Multi-Channel Communications

Mini-Project #2

Beamforming

Due September 22, 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 are going to develop transmit and receive beamforming techniques in complex baseband. 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 transmit and receive beamforming techniques. Specifically, you will implement a receive.m function that (a) implements maximum SNR receive beamforming and (b) MMSE (receive) beamforming. The transmit.m function should include options which implement maximum SNR transmit beamforming. Note that the transmitter code should take three inputs: (a) the transmit signal $x(t)$, (b) the transmit weights $\mathbf{w}$, and (c) the array geometry (e.g. spacing and shape). 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. Note that known symbols (pilots) should be included in your transmit signal in known locations for MMSE beamforming.

Once you have completed the function, you should create a short report detailing your work and validating its performance. The report should have the following sections:

1. Introduction - this section briefly outlines the goals of the project.
2. Description - this section outlines the basic theory behind the implementation and briefly describes the created function.
3. Validation - this section provides validation that the created function works properly by meeting the theoretical expectations. The required validations are listed below.
4. Conclusion - this section concludes the report and outlines any issues experienced.

3 Required Validation

As described above, 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:

1. **Max-SNR Beamforming**

   (a) Demonstrate that the max-SNR (transmit and receive) beamforming techniques are correct by plotting simulated BER curves for an AWGN channel with $N_t = 4$ ($M_r = 1$) and $M_r = 4$ ($N_t = 1$) antennas (for transmit and receive beamforming respectively). Assume QPSK modulation. Plot theory for a single transmit/receive antenna. Plot the BER for an SNR per receive antenna of -1dB to 5dB in 0.5dB steps. The array should be linear with 1/2 wavelength spacing. You may assume any angle of arrival you wish for the BER plot (should it matter?). Note that the plot should have the SNR for a single antenna as the x-axis.

(b) Explain your results from above.

(c) Plot the transmit beampattern for transmit angle of 35^o.

(d) Plot the receive beampattern for received angles of 15^o and 65^o.

2. **MMSE Beamforming**

   (a) Simulate MMSE receive beamforming. Pilots should be used to aid in estimating the needed weights. Try different numbers of known symbols. Assume a desired signal at 45^o with no interferers. The array should be linear with 1/2 wavelength spacing. Plot the BER for an SNR per receive antenna of -1dB to 5dB in 0.5dB steps. Include an ideal MMSE beamformer with perfect channel information. How many pilots are needed to approach the ideal case? How does MMSE compare to the max-SNR beamformer?

   (b) Plot the beampattern for the above validation.

   (c) Repeat (2a) when there is an interferer at 0^o. How does the BER compare?

   (d) Repeat (2a) when there are interferers at 0^o and 25^o. How does the BER compare? (You should ultimately have six plots - three scenarios and two different beamformers).

   (e) Choose one of the above validations and compare with either LMS/RLS. Explain your results.

   (f) How would your beamformers perform if the spacing on the four antennas was 10λ and the channel was Rayleigh fading (independent on each antenna)? Prove your answer by providing a simulated BER plot of (a) one desired signal and (b) one desired signal with one interferer (SIR = 0dB).