1 Introduction

1.1 Background

It is undeniable that in the last two decades modern wireless devices have become extremely ubiquitous, and are no longer employed under carefully chosen conditions.

Nowadays smart phones and internet of things (IoT) devices are carried around by everyone and have to work in environments that are very far from ideal. Furthermore, next generation wireless devices in urban environments will also include vehicles (cars, buses and trains)[1], where reliability of intra-vehicular communication directly translates into safety. Whereas in rural regions, developing countries as well as other low-user density areas wireless transmission links using mesh networks have become a practical alternative to wired broadband[2]–[4].

All of the mentioned cases have a common problem caused by *the fading effect*, which degrade the reliability of the link[5]. This was foreseen[6], [7] and today most modern transmission schemes implement measures to reduce the effects fading[5], [8].

1.2 Task description

As described in the document given at the beginning of the semester:

> The goal is to develop a SDR-based demonstrator, consisting of one transmitter and one receiver, to illustrate the impact of different fading effects on the signal. To get a brief understanding of the concept of fading channels, the project should be started with a literature research followed by simulation of different scenarios, which then can be reproduced by measurements.

The task description document is found in the appendix.

1.3 Overview

2 Theory

In this section we will briefly give the mathematical background required by the modulation schemes used in the project. The notation used is summarised in figure 2.1. For conciseness encoding schemes and (digital) signal processing calculations are left out and discussed later. Thus for this section $m_e = m$.

2.1 Quadrature amplitude modulation

Quadrature amplitude modulation is a family of modern digital modulation methods, that use an analog carrier signal. The simple yet effective idea behind QAM is to encode extra information into an orthogonal carrier signal, thus increasing the number of bits sent per unit of time. A diagram showing the process is found in figure **??**.

Bit splitter As mentioned earlier, quadrature modulation allows sending more than one bit per unit time. The first step to do it is to use a so called bit splitter, that takes 2 chunks of $\sqrt{M}$ bits from the continuous data stream $m(n)$. The two bit vectors of length $\sqrt{M}$, denoted with $\mathbf{m}_i$ and $\mathbf{m}_q$ are called in-phase and quadrature component respectively. The reason will become more clear later.

Binary to level converter Both bit vectors $\mathbf{m}_i, \mathbf{m}_q \in \{0, 1\}^{\sqrt{M}}$ are sent through a binary to level converter. It's purpose is to reinterpret the bit vector as a number, usually in gray code, and to convert them into an analog amplitude levels, which we will denote with $m_i(t)$ and $m_q(t)$. So at this point the analog amplitude level is already encoding $\sqrt{M}$ bits per unit time. But it is possible to improve further.

Mixer Having analog level signals, it is this now possible to mix them with a high frequency carrier. The two component $m_i(t)$ and $m_q(t)$ are mixed with two different periodic signals $\phi_i(t)$ and $\phi_q(t)$ that have the same frequency ω_c. Now the clever part, the carrier functions are picked to be *orthogonal* to each other, mathematically expressed as

$$\langle \phi_i | \phi_q \rangle = \int_T \phi_i^* \phi_q \, dt = 0, \tag{2.1}$$

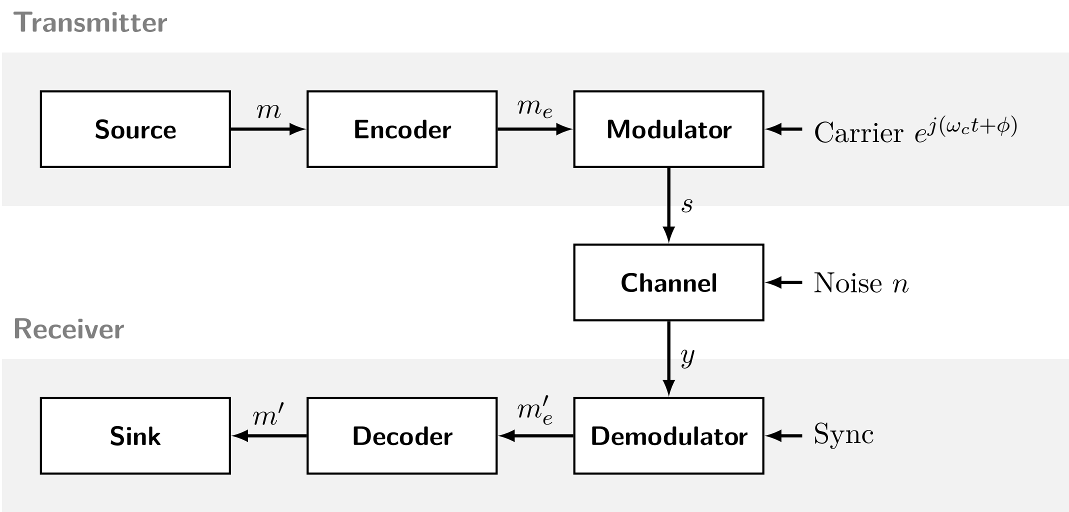

Figure 2.1: Block diagram for a general wireless communication system with annotated signal names. Frequency domain representations of signals use the uppercase symbol of their respective time domain name.

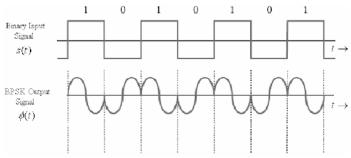

Figure – 2. Input Signal and BPSK Output

i.e. their inner product is zero.

$$s(t) = m_i \cdot \phi_i + m_q \cdot \phi_q, \tag{2.2}$$

without any issue.

2.1.1 Phase Shift Keying (PSK)

PSK is a popular modulation type for data transmission[9]. With a bipolar binary signal, the amplitude remains constant and only the phase will be changed with phase jumps of 180 degrees, which can be seen as a multiplication of the carrier signal with ± 1. That is alow known as binary phase shift keying.

2.1.2 Quadrature Phase Shift Keying (QPSK)

Two bits are modulated at ones with the same bandwidth as a 2-PSK so more informations are transmitted at the same time. [9] Most times there is noise and the points on the constellation diagram become a surface. If the surfaces overlap there will be a problem with decoding.

2.2 Fading

2.2.1 Geometric Model

2.2.2 Statistical Model

Continuous time model Continuous time small scale fading channel response.

time varying channel impulse response:

$$h(t, \tau) = \sum_k c_k(t)\delta(\tau - \tau_k(t)) \tag{2.3}$$

received signal $y = h * x$, i.e. convolution with channel model.

2.2.3 Time discretization of the model

Assume x is a time discrete signal with and bandwidth W, thus the pulse is sinc shaped

$$x(t) = \sum_n x[n] \operatorname{sinc}(t/T - n) \tag{2.4}$$

Ideal sampling at rate $2W$ of y gives

3 Implementation

3.1 Simulaton

For

3.2 Hardware

USRP B210 RF frequencies from 70MHz to 6GHz Bandwidth 200kHz-56MHz

3.3 Measurements

3.4 Results

4 Conclusions

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