1 | Link Budget

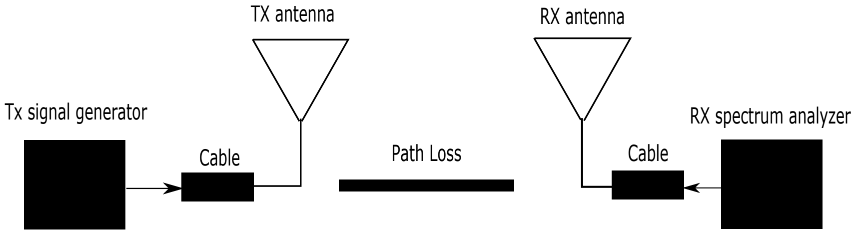

Figure 1.1: Link budget illustration

A link budget is calculated to find the received power for the whole system, based on the transmission power, antenna gains, system loss and path loss.

Such a calculation is given as:

$$P_r = \frac{P_t G_t G_r}{L_p L_{sys}} \tag{1.1}$$

Where:

P_r	Power Received	[W]
P_t	Power transmitted	[W]
G_t	Transmitter antenna gain	[1]
L_p	Path Loss	[1]
L_{sys}	system loss(polarization losses, other losses)	[1]
G_r	Receiver antenna gain	[1]

1.1 Polarization loss factor (PLF)

Polarization loss [Bevelacqua, 2016] plays a factor in the link budget calculation. There is linear polarization and circular polarization. For linear polarization the antenna can be turned horizontal and vertical direction this is illustrated in the following Figure:

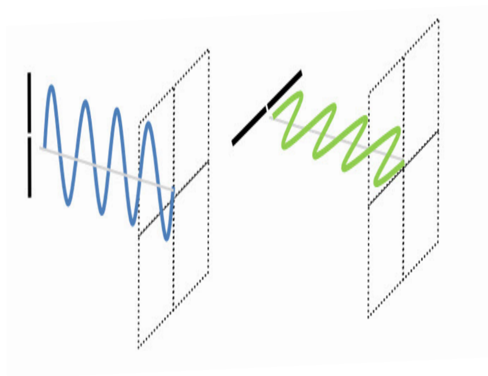

Figure 1.2: Linear horizontal and vertical polarization [Rodrigo, 2010]

The PLF for linear polarized antennas can be calculated by the equations given on the following Figure depending on the angle of the the antennas, an illustration of the PLF for max, non and signal loss with dependence on an angle:

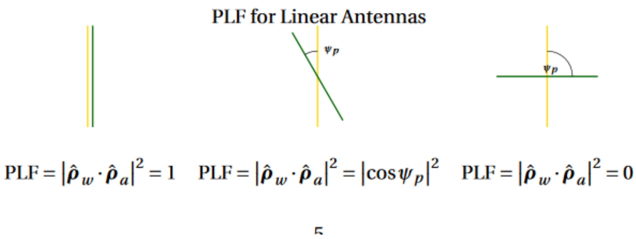

Figure 1.3: Minimum, PLF loss depending on the angle and maximum [Rodrigo, 2010]

As it can be seen if the two antennas are pointing directly at each other with the same polarization there will be no PLF. While if one antenna is vertically polarized and the other is horizontally polarized, then no power will be transferred. While there will be some power loss if the two antennas are not 100% aligned, meaning there is an polarization miss match ,there will be some power loss depending on the angle.

1.1.1 PLF loss calculated

For the measurements conducted the PLF factor is calculated with an angle ψ of 5°, as a margin for the two antennas alignment, this gives the following PLF loss factor:

$$cos(\psi)^2 = cos(5)^2 = 0.9962 \tag{1.2}$$

Then to get it in dB:

$$10 \cdot log(0.9962) = -0.0381dB \tag{1.3}$$

1.2 Cable Loss

As a part of the link budget cable loss is also included. The cable loss is depended on the length of the cable, where the longer the cable the more cable loss there will be as the signal will lose strength travelling through the cable. Where for each cable it is indicated in the data sheet how much power is lost per meter at different frequencies, this is different for each type of cable.

1.2.1 Calculated cable loss

Two different types of cables were used these are:

- rg223/u
- SUCOFLEX_104

The length for the rg223/u [pasternack, 2016] cable is of 1m, while for the SUCOFLEX_104 cable [Elektronik, 2016], two SUCOFLEX_104 cables where used with different lengths of 1.5m and 2.5m.

The cable loss for the rg223/u cable is read from the data sheet then interpolated, from the data sheet it is given that the attenuation factor is given in dB per 100 meters.

In the data sheet it can be read that for 1000MHz a loss of 13.4dB per 100 m, while for 3 GHz it is 24.8dB per 100 m. There has been made an interpolation of the attenuation factors, so that a more precise attenuation factor can be calculated so for 2.58 GHz and 856 MHz the following attenuation factors have been calculated, for 1 m:

$$Attenuationfactor\_2.58 = \frac{22.4}{100} = 0.224dB \tag{1.4}$$

$$Attenuationfactor\_858 = \frac{12.7}{100} = 0.127dB \tag{1.5}$$

While for the SUCOFLEX_104 cable the following formula has been used to calculate the attenuation factor, for both 1.5m and 2.20m:

$$a_{25} = a \cdot \sqrt{f(Ghz)} + b \cdot f(Ghz) \quad [db/m] \tag{1.6}$$

Where:

a	Nom.attenuation = 0.2291	[-]
b	Nom.attenuation = 0.0071	[-]

The attenuation factor for 858 MHz is equal to 0.327 dB while for 2.58 GHz it is 0.579dB for 1.5m. While for 2.20m the attenuation factor for 858 MHz is equal to 0.480 dB, while for 2.58 GHz it is 0.850 dB. In the following an Table of the cable loss can be seen:

Table 1.1: Cable loss table

	Mono	Mono	Patch	Patch	Demo board
Cable loss: rg223_u	-0.224dB	-0.127dB	-0.224dB	-0.127dB	-
Cable loss: SUCOFLEX_104 (1.5m)	-0.579dB	-0.327dB	-0.579dB	-0.327dB	-
Cable loss: SUCOFLEX_104 (2.5m)	-0.850dB	-0.480dB	-0.850dB	-0.480dB	-
Cable loss: Demoboard		-	-	-	-2dB
Total Loss	-1.6530dB		-1.6530dB	-0.9340dB	-2dB

1.3 LOS, nLOS and NLOS

Other factors to consider when calculating a link budget is if there is Line-Of-Sight(LOS) [l com, 2010]. LOS is when there is no obstacle blocking the signal between the transmitter and receiver antenna. This is illustrated on the following Figure:

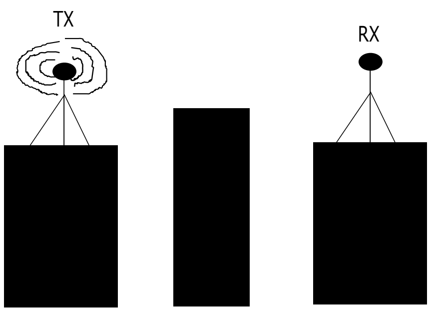

Figure 1.4: LOS illustration

Where the counter-part is Non-Line-Of-Sight(NLOS)[l com, 2010], which means that the path is interfered, which could be by a building standing in-between the transmitter antenna and the receiver antenna, where the two antennas cannot see each other, this is illustrated on the following Figure:

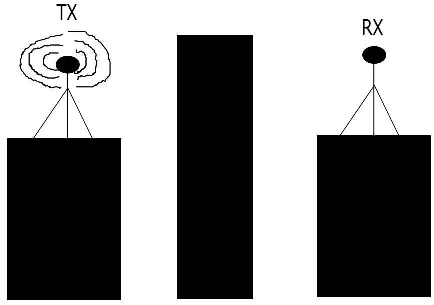

Figure 1.5: NLOS illustration

Another one is Near Line Of Sight(nLOS) [l com, 2010], which means that the path is partially interfered, which could be by a building. Which is illustrated on the following Figure:

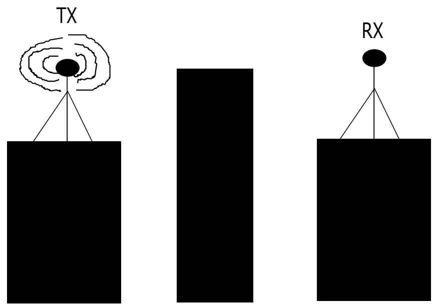

Figure 1.6: nLOS illustration

The different line-of-sights, play a big factor when considering the Fresnel Zones which is further explained in worksheet Fresnel Zones, which also plays a big part in the received Power. As explained in the Fresnel Zone chapter there must be 60% clearance in the first Fresnel zone, as the strongest signals are in the first Fresnel zone ,this could be a problem if there is too much NLOS, as the antennas would need to be risen higher.

Bibliography

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