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Digital Filter Enhancement of Electrocardiographic Signal Using Parzen Window

V. O. Mmeremikwu

Abstract— **The heart may be described as the engine room of all mammals. It is responsible for pumping of blood to every part of the body. Digested food nutrient, oxygen and blood are transported to all parts of the body through the a network of veins in a process known as the circulatory system. This transportation is initiated by the heart pumping blood into the system. Therefore the heart is a very important organ of the body and should be cared for. Medically, the wellness of the heart can be determined by the electrical potential it produces. This electrical potential is called electrocardiogram (ECG). ECG may be affected by unwanted signals that may be recorded in the process of recording the signal. One of those unwanted signals is the power line interference (PLI). This paper proposes and demonstrates the removal 0.1mV 50Hz PLI from a contaminated single cycle ECG signal using a Parzen windowed Finite Impulse Response (FIR) filter.**

Index **Electrocardiographic signal, Power line interference, FIR filter, Digital filter, Parzen window, Noise removal.**

I. Introduction

The heart is a very important organ to life. As important as it is, it is responsible for pumping of blood and circulation of same to every part of the body through the veins. The heart generates an electrical signal called electrocardiogram (ECG). This electrical potential is responsible for synchronizing the four blood pumping chambers of the heart [1]. ECG originates from a portion of the heart known as sino-atrial (SA) node [1] and it is detected and recorded with electrocardiograph. The recording of ECG consists of a system of 12 electrodes placement around the heart. The term electrocardiogram was first used by Willem Einthoven in 1893 [2]. But the first ECG record of a human was published in 1877 by the same man called Willem Einthoven. This publication is a giant step that was preceded by Carlo Mattencci's demonstration of the presence of electrical impulse in the heart of a frog in 1842 [2]. Since the advent of ECG in solving cardiovascular problems and other heart related illness, a lot of work has been done to better the understanding, improvement and usefulness of ECG. This involves the Willem Einthoven's use of the alphabets series (PQRST) in identifying the deflections of ECG curve in 1893 [2] [3] and the electrode number increase from 6 to 12 electrodes.

As important as the ECG is in cardiac health care delivery, there is a problem of noise contamination facing recording of the signal. Noise is any unwanted signal present in the desired signal. Unwanted signals in ECG include electroencephalogram (EEG), electromyogram (EMG), power line interference (PLI) and base line wander (BLW) [4] [5] [6] [7]. EEG and EMG are electrical impulses produced by the brain and the muscles respectively. PLI is electrical signal generated by the capacitive-inductive coupling effect of the electronic elements of the electrocardiographic device. Meanwhile, BLW is signal generated due to respiratory activity. BLW is always below 1Hz [5] while the frequency range of ECG is within 0.05 to 100Hz [4] [6] [8]. The importance of removing these unwanted signal from ECG cannot be over emphasized. This has motivated some researchers into proposing different ways of removing these artifacts from ECG with the view of presenting the clinical personnel with artifact free ECG signals. Mbachu and Kennedy [4] proposed the use of finite impulse response (FIR) filter modeled with the triangular window to attenuate 50Hz PLI from ECG. More so, Kumar et al in [7] worked on ECG noise removal. The researchers used some windows namely rectangular, hann, blackman and hamming windows as well as the kaiser window in designing various digital filters. The digital filters were such that a low pass filter was made to remove EMG from ECG. Then a high pass FIR filter made and used to remove BLW while the third filter, a band stop filter removed 50Hz PLI from the same ECG. Mmeremikwu et al [8] used nuttall windowed FIR filter to filter out 1mV 50Hz PLI from ECG. In this work, a digital FIR filter is proposed for the removal of 50Hz PLI from ECG. A digital FIR filters modeled with parzen window is used to implement a band stop filter to remove 50Hz PLI from a single segment ECG signal.

II. Parzen Window Development

This work showcases the modeling of FIR window-based filter using parzen window and applying the digital filter on 50Hz PLI corrupted ECG to reduce the noise from ECG signal. Designing FIR filters starts with a windowing process. Windowing in FIR filters design, generally implies limiting the infinite sequence of desired unit sample response $h_d(n)$ of the filter with the definite boundaries of a window. This is done by multiplying the desired unit sample response $h_d(n)$ with the mathematical expression of the chosen window as shown in (1). In this design, the mathematical expression used W_n is that of the parzen window. It is shown in (2) [9] [10].

$$h(n) = h_d(n) * W_n \qquad (1)$$

V. O. Mmeremikwu, Department of Electrical and Electronic Engineering, Chukwuemeka Odumegwu Ojukwu University, Uli, Anambra State, Nigeria.

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

Where n is the number of filter tap and N is the filter order.

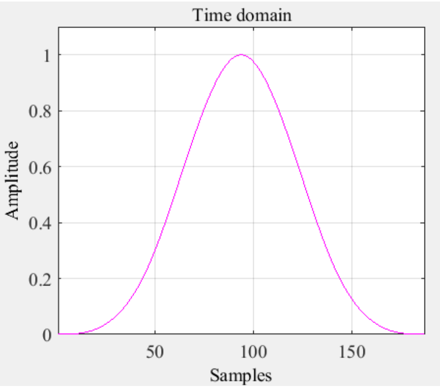

Fig 1: Time domain plot of Parzen window for filter order 187 units.

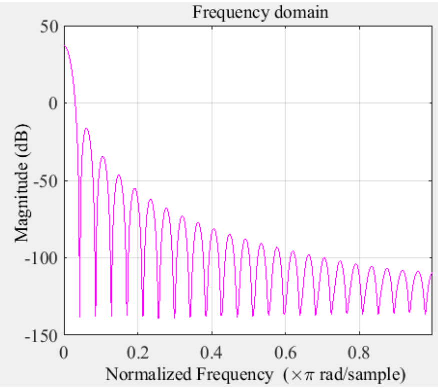

Fig 2: Frequency domain plot of Parzen window for filter order 187 units.

Parzen window is graphically represented in time domain and in frequency domain as shown in fig 1 and fig 2 respectively. In the diagram in fig 1 and fig 2, the window order used to generate the plots are of 187 units. The plots were generated with MATLAB Window Design and Analysis Tool initiated by typing the command 'wintool' in the MATLAB Command Window. The Parzen windowed FIR filter is modeled in MATLAB environment using MATLAB codes. Since the target noise to be removed from the ECG signal is 50Hz, a stop band filter frame is used to implement the digital filter. The following parameters constitute the filter specifications used in the design; filter order of 187, lower sideband cutoff frequency is equal to 40Hz and upper sideband cutoff frequency is equal to 60Hz.

More so, a single plot of 4.5mV ECG signal and a 0.1mV 50Hz PLI were also generated in the same environment. Both the ECG and the noise were mixed together to form a contaminated ECG. After the modeled FIR filter was applied on the corrupted ECG signal, a noise free ECG was produced. Fig 3, fig 4 and fig 5 show impulse, magnitude and phase responses of FIR Parzen window-based filter while fig 6 shows the block diagram the FIR filter. In fig 6, the ECG and PLI generators produce the ECG (e) and the 0.1V 50Hz PLI (n) respectively. The two signals were summed up to form the corrupted ECG (x). On the application of the FIR Parzen window-based filter, a filtered ECG is produced and a four segment display system displays the (e), (n), (x) and (y).

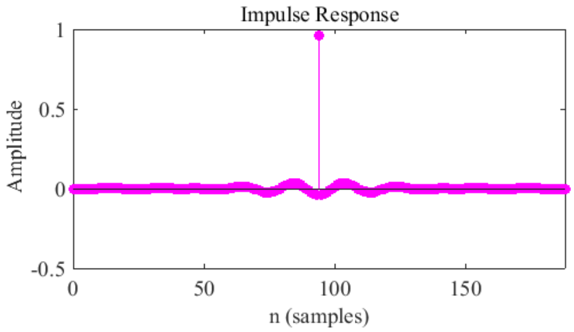

Fig 3: Impulse response of FIR Parzen window-based filter.

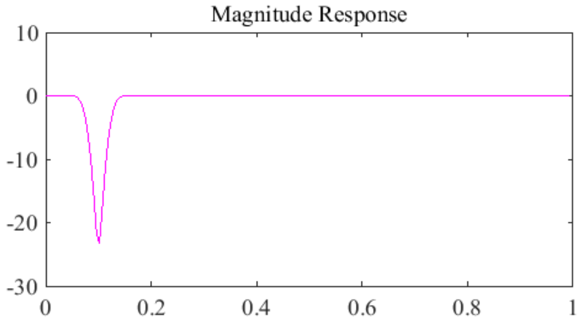

Fig 4: Magnitude response of FIR Parzen window-based filter.

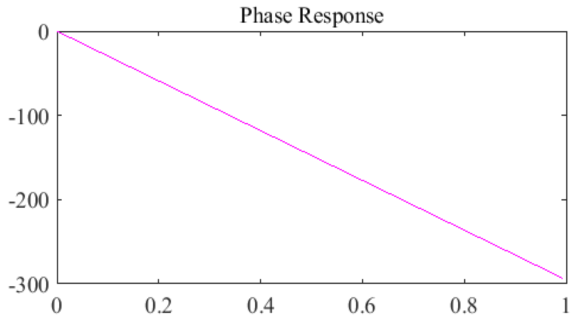

Fig 5: Phase response of FIR Parzen window-based filter

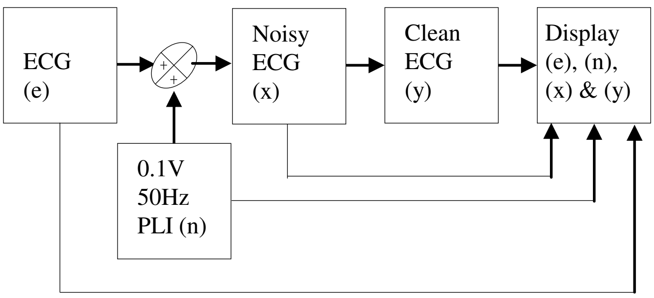

Fig 6 Block diagram of FIR Parzen window-based filter

III. RESULTS AND FINDINGS

Fig 7 shows a single plot signal of a 4.5mV ECG generated in a MATLAB R2015a environment. Fig 8 is a 0.1mV 50Hz PLI also generated with MATLAB. The ECG signal was made to be corrupted with PLI and the corrupted signal displayed in fig 9. When the Parzen window-based FIR filter was applied on the noisy signal, a filtered ECG signal, very much akin to the one in fig 7 was obtained in fig 10. This demonstrates that the Parzen window-based FIR filter is effective in 50Hz PLI reduction in ECG signal.

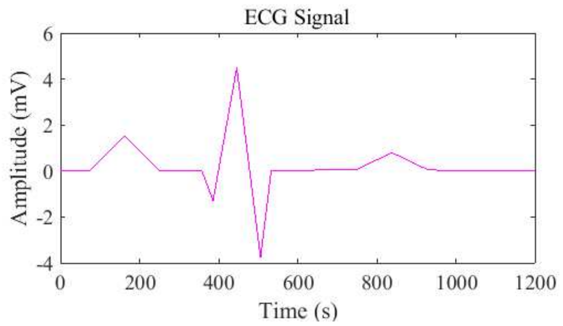

Fig 7: Graphics of Clean ECG

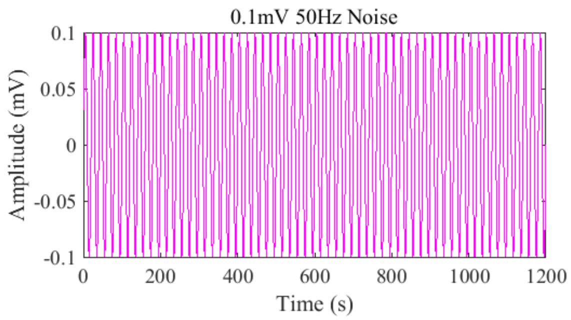

Fig 8: Graphics of 50Hz interference

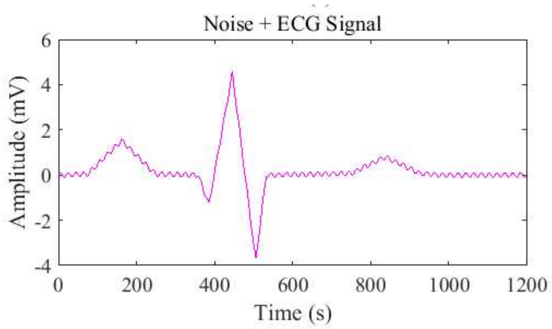

Fig 9: Graphics of contaminated ECG

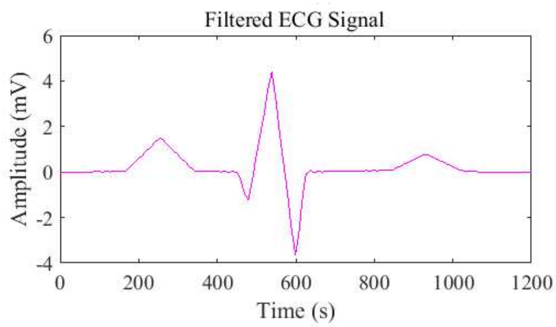

Fig 10: Graphics of filtered ECG

Further investigations on the filtering ability of the modeled digital filter were executed with MATLAB Filter Visualization Tool (fvtool) command where the magnitude responses the ECG, PLI and corrupted ECG signals were investigated as displayed in fig 11, fig 12 and fig 13 respectively. In fig 12, the magnitude responses (dB) of the PLI signal is displayed. A spike indicating the 50Hz interference is clearly shown at the normalized frequency of 0.1 π rad/sample with the value 35.38dB. Note that in fig 11 and fig 13, the magnitude responses of the ECG and contaminated ECG are equal to 11.15dB and 35.11dB respectively. But after the application of the Parzen window-based FIR filter, a filtered ECG whose magnitude response is shown in fig 14 was obtained. The magnitude response of the filtered ECG is approximately equal to 11.09dB showing that the spike has been removed. In other to determine the most effective filter order for the digital filter, the magnitude response of the filtered ECG obtained with various filter orders were compared with the magnitude response of the original ECG. These involved filter orders 179, 181, 183, 185, 187, 189 and 191. Their results show that the most effective filter order is 187. Table 1 below summarizes the results of magnitude response of the filtered ECG at those filter orders.

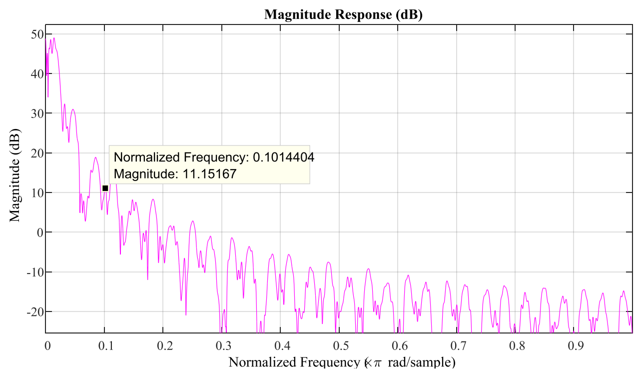

Fig 11: Magnitude responses (dB) of clean ECG signal

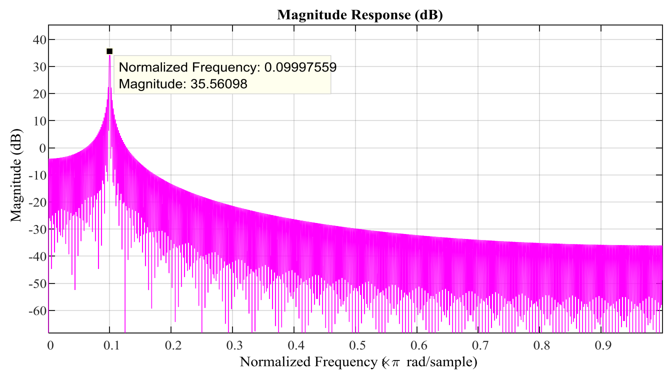

Fig 12: Magnitude responses (dB) of 50Hz PLI signal

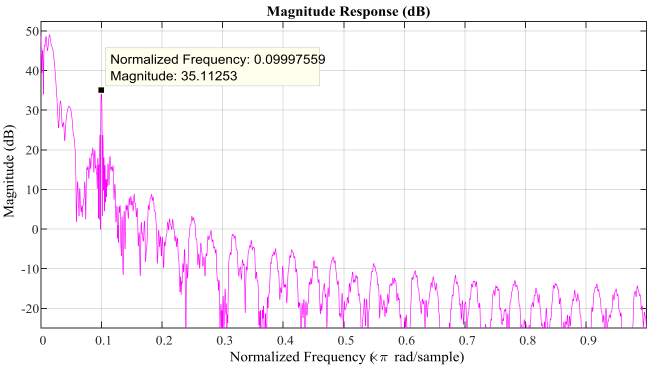

Fig 13: Magnitude responses (dB) of contaminated ECG signal

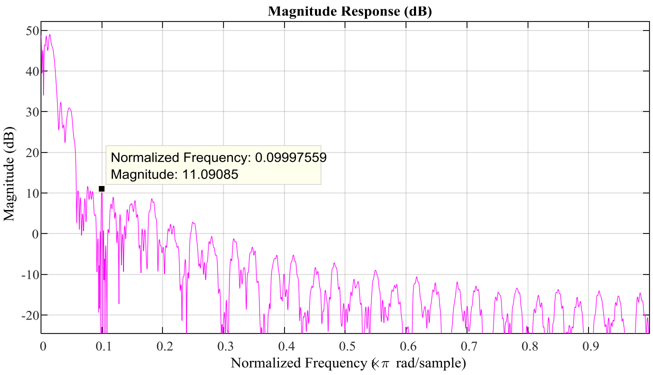

Fig 14: Magnitude responses (dB) of clean ECG signal

Table 1. Magnitude response for different filter orders

Filter order	Magnitude Response (dB)
179	12.08
181	12.28
183	11.63
185	11.41
187	11.09
189	10.67
191	10.01

IV. CONCLUSION

It has been demonstrated that Parzen windowed FIR filter is effective in removing 50Hz PLI from ECG signal. The digital filter modeled with filter order of 187 units successfully reduced the magnitude of the noisy signal from 35.11dB to 11.09dB as against 11.15dB of the original ECG. Parzen window has a linear phase response hence it is recommended for the modeling of window based FIR filters.

V. REFERENCES

[1] R. Vecht, M. A. Gatzoulis and N. S. Peters. "ECG Diagnosis in Clinical Practice". 2nd Edition, Springer-Verlag London ltd, 2009. pp 1-10.

[2] M. AlGhatrif and J. Lindsay, "A Brief Review: History to Understand Fundamentals of Electrocardiography". Journal of Community Hospital Internal Medicine Perspective. Vol 2, 2012. pp 1-5.

[3] E. M. M. Besterman. "The Beginnings and Development of the Electrocardiograph". West Indian Med J, 54(3), 2005. pp 213-215.

[4] C. B. Mbachu and K. Offor. "Evaluation of the Effectiveness of Triangular Window-Based FIR Digital Filter for Enhancement of ECG Signal". International Journal of Science, Environment and Technology, Vol. 2, Issue 6, 2013. pp 1327-1334.

[5] C. B. Mbachu, V. Idigo, E. Ifeagwu. and I. I. Nsionu. "Filtration of Artifacts in ECG Signal Using Rectangular Window-Based Digital Filters" International Journal of Computer Science Issues, Vol. 8, Issue 5, 2011. pp 279-285.

[6] V. O. Mmeremikwu, C. B. Mbachu and J. P. Iloh, "Improving ECG Signal using Nuttall Window-Based FIR Filter" International Journal of Precious Engineering Research and Applications (IJPERA), Volume 2 Issue 5, 2017. pp 17-22.

[7] K. S. Kumar, B. Yazdanpanah and G. S. N. Raju. "Performance Comparison of Windowing Techniques for ECG Signal Enhancement" International Journal of Engineering Research, Vol. 3, Issue 3, 2014. pp 753-756.

[8] S. K. Jaytap amd M. D. Uplane. "A Real Time Approach: ECG Noise Reduction in Chebyshev Type II Digital Filter". International Journal of Computer Applications, Vol. 49, No 9, 2012. pp 52-59.

[9] J. H. Fredric. "On the Use of Windows for Harmonic Analysis with the Discrete Fourier Transform" *IEEE. 66 (1),* 1978. pp 51-83.

[10] V. O. Mmeremikwu, and C. B. Mbachu. "EEG Signal Enhancement – FIR Parzen Window Filter Method". American Journal of Engineering Research (AJER), Vol. 7, No. 6, 2018. pp 51-55.