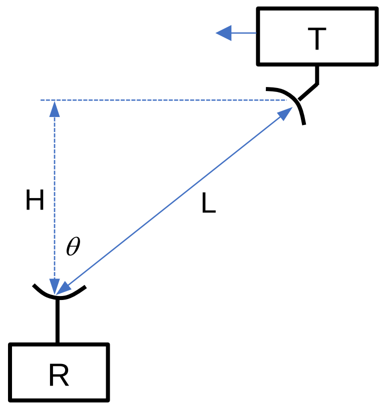
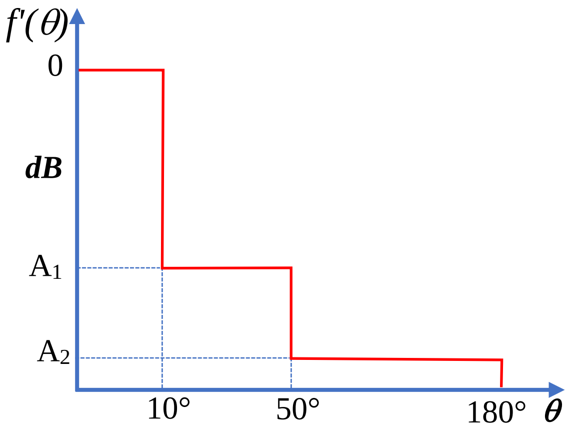
RF SYSTEMS – 1th Midterm test
30 October 2017

Surname & Name
Identification Number
Signature

Exercise 1





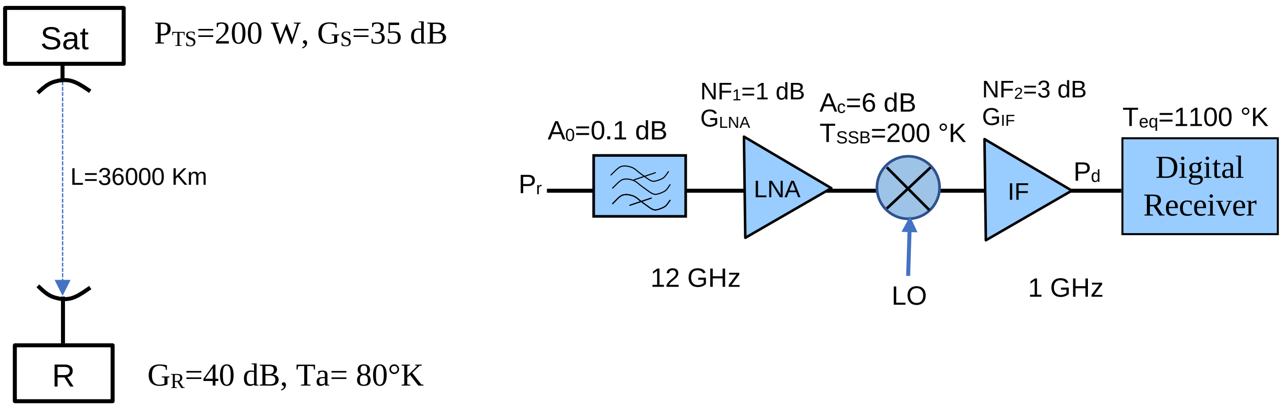
The transmitter T (P_T=20 W, f_0=4 GHz) is located on an aircraft flying parallel to ground at an altitude H=10 Km. The antenna on T is optimally directed toward the receiving station R on ground and has the gain G_T=10 dB.

The antenna at the ground station R is directed along the vertical direction and exhibits the following directivity diagram: $f(\theta,\varphi) = f'(\theta)\cdot\cos(\varphi/2)$ where $f'(\theta)$ is shown on the figure (A_1= -10 dB). Note that the range of φ is: $-\pi < \varphi < \pi$. The scheme on the above figure (left) refers to the plane φ=0.

1) Compute the parameter A_2 of the directivity diagram in order that the gain of the receiving antenna (G_R) is equal to 17 dB. Assume the radiation impedance Z_R=50 Ω e the loss resistance R_p=10Ω.
2) Compute the 3dB beamwidth $\Delta\varphi_{3dB}$ of the antenna in the plane θ=0.
3) Compute the power received by R when the aircraft crosses the positions where θ is equal 10° and 50° (with φ=0)
4) It is known the sensitivity of the receiver S=-90 dBm. Evaluate the maximum value of L where the signal is still detected (note that θ>50° for this distance)

<u>Exercise 2</u>

Consider the Satellite link in the figure (left) operating at 12 GHz. The transmitter on the satellite has P_{TS}=200 W and the onboard antenna has the gain G_S=35 dB. The ground station uses an antenna with G_R=40 dB; the antenna noise temperature (Ta) is 80°K. The transmitting and receiving antennas are optimally directed.



1) Evaluate the receiver power P_r at the ground station (antenna output)
2) Let consider the architecture of the receiving station (top figure, right). It is know that the digital receiver must operate with (E_b/N_0)=14 dB in order to get the data rate R=150 Mbit/sec. Compute the SNR_{sys} of the system for a signal bandwidth B=30 MHz.
3) Evaluate the equivalent noise temperature of the system (T_{sys}) imposing SNR_{sys} and the received signal power (P_r)
4) The minimum power at the input of the digital receiver must be P_d=-60 dBm. Find the value of the product $G_{LNA} \cdot G_{IF}$ (not in dB!) requested for satisfying this requirement
5) Draw the equivalent scheme of the receiver with the noise temperature sources. Write the expression of T_{sys} as function of the blocks parameters. Imposing the requested T_{sys} and the value of $G_{LNA} \cdot G_{IF}$ computed above, evaluate G_{LNA} and G_{IF} in dB.

Exercise 1

1) First the directivity gain D_{max} is computed:

$$D_{\max} = \frac{4\pi}{\int_{-\pi}^{\pi}\int_{0}^{\pi} \sin(\varphi)\sin(\theta)\, f'(\theta)\, d\varphi d\theta} = \frac{4\pi}{4\left[\left(1-\cos(10°)\right) + A_1\left(\cos(10°)-\cos(50°)\right) + A_2\left(1+\cos(50°)\right)\right]} =$$

$$= \frac{\pi}{0.0494 + A_2 1.6428} = \frac{G}{\eta} = 60.1425$$

Where $\eta = Z_{rad}/(Z_{rad}+R_p) = 0.8333$ and G=10^1.7=50.1187

From the above equation it is found A_2=0.00173 (-27.6 dB)

2) The directivity in φ is:

$$f(\overline{\varphi}) = \cos\left(\frac{\overline{\varphi}}{2}\right) = 0.5 \Rightarrow \overline{\varphi} = 120°$$

The 3dB beamwidth is then $\varphi = 2\overline{\varphi} = 240°$

3) At i-th crossing the distance L is equal to:

$L_i = H/\cos(\theta_i)$ with θ_i equal to 10° and 50°. The received power is obtained from the Friis eqution:

$$P_r = P_t + G_T + G_R - L_{f,i} + A_i$$

For θ_i =10°, L_1=H/cos(10°)=10.154 Km, $L_{f,i}$=20log(4πL_1/λ)=124.61 Km

For θ_i =50°, L_2=H/cos(50°)=15.557 Km, $L_{f,i}$=20log(4πL_2/λ)=128.32 Km

Replacing on the Friis equation (Pt=43dBm, G_T=10dB, G_R=17dB) it has:

Pr1=-64.616 dBm, Pr2=-85.94 dBm

4) From the Friis equation:

$$P_r = P_t + G_T + G_R - L_f + A_2 = -90 \Rightarrow L_f = 132.4 \text{ dBm}$$

Then replacing the expression of L_f:

$$L = \frac{\lambda}{4\pi} 10^{L_f/20} = 24.88 \text{ Km}$$

Exercise 2

1) Applying the Friis equation we get the received power at the ground station:

$$P_r = P_t + G_T + G_R - L_f = 53 + 35 + 40 - 20\log\left(\frac{4\pi 36\cdot 10^6}{0.025}\right) = -77.15 \text{ dBm}$$

2) The SNRsys is related to Eb/No as follows:

$$SNR_{sys} = \frac{E_b}{N_0}\frac{R}{B} = 14 + 10\log\left(\frac{150}{30}\right) = 21 \text{ dB}$$

3) It has:

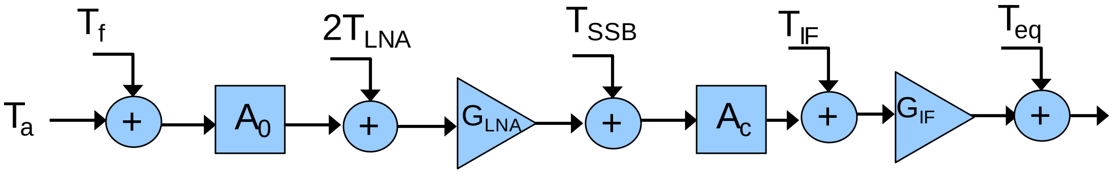
$$SNR_{sys} = \frac{P_r}{KT_{sys}B} = 21 \text{ dB} \Rightarrow T_{sys} = 369.83 \text{ °K}$$

4) The power Pd is given by:

Pd=P_r-A_0+G_{LNA}-A_c+G_{IF}=-60 dBm.

Replacing we get G_{LNA}+G_{IF}=23.25 dB that is, in natural units, $G_{LNA}.G_{IF}$=211.4

5) Equivalent scheme:



The expression of Tsys results:

$$T_{sys} = T_a + T_f + 2T_{LNA}A_0 + \frac{A_0}{G_{LNA}}\left(T_{SSB} + T_{IF}A_c\right) + \frac{T_{eq}A_0A_c}{G_{LNA}G_{IF}}$$

Equating the above expression to the previously computed values we get the following expression for G_{LNA}:

$$G_{LNA} = \frac{A_0\left(T_{SSB} + T_{IF}A_c\right)}{T_{sys} - \left(T_a + T_f + 2T_{LNA}A_0 + \frac{T_{eq}A_0A_c}{G_{LNA}G_{IF}}\right)} = 12.54 \ \ (11 \text{ dB})$$

Then:

$$G_{IF} = \frac{G_{LNA}G_{IF}}{G_{LNA}} = 18.5 \ \ (12.67 \text{ dB})$$