Student Name: Mohammad Mohammad Beigi
Student ID: 99102189
Subject: Noise Correlation

Advanced Topics in Neuroscience - Dr. Ali Ghazizadeh
Assignment 3

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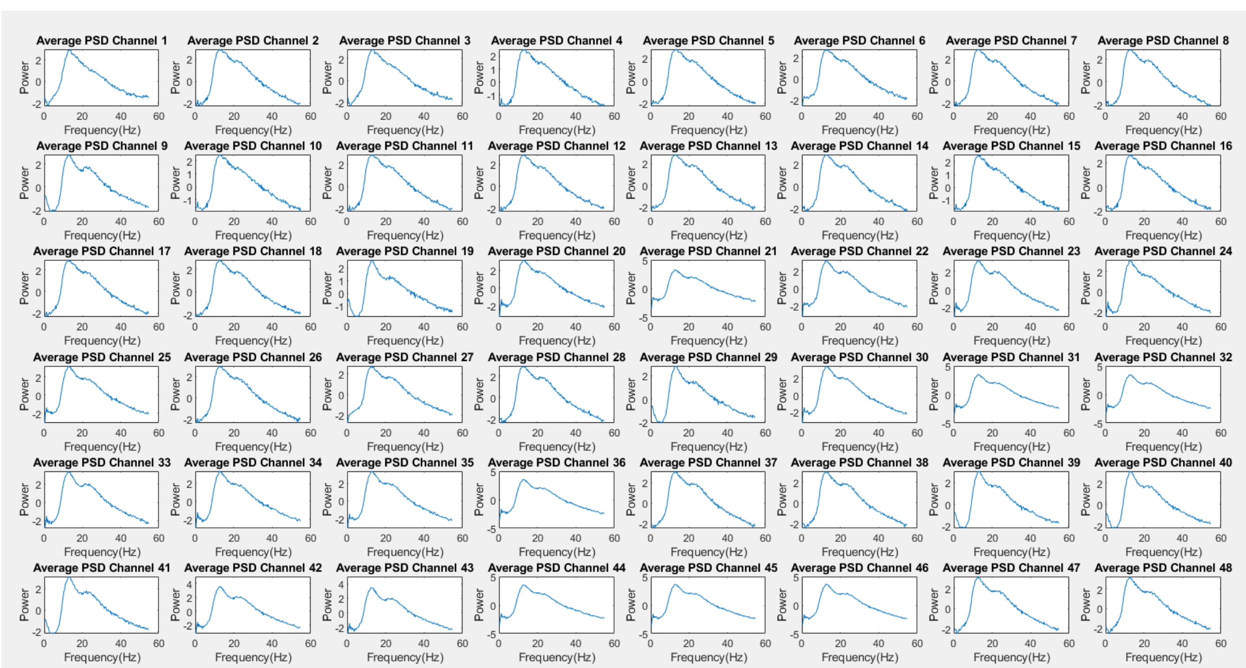
1. We should find out the most dominant frequency oscillation. To do so you must plot averaged power spectrum after doing color noise cancelation.

   Sampling Frequency is 200Hz. After calculating power spectral density for 0-100Hz frequency band, we delete the frequencies higher than 55 Hz. Then the following function we delete pink noise from the signals of all clean trials.

```
function newX = deletePinkNoise(x, freq)
X = [ones(length(log2(freq)),1) log2(freq)'];
Y = log2(x)';
b = X\Y;
newX = Y - log2(freq)'*b(2) - b(1)*ones(length(log2(freq)),1);
end
```

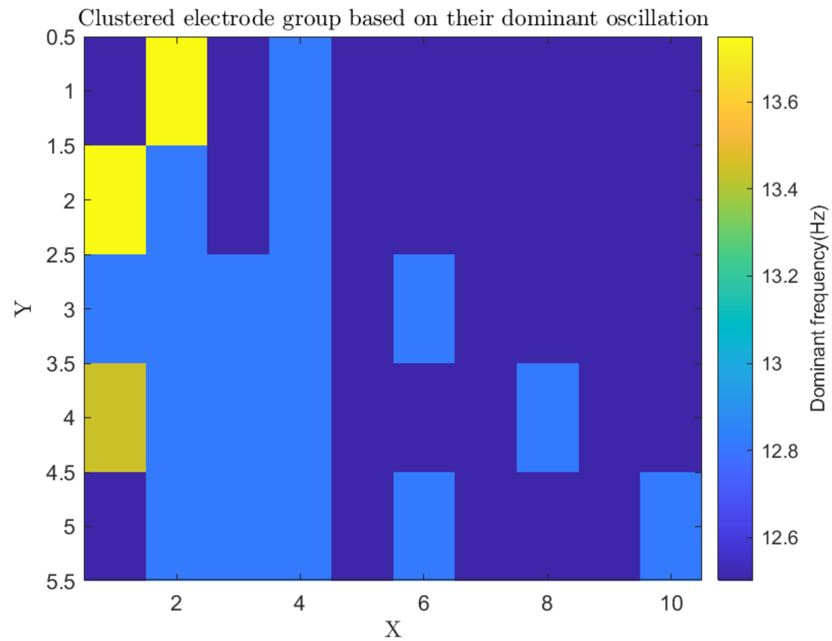
   Now After calculating average PSD over clean trials of each channel, we find the frequency which average PSD is maximum in it. In third part of this section we have plotted the average PSD for each channel. Here we plot power spectrogram(Time Frequency Analysis):



The dominant frequencies are as below:

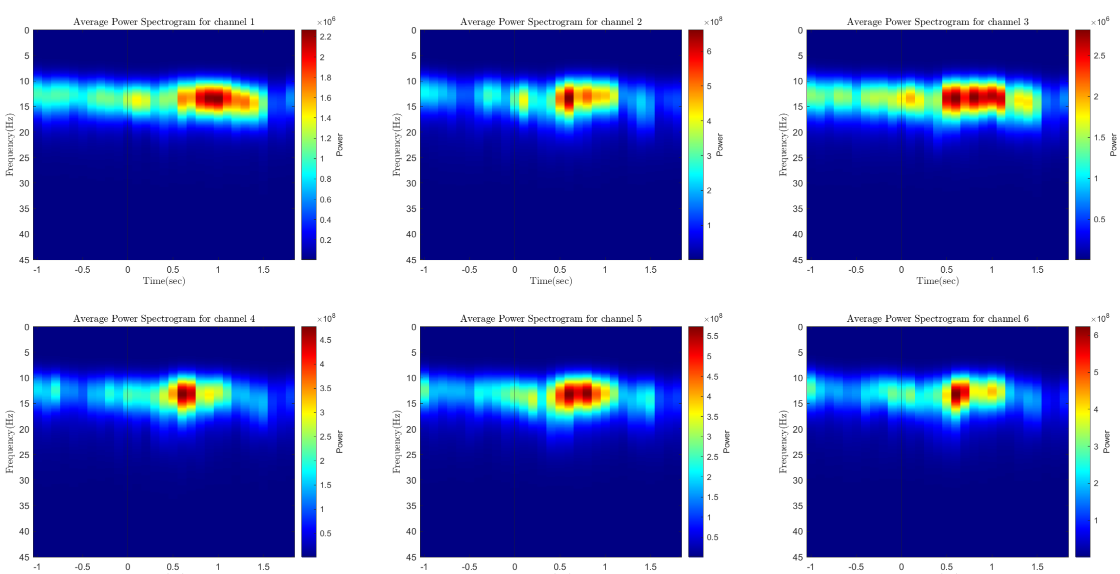
	1	2	3	4	5	6	7	8	9	10
1	NaN	13.7500	12.5000	12.8125	12.5000	12.5000	12.5000	12.5000	12.5000	12.5000
2	13.7500	12.8125	12.5000	12.8125	12.5000	12.5000	12.5000	12.5000	12.5000	12.5000
3	12.8125	12.8125	12.8125	12.8125	12.5000	12.8125	12.5000	12.5000	12.5000	12.5000
4	13.4375	12.8125	12.8125	12.8125	12.5000	12.5000	12.5000	12.8125	12.5000	12.5000
5	NaN	12.8125	12.8125	12.8125	12.5000	12.8125	12.5000	12.5000	12.5000	12.8125

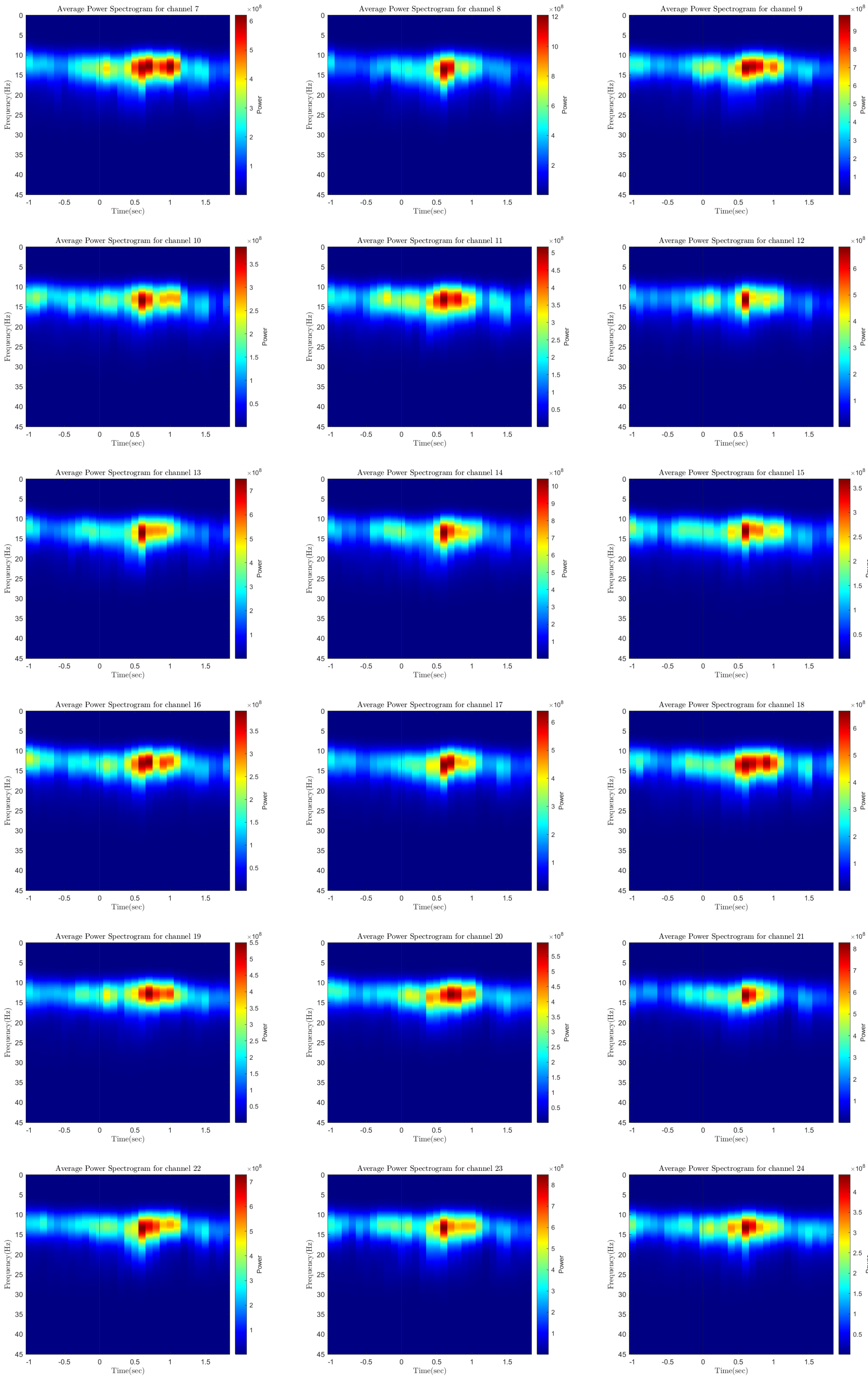
Now we cluster electrode group based on their dominant oscillation frequency

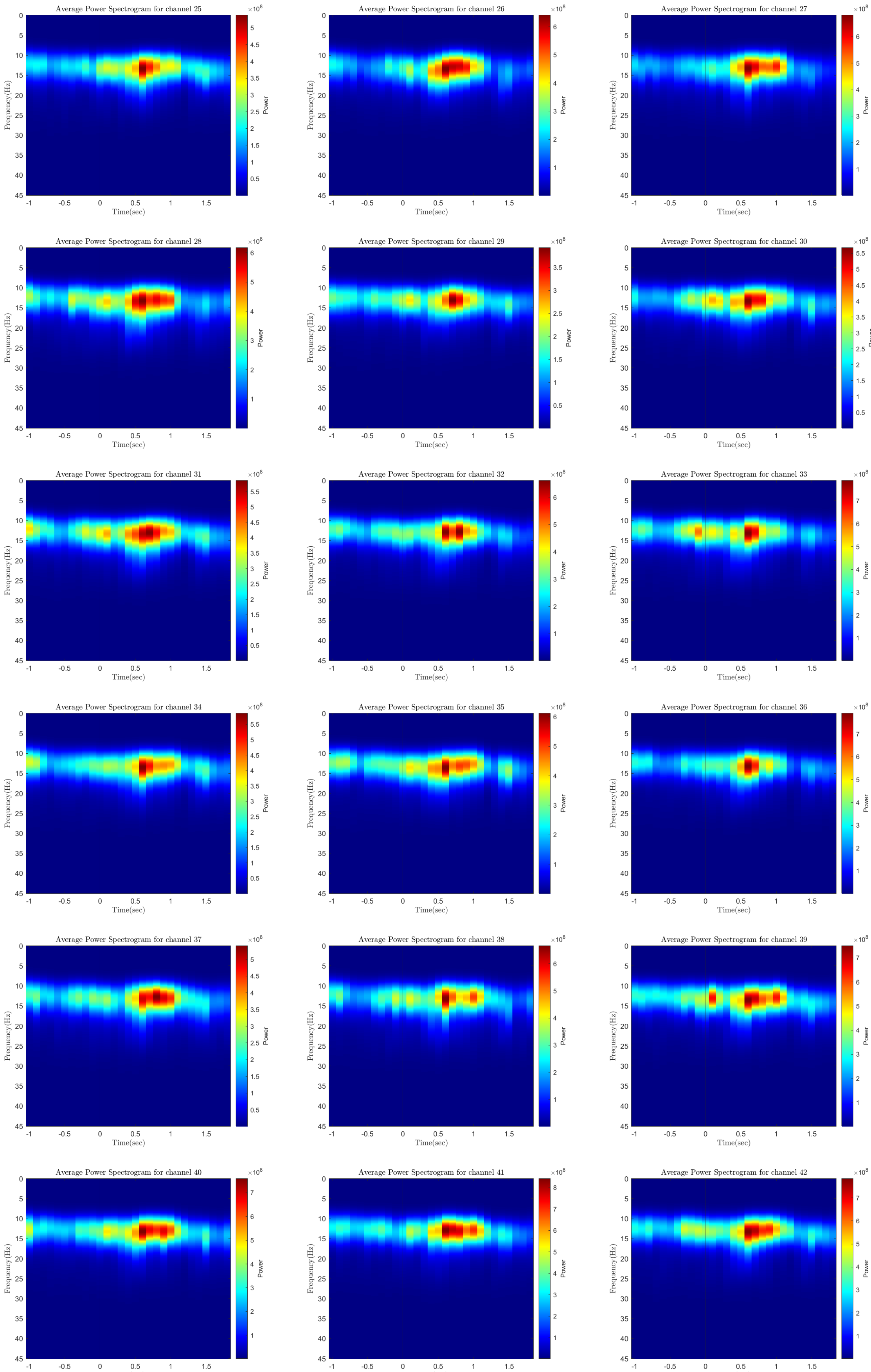


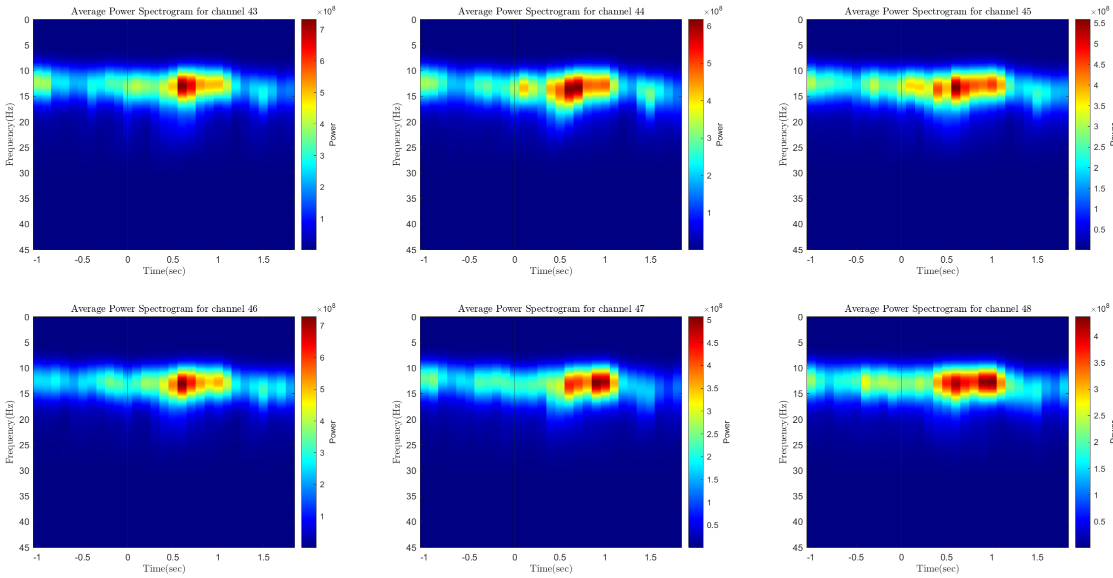
We can see that most dominant frequency in near electrodes is same.

Now we plot Average power spectrogram of each channel:



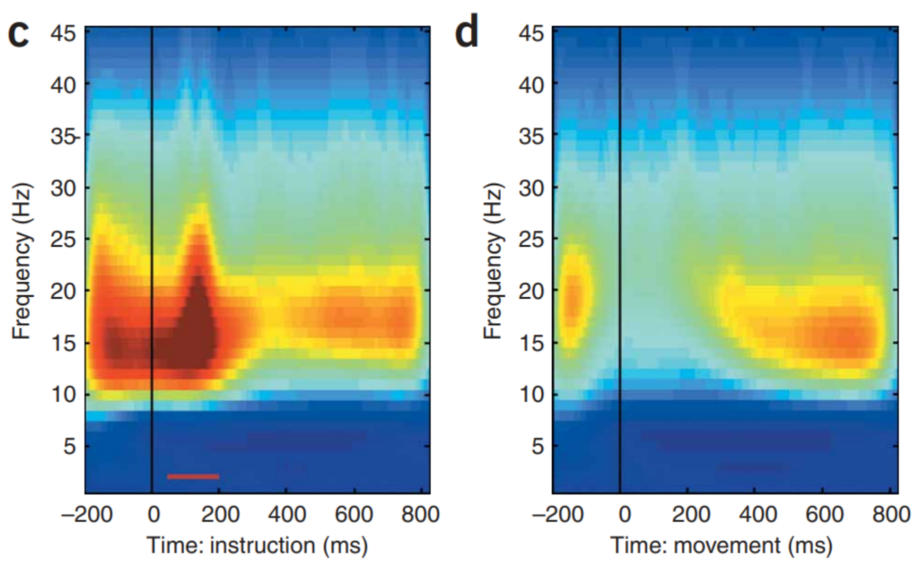

Average Power Spectrogram for channel 7
Average Power Spectrogram for channel 8
Average Power Spectrogram for channel 9
Average Power Spectrogram for channel 10
Average Power Spectrogram for channel 11
Average Power Spectrogram for channel 12
Average Power Spectrogram for channel 13
Average Power Spectrogram for channel 14
Average Power Spectrogram for channel 15
Average Power Spectrogram for channel 16
Average Power Spectrogram for channel 17
Average Power Spectrogram for channel 18
Average Power Spectrogram for channel 19
Average Power Spectrogram for channel 20
Average Power Spectrogram for channel 21
Average Power Spectrogram for channel 22
Average Power Spectrogram for channel 23
Average Power Spectrogram for channel 24
Frequency(Hz)
Time(sec)
Power
$\times 10^8$


Average Power Spectrogram for channel 25
Average Power Spectrogram for channel 26
Average Power Spectrogram for channel 27
Average Power Spectrogram for channel 28
Average Power Spectrogram for channel 29
Average Power Spectrogram for channel 30
Average Power Spectrogram for channel 31
Average Power Spectrogram for channel 32
Average Power Spectrogram for channel 33
Average Power Spectrogram for channel 34
Average Power Spectrogram for channel 35
Average Power Spectrogram for channel 36
Average Power Spectrogram for channel 37
Average Power Spectrogram for channel 38
Average Power Spectrogram for channel 39
Average Power Spectrogram for channel 40
Average Power Spectrogram for channel 41
Average Power Spectrogram for channel 42
Frequency(Hz)
Time(sec)
Power



Note that these averages have been calculated over 200(from 490) clean random trials(Because of time of processing).

As you see in all figures beta frequency band has the most power. In Hatsopoulos et.al 2006 averaged wavelet spectrogram computed with respect to onset of the movement has been plotted(Spectrograms were computed independently for each channel of each trial and averaged.):



By comparing both results we can conclude that there is a growth in power of beta frequency band in the time intervals around the instruction stimulus and after that. In most of our channels the change can be seen. In description of task timing the monkey after 0.3-0.5 ms fixating at fixation point and up to 100ms there is a growth in cellular events. So the task description corresponds to the results of our data.

2. By the following function we use a band-pass Butterworth filter (2nd order) to select most dominant oscillation of each electrodes LFP signal:

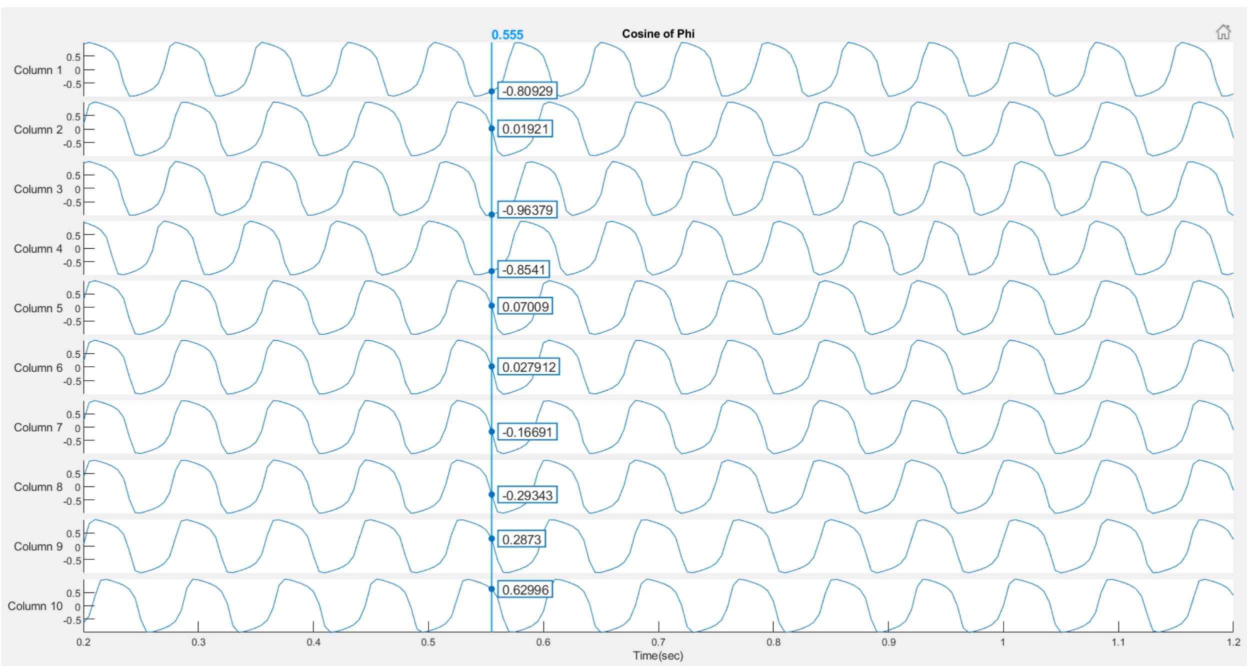
```
function output_data = BFilt(fc1, fc2,fs, input_data)
[b,a] = butter(2,[fc1/(fs/2) fc2/(fs/2)]);
output_data=filter(b,a,input_data);
end
```

(fc1 = dominant frequency - 0.75 and fc2 = dominant frequency + 0.75)

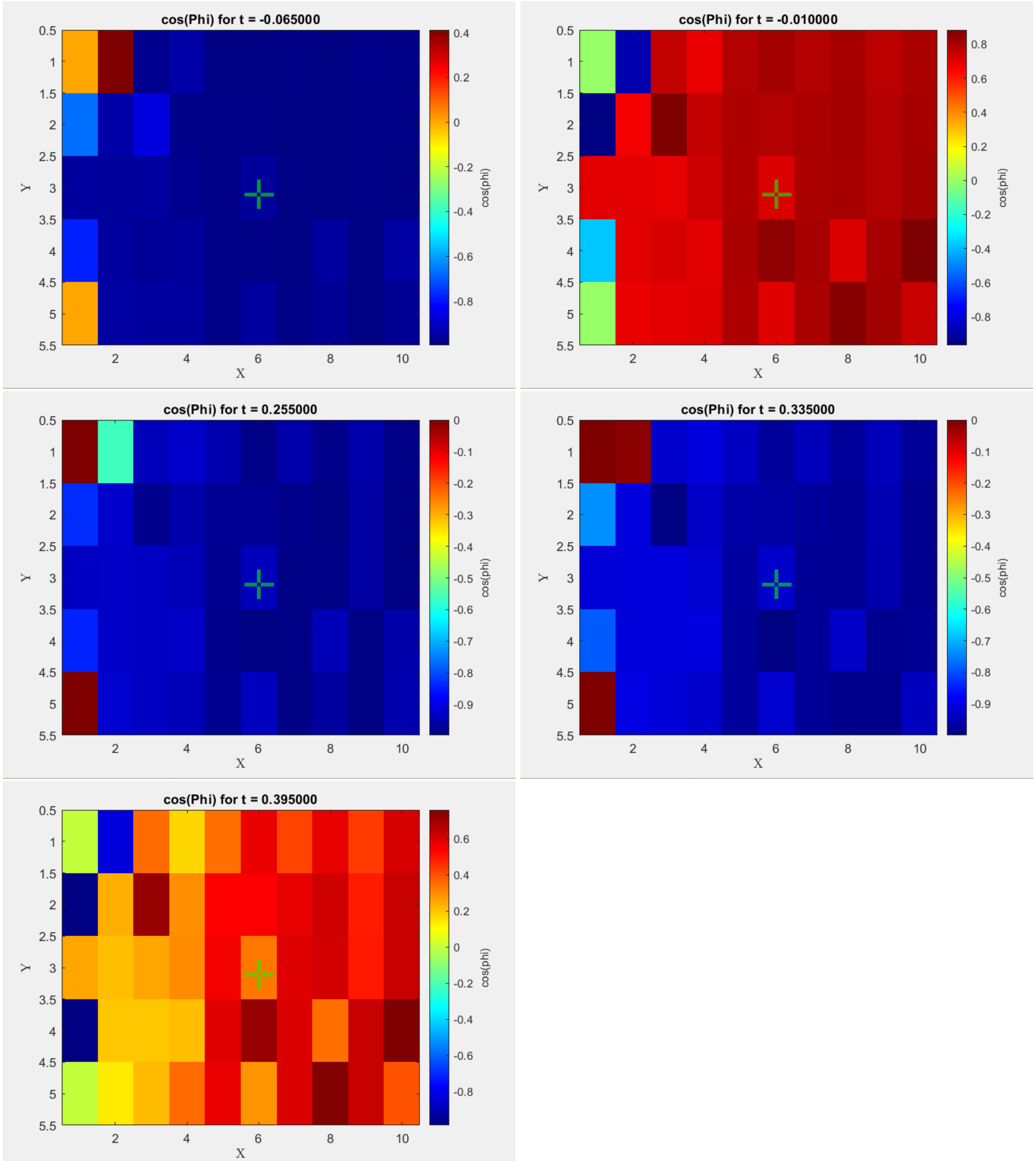
By the following code we save ϕ matrix and then calculate its cosine:

```
%% calculate Sa = s + j s_hat for each signal
Sa = zeros(numOfChan, 641, size(Intersect_Clean_Trials, 1));
for k = 1 : numOfChan
    mat = chan(k).lfp;
    for j = 1:490
        Sa(k, :, j) = signal(k, :, j)+hilbert(signal(k, :, j))*1i;
    end
end
% Calculate Phi function
PHI = angle(Sa);
% cosine
COSPHI = cos(PHI);
```

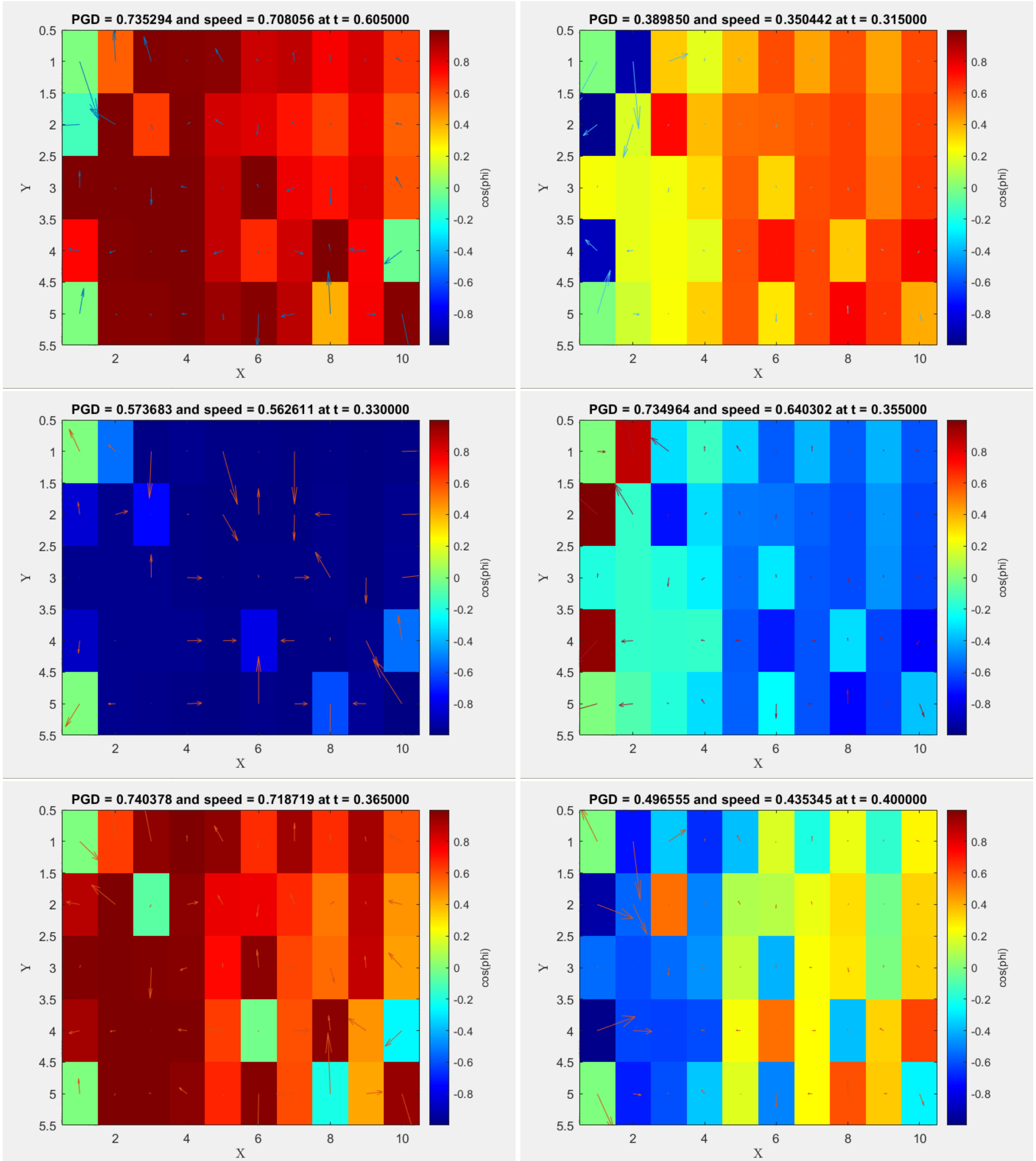
Here we have plotted $\cos\phi$ for 10 channels:

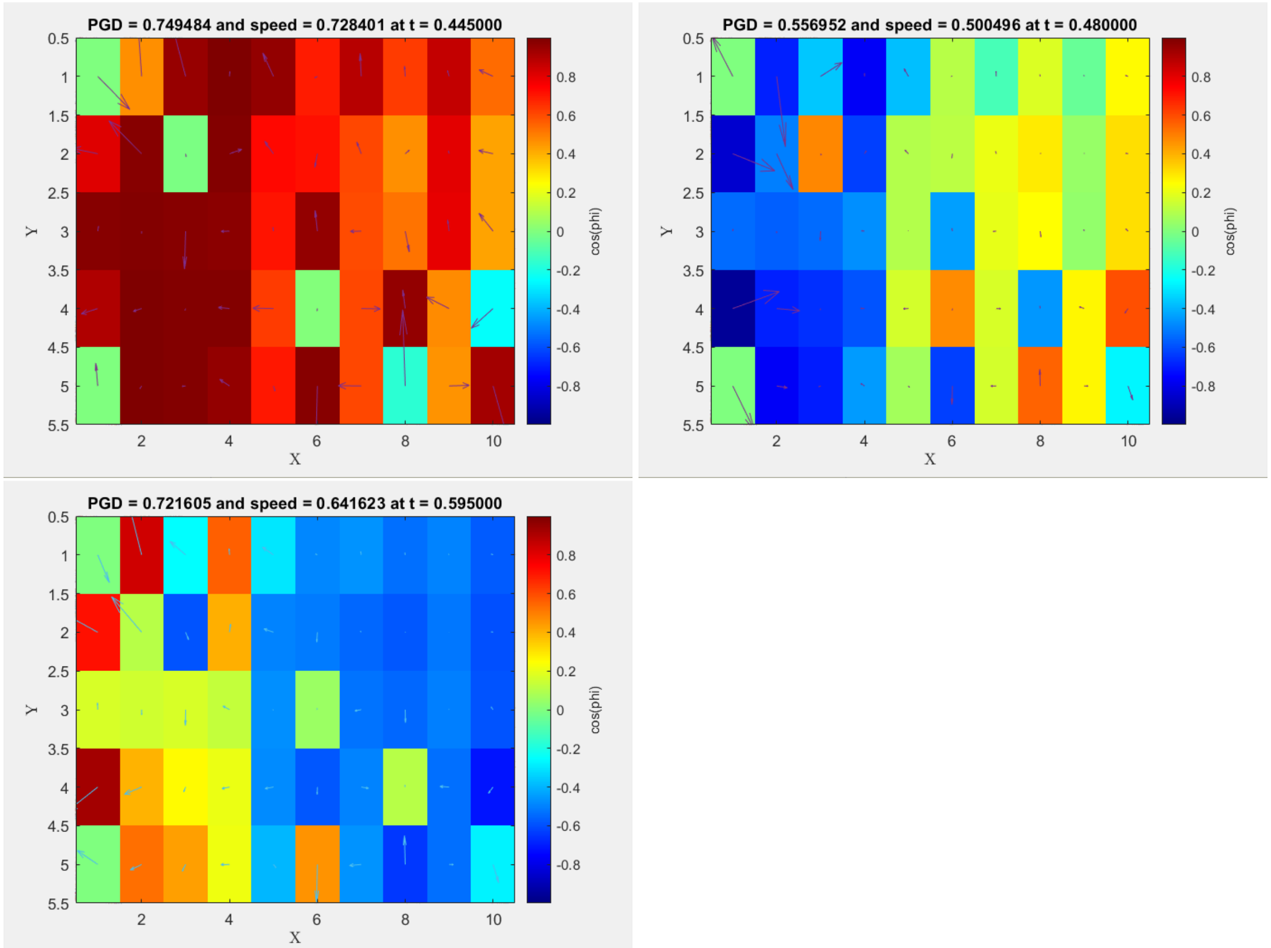


Then we design a demo to show the $\cos(\phi(x, y, t))$ during different time points in interval -0.2sec-1sec of trial 20. The demo is saved as demo.mp4 . We can observe travelling waves in the demo.



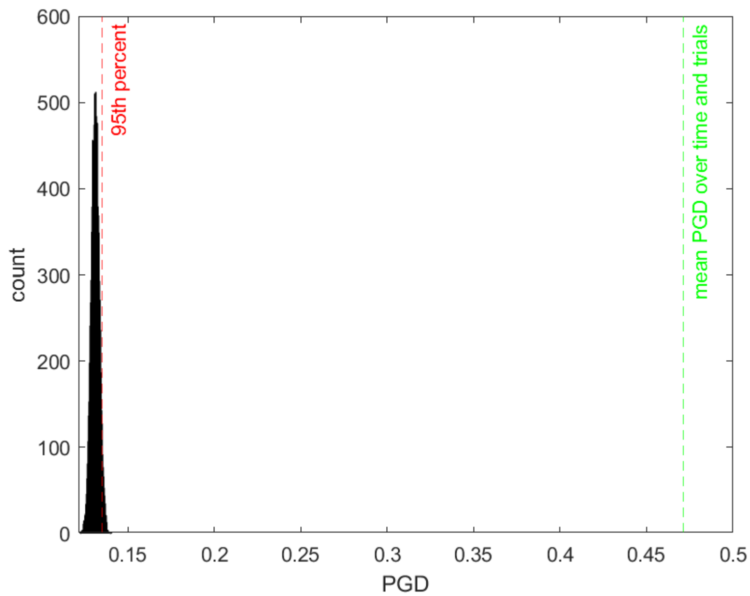
Now we should calculate the Phase Gradient Directionality, Direction of Propagation, and Speed of these travelling waves. Then we add calculated travelling waves properties to our Demo for validation.


PGD = 0.735294 and speed = 0.708056 at t = 0.605000
PGD = 0.389850 and speed = 0.350442 at t = 0.315000
PGD = 0.573683 and speed = 0.562611 at t = 0.330000
PGD = 0.734964 and speed = 0.640302 at t = 0.355000
PGD = 0.740378 and speed = 0.718719 at t = 0.365000
PGD = 0.496555 and speed = 0.435345 at t = 0.400000
X
Y
cos(phi)

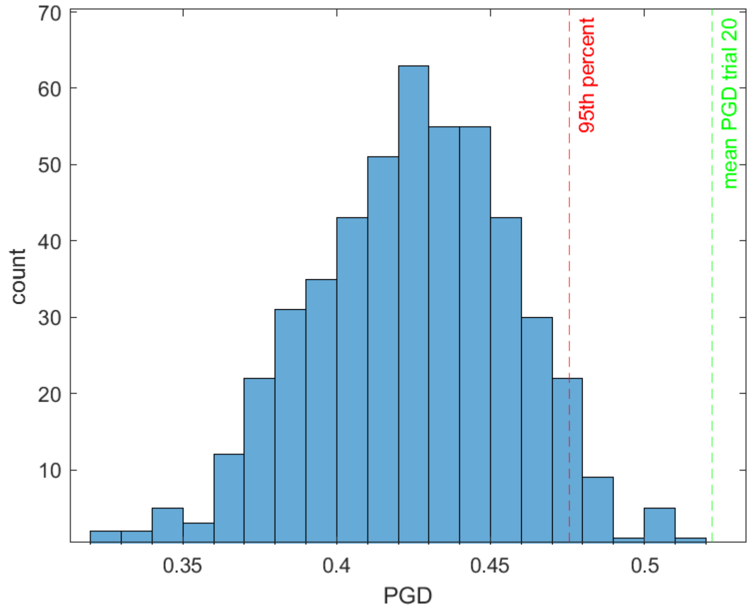


Now we design a test to validate the significance of existence of preferred direction propagation for travelling waves.

First we generate 1000 samples of ϕ matrix and calculate mean of PGD for each one. Then apply the test:



Another way is to shuffle just rows and columns of matrix many times and calculate mean of PGD:



So we can see that there is preferred direction propagation for travelling waves with confidence more than 95 percent.

In the figures of complete demo we can see that the speed is always between 0.1-0.8 meter per second. Mean propagation speed over trials and time is:

```
meanSpeed =

    0.3906
```