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EEG Signal Enhancement – FIRParzen Window Filter Method

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ABSTRACT: *Most times the illness of the brain is diagnosed with the electrical signal that is generated from the brain. The electrical potential that emanates from the brain is called the electroencephalogram (EEG). EEG is measured and recorded with an electronic device known as the electroencephalograph. The signal gives vital information about the wellness of the human brain. One of the challenges of the treatment of the brain illness occurs when EEG is recorded alongside with order unwanted signals generated around the brain. These unwanted signals are electrical potentials discharged due to the movement of the eye and blinking of the eye, electrical potentials discharged due to heart beat and electrical potentials discharged due to muscle movement as well as electrical potentials discharged due to the interference of electricity supplied to the EEG device. This work introduces a finite impulse response (FIR) filter modeled withParzen window to reduce 50HZ power line interference from EEG Signal. The researcher used a real life EEG signal obtained from a patient to demonstrate the potency of the filter in a MATLAB environment. It was successfully demonstrated that Parzen window-based FIR filter effectively cancelled out 5mV 50$H_Z$power line interference from the EEG signal.*
KEYWORDS *-EEG Signals, 50Hz Power line interference, FIRfilter, Parzen Window, Noise Removal.*

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I INTRODUCTION

Information are passed from the five sense organs of the human system to the brain for processing, interpretations and feedback. The brain handles signals from the eye, nose, tongue, ear and skin which are referred to as the sense organs as well as information from some other internal organs and the body systems. Sensations like headache, child birthlabour, pains, hunger, thirst, backache and many other stimuli from the human internal organs are all sent to the brain for interpretations. Sensations that relate to urine, defecation, vomiting and so on are also sent to the brain for the same purpose. The brain also gives interpretation to all the human metaphysical experiences and feelings. These involves emotions, anger, hate, love and so on. When the brain interprets the signal and sends back the interpretation, then the body begins to take necessary actions.The brain is simply the microprocessor of all animals. The brain suffers some illness whichcauses the brain to malfunction, hence EEG is vital for the clinical rounds for treating brain of the illness and to ensure its wellness.

Since the measurement of EEG is done by systematically placing the probes of the electroencephalograph on the scalp. The probes pick the EEG and other unwanted electrical potentials generated around the head. Theseunwanted signal include the electrical potentials discharged as a result of eye blink and movement of the eye ball, which is referred to as the electrooculogram (EOG), and electromyogram (EMG) produced by the stripes of muscle found around the head. Other unwanted artifacts traceable to the EEG device is theelectrocardiogram (ECG) which is the electrical potential generated due to heart beat. EOG, ECG and EMG can be referred to as biological noise to EEG. Another noise that can be generally referred to as physical noise is a class of unwanted signal produced by the electroencephalograph itself, this is called the power line interference. Power line interference is produced by the inductive-capacitive coupling effectof the electronic components used in manufacturing the electroencephalograph. This artifact can be rated 50Hz or 60Hz depending on the frequency of electricity that drives the EEG recording device. In other to record the brain potential that will give the true medical status of the brain for good treatment, all artifacts have to be removed. This work evaluates the effectiveness of the Parzen window in the design of FIR window based filter.

II LITERATURE REVIEW

A lot of work have been done using different techniques to remove these artifacts. Different filters have been introduced by different researchers which include adaptive filters, finite impulse response (FIR) window based filters and many more. In FIR window based filter modeling, researchers have used different windows namely; Triangular, Nuttall, Kaiser, Rectangular, Hamming, Hanning, Sine and many others, in the FIR window based filter modeling. In [1] Mbachu et al used triangular window to model an FIR filter and used same to reduce 50Hz powerline artifact from ECG signal. A demonstration of artifact removal using Nuttall window FIR filter on ECG was shown in [2]. FIR filter designed with Kaiser window-based, in [3] was shown to have been used to attenuate noise from ECG Signal. Researchers in [4] also demonstrated that Rectangular window can be used to do noise cancellation in ECG. The chronicle of windows used in FIR filter design, includes the introduction of Hamming window [5]. Lastly, in this review, aresearcher worked on FIR filter successfully,and demonstrated that Hanning window could be used in signal processing filtration [6].

III MODELINGOF FILTER

This work show cases the modeling of FIR window-based filter using Parzen window. Mathematically, the Parzen window is expressed as in; (1) [7].

$$W_{(n)} = \begin{cases} 1 - 6\left(\frac{n}{\frac{N}{2}}\right)^2 \left(1 - \frac{|n|}{\frac{N}{2}}\right) for\ 0 \le |n| \le \frac{N}{4} \\ 2\left(1 - \left(\frac{|n|}{\frac{N}{2}}\right)^3 for \frac{N}{4} \le |n| \le \frac{N}{2} \end{cases} \quad (1)$$

Where N is the number of filter tap.

The graphics of the Parzen window in the time and the frequency domains are shown in Fig 1 for window length 101 taps.

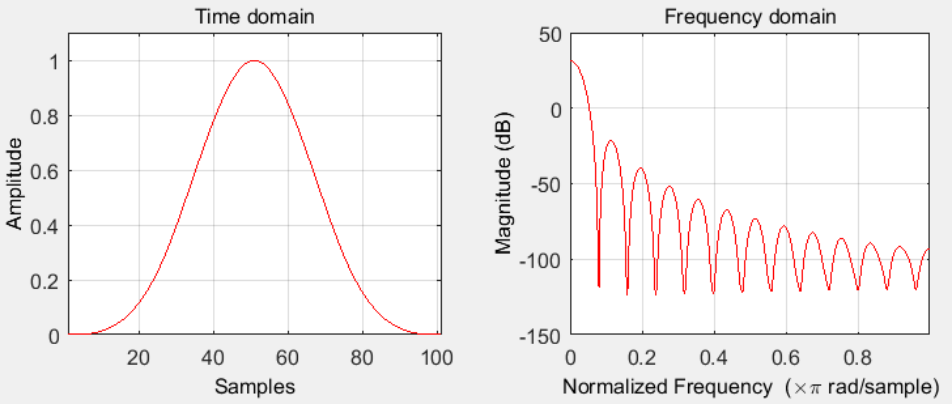

Fig 1: Graphics of Time domain and Frequency domain of Parzen window

FIR filters are designed by the process of truncating the desired unit sample response $h_d(n) of$ the filter with a window function. This is called Windowing [8]. Windowing is achieved by multiplying the desired unit sample response $h_d(n)$ by window function (W_n) to obtain the unit sample response of FIR filter h(n)as shown in; (2);

$$h(n) = h_d(n) * W_n \quad (2)$$

In this case, W_n represents the Parzen window function shown in (1). The modeling of the FIR Parzen window-based filter was accomplished in MATLAB environment where it was successfully demonstrated that the Parzen window FIR filter effectively cancelled out 5mv $50H_Z$ power line interference from the EEG signal. The filter specification is such thatthe filter order is101, lower sideband cutoff frequency is equal to $40H_Z$ and upper sideband cutoff frequency is $60H_Z$. Fig 2 shows the Impulse response and the Magnitude response of the filter while fig 3 shows the Phase response of the filter. From fig 3, it can be seen that the filter has a linear output and satisfies the conditions of FIR filters.

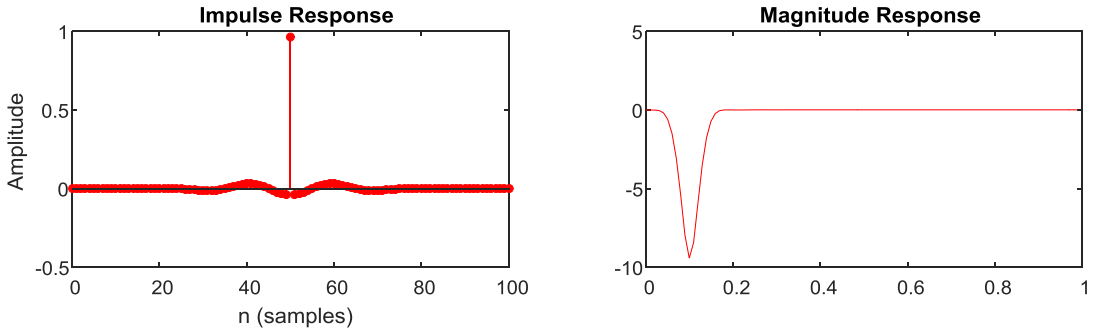

Fig 2: Impulse response and Magnitude response of FIR Parzen window-based filter

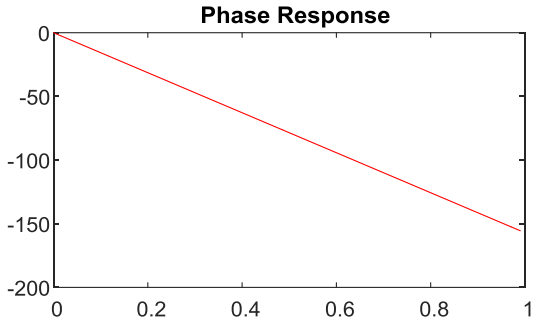

Fig 3: Phase response of FIR Parzen window-based filter

IV RESULTS

A section of a 10-second EEG signal of an 18 year old lady from Nigeriaobtained in 2012is shown in fig 4(a). The signal was corrupted with a MATLAB generated 5mV 50Hz noise shown in fig 4(b) to yield a signal mixture shown in fig 4(c). On application of the FIR Parzen window-based filter on the corrupted signal, a filtered EEG signal shown in fig 4(d) appeared. This shows that the FIR Parzen window-based filter has the capability to effectively attenuate 50Hz power line interference in EEG signal.

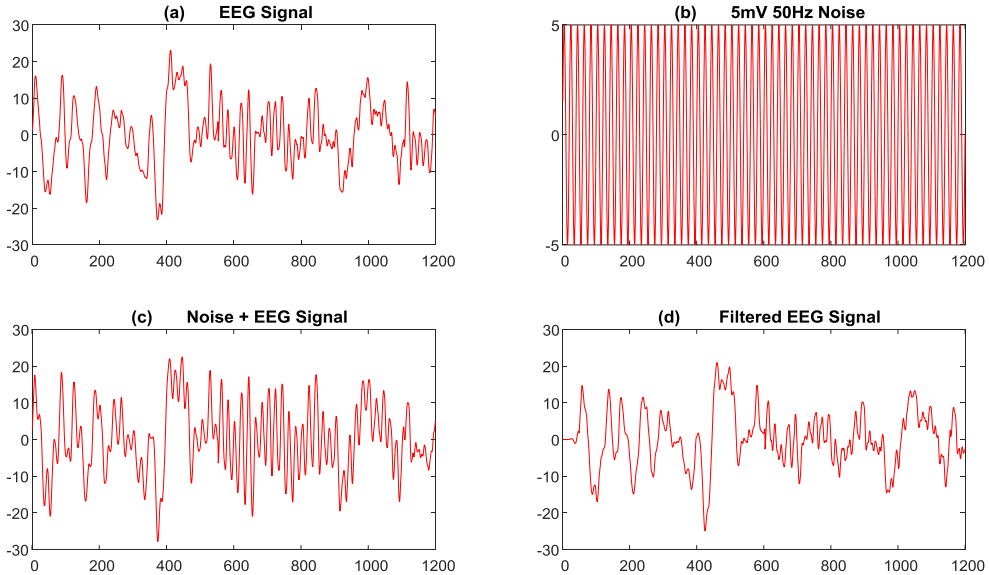

Fig 4: Graphics of (a) Clean EEG, (b) 50Hz interference, (c) contaminated EEG and (d) filtered EEG

In other to determine the most effective filter order for the FIR filter, the magnitude response (in dB) of the filtered EEG obtained with FIR Parzen window-based filter modeled with various filter orders were compared with the magnitude response (dB) of clean EEG. Magnitude response for the clean EEG is shown in fig 5. It was observed that the filter order of 101 tap made the best comparable output of 61.72dB nearest to

magnitude response of 61.74dB of the clean EEG. Table 1 shows results of various filter orders versus their corresponding magnitude responses. Magnitude response (dB) of50Hz power line interference (fig 6) shows that 50Hz interference occurred at normalized frequency of 0.1 π rad/sample with a magnitude responses of 69.54dB. When contaminated, the magnitude responses shoots up to 71.17dB (fig 7). Magnitude responses (dB) of filtered EEG is shown in fig 8and it is equal to 61.72dB.

Table 1; Various filter orders against their magnitude responses in dB

Filter order	95	97	99	101	103	105	107	109	111	113	115
Mag. (dB)	62.50	62.06	61.98	61.72	61.46	61.20	60.95	60.65	60.46	60.16	59.92

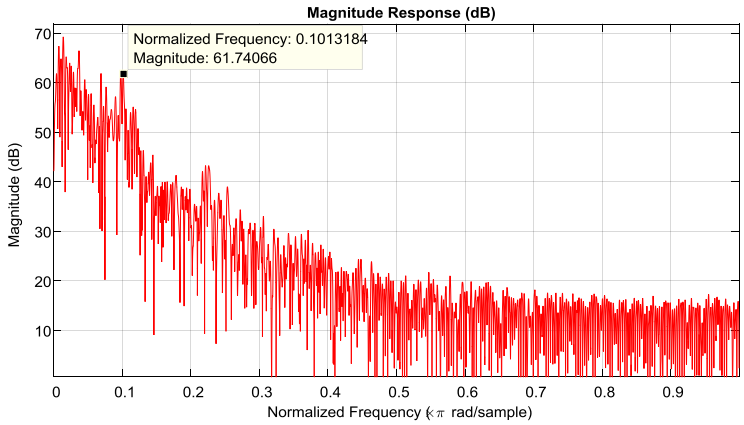

Fig 5: Magnitude responses (dB) of clean EEG signal

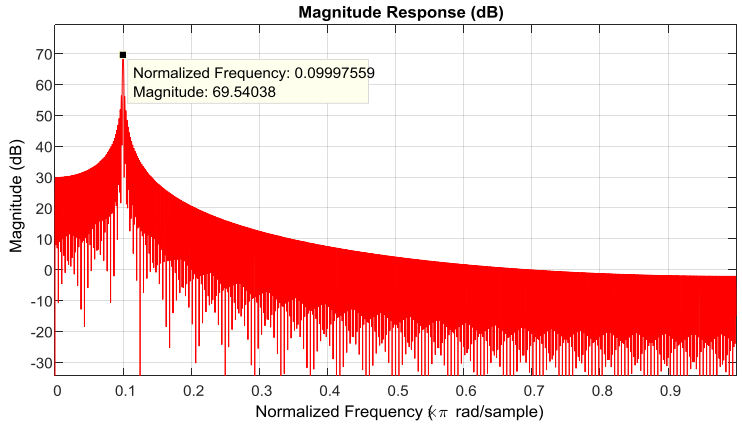

Fig 6: Magnitude responses (dB) of 5mV 50Hz power line interference

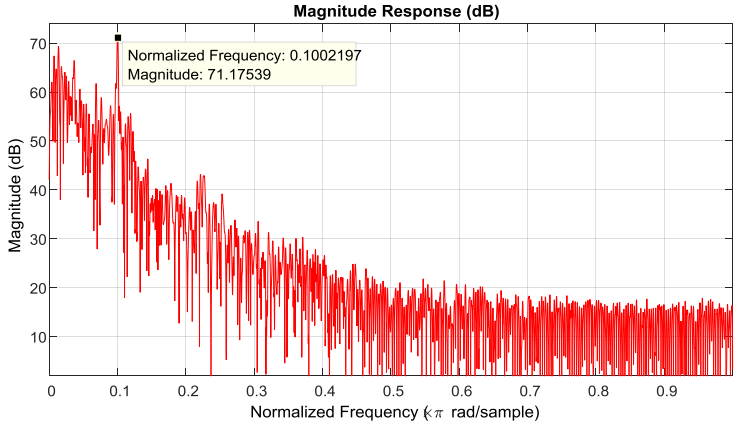

Fig 7: Magnitude responses (dB) of contaminated EEG signal

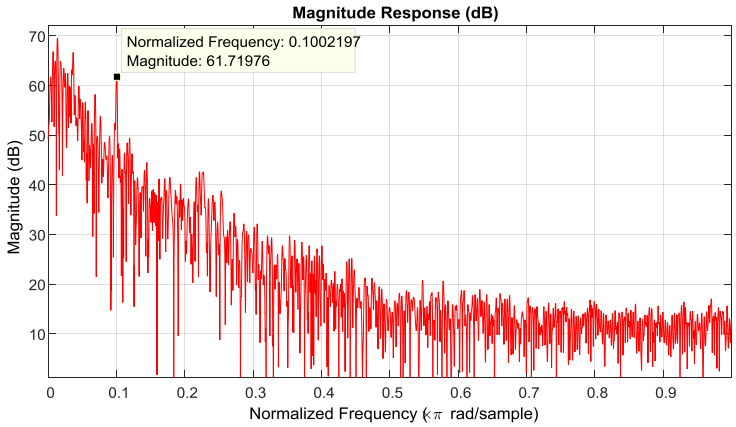

Fig 8: Magnitude responses (dB) of filtered EEG signal

V CONCLUSION

The FIR Parzen window-based filter is effective in the removalof 50Hz power line artifact from EEG signal. This has been demonstrated. The filter modeled with Parzen window of window length of 101 taps, successfully reduced magnitude of 71.17dB artifact at 0.1 π rad/sample to 61.72dB.Parzen windowhas a linear phase response hence it is recommended for the modeling of window based FIR filters.

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