Introduction

Study suggests that electroencephalography, also known as EEG, is an accurate and reliable way of collecting brain impulses, helping to establish the actual condition of brain function and to identify possible brain disorders[1]. EEG is produced by postsynaptic currents of neurons in the brain which is because of the brain geometry and the neural organization in the brain. The signal potential in the brain is too small in amplitude and it cannot be detected from electrodes on the scalp. Therefore, EEG is the summation of the electrical signals of many neurons that produce over on period of time [2].

Moreover, EEG signal break down to different components. There are 4 main components which are alpha, beta, theta, and delta. Alpha waves are found when the patient is awake in a quite sate [2]. It is mainly detected from occipital lob and from parietal and frontal region of cerebral cortex [2]. Beta waves are found when the patient is doing some specific type of mental activity or are attentive to an external stimulus [2]. It can be detected from parietal and frontal lobe. Theta wave produces during emotional stress and sometimes in degenerative brain states [2]. It occurs in the parietal and temporal regions [2]. Delta waves are very low in amplitude. It mostly appears during sleep and have a high amplitude when there is a disease [2]. Table 1 shows the frequency and amplitude range of each wave.

Rhythm	Typical Frequencies (Hz)	Typical Amplitude (uV)
α	8 - 13	2-100
β	13 - 22	5-10
Δ	0.5 - 4	20-100
θ	4 - 8	10

Table 1 The typical frequencies and amplitudes of the different brainwave components are listed

Experiment 1

In this part we tried to find the best suited filter to extract noises from the EEG O1, O2, FP1, and FP2. Based on analyses on the signals and filtered signals in the frequency domain and from previous experiments on ECG signal for designing filters, we have realized that the best filter for our signal is Butterworth bandpass 0.1 to 30 Hz with order 6. The reason for this frequency range is because the 4 waves of EEG signal is between 0.5 to 22; therefore, we decided to make the range wider for errors [2]. While higher-order filters are much better able to deploy the bandwidth gain at a sharper rate compared to lower-order filters, this could lead to more sounds, which we want to avoid. However, we did not notice a difference between order 6 and 4; therefore, we decided to go with order 6 because the higher the more accurate it can be.

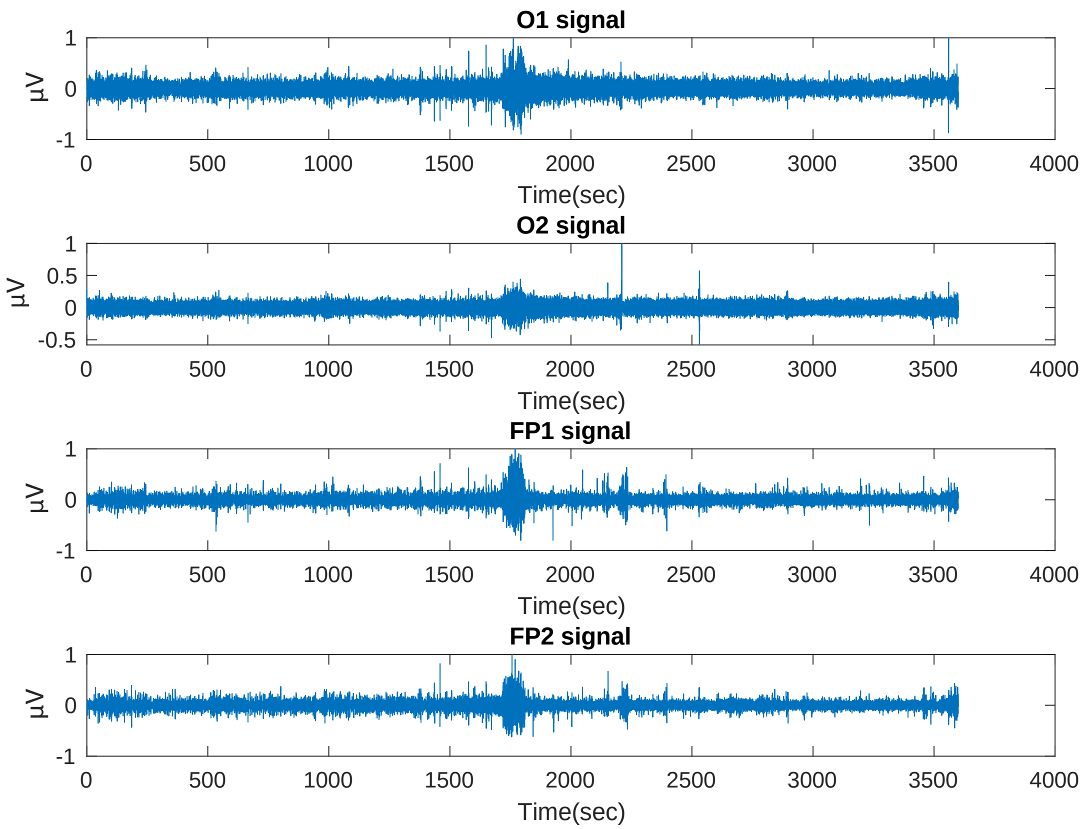

Figure 1: EEG sub1 O1, O2, FP2 and FP1 signal

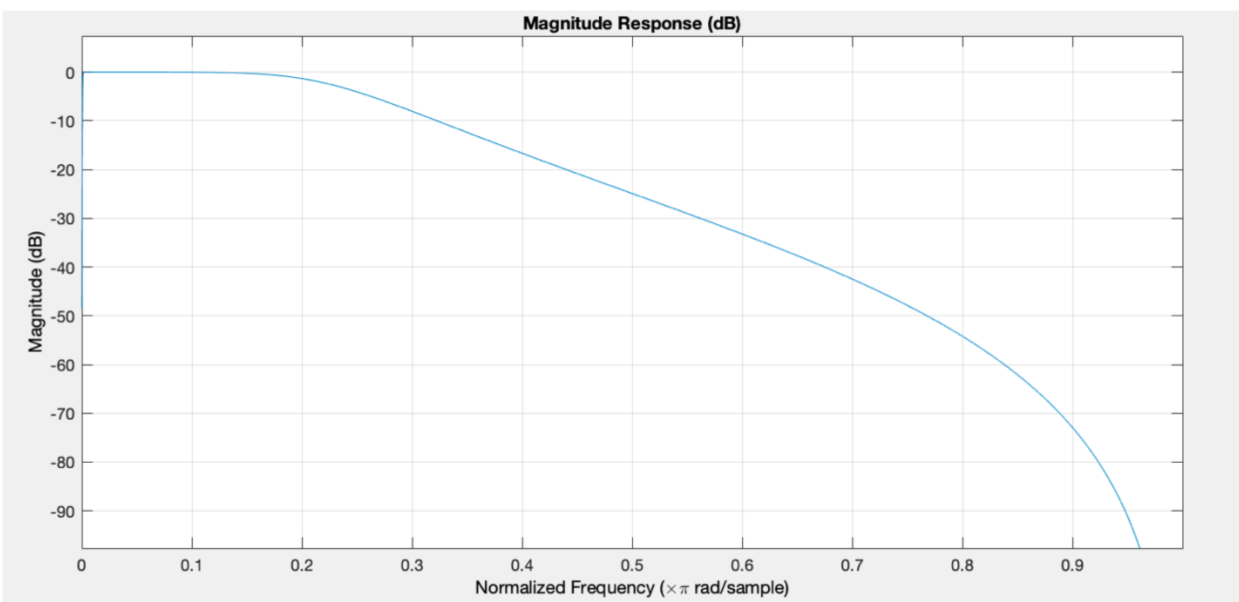

Figure 2: Butterworth order 6 bandpass filter plot

Experiment 2

As the it can be seen in the Fig. 3 ,the effect of filter on the signal in time domain is not noticeable. However, in Fig.4 it can be seen that the filter out the signals after 30 Hz.

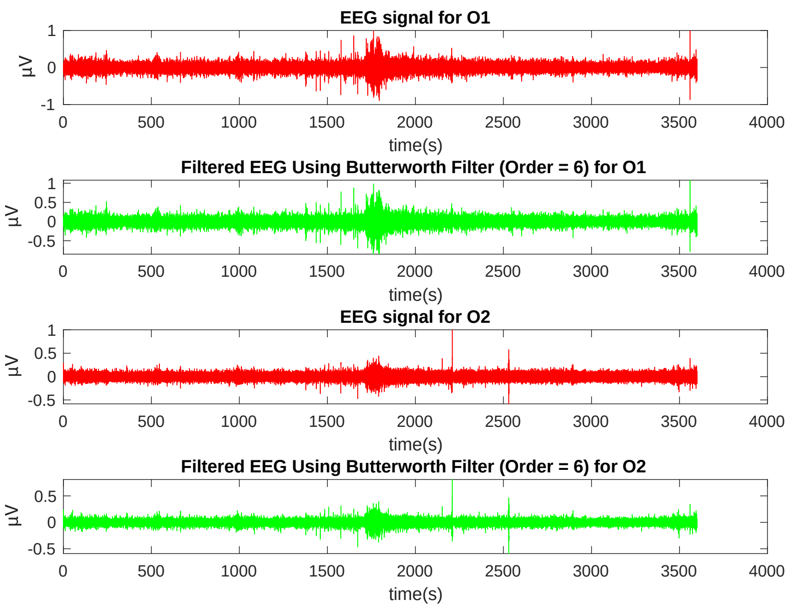

Figure 3: original and filtered sO1 and O2 signal

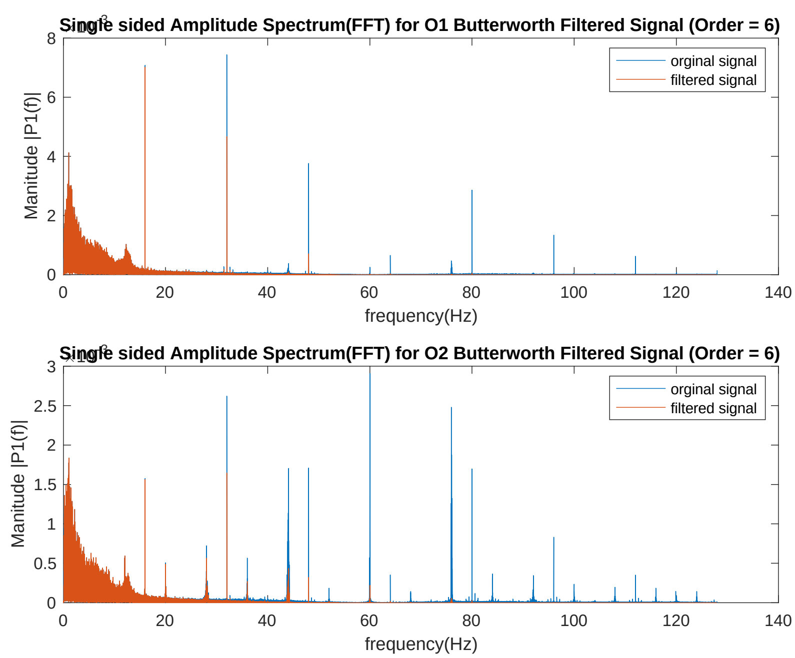

Figure 4: Single sided frequency spectrum of O1 and O2 signal with filter applied on it

Experiment 3

As discussed in the beginning, the research has shown that there are four rhythms of delta, theta, alpha and beta waves within the frequency bandwidth of EEG signals [3]. The first figure shows that the filter bandpass created and filtered data not covering 7Hz to 14Hz to filter out noise and maintain alpha wave data. During analyzes on the O1, O2 , FP1 and FP2 signal we realized Butterworth bandpass order 4 is the best filter for extracting alpha, beta, theta and delta waves. We realized with order 4 the losses of the original signal in our desired frequency is less than order 2 and 6.

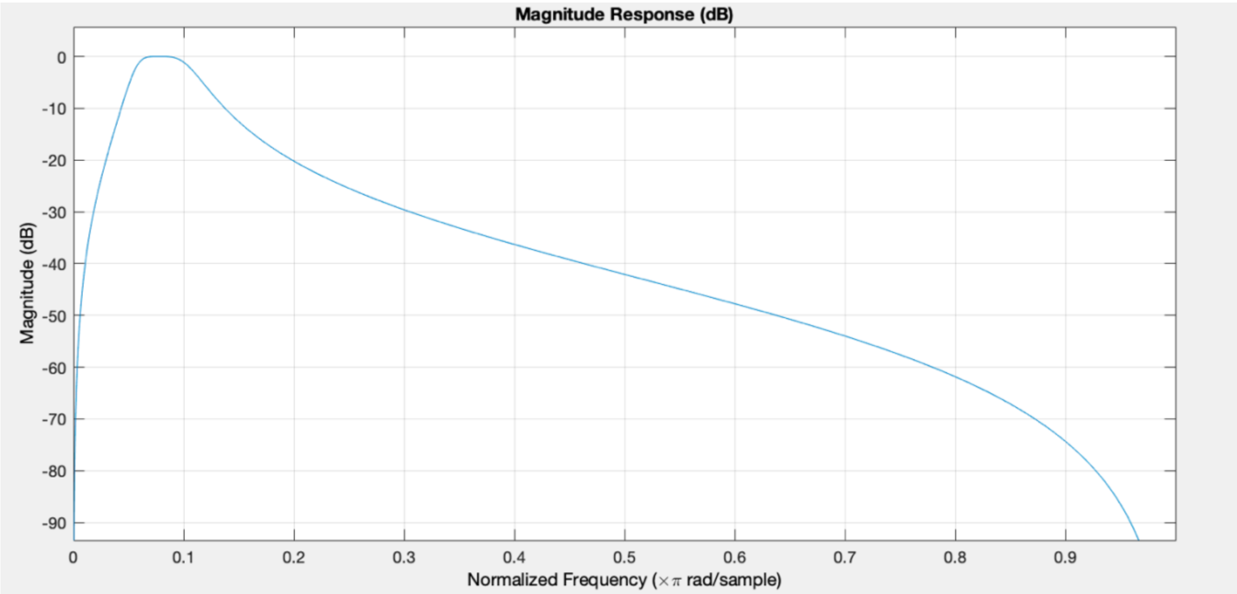

Figure 5: Butterworth filter for extracting alpha wave with frequency range 7 to 14 Hz

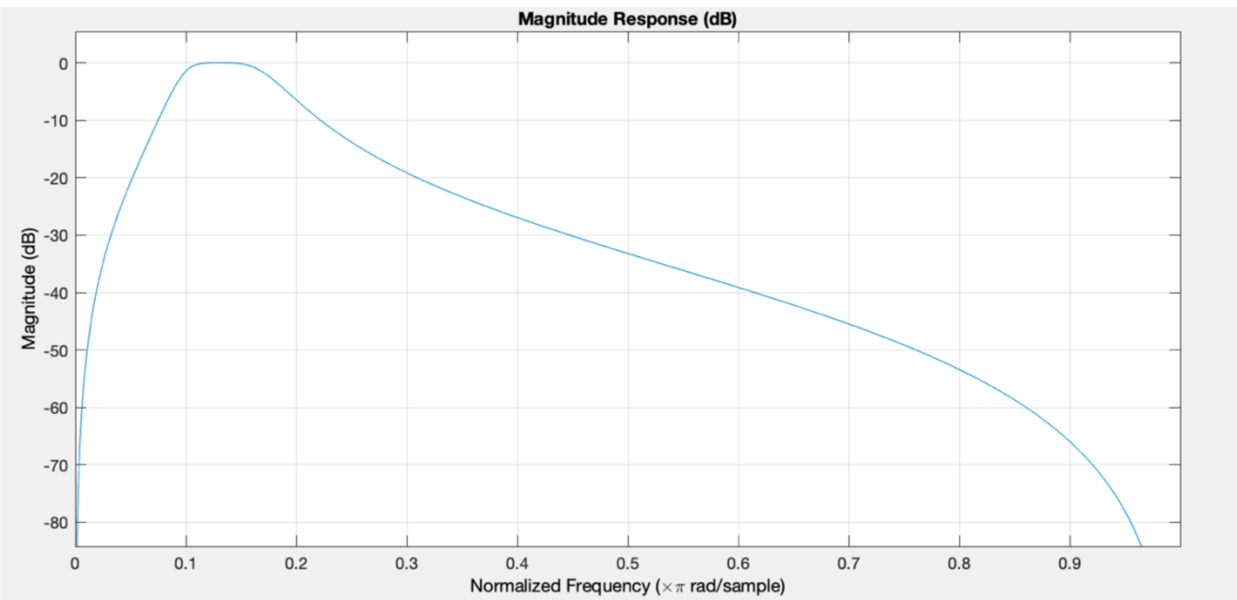

Figure 6: Butterworth filter for extracting beta wave with frequency range 12 to 23 Hz

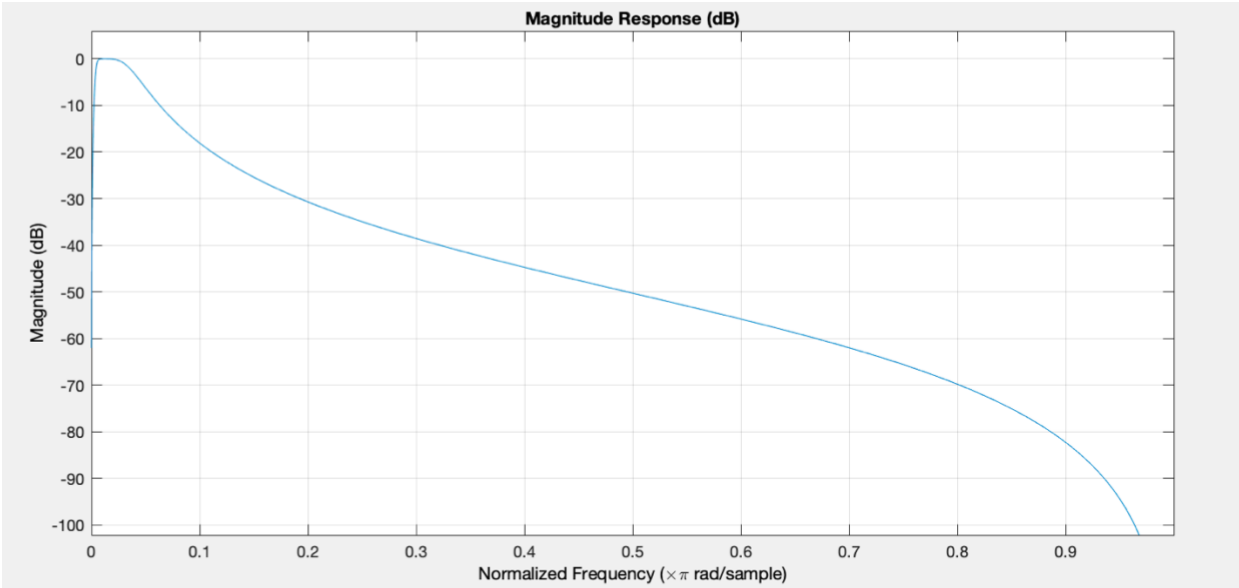

Figure 7: Butterworth filter for extracting delta wave with frequency range 0.5 to 5 Hz

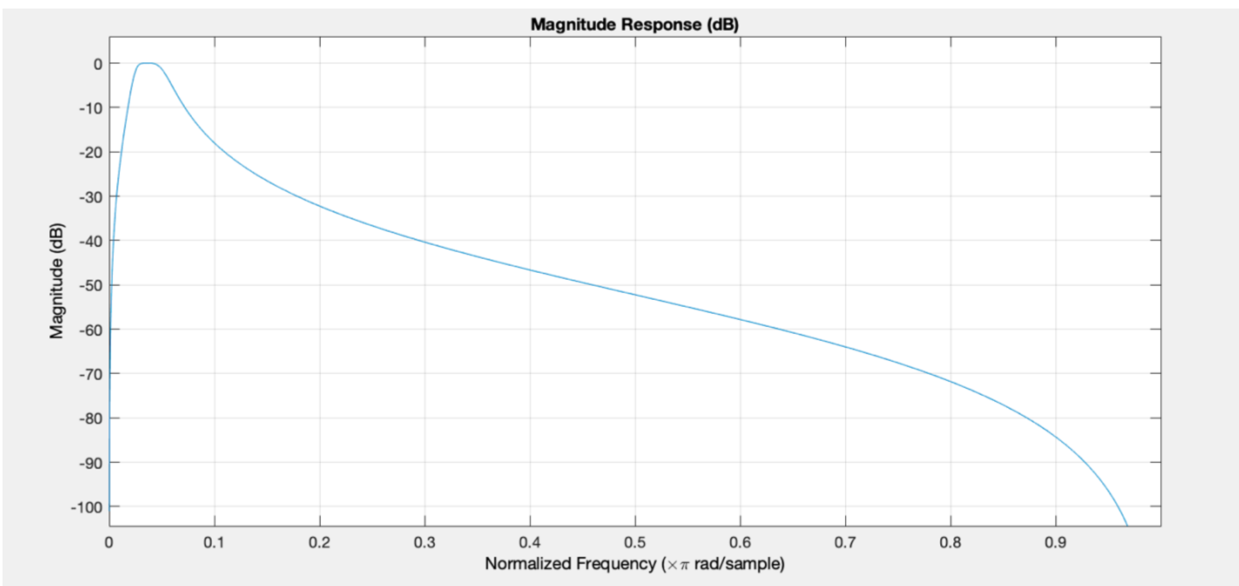

Figure 8: Butterworth filter for extracting delta wave with frequency range 3 to 7 Hz

Experiment 4

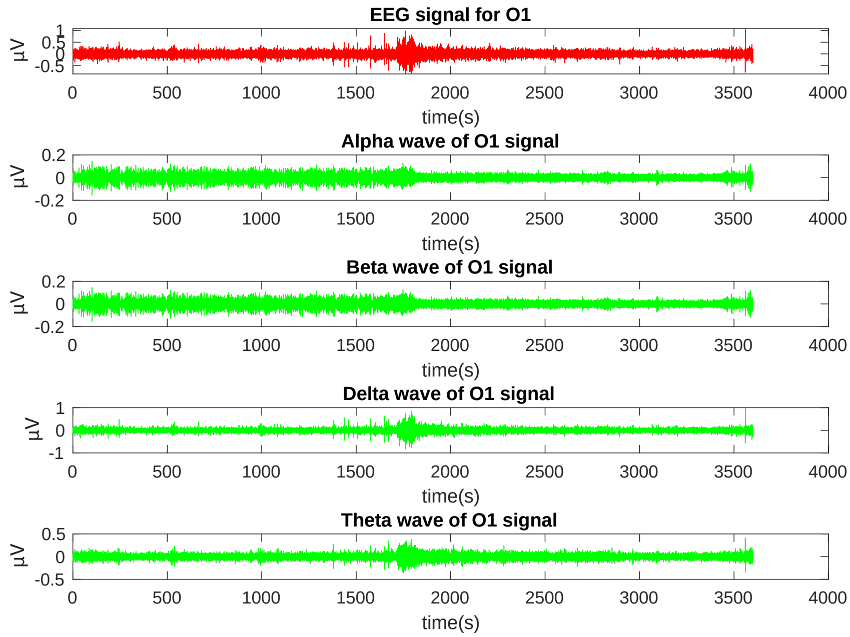

Figure 9: Alpha, beta, theta, and delta signal of O1

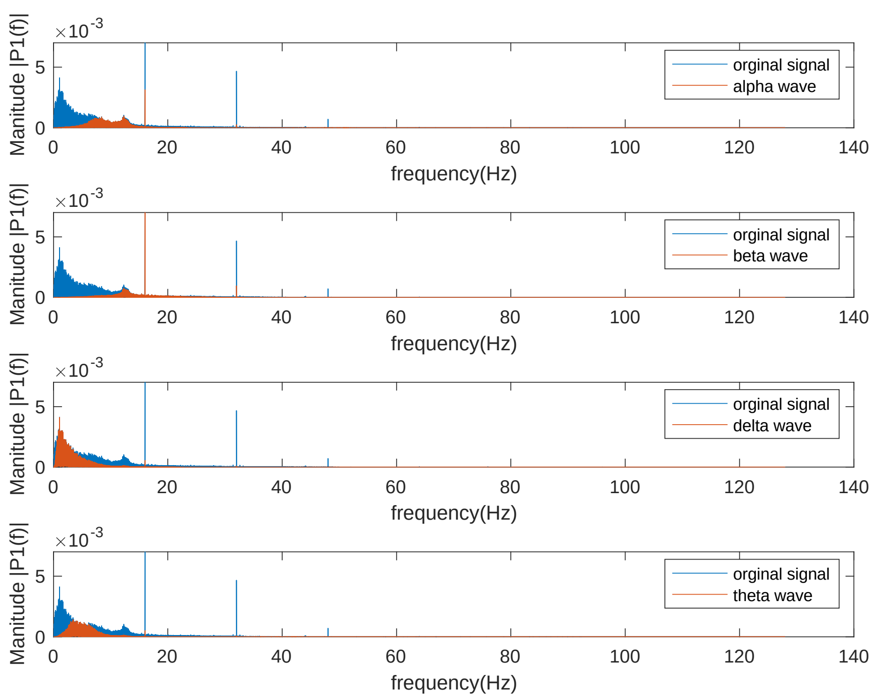

Figure 10: Plot of Single sided Amplitude Spectrum (FFT) for alpha, beta, theta, and delta wave on the O1 signal

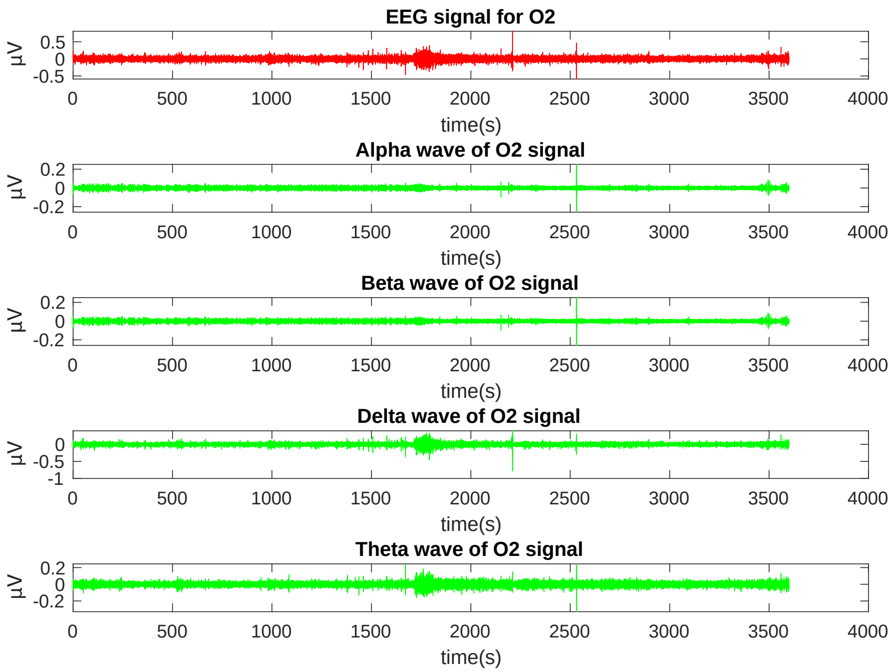

Figure 11: Alpha, beta, theta, and delta signal of O2

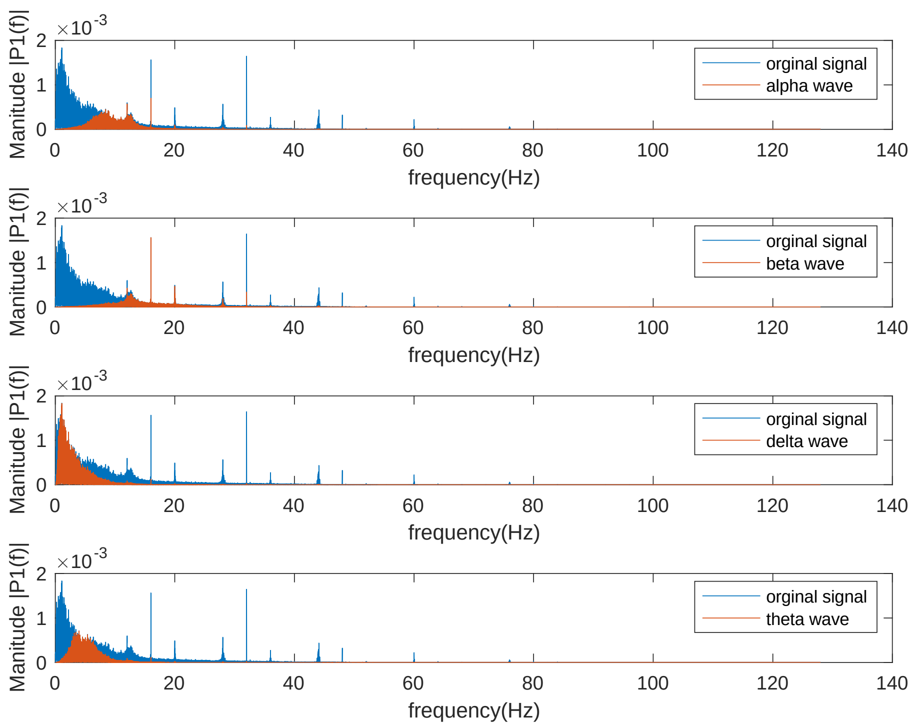

Figure 12: Plot of Single sided Amplitude Spectrum (FFT) for alpha, beta, theta, and delta wave on the O2 signal

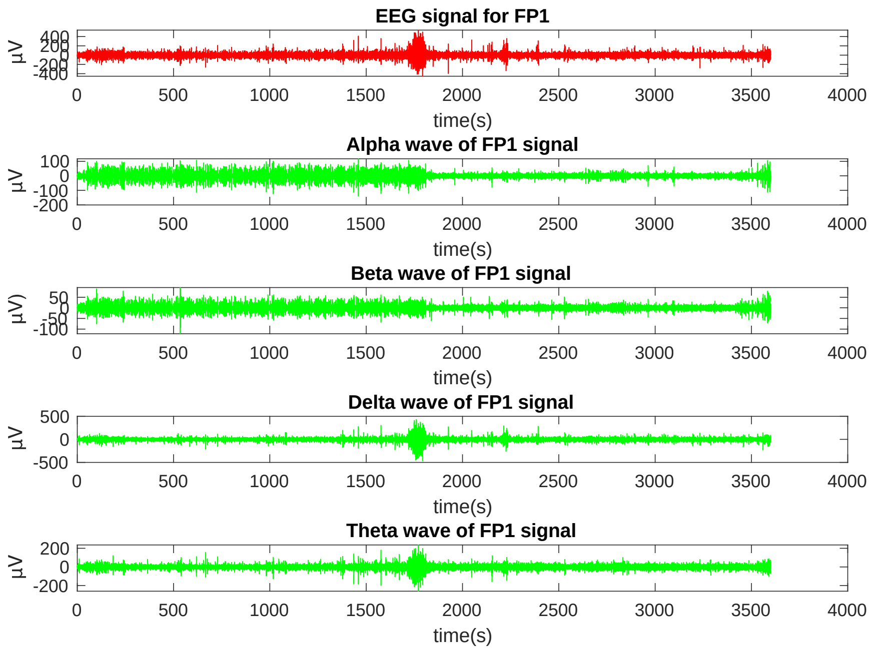

Figure 13: Alpha, beta, theta, and delta signal of FP1

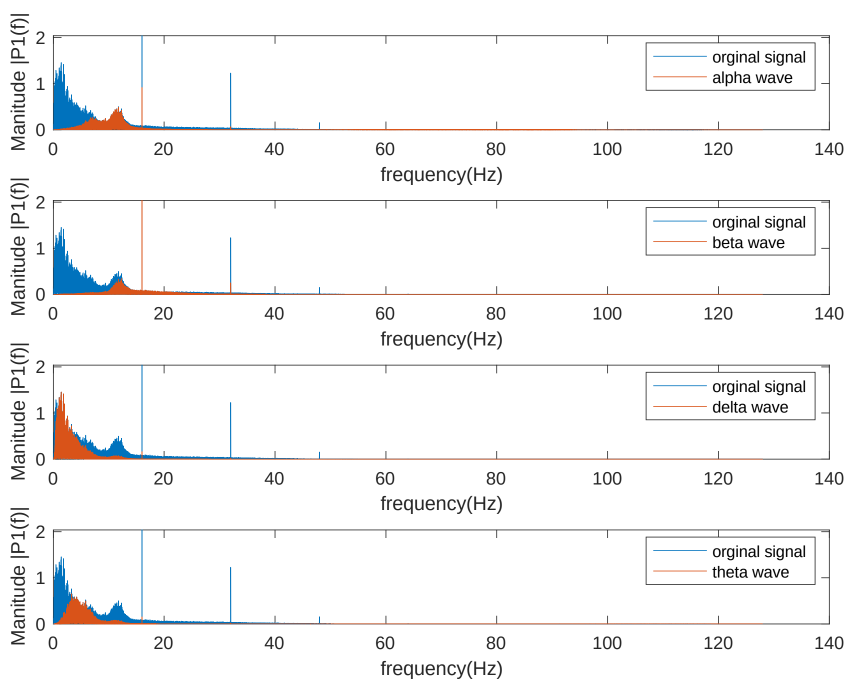

Figure 14: Plot of Single sided Amplitude Spectrum (FFT) for alpha, beta, theta, and delta wave on the FP1 signal

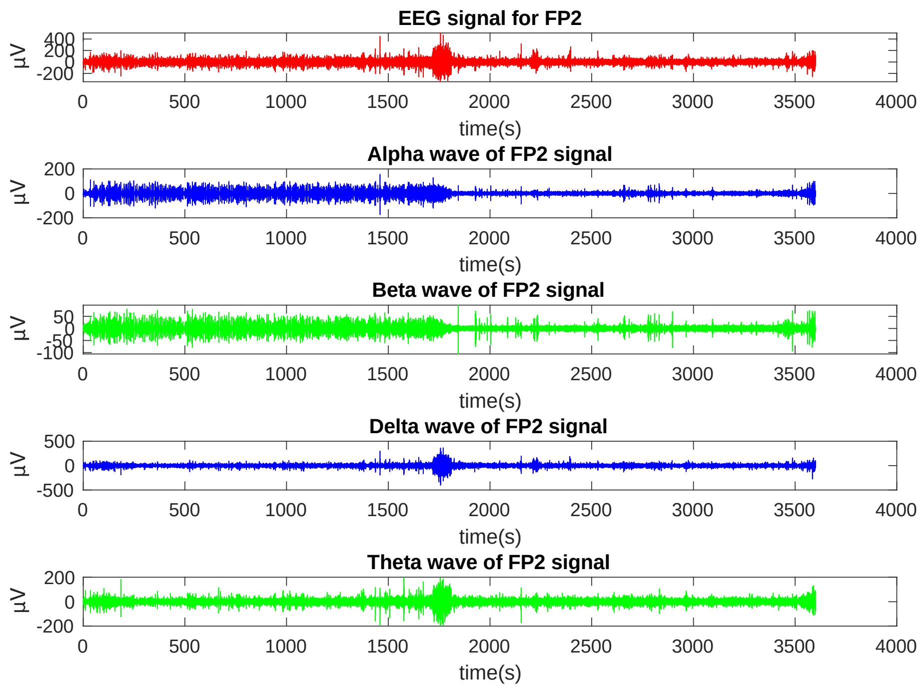

Figure 15: Alpha, beta, theta, and delta signal of FP2

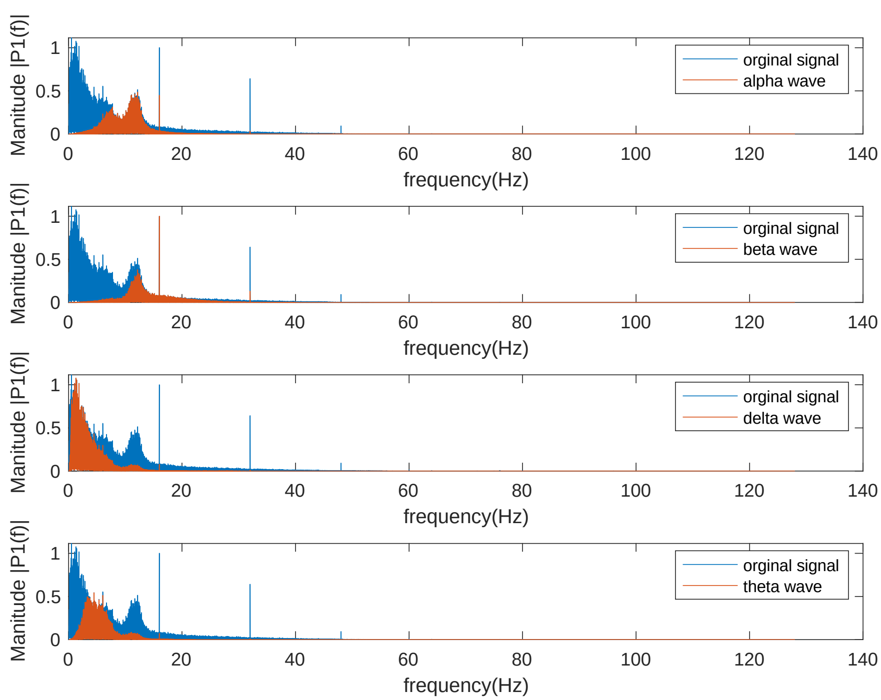

Figure 16: Plot of Single sided Amplitude Spectrum (FFT) for alpha, beta, theta, and delta wave on the FP2 signal

8 seconds of O1, O2,FP1 and FP2 signal to show better the difference between alpha, beta, delta, and theta waves for each signal.

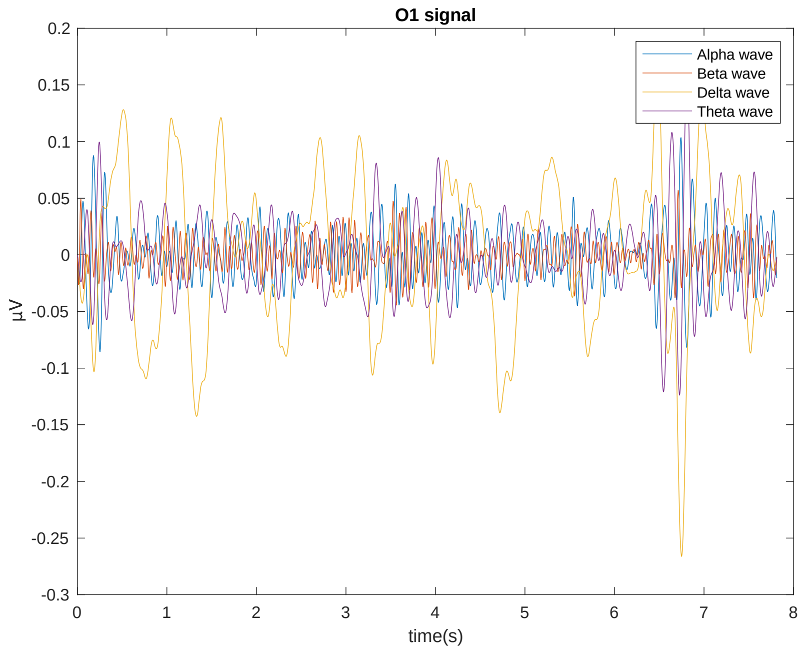

Figure 17: alpha, beta, delta, and theta wave of O1

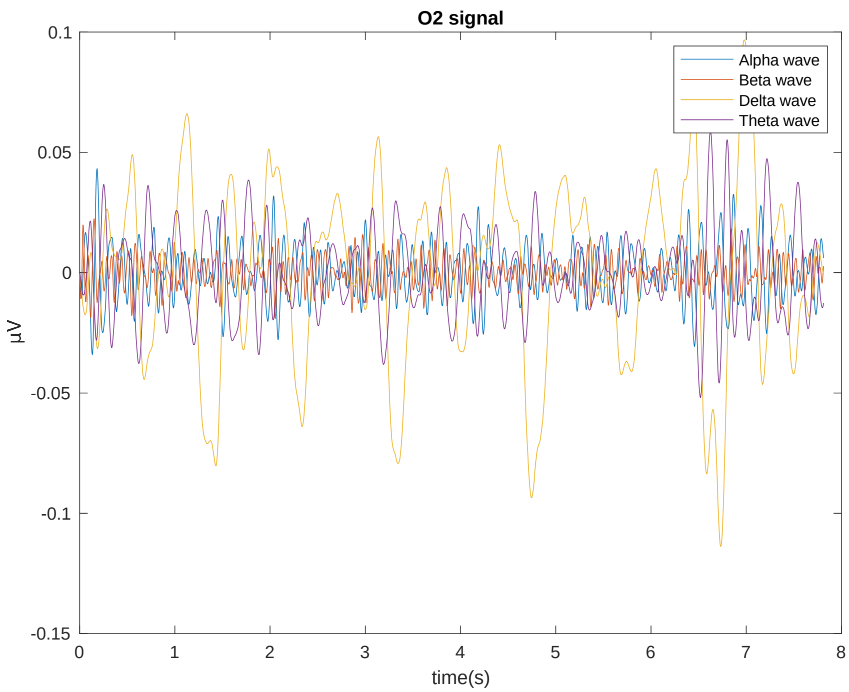

Figure 18: alpha, beta, delta, and theta wave of O2

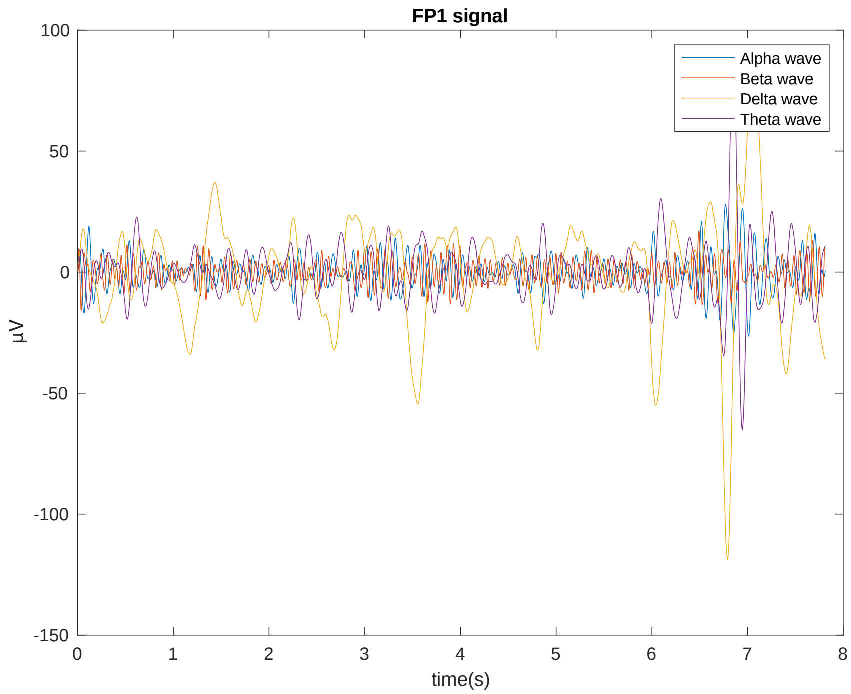

Figure 19: alpha, beta, delta, and theta wave of FP1

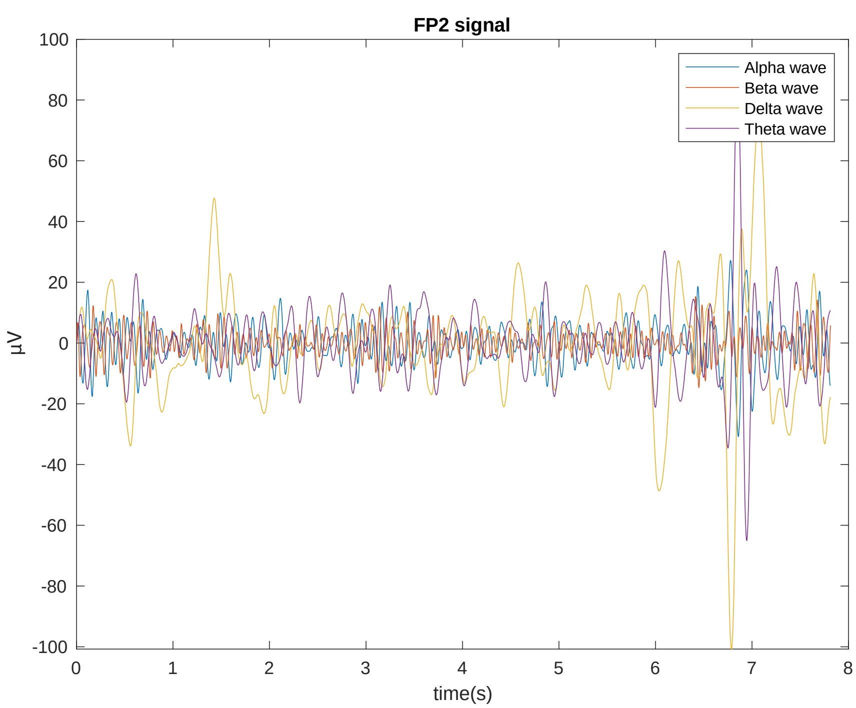

Figure 20: alpha, beta, delta, and theta wave of FP2

Experiment 5

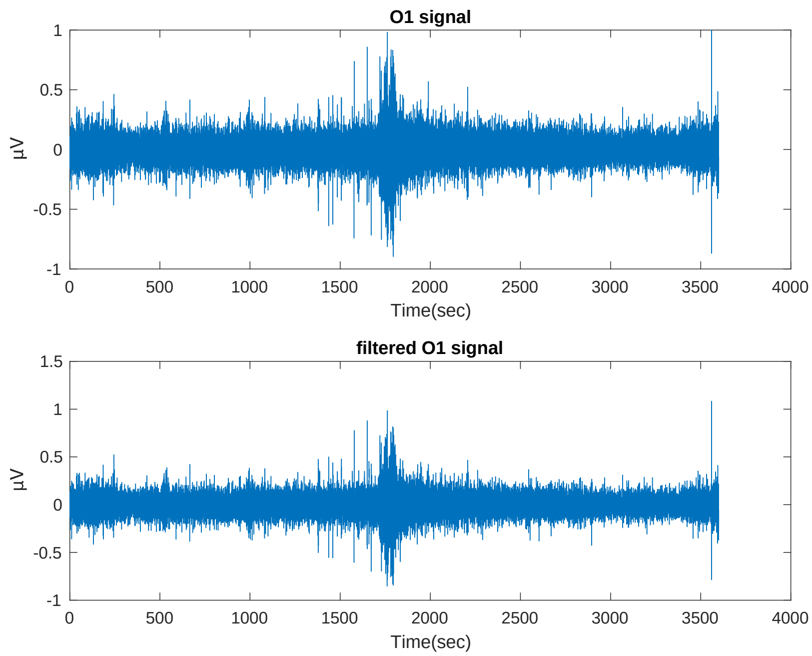

Figure 21: unfiltered and filtered O1 signal

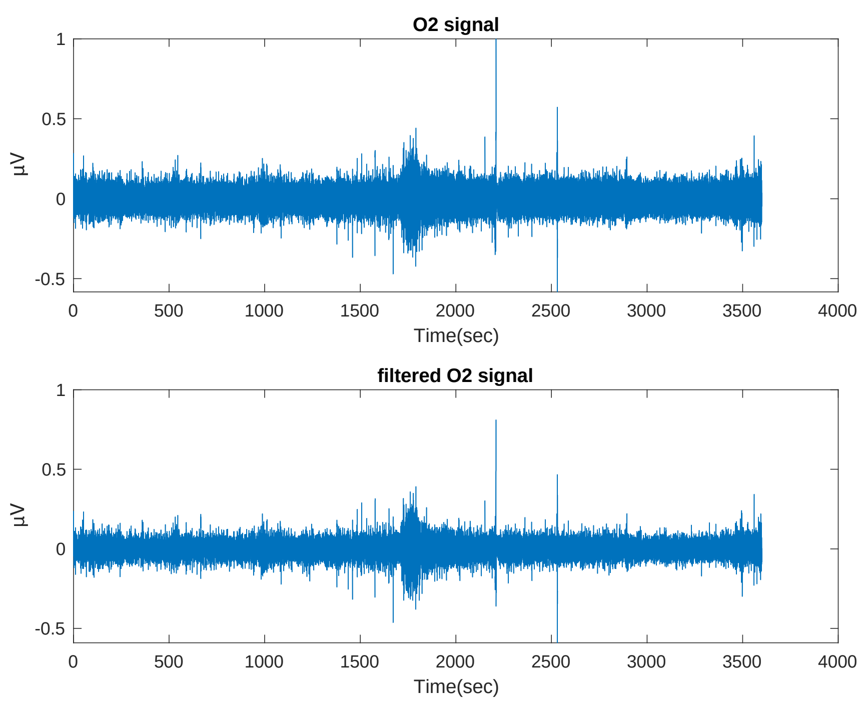

Figure 22: unfiltered and filtered O2 signal

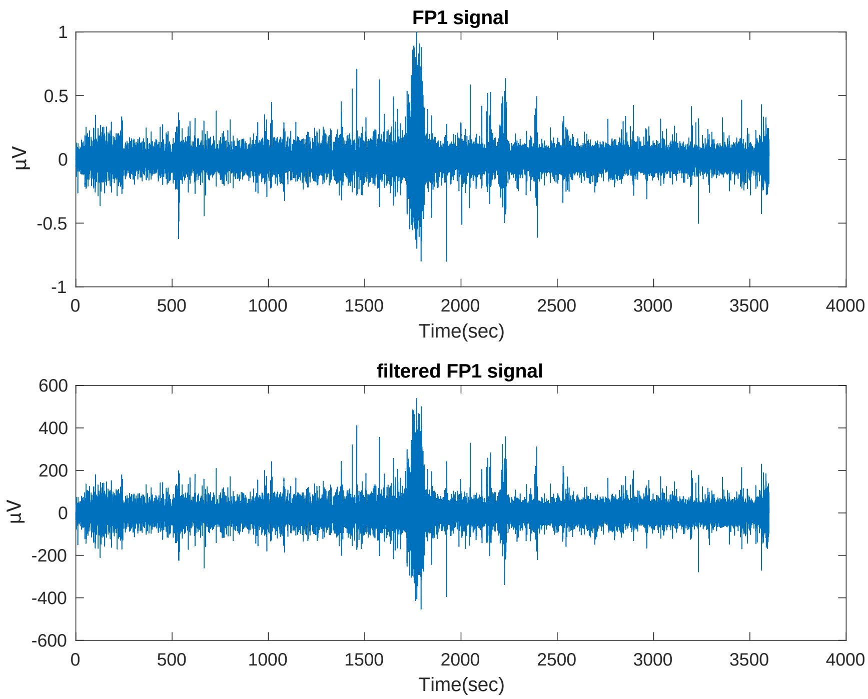

Figure 23: unfiltered and filtered FP1 signal

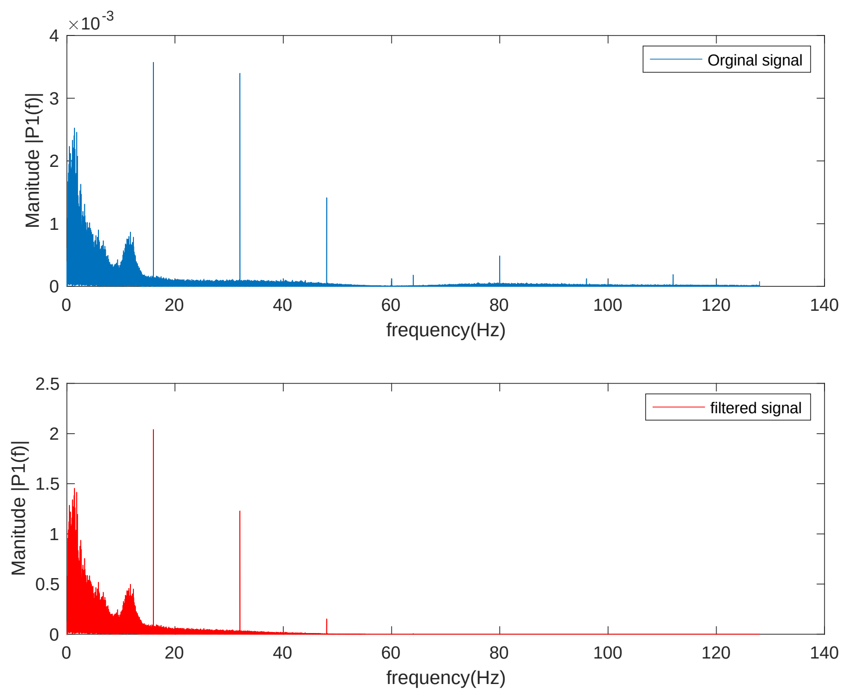

Figure 24: single sided frequency spectrum of FP1 unfiltered and filtered signal

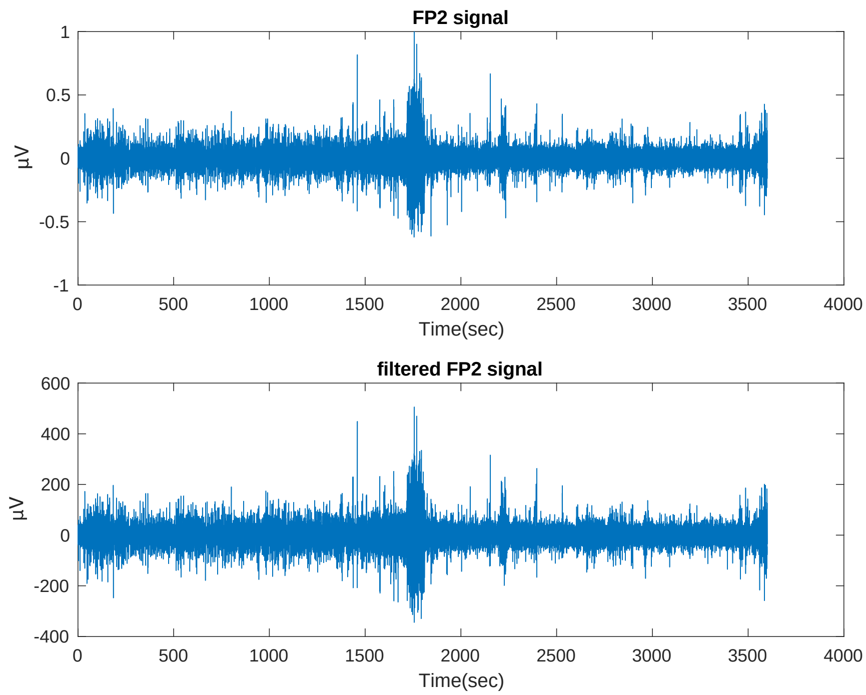

Figure 25: unfiltered and filtered FP2 signal

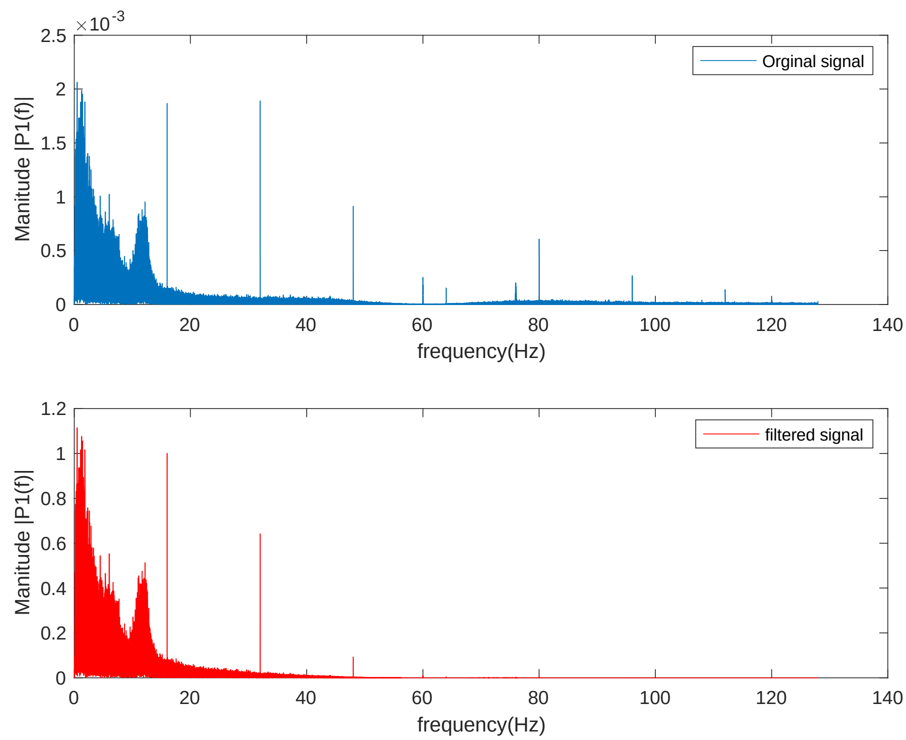

Figure 26: single sided frequency spectrum of FP2 unfiltered and filtered signal

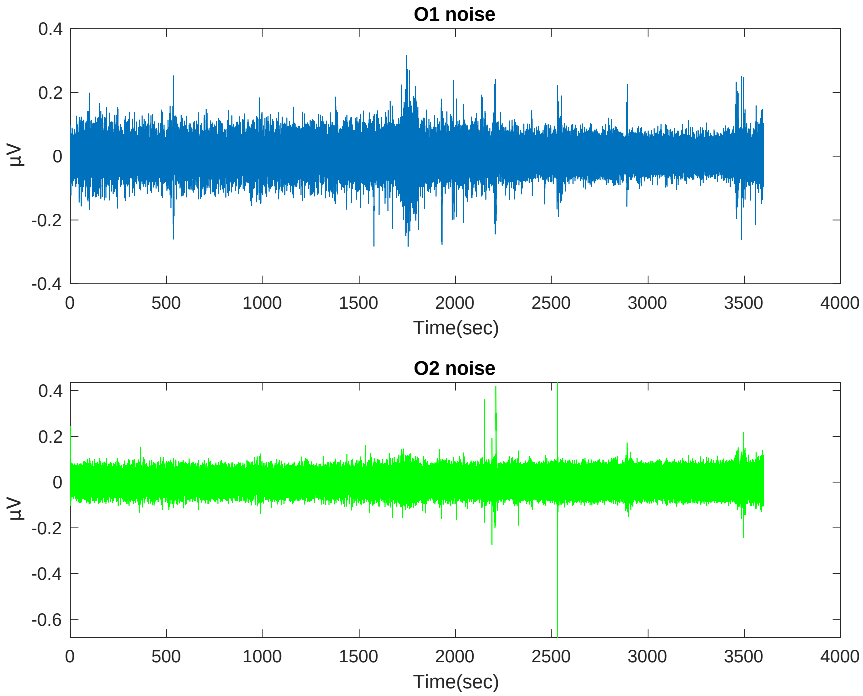

Figure 27: time domain plot of the noise that has been filtered for O1 and O2

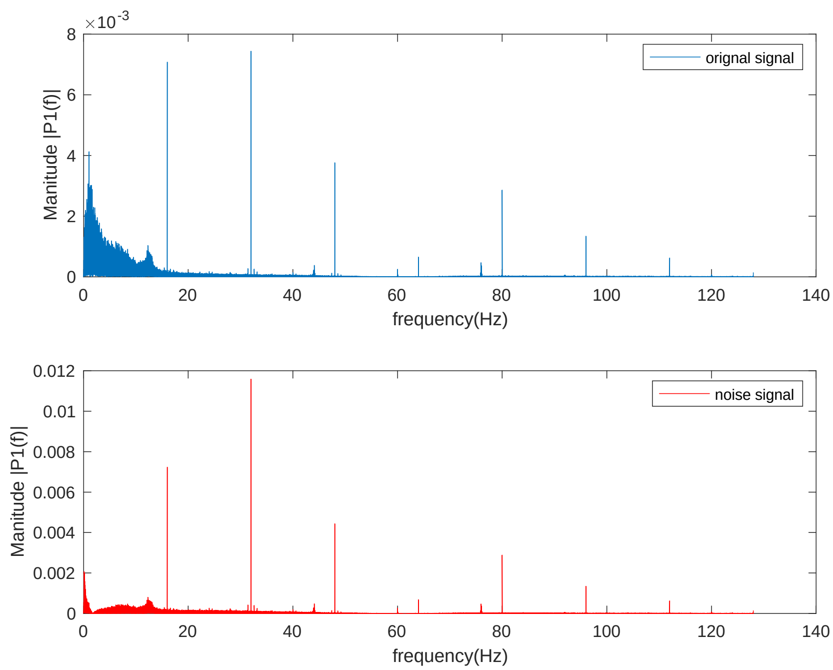

Figure 28: Frequency spectrum of O1 noise

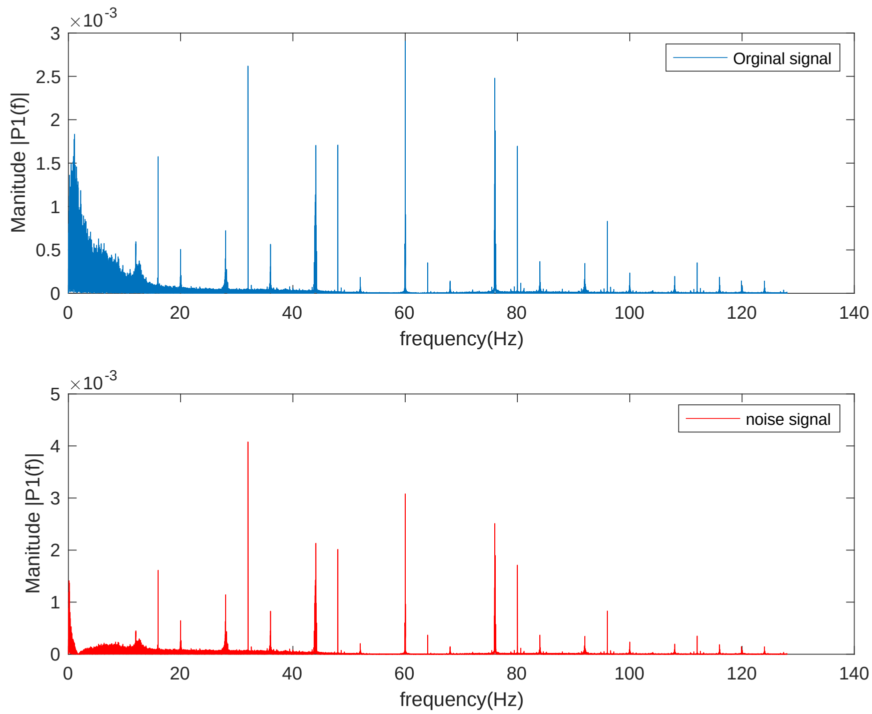

Figure 29: Frequency spectrum of O2 noise

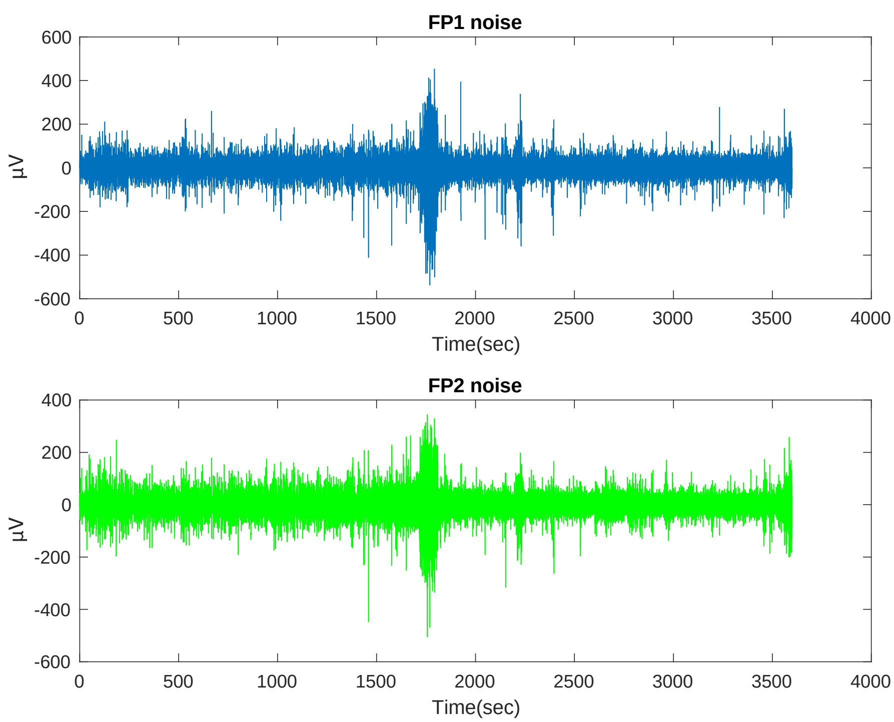

Figure 30: time domain plot of the noise that has been filtered for FP1 and FP2

Describe the noise - what are the properties of the noise? How are they different from the EEG bands and rhythms? Is the denoising filter you designed adequate?

As it can be seen in the Fig.29 & 28 the magnitude of the noise compare to original signal is smaller. Also, it shows that the noise was extracted from the signal is mostly after 30 Hz. However, there is still some data being extracted from the 0.1 to 30 Hz. This implies that, unlike other wave-like bands/rhythms, the use of this noise filter actually reduces the average amplitude of the EEG outputs by a comparatively coherent sum to eliminate the noise from the signal. Because noise is not really a permanent value, however, other filters can be used for a more precise reading.

References

[1] J. Satheesh Kumar, P. Bhuvaneswari, Analysis of Electroencephalography (EEG) Signals and Its Categorization–A Study, Procedia Engineering, Volume 38, 2012, Pages 2525-2536, ISSN 1877-7058, https://doi.org/10.1016/j.proeng.2012.06.298.
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