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Denoising EEG Signal using Different Adaptive Filter Algorithms

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ABSTRACT

Electroencephalography (EEG) signals have been proven a very versatile tool for detection of different kinds of Brain diseases. But during recording of these signals, the EEG data gets contaminated by various noise signals caused by power line interference, base line wander, electrode movement, muscle movement (EMG) etc. These noise signals mislead the diagnosis of brain which is not desired. To avoid this problem removal of these noise signals have become essential. Due to advancement of information and communication technology Telemedicine and E-health has become popular in developing and developed countries. In telemedicine system different types of biomedical signals like ECG and EEG needs to be transmitted through our communication infrastructure. During transmission of this type of biomedical signals the probability of getting corrupted by common noise (Random noise, Gaussian noise) is very high. In this research work we have tested three different types of Adaptive filtering algorithms (LMS, NLMS and RLS) to compare the performances for designing EEG signal from Random noise and Gaussian noise. Finally EEG signal data format has been taken from MIT– BIH Database (http://www.physionet.org/physiobank/database/mitdb/).We have taken 250mV amplitude EEG signal from MIT-BIH database and 5mV (2% of original EEG signal), 10mV (4% of original EEG signal), 15mV (6% of original EEG signal), 20mv (8% of original EEG signal) and 25mV (10% of original EEG signal) of random noise and white Gaussian noise is added with EEG signal and Adaptive filter with three different algorithms have been tested to reduce the noise that is added during transmission through the telemedicine system. Normalized mean square error was calculated. For highest amplitude random noise, 25mV (10% of original EEG signal) added EEG signal, we have got normalized mean square error for LMS, NLMS add RLS adaptive filter respectively 3.5566×10^{-4} , 2.8322×10^{-4} , 1.5938×10^{-5} . For the case of 25 mV amplitude Gaussian Noise we have found simulation result of normalized mean square error for LMS, NLMS and RLS adaptive filters respectively 4.2407×10^{-4} ,2.459×10^{-4} and 7.0148×10^{-5} . The errors are very less in all of the cases and we found RLS Filter performed the best amongst the three filters mentioned in our MATLAB simulation for denoising the EEG signal.

Keywords: Telemedicine, EEG, LMS, NLMS, RLS.

1. INTRODUCTION

The EEG signal measured with an electroencephalograph, is a bio medical electrical signal occurring on the surface of the body related to the contraction and relaxation of the brain. This signal represents an extremely important measure for doctors as it provides vital information about a patient brain condition and general health. Generally the frequency band of the EEG signal is 1to 50 Hz [1]. Inside the brain there is a specialized electrical conduction system that ensures the brain to relax and contracts in a coordinated and effective fashion. EEG recordings may have common artifacts with noise caused by factors such as power line interference, external electromagnetic field, random body movements and respiration. Different types of digital filters may be used to remove signal components from unwanted frequency ranges [2]. As it is difficult to apply filters with fixed coefficients to reduce biomedical signal noises because human be haviour is not exact depending on time, an adaptive filtering technique is required to overcome the problem. Adaptive filter is designed using different algorithms such as least mean square (LMS), Normalized least means square (NLMS) and Recursive least square (RLS) [3].

Least square algorithms aims at minimization of sum of the squares of difference between the desired signal and model filter output when new samples of the incoming signals are received at every iteration, the solution for the least square problem can be computed in recursive form resulting in the recursive least square algorithm. The goal for EEG signal enhancement is to separate the valid signal components from the undesired artifacts so as to present an EEG that facilitates an easy and accurate interpretation. The basic idea for adaptive filter is to predict the amount of noise in the primary signal and then subtract noise from it. As sinusoidal signals are known to be corrupted during transmission it is expected that similarly an EEG signal will be corrupted. We have therefore designed an adaptive filter with three different algorithms (LMS, NLMS and RLS) and simulated in MATLAB platform to compare the performance of denoising of EEG signal. In this research work our simulation result suggest that RLS could be the best option for recovering or denoising EEG signal during transmission through Telemedicine system.

2. RELATED WORKS AND LITERATURE REVIEW

The extraction of high-resolution EEG signals from recordings contaminated with system noise is an important issue to investigate in Telemedicine system. The goal for EEG signal enhancement is to separate the valid signal components from the undesired artifacts, so as to present an EEG that facilitates easy and accurate interpretation. In our literature review we have found that "Denoising EEG signal Using Wavelet Transform, R. PRINCY, P. THAMARAI, B. KARTHIK, International Journal of Advanced Research in Computer Engineering & Technology (IJARCET), Volume 4 Issue 3, March 2015" where Wavelet has been used for denoising EEG signal but no other related research paper has not been found where Common adaptive filter algorithms (LMS, NLMS And RLS) have been not used. In this paper the LMS algorithm operates on an instantaneous basis such that the weight vector is updated every new sample within the occurrence, based on an instantaneous gradient estimate. There are certain clinical application of EEG signal processing that require adaptive filters with large number of taps. In such application the conventional LMS algorithm is computationally expensive to implement.

The LMS algorithms and NLMS (normalized LMS) algorithm require few computations, and are, therefore, widely applied for acoustic echo cancellers. However, there is a strong need to improve the convergence speed of the LMS and NLMS algorithms. The RLS (recursive least-squares) algorithm, whose convergence does not depend on the input signal, is the fastest of all conventional adaptive algorithms. The major drawback of RLS algorithm is its large computational cost. However, fast (small computational cost) RLS algorithms have been studied recently. In this paper we aim to obtain a comparative study of faster algorithm. Unlike the NLMS and projection algorithms, the RLS does not have a scalar step size. Therefore, the variation characteristics of an EEG signal cannot be reflected directly in the RLS algorithm. Here, we study the RLS algorithm from the viewpoint of the adaptive filter because (a) the RLS algorithm can be regarded as a special version of the adaptive filter and (b) each parameter of the adaptive filter has physical meaning. Computer simulations demonstrate that this algorithm converges twice as fast as the conventional algorithm.

These characteristics may plays a vital role in biotelemetry, where extraction of noise free EEG signal for efficient diagnosis and fast computations, high data transfer rate are need to avoid overlapping of pulses and to resolve ambiguities. To the best of our knowledge, transform domain has not been considered previously within the context of filtering artifacts in EEG signals. In this Paper we compare the performance of LMS, NLMS and RLS algorithms to remove the artifacts from EEG. This algorithm enjoys less computational complexity and good filtering capability. To study performance of the algorithms to effectively remove the noise from the EEG signal, we carried out simulations on MIT-BIH database. During transmission of EEG signal it may be corrupted due to common noise (random noise and Gaussian noise). So we have tested the performances of LMS, NLMS and RLS algorithm of adaptive filter. Our simulation result suggests that RLS could be the best option for denoising EEG signal during transmission through Telemedicine system.

3. ADAPTIVE FILTER ALGORITHMS

During transmission of EEG signal through Telecommunication network it may be corrupted by random noise or white Gaussian noise of the network. Adaptive filter using different algorithms have been used to reduce noise of the transmitted EEG signal. A MATLAB coding has been done to reduce the noise of the EEG signal and for reducing noise of digitized EEG signal, transmitted EEG signal needs to be loaded in MATLAB and then it is filtered suing adaptive filter with different algorithms and performances of different algorithms are measured based on their de-noising capabilities.

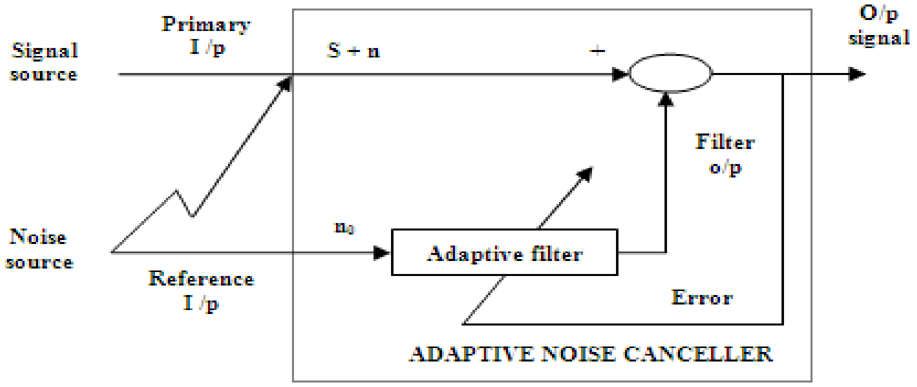

Fig.1: Adaptive Noise Canceller (ANC)

Least Mean square Algorithm (LMS), Normalized Mean Square Algorithm (NLMS) and Recursive Least Square Algorithm (RLS) has been designed and implemented for denoising EEG signal in MATLAB platform [3, 4, 5]. In this thesis work simulation result suggests that RLS could be the best option for recovering EEG signal or denoising EEG signal during transmission telemedicine system.

4. RESULT

In this thesis work we have taken pure EEG signal from MIT-BIH database. The amplitude of our taken EEG signal was 250mV which amplified form as it will come through Instrumentation Amplifier. 5mV (2% of original EEG signal), 10mV (4% of original EEG signal), 15mV (6% of original EEG signal), 20mV (8% of original EEG signal) and 25mV (10% of original EEG signal) of random noise and white Gaussian is added with EEG signal. Three different algorithms of Adaptive filter were implemented and tested their performances of denoising EEG signal. We have taken EEG signal with 250mV amplitude and 5000 samples were taken from MIT-BIH database.

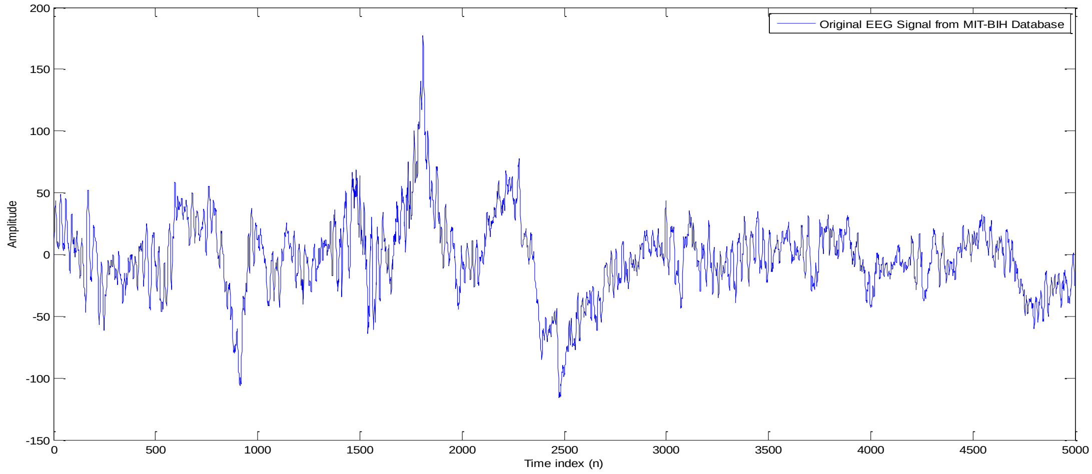

Fig. 2: Pure EEG signal taken from MIT-BIH database

In our simulation work we have denoised 5mV, 10mV, 15mV, 20mV and 25mV random and Gaussian noises but for this particular case we have demonstrated the simulation result of 25mV random and Gaussian noises.

25 mV amplitude Random Noise (10% of Original Amplified EEG Signal Amplitude):

Least Mean Square (LMS) algorithms:

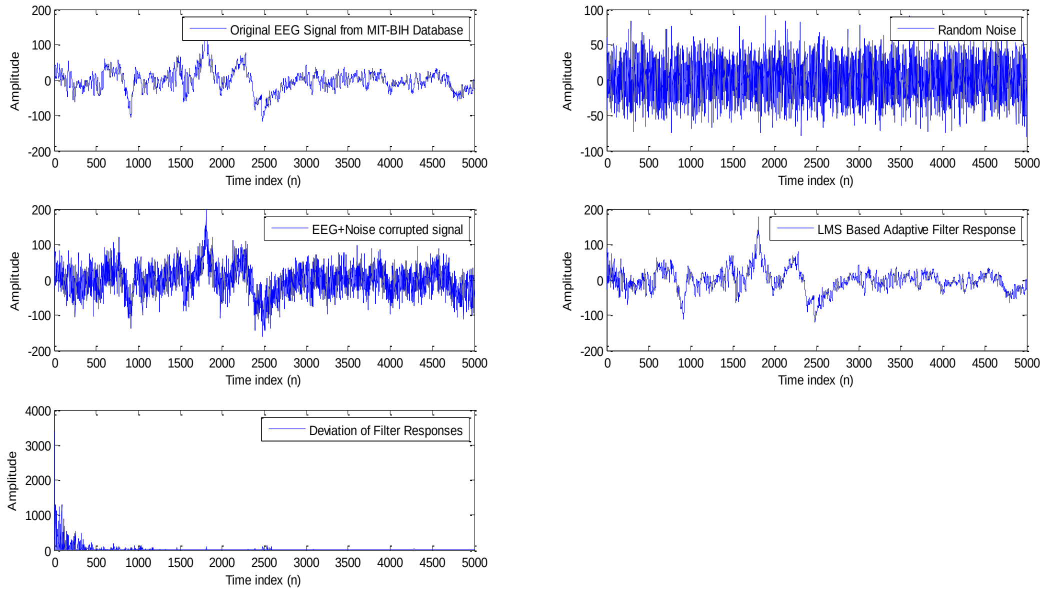

Fig.3: (a) Pure EEG signal taken from MIT-BIH Database (b) Random Noise with average amplitude 25 mV (c) EEG signal is mixed with pure EEG signal (d) LMS based Adaptive Filter response (e) Square Deviation of LMS based adaptive filter

Normalized Mean Square (NLMS) Algorithms:

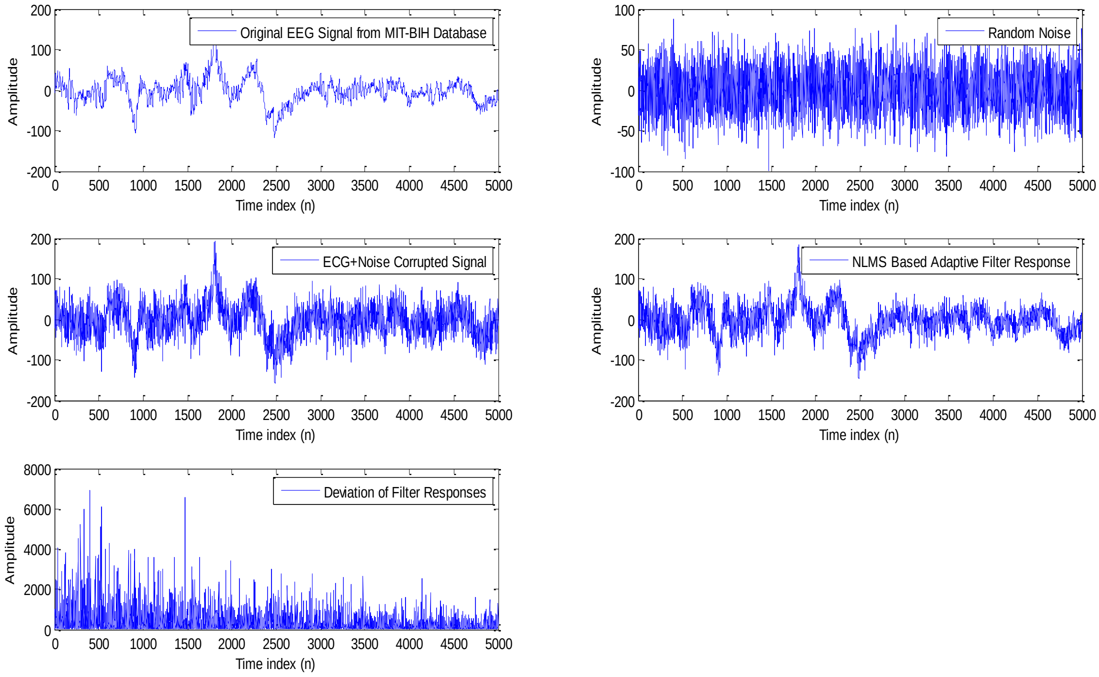

Fig. 4: (a) Pure EEG signal taken from MIT-BIH Database (b) Random Noise with average amplitude 25mV (c) EEG signal is mixed with pure EEG signal (d) NLMS based adaptive Filter response (e) Square Deviation of NLMS based adaptive filter

Recursive Least Square (RLS) Algorithms:

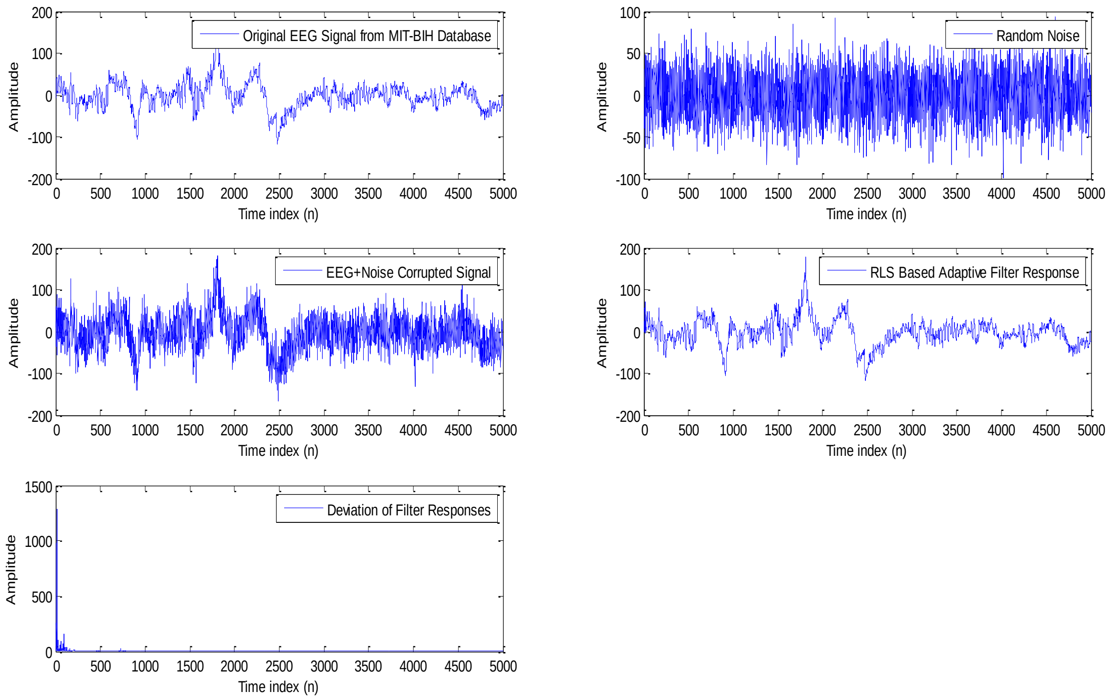

Fig.5: (a) Pure EEG signal taken from MIT-BIH Database (b) Random Noise with average amplitude 25mV (c) EEG signal is mixed with pure EEG signal (d) RLS based Adaptive Filter response (e) Square Deviation of RLS based adaptive filter

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25mV amplitude White Gaussian Noise (10% of original Amplified EEG Signal Amplitude)

Least Mean square (LMS) Algorithms:

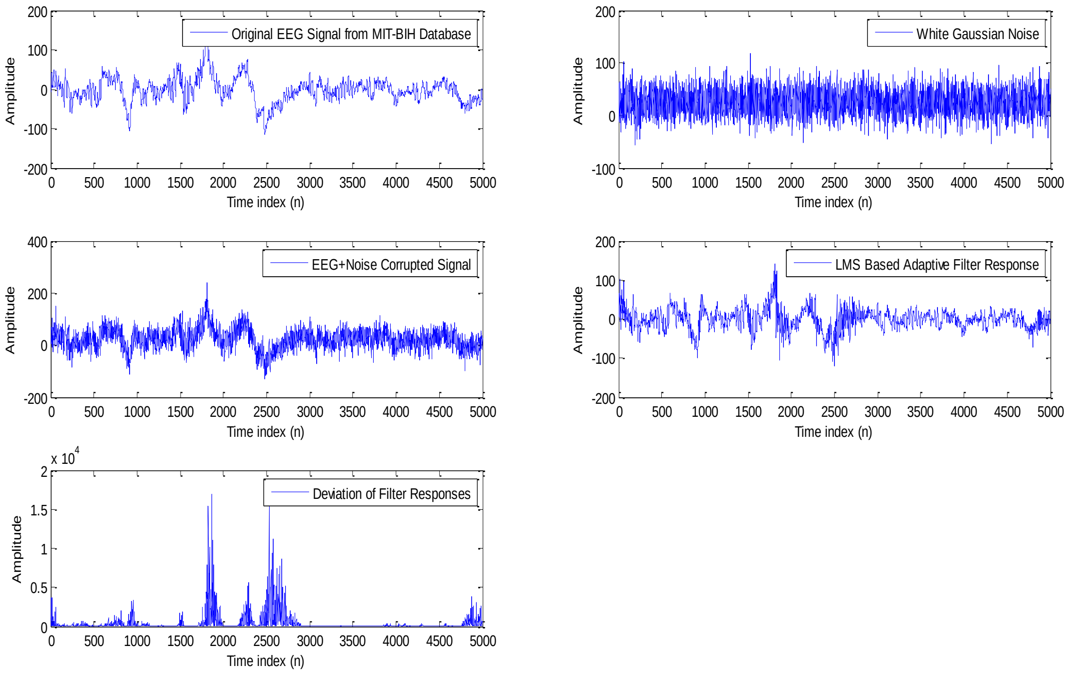

Fig.6: (a) Pure EEG signal taken from MIT-BIH Database (b) White Gaussian Noise with average amplitude 25mV (c) EEG signal is mixed with pure EEG signal (d) based adaptive Filter response (e) Squared Deviation of LMS based adaptive filter

Normalized Mean Square (NLMS) Algorithms:

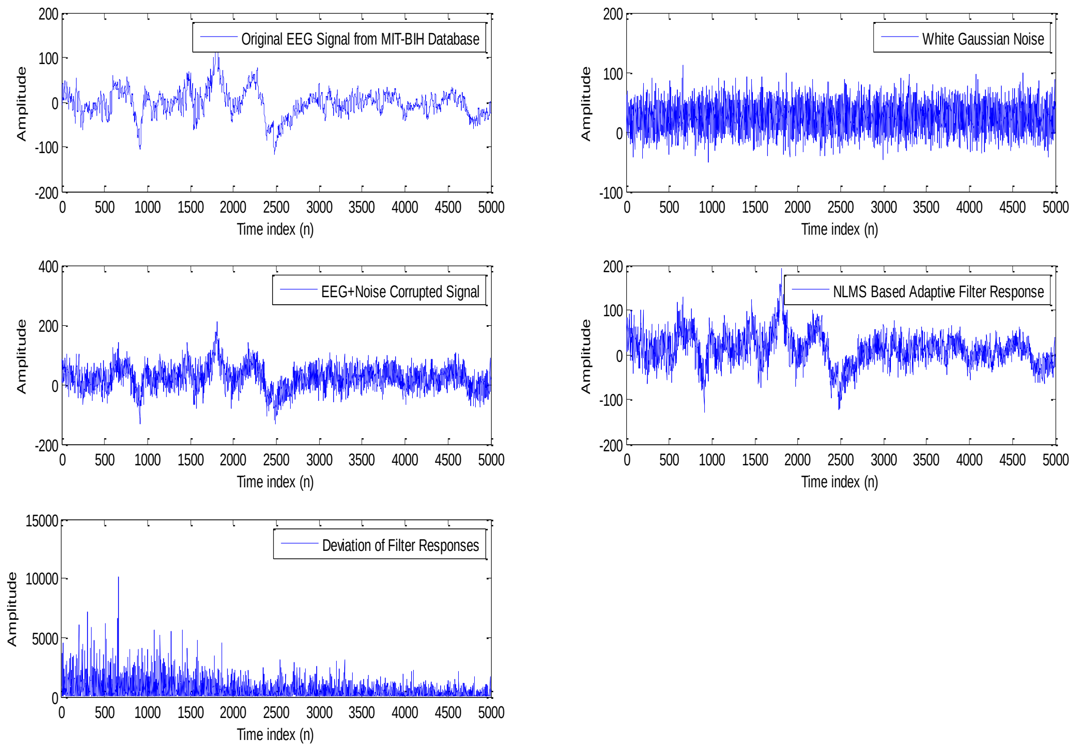

Fig.7: (a) Pure EEG signal taken from MIT-BIH Database (b) White Gaussian Noise with average amplitude 25mV (c) EEG signal mixed with pure EEG signal (d) NLMS based Adaptive Filter response (e) Square Deviation of NLMS based adaptive filter

Recursive Least Square (RLS) Algorithms:

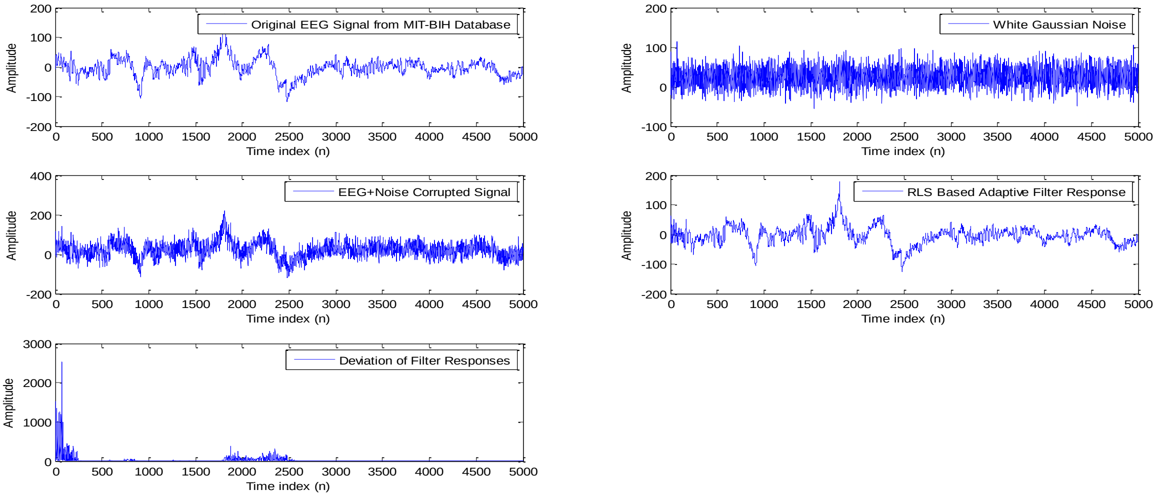

Fig.8: (a) Pure EEG signal taken from MIT-BIH Database (b) White Gaussian noise with average amplitude 25mV (c) EEG signal is mixed with pure EEG signal (d) RLS based Adaptive Filter response (e) Square Deviation of RLS based adaptive filter

Normalized Lest Mean Square (NLMS) calculation:

Random Noise (Amplitude)	**Least Mean Square (LMS)**	**Normalized Least Mean Square (NLMS)**	**Recursive Least Square (RLS)**
5mV (2% of original amplified EEG Signal Amplitude)	2.4360×10^{-4}	4.262×10^{-4}	3.3103×10^{-5}
10mV (4% of original amplified EEG Signal Amplitude)	7.9334×10^{-4}	1.6743×10^{-4}	2.2612×10^{-5}
15mV (6% of original amplified EEG Signal Amplitude)	2.2585×10^{-4}	1.3418×10^{-4}	1.2008×10^{-5}
20mV (8% of original amplified EEG Signal Amplitude)	5.9643×10^{-4}	2.4246×10^{-4}	6.2567×0^{-5}
25mV (10% of original amplified EEG Signal amplitude)	3.5566×10^{-4}	2.8322×10^{-4}	1.5938×10^{-5}
White Gaussian Noise (Amplitude)	**Least Mean Square (LMS)**	**Normalized Least Mean Square (NLMS)**	**Recursive Least Square (RLS)**
5mV (2% of original amplified EEG Signal Amplitude)	1.6212×10^{-4}	1.1086×10^{-4}	7.5146×10^{-5}
10mV (4% of original amplified EEG Signal Amplitude)	1.9208×10^{-4}	6.5963×10^{-4}	3.4666×0^{-5}
15mV (6% of original amplified EEG Signal Amplitude)	1.4405×10^{-4}	6.0342×10^{-4}	$3.8241\times^{-5}$
20mV (8% of original amplified EEG Signal amplitude)	8.4139×10^{-4}	4.2179×10^{-4}	1.5327×10^{-5}
25mV (10% of original amplified EEG Signal Amplitude)	4.2407×10^{-4}	2.4590×10^{-4}	7.0148×10^{-5}

The above simulation result suggests that Recursive Least Square algorithm (RLS) performs better than other two algorithms. RLS could be the best option for Telemedicine system to denoise EEG signal during transmission.

5. CONCLUSION

During transmission of EEG signal it may be corrupted due to random noise and Gaussian noise. So we have tested the performances of LMS, NLMS and RLS algorithm of adaptive filter. Our simulation result suggest that RLS could be the best option for recovering EEG signal or denoising EEG signal during transmission through Telemedicine system.

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