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Sharp Filters To Extract Absence Seizures EEG Signals

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***Abstract*—** Reliable and accurate analysis of the electroencephalogram (EEG) waveforms can be very important to the current medical research and clinical fraternity to analyze the EEG signals and accordingly treat the subjects for any neurological abnormalities such as seizures etc. This paper introduces the types of EEG and pin points the absence seizure (or petit mal seizures) among children. The paper analyses the use of a novel method of using a sharp finite impulse response (FIR) filter that can extract time domain EEG signals of patients who are inflicted with absence seizures. The sharp FIR filter comfortably extracts the noise free delta EEG frequency of 3.04Hz for a cutoff of 3Hz. The filter displays flat passband and stopband attenuation, and also possesses a linear phase response. A transition width of 1 Hz is achieved using our sharp filter

***Keywords*—** Electroencephalogram, absence seizure, petit mal seizure, linear phase, FIR filters.

I. INTRODUCTION

The analysis of EEG signals is predominantly become an important feature in the medical research among doctors and biomedical engineers. The challenging task of acquiring large data of time domain EEG measurements from patients and analyzing the waveforms also haunts researchers. Moreover, extracting and detecting abnormal EEG signals for epileptic seizure is of utmost important for the treatment and medication of patients at the appropriate time. The early detection of these neurological abnormalities surely help the community at large especially in children.

Table 1. EEG Parameters [1]

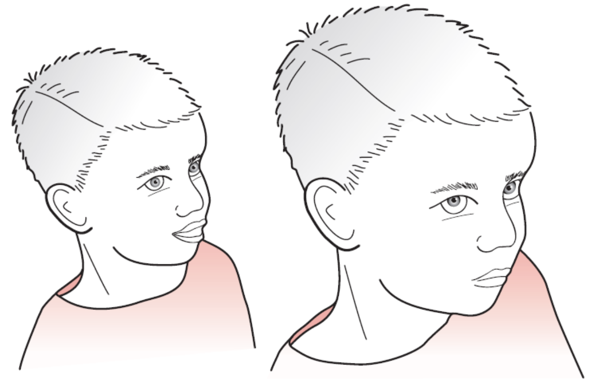
EEG Frequency band	Associated feature
Delta 3Hz or below	Deep meditation and dreamless sleep
Theta 3.5-8 Hz	Occur most often in sleep or deep meditation
Alpha 8-13 Hz	During quietly flowing thoughts
Beta 14 -38 Hz	Normal state of consciousness
Gamma 38-42 Hz	Simultaneously processing of information from different brain areas.

The EEG waveforms are primarily of five types in the order of frequency as shown in the Table 1. The type or frequency indicates the correlates to the state in which the subject is in or an occurrence of a seizure or epilepsy in a patient. For example, the presence of large spike waves in a patient while lying down may indicate a seizure or a stroke [2].

A. Absence or petit mal seizure

Petit mal or absence seizure is a brief moment of suspension of normal activity, impairment of self-consciousness and is sometimes accompanied by a change in facial expression [3]. Although absence seizures account for only 10% of seizures [2] they begin between 3- 12 years in children [4] and wither off at 15 years and are mostly seen in the girl child [3]. These are seizures that may even go unnoticed in children if parents and teachers are not alert. The frequency of occurrence of these seizures can be as many as 10 – 30 times a day for lapses in attention between 5 - 30 seconds for each episode [5].

During a petit mal seizure, the patient may suddenly appear staring while engaged in an activity as shown in Figure 1. He becomes glassy-eyed and mute, and may roll his eyes upward or downward and blinks rhythmically at 2.5 - 3 Hz [6]. Although he loses self-consciousness, he maintains muscle tone and bladder control. Certain behaviors, such as touching the face or gently scratching the hands or clothes, licking the lips, etc. are seen during the episode [3, 7]. At the end of his 5-30 seconds seizure, he may resume with the activity he had engaged with and will be completely unaware of the lost time. With timely treatment these absence seizures can be controlled.



(a) (b)

Figure 1. The patient is seen normal in (a), suddenly the patient appears glassy-eyed and mute [6].

B. EEG during absence seizure

During an absence seizure, all channels indicate the delta 3 Hz EEG spikey waveforms for the entire episode as shown in Figure 2. The electrical discharge from the brain reflects the abnormality in the reciprocal circuits between the thalamus and the cerebral cortex [6]. For the clinical measurements of these seizures, patients are subjected to either hyperventilation or photic stimulation.

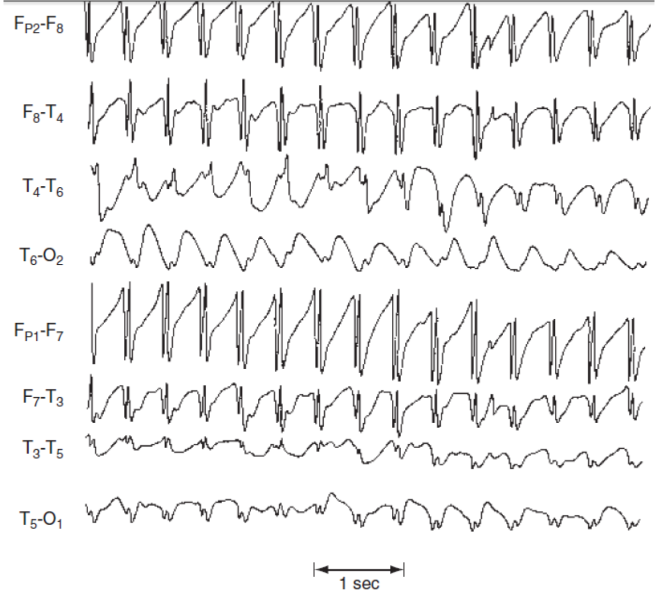


Figure 2. Absence seizures of 5-6 seconds in a patient of 3-Hz spike-and-wave complexes, then returns to normal EEG [6].

C. Filtering raw EEG signals

The EEG measurement is acquired by placing the scalp electrodes on the cerebral region as shown in Figure 3. The EEG frequency ranges from 0.1 – 100 Hz while the amplitude ranges from 10 – 100 µv [1].

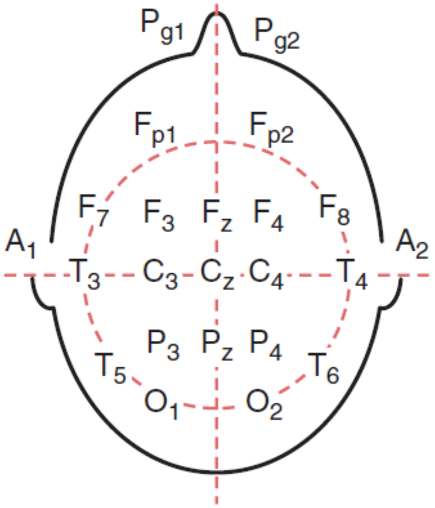


Figure 3. Standard scalp electrodes for the cerebral region (e.g., frontal, temporal, central, parietal, and occipital) [6].

This extracted raw EEG waveform can include artefacts from movement based signals such as facial muscles or eye blinks [8]. Furthermore, signals from the subject’s ECG, power line interference or electrode noise can also be picked up as noise or harmonics and may get mixed up in the original raw EEG signal. Thus these biomedical artefacts need to be cleaned up first to obtain a clean set of EEG frequency band for accurate analysis and interpretation of the disease.

To eliminate the artefacts, the raw EEG signal can be filtered by using various known filters. However using sharp finite impulse response filter (FIR) can be advantageous because of the filter’s stability, linearity, sharp transition and ease of designing such filters [9, 10]. The filtered EEG signals can be further used for epileptic seizure detection and prediction [11, 12]. In this paper, we took the task of filtering the EEG signal of the subject who had experienced seizures. In the following section we propose the sharp low pass filter (LPF) to extract the low frequency EEG signals (0-3 Hz) thus eliminating the higher frequency artefacts.

II. SHARP FIR FILTER

We propose a sharp FIR LPF modelled using trigonometric functions to fit the curve of the magnitude frequency response H (ω) shown in Figure 4. Using simple sin and cosine functions the three regions in the H (ω) can be designed. A sharp transition of 2π (1 Hz) is to be achieved using this methodology. The δp and δs are the ripple constants while ω_{cl} and ω_{sl} are the passband and stopband cut off frequencies.

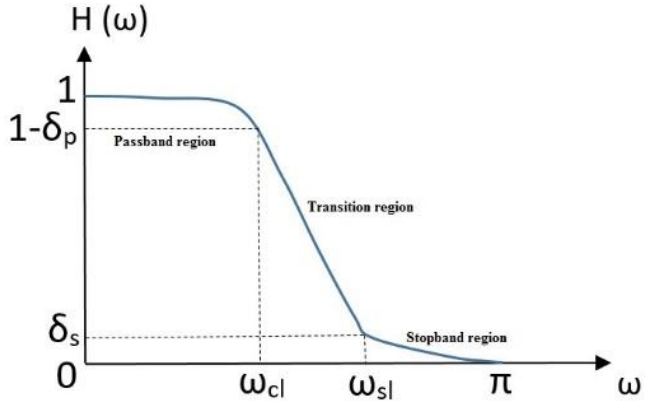


Figure 4. Magnitude response of the sharp LPF.

After designing the approximate curve fitting trigonometric equations and obtaining the filter design parameters for each of the regions in the H (ω), the impulse response coefficients h (n) can be computed. According to the linear phase FIR filters, Proakis J., and Manolakis D. (2001) [14] clearly describe that the following filter type: Symmetric (N = even) suits our application for LPF where the frequency response H(ω) is,

$$H(\omega) = H_r(\omega)\, e^{-j\omega(N-1)/2} \qquad (1)$$

and

$$H_r(\omega) = 2\sum_{n=0}^{\left(\frac{N}{2}\right)-1} h(n)\cos\omega\left(\frac{N-1}{2}-n\right) \qquad (2)$$

where , N = filter order.

For Symmetric even type as per [13,14], h (n) = h (N-1-n), the number of filter coefficients is N/2. The h (n) can be computed by using equation (3) by integrating the three regions from figure 4.

$$h(n) = \frac{1}{\pi}\left\{\int_{0}^{\pi} H(\omega)\cos k\omega\,\partial\omega\right. \qquad (3)$$

III. RESULTS AND DISCUSSION

A five minute EEG recording of a subject was taken using 20 scalp electrodes with the sampling frequency of fs = 265 Hz. Our sharp FIR filter was used to chip off the frequencies outside the delta range (frequencies above 3 Hz). The LPF retained the frequencies below 3 Hz by fixing the fiduciary band frequencies. ie. ωcl- ωsl = 2.5 – 3 Hz. The Figure 5 shows the magnitude response as compared to the ideal case. A sharp transition of 2π is easily achieved. The Figure 6 shows the characteristic of the linear phase response of our proposed FIR LPF. The time series raw EEG signals from the 20 channels acquired from the subject are shown in Figure 7. For convenience sake, we have shown channels 1 to 4 and the 20th channel.

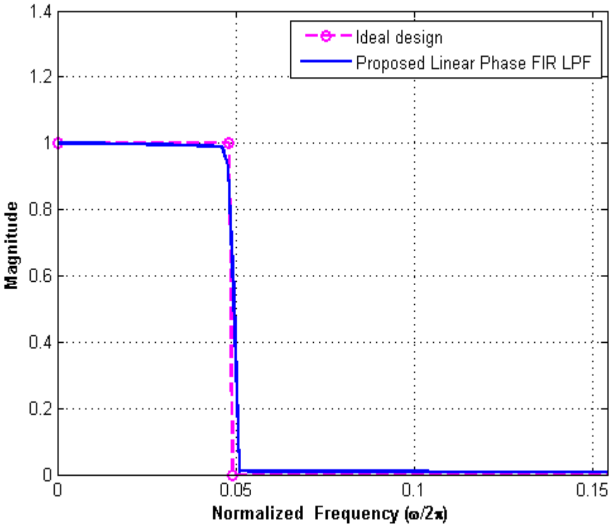


Figure 5. Magnitude response of the FIR LPF as compared to an ideal design.

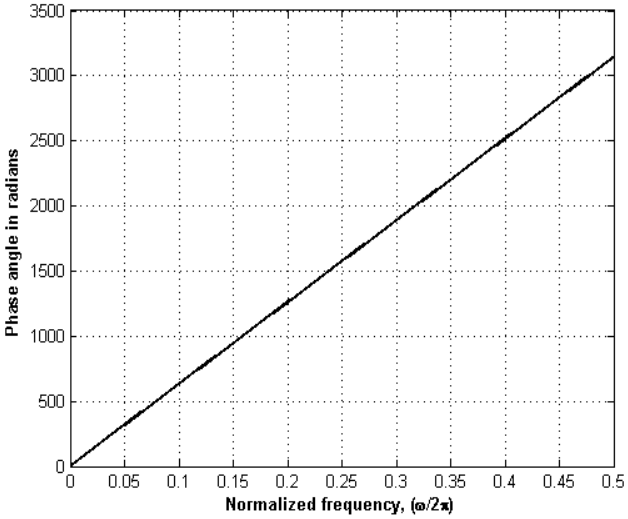


Figure 6. Phase response of the designed FIR LPF.

Applying the sharp FIR low pass filter, for the above fiduciary band edges to the raw EEG signal, we can compare the frequency domain of the filtered and the unfiltered EEG signals. As seen in Figure 8, we can monitor the sharp transition of the filter at the designed fiduciary edges. The cutoff frequency at 0.01191 and the sampling frequency (fs) is 256 Hz which gives, 0.01191 x 256 Hz = 3.04 Hz. Thus, all frequencies including the artefacts outside the delta range will be omitted. The filtered time series EEG signal obtained as seen in Figure 9 shows a clean and clear EEG signal for a particular chosen channel. This signal can be further processed for detection and prediction.

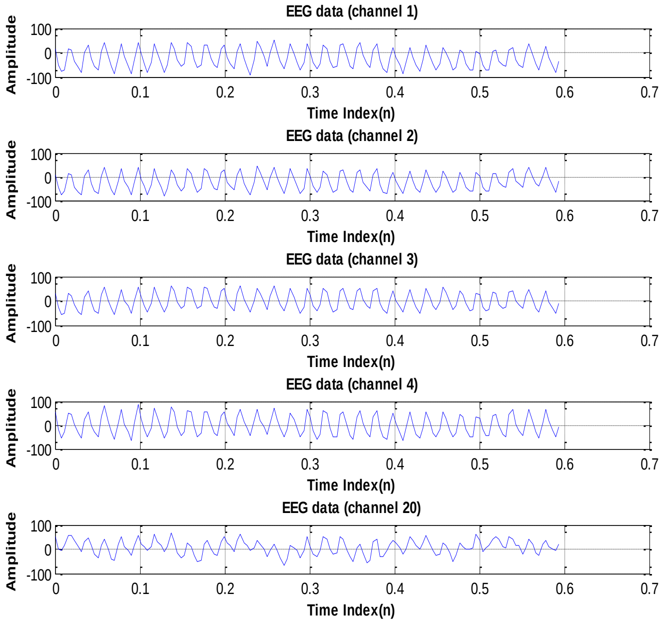


Figure 7. The Time series raw EEG signals from a single subject. Only 1 to 4 channels and 20th EEG signals are shown for convenience sake (6 secs).

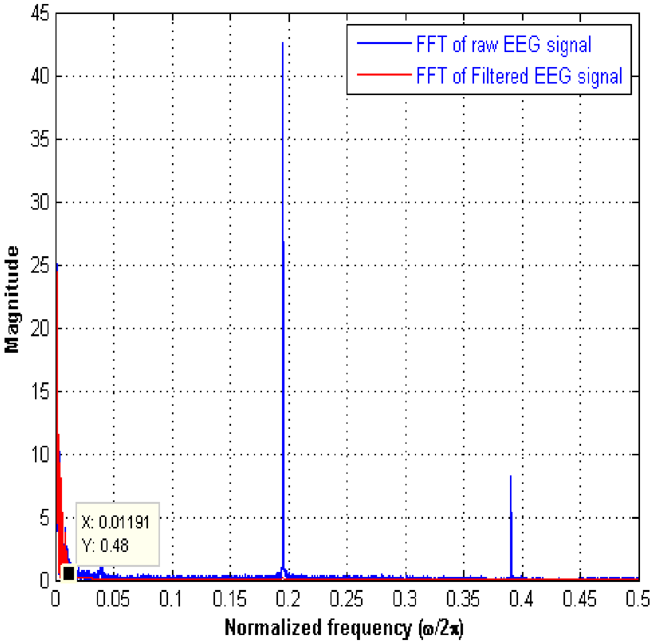


Figure 8. Comparison of the filtered and unfiltered EEG signal. Cut-off seen at the designed ω = 0.01191 (3 Hz).

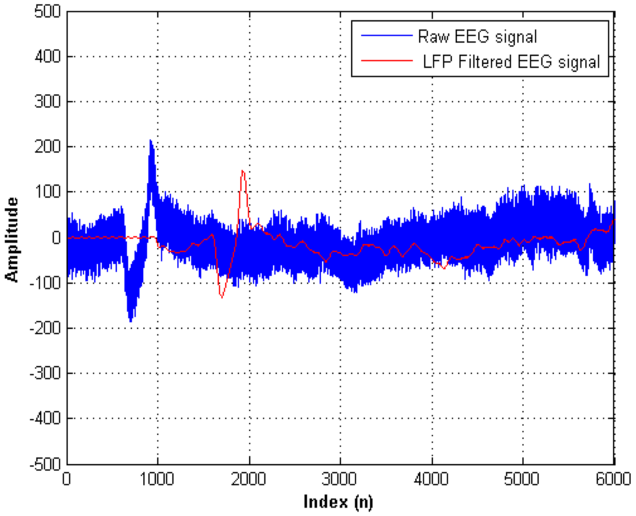


Figure 9. Comparison of the filtered and unfiltered EEG time series signal of a particular EEG channel (one minute duration).

IV. CONCLUSION

Reliable analysis of EEG signals are important to biomedical and clinical community, especially to analyse and treat the patients for any neurological abnormalities such as seizures. The paper proposed a sharp FIR filter which comfortably extracted the required EEG signals less then 3Hz and omitted the higher frequency artefacts and the power line interference and its harmonics. It was seen that the filter has flat passband and stopband attenuation. It was also seen that the filter possessed a linear phase response. We conclude that our proposed filter can be used for any sharp cut-off frequencies with a transition width of 1 Hz.

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