ALaRI: Digital Signal Processing

Exercise Session 6: Channel identification and training for OFDM modulation

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Goal: to create m-files for identifying the frequency response of a transmission channel in an OFDM-based communication system, and for repeating the identification using training packets.

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

Outcome: 2 m-files (ofdm_experiment_channelident.m, ofdm_experiment_training.m).

Exercise 6-1: OFDM – channel identification in the frequency domain

In Exercises 2-2 and 2-3, you have developed a time domain method for channel identification in the communication system. In this exercise, you are expected to develop a frequency domain channel identification method, which will appear to be more efficient than the time domain approach. Create an m-file "ofdm_experiment_channelident.m" in which the following four steps are implemented (and try to reuse as much as possible the m-files and functions ofdm_mod.m, ofdm_demod.m, ofdm_experiment_channel.m that you created in Exercises 4-1 and 5-1):

1. Simulate an OFDM transmission over a frequency-selective channel (= recap of exercise 5-1): Generate a random bit sequence, and use the OFDM modulator ofdm_mod.m which you have designed in Exercise 4-1 to generate a time-domain signal that can be transmitted over a channel. Simulate the transmission of the signal over a frequency-selective (multipath) channel with a transfer function $H(z) = h_0 + h_1 z^{-1} + \cdots + h_L z^{-L}$ and a user-specified order L. Keep in mind that the cyclic prefix in your modem must be longer than the length of the channel! Demodulate the received (time domain) OFDM signal back to (frequency domain) QAM symbols using the function ofdm_demod.m.

2. Determine the frequency response of the channel by using the transmitted QAM symbols and the received QAM symbols, and performing a least squares estimation. Notice that, in the discrete frequency domain, the

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channel identification requires the estimation of only one channel coefficient per "subcarrier" (or "tone") in the OFDM frames. Can you explain why? (maybe take a look into the slides of Chapter-3).

3. Transform the estimated channel frequency response to the time domain, and compare it with the (true) impulse response of the channel. Do they match? Why (not)?

4. Redo the previous experiment but do not use a cyclic prefix (or make it shorter than the channel length). Do they match now? Why (not)?

Exercise 6-2: OFDM – time-varying channel identification by training

In a practical system, the channel can change during operation, and therefore an a priori channel estimate will generally not be sufficient. This is why we use training frames to (re-)estimate the channel response during operation of the communication system. Create an m-file "ofdm_experiment_training.m" in which the existing OFDM modulation/demodulation is extended with the use of training packets (containing training frames), interleaved with data packets, allowing for a repeated channel identification over time.

1. An OFDM training frame looks the same as a data frame, but unlike a data frame it is known both to the transmitter and the receiver. Generate an OFDM training packet consisting of N_t OFDM training frames. Each OFDM training frame consists of $\frac{N}{2}$ subcarriers modulated by M-ary QAM symbols (except the DC and $\frac{N}{2}$ subcarrier, cf. Fig. 1 in Exercise 4-1). Insert this training packet at the beginning of every OFDM data packet. The length of the data packets N_l is user-defined and it is usually much higher than N_t.

2. How does the parameter N_t influence the transmission rate of your modem?

3. For each OFDM subcarrier, a set of L_t training symbols is available to estimate the channel coefficient for that subcarrier in the least squares sense, as in Exercise 6-1. The demodulator should (re-)estimate these channel coefficients, every time a training packet arrives.