Study and Analysis of Various Window Techniques Used in Removal of High Frequency Noise Associated in Electroencephalogram (EEG)

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***Abstract*: EEG signals are the versatile tool for detection of various kinds of Brain activities and diseases. But when the EEG data has been recorded for analysis purpose it is contaminated by different noise signals which are caused due to power line interference, electrode movement, base line wander, muscle movement (EMG) etc. and these days the E-health care system introduces in which there is a need of transmission of signals so at the time of transmission noise introduces. These noise signals are being proved hurdles in the diagnosis of brain which is not good and also not acceptable. To avoid the problem of these noise signals there are several techniques present which are able to reduce the presence of noise in the EEG signals. This research article presents the study of commonly used various window techniques in the removal of high frequency noise associated with EEG. During the study author has analyzed four window techniques as wavelet based de-noising technique, Adaptive filter algorithm, empirical mode decomposition (EMD) based de-noising technique and thresholding techniques. There is a comparative analysis between these four de-noising techniques.**

Keywords: Wavelet based DT; Adaptive filter algorithm; EMD-DT; Threshold techniques.

I. INTRODUCTION

EEG signals are measured with the help of an electroencephalograph. It is a bio-medical device which reads the electric signal occurring on surface of body which are related to contraction of brain and relaxation of brain. These signals are extremely important for the doctors because it provides the vital information of the brain and general health of the patient. The frequency band of the EEG bands is in the range of 1-50Hz [1]. A human brain contains a specialized electrical conductive system which ensures brain to contracts and relaxes in an effective fashion and coordinated way. When EEG signals are recorded there may have some basic artifacts with additional noise caused by some factors such as external electromagnetic field, power line interference, respiration and random body movements. We need to remove different type of noise or unwanted frequency ranges [2] by using various types of digital filters. It is known that it is difficult to apply filters having fixed coefficients for the reduction in bio-medical signal noises because the behavior of a human being is not time dependent, so these various filtering techniques available to solve these problems.

The electric pulses are flow through the membrane and these are recorded in the form of EEG [3]. EEG is a recording of a small period of time [12], [13]. Nervous system of a human body is communicating in the form of electric signals. The flow of electric current is passed when the neurons sends or receives any information, electric pulses passes across their membrane. The change in electric current creates a electric and magnetic signals and that signals are recorded from the scalp of human head [14].

These recorded EEG signals are used for the evaluation and investigation of brain disorders of a human brain. It help in evaluation of the person, who are suffering from brain problems. The continuous analysis of EEG signals is difficult. There are many types of EEG waves and are characterized as Alpha waves (7-14Hz), Beta waves (14-40 Hz), Theta waves (4-7.5 Hz), Gamma waves (above 40 Hz), and Delta waves (0.5-4 Hz). Every wave defines different state of human brain.

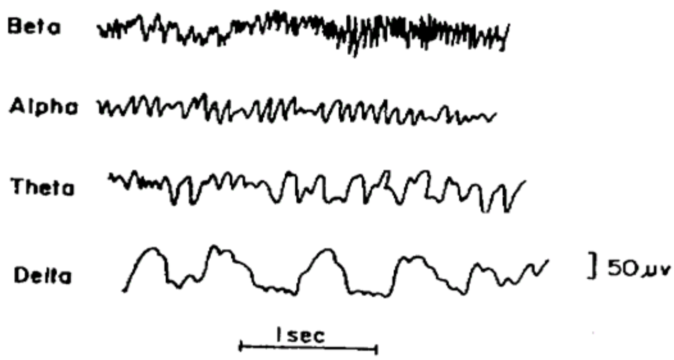


Fig.1. Classification of EEG waves.

In the above figure 1, shows four types of EEG signals. These signals contains very small amplitudes and this is the reason they can easily effected by the noise [14], [15]. This noise can be introduced by the electrodes or form the body itself. Noise signals are known as artifacts in EEG signals [16]. Various de-noising techniques are implemented for the removal of artifacts from these signals. All four methods are used here for the de-noising of EEG signals.

II. DE-NOISING TECHNIQUES

There are various filter available to de-noise any signal but when we are taking bio-medical signals or as here EEG signals have been taken for de-noise, some special techniques are used for them. They are as follows:

A. *Wavelet Based De-noising Technique*

The signal usually have noise and it is not normally eliminated in signal processing. According to the usual signal characteristic, frequency spectrum distribution and noise statistical property, there are many methods available for removing noises. These methods are divided into space and the transformation fields. Computers are discrete in nature so computer programs use discrete wavelet transform. Here the modeling of wavelet transform coefficients of original images and the applications to the signal de-noising problem.

De-noising of the original signal is corrupted by Gaussian noise and it is a traditional problem in signal processing. Due to energy compaction property, this transform is an important tool. In other words, wavelets are providing a framework for the signal de-composition in form of sequential signals which are known as approximation signals with a decreasing resolution.

Signal de-noising algorithm consists few steps, they are considered as noise signal n(t) and input signal x(t). When these components are added the noisy data y(t) i.e.

$$y(t) = x(t) + n(t) \quad (1)$$

The noise entered in the given system can be Gaussian or random, then apply wavelet transform to derive w(t)

$$y(t) \rightarrow w(t) \quad (2)$$

Modify wavelet coefficient w(t) by using a different algorithm i.e. inverse wavelet transform. And we get the x'(t).

$$w(t) \rightarrow x'(t) \quad (3)$$

The system shown in below figure has the complete wavelet based de-noising signals.

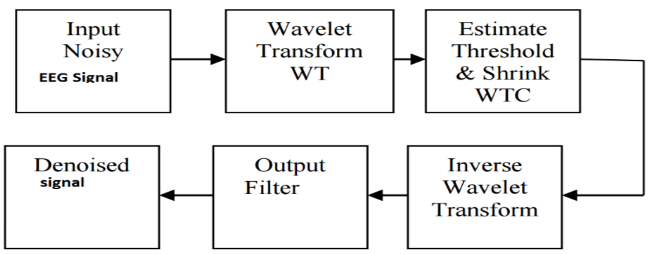


Fig.2. Signal De-noising using Wavelet Transform

The signal quality is based on signal to noise ratio of the de-noised signal.

B. Adaptive Filter Algorithm

When the EEG signals are transmitted through any telecommunication network, there is a possibility that it may be corrupted by white Gaussian noise or random noise available in the network. This Adaptive filter is using various algorithms which have been used to reduce noise from the transmitted EEG signal. MATLAB coding has been worked to reduce noise in EEG signals and for the reduction in noise we use digitalized EEG signal, those signals which are transmitted needs to be uploaded on MATLAB and then they are filtered using this filter with various algorithms and performance of these algorithms and also measured based on its de-noising capabilities.

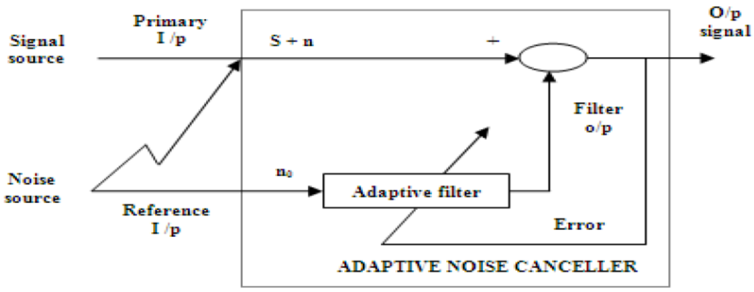


Fig.3. Adaptive Noise Canceller (ANC)

NLMS (Normalized Mean Square Algorithm), LMS (Least Mean Square) and RLS (Recursive Least Square Algorithm) has been designed for de-noising the EEG signal in MATLAB platform [4, 5, 6]. The simulation result suggest that RLS could be best option for the recovering EEG waves or removing noise from EEG signals during the transmission through telemedicine system.

C. EMD De-noising Technique

This univariate EMD algorithm [11] was defined as means of opening the highly localized time and frequency domain analysis of the non-linear and non-stationary signals. This is not similar as projection based scheme such as Fourier and it must sacrifice time location for the frequency location or vice versa, and Hilbert Transform obtained a physically meaningful concept of estimation of frequency at every time instant if input satisfying the narrow band criteria's. The principle concept of this EMD operation is for decomposing any vector in a set of AM/FM components and it also satisfies such criteria's. These components are also known as IMF's (intrinsic mode functions) and representing oscillation modes for data embedding.

This algorithm is decomposing an input as

$$S^{\lambda(d_k)} = \begin{cases} d_k = 0; D_k^2 \le \lambda^2 \\ d_k = d_k\left(1 - \dfrac{\lambda^2}{D_k^2}\right); D_k^2 > \lambda^2 \end{cases} \quad (4)$$

Where i=1, 2, 3, 4, ……, M

This equation denotes IMFs which extracting via shifting process. These lowest indexing IMFs are containing lowest frequency and the highest frequency dynamics.

D. Threshold Technique

When the DWT or complex form of Discrete Wavelet Transform are being applied on the noise corrupted EEG signals, many of the EEG signals energy are dependent on few components. The shrinkage step or the noise removal step is involving comparison of the magnitude of wavelet coefficient with a new estimated threshold value. The large magnitude represents the signal which are kept while in smaller magnitude coefficients (represents noise) set to be zero. To complete this task, standard deviation of the noise in signal required for calculate an optimized level of threshold.

There are many popular methods for estimating of, proposing by proposed by Donoho & Johnstone [7-8], it is based on the median absolute deviation (MAD) of a detail coefficients and it is given by this following formula,

$$\sigma = \frac{median\left(\left|x - x'\right|\right)}{0.6745} \quad (5)$$

0.6745 is used as the scaling factor for a normally distributed data. A threshold, which is identical all over world, function of the noise level σ and length of the signal "K", is used to state the threshold level (λ) and also it is given as

$$\lambda = \sigma\sqrt{2\log(k)} \qquad (6)$$

The thresholding is not applied on brief coefficients since the approximation coefficients have a very low frequency components so that they are least affected by the noise. These different thresholding techniques are used in the research paper are:

a. Hard Thresholding

This shrinkage function is given by [9]

$$S^{\lambda}(d) = \begin{cases} d, |d| \geq \lambda \\ 0, |d| < \lambda \end{cases} \qquad (7)$$

Where,

d = Single detail coefficient

Sλ(.) = Shrinkage function for λ threshold level.

b. Soft Thresholding

This shrinkage function is given by [9]

$$S^{\lambda}(d) = \begin{cases} sign(d), (|d| - \lambda), |d| \geq \lambda \\ 0, |d| < \lambda \end{cases} \qquad (8)$$

Where,

sign (.) is the signum function.

c. Semi-Soft Thresholding

This shrinkage function is given by [10]

$$S^{\lambda\lambda'} = \begin{cases} 0, |d| \leq \lambda \\ sign(d)\dfrac{\lambda'(|d| - \lambda)}{\lambda' - \lambda}, \lambda < |d| \leq \lambda' \\ d, |d| > \lambda \end{cases} \qquad (9)$$

Where,

λ”= μ x λ and value of the μ is decided by the experimental results.

For μ=1and ∞, it becomes equal to the Hard Thresholding and the Soft Thresholding respectively.

d. Neighboring Coefficients (NC) Thresholding

In this case, threshold function is determined by using neighboring coefficients also. Wavelet coefficient is modified as: ??2=??−12+??2+??+12 [10]

so that the two neighboring coefficients are also involved.

$$S^{\lambda(d_k)} = \begin{cases} d_k = 0; D_k^2 \leq \lambda^2 \\ d_k = d_k\left(1 - \dfrac{\lambda^2}{D_k^2}\right); D_k^2 > \lambda^2 \end{cases} \qquad (10)$$

III. METHODOLOGY

Acquiring the EEG signal from placing the electrodes on human scalp. The sensor position is shown in following figure 4 shown.

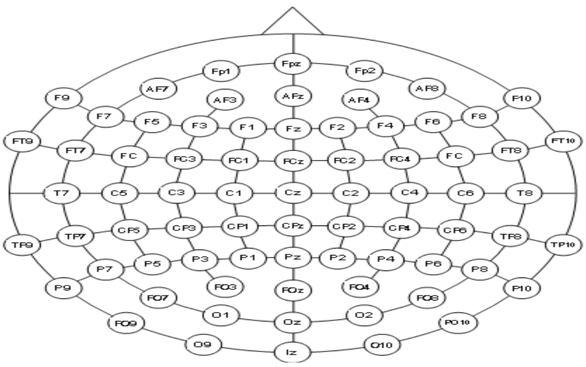


Fig.4. Position of electrode on human scalp

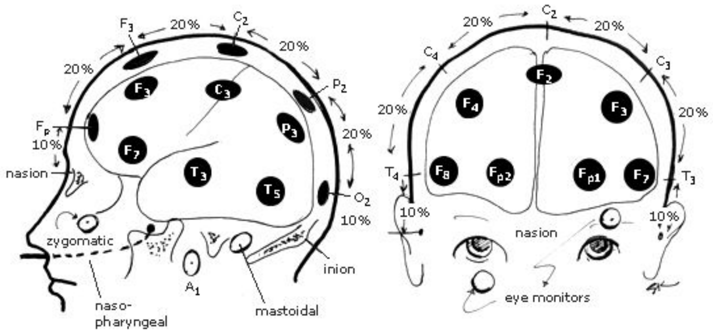
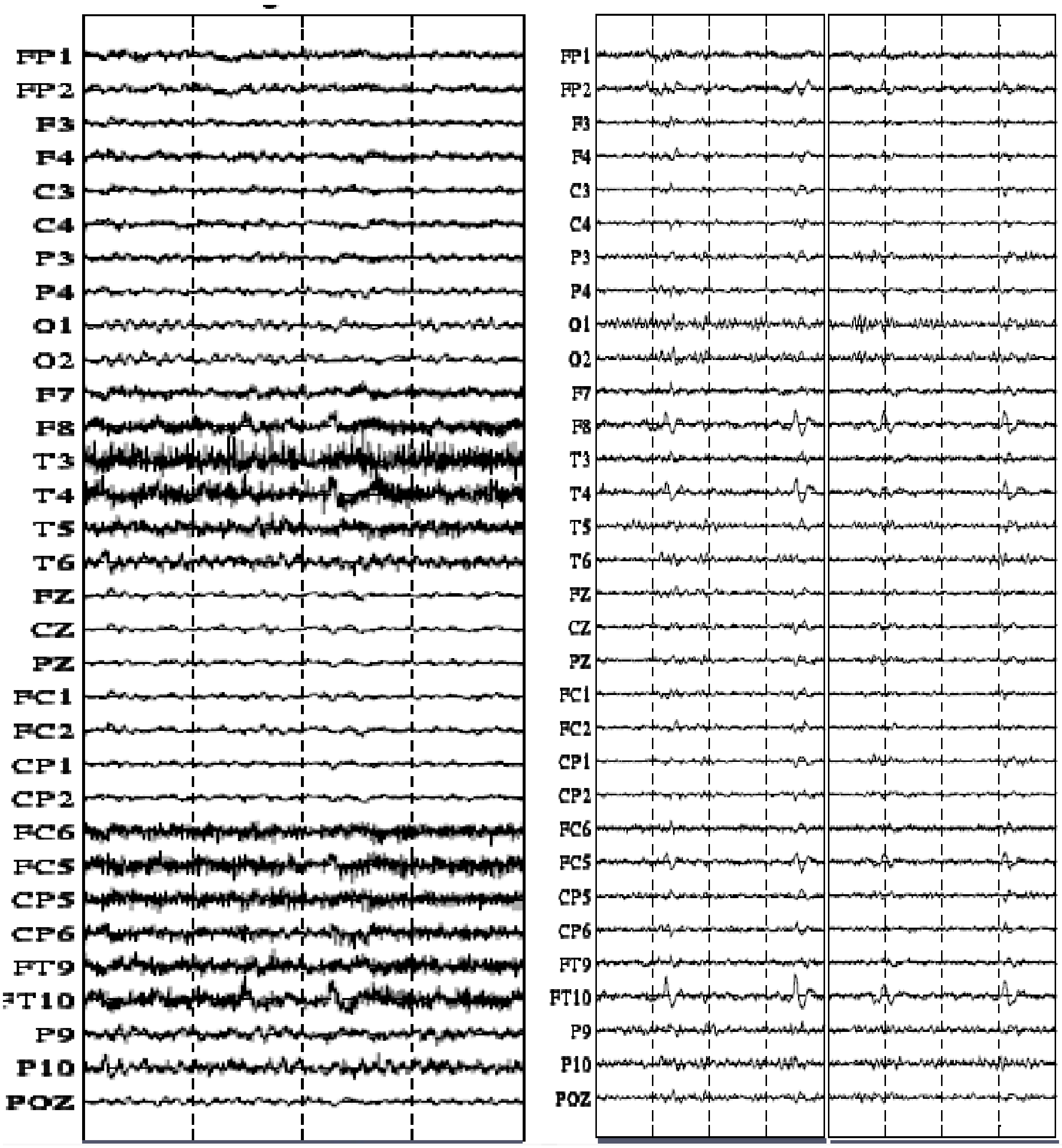


Fig.5. Distance calculation between any two electrodes

The electrodes are placed at the given location and acquire the signals by applying it to a system having MATLAB. Every de-noising window has been designed on it and the acquired signals are de-noised by them.



(a) (b)

Fig.6. (a) EEG signals (with noise) recorded directly by electrodes (b) EEG signals (without noise) after passing through filter or de-noising algorithm

The above figure 6 (a) showing the recorded EEG waves from the electrodes which contains noise. There is a following block diagram shown in figure 7 which the reduction of noise has been done by using the above explained four algorithms.

Filter designing in MATLAB

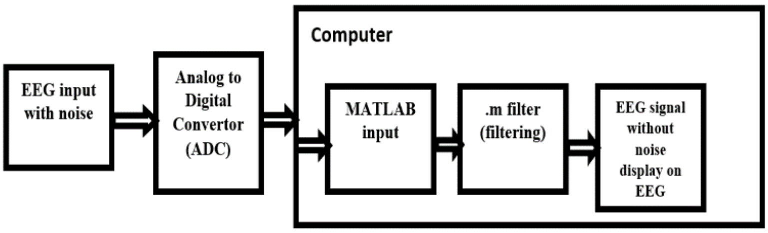


Fig.7. Block diagram of complete methodology

In above figure 6 (b) shown the de-noised EEG signal after using the above mentioned algorithms. The values are taken by every electrode for a certain time interval and showing the reduced level on noise which was previously introduced in the signals.

IV. RESULT AND DISCUSSION

Real Time EEG waves and how EMG corrupted EEG signals are look like shown in below figure 9. In the research section as we studied various window techniques for the removal of these noise signal and the result has been recorded by every algorithm are shown in figures below. After acquiring the result we can conclude that which window technique can be used for de-noising of signals easily.

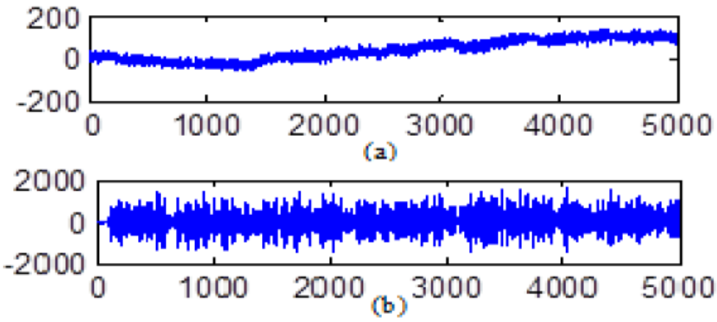


Fig. 9. (a) Real Time EEG (b) EMG interruption in EEG

Wavelet based de-noising technique result is showing in below figure 10.

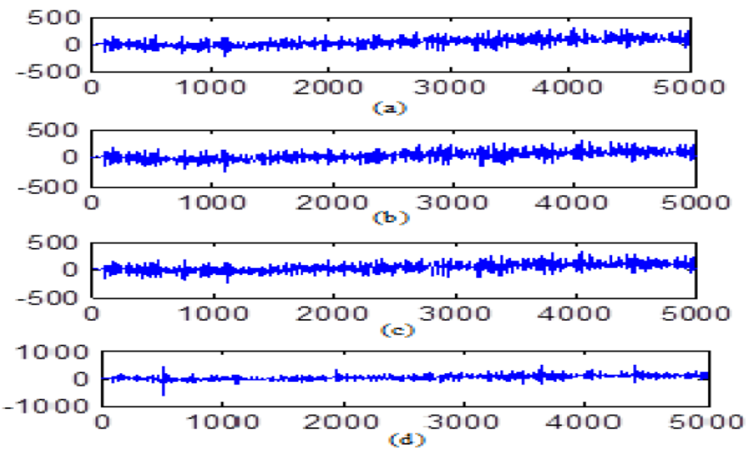


Fig. 10. Wavelet method used at different threshold levels

Adaptive filter Algorithm is used for de-noising and the following result is being obtained.

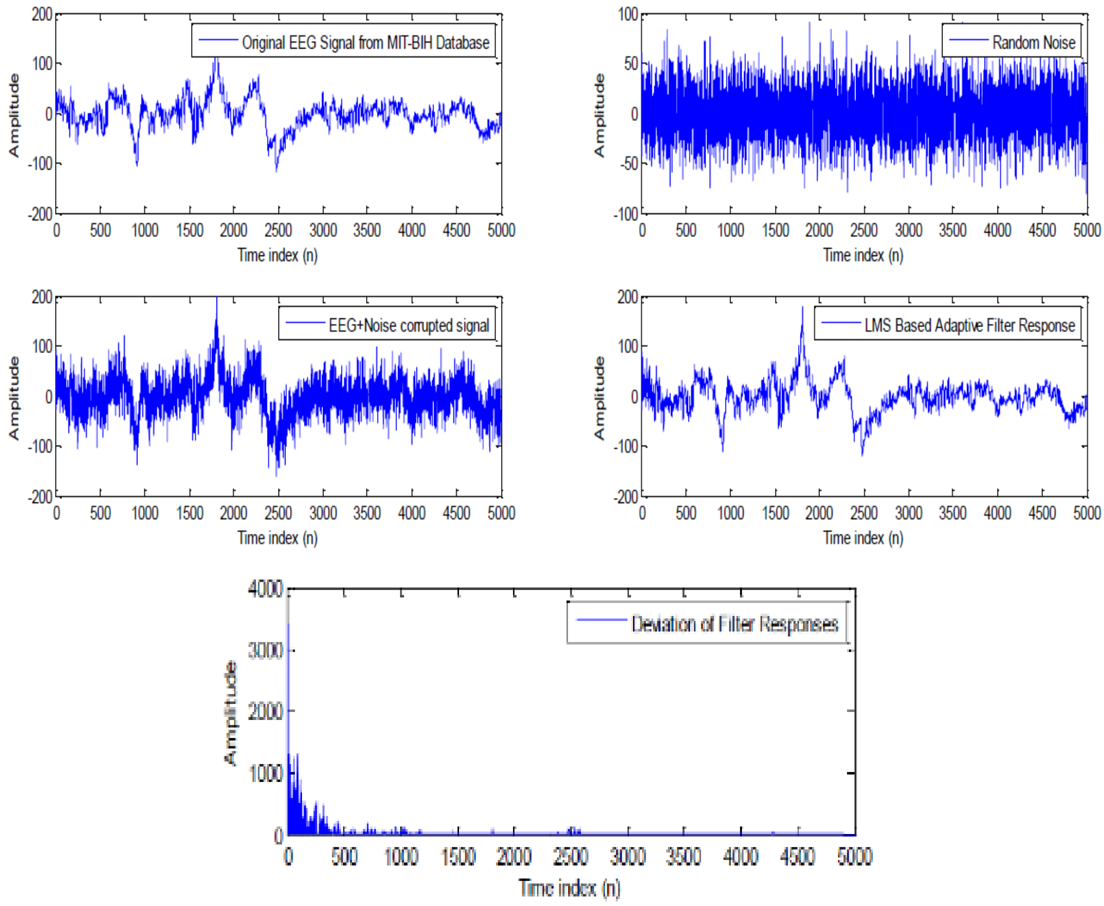


Fig.11. (a) Original EEG signals taken from EEG lab (b) Random Noise added with average amplitude 25mV (c) Noise signals mixed with Original EEG (d) Adaptive filter response € Square deviation based on adaptive filter

EMD de-noising technique is used for de-noising the recorded EEG waves and the result shown in figure 12.

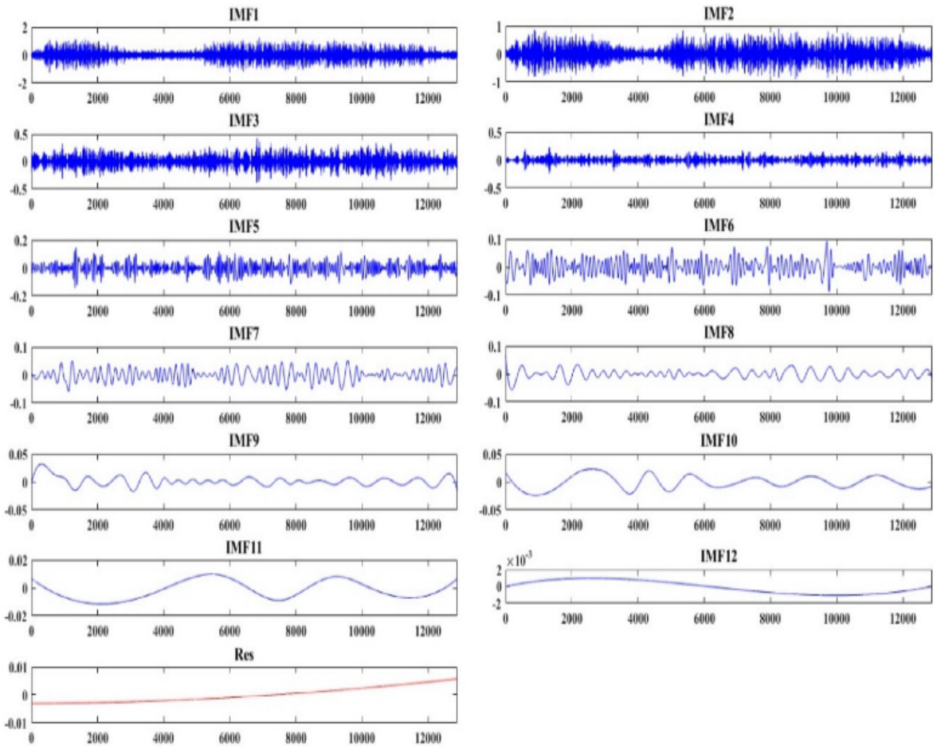


Fig.12. Removal of motion artifacts using sensor model for the compromised EEG recording which is obtained with the help of sensors

Threshold techniques result shown in figure 13 shown below.

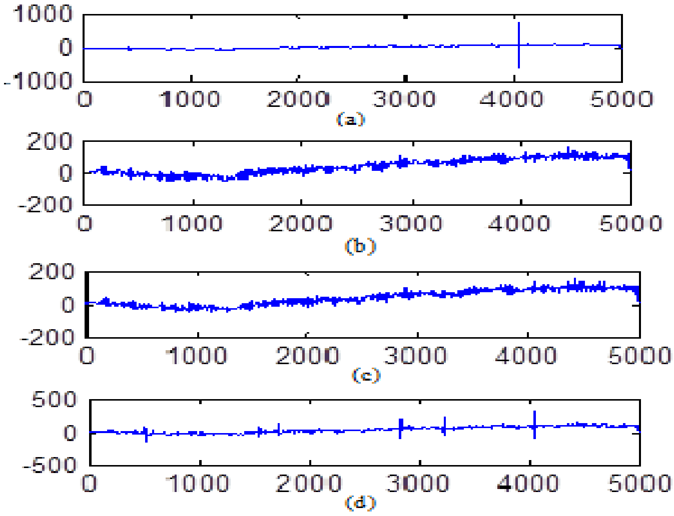


Fig.13. De-noising of real time EEG signal by using threshold level techniques

Every algorithm is used for de-noise the same signal and the result shows in following table 1 the SNR calculation is recording of input EEG waves. Table 2 shows the output SNR ratio.

Table 1. SNR calculation at Input part

Trial	WT	AF	EMD	Threshold
1	-13.113	-13.119	-13.444	-13.023
2	-13.126	-13.006	-13.568	-13.116
3	-13.022	-13.012	-13.116	-13.103

Table 2. SNR calculation at Output section

Trial	WT	AF	EMD	Threshold
1	-29.613	-29.549	-30.360	-26.403
2	-29.516	-29.506	-30.276	-26.107
3	-29.622	-26.512	-30.301	-26.113

V. Conclusion

The advanced epilepsy study and diagnosis which requires precise information, and it can be extracted from the non-invasive EEG data. But, the signals may be un-fortunately contaminated by the instrumental noise and various artifacts obtained from electrophysiological, such as the power noise, from the broken wire contacts, the ocular and other muscular activities. These noises and artifacts may hide the physiological activities. Among all errors muscular activities and ocular activities harm the EEG signal. The results which are observed that this general trend in the de-noising of EEG signals, these signals are distorted by EMG noise and there are four de-noising techniques which are used in this paper and here is an observation between the results of wavelet based transform, adaptive filter based de-noising technique, EMD based de-noising technique and various threshold techniques. During the transmission of real EEG signal, these signals may be corrupted by random noise and the Gaussian noise. Therefore, the testing of the real time EEG signals with the help of given four algorithms. The results are showed in form of waves which are simulation results.

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