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Chapter 2

Channel model

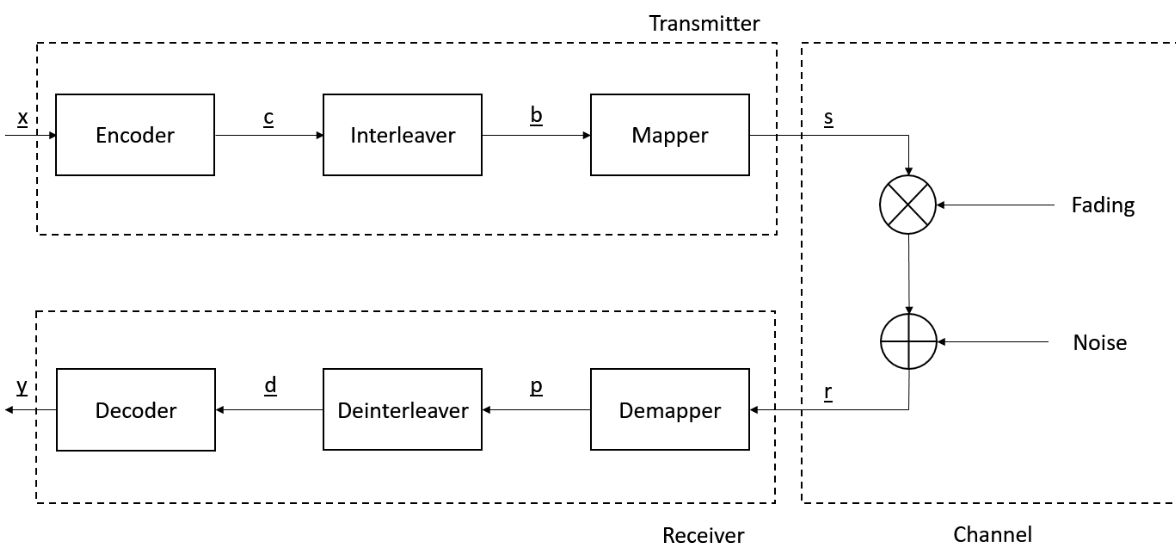

Figure 2.1: Channel model for general Transmitter/Receiver Chain

First, a short introduction of the system for all simulations will be given (Fig. 2.1). A few crucial parts of channel blocks are needed for every communication link and a few blocks are added for improvement in performance. All the blocks were chosen in direct benefit to a LDPC transmission of code words to make the simulations as simple and efficient as possible. The link is built up of three main blocks: The transmitter, the channel and the receiver. With the transmitter handling the creation of the random code words, coding with low-density parity check (LDPC) and mapping in different modulation schemes. The channel will simulate any incoming and existing noise, e.g., additive white Gaussian noise (AWGN). In the end the receiver will demap and decode our transmitted symbols and

compare the decoded bit stream with the initially created code word.
The single channel blocks will be explained shortly in the following sections.

2.1 Encoder/Decoder

There are many ways to make our transmission more stable and less error prone. A major role in this protection plays the encoder and its counterpart the decoder. Encoder/decoder come in many different forms taking form in hardware coder and also as software coder. They reach from simple linear block codes to more complex convolutional coding to the latest turbo codes. It is also important to note, that codes working well in an AWGN-channel will often not have the same performance in a fading channel. A further look will be taken into LDPC codes and the based on these, the WiMax code according to the standard IEEE 802.16e. **citation**. While LDPC was mainly ignored in the past, in the 1990's the introduction of turbo codes and an sharp increase in computing power helped the recognition of these forms of decoding.
LDPC-codes are linear block codes with a particular structure for their parity check matrix **[H]**. In the case of LDPC-codes **H** has a small amount of nonzero entries, which means that there is a low density in the parity check matrix. Another important difference in LDPC to turbo codes is the complexity of encoding and decoding. While turbo codes have low complexity in encoding they have high complexity in decoding. The total opposite can be said about LDPC with high complexity in encoding and low complexity in decoding. Another advantage of LDPC is the ability of self-correction after decoding with the help of the decoding algorithm and the parity check matrix.
WiMax IEEE 802.16e is a standard code model used in small and medium distances in urban areas, which fits the simulations quite well. With WiMax there are different given block sizes ranging from 576 code words up to 2304 code words. The code rates are also set, which are the following: 1/2, 2/3, 3/4, and 5/6. While there are also two different classes of encoding (A/B), only encoding class A will be used in this setup.

2.2 Bit interleave/Deinterleaver

While the above mentioned coder LDPC (Chapter 2.1) works really well for an AWGN channel this is not always the case in a fading channel. This is where the next important channel block comes into play. To guarantee a stable performance the method of interleaving will be introduced. Interleaving will handle a major problem in fading channels, the appearance of burst errors mainly caused by deep fading over a set time. While LDPC has the ability to correct single code errors it is usually not able to correct a stream of errors. With the interleaver the code word will be shuffled into a new random Gaussian distributed code word, which will be passed through our channel. At the receiver a restoration of the shuffled code word back into its initial state will take place.

Initial code word:	aaaabbbbccccddddeeeeffffgggg
Transmission with burst error:	aaaabbbccc_____deeeeffffgggg
Interleaved code word:	abcdefgabcdefgabcdefgabcdefg
Trans. with burst error:	abcdefgabcd____bcdefgabcdefg
Return into initial state:	aa_abbbbccccdddde_eef_ffg_gg

Figure 2.2: Example for interleaving

As clearly seen in figure 2.2 the interleaver will not remove any errors but will prevent or at least mitigate the presence of burst errors. The LDPC algorithm can correct single errors again. There are two main methods of interleaving today: symbol-interleaved coded modulation (SICM) will interleave our symbols after the modulator while bit-interleaved coded modulation (BICM) will interleave the single bits before the modulator, with BICM being the more dominant one of these two methods. BICM will also be used for this thesis for its more dominant position in practical communication systems. **cite**

2.3 Mapper/Demapper

In the mapper, also called modulator, it is possible to compress the code word into a set sequence of symbols. Group of bits are taken from the bit stream to combine them to specific constellation points. The symbols are located in a real/imaginary plane, also called Inphase/Quadrature Planes (I/Q-Planes). With the distance from the nullpoint of the axis giving the magnitude of the signal and the angle to the real axis the phase shift. There are many forms of modulation schemes, with the most common ones being M-phase shift keying (PSK), M-frequency shift keying (FSK), M-amplitude modulation (AM) and M-quadrature amplitude modulation (QAM). For the simulation, a further look will be taken at quadrature phase shift keying (QPSK), 16-QAM and 64-QAM, which are depicted below (Fig. 3.1). All three modulations share the common fact of being differential, which means that the symbols are located in both the real and imaginary plane. One important aspect of differential modulation is the requirement of coherent demodulation, which means that the transmitter and receiver must have matched phase φ. In the simulation it will be assumed that perfect phase match is guaranteed between those two. If not, a phase recovery has to be done.

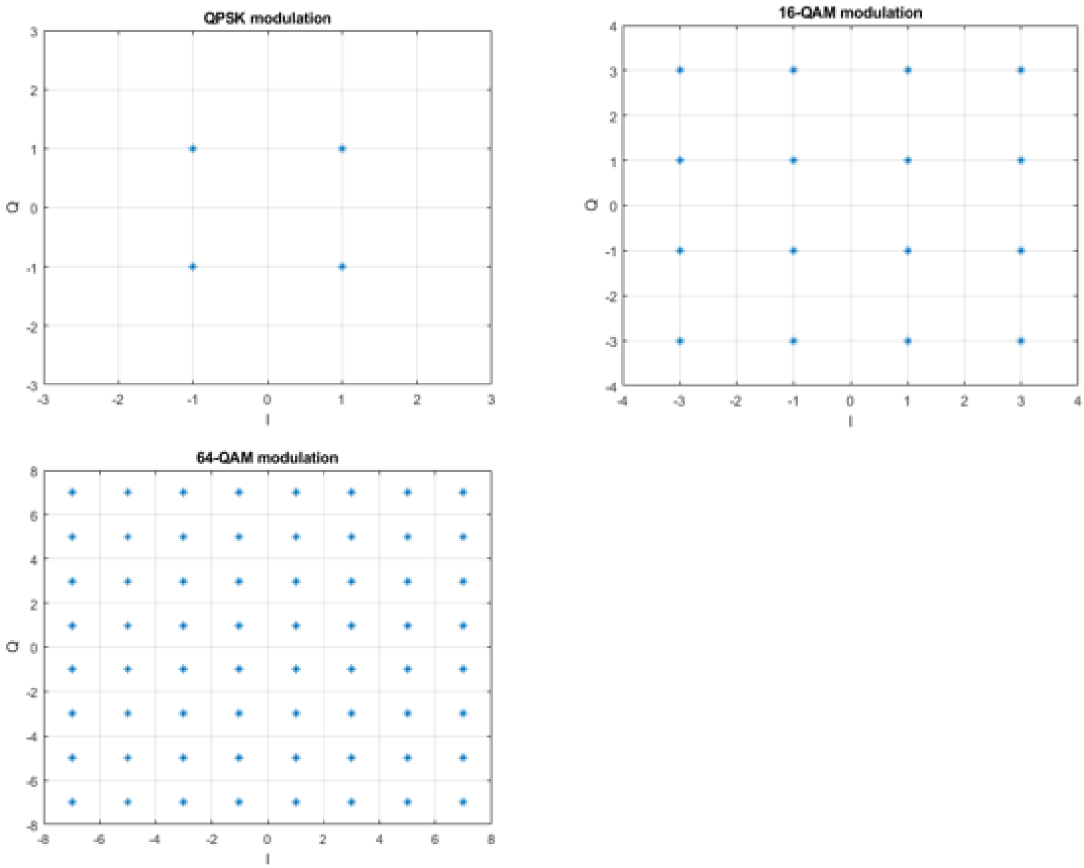

Figure 2.3: Modulation in I/Q planes for QPSK, 16-QAM and 64-QAM

With QPSK the symbols all share the same amplitude and only differ in their respective phase angle. With the information entropy $S = log_2(M)$**cite** the maximum number of bits can be identified which are assigned in every symbol, with M being the number of symbols in the modulation scheme. Therefore, for QPSK the number of bits per symbol amounts to 2.

With M-QAM, the phase shift already implemented in QPSK will be used and a differentiation by magnitude of the signal will be added. So for QAM, signals which differ in their phase shift and also their amplitude, will be send. For 16-QAM a maximum of 4 bits per symbols and for 64-QAM 6 bits per symbol can be achieved.

The modulation schemes make it possible to increase the rate/speed of transmission and are used for any kind of practical communication link. In a practical case, modulation will protect the signal from outside noise and interferences, e.g., other mobile handheld devices, GPS-signals or Wi-Fi signals. It can also increase the range of communication by transmitting over higher carrier frequencies.

2.4 Channel

The channel can be modified in many different ways. Different sources of noise or fading can be applied, which relate to real world interferences. Some interferences experienced in real life transmission are, e.g., thermal noise, distance fading, doppler effect and reflection of signals. To approach those kind of interferences there are many different channel models in simulations, like an AWGN-Channel or Rayleigh/Rician fading. A further look into the AWGN-Channel and the Rayleigh fading will be given. A small graphic will further illustrate the usual culprits for degradation of signal power and resulting loss in communication performance (Fig. 2.4).

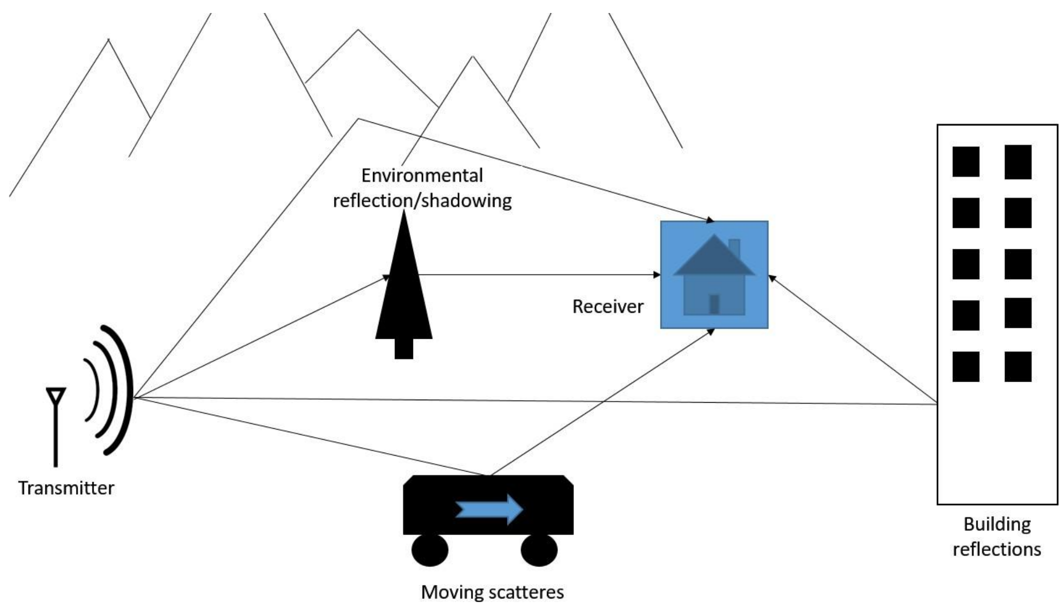

Figure 2.4: Interferences in a normal transmission between two devices

Ausführen, beispiele, bilder

2.4.1 AWGN-Channel

Lookup math

The easiest kind of channel manipulation is to add random Gaussian noise to the channel, also commonly known as an AWGN-Channel. Like the name says we will add noise, which is a random Gaussian distribution with flat spectral density, to an existing transmitted signal. Our channel will receive a signal like this:

$$Y = X + N, \tag{2.1}$$

with Y being the received signal, X the send code word and N the AWGN noise.
The probability density function is defined as follows:

$$f(x|\mu, \sigma^2) = \frac{1}{\sqrt{2\pi\sigma^2}} * e^{-\frac{(x-\mu)^2}{2\mu}}, \tag{2.2}$$

with x being the acquired point, μ being the mean or expectation of the distribution and σ^2 the variance of the distribution.
More or less every communication link will have some kind of Gaussian noise interference, so the AWGN-channel will be added to every simulation run. Below (Fig. 2.5) a depiction of the spectral power distribution of AWGN. It can be clearly seen that it is flat and spread evenly over the whole spectrum.

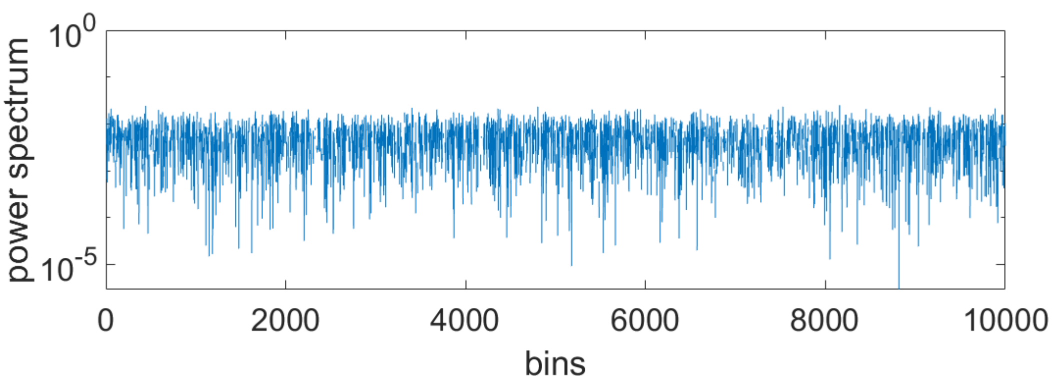

Figure 2.5: Power spectral density for a AWGN channel

Add picture of AWGN, pdf or distribution

2.4.2 Rayleigh-Channel

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Another common channel model used in communication theory is Rayleigh fading. Rayleigh fading is used to simulate multipath reception, which means that for a receiver antenna in a wireless link there are many reflected and scattered signals reaching it (Fig. 2.4). These kind of reflections are common for high-density urban areas. This results into construction or destruction of waves. Rayleigh distribution can be defined like this:

$$H = \sqrt{X^2 + Y^2}, \tag{2.3}$$

with X and Y being two independent Gaussian distributed random variables. This leads our channel to look like this:

$$Y = H * X + N, \tag{2.4}$$

with the newly added fading coefficient H.
Further calculations will lead to the following pdf:

$$f(x\sigma) = \frac{1}{\sigma^2} e^{-\frac{x^2}{2\sigma^2}}, \tag{2.5}$$

this time only with sigma being the variance of the pdf. The graphic (Fig. 2.6) shows the power distribution over 12000 samples. Being Gaussian randomly distributed there are now these so called ”deep fadings” where the power of the fading drops, which will also decrease the signal power of the received signal to drop significantly. This results in the so-called burst errors, which were mentioned in chapter 2.2.

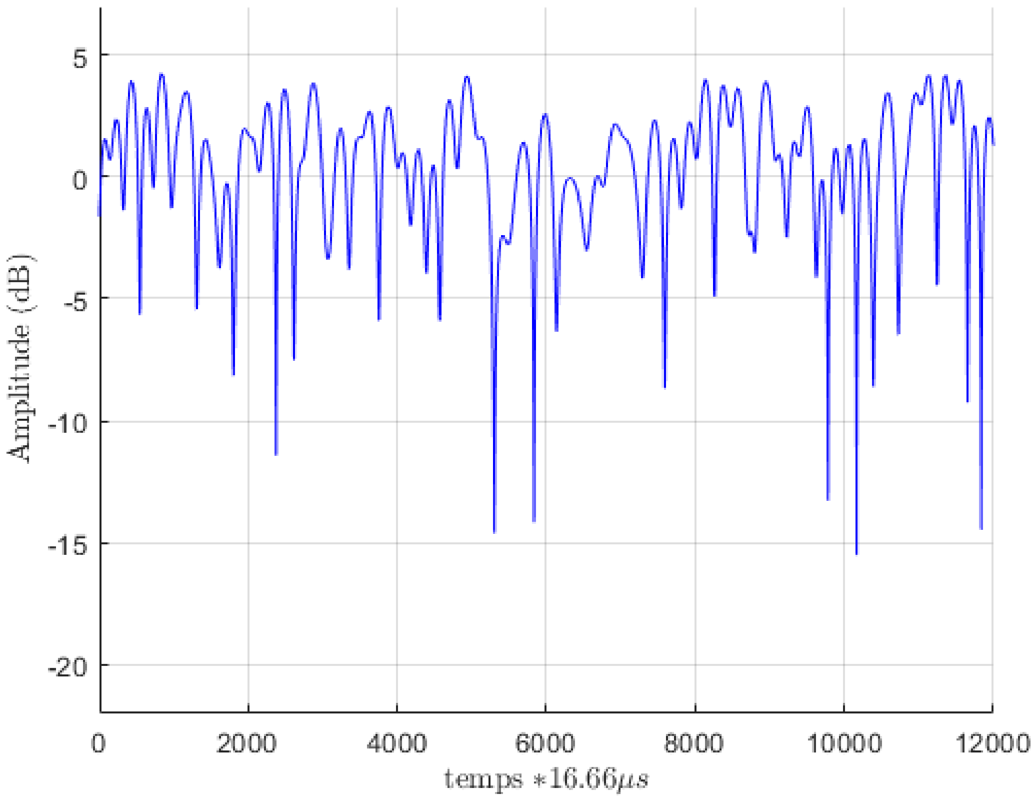

Figure 2.6: Power spectral density for a rayleigh channel

Add pictures, spreading, reflection...