University: Sharif University of Technology

Department: Electrical Engineering

Course Name: Advanced Neuroscience

Homework 4 Report

Traveling Waves

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LFP Ananlysis

a) Before starting any analysis, we do the pre-process. Using *bandstop()* function, we remove the line noise from the data and using constant regression, we fit a pink noise (line with slope -1) to each channel and denoise the data (Figure 1). We fitted the pink noise to each channel separately because the amplitude of noise can vary along electrodes.

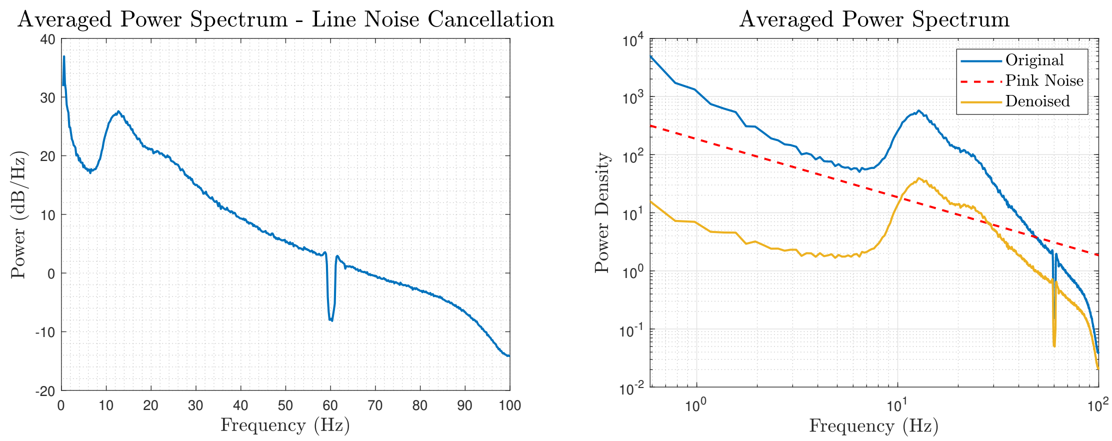

Figure 1: Line Noise and Pink Noise Removal

As can be seen above, the most dominant frequency is about $10^{Hz} - 15^{Hz}$.

b) After removing pink noise, we have averaged power spectral density of each channel. If we find the peak frequency in each channel, Figure 2 would be obtained.

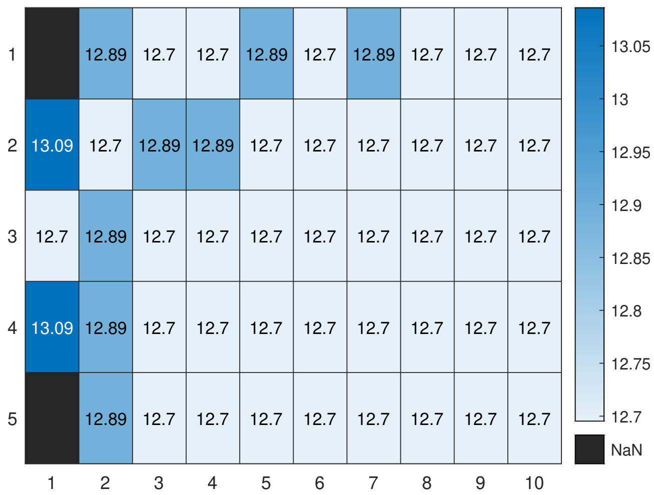

Figure 2: Clustering Dominant Frequencies

Dominant frequency for all channels is ~ 12.6953.

c) Figure 3 shows power spectrum before and after pink noise cancellation. Clearly, we can see that β band is more active.

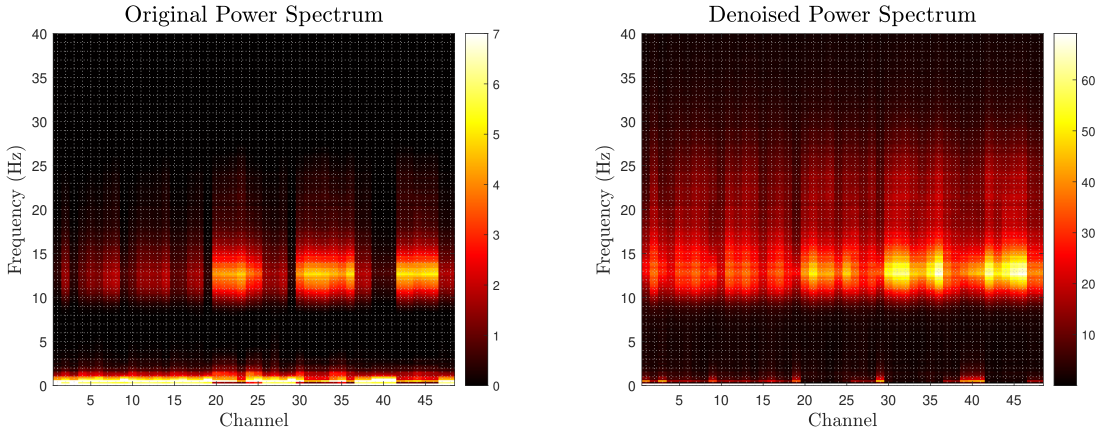

Figure 3: Power Spectrum

- **STFT:** First we calculate STFT of original signal and then we remove pink noise from it. Figure 4 shows STFT color maps.

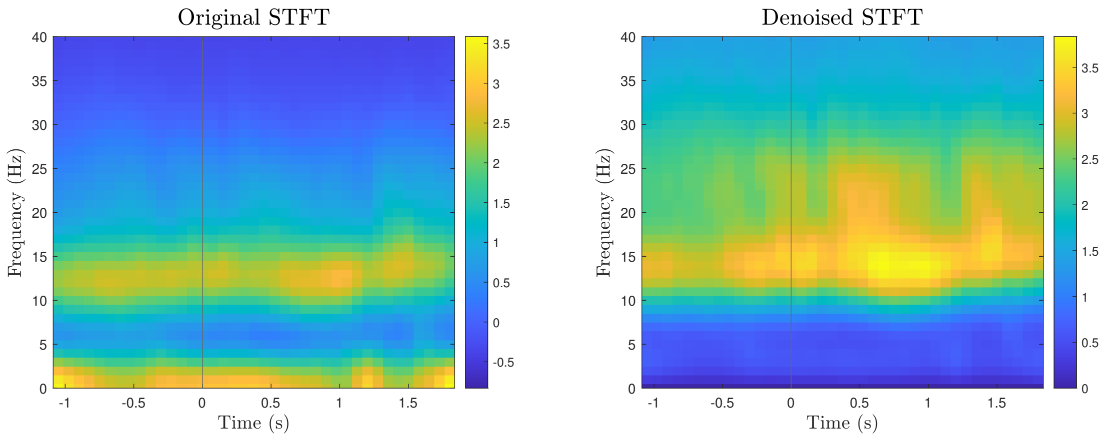

Figure 4: STFT - Power Spectrum

- **WELCH:** First we buffer the signal into overlapping frames, the calculate *pwelch()* of each time frame.

d) Results indicate that the interval $10^{Hz} - 15^{Hz}$ is the most strongest band specially around 0.6 sec after onset. Comparing to [1], Figure 6 is obtained.

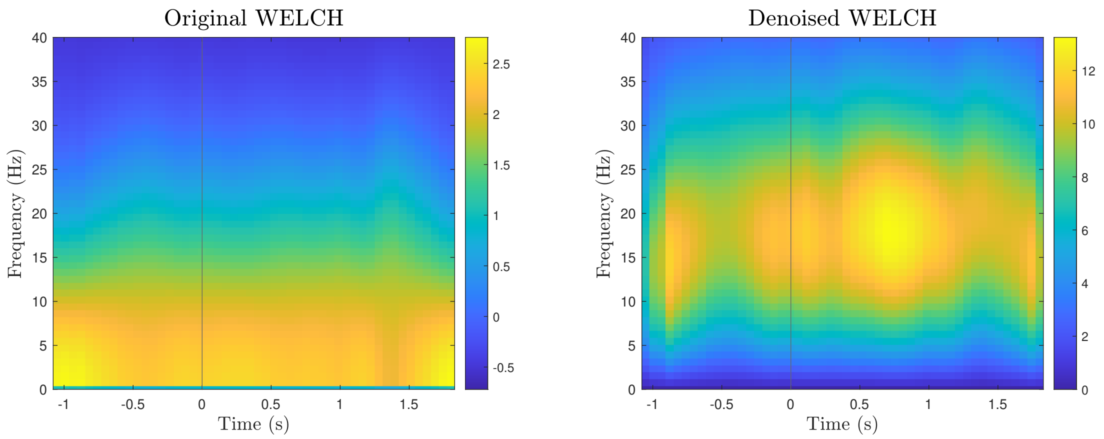

Figure 5: WELCH - Power Spectrum

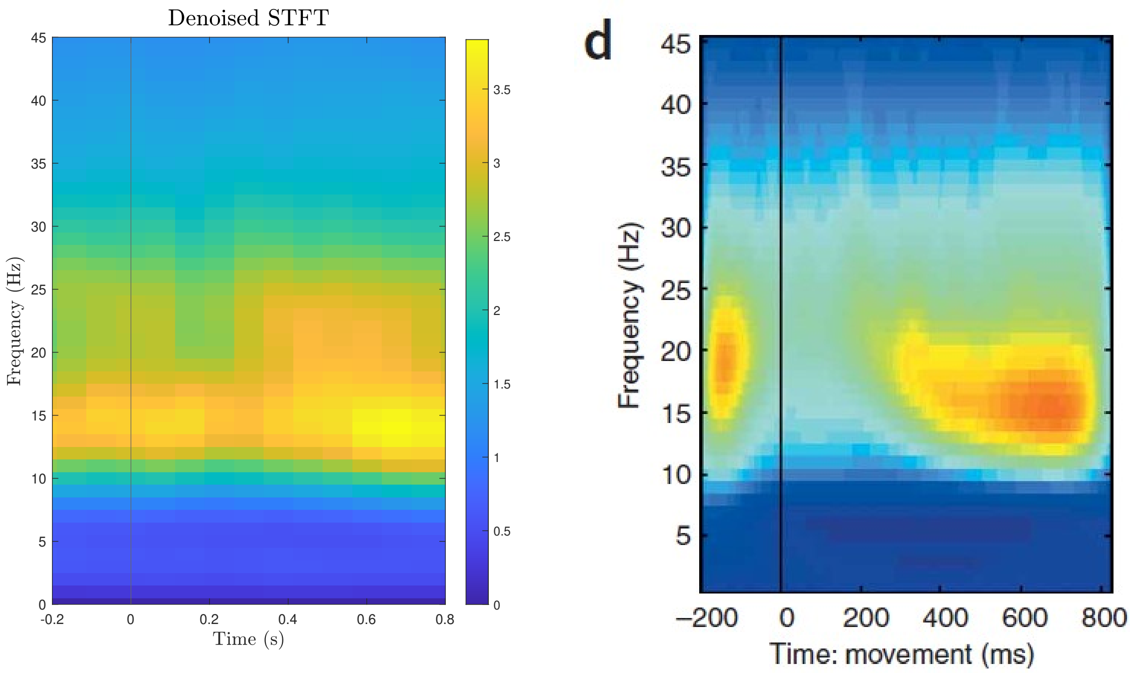

Figure 6: Comparing to [1]

Phase Propagation (Traveling Waves)

a) Using *butter()* function, we design a second-order Butter-worth filter described as in Figure 7. The important point is that it's phase is linear around dominant frequency and we would still be able to see wave.

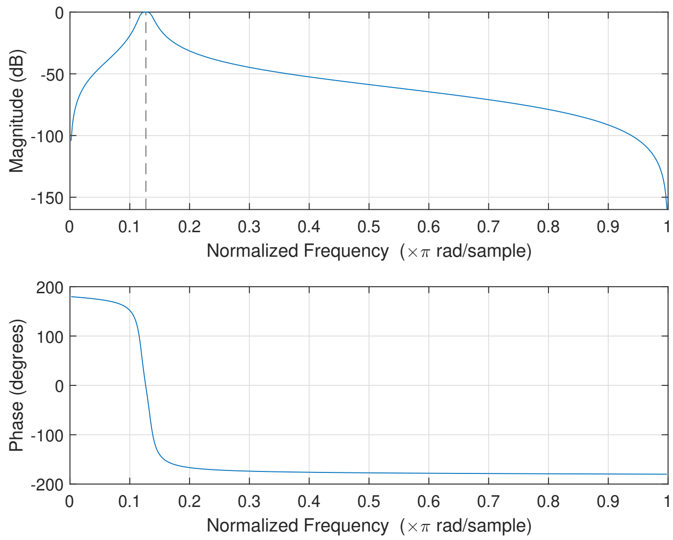

Figure 7: Butter-worth Filter Specification

b) Here, we take the angle of hilbert transform of LFP data using this simple line code, resulting $\phi(x, y, t)$:

```
phase_mat(i, j, :, :) = angle(hilbert(clear_chan(ch).filt_lfp));
```

c) Part c and e are done together as `demo.mp4` and `demo_filt.mp4`.

d) In each time step, we calculate the *gradient()* of phase in the electrodes and take the average vector as direction of propagation. PGD and SPEED are calculated as mentioned in [1]:

$$PGD(t) = \|\overline{\nabla\phi}\| / \overline{\|\nabla\phi\|}$$

$$speed(t) = \overline{|\partial\phi/\partial t|} / \overline{\|\nabla\phi\|}$$

e) Part c and e are done together as `demo.mp4` and `demo_filt.mp4`.

f) If we calculate all parameters in `demo.mp4` for all trials, we can plot some histograms to test our hypothesis.

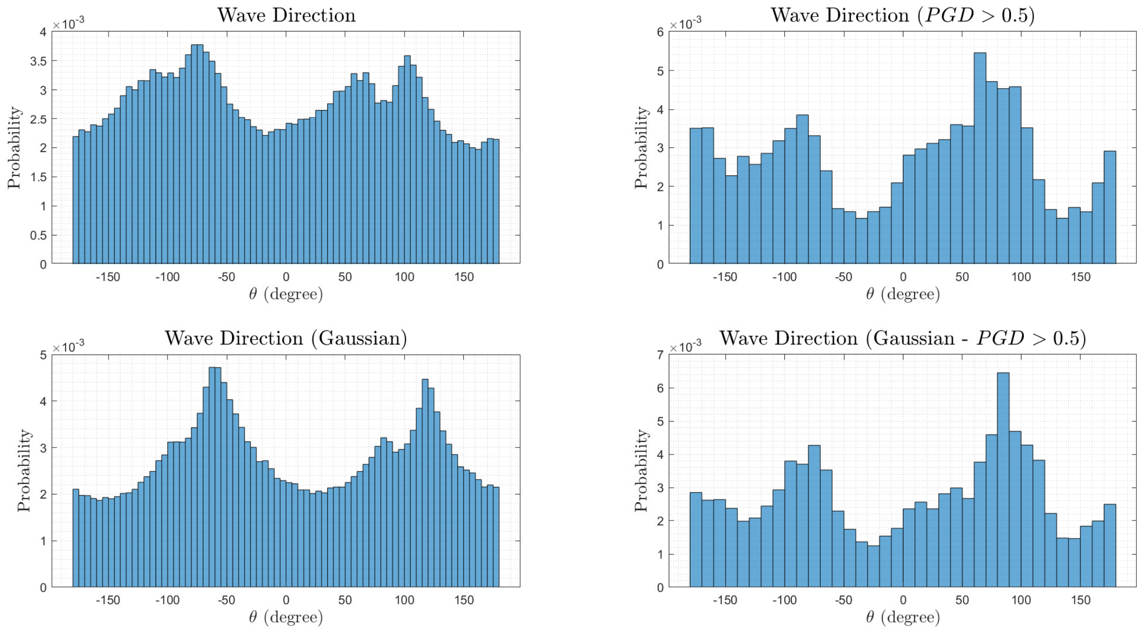

Figure 8: Wave Direction Histogram

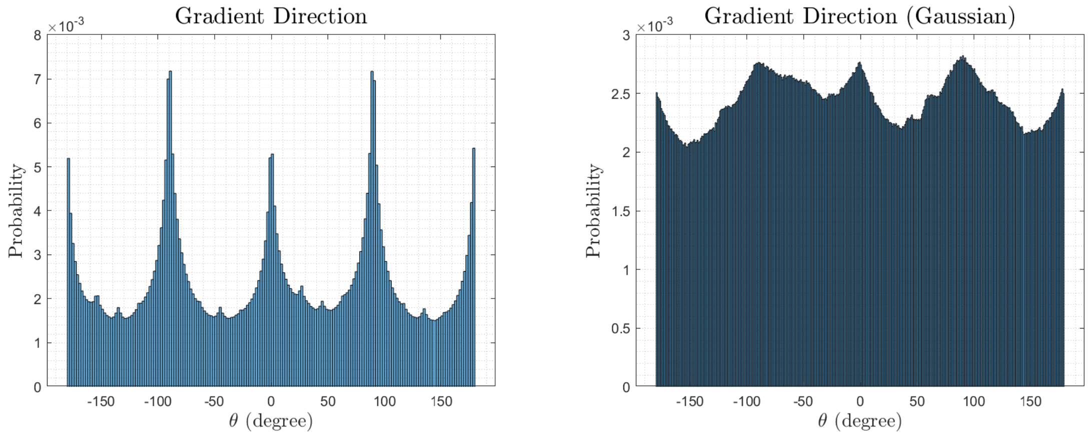

Figure 9: Gradient Direction Histogram

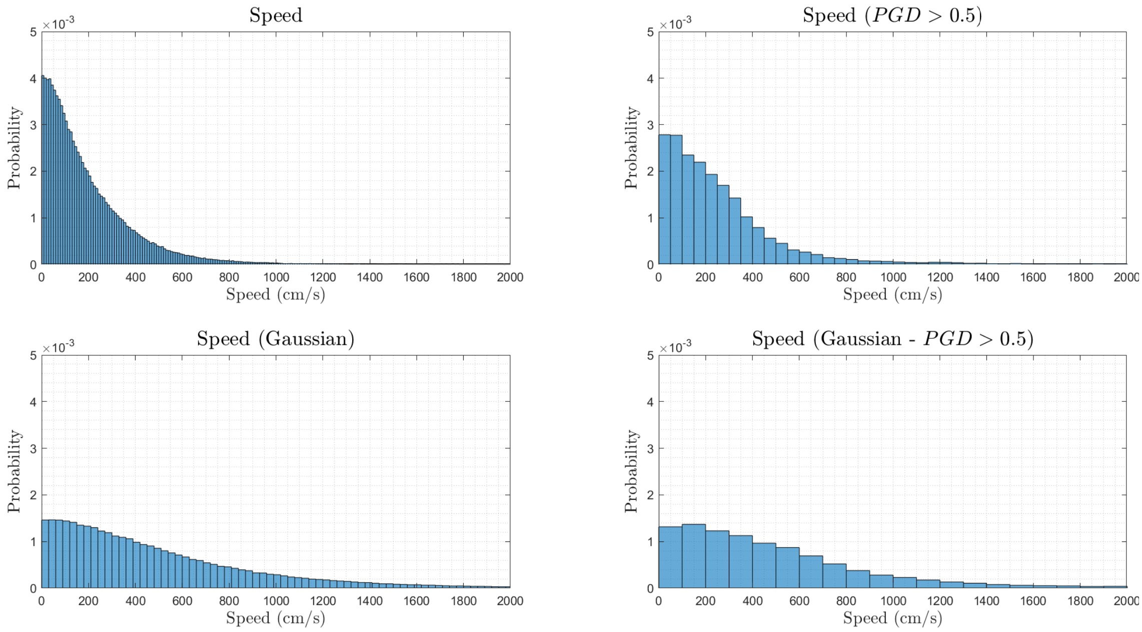

Figure 10: Speed Histogram

References

[1] Doug Rubino, Kay A Robbins, and Nicholas G Hatsopoulos. "Propagating waves mediate information transfer in the motor cortex". en. In: *Nat. Neurosci.* 9.12 (Dec. 2006), pp. 1549–1557.