American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-7, Issue-10, pp-240-244
www.ajer.org
Research Paper Open Access

Removal of Baseline Wander from Ecg Signals Using Cosine Window Based Fir Digital Filter

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ABSTRACT: *Electrocardiography (ECG) describes the electrical activities of the heart and is very vital in the clinical monitoring and diagnosis of the health conditions of the human heart. During acquisition, the ECG signals by default get distorted by different artifacts such as Baseline Wander, Muscle Contractions, Equipment Artifact, Power line Interference etc., which must be removed otherwise, incorrect information will be conveyed. Hence, for correct extraction of the features of the ECG signal, it is paramount to separate the wanted signal from noises. To achieve this, different types of digital filters can be used. Here, a Modified Cosine Window based FIR digital filter is used for the removal of Baseline Wander in the ECG. Matlab tools were used in designing the filter, generation of the noisy ECG signal and filtering of the noise thus, obtaining the filtered ECG Signal.*

KEYWORDS: *Cosine window, Digital filter, ECG Signals, FIR filter, Power line interference.*

DATE OF SUBMISSION:08-10-2018 DATE OF ACCEPTANCE: 23-10-2018

I. INTRODUCTION

Electrocardiogram (ECG) signals are a measure of the electrical activity of the heart. These electrical signals are collected using the electrodes. The amplitude and the timing of the various waves in ECG viz, P, Q, R, S and T (See Fig 2) give the vital information about the heart's condition. A physician can detect a heart problem from this information and can suggest timely measures. But during the acquisition of ECG signal, it may get corrupted by different types of noises making it difficult for the physician to give his diagnosis (Tang, Zou, Tang, Liu and Zhang, 2007). Baseline wander which is a low-frequency component present in the ECG system, results due to movement of the electrodes i.e. voltages in the electrodes. It can also be due to respiration and body movement. Baseline Wander can cause problems to analysis, especially when examining the low-frequency ST segment (Abbas, 2011). The typical frequency range of baseline wander is usually between 0.1Hz and 0.3Hz. Therefore in making the choice of the filter cut-off frequency, it is essential to find the lowest frequency component of the ECG spectrum such that the baseline wander is removed. Hence high pass filter with cutoff frequency of 0.5Hz can serve the purpose of filtering (Hargittai, 2008).

Researchers are consistently working to see how to remove or suppress interferences related to ECG signals. Mahesh, Agarwala and Uplane, (2008) designed and implemented low pass filter, high pass filter and notch filter. The filter order and sampling frequency used were 50 and 1000Hz respectively. Application of the filters to a corrupted ECG signal indicated filtering effects on the ECG signal. However, the disadvantage of this type of filter is the presence of ripples in the pass band due to Gibbs' phenomenon. Manpreet and Birmohan, (2009) on the other hand, suggested a combination of Moving Average (MA) method and IIR notch filter for power line interference removal in ECG. This was done because of the IIR notch eigenvalue problem caused by using Remez multiple exchange algorithms. Hence the filter coefficients can easily be calculated by solving the eigenvalue problem, and then the complex Chebyshev approximation is attained through a few iterations starting with an initial guess. Renumadhavi, Madhava, Ananth and Nirupama, (2006) also proposed a new method of finding Signal to Noise Ratio (SNR) in ECG noise filtration of which the Noise Power is equal to the Mean Square difference between actual and expected signal. The essence of this approach is to evaluate the SNR of various filters when used to remove noise in ECG signals. The approach proved a success but the algorithm used is not so clear.

II. THEORY

Electrical System of the Heart

The ECG is a bioelectric signal, which records the electrical activity of heart versus time. Therefore, it is an important diagnostic tool for assessing heart function. The ECG is acquired by placing electrodes on the skin of the patient. The ECG signal provides the following information of a human heart as shown in Fig 1:

- Disturbances in heart rhythm and conduction
- Abnormalities in the spread of electrical impulse across the heart
- Information about a prior heart attack
- Sign of coronary artery disease
- Abnormal thickening of heart muscle
- Indication of decreased oxygen delivery to the heart
- Extent and location of myocardial ischemia
- Changes in electrolyte concentrations
- Effects of drugs on the heart

An electrical stimulus is generated by the sinus node (also called the sinoatrial node, or SA node), which is a small mass of specialized tissue located in the right atrium (right upper chamber) of the heart. The sinus node generates an electrical stimulus regularly (60-100 times per minute under normal conditions). This electrical stimulus travels down through the conduction pathways (similar to the way electricity flows through power lines from the power plant to your house) and causes the heart's lower chambers to contract and pump out blood. The right and left atria (the two upper chambers of the heart) are stimulated first and contract a short period of time before the right and left ventricles The electrical impulse travels from the sinus node to the atrio-ventricular node (also called AV node), where impulses are slowed down for a very short period, then continue down the conduction pathway to provide electrical stimulation to the right and left bundles.

Normally at rest, as the electrical impulse moves through the heart, the heart contracts about 60 to 140 times a minute, depending on a person's age. Each contraction of the ventricles represents one heartbeat. The atria contract a fraction of a second before the ventricles so that their blood empties into the ventricles before the ventricles contract Any dysfunction in the heart's electrical conduction system can make the heartbeat too fast, too slow, or at an uneven rate, thus, causing an arrhythmia.

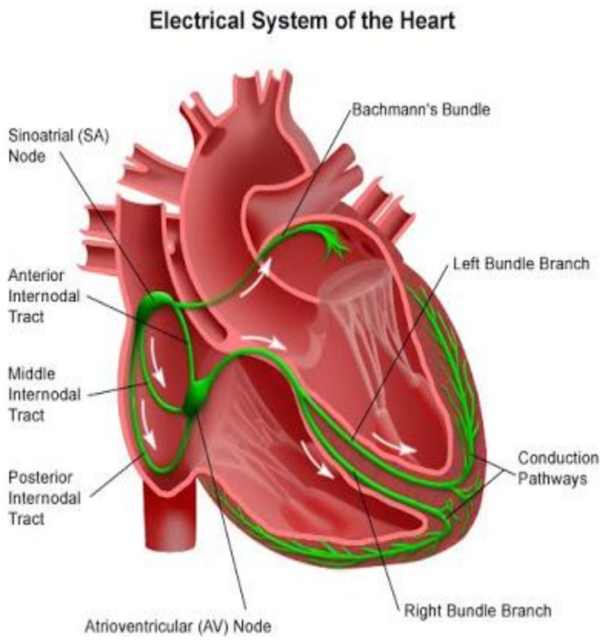

Fig 1: Conduction path of electrical potential for heart beat.

ECG waveform of a normal individual consists of the P wave, QRS complex, ST segment, T wave and U wave. The labels of Fig 2 are commonly used in medical ECG terminology.

P wave: The first wave in ECG is called the P wave which is generated due to electrical activity of atria. That is, the depolarization of atria results the P Wave in the ECG (Pandey, 2011).

QRS complex: The most important complex in the electrocardiogram is the QRS which shows electrical activities of ventricles.

T wave: The T wave represents re-polarization of ventricles.

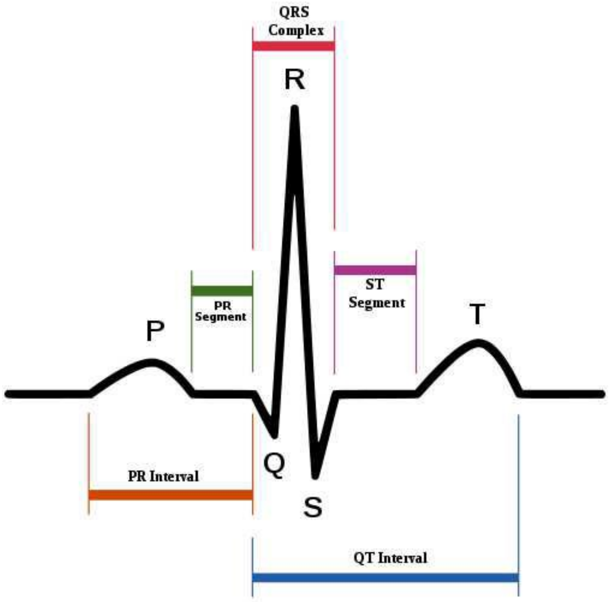

Fig2: ECG waveform

III. METHODOLOGY

Cosine Window Function

Cosine Window represents a cosine window function of x.At different occasions, windows are used in the design of digital filters, especially in the window design of finite impulse response (FIR) filters, with additional applications in spectral and spatial analysis. In filter design, windows are usually used to remove or reduce unwanted ripples in the frequency response of a filter. Windows can be grouped into Parameterized and Non parameterized Windows. Parameterized windows include Kaiser Window, Hann Window, Cauchy Window, Cosine Window, Gaussian Window, Poisson Window etc. On the other hand, Non parameterized Windows are such windows as Dirichlet Window, Hamming Window, Blackman Window, Bartlett Hann Window, Bartlett Window, Blackman Harris Window, Bohman Window, Kaiser Bessel Window etc.

The Cosine Window Function is given by the expression (Poularikas, 1999):

$$w(n) = cos^{\alpha}\left[\left(\frac{n}{N}\right)\Pi\right] \quad (1)$$

$$n = -\frac{N}{2}, \dots \dots - 1{,}0{,}1 \dots \frac{N}{2}$$

$$w(n) = sin^{\alpha}\left[\left(\frac{n}{N}\right)\Pi\right] \quad (2)$$

$$n = 0{,}1, \dots \dots N - 1$$

Common values of α: $1 \leq \alpha \leq 4$

Where N represents the width. Equation (2) is so because;

$$w(n) = sin^{\alpha}\left(\frac{\pi n}{N-1}\right) = cos^{\alpha}\left(\frac{\pi n}{N-1} - \frac{\pi}{2}\right) \quad (3)$$

The cosine without the $\frac{\Pi}{2}$ phase shift is the corresponding $w_0(n)$ function.

4. FIR Filtering

The digital filters are divided into two basic types, Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) filters, which are known as non- recursive and recursive filters. FIR filter was chosen since it is simple and stable. The choice between the filter type (recursive and non-recursive) is due to the computational property and the storage required for the implementation.

The simplest method of FIR filter design is called the window method. A window is an array $w[n]$ consisting of coefficients that meet proposed filter requirements. The design of the FIR filter using the window method requires specifying which window functions is used. All frequencies below the cutoff frequency f_c are passed

with unity amplitude while all higher frequencies are blocked. By taking the in-verse Fourier Transform of this ideal frequency response, the ideal filter kernel (impulse response) is obtained.
The FIR filters are stable and having linear phase characteristics. FIR filters are having a transfer function of a polynomial in z-plane and is an all-zero filter that means the zeros in the z-plane determine the frequency response magnitude characteristic.
FIR filters are particularly useful for applications where exact linear phase response is required. The FIR filter is generally implemented in a non-recursive way which guarantees a stable filter. FIR filter using different windows are preferred due to ease of design and simplicity of programming.

5. Baseline Wander Filtering Using Cosine Window Based FIR Filter

In this work the value of alpha (α) is0.02 and in defining further the filter specification, the sampling frequency (f_s) is taken to be 1000Hzand the cut off frequency(f_c) is 0.5Hz and the filter order is taken to be 100. The weighting window is the Cosine Window function with the expression presented in Equation (1).

IV. SIMULATION AND RESULTS

Simulation was done in Mat lab using considered parameters as presented in section 5. A raw noisy ECG signals which was contaminated with low frequency, 50Hz power line interference and random noise was used. The average power of ECG signals above 100Hz is -58dB. Fig 3 shows the Phase Response of the FIR filter.

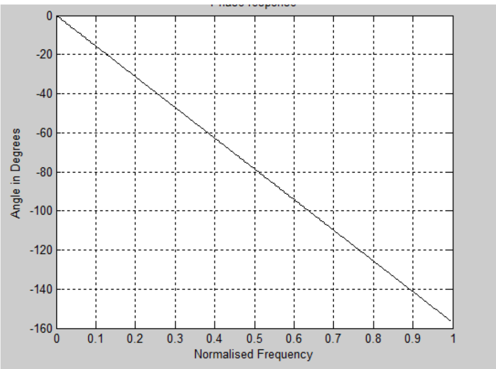

Fig 3: Phase Response of the FIR filter

The graph of Fig 3 by observation is absolutely linear, which is a characteristic of FIR filters. A filter with linear phase is desirable in order to avoid phase distortion that can alter various temporal relationships in the cardiac cycle.

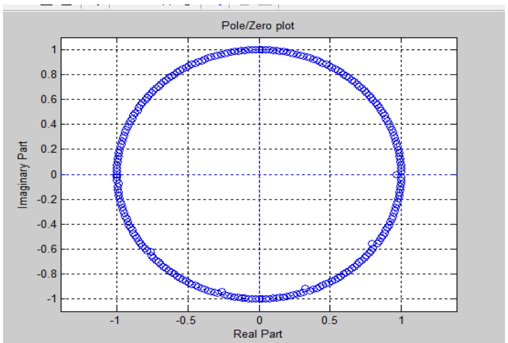

Fig 4: Pole-Zero Plot of the FIR Filter

The pole–zero plot in Fig 4shows the location in the complex plane of the poles and zeros of the transfer function of the filter. Depiction of the graph helps in conveying certain properties of the system such as stability. The graph of Figures 5 and 6 presents the Frequency Response of the system before and after filtration respectively.

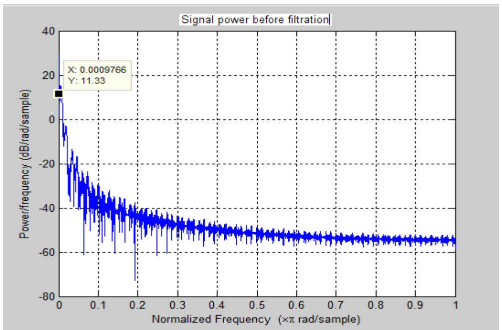

Fig 5: Frequency Response before filtration

From Fig 5, it could be seen that the signal power of the filter before filtration is -58dB while on the other hand, the signal power was -60dB from Fig 6.The implication of the reduction in the signal power is that the FIR filter was able to filter out the low frequency noise (Baseline Wander) from the ECG signal.

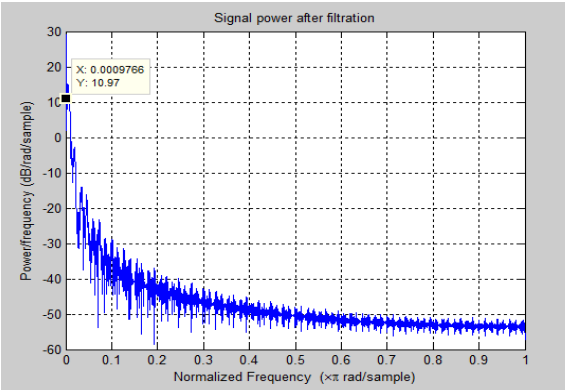

Fig 6: Frequency Response after filtration

The implication of the reduction in the power is that the filter was able to filter out the low frequency from the original ECG signal.

V. CONCLUSION

The developed FIR digital filter was stable in instantaneous impulse and magnitude responses. Result shows that the linearity in the Phase Response implies that the developed system can avoid phase distortion which can alter various temporal relationships in the cardiac cycle. Also, reduction in the signal power of the ECG is an affirmation that the developed FIR filter using the Cosine Window function was able to filter out the low frequency noise (Baseline Wander) from the ECG signal.

REFERENCES

[1]. Tang J., Zou Q., Tang Y., Liu B. and Zhang X.(2007).*"Hilbert-Huang Transform for ECG De-noising"* Bioinformatics and Biomedical Engineering, ICBBE, pp. 664 – 667.

[2]. Abbas H. (2011).*"Removing 0.5 Hz Baseline Wander From ECG Signal Using Multistage Adaptive Filter"* Eng. & Tech. Journal, Vol. 29, No.11.

[3]. Hargittai S, (2008). *"Efficient and Fast ECG Baseline Wander Reduction without Distortion of Important Clinical Information"* Computers in Cardiology; Vol. 35: pp. 841−844.

[4]. Mahesh S., Agarwala R. and Uplane M. (2008), Interference reduction in ECG using digital FIR filters based on rectangular window". *WSEAS transactions on signal processing, issue 5 Vol. 4, pages 340 – 349;.*

[5]. Manpreet K. and Birmohan S. (2009)."Powerline interference reduction in ECG using combination of M.A method and IIR notch". *International journal of recent trends in Engineering, Vol. 2, No. 6;.*

[6]. Renumadhavi C., Madhava S., Ananth A. and Nirupama S. (2006); "A new approach for evaluating SNR of ECG signal and its implementation".*Proceedings of the 6th international conference on simulation, modeling and optimization, Lisbon, Portugal, pp. 202 – 205.*

[7]. Poularikas A. D. (1999). "Windows The Handbook of Formulas and Tables for Signal Processing.Ed. Boca Raton: CRC Press LLC.

Okafor, P.U., " Removal of Baseline Wanderfrom Ecg Signals Using Cosine Window Based Fir Digital Filter "American Journal of Engineering Research (AJER), vol. 7, no. 10, 2018, pp. 240-244