

POLITECNICO DI MILANO



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DIPARTIMENTO DI ELETTRONICA E INFORMAZIONE

RF Systems

NOTES ON EXERCISES
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Chapter 1

Antennas

1.1 Antennas Parameters

1.1.1 Directive Gain

The power radiated by an antenna depends on the direction. The *directive gain* toward a given direction is expressed as:

$$D(\theta, \phi) = \frac{\text{Radiation Intensity}}{\text{Isotropic Intensity}} = \frac{U(\theta, \phi)}{P_{\text{rad}}/4\pi} \quad (1.1)$$

1.2 Radio Link

1.2.1 Link Budget



Figure 1.1: Simplified scheme of a Radio Link

Supposing to have a Radio Link as in Figure 1.1 between 2 Antennas at a certain relative distance R the link budget may be evaluated by means of the **Friis equation** which at the end leads to a simple analytical expression for the receiving power¹:

$$P_{r|dB} = P_{t|dB} - 10 \log \frac{4\pi R}{\lambda} + G_{t|dB} + G_{r|dB} \quad (1.2)$$

in which:

- $P_{r|dB}$ is the effective power received by the antenna.
- $P_{t|dB}$ is the overall transmitted power of the TX side.

¹which is the logarithmic form of the Friis equation

- $G_{r|dB}$ is the gain of the receiving antenna.
- $G_{t|dB}$ is the gain of the transmitting antenna.

while the term $20 \log \frac{\lambda}{4\pi R}$ stands for the free space losses. Note from a practical point of view there as at least a couple of DoF in the design flow to obtain a certain receiving power.

1.2.2 Attenuators' Noise

In any RF receiver we are going to have at least some losses between the antenna and the LNA. Sometimes also in other sections of the receiver path attenuation couldn't be avoided. We may evaluate the additional noise introduced by an attenuator A_{f1} for example the one in Figure 1.2 as:

$$T_{f1} = T_0(10^{\frac{A_{f1}}{10}} - 1) \quad (1.3)$$

1.2.3 Equivalent Temperature

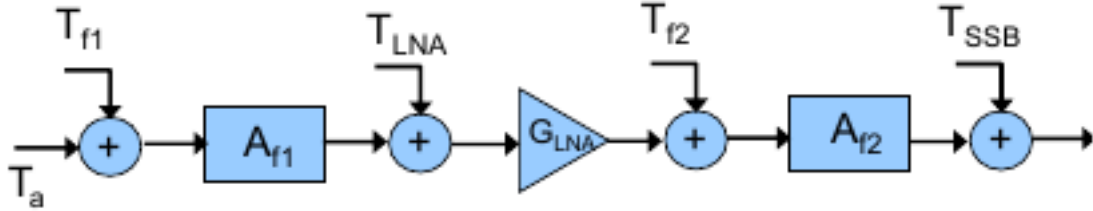


Figure 1.2: General structure of a noisy receiving chain

Supposing to have a receiving chain as in Figure² 1.2 we may want to represent the system with noiseless components and an input referred noise considering all contribution. This could be very useful because using this model the Signal-to-Noise Ratio evaluation turns out to be extremely simple, while we can just compare the receiving power with the overall noise directly at the input port.

To get an $T_{equivalent}$ we have to refer at the input any additional noise by dividing it by the Gain from input to the point where the noise is injected.

At the end for the example in figure we get:

$$T_{sys} = T_{eq} = T_a + T_{f1} + T_{LNA}A_{f1} + T_{f2}\frac{A_{f1}}{G_{LNA}} + T_{SSB}\frac{A_{f1}A_{f2}}{G_{LNA}} \quad (1.4)$$

where:

- T_{f1} is the noise introduced by the first attenuator
- T_{LNA} is the noise introduced by the LNA
- T_{f2} is the noise introduced by the second attenuator

²note that here A_x stands for an attenuation = $\frac{1}{Gain}$ and G stands for a Gain

- T_{SSB} is the noise introduced by the mixer

With the same concept we may find the *Output Referred Noise* T_{out} by simply applying the relative transfer function at each noise to the output:

$$T_{out} = T_a \frac{G_{LNA}}{A_{f1}A_{f2}} + T_{f1} \frac{G_{LNA}}{A_{f1}A_{f2}} + T_{LNA} \frac{G_{LNA}}{A_{f2}} + T_{f2} \frac{1}{A_{f2}} + T_{SSB} \quad (1.5)$$

and to get T_{eq} we may divide T_{out} by the noiseless gain $\frac{G_{LNA}}{A_{f1}A_{f2}}$

$$T_{eq} = \frac{T_{out}}{\frac{G_{LNA}}{A_{f1}A_{f2}}} \quad (1.6)$$

after some algebra it's clear that the two different approaches are absolutely equivalent.

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