

POLITECNICO DI MILANO



FACOLTÀ DI INGEGNERIA  
DEIB

# RF Systems

NOTES ON EXERCISES  
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DRAFT

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# Chapter 1

## Antennas

### 1.1 Radio Link

#### 1.1.1 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 power:

$$P_{r|dB} = P_{t|dB} - 10 \log \frac{\lambda^2}{4\pi R^2} + G_{t|dB} + G_{r|dB} \quad (1.1)$$

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.
- $G_{r|dB}$  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.

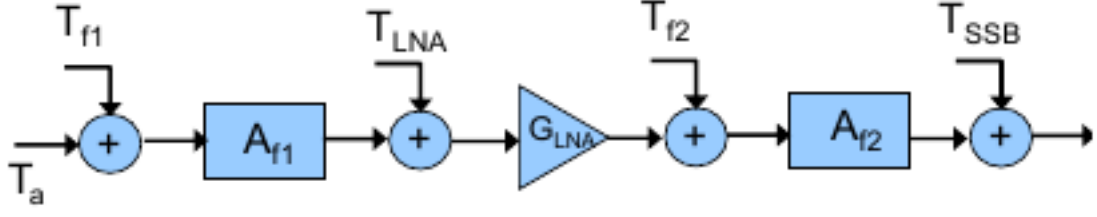


Figure 1.2: General structure of a noisy receiving chain

### 1.1.2 Antennas' Gain

### 1.1.3 Equivalent Temperature

Supposing to have a receiving chain as in Figure<sup>1</sup> 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 the input to the point where the noise is injected.

At the end for the example in figure we get:

$$T_{sys} = T_{eq} = T_a + T_{f1} + T_{LNA} A_{f1} + T_{f2} \frac{A_{f1}}{G_{LNA}} + T_{SSB} \frac{A_{f1} A_{f2}}{G_{LNA}} \quad (1.2)$$

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:

$$T_{out} = T_a \frac{G_{LNA}}{A_{f1} A_{f2}} + T_{f1} \frac{G_{LNA}}{A_{f1} A_{f2}} + T_{LNA} \frac{G_{LNA}}{A_{f2}} + T_{f2} \frac{1}{A_{f2}} + T_{SSB} \quad (1.3)$$

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

$$T_{eq} = \frac{T_{out}}{\frac{G_{LNA}}{A_{f1} A_{f2}}} \quad (1.4)$$

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

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<sup>1</sup>note that here  $A_x$  stands for an attenuation =  $\frac{1}{Gain}$  and G stands for a Gain

## Bibliography

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