Application of Adaptive Filter Algorithms for Cancelling the Effects of Power Line Interference and Baseline Wander Noises in ECG Signals

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Abstract- *High quality Electrocardiography (ECG) is very essential for the diagnosis of various cardiac diseases such as heart arrhythmias, heart enlargement, heart inflammation and coronary heart diseases. ECG being a weak signal is easily corrupted by various noises such as PLI (Power Line Interference) and base line wander. These noises are non stationary and effect the reliability of ECG signal. In this paper we present the analysis of various adaptive filter algorithms such as LMS, NLMS, SLMS and SSLMS in eliminating the various noises. The performance of these algorithms are compared with SNR (Signal to Noise Ratio) and MSE (Mean Square Error). MIT-BIH base is used to extract the real time recorded ECG signal. SSLMS is found exhibit high SNR and lower MSE.*

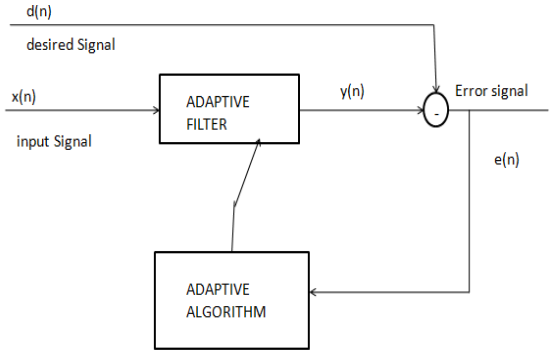
Keywords- ECG signal, Power line interferences, Base line wander, LMS, NLMS, SLMS, SSLMS, SNR and MSE.

I. INTRODUCTION

ECG is a graphical representation of the heart it is generated by a nerve impulse stimulus to the heart. Each portion of ECG consists of various types of information for analysing the patient's heart condition. An adaptive filter is a system with a linear filter that adjusts the filter coefficients themselves iteratively in order to cancel the non stationary noise if any present. ECG is conducted to monitor the electrical activity of the heart by presenting small amplitude and duration signals as a result. But the hidden information present in ECG data is difficult to determine because ECG consist of noise which is non stationary that affects the reliability of ECG waveform. This ECG signal gets polluted with few disturbances namely PLI (Power Line Interference) i.e. the interference of the alternating current of frequency 50Hz to 60Hz from the power chords and base wander line noise that comes into existence from the body movements and poor electrode contact.

II. ADAPTIVE FILTERS

Filter is an electronic device that passes and blocks certain frequencies. Filtering is a type of signal processing it is used to manipulate the information contained in the signal. Adaptive Filter is a nonlinear filter that is controlled by the error function, which determines the performance of the filter.



Here the output signal is compared with the desired signal and by subtracting the two samples at time *n.*
This difference signal, given by

$$e(n) = d(n) - y(n)$$

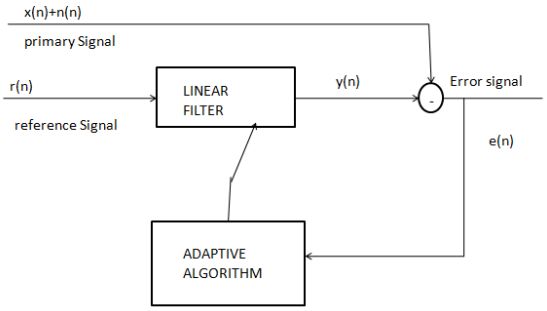
Where e(n) is error function, d(n) is desired function and y(n) is estimated function.

In adaptive filter coefficients are adjust themselves to achieve the desired Results. The basic equation for the adaptive filters is given by

$$w(n + 1) = w(n) + \Delta w$$

A. Least Mean Square (LMS)Algorithm

The least mean square (LMS) algorithm is used to minimize the error between desired signal and output of the filter by adjusting the parameters of a linear filter. In general LMS adaptive filter removes noise or obtains a desired signal by adapting the filter coefficient with least-square algorithm based on given filter order. In LMS algorithm there are two inputs and one output. The primary input contains signal plus noise and the reference input contains noise alone. The primary and reference noises must be uncorrelated with the primary signal, but correlated with each other.



The output signal y(n) from the adaptive filter is

$$y(n) = \sum_{i=0}^{N-1} w_i(n)x(n-i)$$

The adjustment of the filter coefficients using the equation

$$w(n+1) = w(n) + 2\mu e(n)x(n)$$

The performance of LMS algorithm is depends on the μ value if it is too small optimal solution will be too long and if it is too large then the filter becomes unstable. For each iteration the LMS algorithm requires 2N additions and 2N+1 multiplications.

B. Normalized Least Mean Square (NLMS) Algorithm

NLMS is an extension to LMS algorithm. For each iteration, the step size parameter in LMS algorithm is fixed, which is the primary drawback of LMS algorithm.The larger step size fluctuates the coefficient and so LMS algorithm experiences gradient noise amplification problem. To overcome this problem a normalized step size is used which is known as Normalized LMS (NLMS) algorithm. Step size is proportional to the inverse of the total expected energy of the instantaneous values of the coefficients of the input vector x(n)

$$\mu(n) = \frac{1}{2x^T(n)x(n)}$$

The recursion formula for the NLMS algorithm is

$$w(n+1) = w(n) + \frac{1}{x^T(n)x(n)}e(n)x(n)$$

The parameter μ is a constant step size value used to alter the convergence rate of NLMS algorithm. Each iteration of NLMS requires 3N+1 multiplications.

C. Sign Least Mean Square (SLMS) Algorithm

Sign LMS algorithm is obtained from basic LMS recursion by replacing the cost function e(n) by its sign. Sign LMS algorithm is used to simplify the implementation and hardware compatibility. SLMS algorithm creates an equalizer object to equalize the function with the signal. This algorithm reduces the cost in terms of speed and hardware by evaluating the cost function in terms of its sign value. This also reduces the nonlinearity with its sign value.

The weight updating equation for the Sign LMS algorithm is

$$w(n+1) = w(n) + \mu x(n)sgn\{e(n)\}$$

Sign LMS should be operated at smaller step-sizes to get a similar behaviour as standard LMS algorithm

E. Sign Sign Least Mean Square (SSLMS) Algorithm

Sign-Sign LMS algorithm is the combination of signed regressor and sign LMS algorithms. This algorithm is obtained by replacing the tap-input vector x(n) with the vector sgn{x(n)} and cost function e(n) by its sign.

The weight updating equation for the sign-sign LMS algorithm is

$$w(n+1) = w(n) + \mu sgn\{x(n)\}sgn\{e(n)\}$$

When either e(n) or μ(n) is zero, this algorithm does not involve multiplication operation.

When either e(n) or μ(n) is zero, this algorithm involve one multiplication operation.

The sign–sign algorithm is slower than the LMS algorithm. Its convergence behaviour is also peculiar. It converge very slowly at the beginning, but speed up as the MSE level drops. The performance of SSLMS is quite good and is robust in nature

III. METHODOLGY

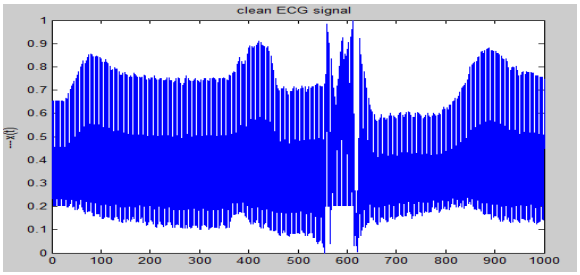
ECG signal is taken from MIT-BIH database with 1000 samples per second and amplitude 1mV. Random noise is generated using MATLAB and is added to this recorded ECG signal to get the mixed primary signal. The parameters to be considered in the implementation of any FIR filter are filter order, cut-off frequency. Here the filter order determines the width of the transition band. Cut-off frequency which enables a noise free ECG to be extracted by a FIR filter and the signal which is having above this frequency is considered as distorted ECG signal. Here first considering random noise signal as reference signal to the adaptive filter that produces the output based on different adaptive algorithms. Then that output will be free from the random noise which is present in the ECG signal. Later we are giving Base line wander noise which is generated by using wavelet transform as reference signal to the adaptive filter that produces the output which is

free from if that noise present in ECG signal. Finally we are giving PLI noise it is a 50Hz signal as reference to the adaptive filter that produces the output which is free from that noise present in ECG signal.

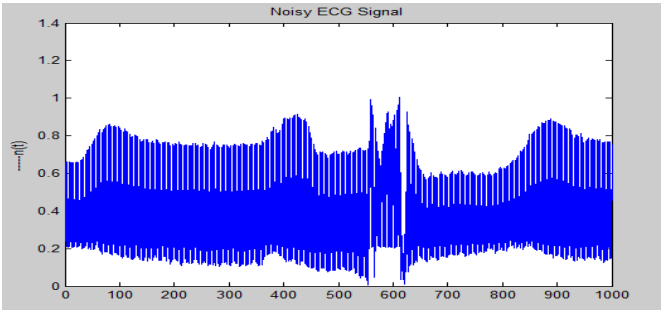
IV. RESULTS/OBERVATIONS

PARAMETER	LMS	NLMS	SLMS	SSLMS
SNR	47.254	50.703	52.338	55.211
MSE	0.0035	0.0029	0.0022	0.0016

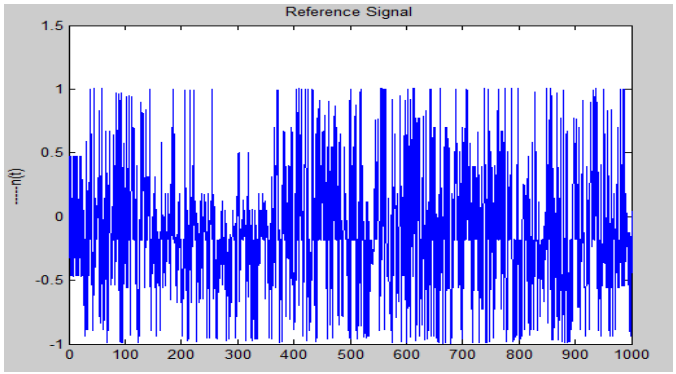
1.CLEAN ECG SIGNAL



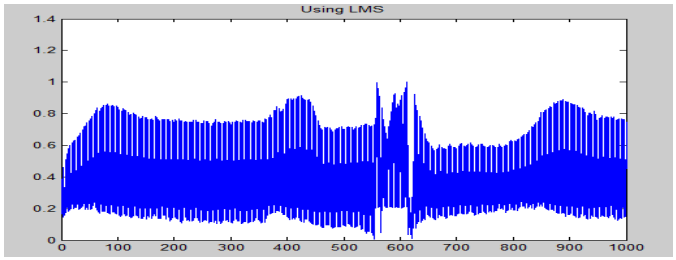
2. NOISY ECG SIGNAL



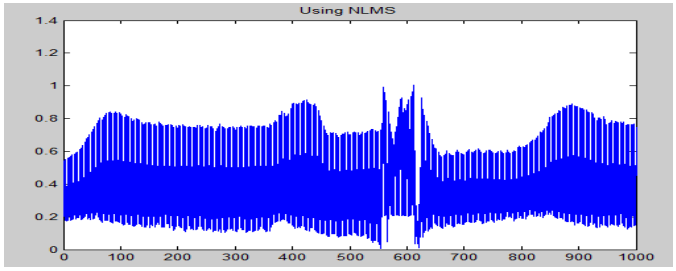
3. REFERENCE ECG SIGNAL



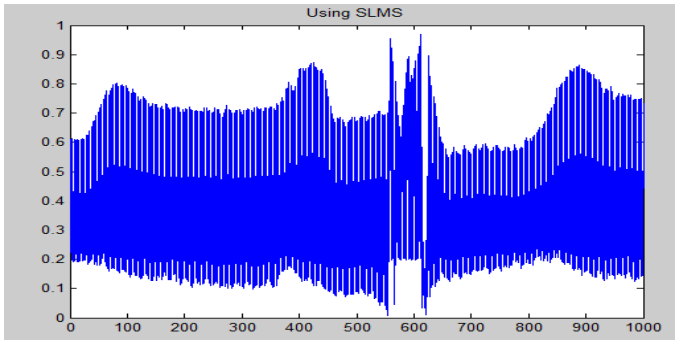
4. RANDOM NOISE ELIMINATION USING LMS ALGORITHM



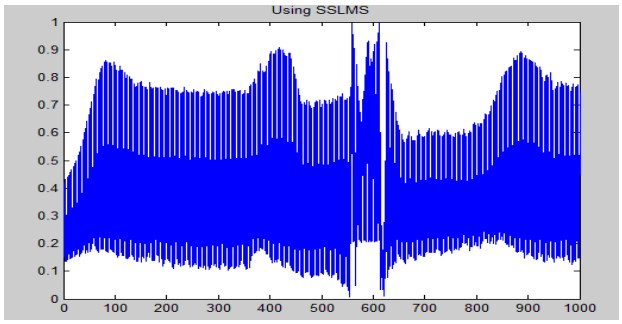
5. RANDOM NOISE ELIMINATION USING NLMS ALGORITHM



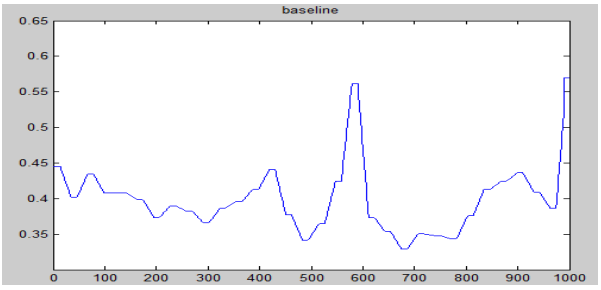
6. RANDOM NOISE ELIMINATION USING SLMS ALGORITHM



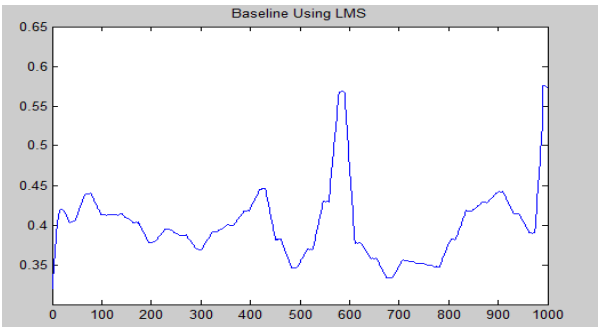
7. RANDOM NOISE ELIMINATION USING SSLMS ALGORITHM



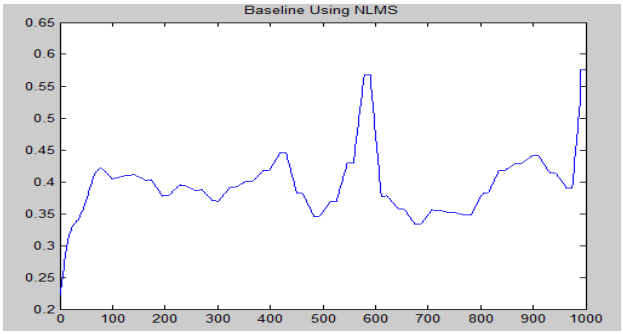
8. BASE LINE WANDER NOISE



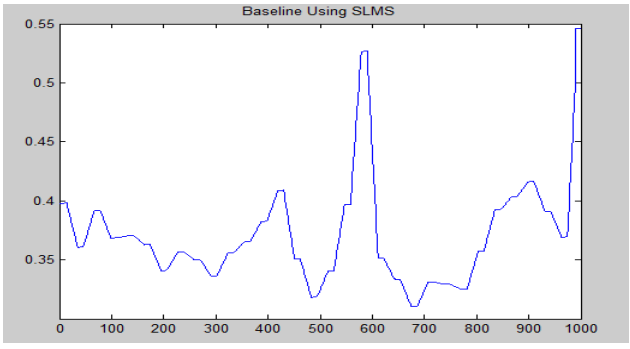
9. BASE LINE WANDER NOISE ELIMINATION USING LMS ALGORITHM



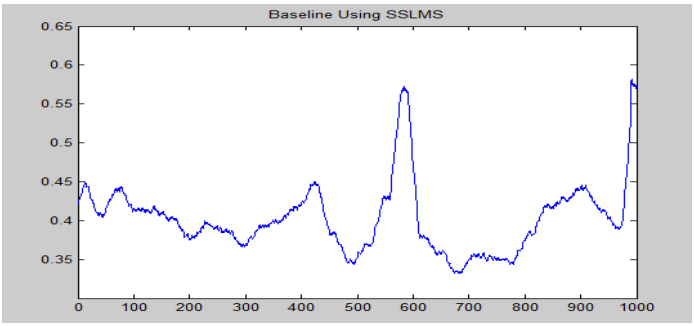
10. BASE LINE WANDER NOISE ELIMINATION USING NLMS ALGORITHM



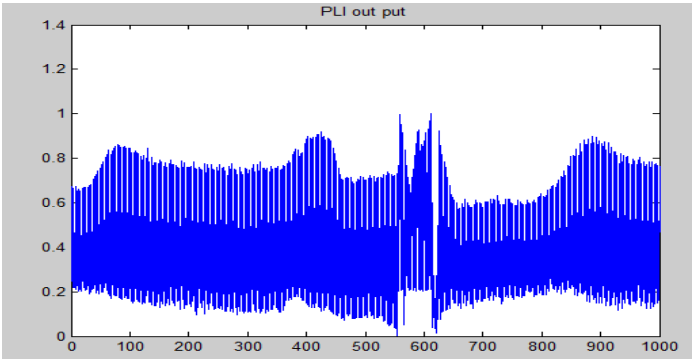
11. BASE LINE WANDER NOISE ELIMINATION USING SLMS ALGORITHM



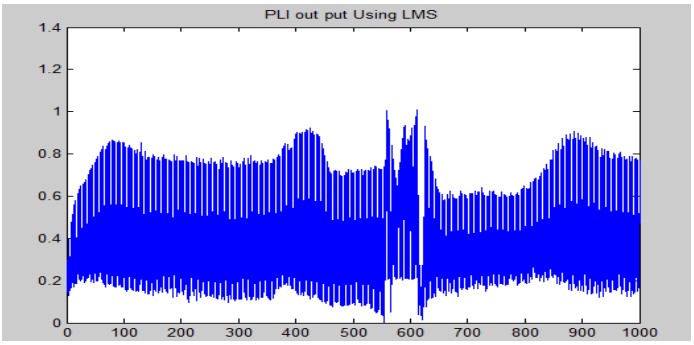
12. BASE LINE WANDER NOISE ELIMINATION USING SSLMS ALGORITHM



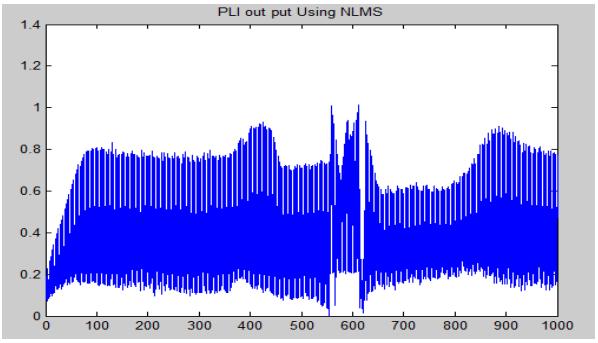
13. PLI NOISE



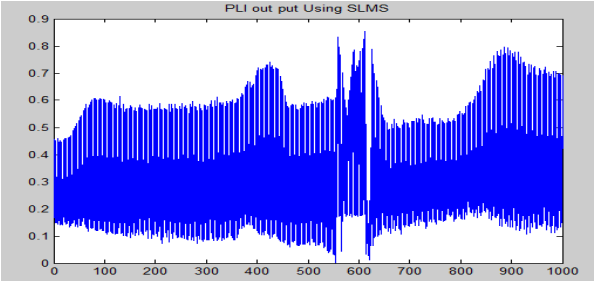
14. PLI NOISE ELIMINATION USING LMS



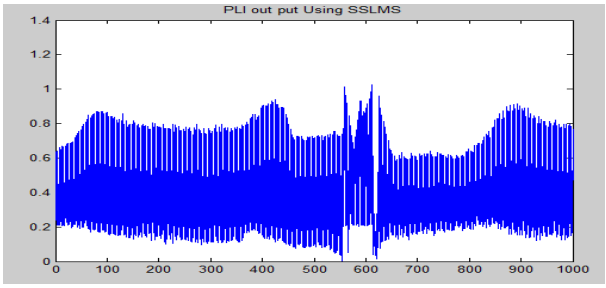
15. PLI NOISE ELIMINATION USING NLMS



16. PLI NOISE ELIMINATION USING SSLMS



17. PLI NOISE ELIMINATION USING SSLMS



V. CONCLUSIONS

In this paper we are presenting various adaptive algorithms such as LMS, NLMS, SLMS and SSLMS are used to reduces the noises in the ECG signal. Appropriate step size is calculated for each adaptive filter and their performances are observed. Here the major noises base line wander noise and PLI in ECG signal is reduced so that we are observing high SNR and lower MSE for SSLMS.

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