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A Review On Methodological Analysis of Noise Reduction in ECG

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Abstract: *Due to fast life style Heart related problems are increasing day by day and it's very important that disease related to heart can be diagnosed easily by simple medical techniques. These diseases can be diagnosed by ECG (Electrocardiogram) signals. ECG measures electrical potentials from the body surface with contact electrodes, thus it is treated as one of the important signals. The ECG recording is often deteriorated by several factors such as power line interference and baseline wander noise. Various noises have to be removed for better clinical evaluation. This paper reviews the ways in which noise occurs & methodologies to remove such addition in the ECG signal. Some parameters like, Power Spectral Density (PSD), average power and signal to noise ratio (SNR) are calculated from ECG signal and compared with the performance of different methods used for removal of ECG noise.*
Keywords: *ECG, power line interference, FIR filters, Windows, Power spectrums.*

I. Introduction

The electrocardiogram(ECG)[1] is a non-invasive test that shows the electrical activity of the cardiac over time and it is very useful in the study and investigation of cardiac disease, for example a cardiac arrhythmia. In recording an ECG signal is frequently corrupted with different types of noises in the form electrical and mechanical noises .electrical noise such as 50Hz power line interference baseline drift, electrode movement, white noise and motion artifact etc. Hence, removal of artifacts in ECG signal is as a pre-processing action in number of disease analysis for diagnosis and clinical applications. When we try to de noise the ECG signal, gets some sort of success when using traditional methods such as linear filers, signal averaging, and their combination. Recently, adaptive and non adaptive filter and wavelet transformation have been developed as one of the most common and effective tools in processing and analysis of biomedical signals such as ECG. It can be recorded by electrodes placed on the surface of body. Fig.1 shows ECG signal of normal heart beat. The power line interference noise (50 Hz) introduce in system due to the electromagnetic interference from the electric-power system. The main cause for the power line interference is poor grounding of ECG machine. Such noise can cause problems interpreting low-amplitude waveforms. Baseline wander noise, usually in the range of 0.15Hz - 0.3Hz occurs due to perspiration, respiration, body movements of the human. The least mean squares (LMS) criterion is a search algorithm that can be used to provide the strategy for adjusting the filter coefficients. A number of adaptive structures have been used for different applications in adaptive filtering [2].

The objective of this paper is review of the removal of noise from ECG signal. The paper suggests the method which are not much complicated. ECG signal is shown in Fig. 1

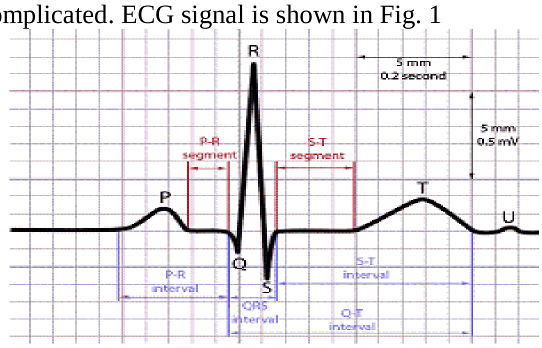

Fig.1. Normal ECG Signal

Signal processing is a big challenge since the actual signal value will be 0.5mV in an offset environment of 300mV. Other factors like AC power-supply interference, RF interference from surgery equipment, and implanted devices like pace makers and physiological monitoring systems can also impact accuracy [3]. The main sources of noise in ECG are

- Baseline wander (low frequency noise)

•Power line interference (50Hz or 60Hz noise from power lines depends upon country)
•Muscle noise (This noise is very difficult to remove as it is in the same region as the actual signal. It is usually corrected in software.)
•Other interference (i.e., radio frequency noise from other equipment)

II. Various Noises In Ecg

Different values of artificial noise patterns were assessed for each of the noise categories. Potential differences of 1 to 3 mV generated at the body surface by the current sources in the heart are picked up by the electrodes and are amplified in order to improve the signal to noise ratio (SNR).

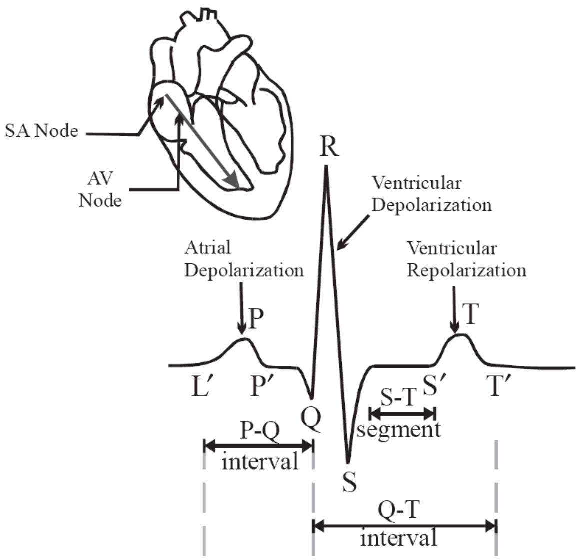

Fig.2. The SA node causes atrial depolarization (P complex).

The digitization process should use a sampling rate of at least 1 kHz to ensure that the ECG trace is of a high enough resolution as required for biometric purposes [4].ECG measurements may be corrupted by many sorts of noise. The ones of primary interest are,

1. Power line interference
2. Base Line Wandering
3. Motion artifacts

2.1 Power line interference

Plotting a Fourier power spectrum of a typical ECG signal reveals various common ECG frequency components. Several interesting features are readily identifiable.

- The 1.2 Hz heart beat information(72 BPM)
- The 50Hz power line interference

The remainder of the frequency components represents the subject information (situated between 0.1 Hz and 40 Hz) and contributions of other noise sources. power line interference has two mechanisms, capacitive and inductive coupling. Capacitive coupling refers to the transfer of energy between two circuits by a coupling capacitance present between the two circuits. The value of the coupling capacitance decreases with increasing isolation of the circuits. Inductive coupling on the other hand occurs because of mutual inductance between two conductors. When current flows through wires it produces a magnetic flux, which can induce a current in near by circuits. The geometry of the conductors as well as the separation between them determines the value of the mutual inductance, and so is the degree of the inductive coupling. the capacitive coupling is responsible for high frequency noise while inductive coupling introduces low frequency noise. For this reason inductive coupling is the dominant mechanism of power line interference in electro cardiology. Ensuring the electrodes are applied properly, that there are no loose wires, and that all components have a sufficient shielding should limit the amount of power line interference.[3][4][5]

2.2 Base Line Wandering

This is due to variations in the position of the electrode with respect to the heart and changes in the propagation medium between the heart and the electrodes. This causes sudden changes in the amplitude of the ECG signal [3][6]. In addition, poor conductivity between the electrodes and the skin reduces the amplitude of the ECG signal and increases the probability of disturbances (by reducing SNR). The underlying mechanism[7] resulting in these baseline disturbances is electrode-skin impedance variation. The larger the electrode-skin impedance, the smaller the relative impedance change needed to cause a major shift in the baseline of the ECG signal. If the skin impedance is extraordinarily high, it may be impossible to detect the signal features reliably in the presence of body movement [8]. Sudden changes in the skin-electrode impedance induce sharp baseline transients which decay exponentially to the baseline value.[9]

2.3 Motion artifacts

These type of noise can be remove by taking great care at time of ECG signal recording. These type of artifacts are introduce due to movement of patient.

III. Methodologies To Remove Noise

There are various method to remove noise from ECG signal. Some of these method are review here which are fallow

1. Digital filters structure
2. Digital FIR filter Method
3. Adaptive filters method
4. Order Averaging method
5. Modulus Maxima algorithm
6. QRS Detection method

3.1 Digital filters structure

A digital filter structure is used [10] to maximally de noise ECG signals. This system is based on cascading a zero-phase band- pass, an adaptive filter and multi-band-pass filter. these structure provides an efficient method for removing noise from the ECG signals. This filter structure has low implementation complexity and introduces little noise into a typical ECG signal. It can be applied to real-time applications particularly automatic cardiac arrhythmia classifiers.

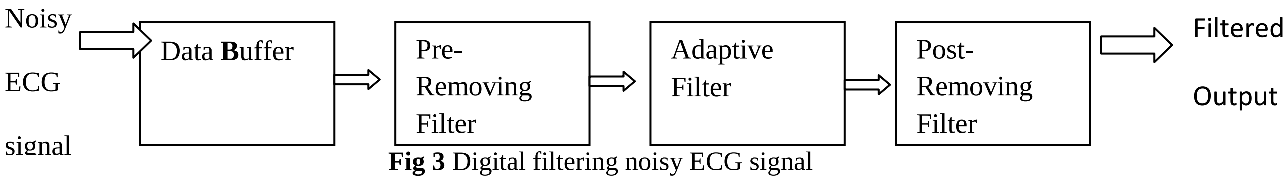

Fig 3 Digital filtering noisy ECG signal

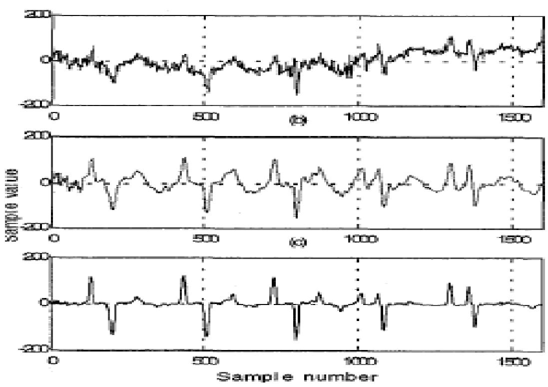

Fig 4. Result of Digital Filter[6]

3. 2 Digital FIR filter method

Digital FIR filters are successfully employed in processing electrocardiographic signals for measurement. ECG which is a biomedical signal is naturally corrupt by various interferences such as 50Hz Power Line Interferences (PLI) and some other biomedical signals like baseline wander ECG signal frequency is approximately between 0.05Hz and 100Hz. Baseline Wander frequency is below 1 Hz.[1] These interferences have to be removed from ECG signal in order to obtain correct clinical information of the heart. Since the frequency of ECG depends on the muscle movement rate and pressure it can be reduced to the barest minimum during ECG measurement by the patient staying still and quiet so that the muscles are fully relaxed.

In signal processing,[11] the function of a filter is to remove unwanted parts of a signal, such as random noise, or to specify useful parts of the signals, such as components lying in a certain important frequency range. There are two main kinds of filters; Analog and Digital filters. General digital filter design process is used as they have many advantages including size, cost, component tolerance, speed etc [12]. The window method is most commonly used method for designing FIR filters. The simplicity of design process makes this method very popular. A window is a finite array consisting of coefficients selected to satisfy the desirable requirements.

When designing digital FIR filters using window functions it is necessary to specify:[1][12]

- A window function to be used; and
- The filter order according to the required specifications (selectivity and stop band attenuation).

These two requirements are interrelated. Each function is a kind of compromise between the two following requirements:

- The higher the selectivity, i.e. the narrower the transition region; and
- The higher suppression of undesirable spectrum, i.e. the higher the stop band attenuation.

There are two categories of digital filter: the recursive filter and the non recursive filter. The desired frequency response specification$Hd(\omega)$, corresponding unit sample response $hd(n)$is[1][12][13] determine using the following relation

$$hd(n) = \frac{1}{2\pi}\int_{-\pi}^{\pi} \mathrm{Hd}(\omega)e^{j\omega n}\mathrm{d}\omega \qquad (1)$$

Where

$$Hd(\omega) = \sum_{n=-\infty}^{\infty} hd(n)e^{-j\omega n} \qquad (2)$$

Unit sample response $h_d(n)$ above relation for infinite in duration, so it must be truncate to some point to yield an FIR filter of length M(0 to M-1).The different windowing methods are used in designing which include Rectangular, Kaiser, Gaussian, Hamming.A comparison is also done for all the different windows. In this section we present different window methods which are used to design of FIR filters.[1][12][13]

3.2.1Kaiser Window

In this window the side lobe level can be controlled by with respect to the main lobe peak by varying a parameter α. Kaiser window parameter β affects by side lobe attenuation α db [1][12][13]. The width of main lobe can be varied by adjusting the length of the filter.

$$\beta = \begin{cases} 0.1102(\alpha - 8.7), \alpha > 50 \\ 0.582(\alpha - 21)^{0.4} + 0.7886(\alpha - 21), 21 \le \alpha \le 50 \\ 0, \alpha < 21 \end{cases} \qquad (3)$$

Where α =-20log10δ is the stop band attenuation in db. Increasing β then decreases the amplitude of side lobe. Filter order for FIR filter is

.
$$N = \frac{\alpha - 8}{2.285\,\Delta\omega} + 1 \qquad (4)$$

Here N is the filter order and Δω is the width of the smallest transition region.

3.2.2Hanning window

The coefficient of a Han window is calculated from the following equation.

$$\omega(n) = \begin{cases} 0.5 - 0.5\cos\frac{2\pi n}{N}, 0 \le n \le M-1 \\ 0, Otherwise \end{cases} \quad (5)$$

The width of main lobe is approximately 8π/M and peak of first side lobe is at –32dB [1][12][13].

3.2.3Hamming Window

The causal Hamming window function are calculated by

$$\omega(n) = \begin{cases} 0.5\,4 - 0.46\cos\frac{2\pi n}{M-1}, 0 \le n \le M-1 \\ 0, Otherwise \end{cases} \quad (6)$$

The width of main lobe is approximately 8π /M and the peaks of first lobe is at –43dB[1][12][13]

3.3 Adaptive filters

Modern era of medical treatment is equipped with by computerized processes. Signals generated from the human body provide valuable information about the biological activities of body organs. The organs' characteristic topologies with temporal and spectral, properties, can be correlated with a normal or pathological function. In response to dynamic changes in the behavior of those body parts , the signals exhibit time varying, non-stationary responses. The signals are always contaminated by a drift and interference caused by several bioelectric phenomena, or by various types of noise, such as intrinsic noise from the recorder and noisefrom electrode-skin contact. In paper[14][15] has been mentioned use of adaptive Filters for noise cancellation and analysis ECGSignals Figure 5 shows the simple and advance adaptive structure for a noise cancellation application.The desired signal *d* is de noise by uncorrelated additive noise *n*. The input to the adaptive filter is a noise n' that is correlated with the noise *n*. The noise *n*' could come from the same source as *n* but modified by the environment. The adaptive filter's output *y* is adapted to the noise *n*. When this happens, the error signal approaches the desired signal *d*. The overall output is this error signal and not the adaptive filter's output *y [14]*.

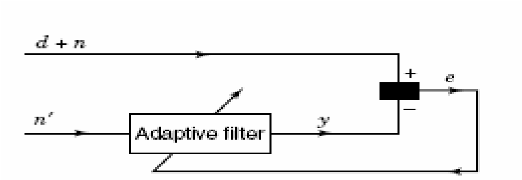

Figure 5 Adaptive Filter structure for noise cancellation

3.4Order Averaging method.

Ordered averaging allows to improve noise reduction, especially when it is non stationary. Noisy cycles are rejected when they do not contribute to reduction. The results of ordered averaging depend on the correct estimation of noise variance, which estimate depends on several parameters. One parameter is window's length, because a small window contributes with a large random error which affects the ordering. The location of this window inside the cycle is also important because if any useful signal is included the noise will be overestimated. Another parameter is the method to evaluate the noise in the averaged signal. It is better to estimate the noise variance of the averaged signal from the estimated variance of every cycle than to estimate from the averaged signal[16]

3.5 Modulus Maxima algorithm

Removal of noise from ECG has always been an important tissue in biomedical engineering. The purposes[12] of de noising are reducing noise level and improving signal to noise ratio (SNR)without distorting the signal. This paper[17]suggest to remove white Gaussian noise from ECG signals. The concepts of singularity and local maxima of the wavelet transform modulus are used for analyzing singularity and re constructing the ECG signal. Adaptive thresholding was used to remove white Gaussian noise modulus maximum of wavelet transform and then signal is reconstructed.

Fig 6 Filtering of ECG Signal By Modulus Maxima

3.6 QRS Detection

QRS complex detection method combined with several artifact sources reduction methods has been use to performed to removal of Baseline drift, Butterworth filtering, notch filtering and extracting five special features from ECG included inQRS detection algorithm to identify QRS complex. In order to validate the robustness of QRS detection [18],four important artifact sources such as power line interference, electrode contact noise, muscle contraction(EMG)and motion artifact have been produced and added with ECG signal. The performance of this approach against these noises based on three MIT-BIH recording classes (Normal TWA and LQT) has been discussed with Receiver Operating Characteristics. 100% and 94.88% accuracy has been achieved by QRS detection algorithm in best and worst case respectively. Reduce EMG noise, motion and power line artifacts effectively and respiration modulation cancelled by this method.QRS complex with more accurate performance comparing with Pan-Tompkins and Hamilton Tompkins method. Some different methods such as morphological derivative transforms have been considered in studies for wave detection in ECGs. To determine the performance of QRS detection algorithm in a noisy environment with power line interference, electrode contact artifact, motion artifact and muscle contraction the following procedure is applied as shown in figure(7) (a) recalling suitable ECG database (b) produce and applying noise sources (c) de-noising (d) QRS-complex detection.[18]

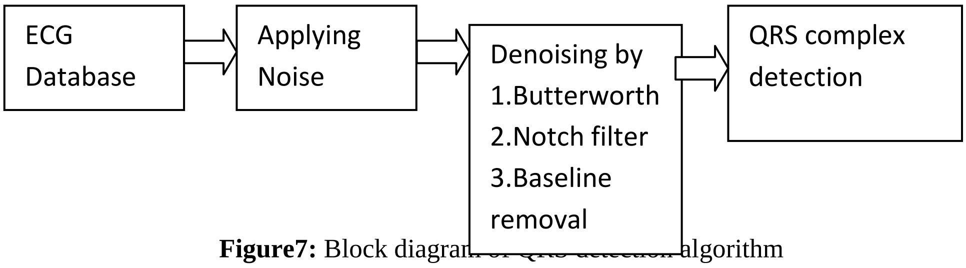

Figure7: Block diagram of QRS detection algorithm

IV. Latest Trends

A hybrid model [19] which combines the wavelet transforms and Empirical Mode De composition (EMD) is used. Noisy ECG is given as input of EMD. EMD is used for decomposition of signals in IMF's and by using wavelet thresholding method, de-noising is performed on all the IMF's and clean IMF's are taken. Finally there construction of all the IMF's is performed. Then clean ECG is taken as an output. EMD is good in decomposition and wavelet thresholding has better noise removing ability. Using the advantages of these hybrid techniques improved results is obtained.

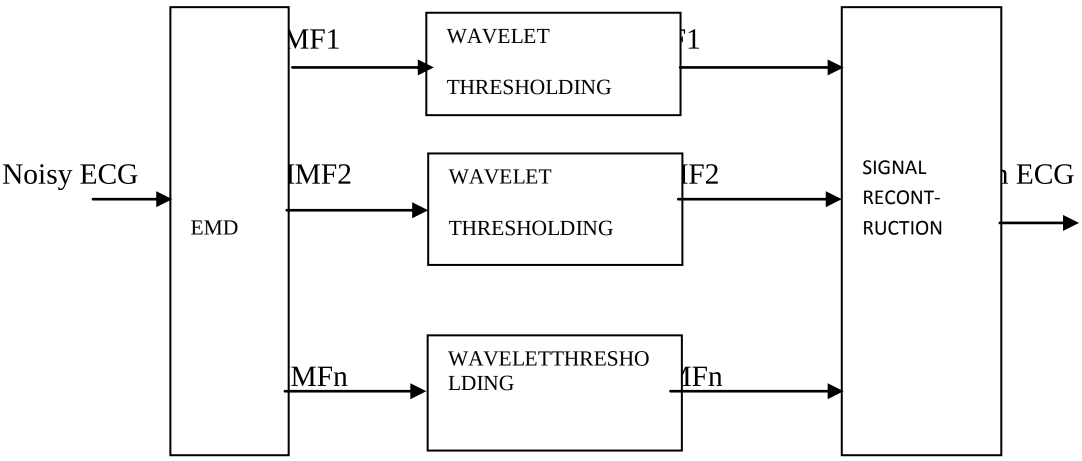

Fig. 7 Hybrid model

Adaptive filtering used to removing artifacts from cardiac signals. It's results indicate that LMS and NLMS algorithm based adaptive filters have estimated the respective signals from the noisy environment accurately.[20]

When using two different noisy ECG signals have been analyzed and compared after passing through FIR and IIR low pass filters. These filters are designed and simulated using Kaiser Window and Elliptic techniques respectively. These comparisons are made based on signal to noise ratio (SNR). The results show that the signal to noise ratio (SNR) varies according to the sample length of the ECG signal. It is clear from the results that Kaiser Window based FIR filter has better signal to noise ratio (SNR) as compared to Elliptic based IIR filter design. This means that Kaiser Window technique reduces the maximum noise from the ECG signal.[21]

V. Conclusion

The adaptive filter can also improve the performance of proposed structure in solving the source dependency problem also acting as self-adapting algorithm which process according to characteristics of present data instead of using the general parameter of ECG Signal.FIR FILTER is easy to implement but it has poor result when we increasing order of filter drawback of wavelet transformation is that it is not good in de composition , since it has frequency limits while decomposing. Although digital filter has less efficiency but they are easy to implement and feasible practically. Drawback in neural network sis that, if the number of neurons in the layer increases, performance of the technique will degrade. A disadvantage of fuzzy is that, it is difficult to estimate the membership function. Drawback in wavelet transform is that, it is not good in decomposition, since it has some frequency limits while decomposing. Since every method has some disadvantages ,hybrid techniques is proposed. Empirical Mode De composition(EMD) and Wavelet thresholding techniques are combined in this proposed method. EMD has the good ability to decompose the signal. Wavelet thresholding is good in removing noise from decomposed signal. Using the advantages of both methods, performance of de-noising has been improved. Signal to noise ratio (SNR) is the main parameter used in ECG de noising techniques.

References

[1] RavindraPratapNarwaria,"Reduction of noise from ecg signal using fir low pass filter with various window techniques", Current Research in Engineering, Science and Technology (CREST) Journals, ISSN 2320-706X

[2] Cramer E, McManus CD, Neubert D., "Estimation and removal of power line interference in the electrocardiogram: A comparison of digital approaches", Comput Biomed Res. 1987 Feb; 20(1):12-28

[3] Mahesh chavan, * RA.Agarwala, ** M.D.Uplane"Suppression of Baseline Wander and power line interference in ECG using Digital IIR Filter" , Issue 2, Volume 2, 2008 356 Manuscript Received August 3, 2007; Revised Received December 5, 2007

[4] Mbachu C.B and Offor K.J, "reduction of powerline noise in ecg signal using fir digital filter implemented with hammingwindow", International Journal of Science, Environment and Technology, Vol. 2, No 6, 2013, 1380 – 1387 ISSN 2278-3687 (O)

[5] RinkyLakhwani, J.P. Saini, "DESIGN AND COMPARISION OF DIGITAL FILTERS FOR REMOVAL OF BASELINE wandering from ecg signal", 2013 5th International Conference on Computational Intelligence and Communication Networks, 978-0-7695-5069-5/13 $26.00 © 2013 IEEE

[6] Na pan, VaiMang, Mai Peng Un,PunSio Hang, "Accurate Removal Of Baseline Wander In ECG Using Empirical Mode Decomposition", Proceedings of NFSI & ICFBI., China, October 2007.

[7] Sornmo L. "Time-varying digital filtering of ECG baseline wander", Med BiolEng Computer. 1993Sep; 31(5):503-8

[8] Kanhaiya Kumar1, Saurabh Anand2 and Ram Lal Yadava3" Advanced DSP Technique to Remove Baseline Noise from ECG Signal "International Journal of Electronics and Computer Science Engineering 1013 Available Online at www.ijecse.org ISSN-2277-1956

[9] Min Daia, b,, Shi-Liu Liana, b, Removal of Baseline Wander from DynamicElectrocardiogram Signals, This work is sponsored by the foundation of Tianjin Municipal Education Commission (SB20080044). IEEE 978-1-4244-4131-0/09,2009.

[10] Hamid Gholam-Hosseini, Homer Nazeran, Karen J. Reynolds ,ECG Noise Cancellation Using Digital Filters,2nd lntemational Conference on Bioelectromagnetism, MelboumeAUSTRALIA, February 1998

[11] Digital signal processing –Principles, Algorithms, and Applications–John G.Proakis

[12] Kaiser, J.F., "Nonrecursive Digital Filter Design Using the I0-sinhWindow Function," Proc. 1974 IEEE® Symp. Circuits and Systems, (April 1974), pp.20-23.

[13] Emmanuel. C. Ifeachor, Barrie. W. Jervis, Digital Signal Processing

[14] SoroorBehbahani ,Investigation of Adaptive Filtering for Noise Cancellation in ECG signals'Second International Multisymposium on Computer and Computational Sciences IEEE DOI 10.1109/IMSCCS.2007.77, 2007

[15] AkankshaDeo, " De-noising of ECG Signals with Adaptive Filters**",** *IRACST – International Journal of Computer Networks and Wireless Communications (IJCNWC), ISSN: 2250-3501 Vol.3, No3, June 2013*

[16] Juan Ramos and 1Ramd.n Pallas-Areny,ecg noise reduction by ordered averaging, 18th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 4.2.2,Amsterdam 1996

[17] Mohammad Ayat, Mohammad B. Shamsollahi1, BehroozMozaffari, Shahrzad Kharabian1,"ECG De-noising Using Modulus Maxima of Wavelet Transform" ,31st Annual International Conference of the IEEE EMBS Minneapolis, Minnesota, USA, 978-1-4244-3296-7/09 , September 2-6, 2009

[18] ElhamZeraatkar, SaeedKermani, AlirezaMehridehnavi ,ArashAminzadeh, Improving QRS Detection for Artifacts Reduction, 17th Iranian Conference of Biomedical Engineering (ICBME2010), IEEE 978-1-4244-7484-4/10,3-4 November 2010

[19] B.pradeep Kumar,S.Balambigai,Dr.R.Asokan"ECG De-noising based on Hybrid Technique"IEEE International conference on Advance in engineering science and management March 30,31,2012

[20] arpit sharma1, sandeep toshniwal2, richa sharma3" noise reduction technique for ecg signals using adaptive filters" international journal of recent research and review, vol. vii, issue 2, june 2014

[21] manish chauhan1, rajesh mehra"ECG noise reduction filter using elliptic & kaiser techniques" international journal of advanced engineering research and technology (ijaert), issn: 2348–8190icrtiet-2014 conference proceeding, 30th -31st august 2014