In The Name Of God

HW04

Advanced Neuroscience

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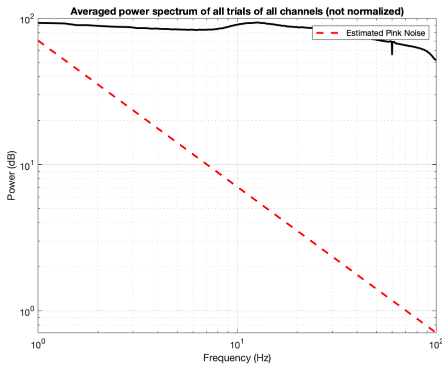
It is noteworthy to mention that I have only used the trials which were marked as clean trials.

■ LFP analysis

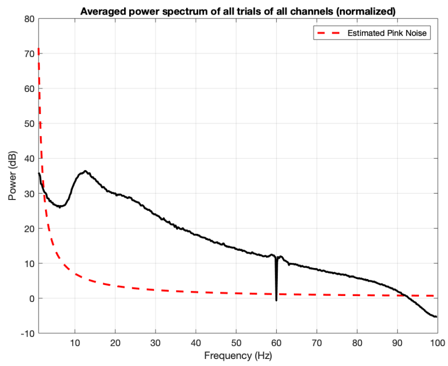
□ Part a - Removing Pink Noise

Pink Noise

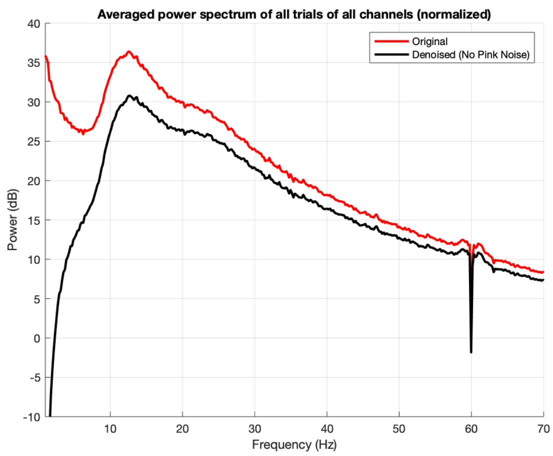
Pink noise or $\frac{1}{f}$ noise is a signal with a frequency spectrum such that the power spectral density is inversely proportional to the frequency of the signal. In order to removing pink noise, I fitted a line with slope equal to -1 to log-log FFT of the signal and then subtracted this line from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

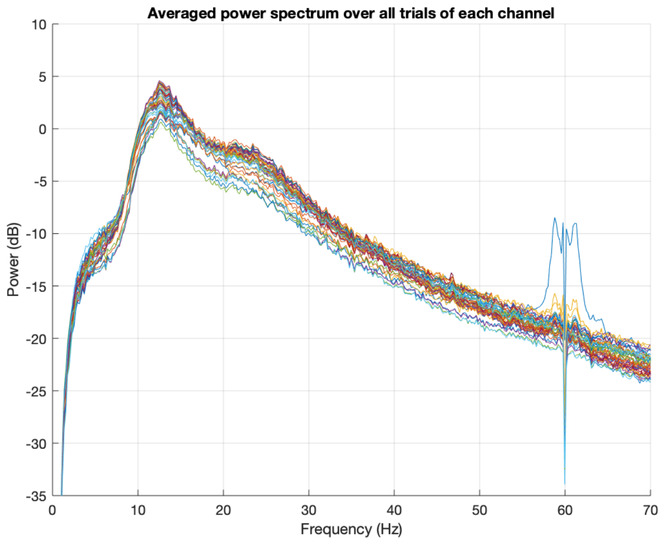
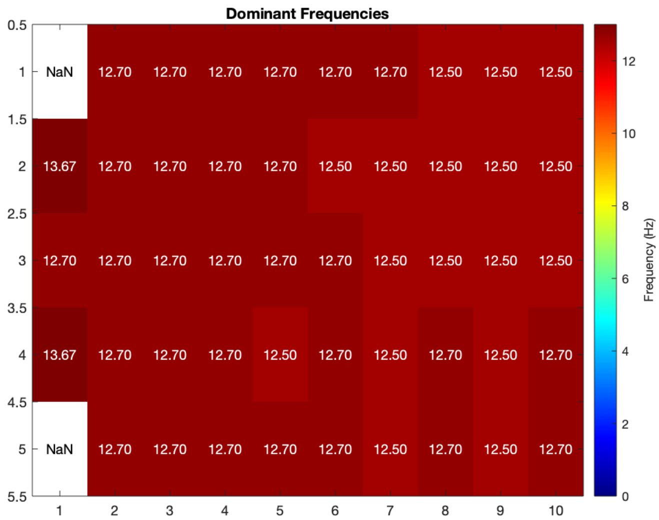


Figure 2: Average Power Spectrum of each Channel

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



	1	2	3	4	5	6	7	8	9	10
1	NaN	12.70	12.70	12.70	12.70	12.70	12.70	12.50	12.50	12.50
2	13.67	12.70	12.70	12.70	12.70	12.50	12.50	12.50	12.50	12.50
3	12.70	12.70	12.70	12.70	12.70	12.70	12.50	12.50	12.50	12.50
4	13.67	12.70	12.70	12.70	12.50	12.70	12.50	12.70	12.50	12.70
5	NaN	12.70	12.70	12.70	12.70	12.70	12.50	12.70	12.50	12.70

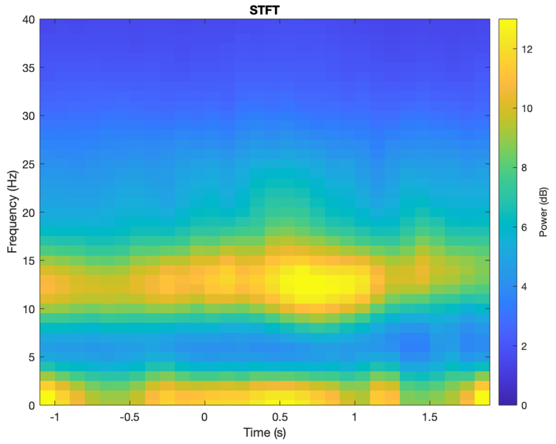
Figure 3: Dominant Frequency of each Channel

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.

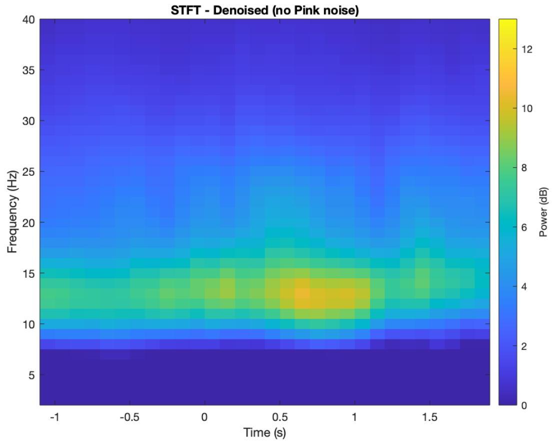
☐ Part c - Time-Frequency Analysis

Removing Pink Noise

STFT



(a) Original



(b) Denoised

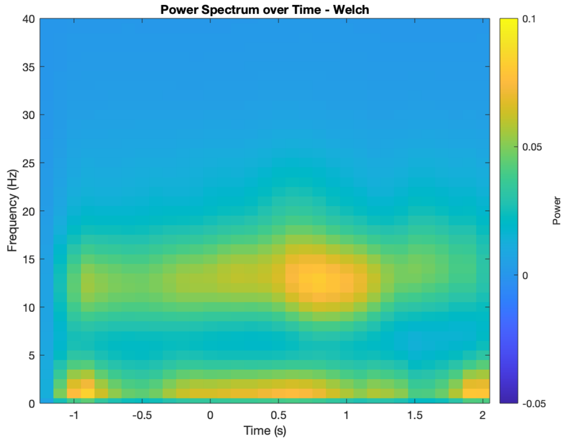
Figure 4: Average Power Spectrum over Time of all Trials of all Channels - STFT

Table 1: Parameters of STFT

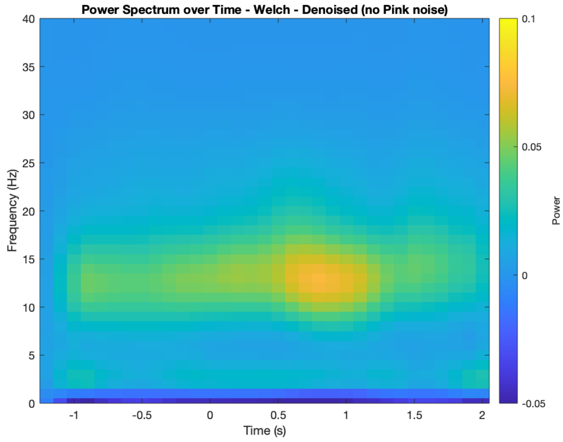
Window type	kaiser
Window gain	5
Window size	300ms
Overlap length	200ms
FFT Length	200

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

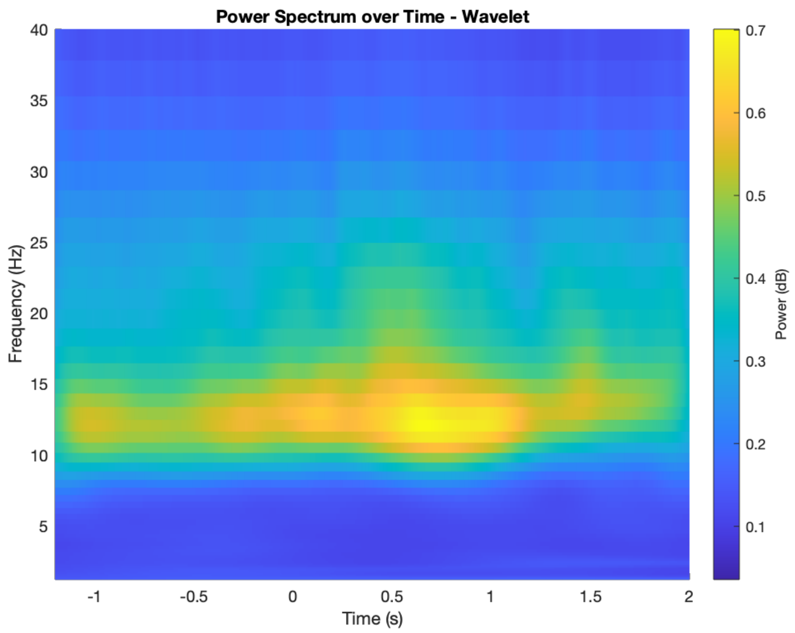
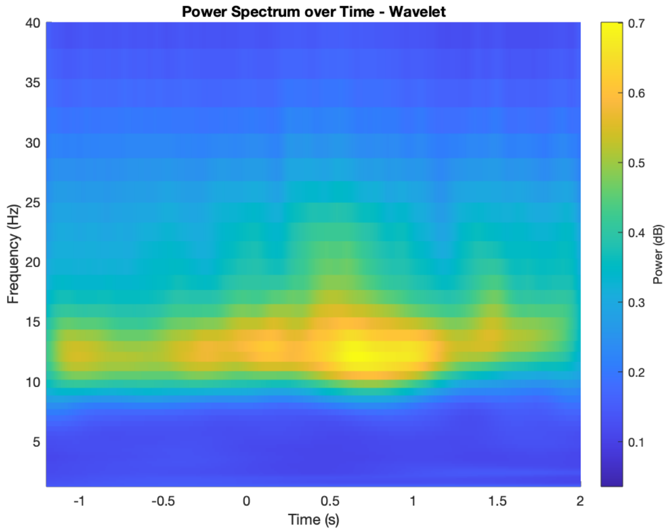


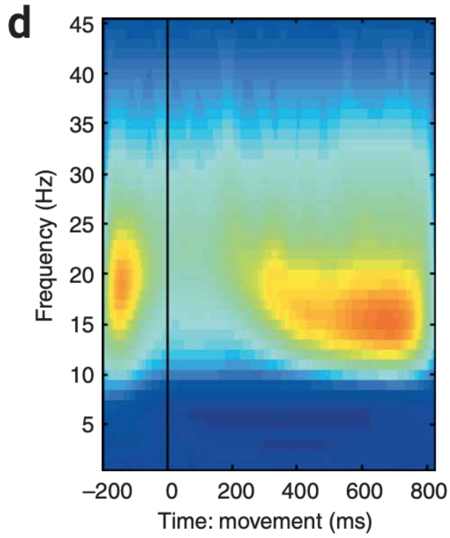
Figure 6: Average Power Spectrum over Time of all Trials of all Channels - Wavelet

□ 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 ones in Hatsopoulos et.al 2006.

■ Phase propagation (Traveling waves)

□ Part a - Bandpass filtering the recorded signals

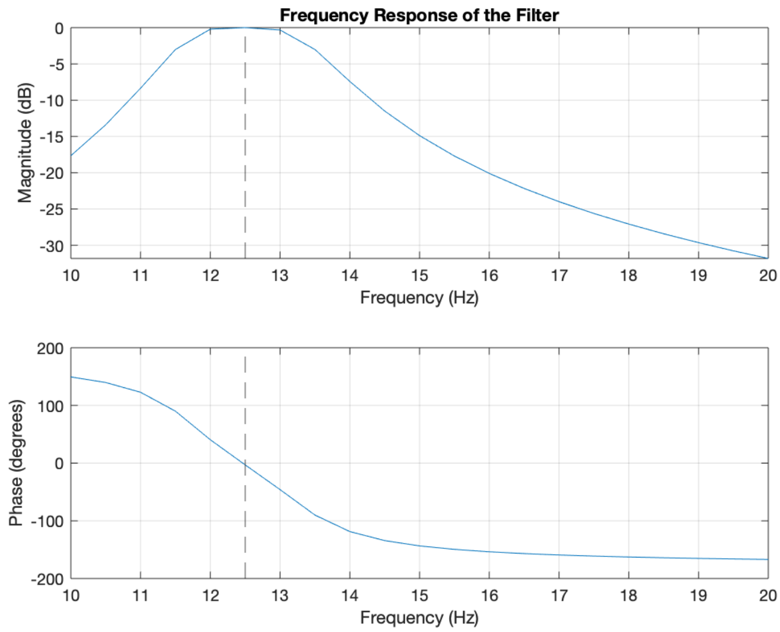


Figure 8: Frequency response of the filter $(12 - 13\text{Hz})$

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 8 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

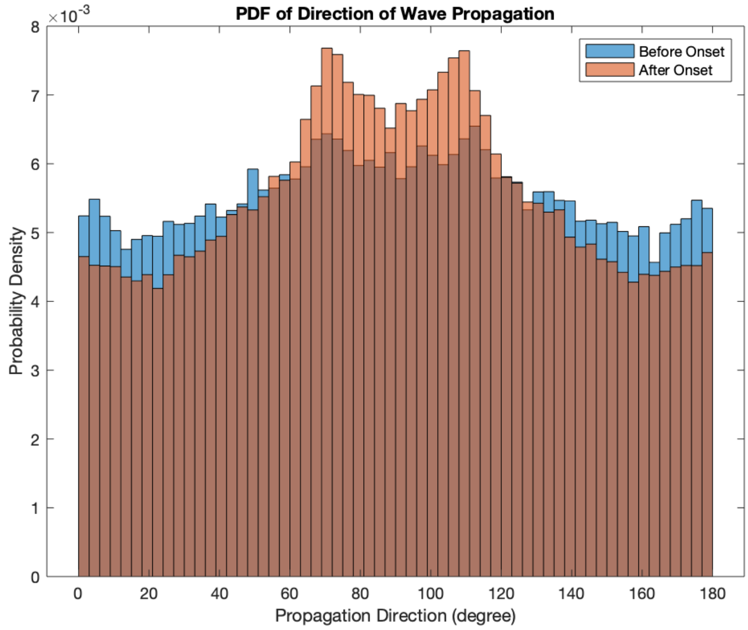


Figure 9: Direction of wave propagation (all trials)

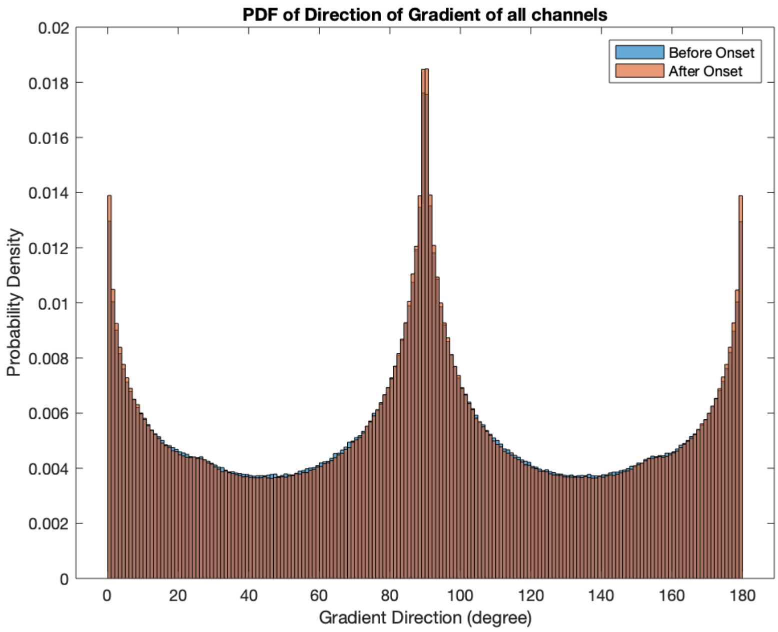


Figure 10: Direction of wave propagation (all trials of all channels)

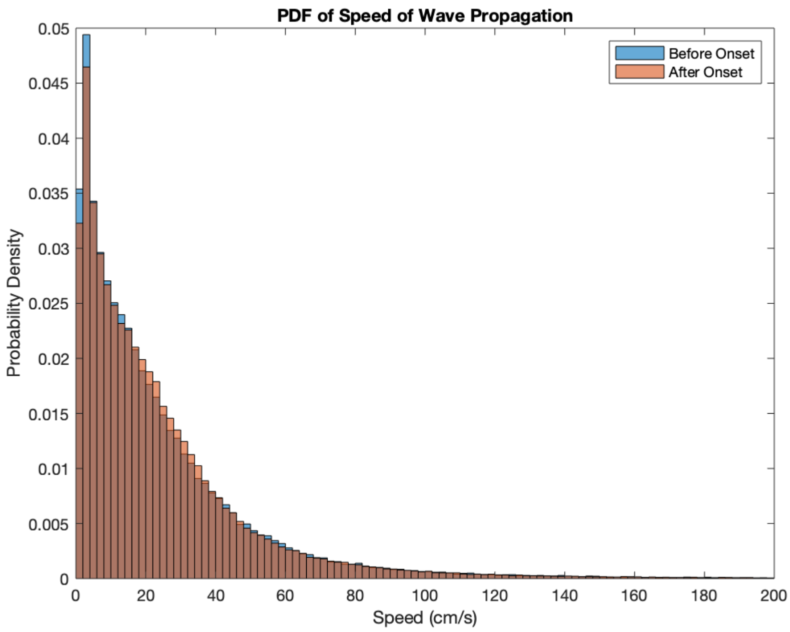


Figure 11: Direction of gradient of all channels