Computational Neuroscience

*Lab: Digital Signal Processing, LFPs and Synchronicity.*

**Part 1: Amplitude and Power spectrum, Sampling of a signal**

1. Using the randn function in Matlab, create a signal that lasts 10 seconds, sampled at 1000Hz. On this signal add the following three signals
2. Using the subplot command, plot the four different components of the signal individually, and the resulting signal when everything is added. (hint: make sure all four signals added have the same size by initializing them).
3. Using the fft command, compute the 1024-point discrete Fourier transform (DFT) of the final signal and plot the single sided normalized amplitude spectrum. Explain the result. Do the necessary changes to get a better estimate of the amplitude spectrum using the fft command. Compute and plot the power spectrum, as described in equation 7.13 from MFN.
4. Re-sample the signal using the downsample command, at two lower sampling rates (100Hz and 500Hz) and plot the resulting signals, as well as their single sided normalized amplitude spectrum. Explain the changes in the amplitude spectrum, especially regarding the peaks of the spectrum.

**Part 2: Wavelets**

1. Using the function morlet\_wavelet included in the .zip file, calculate the wavelet coefficients of the signal you created in Part 1 and plot the absolute values of the coefficients (frequency vs time) using the command imagesc. Create the frequency vector F, needed as an input to the morlet\_wavelet function, with the matlab function linspace, from 2Hz to 500Hz with 100 generated points.
2. Load the signal included in the signals.mat, named lfp1. This is a Local Field Potential (LFP) signal sampled at 500Hz, recorded from area V4, while the subject is performing saccades. Create the frequency vector F, needed as an input to the morlet\_wavelet function, with the matlab function logspace, from 2Hz to 150Hz with 100 generated points. Compute the wavelet coefficients for the first 5 seconds of the signal and plot the results. Modify the colorscale of the imagesc plot accordingly so you can see more details on frequencies above 25Hz. Use a better way to account for the power law and plot the result.
3. In the signals.mat there is also a variable called sacc\_end Wavelet Average (STWA), for 200 msec before and 300 msec after each saccade ends, using the same frequency vector as in step 2. In order to do that, take this 500 msec snippet of the LFP for each saccade, calculate the wavelet coefficients and store them in a 3-d matrix (saccades x freq x time). Take the average of that for the first dimension and plot the resulting STWA.
4. As discussed in the lecture, you can see the edge artifacts. Use a different approach than the one proposed in the previous step to get rid of them and plot an STWA free of edge artifacts.

**Part 3: Synchronicity in the time and frequency domain**

In the signals.mat there are 3 variables, lfp1, lfp2 and lfp3, containing LFPs sampled at 500Hz, (filtered from 0.5 to 200Hz) derived from extracellular recordings from different electrodes in area V4.

1. Compute the cross correlation using the xcorr function in Matlab, for all three signal combinations and plot in three subplots the results for relative shifts of -1 to 1 seconds.
2. Compute and plot the coherence of all three combinations, using the mscohere function in Matlab.
3. The variables betalfp1, betalfp2 and betalfp3 are filtered versions of the same signals for the beta frequency band (filtered from 20-40Hz). Compute the phase coherence for the beta filtered signals (betalfp1, betalfp2 and betalfp3). (hint: you need to extract the phase information from the complex wavelet coefficients of one frequency - the one closest to 30Hz - of the filtered signals and then use the equation in slide #).
4. Compute the granger causality for the regular and the beta LFP signals, using the function granger\_cause.m included in the .zip file and assess which signal is causally related to which.
5. From all the measures you calculated, provide an overview of the connectivity of the three brain sites where electrodes 1, 2 and 3 pick up the LFP signals. Comment on the results of each connectivity measure.