MCC125 Wireless link project
Link Budget
Microwave Surfers Group

Bingcheng Chen
Filip Aldebrink
Geo Philip Muppathiyil
Jiquan Mao
Malik Fahd

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Chalmers University of Technology
Wireless link project MCC125

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.
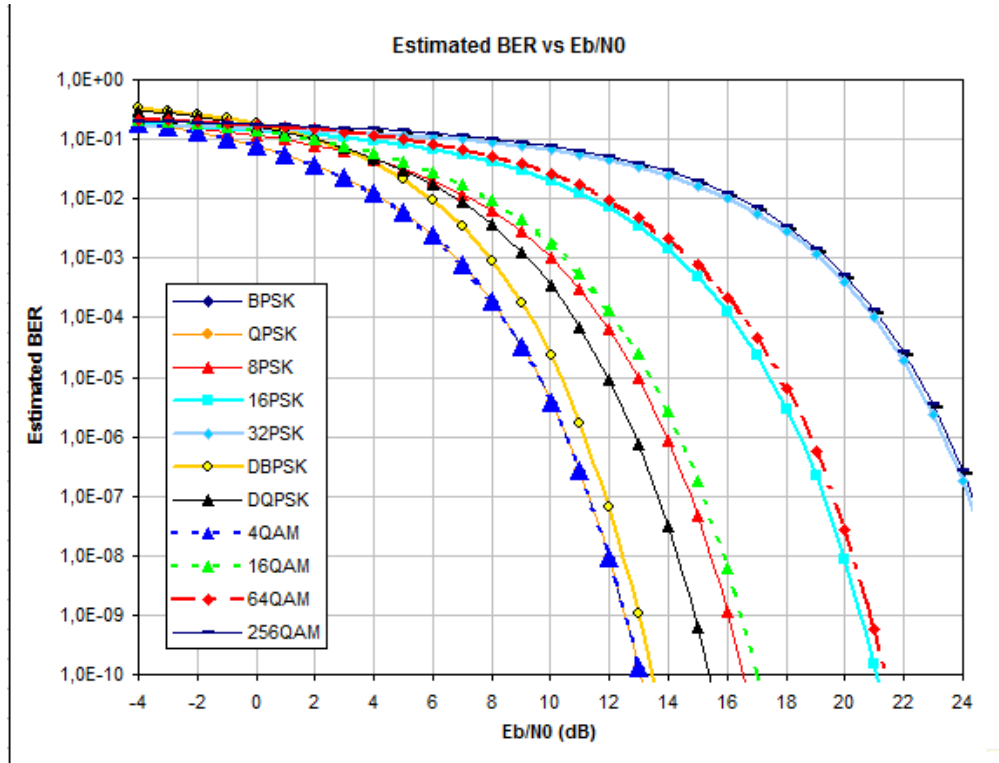

Figure 1: Estimated BER vs E_b/N_0 [1].

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

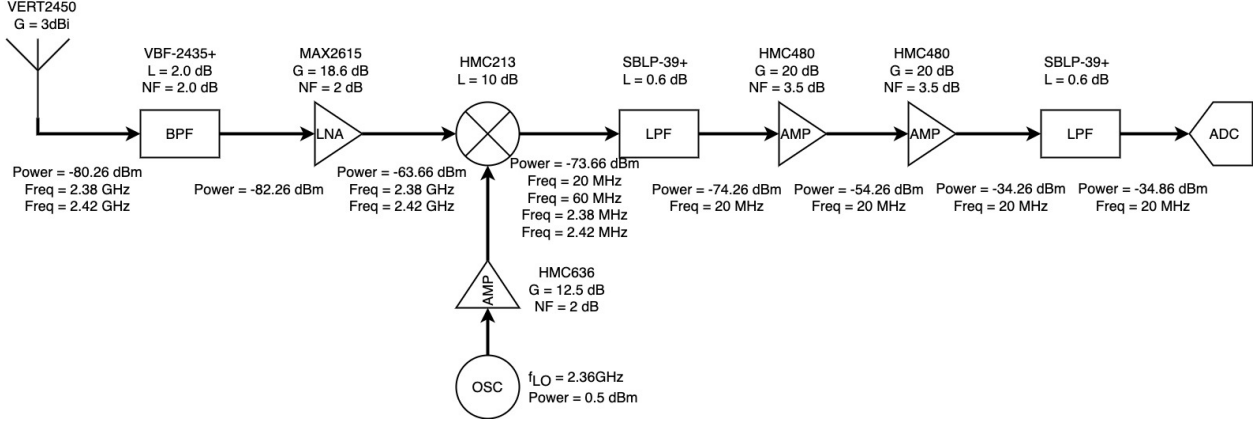The block diagram of the receiver are illustrated in Figure 2.

Figure 2: Receiver Block Diagram

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

$$NF_{tot} = 10log_{10}(NF_1 + \frac{NF_2 - 1}{G_1} + \frac{NF_3 - 1}{G_1G_2} + \cdots) = 4.74\,\text{dB}$$

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 $2.4\,\text{GHz}$ and a distance of $100\,\text{m}$ 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:

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

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2.3 Transmitter Details

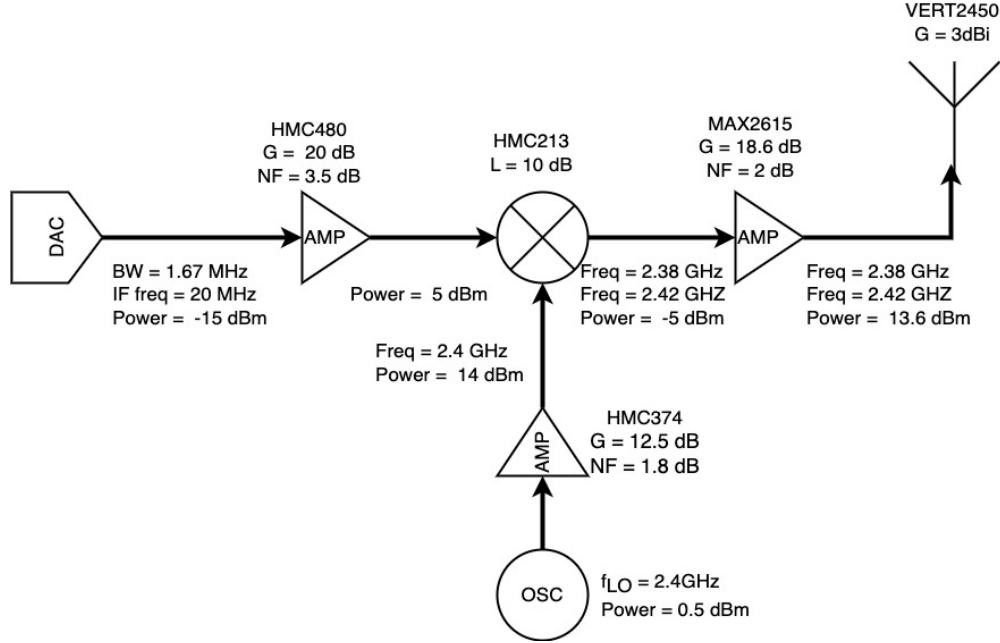The block diagram of the transmitter can be seen in Figure 3.

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,

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

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

```matlab
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
```