RF SYSTEMS
Written Test of July 24th, 2018

Surname & Name
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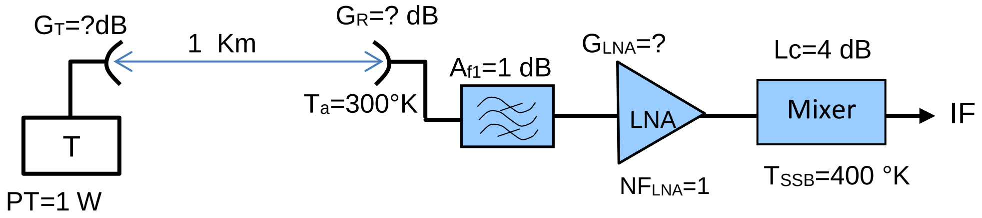
<u>Exercise 1</u>

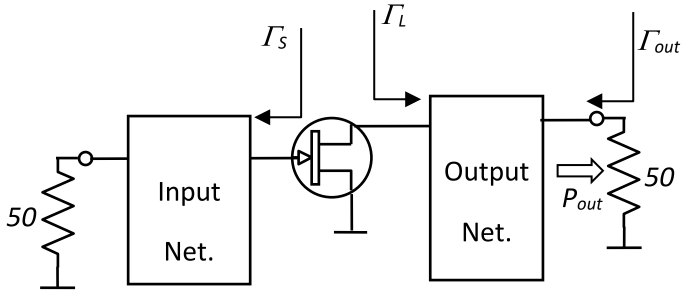


Consider the scheme in the figure, which refers to a point-to-point communication system operating at 60 GHz with a signal having B=1000 MHz bandwidth (1024 QAM). All the relevant system parameters are reported in the scheme (except G_{LNA} and G_R=G_T to be assessed).

1) Evaluate the minimum gain of the antennas (imposed equal), assuming the received power $P_R \geq -50$ dBm
2) Imposing the minimum data rate R of the system equal to 7.5 Gbit/s with E_b/N_0=22 dB, evaluate the requested value of the system equivalent temperature (T_{sys})
3) Evaluate G_{LNA} in order to get the requested T_{sys}
4) If the LNA is removed, what is the new value of T_{SSB} for maintaining T_{sys} unchanged?

Exercise 2

We want design a single stage amplifier at 12 GHz delivering P_L=20 dBm to the load, using the scheme in the following figure (input and output networks are lossless):



The transistor has the following parameters:

$S_{11}=0.57\angle 166°$ $S_{21}=2.59\angle -21°$ $S_{12}=0.144\angle -50°$ $S_{22}=0.39\angle -148°$

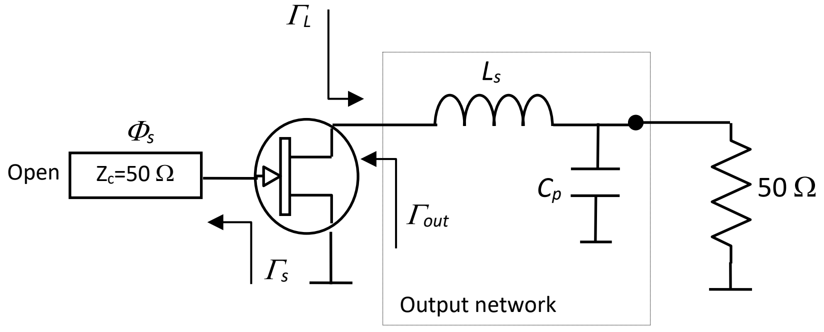
$\Gamma_{opt}=0.435\angle 168°$ $F_{min}=1.15$ dB $R_n=0.095$ (Noise parameters)

The amplifier must exhibit the noise figure as small as possible, compatibly with the stability requirement and with the Transducer Gain not lower than 11 dB.

1) Select a proper value for Γ_S and Γ_L in order to satisfy the above requirements
2) Select for the output network the topology you prefer and evaluate all the components.
3) Assume the signal constituted by 2-tone at 11.99 and 12.01 GHz with P_L (20 dBm) average power on the load. Determine the requested value of the 3th order Intercept point (IP3) in order CI (carrier-to-intermodulation ratio) at the output is equal to 30 dB. Compute also the power at each intermodulation frequency (specify the value of these frequencies)

Exercise 3

We want design the oscillator in the following figure, operating at 5 GHz:



The scattering parameters of the transistor are given by:

S_{11}= 0.844∠-62.3°, S_{21}=5.273∠121.7°, S_{12}=0.069∠42.7°, S_{22}=0.521∠-52.6°

a) Select a value for Γ_s and evaluate the electrical length Φ_s of the first line. (Hint: set $|\Gamma_{out}|$=1.2 and select the Γ_s which determines the minimum value of Φ_s)

b) Design the output network, once the required value of Γ_L has been computed (L_s and C_p must be positive numbers)

Solutions

Ex.1

$K = 1.38 \cdot 10^{-23}$ $\quad L = 1000\ m$ $\quad \lambda = 3 \cdot 10^{8} / 60 \cdot 10^{9} =$ 0.005m

$G = G_T = G_R$

1) $P_R = P_T - 20\log_{10}\left(\frac{4\pi L}{\lambda}\right) + 2G$

$G = (-80+128-0)/2 = 24\ dB$

2) $SNR = \frac{P_R}{K T_{sys} \cdot B} = \frac{E_b}{N_0} \cdot \frac{R}{B} \Rightarrow$

$\Rightarrow T_{sys} = \frac{1}{K} \frac{P_R}{\frac{E_b}{N_0} \cdot R} = 609.62\ °K$

3) $T_{sys} = T_a + T_f + 2\, T_{LNA} \cdot a_f + T_{SSB} \frac{\cdot a_f}{g_{lna}}$

$T_f = T_0 (10^{0.1} - 1) = 75.09$ $\quad T_0 = 290°$ $\quad a_f = 10^{0.1} = 1.26$

$T_{lna} = T_0 (10^{0.1} - 1) = 75.09$ $\quad nf = 10^{0.1} = 1.26$

$g_{lna} = \frac{T_{SSB} \cdot a_f}{T_{sys} - T_a - T_f - 2\, T_{lna} \cdot a_f} = 11.07\ (10.7\ dB)$

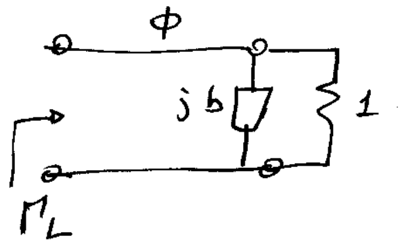
4) $T_{sys} = T_a + T_f + a_f \cdot T'_{SSB}$

$T'_{SSB} = \frac{T_{sys} - T_a - T_f}{a_f} = 186.29\ °K$

Ex. 2

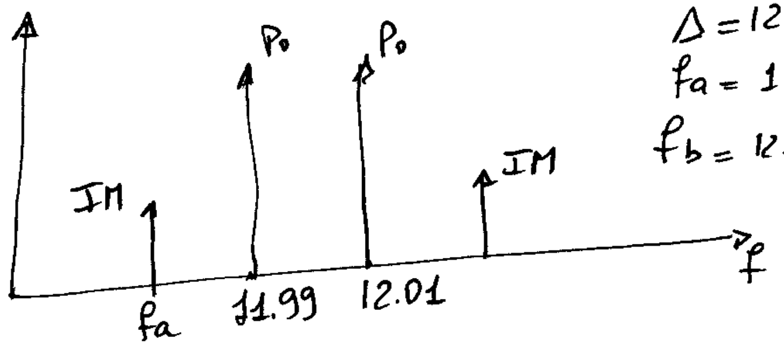
1) Assign $G_{AV} = 11$. Draw the circle G_{AV} = const. on the S.C. Draw few circles at NF = const (> 1.15) - Find the circle tangent to the circle G_{AV} = const -
The tangent point is $\Gamma_S = 0.517 \angle -168.8$.
Select "optimum Γ_L" to find $\Gamma_L = 0.465 \angle -176$.
The transistor is potentially instable so it must be verified that Γ_S an Γ_L selected are outside the forbidden regions on the SC.

2) Design of a single stub network



$$\Phi = \frac{58.6}{2} = 29.3$$
$$b = 1.045$$

3) Signal at amplifier output:



$\Delta = 12.01 - 11.99 = 0.02$
$f_a = 11.99 - \Delta = 11.97$
$f_b = 12.01 + \Delta = 12.03$

$P_L = P_0 + 3 \Rightarrow P_0 = 17\ dBm$

$GI = 2IP_3 - 2P_L + 6 \Rightarrow IP3 = \frac{70-6}{2} = 32\ dBm$

$IM = 3P_0 - 2IP_3 = 3 \cdot 17 - 64 = -13\ dBm$

$IM = P_0 - GI = 17 - 30 = -13\ dBm$

Ex. 3

a) Draw the circle "Map Gamma Source" on the S. C. with $|\Gamma_L| = 1.2$ _ Select the intersection of this circle with the outer circle ($|\Gamma| = 1$) which is closer to the open circuit (moving in the load direction) - We get $\Gamma_S = 1 \angle 94.4°$.

Select "Gamma Out" : $\Gamma_{out} = 1.2 \angle -47.6$
$Z_{out} = -0.535 - j\,2.16$

b) Assign $Z_L = \frac{|R_{out}|}{3} - j X_{out} = 0.18 + j\,2.16$ to the current point _ Draw the circle $R = const$ passing for Z_L and the circle $g = 1$ _ There are two intersections between these circles, chose the one where the current value of b is positive : $Y = 1 + j\,2.14$. From "Delta Z" we have $\Delta Z = 0 - j\,2.54$, then $X_S = 2.54 \cdot 50 = 127\,\Omega$

$L_S = \frac{X_S}{2\pi f_0} = 4.05\ uH$

$B_p = Im\{Y\} \cdot 0.02 = 2.14 \cdot 0.02 = 4.28 \cdot 10^{-2}$

$C_p = \frac{B_p}{2\pi f_0} = 1.36\ pF$