EE4820: Biomedical Signal Processing
Frequency Responses and Filtering

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DUE: Monday May 9

1. Rhythms within noisy EEG

   (a) Download `sig_2.mat`. This is an EEG recording sampled at 100 samples per second.

   (b) Examine both the time-domain signal and the frequency spectrum of this EEG signal.

   (c) Create a Butterworth infinite impulse response filter which extracts the alpha band in the 4-7 Hz range.

   (d) Filter the EEG to obtain the alpha rhythm. Show the output and compare to the original EEG.

   (e) Show the frequency response of the filter, and its effect on the frequency spectrum of the EEG signal. Compare the frequency spectrum of the output of the filter to demonstrate the effectiveness of the filter in obtaining the alpha rhythm.

2. ECG with low frequency noise

   In this exercise you will be filtering an ECG signal to remove noise.

   (a) Download the data **ecg_lfn.dat.mat**. The data set `ecg_lfn.dat` contains one channel of ECG. Let's call this signal $x[k]$. It was sampled at 1000 samples per second.

   (b) Plot the ECG signal versus time in seconds (i.e, plot $x(t_k)$ vs t_k in seconds).

   (c) What type of filter do you need and why? What cutoff frequency will you choose for your filter design?

   (d) Try a few different filter types - Butterworth, Chebychev I, and Elliptical. First, try Butterworth: Create an appropriate 4th order Butterworth filter $H[f]$ to filter this signal.

   (e) Plot the magnitude of the frequency response of your filter $|H[f]|$ to check that it has the desired frequency response you believe will be effective for filtering out the noise.

   (f) Apply the filter, and show the output of the filter $y(t_k)$.

   (g) Show the magnitude spectrum $|Y[f]|$ of the filter's output $y[k]$, and compare it to the input spectrum $|X[f]|$.

   (h) Compare the performance of this filter with a Chebychev I and Elliptical, using the same order and same cutoff frequency, but you may decide any other needed parameters.

(i) Write any conclusions about which filter(s) was most effective.

3. EMG Envelope Detection

In this exercise, you will write MATLAB code to detect bursts from the EMG signal recorded from the right leg. Show your MATLAB code and include figures to show your results. Questions that should be answered are in bold.

(a) Load the data `rat4_10282011_110956.mat`. The file can be downloaded from the course web page under the `Data` section. The data was sampled at $f_s = 3000$Hz.

(b) The EMG data is stored in the matrix `s` with the signals from each channel stored in a different column: column 1 = channel 1; column 2 = channel 2, etc. The EMG from the left hindlimb was recorded on Channel 2. Analyze the EMG profile on the left hindlimb for this problem. The position signals are stored in this order: right x, right y, left x, left y. Use the y position for step detection.

(c) Look at the raw data. Let's call the raw EMG signal x_{raw}.

(d) First rectify the original EMG signal, and look at the output. Let's call it x_{rect}.

(e) Create a moving average of the EMG signal, called x_{MA}. Use a window size of 80ms.

(f) Plot the raw EMG and the moving average on the same time scale so that you can compare the two. Note: the convolution process causes you to have to think about what time corresponds to the samples of x_{MA}.

(g) Find the peak burst times for each burst in this data by using the data cursor on the x_{MA} signal.

(h) **How does increasing or decreasing the window size change your results? Explain what is happening.**