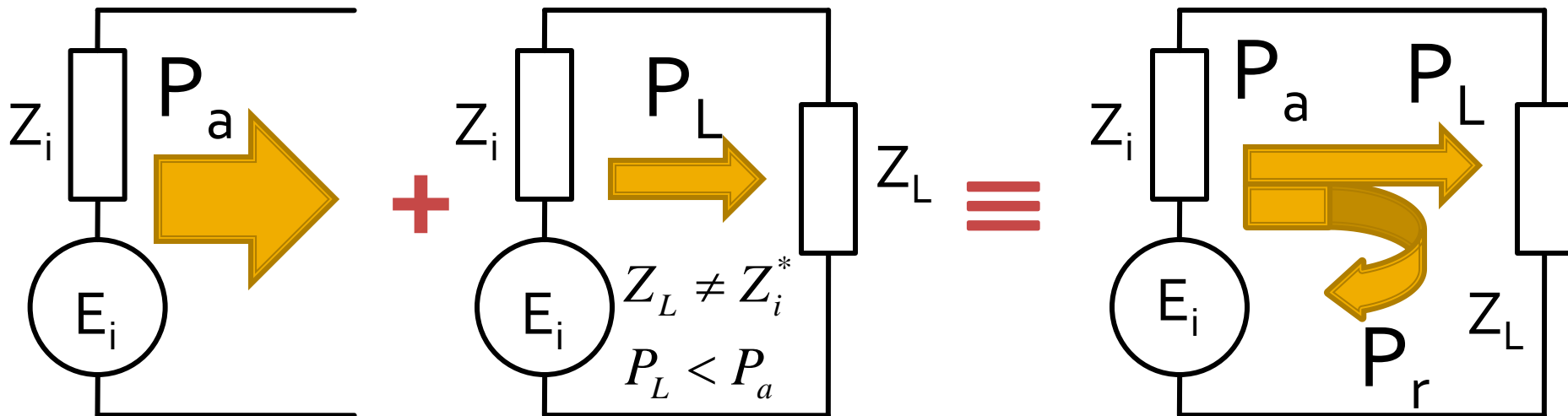
$$\Gamma = \frac{Z - Z_0}{Z + Z_0}$$

$$\Gamma_L = \Gamma_i^*$$

- numere complexe
- in planul complex

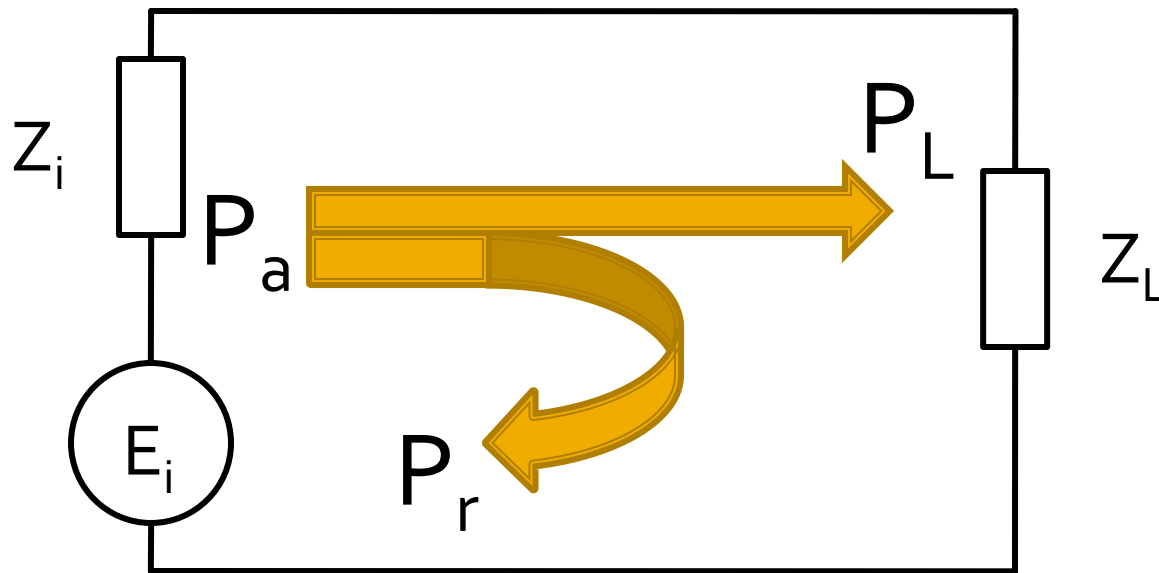


Reflexie de putere / Model



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

Reflexie de putere / Model



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

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

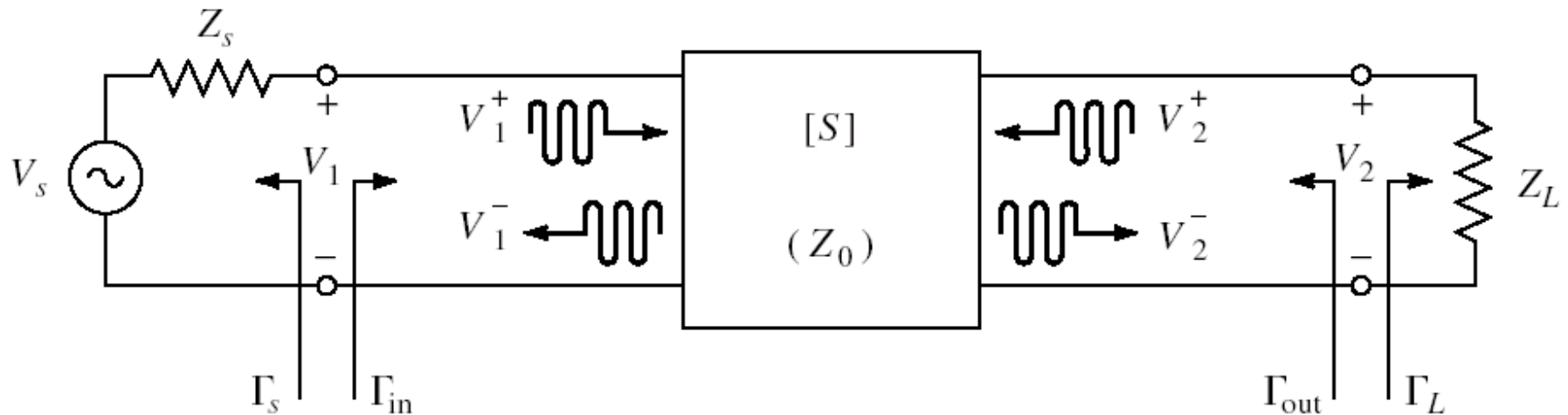
$$P_r = P_a - P_L = \frac{|E_i|^2}{4R_i} - \frac{R_L \cdot |E_i|^2}{(R_i + R_L)^2 + (X_i + X_L)^2} = \frac{|E_i|^2}{4R_i} \cdot \left[1 - \frac{4R_L \cdot R_i}{(R_i + R_L)^2 + (X_i + X_L)^2} \right]$$

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

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

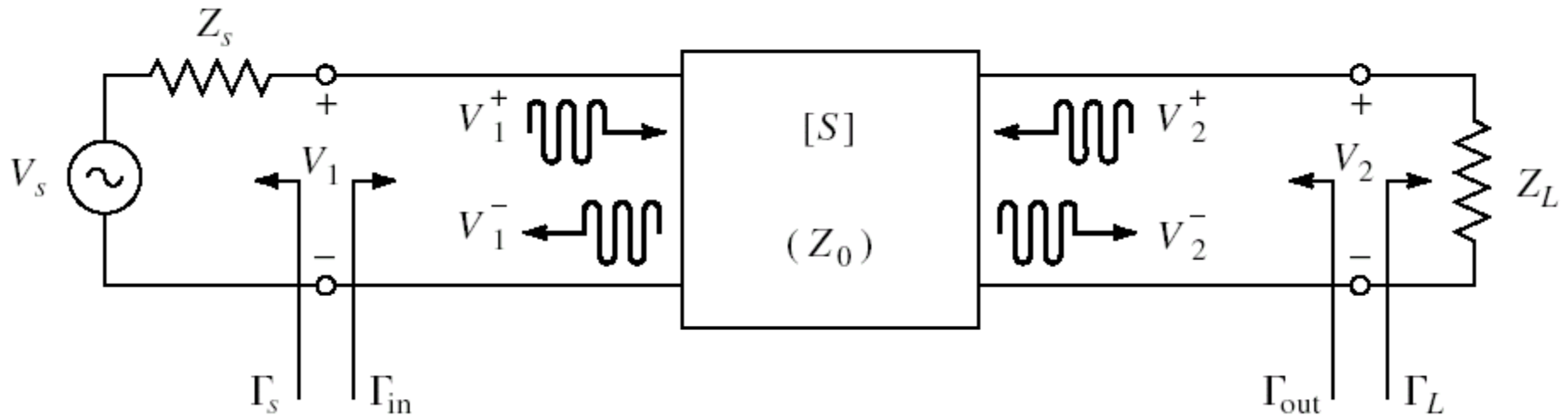
Amplificatoare de microunde

Cuadripol Amplificator (diport)



- Caracterizare cu parametri S
- Normalizati la Z_0 (implicit 50Ω)
- Cataloage: parametri S pentru anumite polarizari

Diport amplificador

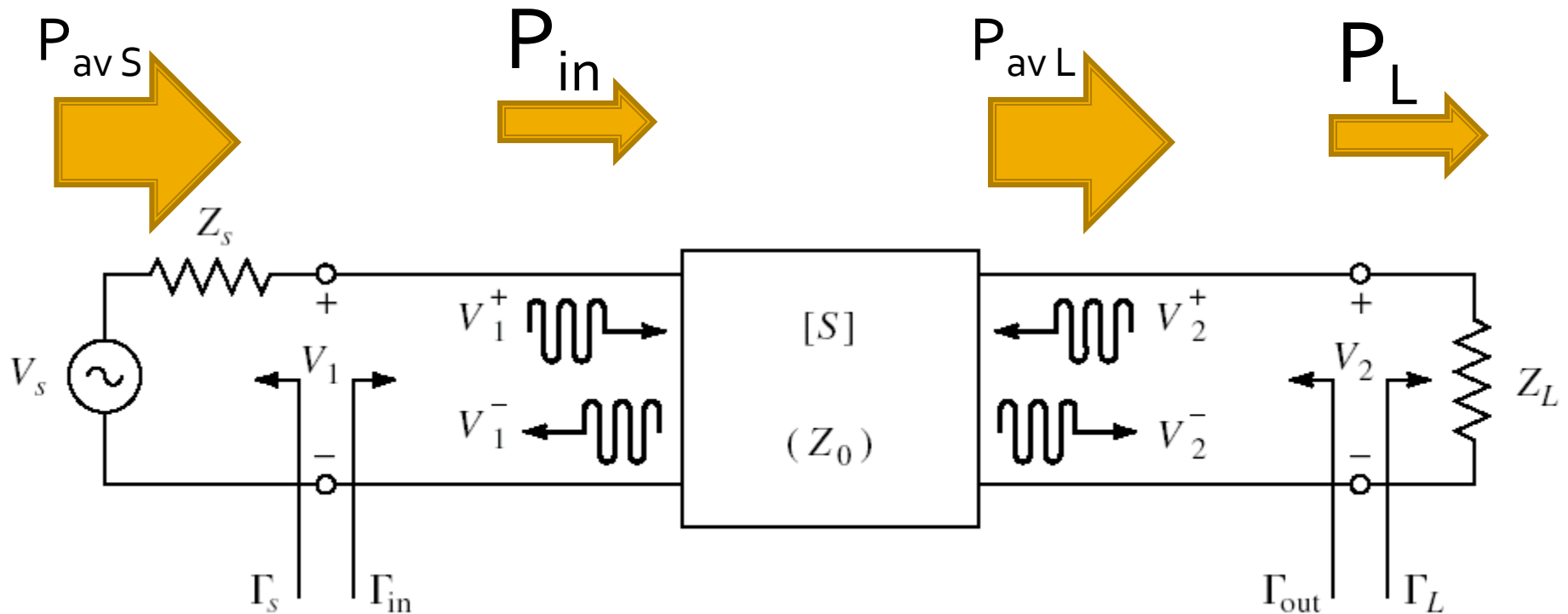


$$\Gamma_{in} = \frac{V_1^-}{V_1^+} = S_{11} + \frac{S_{12} \cdot S_{21} \cdot \Gamma_L}{1 - S_{22} \cdot \Gamma_L}$$

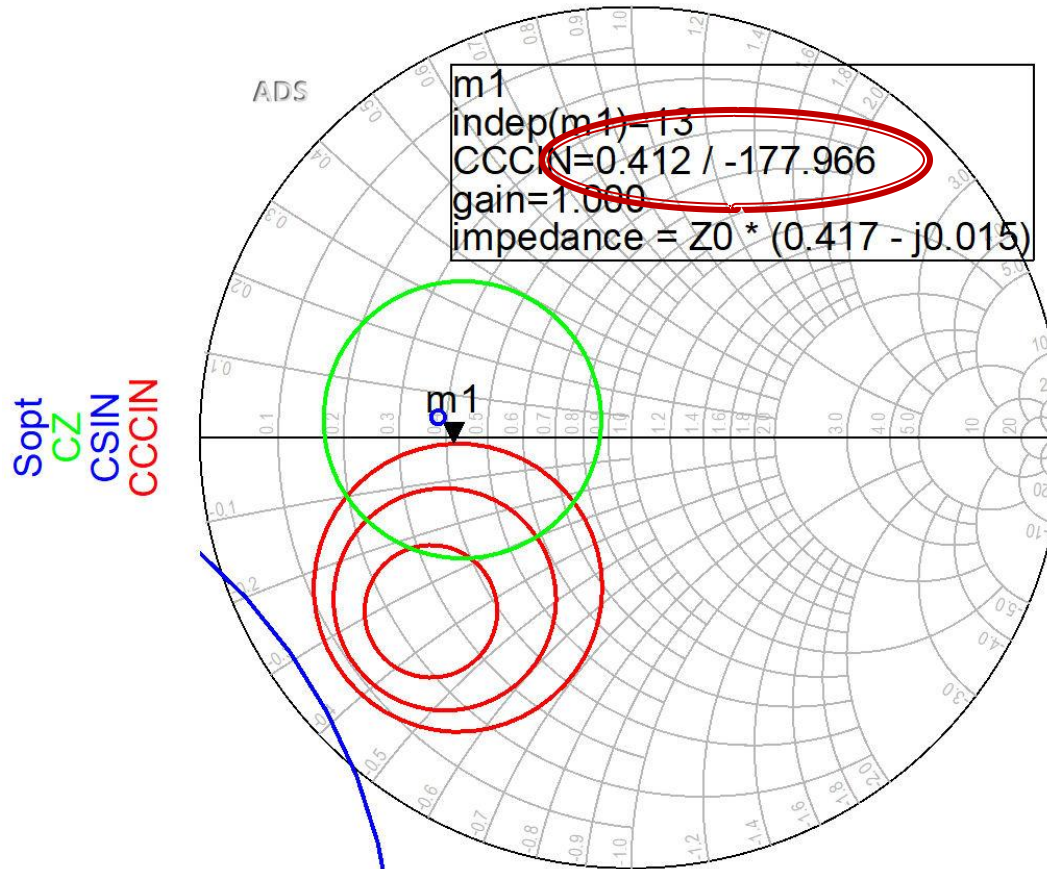
$$\Gamma_{out} = \frac{V_2^-}{V_2^+} = S_{22} + \frac{S_{12} \cdot S_{21} \cdot \Gamma_s}{1 - S_{11} \cdot \Gamma_s}$$

Puteri / Adaptare

- Doua porturi in care adaptarea influenteaza transferul de putere

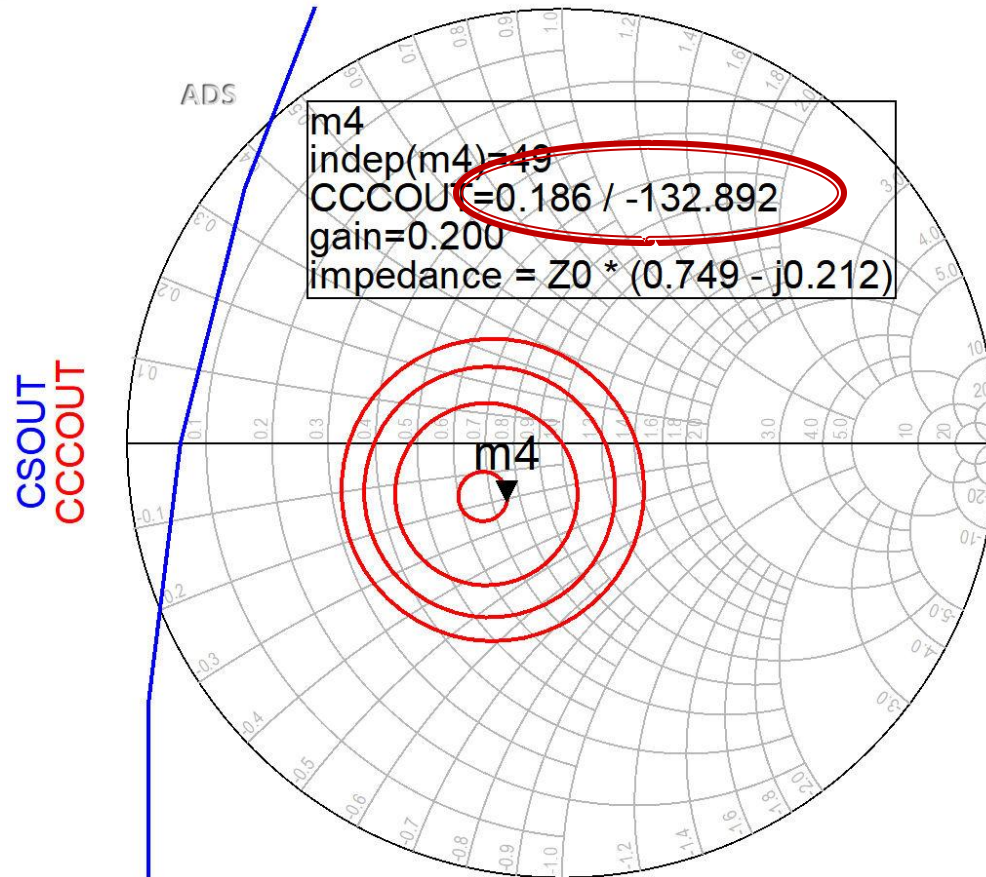


Adaptare la intrare



- 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)

Amplificatoare de banda larga

Amplificatoare de microunde

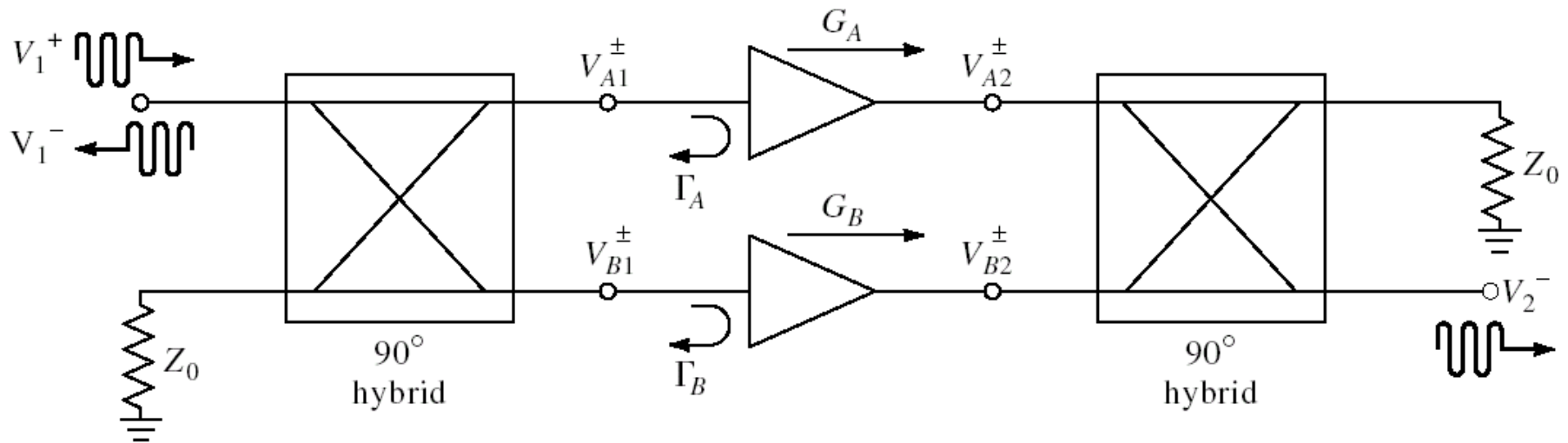
Cuprins

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

Amplificatoare de banda larga

- Se pot obtine prin un numar de tehnici de proiectare
 1. Retele de adaptare care sa compenseze scaderea castigului cu frecventa
 2. Retele de adaptare rezistive
 3. Reactie negativa
 4. Amplificatoare echilibrate
 5. Amplificatoare distribuite
 6. Amplificatoare differentiale

Amplificatoare echilibrate



- 2 Amplificatoare (identice) cu doua cuploare hibride 3 dB / 90° la intrare si iesire

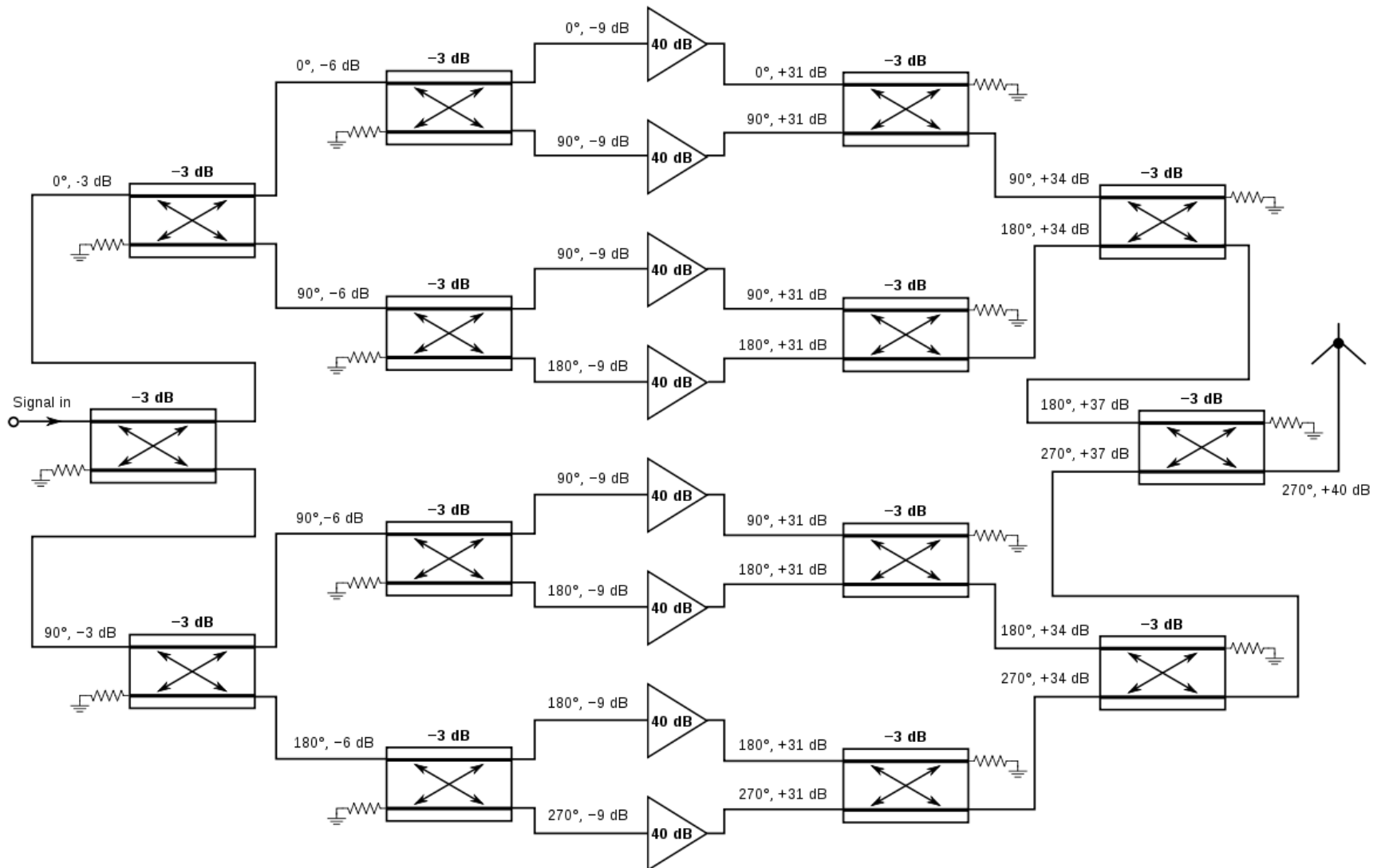
$$S_{21} = \frac{-j}{2} \cdot (G_A + G_B)$$

$$S_{21}|_{A=B} = -j \cdot G$$

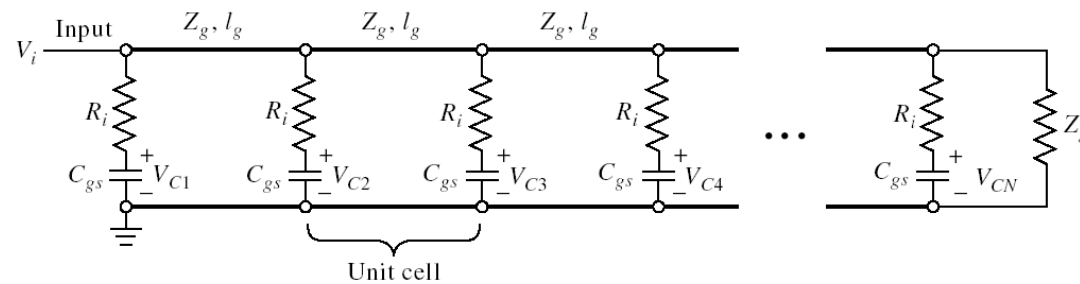
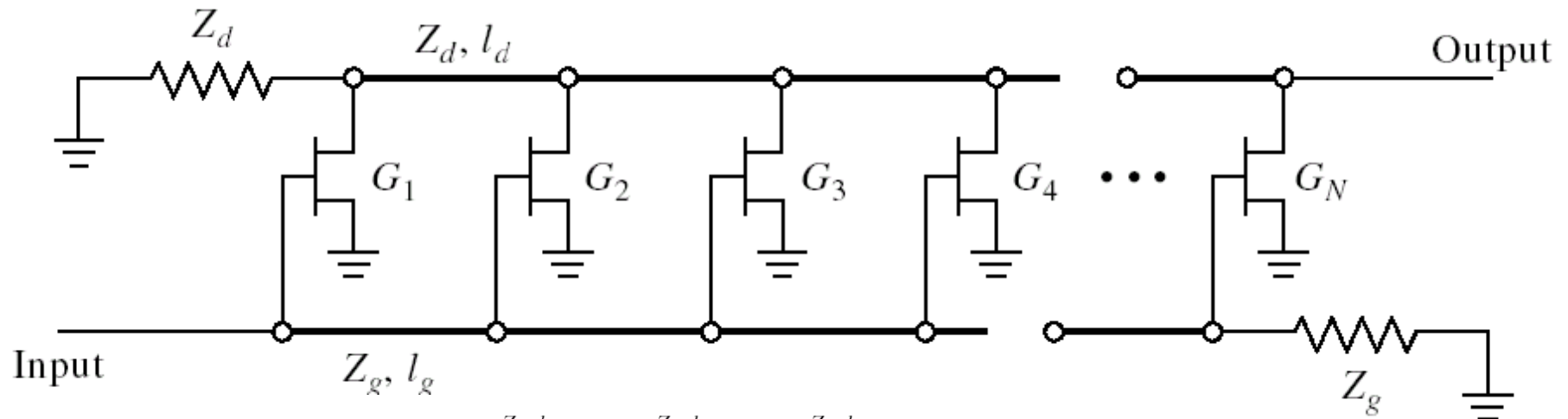
$$S_{11} = \frac{1}{2} \cdot (\Gamma_A - \Gamma_B) \quad F = \frac{1}{2} \cdot (F_A + F_B)$$

$$S_{11}|_{A=B} = 0$$

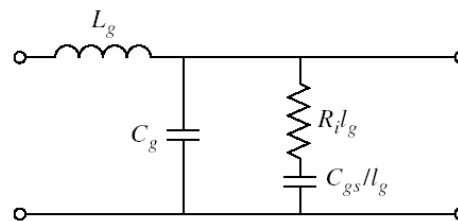
Amplificatoare echilibrate



Amplificatoare distribuite



(a)



(b)

Amplificatoare distribuite

- Conditia de sincronizare

- intarzierea pe liniile de intrare (grila) egala cu cea de pe liniile de iesire (drena)

$$\gamma_g = \alpha_g + j \cdot \beta_g \quad \gamma_d = \alpha_d + j \cdot \beta_d \quad \beta_g \cdot l_g = \beta_d \cdot l_d$$

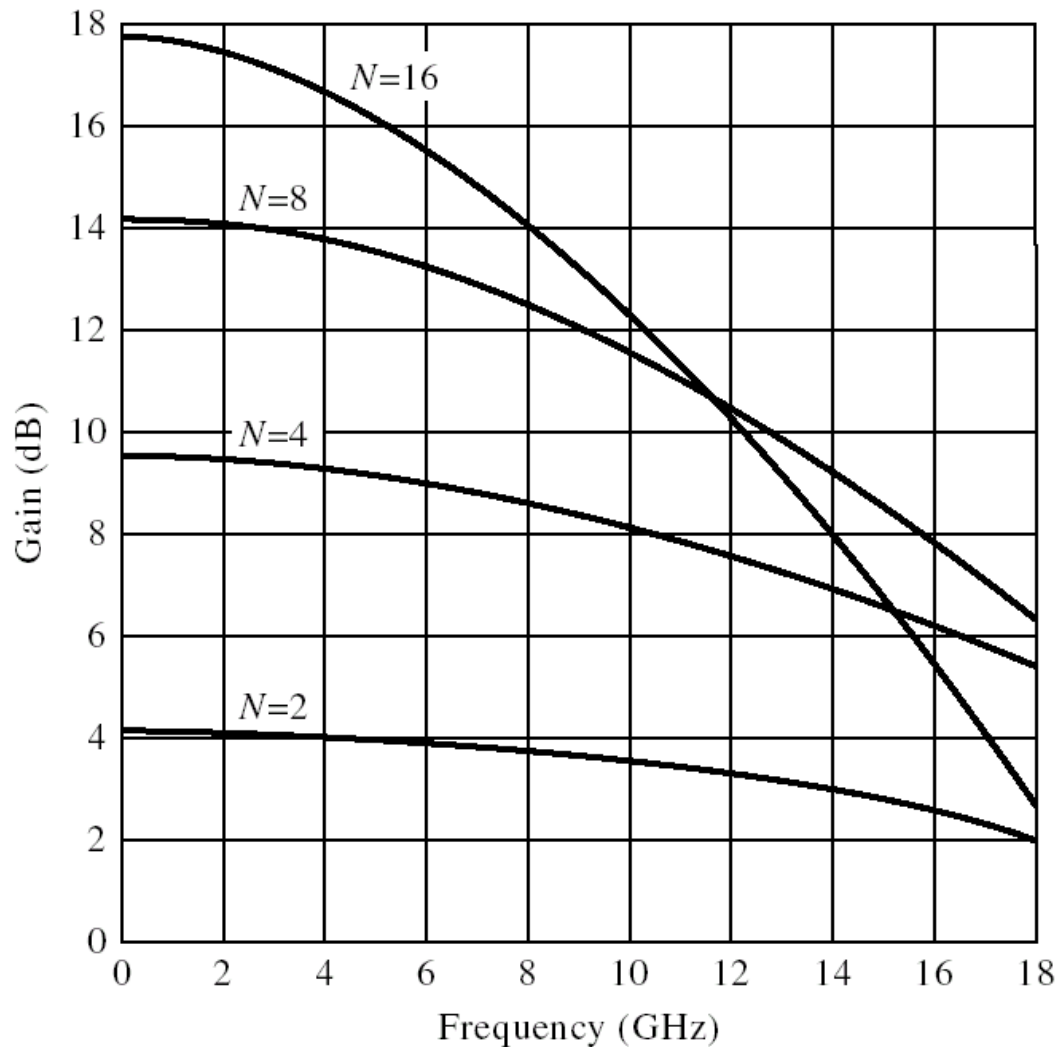
- Castigul de putere

$$G = \frac{g_m^2 \cdot Z_d \cdot Z_g}{4} \cdot \frac{\left(e^{-N \cdot \alpha_g \cdot l_g} - e^{-N \cdot \alpha_d \cdot l_d} \right)^2}{\left(e^{-\alpha_g \cdot l_g} - e^{-\alpha_d \cdot l_d} \right)^2}$$

- Castigul de putere fara pierderi

$$G = \frac{g_m^2 \cdot Z_d \cdot Z_g \cdot N^2}{4}$$

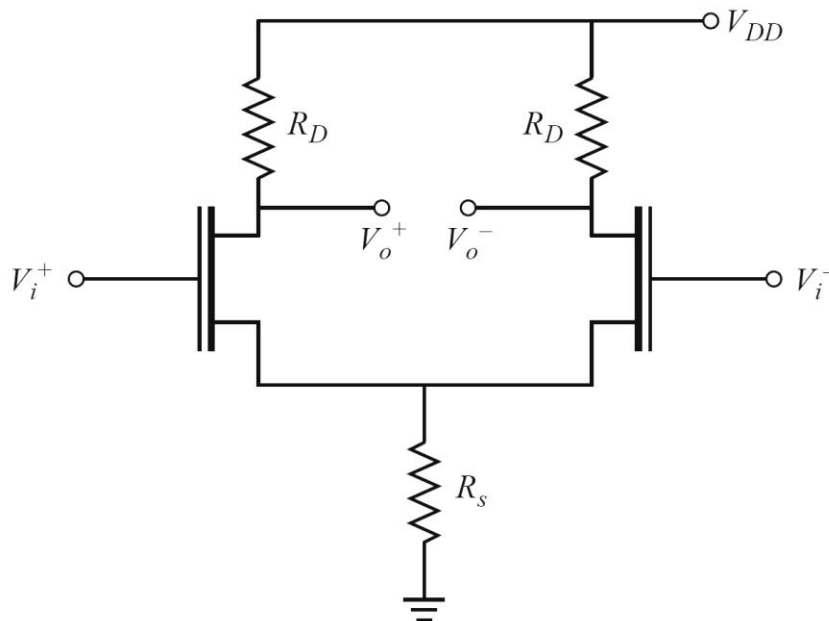
Amplificatoare distribuite



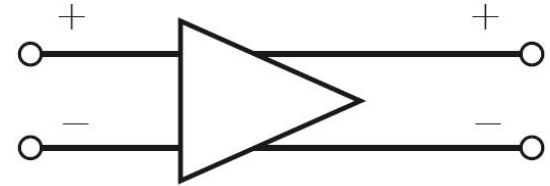
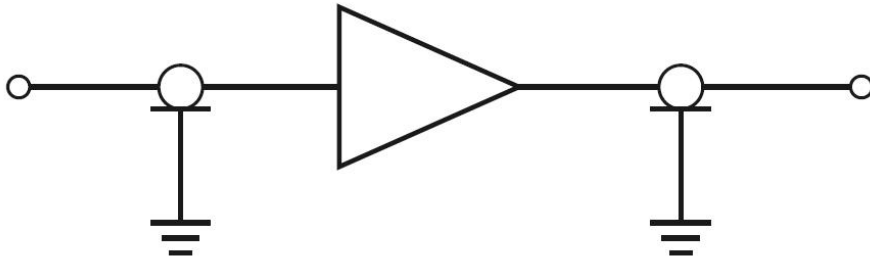
$$N_{opt} = \frac{\ln(\alpha_g \cdot l_g) - \ln(\alpha_d \cdot l_d)}{\alpha_g \cdot l_g - \alpha_d \cdot l_d}$$

Amplificatoare diferențiale

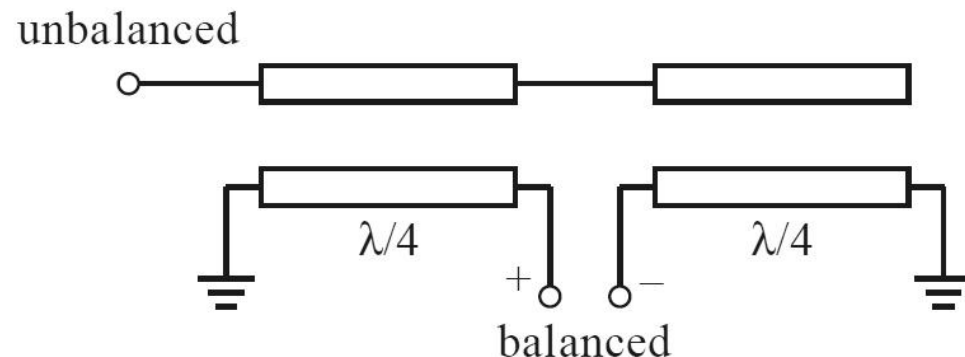
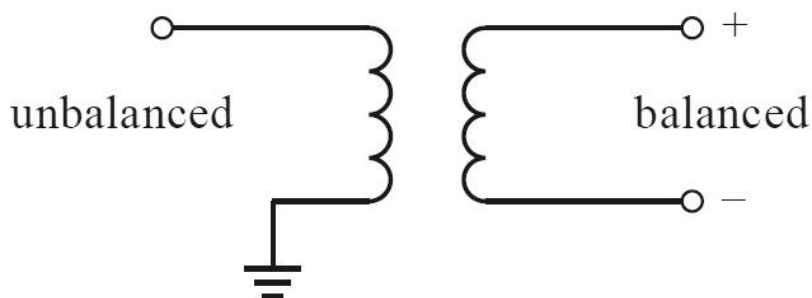
- Capacitățile de intrare în cele două tranzistoare în conexiune diferențială apar conectate în serie
- Se dublează astfel frecvența unitară



Amplificatoare diferențiale



- Se utilizează structuri de circuit care să facă conversia de la dispozitivele unipolare la cele diferențiale
 - cuploare hibride 3dB / 180°
 - "balun" (balanced - unbalanced)



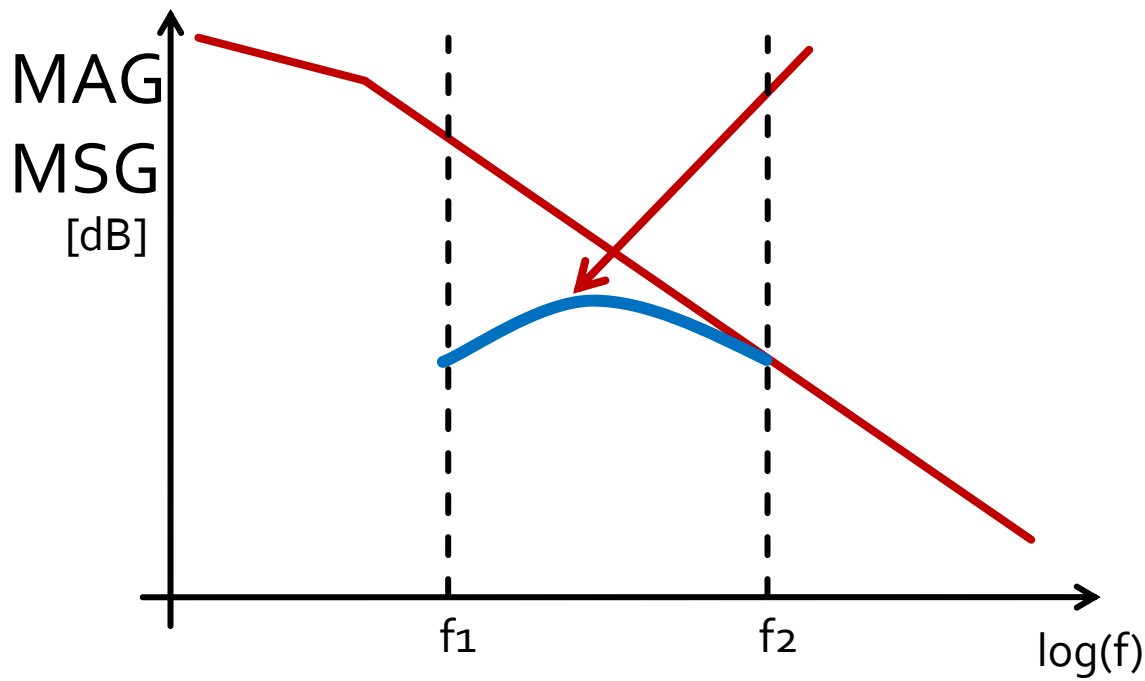
Amplificatoare de banda larga

- Se pot obtine prin un numar de tehnici de proiectare
 1. **Retele de adaptare care sa compenseze scaderea castigului cu frecventa**
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Amplificatoare de banda larga

1. **Retele de adaptare care sa compenseze scaderea castigului cu frecventa**

- Metoda utilizata este de a repeta proiectarea la mai multe (macar 2) frecvente si impunerea unui castig egal la acestea

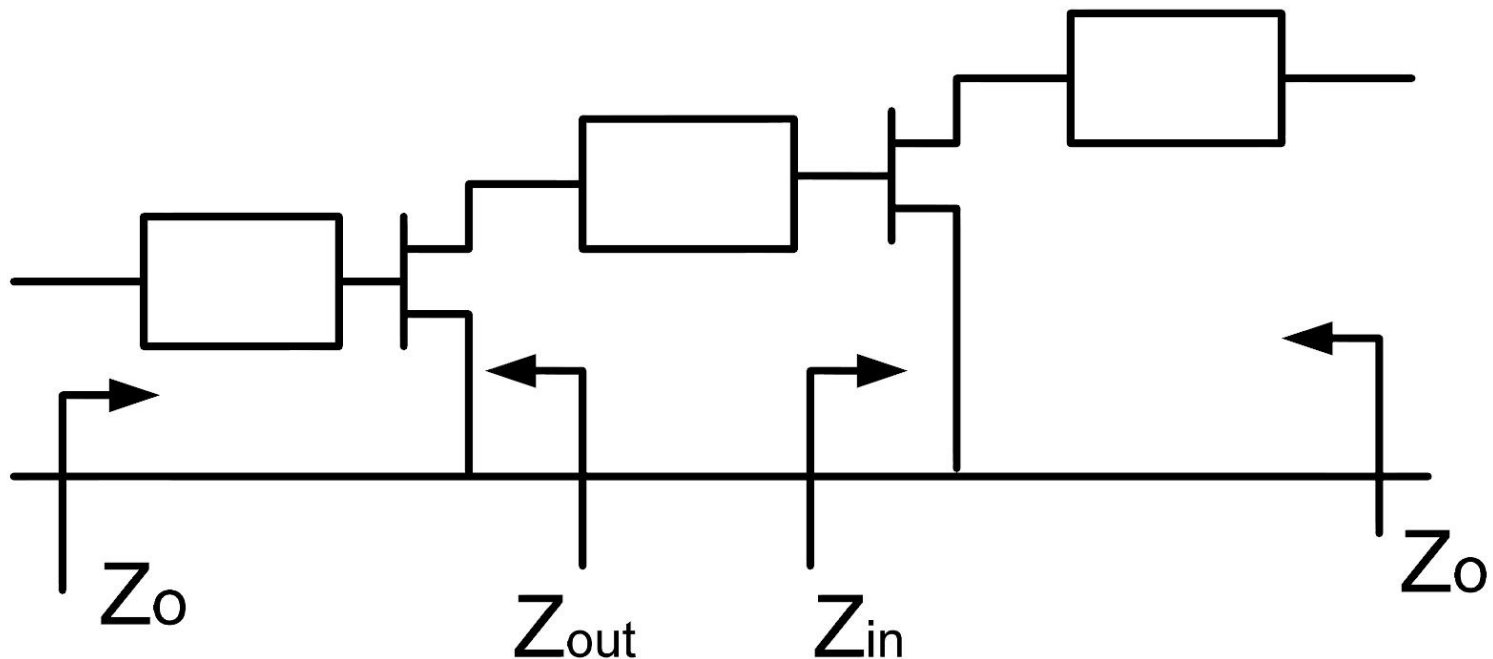


Amplificatoare in cascada

Amplificatoare de microunde

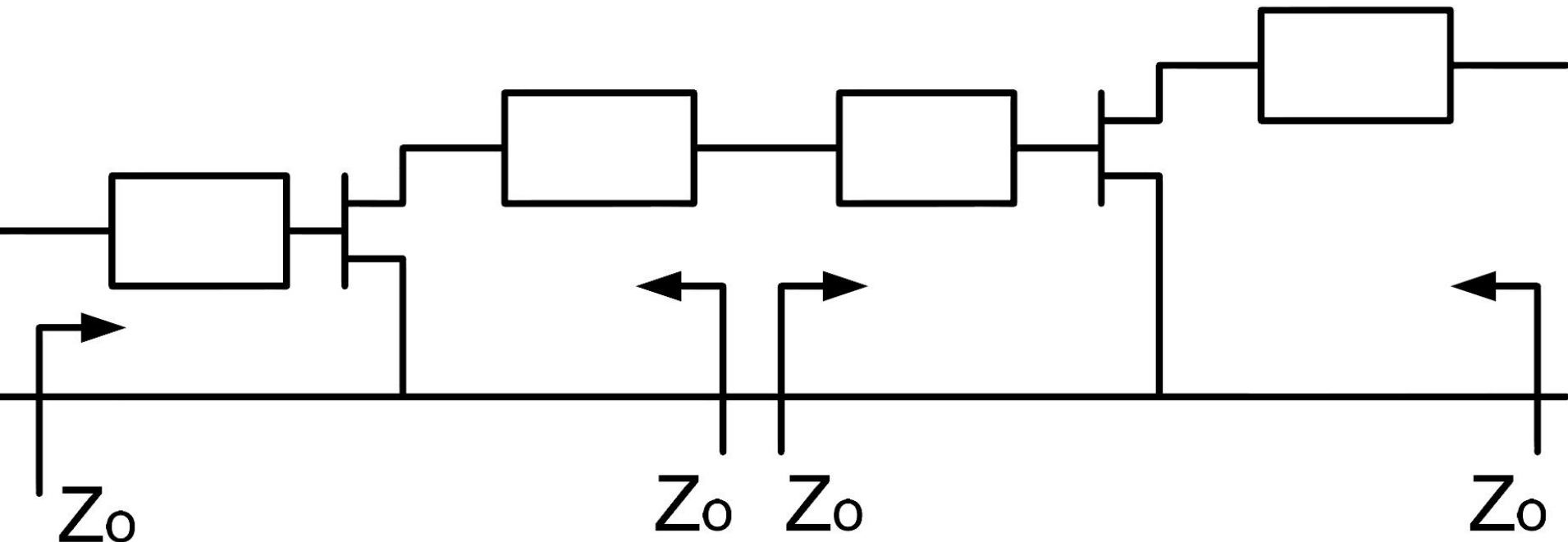
Amplificatoare in cascada

- Adaptarea inter-etaje se poate proiecta in doua moduri:
 - adaptarea unui etaj spre Γ necesar pentru celalalt



Amplificatoare in cascada

- Adaptarea inter-etaje se poate proiecta in doua moduri:
 - adaptarea fiecarui etaj spre un $\Gamma = 0$ intermediar

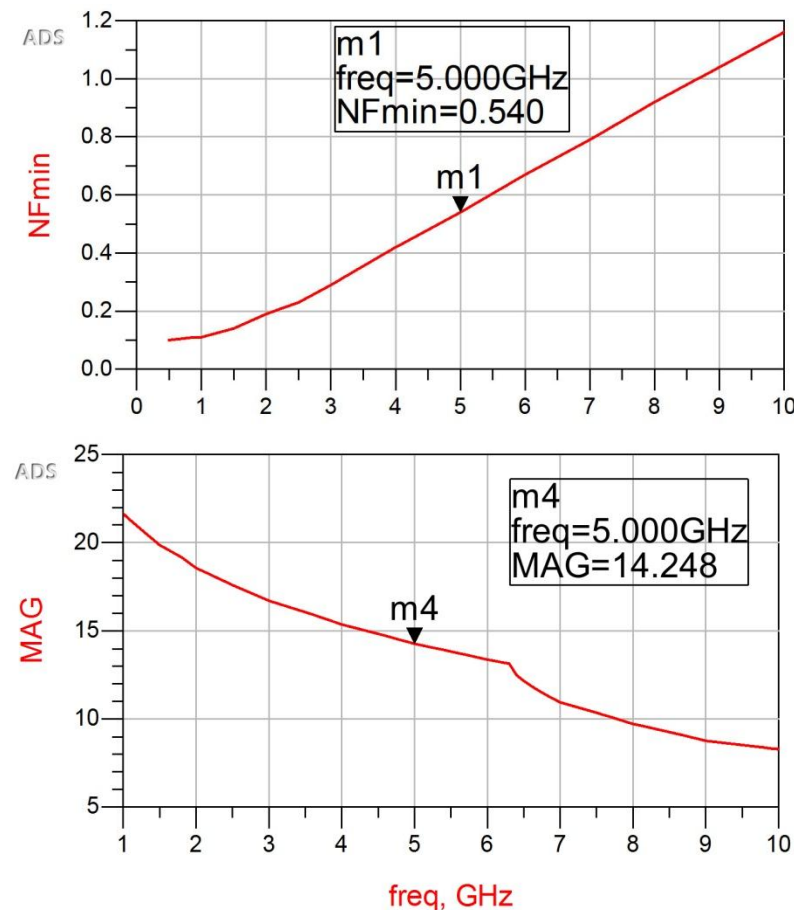


Exemplu LNA cascada

- Similar cu tema de la mini-proiect
- Amplificator LNA cu ATF-34143 avand caracteristicile:
 - $G = 20\text{dB}$
 - $F = 1\text{dB}$
 - $@f = 5\text{GHz}$

Exemplu

- ATF-34143 at $V_{ds}=3V$ $I_d=20mA$.
- @5GHz
 - $S_{11} = 0.64 \angle 139^\circ$
 - $S_{12} = 0.119 \angle -21^\circ$
 - $S_{21} = 3.165 \angle 16^\circ$
 - $S_{22} = 0.22 \angle 146^\circ$
 - $F_{min} = 0.54$ (**tipic [dB] !**)
 - $\Gamma_{opt} = 0.45 \angle 174^\circ$
 - $r_n = 0.03$



Exemplu, LNA @ 5 GHz

■ ATF-34143 at $V_{ds}=3V$ $I_d=20mA$.

■ @5GHz

■ $S_{11} = 0.64 \angle 139^\circ$

■ $S_{12} = 0.119 \angle -21^\circ$

■ $S_{21} = 3.165 \angle 16^\circ$

■ $S_{22} = 0.22 \angle 146^\circ$

■ $F_{min} = 0.54$ (tipic [dB])

■ $\Gamma_{opt} = 0.45 \angle 174^\circ$

■ $r_n = 0.03$

IATF-34143

IS-PARAMETERS at Vds=3V Id=20mA. LAST UPDATED 01-29-99

ghz s ma r 50

2.0	0.75	-126	6.306	90	0.088	23	0.26	-120
2.5	0.72	-145	5.438	75	0.095	15	0.25	-140
3.0	0.69	-162	4.762	62	0.102	7	0.23	-156
4.0	0.65	166	3.806	38	0.111	-8	0.22	174
5.0	0.64	139	3.165	16	0.119	-21	0.22	146
6.0	0.65	114	2.706	-5	0.125	-35	0.23	118
7.0	0.66	89	2.326	-27	0.129	-49	0.25	91
8.0	0.69	67	2.017	-47	0.133	-62	0.29	67
9.0	0.72	48	1.758	-66	0.135	-75	0.34	46

IFREQ	Fopt	GAMMA	OPT	RN/Zo
IGHZ	dB	MAG	ANG	-

2.0	0.19	0.71	66	0.09
2.5	0.23	0.65	83	0.07
3.0	0.29	0.59	102	0.06
4.0	0.42	0.51	138	0.03
5.0	0.54	0.45	174	0.03
6.0	0.67	0.42	-151	0.05
7.0	0.79	0.42	-118	0.10
8.0	0.92	0.45	-88	0.18
9.0	1.04	0.51	-63	0.30
10.0	1.16	0.61	-43	0.46

Amplificatoare in cascada

- Daca e necesar un castig mai mare decat cel care poate fi oferit de un singur tranzistor
 - necesar 20dB
 - $MAG @ 5GHz = 14.248 \text{ dB} < 20\text{dB}$
- Se utilizeaza formula lui Friis pentru a imparti necesarul de:
 - castig
 - zgomot
- pe cele doua etaje individuale

Formula lui Friis (zgomot)

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

- Formula lui Friis, efecte:
 - e esential ca primul etaj de amplificare sa fie **nezgomotos**, chiar cu sacrificarea in parte a castigului
 - urmatoarele etaje pot fi optimizate pentru **castig**
- Formula lui Friis trebuie utilizata in **coordonate liniare**
- **Avago/Broadcom AppCAD**
 - AppCAD Free Design Assistant Tool for Microsoft Windows → Google

Formula lui Friis (zgomot)

$$G_{cas} = G_1 \cdot G_2$$

$$F_{cas} = F_1 + \frac{1}{G_1} (F_2 - 1)$$

■ Formula lui Friis

- primul etaj factor de zgomot mai mic, probabil insotit de un castig mai mic
- al doilea etaj castig mare, probabil insotit de un factor de zgomot mai mare

■ Este esential sa se pastreze o rezerva

- $G = G_{tema} + \Delta G$
- $F = F_{tema} - \Delta F$

■ Tema se interpreteaza

- $G > G_{tema}$, mai bine, fara a fi nevoie sa se sacrifice alti parametri pentru castiguri mult mai mari
- $F < F_{tema}$, mai bine, cu cat mai mic cu atat mai bine, e util sa se incerce obtinerea unui **zgomot cat mai mic, cu indeplinirea** celorlalte conditii

Formula lui Friis (zgomot)

- Formula lui Friis
 - primul etaj factor de zgomot mai mic, probabil insotit de un castig mai mic
 - al doilea etaj castig mare, probabil insotit de un factor de zgomot mai mare
- Impartire pe cele doua etaje (Estimat)
 - intrare: $F_1 = 0.7 \text{ dB}$, $G_1 = 9 \text{ dB}$
 - iesire: $F_2 = 1.2 \text{ dB}$, $G_2 = 13 \text{ dB}$
- Transformare **in coordonate liniare !**

$$F_1 = 10^{\frac{F_1[dB]}{10}} = 10^{0.07} = 1.175$$

$$F_2 = 10^{\frac{F_2[dB]}{10}} = 10^{0.12} = 1.318$$

$$F_{cas} = F_1 + \frac{1}{G_1} (F_2 - 1) = 1.215$$

$$F_{cas} = 10 \cdot \log(1.215) = 0.846 \text{ dB}$$

$$G_1 = 10^{\frac{G_1[dB]}{10}} = 10^{0.9} = 7.943$$

$$G_2 = 10^{\frac{G_2[dB]}{10}} = 10^{1.3} = 19.953$$

$$G_{cas} = G_1 \cdot G_2 = 158.49$$

$$G_{cas} = 10 \cdot \log(158.49) = 22 \text{ dB}$$

Formula lui Friis (zgomot)

■ Avago/Broadcom AppCAD

AppCAD - [NoiseCalc]

File Calculate Application Examples Options Help

NoiseCalc Set Number of Stages = 2 Calculate [F4]

Stage Data	Units	Stage 1	Stage 2
Stage Name:		Avago Duplexer	Avago ATF-36xxx
Noise Figure	dB	0.7	1.2
Gain	dB	9	13
Output IP3	dBm	100	14.5
dNF/dTemp	dB/°C	0	0
dG/dTemp	dB/°C	0	0
Stage Analysis:			
NF (Temp corr)	dB	0.70	1.20
Gain (Temp corr)	dB	9.00	13.00
Input Power	dBm	-50.00	-41.00
Output Power	dBm	-41.00	-28.00
d NF/d NF	dB/dB	0.97	0.15
d NF/d Gain	dB/dB	-0.03	0.00
d IP3/d IP3	dBm/dBm	0.00	1.00

Enter System Parameters:

Input Power	-50	dBm
Analysis Temperature	25	°C
Noise BW	1	MHz
Ref Temperature	25	°C
S/N (for sensitivity)	10	dB
Noise Source (Ref)	290	°K

System Analysis:

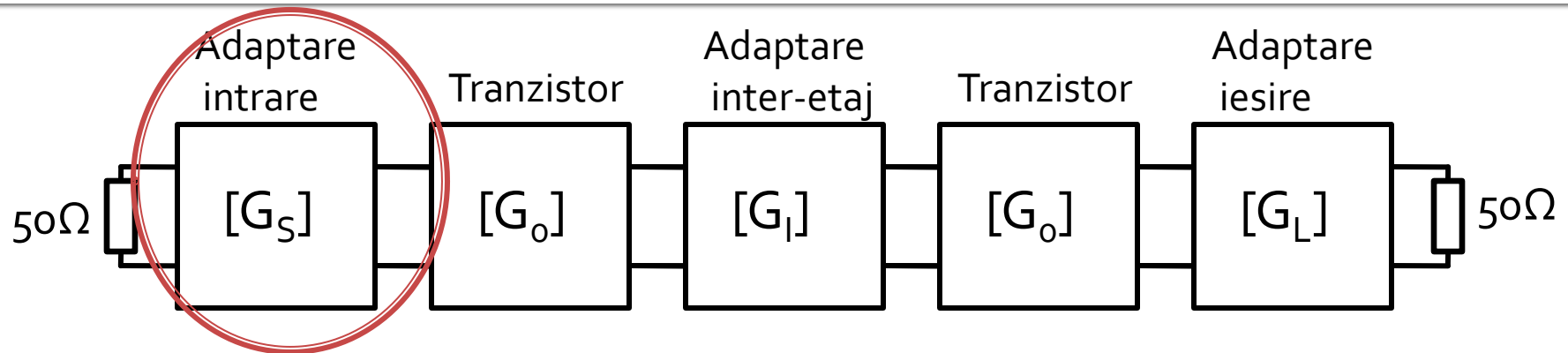
Gain	22.00	dB
Noise Figure	0.85	dB
Noise Temp	82.34	°K
SNR	63.13	dB
MDS	-113.13	dBm
Sensitivity	-103.13	dBm
Noise Floor	-173.13	dBm/Hz

Input IP3	-7.50	dBm
Output IP3	14.50	dBm
Input IM level	-135.00	dBm
Input IM level	-85.00	dbc
Output IM level	-113.00	dBm
Output IM level	-85.00	dbc
SFDR	70.42	dB

Proiectare etaje cascade

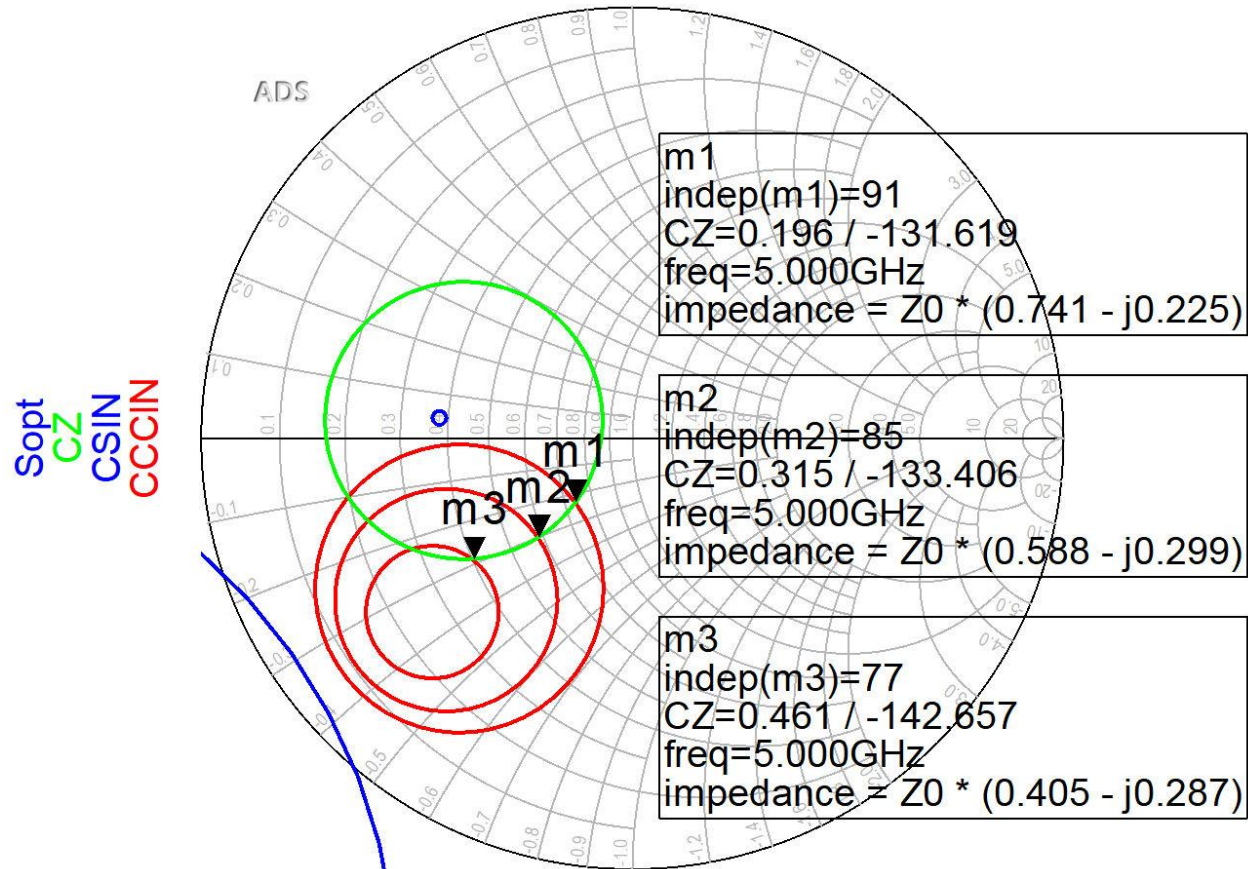
- Impartire pe cele doua etaje (Estimat)
 - intrare: $F_1 = 0.7 \text{ dB}$, $G_1 = 9 \text{ dB}$
 - iesire: $F_2 = 1.2 \text{ dB}$, $G_2 = 13 \text{ dB}$
 - total: $F = 0.85 \text{ dB}$, $G = 22 \text{ dB}$
- Indeplineste conditiile din tema (cu rezerva corespunzatoare)
- Se poate refolosi o parte din calculul amplificatorului cu un singur etaj (C8)
 - adaptarea la intrare anterioara este potrivita la intrarea amplificatorului multietaj – zgomot f. mic, castig onorabil
 - adaptare la iesire este conceputa pentru castig maxim
 - intrarea si iesirea erau proiectate pentru 50Ω la intrare si iesire (similar cu situatia curenta)

Adaptare la intrare



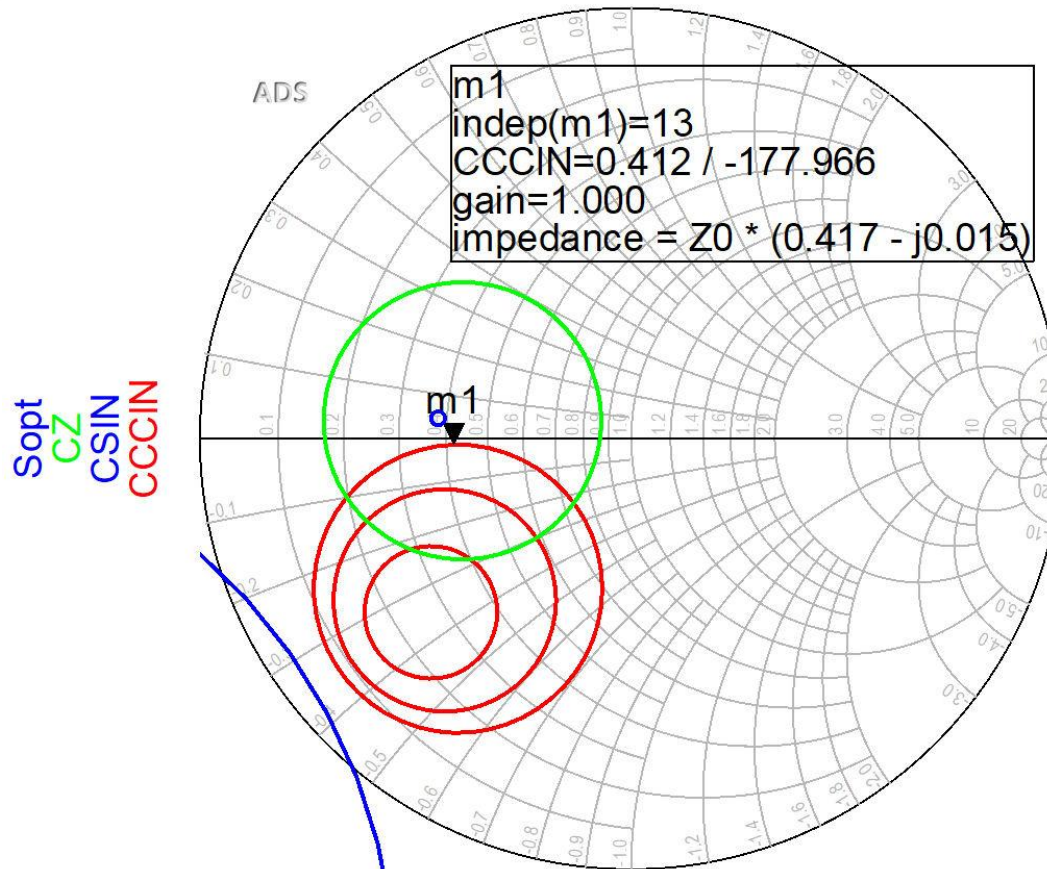
- Se acorda importanta in special comportarii la **zgomot** (mic/minim)
- Se mai tine cont de
 - Castig (sacrificat, dar nu foarte mult)
 - Banda dorita (prin factorul de calitate Q)
 - Stabilitate

Adaptare la intrare



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

Adaptare la intrarea etajului 1 (S1)



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

Adaptare la intrarea etajului 1 (S1)

- G_{S1} : Pozitia m1 de pe grafic, **1dB**

$$\Gamma_S = 0.412 \angle -178^\circ$$

$$|\Gamma_S| = 0.412; \quad \varphi = -178^\circ$$

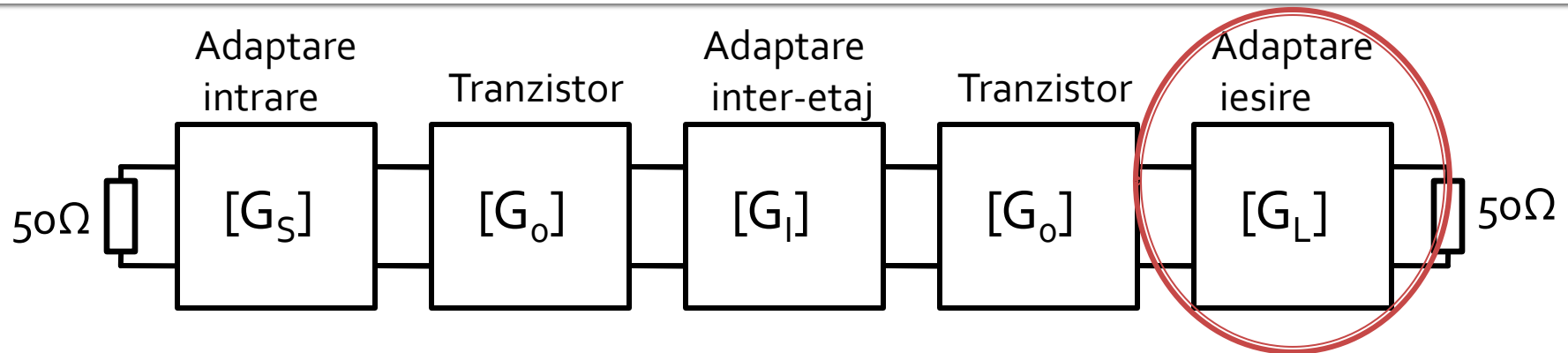
$$\cos(\varphi + 2\theta) = -|\Gamma_S| \quad \text{Im}[y_S(\theta)] = \frac{\mp 2 \cdot |\Gamma_S|}{\sqrt{1 - |\Gamma_S|^2}}$$

$$\cos(\varphi + 2\theta) = -0.412 \Rightarrow (\varphi + 2\theta) = \pm 114.33^\circ$$

$$\theta_{sp} = \tan^{-1}(\text{Im}[y_S(\theta)]) = \tan^{-1}\left(\frac{\mp 2 \cdot |\Gamma_S|}{\sqrt{1 - |\Gamma_S|^2}}\right)$$

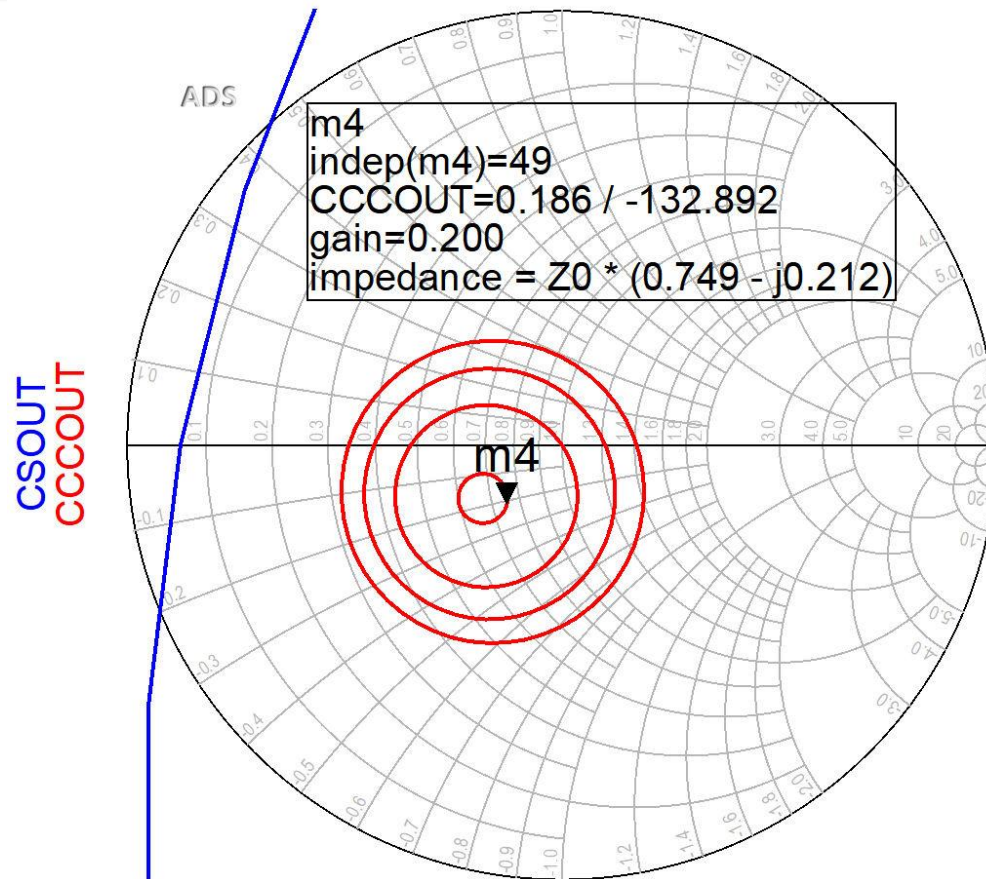
$$(\varphi + 2\theta) = \begin{cases} +114.33^\circ \\ -114.33^\circ \end{cases} \quad \theta = \begin{cases} 146.2^\circ \\ 31.8^\circ \end{cases} \quad \text{Im}[y_S(\theta)] = \begin{cases} -0.904 \\ +0.904 \end{cases} \quad \theta_{sp} = \begin{cases} 137.9^\circ \\ 42.1^\circ \end{cases}$$

Adaptare la iesire



- Se acorda importanta in special **castigului** (mare/maxim)
- Se mai tine cont de
 - Banda dorita (prin factorul de calitate Q)
 - Stabilitate
 - Zgomotul **nu** intervine, nu este afectat

Adaptare la iesirea etajului 2 (L2)



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

Adaptare la iesirea etajului 2 (L2)

- G_{L_2} : Pozitia m_4 de pe grafic, **0.2dB**

$$\Gamma_L = 0.186 \angle -132.9^\circ$$

$$|\Gamma_L| = 0.186; \quad \varphi = -132.9^\circ$$

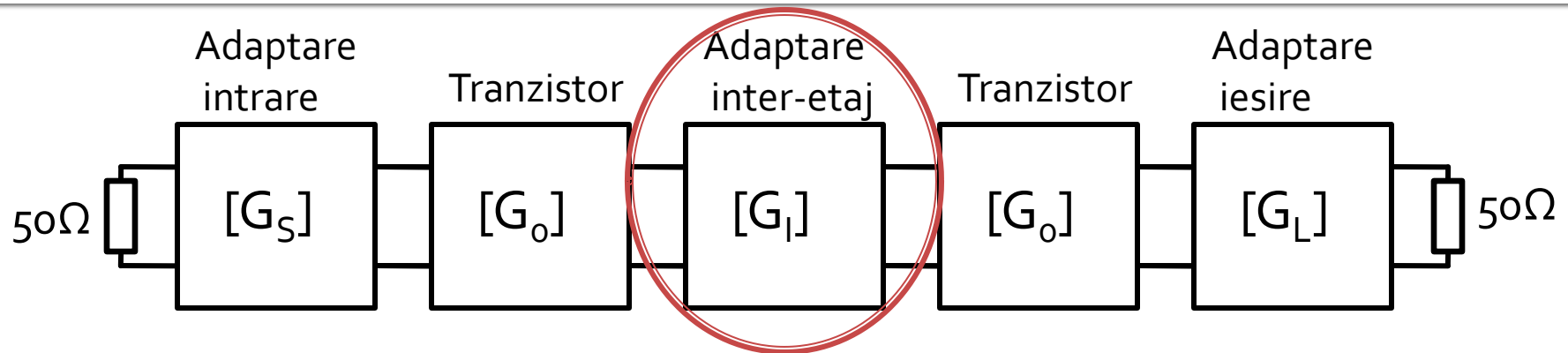
$$\cos(\varphi + 2\theta) = -|\Gamma_L| \qquad \text{Im}[y_L(\theta)] = \frac{-2 \cdot |\Gamma_L|}{\sqrt{1 - |\Gamma_L|^2}} = -0.379$$

$$\cos(\varphi + 2\theta) = -0.186 \Rightarrow (\varphi + 2\theta) = \pm 100.72^\circ$$

$$\theta_{sp} = \tan^{-1}(\text{Im}[y_L(\theta)]) = \tan^{-1}\left(\frac{\mp 2 \cdot |\Gamma_L|}{\sqrt{1 - |\Gamma_L|^2}}\right)$$

$$(\varphi + 2\theta) = \begin{cases} +100.72^\circ \\ -100.72^\circ \end{cases} \quad \theta = \begin{cases} 116.8^\circ \\ 16.1^\circ \end{cases} \quad \text{Im}[y_L(\theta)] = \begin{cases} -0.379 \\ +0.379 \end{cases} \quad \theta_{sp} = \begin{cases} 159.3^\circ \\ 20.7^\circ \end{cases}$$

Adaptare inter etaj



- Se acorda importanta **castigului** (mare) dar si zgomotului
- Se mai tine cont de
 - Banda dorita (prin factorul de calitate Q)
 - Stabilitate
 - Prin afectarea factorului de zgomot al celui de-al doilea etaj (acceptat mai mare cu Friis), zgomotul trebuie considerat dar cu conditii mai putin restrictive

Proiectare etaje cascade

- Castig

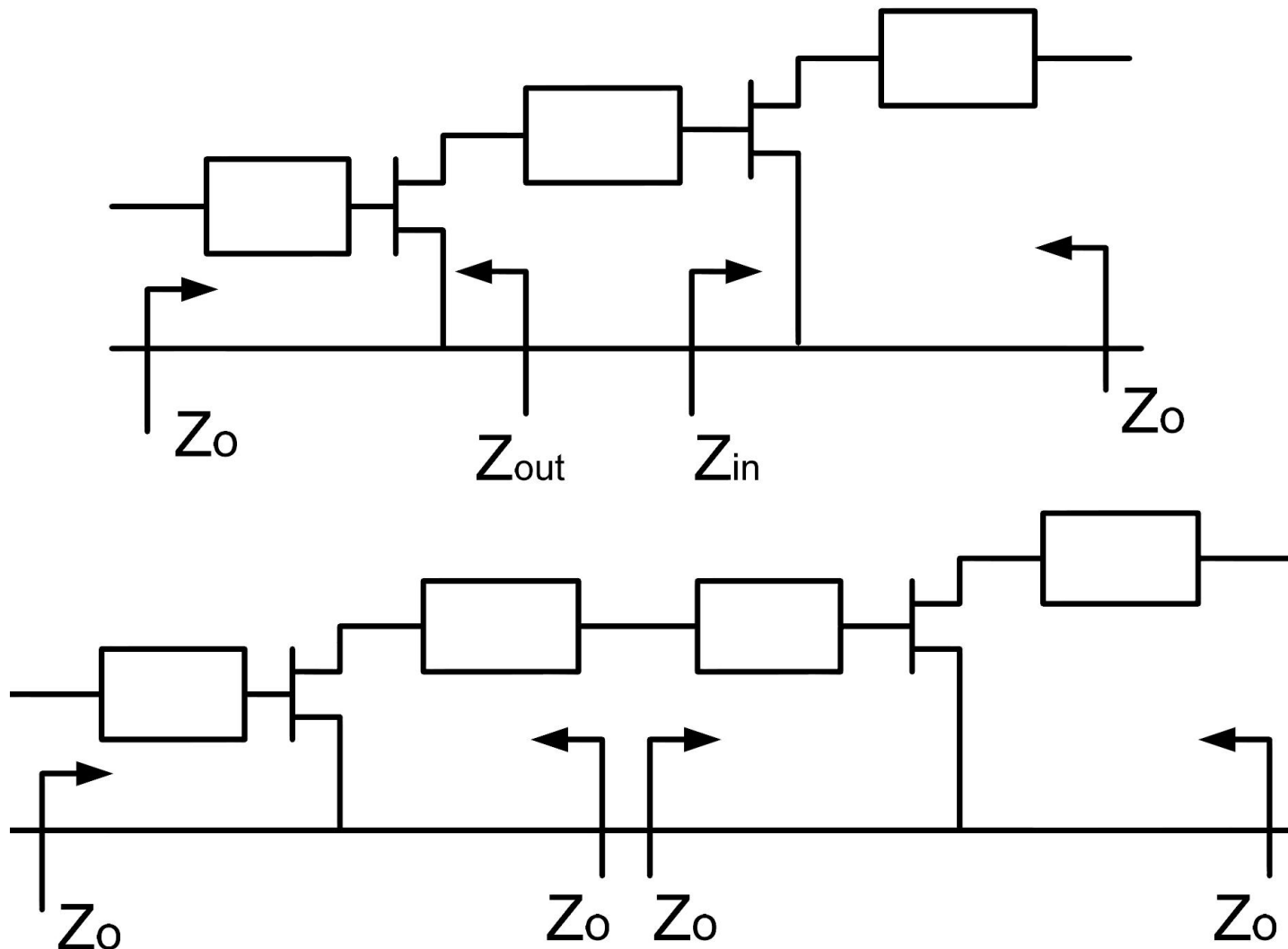
$$G_T[dB] = G_{S1}[dB] + G_0[dB] + G_I[dB] + G_0[dB] + G_{L2}[dB]$$

$$G_T[dB] = 1\text{ dB} + 10\text{ dB} + G_I[dB] + 10\text{ dB} + 0.2\text{ dB}$$

$$G_T[dB] = 21.2\text{ dB} + G_I[dB]$$

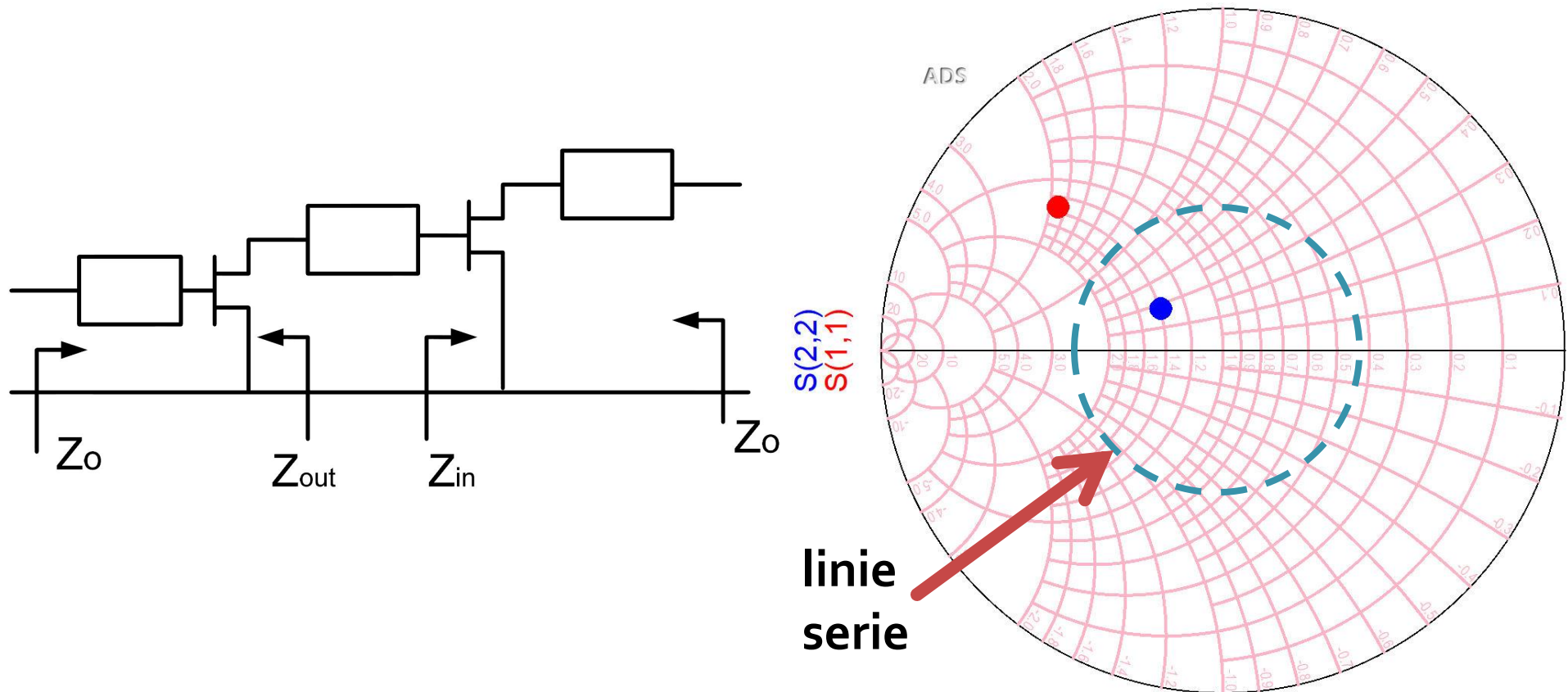
- Prin proiectarea inter-etaje trebuie obtinut un castig de minim 0.8dB prin adaptare mai buna a primului etaj la iesire si a celui de-al doilea la intrare

Adaptare inter-etaje 1/2



Adaptare inter-etaje 1

- O singura linie de transmisie pastreaza modulul coeficientului de reflexie

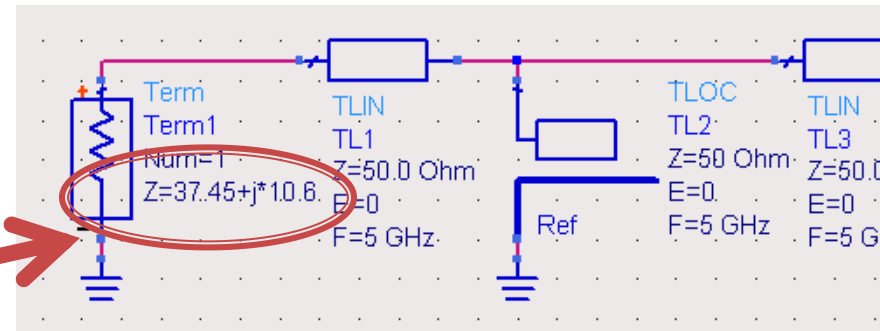
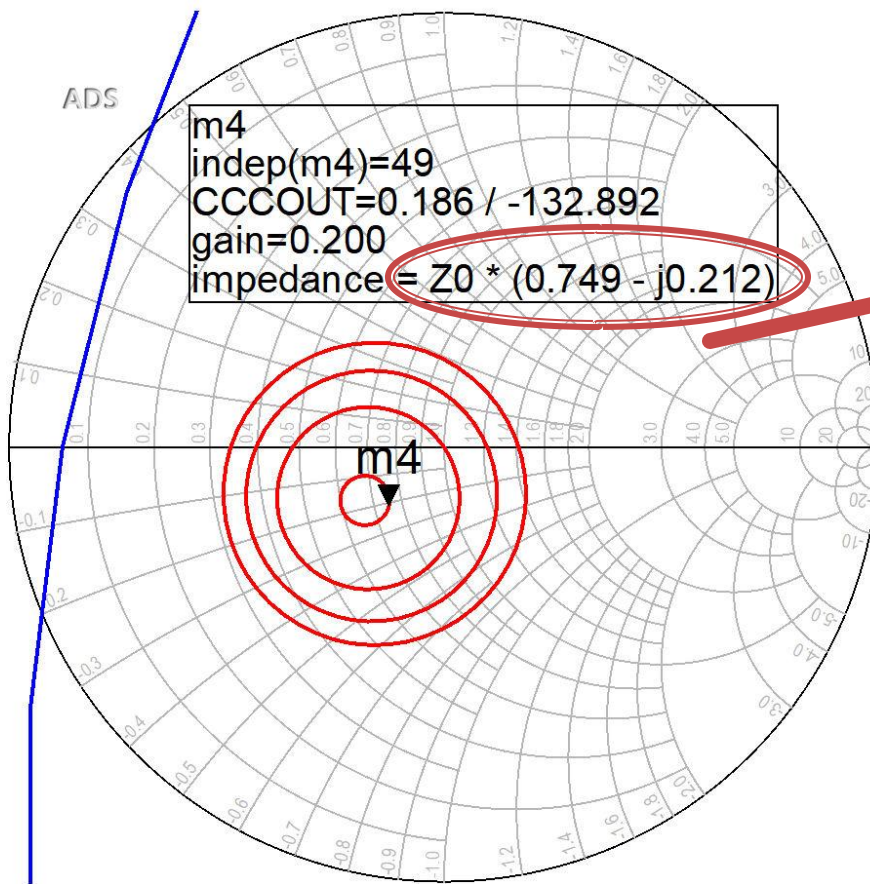


Adaptare inter-etaje 1

- Se poate face in doua moduri:
 - plecand de la iesirea primului etaj (coeficient de reflexie S_{22}^*) spre cercurile (desenate pentru etajul al doilea) de:
 - stabilitate
 - castig
 - zgomot
 - plecand de la intrarea celui de-al doilea etaj (coeficient de reflexie S_{11}^*) spre cercurile (desenate pentru primul etaj) de:
 - stabilitate
 - castig
- Prima varianta are avantajul de a controla zgomotul introdus de al doilea etaj

Adaptare inter etal

- Punct de pornire – complex conjugat



$$Z = 50\Omega \cdot (0.749 - j \cdot 0.212)$$

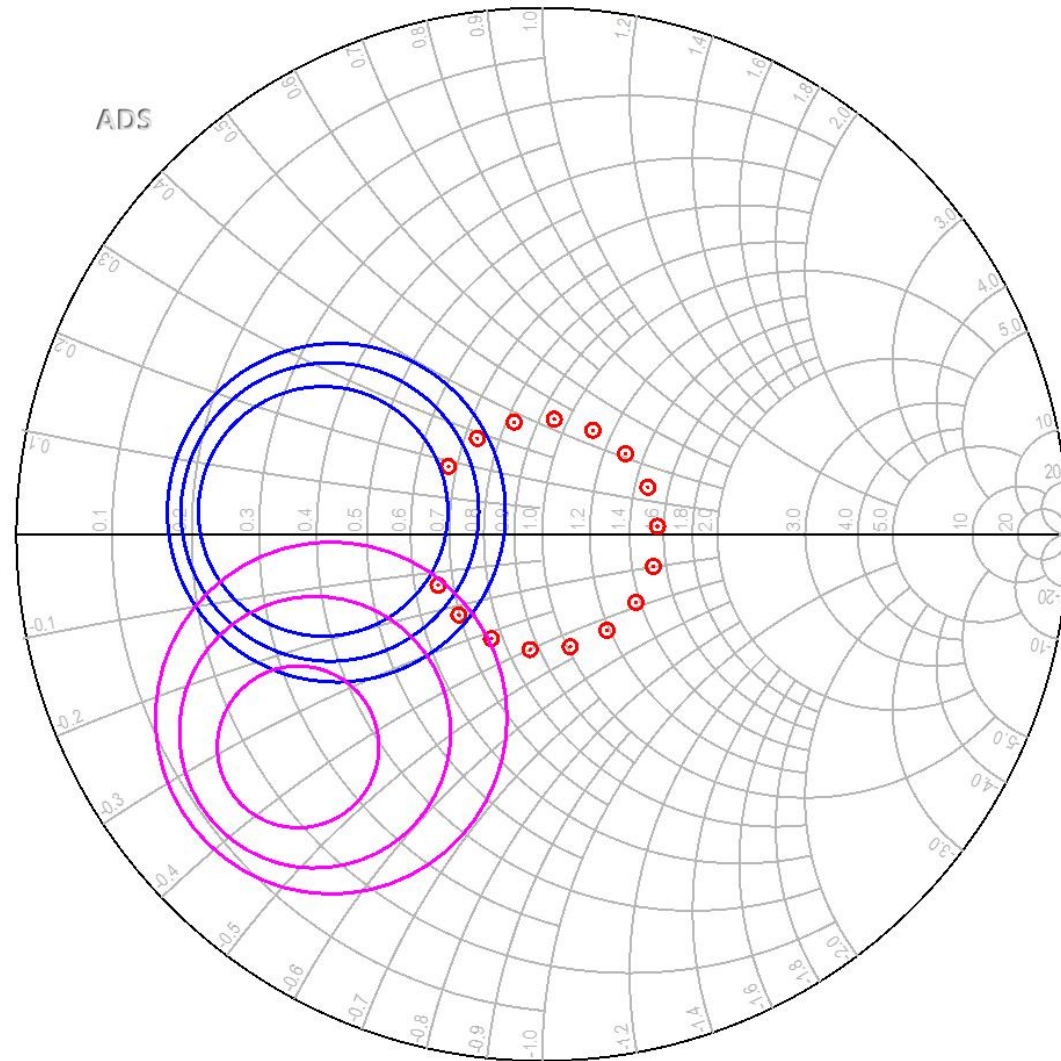
$$Z = 37.45\Omega - j \cdot 10.6\Omega$$

$$Z^* = 37.45\Omega + j \cdot 10.6\Omega$$

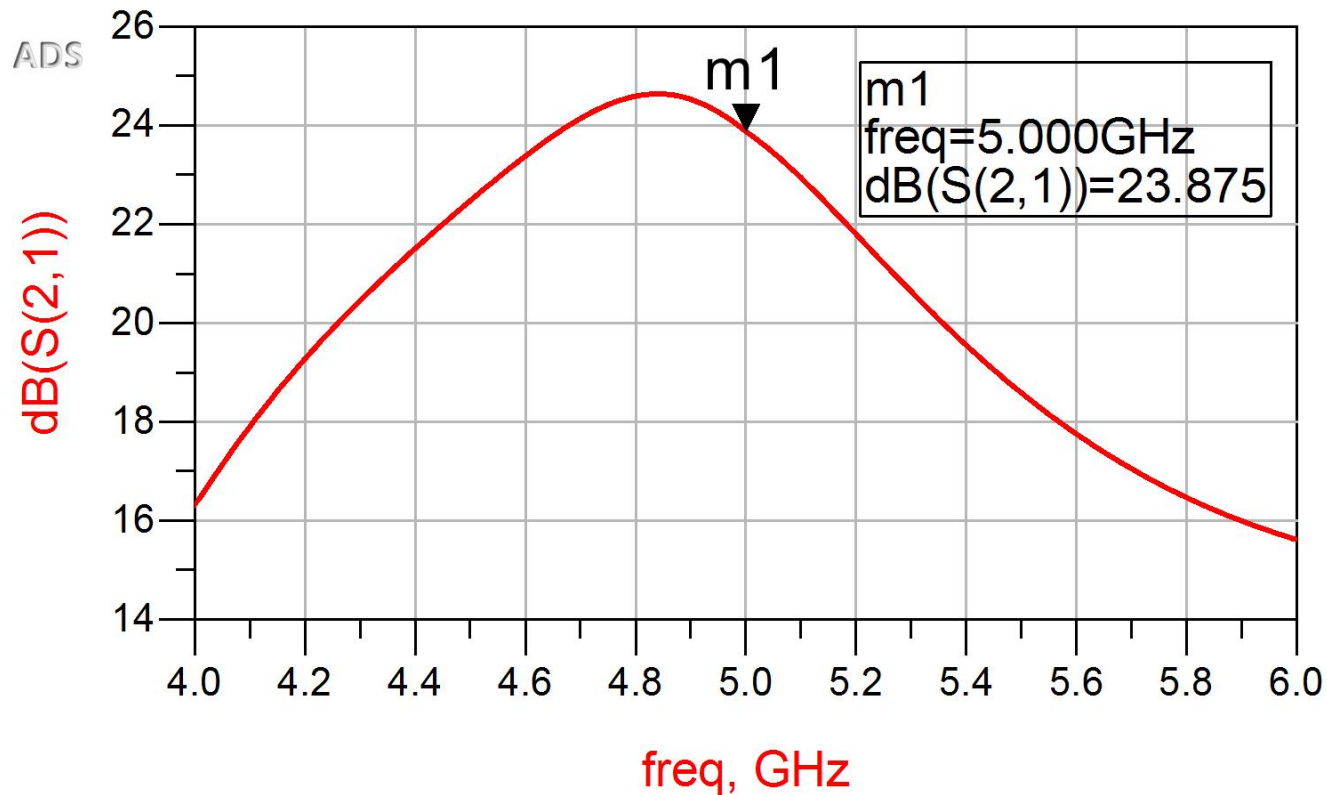
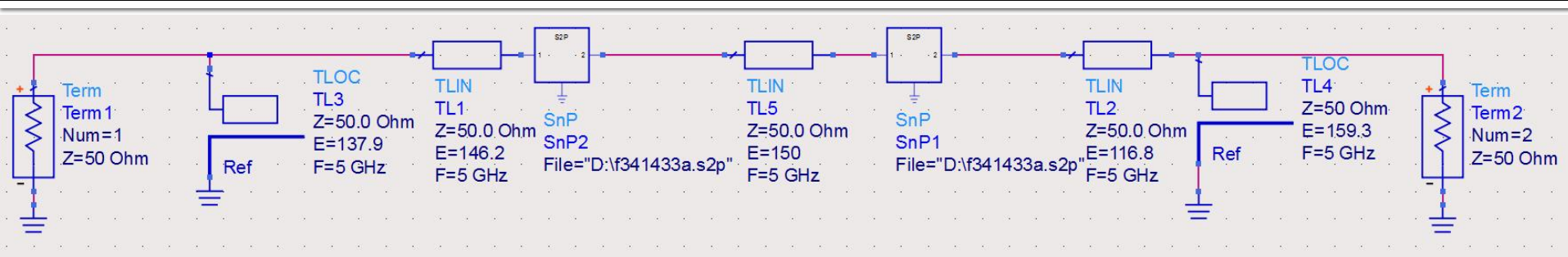
Adaptare inter-etaje 1

- O **singura** linie de transmisie permite atingerea unui punct care nu poate fi optimizat
 - $G_{L1} = 0.2 \text{ dB}$
 - $G_{S2} = 1 \text{ dB}$
 - $F_2 = 0.7 \text{ dB}$
- Elimina posibilitatea de reglaj pentru controlul in banda larga a amplificarii

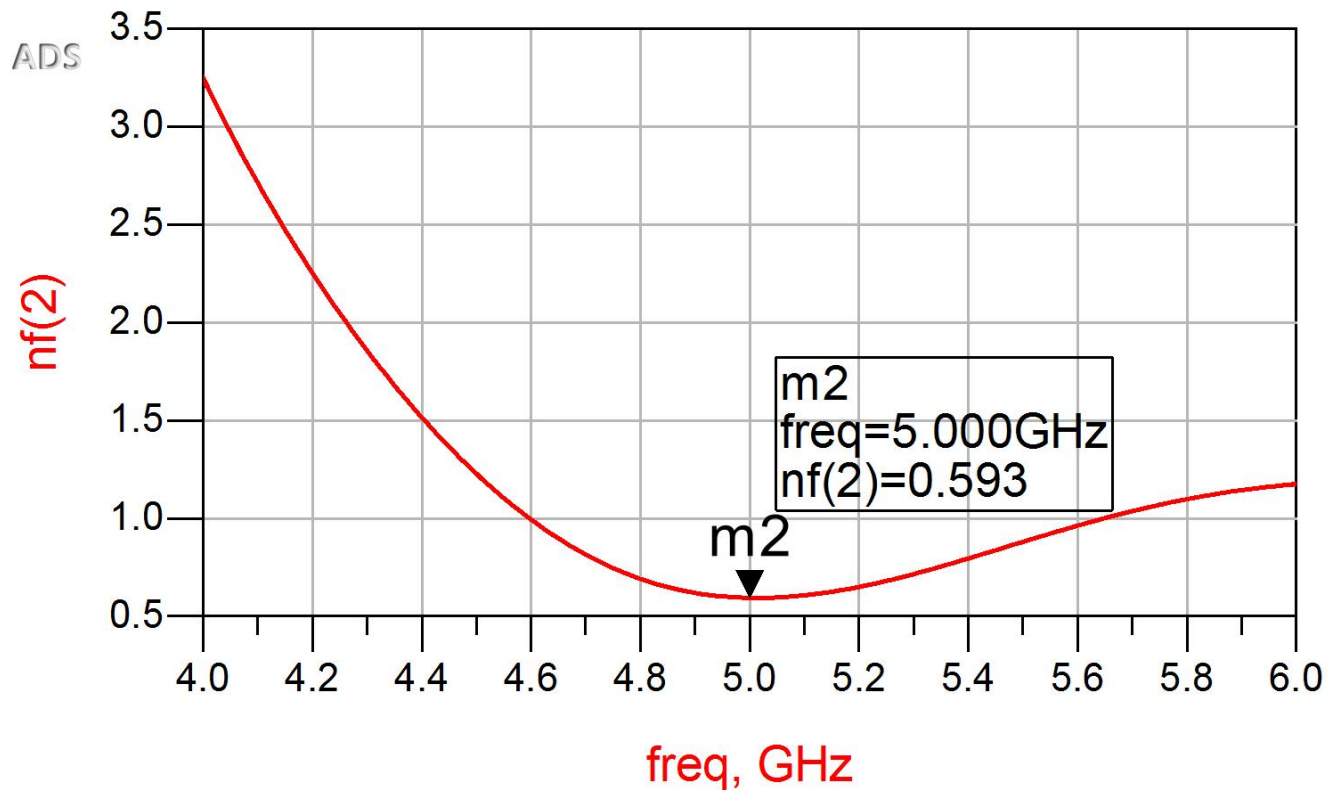
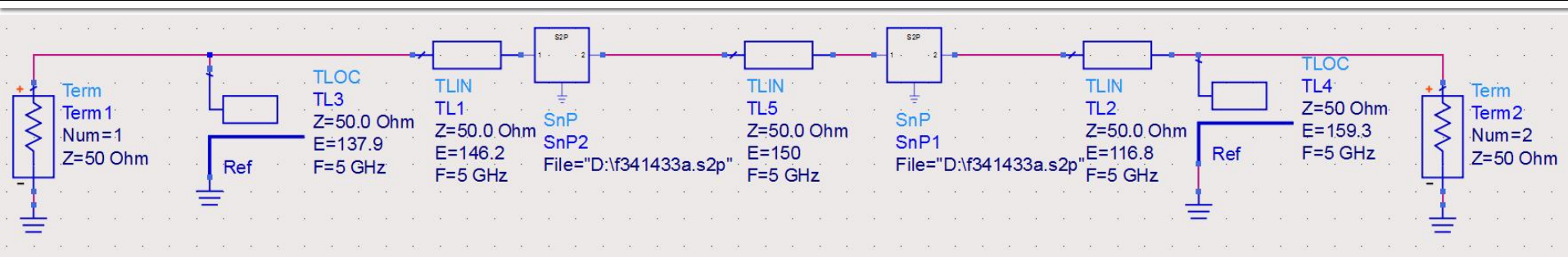
ref..CCCIN
ref..CZ
S(2,2)



ADS

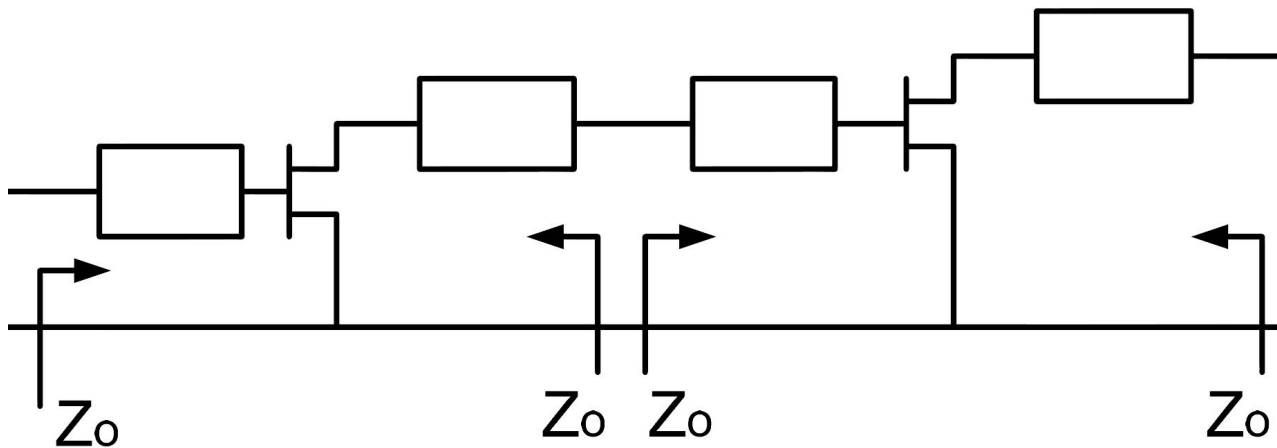


ADS

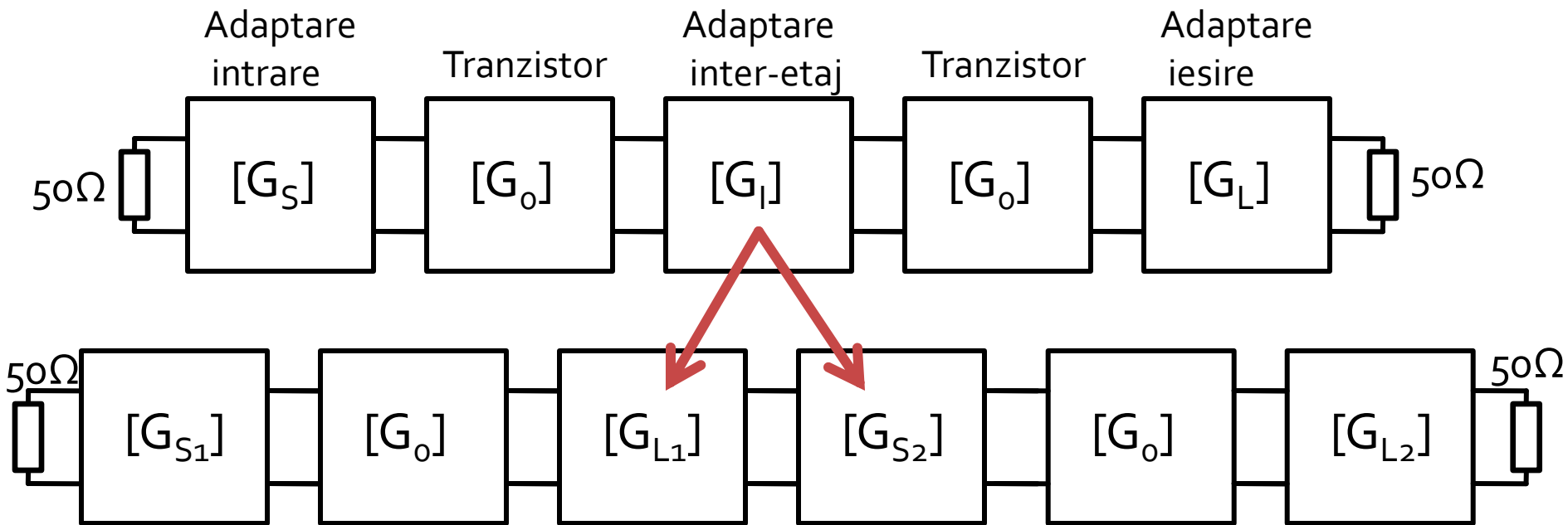


Adaptare inter-etaje 2

- Utilizarea mai multor linii de transmisie pentru adaptarea la un punct intermediar cu coeficient de reflexie $\Gamma=0$ permite controlul in detaliu al punctului final



Proiectare etaje cascade



- **Calcul castig**
 - Adaptarea inter-etaje poate aduce un supliment de castig la ambele etaje de amplificare
 - Proiectarea pentru etajele de intrare si iesire e recomandabil sa se faca pe schema mai simpla cu un singur tranzistor

Proiectare etaje cascade

- Castig

$$G_T[dB] = G_{S1}[dB] + G_0[dB] + G_{L1}[dB] + G_{S2}[dB] + G_0[dB] + G_{L2}[dB]$$

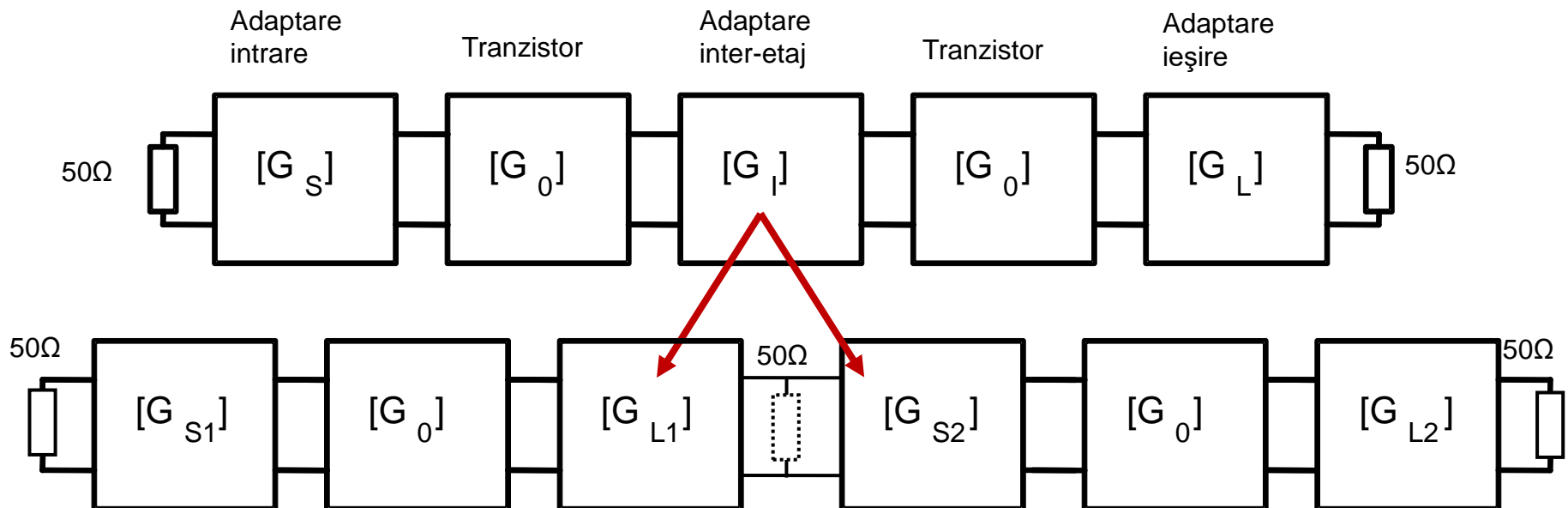
$$G_T[dB] = 1\text{ dB} + 10\text{ dB} + G_{L1}[dB] + G_{S2}[dB] + 10\text{ dB} + 0.2\text{ dB}$$

$$G_T[dB] = 21.2\text{ dB} + G_{L1}[dB] + G_{S2}[dB]$$

- Prin proiectarea inter-etaje trebuie obtinut un castig de minim 0.8dB prin adaptare mai buna a primului etaj la iesire si a celui de-al doilea la intrare

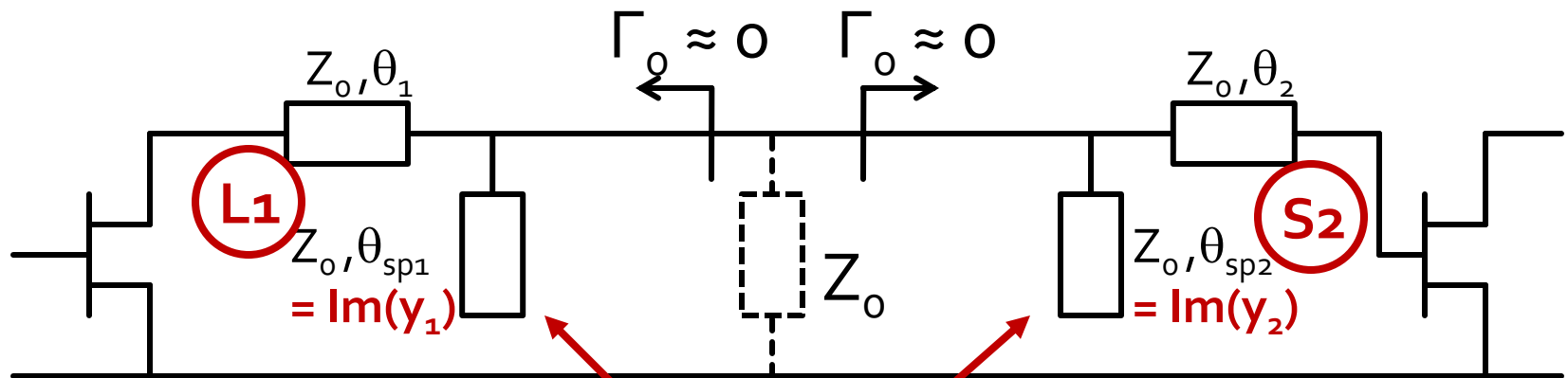
Adaptare inter-etaje 2

- Utilizarea mai multor linii de transmisie pentru adaptarea la un punct intermediar cu coeficient de reflexie $\Gamma=0$ permite controlul in detaliu al punctului final



Adaptare inter-etaje 2

- Unul din etaje **creaza** prin reteaua sa de adaptare un coeficient de reflexie $\Gamma=0$ la care apoi se adapteaza celalalt etaj



Cele doua stub-uri in paralel se combina intr-unul singur

Adaptare inter-etaje 2

- Cele doua stub-uri in paralel se combina intr-unul singur

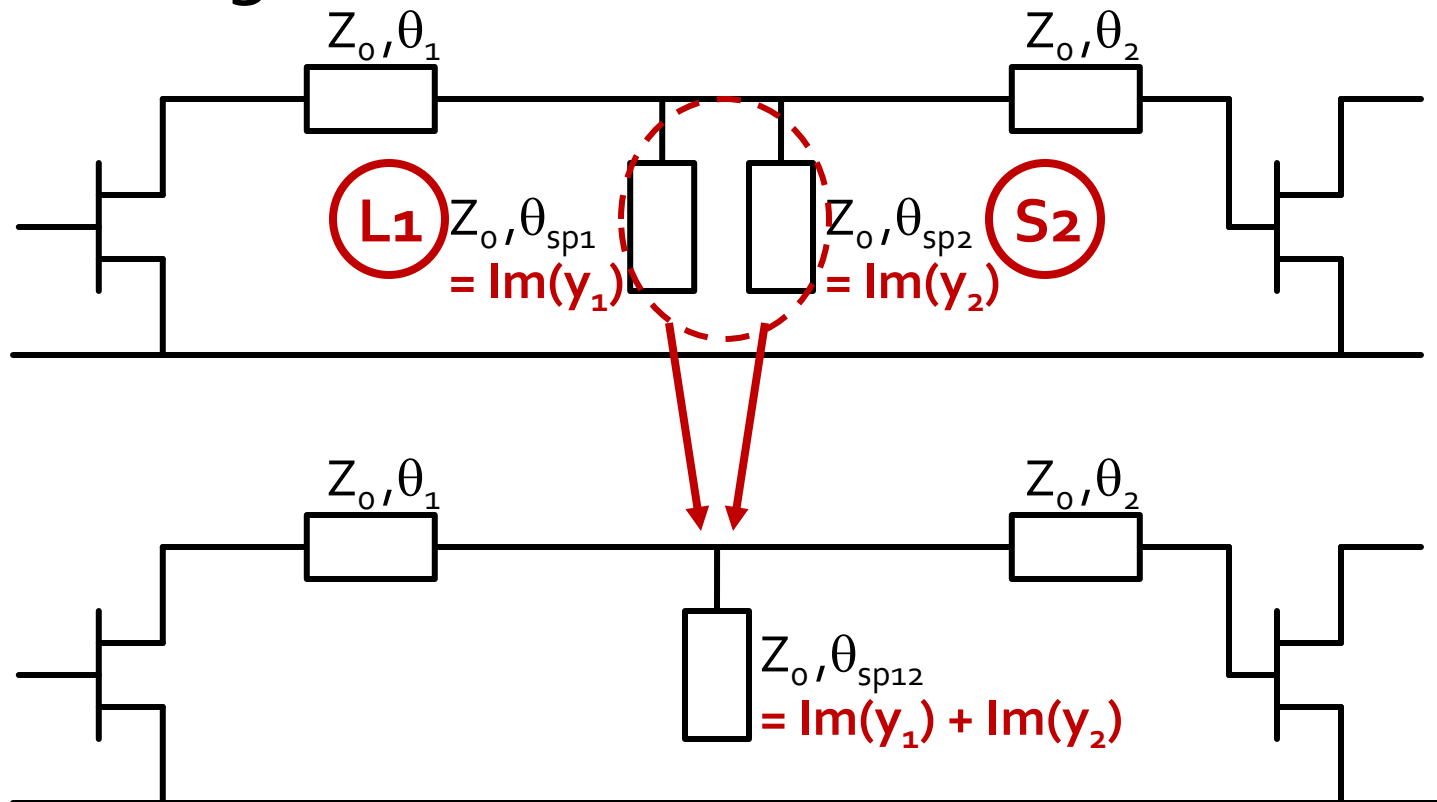
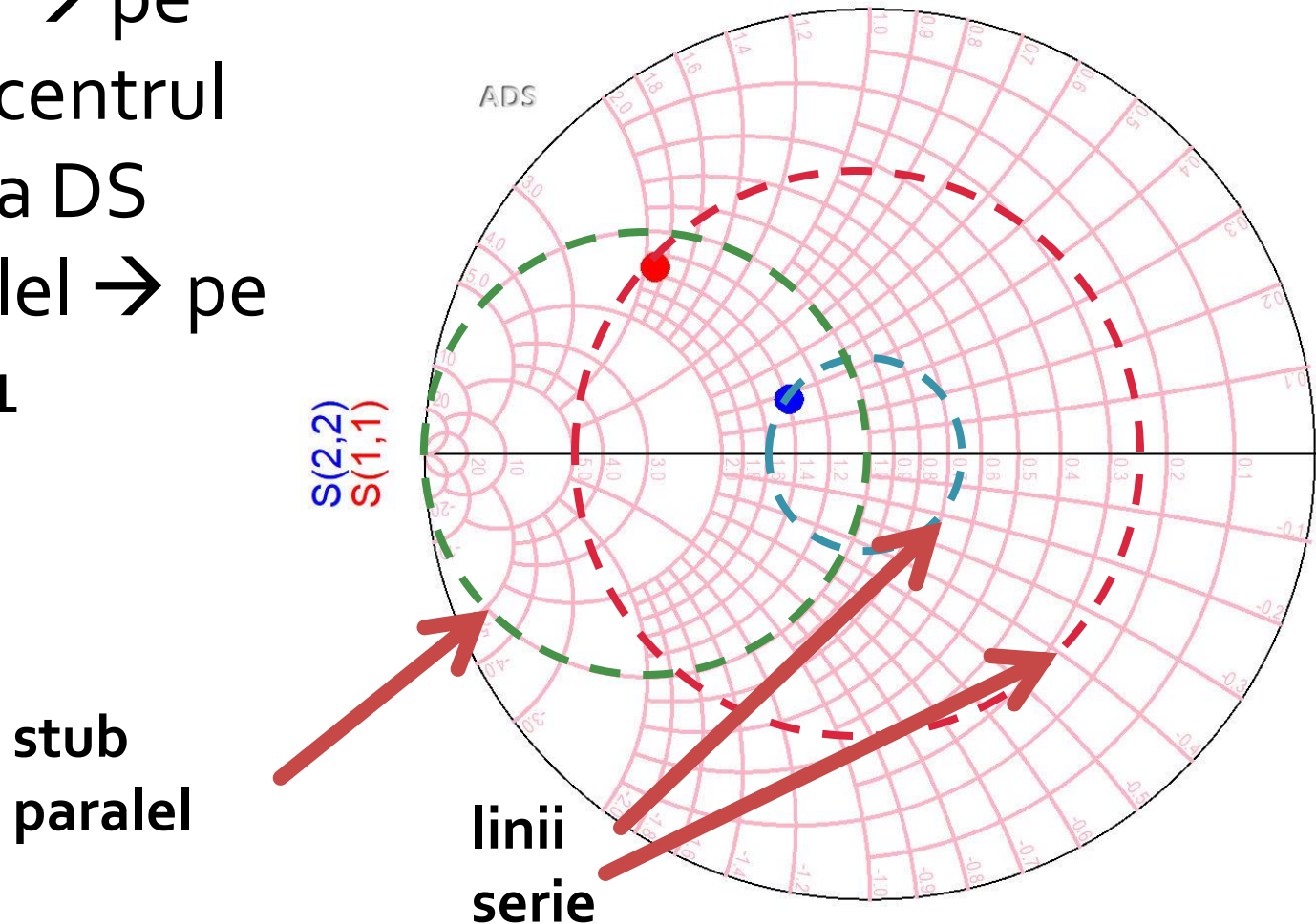


Diagrama Smith

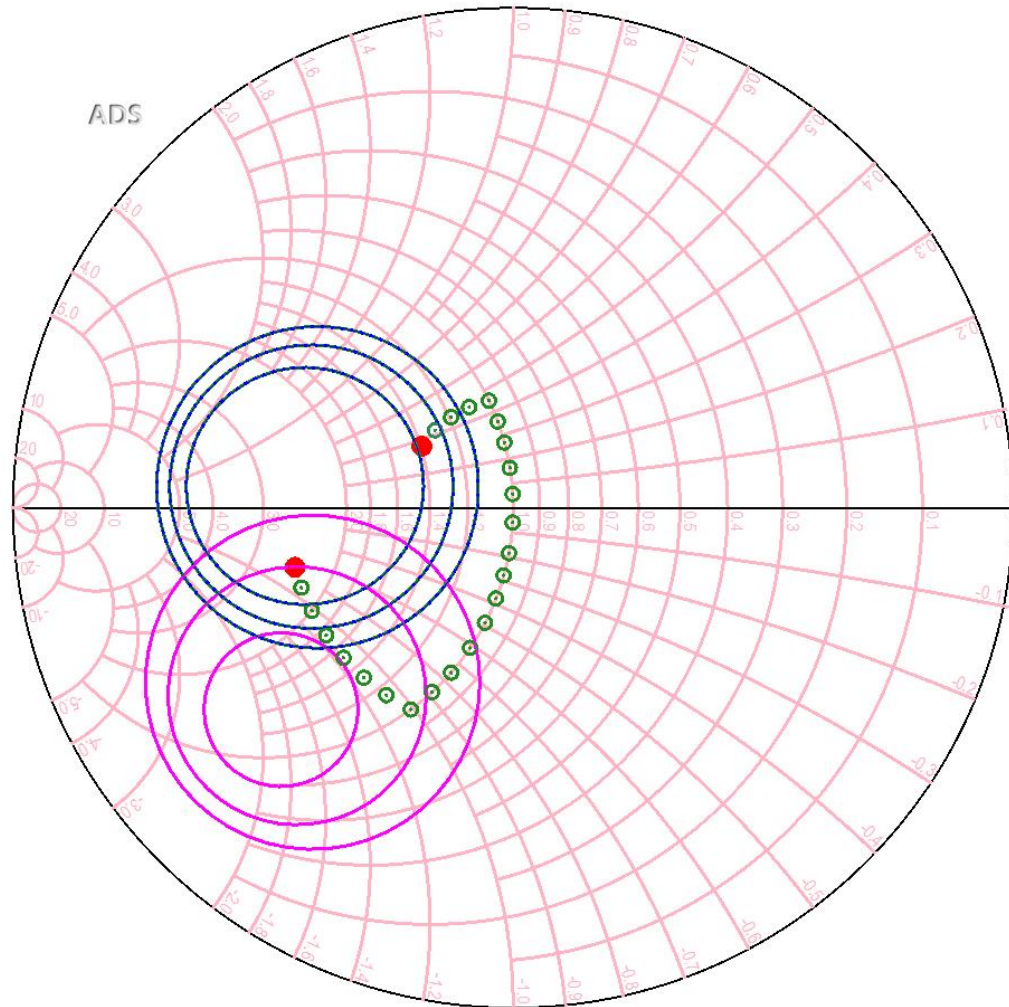
- linie serie \rightarrow pe cercul cu centrul in originea DS
- stub paralel \rightarrow pe cercul $g=1$



Adaptare inter-etaje 2

- Pentru fiecare etaj utilizam o linie serie si un stub paralel
 - Linia serie muta coeficientul de reflexie pe cercul unitate $g=1$
 - Stub-ul paralel muta punctul in centrul diagramei (adaptare la Z_0)
- Cele doua stub-uri in paralel se combina intr-unul singur

ref..CCCIN
ref..CZ
S(2,2)



Adaptare la iesirea etajului 1 (L1)

- G_{L1} (putem folosi tot punctul de la iesirea L2)

$$\Gamma_L = 0.186 \angle -132.9^\circ$$

$$|\Gamma_L| = 0.186; \quad \varphi = -132.9^\circ$$


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

$$\operatorname{Im}[y_L(\theta)] = \frac{-2 \cdot |\Gamma_L|}{\sqrt{1 - |\Gamma_L|^2}} = -0.379$$

$$\cos(\varphi + 2\theta) = -0.186 \Rightarrow (\varphi + 2\theta) = \pm 100.72^\circ$$

- nu e obligatoriu sa se calculeze θ_{sp} deoarece **nu** va fi necesar

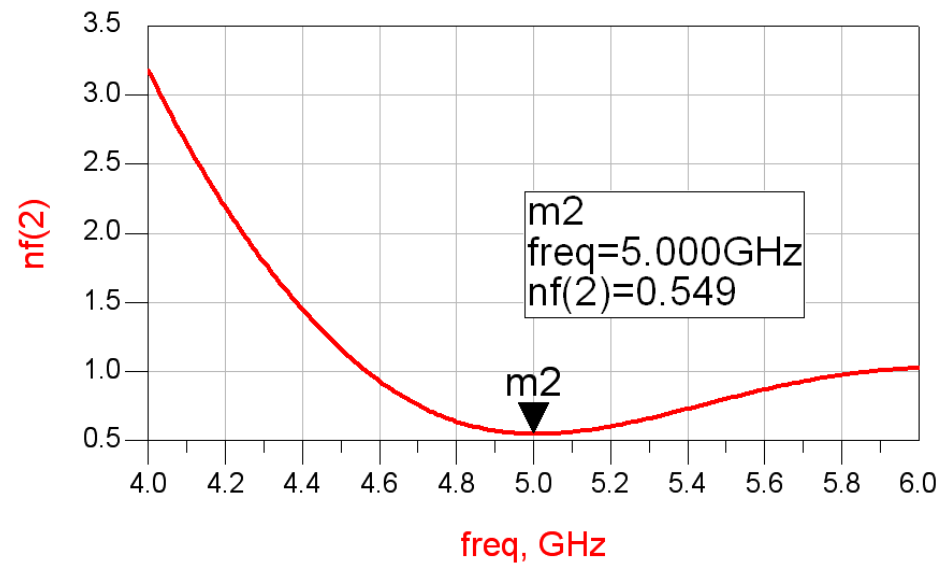
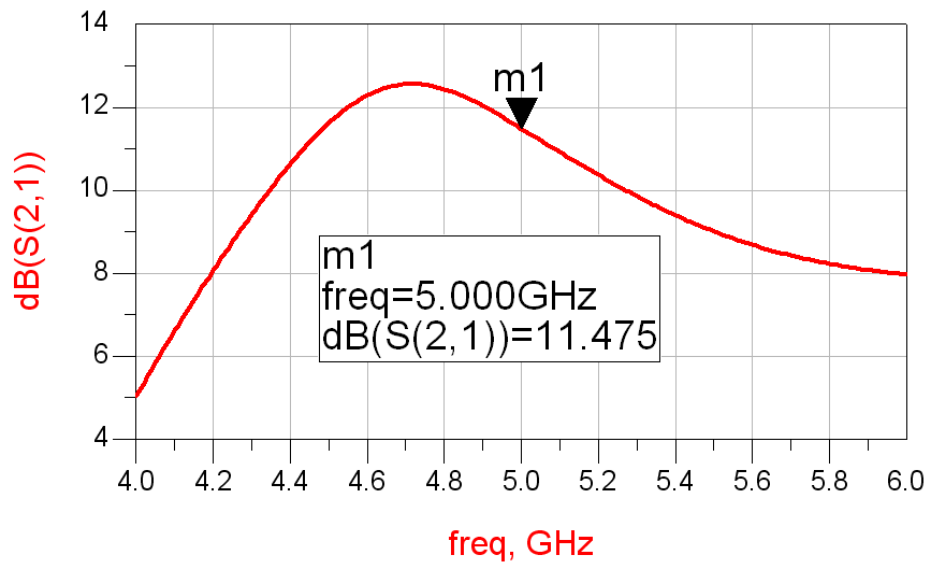
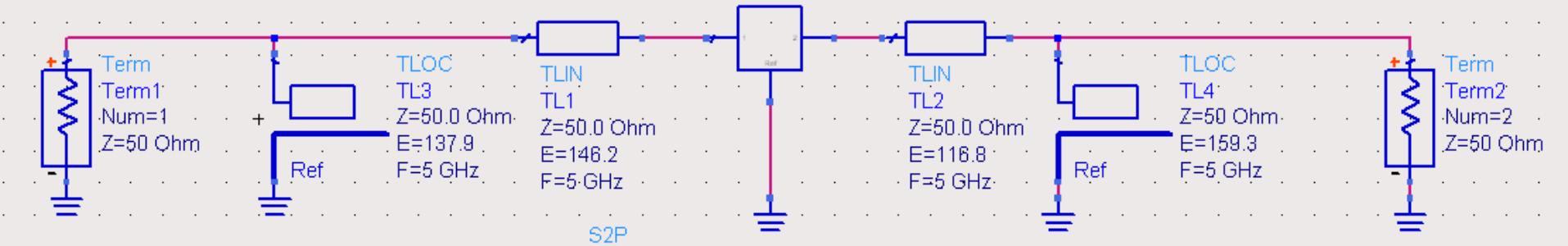
- decat daca doresc simularea/verificarea amplificatorului 1 separat (**recomandat**)

$$(\varphi + 2\theta) = \begin{cases} +100.72^\circ \\ -100.72^\circ \end{cases} \quad \theta = \begin{cases} 116.8^\circ \\ 16.1^\circ \end{cases} \quad \operatorname{Im}[y_L(\theta)] = \begin{cases} -0.379 \\ +0.379 \end{cases}$$


Adaptare la iesirea etajului 1 (L1)

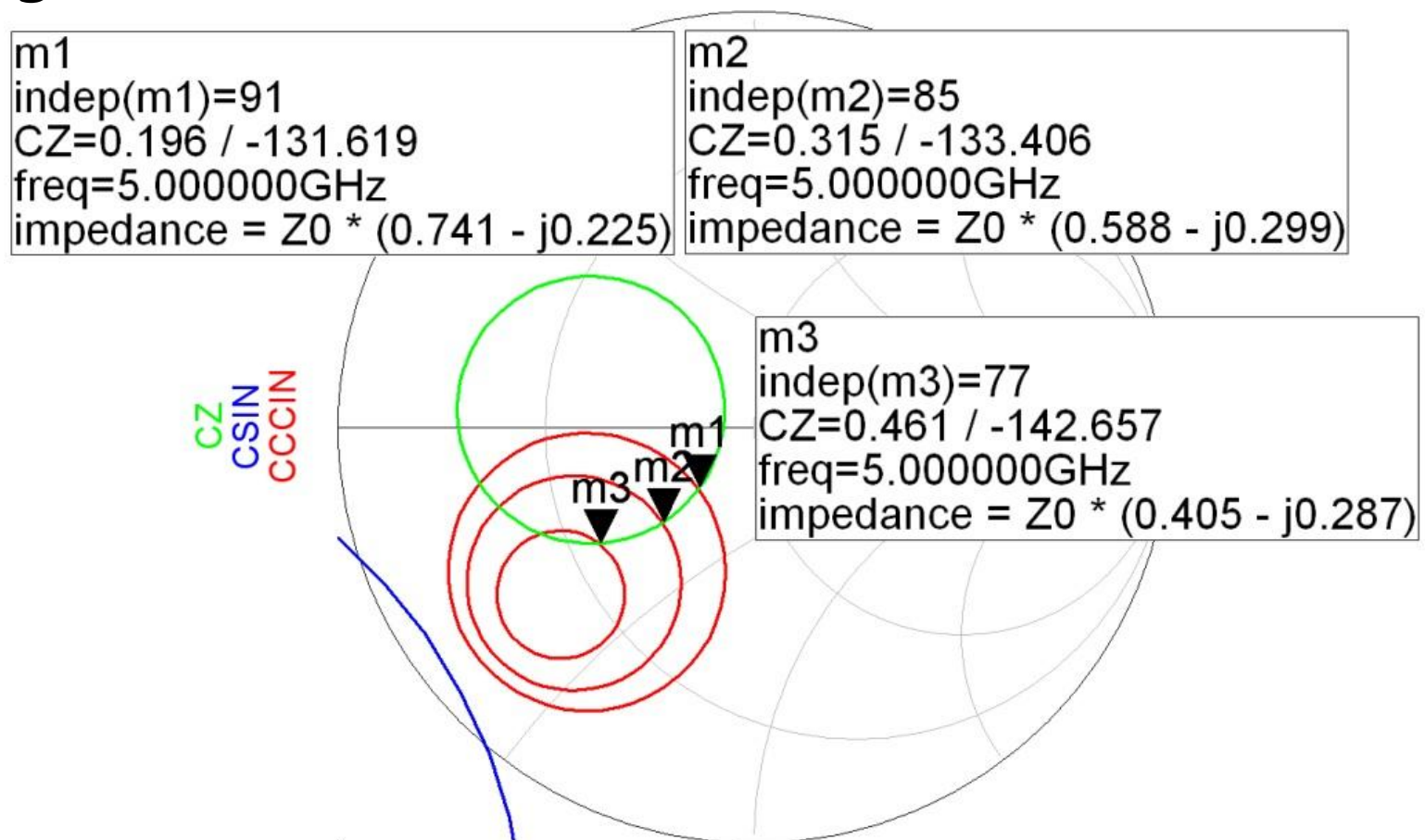
Ecuatie	Soluția L1A	Soluția L1B
$\Phi+2\theta$	$+100.72^\circ$	-100.72°
θ	116.8°	16.1°
$\text{Im}[y(\theta)]$	-0.379	$+0.379$

Verificare etaj 1



Adaptare la intrarea etajului 2 (S2)

- G_{S_2} (plecare din Γ_{S_2} ales spre origine – m3 – castig 2dB)



Adaptare la intrarea etajului 2 (S2)


- G_{S_2} (plecare din m3 spre origine)

$$\Gamma_{S_2} = 0.461 \angle -142.66^\circ \quad |\Gamma_{S_2}| = 0.461; \quad \varphi = -142.66^\circ$$

$$\cos(\varphi + 2\theta) = -|\Gamma_{S_2}| \quad \text{Im}[y_{S_2}(\theta)] = \frac{\mp 2 \cdot |\Gamma_{S_2}|}{\sqrt{1 - |\Gamma_{S_2}|^2}}$$

$$\cos(\varphi + 2\theta) = -0.461 \Rightarrow (\varphi + 2\theta) = \pm 117.45^\circ$$

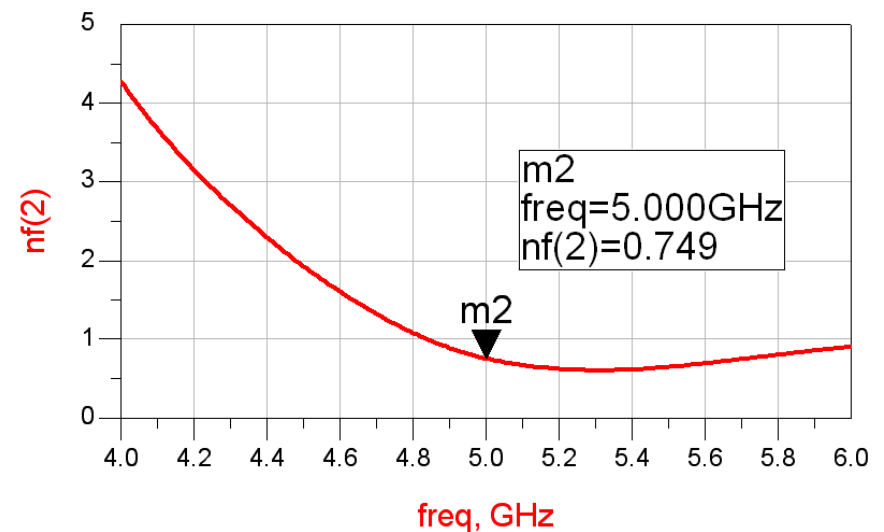
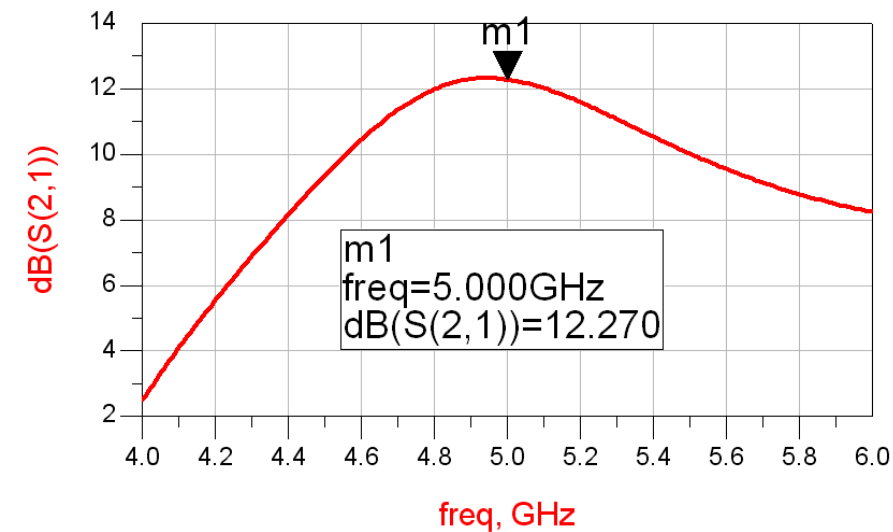
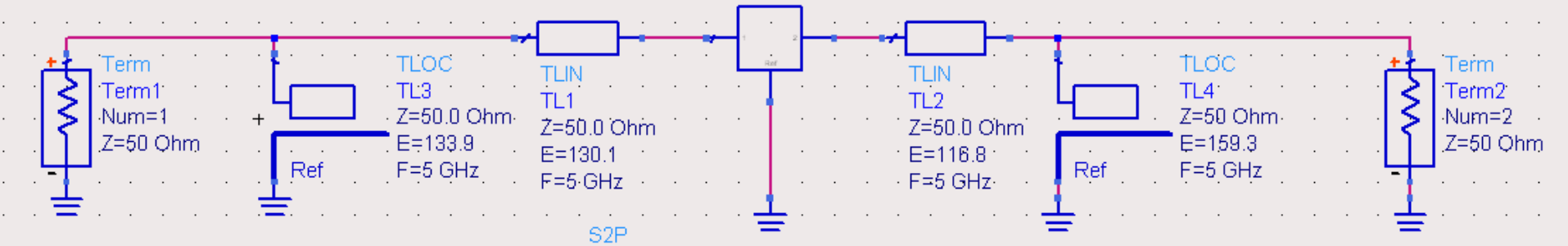
- nu e obligatoriu sa se calculeze θ_{sp} deoarece **nu** va fi necesar
 - decat daca doresc simularea/verificarea amplificatorului 2 separat (**recomandat**)

$$(\varphi + 2\theta) = \begin{cases} +117.45^\circ \\ -117.45^\circ \end{cases} \quad \theta = \begin{cases} 130.1^\circ \\ 12.6^\circ \end{cases} \quad \text{Im}[y_{S_2}(\theta)] = \begin{cases} -1.039 \\ +1.039 \end{cases}$$


Adaptare la intrarea etajului 2 (S2)

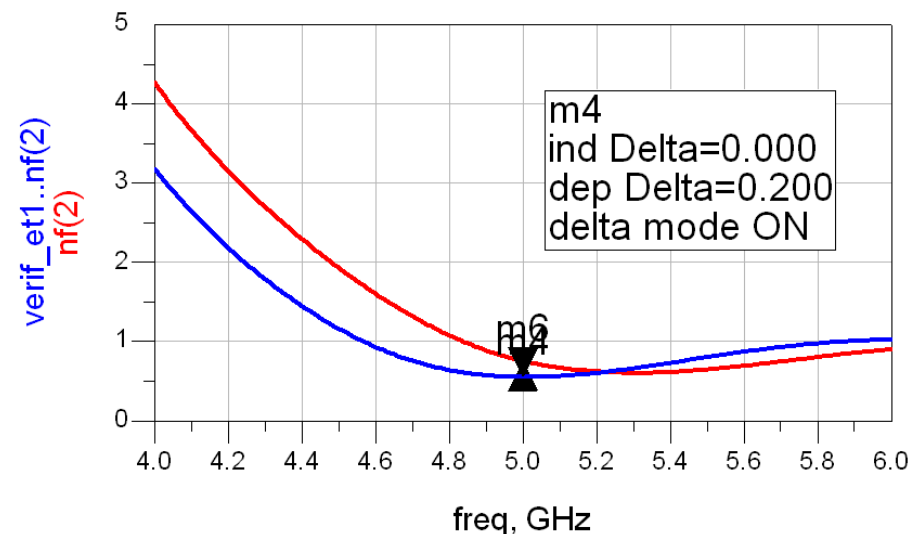
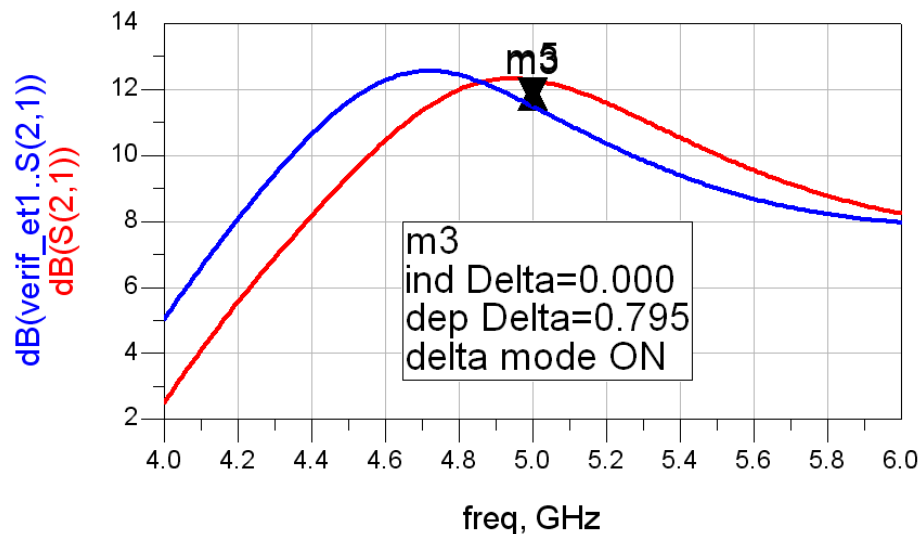
Ecuatie	Soluția S2A	Soluția S2B
$\Phi+2\theta$	$+117.45^\circ$	-117.45°
θ	130.1°	12.6°
$\text{Im}[y(\theta)]$	-1.039	$+1.039$

Verificare etaj 2



Etaj 1/2

- Conform concluziilor obtinute din formula Friis al doilea etaj obtine castig mai mare deoarece se accepta un zgomot mai mare



Combinarea celor 2 stub-uri paralel

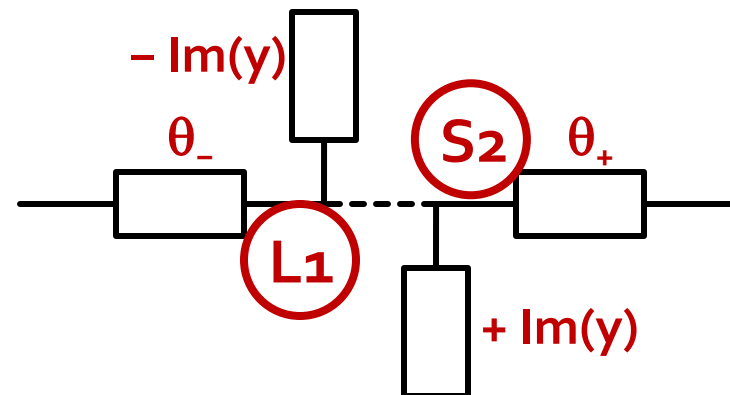
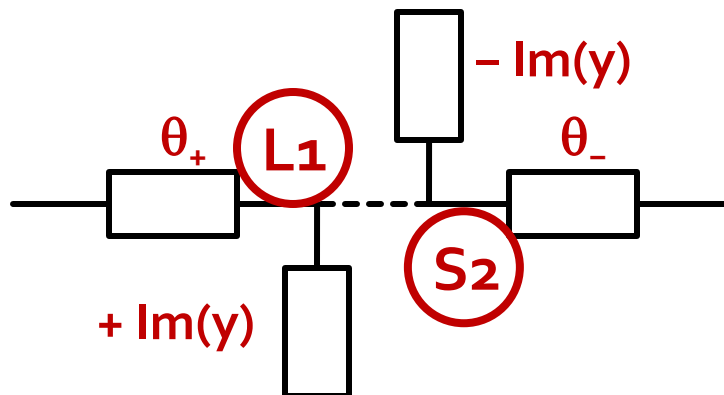
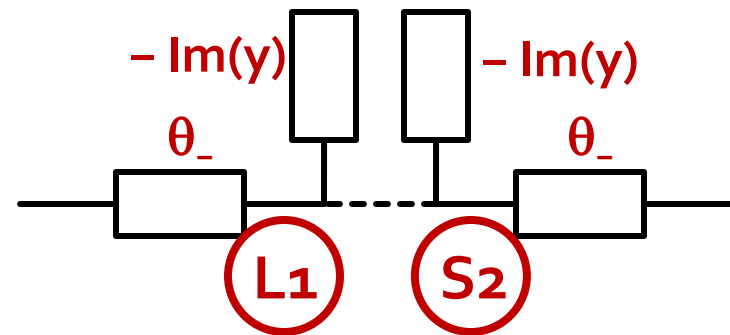
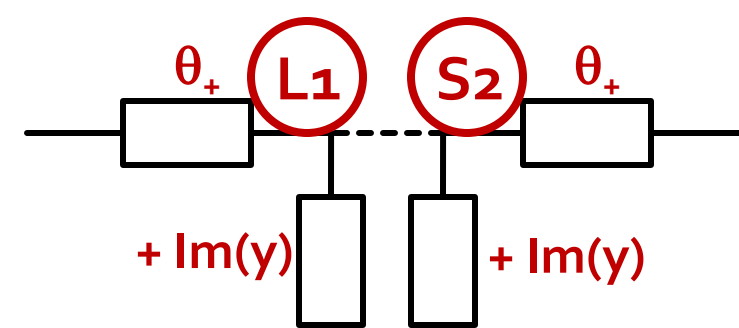
- Cele doua stub-uri in paralel se combina intr-unul singur
- Exista **4 combinatii posibile** in functie de cum se combina lungimile electrice alese pentru cele doua linii serie
 - pentru fiecare lungime electrica aleasa (θ) se foloseste obligatoriu $\text{Im}[y(\theta)]$ corespunzator

■ Ex:

$$\theta_{L1} = 116.8^\circ \quad \theta_{S2} = 130.1^\circ \quad \text{Im}[y_{sp}] = \text{Im}[y_{L1}(\theta)] + \text{Im}[y_{S2}(\theta)] = -1.418$$
$$\theta_{sp} = \tan^{-1}(\text{Im}[y_{sp}]) \quad \theta_{sp} = 125.2^\circ$$

Combinarea celor 2 stub-uri paralel

- 4 combinatii posibile
 - admitantele** sunt in paralel si se **aduna**, nu lungimile electrice



$$\text{Im}[y_{sp}] = \text{Im}[y_{L1}(\theta)] + \text{Im}[y_{S2}(\theta)]$$

$$\theta_{sp} = \tan^{-1}(\text{Im}[y_{sp}])$$

Combinarea celor 2 stub-uri paralel

		Soluția S2A	Soluția S2B
		$\theta = 130.1^\circ$ $\text{Im}[y(\theta)] = -1.039$	$\theta = 12.6^\circ$ $\text{Im}[y(\theta)] = +1.039$
Soluția L1A	$\theta = 116.8^\circ$ $\text{Im}[y(\theta)] = -0.379$	$\theta_{L1} = 116.8^\circ$ $\text{Im}[y(\theta)] = -1.418$ $\theta_p = 125.2^\circ$ $\theta_{S2} = 130.1^\circ$	$\theta_{L1} = 116.8^\circ$ $\text{Im}[y(\theta)] = +0.66$ $\theta_p = 33.4^\circ$ $\theta_{S2} = 12.6^\circ$
Soluția L1B	$\theta = 16.1^\circ$ $\text{Im}[y(\theta)] = +0.379$	$\theta_{L1} = 16.1^\circ$ $\text{Im}[y(\theta)] = -0.66$ $\theta_p = 146.6^\circ$ $\theta_{S2} = 130.1^\circ$	$\theta_{L1} = 16.1^\circ$ $\text{Im}[y(\theta)] = 1.418$ $\theta_p = 54.8^\circ$ $\theta_{S2} = 12.6^\circ$

Diagrama Smith

- linie serie \rightarrow pe cercul cu centrul in originea DS
- stub paralel \rightarrow pe cercul $g=1$

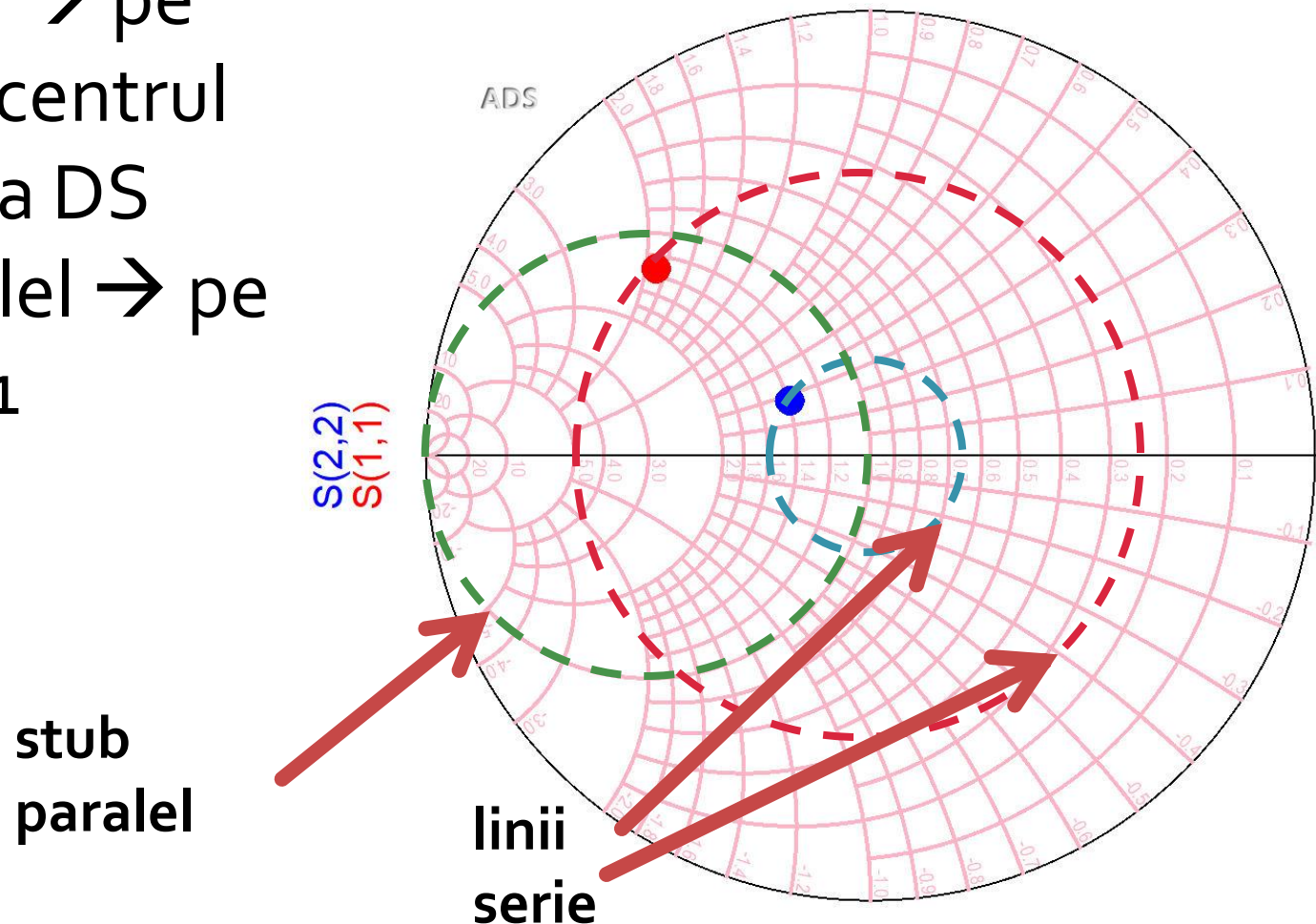


Diagrama Smith 1

$$\theta_{L1} = 116.8^\circ \quad \theta_{S2} = 130.1^\circ$$

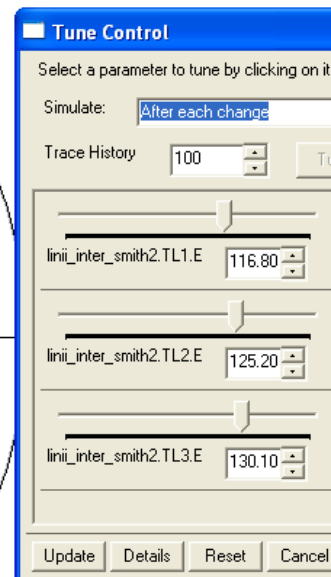
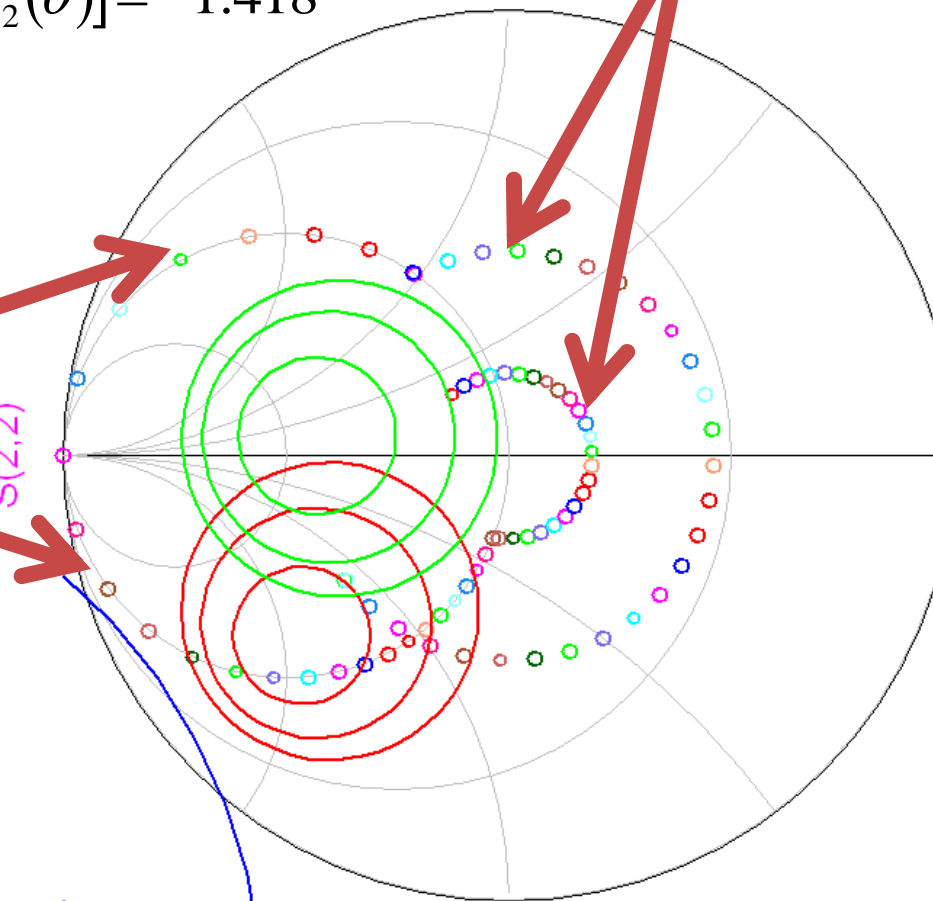
$$\text{Im}[y_{sp}] = \text{Im}[y_{L1}(\theta)] + \text{Im}[y_{S2}(\theta)] = -1.418$$

$$\theta_{sp} = 125.2^\circ$$

stub
"combinat"

ref..CSIN
ref..CZ
ref..CCCIN
S(2,2)

linii
serie



ADS 1

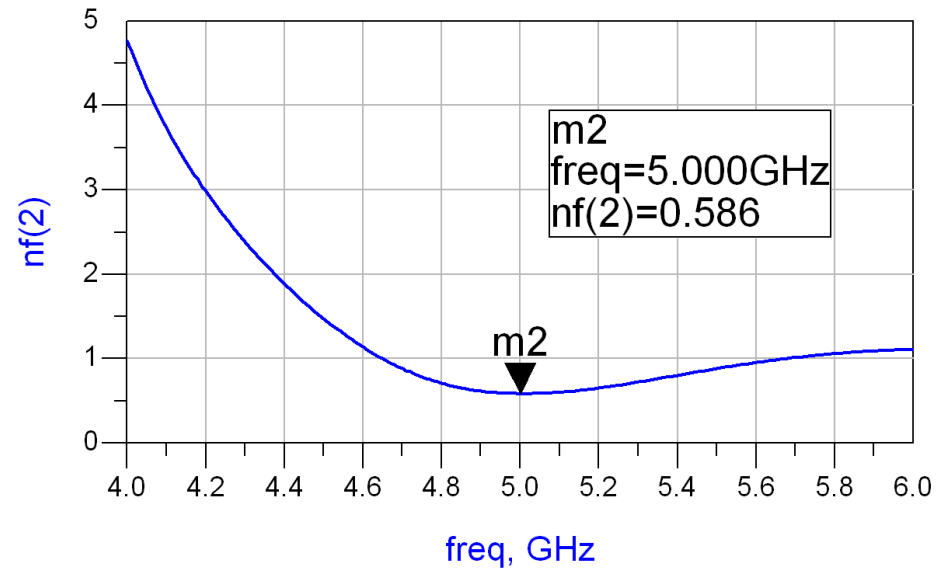
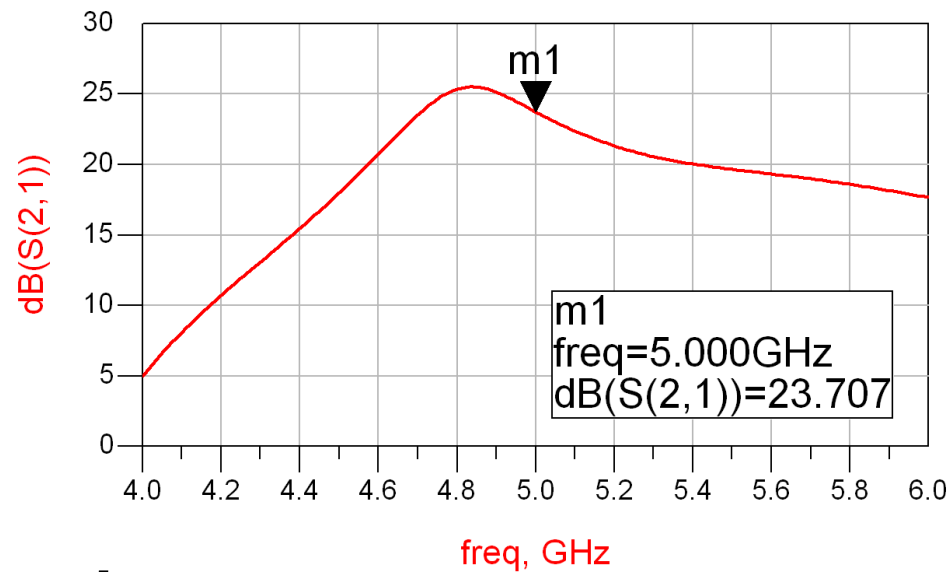
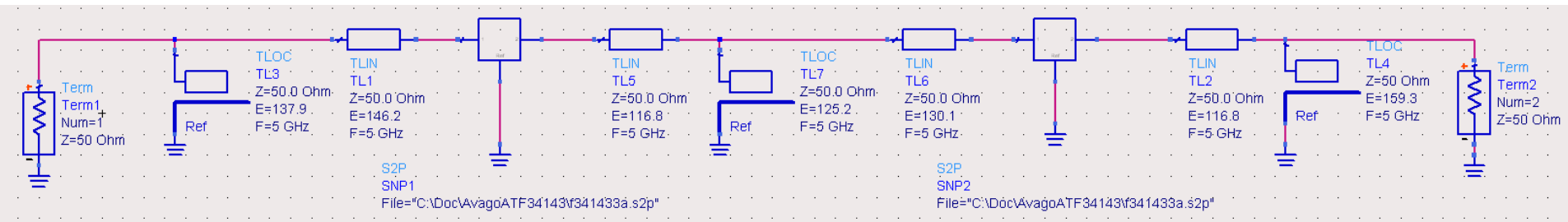


Diagrama Smith 2

$$\theta_{L1} = 116.8^\circ \quad \theta_{S2} = 12.6^\circ$$

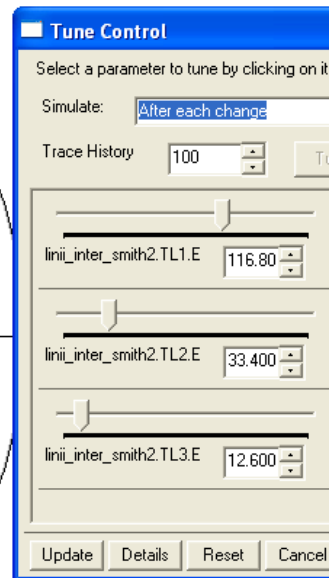
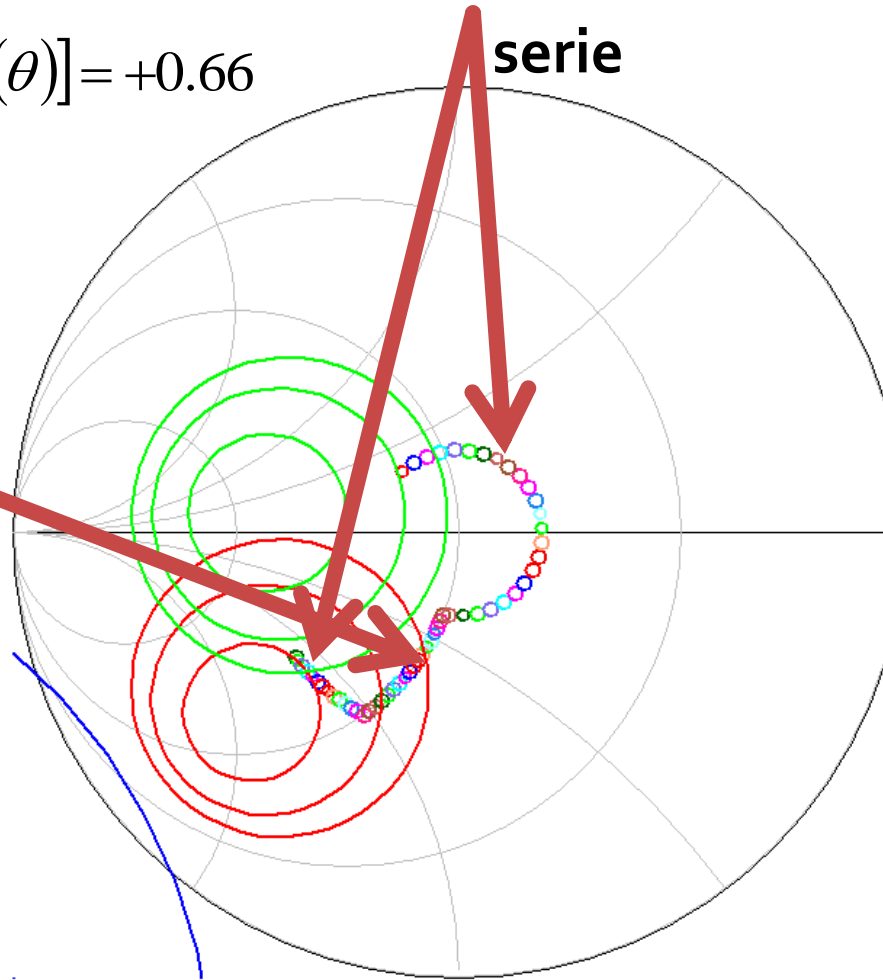
$$\text{Im}[y_{sp}] = \text{Im}[y_{L1}(\theta)] + \text{Im}[y_{S2}(\theta)] = +0.66$$

$$\theta_{sp} = 33.4^\circ$$

stub
"combinat"

ref..CSIN
ref..CZ
ref..CCCN
S(2,2)

linii
serie



ADS 2

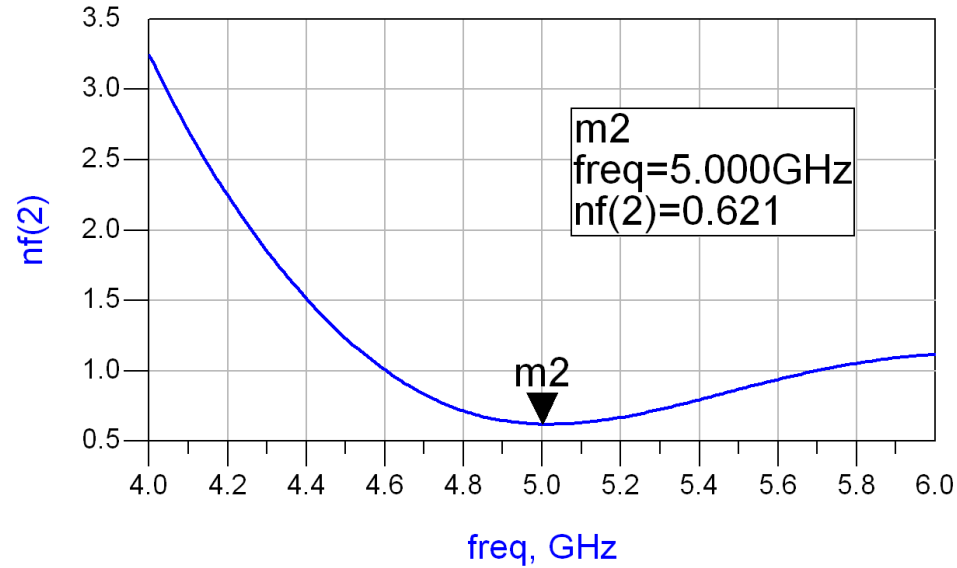
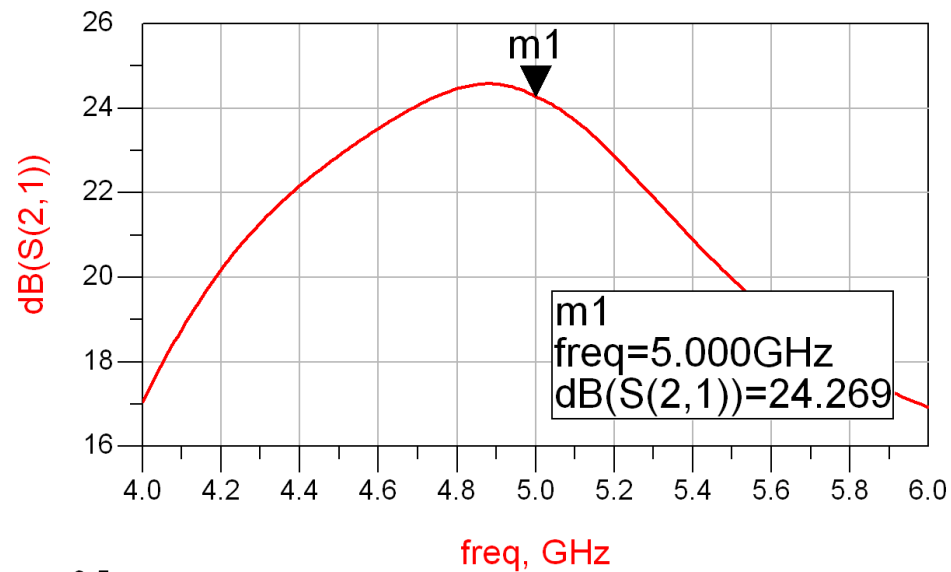
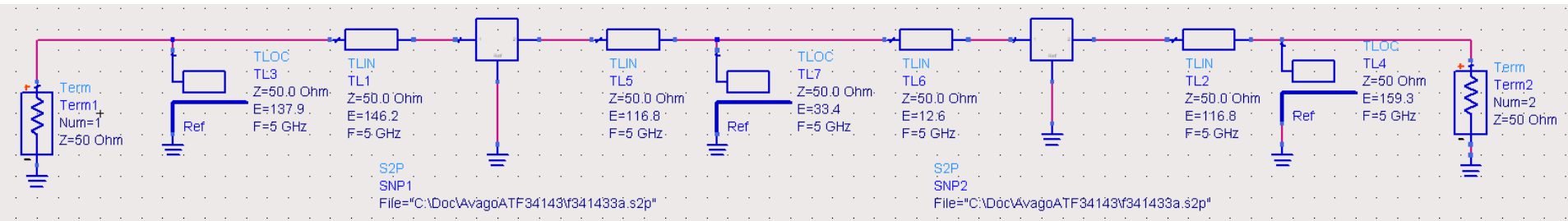


Diagrama Smith 3

$$\theta_{L1} = 16.1^\circ \quad \theta_{S2} = 130.1^\circ$$

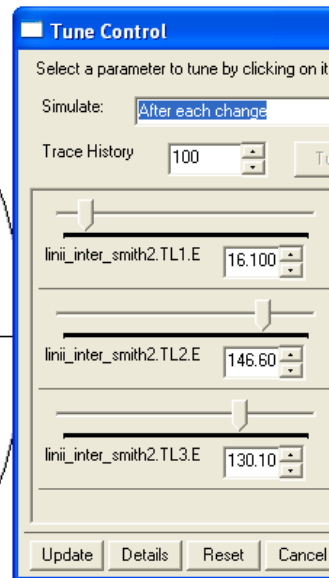
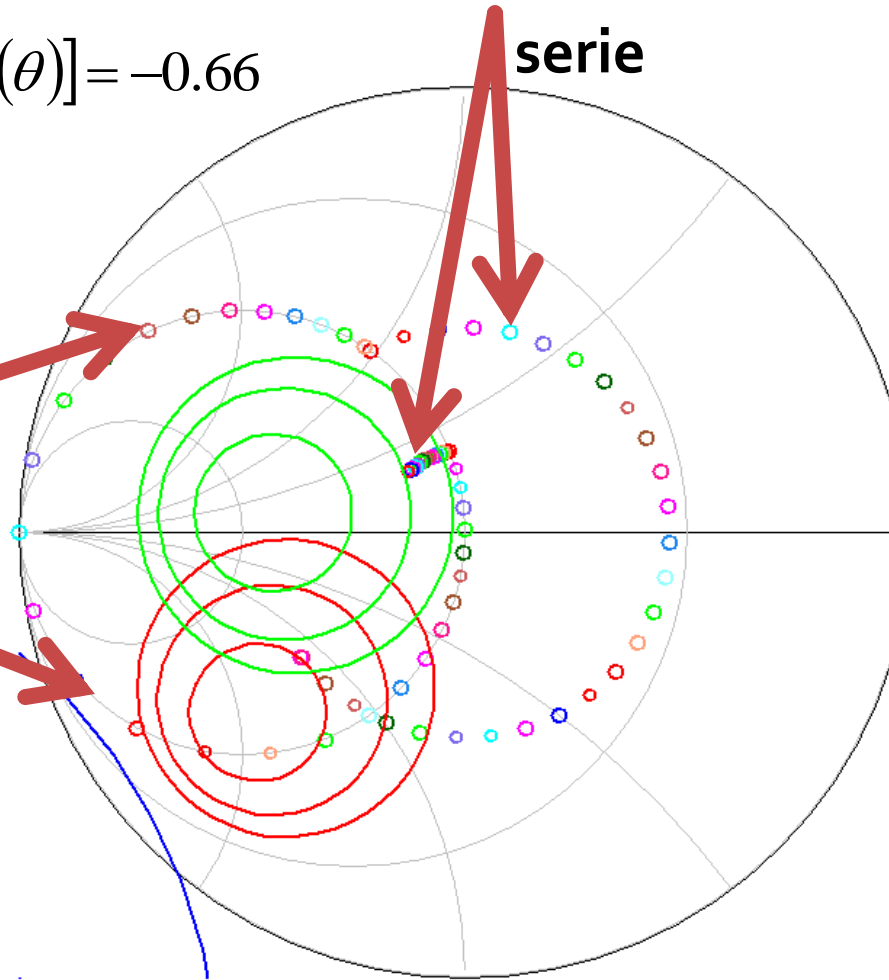
$$\text{Im}[y_{sp}] = \text{Im}[y_{L1}(\theta)] + \text{Im}[y_{S2}(\theta)] = -0.66$$

$$\theta_{sp} = 146.6^\circ$$

stub
"combinat"

ref..CSIN
ref..CZ
ef..CCCN
S(2,2)

linii
serie



ADS 3

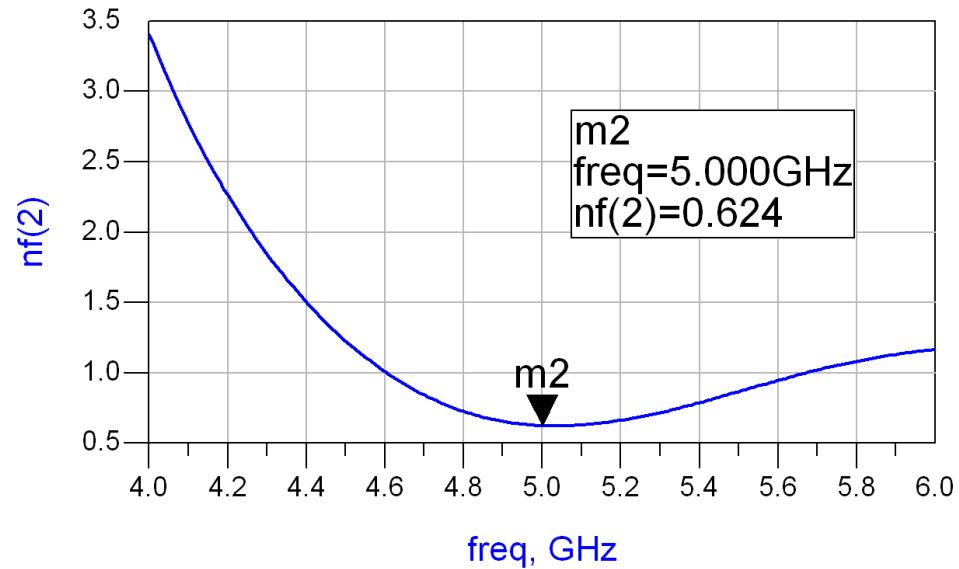
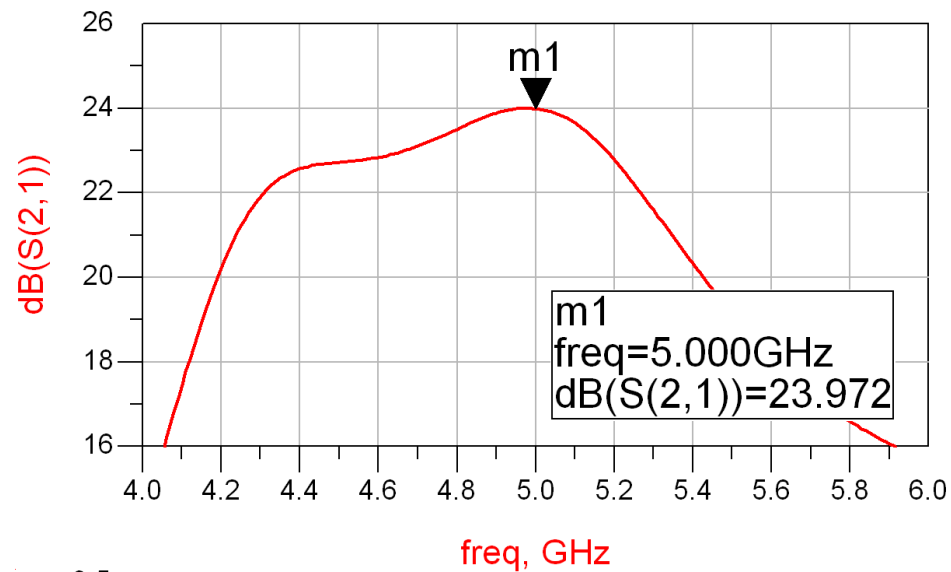
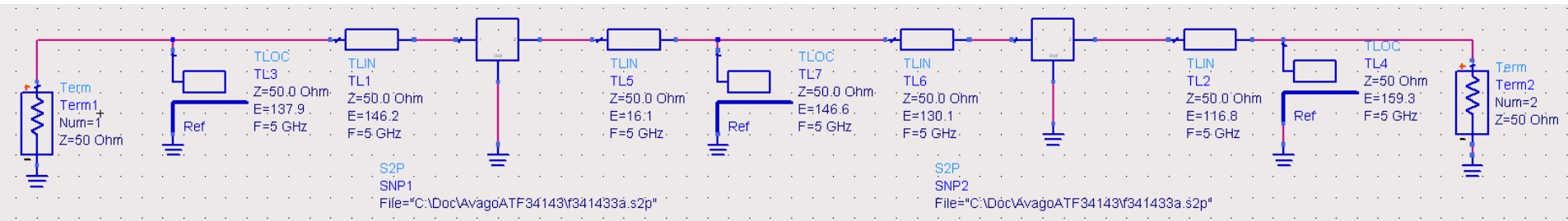


Diagrama Smith 4

$$\theta_{L1} = 16.1^\circ \quad \theta_{S2} = 12.6^\circ$$

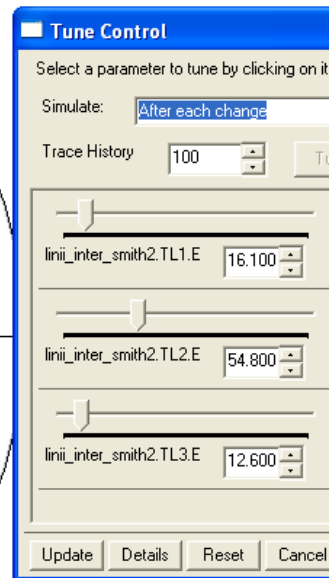
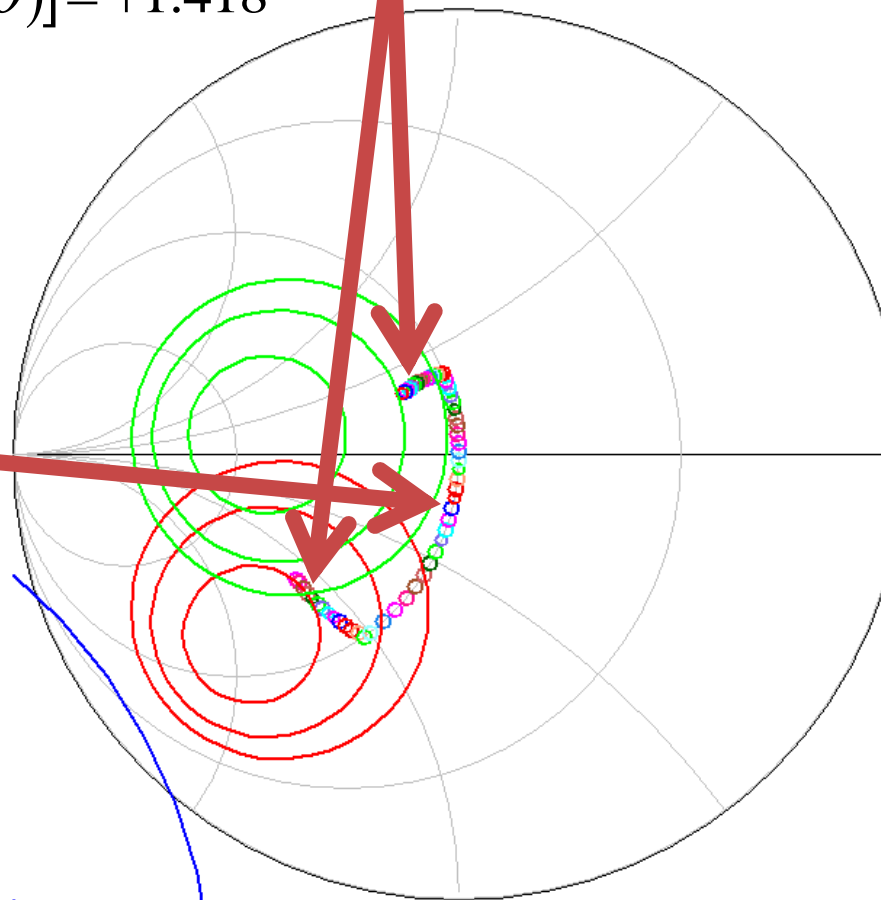
$$\text{Im}[y_{sp}] = \text{Im}[y_{L1}(\theta)] + \text{Im}[y_{S2}(\theta)] = +1.418$$

$$\theta_{sp} = 54.8^\circ$$

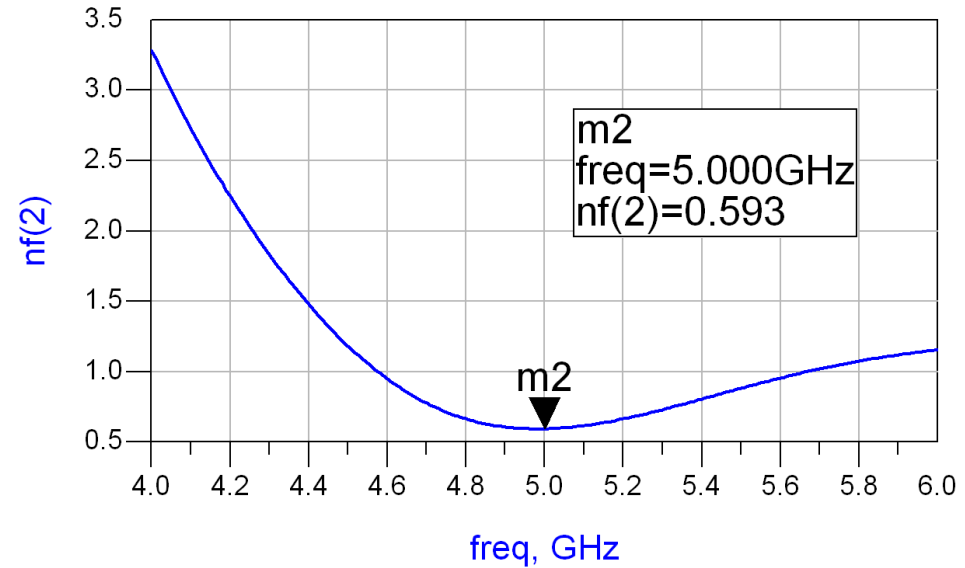
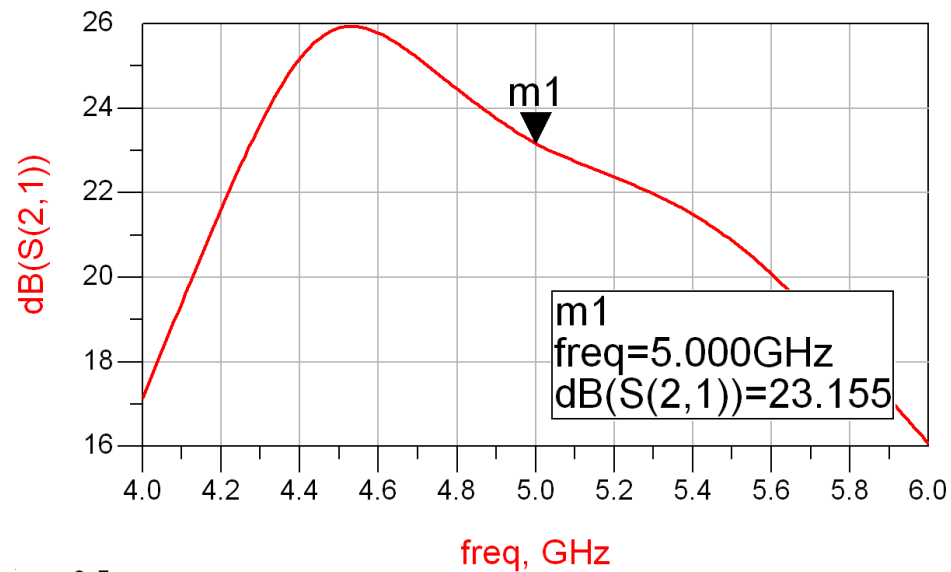
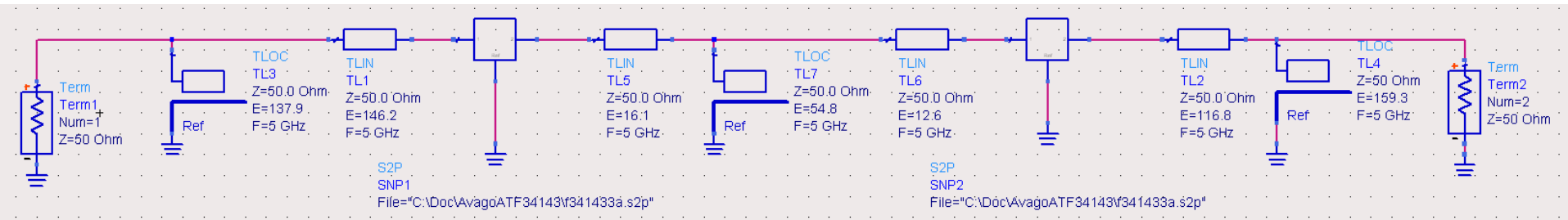
stub
"combinat"

ref.: SIN
ref.: CZ
ref.: CCIN
S(,2)

linii
serie



ADS 4



Adaptare inter-etaje

- Toate variantele obtinute indeplinesc conditiile de castig si zgomot
- Se alege una convenabila in functie de:
 - dimensiunile fizice ale liniilor $l = \frac{\theta}{360^\circ} \cdot \lambda$
 - comportare in frecventa
 - stabilitate
 - performanta (zgomot/castig)
 - reflexie intrare iesire
 - etc.

Supliment Mini Proiect

Implementare cu linii microstrip

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

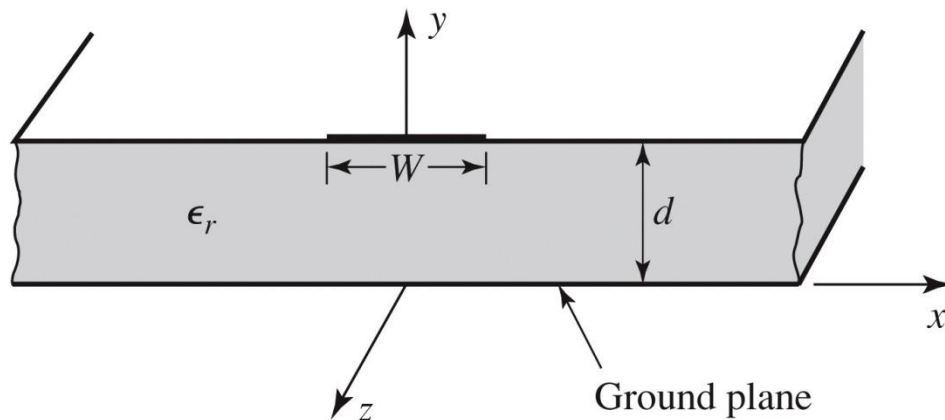


Figure 3.25a
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Implementare cu linii microstrip

- Linie quasi TEM

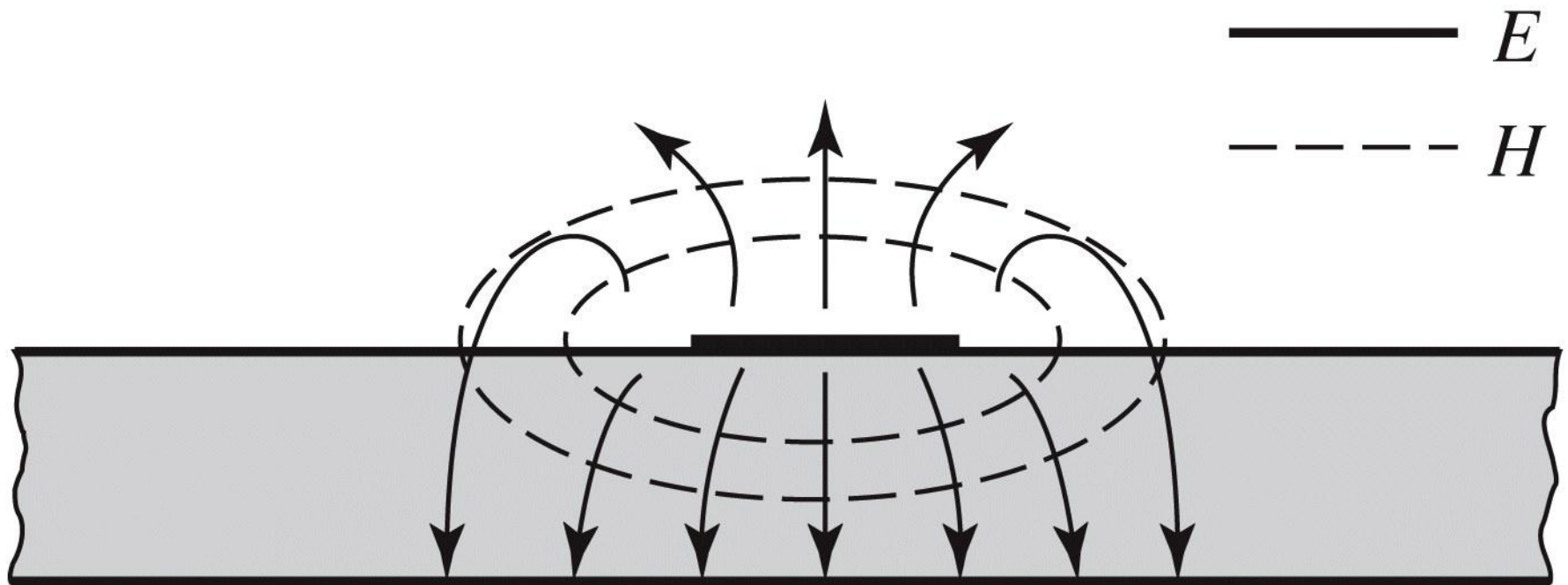
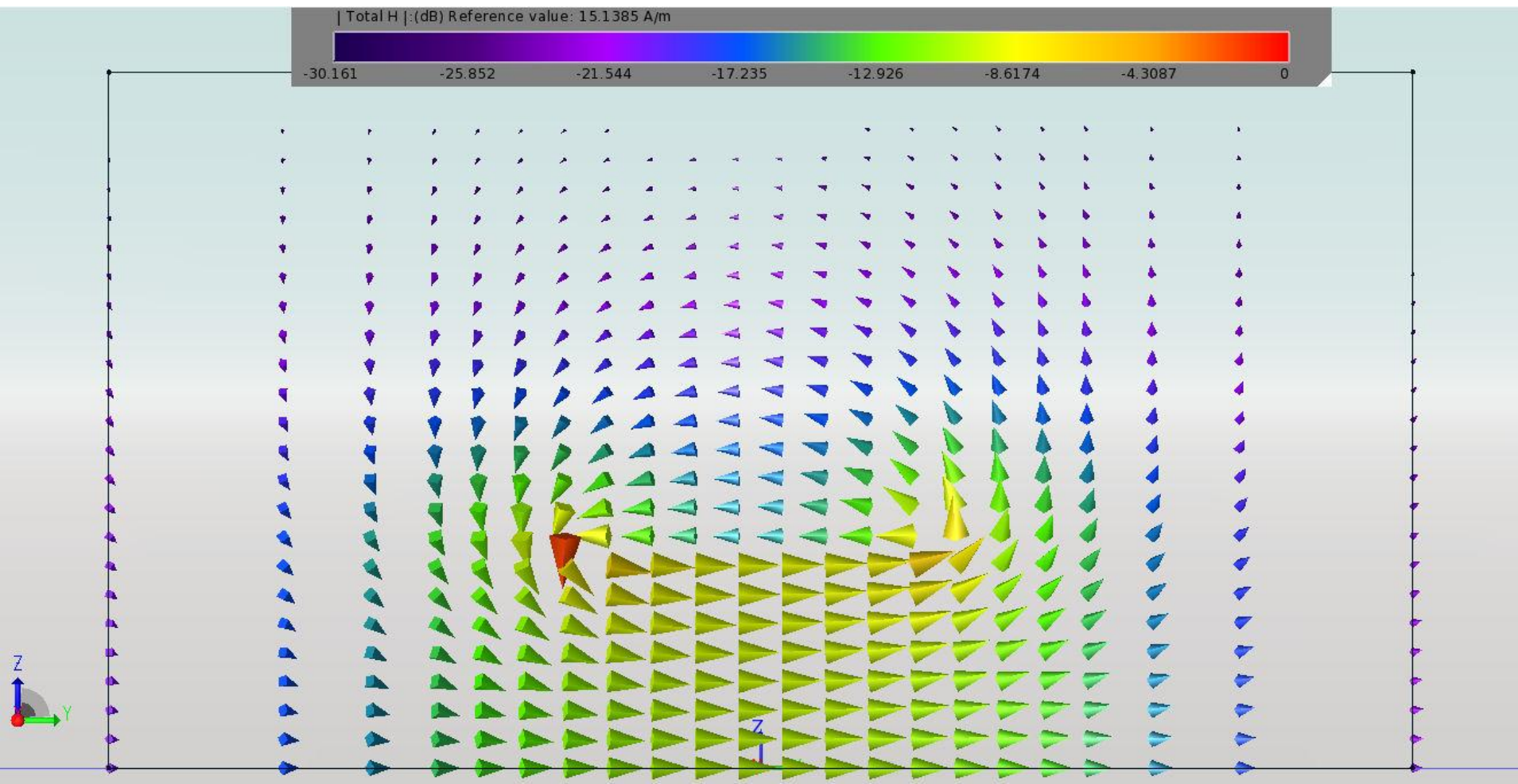


Figure 3.25b

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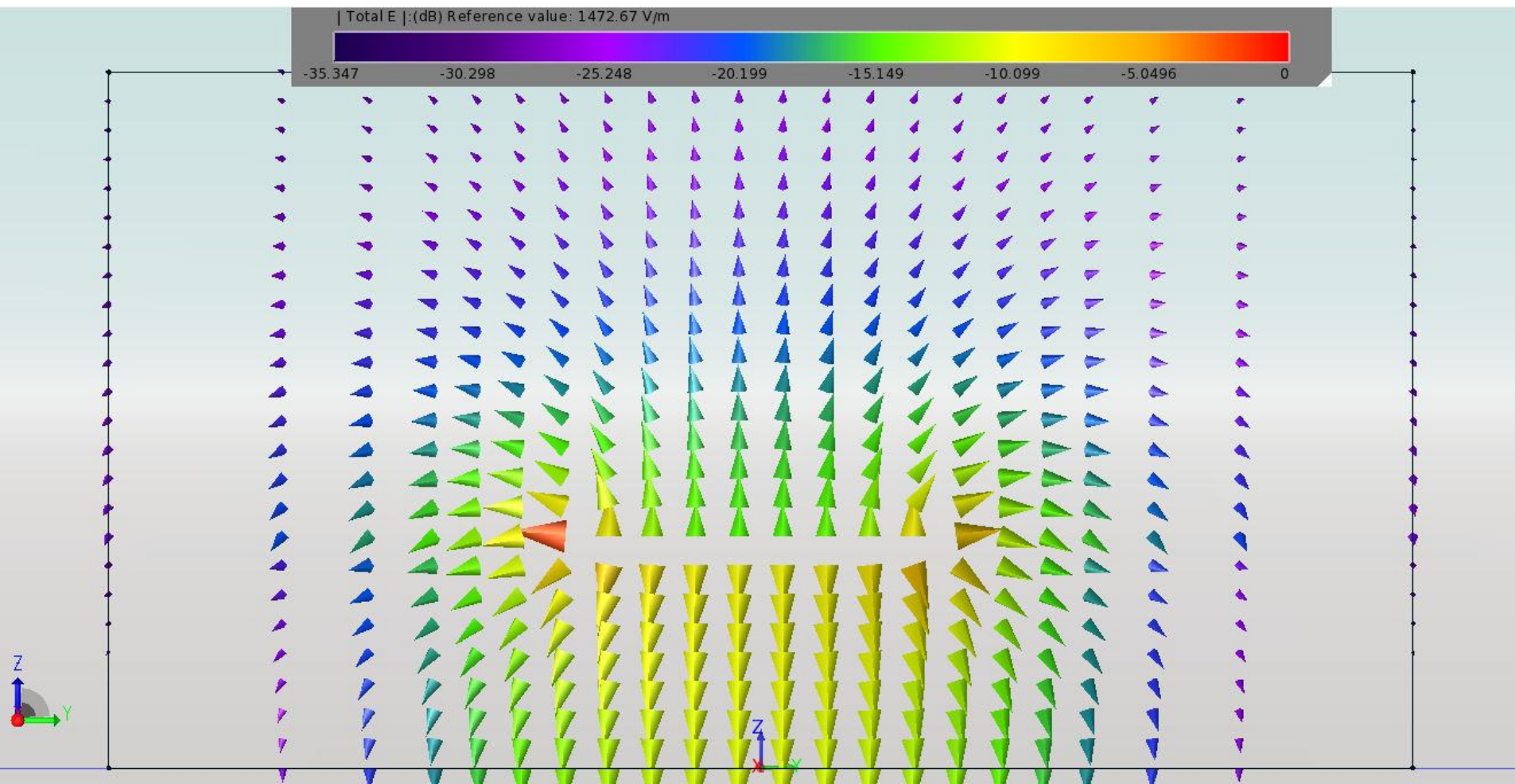
Implementare cu linii microstrip

- Linie quasi TEM, EmPro



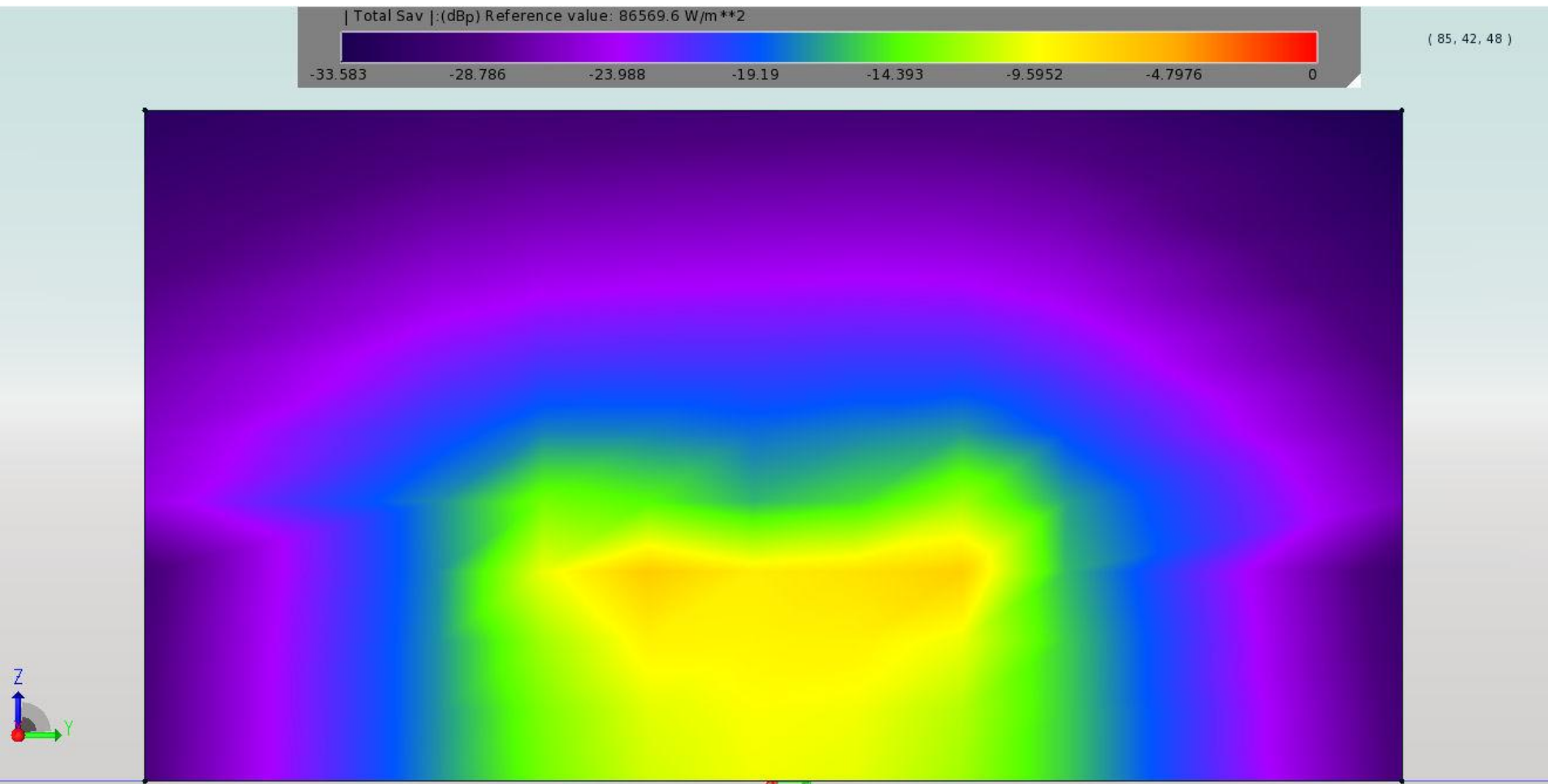
Implementare cu linii microstrip

- Linie quasi TEM, EmPro



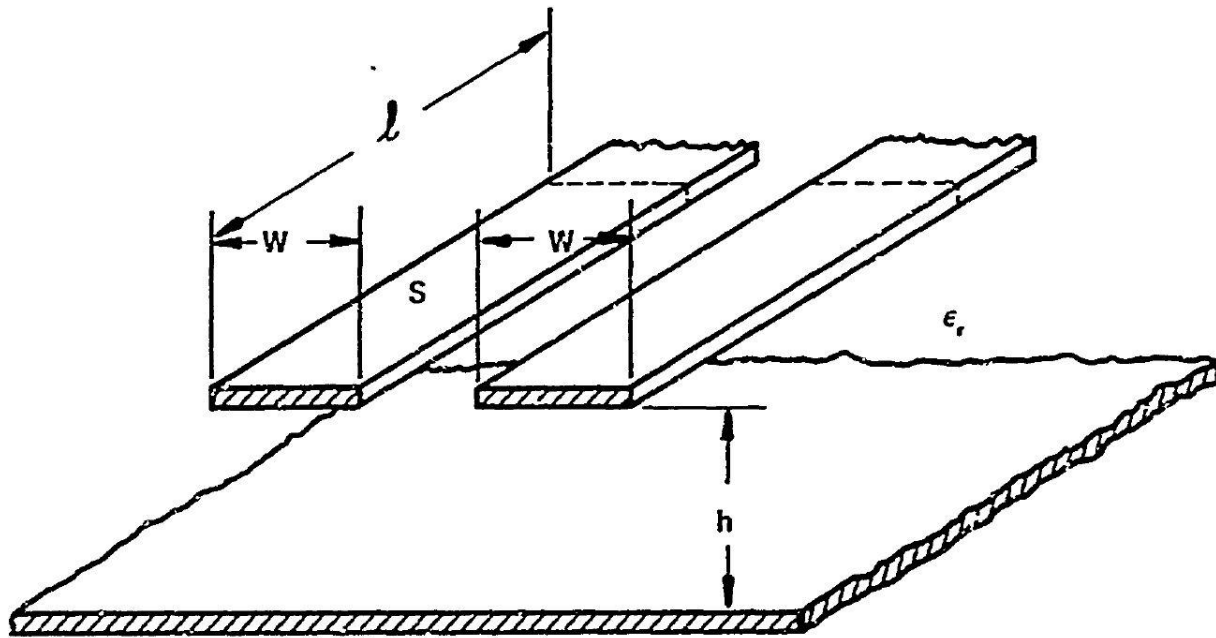
Implementare cu linii microstrip

- Linie quasi TEM, EmPro



Implementare cu linii microstrip

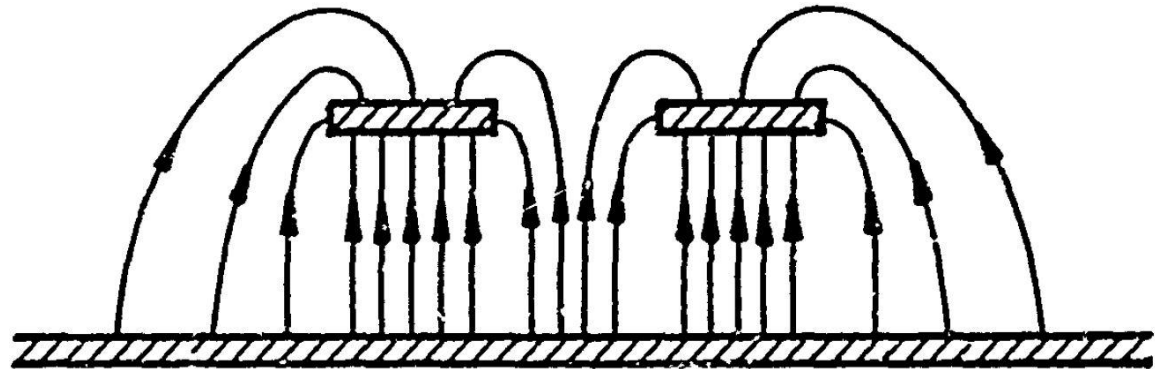
- ~ Aproximativ TEM



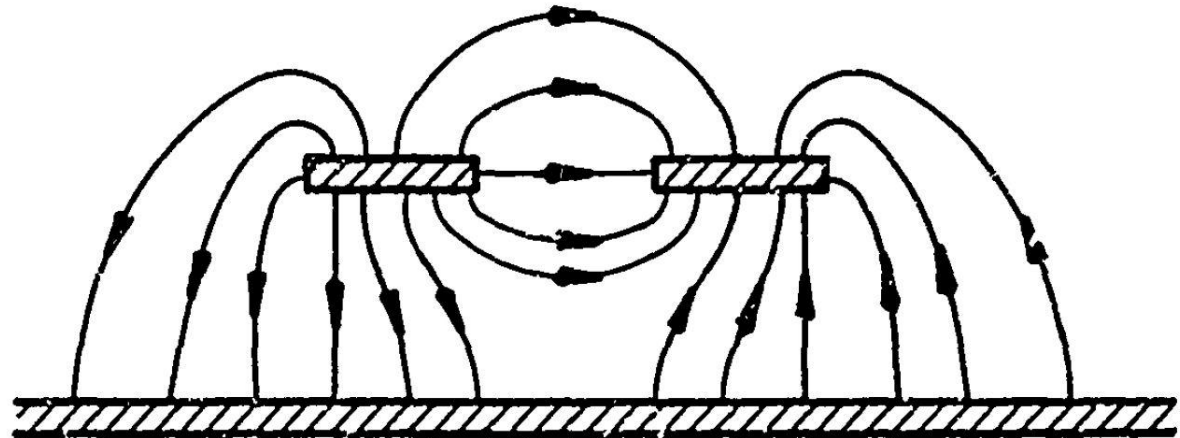
a) COUPLED STRIP GEOMETRY

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

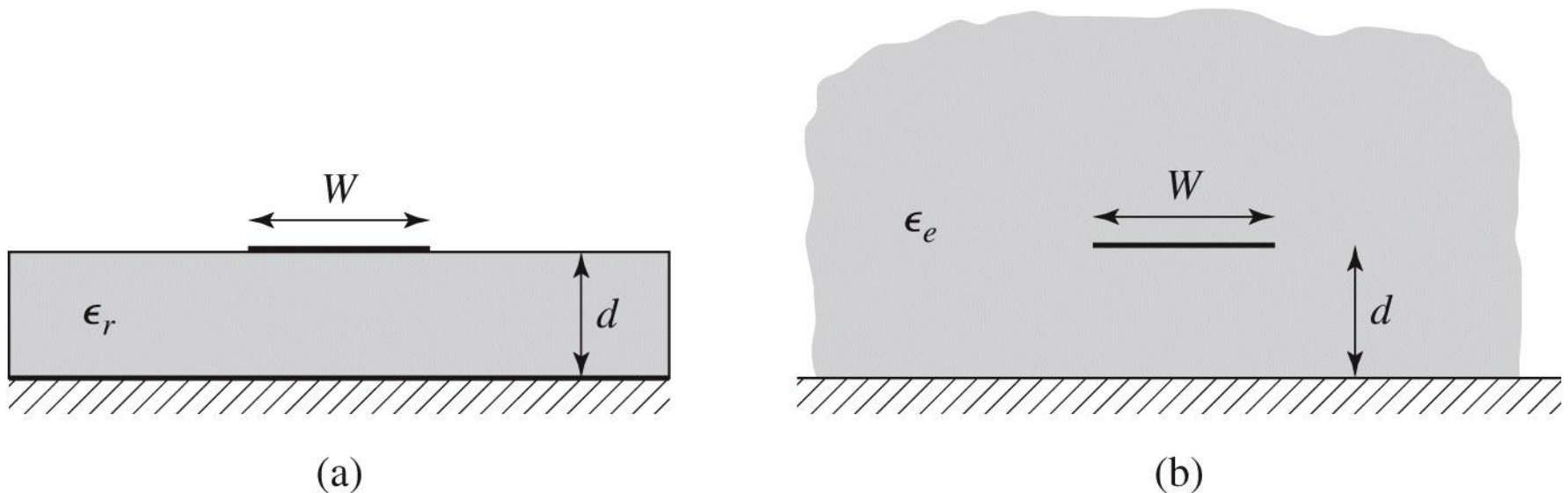


Figure 3.26
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Calcul

■ Calcul empiric

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

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

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

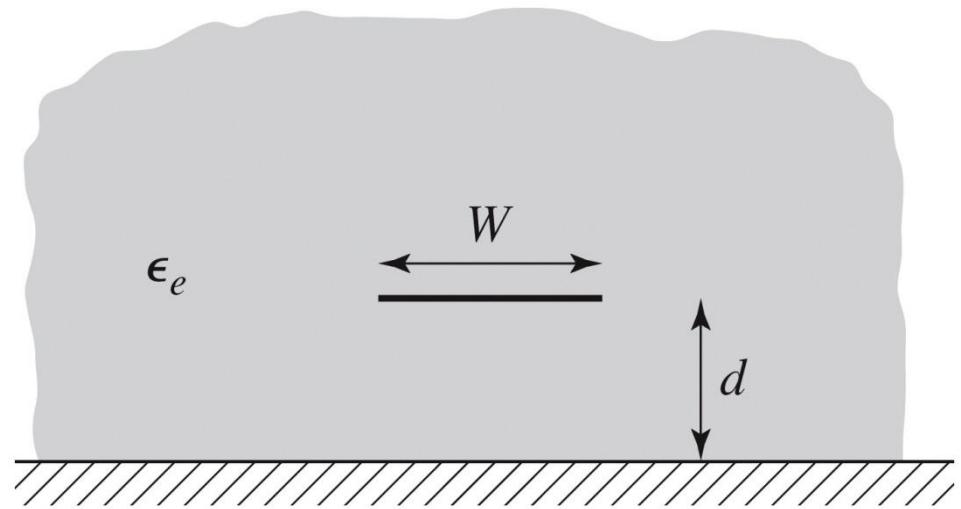


Figure 3.26b
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$$Z_0 = \begin{cases} \frac{60}{\sqrt{\epsilon_e}} \ln \left(\frac{8d}{W} + \frac{W}{4d} \right) & \text{for } W/d \leq 1 \\ \frac{120\pi}{\sqrt{\epsilon_e} [W/d + 1.393 + 0.667 \ln (W/d + 1.444)]} & \text{for } W/d \geq 1. \end{cases}$$

Calcul

■ Calcul empiric

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

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

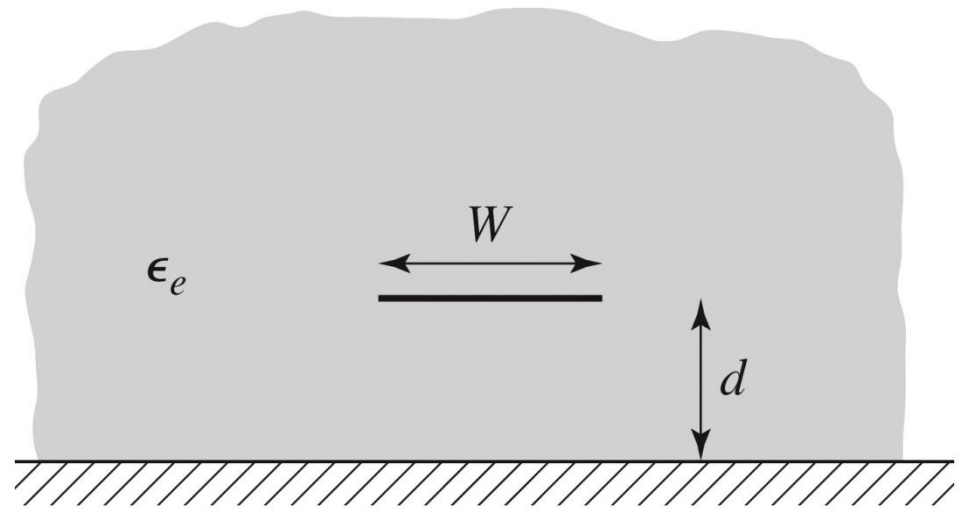
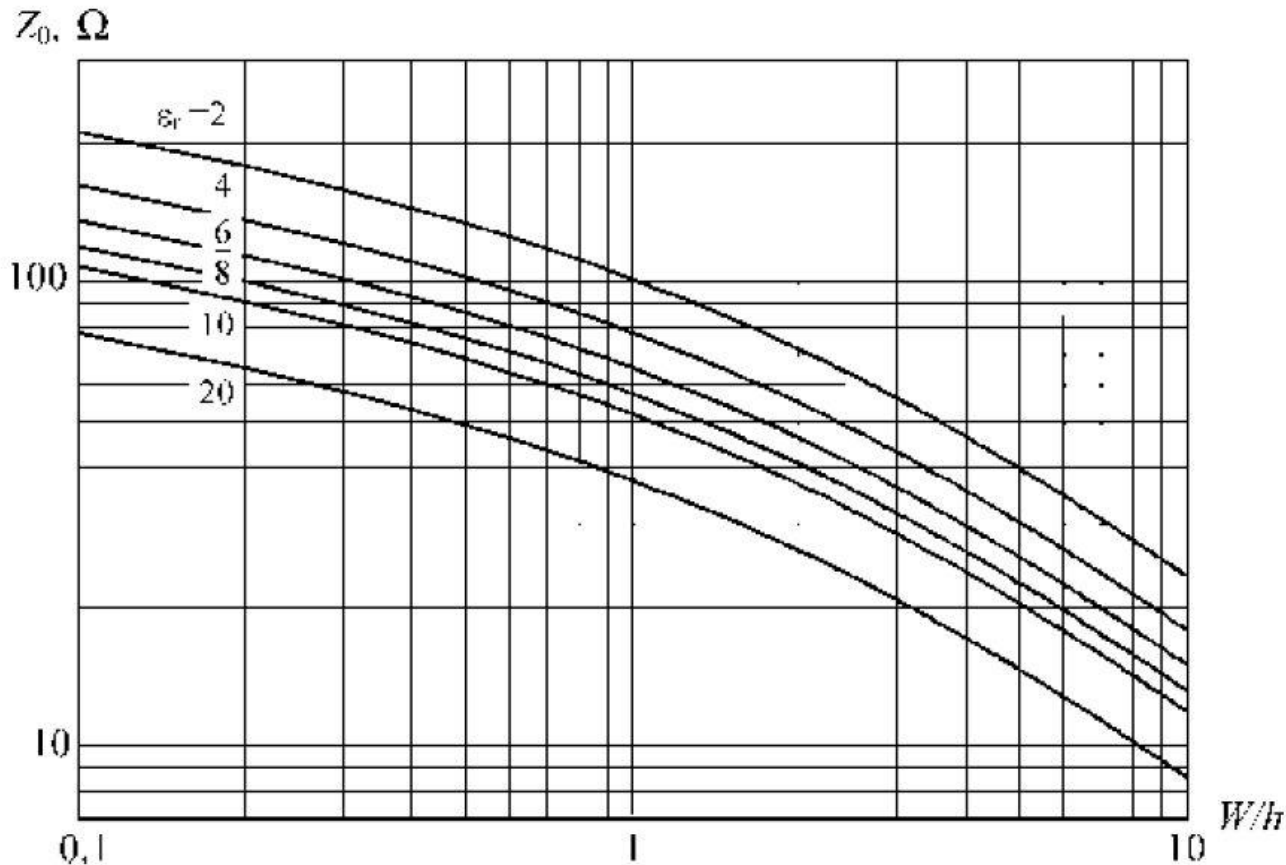


Figure 3.26b
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$$\frac{W}{d} = \begin{cases} \frac{8e^A}{e^{2A} - 2} & \text{for } W/d < 2 \\ \frac{2}{\pi} \left[B - 1 - \ln(2B - 1) + \frac{\epsilon_r - 1}{2\epsilon_r} \left\{ \ln(B - 1) + 0.39 - \frac{0.61}{\epsilon_r} \right\} \right] & \text{for } W/d > 2, \end{cases}$$

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/ft²)
 - 10z=28.35g și 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

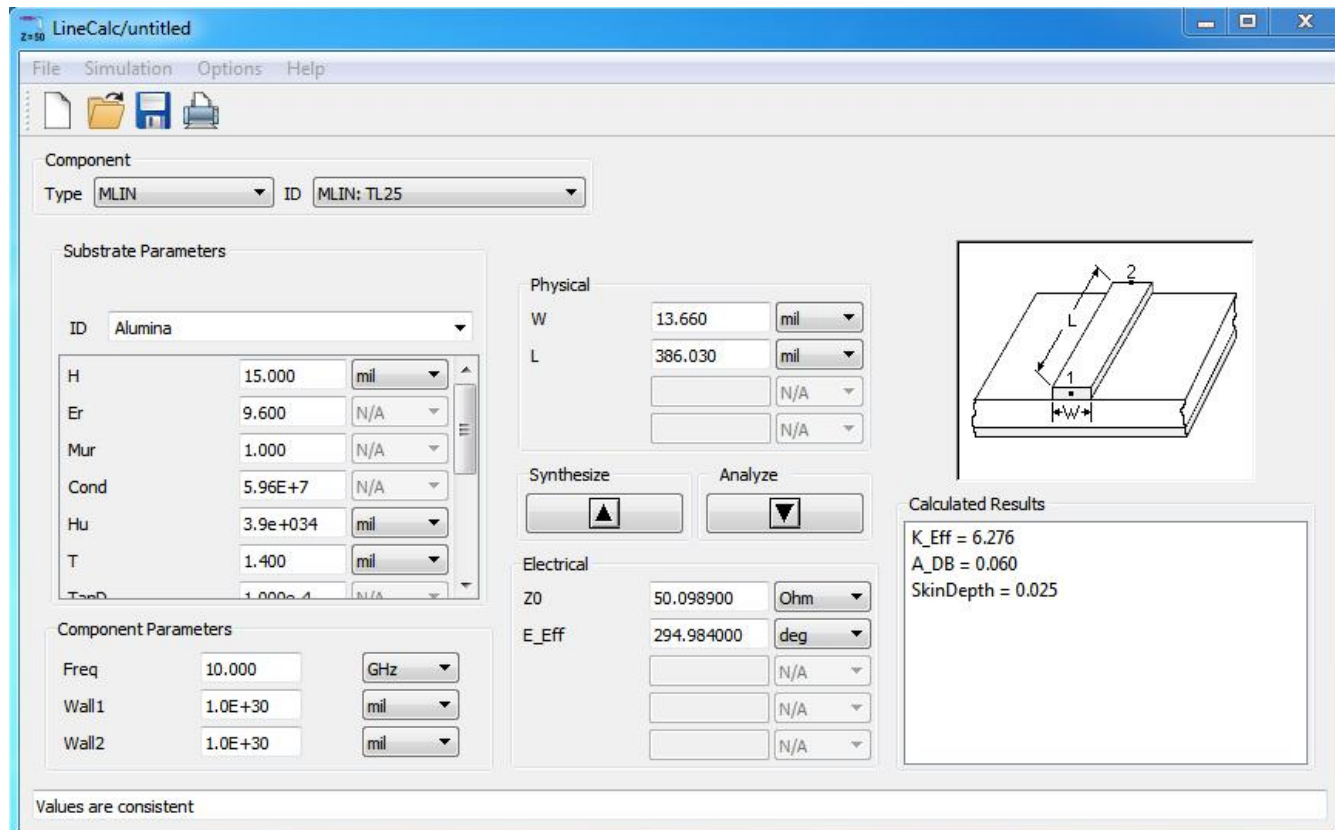
Standard Thickness
RO4003C: 0.008" (0.203mm), 0.012 (0.305mm), 0.016" (0.406mm), 0.020" (0.508mm) 0.032" (0.813mm), 0.060" (1.524mm) RO4350B: *0.004" (0.101mm), 0.0066" (0.168mm) 0.010" (0.254mm), 0.0133 (0.338mm), 0.0166 (0.422mm), 0.020" (0.508mm) 0.030" (0.762mm), 0.060" (1.524mm)

Microstrip, materiale substrat

	Constanta dielectrică relativă	Factorul de pierderi dielectrice	Conductivitate termică	Coeficient liniar de expansiune	Coeficient de temperatură a lui ϵ_r
Material	-	-	W/cm/K	ppm/K	ppm/K
Al ₂ O ₃ (99.5%)	9.8	0.0001	0.37	6.3	+136
Al ₂ O ₃ (96%)	9.4	0.001	0.35	6.4	-
Safir	9.4;11.6	0.0001	0.42	6.0	+110-+140
Sticlă cuarț	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 ₄ O 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	-	-	-

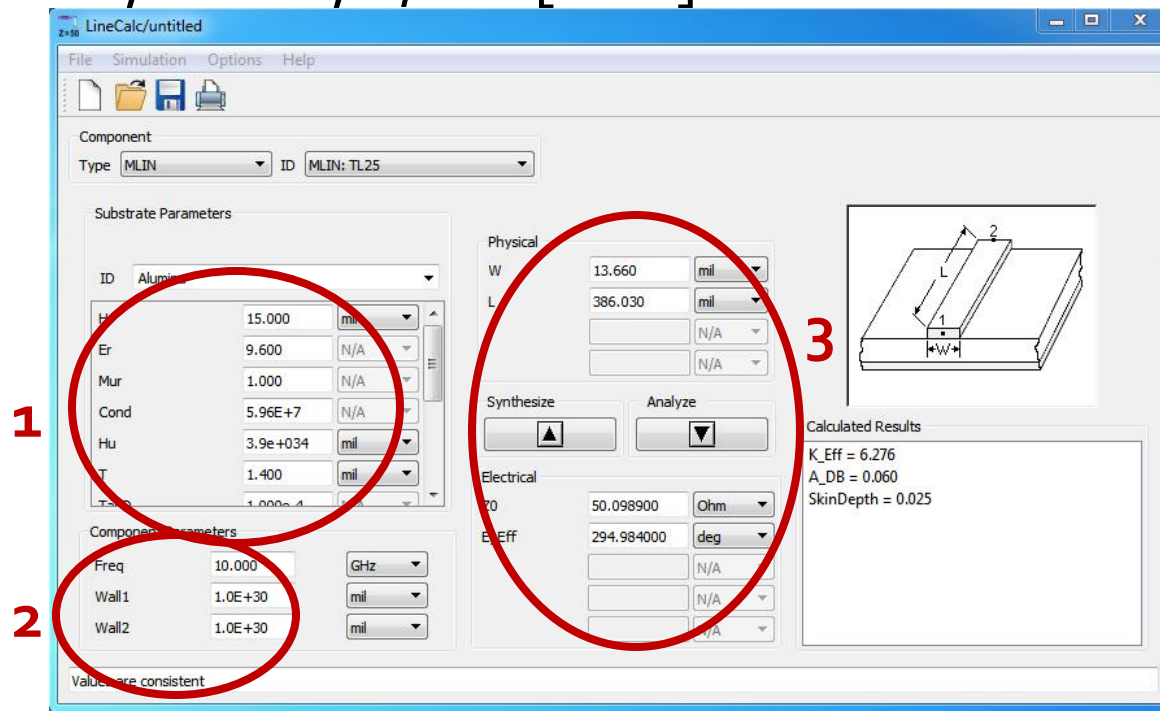
ADS linecalc

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



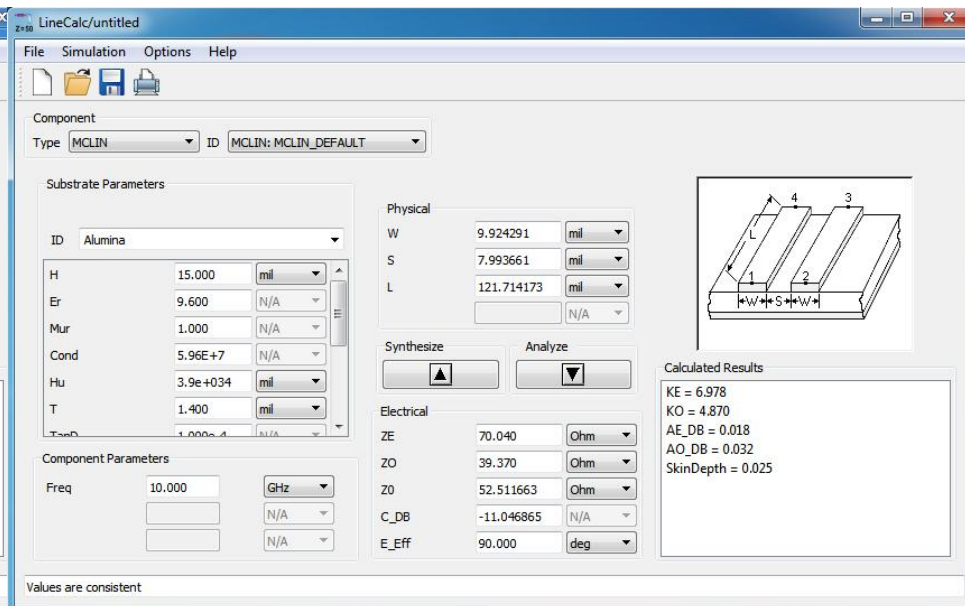
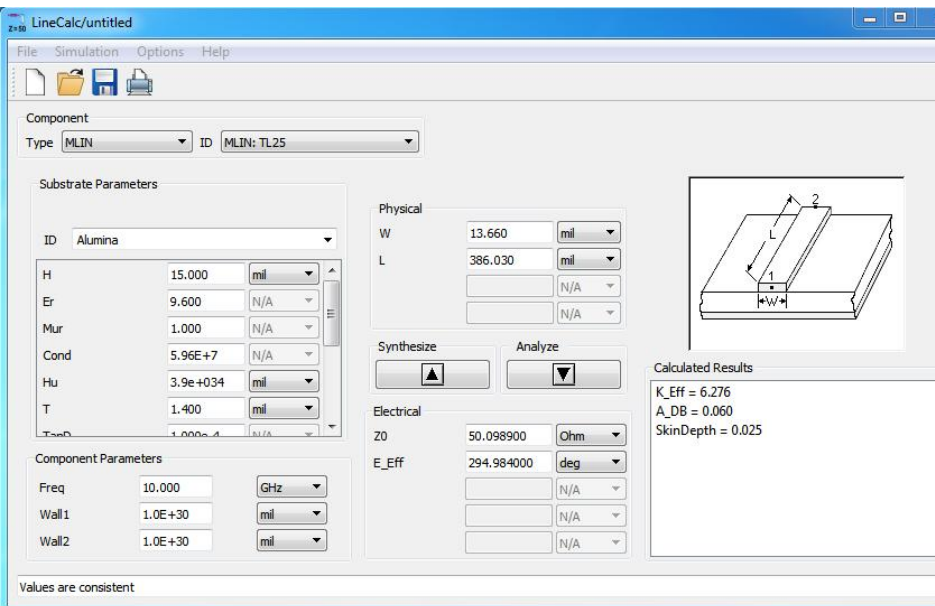
ADS linecalc

- 1. Definire (receptie din schema) substrat
- 2. Introducere frecventa
- 3. Introducere date de intrare
 - Analiza: $W, L \rightarrow Z_0, E$ sau $Z_e, Z_0, E / I_a f$ [GHz]
 - Sinteza: $Z_0, E \rightarrow W, L / I_a f$ [GHz]



ADS linecalc

- Se poate utiliza pentru:
 - linii microstrip MLIN: $W, L \Leftrightarrow Z_0, E$
 - linii cuplate microstrip MCLIN: $W, L \Leftrightarrow Z_e, Z_0, E$



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	52.511663 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

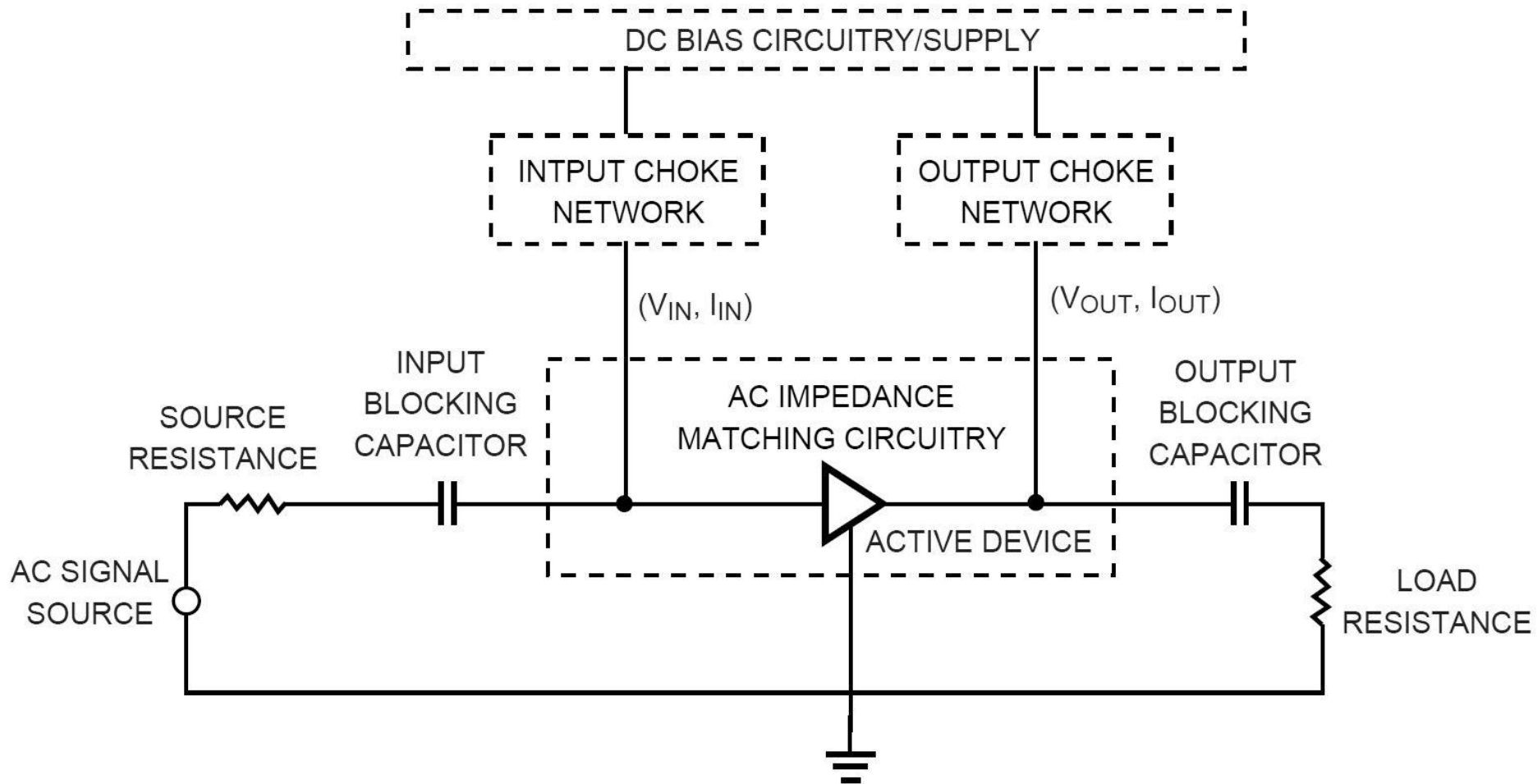
Linii de transmisie

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

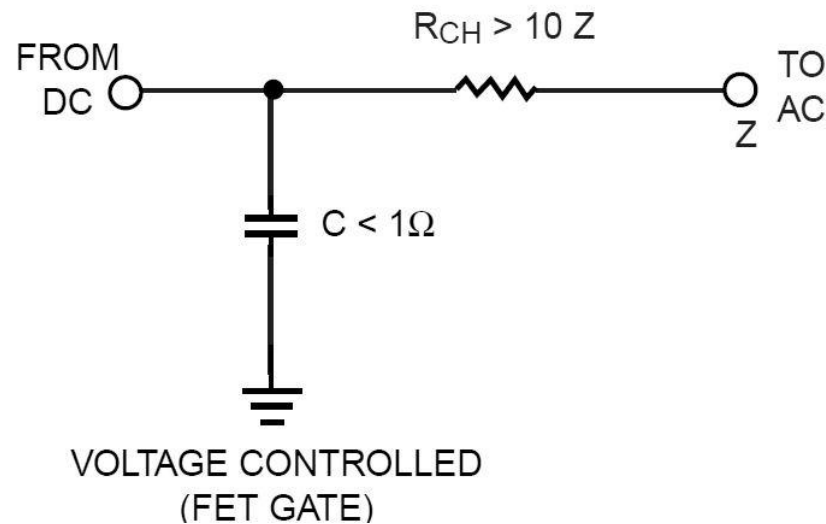
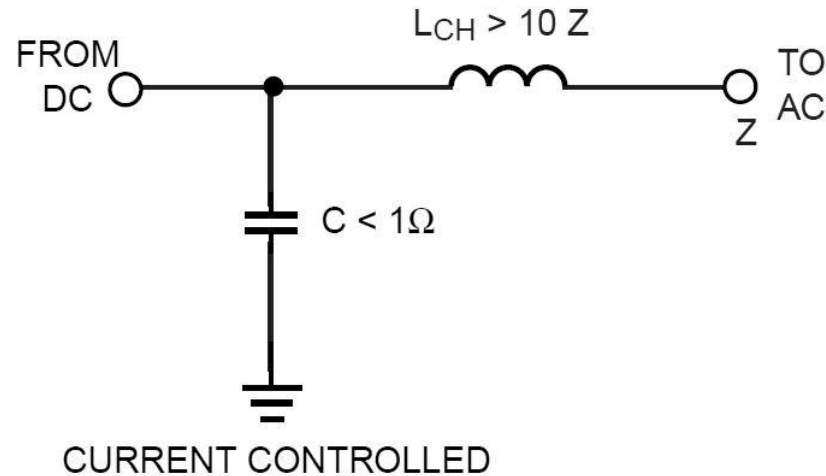
Polarizare

- <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

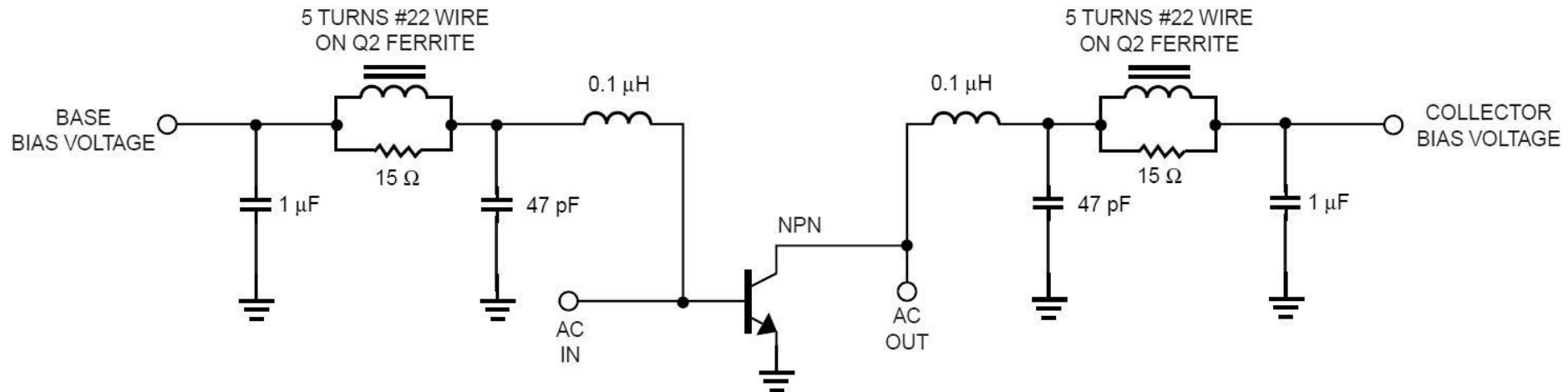
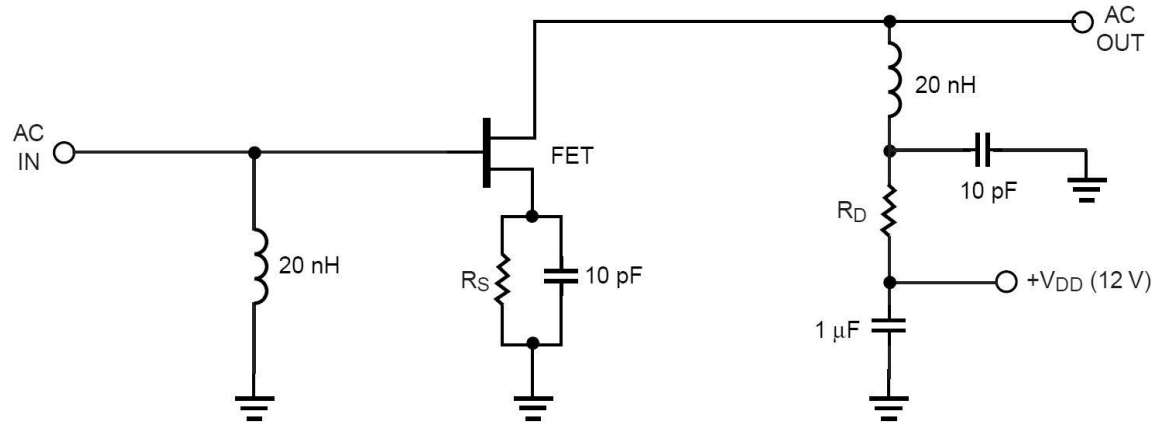
Polarizare



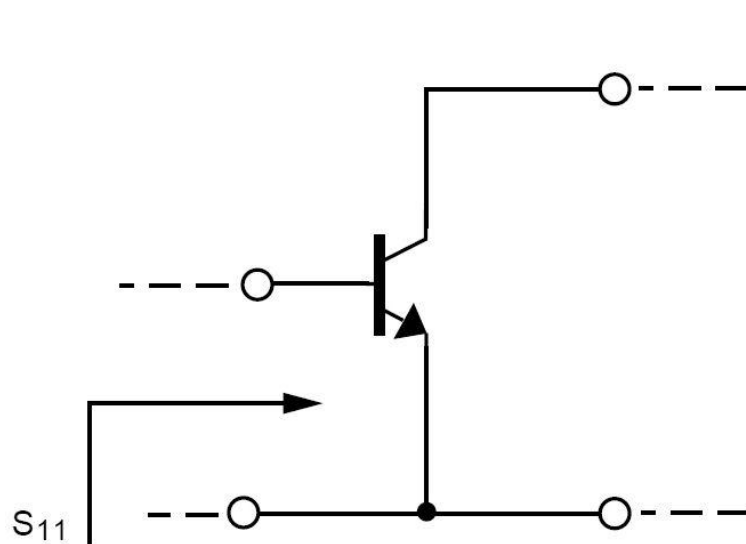
Polarizare, soc tipic



Polarizzare, scheme/valori tipice

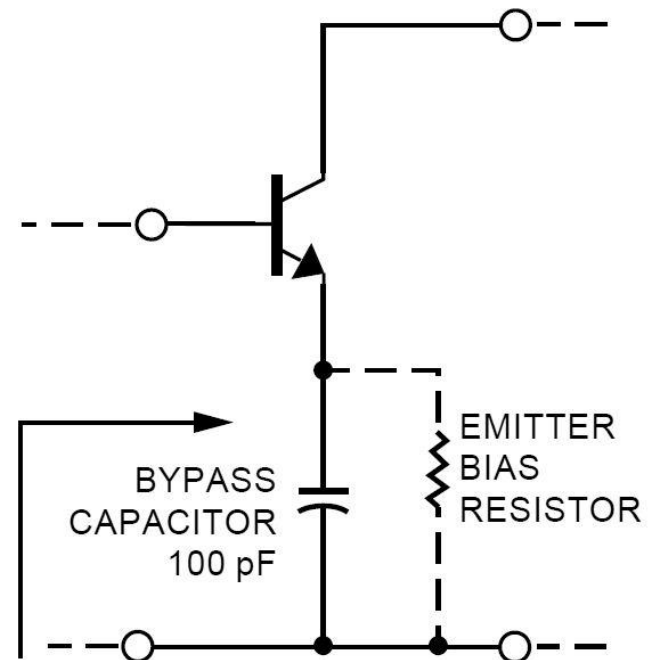


Polarizare, problema elementelor conectate in E/S



$$S_{11} \text{ (AT 4 GHz)} = 0.52 \angle 154^\circ$$

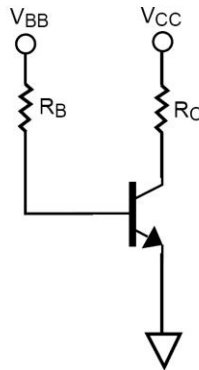
$$S_{11} \text{ (AT 0.1 GHz)} = 0.901 \angle -14.9^\circ$$



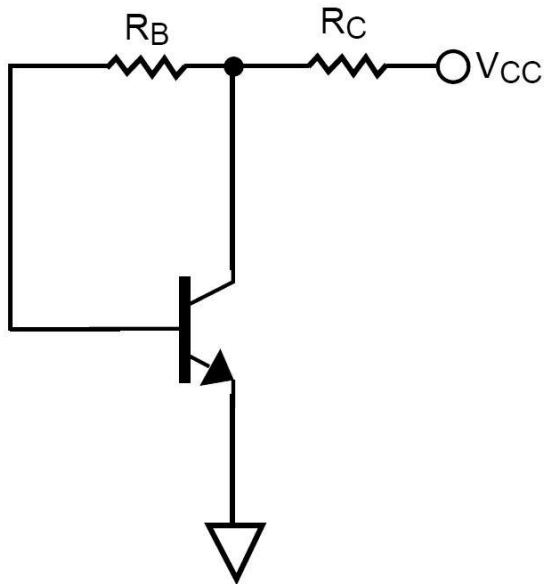
$$S'_{11} \text{ (AT 4 GHz)} = 0.52 \angle 154^\circ \text{ UNCHANGED AT 4 GHz}$$

$$S'_{11} \text{ (AT 0.1 GHz)} = 1.066 \angle -8.5^\circ \quad |S_{11}| > 1 \text{ AT 0.1 GHz}$$

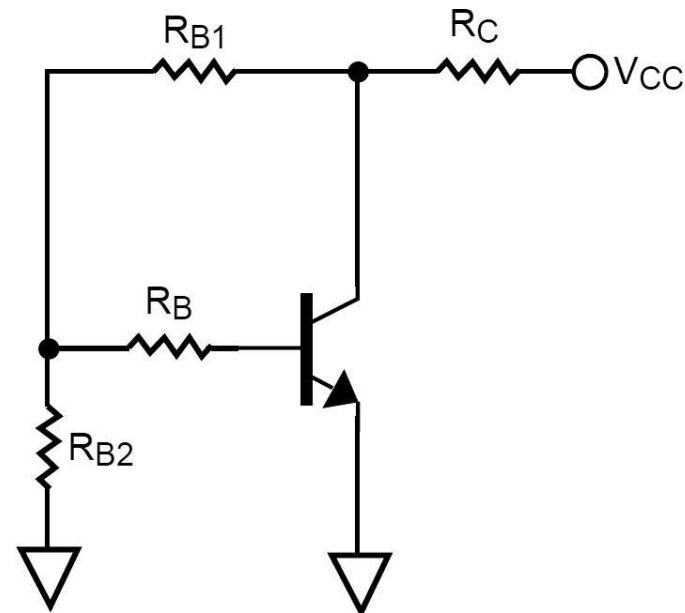
Polarizare TB scheme de polarizare



NON-STABILIZED



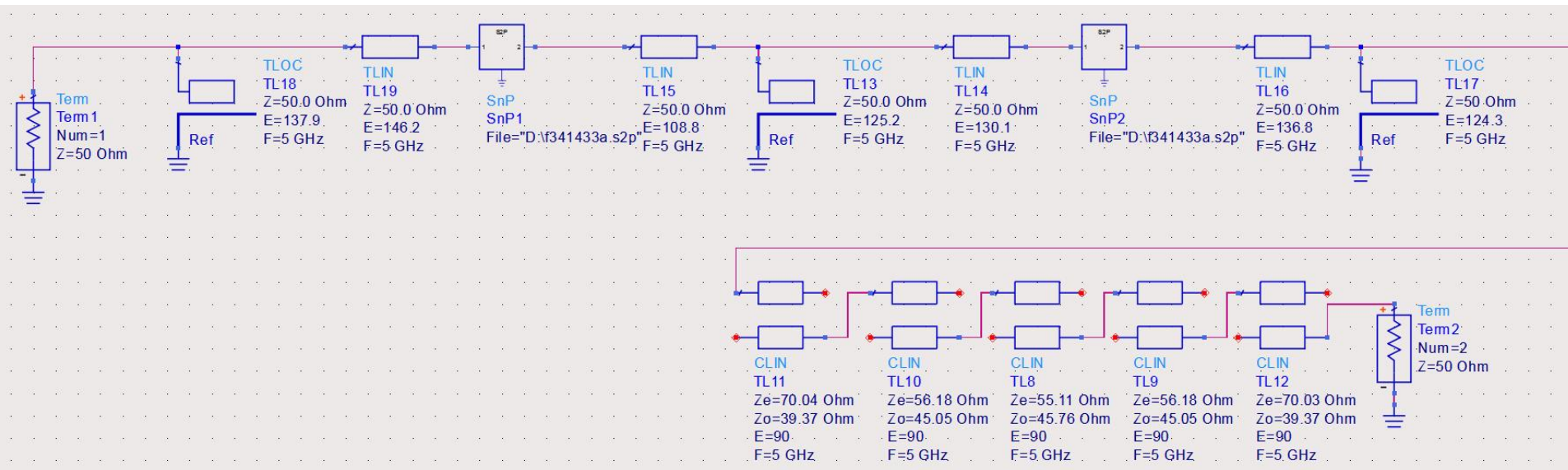
VOLTAGE FEEDBACK



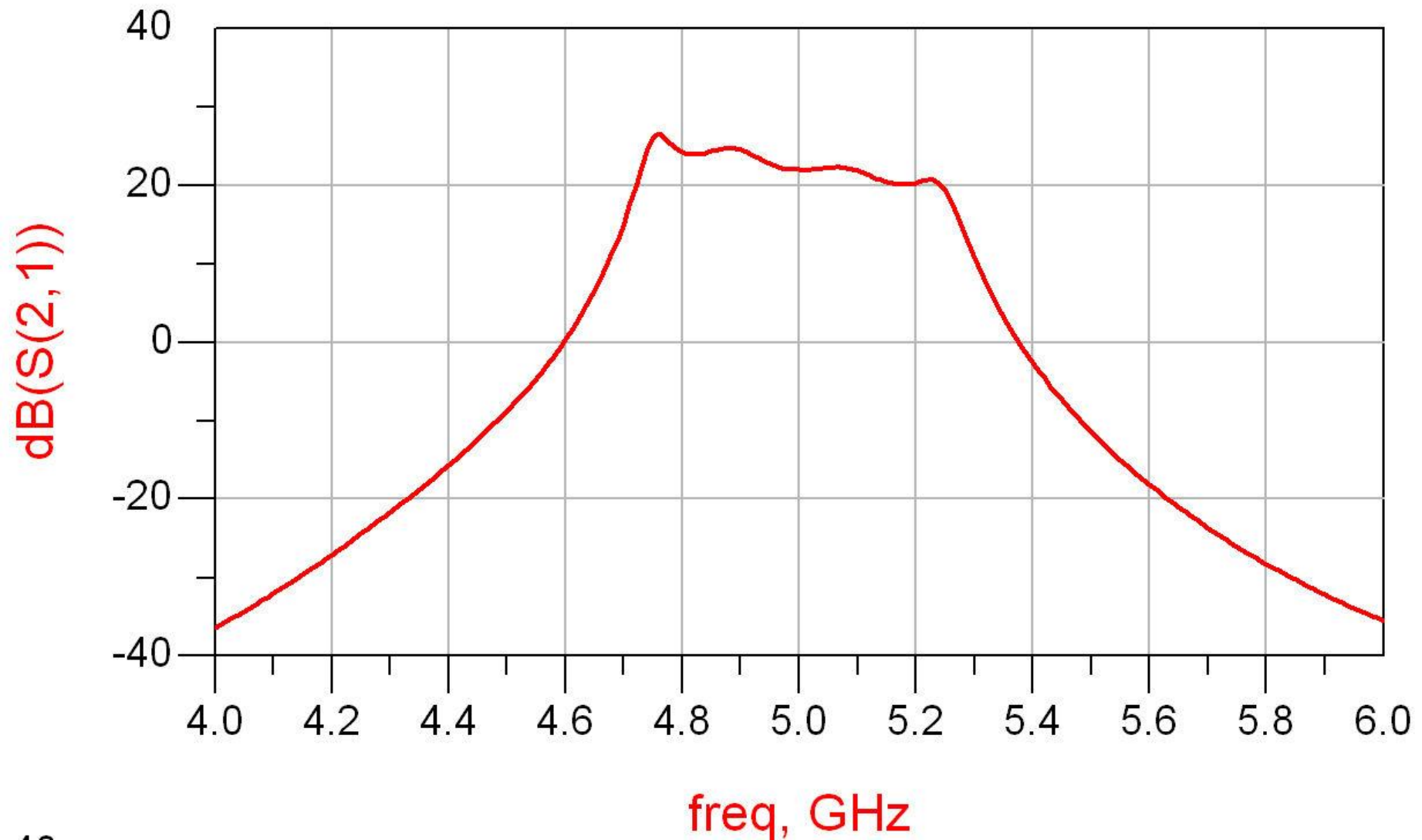
VOLTAGE FEEDBACK AND CONSTANT
BASE CURRENT SOURCE

Exemplu proiect

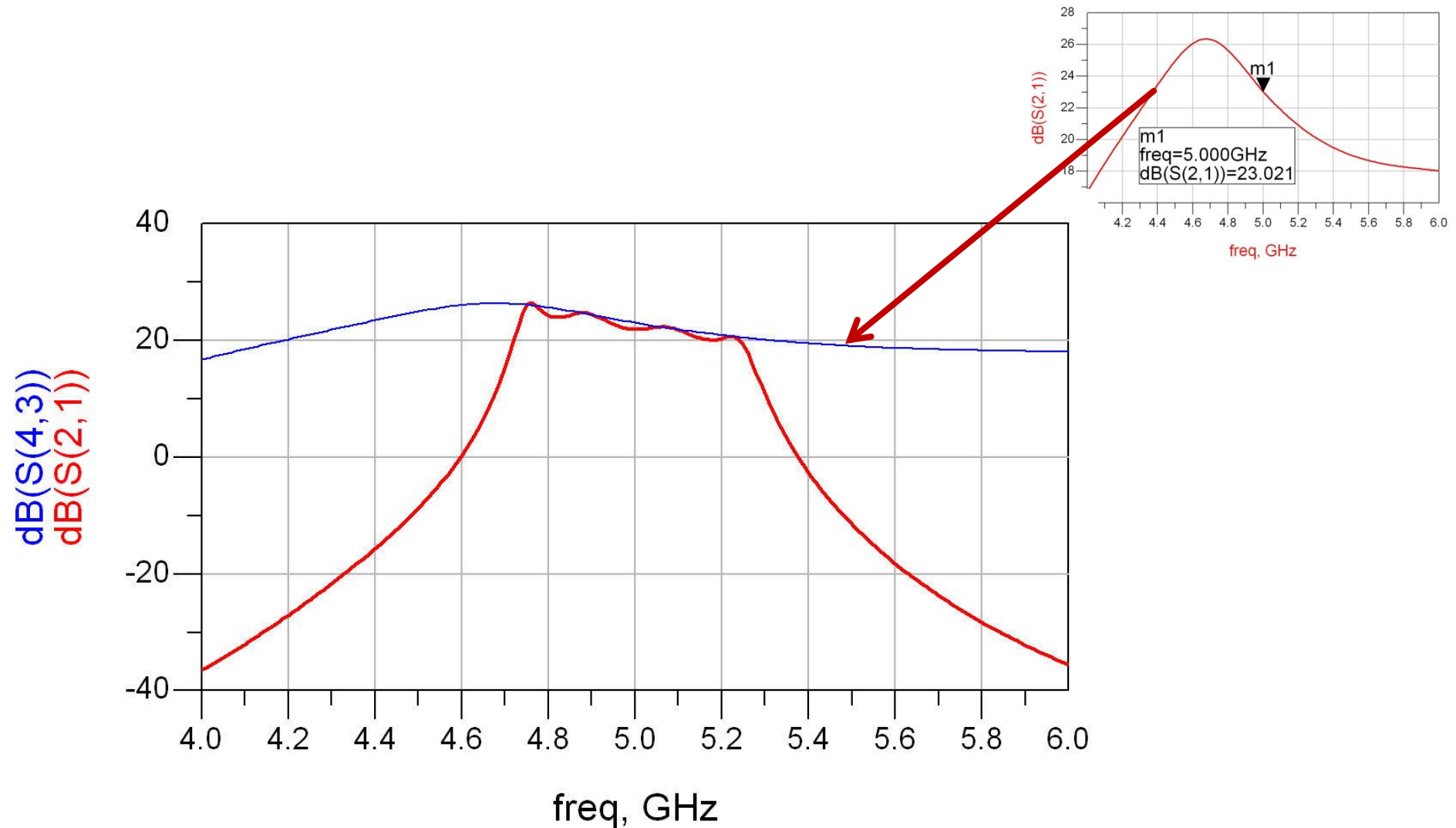
- Unirea celor doua scheme
 - C₉ – amplificator
 - C₁₂ – filtru



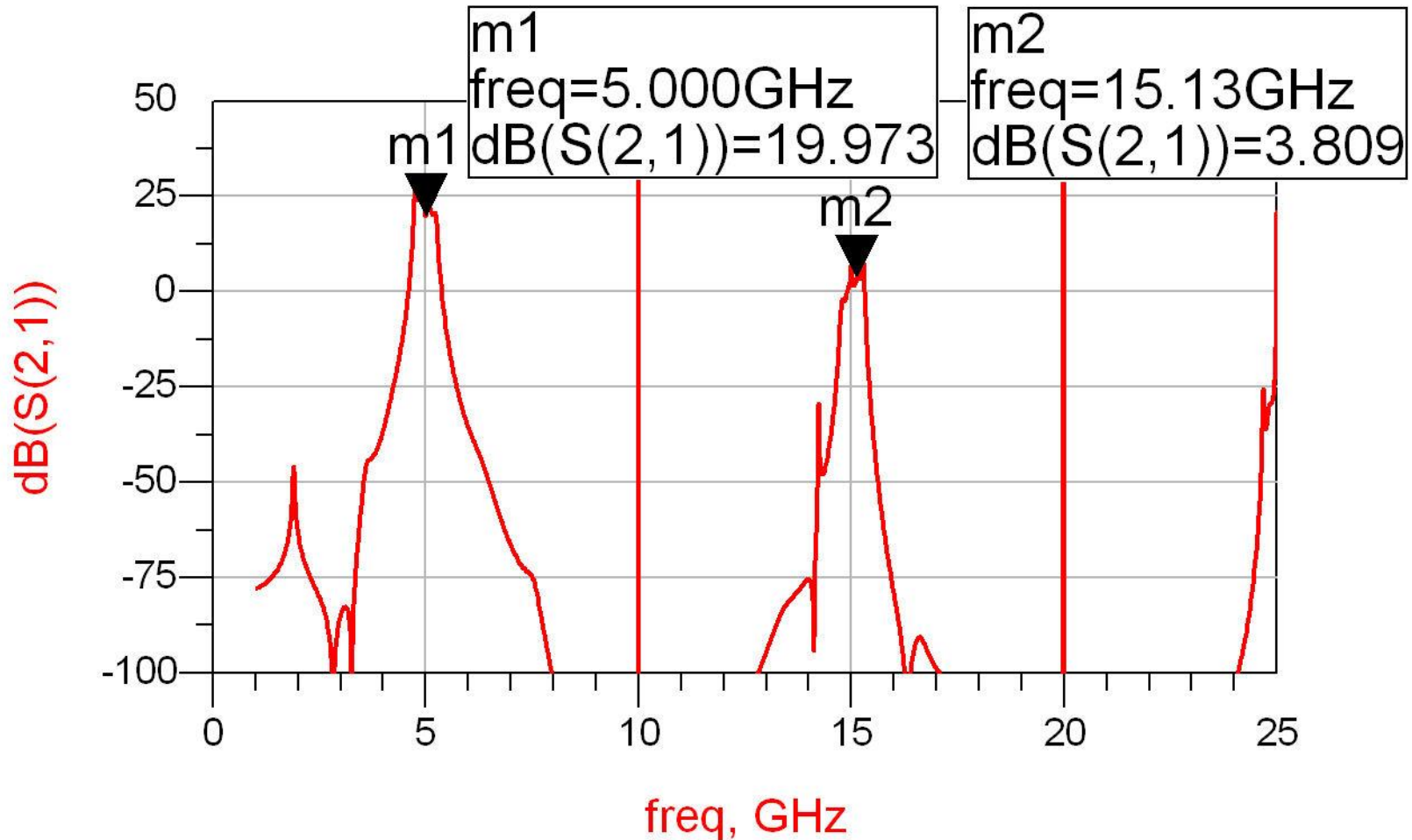
Rezultat (dezechilibrat)



Rezultat (dezechilibrat)

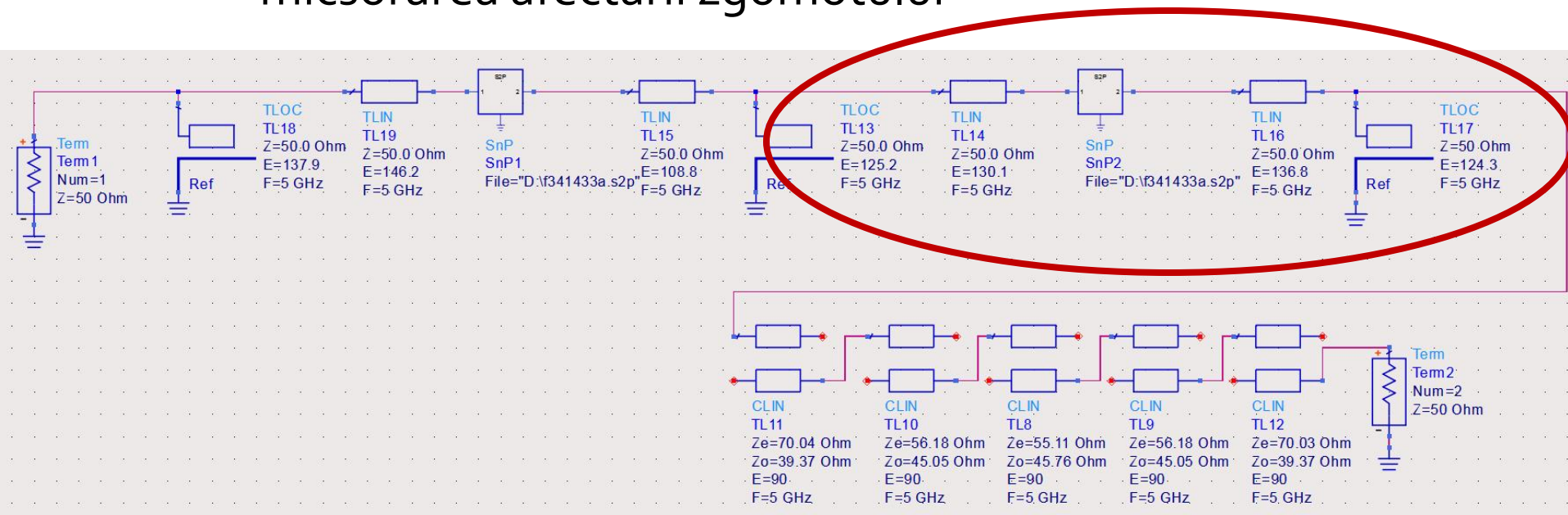


Rezultat (periodic in frecventa)

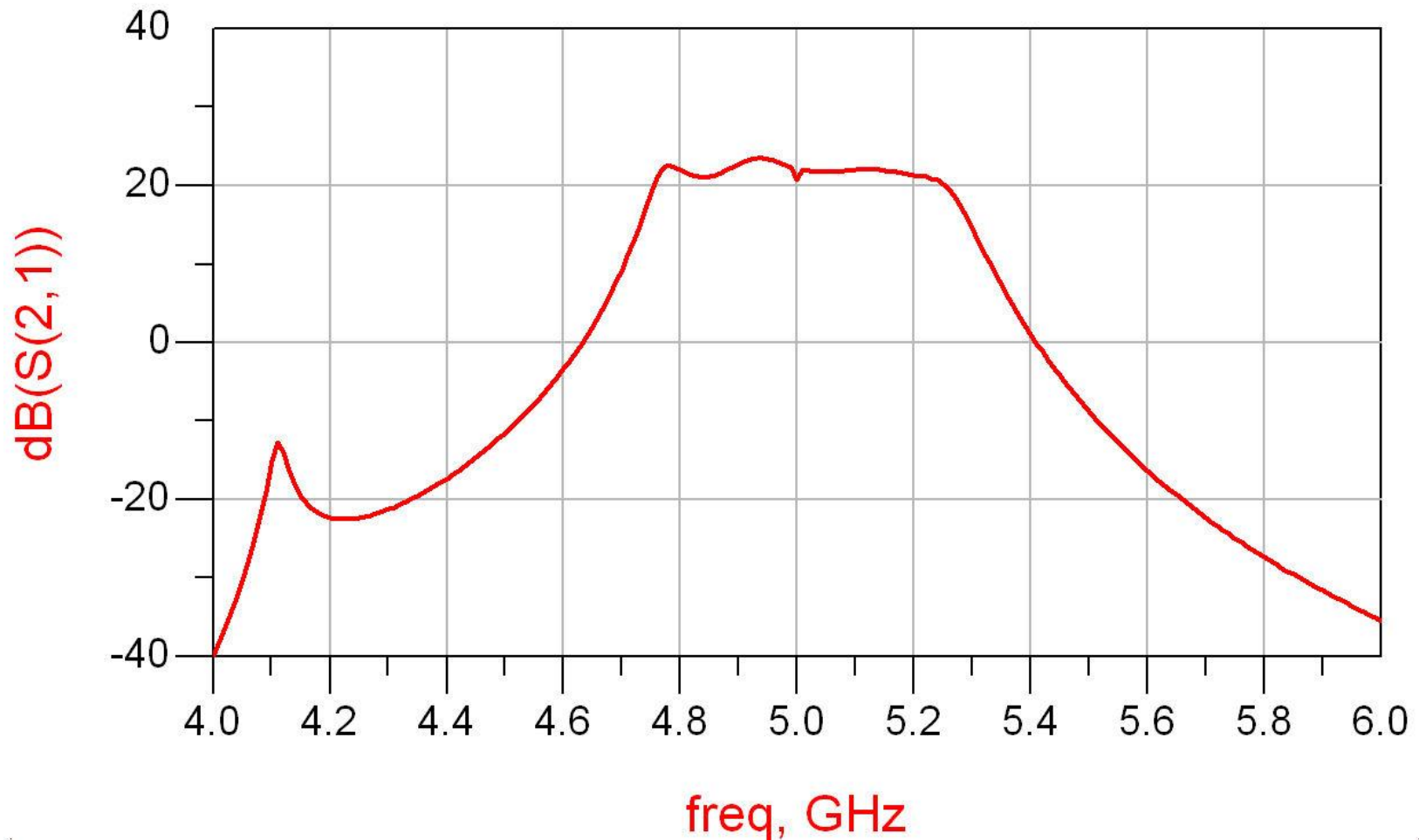


Reglaj -> echilibrare

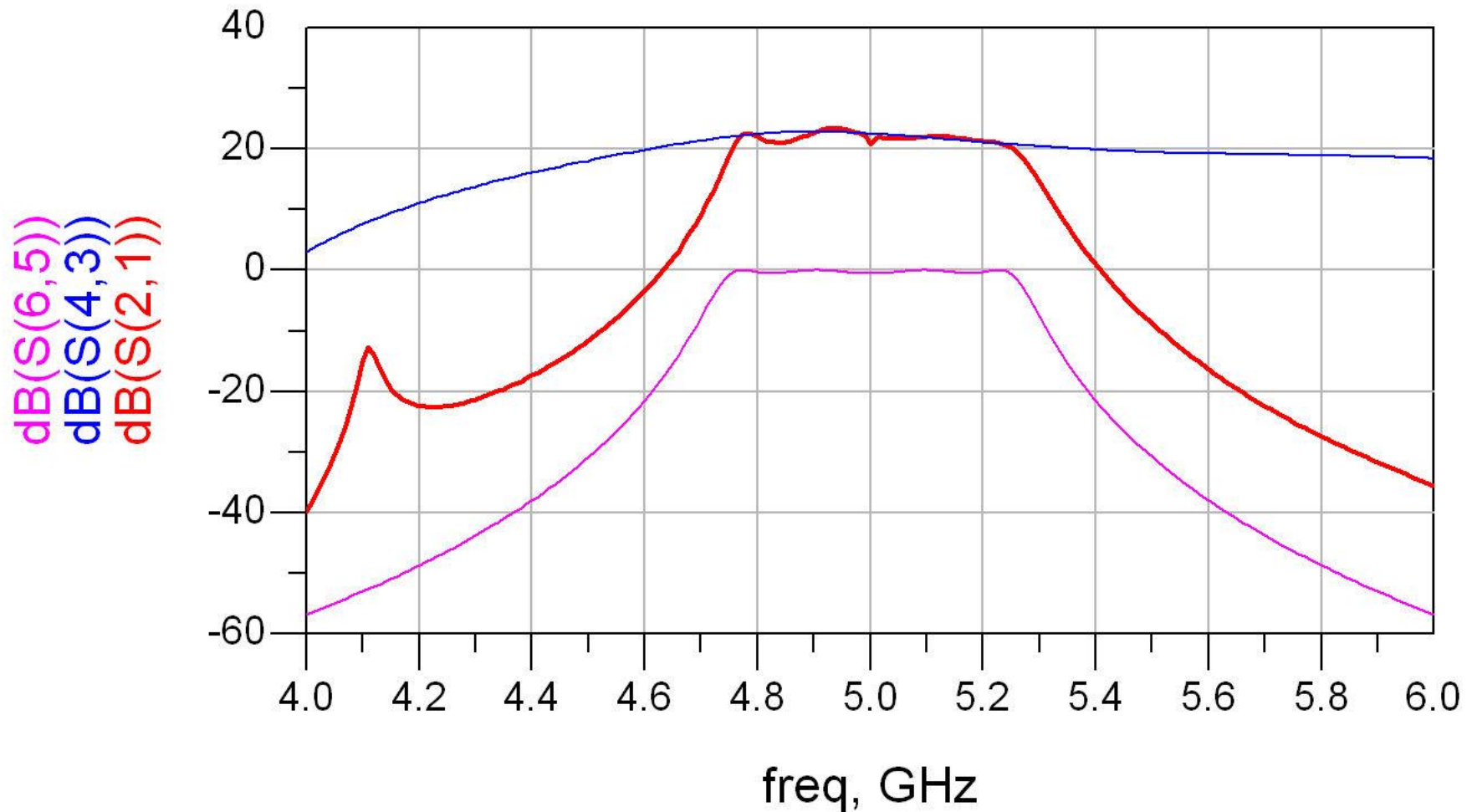
- scopul: echilibrarea caracteristicii amplificatorului (maxim la frecventa centrala)
 - se prefera reglarea lungimii liniilor de la iesirea amplificatorului
 - micsorarea afectarii zgomotului



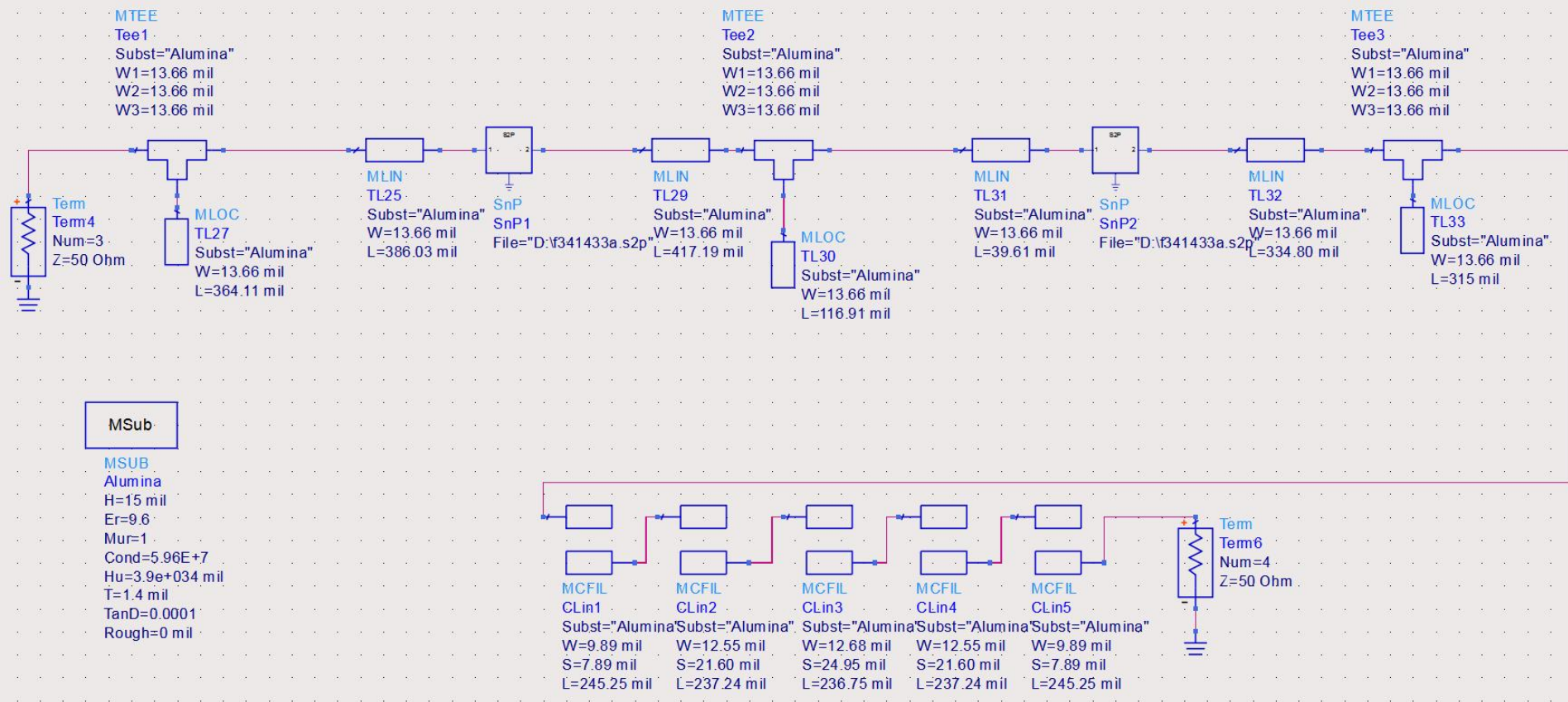
Reglaj -> echilibrare, efect



Amplificator, Filtru, Total

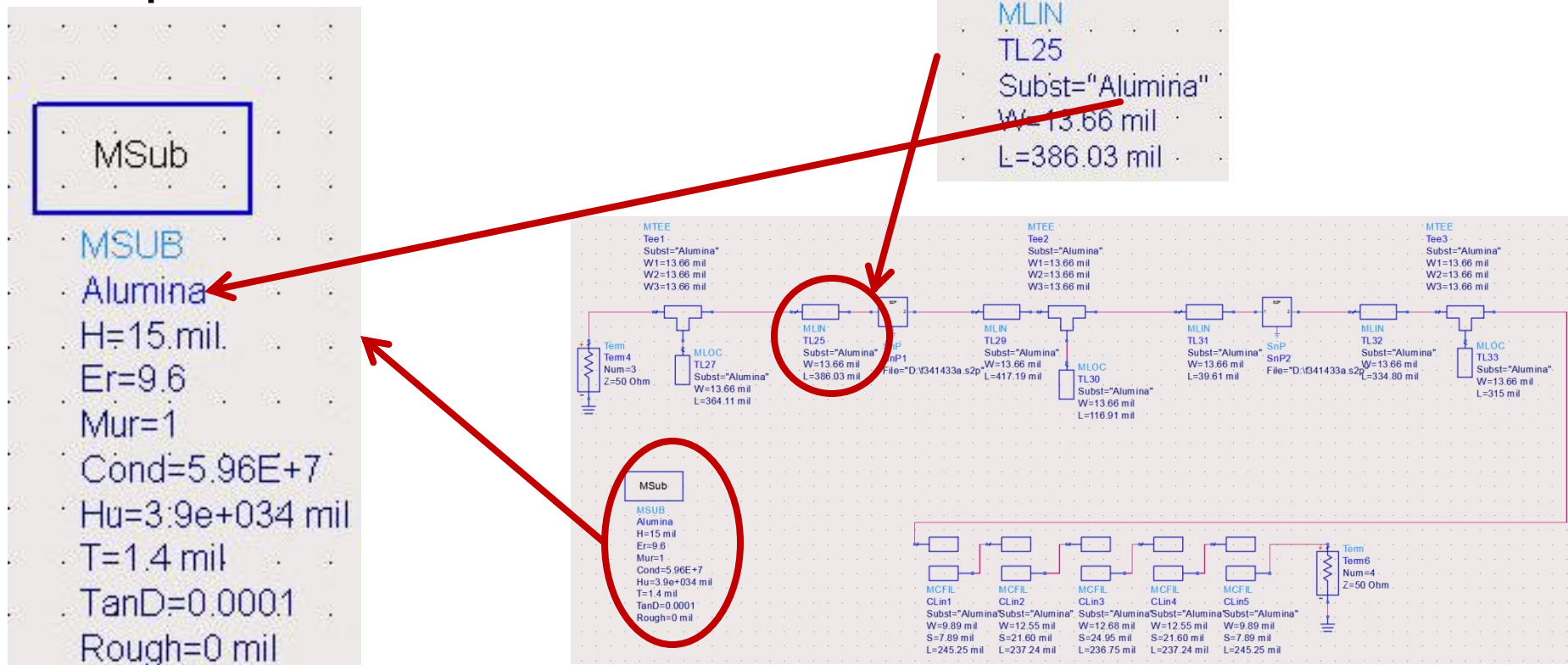


Implementare cu linii microstrip



Implementare cu linii microstrip

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

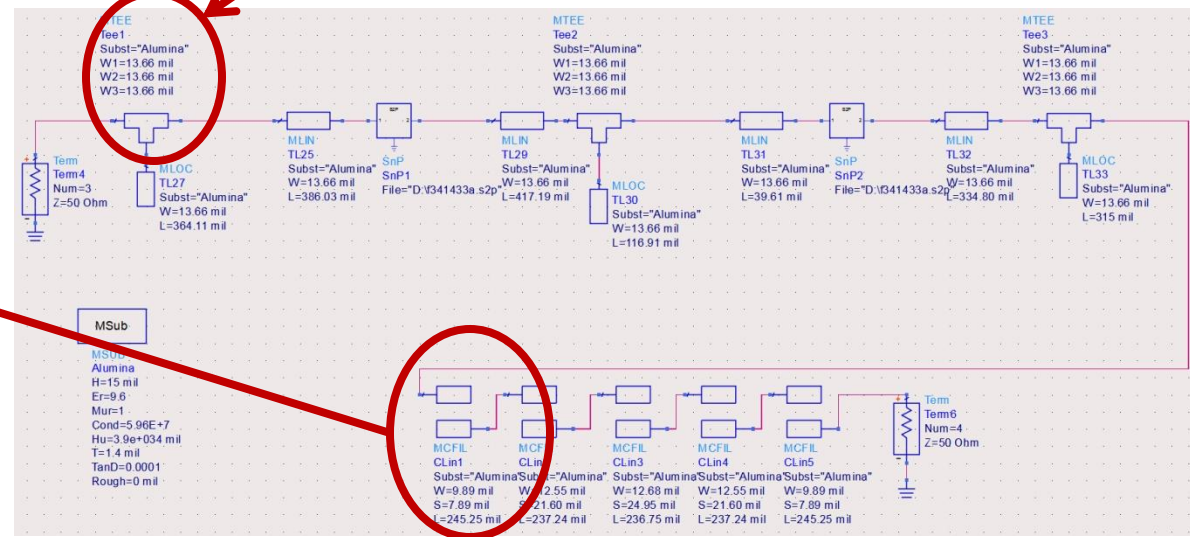
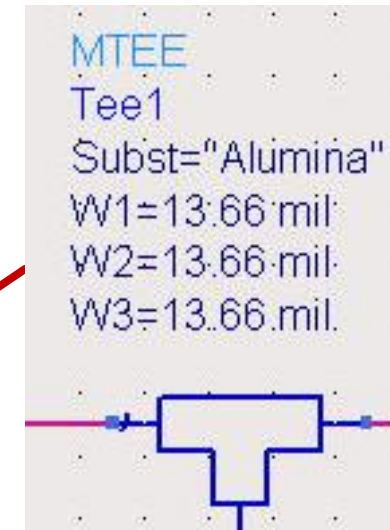


Implementare cu linii microstrip

- 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

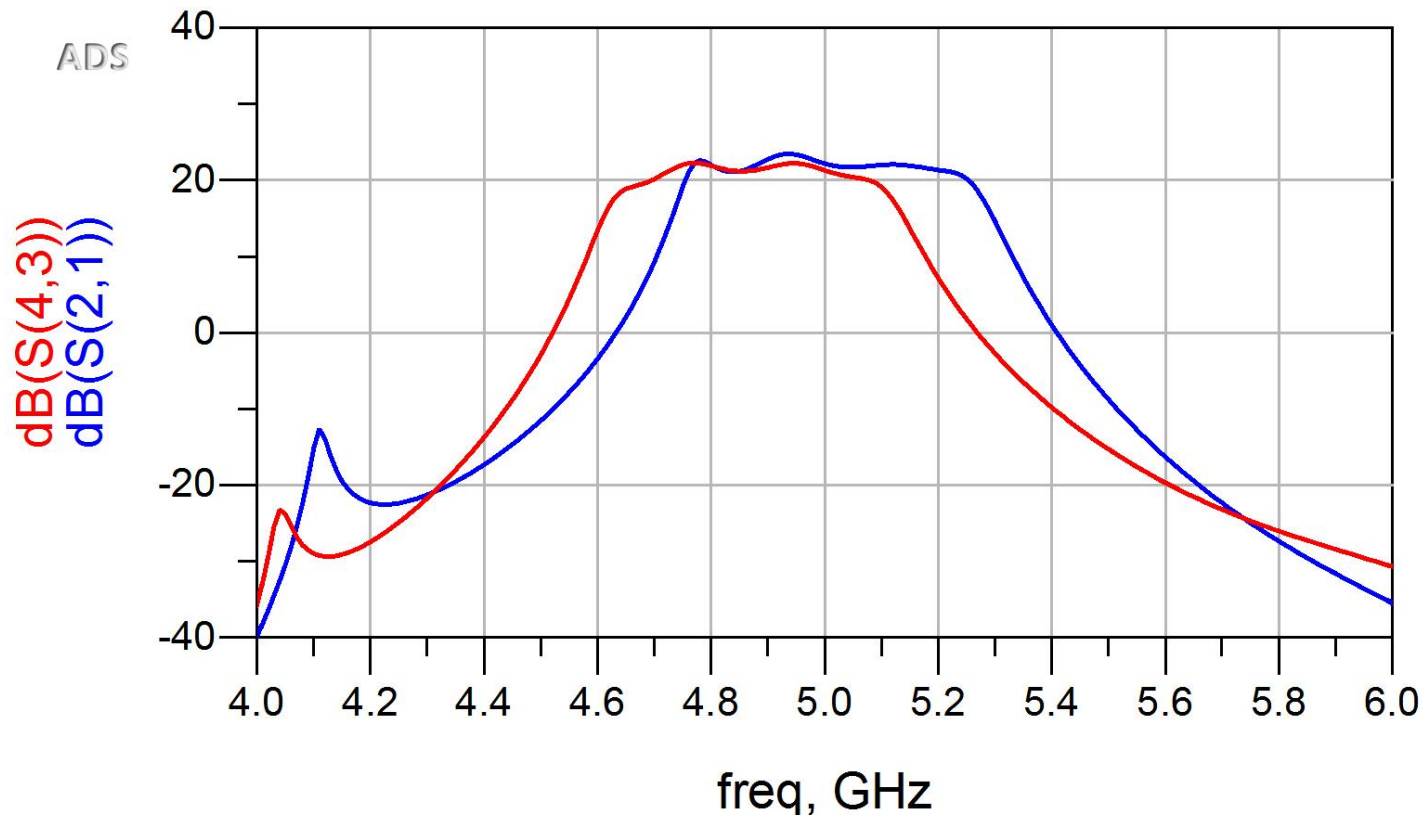
- E necesara atentie la completarea parametrilor pentru MTEE si MCFIL prin verificarea in schema a latimii liniilor conectate la fiecare terminal



Implementare cu linii microstrip

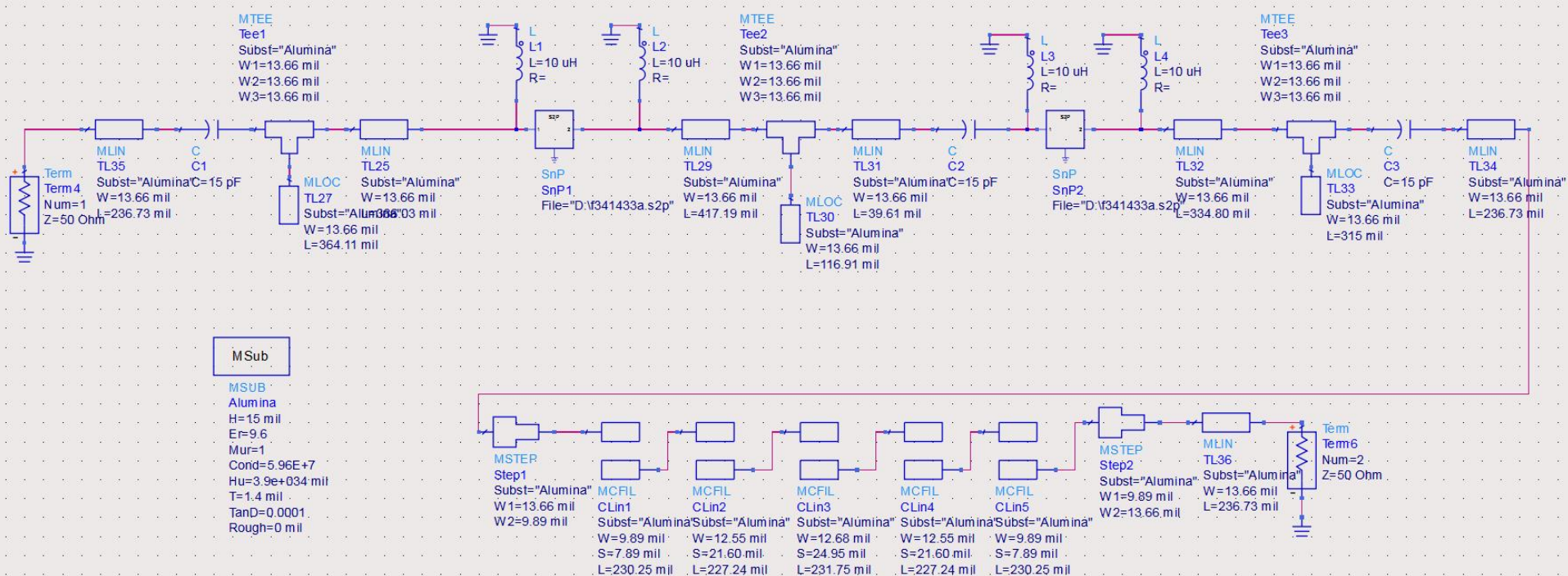
Rezultat

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

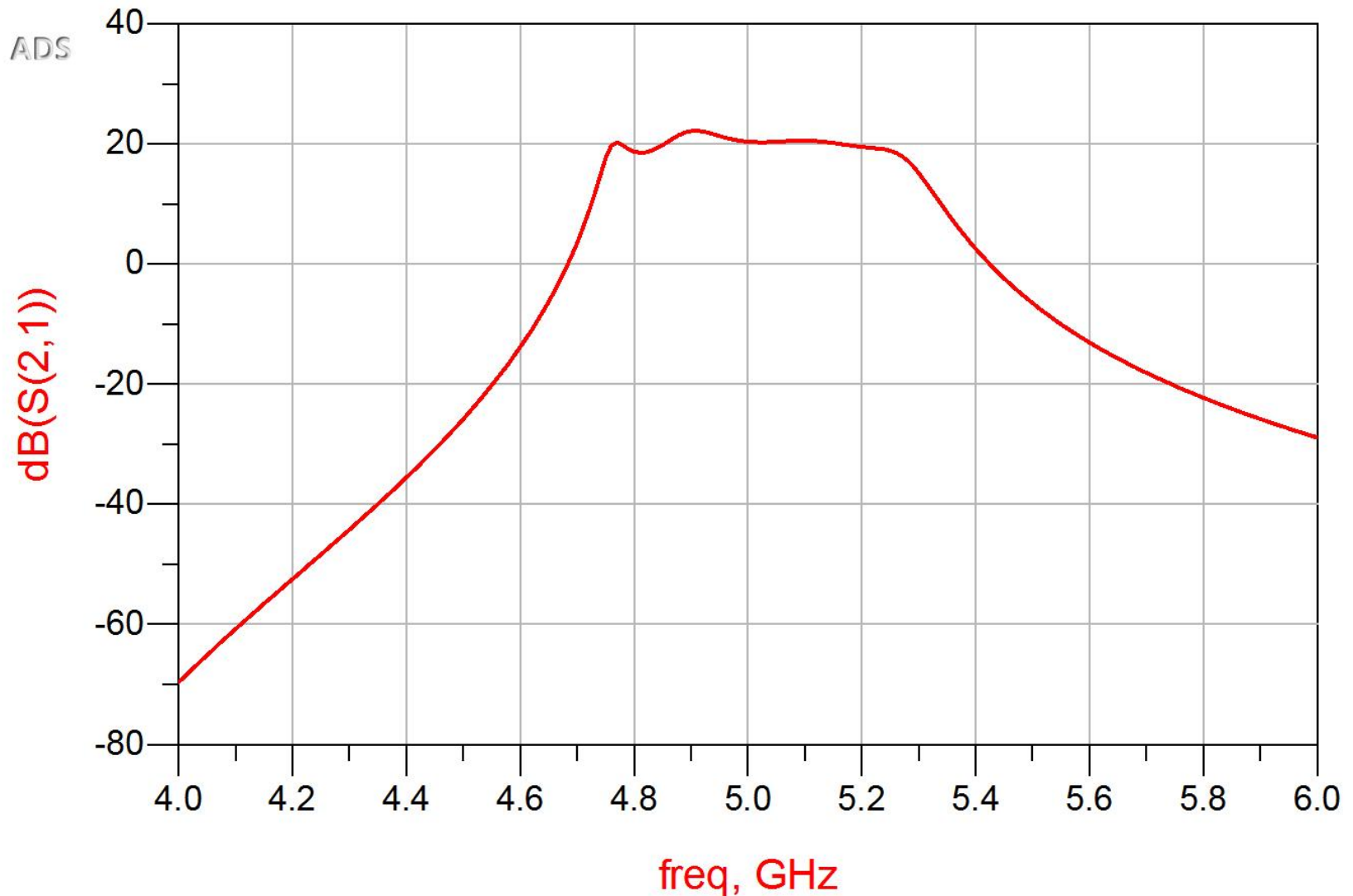


Introducere elemente de polarizare

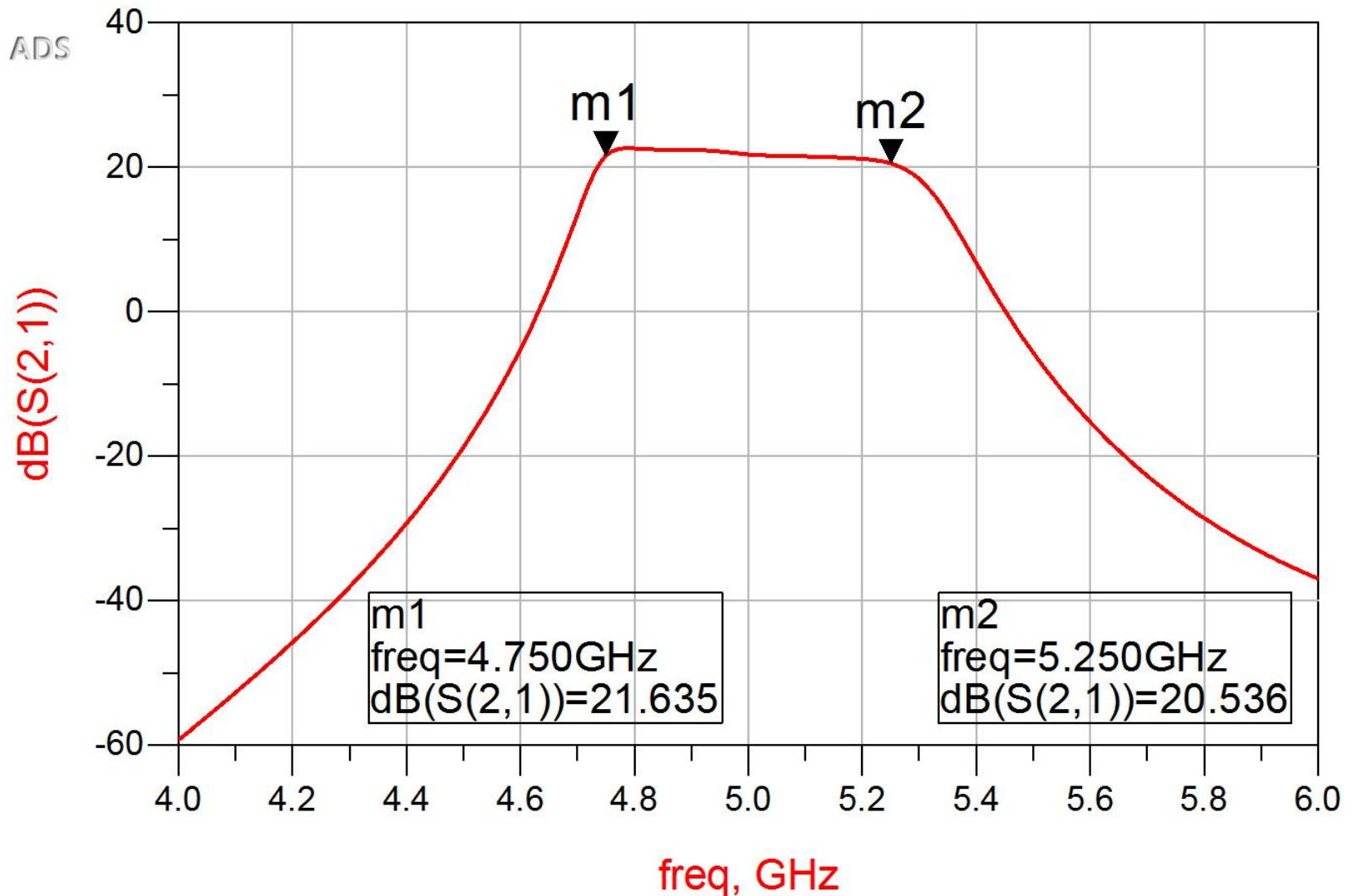
- Reglaj de lungimi la elementele filtrului pentru reglarea frecventelor in jurul $f_0 = 5\text{GHz}$
- Introducere L (soc RF) si C (decuplare)



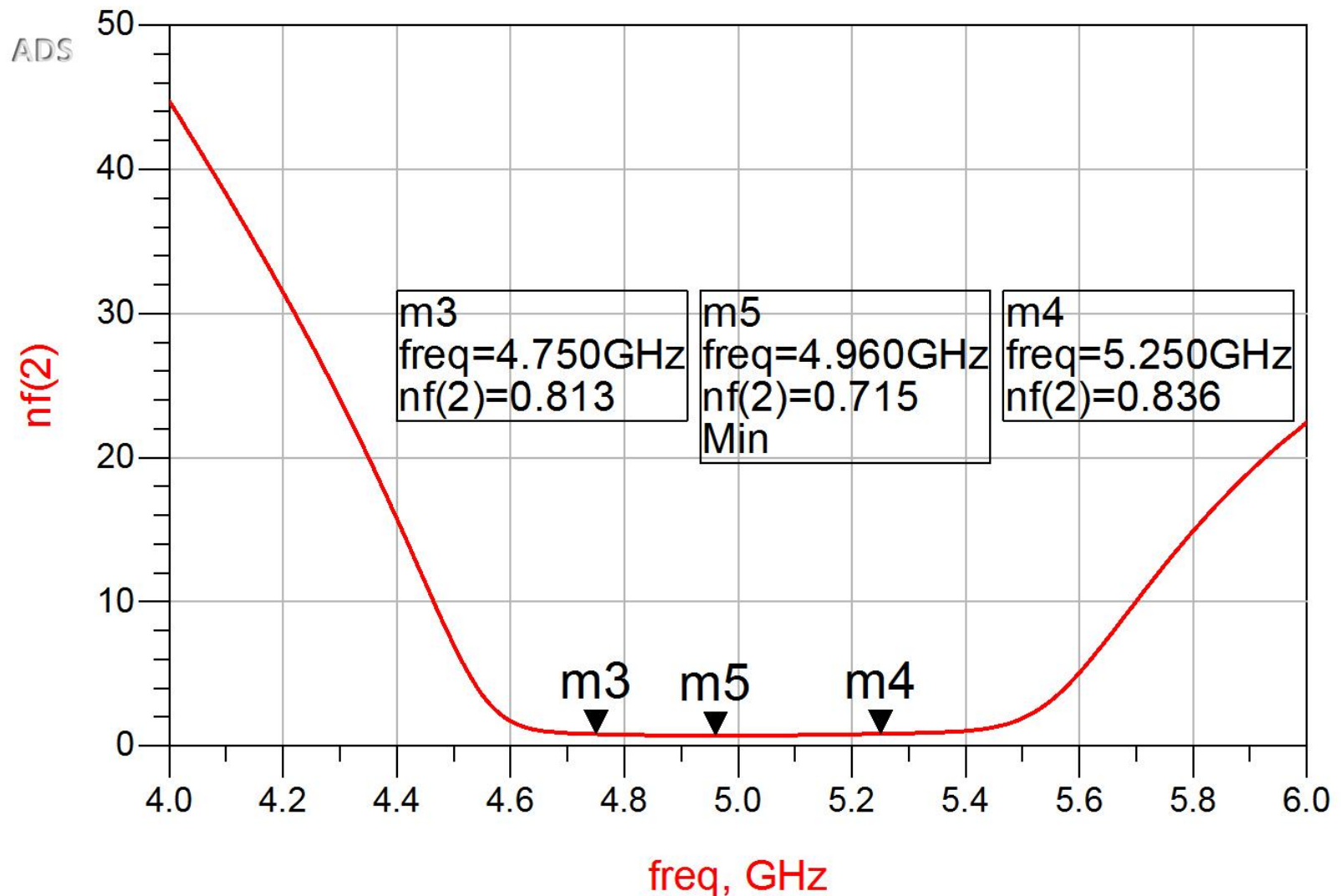
Castig -> Reglaj/Optimizare



Rezultat final (Castig)

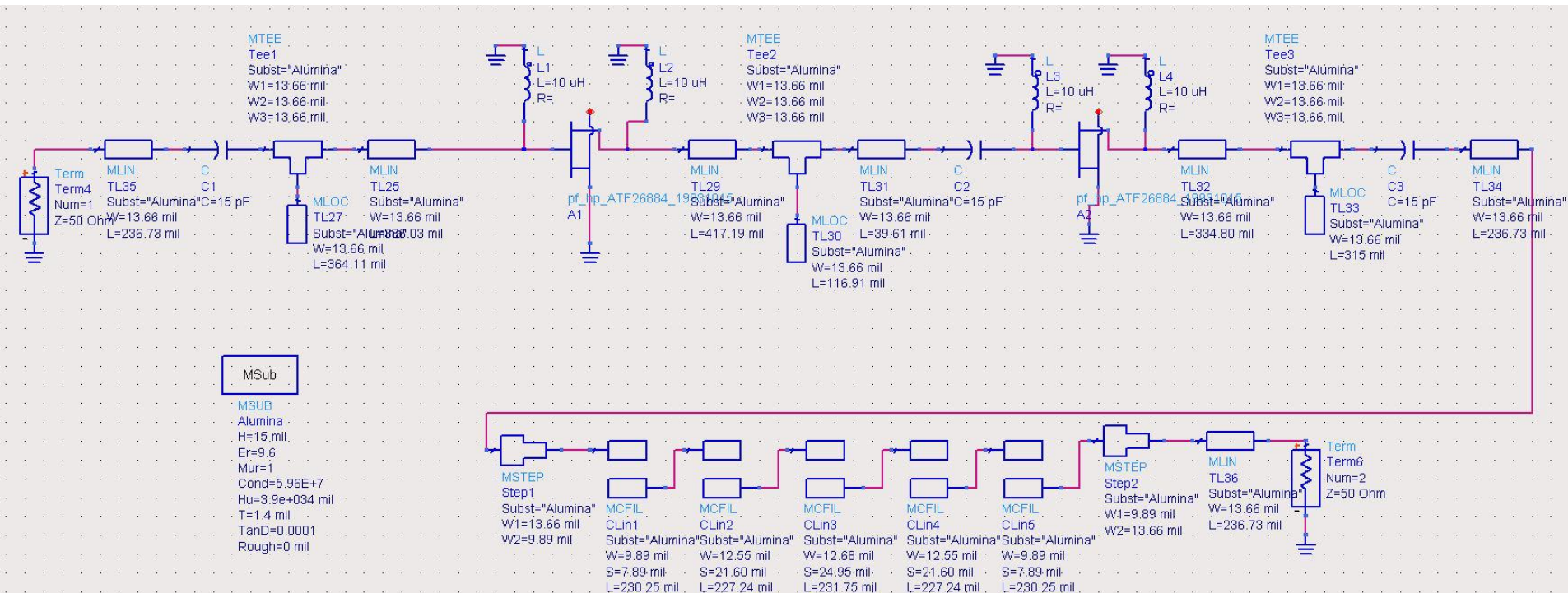


Rezultat final (Zgomot)

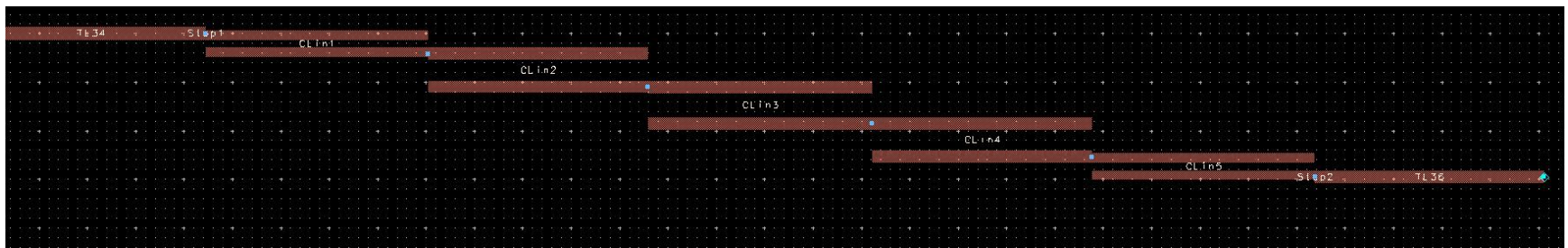
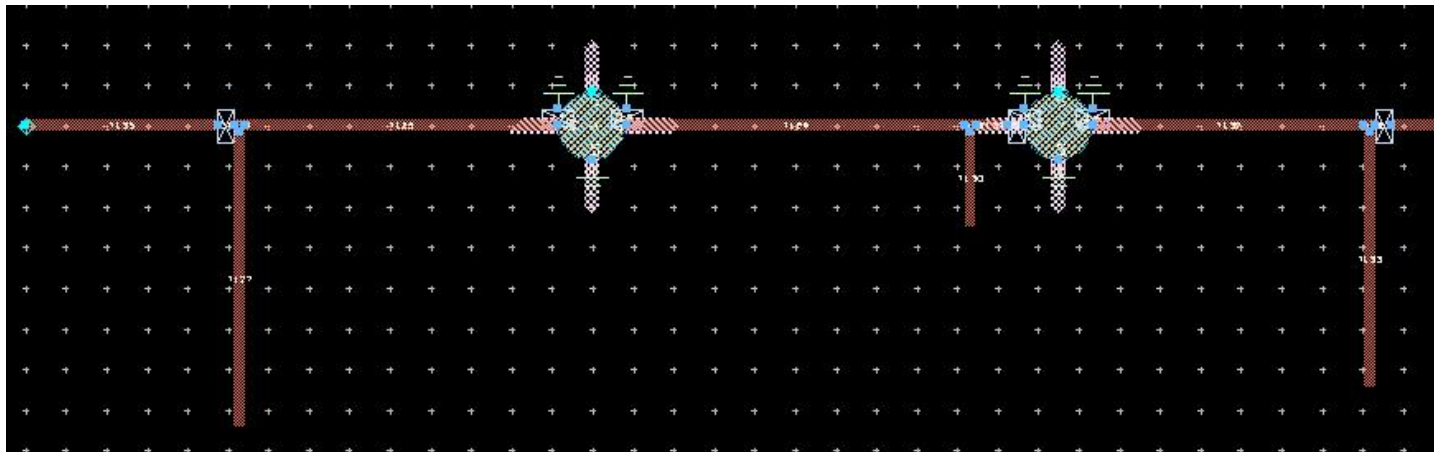
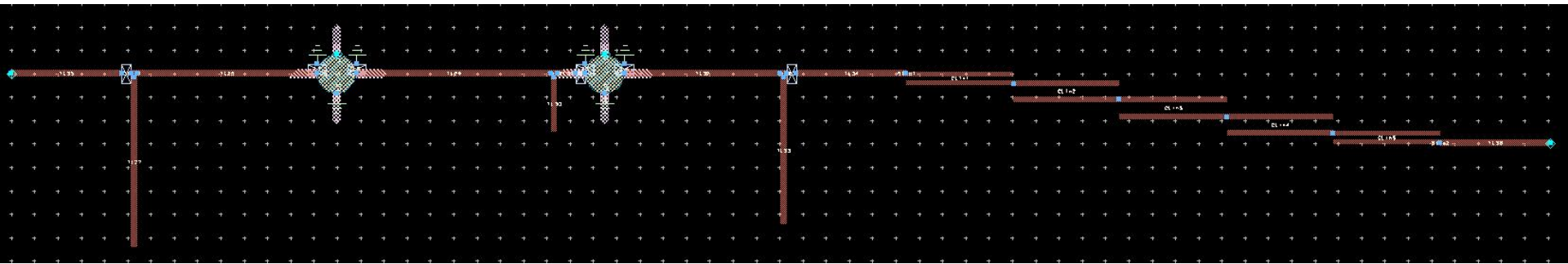


Layout (Exemplu)

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



Layout (Exemplu)



Contact

- Laboratorul de microunde si optoelectronica
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- rdamian@etti.tuiasi.ro