Advance Neuroscience HW4

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Preprocessing and Pre-Analysis

First we plot the LFP of all the channels averaged over all trials (including bad and good trials) in figure 1. Here in the figure 1 two channels that are different from others are shown using black colors and are called bad channels.

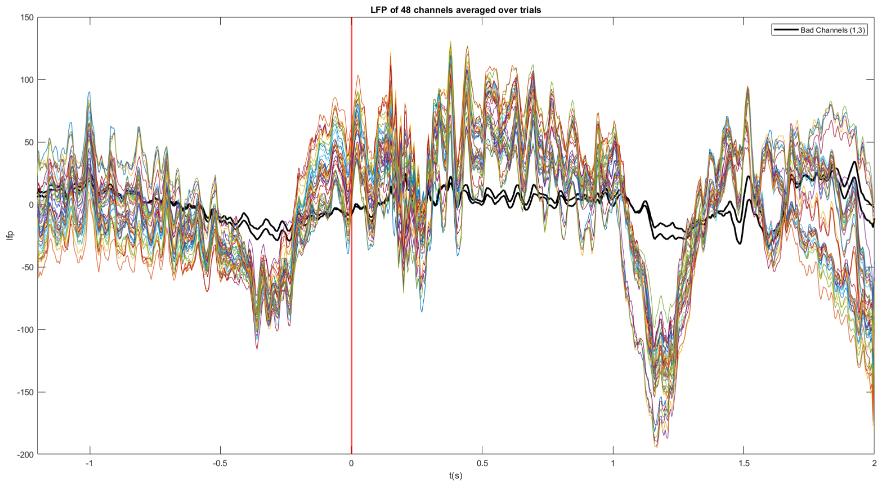

Figure 1: LFP plot over time for all channels averaged over all trials. The black curves are channel 1 and 3 which are refered to as bad channels in this paper.

Also in order to understand the difference between good and bad trials we plot the LFP of channel 2 for all the trials in figure 2.

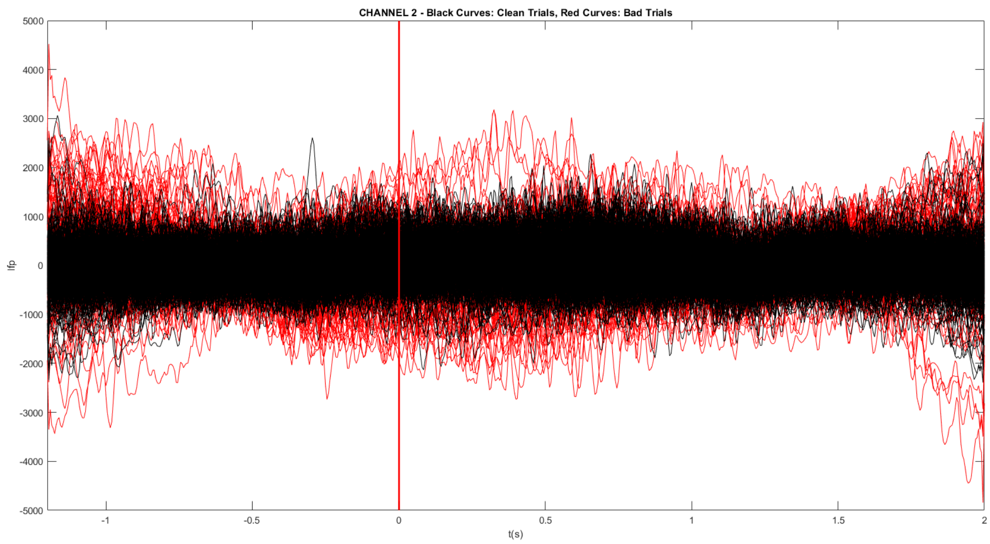

Figure 2: LFP on clean(black) and bad(red) trials of channel 2. We can see that red curves are more varient and noisy.

In figure 2 we denote the clean trials with black color and bad trials with red color. As apparent from the figure, the provided clean trials are less noisy than the bad trials. In the order to see the effect of bad trials on the LFP, we plot the LFP of some channels averaged only over clean trials and show them by black color and only over bad trials and show them by red color. (Figure 3) We can abviously see that there is a difference between bad trials and clean trials.

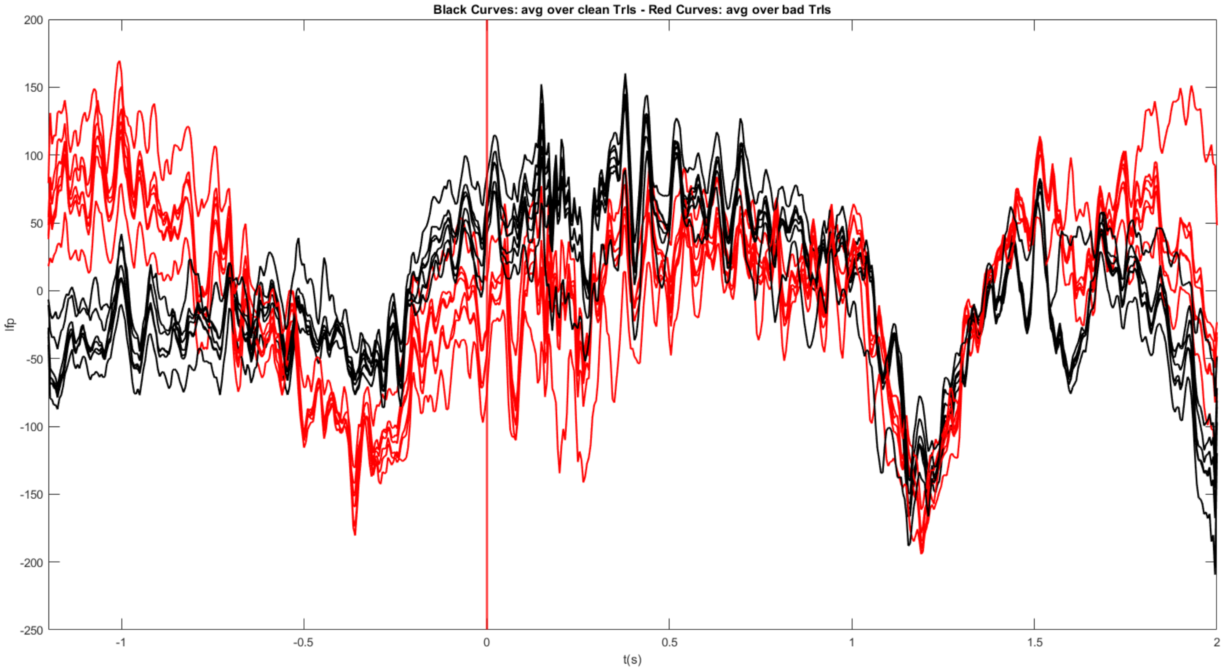

Figure 3: LFP of some channels averaged only on bad trails(red) and clean trails(black)

So we again plot the LFP of good channels (all except 1 and 3) over only clean trials in figure 4 and compare it with figure 1. As expected there is a less noise on channels and the LFPs are cleaner.

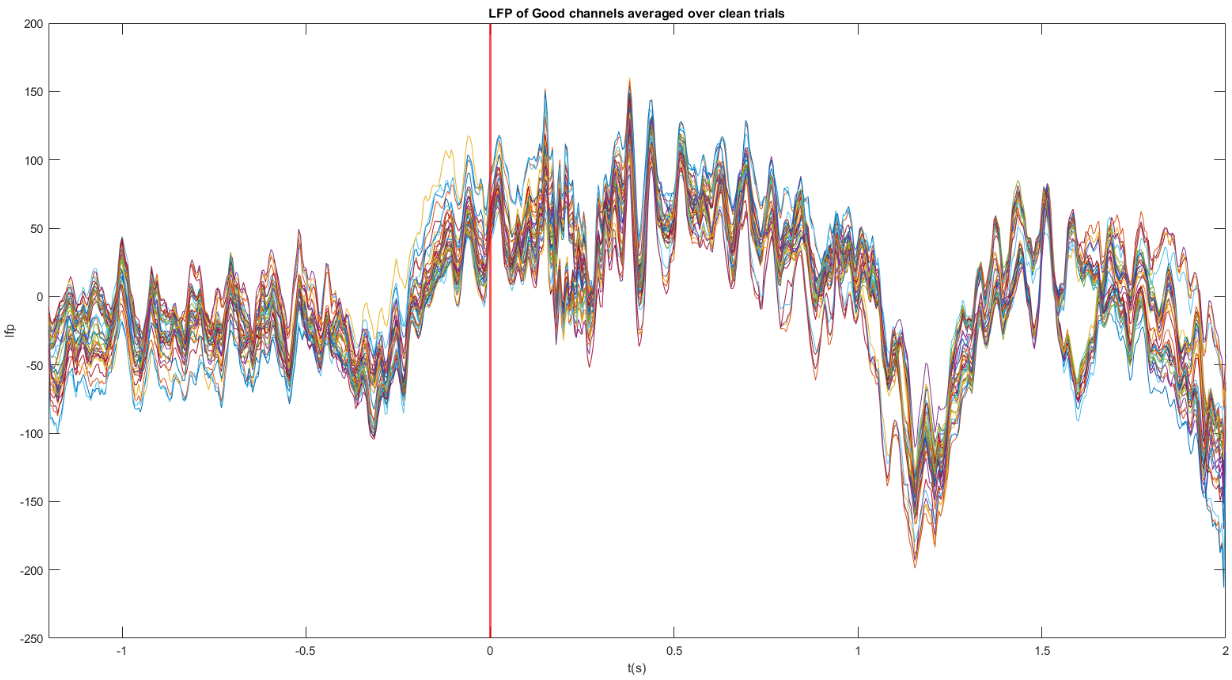

Figure 4: LFP of good channels over clean trials. Stimulus onset is denoted by vertical red line.

Also we plot the logarithmic power spectral density of LFPs for all the channels to again see if the bad channels are different.

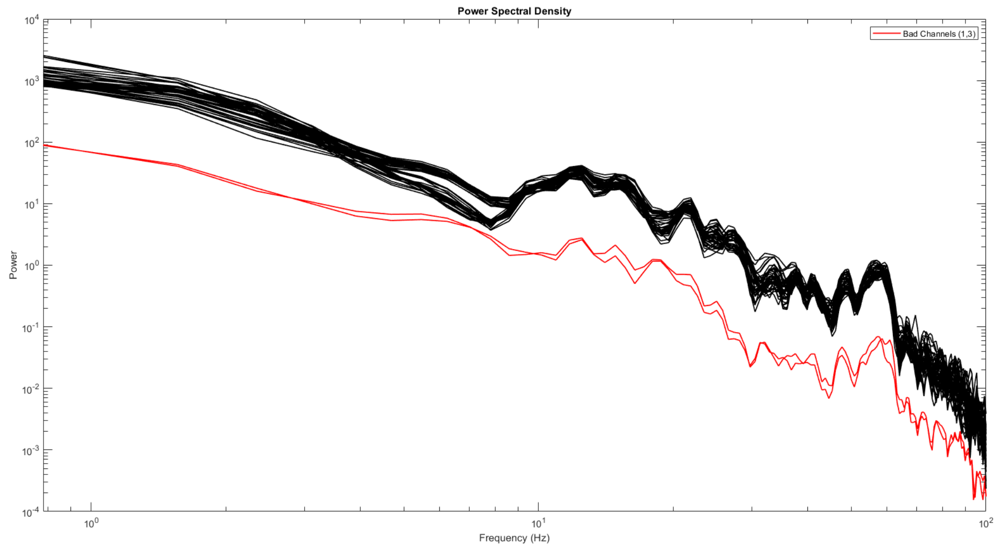

Figure 5: Power spectral density of all the channels. Channels 1 and 3 (bad channels) are denoted by red color.

Part B

Here we will find dominant frequencies and the topography using two different methods. First, we use power spectral densities to find the dominant frequencies and then, we use the fft of the LFP to find the frequencies.

Method 1 - Power

First we calculate the power spectral densities of all the good channels (LFP averaged over clean trials) and then, we fit lines to the logarithmic data becuase we know that the underlying process noise is proportional to $\frac{1}{f}$ so in the logarithmic scale it equals to a line which we find by fitting to the data using linear regression. Figure 6 shows the logarihtmic powers and regressed lines.

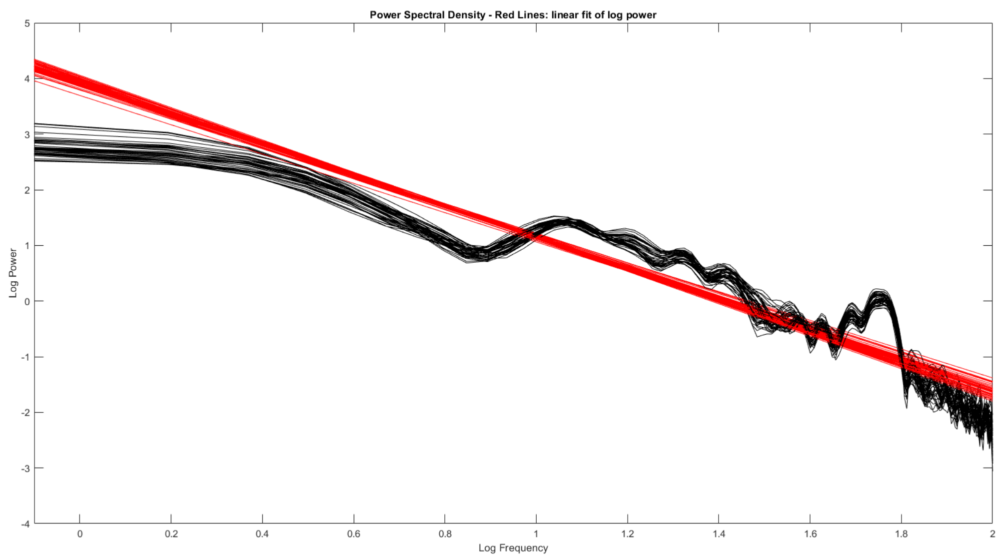

Figure 6: Power spectral density of good channels. Red lines are fitted to the spectral densities.

The denoised spectral density plot is brought in figure 7. We have two peaks. One around 60Hz and one in the 10Hz to 25Hz interval.

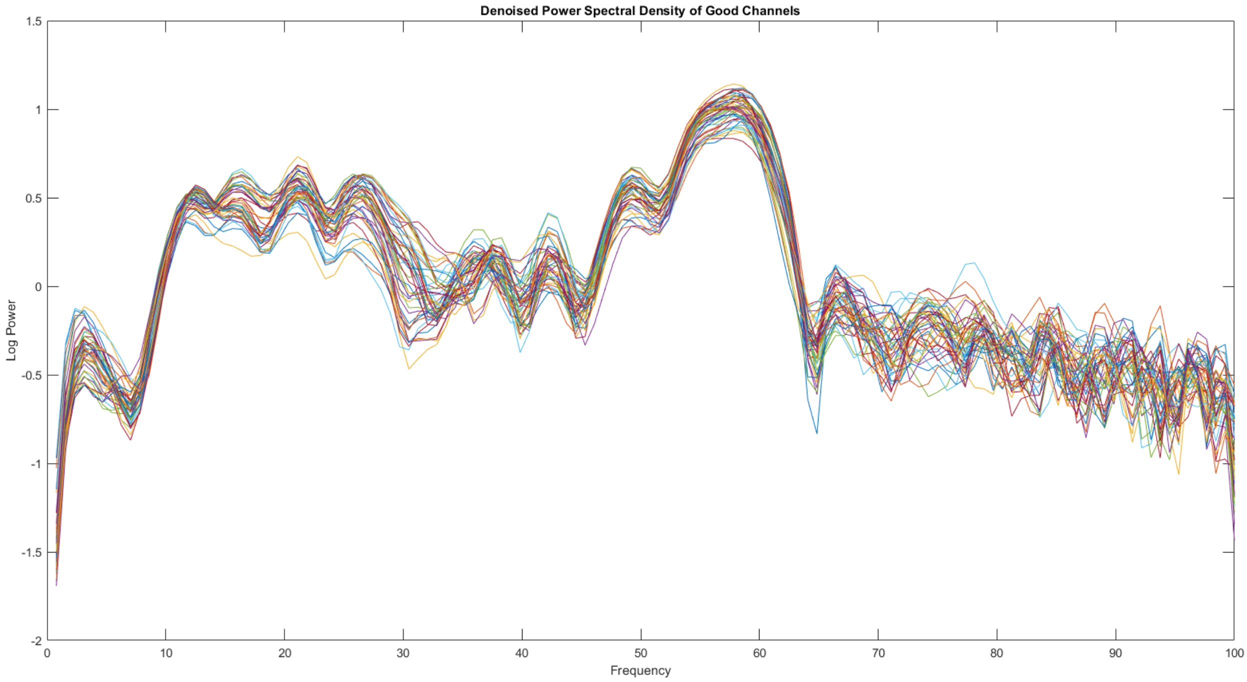

Figure 7: Denoised power spectral density of good channels.

Finally the dominant frequencies are found in the interval of 0Hz to 45Hz and color coded on a figure based on channel positions. (Figure 8)

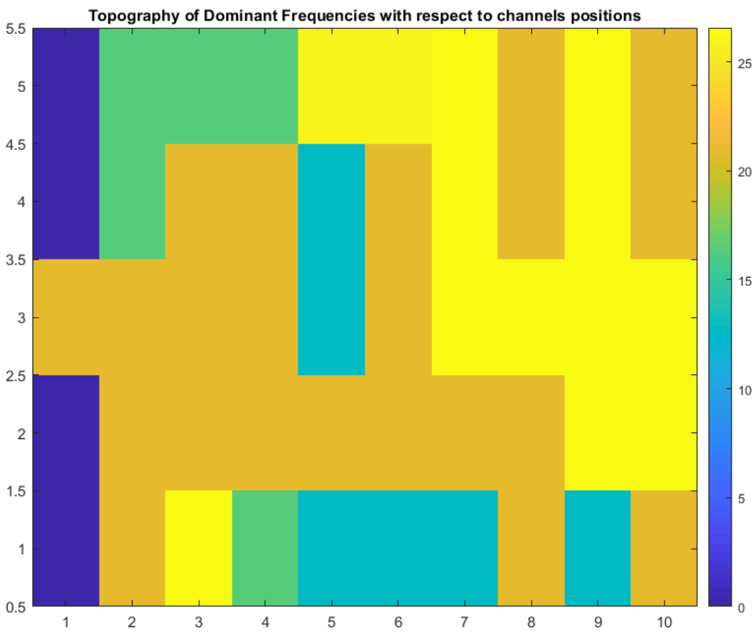

Figure 8: Topography of dominant frequencies.

It kind of looks like that by going from left to right, the dominant frequency rises.

Method 2 - FFT

We do all the things we did in the previous method but using the fft of the LFPs. Figure 9 is the logarithmic fft plot of good channels. The red lines are the fitted lines.

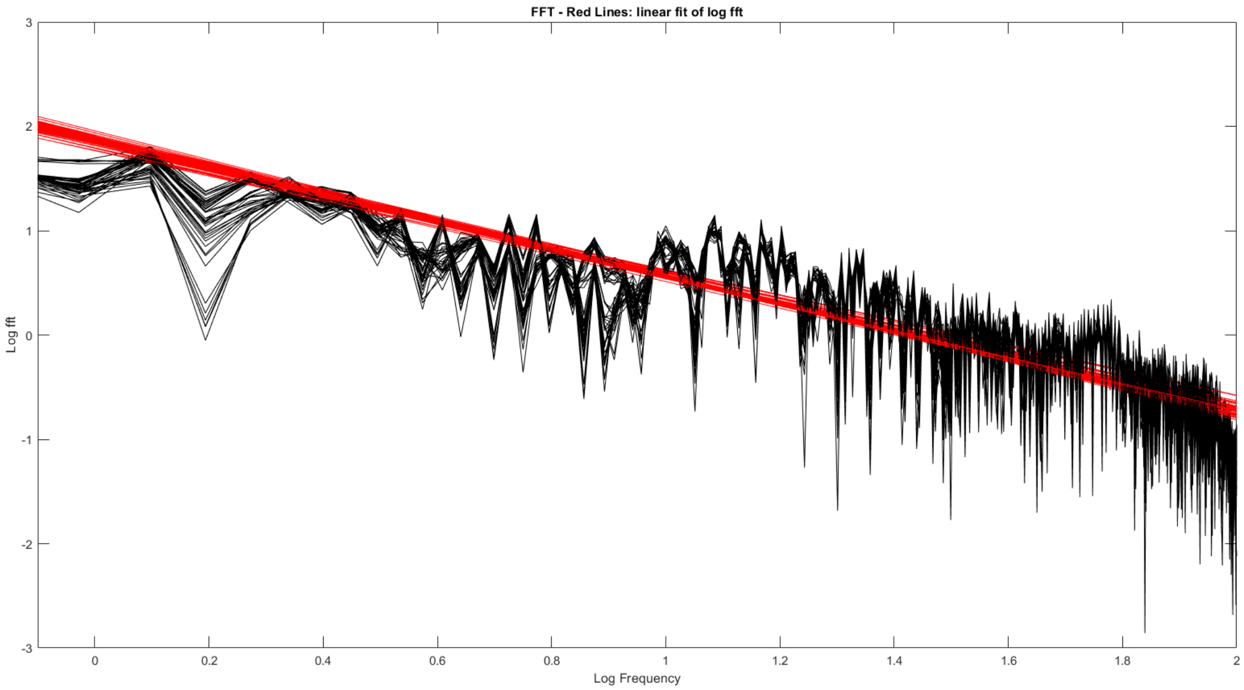

Figure 9: fft of good channels. Red lines are fitted to the ffts.

Then, by subtracting the lines from the ffts we get figure 10. We can again kind of see the maximum frequencies in the 60Hz and in the interval of 10Hz to 30Hz.

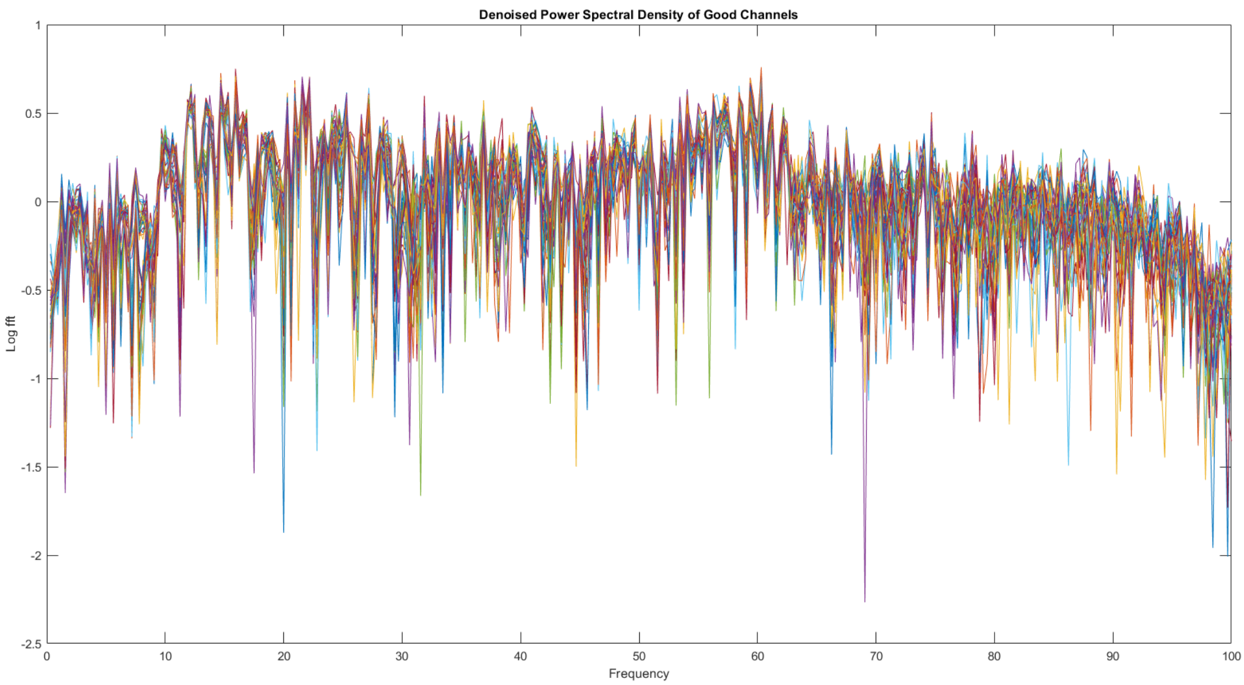

Figure 10: denoised fft of good channels.

Now we can find the dominant frequencies and plot the topography same as we did in the method 1 in figure 11.

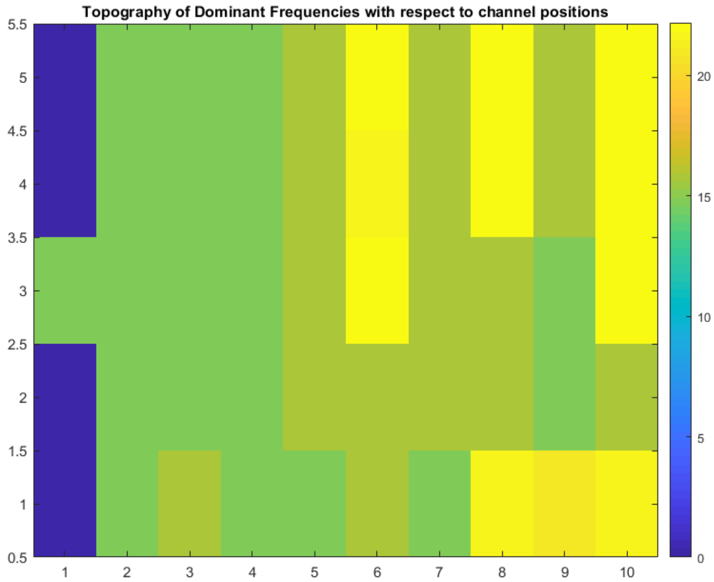

Figure 11: Topography of dominant frequencies.

Figure 11 is the dominant frequencies color coded in a matrix of channel positions. Again by moving to the right, the dominant frequency tends to rise. The reason behind this topography could be because of that the posterior areas work in higher frequencies.

Part C and D

Using the Welch's method the power spectrum plot is brought in figure 12. We can see that the interval of 5Hz to 25Hz has the most power among other bands. Also we can see that almost 250ms after the stimulus onset, the power rises in this band and continues to rise till about 1200ms. then fades away. Also before the stimulus onset we have some activity in this band.

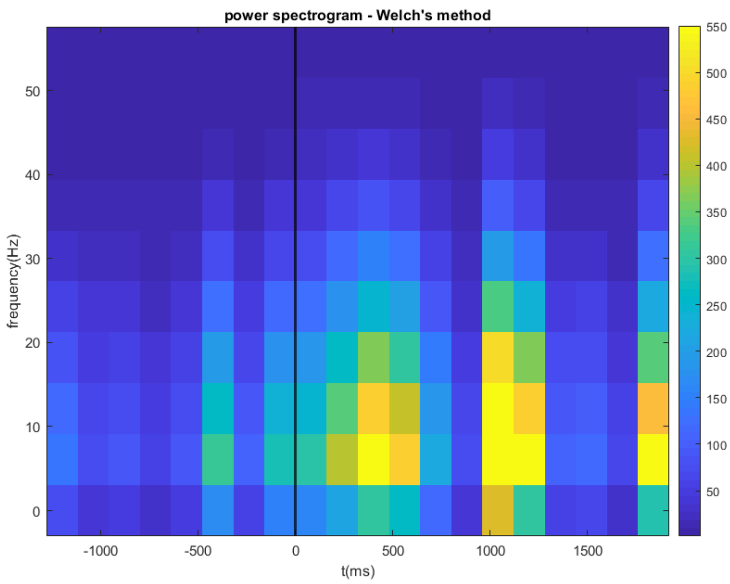

Figure 12: Power spectrum using Welch's method.

Also, using the multitaper method we do the same thing. (figure 13) We again can see almost the same thing we saw in last figure. Also this time it is more visibile that we had some activity in the 5Hz to 25Hz before the sitmulus onset and right after the stimuli onset the power falls and again rises till about 1200ms.

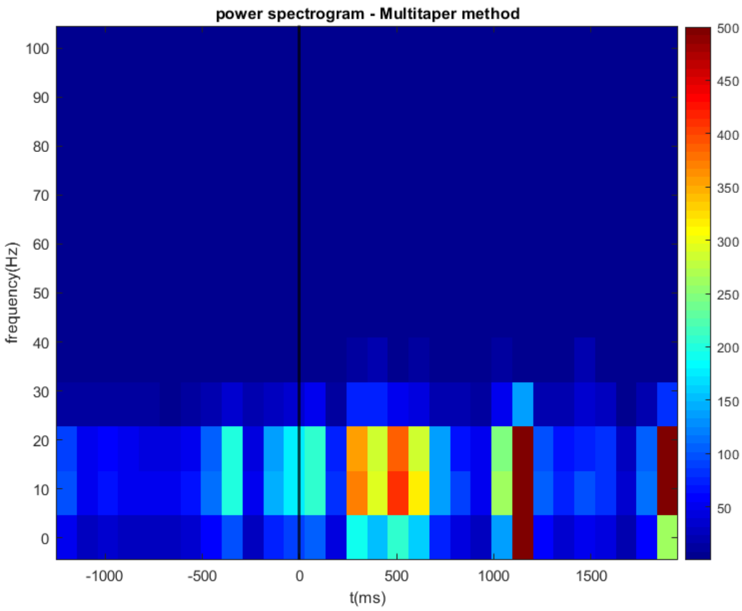

Figure 13: Power spectrum using multitaper method.

We also reconstruct figure 1a of the Hastopoulos paper in order to see if there are similarities and if we are doing he right thing. The power is calculated using Welch's method. (Figure 14)

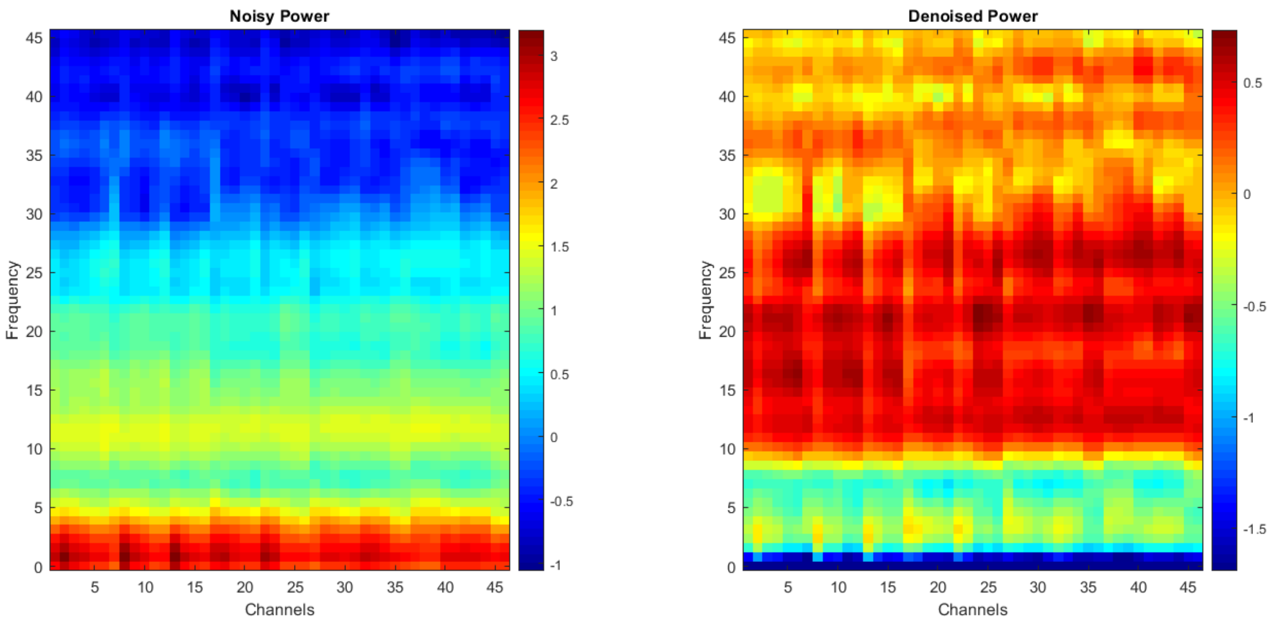

Figure 14: Left panel: It is the same figure as figure 1a of the Hastopoulos paper. The power spectrogram is calculated over all channels. Just like the paper, we have high activity in 0Hz to 7Hz and 10Hz to 20Hz. Right panel: Same figure but this time the underlying noise is reduced from each channel by fitting a line to logarithmic power. We can now see the activity in 10Hz to 28Hz

Phase Propagation (Traveling Waves)

The signals are filtered using a Butterworth filter of 2nd order at 1hz around the dominant frequency. The the instantaneous phase is calculated by the equations bellow:

$$\phi(t) = arg[S_a(t)] = arg[s(t) + j\hat{s}(t)]$$

Then, a demo is calculated from trial 89 and is provided along with other files. In the demo the gradient direction between channels is denoted using an arrow which changes during time. Also, the direction polar histogram is shown in the demo. Note that this histogram only shows the angles between -90 and 90 and the 0 angle means the overall direction is either left or right. The angle of 90 and -90 also can be seen in some timepoints whcih we are going to see again later. Also the PGD and speed of propagation is calculated. Some moments of the demo is brought in figure 15.

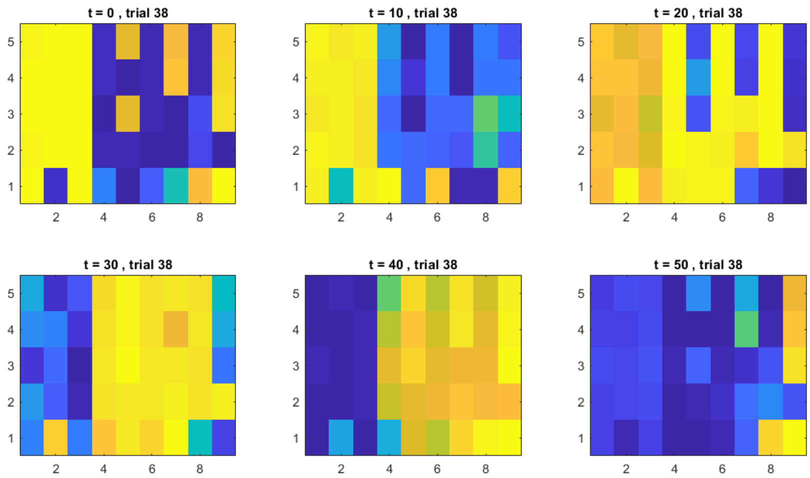

Figure 15: $cos(\phi(x, y, t))$ for different times. A travelling wave can be seen moving from left to right.

In order to see if the directions of waves are not random and whther there is a consentration in directions, we plot the histogram of directions for all channels. Figure 16 is directions while taking direction of 180 and 0 the same. (We do that because we want to see the overall directions not the exact angles)

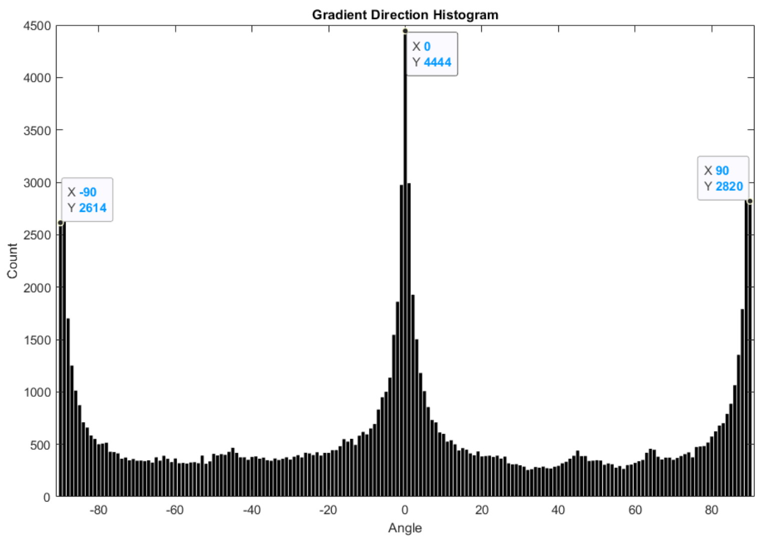

Figure 16: Direction of wave propagation histogram. 0 and 180 are taken to be the same direction.

In figure 16 it is apparent that the most overall directions are 90 and 0. So the wave either travels from left to right (right to left) or it travels from top to bottom (bottom to top). In figure 17 we have made a distinction between direction of 0 and 180.

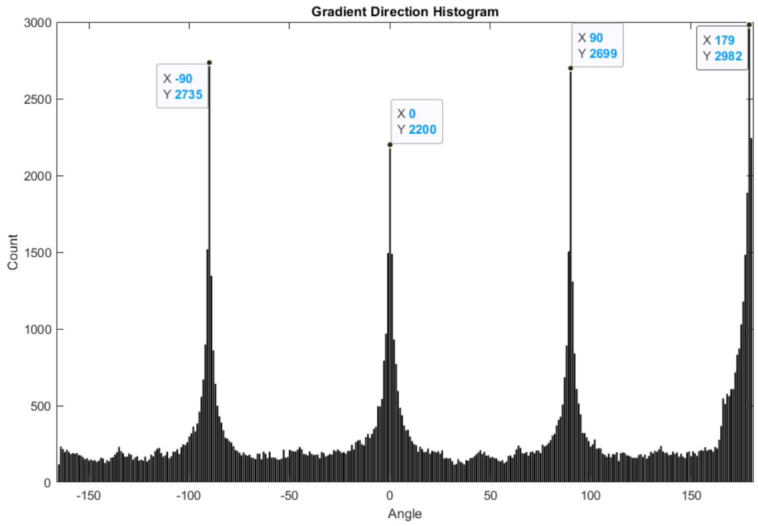

Figure 17: Direction of wave propagation histogram.

We can see that we also have degrees of 180 in this figure. Which means we have movement from left to right and also from right to left. Now we also compare our results with Sejnowski's criteria in phase propagation speed by making a histogram plot of speeds from all channels. (FIgure 18)

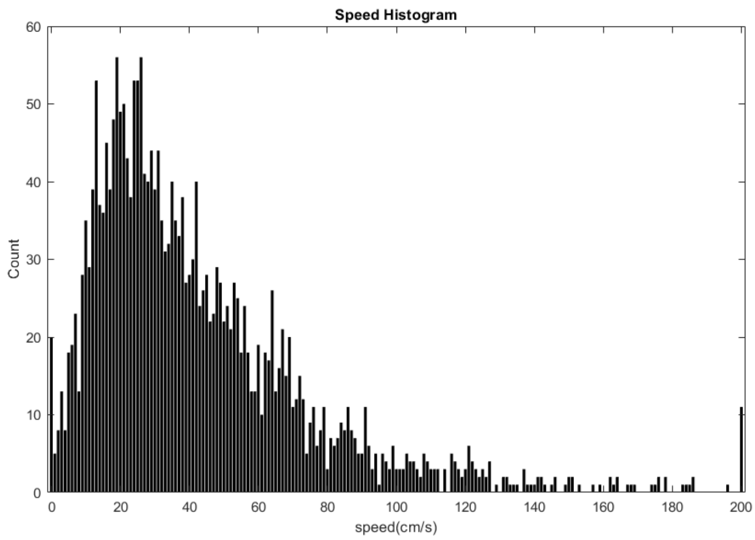

Figure 18: Speed of wave propagation histogram.

As can be seen in figure 18, the speeds are actually concentrated between 10cm/s and 100 cm/s.