

Nyquist Filter Design to Remove Power Line Interference From Bio-Electric Signals

Aarti J. Patel^{#1}, Prof. Vandana Patel^{#2}

[#]Instrumentation and Control Department, L.D. College of Engineering
Ahmedabad Gujarat India 380015

Abstract—Once analog ECG signal is converted into digital format; a suitable digital filter can be used to remove the embedded noise. In this paper detail study of related work has been discussed. Here the focus is on the use of finite impulse response filter to remove noise from bio-electric signals without introducing the phase distortion. In this paper the proposed filter is nyquist filter designed using Kaiser Window method and Equiripple algorithm to remove 50Hz power line noise from ECG. Simulation results are also shown.

Keywords—ECG signals, Noise reduction, Filter, MATLAB

I. INTRODUCTION

The electrocardiographic (ECG) signal is the electrical representation of the hearts activity. Computerized ECG analysis is widely used as a reliable technique for the diagnosis of cardiovascular diseases, and the ECG signal is most commonly used biomedical signal in clinical practice. This ECG signal is Commonly encountered artifacts include baseline wander, power-line interference, physiological signals generated by other organ of the body or included by muscular contractions related to breathing, and high frequency random noise. Baseline wander and power-line interference reduction is the first step in all electrocardiographic (ECG) signal processing. The baseline wander is caused by varying electrode-skin impedance, patient's movement and breath. This kind of disturbances is especially present in exercise electrocardiography, as well as during ambulatory and Holter monitoring. The ECG signal is also degraded by additive 50 Hz or 60 Hz power line (AC) interference. This kind of disturbance can be modelled by sinusoid with respective frequency and random phase. These two artifacts are the dominant artifacts and strongly affect the ST segment, degrade the signal quality, frequency resolution, produces large amplitude signals in ECG that can resemble PORST waveforms and masks tiny features that are important for clinical monitoring and diagnosis. Hence the extraction of high-resolution ECG signals from recordings which are contaminated with background noise is an important issue to investigate. The goal of ECG signal enhancement is to separate the valid signal components from the undesired artifacts, so as to present an ECG that facilitates easy and accurate interpretation [1]. Here we have focused on removal of 50 Hz power line interference.

The typical DSP methods include z-transform, Fourier transform, convolution, correlation, and filtering, etc. The

advantages of DSP methods are that they are programmable, reliable, high precision and maintainable, as well as easy to design and obtain a linear phase from which can ascertain that the filters won't distort the original signal [2], [3].

Many methods were proposed in the past for the removal of power line interference in the ECG [1]-[8]. They can be categorized into two: non-adaptive and adaptive filtering. The non-adaptive filtering approach employs a sharp notch filter either in analog or digital form and has advantages of easy implementation and low cost. However its performance depends on the stability of the frequency of power line. Adaptive filtering on the other hand is able to remove the time-varying power line signal effectively. But it requires considerable computational power which is not suitable for the portable ECG devices. One of the ways to lower the power consumption is to utilize non-adaptive filters [4], [5].

II. THE RELATED FIR FILTER MATHEMATICAL FORMULA

An FIR digital filter is a system with input $x(n)$ and output $y(n)$. The output $y(n)$ at any discrete value n depends on the present and past values of $x(n)$ and not on the current or past values of $y(n)$. This type of system is known as a non-recursive system.

FIR digital filters are known for their finite duration responses where the impulse response, $h(n)$, of an FIR filter is nonzero for $n = 0, \dots, N - 1$ where N is the number of samples in $h(n)$. Also, FIR filters (systems) are found to be always stable, and thus very popular. In addition to stability, FIR filters can have linear phase. A nonlinear phase system can distort the input signal to the system. A disadvantage to the FIR digital filter is the complexity of the implementation if N is very large. The larger the N is, the better the frequency response of the FIR filter[9].

The typical operation of an FIR digital filtering is defined as Eq. (1).

$$y(n) = \sum_{k=0}^N h(k)x(n-k), \quad (1)$$

Where, $h(k)$, $k = 0, 1, \dots, N$ are the coefficients of the filter, and are, respectively, the input and output of the filter. The transfer function is very useful in evaluating the frequency response of digital filter and is given in Eq. (2).

$$H(z) = \sum_{k=0}^N h(k)z^{-k}, \quad (2)$$

The relation between the frequency response and the transfer function of digital filters is given in Eq. (3).

$$H(e^{j\omega}) = H(z)|_{z=e^{j\omega}}, \quad (3)$$

In Eq. (1), Z^{-1} represents a delay of one sample time and N is the filter order [2][3].

Here we have designed the linear phase nyquist filter for cancellation of noise. To evaluate the performance of the filter we need to construct an ECG signal model simulation. Here we show how we construct the standard ECG signal model which we need to simulate the noise reduction. The standard 745-point ECG signal model is show in Fig. 1 [2], [3].

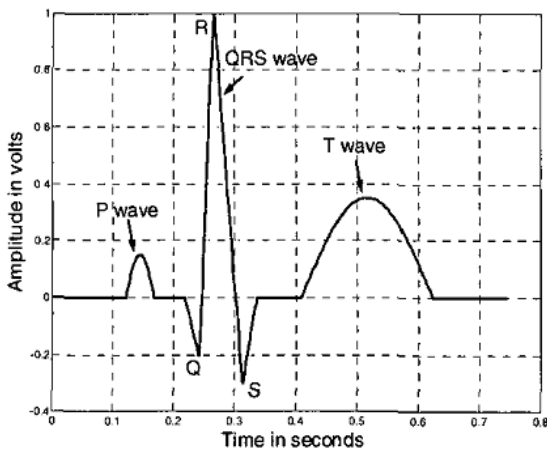


Fig.1 The standard 745-point ECG signal model

In general electrocardiograms of people won't be the same due to their different of bodies, emotions, and other external factors. Consequently, magnitudes, periods of P, R and T waves of ECG signals all vary with the different conditions. Therefore, we assume that the standard ECG signal model derives from a patient who has no electrocardiogram diseases and whose physical and psychological conditions are stable. Furthermore, the patient's electrocardiogram would show all the features which have been presented. Finally, we use the electrocardiogram reference to create the standard ECG signal, which including the following features:

1. The magnitude of the P wave never exceeds 2.5mV.
2. The PR interval is approximately between 0.12 and 0.2 Seconds.
3. The QRS wave lasts for 0.06-0.1 Seconds.
4. The QT interval is about 40% of the R wave to the next R wave when the body is not in the state of exercise.

5. The T wave's magnitude is usually 1/3-2/3 of the R wave's, and the T wave's interval is longer than that of the QRS's [2], [3].

We follow the above feature and construct the ECG signal using MATLAB®.

While we are designing the filter generally, we consider the filter order, transition bandwidth and some other related parameters. Here we have designed the nyquist filter using equiripple algorithm and also using window method that is Kaiser Window. The magnitude of nyquist filter using Kaiser Window method is presented in Fig. 2.

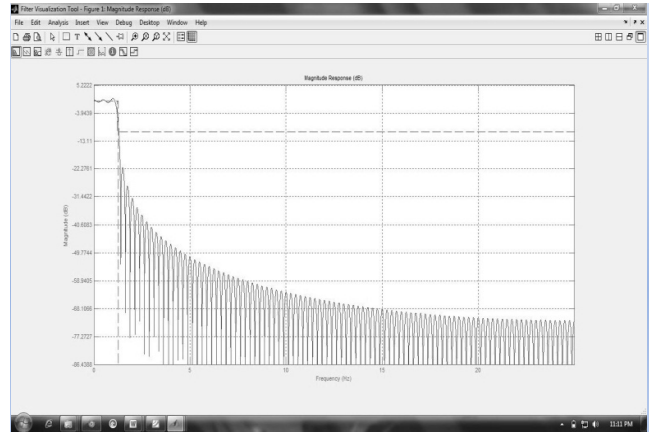


Fig. 2 Magnitude response of the Nyquist filter designed by Kaiser Window method

Where the filter order is minimum, the normalised transition width is $\Delta\omega=0.04\pi$, filter structure is Direct-Form FIR, sampling frequency is 50 Hz, stop band attenuation $A_{stop} = 10$ dB.

Magnitude response of Nyquist filter using the Equiripple algorithm is shown in Fig. 3.

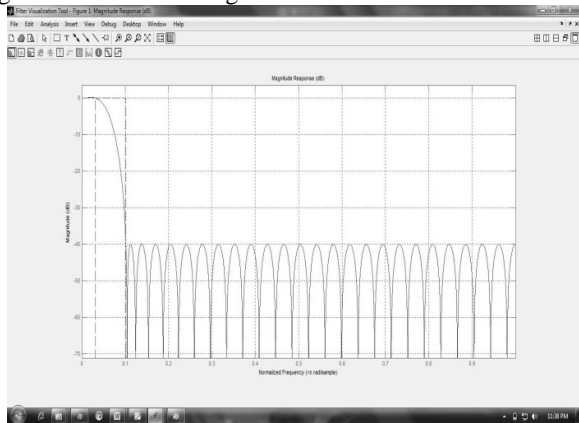


Fig. 3 Magnitude response of the nyquist filter designed by the Equiripple algorithm

Where the filter order is 52, transition width is $\Delta\omega=0.07\pi$, stop band attenuation is $A_{stop}=40\text{dB}$.

III. SIMULATION RESULTS

Simulation result using Kaiser Window method to remove 50Hz power line noise from ECG signal is shown in Fig. 4. And simulation result using Equiripple algorithm is shown in Fig. 5.

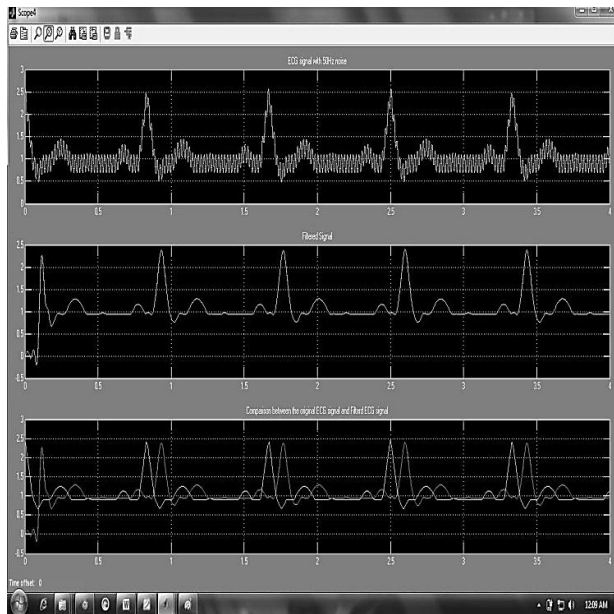


Fig. 4 The 50Hz noise filtered from ECG signal using nyquist filter designed by Kaiser Window (ECG signal with 50 Hz noise, filtered signal, comparison between the pure ECG signal and filtered signal)



Fig. 5 The 50Hz noise filtered from ECG signal using nyquist filter designed by Equiripple Algorithm (ECG signal with 50 Hz noise, filtered signal, comparison between the pure ECG signal and filtered signal)

IV. CONCLUSION

In this paper a linear phase nyquist filter is designed for suppression of 50 Hz power line interference from ECG signal. The nyquist filter is designed using Kaiser Window method and Equiripple algorithm. Simulation result shows that the power line interference has been removed effectively. It is observed from the simulation work that filtered signal obtained by nyquist filter using Equiripple algorithm is much better and faster than the Kaiser Window method.

ACKNOWLEDGMENT

This work has been supported by L.D. College of Engineering affiliated by Gujarat Technological University Ahmedabad India.

REFERENCES

- [1] D V Rama Koti Reddy, Mohammad Zia Ur Rahman, Y Saneetha, N SruthiSudha, "Base line wander and power line interference elimination from cardiac signals using a Novel LMS algorithm based on differential inputs and error," *Proceeding of the International Journal of Advanced Engineering & Application*, Jan 2011
- [2] Ying-Wen Bai, Wen-Yang Chu, Chien-Yu Chen, Yi-Ting Lee, Yi-Ching Tsai and Cheng-Hung Tsai, "Adjustable 60Hz Noise Reduction by a Notch Filter for ECG Signals," *Proceedings of the Instrumentation and Measurement 'technology Conference Como, Italy. 18-20 May 2004*
- [3] Ying-Wen Bai, Wen-Yang Chu, Chien-Yu Chen, Yi-Ting Lee, Yi - Ching Tsai and Cheng-Hung Tsai , "The Combination of Kaiser Window and Moving Average for the Low-Pass Filtering of the Remote ECG Signals," *Proceedings of the 17th IEEE Symposium on Computer-Based Medical Systems (CBMS'04)*, 2004.
- [4] Yong Lian and PohChoo Ho, "ECG noise reduction using multiplier-free FIR digital filters," *Proceedings of the ICSP'2004*
- [5] JacekPiskorowski, "Digital Notch Filter with Time-Varying Quality Factor for the Reduction of Power-line Interference," *978-1-4244-5309-2/10/\$26.00 ©2010 IEEE*.
- [6] Yong Lian and Jiang Hong Yu , "The reduction of noises in ECG signal using a frequency response masking based FIR filter," *Proceedings of the IEEE International Workshop on Biomedical Circuits & Systems, 2004*.
- [7] Valtino X. Afonso, Willis J. Tompkins, Truong Q. Nguyen, Steffen Trautmann, ShenLuo, "Filter bank-based processing of the stress ECG," *Proceedings of the IEEE-EMBC and CMBEC theme 4: Signal Processing, 1997*.
- [8] GuanghaoShen, ErpingLuo, Lihua Lu, QiaolingXu, Xiaoming Wu , "New method of designing digital notch filter of mains frequency," *Proceedings of the 978-1-4244-2902-8/09/\$25.00 ©2009 IEEE*.
- [9] Taan S. ElAli, "Discrete Systems and digital Signal processing with MATLAB"; *Printed in CRC Press, BOCA Raton London New York Washington, D.C. , pp 591*.