Amplifier non-linearity

We need to select an amplifier which is able to deliver 100 W (average power, signal peak factor 3 dB) with a gain 10 dB.
Assuming that a 2-tone signal with the same average power produce the same non-linear distortion of the given signal, compute the 3th order Intercept point which determine the Carrier-to-intermodulation (CI) equal to 40 dB

$$P_m = 50 \text{ dBm},$$
$$CI = 2IP_3 - 2P_m + 6 \Rightarrow$$
$$IP_3 = \frac{CI + 2P_m - 6}{2} = 67 \text{ dBm}$$

Assume now the Back-off obtained from the amplifier is 8 dB. What are the corresponding parameters Δ_p and P_{1dB}?

$$BO = \frac{CI}{2} - \Delta_p - 3 \Rightarrow$$
$$\Delta_p = \frac{CI}{2} - BO - 3 = 9 \text{ dB}$$
$$P_{1dB} = IP_3 - \Delta_p = 58 \text{ dBm}$$
$$P_{1dB} = P_m + BO = 58 \text{ dBm}$$

Dynamic range of an amplifier

Definition:

$$DR = P_{\max,dBm} - P_{\min,dBm}$$

$P_{\max,dBm}$ = Maximum Power determining a given CI (2-tone signal)

$P_{\min,dBm}$ = Minimum power determining a given SNR (thermal noise)

P_{max} and P_{min} represent average power at the amplifier output

$$P_{\min} = SNR + \left(KT_{eq}B\right)_{dBm} + G$$

T_{eq} is the ampifier equivalent temperature $=293 \cdot \left(10^{NF/10} - 1\right)$

G is the amplifier gain

$$CI = 2IP_3 - 2P_{\max} + 6 \Rightarrow P_{\max} = \frac{2IP_3 - CI + 6}{2}$$

$$DR = P_{\max} - P_{\min} = IP_3 - \frac{CI}{2} - \left(KT_{eq}B\right)_{dBm} - G - SNR + 3$$

For IP3=30 dBm, SNR=20 dB, CI=30 dB, G=20 dB, B=1 MHz:

$$DR = 30 - 15 + 116.3 - 20 - 20 + 3 = 94.3 \text{ dB}$$

Another possible definition for P_{max} is the output mean power which determine the mean intermodulation power equal to the noise power:

$$P_{\text{int}} = 3P_{\text{max}} - 2IP_3 - 6 = \left(KT_{eq}B\right)_{dBm} + G \;\Rightarrow P_{\text{max}} = \frac{2IP_3 + 6 + \left(KT_{eq}B\right)_{dBm} + G}{3}$$

DR becomes then:

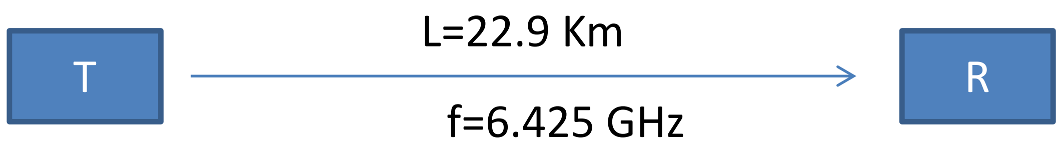
$$DR = P_{\text{max}} - P_{\text{min}} = \frac{2IP_3 + 6 + \left(KT_{eq}B\right)_{dBm} + G}{3} - \left(KT_{eq}B\right)_{dBm} - G - SNR$$

$$= \frac{2}{3}\left(IP_3 - \left(KT_{eq}B\right)_{dBm} - G\right) - SNR + 2$$

For the amplifier of the previous case:

$$DR = \frac{2}{3}\left(30 + 116.3 - 20\right) - 20 + 2 = 66.2 \text{ dB}$$

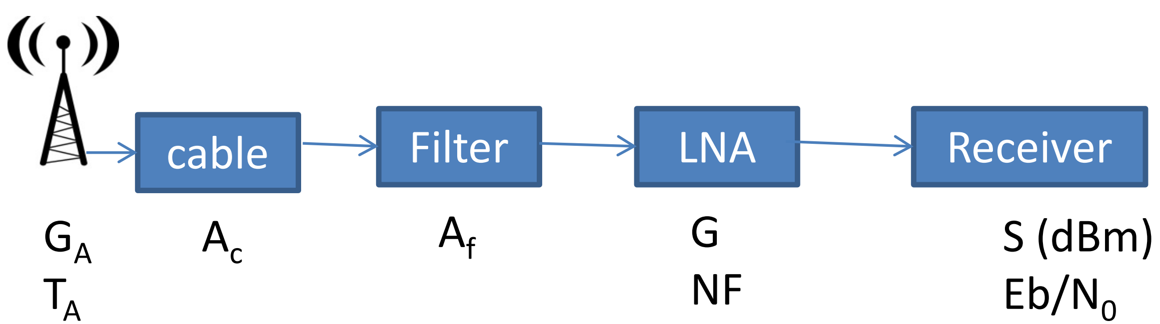
Terrestrial Link



The above link operates with a 64-QAM signal (α=0.2) at R=167.9 Mbit/sec. Transmitting and receiving antennas have the same gain (G_A=38.7 dB).
The link is requested to guarantee operation for 99.9% of time. Taking into account as additional attenuation that produced by meteorological phenomena (rain), it is found out that 10 dB are exceeded for less that 0.01% of time. So 10 dB are added to the free space attenuation:

$$L_f = 20\log\left(\frac{4\pi L}{\lambda}\right) + 10 = 145.8 \text{ dB}$$

The RF front-end at the receiving side is the following:



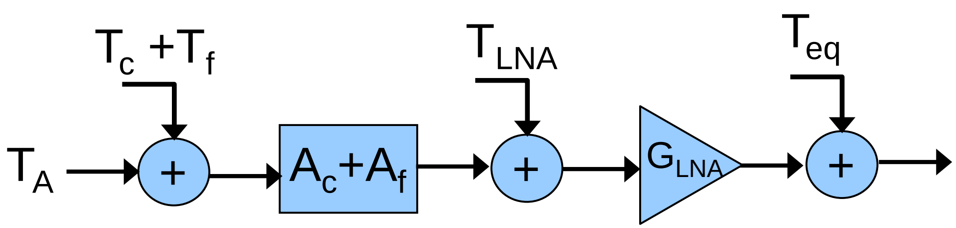
The following parameters are assigned:
Cable attenuation Ac=2 dB. Antenna Gain G=38.7 dB, Antenna noise temp. T_A=150 °K
Filter passband attenuation Af=2 dB
Gain of LNA G=10 dB, Noise figure of LNA NF=2 dB
S represents the minimum signal power (-73 dBm) at the receiver input for a specified Eb/N0 (15 dB).
Compute the value or the transmitted power necessary for satisfying the receiver specs in the worst condition (i.e. maximum link attenuation)-

The bandwidth B of the 64-QAM signal is given by B=(1+α)R/$\log_2$(64)=33.6 MHz.

Evaluation of the receiver equivalent temperature T_{rec} and SNR_{rec} :

$$SNR_{rec} = \frac{S}{KT_{eq}B} = \frac{E}{N_o}\frac{R}{B} = 15 + 7 = 22 \text{ dB}, \quad T_{rec} = \frac{S}{\left(\frac{E}{N_o}\right) R \cdot K} = 683.8 \text{ °K}$$

Evaluation of the system equivalent noise temperature (T_{sys}):



$$A_c + A_f = 10^{0.4} = 2.511$$

$$T_c + T_f = 293\left(10^{0.4} - 1\right) = 443 \text{ °K}$$

$$T_{LNA} = 293\left(10^{0.2} - 1\right) = 171.4 \text{ °K}$$

T_{sys} is then given by:

$$T_{sys} = \left(T_A + T_c + T_f\right) + \left(A_f + A_c\right)T_{LNA} + T_{rec}\frac{\left(A_f + A_c\right)}{G_{LNA}} = 593 + 438.38 + 171.7 = 1195.1\ °\text{K}$$

In order to get the imposed Eb/N0 at baseband the same SNR or the receiver alone must be verified at the antenna output:

$$SNR = P_r - \left(KT_{sys}B\right)_{dBm} = 22\ \text{dB}\ \Rightarrow P_r = 22 - 92.56 = -70.56\ \text{dBm}$$

P_r is related to the transmitted power by the Friis equation:

$$P_r = P_t - L_f + 2G_A \Rightarrow P_t = P_r + L_f - 2G_A = -70.56 + 145.8 - 77.4 = -2.16\ \text{dBm}$$

It can be noted that the signal power at the receiver (P_{rec}) input is equal to -70.56+7.5 =-63.06 dBm, well above the receiver sensitivity (this level should be possible with only the noise contribution from the receiver)