ECG SIGNAL INTERFERENCE SUPRESSION USING MEDICAL ELECTRONICS : A SURVEY

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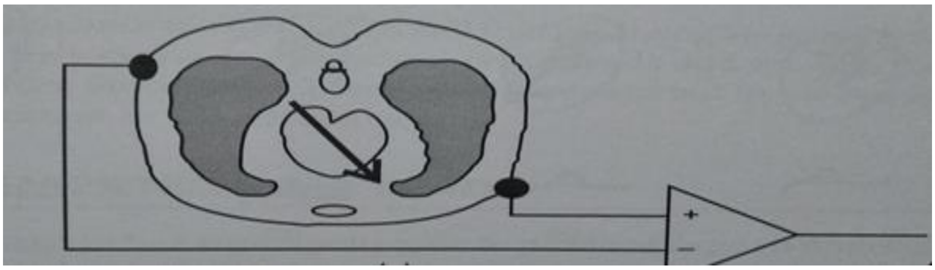
Abstract : This paper illustrate different process for ECG denoising. The moto of electrocardiography is to conclude the electrical and mechanical condition of the heart by taking body surface potential measurements empirically.ECG signal is distorted by power line interference, channel noise, baseline wander, electromyogram (EMG) Noise, electrode contact noise, and motion artifacts that may guide the wrong clarification in diagnosis. Accurate denoising techniques are needed for the proper diagnosis of the cardiac problems.

Keywords **- Electrocardiogram, Denoising, Emperical mode decomposition, Discrete wavelet transform, Adaptive filtering, Bayseian filtering.**

I. INTRODUCTION

Signal processing is an important part in biomedical engineering and diagnostics. Signal processing has a dominant contribution in pattern analysis and feature extraction For efficient diagnosis of various diseases. Due to cardiac diaorder like arrhythmia every year, around 25% of deaths in the world.

This figure help to explain how ECG is measured using electrodes attached to the body surface and connected to the ECG amplifier



The points towards positive electrode ,the ecg signal will be positive going ,if the vector points towards negative electrode ,ECG will be negative.Each heart beat starts with an impulse from the heart's pacemaker .This impuls works the upper chambers of heart which is known as atria.The" P "wave represents activation of atria.The lower chamber of heart is known as ventricles.The electric current flows down to the ventricles.The "QRS" complex represents activation of ventricles part.After that the electric current back over the ventricles in opposite direction.This process is known as Recovery wave which is denoted by "T" wave.

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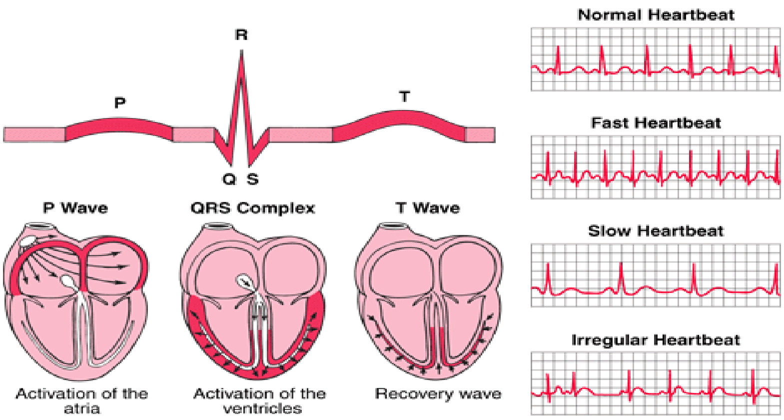

. Fig : Normal ECG waveform

II.NOISES IN ECG SIGNAL

Power line interference, Electrode contact noise, Motion artifacts, Muscle contraction, Base line wander, Instrumentation noise generated by electronic devices and Electrosurgical noise are the different type of noises which contaminate the ECG signal.

1- **POWER LINE INTERFERENCE**: The power line interference of 50/60 Hz is the source of interference and it distort the recordings of Electrocardiogram (ECG) . This interference occured due to:

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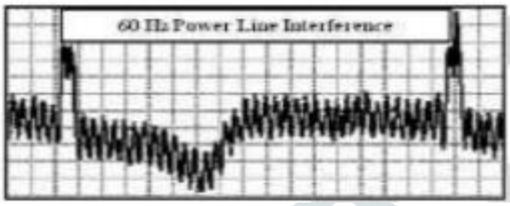
a. Electromagnetic interference is created from power line.
b. Electromagnetic field (EMF) by the machinery which is placed nearby. The signal component holds harmonics with different amplitude and frequency. The harmonics frequency is integral multiple of fundamental frequency such as 50Hz.
c. stray effect created due to the loops in the cables.
d .improper grounding of ECG machine or disconnected electrode on the patient's body.



. fig : 60 Hz Fig Power Line Interference

2-**ELECTRODE CONTACT POTENTIAL:** when the electrodes between patient and measuring system doesnot connect properly then electrode contact noise is created. Electrode contact potential has a duration of 1 sec and amplitude of which is maximum recorded output of ECG signal with frequency of 60Hz.

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3-**MOTION ARTIFACTS:** Due to the movement of patient will cause changes in electrode skin impedance,when ECG is recorded. Duration of motion artifacts is 100- 500 ms and its amplitude is 500% peak to peak ECG amplitude.

4-**ELECTROMYOGRAPHY NOISE:** Due to movement of the patient muscle contractions is occurred which is also known as EMG (electromyography) noise and it is responsible for artefactual milivolt level potentials change in ECG signal. The standard deviation of EMG noise is 10% of peak to peak ECG amplitude with duration of 50ms and the frequency content being dc to 10 KHz.

5-**BASELINE WANDER:** Baseline wander is occurred due to respiration and movement of the patient .It may produce problems in the peak detection. Due to the presence of baseline wander, T peak would be higher than R peak which might lead to misinterpretation of detected T peak as R peak. Amplitude variation is 15% of peak to peak ECG amplitude.

III. ECG DENOISING TECHNIQUES: ECG signal is recorded from patient's body by placing electrodes on patient body. ECG signal is restricted by presence of different noises like power line interference, channel noise, baseline wander, electromyogram (EMG) Noise, electrode contact noise, and motion artifacts which may lead to wrong interpretation in diagnosis.Proper denoising techniques are required for the accurate diagnosis of cardiac problems. Different ECG denoising techniques are explained here .

1- **Wavelet Based Technique** : Based on wavelet theory for ECG signal denoising, MM Elena, JM Quero, I Borrego[1] introduced the optimal method SGM that uses the global universal threshold modified using standard deviation, to estimate thevalue and to apply this to complete wavelet co-efficient vector. The algorithm tries to improve the compression ratio of the captured signal by means of an optimal noise threshold in terms of hardware complexity and memory requirements.The quality of recovered signal found to be good for the clinical diagnosis, obtaining a superior compression rate inspite of using instantaneously captured signals. The results obtained shows that the use of the standard deviation in the estimation of the threshold allowss simplification in the complexity of the hardware and resources required in the electronic implementation.

L Chmelka et. al. in [2] used a wavelet based wiener filter to suppress the EMG noise from ECG signal. The filtering is done by modifying the coefficients of wavelet transform depending on estimated noise level. For pilot estimation, hybrid thresholding based wavelet filtering is used. The results obtained shows that this filters are good for filter banks with short impulse response while worst for filter banks with long impulse response.

Wei Zhang et. al. in [3] proposed a sub-band adaptation filtered algorithm based on wavelet transform that extract a weak ECG signal in a strong noisy environment. It is a hybrid approach which uses a fixed sub-band decomposition and the decorrelation property of wavelet transform and property of adaptation filter. The algorithm successfully improves the extracting precision and speed and provides strong stability.

P. Mithun et. al. in [4] proposed a denoising technique for suppressing EMG noise and motion artifact in ECG signal based on wavelet. Advantages of this approach is that it does not require a reference as required in adaptive filtering techniques and also it does not require multi-channel signals as required by ICA-based techniques. Also identification of R-peaks as required in the cubic spline and EMD based techniques are not needed. Selected wavelet basis function is discrete Meyer wavelet. Combining the features of hard and soft thresholding, EMG noise was reduced while by limiting the wavelet coefficients Motion artifact was reduced.

Donghui Zhang in [5] proposed an approach based on discrete wavelet transform for baseline wander correction and denoising. In order to reduce the high- wavelet. frequency noise, wavelet shrinkage method using Empirical Bayes posterior median is used The Symmlet wavelet with order 8and decomposition level up to 6 is used as the mother wavelet.

Gordan Cornelia et. al. in [6] used wavelet transform to filter and analyze noisy ECG signal. All relevant noise are removed by using wavelet thresholding. A three level wavelet decomposition was used to decompose the signal. The Daubechies db1 and db3 wavelets, the symlet sym2 and the first order coiflet coif-1 wavelets were used for analysis and it was found that the best results are obtained with the db3 wavelet, and the worst ones with the sym wavelet.

Omid Sayadi proposed an bionic wavelet transform (BWT) [7] for ECG denoising. The most distinguishing characteristics of BWT is that its resolution in the time–frequency domain can be adaptively adjusted not only by the signal frequency but also by the signal instantaneous amplitude and its first-order differential [7]. In denoising first the BWT is optimized and then the BWT coefficients are calculated after that hard thresholding and soft thresholding is done. This algorithm has many advantages like the signal denoised by BWT is a smoothed version, Single artifacts do no longer exist, Interference removal is achieved by properly adjusting the center frequency of mother function and the number of decomposition levels [8], For higher input SNR more improvement is obtained.

2-<u>Emperical mode and Decomposition:</u> Empirical Mode Decomposition (EMD) is proposed in [9] method to remove high frequency noise and baseline wander. The signal is decomposed as a sum of several intrinsic mode functions which represents simple oscillatory mode. In order to achieve baseline wander removal, different Intrinsic Mode Functions (IMF) are processed. Partial signal reconstruction causes high frequency denoising. The method is suitable for real noise cases too.

Md. Ashfanoor Kabir et. Al. in [10] proposed a new windowing method in Empirical Mode Decomposition domain. This method preserves the QRS complex information in the first three high frequency intrinsic mode functions. The intrinsic oscillatory modes are identified and then signal is decomposes into IMF. The noisy signal is enhanced in the EMD domain and then transformed into the wavelet domain in which adaptive thresholding scheme is applied to the wavelet co-efficients to preserve the QRS information. In order to reduce the noise that remains after the EMD, an adaptive soft thresholding is performed in DWT domain.

Abdul Qayoom Bhat [11] proposed a new method which combines EMD with wavelet. This method to some extent minimizes the limitation of EMD alone or Wavelet alone. The proposed noise removal method using EMD is as, the different steps are explain below

Step 1: The ECG signal are taken from MIT/BIH arrhythmia data base. Every file in the database consists of two lead recordings sampled at 360 Hz sampling frequency with 11 bits per sample of resolution. The noisy signal s(t) is obtained as s(t)=x(t) + n(t) where, x(t) is orifinal ECG and n(t) is the noise signal.

Step 2: The noisy ECG is decomposed into IMFs using EMD method.

Step 3: The number of noisy IMFs, n, is obtained using a bank of LPFs.

Step 4: The noisy IMFs are filtered using Wavelet Transform (WT), by selecting a proper threshold.

Step 5: After these IMFs are filtered, the signal is reconstructed by adding the filtered IMFs with noise free IMFs. From the results obtained, the author concluded that the EMD method used with WT filtering removes the base line wander effectively.

3-<u>BAYESIAN FILTERING</u>: A nonlinear Bayesian filtering frame-work is proposed by Kazi M D in [8] for the filtering of single channel noisy ECG recordings. The necessary dynamic models of the ECG are based on a modified nonlinear dynamic model, previously suggested for the generation of a highly realistic synthetic ECG. An automatic parameter selection method is also used to facilitate the adaptation of the model parameters to a vast variety of ECGs. This approach is evaluated on several normal ECGs, by artificially adding white and colored Gaussian noises to visually inspected clean ECG recordings, and studying the SNR and morphology of the filter outputs. The results of the study demonstrate superior results compared with conventional ECG denoising approaches such as band-pass filtering, adaptive filtering, and wavelet denoising over a wide range of ECG SNRs. The method is also successfully evaluated on real non-stationary muscle artifact. This method may therefore serve as an effective framework for the model-based filtering of noisy ECG recordings.

4-<u>Adaptive filtering</u> :Soumyadipta Acharya, Dale H. Mugler, Bruce C. Taylor in [16] proposed a new adaptive filter structure to reduce power line interference from ECGs. It is based on principle of continuously tracking the frequency, amplitude and phase of the noise, using a modified form of Short Time Fourier Transform. This information is used to reconstruct the noise signal, which is then subtracted from the noisy ECG. The proposed method is very effective in tracking relatively large and sudden changes in frequency, phase and amplitude of PLI, without distorting the underlying ECG. It is computationally simple enough for real time implementation. However with ECGs sampled at a higher rate than usual, real time implementation might not be feasible owing to increased computational time.

Yong Lian and Jiang Hong Yu in [15] presented a way to remove the noises using the computational efficient linear phase FIR digital filters. The filter is developed based on the frequency response masking technique [12-14]. The proposed filter requires considerable less delay components compared to a recursive running sum based filter. The filter is suitable for the VLSI implementation of portable ECG device.

Sigi Hussain and Babitha. M. S in [17] implemented adaptive algorithms viz. LMS, NLMS, CSLMS for noise removal from cardiac signals. They concluded that CSLMS based filter shows an improved simulation result compared to LMS and NLMS algorithm. The best least square estimate of original signal is obtained by modification in weight update formula. This algorithm has an ability to remove both stationary and non- stationary noise in an ECG signal at a time. The simulation results confirms that the performance of CSLMS is better than LMS and NLMS in terms of MSE and SNR improvement.

IV.conclusion: This paper presents a survey which includes the work by different researchers on signal denoising methods. ECG signal is distorted by by different type of noises like power line interference, channel noise, baseline wander, Electromyogram (EMG) Noise, electrode contact noise, and motion artifacts. Among of all denoising technique Adaptive filtering is the best filtering technique for ECG signal with low frequency SNR. Wavelet technique can be used if signal beat to beat variation is high.

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