ALaRI: Digital Signal Processing

Exercise Session 7: OFDM equalization

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Goal: to create m-files for equalizing the frequency response of a transmission channel in an OFDM-based communication system.

Requirements: Matlab in Windows or Linux, 3 m-files (ofdm_mod.m, ofdm_demod.m, ofdm_experiment_training.m).

Outcome: 2 m-files (ofdm_experiment_zfeq.m, ofdm_experiment_mmseeq.m).

Exercise 7-1: OFDM – zero-forcing equalization

Due to the influence of the transmission channel, the QAM symbols obtained at the receiver after OFDM demodulation are distorted. To compensate for the channel influence, we can multiply each received QAM symbol by the inverse channel coefficient for the corresponding subcarrier. Since the channel can change during operation, training frames should be used to (re-)estimate the channel response. Create an m-file "ofdm_experiment_zfeq.m" in which the following four steps are implemented:

1. Implement an equalizer in your demodulator that compensates for the channel influence by multiplying the respective subcarrier symbols with the inverse of the channel coefficients, estimated using the training method implemented in the m-file "ofdm_experiment_training.m" (Exercise 6-2). This is called a "zero-forcing" (ZF) equalizer.

2. In Exercise 3-1, you created a function ber.m to evaluate the bit error rate (BER). Now create another function "ser.m" in which the symbol error rate (SER) is calculated. Make sure that the training symbols are *not* incorporated in this calculation.

3. Transmit everything (training+data) over a random channel $H(z) = h_0 + h_1 z^{-1} + \cdots + h_L z^{-L}$. Check the constellation diagram of the received QAM data symbols, the BER, and the SER, if $L > L_{CP}$ and if $L \leq L_{CP}$, where L_{CP} denotes the length of the cyclic prefix. What do you observe? Can you explain this?

4. Repeat the experiment, but now add Gaussian white noise to the channel output at a given SNR. Check the constellation diagram of the received QAM data symbols, the BER, and the SER for a range of SNRs, for example from 10–50 dB. Do the same for different QAM modulation formats.

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(Optional) Exercise 7-2: OFDM – MMSE equalization

1. A more balanced equalizer is the minimum mean squared error (MMSE) equalizer, a.k.a. the least squares equalizer. It is similar to a ZF-equalizer, but it estimates the *inverse* channel coefficients directly. Create a new m-file "ofdm_experiment_mmseeq.m", in which the ZF-equalizer that you implemented in the previous section is replaced with an MMSE-equalizer (it should be a minor modification).

2. Transmit everything (training+data) over a noiseless channel. Check the constellation diagram of the received QAM data symbols, the BER, and the SER, if $L \leq L_{CP}$.

3. Repeat the previous experiment, but now add Gaussian white noise to the channel output at a given SNR. Check the constellation diagram of the received QAM data symbols, the BER, and the SER for a range of SNRs, for example from 10–50 dB. Do the same for different QAM modulation formats.

4. Can you intuitively explain why an MMSE-equalizer performs better than a ZF-equalizer?