International Journal on Emerging Technologies (Special Issue on ICRIET-2016) **7**(2): 8-13(2016)

ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

A Survey on Sources of Noise and Advanced Noise Removal Techniques of Biosignals

Umera Banu*, Dr. G.M Patil[**] and Dr. Ruksar Fatima[***]

**Ph.D Scholar, Dept. of Biomedical Engineering, KBNCE, Kalaburagi, Karnataka, India*
[**]Professor, Dept. of E & I, DSCE, Bangaluru, Karnataka, India
[***]Professor, Dept. of Biomedical Engineering, KBNCE, Kalaburagi, Karnataka, India

(Corresponding author: Umera Banu)
(Received 16 September, 2016 Accepted 19 October, 2016)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Biosignal is a signal senses from a biological tissues or medical source. Biosignal reflects nature and activities of physiological processes. Such signals could be of many types like biochemical in the form of hormones, electrical in the form of potential such as ECG, EEG, EMG, EOG etc. Biosignals are low voltage signals that are contaminated by various types of noises that are also called as artifacts. These biosignals have been tested in the frequency domain. Frequency domain gives more useful information than the time domain. There are various artifacts which get added in these signals and change the original signal therefore it is necessary to remove these artifacts from the original signal. Several time- or frequency domain digital signal processing (DSP) techniques can be used in order to remove artifacts.DSP also involves adjusting signal characteristics, spectral estimation, multiplying two signals to perform modulation or correlation, Filtering and Averaging. Biosignals like ECG and EEG are used to diagnose various types of heart and brain related diseases. It becomes necessary to make these signals free from artifacts for proper analysis and detection of the diseases. Various noise removal techniques are available and can be implemented in MATLAB. This paper is intended to review different noise sources associated with ECG and EEG signal acquisition and processing along with a brief survey of various methods implemented to reduce the same.

Keywords: ECG, EEG, artifacts and DSP techniques.

I. INTRODUCTION

Cardiac diseases and heart 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. 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. The EEG is the recording of brain's electrical activity. The EEG is used in the evaluation of brain disorders. It is also used to evaluate people who are having problems associated with brain.ECG and EEG signals are having very small amplitudes and because of that they can be easily contaminated by noise. The noise can be electrode noise or can be generated from the body itself. The noises in the ECG and EEG signals are called the artifacts. These artifacts are needed to be removed from the original signal for the proper analysis. The various types of noises that can occur during recordings are the electrode noise, baseline movement, power line interference, poor contact, machine malfunction, EMG disturbance etc.

Signal processing is an important and evident tool in the field of biomedical engineering. DSP is a technique that deals with processing signals in digital domain. There are many applications of signal processing in biomedical field to perform different function. The various techniques are Echo cancellation, Noise cancellation, Spectrum Analysis, Detection, Correlation, Computer Graphics, Image Processing, and Data Compression etc.

This paper provides an extensive survey on various types of artifacts associates with biosignals and most advanced digital signal processing techniques used to remove noises from biosignals.

II. ARTIFACTS IN ECG SIGNAL

The ECG is the electrical manifestation of the contractile activity of the heart and can be recorded with surface electrodes on the limbs or chest. One normal sinus cycle of the ECG corresponds to a single heartbeat. An ECG signal is typically labeled with the letters P, Q, R, S, and T as shown in Fig. 1.

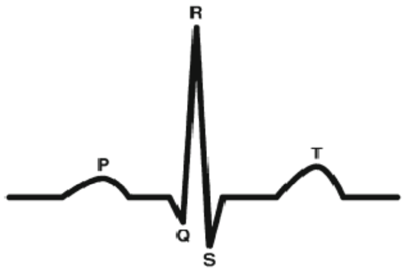


Fig. 1. Typical an ECG signal.

In a conventional 12 lead ECG recording system, electrodes are placed on the patient's limbs and on the surface of the chest. Twelve leads at different angles record the overall magnitude of the heart's electrical potential over a period of time. In this way, the overall magnitude along with the direction of the heart's electrical depolarization is captured. These recordings are subjected to different kind of artifacts or noises which have different frequency ranges. There are two categories which briefly classify the noise namely persistent and burst noises.

A. Persistent Noises

The persistent noise in the signal comes from all the leads having a similar temporal distribution but with different intensity level. These noises contain variety of frequency bands. The low-frequency band signifies baseline wander (BW), the medium frequency range signifies the power line interference (PLI) and the high frequency band signify the electromyography noise [1].

Power-line interference (PLI). Power line interference (PLI) arises due to difference in the electrode impedance and stray currents in the cable connected to patient. 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. The frequency of the power line interference lies within the frequency range of the ECG and EEG signal [2, 3]. PLI is a significant source of noise during biosignal l measurement..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 [4].An ECG signal corrupted with PLI is shown in Fig. 2.

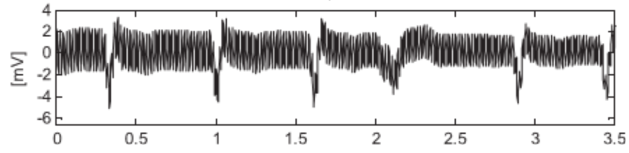


Fig. 2. ECG signal corrupted by PLI.

Capacitive and inductive coupling are the sources that causes Power line interference. Typically high frequency noise is contributed by capacitive coupling and inductive coupling introduces low frequency noise. Inductive coupling is the significant source of power line interference in electro-cardiology.

Baseline Wander (BW). Variations in electrode-skin impedance, patient's movements and breathe cause Baseline wander [5].Baseline wander disturbance is especially dominant in exercise electrocardiography and in ambulatory 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 [6]. It is also caused by changes in electrode-to-skin polarization voltages, electrode movement, respiratory muscular movement and body movement. Figure 3 Illustrates the ECG signal with significant baseline wander.

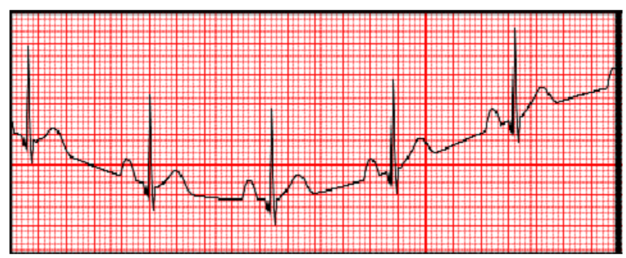


Fig. 3. ECG signal with Baseline Wander.

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, generation of depolarization and re-polarization waves takes place and these waves are picked up by the ECG. 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 non habitual of the ECG procedure.

C. 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. Examples of these noises are electrode pop noise, electrode motion artifact, electro surgical noise, instrumentation noise etc. [7].

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 electrodes initiate Electrode contact noise. This causes sudden changes in the amplitude of the ECG signal, and low frequency baseline shifts.

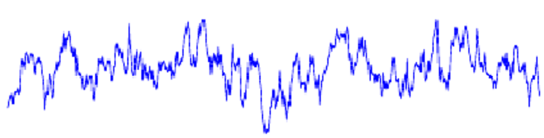
In addition, poor conductivity between the electrodes and the skin both reduces the signal amplitude of the ECG signal and thereby increases the probability of disturbance by reducing SNR. Baseline disturbances are caused by electrode-skin impedance variation. The larger the electrode-skin impedance, smaller are the relative impedance changes. If the skin impedance is significantly high, it might be impossible to detect the signal features reliably in the presence of body movement [8]. Sudden changes in the skin-electrode impedance cause sharp baseline transients. Amplitude of the initial transition and the time constant of the decay are the major characteristics of such noise.

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 changes occurs at 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 [9].

Instrumentation Noise. In an electrical equipment which is used in ECG measurements, Electrode probes, cables, signal processor/amplifier, and the Analog-to-Digital converter are the major sources of instrumentation noise. 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) produced by random fluctuations of the electrons due to thermal agitation. Another form of noise, called flicker noise, is important in ECG measurements, due to 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. 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 in the order of milli volts.

III. ARTIFACTS IN EEG SIGNAL

EEG signal may be contaminated at many points during the recording and transmission process. Most of the artifacts are generated by sources external to the brain. Some common EEG artifacts are as shown in fig.4



(a)

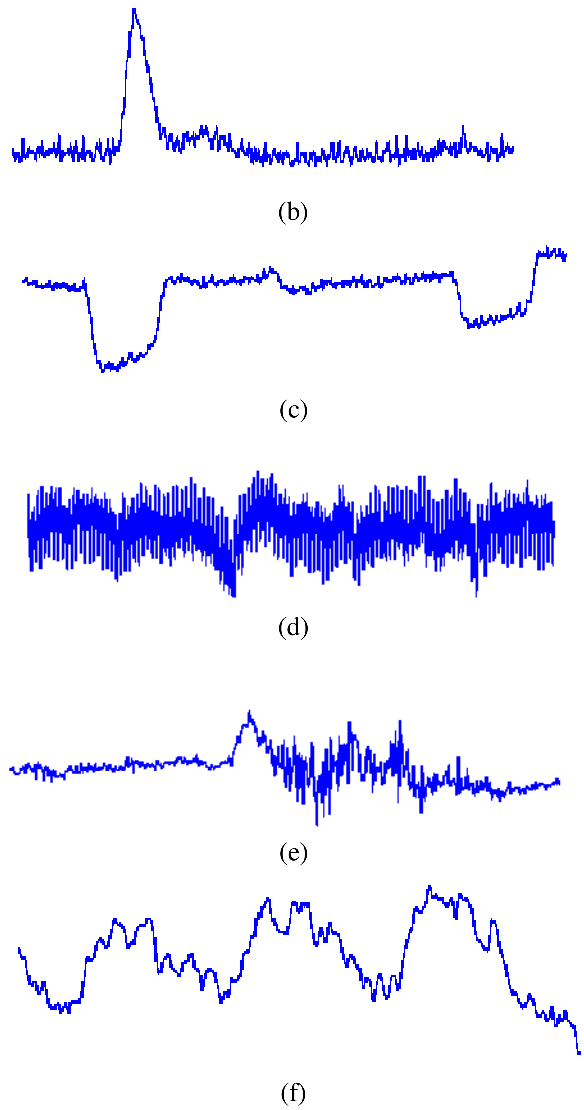


Fig. 4. (a) Typical EEG signal, (b) Eye blink, (c) Eye movement, (d)Line noise(50Hz), (e) Muscle activity, (f) Pulse artifact.

A. Eye Blink artifact

It is very common in EEG data, produces a high amplitude signal that can be many times greater than EEG signals of interest. Because of its high amplitude an eye blink can corrupt data on all electrodes, even those at the back of the head. Eye artifacts are often measured more directly in the electrooculargram (EOG), pairs of electrodes placed above and around the eyes.

B. Eye Movement

These artifacts are caused by the reorientation of the retinocorneal dipole [10]. The effect of this artifact is stronger than that of the eye blink artifact. Eye blinks and movements often occur at close intervals.

C. Line Noise

Strong signals from A/C power supplies can corrupt EEG signal during transfer from the scalp electrodes to the recording machine. Notch filters are often used to filter this artifact.

D. Muscle Activity

These artifacts are caused by activity in different muscle groups such as neck and facial muscles. These signals have a wide frequency range and can be distributed across different sets of electrodes depending on the location of the source muscles.

E. Pulse artifact

When an electrode is placed on or near a blood vessel, it causes pulse, or heart beat artifact. The expansion and contraction of the vessel introduce voltage changes into the recordings. The artifact signal has a frequency around 1.2Hz, and can vary with the state of the object. This artifact can appear as a sharp spike or smooth wave [11].

IV. SURVEY ON ADVANCED NOISE REMOVAL TECHNIQUES

The various methods of denoising techniques for removal of noise available for the ECG and EEG signals are discussed below.

In [12], Verma presents a digital Notch filter design using Hamming window to remove the effect of power line interference (PLI) with frequency of 50 Hz and 13.4dB attenuation. Also presents an adaptive filter design to remove the effect of PLI with a attenuation of 34.2 dB. Paul *et al* [13] have been proposed a transform domain Singular Value Decomposition (SVD) filter for suppression of muscle noise in exercise ECG. A significant advantage of this method lies in its ability to perform noise suppression independently on a single lead ECG record with only a limited number of data samples. Nikolaev *et al* [14] have been proposed transform domain denoising to suppress EMG interference in ECG signal. Daqrouq [15] had used discrete wavelet transform (DWT) for ECG signal processing, specifically for reduction of ECG baseline wandering. The discrete wavelet transform has the properties which enable good representation of non-stationary signal such as ECG signal and divide the signal into different bands of frequency. 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 [16] 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 median wavelet shrinkage method with level dependent and position dependent thresh holding values. Different filter structures have been proposed by Thakor *et al* to eliminate the baseline wander, 60 Hz power line interference, muscle noise and motion artifact. Hyung-Min Park et. al., have proposed ANC based on Independent Component Analysis (ICA) which utilized higher-order statistics. Experimental results show that the proposed method provides much better performances than conventional LMS approach in real world problems. Ping Zhou *et al*., have presented the performances of different methods that used for ECG artifact removal like: HPF, spike clipping, template subtracting, wavelet threshold and adaptive filtering. He examined the ECG artifacts removal from the myoelectric prosthesis control signals, taken from the reinnervated pectoralis muscles of a patient with bilateral amputations at shoulder disarticulation level.

Artifacts in EEG are commonly handled by discarding the affected segments of EEG. The simplest approach is to discard a fixed length segment, perhaps one second, from the time an artifact is detected. Jung *et al*., have presented the successful application of ICA for removing EEG artifacts, the results showed that a number of different artifacts have been cancelled and separated successfully from EEG And magnetoencephalogram (MEG) recordings. Hyung-Min Park *et al*., [17] have proposed ANC based on Independent Component Analysis (ICA) by using higher-order statistics .Nicolaou *et al*., have proposed the application of TDSEP (Temporal Decorrelation Source Separation which is a specific extension of ICA) for automatic artifact removal from EEG signals. This analysis has an advantage of separating signals with Gaussian amplitude distribution (because separation is based on the correlation of the sources). Browne et al [18] have used statistical wavelet threshold as a means of distinguishing the EEG and the artifact signals. It is only capable of separating artifacts that are well localized in the time-frequency domain or that have a spectrum which is uncharacteristic of the EEG. These results are better when compared to expert artifact rejection in some cases, but they fail to improve the removal of baseline drift, eye movement and step artifact.

Tatzana Zikov *et al* [19] have proposed a wavelet based denoising technique for removal of ocular artifacts in EEG. This method relies upon neither the reference EOG nor visual inspection. However, the threshold limit is estimated from the uncontaminated baseline EEG, which is recorded from the same patient.

Jung *et al.* used regression model for a baseline artifact removal method. Multivariate statistical analysis techniques, such as principal component analysis, have been used to separate and remove noise signals from the brain activity of interest [20]. Comparisons of artifact removal using different transformations can be found in [21, 22]. Comparison of four methods for artifact removal by artificially mixing an artifact signal from one subject with a set of EEG signals from another subject is given in[23]. Michal Kubinyi et.al [24] proposed wavelet packet denoising method which was implemented for EMAT noise suppression .The method was evaluated on signals measured with EMAT probes and under various SNR conditions; it outperforms the wavelet transform with the Stein unbiased risk estimate (SURE) threshold estimation method and split-spectrum processing (SSP). The results indicate SNR enhancement of 19 dB with real EMAT data.

V. CONCLUSION

After signal acquisition, signals are to be pre-processed. Signal pre-processing is also called as Signal Enhancement. In general, the acquired bio signals such as ECG and EEG are contaminated by noise or artifacts. The artifacts are baseline wander PLI, eye blinks, eye movements (EOG), heart beat (ECG) etc. The examination of the ECG and EEG has been used for diagnosing heart and brain related diseases. This paper has presented an overview of various types of noise sources associated with ECG and EEG signals and a brief survey of advanced techniques available for removal of Baseline Wander, powerline interference, eyeblink and eye movement etc. 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. The PCA and ICA can analyze the signal only in time domain, PCA method depends on the size of data set of the signal which is to be denoised. From the literature survey it is clear that wavelets gave the best result for denoising .Currently only simple wavelet transform is implemented for ECG and EEG denoising in future its advancement wavelet packets can be used for removing noises from ECG and EEG signals which will give better results.

This paper has been portrayed the various techniques used for noise cancellation in biosignals. The various techniques are analyzed in detail for possible usage for the future researchers. Several other novel ideas can also be derived from these works described in this paper.

REFERENCES

[1]. Turner, D.D., Knuteson and 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.

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

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

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

[5]. 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.

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

[7]. 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.

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

[9]. D.A. Overton and C. Shagass. "Distribution of eye movement and eye blink potentials over the scalp", Electroencephalography and Clinical Neurophysiology, 27:546, 1969.

[10]. J.F. Cardoso," High-order contrasts for independent component anslysis", *Neural Computation*, **11**(1): 157-192, 1999.

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

[12]. Paul J.S., Reddy M.R. and Kumar V.J, "A transform domain SVD filter for suppression of muscle noise artefacts in exercise ECG", *IEEE Transaction on Biomedical Engineering,* Vol. 47, No.5, pp. 654-663 , 2002.

[13]. Nikolaev N., Gotchev A., Egiazarian K. and Nikolov Z. "Suppression of electromyogram interference on the electrocardiogram by transform domain denoising", *Medical and Biological Engineering and Computing*, Vol. **39**, No. 6, pp. 649-655, 2006.

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

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

[16]. Hyung-Min Park, Sang-Hoon Oh, Soo-Young Lee, “On adaptive noise cancelling based on independent component analysis”, *Electronics Letters,* Vol. **38**, No.15, pp.832-833, 2002.

[17]. Browne M. and Cutmore T.R.H, “Lowprobability event-detection and separation via statistical wavelet thresholding: An application to psychophysiological de-noising”, *In Clinical Neurophysiology,* Vol. **113**, No. 9, pp. 1403-1411.

[18]. Tatjana Zikov, Stephane Bibian, Guy A. Dumont and Mihai Huzmezan, ”A wavelet based de-noising technique for ocular artifact correction of the electroencephalogram”, *Proceedings of the Second Joint EMBS/BMES Conference*, Vol. 1, pp. 98-105, 2002.

[19]. P. Ashok Babu1, “*Removal of ocular artifacts from EEG signals using adaptive threshold PCA and Wavelet Transforms”*, International Journal of Electronic Signals and Systems, vol. 1,2012.

[20]. S. Verobyov and A. Cichocki,” Blind noise reduction fo multisensory signals using ICA and subspace filtering, with application to EEG analysis”, *Biological Cybernetics*, **86**: 293-303, 2002.

[21]. L. Vigon, M.R. Saatchi, J.E.W. Mayhew, and R. Fernandes, “Quantitative evaulation of techniques for ocular artefact removal”, *IEE Proc.-Sci. Meas. Technol.*, **147**(5), September 2000.

[22]. Janett Walters-Williams & Yan Li,” *A New Approach to Denoising EEG Signals” - Merger of Translation Invariant Wavelet and ICA*, International Journal of Biometrics and Bioinformatics Volume (**5**) : Issue (2) : 2011.

[23]. MichalKubinyi et.al, “EMAT Noise Suppression Using Information Fusion in Stationary Wavelet Packets”, *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control,* vol. **58**, no. 5, May 2011.

[24]. Majkowski,, “A. Denoising based on wavelet and PCA signal compression”, Intelligent Signal Processing, 2005 *IEEE International Workshop*, pg: 70 -73 , 1-3 Sept. 2005

[25]. Garg, G.; Singh, V.; Gupta, J.R.P.; Mittal , “ algorithm for ECG denoising using Discrete Wavelet Transforms”, Computational Intelligence and Computing Research (ICCIC), 2010 IEEE International Conference on, vol., no., pp.1-4, 28-29 Dec. 2010.

[26] .Rangaraj M. Rangayyan “Biomedical signal analysis A case study approach.”, IEEE press series, John Wiley & Sons 2002.