Multi-Channel Communications

Mini-Project #4
Spatial Multiplexing
Due October 30, 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 fourth project you are going to develop transmit and receive techniques in complex baseband to perform spatial multiplexing. This simulator will also likley be included in your final project. 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

In this project you will develop spatial multiplexing techniques for the MIMO transceiver. Specifically, you will implement a receive.m function that implements (a) SIC with MMSE nulling, (b) Maximum Likelihood detection, and (c) SVD-based receive beamforming. The transmit.m function should include options which (a) transmit BPSK, QPSK and 16-QAM independently on all N_t transmit antennas (this will be used with options (a) and (b) of the receiver) and (b) SVD-based transmit beamforming (used with option (c) of the receiver). Note that the transmitter code should take three inputs: a block of N_b input data bits, a block N_{fb} feedback bits and an object/struct named "parameters" which provides the input parameters defining the modulation scheme, and any other needed parameters. The feedback bits are to be used for SVD-based transmit beamforming. The receiver function should take two inputs: the complex received samples (after going through your channel function) and a parameters object/structure that has the necessary details concerning the beamforming technique, modulation scheme used, etc.

3 Required Validation

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

- Demonstrate the performance of SIC with MMSE nulling and ML detection in 2×2 and 4×4 fully independent channels. Compare this to a zero-forcing receiver. What is the theoretical performance of zero-forcing? Show that your simulations match theory. You may assume perfect channel knowledge in order to demonstrate the spatial mulitplexing functionality. Assume independent channels. Use QPSK and 16-QAM. Also compare QPSK with SIMO transmission *with the same spectral efficiency.*

- Compare SIC with MMSE nulling with independent and correlated (receive correlation of $\rho = 0.7$) for 2×2 channel using BPSK. You may assume perfect channel knowledge in order to demonstrate the spatial mulitplexing functionality.

- Demonstrate the performance of SVD-based tx/rx beamforming with 16-QAM and in a 4×4 channel with independent fading on all antennas. You may assume perfect channel knowledge in order to demonstrate the spatial mulitplexing functionality. How else could you achieve this level of spectral efficiency? How do you think it would perform?

- In this project you have assumed perfect channel knowledge. How would you estimate the channel in a practical system? Compare a 2×2 channel using QPSK and an SIC/MMSE receiver with perfect channel knowledge to one that estimates the channel. How many pilots are needed to get good performance? Plot the performance with 10 pilots, 20 pilots and 50 pilots per 500 symbols.