Multi-Channel Communications

Mini-Project #5

The Frequency-Selective Channel and OFDM

Due November 15, 2022

Note: You may use outside references including books and notes and may discuss the project with your classmates in general terms. However, you may not obtain code or direct assistance from another person.

PLEASE MAKE SURE YOU ANSWER ALL PARTS OF EACH PROBLEM AND CLEARLY MARK YOUR ANSWERS BY PUTTING A BOX AROUND EACH ANSWER. YOUR ANSWERS SHOULD BE AS COMPLETE AND CLEAR AS POSSIBLE – NOT JUST A LISTING OF THE ANSWER. MATLAB CODE SHOULD BE CLEARLY DOCUMENTED AND SUBMITTED SEPARATELY FROM YOUR REPORT.

I pledge that I have neither given nor received any unauthorized assistance on this project.

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(signed)

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Name (print) Student Number

1 Mini-Project Overview

In this project you will create a simulator for a frequency selective channel. This simulator will be used to test a transceiver that incorporates OFDM. You will turn in two primary components: (1) Matlab code (uploaded to Canvas as a zip file) and (2) A report validating your design (uploaded to Canvas as a pdf file and a hard copy submitted in class).

2 Detailed Description

You will create a Matlab function titled channel.m which incorporates frequency correlation (i.e., delay spread), and the severity of the fading (e.g., Ricean K-factor or Nakagmai m-factor). *Note that the channel function should result in unit average gain between the transmit antenna and the receive antenna.*

The transmitter function created in the previous project should be modified to include an option for transmitting an OFDM signal. Note that the transmitter code should take three inputs: a block of N_b input data bits, a block N_{fb} feedback bits (needed for adaptive modulation in the next project) and an object/struct named "parameters" which provides the input parameters defining the modulation scheme, and any other needed parameters (you will need to add various items to the Parameters struct including the number of subcarriers, the pilot locations, etc.). The receiver function should take two inputs: the complex received samples (after going through a channel function) and a parameters object/structure that has the necessary details concerning the OFDM scheme, the modulation scheme used, etc. Note that channel estimation will be ultimately be needed (although not in this project) so eventually pilots should be included in your transmit signal in known locations.

3 Required Validation

You will create a report describing your function briefly and providing validation plots. Specifically, you must validate the channel function by providing the following plots/analyses:

- Frequency Selective Channel
  - Create a frequency-selective fading channel (Rayleigh fading) with a specified delay spread of approximately $\tau_rms = 100$ns. Assume a sampling frequency in the time domain of 100MHz (a frequency spacing of 781.25kHz when $N = 128$ samples are plotted in frequency). The channel need not be time-varying. Plot an example of the magnitude and phase response using $N = 128$ samples in the frequency domain. Using a log plot show that the simulated multipath profile (in the time domain) matches the desired power delay profile (i.e., provides the desired delay spread). You can use either a discrete power delay profile (PDP) in the time domain, or a continuous PDP model.
  - Plot the histogram of the envelope of one sample in the frequency domain and compare with theory.
  - Plot the correlation between frequency domain samples vs. frequency separation. Does it match theory/expectations?

  - Increase the delay spread to 1μs and (a) plot an example frequency domain channel (magnitude and phase), (b) show the impact on simulated PDP, and (c) determine/demonstrate the effect on frequency correlation.

- OFDM
  - Simulate the performance of OFDM with 16-QAM in an AWGN channel for EbNo ranging from 0dB to 8dB in 1dB steps. Plot the resulting BER vs EbNo in dB for both theory and simulated. Note that no channel estimation is needed.
  - Simulate and plot the performance of OFDM (simulated and theoretical) with BPSK and E_b/N_o ranging from 0dB to 20dB in a flat Rayleigh fading channel. You can assume perfect channel estimation.
  - Determine the impact frequency offset on the received OFDM signal. Plot the simulated performance of OFDM with BPSK at EbNo=6dB for a normalized frequency offset ranging from 0 to 0.2 (in steps of 0.005). By normalized we mean as a fraction of the fundamental frequency 1/N.
  - Simulate OFDM with BPSK in the frequency selective Rayleigh channel described above. Plot the BER (simulated and theoretical) for Eb/No ranging from 0dB to 20dB. Describe the pilot locations assumed to achieve proper channel estimation. Again, you can assume perfect channel estimation. Does the performance differ from the flat fading case? Why or why not? Does your choice of cyclic prefix length matter?
  - In the last validation you will examine the impact of coding. Using the error correction coding option of your choice, add coding to a QPSK modulated OFDM signal. You may use a MATLAB or other externally provided encoder/decoder. Assume that your block size is equal to $12kN$ where $k = 2$ is the number of bits per symbol, N is the number of sub-carriers, and 12 is the number of OFDM symbols in one block. You can also assume that the channel is constant over a block but is completely independent from block to block. You can also assume perfect channel knowledge. Compare the performance of flat Rayleigh fading and frequency selective fading (using both frequency-selective channels specified above). Does the delay spread (0, 100ns, $1\mu s$) impact performance in this case? Why or why not? Does interleaving help performance?