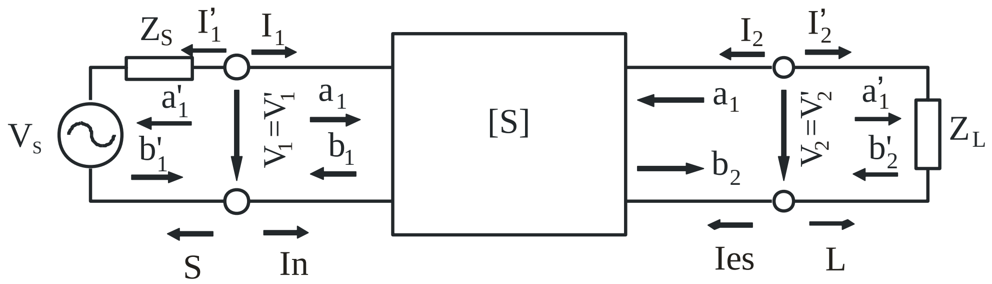
Amplificatoare de Microunde

Proiectarea unui singur etaj

Cîştigurile în putere ale unui diport



$$G = \frac{P_L}{P_{in}} = \frac{|S_{21}|^2\left(1-|\Gamma_L|^2\right)}{\left(1-|\Gamma_{in}|^2\right)|1-S_{22}\Gamma_L|^2}$$

$$G_A = \frac{P_{avL}}{P_{avS}} = \frac{P_L|_{\Gamma_L=\Gamma_{ies}^*}}{P_{in}|_{\Gamma_{in}=\Gamma_S^*}} = \frac{|S_{21}|^2\left(1-|\Gamma_S|^2\right)}{|1-S_{11}\Gamma_S|^2\left(1-|\Gamma_L|^2\right)}$$

$$G_T = \frac{P_L}{P_{avS}} = \frac{|S_{21}|^2\left(1-|\Gamma_S|^2\right)\left(1-|\Gamma_L|^2\right)}{|1-\Gamma_S\Gamma_{in}|^2|1-S_{22}\Gamma_L|^2}$$

$$\Gamma_L = \frac{Z_L-Z_0}{Z_L+Z_0} \qquad \Gamma_S = \frac{Z_S-Z_0}{Z_S+Z_0}$$

$$\Gamma_{in} = \frac{Z_{in}-Z_0}{Z_{in}+Z_0} = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1-S_{22}\Gamma_L}$$

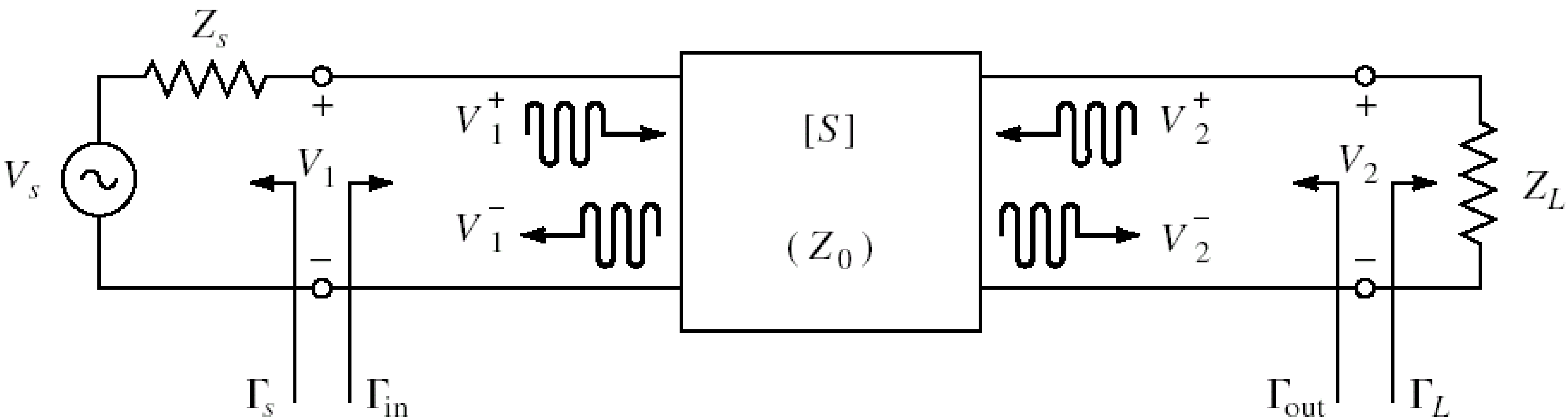
$$\Gamma_{ies} = \frac{Z_{ies}-Z_0}{Z_{ies}+Z_0} = S_{22} + \frac{S_{12}S_{21}\Gamma_S}{1-S_{11}\Gamma_S}$$

- Reflexii nule $\Gamma_L = \Gamma_S = 0$

$$G_T = |S_{21}|^2$$

Dispozitiv unilateral $S_{12} = 0$

$$G_{TU} = \frac{|S_{21}|^2\left(1-|\Gamma_S|^2\right)\left(1-|\Gamma_L|^2\right)}{|1-\Gamma_S S_{11}|^2|1-S_{22}\Gamma_L|^2}$$



$$V_1^- = S_{11}V_1^+ + S_{12}V_2^+ = S_{11}V_1^+ + S_{12}\Gamma_L V_2^-,$$

$$V_2^- = S_{21}V_1^+ + S_{22}V_2^+ = S_{21}V_1^+ + S_{22}\Gamma_L V_2^-.$$

$$\Gamma_{in} = \frac{V_1^-}{V_1^+} = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1 - S_{22}\Gamma_L} = \frac{Z_{in} - Z_0}{Z_{in} + Z_0},$$

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

$$V_1 = V_S \frac{Z_{in}}{Z_S + Z_{in}} = V_1^+ + V_1^- = V_1^+ (1 + \Gamma_{in}). \qquad V_1^+ = \frac{V_S}{2} \frac{(1 - \Gamma_S)}{(1 - \Gamma_S \Gamma_{in})}.$$

$$P_{in} = \frac{1}{2Z_0} \left| V_1^+ \right|^2 \left(1 - |\Gamma_{in}|^2\right) = \frac{|V_S|^2}{8Z_0} \frac{|1 - \Gamma_S|^2}{|1 - \Gamma_S \Gamma_{in}|^2} \left(1 - |\Gamma_{in}|^2\right)$$

$$P_L = \frac{\left| V_2^- \right|^2}{2Z_0} \left(1 - |\Gamma_L|^2\right) \quad P_L = \frac{\left| V_1^+ \right|^2}{2Z_0} \frac{|S_{21}|^2 \left(1 - |\Gamma_L|^2\right)}{|1 - S_{22}\Gamma_L|^2} = \frac{|V_S|^2}{8Z_0} \frac{|S_{21}|^2 \left(1 - |\Gamma_L|^2\right) |1 - \Gamma_S|^2}{|1 - S_{22}\Gamma_L|^2 \, |1 - \Gamma_S \Gamma_{in}|^2}.$$

$$G = \frac{P_L}{P_{in}} = \frac{|S_{21}|^2 \left(1 - |\Gamma_L|^2\right)}{\left(1 - |\Gamma_{in}|^2\right) |1 - S_{22}\Gamma_L|^2}.$$

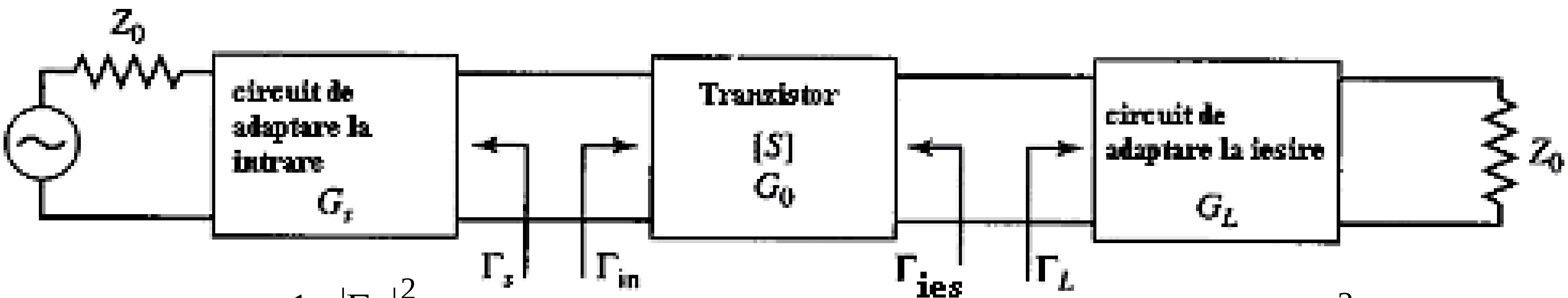
$$P_{avs} = P_{in}\Big|_{\Gamma_{in} = \Gamma_S^*} = \frac{|V_S|^2}{8Z_0} \frac{|1 - \Gamma_S|^2}{\left(1 - |\Gamma_S|^2\right)}.$$

$$P_{avn} = P_L\Big|_{\Gamma_L = \Gamma_{out}^*} = \frac{|V_S|^2}{8Z_0} \frac{|S_{21}|^2 \left(1 - |\Gamma_{out}|^2\right) |1 - \Gamma_S|^2}{\left|1 - S_{22}\Gamma_{out}^*\right|^2 |1 - \Gamma_S \Gamma_{in}|^2}\Bigg|_{\Gamma_L = \Gamma_{out}^*}. \quad P_{avn} = \frac{|V_S|^2}{8Z_0} \frac{|S_{21}|^2 \, |1 - \Gamma_S|^2}{|1 - S_{11}\Gamma_S|^2 \left(1 - |\Gamma_{out}|^2\right)}.$$

$$G_A = \frac{P_{avn}}{P_{avs}} = \frac{|S_{21}|^2 \left(1 - |\Gamma_S|^2\right)}{|1 - S_{11}\Gamma_S|^2 \left(1 - |\Gamma_{out}|^2\right)}.$$

$$G_T = \frac{P_L}{P_{avs}} = \frac{|S_{21}|^2 \left(1 - |\Gamma_S|^2\right) \left(1 - |\Gamma_L|^2\right)}{|1 - \Gamma_S \Gamma_{in}|^2 \, |1 - S_{22}\Gamma_L|^2}.$$

Schema bloc a unui amplificator cu un tranzistor



$$G_S = \frac{1-|\Gamma_S|^2}{|1-\Gamma_S\Gamma_{in}|^2}$$

$$G_0 = |S_{21}|^2$$

$$G_L = \frac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2}$$

$$G_T = G_S G_0 G_L$$

Stabilitatea

- **Stabilitatea necondiţionată**: circuitul este necondiţionat stabil dacă $|\Gamma_{in}| < 1$ şi $|\Gamma_{ies}| < 1$ pentru orice impedanţă pasivă a sarcinii şi sursei.

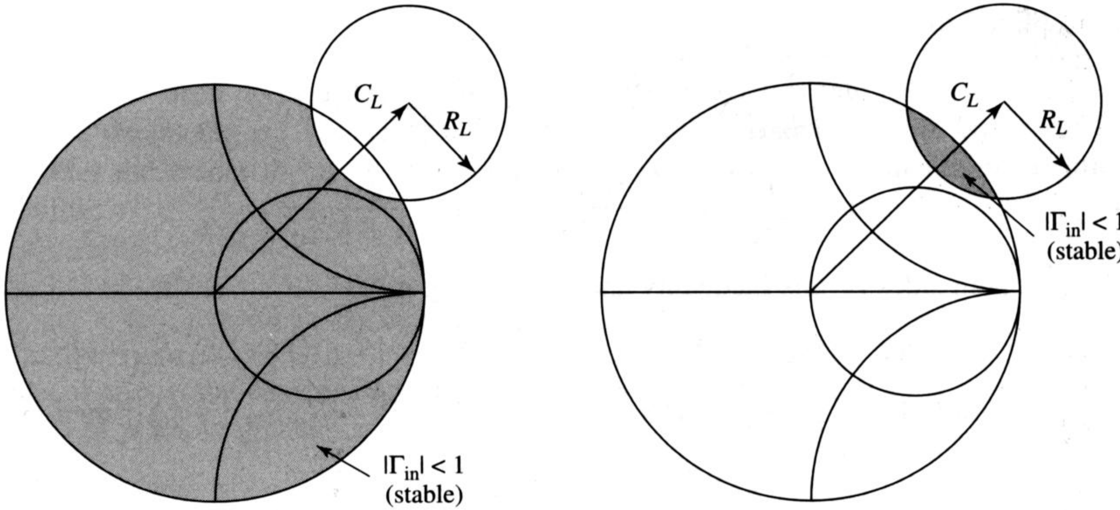
- **Stabilitatea condiţionată**: circuitul este condiţionat stabil dacă $|\Gamma_{in}| < 1$ şi $|\Gamma_{ies}| < 1$ doar pentru un anumit interval de valori pentru impedanţa pasivă a sarcinii şi sursei.

Cercurile de stabilitate

cercul de stabilitate la ieşire : $\left|\Gamma_{\text{in}}\right| = 1$ *cercul de stabilitate la intrare* $\left|\Gamma_{ies}\right| = 1$

$$C_L = \frac{\left(S_{22} - \Delta S_{11}^*\right)^*}{\left|S_{22}\right|^2 - \left|\Delta\right|^2} \quad R_L = \frac{\left|S_{12} S_{21}\right|}{\left|\left|S_{22}\right|^2 - \left|\Delta\right|^2\right|}$$

$$C_S = \frac{\left(S_{11} - \Delta S_{22}^*\right)^*}{\left|S_{11}\right|^2 - \left|\Delta\right|^2} \quad R_S = \frac{\left|S_{12} S_{21}\right|}{\left|\left|S_{11}\right|^2 - \left|\Delta\right|^2\right|}$$



(a) (b)

$$\left|\Delta\right| < 1$$

$$K = \frac{1 - \left|S_{11}\right|^2 - \left|S_{22}\right|^2 + \left|\Delta\right|^2}{2\left|S_{12} S_{21}\right|} > 1$$

$$\mu = \frac{1 - \left|S_{11}\right|^2}{\left|S_{22} - S_{11}^* \Delta\right| + \left|S_{12} S_{21}\right|} > 1$$

$$|\Gamma_{in}| = \left| S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1 - S_{22}\Gamma_L} \right| < 1,$$

$$|\Gamma_{out}| = \left| S_{22} + \frac{S_{12}S_{21}\Gamma_S}{1 - S_{11}\Gamma_S} \right| < 1.$$

$$\left| S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1 - S_{22}\Gamma_L} \right| = 1,$$

$$|S_{11}(1 - S_{22}\Gamma_L) + S_{12}S_{21}\Gamma_L| = |1 - S_{22}\Gamma_L|.$$

$$\Delta = S_{11}S_{22} - S_{12}S_{21} \qquad |S_{11} - \Delta\Gamma_L| = |1 - S_{22}\Gamma_L|$$

$$|S_{11}|^2 + |\Delta|^2|\Gamma_L|^2 - (\Delta\Gamma_L S_{11}^* + \Delta^*\Gamma_L^* S_{11}) = 1 + |S_{22}|^2|\Gamma_L|^2 - (S_{22}^*\Gamma_L^* + S_{22}\Gamma_L)$$

$$(|S_{22}|^2 - |\Delta|^2)\Gamma_L\Gamma_L^* - (S_{22} - \Delta S_{11}^*)\Gamma_L - (S_{22}^* - \Delta^* S_{11})\Gamma_L^* = |S_{11}|^2 - 1$$

$$\Gamma_L\Gamma_L^* - \frac{(S_{22} - \Delta S_{11}^*)\Gamma_L + (S_{22}^* - \Delta^* S_{11})\Gamma_L^*}{|S_{22}|^2 - |\Delta|^2} = \frac{|S_{11}|^2 - 1}{|S_{22}|^2 - |\Delta|^2}.$$

$$\left| \Gamma_L - \frac{(S_{22} - \Delta S_{11}^*)^*}{|S_{22}|^2 - |\Delta|^2} \right|^2 = \frac{|S_{11}|^2 - 1}{|S_{22}|^2 - |\Delta|^2} + \frac{|S_{22} - \Delta S_{11}^*|^2}{(|S_{22}|^2 - |\Delta|^2)^2},$$

$$\left| \Gamma_L - \frac{(S_{22} - \Delta S_{11}^*)^*}{|S_{22}|^2 - |\Delta|^2} \right| = \left| \frac{S_{12}S_{21}}{|S_{22}|^2 - |\Delta|^2} \right|.$$

$$|\Gamma - C| = R$$

Conditia Rollet

$$K = \frac{1-|S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12}S_{21}|} > 1 \qquad |\Delta| < 1 \qquad |S_{11}| < 1 \qquad |S_{22}| < 1$$

Criteriul μ

$$\mu = \frac{1-|S_{11}|^2}{\left|S_{22} - S_{11}^*\Delta\right| + |S_{12}S_{21}|} > 1$$

$$\Gamma_{out} = S_{22} + \frac{S_{12}S_{21}\Gamma_S}{1 - S_{11}\Gamma_S} = \frac{S_{22} - \Delta\Gamma_S}{1 - S_{11}\Gamma_S}$$

$$\Gamma_S = e^{j\phi} \qquad e^{j\phi} = \frac{S_{22} - \Gamma_{out}}{\Delta - S_{11}\Gamma_{out}} \qquad \left|\frac{S_{22} - \Gamma_{out}}{\Delta - S_{11}\Gamma_{out}}\right| = 1$$

$$|\Gamma_{out}|^2\left(1 - |S_{11}|^2\right) + \Gamma_{out}(\Delta^* S_{11} - S_{22}^*) + \Gamma_{out}^*(\Delta S_{11}^* - S_{22}) = |\Delta|^2 - |S_{22}|^2$$

$$|\Gamma_{out}|^2 + \frac{(\Delta^* S_{11} - S_{22}^*)\Gamma_{out} + (\Delta S_{11}^* - S_{22})\Gamma_{out}^*}{1 - |S_{11}|^2} = \frac{|\Delta|^2 - |S_{22}|^2}{1 - |S_{11}|^2}$$

$$\left|\Gamma_{out} + \frac{\Delta S_{11}^* - S_{22}}{1-|S_{11}|^2}\right|^2 = \frac{|\Delta|^2 - |S_{22}|^2}{1-|S_{11}|^2} + \frac{|\Delta^* S_{11} - S_{22}^*|^2}{(1-|S_{11}|^2)^2} = \frac{|S_{12}S_{21}|^2}{(1-|S_{11}|^2)^2}$$

$$\left|\Gamma_{out} - C\right| = R$$

$$C = \frac{S_{22} - \Delta S_{11}^*}{1-|S_{11}|^2},$$

$$R = \frac{|S_{12}S_{21}|}{1-|S_{11}|^2},$$

$$|C| + R < 1 \qquad |S_{22} - \Delta S_{11}^*| + |S_{12}S_{21}| < 1 - |S_{11}|^2$$

$$\mu = \frac{1-\left|S_{11}\right|^2}{\left|S_{22} - S_{11}^*\Delta\right| + \left|S_{12}S_{21}\right|} > 1$$

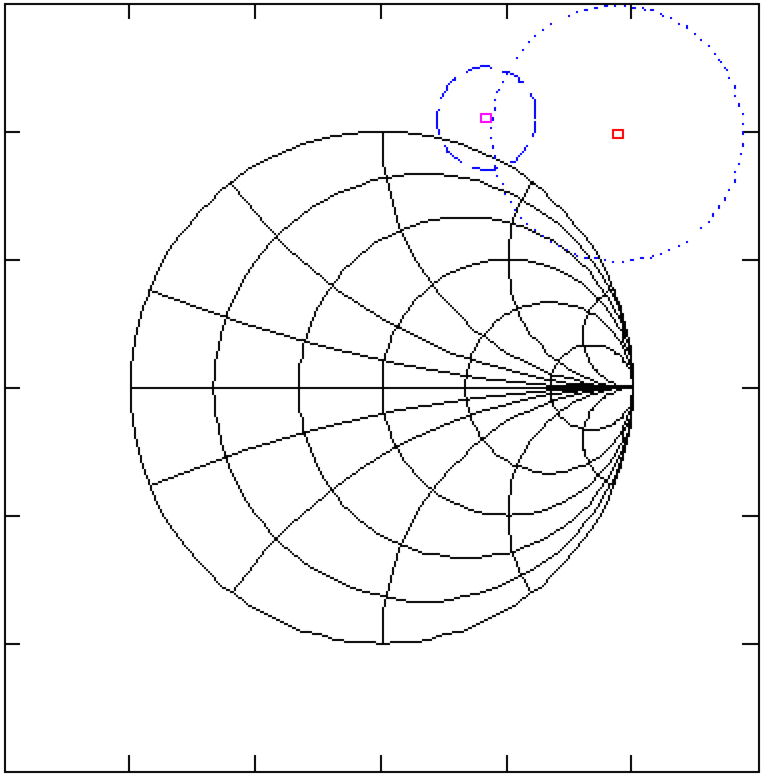
Exemplu

$$S = \begin{bmatrix} 0.894e^{-j60.6^\circ} & 0.02e^{j62.4^\circ} \\ 3.122e^{j123.6^\circ} & 0.781e^{-j27.6^\circ} \end{bmatrix}$$

$$\Delta = S_{11}S_{22} - S_{21}S_{12} = 0.696\angle -83^\circ$$

$$K = \frac{1 + |\Delta|^2 - |S_{11}|^2 - |S_{22}|^2}{2|S_{12}S_{21}|} = 0.607$$

$$\mu = 0.86$$



$$C_L = \frac{\left(S_{22} - \Delta S_{11}^*\right)^*}{|S_{22}|^2 - |\Delta|^2} = 1.361\angle 47^\circ$$

$$C_S = \frac{\left(S_{11} - \Delta S_{22}^*\right)^*}{|S_{11}|^2 - |\Delta|^2} = 1.132\angle 68^\circ$$

$$R_L = \frac{|S_{12}S_{21}|}{|S_{22}|^2 - |\Delta|^2} = 0.5$$

$$R_S = \frac{|S_{12}S_{21}|}{|S_{11}|^2 - |\Delta|^2} = 0.199$$

Adaptarea simultana - tranzistorul bilateral

$$\Gamma_{in} = \Gamma_S^*$$

$$\Gamma_{ies} = \Gamma_L^*$$

$$G_{T\max} = \frac{1}{1-|\Gamma_S|^2}|S_{21}|^2\frac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2}$$

$$\Gamma_S^* = S_{11} + \frac{S_{12}S_{21}}{\frac{1}{\Gamma_L} - S_{22}} \qquad \Gamma_L^* = S_{22} + \frac{S_{12}S_{21}}{\frac{1}{\Gamma_S} - S_{11}}$$

$$\Gamma_S = S_{11}^* + \frac{S_{12}^* S_{21}^*}{1/\Gamma_L^* - S_{22}^*},$$

$$\Gamma_L^* = \frac{S_{22} - \Delta\Gamma_S}{1 - S_{11}\Gamma_S},$$

$$\Gamma_S\left(1 - |S_{22}|^2\right) + \Gamma_S^2(\Delta S_{22}^* - S_{11}) = \Gamma_S\left(\Delta S_{11}^* S_{22}^* - |S_{11}|^2 - \Delta S_{12}^* S_{21}^*\right) + S_{11}^*\left(1 - |S_{22}|^2\right) + S_{12}^* S_{21}^* S_{22}.$$

$$(S_{11} - \Delta S_{22}^*)\Gamma_S^2 + \left(|\Delta|^2 - |S_{11}|^2 + |S_{22}|^2 - 1\right)\Gamma_S + (S_{11}^* - \Delta^* S_{22}) = 0$$

$$\Gamma_S = \frac{B_1 \pm \sqrt{B_1^2 - 4|C_1|^2}}{2C_1} \qquad \Gamma_L = \frac{B_2 \pm \sqrt{B_2^2 - 4|C_2|^2}}{2C_2}$$

$$B_1 = 1 + |S_{11}|^2 - |S_{22}|^2 - |\Delta|^2 \qquad B_2 = 1 + |S_{22}|^2 - |S_{11}|^2 - |\Delta|^2$$

$$C_1 = S_{11} - \Delta S_{22}^* \qquad C_2 = S_{22} - \Delta S_{11}^*$$

$$B_1^2 - 4|C_1|^2 = B_2^2 - 4|C_2|^2 = 4(K^2 - 1)|S_{12}|^2|S_{21}|^2$$

$$G_{TU_{\max}} = \frac{1}{1 - |S_{11}|^2}|S_{21}|^2\frac{1}{1 - |S_{22}|^2}.$$

$$G_{T_{\max}} = \frac{|S_{21}|}{|S_{12}|}(K - \sqrt{K^2 - 1}).$$

$$G_{msg} = \frac{|S_{21}|}{|S_{12}|}$$

Exemplu

- *Să proiectăm un amplificator pentru un cîştig maxim la 4 GHz utilizînd un circuit de adaptare cu un singur stub. Să se calculeze şi să se reprezinte grafic pierderile de intoarcere la intrare şi cîştigul între 3 şi 5 GHz.*

Solutie

$$\Delta = S_{11}S_{22} - S_{12}S_{21} = 0.488\angle -162.289°$$

$$K = \frac{1-|S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12}S_{21}|} = 1.195$$

$$\Gamma_S = \frac{B_1 \pm \sqrt{B_1^2 - 4|C_1|^2}}{2C_1} = 0.872\angle 123.407°$$

$$\Gamma_L = \frac{B_2 \pm \sqrt{B_2^2 - 4|C_2|^2}}{2C_2} = 0.876\angle 61.026°$$

$$G_S = \frac{1}{1-|\Gamma_S|^2} = 4.17 = 6.201dB$$

$$G_0 = |S_{21}|^2 = 6.76 = 8.299dB$$

$$G_L = \frac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2} = 1.67 = 2.227dB$$

$$G_{T\max} = 6.201 + 8.229 + 2.227 = 16.657dB$$

$$y_S = \frac{Y_S}{Y_0} = Y_S Z_0 = Y_S \cdot 50 = \frac{1-\Gamma_S}{1+\Gamma_S} = 0.3 - j \cdot 1.819$$

$$y_L = \frac{1-\Gamma_L}{1+\Gamma_L} = 0.089 - j \cdot 0.586$$

$$y_S(\theta) = \frac{1-\Gamma_S \cdot e^{2j\theta}}{1+\Gamma_S \cdot e^{2j\theta}} \quad \Re e[y_S(\theta)] = 1 \quad \theta = 0.75$$

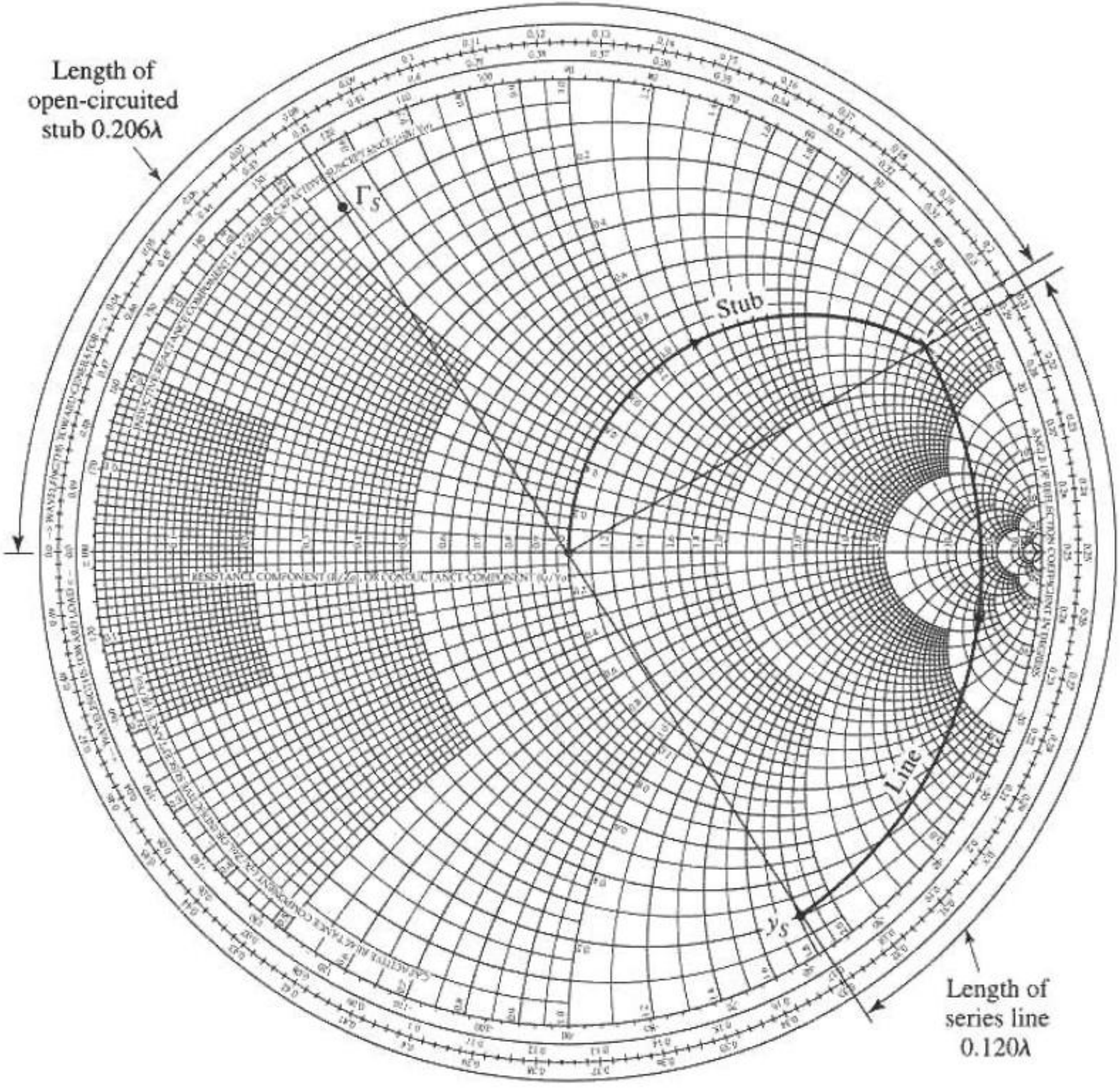
$$l_{L1} = 0.206\lambda$$

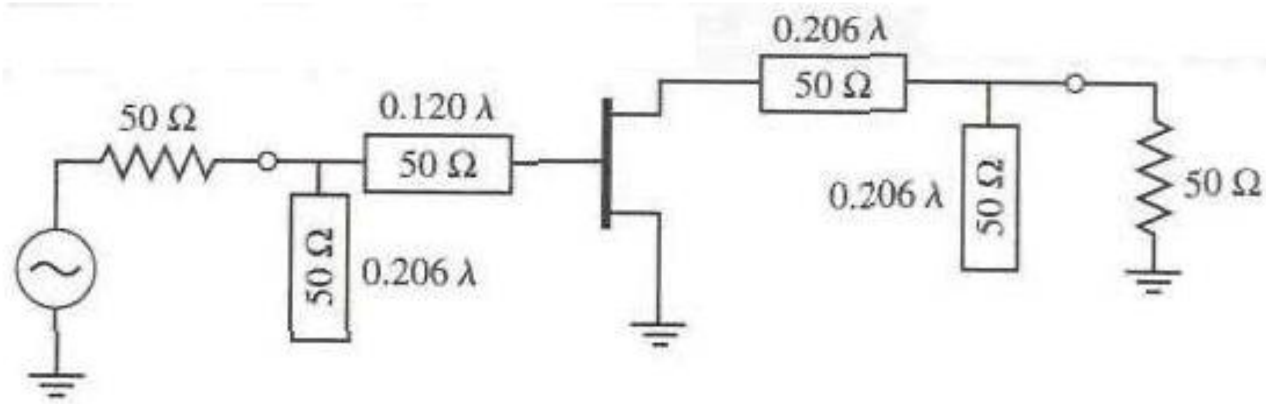
$$l_{S1} = \frac{\theta}{2\pi} = 0.119\lambda \quad y_S(0.75) = 1 + j \cdot 3.559$$

$$l_{Lstub} = 0.206\lambda$$

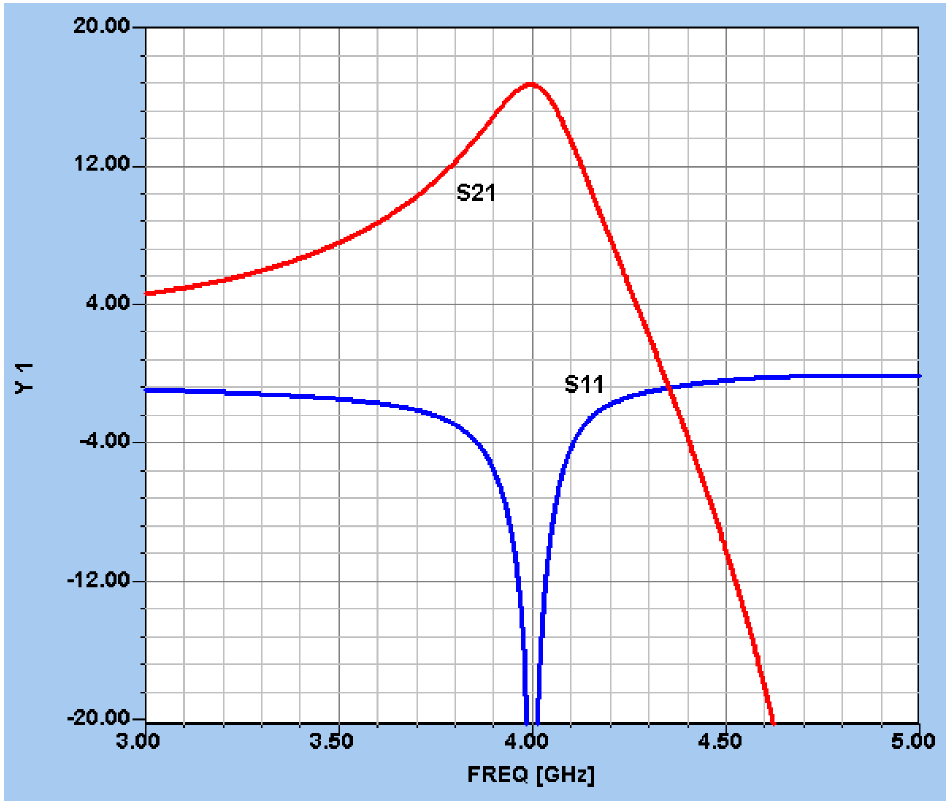
$$l_{Sstub} = \frac{1}{2\pi}\arctan(\Im m(y_S(0.75))) = 0.206\lambda$$

$$Z_{in} = Z_1 \frac{1+\Gamma e^{-2j\beta l}}{1-\Gamma e^{-2j\beta l}}$$


Length of
open-circuited
stub 0.206λ
Γ_S
Stub
Line
y_S
Length of
series line
0.120λ



50 Ω
0.120 λ
50 Ω
50 Ω
0.206 λ
0.206 λ
50 Ω
0.206 λ
50 Ω
50 Ω



20.00
12.00
4.00
-4.00
-12.00
-20.00
Y 1
S21
S11
3.00
3.50
4.00
4.50
5.00
FREQ [GHz]

Proiectarea pentru un cîştig specificat

$$\frac{1}{(1+U)^2} < \frac{G_T}{G_{TU}} < \frac{1}{(1-U)^2}$$

$$U = \frac{|S_{12}||S_{21}||S_{11}||S_{22}|}{\left(1-|S_{11}|^2\right)\left(1-|S_{22}|^2\right)}$$

$$G_S = \frac{1-|\Gamma_S|^2}{|1-S_{11}\Gamma_S|^2}$$

$$G_0 = |S_{21}|^2$$

$$G_L = \frac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2}$$

$$\Gamma_S = S_{11}^*$$

$$G_{S\,max} = \frac{1}{1-|S_{11}|^2}$$

$$\Gamma_L = S_{22}^*$$

$$G_{L\,max} = \frac{1}{1-|S_{22}|^2}$$

$$g_S = \frac{G_S}{G_{S\,max}} = \frac{1-|\Gamma_S|^2}{1-|S_{11}\Gamma_S|^2}\left(1-|S_{11}|^2\right)$$

$$g_L = \frac{1-|\Gamma_L|^2}{1-|S_{22}\Gamma_L|^2}\left(1-|S_{22}|^2\right)$$

$$C_L = \frac{g_L S_{22}^*}{1-(1-g_L)|S_{22}|^2}$$

$$C_S = \frac{g_S S_{11}^*}{1-(1-g_S)|S_{11}|^2}$$

$$R_L = \frac{\sqrt{1-g_L}\left(1-|S_{22}|^2\right)}{1-(1-g_L)|S_{22}|^2}$$

$$R_S = \frac{\sqrt{1-g_S}\left(1-|S_{11}|^2\right)}{1-(1-g_S)|S_{11}|^2}$$

$$g_S|1 - S_{11}\Gamma_S|^2 = \left(1 - |\Gamma_S|^2\right)\left(1 - |S_{11}|^2\right),$$

$$\left(g_S|S_{11}|^2 + 1 - |S_{11}|^2\right)|\Gamma_S|^2 - g_S(S_{11}\Gamma_S + S_{11}^*\Gamma_S^*) = 1 - |S_{11}|^2 - g_S.$$

$$\Gamma_S\Gamma_S^* - \frac{g_S(S_{11}\Gamma_S + S_{11}^*\Gamma_S^*)}{1-(1-g_S)|S_{11}|^2} = \frac{1-|S_{11}|^2 - g_S}{1-(1-g_S)|S_{11}|^2}.$$

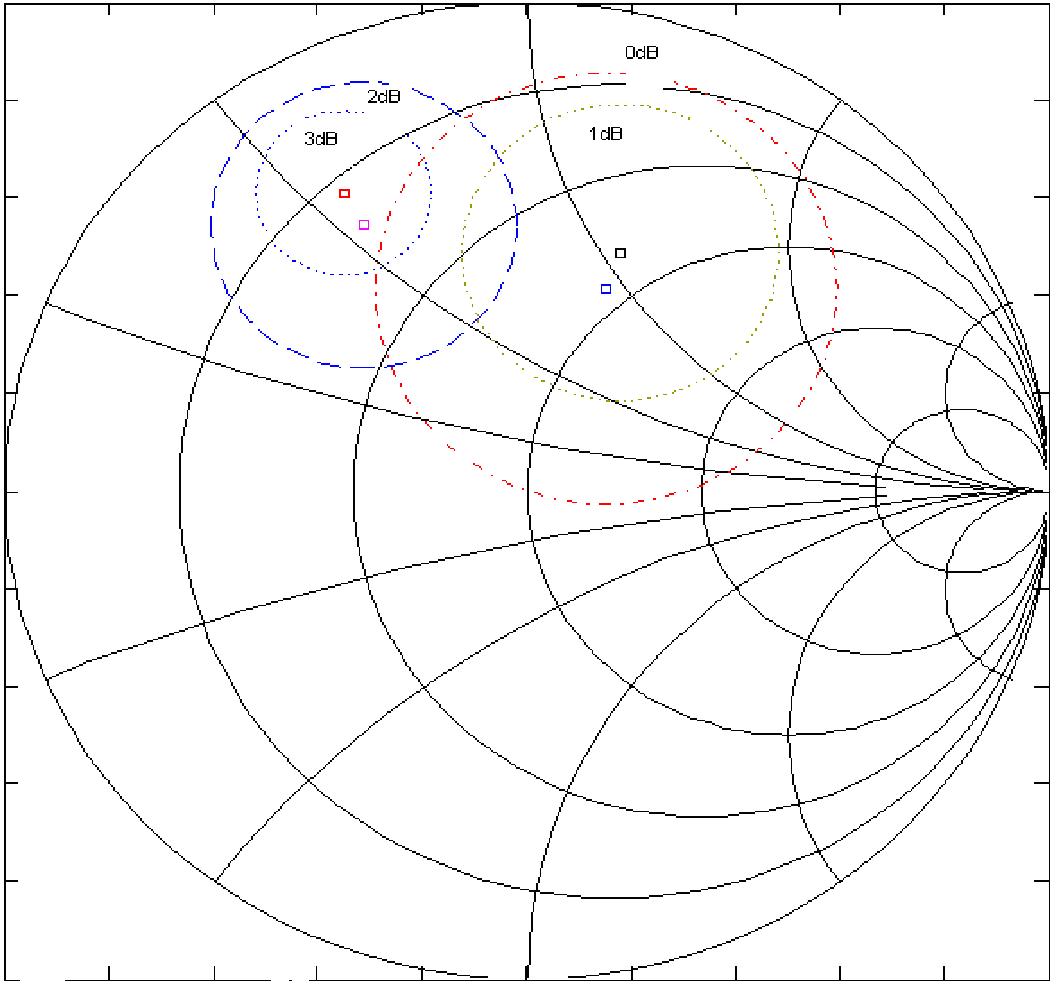
/+ $(g_S^2|S_{11}|^2)/[1-(1-g_S)|S_{11}|^2]^2$

$$\left|\Gamma_S - \frac{g_S S_{11}^*}{1-(1-g_S)|S_{11}|^2}\right|^2 = \frac{(1-|S_{11}|^2 - g_S)\left[1-(1-g_S)|S_{11}|^2\right] + g_S^2|S_{11}|^2}{\left[1-(1-g_S)|S_{11}|^2\right]^2}$$

$$\left|\Gamma_S - \frac{g_S S_{11}^*}{1-(1-g_S)|S_{11}|^2}\right| = \frac{\sqrt{1-g_S}\left(1-|S_{11}|^2\right)}{1-(1-g_S)|S_{11}|^2}$$

$$|\Gamma - C| = R$$

Cercuri de cistig constant



Exemplu

Să proiectăm un amplificator care să aibă un cîştig de 11 dB la 4 GHz. Desenaţi cercurile de cîştig constant pentru G_S = 2dB şi 3dB, şi G_L = 0dB şi 1 dB. Calculaţi şi desenaţi pierderile de întoarcere şi cîştigul global al amplificatorului între 3 şi 5 GHz. Tranzistorul TEC are următorii parametri S

f (GHz)	S_{11}	S_{21}	S_{12}	S_{22}
3	$0.80\angle -90^\circ$	$2.8\angle 100^\circ$	0	$0.66\angle -50^\circ$
4	$0.75\angle -120^\circ$	$2.5\angle 80^\circ$	0	$0.60\angle -70^\circ$
5	$0.71\angle -140^\circ$	$2.3\angle 60^\circ$	0	$0.58\angle -85^\circ$

Solutie

$$G_{S\max} = \frac{1}{1-|S_{11}|^2} = 2.29 = 3.59dB \qquad G_0 = |S_{21}|^2 = 6.25 = 7.959dB \qquad G_{L\max} = \frac{1}{1-|S_{22}|^2} = 1.56 = 1.938dB$$

$$G_{TU\max} = 3.59 + 1.938 + 7.959 = 13.487dB$$

$$G_{SdB3} = 3dB$$

$$G_{S3} = 10^{G_{SdB3}/10} = 1.995$$

$$g_S(G_{S3}) = G_{S3}\left[1-|S_{11}|^2\right] = 0.873$$

$$C_S(G_{S3}) = 0.706\angle 120°$$

$$R_S(G_{S3}) = 0.168$$

$$G_{SdB2} = 2dB$$

$$G_{S2} = 10^{G_{SdB2}/10} = 1.585$$

$$g_S(G_{S2}) = G_{S2}\left[1-|S_{11}|^2\right] = 0.693$$

$$C_S(G_{S2}) = 0.628\angle 120°$$

$$R_S(G_{S2}) = 0.293$$

$$G_{LdB1} = 1dB$$

$$G_{L1} = 10^{G_{LdB1}/10} = 1.259$$

$$g_L(G_{L1}) = G_{L1}\left[1-|S_{22}|^2\right] = 0.806$$

$$C_L(G_{L1}) = 0.520\angle 70°$$

$$R_L(G_{L1}) = 0.303$$

$$G_{LdB0} = 0dB$$

$$G_{L0} = 10^{G_{Ldb0}/10} = 1$$

$$g_L(G_{L0}) = G_{L0}\left[1-|S_{22}|^2\right] = 0.64$$

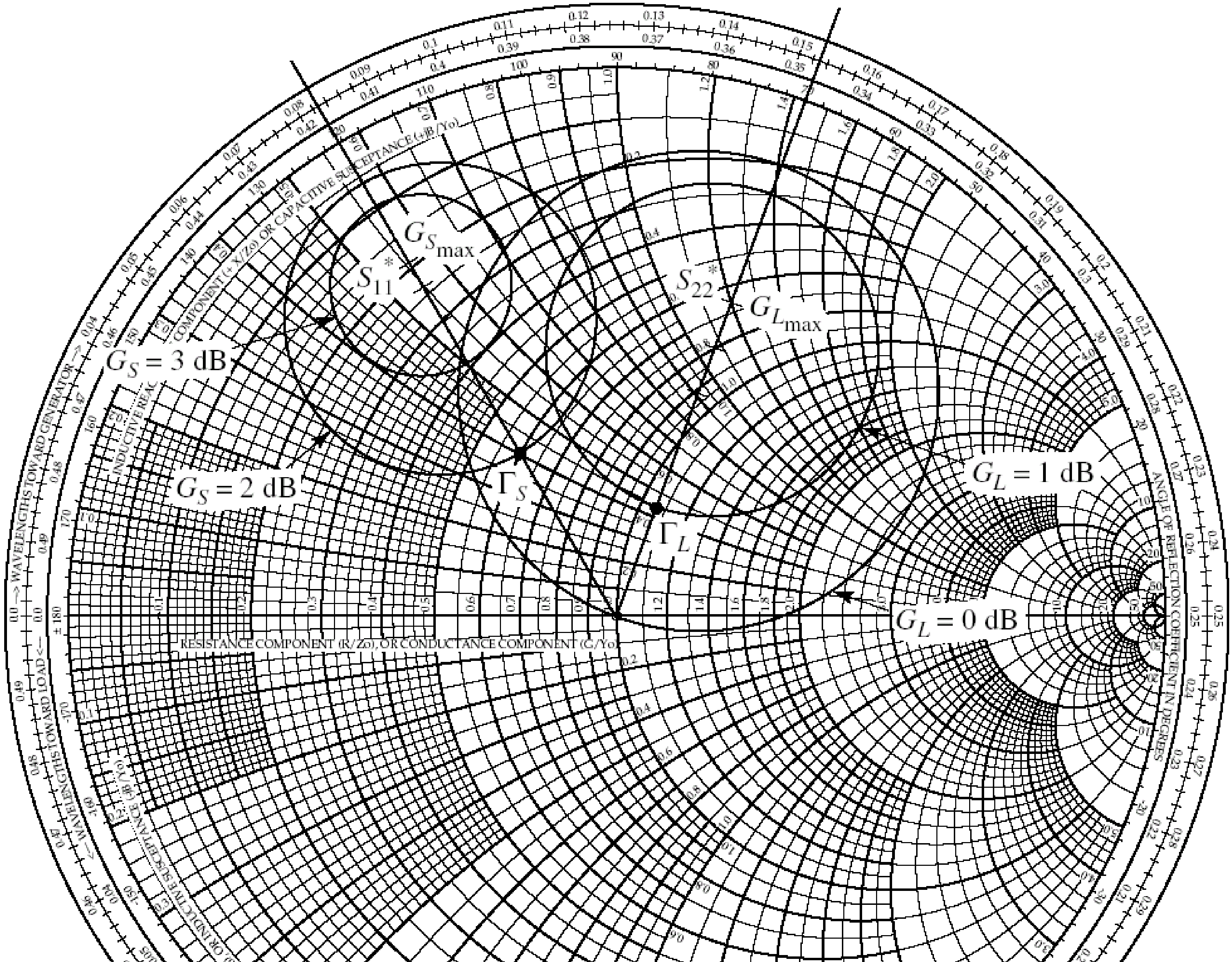
$$C_L(G_{L0}) = 0.440\angle 70°$$

$$R_L(G_{L0}) = 0.441$$

,

$$G_S = 2dB \qquad G_L = 1dB$$

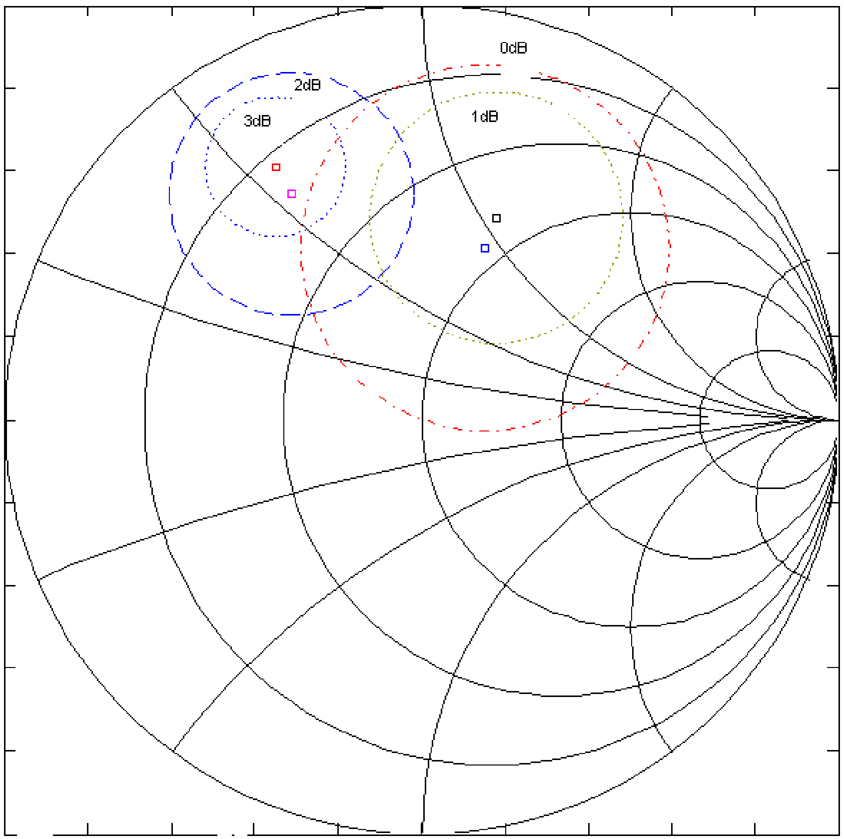
$$G_T = 10.9dB$$



$G_{S_{\max}}$
S_{11}^*
S_{22}^*
$G_{L_{\max}}$
$G_S = 3$ dB
$G_S = 2$ dB
Γ_S
Γ_L
$G_L = 1$ dB
$G_L = 0$ dB
RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
ANGLE OF REFLECTION COEFFICIENT IN DEGREES

$$\Gamma_S = \left(\left|C_S(G_{S2})\right| - R_S(G_{S2})\right)\cdot e^{j\cdot\arg(C_S(G_{S2}))} = 0.336\angle 120^\circ$$

$$\Gamma_L = \left(\left|C_L(G_{L1})\right| - R_L(G_{L1})\right)\cdot e^{j\cdot\arg(C_L(G_{L1}))} = 0.216\angle 70^\circ$$



$$y_S = \frac{1-\Gamma_S}{1+\Gamma_S} = 1.142 - j\cdot 0.748$$

$$\Re e(y_S(\theta)) = \Re e\left(\frac{1-\Gamma_S\cdot e^{2j\theta}}{1+\Gamma_S\cdot e^{2j\theta}}\right) = 1 \quad \theta = 1.138 \quad l_{S1} = \frac{\theta}{2\pi} = 0.181\lambda$$

$$y_S(2\pi l_{S1}) = 1 + j\cdot 0.713$$

$$l_{stub} = \frac{1}{2\pi}\,a\tan(\Im m(y_S(2\pi l_{S1}))) = 0.099\lambda$$

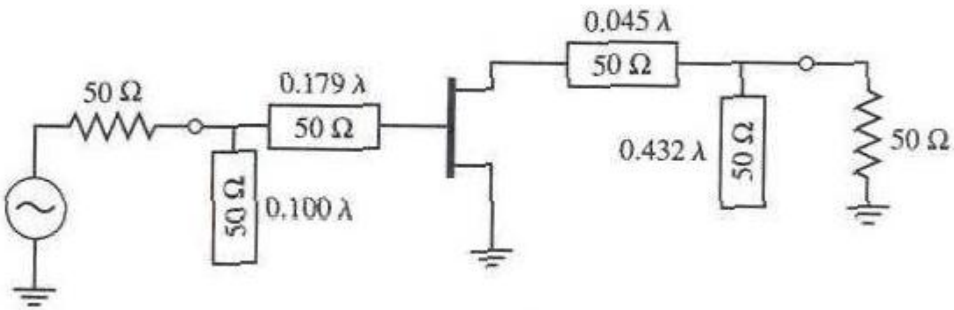
$$y_L = \frac{1-\Gamma_L}{1+\Gamma_L} = 0.798 - j\cdot 0.34$$

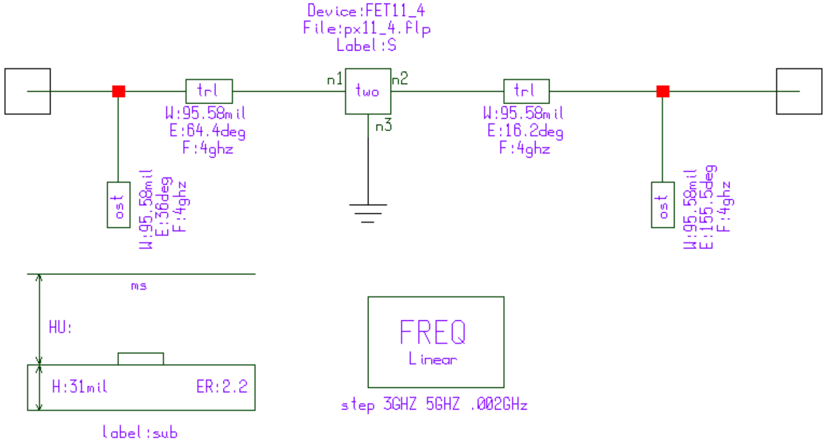
$$\Re e(y_L(\theta)) = 1 \quad \theta = 0.284 \quad l_{L1} = \frac{\theta}{2\pi} = 0.045\lambda$$

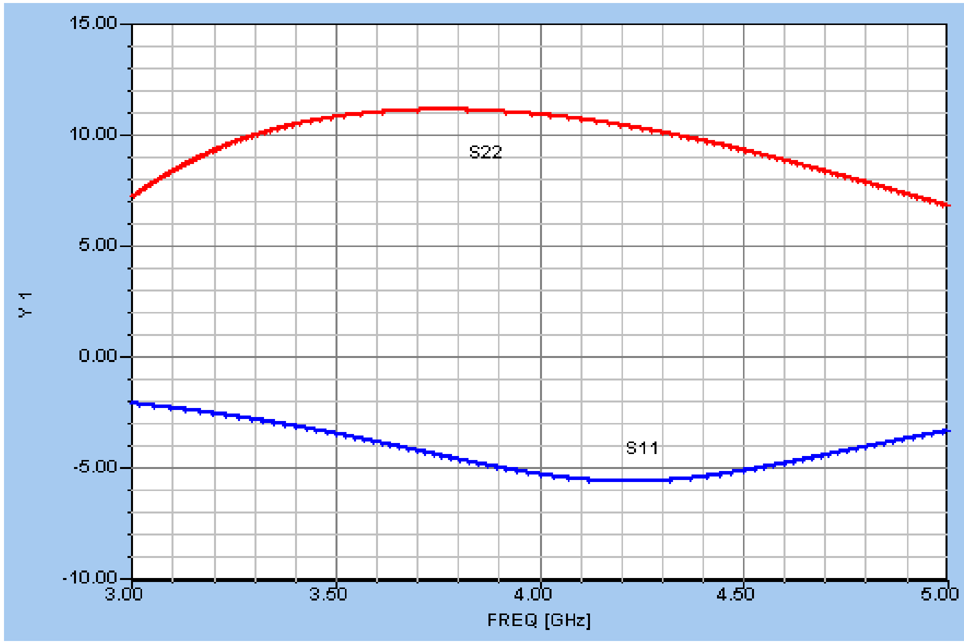
$$y_L(2\pi l_{L1}) = 1 - j\cdot 0.443$$

$$l_{stub} = \frac{1}{2\pi}\,a\tan(\Im m(y_L(2\pi l_{L1}))) = -0.066\lambda$$

$$l_{Lstub} = l_{stub} + 0.5\lambda = 0.434\lambda$$


0.045 λ
50 Ω
50 Ω
0.179 λ
50 Ω
0.432 λ
50 Ω
50 Ω
50 Ω
0.100 λ


Device:FET11_4
File:px11_4.flp
Label:S
n1
two
n2
n3
trl
W:95.58mil
E:64.4deg
F:4ghz
trl
W:95.58mil
E:16.2deg
F:4ghz
ost
W:95.58mil
E:36deg
F:4ghz
ost
W:95.58mil
E:155.5deg
F:4ghz
ms
HU:
H:31mil
ER:2.2
label:sub
FREQ
Linear
step 3GHZ 5GHZ .002GHz


15.00
10.00
5.00
0.00
-5.00
-10.00
Y 1
S22
S11
3.00
3.50
4.00
4.50
5.00
FREQ [GHz]

Proiectarea de zgomot mic

$$F = F_{min} + \frac{R_N}{G_S}\left|Y_S - Y_{opt}\right|^2$$

$$F = F_{min} + 4r_n \frac{\left|\Gamma_S - \Gamma_{opt}\right|^2}{(1-\left|\Gamma_S\right|^2)\left|1+\Gamma_{opt}\right|^2}$$

$$N = \frac{|\Gamma_S - \Gamma_{opt}|^2}{1 - |\Gamma_S|^2} = \frac{F - F_{min}}{4R_N/Z_0}|1 + \Gamma_{opt}|^2$$

$$(\Gamma_S - \Gamma_{opt})(\Gamma_S^* - \Gamma_{opt}^*) = N\left(1 - |\Gamma_S|^2\right),$$

$$\Gamma_S\Gamma_S^* - (\Gamma_S\Gamma_{opt}^* + \Gamma_S^*\Gamma_{opt}) + \Gamma_{opt}\Gamma_{opt}^* = N - N|\Gamma_S|^2.$$

$$\Gamma_S\Gamma_S^* - \frac{(\Gamma_S\Gamma_{opt}^* + \Gamma_S^*\Gamma_{opt})}{N+1} = \frac{N - |\Gamma_{opt}|^2}{N+1}.$$ /+ $|\Gamma_{opt}|^2/(N+1)^2$

$$\left|\Gamma - C\right| = R$$

$$R_F = \frac{\sqrt{N\left(N+1-\left|\Gamma_{opt}\right|^2\right)}}{N+1}$$

$$C_F = \frac{\Gamma_{opt}}{N+1}$$

$$N = \frac{F - F_{min}}{4R_N/Z_0}\left|1+\Gamma_{opt}\right|^2$$

EXEMPLU

Un tranzistor TEC pe GaAs este polarizat pentru factorul de zgomot minim şi are următorii parametri S

şi de zgomot la frecvenţa de 4 GHz

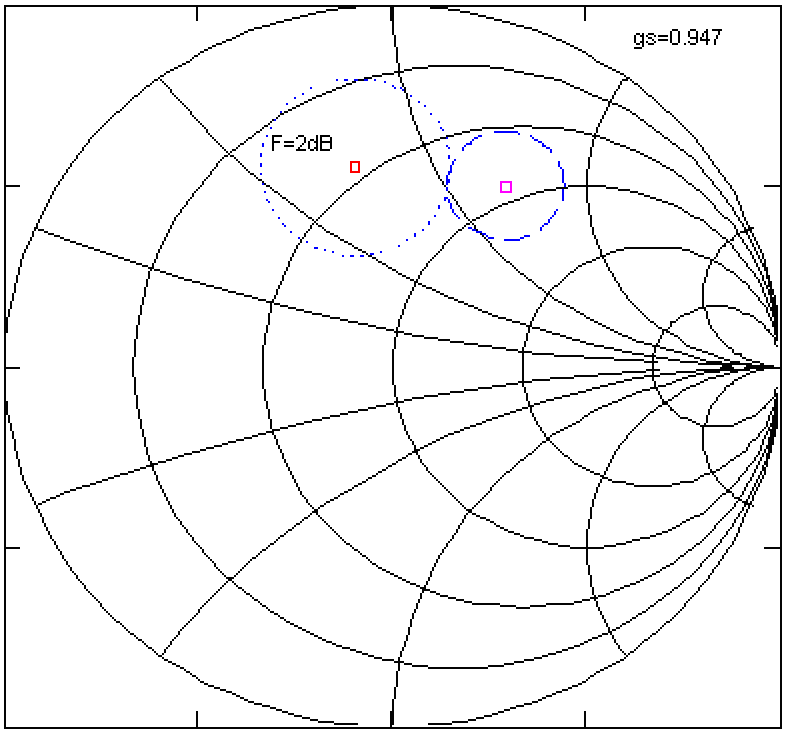
$$S = \begin{bmatrix} 0.6\angle -60^\circ & 0.05\angle 26^\circ \\ 1.9\angle 81^\circ & 0.5\angle -60^\circ \end{bmatrix} \quad F_{min} = 1.6dB \quad \Gamma_{opt} = 0.62\angle 100^\circ \quad R_N = 20\Omega$$

Pentru proiectare presupunem tranzistorul unilateral şi vom calcula ulterior eroarea maximă în rezultată din această presupunere. Amplificatorul se va proiecta pentru o cifră de zgomot de 2.0 dB cu cîştigul maxim compatibil cu această cifră de zgomot.

Solutie

$$U = \frac{|S_{11}S_{22}S_{12}S_{22}|}{\left(1-|S_{11}|^2\right)\left(1-|S_{22}|^2\right)} = 0.059 \qquad \frac{1}{(1+U)^2} < \frac{G_T}{G_{TU}} < \frac{1}{(1-U)^2} \qquad 0.891 < \frac{G_T}{G_{TU}} < 1.130 \qquad -0.50dB < G_T - G_{TU} < 0.53dB$$

$$F = 10^{\frac{2}{10}} = 1.584 \qquad N = \frac{F - F_{min}}{4R_N/Z_0}\left|1+\Gamma_{opt}\right|^2 = 0.102 \qquad C_F = \frac{\Gamma_{opt}}{N+1} = 0.563\angle 100° \qquad R_F = \frac{\sqrt{N\left(N+1-|\Gamma_{opt}|^2\right)}}{N+1} = 0.245$$



$$\Gamma_S = 0.141035 + j\cdot 0.522189 = 0.541\angle 74.886°$$

$$G_S = 10\log\left[\frac{1-|\Gamma_S|^2}{|1-S_{11}\Gamma_S|^2}\right] = 1.702dB$$

$$G_L = 10\log\left[\frac{1}{1-|S_{22}|^2}\right] = 1.249dB \qquad \Gamma_L = S_{22}^*$$

$$G_0 = 10\log\left[|S_{21}|^2\right] = 5.575dB$$

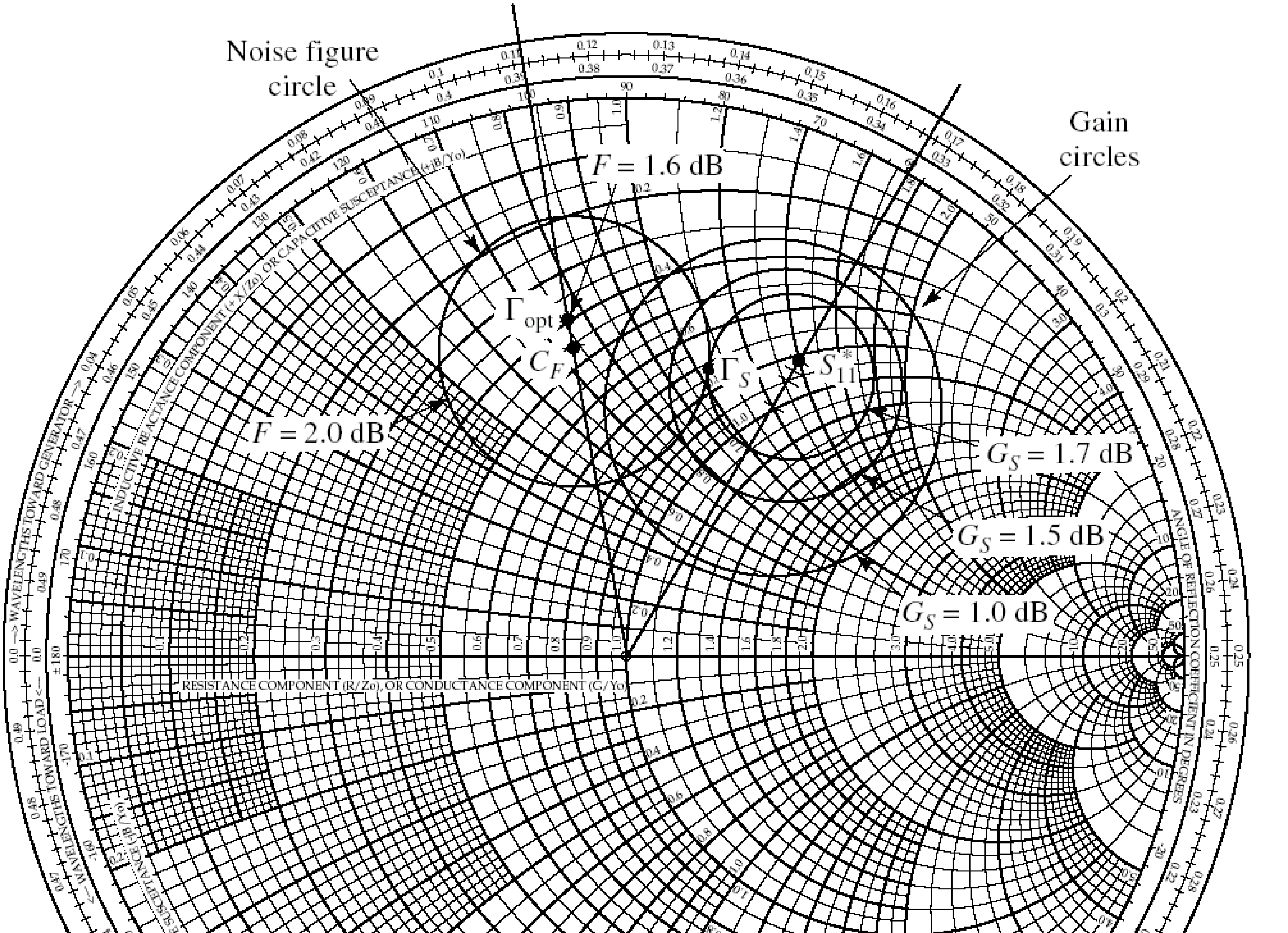
$$G_{TU} = G_S + G_0 + G_L = 8.527dB$$

$$y_S = \frac{1-\Gamma_S}{1+\Gamma_S} = 0.449 - j\cdot 0.663 \qquad \Gamma_L = \frac{B_2 - \sqrt{B_2^2 - 4|C_2|^2}}{2C_2} = 0.457\angle 68.435°$$

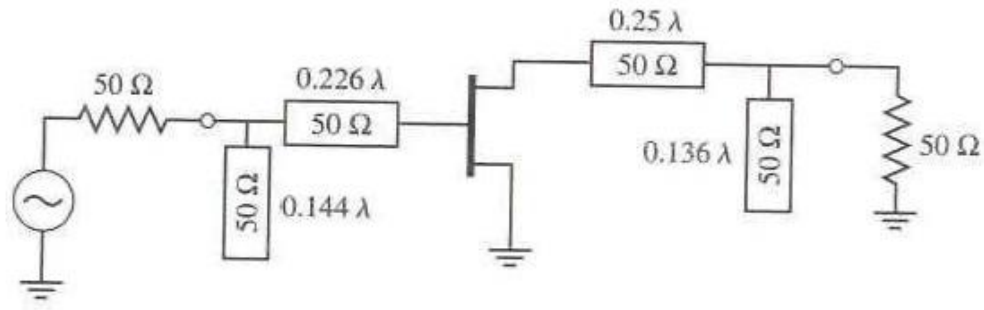
$$l_{S1} = \frac{\theta}{2\pi} = 0.226\lambda \qquad y_L = \frac{1-\Gamma_L}{1+\Gamma_L} = 0.512 - j\cdot 0.55$$

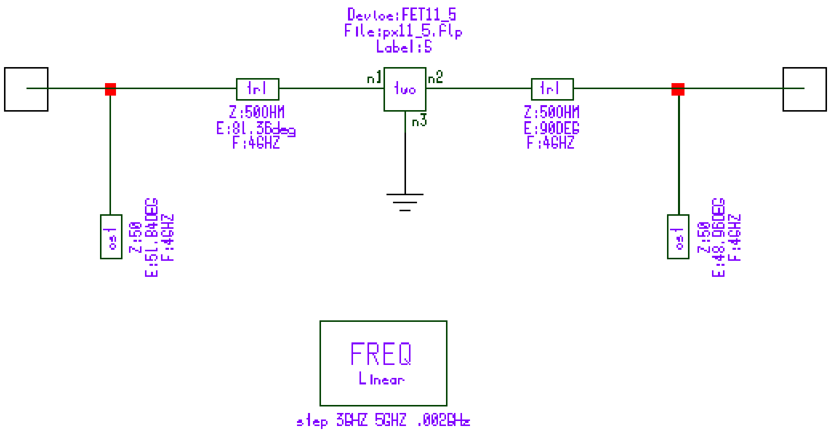
$$l_{Sstub} = \frac{1}{2\cdot\pi}\,a\tan\left(\Im m\left(y_S\left(2\cdot\pi\cdot l_{S1}\right)\right)\right) = 0.145\lambda \qquad l_{L1} = \frac{\theta}{2\cdot\pi} = 0.242\lambda$$

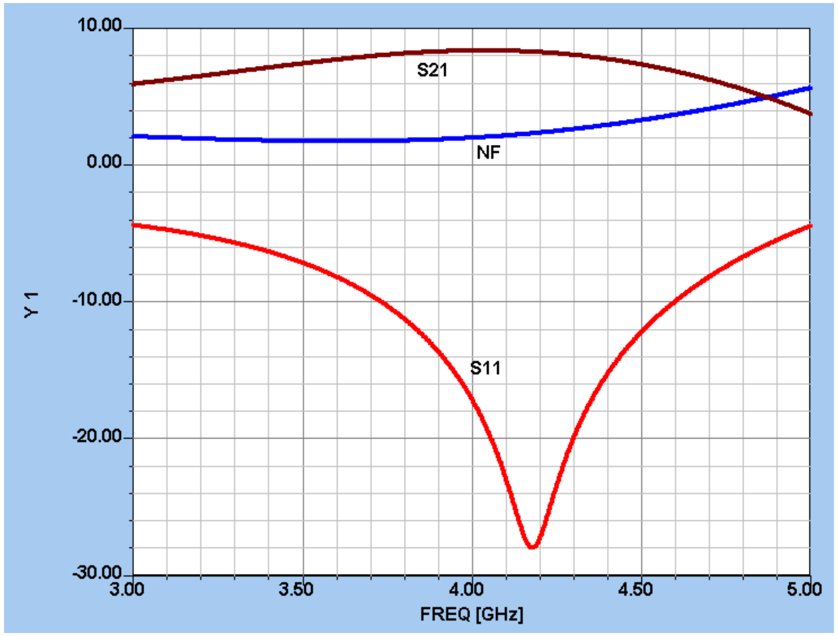
$$l_{Lstub} = \frac{1}{2\cdot\pi}\,a\tan\left(\Im m\left(y_L\left(2\cdot\pi\cdot l_{L1}\right)\right)\right) = 0.127\lambda$$



Noise figure circle
Gain circles
F = 1.6 dB
F = 2.0 dB
Γopt
CF
ΓS
S11*
GS = 1.7 dB
GS = 1.5 dB
GS = 1.0 dB
RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
INDUCTIVE REACTANCE COMPONENT (+jX/Zo), OR CAPACITIVE SUSCEPTANCE (+jB/Yo)
WAVELENGTHS TOWARD GENERATOR
WAVELENGTHS TOWARD LOAD
ANGLE OF REFLECTION COEFFICIENT IN DEGREES


50 Ω
0.226 λ
50 Ω
0.25 λ
50 Ω
50 Ω
0.144 λ
0.136 λ
50 Ω
50 Ω


Device:FET11_5
File:px11_5.Flp
Label:5
n1
n2
n3
tuo
trl
Z:50OHM
E:81.36deg
F:4GHZ
trl
Z:50OHM
E:90DEG
F:4GHZ
osl
Z:50
E:51.84DEG
F:4GHZ
osl
Z:50
E:48.96DEG
F:4GHZ
FREQ
Linear
step 3GHZ 5GHZ .002GHz


10.00
0.00
-10.00
-20.00
-30.00
Y 1
S21
NF
S11
3.00
3.50
4.00
4.50
5.00
FREQ [GHz]