FIR Equiripple Digital Filter for reduction of power line interference in the ECG Signal

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Abstract: - Present paper deals with design and development of digital FIR equiripple filter. The basic ECG has the frequency range from .5Hz to 100Hz. Artifacts plays the vital role in the processing of the ECG signal. It becomes difficult for the Specialist to diagnose the diseases if the artifacts are present in the ECG signal. In the present work notch filter is designed. Designed filter is applied to the ECG signal containing powerline noise. Complete design is performed with FDA tool in the Mathlab. The notch equiripple filter designed is having higher order which increasing the computational complexity. For accessing real time ECG the advantech add-on card has been used. The result shows the before filtering and after filtering results which clearly indicates the removal of the power line interference in the ECG signal.

Key Words: - Electrocardiogram, Simulation, Equiripple Filter, Real Time Filtering.

1 Introduction

The registration of the ECG signal Known as electrocardiogram, Represents the recording of the electrical potential of the heart. Physicians record ECG signal easily and noninvasively by attaching small electrodes to the human body. Electrocardiogram is the standard tool to diagnose the heart disease. While diagnosis the different artifacts get introduced in the ECG signal like Electrode contact noise, motion artifacts, base line drift electrosurgical noise, and power line interference. Removal of this noise signal is important. Processing of the biomedical signal basically deals with filtering of the signal.

Many researchers are working on noise reduction in the ECG signal. Mitov shows a method for reduction of power line interference (PLI) in electrocardiograms with sampling rate integer multiple of the nominal power line frequency is developed and tested using simulated signals and records from the databases[1]. Cramer E., McManus C. D. and Neubert D. have suggested two different filters. One is based on a least-squares error fit, the other uses a special summation method. Both methods are compared with a local predictive filter by applying each filter to artificial signals and to real ECGs [2]. Ferdjallah M., Barr R.E. has given Frequency-domain digital filtering techniques for the removal of powerline noise [3]. A method for line interference reduction to be used in signal-averaged electrocardiography performance is analyzed by Ider YZ, Saki MC, Gcer HA [4]. Batchvarov V, Hnatkova K, Malik M. has done assessment study on the Electrocardiogram[5]. Christov II, Daskalov IK have worked on filtering of the electromyogram from the electrocardiogram[5]. von Wagner G, Kunzmann U, Schochlin J, Bolz A have described Simulation methods for the online extraction of ECG parameters under Matlab/Simulink [6]. Some of the researchers have worked on design and implementation of digital FIR filters [10, 11].

2 Removal of power line interference Equiripple notch filter Application

Power line interference is one of the reasons of corruption of the ECG signal. Mostly it causes the 50Hz interference and there higher order harmonics gets added to the ECG [2, 7, 8, 9]. To remove the powerline interference from ECG, the equiripple notch filter is implemented and the performance of the filter is explained in detail in the following section.

3 Design of the Equiripple notch filter

The minimum order of the filter selected was 580 and the sampling frequency of 1000Hz. Figure 1 shows the Magnitude response and Figure 2 shows phase response of the equiripple notch filter.

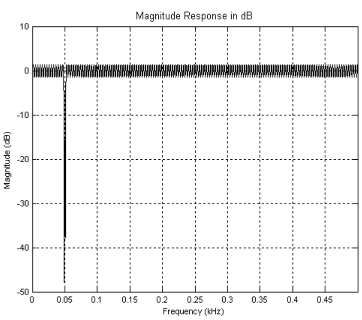

Fig. 1: Magnitude response of the Equiripple filter.

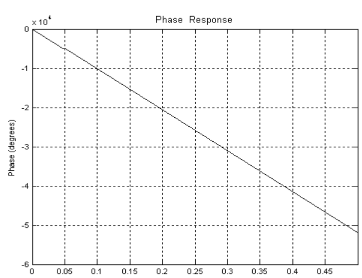

Fig. 2: Phase response of the filter

From the results following observations are made:

- It requires higher order to get the desired magnitude response which increases computational overhead.
- It gives linear phase.
- It provides the stable response. Equiripple notch filter.

4 Realization of the Equiripple notch filter

Realization of the filter requires large number of multipliers, delays and adder elements. Approximately 580 multipliers, 579 delay and 579 adder elements are required. It shows that with increase in order of the filter the computational complexity is increase and it adds delay in response. Figure 3 shows the implementation of the designed notch filter to real time ECG signal.

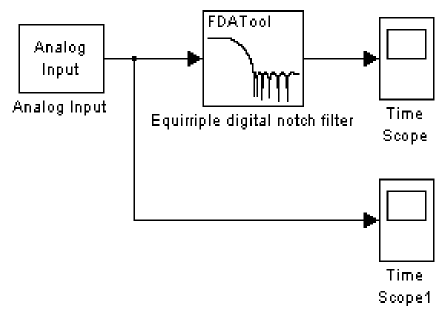

Fig. 3: real time filter model for ECG using equiripple high pass filter.

5 Results of the implementation of the Equiripple notch filter

Figure 4 and 5 shows ECG signal before and after application of equiripple notch filter. Corresponding frequency spectrums are shown in Figure 6 and Figure 7 respectively. From the frequency spectrum of unfiltered ECG it is seen that power corresponding to the 50 Hz is-26.29dB. When the notch filter is used the power corresponds to the 50 Hz signal is reduces to -35.75dB. Which shows that filter reduces the power line interference in the ECG signal. The limitation of this filter is requirement of higher order filter; which increase computational complexity and becomes difficult to realize the filter. From the figure 5 it is seen that, due to computational complexity delay is introduced in the filter response therefore this type of filter is unsuitable for real time application.

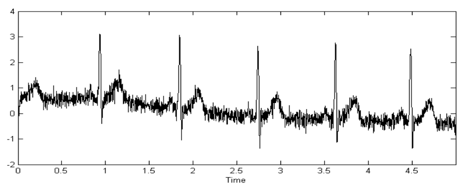

Fig. 4: ECG signal before application of notch filter.

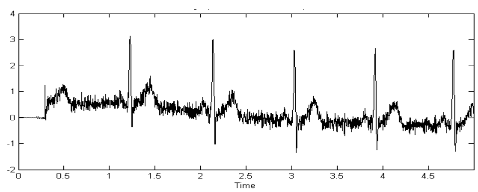

Fig. 5: ECG signal after filtration.

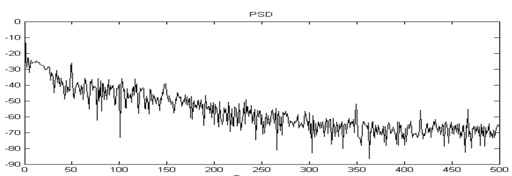

Fig. 6: Frequency spectrum of the ECG before Filtration.

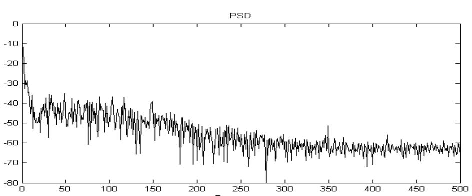

Figure 7: Frequency spectrum of the ECG after filtration.

6 Results and discussion

In dealing with the removal of power line interference FIR notch filters of 50 Hz was designed using above methods. When equiripple filter was used for getting desired responses, order of the filter required was very high. From the frequency spectrum of the ECG, it is seen that power corresponding to the 50 Hz signal is -26.29dB. When the notch filter is used the power corresponds to the 50 Hz signal is reduced to -35.75dB. It clears that filter reduces the power line interference in the ECG signal. The limitation of this filter is that it requires higher order which increases computational complexity and very difficult to realize the filter.

7 Conclusions

The design of an ideal power line noise filter that has narrowly frequency selective band, that is sensitive and self adjusting to slow or abrupt variations of the power line noise frequency and that can implemented in real time has long been the goal of many researchers. In the present work to eliminate power line interference from the ECG FIR filtering technique using equiripple notch filter works satisfactory. Table 1 shows comparison of proposed work with others. selective band, that is sensitive and self adjusting to slow or abrupt variations of the power line noise frequency and that can implemented in real time has long been the goal of many researchers.

Table 1: Comparison of different FIR structures For PLI Reduction.

Filter Design Method	Multipliers	Adders	Delays	Power at 50Hz Before filtration	Power at 50 Hz after filtration
Multiplier free RSS filter	0	37	2248	10dB	-40dB
Kaiser Window	100	101	101	-27.18 dB	-29.59dB
Equiripple Method	580	579	579	-26.29dB	-35.75dB
L. S. Method	101	1010	100	-36.00dB	-42.00dB

In the present work to eliminate power line interference from the ECG FIR filtering technique using equiripple notch filter works satisfactory.

Acknowledgement: Authors are thankful to Department Electronics and Communication Engineering NIT Kurukshetra, India for their co-operation and help.

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