In The Name Of God

HW04

Advanced Neuroscience

MohammadAmin Alamalhoda

97102099

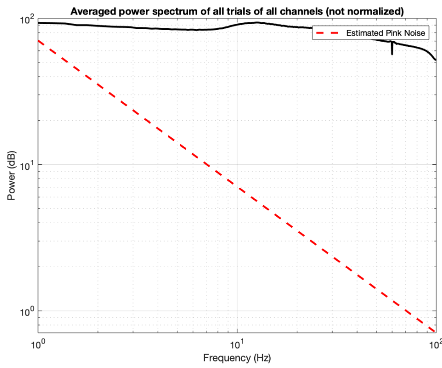
It is noteworthy to mention that I have only used the trials which were marked as clean trials.

■ LFP analysis

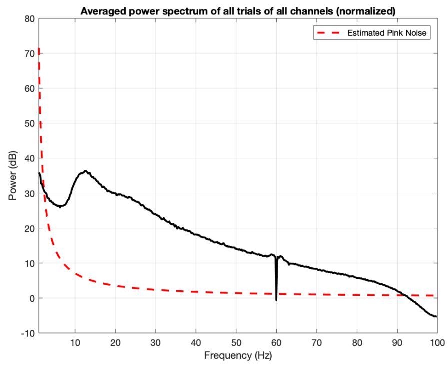
□ Part a - Removing Pink Noise

Pink Noise

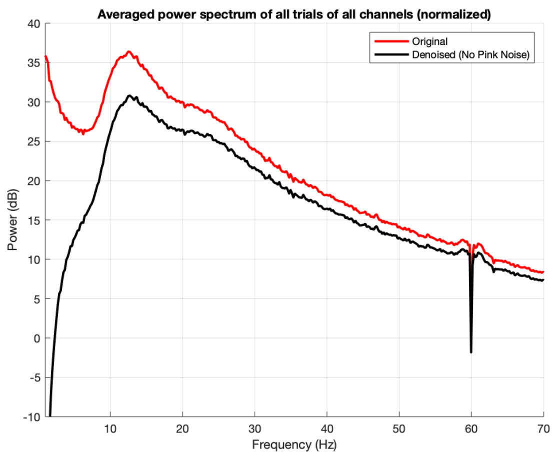
Pink noise or $\frac{1}{f}$ noise is a signal with a frequency spectrum such that the power spectral density is inversely proportional to the frequency of the signal. In order to removing pink noise, I fitted a line with slope equal to -1 to log-log FFT of the signal and then subtracted this line from the FFT. You can see the fitted line and original and denoised power spectrums of the signal in the figure 1.



(a) Averaged Power Spectrum (Log-Log)



(b) Averaged Power Spectrum



(c) Original and Denoised Power Spectrum

Figure 1: Pink noise, Original Power Spectrum, and Denoised Power Spectrum

As can be seen in the Figure 1, dominant frequency is in the $10 - 15$Hz frequency band.

□ Part b - Dominant Frequency

In order to cluster the electrodes based on their dominant frequency, I calculated FFT of each trial of channels and then plotted the average power spectrum of trials of each channel in Figure 2.

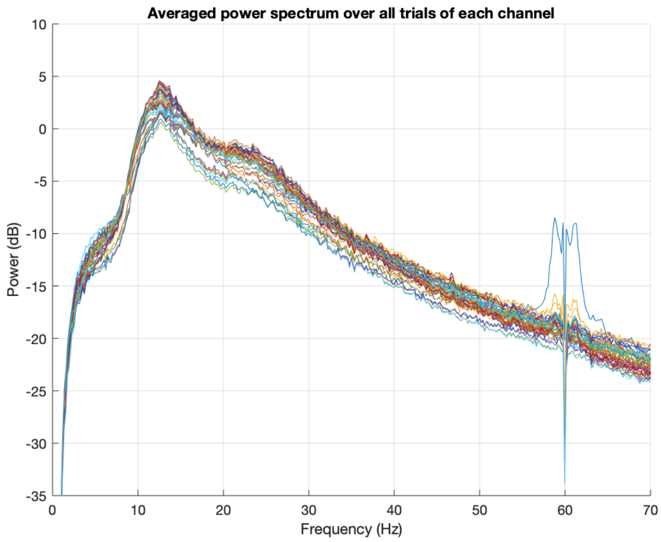


Figure 2: Average Power Spectrum of each Channel

As can be seen in the Figure 2, dominant frequency of all the channels is between $10 - 15$Hz.

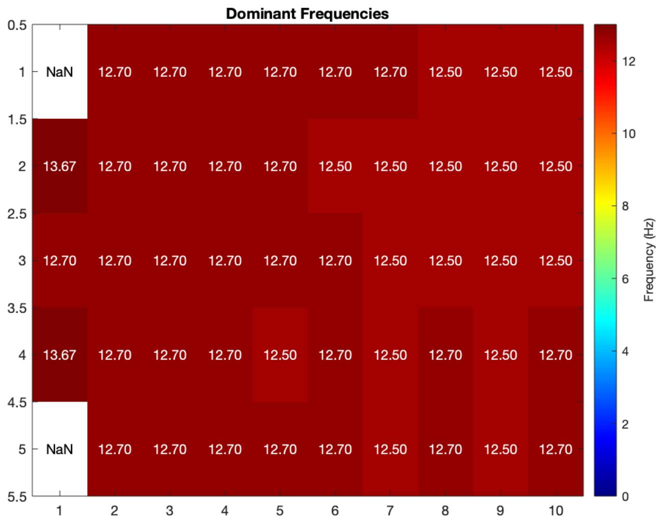


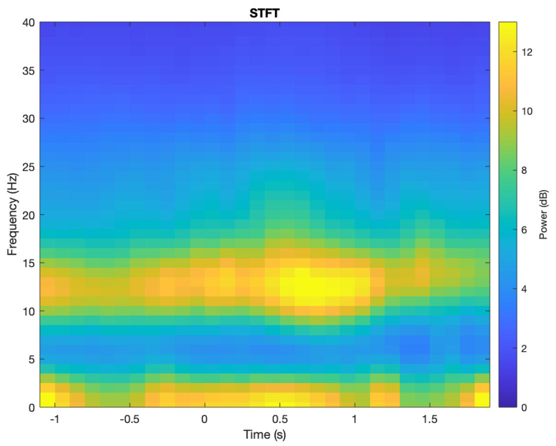
Figure 3: Dominant Frequency of each Channel

As mentioned in the last part, dominant frequency of all of the channels is about 12.5Hz which is in $10 - 15$Hz frequency band.

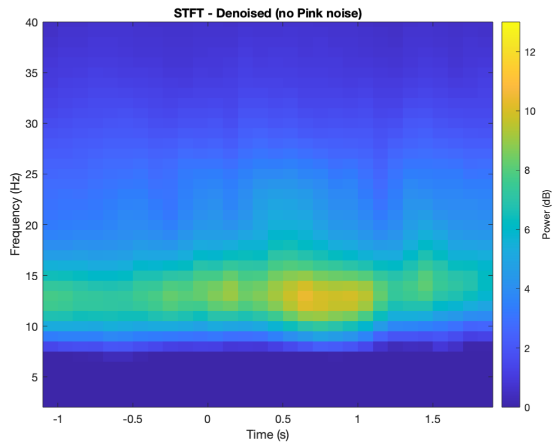
☐ Part c - Time-Frequency Analysis

Removing Pink Noise

STFT



(a) Original



(b) Denoised

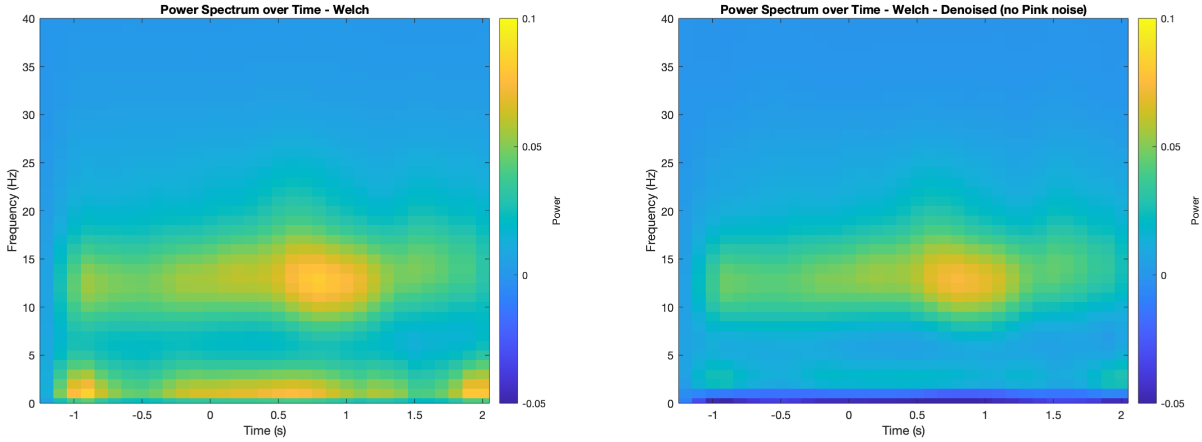
Figure 4: Average Power Spectrum over Time of all Trials of all Channels - STFT

Table 1: Parameters of STFT

Window type	kaiser
Window gain	5
Window size	300ms
Overlap length	200ms
FFT Length	200

Parameters which were used to obtain STFT of the signal are written down in Table 1. While using smaller window sizes gives better time resolution, low frequency components would be missed. so I chose these parameters.

Welch



(a) Original

(b) Denoised

Figure 5: Average Power Spectrum over Time of all Trials of all Channels - Welch

Table 2: Parameters of PWelch

Window size	200ms
Overlap length	100ms
FFT Length	200

As can be seen in the Figures 4 an 5, after 500ms of the onset there is an increase in the power of $10 - 15$Hz frequency band.

Wavelet

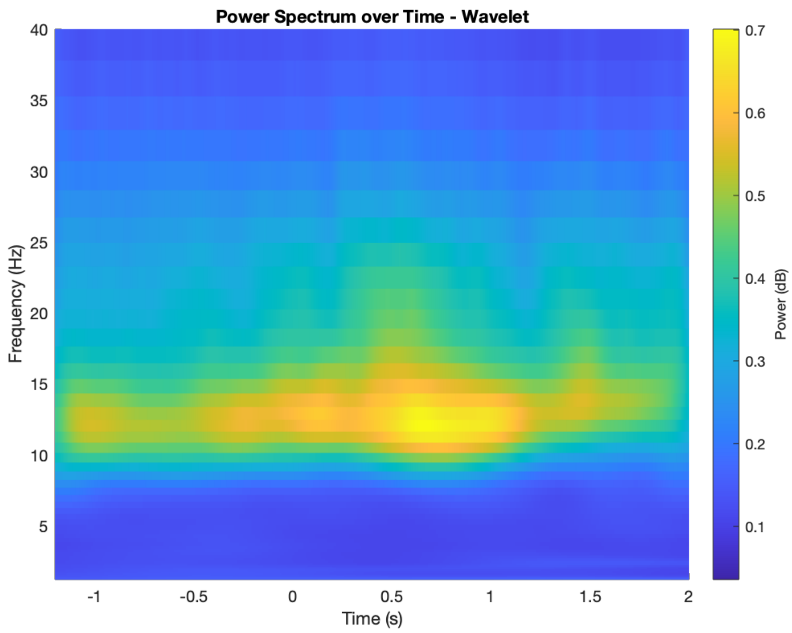
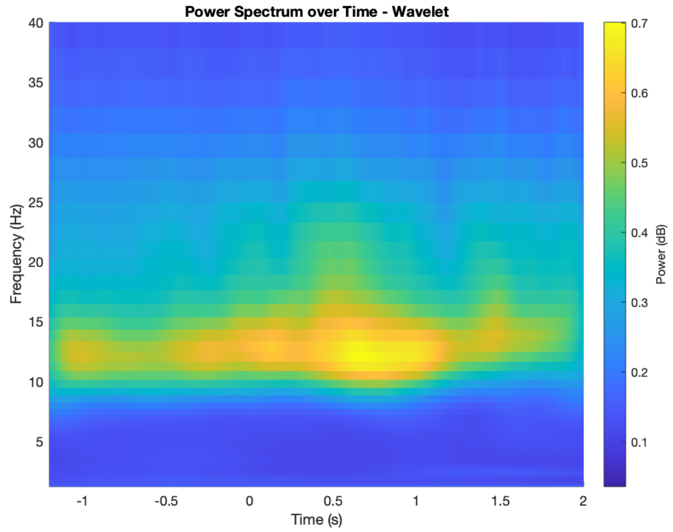


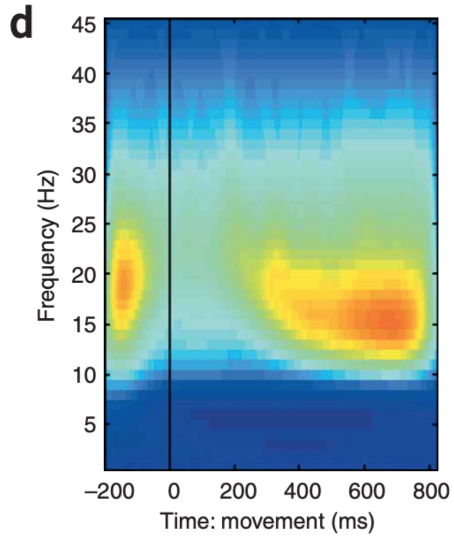
Figure 6: Average Power Spectrum over Time of all Trials of all Channels - Wavelet

☐ Part d - Comparing the Results with Hatsopoulos et.al 2006

Beta frequency band shows stronger power compared to the other frequency bands (Figures 2, 4, 5, and 6). I have plotted Fig. 1d of the paper which is average wavelet spectrogram of the signals and my average wavelet power spectrum in Figure 7.



(a) My Wavelet



(b) Paper Figure

Figure 7: Average Power Spectrum over Time of all Trials of all Channels - Wavelet

As can be seen in both of the plots of Figure 7, there is an increase in the power of $10 - 20$Hz frequency band after 500ms of onset. So, the obtained results are similar to the results of Hatsopoulos et.al 2006.

■ Phase propagation (Traveling waves)

□ Part a - Bandpass filtering the recorded signals

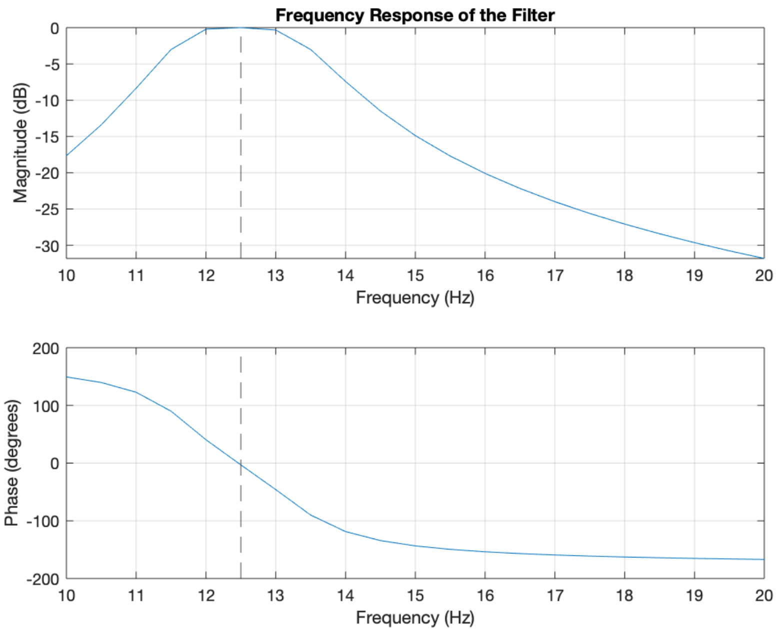


Figure 8: Frequency response of the filter $(12 - 13\text{Hz})$

I have bandpass filtered the recorded signals using 2^{nd} order Butterworth filter. The most important property of this signal is that its phase is linear over the specified frequency. Figure 11 shows this property very well.

□ Part b - Calculating instantaneous phase

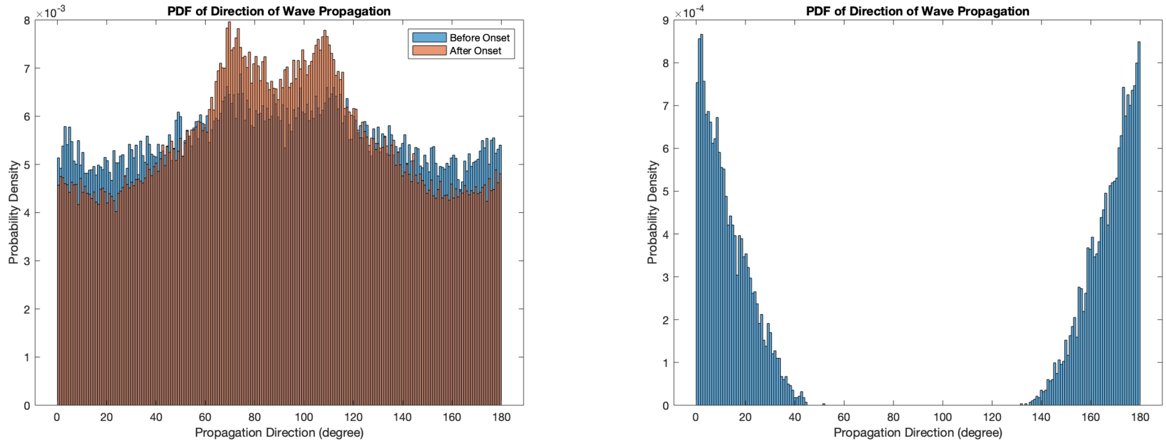
I have calculated the instantaneous phase using the following formula:

$$\phi(t) = \angle(Hilbert(x(t)))$$

□ Part c - Wave Demo

I have observed a wave propagating from right to left in most of the trials.

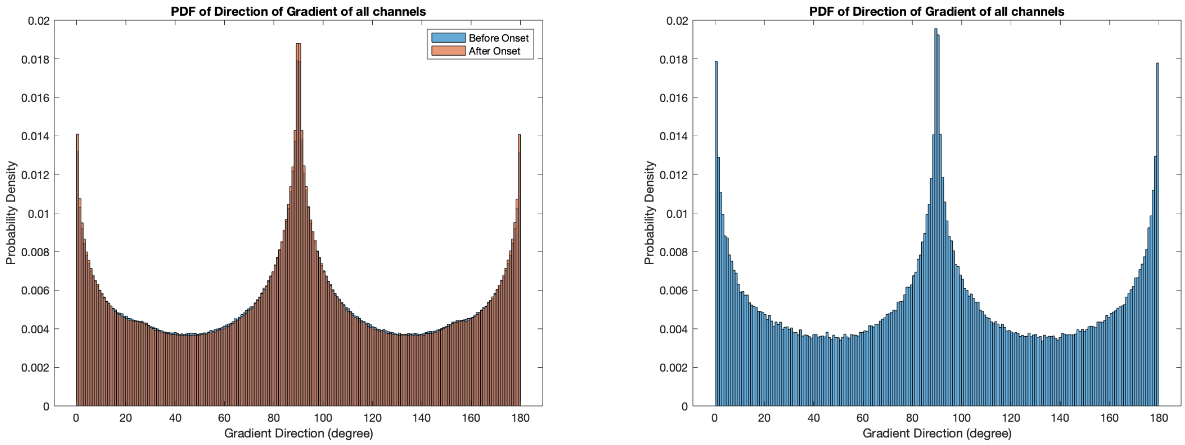
☐ Parts d and e - Calculating Wave Metrics



(a) All times (b) Times with $PGD > 0.5$

Figure 9: Direction of wave propagation (all trials)

As can be seen in the Figure 9, PDF of direction of wave propagation for the times with $PGD > 0.5$ has peaks about 0 and 180 degrees which validates that wave propagates from right to left as same as I observed in the demo. There is a peak about 0 degree because when the wave is propagating from right to left, the gradients on the left side of the wave peak has direction degree close to 180 and the gradient of the right side of the wave peak has direction degree close to 0.



(a) All times (b) Times with $PGD > 0.5$

Figure 10: Direction of gradients (all trials of all channels)

As can be seen in the Figure 12, PDF of direction of gradients has peaks about 0, 90, and 180 degrees. The reasons for 0 and 180 degree peaks are explained in the last part and there is a peak about 90 degree because the electrodes in first and last rows of the array have can only have gradient directions close to -90 and 90 degrees.

☐ Part f - Designing a test for validating propagation direction significance

As can be seen in the Figure 9 b, direction of wave propagation during the times with $PGD > 0.5$ is mostly 0 and 180 degree. In order to validate this observation, I have validated the null-hypothesis that the following distribution comes from a population with mean equal to zero.

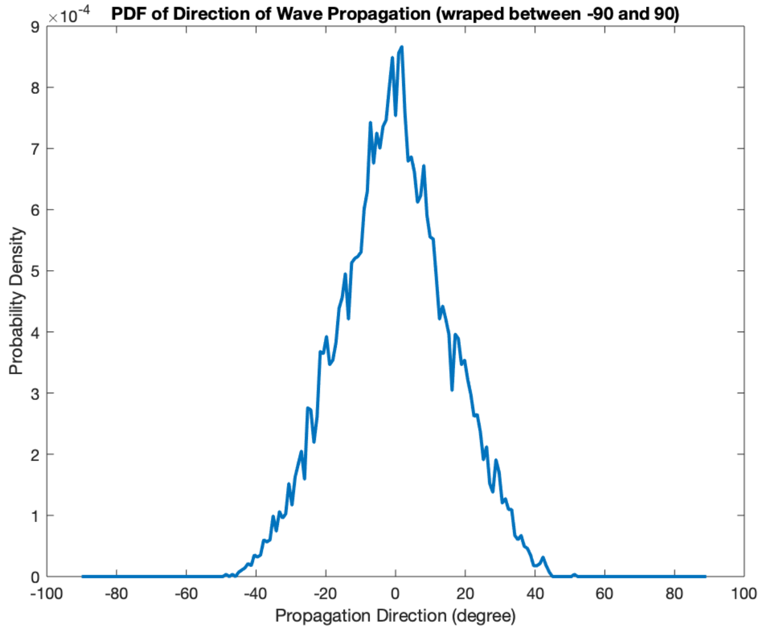
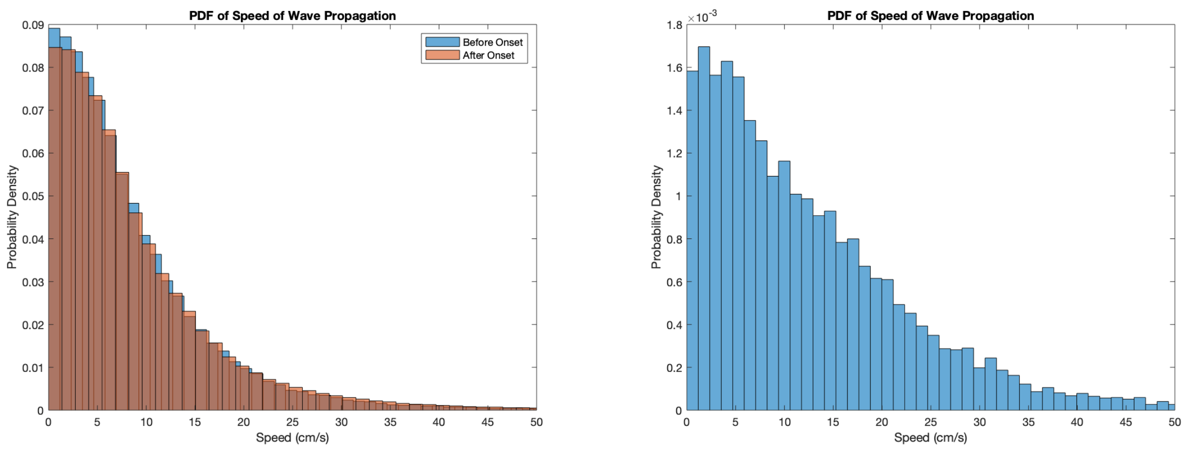


Figure 11: PDF of Direction of Wave Propagation - direction bigger than 90 degree are subtracted from 180

T-Test validates the null hypothesis with probability equal to 0.9.

☐ Part g - Comparing wave speed with criteria's in Sejnowski et.al 2018



(a) All times

(b) Times with $PGD > 0.5$

Figure 12: Direction of gradient of all channels

As can be seen in the Figure 12, wave speed is about $0 - 0.5$ m/s which is mostly close to what Sejnowski has mentioned in his paper.