RF SYSTEMS
Mid-course Test - November 19th, 2015

Surname & Name
Identification Number
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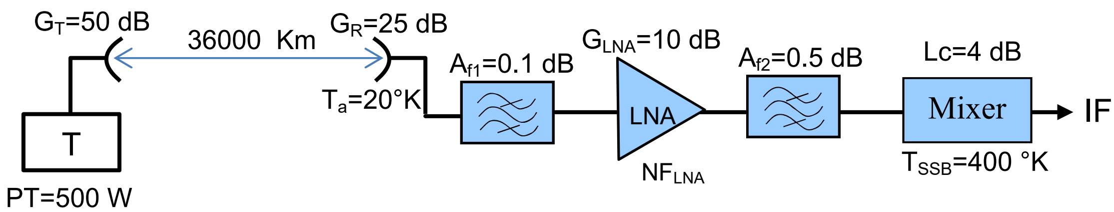
Exercise 1



Consider the scheme in the figure, which refers to the up-link of a satellite communication system operating at 6.4 GHz with a signal having B=32 MHz bandwidth. All the relevant system parameters are reported in the scheme (except NF_{LNA} to be assessed).

1) Evaluate the received power P_r of the signal at the output of the satellite receiving antenna
2) Imposing SNR=30 dB at the receiving antenna, find the equivalent input temperature T_{eq} of the receiver
3) Evaluate NF_{LNA} in order to get the requested T_{eq}
4) If the LNA and the second filter are removed, what is the new value of T_{SSB} for maintaining T_{eq} unchanged?
5) 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 $K \cdot T_{eq} \cdot B$ (use a 2-tone signal with 500 W mean power). What is the back-off of the transmitter?

Exercise 2

It is known the directivity function of an antenna operating at 1 GHz: $f(\theta,\varphi) = \sin(\theta) \cdot \sin^2(\varphi/2)$.

1) Evaluate the directivity gain D_M
2) Find the direction (θ_{MAX}, φ_{MAX}) where $D(\theta,\varphi) = D_M$.
3) Evaluate the exact value of the half-power beamwidth in the elevation plane (θ_{3dB}). Note that the reference axis is along θ_{MAX}.
4) Assuming the radiation impedance Z_{rad}=50 Ω and the loss resistance R_p=12.5 Ω, evaluate the antenna efficiency factor η
5) Compute the intensity of the electric field |E| at 30 m from the antenna in the direction (θ=135°, φ=180°). Assume the transmitted power P_T=1500 W.

Note: $\int \sin^2(x)\,dx = \frac{1}{2}\left[x - \frac{\sin(2x)}{2}\right]$

Solution

Exercise 1

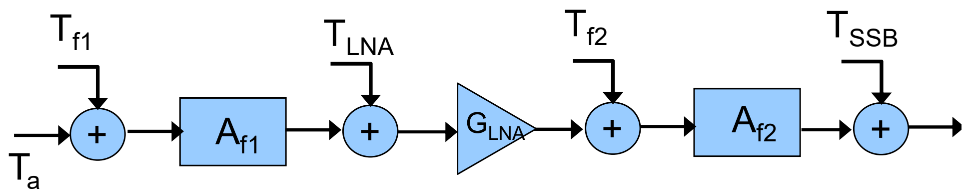
Link equation (in dBm):

$$P_r = P_t + 20\log\left(\frac{\lambda}{4\pi R}\right) + G_T + G_R = 57 + 50 + 25 - 199.7 = -67.7 \text{ dBm}$$

Evaluation of T_{eq}:

$$SNR = P_r - 10\log\left(KT_{eq}B\right) = 30 \Rightarrow T_{eq} = 384.41\ °\text{K}$$

NF_{LNA}:



A_{f1}=1.023, A_{f2}=1.122 $\quad T_{f1} = T_0\left(10^{A_{f1}/10} - 1\right) = 6.75°K,\ \ T_{f2} = T_0\left(10^{A_{f2}/10} - 1\right) = 35.38°K \qquad g_{LNA} = 10$

$$T_{eq} = T_a + T_{f1} + A_{f1}T_{LNA} + \frac{A_{f1}\left[T_{SSB}A_{f2} + T_{f2}\right]}{G_{LNA}} = 384.41°K$$

$$T_{LNA} = \frac{1}{A_{f1}}\left\{384.41 - \left[T_a + T_{f1} + \frac{A_{f1}\left[T_{SSB}A_{f2} + T_{f2}\right]}{G_{LNA}}\right]\right\} = 301.1°K$$

$$NF_{LNA} = 10\log\left(1 + \frac{T_{LNA}}{290}\right) = 3.09dB$$

Removing the LNA and second filter:

$$T_{eq} = T_a + T_{f1} + A_{f1}T_{SSB} = 384.41°K$$

$$T_{SSB} = \frac{1}{A_{f1}}\left\{384.41 - \left[T_a + T_{f1}\right]\right\} = 349.52°K$$

As the noise power is imposed equal to the power of intermodulation, the CI (carrier-to-intermodulation) is equal to SNR (30 dB). Moreover, CI value is conserved moving from the receiver input to the transmitter output. It has then: $CI = 2\left(IP_3 - P_m\right) + 6 = 30$ with P_m=57dBm.

We get IP_3 and P_{1dB}:

$$IP_3 = \frac{CI}{2} + P_m - 3 = 69 \quad \Rightarrow \quad P_{1dB} = IP_3 - 10 = 59 \text{ dBm}$$

The back-off is given by: BO=P_{1dB}-P_m=2 dB (with $\Delta_p \cong$10 dB)

Exercise 2

1) $D_M = 4\pi \Big/ \int_0^{\pi}\int_0^{2\pi} f(\vartheta,\varphi)\sin(\theta)\,d\theta d\varphi = 4\pi \Big/ \int_0^{\pi}\int_0^{2\pi} \sin^2(\theta)\sin^2\left(\frac{\varphi}{2}\right)d\theta d\varphi = 4\pi\left[\frac{2}{\pi^2}\right] = \frac{8}{\pi}$

2) $\theta_{MAX} = 90°, \quad \varphi_{MAX} = 180°$

3) Imposing $f(\theta_B,\varphi)=f(\theta_{MAX},\varphi)/2=0.5\cdot\sin^2(\varphi/2)$ we get $\sin(\theta_B)=0.5$ and $\theta_B=30°$. Taking into account that the reference direction is $\theta=90°$, it has: $\theta_{3dB}=2\cdot(90-30)=120°$.

4) $\eta = \dfrac{R_{rad}}{R_{rad}+R_p} = 0.8$

5) We know that:

$|E| = \dfrac{1}{R}\sqrt{\dfrac{Z_0 \cdot P_{ERP}}{2\pi}}$ with R=30m, $Z_0=377\Omega$, $P_{ERP}=\eta D_M P_T f(135°,180°)=2160.1$

Then |E|=12 V/m