# RF SYSTEMS – 1th part
## 30 January 2018

| Surname & Name |
|---|
| **Identification Number** |
| **Signature** |

## Exercise 1

Consider an FM broadcasting radio operating in 88-108 MHz band. The antenna connected to the transmitter is omnidirectional in the horizontal plane (parallel to ground, directivity $f(\varphi)=1$). The directivity in the vertical plane is represented in the following figure (note that $\theta=0$ represents the direction orthogonal to ground). The transmitted power must be selected in order to guarantee an adequate coverage of the area surrounding the radio station. Specifically, it is assigned the minimum value of the electric field intensity $|E_{min}|=0.04$ V/m requested up to the distance L=10 Km from the transmitter (at ground level).
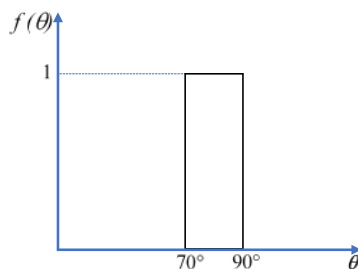


1) Compute the gain of the transmitting antenna (assume the efficiency $\eta=0.8$)
2) Compute the minimum power requested by the transmitter (in W)
3) Evaluate the maximum altitude above ground at 10 Km from the station where the signal can be still received. Compute the power density (W/m$^2$) of the signal at this position.
4) Consider a radio receiver located at 10 Km from the station, at ground level. It is known the gain of the receiving antenna ($G_R$=2 dB), the mismatch factor ($k_{mis}$=.95) and the polarization loss factor ($k_{pol}$=0.9). Assuming the antenna is optimally directed, evaluate the minimum received power at the antenna output (in dBm) in the assigned frequency range (specify the frequency)

## Exercise 2

Consider the scheme of a RF front-end operating at 30 GHz with a signal bandwidth B=32 MHz.
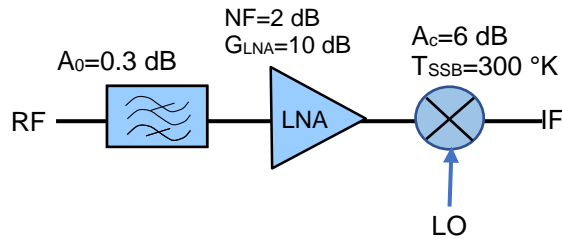


It is known that the local oscillator (LO) is affected by phase noise that produces, at IF, a noise power density $N_{LO}$=-180 dBm/Hz (assume white spectrum for noise)

1) Draw the equivalent scheme of the receiver with the noise temperature sources.
2) Evaluate the overall noise power density (dBm/Hz) at IF
3) Evaluate the equivalent noise temperature ($T_{eq}$) at front-end input
4) If we remove the LNA, what must be the new $T_{SSB}$ of the mixer in order to get the same $T_{eq}$ previously computed? Draw the scheme with the noise sources also in this case

Consider the original scheme (with LNA included). This front-end is used in the receiving system depicted in the following figure:
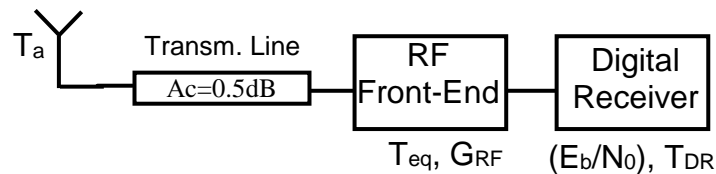


Note that $G_{RF}$ represents the overall gain of the front-end from input (RF) to IF. The digital receiver is characterized by $(E_b/N_0)$=10 dB and $T_{DR}$=150 °K (equivalent noise temperature at input)
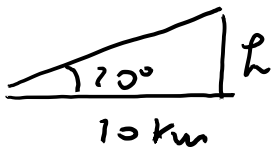
1) Evaluate the equivalent system noise temperature ($T_{sys}$) of the receiving system (assume Ta=50 °K).
2) Evaluate the minimum power (in dBm) of the received signal (antenna output) allowing the data rate R to be at least 100 MBit/sec.

## Solutions

(Ex. 1)

1) $G = \dfrac{2\eta}{\displaystyle\int_{75°}^{90°} \sin\theta\, d\theta} = \dfrac{2.08}{\cos(75°)} = 4.68 \ (6.7 \ dB)$

2) $S_R = \dfrac{P_T \cdot G}{4\pi R^2} = \dfrac{1}{2}\dfrac{|E|^2}{Z_0} \implies P_T = 569.3 \ W$

3) 



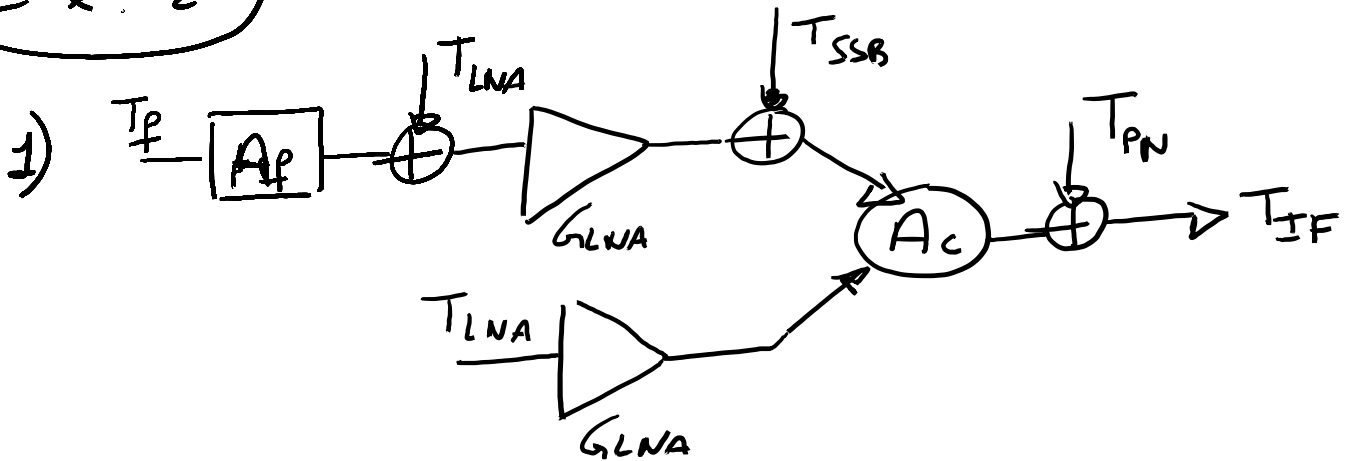$h = 10 \ Km \ \tan(20°) = 3639.7 \ m$

$R = 10 \ Km / \cos(20°) = 10.64 \ Km$

$S_R = 1.37 \cdot 10^{-6} \ W/m^2$

4) $(P_R)_{AV} = S_R \cdot G \cdot \dfrac{c^2}{4\pi f^2} \qquad (f = f_{MAX})$

$\implies \dfrac{1}{2} \dfrac{|E|^2}{Z_0} \dfrac{c^2 \, G}{4\pi f_{MAX}^2} = 7.06 \cdot 10^{-6} \ W$

$P_R = (P_R)_{AV} \ K_{mis}^2 \cdot K_{pol}^2 = 1.51 \mu W \ (-28.2 \ dBm)$

$\boxed{Ex.\ 2}$

1)
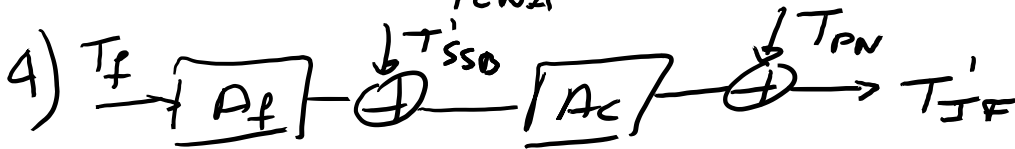


2) $T_{IF} = T_{PN} + \dfrac{T_{SSB}}{A_c} + 2\dfrac{T_{LNA} \cdot G_{LNA}}{A_c} + \dfrac{T_f}{A_f} \cdot \dfrac{G_{LNA}}{A_c}$

$\quad\quad | $

$\quad\quad = 1057.9\ °K$

$N_{IF} = K \cdot T_{IF} = 1.46 \cdot 10^{-20}\ W/Hz \quad \left(-168.35\ \dfrac{dBm}{Hz}\right)$

3) $T_{eq} = \dfrac{T_{IF} \cdot A_c \cdot A_f}{G_{LNA}} = 451.27\ °K$

4)



$T_{eq}' = T_f + T_{SSB}' \cdot A_f + T_{PN} \cdot A_c \cdot A_f = T_{eq}$

$\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad \overset{!}{=} 451.27$

$T_{SSB}' = \dfrac{(T_{eq} - T_f - T_{PN} \cdot A_c \cdot A_f)}{A_f} = 113.11\ °K$

1) $T_{sys} = T_a + T_c + T_{eq} \cdot A_c + \dfrac{T_{Ae} \cdot A_c}{G_{RF}} = 6639\ °K$

2) $P_z = (K T_{sys} \cdot B) \cdot \dfrac{E_b}{N_o} \cdot \dfrac{R}{B} = 9.16 \cdot 10^{-12} \quad (-80.38\ dBm)$