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IMPLEMENTATION OF ADAPTIVE FILTER FOR REMOVAL OF POWER LINE INTERFERENCE FROM ECG SIGNAL

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ABSTRACT

An ECG signal is basically an index of the functionality of the heart. For example, a physician can detect arrhythmia by studying abnormalities in the electrocardiography (ECG) signal. Since very fine features present in an ECG signal may convey important information, it is important to have the signal as clean as possible. ECG signals may be polluted by power line. The major difficulty in removing this power line interference is that the frequency can vary about fractions of a Hertz, or even a few Hertz. For this use of notch filter to eliminate only the undesirable power line interference while automatically adapting itself to variations in the frequency and level of the noise is one of the best solution. Proposed method uses the adaptive least mean square (LMS) algorithm for updating the coefficient of notch filter. A method for adaptive notch filter to eliminate power line interference from ECG signal's output is then passes through error filter for achieving the best result. This method can be used in the medical equipments to remove noise caused due to AC supply

KEYWORDS: LMS algorithm, Adaptive filter, ECG signal, Notch filter

I. INTRODUCTION

Power line interference coupled to signal carrying cables is particularly troublesome in medical equipment such as electrocardiograms (ECGs). Cables carrying ECG signals from the examination room to the monitoring equipment are susceptible to electromagnetic interference (EMI) of power frequency (50 Hz or 60 Hz) by supply lines and plugs noise that sometimes the ECG signal is totally masked.

Filtering such EMI signal is a challenging problem given that the frequency of the time-varying power line signal lies within the frequency range of the ECG signal. There are some other technical difficulties involved, the most important of which is the low sampling frequency at which the ECG signals are taken and the low computational resources available at the level of the apparatus. An ECG signal is basically an index of the functionality of the heart. For example, a physician can detect arrhythmia by studying abnormalities in the ECG signal. Since very fine features present in an ECG signal may convey important information, it is important to have the signal as clean as possible.

The frequency spectrum of this signal spans from near dc frequencies to about 150 Hz. The sampling frequency in most ECG devices is 240 Hz or 360 Hz. Therefore, the spectrum can theoretically include frequencies from zero to 180 Hz. ECG signals are severely distorted by power line noise. Therefore sharp notch filter is essential to separate and eliminate the noise. The notch filter is ineffective because frequency of power line is unstable and varies about fractions of a Hertz, or even a few Hertz. The sharper the notch filter is designed, the more inoperative, or rather destructive, it becomes if any change in the frequency of the power line occurs, turning the notch filter into a band-stop filter by widening its rejection band, and thereby accommodating frequency variations, does not offer any better solution since it will undesirably distort the ECG signal itself. The frequency of the power grid is usually taken as being constant when conventional EMI filters for ECGs are designed.

In such arrangements, the system is very delicate with respect to power frequency variations and can become completely inoperative. One of the possible alternatives to take frequency variations into account is the use of an external reference power line signal. This technique, available by the use of adaptive filters only. An ideal EMI

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filter for ECG should act as a sharp notch filter to eliminate only the undesirable power line interference while automatically adapting itself to variations in the frequency and level of the noise. This adaptation must be done very quickly so as to keep the signal clean all the time. It is supposed to be able to work in low information background, namely that dictated by low sampling frequency, and must be robust with respect to variations in its internal as well as external conditions. An example of internal condition is its settings. External conditions can range from the temperature of the environment in which the equipment is supposed to function to the superimposed noise/distortion on the interfering power signal.

The interference is commonly modeled as an additive signal. Therefore, the measured corrupted signal is the sum of the signal of interest and the interference. An ideal power line interference suppression method should eliminate the power line interference while preserving the signal of interest. For this purpose, notch filters and adaptive interference cancellers are two different approaches which can be used. Notch filters reduce the power line interference by suppressing predetermined frequencies. The magnitude and phase spectrum of the ECG signal are less affected by narrow suppression band filters.

Therefore, the suppression band of the notch filter should be as narrow as possible. However, this leads to problems whenever the power line frequency is not stable or not accurately known, a mismatch between the suppression band and the power line frequency might lead to inadequate reduction of the power line interference.

II. LITERATURE REVIEW

This paper proposes an intelligent adaptive noise rejection filter, which tracks and eliminates PLI as well as its harmonics. The proposed system can estimate the frequency of PLI and tune the adaptive filter for precise elimination of PLI as well as its harmonics without the requirement of an auxiliary reference input. The proposed system is based on recursive state space model, inherited with less computational complexity and performs well in a non-stationary environment. The proposed system responds well to the ongoing variations in amplitude and frequency of PLI present in the HRECG signal as well as intra-cardiac signal. In this case the SNR level of input signal is 7.46 dB and the output of proposed system achieves SNR level of 22.14 dB whereas output of notch filter has the SNR level of 15.95 dB [1].

This paper proposes an improved adaptive canceller for the reduction of the fundamental power line interference component and harmonics in electrocardiogram (ECG) recordings. The method tracks the amplitude, phase, and frequency of all the interference components for power line frequency deviations upto 4 Hz. A comparison is made between the performance of our method, former adaptive cancellers, and a narrow and a wide notch filter in suppressing the fundamental power line interference component. For this purpose a real ECG signal is corrupted by an artificial power line interference signal. The cleaned signal after applying all methods is compared with the original ECG signal. Our improved adaptive canceller shows a signal-to-power-line-interference ratio for the fundamental component up to 30 dB higher than that produced by the other methods [2].

This paper proposes, an existing adaptive interference canceller is modified by considering the error at the neighboring samples in estimating the power line interference parameters. The performance of the modified adaptive canceller is further improved by using error filtering. The adaptive interference canceller has been modified by replacing the squared-error at each sample by mean-square-error of an error vector in the LMS algorithm [3].

This paper proposes, Kalman based least mean square (KLMS) filter has been proposed. The Kalman based Least mean square filter essentially minimize the mean square error and remove the 50Hz power line interferences. The experimental results shows that the Kalman based LMS filter is more effective compare to other filter techniques. The 4-beat original ECG signal is generated by using MATLAB whose sampling frequency is 500 Hz for each beat and amplitude is 1mv. The 50 Hz power line interference is also generated with sampling frequency of 2000 Hz. The power line interference is then added to the original ECG signal to get the mixed signal. Finally, the power line interference is removed using different adaptive filters based on different algorithms, such as, BLMS, DLMS, XLMS and Kalman based LMS algorithm [4].

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One of the major difficulties in biomedical signal processing like ECG is the segregation of the useful signal from unwanted signal affected by Baseline Wander, Power line Interference, High –frequency Noise, Physiological Artifacts etc [5]. Various methods of digital filters are introduced to eliminate real ECG signal from undesirable frequency ranges. It is hard to exert filters with constant coefficients to remove random artifacts, because hum manner is not accurate known relevant on the time. Digital filter method is needed to solve this problem. In usual two kinds of techniques can be subdivided in this paper; there is non-adaptive filters like FIR, IIR and adaptive filters as LMS, NLMS algorithms. Finally we conclude by comparing all filters SNRs, MSEs and frequency spectrum adaptive NLMS algorithm will be the best filter for removing contaminated noises in ECG signal.

This paper propose, Adaptive filtering method can realize effective extraction of non-stationary signals without knowing a prior knowledge about signal and noise, this paper presents an adaptive noise cancellation system for ECG signal base line filtering and power interference suppression, constructs an iterative time LMS algorithm combining variable and fixed step size, which effectively solves the problems of filtering SNR and convergence rate. The experiment results show that this method improves 26.36dB in SNR eliminates base line drift and power interference effectively, extracts ECG signal accurately and converges quickly, has important practical value in medical clinical diagnosis. A new method of elimination of power line noise in electrocardiogram signals is presented [6].

The proposed method employs, as its main building block, a recently developed signal processing algorithm capable of extracting a specified component of a signal and tracking its variations over time [7]. Design considerations and performance of the proposed method are presented with the aid of computer simulations. The proposed method presents a simple and robust structure which complies with practical constraints involved in the problem such as low computational resource availability and low sampling frequency.

In this paper, a model that includes both interference external to the measuring system and interference coming from its internal power supply is proposed. Moreover, the model considers interference directly coupled to the measuring electrodes, because, as opposed to connecting leads, electrodes are not usually shielded. Experimental results confirm that reducing interference coupled through electrodes yields a negligible interference. The proposed model can be applied to other differential measurement systems, particularly those involving electrodes or sensors placed far apart [8].

III. ADAPTIVE LEAST MEAN SQUARE (LMS) ALGORITHM:

An adaptive filter has two major components: an FIR filter and an adaptive algorithm. The FIR filter transfer function is controlled by variable parameter, computed by adaptive algorithm. Adaptive filters are required for some applications because some parameters of the desired processing operation are not known in advance or are changing. The closed loop adaptive filter uses feedback in the form of an error signal to refine its transfer function. The algorithm for this project is least mean square (LMS).

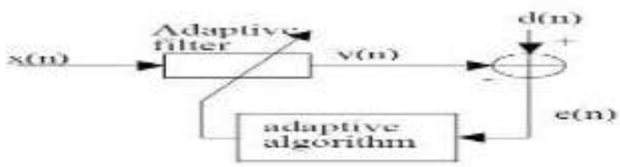

Figure 1. Adaptive Filter [10].

IV. PROPOSED METHOD

Proposed method follows the steps as below:

1. Taking input ECG signal.
2. Adding power line interference to ECG signal.
3. Passing it through Notch filter.
4. Output of Notch filter and noisy ECG signal is going in summation block.
5. Output is drawn out of summation box y(n).
6. Same output goes through Error Filter.
7. Output of error filter goes through Adaptive Filter.

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8. Getting Final output y(n).
9. Determine SNR and correlation coefficient.

Without error filter module of the proposed system has been implemented, its given as follows with its simulation results.

Implemented Module Without Error Filter:

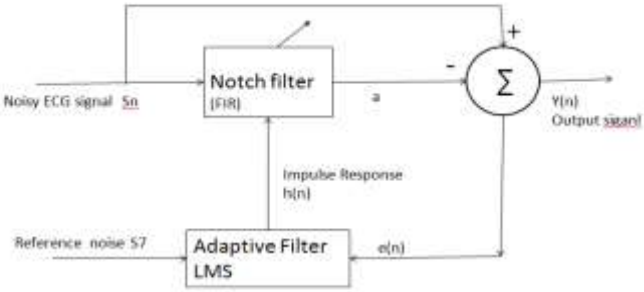

Figure 2: Block diagram of implemented module without error filter

The original ECG signal is taken from MIT BIH Database. The 50 Hz or 60 Hz power line interference is generated by using MATLAB. This noise signal is added with the original ECG signal. In order to remove the 50Hz or 60 Hz power line interference and to reconstruct the ECG signal from mixed signal, we use notch filter and adaptive least mean square (LMS) Algorithm. A least mean square (LMS) algorithm is a procedure of adjusting the impulse of the adaptive filter. Noisy ECG signal is given by
s(n) = s + s7

The desired signal is represented by s. The error signal is denoted by e(n) which is the difference between estimated signal y(n) and a.
e(n) = y(n)
where s7 is the reference signal.

The noise is generated by MATLAB to produce s7.
s7 = [Sin (2 pi f0 n) / fs]
Where f0 is frequency of power line and fs is sampling frequency.

The Adaptive Algorithm used here is LMS (Least Mean Square). The filter is designed by adapting the filter co-efficient in each iteration by using the previous filter co-efficient and error signal. The updated filter co-efficient for LMS Algorithm is
h(n+1) = h(n) + [mu*s7*e(n)]

where
mu → step size parameter.
Signal to Noise ratio is given by
SNR (db) = 20 log1o * S/N

Where S is power of the ECG signal and N is power of sinusoidal interference.
e(n) = output signal.

V. SIMULATION RESULTS OF IMPLEMENTED MODULE:

In order to validate the performance of adaptive filter for elimination of power line interference using least mean square (LMS) algorithm, simulation is carried out using ECG signals. The ECG signal with sampling frequency of 200 Hz. Signal to noise ratio (SNR) is measured at the input and output of the adaptive filter. The input Signal to noise ratio (SNR) is defined as ratio of the power of the ECG signal to the power of sinusoidal interference and output Signal to noise ratio (SNR) is defined as the ratio of the power of the ECG signal to the

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residual interference power. Correlation coefficient is between the original ECG signal and the ECG signal with interference removed.

Simulation result for Record 100 is as follows:

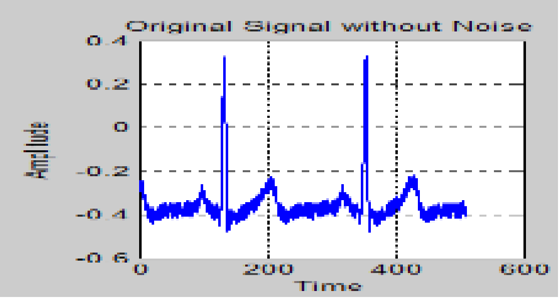

Fig. 3 Original ECG Signal

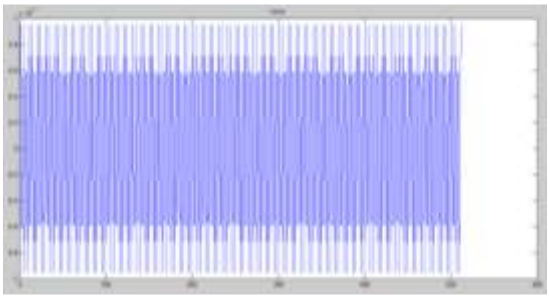

Fig. 4 Noise

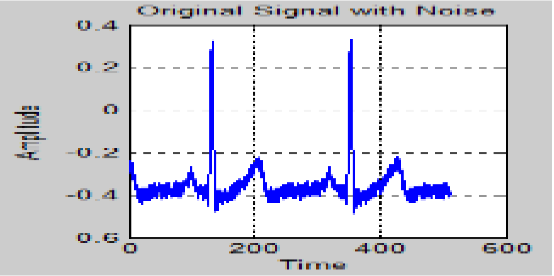

Fig. 5 Noisy ECG signal

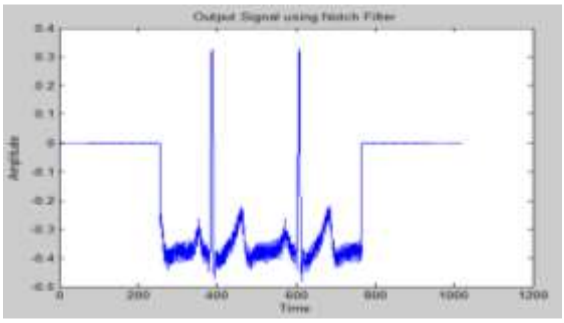

Fig. 6 Output of notch filter

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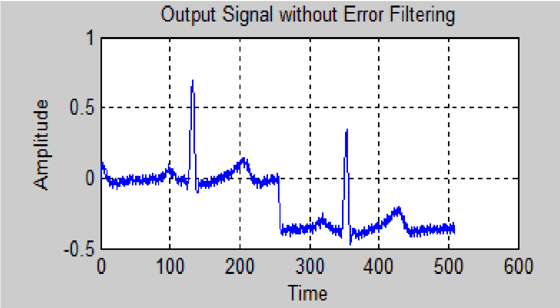

Fig. 7 Output signal without error filter

This method is applied on ECG's having record number 100, 101, 103,105 and 106. The obtained results are as follows:

Table 1 Output SNR (db)

Record no.	ECG amplitude (mV)	SNR(db) Output without error filter
100	0.4100	1.9782
101	0.8	7.3320
103	0.4760	6.1910
105	0.458	0.3302
106	0.5220	9.0616

Table 2 Output Correlation Coefficient

Record no.	Correlation Coefficient (CC) Output without error filter
100	0.4601
101	0.7061
103	0.8491
105	0.3845
106	0.8983

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