ECG Noise Sources and Various Noise Removal Techniques: A Survey

Mr. Hrishikesh Limaye[1], Mrs. V.V. Deshmukh[2]

[1]P.G Student, Department of Electronics and Telecommunication Engineering, RMDSSOE Pune, India

[2]Assistant Professor, Department of Electronics and Telecommunication Engineering, RMDSSOE Pune, India

ABSTRACT

Heart disease is one of the major causes of deaths worldwide. It is an equal opportunity killer which claims million lives annually. Doctors use electrocardiogram (ECG) to detect abnormal heart rhythms and to investigate the cause of chest pains. This test detects and records the heart's electrical activity. An ECG is nothing but a record of the strength and timing information of electrical signals as they pass through the heart. A common problem in ECG interpretation is the removal of unwanted artifacts and noise. There are various artifacts which get added in these signals and change the original signal therefore the need to remove these artifacts from the original signal is significant. An ECG signal consists of very low frequency signals of about 0.5 Hz-100Hz and digital filters are very efficient for noise removal of such low frequency signals.Cardiac monitors are the devices which provide a means to filter the ECG recording. Methods of noise filtering have decisive influence on performance of all ECG signal processing systems. This paper is intended to review different noise sources associated with ECG signal acquisition and processing along with a brief survey of various methods implemented to reduce the same.
Keywords:ECG, Noise filtering,artifacts, digital filters.

1. INTRODUCTION

Today cardiac diseases and related failures are among the main causes of death in the world. Therefore it is necessary to have a proper method which determines the cardiac condition of the patient. Inspection of ECG is one of the methods.Electrocardiography (ECG) is a tool which is used to understand the condition of the heart. ECG records the electrical signals (activity)which are generated over the cardiac cycle via electrodes positioned at various locations on the body surface.ECG of a patient is examined visually in the time domain. But this ECG is full of noise which can be reduced by means of signal processing. Signal processing is an important and evident tool in fields of biomedical engineering. Today the biomedical signal processing stream has advanced to the stage of practical application of signal processing and pattern analysis techniques.ECG signal is a graphical representation of cardiac activity and it is used to investigate various abnormalities which are present in theheart.Typically an ECG signal consists of P wave, QRS complex, T wave and any deviation in these parameters predict and justifythe abnormalities present in heart. Electrocardiogram (ECG) signals are usually contaminated by baseline wander (BW). Electrode-skin impedance changes due to perspiration, patient movement, and respiration which contributes to baseline wander.The computer based processing is influenced due to baseline wander. Reduction of noise such as BW and power interference is a must,so that the ECG signal can be automatically analyzed by a computer and finally interpreted by a cardiologist. The removal of various disturbances is one of the first steps in the processing of the ECG not only before further automatic processing, but also as a first step in visual diagnosis. The purpose of such diagnosis is to make the processing easier and to enable reliable ST segment measurements [1]. Ambulatory ECG recordings which are taken by placing electrodes on the subject's chest are contaminated by several different types of artifacts. ECG artifacts are the disturbances on ECG which is a measurement of cardiac potentials on human body. Normal components of ECG can get distorted due to artifacts. Artifacts are pretty common and adequate knowledge of them is necessary to prevent misinterpretation of patients ECG. Artifacts can be generated due to electrical interference by outside source, electrical noise elsewhere in the body, poor contact and machine malfunction. Positive stress ECG test indicates that the QRS-complex alternas is increased and the patients might have significant coronary artery disease [2].

2. ECG SIGNAL

Electrical activity which is caused due to the muscle contraction gets reflected in the ECG signal which is typically analyzed in the time domain. One normalsinus cycle of the ECG corresponds to a single heartbeat.AnECG signal is typically labeled with the letters P, Q, R,S, and T which signifies its critical points as illustrated in Figure.1.
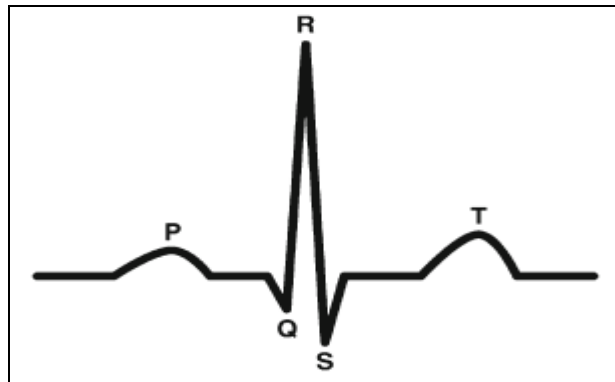
International Journal of Application or Innovation in Engineering & Management (IJAIEM)
Web Site: www.ijaiem.org Email: editor@ijaiem.org
Volume 5, Issue 2, February 2016   ISSN 2319 - 4847

Figure.1.ECG signal demonstrating different Components.

The frequency ranges from 0.67 to 120 Hz, and 0.67 Hz is the frequency (minimum) which is observed when the pulse rate is 40 beats/min [3].Low frequency components consist of the P and T waves, (5–9 Hz) [4, 5] while the QRS complex resides at higher frequency.In a conventional 12 lead ECG, electrodes (ten)are placed on the patient's limbs and on the surface of the chest. Twelve different angles (leads)record the overall magnitude of the heart's electrical potential and are recorded over a period of time. In this way, the overall magnitude along with the direction of the heart's electrical depolarization is captured throughout the cardiac cycle. Theserecordings are subjected to different kind of noises which have different frequency ranges. Thus, significant noise removal cannot be achievedusing a single filter. There are two categories which briefly classify the noise: persistent and burst noises.

2.1 Persistent Noises

The noise is correlated in the signal which comes from all the leads having a similar temporal distribution but with different intensity level. These noises exhibita variety of frequency bands.The low-frequency range signifies baseline wander (BW), the medium frequency signifies the power line interference (PLI) and the high frequency (EMG) signals signify the electromyography noise [6].

2.1.1 *Power-line interference Noise (PLI)*

Power line interference (PLI) coupled to signal carrying cables is particularly troublesome in medicalequipment. Cables carrying signals from the examination room to the monitoring equipment are prone to electromagnetic interference (EMI) of frequency (50 Hz or 60 Hz) by ubiquitous supply lines. Sometimes the recordings (like ECG or EEG) are totally dominated by this type of noise. Reducing (filtering) such PLI signal is a significant challenge given that the frequency of the power line signal lies within the frequency range of the ECG and EEG signals [7, 8].PLI is a significant source of noise during bio-potential measurements. EMI degrades the signal quality and disturbs the tiny features that may be crucial for monitoring and diagnosis, and it is observed that it can strongly distort bio potentials. Various biomedical signals contain distinct features in the time-domain analysis.It is seen that the PLI can contaminate the ECG recordings, due to differences in the electrode impedance and stray currents through the patient, cables, or in instruments with a floating input for a higher patient safety [9].An ECG signal corrupted with PLI is illustrated in Figure.2.
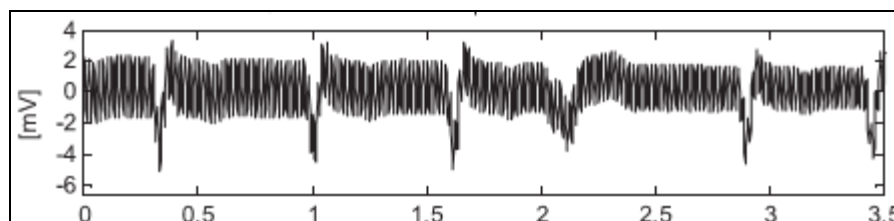

Figure.2.ECG signal + power line Interference

Capacitive and inductive couplingare the mechanisms that contribute to Power line interference. Capacitive coupling refers to the transfer of energy between circuits by means of a capacitance present between the circuits [10].The coupling capacitance decreases with increase in the separation between the circuits. On the other hand,Inductive coupling is caused by inductance which exists between the conductors.Current flowing through the wiretends to produce a magnetic fluxthatinduces a current in adjacent circuits. The structure of the conductors as well as the separation between them decides the value of the mutual inductance, and thus the degree of the inductive coupling.Typically,high frequency noise is contributed by capacitive coupling and inductive coupling introduces low frequency noise. Inductive coupling is the significant mechanism of power line interference in electro-cardiology.

Ensuring the electrodes are applied properly, and there are no loose wires, and all components have adequate shielding should limit the amount of power line interference.The manifestation of power line noise can be modeled as

$$n_{50Hz}(t) = A\sin(2\pi \cdot 50 + \theta)$$

The average peak value, *A*, of the noise depends on the amount of coupling betweenthe ECG equipment and the power lines, and willvary between measurements. During measurement the peak-to-peak value is also liable to fluctuate due to changing environmental conditions, which influence the amount of inductive or capacitive coupling of power lines to the ECG equipment.The simplistic model assumes that the noise will occur only at 50 Hz, but in reality the power line noise will have a finite bandwidth around its nominal centerfrequency, suggesting that the total noise is composed of many sinusoids of similar frequency.

2.1.2   Baseline Wander (BW)

Variations in electrode-skin impedance and activities like patient's movements and breathecause Baseline wander [11, 12].Baseline wanderdisturbance is especiallydominant in exercise electrocardiography, and in ambulatory and Holter monitoring.The range of frequency in which baseline wander is dominant is typically less than 1.0 Hz, however for exercise ECG this range can be wider [12].It is caused by changes in electrode-to-skin polarization voltages, or by electrode movement, or by respiration movement or by body movement.In wandering baseline, the isoelectric line change positions. One possible cause is the movement of cables. Patient movement, dirty lead wires/electrodes, and a variety of other things can cause this as well.Figure.3. Illustrates the ECG signal with significant baseline wander.

Figure.3. ECG signal with Baseline Wander.

2.1.3   Electromyography noise (EMG)

Contraction of the muscles besides the heart contributes to the EMG noise. When other muscles in the vicinity of the electrodes contract, generationof depolarization and re-polarization waves takes place and these waves are picked up by the ECG. The gravity of the crosstalk depends on the amount of muscular contraction (subject movement), and the quality of the probes. It is well established fact that the amplitude of the EMG signal is stochastic (random) in nature and is typically modeled by a Gaussian distribution function [13]. The mean of the noise can be assumed to be zerohowever the variance is dependent on the environmental variables and will change depending on the conditions. While the actual statistical model is unknown, it should be noted that the electrical activity of muscles during periods of contraction can generate surface potentials comparable to those from the heart, and could completely drown out the desired signal. EMG noise is common in subjects with uncontrollable tremor, disabled persons, kids and persons fearing the ECG procedure.

2.2 Burst Noises

Burst noise is typically classified as a white Gaussian noise (WGN) which appear on a subset of leads for a very short duration, examplesof these noises are electrode pop noise, electrode motion artifact, electro surgical noise, instrumentation noise etc. [14]. The frequency ranges for these noises are not well defined.

2.2.1   Electrode popup or Contact noise

Position of the heart with respect to the electrodes (variation) and changes in the propagation medium between the heart and the electrodesinitiateElectrode contact noise.This causes sudden changes in the amplitude of the ECG signal, and low frequency baseline shifts. In addition, poor conductivity between the electrodes and the skin both reduces the signal amplitude of the ECG signal and thereby increases the probability of disturbances (by reducing SNR). The mechanism responsiblefor baseline disturbances is electrode-skin impedance variation. The larger the electrode-skin impedance, smaller are the relative impedance change which is required to cause a major shift in the baseline of the ECG signal. If the skin impedance is significantly high, it might be impossible to detect the signal features reliably in the presence of body movement [15]. Sudden changes in the skin-electrode impedance induce sharp baseline transients which decay exponentially to the baseline value. This transition may occur only once or rapidly several times in succession. Amplitude of the initial transition and the time constant of the decay are the major characteristics of such noise.

International Journal of Application or Innovation in Engineering & Management (IJAIEM)
Web Site: www.ijaiem.org Email: editor@ijaiem.org

Volume 5, Issue 2, February 2016   ISSN 2319 - 4847

2.2.2 Patient Electrode motion artifact

Motion artifacts are baseline changes which are caused by electrode motion. Usually vibrations, movement, or respiration of the subject contribute to motion artifacts. The peak amplitude and duration of the artifact depend on various unknown quantities such as the electrode properties, electrolyte properties, skin impedance, and the movement of the patient. In ECG signal, the baseline drift occurs at an unusually low frequency (approximately 0.014Hz), and most likely results from very slow changes in the skin-electrode impedance. This noise can also be observed on the Fourier power spectrum, the large peak nearest to DC [13].

2.2.3 Instrumentation Noise

The electrical equipment which isused in ECG measurements also contributes noise. Electrode probes, cables, signal processor/amplifier, and the Analog-to-Digital converterare the major sources of this form of noise.Unfortunately instrumentation noise cannot be eliminated, but it can be reduced through higher quality equipment and careful circuit design.One type of electrical noise is resistor thermal noise (also known as Johnson noise).Random fluctuations of the electrons due to thermal agitation produce this noise.The power spectrum is given as

$$\overline{V}_n^2 = 4kTR$$

Where$k$ is the Boltzmann's constant [16], T is the temperature, and R is the resistance. This equation suggests that the resistor thermal noise is white for all frequencies; however, at frequencies larger than 100 Hz the power spectrum starts to drop off.Another form of noise, called flicker noise, is important in ECG measurements, due its low frequency. The actual mechanism that causes this type of noise is not yet understood, but one widely accepted theory is that it is caused by the energy traps which occur between the interfaces of two materials. It is believed that the charge carriers get randomly trapped/released and cause flicker noise.Flicker noise contributions would be most noticeable at the electrodes since the amplitude of the detected signal is on the order of millivolts.

3. SURVEY OF LATEST NOISE REDUCTION METHODOLOGIES

The removal or reduction of baseline wanders and power line interference from biomedical signals has been studied since ages and lots of advanced techniques have been proposed for that.Many approaches have been reported in the literature to address ECG enhancement. Some contributions have proposed solutions using a wide range of different techniques, which include maximally decimated filter banks and nonlinear filter banks, advanced averaging, wavelet transform, filtering using adaptive technique, singular value decomposition, andprinciple component analysis to name a few.In all ECG devices, typically digital FIR filters are used to filter and select the ECG signal in the presence of different interference signals, thefilters can be classified as: Low pass filter (LPF) which is implemented to remove the undesired high frequency noise signal. High pass filter (HPF) is implemented to remove the low frequency noise signal. Band stop filter (BSF) is used to remove the noise signal for power line frequencies of 50, 60 Hz. BSF to remove the noise signal for muscles with frequencies of 25, 35, 45 Hz.

In[17], Mbachu presents a method of designing LPF, HPF, BSF with Kaiser window where these three filters are serially connected which process the signal within the range (from 0 to 100 Hz), and with order of 200 for every filter and with interference signals attenuation of 13 dB

In [18], Verma presents a digital Notch filter design using Hamming window to remove the effect of power line interference (PLI) with frequency of 50 Hz,which achieves 13.4dB attenuation. Also, presents an adaptive filter design to remove the effect of PLI and attenuation of 34.2 dB is obtained.

In [19], MadhukarNarsale et al. present a digital Notch filter design with frequency of 50 Hz and with band width of 45 to 55 Hz. They haveimplemented this filter on FPGA with sampling frequency of 500 Hz, and attenuation of 13 dB

In [20], Sharma and Dalalhave presented a FIR filter whose order is 450 and different windows have been applied to remove the effect of power line interferencewhich has achieved the attenuation of 18 dB.

McManus et al. developed proceduresthatestimate baseline drift using cubic spline, polynomial, and rational functions. 50 electrocardiograms (ECGs) have been used as a set, each of 2.5-sec duration. Baseline stability was significantly improved by following of any of these procedures except rational function approximation. Amplitude histograms after implementing subtraction of estimated baseline distortions showed only small baseline variations over the recording period. For validation of the estimation procedures, 10 ECGs with artificial baseline drift were constructed and analyzed using mean square error calculations [21].

Sornmohas tried applying the time-varying filtering to the problem of baseline correction. The cut-offfrequency of a linear filter is efficiently controlled by the low-frequency characteristics of the ECG signal. Sampling rate decimation and interpolation has been used so that the design of a filter for baseline reduction can be treated as a narrowband filtering problem. All filters that have been selected and implemented have a linear phase response to reduce distortion. The performance of the method implementedwas studied on ECG signals withdifferent typesof simulated baseline

International Journal of Application or Innovation in Engineering & Management (IJAIEM)
Web Site: www.ijaiem.org Email: editor@ijaiem.org
Volume 5, Issue 2, February 2016   **ISSN 2319 - 4847**

wander. The results were compared with the performance of time-invariant linear filtering and cubic spline interpolation [22].

A method that can be implemented for removing low frequency interference from an ECG signal is presented by Allen et al. which actas a simple alternative to more computationally intensive techniques. The performance of the method was evaluatedbyexamining changes in body surfaceiso-potential map feature locations, due to baseline wander. The results show that even though the baseline wander can seriously interfere with iso-potential map features, integrity can be restored by relatively simple methods [23].

Choy TT, Leung P M. have implemented 50 Hz notch filters for the real time application on the ECG signal. That filter was capable of filtering noise (by 40 dB) with bandwidth of 4Hz and causes the attenuation in the QRS complex [24].

Markovsky used Band-pass, Kalman, and adaptive filters for removal of resuscitation artifacts from human ECG signals. A database of separately recorded human ECG was used f or evaluation of this method. The performance criterion considered is the signal to-noise ratio (SNR) improvement, which is defined as the ratio of the SNRs of the filtered signal and the given ECG signal. The results show that for low SNR of the given signal, a band-pass filter yields the good performance, on the other hand for high SNR, an adaptive filter yields the good performance [25].

Lebedeva SV et al has described and demonstrated the structure and algorithm of a digital suppression filter for circuit noise at 50 Hz. The filter is seen slightly corruptingthe electro-cardio-graphic signal [26].

Daqrouq [27] had used discrete wavelet transform (DWT) for ECG signal processing, specifically for reduction of ECG baseline wandering. Thediscrete wavelet transformhas the properties which enable good representation of non-stationary signal such as ECG signal and divide the signal into different bands offrequency. This enables the detection followed by the reduction of ECG baseline wandering in low frequency subsignals. For testing presented method, ECG signals taken from MIT-BIH arrhythmia database are considered. The method has been evaluated and compared with the traditional methods such FIR and averaging method and with advanced method such as wavelet adaptive filters (WAF).

Zhang [28] approached for BW correction and denoising based on discrete wavelet transformation (DWT). They estimate the BW via coarse approximation in DWT and they recommend how to select wavelets and the maximum depth for decomposition level. They have reduced the high-frequency noise by implementing Empirical Bayes posterior medianwavelet shrinkage method with level dependent and position dependent thresh holding values.

Sayadi [29] presented a method for ECG baseline correction which implements an adaptive bionic wavelet transform (BWT). By using BWT, the resolution in the time-frequency domain can be adaptively adjusted not only by the signal frequency but also by the signal amplitude which is instantaneous and its first-order differential. First an estimation of the baseline wandering frequency is obtained followed by the adaptation which can be used only in three successive scales. The mid-scale has the closest center frequency to the estimated frequency. Thus the implementation is possiblytime consuming.

4. CONCLUSION AND FUTURE WORK

The examination of the ECG has been used for diagnosing heart diseases. Various techniques have been proposed which reduce of baseline wander and power line interference from ECG. This paper provides an overview of various types of noise sources associated with ECG signal and a brief survey of filtration techniquesavailable for removal of Baseline Wander and Powerline interference. The survey indicates that the filtration techniques for ECG must be highly accurate andshould ensure fast filtration. Although several methods have been proposed, most approaches lack implementation details and most of these developments do not address noise reduction for wirelessly transmitted ECG data.

Finally, the future work may concentrate on designing of filters for accurate and fast filtration of Real Time ECG which ultimatelyresults in the improvement of accuracy during diagnosing the cardiac disease at the earliest in the useof patientmonitoring systems. Also development of mobile ECG recognition system using a mobile phone integrated with external ECG sensors can be thought of in this era of advances in mobile networking technologies.

References

[1] J.A.VAN ALSTE: Removal of Base-Line Wander and Power-Line Interference from the ECG by an Efficient FIR Filter with a Reduced Number of Taps, IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, VOL. BME-32:1052-1060,1985

[2] I.I. Christov, G. Bortolan, I. Simova, T. Katova, T-wave and QRS complex alternans during standard diagnostic stress ECG test, Comput. Cardiol. 37 (2010) 1039–1042

[3] Clifford, G.D.; Azuaje F.; McSharry, P.E.: Advanced Methods and Tools for ECG Data Analysis. Artech house. . ISBN-13: 978-1-58053-966-1 (2006)

[4] Wung, N.C.; Hung, J.W.; Lee, L.S.: Data driven temporal filters based on multi-eigen vector for robust feature in speech recognition In: IEEE International Conference on Acoustics, Speech, and Signal Processing, pp. I400–I403 (2003)

[5] Chazal, P.D.; Reilly, R.B.: A comparison of the ECG classification performance of different feature sets. . IEEE Comput. Cardiol 27, 327–330 (2000)

[6] Turner, D.D., Knuteson, R.O.: A principal component analysis noise filter value-added procedure to remove uncorrelated noise from atmospheric emitted radiance interferometer(AERI) observations Pacific Northwest National Laboratory USA(2006)

[7] Sörnmo L, Laguna P. Bioelectrical signal processing in cardiac an neurological applications. Elsevier Academic Press; 2005

[8] Rangayyan RM. Biomedical signal analysis: a case-study approach. IEEE Press Ser Biomed Eng 2002.

[9] C. Levkov, G. Mihov, R. Ivanov, I. Daskalov, I.I. Christov, I. Dotsinsky, Removal of power-line interference from the ECG: a review of the subtraction procedure, Biomed. Eng. Online 4 (2005) 50.

[10] The Elimination of 50 Hz Power Line Interference from ECG Using a Variable Step Adaptive Algorithm, LifeScienceJournal, 3(4), 2006,

[11] P. Ciarlini, P. Barone, A recursive algorithm to compute the baseline drift in recorded biological signals, Comput. Biomed. Res. 21 (1988) 221–226.

[12] C.R. Meyer, H.N. Keiser Electrocardiogram baseline noise estimation and removal using cubic splines and state-space computation techniques, Comput. Biomed. Res. 10 (1977) 459–470.

[13] P. Tikkanen, "Characterization and Application of Analysis Methods for ECG and Time Interval Variability Data," Ph.D. dissertation, University Of Oulu, Oulu, Finland, 1999

[14] Castells, F.; Laguna, P.; S'ornmo, L.; Bollmann, A.; Roig, J.: Principal component analysis in ECG signal processing. EURASIP J.Adv. Signal Process. (2007). doi:10.1155/2007/74580

[15] S. A. Israel, J. M. Irvine, A. Cheng, M. D. Wiederhold, and B. K. Wiederhold, "ECG to Identify Individuals," *Pattern Recognition, Elsevier*, Vol. 38(1), January 2005 pp.133-142

[16] D. L. Carlo, "Surface Electromyography: Detection and Recording," DelSys Incorporated, pp. 2-6.

[17] C.B. Mbachu, et al., Processing ECG signal with Kaiser window-based FIRdigital filters, Int. J. Eng. Sci. Technol. 3 (8) (2011) 6675–6783, August

[18] SeemaVerma, Reduction of noise from ECG signal using FIR low pass filterwith various window techniquesEng. Sci. Technol. J.1 (5) (2013) 117–122,July

[19] RupaliMadhukarNarsale, DhanashriGawali, AmitKulkarni, FPGA baseddesign & implementationof low power FIRfilter for ECGSignal Process./IntJ. Sci. Eng.Technol. Res. 3 (6)(2014) 1673, June

[20] Manoj Sharma, HemantDalal, Designing and implementation of digitalfilterfor power line interference suppressionInt. J. Sci. Eng. Technol. Res. 3 (6)(2014) 1831–1836, June

[21] McManus, C.D.; Teppner, U.; Neubert, D. and LobodzinskiS.M. 1985"Estimation and Removal of Baseline Drift inthe Electrocardiogram",Computers and BiomedicalResearch, 18,issue1, February, pp. 1-9

[22] Sornmo, L. 1993, "Time-Varying Digital Filteringof ECGBaseline Wander,"Medical and Biological Engineering andComputing, 31, Number 5pp. 503-508

[23] Allen, J.; Anderson, J. McC.; Dempsey, G.J.; AdgeyA.A.J.;1994, "Efficient Baseline Wander Removal for Feature "Efficient Baseline Wander Removal for Feature," IEEE Proceedings of Engineeringin Medicine and Biology Society ,2,pp1316– 1317

[24] Choy T.T., Leung P.M., "Real Time Microprocessor-Based50 Hz Notch Filter for ECG,"J. Biomed Eng.1988 May; 10 (3): 285-8

[25] Markovsky, Ivan A.;Anton, Van H. and Sabine, 2008"Application of Filtering Methods for Removal ofResuscitation Artifactsfrom Human ECG Signals",IEEEConference of Engineering in Medicineand Biology Societypp 13-16

[26] Lebedeva S.V., Lebedev V.V., "Digital Filter for Circuit NoiseSuppression in the Electrocardiograph",Med Tekh. 1995Sep-Oct;(5):23-5

[27] Daqrouq, K. 2005, "ECG Baseline Wandering ReductionUsing Discrete Wavelet Transform",Asian Journal ofInformation Technology4.issue 11,pp 989-995

[28] Zhang, D. 2005, "Wavelet Approach for ECG BaselineWander Correction and Noise Reduction",Proceedings ofthe IEEE on Engineering in Medicine and Biology 27thAnnual Conference, pp 1212-1215

[29] Sayadi,O.; Mohammad B.S. 2007, "ECG Baseline Correctionwith Adaptive Bionic Wavelet Transform",IEEE InternationalSymposium on Signal Processing and Its Application. pp 1-4

AUTHORS

Mr. Hrishikesh Limaye has received his Bachelor of Engineering (B.E) Degree in Electronics and Telecommunication engineering from KJCOEMR,S.P.Pune University in 2013. Currently he is pursuing his master's degree, with VLSI and Embedded system as specialization.

Prof.Mrs.V.V.Deshmukh has completed BE (Industrial Electronics) in 2001 from S.P.Pune university and masters in Digital Systems (Electronics) in 2011 from S.P.Pune University. She has teaching experience of 13 years and currently working as an Assistant Professor in E&TC dept. of RMDSSOE,Pune, India. She is also perusing her PhD. in Electronics and Telecommunication from MIT, S.P.Pune University.