RF SYSTEMS
Written Test of September 13, 2019

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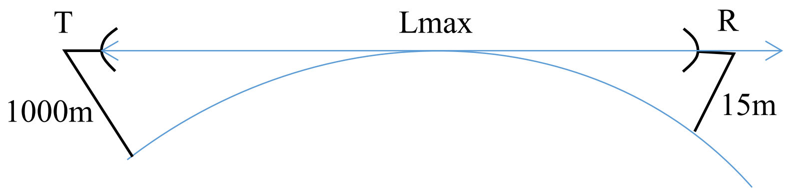
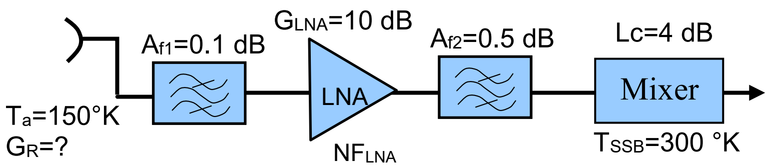
<u>Exercise 1</u>



The figure shows a terrestrial link operating at 12 GHz with bandwidth B=100 MHz. The two stations are located at the maximum distance allowed by their elevation (1000m and 15m respectively). The antennas are identical and exhibit the efficiency η=0.85 and the equivalent beamwidth $\Delta\theta$=10°.

1) Evaluate L_{max}
2) Evaluate the gain G of the antennas

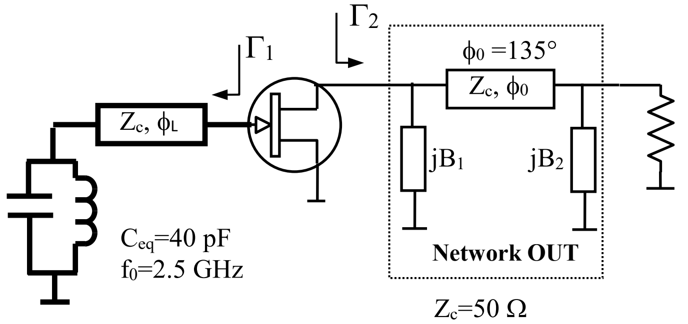
The following figure shows the scheme of the receiving station R with the relevant parameters.



3) Evaluate the received power P_r assuming the transmitted power P_t=10W
4) Imposing SNR=30 dB at the receiving antenna, compute the required equivalent temperature T_{eq} of the receiver (at the input, including the antenna)
5) Evaluate NF_{LNA} in order to get the requested T_{eq}
6) If the LNA and the second filter were removed, what would be the new value of T_{SSB} keep T_{eq} unchanged?
7) Determine the minimum value of P_{1dB} of the transmitter in order to obtain the mean power of intermodulation at the receiver input equal to the system noise power (use a 2-tone signal with 10 W mean power).

Exercise 2

The following figure represents the scheme of a microwave oscillator that is required to oscillate at 2.5 GHz. The scattering parameters of the active device are reported on the figure



S_{11}=0.772∠ 6.17°
S_{12}=0.2∠-82.08°
S_{21}=2.224∠ -137.15°
S_{22}=0.508∠ 37.07°

1) Evaluate the reflection coefficients Γ_1 and Γ_2 ensuring the start of oscillation and the best power transfer to the load (assign the magnitude of Γ_1 equal to 1). Hint: draw the mapping circle of the source with $|\Gamma_{out}|$=1.3 for determining Γ_1.
2) Assign the resonance frequency of the shunt resonator in the input network equal to the oscillation frequency and evaluate the electrical length ϕ_L so that Γ_1 has the value computed previously
3) Design the network OUT, using the scheme in the figure (evaluate the susceptances B_1 and B_2).
4) Verify if oscillation can occur at 2.51 GHz

Solution

Exercise 1

$$(L_{\max})_{Km} = L_1 + L_2 \simeq 3.57\left(\sqrt{(H_1)_{meter}} + \sqrt{(H_2)_{meter}}\right) = 126.71 \text{ Km}$$

$$\Delta\theta = 2\cos^{-1}\left(1 - \frac{2\eta}{G_R}\right) \Rightarrow G_R = \frac{2\eta}{1-\cos(\Delta\theta/2)} = 446.74 \text{ (26.5 dB)}$$

Wavelength: $\lambda=300/f_0=25$ mm
Link equation (in dBW):

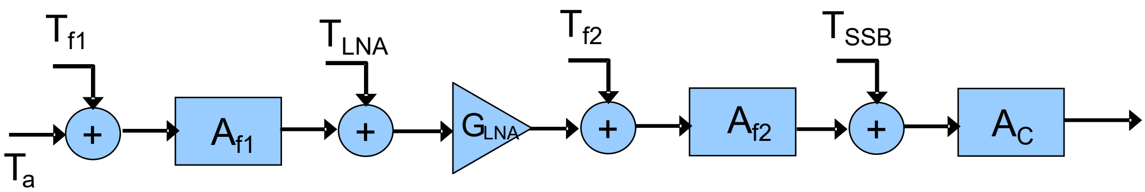
$$P_r = P_t + 20\log\left(\frac{\lambda}{4\pi L_{\max}}\right) + G_T + G_R = -63 \text{ dBm}$$

Evaluation of T_{eq}:

$$P_r - 10\log\left(KT_{eq}B\right) = 30 \Rightarrow T_{eq} = 10^{(P_r - 10\log(KB) - 30)/10} = 356.55 \text{ °K}$$

Evaluation of NF_{LNA}:

A_{f1}=1.023, A_{f2}=1.122, A_c=2.51, $T_{f1} = T_0\left(10^{A_{f1}/10} - 1\right) = 6.825$, $T_{f2} = 35.75$



$$T_{eq} = T_a + T_{f1} + A_{f1}T_{LNA} + \frac{A_{f1}\left[T_{SSB}A_{f2} + T_{f2}\right]}{G_{LNA}}$$

$$T_{LNA} = \frac{T_{eq} - T_a - T_{f1} - \dfrac{A_{f1}\left[T_{SSB}A_{f2} + T_{f2}\right]}{G_{LNA}}}{A_{f1}} = 157.94 \text{ °K}$$

$$NF = 10\log\left(10^{NF/293} - 1\right) = 1.87 \text{ dB}$$

Removing the second filter:

$$T_{eq} = T_a + T_{f1} + A_{f1}T_{SSB} \Rightarrow T_{SSB} = \frac{T_{eq} - T_a - T_{f1}}{A_{f1}} = 195.33 \text{ °K}$$

Evaluation of P_{1dB}:
Note CI is unchanged at the receiver. So, with $P_{t,int}$ the transmitted intermodulation power, $P_{r,int}$ the received intermodulation power we have:

$$CI = P_t - P_{t,int} = P_r - P_{r,int} = P_r - KT_{eq}B = SNR = 30 \text{ dB}$$

From the expression of CI we derive IP_3 and P_{1dB}:

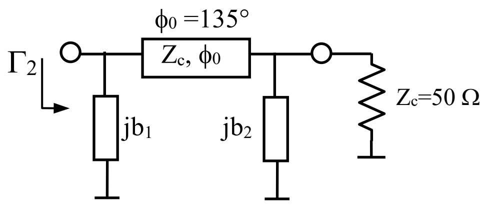
$$IP_3 = \frac{CI + 2P_t - 6}{2} = 52 \text{ dBm}, \; P_{1dB} = IP_3 - 10.63 = 41.37 \text{ dBm}$$

Exercise 2

The assigned transistor is potentially instable (k=0.61), so it can be used for realizing an oscillator. Using the electronic Smith Chart, the mapping circle with $|\Gamma_{out}|=1.3$ is drawn. One of the two intersection with the outer circle is then selected: $\Gamma_1=1\angle-39.5°$.
Selecting "S Param." → "Gamma OUT" the reflection coefficient at port 2 is obtained: $\Gamma_{out}=1.3\angle45.72°$. The S. chart reports also the normalized impedance $Z_{out}=-0.793+j2.125$.
Imposing the condition starting the oscillation, the values of Z_2 and Γ_2 are then obtained:
$Z_2 = 0.2643-j2.125 \rightarrow \Gamma_2 = 0.91\angle-49.85°$.

At the oscillation frequency, the shunt resonator is an open circuit, so the length ϕ_L is given by:
$\phi_L = -\angle(\Gamma_1)/2 = 19.75°$.

The double-stub matching network is designed according the following procedure:



1) Read the normalized admittance at Γ_2 from the S. Chart: $y_2=0.058+j0.463$
2) Draw the circle with constant conductance $g=g_2=0.058$ rotated of 270° toward the load
3) Draw the circle g=1
4) Select one of the two intersections between the above circles: $\Gamma_A=0.922\angle-157.29°$. The value y_A must be in the form $y_A=1+jb_2=1+j4.77$. Then $b_2=4.77$.
5) Rotate Γ_A toward the source of -270°, arriving at $\Gamma_A=0.922\angle-67.29°$. The normalized admittance results $y_B=0.058+j0.664$
6) Note that the real part of y_B coincides with g_2. The unknown b_1 is then obtained by subtracting the imaginary part of y_B from the imaginary part of y_2: $b_1=0.664-0.463=0.201$

At f=2.51 GHz the susceptance of the shunt resonator results $B = 2\pi f \cdot C_{eq}\left(\frac{f}{f_0}-\frac{f_0}{f}\right) = 0.05036\ S$

($B/Y_c=0.2518$). With the S.C. we can compute the value of Γ_1, resulting $1\angle-67.77°$, which produces $|\Gamma_{out}| = 0.983$. The start of the oscillation in then impossible.