

Homework #4 *Random Signals and Correlation*

Assigned on Sunday, March 24, 2024

Due on Friday, March 29, 2024, by 11:59pm

Homework submitted after 11:59pm will be subject to a penalty of 2 points per minute late.

Reading: JSK, chapters 4, 5, 6, and 8, and Appendix B; Course reader appendix L & S;

** Haykin, *Communication Systems*, excerpts (please see the homework hints) **

Office hours for the teaching assistants and Prof. Evans; **bold** indicates a 30-minute timeslot. Note that Prof. Evans' office hours have moved from W 3:30-6:30pm to T 3:30-6:30pm this week only.

| <i>Time Slot</i> | <i>Monday</i> | <i>Tuesday</i> | <i>Wednesday</i> | <i>Thursday</i> | <i>Friday</i> |
|------------------|--------------------------------|----------------|--------------------------------|-------------------------------|----------------------------------|
| 10:30am | Evans (ECJ 1.312) | | Evans (ECJ 1.312) | | |
| 11:00 am | Evans (ECJ 1.312) | | Evans (ECJ 1.312) | | |
| 12:00 pm | | | | | Evans coffee hours (EER Cafe) |
| 1:00 pm | | | | | Evans coffee hours (EER Cafe) |
| 2:00 pm | Evans (EER 6.882 & Zoom) | | Evans (EER 6.882 & Zoom) | | |
| 3:00 pm | Evans (EER 6.882 & Zoom) | | Evans (EER 6.882 & Zoom) | Barati (EER 1.810) | |
| 3:30 pm | | | | Barati (EER 1.810) | |
| 4:00 pm | | | Barati (EER 1.810) | Barati (EER 1.810) | |
| 4:30 pm | | | Barati (EER 1.810) | Eun (EER 1.810) | |
| 5:00 pm | | | Barati (EER 1.810) | Eun (EER 1.810) | Eun (Zoom) |
| 5:30 pm | | | | Eun (EER 1.810) | Eun (Zoom) |
| 6:00 pm | | | | | Eun (Zoom) |
| 6:30 pm | | | | | |

NOTE: In your solutions, please put all work for problem 1 together, then all work for problem 2 together, etc.

Please submit any MATLAB code that you have written for the homework solution.

As stated on the course descriptor, "Discussion of homework questions is encouraged. Please be sure to submit your own independent homework solution."

Pseudo-random binary sequences are also known as pseudo-noise (PN) sequences because the sequences resemble noise. These binary sequences appear to be random but instead have structure. Pseudo-noise sequences are periodic whereas noise is aperiodic (i.e. the period is infinitely long).

PN sequences are widely used to

- generate test, measurement and calibration signals (e.g. in audio, biomedical and communications systems)
- generate training signals in communication systems (homework assignments 4-7)
- scramble and descramble data in communication systems (lab 4)
- generate additive dither in data converters (lecture 10)

4.1. Spectral Analysis of a Random Signal. 40 points. Please read the [homework hints](#).

Before working this problem, please read [Appendix S Adding Random Variables](#).

(a) Johnson, Sethares & Klein, exercise B.2 on page 414. 12 points.

(b) Johnson, Sethares & Klein, exercise 3.4, on page 43. Please submit the plots with your homework solution. 12 points.

(c) Plot the spectrum of a pseudo-noise (PN) sequence of length 31 of +1 and -1 amplitudes; i.e., a bit of value '1' maps to +1 and a bit of value '0' maps to -1. For the spectrum plots, please plot both the discrete Fourier transform (e.g. using the `fft` command) and the discrete-time Fourier transform (e.g. using the `freqz` command). You can find a length 31 PN sequence in Appendix L of the course reader, or you could generate one in Matlab, or you could use the sequence that you generated in lab 4. Are there any frequencies at which the discrete Fourier transform or discrete-time Fourier transform is exactly zero? 16 points.

4.2 Finding a Known Marker in a Noisy Received Signal. 30 points. Please read [homework hints](#).

Johnson, Sethares & Klein, exercise 8.8, page 160. In the code for `correx.m`, define `header` to be

(a) A sequence of length 31 of all +1 entries. The Matlab command `ones` might be helpful.

(b) A maximal length pseudo-noise sequence of length 31 with entries +1 and -1.

Explain why there is a difference in detection performance between the two different headers.

4.3 Finding a Known Marker in a Distorted Received Signal. 30 points. Please read [hints](#).

Johnson, Sethares & Klein, exercise 8.14, page 164. Use the 4-PAM alphabet with symbol amplitudes -3, -1, +1 and +3. Use the same marker sequences in problem 4.2 except use amplitudes of -3 and +3 instead of -1 and +1 and compare their performances. Please plot the magnitude and phase response for each channel model.

This problem uses a finite impulse response (FIR) filter to approximate the linear time-invariant (LTI) component of a communication channel. The FIR filter models the impulse and frequency response of the LTI component of the communication channel. The assigned reading and Lecture 12 on Channel Impairments discuss this model. None of the FIR filters for the channel model has linear phase.