ECG SIGNAL PROCESSING WITH FIR DIGITAL FILTER BY WINDOW TECHNIQUES

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ABSTRACT

ECG plays a significant role in diagnosing most of the cardiac diagrams. So, it is desirable to filter the noisy ECG signal, particularly in the case of recording signals as weak as the ECG. This paper deals with some of the window techniques used to design FIR filter, different parameters like signal to noise ratio and power spectral density are calculated and compared for different window techniques. The results are observed and recorded using mat lab software and MIT-BIH arrhythmia data base.

Keywords: *Electrocardiogram, Window techniques, Input ECG Data Signal 228txt (MIII & VI Lead), FIR digital filter, Average Power, Welch Power Spectrum Density and Signal to Noise Ratio (SNR).*

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1. INTRODUCTION

One of the ways to diagnose heart diseases is to use electrocardiogram (ECG) signals. The function of the heart is to contract rhythmically and pump blood to the lungs for oxygenation and then pump this oxygenated blood into the general circulation. This perfect rhythm is continuously maintained and signaled by the spread of electrical signals generated by the heart pacemaker, the Sinoatrial (SA) node. Detecting such electrical activity of the heart can help identify many heart disorders. This is the main concept behind using an Electrocardiogram, tracing the electrical activity of the heart. ECG signals are formed of *P* wave, QRS complex, and *T* wave. The changes in these parameters indicate an illness of the heart that may occur by any reason. The P wave reflects the activation of the right and left atria. The QRS complex shows depolarization of the right and left ventricles. The T wave, that is after QRS complex reflects ventricular activation [4]. The repolarization of atria is not recorded on the reading of ECG, Waveform of ECG signal shown in Fig.1. ECG signal is one of the most important vital signs monitored from cardiac patients. The ECG signal corrupted due to different types of artifacts and interferences such as Power line interference, Electrode contact noise, Muscle contraction, Base line drift, Instrumentation noise generated by electronic devices and Electrosurgical noise. For the meaningful and accurate detection, steps have to be taken to filter out or discard all these noise sources. The work on design and implementation of Digital filter on the ECG signal is in progress in the different part of the world. Different researchers have worked on the reduction of noise in the ECG signal. Baseline wanders and power line interference reduction is the first step in all electrocardiography signal processing. Mahesh Chavan, R.A. Agrawal, paper deals with design and development of digital FIR equiripple filter. Complete design is performed with FDA tool in the mat lab. For accessing real time ECG the Advantech add-on card has been used [3]. Ferdjallah M., Barr R.E. has given Frequency-domain digital filtering techniques for the removal of power line noise [8]. Choy TT, Leung P M. have used 50 Hz notch filters for the real time application on the ECG signal it is found that filter was capable of filtering noise by 40dB with bandwidth of 4Hz and causes the attenuation in the QRS complex[14]

In Pan et al. proposed method Empirical Mode Decomposition was used for accurate removal of the baseline wander in ECG. The meaning of Base Line Drift noise is continuous drifting of ECG signal from base line. A suitable digital filter can be used to suppress the high-frequency embedded noise. The equiripple FIR low-pass filter by superimposing of the optimal method, the Butterworth IIR low-pass filter, the 8-point moving-average filter, and the FIR filter designed by using a Kaiser window [7]. The
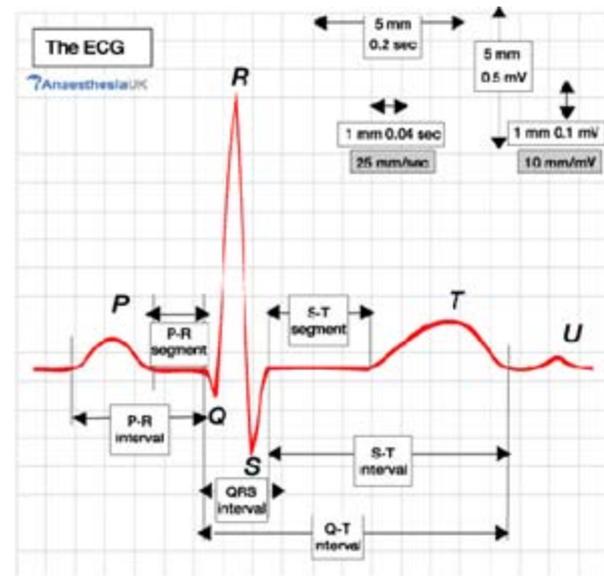

Figure 1. ECG Signal Waveform

drift of the base line with respiration can be represented by a sinusoidal component at the frequency of respiration added to the ECG signal. The amplitude and the frequency of the sinusoidal component should be variables [12]. Some researchers have used analog filters for removal of the power line interference. S.Pooranchandra, N.kumarave[15], have used the wavelet coefficient threshold based hyper shrinkage function to remove power line frequency. Santpal Singh Dhillon and Saswat Chakrabarti[16], have used a simplified lattice based adaptive IIR Notch filter to remove power line interference. Hejjel L, used the analog digital notch filter for the reduction of the power line interference in the ECG signal for the heart rate variability analysis. The investigation addressed the analysis of the effects of AC interference and its filtering on the precision and accuracy of heart rate detection. This paper is concerned with finite impulse response filtering with noisy input and output measurements. A new least-squares (LS) based algorithm is proposed to estimate the FIR filter coefficients [13]. K.D. Chinchkhede, present the implementation of FIR filter with various window techniques [1], with reference of this paper we analysis of other window impulse function by using FDA tool and filter noisy ECG data signal.

2. DIGITAL FIR FILTER

A digital filter is a system that performs mathematical operations on a sampled, discrete time to reduce or enhance certain aspects of that signal. FIR filters are digital filters with finite impulse response. In particular to convert an "ideal" impulse response of infinite duration, such as a sin function to a finite impulse response filter design, that is called the window method. FIR filters are also known as non-recursive digital filter as they do not have the

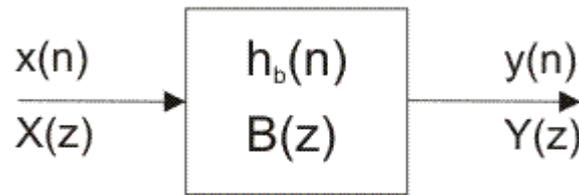feedback (a recursive part of a filter), even though recursive algorithms can be used for FIR filter realization.

Figure 2. FIR Filter

(a) Algorithm

$$b(n) = \omega(n) \cdot h(n), \qquad 1 \le n < N \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (1)$$

Where h(n) impulse response of the ideal filter and ω(n) denotes the window.

(b) Chebyshevs Window Function

The Chebyshev window minimizes the Chebyshev norm of the side lobes for a main- lobe width 2ω$_c$. The optimal Dolph-Chebyshev window transform can be written in close form as

$$w(\omega_k) = \frac{\cos\left\{m \cos^{-1}\left[\beta \cos\left(\frac{\pi k}{m}\right)\right]\right\}}{\cosh m \cosh^{-1}(\beta)} , \qquad k = 0,1,2,\cdots\cdots\cdots, m-1 \quad \cdots\cdots\cdots\cdots (2)$$

$$\beta = \cosh\left[\frac{\cosh^{-1}(10^\alpha)}{m}\right] , \qquad (\alpha \approx 2,3,4) \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (3)$$

The zero- phase Dolph – Chebyshev window, ω(n), is then computed as the inverse DFT of $w(\omega_k)$. The α parameter control the side lobe level via the given formula

$$side\ lobe\ level\ in\ db = -20\alpha \quad \cdots\cdots \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (4)$$

Thus, α = 2 gives side lobes which are 40db below the main lobe peak. Since the side lobes of the Chebyshev window transform are equal height, they are often called "ripple in the stop-band"(the window transform as a low pass filter frequency response).

(c) Nuttall window Function

$$\omega(n) = a_0 - a_1 \cos\left(\frac{2\pi n}{N-1}\right) + a_2 \cos\left(\frac{4\pi n}{N-1}\right) - a_3 \cos\left(\frac{6\pi n}{N-1}\right) \cdots\cdots\cdots (5)$$

Where N represents the width in samples of a discrete-time symmetrical window function and n is an integer with values $0 \le n \le N-1$.

(d) Tukey Window Function

$$\omega(n) = \begin{cases} \frac{1}{2}\left[1 + \cos\left(\pi\left(\frac{2n}{\alpha(N-1)} - \right)\right)\right] & when\ 0 \le n \le \frac{\alpha(N-1)}{2} \cdots\cdots\cdots (6) \\ 1 & when\ \frac{\alpha(N-1)}{2} \le n \le (N-1)\left(1 - \frac{\alpha}{2}\right) \\ \frac{1}{2}\left[1 + \cos\left(\pi\left(\frac{2n}{\alpha(N-1)} - \frac{2}{\alpha} + 1\right)\right)\right] & when(N-1)\left(1 - \frac{\alpha}{2}\right) \le n \le (N-1) \end{cases}$$

Where N represents the width in samples of a discrete-time symmetrical window function and n is an integer with values $0 \le n \le N-1$.

3. METHODOLOGY

In this paper reduce noise from ECG data signal. Input ECG Data signal 228txt(MIII & VI) collected from MIT-BIH. Data signal 228txt has the 3600 data samples. The first group is intended to serve as a representative sample of the variety of waveforms and artifact that an arrhythmia detector might encounter in routine clinical use. The band pass-filtered signals were digitized at 360 Hz per signal relative to real time using hardware constructed at the MIT Biomedical Engineering Center and at the BIH Biomedical Engineering Laboratory. The sampling frequency was chosen to facilitate implementations of 60 Hz (mains frequency) digital notch filters in arrhythmia detectors. Since the recorders were battery-powered, most of the 60 Hz noise present in the database arose during playback. Sampling frequency of the data signal is 360 and amplitude ±1 mv. Filter of noisy ECG signal set up in two step, in first step input data signal removing from the baseline drift after then 10 db awgn noise introduce in input data signal. In second step with the help of FDA tool in matlab software design FIR filter based on Chebyshevs, Nuttal and Tukey window techniques. Filter parameter order 452 and cutoff frequency is 60 Hz. Design filter of these window techniques apply on input noisy ECG data signal. Select parameters order 452 and cutoff frequency 60Hz in FDA tool. Impulse response of the filter using by FDA shown in fig.
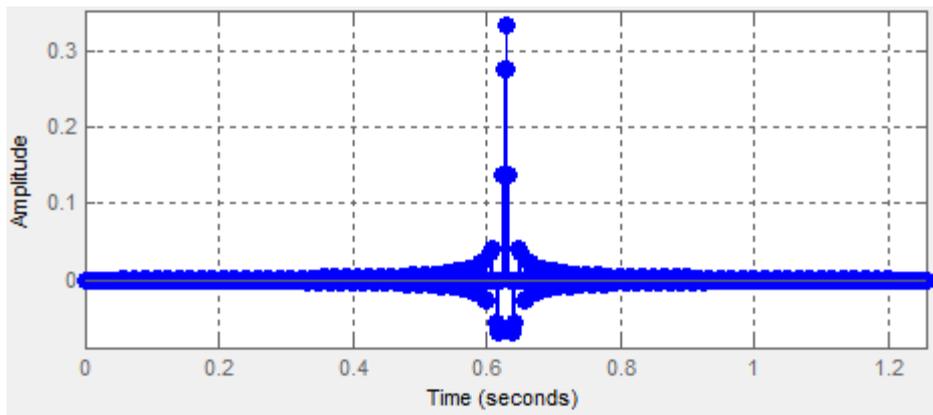
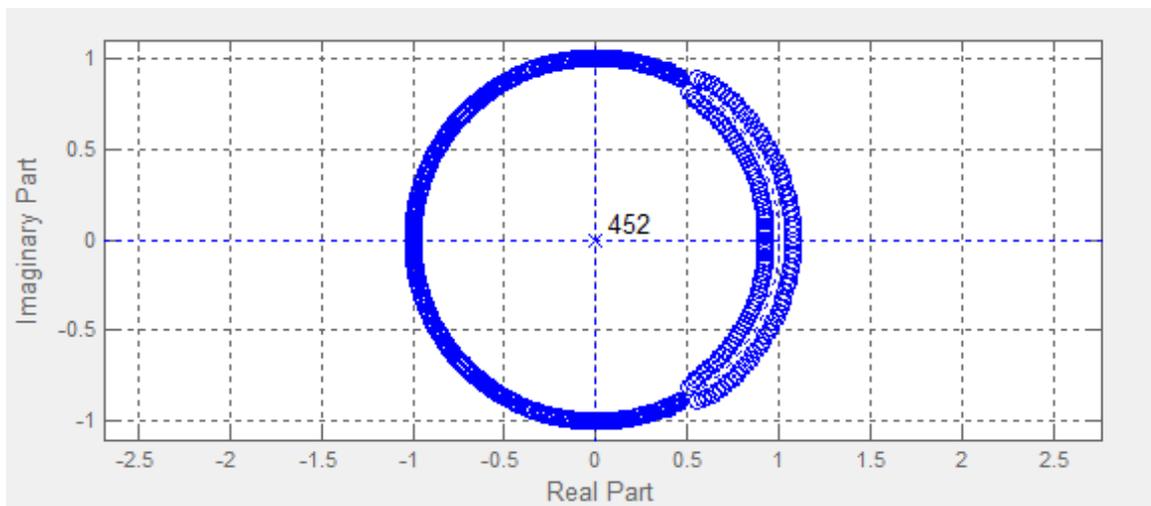Figure 3. Impuse Response of Chevyshevs Filter using FDA tool

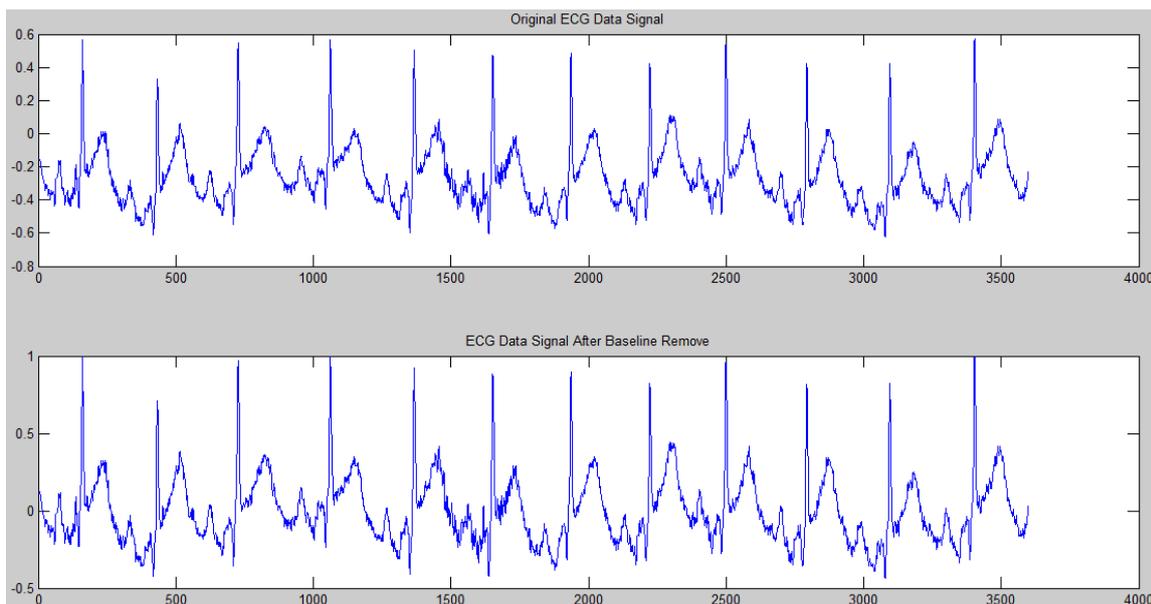Figure 4. Poles and Zero using Nuttal Window FIR Filter

Figure 5. Original Input ECG Data Signal and with baseline remove of 228txt MIII Lead
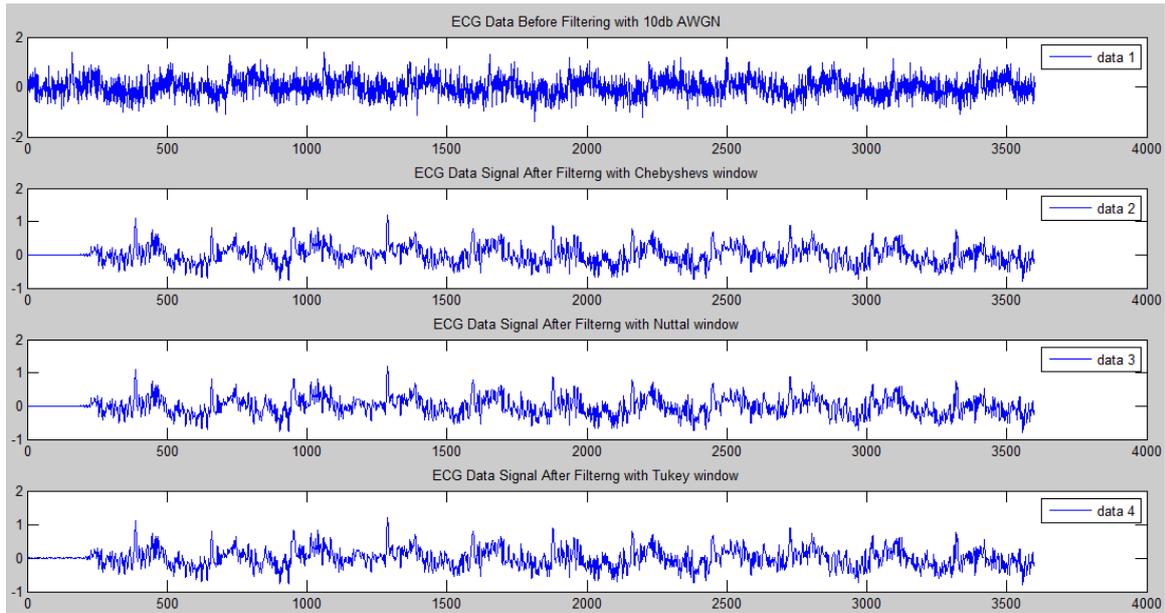
Figure 6. Noisy Data signal and Filtered ECG Data Signal using window techniques of MIII Lead Data

Original data signal with AWGN noise and the filter data signal spectrum analysis at 60 Hz frequency shown by the Welch power spectrum diagram in fig. 5. Signal to Noise power ratio after with various window shown in table 1. Signal to noise ratio of the filtered signal calculated by

$$ SNR = \frac{\mu}{\sigma} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (7) $$

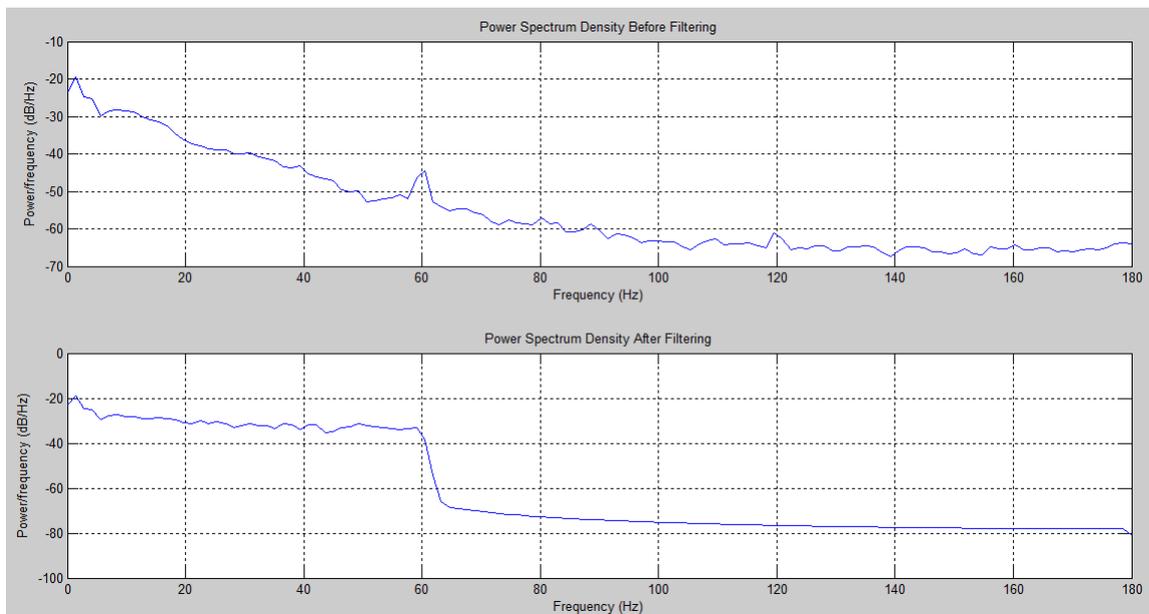Where µ is mean and σ standard deviation of noisy signal.

Figure 7. Welch Power Spectral Density of ECG Data Signal Before and After Filtering

Table 1. SNR for various windows of 228txt (MIII)

Before Filtering	After Filtering		
	Chebyshevs	Nuttal	Tukey
-21.5714	-15.3822	-15.3822	-15.3874

Table 2. Average Power for various windows

Before Filtering	After Filtering		
	Chebyshevs	Nuttal	Tukey
-13.1875	-11.1182	-11.1182	-11.1069

4. CONCLUSION

Figure 6. shows that noise has been reduced when ECG signal is filtered using FIR filter. Results have been concluded for these windows Chebyshevs, Nuttal and Tukey. Table1, shows the comparison of SNR for data 228txt(MIII Lead) and table2 show the comparasion of Average Power for data from the table are find that average power for Tukey window is more than the Chebyshevs and Nuttal window.

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