RF SYSTEMS

Written Test of September 1, 2016

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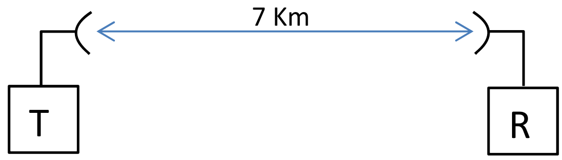
<u>Exercise 1</u>



The figure shows a terrestrial link operating at 4 GHz with bandwidth B=2 MHz. The two stations are located 7 Km away and the antennas are identical with the following features:

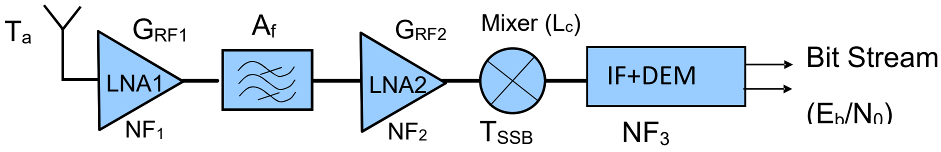
Efficiency η=0.9. Directivity function $f(\theta)$=1 for 0< θ<35°, =0 elsewhere.

1) Evaluate the gain G of the antennas
2) It is known the system noise temperature Tsys=900 °K of the station R. What it the power to be transmitted from T in order to get the system SNR equal to 30 dB? Assume the antennas pointed for the maximum gain.

Exercise 2

The scheme in the figure represents the RF front-end of a receiver for a satellite earth station operating at 4 GHz with signal bandwidth 100 MHz.

The goal is to get the system SNR equal to 27 dB with the power of the received signal equal to -100 dBW



- NF_1 = ?
- G_{RF1}=10 dB
- T_a=60 °K
- A_f=0.1 dB
- G_{RF2}=20 dB
- NF_2=2 dB
- L_c=4 dB
- T_{SSB}=200 °K
- NF_3=2 dB

a) Evaluate the Noise Figure NF_{RF1} of LNA1 in order to meet the goal

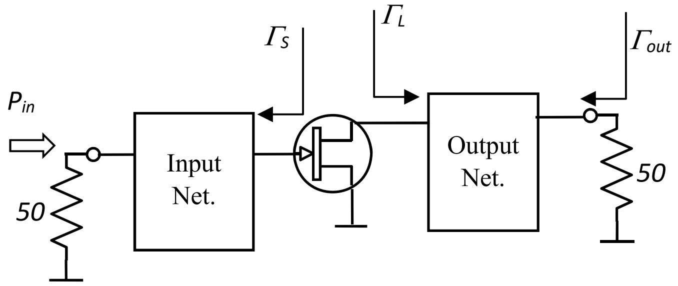
b) What is the maximum data rate R of the demodulated bit stream with (E_b/N_0) =18 dB?

Hint: Use the expression relating the system SNR to E_b/N_0

Use K=-228.6 dBW/(Hz·°K) (Boltzmann Constant)

<u>Exercise 3</u>

We want design a single stage amplifier at 5 GHz using the scheme in the following figure (input and output networks are lossless):



The transistor to be used has the following parameters:

S_{11}=0.52∠143.8° S_{21}=4.255∠ 28.7° S_{12}=0.081∠4.9 S_{22}=0.287∠ -87.7°

Γ_{opt}=0. 19∠-170.4° F_{min}=0.85 dB R_n=0.06 (Noise parameters)

3th order Intercept point (IP3): 20 dBm

The amplifier must exhibit the transducer gain as high as possible compatibly with the stability requirement and the noise figure not larger than 1 dB.

1) Select a proper value for Γ_S and Γ_L in order to satisfy the above requirements

2) Assuming at input a 2-tone signal (4.95 and 5.05 GHz) with available mean power (Pin) equal to -10 dBm, evaluate the output mean power Pout. Compute also the power at each intermodulation frequency (specify the value of these frequencies)

Solution

Exercise 1

The antenna gain is obtained from the formula:

$$G = \eta 4\pi \left[\int_0^{2\pi} d\varphi \int_0^{\pi} g(\theta) \sin\theta d\theta \right]^{-1} = 2\eta \int_0^{20^\circ} \sin\theta d\theta = \frac{2\eta}{1-\cos(35^\circ)} = 9.95 \text{ (10 dB)}$$

The system SNR is defined as:

$$SNR_{sys} = \frac{P_{rec}}{KT_{sys}B} = 30 \text{ dB}$$

Then the received power must be Pr=30+KTsys$|_{dBm}$+10log(B)=30-169+63=-76 dBm

The Friis equation for the given link is:

$$P_{rec} = P_{tr} + 2G - L_f$$

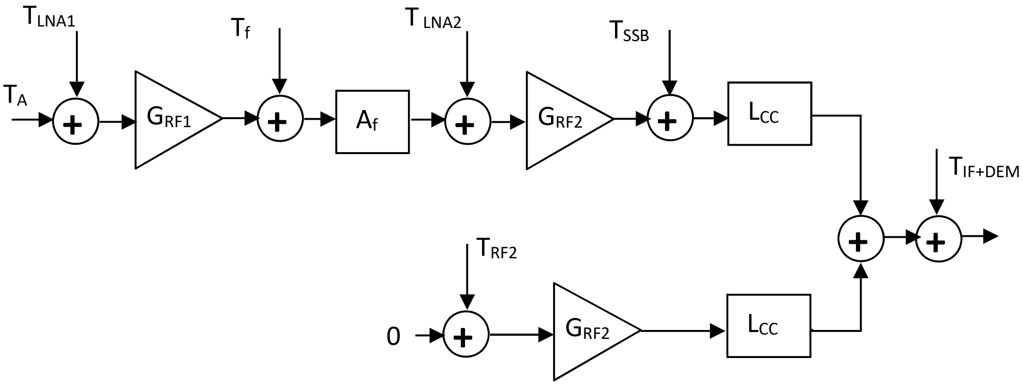
with: $L_f = 20 \cdot \log\left(\frac{4\pi R}{\lambda}\right) = 121.38 \text{ dB}$, (λ=3e8/4e9=0.075m)

Then the transmitted power results:

$$P_{tr} = P_{rec} - 2G + L_f = -76 - 20 + 121.38 = 25.4 \text{ dBm}$$

Exercise 2

Equivalent noise scheme :



Where:

$$T_{LNA2} = 290\left(10^{\frac{NF_2}{10}} - 1\right) = 169.62 \text{ °K}, \qquad T_f = 290\left(10^{\frac{A_f}{10}} - 1\right)T_0 = 6.755 \text{ °K}$$

$$T_{IF+DEM} = 290\left(10^{\frac{NF_3}{10}} - 1\right) = 169.62 \text{ °K}$$

The equivalent noise temperature at the input of the receiver is then given by:

$$T_{sys} = T_A + T_{LNA1} + \frac{T_f}{G_{RF1}} + 2\frac{T_{LNA2}A_f}{G_{RF1}} + \frac{T_{SSB}A_f}{G_{RF1}G_{RF2}} + \frac{T_{IF+DEM}L_cA_f}{G_{RF1}G_{RF2}}$$

$$= T_{LNA1} + 36.03$$

Imposing the SNR it results: $N = KT_{sys}B = P_{rec} - SNR = -127$ dBW. The equivalent temperature is then given by:

$10 \cdot \log(T_{sys}) = -127 - (KB)_{dB} = 21.6$ → $T_{sys} = 144.5$ °K

Finally the NF_1 is obtained:

$$T_{LNA1} = T_{sys} - 36.03 = 48.51 \text{ °}K$$

$$NF_1 = 10\log\left(1 + \frac{T_{LNA1}}{290}\right) = 0.67 \text{ dB}$$

The system SNR is equal to 27 dB and is expressed as:

$$SNR = \frac{P}{N_0 \cdot B} = \frac{E_B}{N_0}\left(\frac{R}{B}\right) = 27 \text{ dB}$$

then: $(R/B)_{dB} = 27 - 18 = 9$ dB → $R = 7.94 \cdot B = 794$ Mbit/sec

Exercise 3

The transistor is unconditionally stable with Gmax=16.8 dB and NFmin=0.85.
We draw first the circle NF=1 dB on the S.C. Then we look for the circle with constant Available power gain that is tangent to NF circle. We get Gav=15.11 dB. Selecting the tangent point on the S.C and imposing conjugate matching at output we get:
$\Gamma_s=.464\angle{-144.6}$, $\Gamma_L=.488\angle 97.6$, NF=1 dB, G_T=15.11 dB.

The power in each tone at output is P0=-10-3+GT=2.11 dBm. The power in each interm. line is given by:
Pint=3*P0-2*IP3=3*2.11-40=-33.67 dBm