Link Budget Calculation: Wireless Link Project

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1 Introduction

In the course Wireless link project (MCC125) the task is to design and construct a wireless communication system that can communicate over 100 m. This document explains the link budget for the project.

2 Design

The system is designed to operate at QPSK and 16-QAM. Assuming a maximum $BER = 10^{-5}$ which requires a $SNR = 24.7$ dB for QPSK and a $SNR = 28.5$ dB for 16-QAM respectively. The transmitted message is a text message using a bit rate of 80 Kbps. The sampling rate is 1562500 Hz and the bandwidth is 28 KHz for QPSK and 14 KHz when using 16-QAM.

2.1 Hardware Design

The transmitter is designed as shown in the figure 1.
The specifications of the transmitter elements @2.4 GHz@+25C are shown in the table 1. The calculated gain delivered by the transmitter is 25 dB with an output power of 22 dBm.

Table 1: Transmitter Block Elements

Elements	**Input Power (dBm)**	**Output Power (dBm)**	**Gain (dB)**	**Noise Figure (dB)**	**Input P1dB (dBm)**
USRP Transm (N210)	-	-2.8	-	-	-
Power Amplifier -1: (HMC347)	-2.8	7.2	10	3	8
Mixer: (HMC213 RF)	7.2	-2.6	-9.8	5	9
Power Amplifier - 2: (HMC347)	-2.6	7.4	10	3	8
Power Amplifier - 3: (HMC636ST89E)	7.4	19.4	12	3	22
Antenna (VERT2450)	19.4	22.4	3	-	-

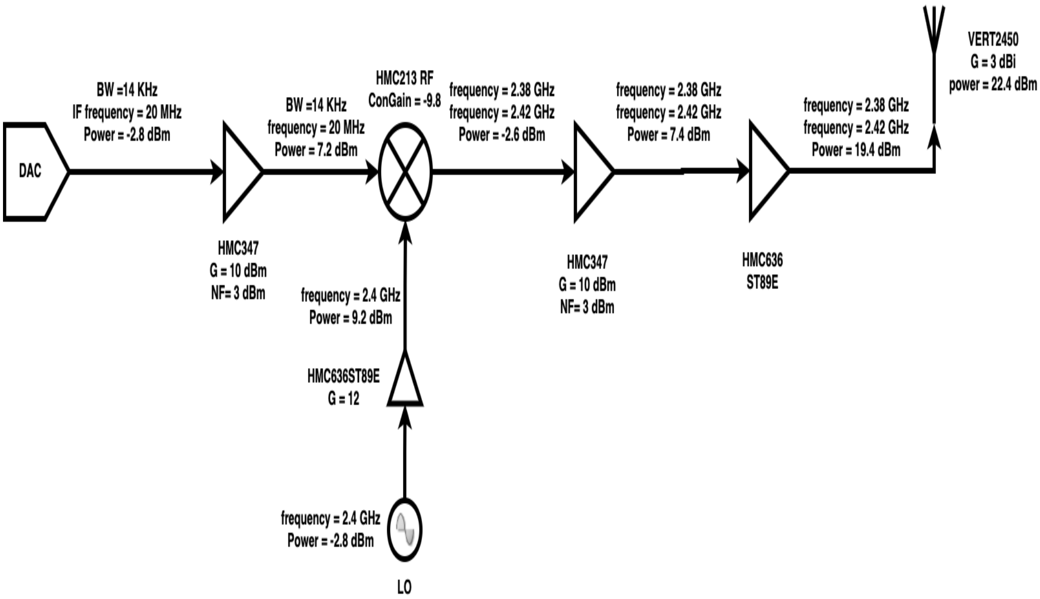

Figure 1: Transmitter Block Diagram

The specifications of the Receiver elements @2.4 GHz@+25C are shown in the table 2.

Table 2: Receiver Block Elements

Elements	**Input Power (dBm)**	**Output Power (dBm)**	**Gain (dB)**	**Noise figure (dB)**
Antenna VERT2450	-57.6	-54.6	3	-
Bandpass filter: VBF2435+	-54.6	-56.5	-1.9	-
Low Noise Amplifier: HMC374E	-56.5	-46.5	10	1.5
Mixer HMC213 IF	-46.5	-56.5	-10	5
Power Amplifier HMC480	-56.5	-41.5	15	3
Power Amplifier HMC480	-41.5	-26.5	15	3
Low-pass Filter SBLP-39+	-26.5	-28.5	-2	2

The receiver is designed as shown in the figure 2. The noise figure of receiver is 7 dB with a total gain of 29 dB.

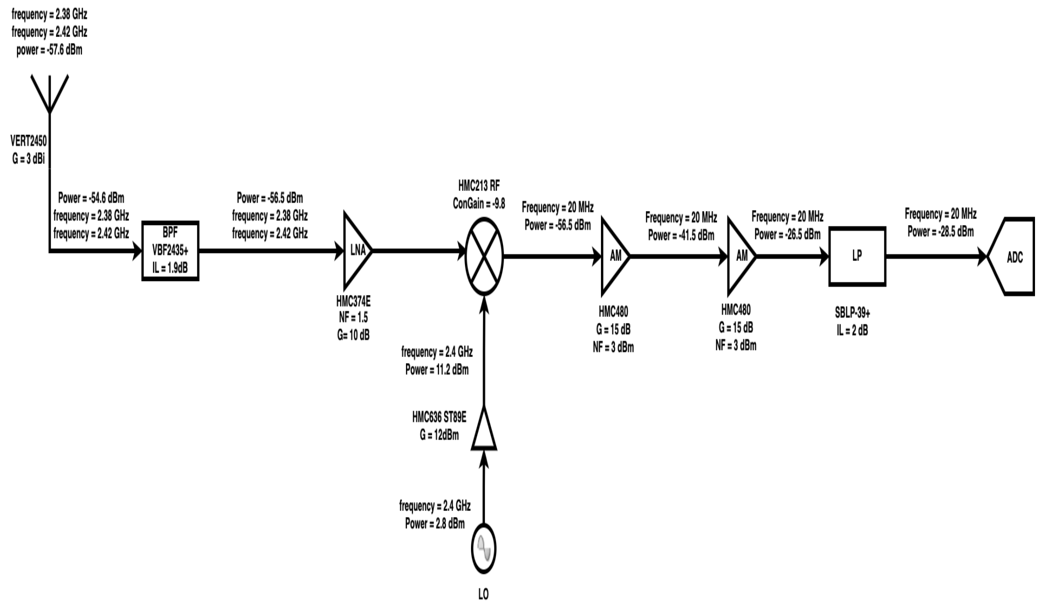

Figure 2: Receiver Block Diagram

3 Frequency

The frequency of the local oscillator (F_{lo}) is set to 2.4 GHz. The intermediate frequency (F_{IF}) is set to 20 MHz. The transmitted frequency can be calculated as Eq.(1).

$$F_{RF} = F_{lo} \pm F_{IF} \tag{1}$$

Hence, the $F_{RF} = 2.4 \pm 0.02$.

4 Total NF of the receiver

The noise floor of the receiver is calculated to be 7 dB. The system input thermal noise depends on the antenna temperature which can be calculated from Eq.(2).

$$T_a = e_r \times T_b + (1 - e_r) \times T_p \tag{2}$$

The equation gives an antenna temperature of 31.7 K and a system bandwidth of 20MHz where the input noise power is calculated as -111 dBm. From the receiver gain and noise figure above, we get the output thermal noise from Eq.(3).

$$\begin{aligned} N_0 &= N_i \times G \times F \\ N_0(dBm) &= -111 + 7 + 29 \\ &= -75dBm \end{aligned} \tag{3}$$

This is lower than the USRP's noise floor of -70 dBm. Therefore, we can consider the the USRP noise which is dominating the system and neglect the thermal noise. So, for the best case the SNR at the receiver output is:

$$\begin{aligned} SNR &= Signal \quad power - N_0 \\ SNR_{16-QAM} &= -28.5 + 70 \\ SNR_{16-QAM} &= 41.5dB \end{aligned} \tag{4}$$

The margin for the SNR can be calculated with the system margin to be SNR-SNR$_{req(16-QAM)}$, so the margin for the SNR = 41.5 - 28 = 13.5dB.

5 Receiver sensitivity and transmit power

The receiver sensitivity is measured to be -70 dB with a noise floor of -97 dB and a power from the USRP = -2.8 dBm. The LO Power is measured in the lab as -3.8 dBm at it's lowest and 4.8 dBm at it's highest.