# MCC125 Wireless link project
# Link Budget

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# 1 Introduction

This document describes the link budget for the project in which we implement a one-way wireless communication system that can communicate over 100 meter.

The parameters we selected for the system are illustrated in Table 1

Table 1: Parameters selected for the system

| Seq | Item | Value |
|---|---|---|
| 1 | RF Frequency | 2.4 GHz |
| 2 | IF frequency | 20 MHz |
| 3 | Target Bitrate $R_b$ | 10 Mbits/s |
| 4 | Modulation Format | 64-QAM |
| 5 | Modulation Order m | 6 |
| 6 | Symbol Rate $R_s$ | 1.67 MBaud/s |
| 7 | Bandwidth | 1.67 MHz |
| 8 | Distance | 100 m |

# 2 System Overview

By choosing a desired BER of $10^{-6}$, we get a $\frac{E_b}{N_0}$, for our chosen modulation, from the graph shown in Figure 1.

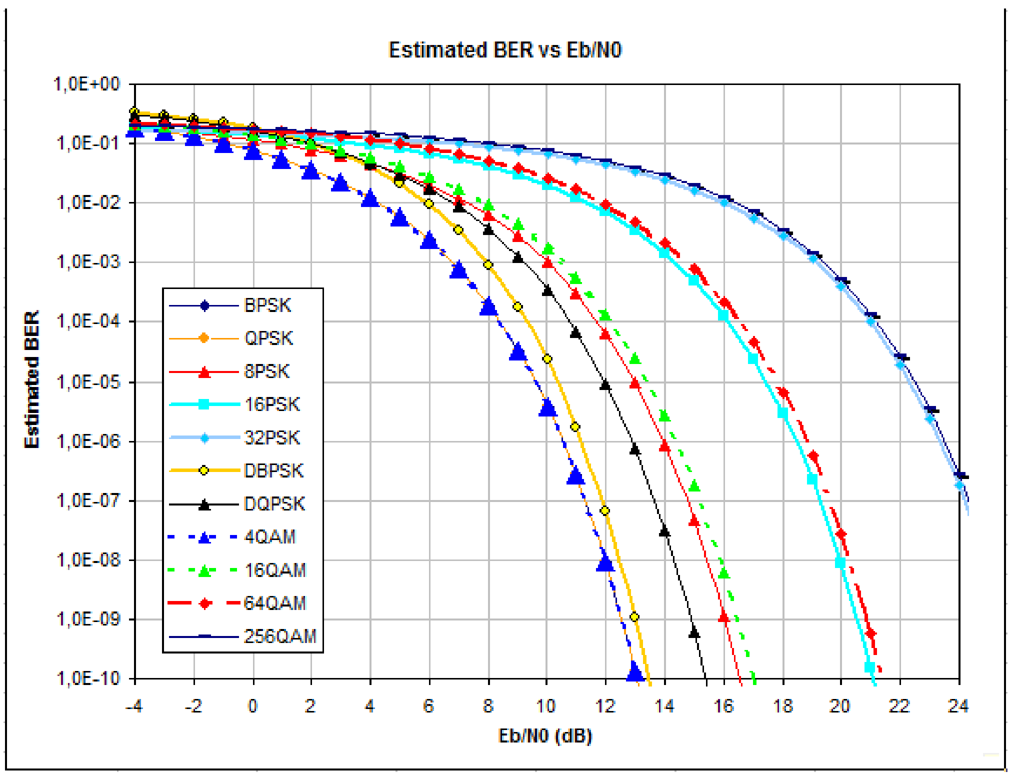


Figure 1: Estimated BER vs $E_b/N_0$ [1].

We can read that we have a $E_b/N_0 = 18.8\,\text{dB}$ when we use 64-QAM with a BER of $10^{-6}$. With this, the required minimum SNR at the receiver is given by, with a $R_b/B = 10\,\text{Mbps}/1.67\,\text{MHz} = 6$, the following equation [2]:

$$SNR_{In} = 10log_{10}(\frac{E_b}{N_0} \cdot \frac{R_b}{B}) = 10log_{10}(\frac{E_b}{N_0} \cdot 6) = 26.78\,\text{dB}$$

## 2.1 Receiver Details

The block diagram of the receiver are illustrated in Figure 2.

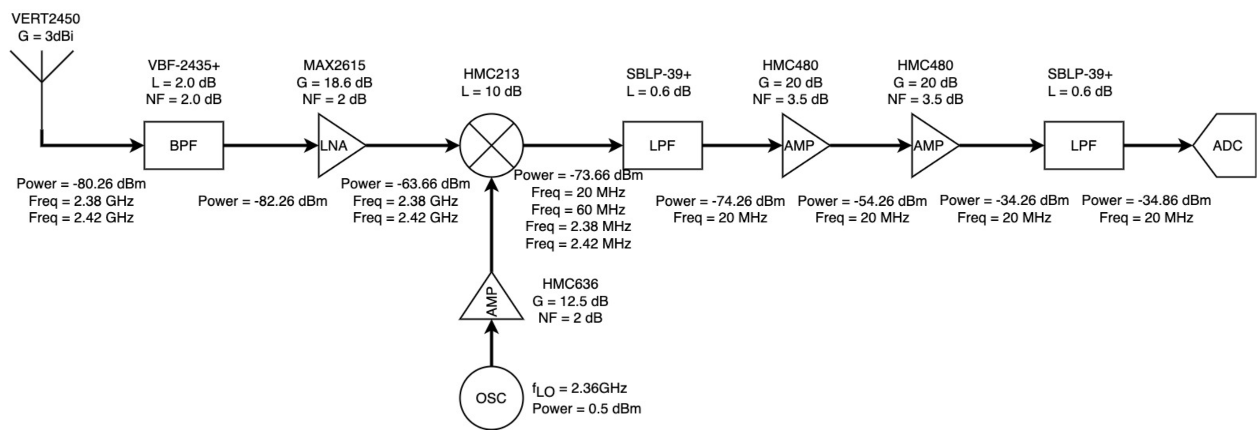


Figure 2: Receiver Block Diagram

From the block diagram shown in Figure 2, we can calculate the noise figure as:

$$NF_{tot} = 10log_{10}(NF_1 + \frac{NF_2 - 1}{G_1} + \frac{NF_3 - 1}{G_1 G_2} + \cdots) = 4.74\,\text{dB}$$

## 2.2 Link Budget Calculation

We can calculate the noise power from the following equation:

$$P_n = -174 + 10log_{10}(BW) + NF_{tot} = -107.04\,\text{dBm}$$

Where -174 is the Boltzmann constant in dBm/Hz. The $SNR_{in}$ is the ratio between the received signal power and the noise power, hence the receiver sensitivity is given by:

$$P_r = P_n + SNR = -80.26\,\text{dBm}$$

With a frequency of 2.4 GHz and a distance of 100 m the free space loss can be calculated by the following equation:

$$FSPL = 20 \cdot log_{10}(\frac{c}{4\pi \cdot d \cdot f}) = 20 \times log_{10}(\frac{3 \times 10^8}{4\pi \times 100 \times 2.4 \times 10^9}) = -80\ dB$$

The minimum required transmitted power in ideal circumstances can be calculated by Friis formula:

$$P_t = P_r - FSPL - G_t - G_r = -6.21\,\text{dBm}$$

## 2.3 Transmitter Details

The block diagram of the transmitter can be seen in Figure 3.

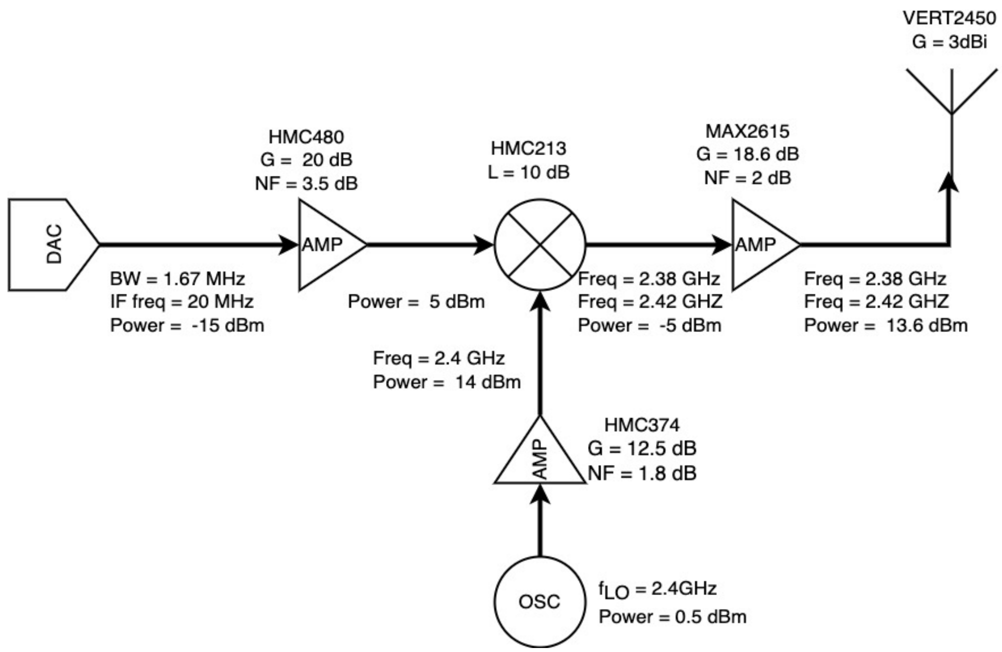


Figure 3: Transmitter Block Diagram

| Seq | Component | Device | Input power (dBm) | Gain/Loss (dB) | Output power (dBm) | 1-dB compression (dBm) |
|---|---|---|---|---|---|---|
| 1 | DAC | USRP N210 | - | - | -15 | - |
| 2 | Amplifier | HMC480 | -15 | 20 | 5 | 20 |
| 3 | Mixer | HMC213 | 5 | -10 | -5 | 8 |
| 4 | Amplifier | MAX2615 | -5 | 18.6 | 13.6 | 19.5 |
| 5 | Antenna | VERT2450 | 13.6 | 3 dBi | 16.6 | |

Table 2: Detailed input and output power of the transmitter

The 1-dB compression point of the transmitter is given by,

$$P_{1dB,tot} = 10log_{10}[(\cdots + \frac{1}{P_{1dB,n-2}G_{n-1}G_n} + \frac{1}{P_{1dB,n-1}G_n} + \frac{1}{P_{1dB,n}})^{-1}] = 18.3\ dBm$$

Our designed transmitter power is 13.6 $dBm$, which is within the safe range of the minimum required transmitted power of $-6.21$ dBm.

# References


[1] Unknown (2023) - "Eb/N0". Retrieved from:
https://www.linuxtv.org/wiki/index.php/Eb/N0 [Online resorce]

[2] Vessen Vassilev (2023) - "Introduction". Retrieved from: https://chalmers.instructure.com/courses/26387/files/3001161?module_item_id=420200 [Lecture]

## A MATLAB code

```
clc, clf, clear all;
c=3e8;
f=2.4e9;
R=100;

Ebn0=19; %dB for 64QAM at e-6 BER
Rb=10e6; %bit/s
M=64;

m=log2(M); %modulation order for 64QAM
B=Rb/m;

SNRin=Ebn0+10*log10(m)

G1=-2;
F1=2;
G2=18.6;
F2=2;
G3=-10;
F3=10;
F4=0.6;
G4=0.6;
F5=3.5;
G5=20;
F6=3.5;
G6=20;

Frx=10*log10(10^(F1/10)+((10^(F2/10)-1)/10^(G1/10))+((10^(F3/10)
    -1)/(10^((G1+G2)/10)))+((10^(F4/10)-1)/(10^((G1+G2+G3)/10)))
    +((10^(F5/10)-1)/(10^((G1+G2+G3+G4)/10)))+((10^(F5/10)-1)/(10^((
    G1+G2+G3+G4+G5)/10))))

Pn=-174+10*log10(B)+Frx
Pr=SNRin+Pn

Lfs=10*log10((c/(4*pi*R*f))^2)

Gr=3; %dBi
Gt=3; %dBi
Pt=Pr-Lfs-Gt-Gr
```