DSP Project Report

EEG SIGNAL ANALYSIS

Group - 17

Group members:

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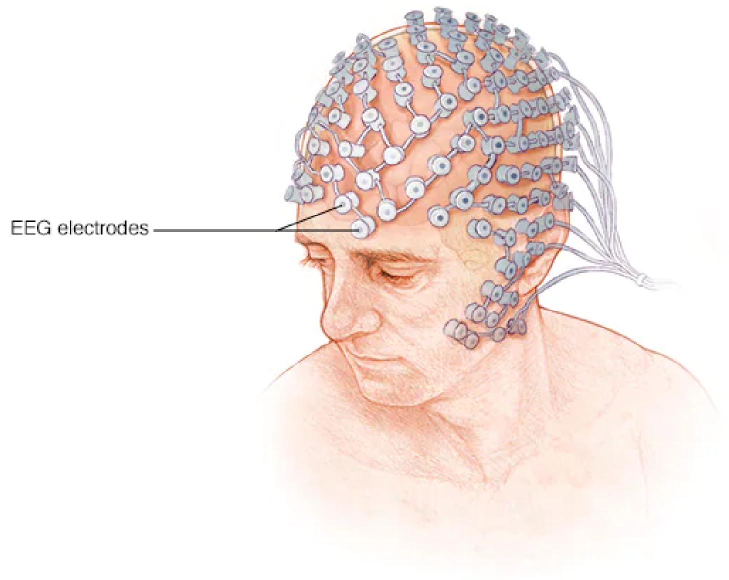
Abstract:

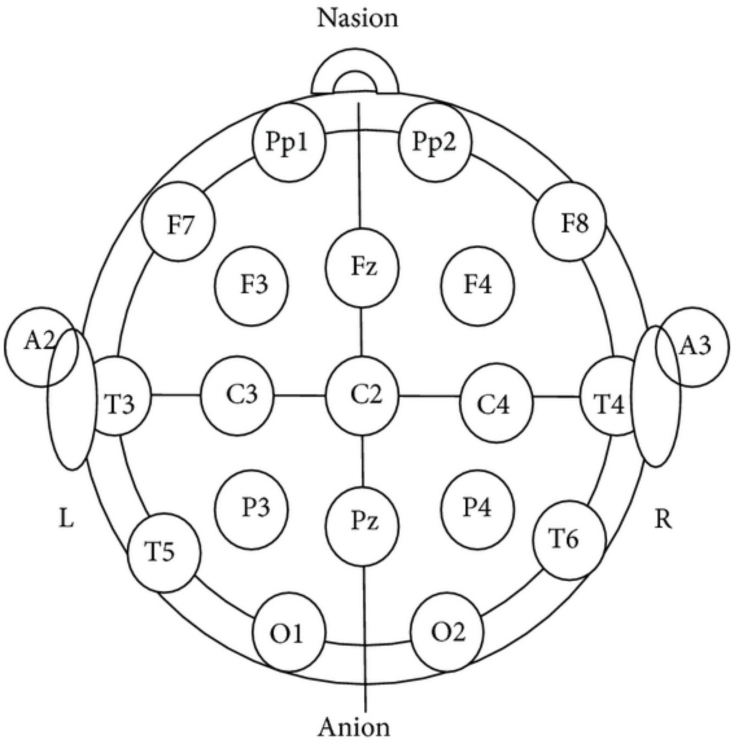
- EEG bands are extracted from EEG signals using wavelet transform.
- EEG bands are converted to frequency domain from time domain using FFT.
- Plot of EEG signal,Calculated **Power Spectral Density**, **Average Power**, **Absolute Power** of Theta band, **Relative Power** of theta and alpha bands
- We used **periodogram**, **welch's**, **multitaper** methods to estimate the power spectral density.
- **Multitaper method** is more accurate for estimation of Power spectral density of EEG signal

Introduction:

Electroencephalography (EEG) is an efficient modality which helps to acquire brain signals corresponding to various states from the scalp surface area. EEG results show changes in brain activity that may be useful in diagnosing brain conditions, especially epilepsy and other seizure disorders.



Standardized Electrode Placement:



The signal noise which can set in when signal is being captured will adversely affect the useful feature in the original signal. The major sources of the artifact are muscular activities, blinking of eyes during signal acquisition procedure, and power line electrical noise.

The EEG signal is non-stationary, the feature extraction can be done using Wavelet Transform from raw data of the EEG signal.

Wavelet Transform is a spectral estimation technique in which any general function can be expressed as an infinite series of wavelets. WT uses variable sized windows, which can give a more flexible way of time-frequency representation of signal. In order to get a finer low-frequency resolution, WT long time windows are used; in contrast in order to get high-frequency information, short time windows are used.

The original EEG signal is represented by secured and simple building blocks known as wavelets.

EEG bands:

- Delta (0.5 - 4Hz)
- Theta (4 - 8Hz)
- Alpha (8 - 12Hz)
- Beta (12 - 30Hz)
- Gamma (30 - 100Hz)

This decomposition of EEG signal into frequency components is achieved through Fast Fourier Transform(FFT), which returns, for each frequency bin, a complex number from which one can then easily extract the amplitude and phase of the signal at that specific frequency. In spectral analysis, it is then common to take the magnitude-Squared of the FFT to obtain an estimate of the power spectral density expressed in (micro)-Volts^2 per Hertz for EEG data.

Nerve conduction is an electrochemical process, which means that it uses electricity made with chemical molecules. The Brain's electricity is caused by the movements of electrically charged molecules through the neuron's membranes.

The membrane of a neuron, like that of any other cell, contains tiny holes known as channels. It is through these channels that charged molecules pass through the neural membrane, but unlike the channels in other cells, the channels in neurons are so specialized that they can coordinate the movements of these charges across the membrane so as to conduct nerve impulses.

Implementation:

Matlab:

1. The EEG raw data is loaded in matlab and using wavelet transform the extraction of bands is done.
2. EEG raw data is loaded using csvread function
3. Stackedplot (plots the variables of a table or timetable in a stacked plot) function is used to plot the EEG signal.

Functions:

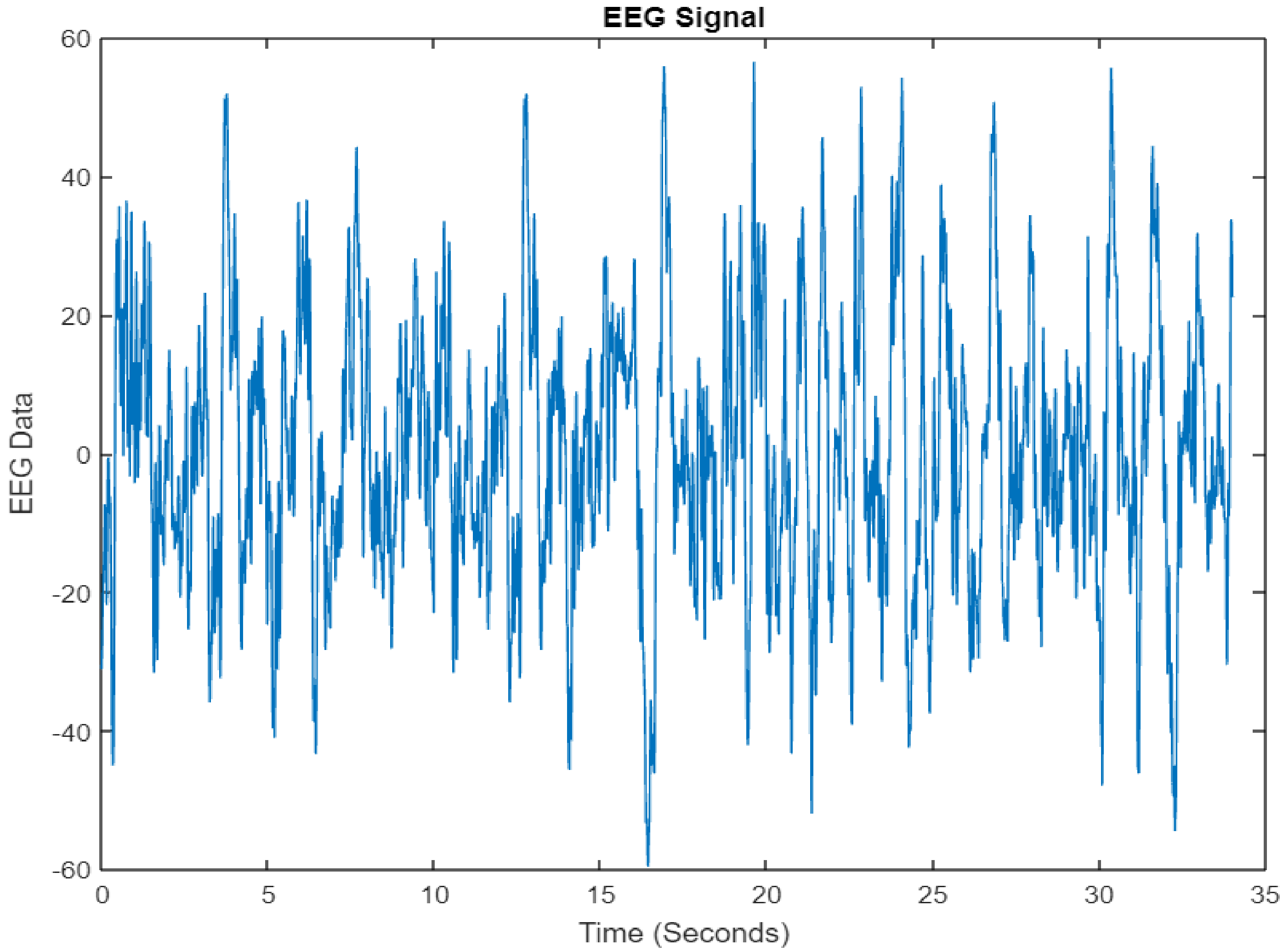
1. wavedec(x,n,lN3) - it performs a multilevel 1-d wavelet analysis using wavelet decomposition filters.
2. detcoef(C,L,N) - detail coefficients from wavelet decomposition structure

   C - wavelet decomposition vector, L - Bookkeeping vector, N - detail level to extract from the wavelet decomposition.

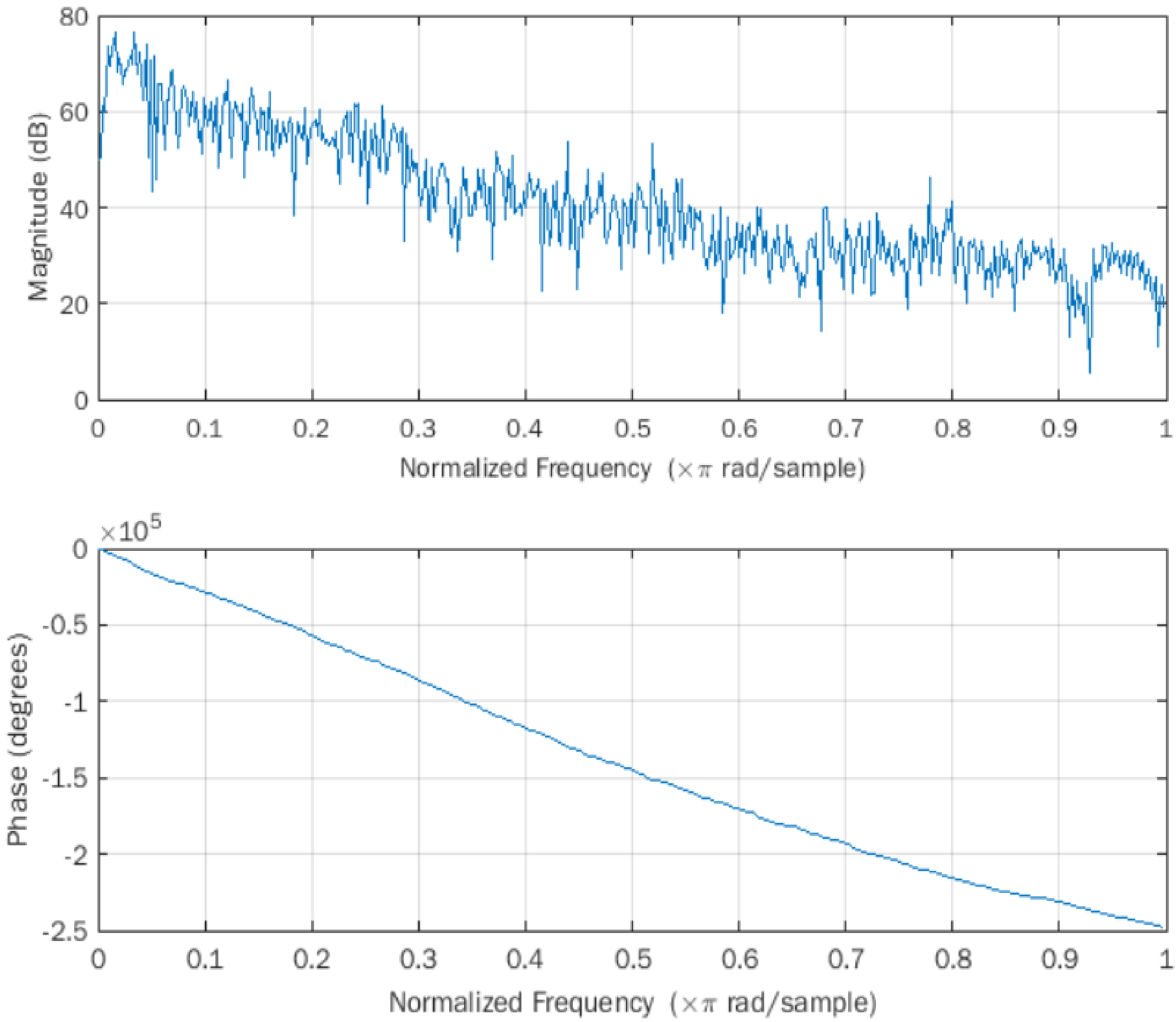
3. appcoef(C,L,wname,N) - computes the approximation coefficients of a 1-d signal.
4. wrcoef(type,C,L,Lor,Hir) - uses filters to reconstruct the coefficient vector of type based on decomposition structure [C,L] of 1-d signal using wavelet specified by wname. LoR - low pass reconstruction filter, HiR is high pass reconstruction filter
5. detrend(x,n) - removes n-th degree polynomial trend. If n = 0, it removes the mean value from x.
6. fft(x) - computes the DFT(discrete fourier transform) of x using Fast Fourier transform(FFT) algorithm.

Result:

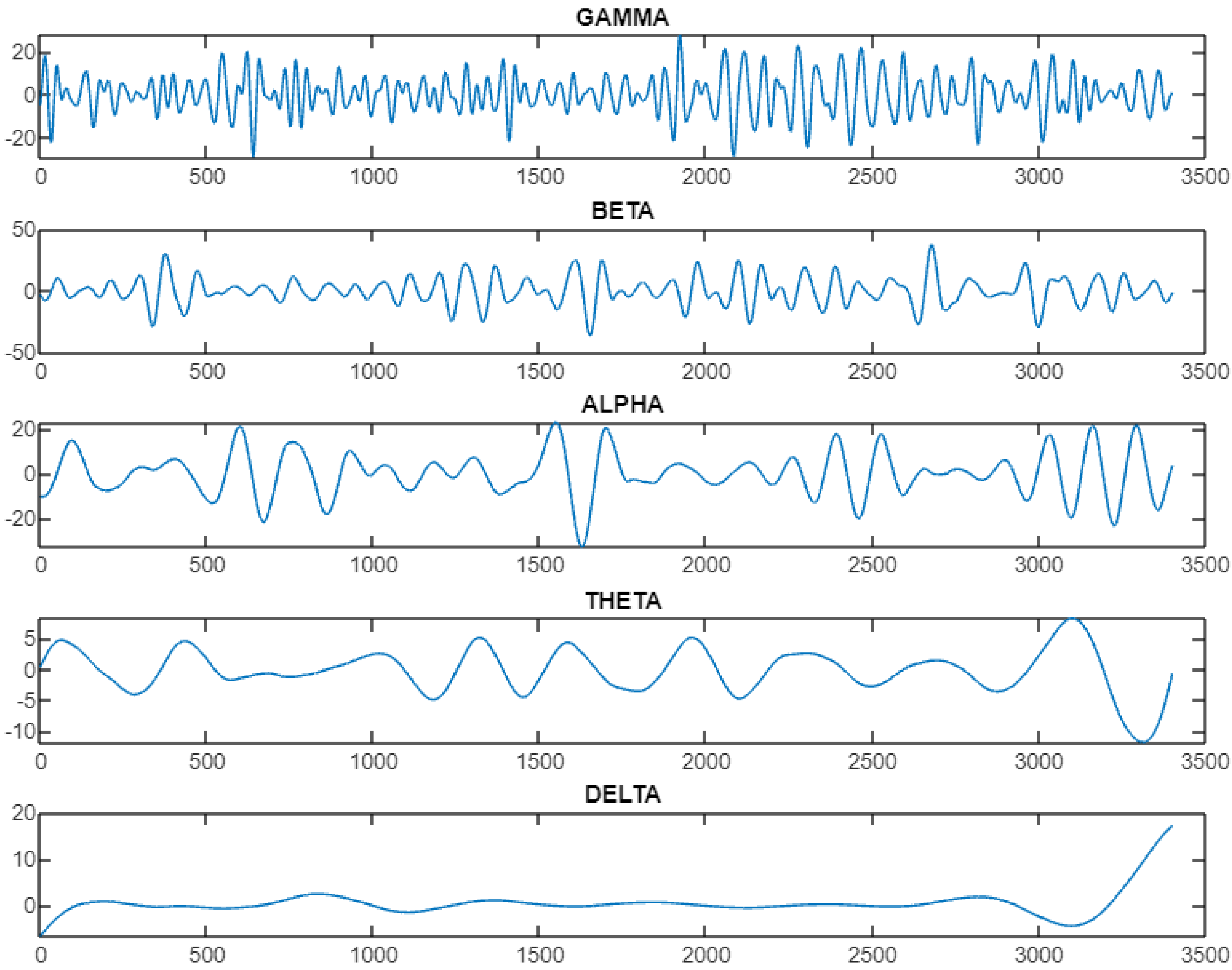
1. Time v/s EEG raw data plot:



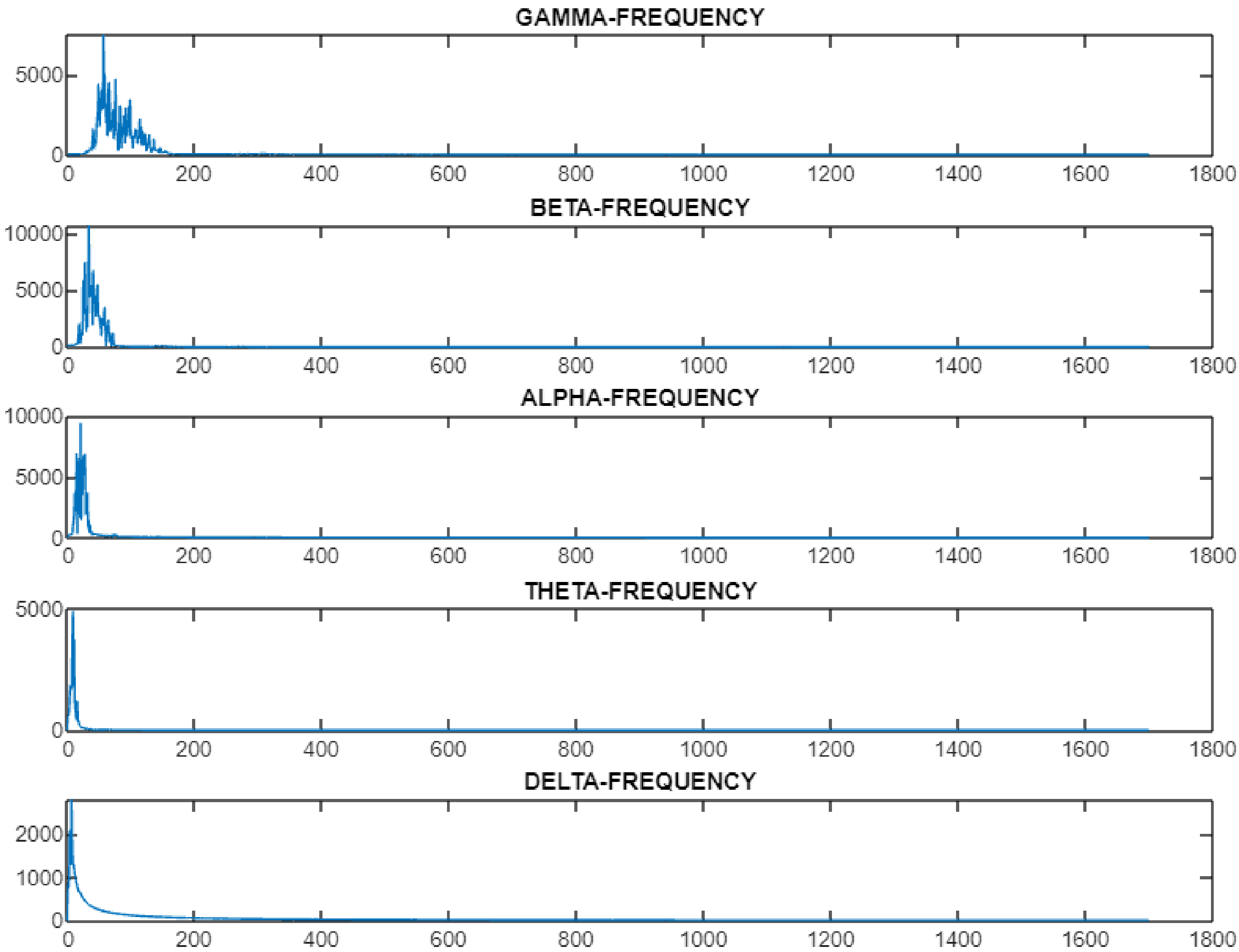
2. Frequency response of EEG raw data:



3. Bands plot (Gamma, Beta, Alpha, Theta, Delta):



4. Plot between Bands and frequency:

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Gamma:Maximum occurs at 57.00 Hz.

Beta:Maximum occurs at 34.00 Hz.

Alpha:Maximum occurs at 21.000000 Hz.

Theta:Maximum occurs at 9.000000 Hz.

Delta:Maximum occurs at 7.000000 Hz.
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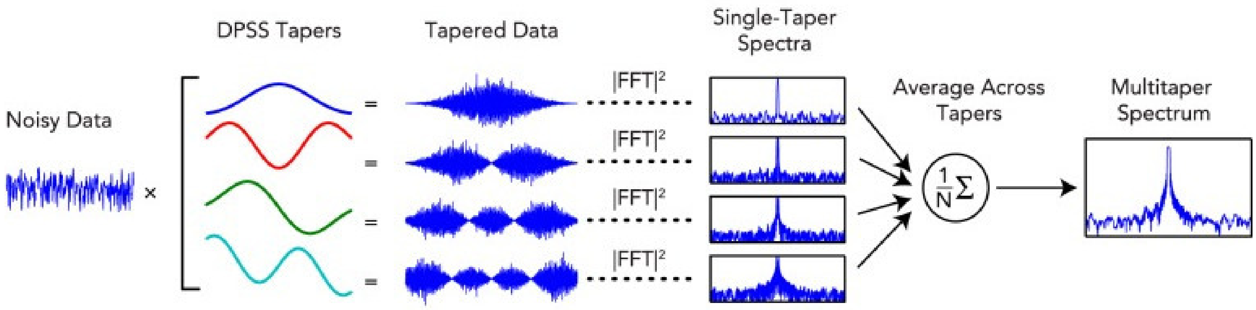
Python:

1. Computing the average power of a signal in a specific frequency range, using welch and the multitaper spectral estimation methods. EEG data is to decompose the signal into functionally distinct frequency bands, such as Delta (0.5 - 4Hz), Theta (4 - 8Hz), Alpha (8 - 12Hz), Beta (12 - 30Hz), Gamma (30 - 100Hz)

   The Average Bandpower is a very relevant metric for sleep research because it allows us to differentiate between the different sleep stages. Theta is often observed during the transition from wakefulness to sleep. In the awake EEG, an increase in theta-range power has been observed with processing of emotional information and during memory-related tasks.

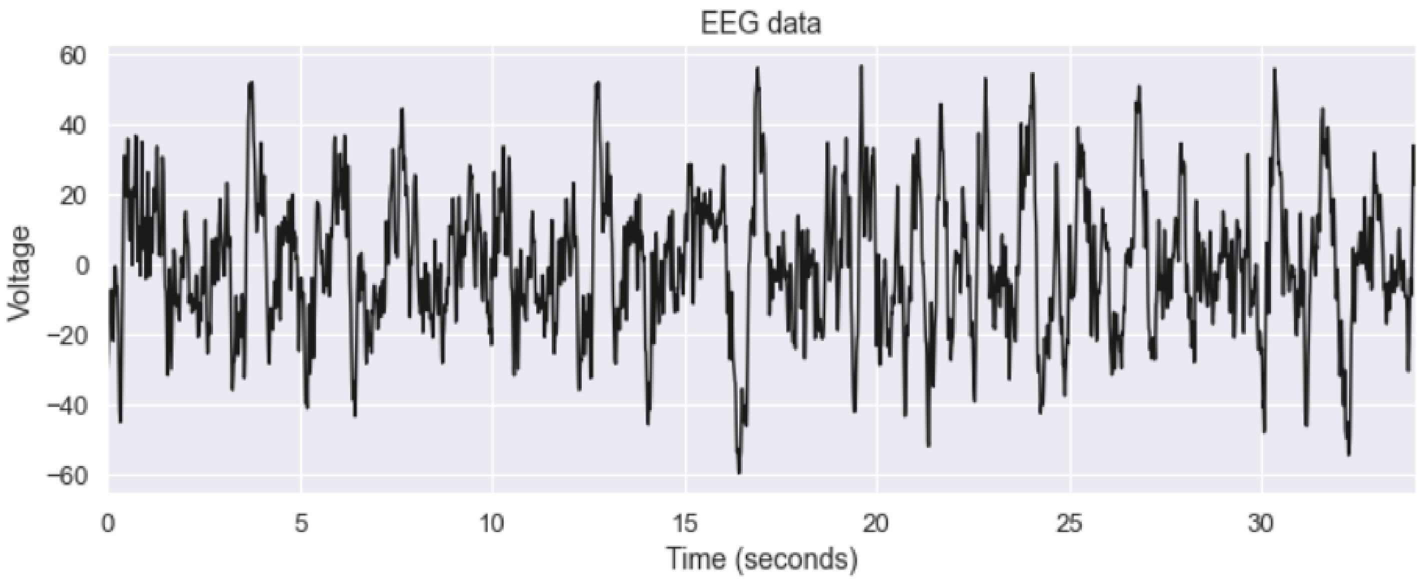
2. Relative Band power - it express the power in a frequency band as a percentage of the total power of a signal.
3. Computing Power Spectral Density, avg power using various methods like

- **Periodograms:** We can estimate the power spectral density of a signal using a periodogram.
- **Welch Method:** Computes an estimate of the power spectral density by dividing the data into overlapping segments, computing a modified periodogram for each segment and averaging the periodograms.
- **Multitaper Method:** It provides a more robust spectral estimation than classical and Welch's periodograms, by combining the advantages of these two methods: high frequency resolution and low variance.

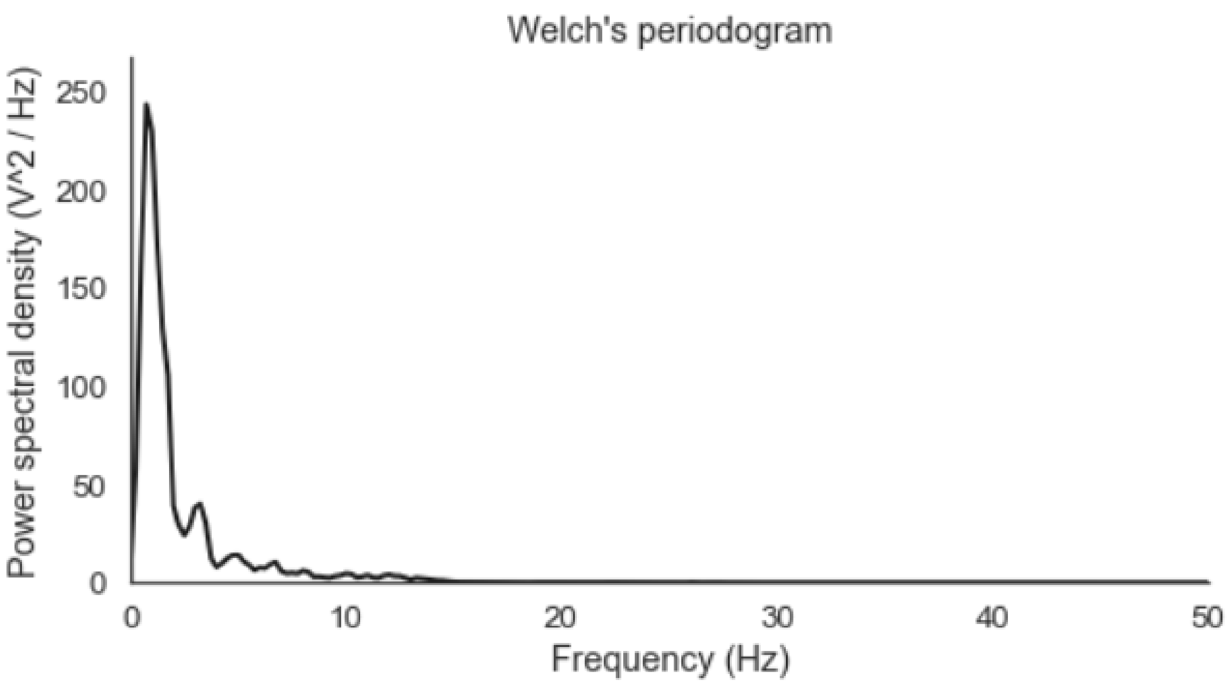


Results:

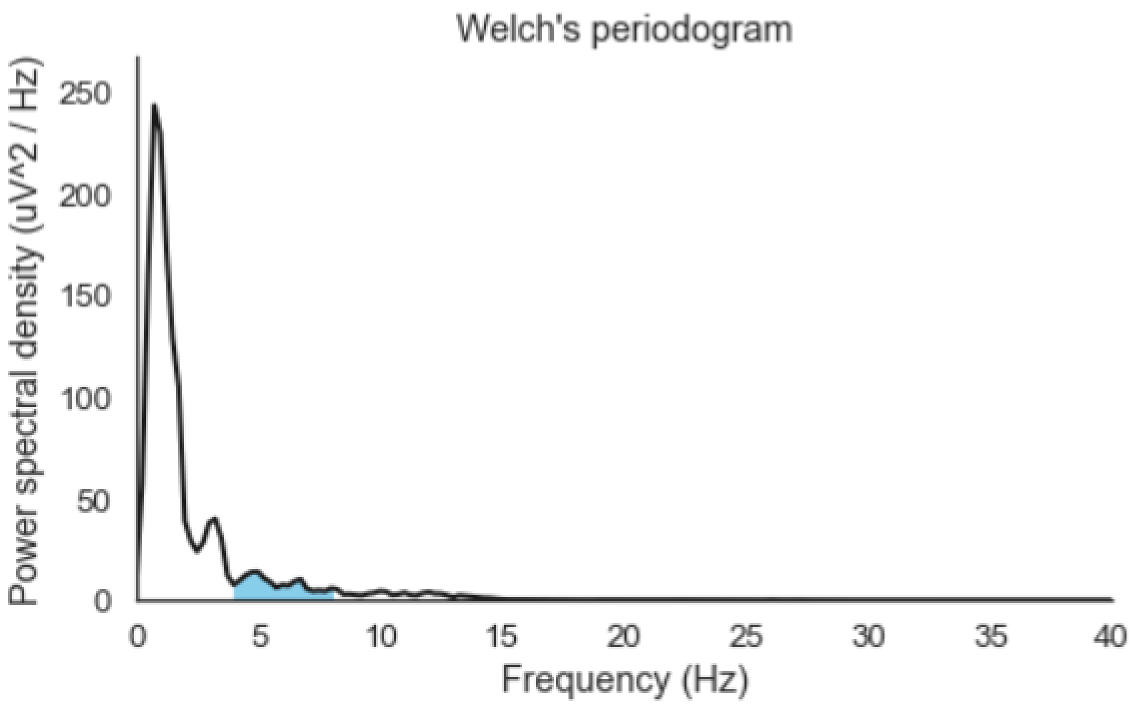
Plot between EEG data and time



Plot between the power spectral density and frequency(Hz)



Plot between power spectral density and filled the Theta band area



- Absolute power of Theta band:

  Absolute power of theta band: 34.202 uV^2

- Relative bandpower of Theta band:

  Relative bandpower of Theta band: 0.087

- Theta/Alpha ratio of absolute and relative bandpower:

  theta/alpha ratio (absolute): 4.331, theta/alpha ratio (relative): 4.331

Using welch's method:

Absolute power, relative bandpower and Theta/Alpha ratio of absolute and relative bandpower:

- ★ Absolute theta power: 41.313
- ★ Relative theta power: 0.209
- ★ theta/alpha ratio (absolute): 4.214,
- ★ theta/alpha ratio (relative): 1.669

Using Multitaper's method:

Absolute power, relative bandpower and Theta/Alpha ratio of absolute and relative bandpower:

- ➢ Absolute theta power: 35.644
- ➢ Relative theta power: 0.093
- ➢ theta/alpha ratio (absolute): 4.645
- ➢ theta/alpha ratio (relative): 4.645

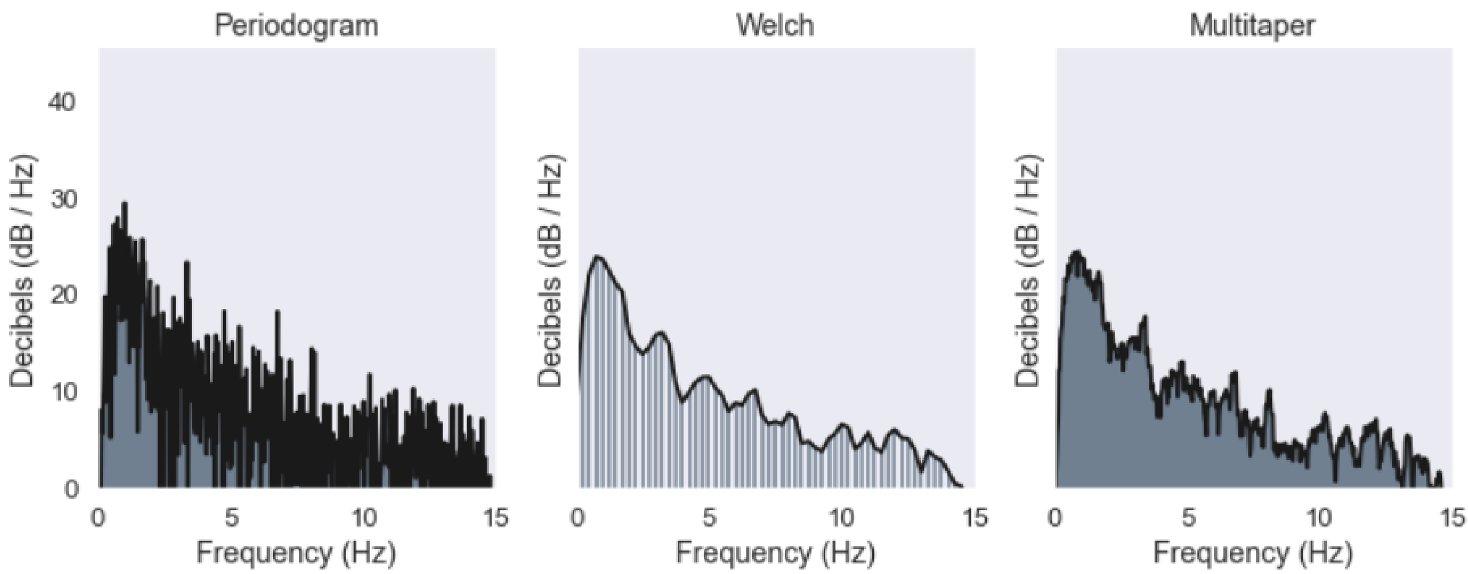
"Multitaper method is more suitable for estimating power spectral density"

Time it takes to calculate bandpower for welch's and multitaper method:

362 µs ± 29.3 µs per loop (mean ± std. dev. of 7 runs, 1000 loops each)

15.3 ms ± 1.14 ms per loop (mean ± std. dev. of 7 runs, 100 loops each)

Plot between periodogram, welch's and multitaper PSD (Power Spectral Density) of theta band (4 - 8Hz):



Contributions:

1. Kakarla V S S Pavan Teja {S20190020216} - Matlab code for plotting EEG signal in time domain, extraction of bands from EEG signal using wavelet transform,plot between bands and frequency.
2. K Sreenivasulu Reddy {S20190020217} - Python code for power spectral density, average power, absolute power, relative power using using periodogram and welch's method, report, ppt
3. K Litheesh Kumar {S20190020218} - Python code for EEG signal plot, plotting theta band region, calculating average power, power spectral density, Relative power, absolute power of theta band, power spectral density of theta band using multitaper method

Reference:

1. https://www.researchgate.net/profile/Sasikumar-Gurumurthy/publication/278678103_Analysis_and_Simulation_of_Brain_Signal_Data_by_EEG_Signal_Processing_Technique_using_MATLAB/links/5583174308aefa35fe30b535/Analysis-and-Simulation-of-Brain-Signal-Data-by-EEG-Signal-Processing-Technique-using-MATLAB.pdf
2. https://en.wikipedia.org/wiki/Electroencephalography
3. https://raphaelvallat.com/bandpower.html
4. https://in.mathworks.com/matlabcentral/fileexchange/55112-eeg-analysis-and-classification