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High Frequency Noise Removal From Electrocardiogram Using Fir Low Pass Filter Bassed On Window Technique

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ABSTRACT
ECG Signal is widely used for detection and diagnosis of various heart related diseases. Feature extraction through ECG is a new application that is rapidly growing these days. While acquiring ECG signal, it gets contaminated to a number of sources with various type of artifacts such as baseline wander interference, motion artifacts, instrumentation noise, electrode contact noise, EMG noise etc. In this research work, different window technique to remove noise in corrupted ECG signal has been analyzed through this model. The windows used are Kaiser, Rectangular, Hanning, Hamming and Blackman Window. The output was analyzed and compared using SNR and MSE. This research work gives an optimal ECG noise removal windowing system that concludes which particular window should be applied for a better denoised signal and better SNR and MSE. Thus, this research concludes that Hamming Window followed by Rectangular Window gives better SNR. Kaiser Window followed by Hanning Window gives better MSE than others. Moreover, all the windows have been optimized for best sampling rate.

Keywords-FIR Filter, Signal to Noise Ratio(SNR), Mean Square Error(MSE), Electrocardiogram(ECG), Denoising

I. INTRODUCTION

Electrocardiogram is essential tool for giving information regarding the functionality of heart. Cardiac disorder occurs when there are deviations in normal electrical pattern of ECG signal. Therefore, it is very important to analyse electrocardiogram signals for detection of cardiac abnormalities. The magnitude and direction electrical activity produced by depolarization and re-polarization of atria and ventricles provide ECG signal graphic record. ECG waveform is characterized by five peaks and valleys labelled as P,Q,R,S and T.With modern machines, surface ECGs are quick and easy to obtain at the bedside and are based on relatively simple electrophysiological concepts. An ECG is simply a representation of the electrical activity of the heart muscles, cardiac muscles contract in response to electrical depolarization of the muscle cells. It is the sum of the electrical activity, when amplified and recorded for just a few seconds that we known as an ECG.

The normal cardiac cycles begins with spontaneous depolarization of the sinus node, an area of specialized tissue situated in the high right atrium(RA). A wave of electrical depolarization then spreads through the RA and across the inter-atrial septum into the left atrium(LA). The atria are separated from the ventricles by an electrical inert fibrous ring, so that in the normal heart the only route of transmission of electrical depolarization from atria to ventricles is through the atrioventricular node(AV). The AV nodes delays the electrical signal for a short time and then the wave of depolarization spreads down the interventricular septum (IVS), via. Hence with normal conduction the two ventricles contract simultaneously, which is important in maximizing cardiac efficiency.

After complete depolarization of the heart, the myocardium must then repolarise, before it can ready to depolarize again for the next cardiac cycle[1].

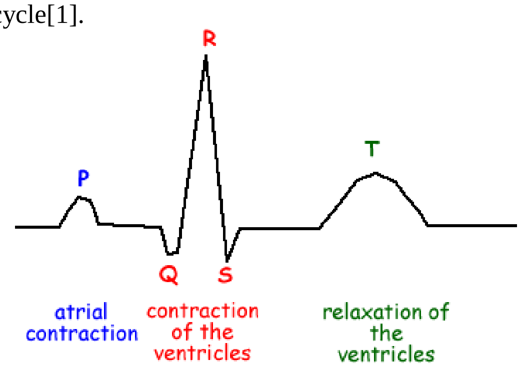

Figure1: Electrocardiogram Waveform[3]

ECG Signal are usually corrupted with undesired interference such ad electrode artifacts, muscle noise, power line interference, baseline wandering, etc. The frequency range of ECG signal 0.05-100 Hz and voltage level of 0.5-4mV. Hence, it is hard to distinguish the peaks of ECG signal and peaks of noisy signal induced by patients movement. The presence of undesired interference cause serious problem in the ECG diagnosis[2].

II. MATERIAL AND METHOD

The data set used in this study is obtained from Physiobank entitled MIT-BIH Arrhythmia Database available online. The recordings were digitized at 360 samples per second per channel with 11-bit resolution over a 10mv range. The MIT-BIH Arrhythmia Database were annotated ECG signals are described a text header file .(hea), a binary file .(dat) and a binnary annoated file .(atr). Header file consists of detailed information such as number of samples, sampling frequency, format of ECG signal, type and number of ECG leads, patient's history and the detialed clinical information. In binary data signal file, the signal is stored in 212 data format which means each sample requires number of lead times 12 bits to be stored and the binary annotation file consists of beat annotation about half (25 of 48 complete records, and reference annotation file for all 48 records) of this data base has been freely available[4].

The record 212 data is of a female age 32. There was a rate-related right bundle branch block which appears when the heart rate exceeds approximately 90 bpm.

Matlab is being used for ECG database extraction which is stored at www.physiobank.org. Stored ECG signal can be called in Simulink Model from workspace of Matlab. Real time noise signal is added with pure ECG in Simulink model. Different types of FIR digital filter are designed to remove high frequency noise i.e.
Sin(2*pi*frequency*t).

III. FIR FILTER:

A filter is an electrical network that alters the amplitude andor phase characteristics of a signal with respect to frequency. Ideally, a filter will not add new frequencies to the input signal, nor will it change the component frequencies of that signal, but it will change the relative amplitudes of the various frequency components and/or their phase relationships. Filters are often used in electronic systems to emphasize signals in certain frequency ranges and reject signals in other frequency ranges. Such a filter has a gain which is dependent on signal frequency.

There are two type of filters:
1. Analog Filters
2. Digital Filters

Digital Filters play an important role in digital signal processing applications. They are widely used in digital signal processing applications such as digital signal filtering, noise reduction, frequency analysis, image enhancement etc. A digital filter is a system which passes some desired signals more than other to reduce or enhance certain aspects of that signal. It can be used to pass the signals according to the specified frequency (pass-band) and reject the other frequency than the pass-band specifications.
The basic filter type can be divided into following categories:
1.Low-pass
2.High-pass
3.Band-pass
4.Band-stop

On the basis of impulse response, there are two fundamental types of digital filters:
1. Infinite Impulse Response(IIR) Filter
2. Finite Impulse Response(FIR) Filter[7]

FIR Filters is one of the digital filter. It stands for Finite Impulse Response Filter. It delays a copy of the input signal (by x number of samples), and combine the delayed input signal with the new input signal. It is a non-recursive signal. As it provides the feed forward path.The impulse response of an Nth-order discrete-time FIR filter lasts exactly N + 1 samples (from first nonzero element through last nonzero element) before it then settles to zero[6].
FIR Filters are frequently used in digital signal processing by virtue of stability and easy implementation[8].

FIR Filters are widely used due to powerful design algorithm that exists for them, their inherent stability. When implement in non-recursive form, the ease with which one can attain linear phase. The different technique for designing FIR filter are:
1. Window Method
2. Frequency Sampling Method
3. Weighted Least Square Method
4. Equiripple Method
5. Optimal Filter Design Method

Window Method:

In this method, we start with the desired frequency response specification $H_d(\omega)$ and the corresponding unit sample response $h_d(n)$ is determined by using inverse Fourier transform. The relation between $H_d(\omega)$ and $h_d(n)$ is as follows: $h(n) = h_d(n)w(n)$. Now, the multiplication of the window function $w(n)$ with $h_d(n)$ is equivalent to convolution of $H_d(\omega)$ with $W(\omega)$, where $W(\omega)$ is the frequency domain representation (Fourier Transform) of the window function[5].

Window Function:

Using appropriate window function which are time domain function, we can reduce the noise and precondition the impulse response. The following window functions are most commonly used are:

1. Kaiser Window
2. Hanning Window
3. Hamming Window
4. Blackman Window
5. Rectangular Window

The basic specification of the design filter are:

1. Cut-off frequency - 100Hz.
2. Sampling Frequency 360 Hz(MIT-BIH database sampled at 360 Hz)

The FIR filter design procedure with window function method can be classified to different stage:

I. Determine the window function according to the filter and defining the filter characteristics.
II. Specify the filter order and filter tap.
III. Now, specify cut-off frequency, sampling frequency.
IV. Compute the noise and filter equation to get the denoised ECG.
V. Find SNR and MSE.
VI. Also, find which window provide best from all the windows used.

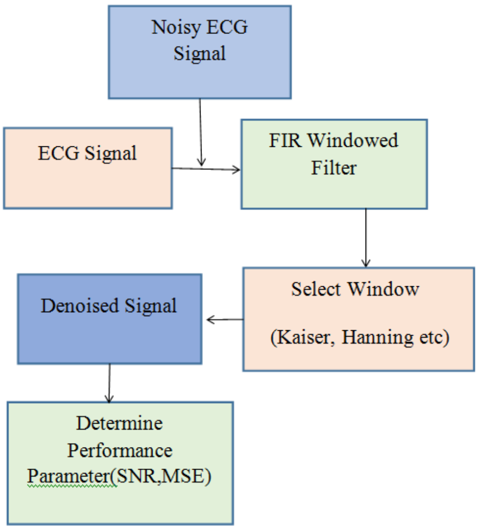

Figure 3.1 Block Diagram of Model Design

IV. RESULTS:

The experiment is simulated on the platform MATLAB 2015b.

1. First the original signal is taken from MIT-BIH database and then high frequency noise signal is added to it.

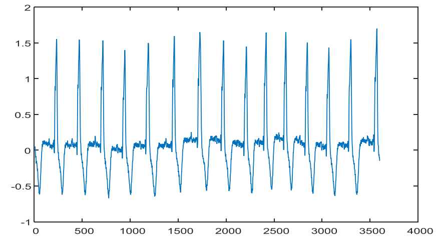

Figure 4.1 Raw ECG Signal

2. In this noise signal is a sin(2*pi*frequency*t)

Where frequency = 100 Hz, t defines the simulation length i.e. samples per second.

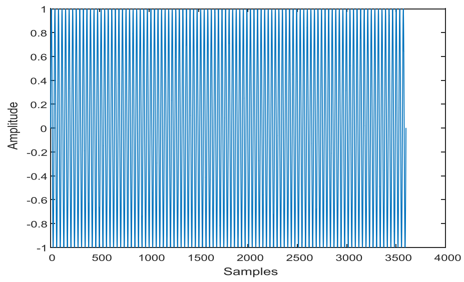

Figure 4.2 Noisy Signal

3. Mixed Signal = Raw ECG + Noise Signal

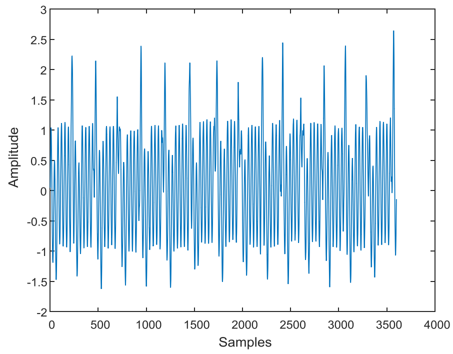

Figure 4.3 Mixed Signal

Kaiser Window:

1. The signal after denoising through Kaiser window having filter order=450 and filter tap = 451 is

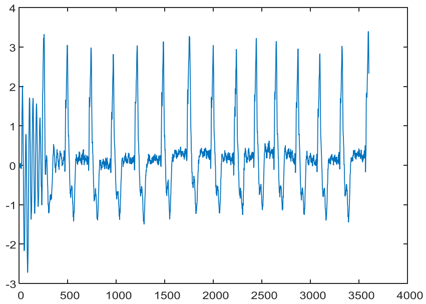

Figure 4.4 Kaiser Denoised Signal 1

Kaiser Window gives SNR= 6.4058 and MSE= 0.9288

2. The signal after denoising through Kaiser window having filter order=13 and filter tap = 14 is

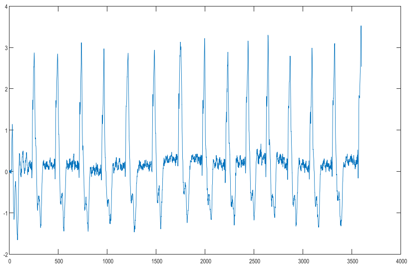

Figure 4.4 Kaiser Denoised Signal 2

Kaiser Window gives SNR= 6.0163 and MSE = 0.8501.

Blackman Window:

1. The signal after denoising through Blackman Window having filter order=1500 and filter tap = 1501 is

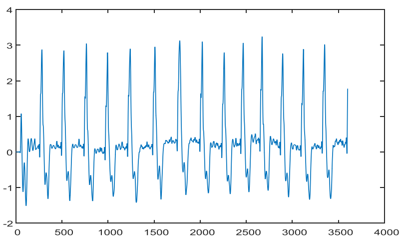

Figure 4.5 Blackman Denoised Signal 1

Blackman Window gives SNR= 5.2756 and MSE= 1.0750

2. The signal after denoising through Blackman window having filter order=19 and filter tap = 20 is

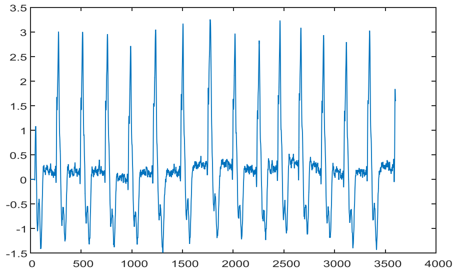

Figure 4.7 Blackman Denoised Signal 2

Blackman Window gives SNR = 5.7468 and MSE = 1.0738.

Hanning Window:

1. The signal after denoising through hanning window having filter order =1200.

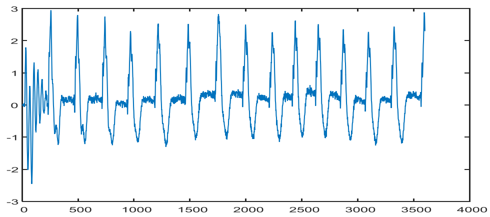

Figure 4.8 Hanning Denoised Signal 1

Hanning Window gives SNR = 5.7929 and MSE = 0.8862

2. The signal after denoising through hanning window having filter order =15 and filter tap = 16.

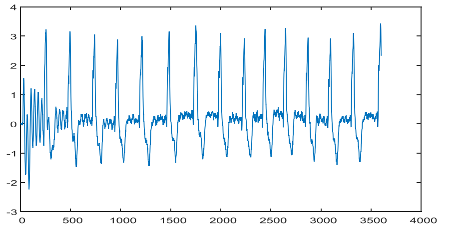

Figure 4.9 Hanning Denoised Signal 2

Hanning Window gives SNR = 6.2513 and MSE=0.8916.

Rectangular Window:

1. The signal after denoising through rectangular window having filter order = 450 and filter tap = 451.

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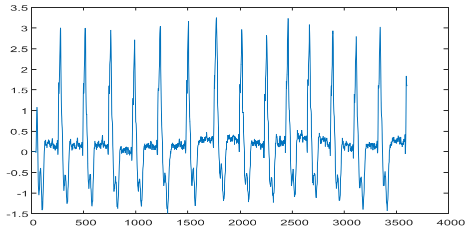

Figure 4.10 Rectangular Denoised Signal 1

Rectangular Window gives SNR = 7.5323 and MSE = 1.2232.

2. The signal after denoising through rectangular window having filter order = 17 and filter tap = 18.

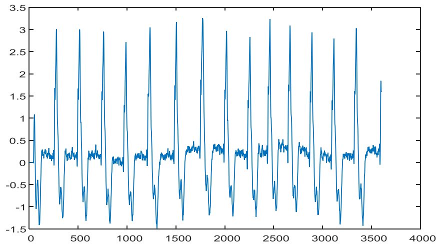

Figure 4.11 Rectangular Denoised Signal 2

Rectangular Window gives SNR = 7.8915 and MSE = 1.1797.

Hamming Window:
1. The signal after denoising through hamming window having filter order = 1200 and filter tap = 1201.

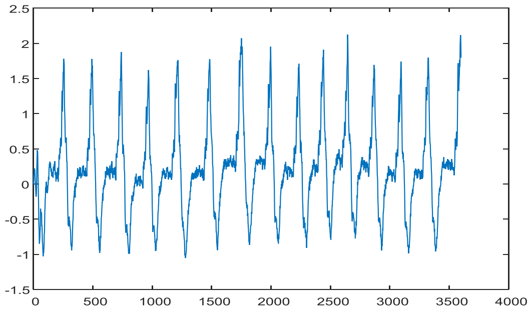

Figure 4.12 Rectangular Denoised Signal 1

Hamming Window gives SNR = 7.8635 and MSE = 1.2610.

2. The signal after denoising through hamming window having filter order = 15 and filter tap = 16.

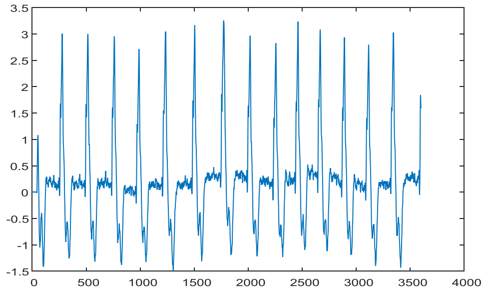

Figure 4.13 Rectangular Denoised Signal 2
Hamming Window gives SNR = 7.8962 and MSE = 1.1723.

Table No.5.1 Details With Higher Filter Order

Window	Order	SNR	MSE
Kaiser	450	6.4058	0.9288
Blackman	1500	5.2756	1.0750
Hanning	1200	5.7929	0.8862
Rectangular	450	7.5323	1.2232
Hamming	1200	7.8635	1.2610

Table No.5.2 Details With Lower Filter Order

Window	Order	SNR	MSE
Kaiser	13	6.0163	0.8501
Blackman	19	5.7468	1.0738
Hanning	15	6.2513	0.8916
Rectangular	17	7.8915	1.1797
Hamming	15	7.8962	1.1723

V. CONCLUSION

As the noise removal from ECG is compulsory task to find the heart rate and for the cardiac diagnosis, here it is done by an experimental study on noise removal by the implementation of FIR filter using different window techniques. The results evaluated by waveform, Signal to Noise Ratio (SNR) and Mean Square Error (MSE) for various FIR filters.
It is found that Hamming Window provides better results with higher filter order by giving improved SNR but Hanning Window provides better result

for MSE followed by Kaiser Window with higher filter order.
It is also found that Hamming Window and Rectangular Window provides better results for SNR with lower filter order but Kaiser Window followed by Hanning Window provides better MSE than other windows with lower filter order.
The presented model gives better quantitative and qualitative in terms of better SNR as compared to technique used in.

Future Scope

The work can be further extended as under:

1. The proposed model with FIR window technique can be applied to other real world signals for denoising EEG signals, muscle noise etc.

2. The proposed can be applied for 2d and 3d i.e. image and video signals.

3. The study can be modified for improving MSE with changing the technique or using some other method

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