ISSN: 2278 – 909X
International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
Volume 4, Issue 7, July 2015

Noise Removal from Electroencephalogram Signal using SWT and RLS Adaptive Filter

Gautam Kaushal[1], Ankit Goyal[1], V.K. Jain[2], Amanpreet Singh[3]
[1]Electronics and Communication Engineering Department,Punjabi University,Patiala, Punjab,India
[2]Department of E.I.E.,Sant Longowal Institute of Engineering and Technology, Longowal (Sangrur) Punjab,India

Abstract: **Electroencephalogram is the signal that measures the electrical activity of brain. In EEG different kind of artifacts gets added. The major types of artifacts that affect the EEG are Power Line noise, eye movements, and Electrocardiogram (ECG). Noise due to eye movement is also called as ocular artifacts. To deal with OAs Different type of techniques and methods are evolved. In this paper new method is presented based on joint use of wavelet and RLS adaptive filter. Stationary Wavelet Transform (SWT) is used to decompose the signal. The SWT decomposes single channel EEG signal into components based upon different frequency Levels. RLS adaptive filter adjust the filter coefficients and make them approach the optimal filter coefficients as close as possible and help in obtaining clean EEG. The performance analysis of the algorithm is done using SNR and FFT.**

INDEX TERMS**:** Electroencephalogram (EEG), Recursive Least Squares (RLS), Stationary Wavelet Transform (SWT), Signal to Noise Ratio (SNR), Fast Fourier Transform (FFT).

I. INTRODUCTION

EEG is defined as the signal that is used to measure the electrical activity of brain. Electro-encephalography waveforms can be categorized into four basic groups: delta (0.4-4 Hz), theta (4-8 Hz), alpha (8-13 Hz), and beta (13-30 Hz). Sometimes one more wave may appear named as Gamma (above 30 Hz).While recording EEG signals, these signals are contaminated by different type of artifacts [1]. Mainly artifacts are divided into two parts technical artifacts and physiological artifacts. Technical artifacts are those artifacts that arise due to electrode placement problems and body movements. Most common physiological artifacts are due to movement of eye balls and eye lids, called as ocular artifacts [2In this paper an algorithm based on hybrid or joint use of SWT and RLS adaptive filter is investigated, and its performance in terms of SNR is compared with SWT and RLS. Stationary Wavelet Transform is used to decompose the signal. Then RLS adaptive filter is applied and Inverse SWT is applied from which components are reconstructed back to form de-noised signal [3, 4].

II. STATIONARY WAVELET TRANSFORM

Wavelet analysis is a time-frequency analysis and has the capacity of representing local characteristics in the time and scale (frequency) domains. Its capability in transforming a time domain signal into time and frequency localization helps to understand more the behavior of a signal. In low frequency, it has lower time resolution and in high frequency, it has higher time resolution and lower frequency resolution [5].
In Stationary Wavelet Transform (SWT) the signal is decomposed in to two levels one is approximation part and the other is detail part. The approximation domain is sequentially decomposed further into the detail and approximation data as shown in the figure 1 given below.

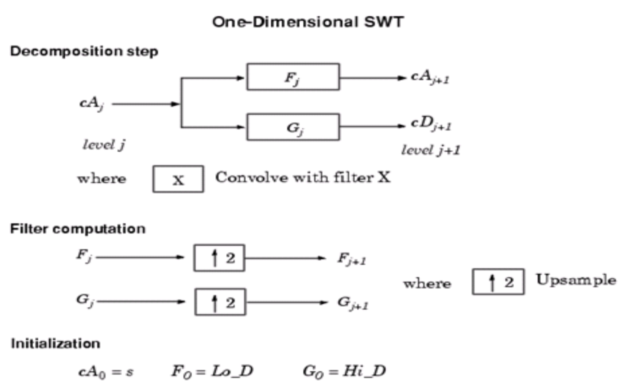

Figure 1: One dimentional SWT

III. RLS ADAPTIVE FILTER:

Figure 2 shows the most common form of adaptive filtering. Here x[n] is the input y[n] is output and d[n] is desired input. The difference between d[n] and y[n] defines the error signal e[n].the value of signal at any particular time say n_0 is used to adjust vector w_n of the adaptive filter at time n_0[6,7].

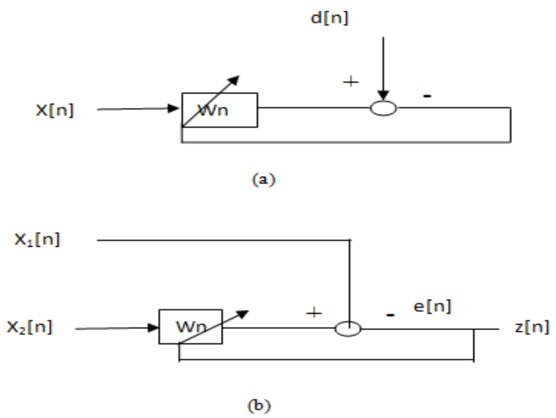

Figure 2(a) generic adaptive filter (AF) and (b) specific AF

$y[n] = w^t n \times x_{2n}$ (1)

The error signal e[n] is thus

$e[n] = x_1[n]-y[n] = x_1[n]- w^t n \times x_{2n}$ (2)

the weight w_n is adapted linearly at each time step according to

$w_{n+1} = w_n + e[n]g_n$ (3)

where g_n is vector of length l, the form of which depends upon particular type of generic adaptive filter used
for RLS g_n is given by

$g_n = \frac{P_{n-1} X_{2n}}{\lambda + X_{2n}^T P_{n-1} X_{2n}}$ (4)

Where the L×L matrix p_n is recursively defined by

$P_{L-1} = \frac{I}{\sigma}, P_n = \frac{P_{n-1}}{\lambda} - \frac{g_n X_{2n}^T P_{n-1}}{\lambda}$ (5)

Where λ is the forgetting factor and is takes as

$\sigma = 10^{-2}$ and $\lambda = 9999 \times 10^{-4}$ as in [8].

IV. *SWT-RLS BASED METHODOLOGY:*

SWT is used to decompose the both EOG and EEG signal into 8 levels. Both EEG and EOG signals are applied to the RLS adaptive filter at each level. To recover the signal in the form of original signal; wavelet reconstruction is done using inverse SWT.

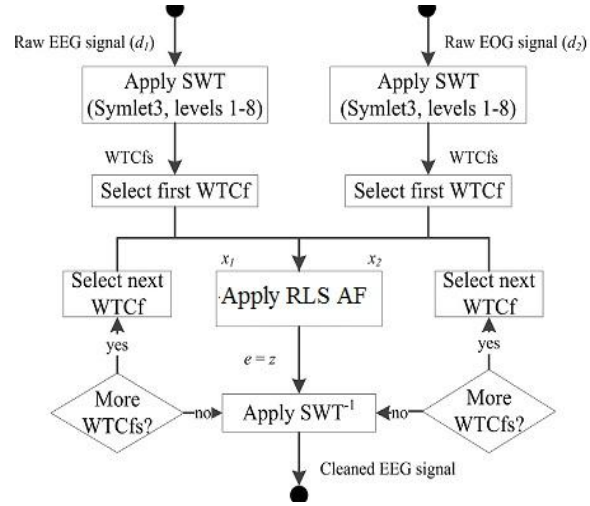

Figure 3 Block diagram of the proposed algorithm.

V. *METHODS FOR COMPARING AND EVALUATING RESULTS:*

In this paper, SNR and FFT plots are used to compare the performance of SWT-RLS joint technique with SWT & RLS Adaptive Filter.

Original ocular artifacts are considered with original EEG signal data is collected from CSIO-CSIR Chandigarh.

Where SNR is given by

$SNR = 20\log\frac{\text{rms (filtered signal)}}{\text{rms (noise)}}$ (6)

VI. *Result and Discussion:*

The Table given below gives the comparison of SNR values, of four data sets, used for noise removal by using three methods named SWT, RLS adaptive filter & a combination of SWT-RLS adaptive filter.

Data Set	SWT (db)	RLS (db)	SWT-RLS (db)
Data set 1	-4.335	10.396	17.790
Data set 2	-3.314	11.551	18.831
Data set 3	-3.660	13.668	20.554
Data set 4	-3.481	12.536	19.001
Avg.	-3.697	12.027	19.004

Table 1: Comparison of SNR

Here four data sets are used for the analysis. SNR values of SWT-RLS are compared with SNR values obtained individually.

Average SNR value of SWT-RLS joint technique is 19.004, which shows positive results as compared with SWT and RLS individually having average values of SNR -3.697 & 12.027.

Comparing the performance based on FFT plots is as shown below :

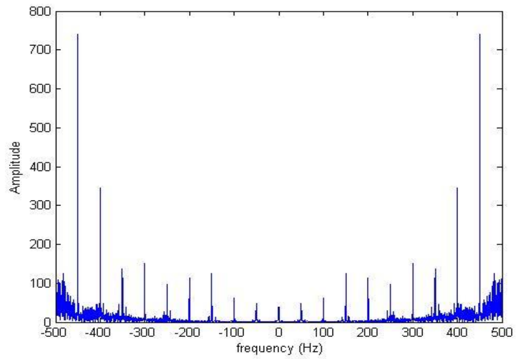

Figure 4.1 FFT of Original Signal

Figure 4.1 shows the FFT plot of original signal i.e. the raw signal having ocular artifacts,
FFT plots of cleaned signal using various techniques are as below:

Figure 4.2 is FFT plot of de-noised signal using SWT.

Figure 4.3 is FFT plot of de-noised signal using RLS.

Figure 4.4 is FFT plot of de-noised signal using SWT-RLS.

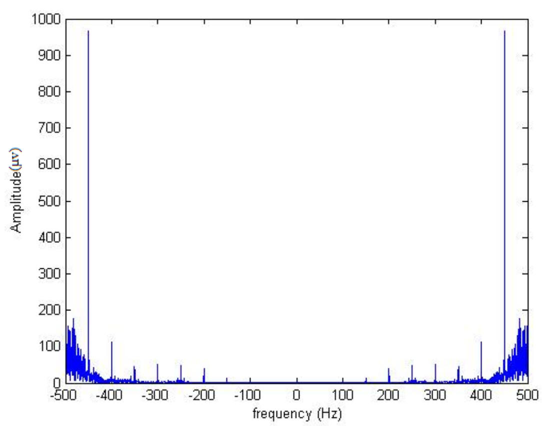

Figure 4.2 FFT after applying SWT

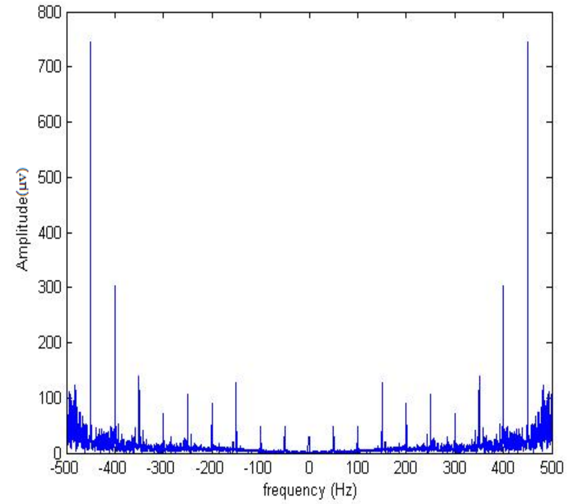

Figure 4.3 FFT after applying RLS Adaptive Filter

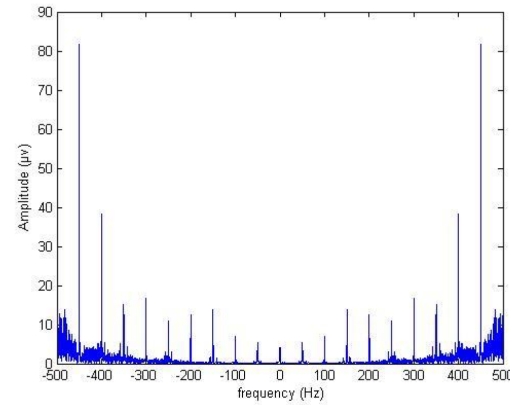

Figure 4.4 FFT after applying SWT-RLS

From the above FFT plots it is found that after applying SWT alone, the results shows that this technique cannot be applied individually on the signal where RLS shows the positive results. When hybrid SWT-RLS is applied it shows much better results than RLS adaptive filter alone..

VII. CONCLUSION:

In this paper, a method is proposed for the removal of Single channel EEG signal on the basis of hybrid use of SWT-RLS technique. The SWT analysis is done to de-compose the signal into 8 levels to find the noise at each level and applying RLS adaptive filter at each level. When compared with SWT and RLS individually, this method shows better results with negligible information loss.

REFERENCES:

[1] Murielle Kirkoven, Clementine Francois, Jacques Verly,"Comparative evaluation of existing and new methods for correcting ocular artifacts in EEG recordings". Elsevier (2013).

[2] Miguel A. Sovierzoski, Fernanda I. M. Argoud, Fernando M. de Azevedo, **"**Identifying Eye Blinks in EEG Signal Analysis" International Conference on Information Technology and Application in Biomedicine, in conjunction with The 2nd International Symposium & Summer School on Biomedical and Health Engineering Shenzhen, China, May 30-31, 2008.

[3] Zhang Xizheng, Yin Ling, Wang Weixiong Wavelet time-frequency analysis of electro-encephalogram (EEG) processing International Journal of Advanced Computer Science and Applications, 2010; Vol. 1(5)

[4] S.Mallat.,"A Wavelet Tour of Signal Processing" second ed. Academic Press, 1999.

[5] Monika Sheoran, Sanjeev Kumar, Amod Kumar, "Wavelet-ICA based Denoising of Electroencephalogram Signal". International Journal of Information & Computation Technology. ISSN 0974-2239 Volume 4, Number 12 (2014), pp. 1205-1210.

[6]Z.Xiao Ping, M.D.Desai, Adaptive denoising based on SURErisk, IEEE Signal Process. Lett5 (10) (1998) 265–267.

[7]C.M.Stein, Estimation of the mean of a multivariate normal distribution, Ann. Stat. 9 (6) (1981) 1135–1151.

[8] P. S. Kumar, R. Arumuganathan, K. Siva kumar, C. Vimal. Removal of artifacts from EEG signals using adaptive filter through wavelet transform signal processing. In: ninth IEEE International Conference on Signal Process ,2008

Author's Profile

Mr. Ankit Goyal was born in Punjab State, India country on 30 April, 1991. Received his B.TECH. degree in the Electronics and Communications Engineering Department from BGIET, PTU in 2012. Currently Pursuing M.TECH. from Electronics and Communications Engineering Department of Punjabi University, Patiala.

Gautam Kaushal was born in Punjab State, India country on 19th July, 1971. Received his B.TECH degree in the Electronics and Communications Engineering, from Nagpur University, Nagpur In 1993, M,Tech in Instrumentation & Control Engineering from SLIET Longowal in 2004. Worked at various posts in industry from 1993 to 2000, Worked as faculty in SLIET Longowal. Presently he is working as Assistant Professor ECE Department, Punjabi University Patiala. His area of interest is Biomedical Signal Processing.