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An Innovative Approach to the Reduction of Noise in ECG Signal through Chebyshev

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Abstract: *We know that biomedical signals carry important information about the behavior of living systems under study. Electrocardiogram i.e. ECG is used to measure the rate and regularities of heartbeat, as well as the size and position of the chambers, the presence of any damage to the heart. An ECG produces a pattern reflecting the electrical activity of the heart and usually requires a trained clinician to interpret it in the context of the signs and symptoms the patient present with. Enhancement of physiological and clinical information is achieved through proper processing of these signals. Power line interference (PLI), baseline drift, muscle contraction noises degrade the quality of biomedical signal. The main purpose of this paper is to overcome degradation of this ECG signal by using Chebyshev type 2 digital filters. This paper deals with the design of Chebyshev type 2 digital filter including lowpass, highpass and notch filter. Reducing noise from the biomedical signal is still a challenging task and rapidly expanding field with a wide range of applications in ECG noise reduction.*

Keywords: *Biomedical Signal, ECG, PLI, Digital Filter, Chebyshev type 2, Noise Reduction.*

1. INTRODUCTION

Electrocardiography is a transthoracic interpretation of the electrical activity of the heart over a period of time, as detected by electrodes attached to the surface of the skin and recorded by a device external to the body. The recording produced by this process is termed as Electrocardiography. Most ECGs are performed for diagnostic or research purposes on human hearts. To intensify the importance of biomedical signal processing, increasing efforts are devoted to reduction of noise in ECG signal. The ECG signal is typically in the range of 2mV and requires a recording bandwidth of 0.05 to 100 Hz. ECG tracing have very predictable amplitude, direction and duration, under normal condition. The schematic representation of a single cycle of ECG corresponding to one heart beat is shown in Fig. 1.

There are two main sources of noise generation in biomedical signal i.e. biological and environmental source. The first group includes muscle contraction or electromyographic (EMG) interface, baseline drift, ECG amplitude modulation due to respiration and motion artifacts caused by changes in electrode skin impedance with electrode motion.

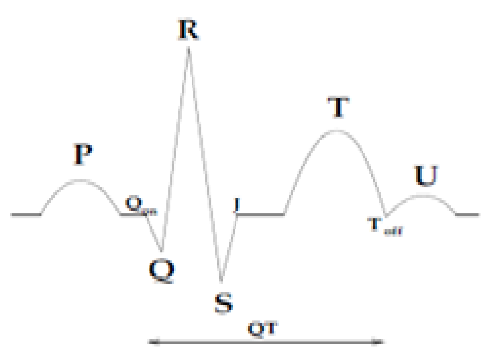

Figure 1: Schematic representation of a single cycle of ECG corresponding to one beat.

The second group includes power line interference, electrode contact noise, instrumentation noise generated by electronic devices used in signal processing, electrosurgical noise and radio frequency. Various types of interferences are shown in Fig. 2.

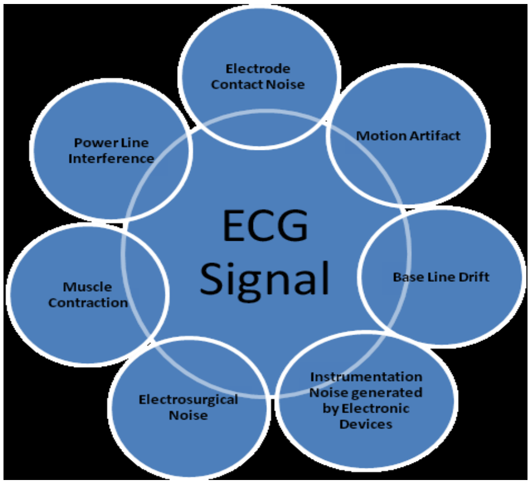

Figure 2: Interferences in the ECG signal.

For effectively reducing the noise in ECG analysis there have been several techniques in the literature. Ferdjallah M. and Barr R. E. introduced frequency domain digital.filtering techniques for removal of PLI [1]. Sornmo L. have applied time varying filtering techniques to the problem of baseline shift [2]. McManus C.D., Neubert K.D. and Cramer E. have compared digital filtering methods for elimination of AC noise in ECG [3]. Patrica Arand patented method and apparatus for removing baseline wander from an ECG signal [4]. Pei S.C., Tseng C.C proposed IIR notch filter with transient suppression in ECG [5]. Hamid Gholam, Hosseini, Homer Nazeran, Karen J. Reynolds elaborated on ECG noise cancellation using application of digital filter [6]., A nonlinear adaptive method of elimination of powerline interference in ECG signals was developed by Ziarani a. K. and Konard A. [7]. Mitov I.P. A method for reduction of power line interference in the ECG [8]. Yong Lian, Poh Choo Ho. Focued on multiplier free digital filter [9]. Lisette P. Harting, Nikolay M. Fedotov, Cornelis H. Slump were discussed on baseline drift suppression in ECG recording [10]. Dotsinky I., Stayanov T. discussed on power-line interference cancellation in ECG signals [11]. Jacek M. Leski, Norbert Hezel have proposed a combination of ECG baseline wander and PLI reduction using nonlinear filter band [12]. Lu G.et al. have suggested a fast convergence of recursive least square algorithm to enable the filter to track complex dystonic EMGs and to effectively remove ECG noise. The adaptive filter procedure proved a reliable and efficient tool to remove ECG artifact from surface EMGs with mixed and varied patterns of transient, short and long lasting dystonic contractions [13]. In this paper Chebyshev type 2 digital filter is designed through MATLAB and filtering of noise is done in ECG signal. Here we are using lowpass, highpass and notch filtrations techniques.

2. USE OF THE MOST OPTIMIZED METHODOLOGY

Chebyshev filters are named from their use of the Chebyshev polynomial developed by the Russian mathematician Pafnuti Chebyshev (1821-1894). These filters are used to separate one band of frequencies from others. Although they cannot match the performance of the windowed-sinc filter, they are more than adequate for many applications. The primary attribute of Chebyshev filters is their speed, typically more than an order of magnitude faster than the windowed-sinc. This is because they are carried out by recursion rather than convolution.

There are two types of Chebyshev filters as follows:

2.1 Chebyshev type I

2.2 Chebyshev type II.

2.1 Chebyshev type I filter

The Chebyshev low pass filter has a magnitude response given by

$$|H(jw)| = \frac{A}{\left[1+\epsilon^2 C_N^2 \frac{\Omega}{\Omega_C}\right]^{\frac{1}{2}}} \qquad (1)$$

where A is the filter gain, ε is a constant and Ω c is the 3 Db cut off frequency.

The magnitude response of the chebyshev filter is shown in fig. 3. It has equiripple pass band and maximally flat stop band. It is further seen that with increase in filter order, the Chebyshev response approximates the ideal response. The phase response of the Chebyshev filter is more non linear than the Butterworth filter for a given filter of length N.

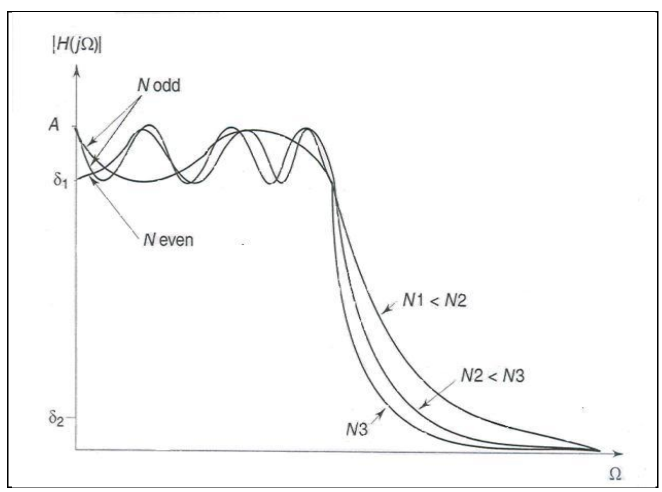

Figure 3: Magnitude response of a low pass Chebyshev Type I filter.

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2.2 Chebyshev type II filter

Inverse Chebyshev filtera are also called type II Chebyshev filters. The inverse Chebyshev low pass filter has a magnitude response given by

$$|H(j\omega)| = \frac{\epsilon C_N(\frac{\Omega 2}{\Omega c})}{\left[1+\epsilon^2 C_N^2 \frac{\Omega_2}{\Omega}\right]^{\frac{1}{2}}} \quad (2)$$

where ε is constant and Ωc is the 3 dB cutoff frequency. The magnitude response of the Chebyshev type II filter is shown in fig.4. It has maximally flat pass band and equiripple stop band, just the opposite of the Chebyshev type I filter response. That is why Chebyshev type II filters are called the inverse Chebyshev filter.

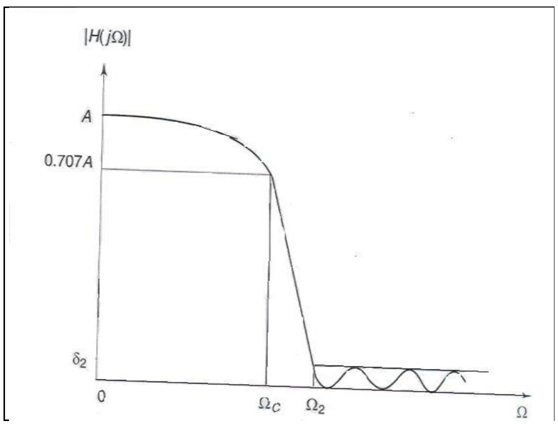

Figure 4: Magnitude response of a low pass Chebyshev Type II filter

3. PERFORMANCE ANALYSIS

In this paper performance analysis has been carried out with the help of Chebyshev Type II filter.

3.1 Chebyshev filter application

The first step in ECG signal analysis is recording the electrical activity of the heart. This can be done non-invasively with the help of electrodes mounted on the surface of the body. The filters designed here are with the help of MATLAB FDA Tool by specifying the filter order, cutoff frequency and sampling frequency. In the present scenario, the design consideration of low pass filter, high pass filter, notch filter are elaborated separately for removal of noise signal from ECG using Chebyshev type II filter. The proposed block diagram of Chebyshev type II filter is shown in fig.5.

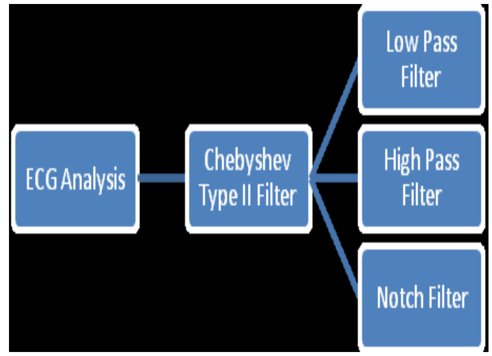

Figure 5: Proposed block diagram of Chebyshev filter

The ECG signal we are taking is shown below in fig 6.

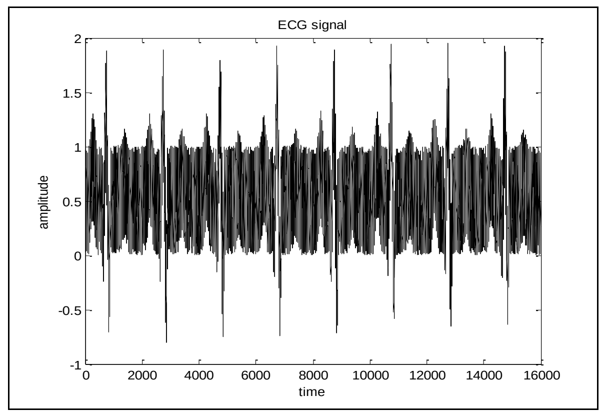

Figure 6: The ECG signals with noise.

3.1.1 Design of Chebyshev Type II Low Pass Filter: Removal of High Frequency Noise

The information is present in frequency range of 0.5Hz to 100 Hz is very useful. All the signals above 100 Hz is treated as noise. The section deals with design and implementation of the low pass filter were designed for sampling frequency 1000 Hz and filter order 5 for the removal of high frequency noise in ECG signal. The filtration is done after this and the response is shown in fig.7.

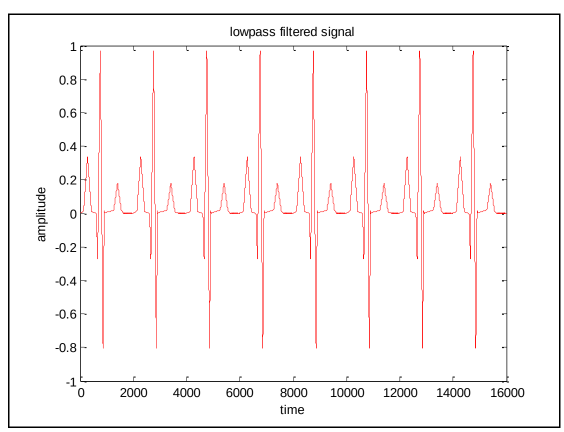

Figure 7: The low pass filtered ECG signal**.**

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3.1.2 Design of Chebyshev Type II High Pass Filter: Removal of Low Frequency Noise

In the present design of high pass filter, the order of the filter is considered is 3. Though the order of filter is less it gives satisfactory results. Baseline wander is minimized by design of high pass filter is focused in this section. Chebyshev Type II high pass filter was designed with filter order 3 and sampling frequency 1000 Hz. The filtration is done after this and the response is shown in fig.8.

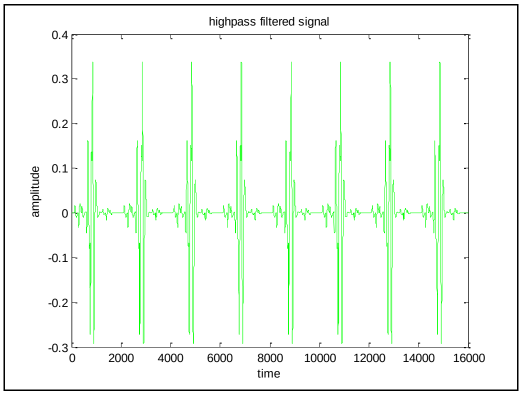

Figure 8: The high pass filtered ECG signal.

3.1.3 Design of Chebyshev Notch Filter: Removal of Power Line Interference

Notch filter is implemented to avoid the problem of PLI in the ECG signal. In the present section the Butterworth notch filter has been designed for order 4 and sampling frequency 1000 Hz and implemented on the ECG signal containing power line interference. The filtration is done after this and the response is shown in fig.9.

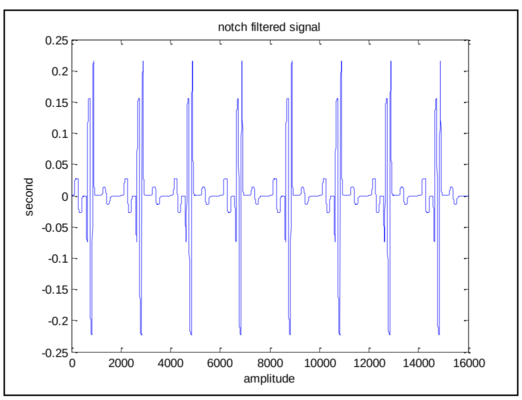

Figure 9: The notch filtered ECG signal.

4. RESULTS ANALYSIS & FUTURE SCOPE OF WORK

Cascading of Chebyshev Type II Filter

Finally the cascading of filters is done and after that filtration technique is applied to it. Individual performance as well as performance of cascade combination of filters has been compared. Fig. 10 shows result of cascading of Chebyshev Type II filter. It has been observed that this method of filtering focuses on maximum suppression of baseline wander with distortions in ST part of the segment.

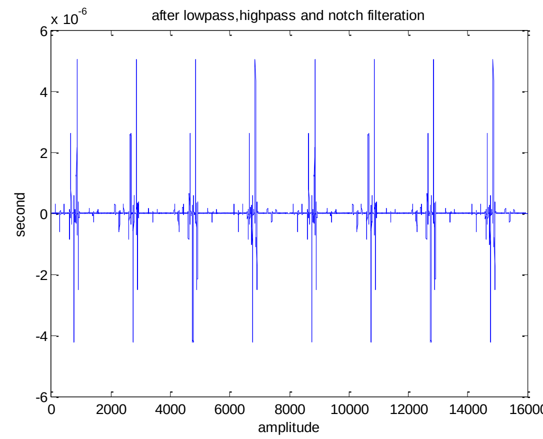

Figure 10: Frequency spectrum with minimum order after application of cascade combination of filters.

Yet a new path has been opened and only the future will be able to judge if this method can be successfully applied with the cascading of IIR and FIR filters for real time ECG systems. Finally, it is seen that an optimum combination can be implemented using FPGA technique.

5. CONCLUSION

Digital filter is the preeminent solution that caters the noise reduction up to satisfactory level. A digital Filter technique is best suited for ECG analysis and thereby helps in improving the quality of ECG signal with the help of Chebyshev Type II filter. From the results, it is seen that the filters reduces the low and high frequency components. The power line noise is also reduced. It is seen tip of the QRS complex is distorted. The outputs of the Chebyshev II filter shows that after using filter there is distortion in the ST part of the waveform. Both the filters work Satisfactory. Further this work can be applied on different types of filters and then depending on performance final model can be implemented to estimate the better quality signal.

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