Introduction to Wireless Communications Systems

Dept. of Electrical Engineering
Prof. Murat Torlak

TEAM PROJECT (A or B): Physical Layer Simulation of an OFDM System

Due Date: 5/6/2013, 5:00PM
Deliverables: The four-page report and the simulation code uploaded to Elearning
Directions: Teams are group of two. No collaboration among project groups is allowed. You are Group A if the sum of the last digits of the team members' UTD-IDs is even. Otherwise your team is group B.
Project Description:
The orthogonal frequency division multiplexing (OFDM) technique has been adopted in Long Term Evolution (LTE) and several wireless LAN standards, including IEEE 802.11a, IEEE 802.11g as well as WiMAX (IEEE 802.16e) and digital audio/video broadcast systems. In this project, we will implement a simplified version of LTE OFDM modulation and demodulation techniques in MATLAB software.
Complete OFDM simulation parameters:

- Channel bandwidth : 20MHz
- Modulation: BPSK
- FFT size (Nfft): 1024
- CP length (Ncp): To be specified by you!
- No. of used sub-carriers (Nused): To be specified by you!
- No. of pilot subcarriers per symbol (Nref): To be specified by you!
- No. of data subcarriers per symbol (Ndata): To be specified by you!
- No. of null subcarriers (Nleft,Ndc,Nright): To be specified by you!

1. **AWGN Channel Simulation**- Build the OFDM transmitter and receiver in either MATLAB using `ifft` and `fft` functions. Use Figure 12.7 in the text as the block diagram for the implementation. You can ignore D/A and A/D, LPF, and cosine modulation and demodulation process. Justify and explain your selections of CP length (Ncp), No. of used sub-carriers (Nused), No. of pilot subcarriers per symbol (Nref), No. of data subcarriers per symbol (Ndata), and No. of null subcarriers (Nleft,Ndc,Nright). You can make these selections to be compatible with LTE or other OFDM based wireless standards.
2. Add additive white Gaussian noise to simulation transmission of OFDM system above for the following average $E_s/N_0 = \{3\ 5\ 7\ 9\ 11\}$ dB SNR values. You report should include BER plot corresponding these average E_s/N_0 values. Note that in this part, no multipath channel is assumed.

3. **Multipath Channel Simulation** - As explained in the class and in the simulation assignment III, multipath channels are often modeled using tap-delay lines with noninfinitesimal amplitude response over a span of L taps

$$h(t,\tau) = c_0(t)\delta[\tau - \tau_0] + c_1(t)\delta[\tau - \tau_1] + \ldots + c_{L-1}(t)\delta[\tau - \tau_{L-1}]$$

   Her, t indicates the time variable and captures the time-variability of the impulse response of each multipath component modeled typically as Rayleigh or Rician fading, and τ indicates the delay associated with each multipath. Empirical multipath channels are often specified using the number of taps L and the relative average power and delay associated with each tap. For purposes of modeling in a simulation environment, the most frequently used multipath intensity profiles are proposed by ITU (International Telecommunication Union). ITU has specified number of multipath profiles for various standards. They are usually specified for vehicular, pedestrian, and indoor channels. Two sets are typically given A and B as listed below.

   - Based on your assigned group, simulate the bit error rate performance of your OFDM system over channel A or channel B for all three multipath channel profiles below. For time varying channels, the channel taps can be assumed to vary only from OFDM block to OFDM block and to remain unchanged during one symbol interval. Include the magnitude of the frequency response of your transmitted OFDM signal averaged over 1000 OFDM blocks in the report for both channels.
   - In simulation, you can generate these parameters randomly for every simulation run to obtain an average BER plot for E_s/N_0 such that BER is shown from 10^{-2} to 10^{-5}.
   - Include your average BER plot in your report. In order to remove the channel effect, you can assume that channel taps are perfectly known by the receiver. The frequency domain equalization can be done using the Fourier transform of the channel.

4. Repeat the above simulation for QPSK and 16 QAM modulation

5. **Adaptive Modulation:** Plot the empirical spectral efficiency for the above channel model w.r.t. to average SNR (ranging from 10 to 30 dB) for target BER of 10^{-3} if an adaptive modulation method is employed. The available modulations are BPSK, QPSK, 8-PSK, 16-QAM, 32-QAM, and 64-QAM over all three multipath intensity profiles. You can use a look-up table to do the modulation size selection. For this part, you may not need to simulate the OFDM transmitter. The results can be obtained by using frequency response of the channel.

ITU/WINNER Multipath Channel Models

Indoor				
	Channel A		Channel B	
Tap Number	Delay (nsec)	Relative Power (dB)	Delay (nsec)	Relative Power (dB)
1	0	0	0	0
2	50	-3	100	-3.6
3	110	-10	200	-7.2
4	170	-18	300	-10.8
5	290	-26	500	-18.0
6	310	-32	700	-25.2

WINNER Model Street level to Street Level				
	Channel A		Channel B	
Tap Number	Delay (nsec)	Relative Power (dB)	Delay (nsec)	Relative Power (dB)
1	0	-2.6	0	-1.5
2	10	-8.5	5	-10.2
3	90	-14.8	30	-16.6
4	135	-17.5	45	-19.2
5	230	-19.2	75	-20.9
6	275	-18.8	90	-20.6
7	310	-14.9	105	-16.6
8	420	-14.9	140	-16.6
9	630	-22.1	210	-23.9
10	635	-10.3	230	-12
11	745	-22.2	250	-23.9
12	815	-19.2	270	-21
13	830	-16	275	-17.7
14	1430	-22.9	475	-24.6
15	1790	-20.3	595	-22
16	2075	-27.4	690	-29.2