Quantitative Investigation of Digital Filters in Electrocardiogram with Simulated Noises

Aung Soe Khaing and Zaw Min Naing

Abstract— **Electrocardiogram (ECG) signal plays a vital role in the primary diagnosis and monitoring of the health of heart. For the features extraction of the ECG signals such as R-peak, QRS complexes, T-waves etc., the significant noises have to be cancelled. The most significant noises corrupted the ECG signal are power line interference (50/60Hz), Electromyographic (EMG) noise due to motion artifacts, muscle contraction, baseline wanders due to respiration and perspiration, and instrumentation noise. Designing digital filters to suppress these noises sits in a quite important position for ECG signal processing and analysis. This paper presents the application of software digital filters in order to effectively eliminate these noises from the ECG signals. Several types of digital filters were designed and implemented along with their strengths and weaknesses. The quantitative properties of implemented digital filters were investigated with the ECG signals from MIT-BIH Arrhythmia Database as the test data. All the work was done with MATLAB®. The noises were simulated and added to the test data. The performance of digital filters was described by the comparison of power spectra of the filtered noisy signal and the original database ECG recordings and the mean square error.**

Index Terms—**Biomedical Signal Processing, Digital Filters, Electrocardiogram, Modeling and Analysis, Noise Reduction.**

I. Introduction

Computer aided ECG signal analysis is a popular research trend in today world. For the process of automated analysis, the noises present in ECG signal are needed to be considered and eliminated for the accurate signal analysis and diagnosis.

Electrocardiogram (ECG) can be corrupted by various types of noise such as baseline wander noise, Electromyographic (EMG) interference and 50 or 60 Hz power line interference, motion artifacts, etc. The ECG signal embedded in these noises is very difficult to correctly interpret for diagnosis.

Therefore, to reduce and remove the noises, digital software filters are widely used in biomedical signal processing. There are many research papers which described the processing of individual noise with different types of filter, but not many papers which discussed the processing of several types of noise present in the ECG. Analog filters can deal with the noises, but they introduce nonlinear phase shifts and depend on the instrumentation such as resistance, temperature and design. Digital filters are more precise and less error with more advantages over analog filters. In this paper, the most significant noises were simulated and processed using different types of digital filters. The performance of the filters were compared and evaluated.

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II. Materials and Methods

A. MIT-BIH Arrhythmia Database

MIT-BIH arrhythmia database consists of 48-half-hour ECG recordings and contains approximately 109,000 manually annotated signal labels. The recordings were digitized at 360 Hz (samples per second per channel) with 11-bit resolution over 10 mV (±5 mV) range. ECG recordings are two channels. In most records, the upper signal is a modified limb lead II (MLII), obtained by placing the electrodes on the chest. The lower signal is usually a modified lead V1 (occasionally V2 or V5, and in one instance V4); as for the upper signal, the electrodes are also placed on the chest. This configuration is routinely used by the BIH Arrhythmia Laboratory. Normal QRS complexes are usually prominent in the upper signal. Therefore, only the first channel was used for the test. In records 102 and 104, it was not possible to use modified lead II because of surgical dressings on the patients; modified lead V5 was used for the upper signal in these records [1].

B. Noises in Electrocardiogram

Electrocardiogram (ECG) signal is the electrical recording of heart activity. It is usually in the range of small voltage in magnitude (10μV (fetal) and 5 mV (adult)) and has a frequency component from about 0.05-100 Hz. The electrical conduction system of the heart, a basic shape of ECG waveform and one of Einthoven's methods for recording are shown in Fig. 1(more details in [2]).

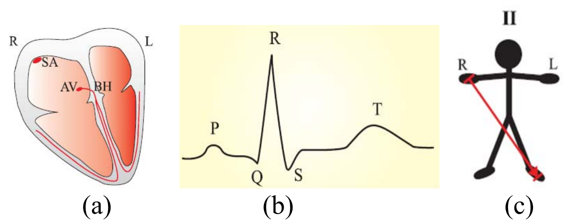

Fig. 1. (a) Electrical conduction system (b) Basic shape of ECG waveform (c) Einthoven's method II recordings

The ECG is frequently corrupted by various noises which can be within the interested frequency band and similar to the morphology of the ECG itself [3], [4] and [5].

1) Power line interference is a significant source of noise. Data cables carrying ECG signal from the patients to display devices are influenced by Electromagnetic interference (EMI) from the 50/60 Hz power line noise. This noise degrades the signal quality and affects the tiny features which can be critical for clinical diagnosis and monitoring and signal processing.
2) Baseline drift can be represented as a sinusoidal component at the frequency of respiration added to the ECG signal. It is usually from respiration with amplitude of around 5% at frequencies drifting between 0.15 and 0.3 Hz. The drift causes problems in the detection of ECG signals, e.g., sometimes the amplitude of T-wave is higher than the peak of R-wave and results in false detection of R-peak.
3) Motion Artifacts are due to either the patient movement or loss of electrode contact, transient baseline changes caused by alterations in the electrode-skin impedance with electrode motion.
4) Electromyographic interference is due to muscle contractions and transient variance and duration of bursts. It usually lasts around 50 ms between dc and 10,000 Hz with amplitude of 10% level.
5) Composite noise means the combination of all mentioned above.

There are other types of noises contaminated ECG signal such as instrumentation noise, electrosurgical noise and other less significant source of noise.

C. Implementation of Digital Filters

A digital filter is a mathematical algorithm implemented in hardware/software that operates on a digital input signal to produce a digital output signal for the purpose of achieving a filtering objective. The term digital filter used in this paper refers to the software filter. Digital filters play a crucial role in digital signal processing, e.g., biomedical signal processing [6]. There are two main types of digital filters: finite impulse response (FIR) filters and infinite impulse response (IIR) filters. The transfer function for IIR filter is

$$H(z) = \frac{a_0 + a_1 z^{-1} + a_2 z^{-2} ... + a_N z^{-N}}{1 + b_1 z^{-1} + b_2 z^{-2} ... + b_M z^{-M}} \quad (1)$$

where *a* and *b* are the coefficients of the filter.

The transfer function of FIR filter is

$$H(z) = \sum_{k=0}^{N} h(k) z^{-k} \quad (2)$$

where *h (k),* k=0, 1, 2, 3…, N are the filter coefficients.

The implementation procedures are described with flow chart as shown in Fig.2. Firstly, the ECG signal from the database is loaded into the MATLAB®. Then, the simulated signal is added to the loaded signal. Then the original ECG signal and the noise added ECG signal are examined in time domain and frequency domain. And the suitable design parameters for different digital filters are chosen based on the frequencies of noises. Thereafter, the ECG signal with simulated noises is passed through the designed digital filters. Finally, the filtered ECG signals are investigated again in time domain and frequency domain. The quantitative properties of the designed and implemented filters are investigated by comparing their spectra before and after filtration. The performance of the filters is mentioned with the mean square error (MSE).

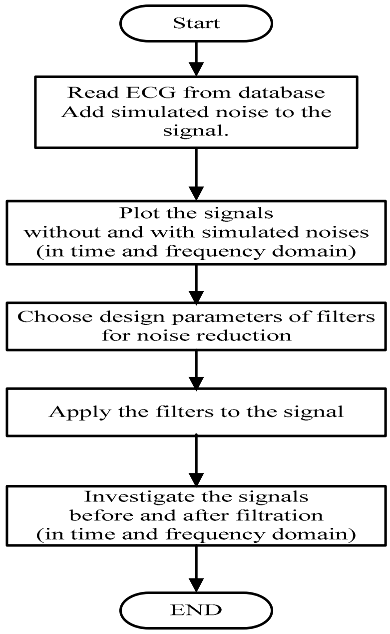

Fig. 2. Flow Chart of the implementation procedures

III. Simulation and Processing of Noises in ECG

Since the goal of this paper is to design and implement digital filters for the processing of noises and to evaluate the performance of the filters, each noise signal is first modeled and simulated. The characteristics of each noise described in section II play a vital role in modeling the noise signal.

A. Processing of Power Line Interference

Power line interference consists of 50/60 Hz and its harmonics which can be modeled as sinusoids and a combination of sinusoids with amplitude up to 50 % of the peak- to-peak of ECG amplitude. The model of power line interference is provided as in (3). Fifty Hertz power line noise is simulated using the MATLAB®. The noise level corresponds to the peak-to-peak amplitude of 0.15 mV. The frequency of power line is 50 Hz.

$$N(t) = A \times \sin(2 \times \pi \times f \times t) \quad (3)$$

where *N (t)* is the power line noise, *A* is the amplitude and *f is* the frequency of power line.

ECG signal from database and ECG signal superimposed with modeled power line interference in time domain are plotted as shown in Fig.3. Also, the Fast Fourier Transform (FFT) of the signals is illustrated in Fig.4. It can be clearly seen that the nature of power line interference, 50 Hz sinusoid is obvious in the power spectrum. From the information gained by plotting the FFT of ECG signals in the frequency domain, the design and implementation of digital filters are proceeded to remove and reduce the noises.

Digital notch filter is mostly the first choice for rejecting the specific frequency of the signal. The FIR and IIR notch filters were designed to suppress the 50 Hz power line noise. The sampling frequency is 360 Hz for all filters. The performance of the filter was evaluated by comparing their power spectra along with the mean square error (MSE).

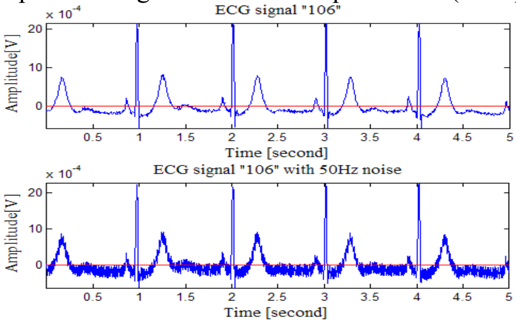

Fig. 3. ECG signal and ECG with power line noise in time domain

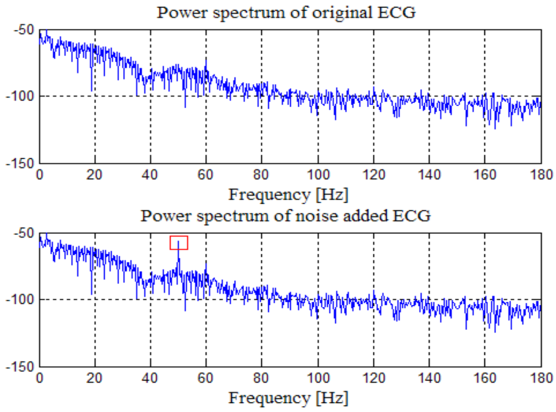

Fig. 4. ECG signal and ECG with simulated noise in frequency domain

An IIR notch filter is designed with the transition bandwidth, Δf of 4 Hz and the center frequency, F_o is 50 Hz using pole-zero placement method. The radius, r, of pole is determined by (4).

$$r \approx 1 - \frac{\Delta f \pi}{f_s} \quad (4)$$

The pole location θ_0 is determined by (5).

$$\theta_0 = \frac{2\pi F_0}{f_s} \quad (5)$$

The transfer function of designed IIR notch filter is obtained from (4) and (5) as shown in (6).

$$H(z) = \frac{1 - 1.2856 z^{-1} + z^{-2}}{1 - 1.2407 z^{-1} + 0.93140 z^{-2}} \quad (6)$$

The noise added signal after the application of designed IIR notch filter in time domain is shown Fig. 5.

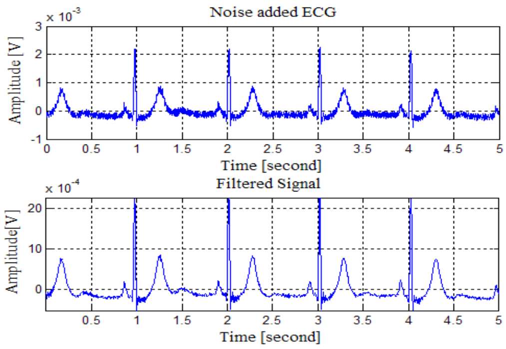

Fig. 5. Noise added ECG signal before and after filtration by IIR notch filter

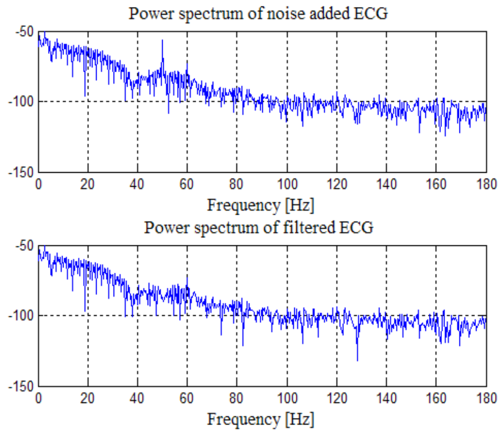

Fig. 6. Power spectra of the signal before and after filtration by IIR notch filter

From the power spectra shown in Fig.6, it can be clearly seen that the designed IIR notch filter could reduce the power line noise from -56.51 dB to – 87.09 dB for the signal 106.

FIR filters are mostly used in ECG signal processing because of their invaluable linear phase shift properties. For the FIR notch filter design, the same parameters are used as in the IIR notch filter design.

The noise added signal after the application of designed FIR notch filter in time domain is shown Fig. 7. From the power spectra shown in Fig. 8, it can be clearly seen that the designed IIR notch filter could reduce the power line noise from -56.51 dB to – 122.8 dB.

In addition to the comparison of the power spectra to evaluate the performance of the filters, the mean square error can be applied to assess the filter's performance. The mean square error (MSE) is expressed as in (7).

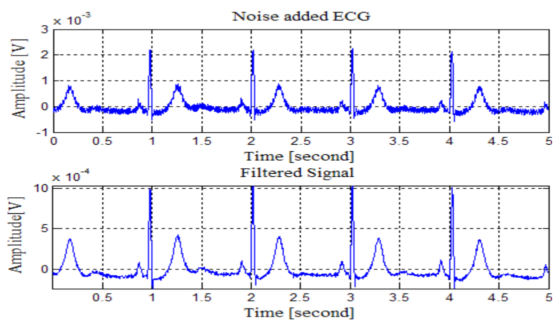

Fig. 7. Noise added ECG signal before and after filtration by FIR notch filter

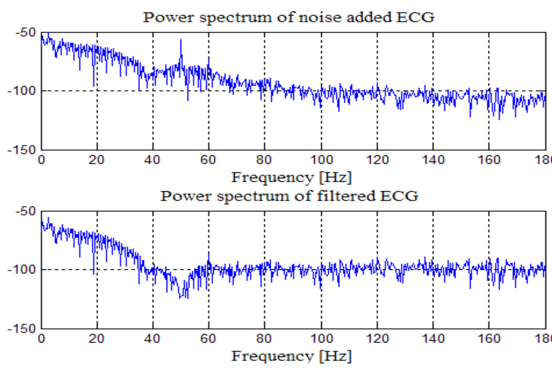

Fig. 8. Power spectra of the signal before and after filtration by FIR notch filter

$$MSE = \frac{1}{N_p} \sum_{n=1}^{N_p} (y[n] - x[n])^2 \quad (7)$$

where N_p is the sampling points, $y[n]$ is the output signal of digital filters and $x[n]$ is the original input signal. The mean square error of the two filters for the database signals is listed in Table I. The mean square error was estimated for all other signals. Compared to the MSE of the two filters, the MSE of FIR filter is more than MSE of IIR filter because the FIR notch filter degrades the amplitude of the signal. However, the FIR filter doesn't distort the whole signal as much as the IIR filter does.

TABLE I: COMPARISON OF DESIGNED FILTERS FOR POWER LINE INTERFERENCE CANCELLATION

MIT-BIH Database Signal	Power before filtration (dB)	Power after filtration (dB)		MSE	
		FIR	IIR	FIR	IIR
100	-56.43	-110.3	-85.85	$1.79\ e^{-12}$	$4.52\ e^{-13}$
106	-56.51	-122.8	-87.09	$6.54\ e^{-13}$	$5.45\ e^{-13}$
107	-56.81	-102	-91.96	$1.04\ e^{-11}$	$2.35\ e^{-13}$
104	-56.50	-93.97	-80.5	$5.87\ e^{-14}$	$2.27\ e^{-12}$
103	-56.51	-111.1	-85.8	$3.59e^{-10}$	$8.39e^{-12}$
101	-56.36	-117.8	-86.03	$1.08\ e^{-12}$	$6.65\ e^{-13}$

B. Processing of Baseline Wanders

Baseline wander is one of the most significant noise sources during the ECG measurement. This noise makes the physician difficult to interpret the ECG signal for the correct treatment. Baseline drift due to respiration and perspiration was simulated as a low frequency sinusoid. The frequency is 0.3 Hz and the amplitude is 1 mV for the simulation. It is modeled similarly to the power line interference in (3). A plot of ECG contaminated by baseline wander due to respiration is described in Fig. 9.

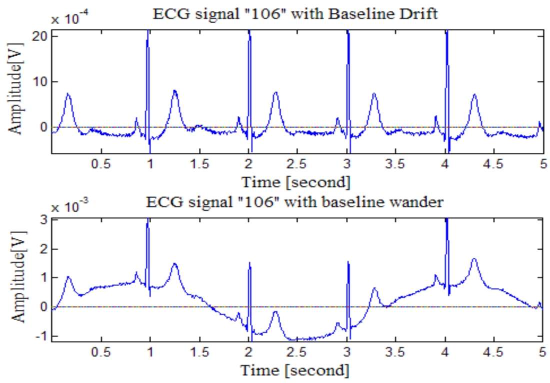

Fig. 9. ECG signal and ECG with baseline wander in time domain

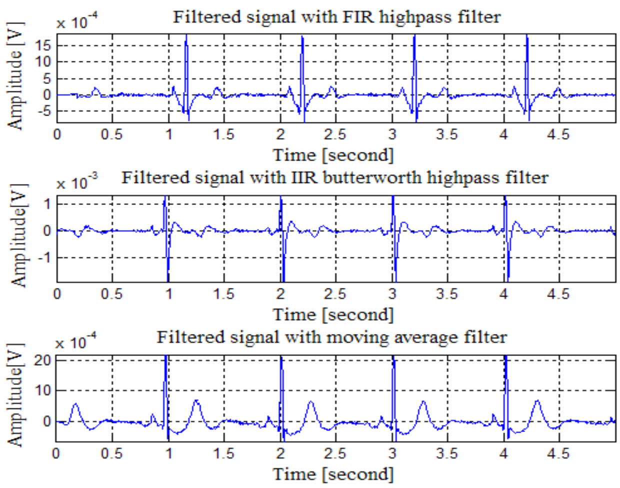

Fig. 10 . Filtered signals with FIR high pass filter (first row), IIR Butterworth high pass filter (second row) and moving average filter (third row)

The frequency content of baseline wander is usually in a range well below 0.5 Hz. These low frequency components can severely affect the visual interpretation of an ECG and the results from computer based ECG analysis. In order to discard baseline drift, a high pass filter was designed with 3 Hz of cutoff frequency and 134 orders for the FIR highpass filter. Also, the IIR Butterworth highpass filter is designed with cut-off frequency of 3 Hz and filter order of 3.Moreover, the moving average filter is applied to the ECG signal corrupted by the baseline wanders. The moving average filter can also be used for data smoothing. The results of the filtered signal in time domain are illustrated in Fig.10.

C. Processing of Abrupt Baseline Drift

Abrupt baseline drift is due to the movement of patient during the measurement of ECG and the changes of skin-electrode impedance. It is simulated by adding DC bias for some period of the ECG. The noise level of +0.5 mV or – 0.5 mV was chosen. A plot of ECG added by abrupt baseline drift is shown in Fig. 11.

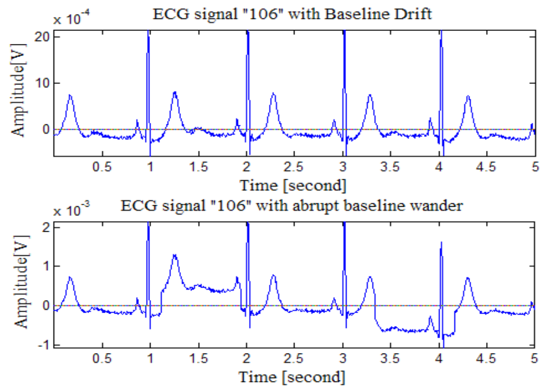

Fig. 11. ECG signal and ECG with baseline wander in time domain

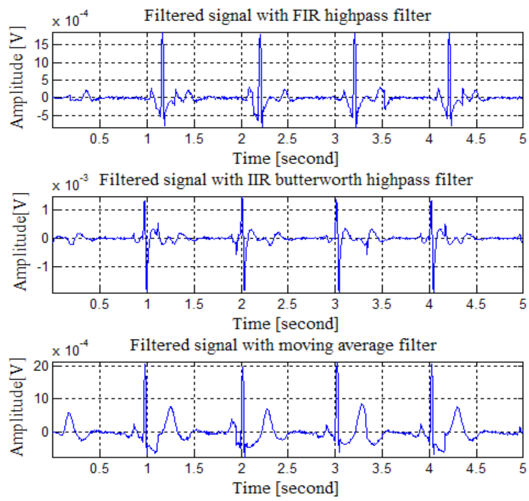

Fig.12 . Filtered signals with FIR highpass filter (first row), IIR Butterworth high pass filter (second row) and moving average filter (third row)

ECG signal with abrupt baseline change is passed through designed FIR highpass filter with cutoff frequency of 3 Hz and 134 orders, IIR Butterworth highpass filter with the same cutoff frequency and order of 3. Again, the moving average filter is applied to the signal contaminated by abrupt baseline drifts because the frequency content of abrupt baseline drift used is also low. Therefore, the same specifications of highpass filters as in processing of baseline wanders are used. The results are plotted as in Fig.12. From the results, it can be said that the moving average filter gives the best performance for the processing of ECG signal corrupted due to abrupt baseline drifts. The FIR highpass filter shifted the signal and changed the amplitude of the signal. And the IIR Butterworth highpass filter could fix the abrupt baseline drift but the signal was distorted.

D. Processing of Electromyographic interference

Electromyographic (EMG) interference is simulated by adding random noise to the ECG. The noise level is ± 50% of the ECG maximum amplitude. A plot of ECG with Electromyographic noise is shown in Fig. 13.

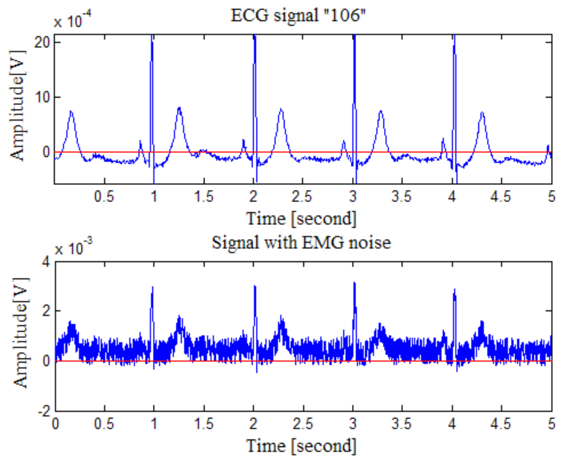

Fig. 13. ECG signal and ECG with EMG noise in time domain

Electromyogram (EMG) signal is the measurement of muscle contractions. It interferes the ECG signal during the measurement of heart's activity. The range of EMG is varied between the species and the muscles. EMG signals contain variable frequencies; however the most common frequency bands recorded are 0.3 Hz to 1 or 2 kHz. The FIR lowpass filter with cutoff frequency of 30 Hz , FIR highpass filter with cutoff frequency of 5 Hz and the FIR Equiripple bandpass filter with the cutoff frequencies [5 30] Hz are designed and implemented. The results of filters are shown in Fig. 14.

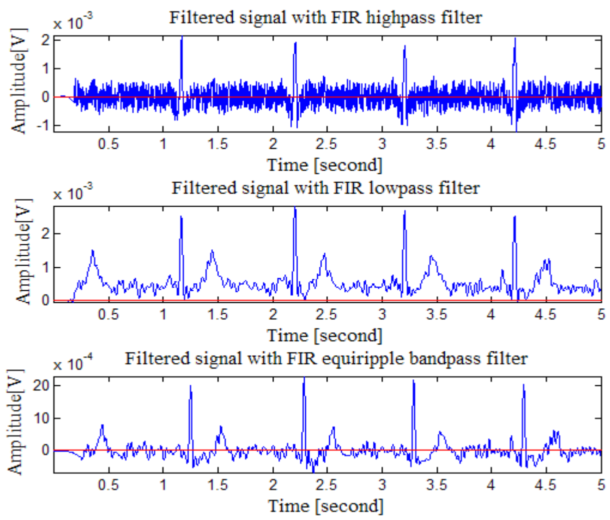

Fig. 14 . Filtered signals with FIR highpass filter (first row), FIR lowpass filter (second row) and FIR Equiripple bandpass filter (third row)

From the results in Fig.14, it can be concluded that the FIR Equiripple bandpass filter provides the better performance than the other two filters. It can also be said that the FIR highpass filter with the corner frequency of 5 Hz is not suitable for the processing of EMG noise in ECG signal.

E. Processing of Composite Noise

The ECG with the composite noise is formed by combining of all of noises discussed above. A plot of ECG with composite noise is shown in Fig. 15. As mentioned, the ECG signal with composite noise includes different kind of frequency and amplitude of noises. It makes a challenge to process to get the noise-free ECG signal for the physician. And also it is the worst case in ECG measurement because there may be all of noise present in ECG recording in reality.

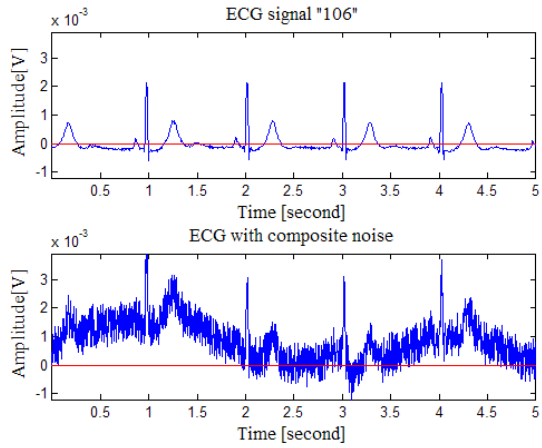

Fig. 15. ECG signal and ECG with composite noise in time domain

For the composite signal, the high-pass or low-pass filter cannot filter to the satisfied extent because the signal was contaminated by various noises with different frequencies. So, the band-pass filter is mostly used to process the ECG signal without knowing the exact frequency of noise and with different frequency bands. FIR Equiripple bandpass filter, FIR bandpass filter and IIR Butterworth bandpass filter with cutoff frequencies [3 43] Hz was designed and applied. However the filters could not fix the abrupt baseline drifts well. Therefore, the cutoff frequencies for all filters are changed to [5 30] Hz. In this time, the filters could attenuate almost all noises, but the signal was distorted. But, the critical information, such as R-peak is not lost as shown in Fig.16.

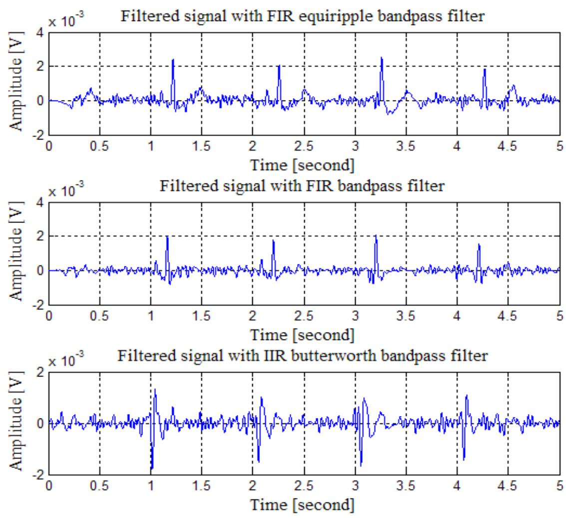

Fig. 16 . Filtered signals with FIR Equiripple bandpass filter (first row), FIR band pass filter (second row) and IIR Butterworth bandpass filter (third row)

IV. Discussion and Conclusion

Noises and artifacts play a vital role in the processing of ECG signal. They make the physicians difficult to diagnose the diseases if the artifacts are present in the ECG signal. In this work, the noises often corrupted the ECG signal are modeled and simulated. Then, design and implementation of digital filters for each type of noise are considered and applied.

For power line interference cancellation, digital notch filters were implemented and the amplitude spectra were compared for the evaluation of their performance as shown in Fig. 6 and Fig.8. FIR is normally preferable because of its linear phase properties. This property is very crucial for ECG signal analysis. In addition, the mean square error is estimated for the performance of digital filters quantitatively. The mean square error of IIR notch filter is lower than that of FIR digital notch filter. Therefore, due to the low computational cost of IIR notch filter, the IIR notch filter is suitable for the real-time implementation in hardware.

For the baseline wander removal due to its lower frequency characteristics, FIR and IIR high-pass filters were implemented. The filter performed to an acceptable extent and no critical information of ECG signal for further processing and analysis is lost. The average moving filter provides the best performance for the processing of baseline wanders as shown in Fig.10.

Abrupt baseline drift is caused by the movement of patient which can provide wrong information for ECG signal processing and diagnosis. FIR highpass filter and IIR Butterworth highpass filter were applied to fix the abrupt change of baseline. As shown in Fig. 12, the moving average filter could fix the abrupt baseline drifts with less signal distortion.

Due to the muscle contraction, Electromyographic (EMG) interference appears and can influence the signal to noise ratio of ECG signal. The three digital filters, FIR highpass and lowpass filter and FIR Equiripple lowpass filter are designed and implemented. The FIR highpass filter is not a suitable choice for EMG interference cancellation. FIR lowpass filter changes the baseline of ECG signal. From the results, it can be said that FIR Equiripple lowpass filter provides the better performance with less signal distortion.

Finally ECG signal contaminated by the composited noise passed through the band-pass filters because of the combination of different frequency contents. The performance of filters for removing the composite noise is enough for basic signal analysis, the critical R-peak is distinct enough for further processing, such Heart Rate Variability (HRV).

To sum up, FIR filters are preferred for ECG signal processing due to the property of linear phase. However, the higher orders of filters are required and the signal was delayed proportionally to the orders of filter. IIR filters need only a few filter orders. So, regarding the hardware complexity and computational cost, IIR filters can be chosen. For the phase linearity, forward/backward IIR filters can be designed and implemented. Although specific type of filter for a single noise can perform very well, different type of filters in cascaded form should be investigated for the processing of the signal corrupted by different noises. Moreover, adaptive digital filters should also be considered for the tracking of noise with better performance.

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References

[1] "MIT-BIH Arrhythmia Database," [online] Available *http://www.physionet.org/physiobank/mitdb*

[2] W.V. Drongelen, *Signal Processing for Neuroscientists*, Academic/Plenum, Elsevier, New York.

[3] G.M. Friesen, C.J. Thomas, M.A. Jadallah, S.L. Yates, S.R. Quint,, and H.T. Nagle, "A Comparison of Noise Sensitivity of Nine QRS Detection Algorithms," *IEEE Trans. Biomed. Eng.*, vol. 37, no. 1, pp. 85–98. , 1990.

[4] G.D. Clifford, F. Azuaje, P. E McSharry, "*Advanced Methods and Tools for ECG Data Analysis*," Engineering in Medicine and Biology, Artech House Inc, Boston, 2006.

[5] A.U. Rajendra, S.S. Jasjit, A.E.S. Jos and S.M. Krishnan, "*Advances in Cardiac Signal Processing*", Springer –Verlag, Berlin , 2007.

[6] E.C. Ifeachor, B.W. Jervis, "*Digital Signal Processing-A Practical Approach,*"Addison-Wesley, 1993.

[7] Aung Soe Khaing, "Performance Evaluation of Digital Filters for Noise Cancellation in Electrocardiogram," in *Proc. 2011 International Conference on Computer Design and Engineering (ICCDE 2011)*, Kuala Lumpur, Malaysia, 2011, pp. 417-423.

[8] Aung Soe Khaing, Zaw Min Naing, Hla Myo Tun, "Power Line Interference Cancellation for ECG," in *Proc. The 2nd Second International Conference on Science and Engineering (ICSE 2010)*, Yangon, Myanmar, 2010, pp. 154-157.

[9] Aung Soe Khaing, "Design and Implementation of Computer Based Electrocardiogram System," Ph.D. dissertation, Dept. Electron. Eng., Mandalay Technological Univ., Mandalay, Myanmar, 2011.

[10] W.J. Tompkins, *Biomedical Digital Signal Processing*, Prentice Hall Publications, New Jersey, 1993.

[11] J.A.V Alsté, T.S. Schilder, "Removal of baseline wander and power line interference from the ECG by an efficient FIR filter with a reduced number of taps," *IEEE Trans. Biomed*. Eng., vol.32, no.12, pp. 1052-1060,1985.

[12] Y.W. Bai et. al, " Adjustable 60 Hz noise rejection by a notch filter for ECG signals," Proc. ICMTC2001- Instrument and Measurement Technology Conference, Como, Italy, 2004.

[13] S.C. Pei, C.C. Tseng, "Elimination of AC interference in Electrocardiogram using IIR Notch filter with transient suppression," *IEEE.Trans. Biomed*.vol 42, no.11, November, 1995.

[14] Y. Lian, J.H. Yu, " The reduction of noises in ECG signal using a frequency response making FIR filters," IEEE Intrenational Workshop on Biomedical Circuits and Systems, 2004.

[15] M.S. Chavan, Ra. Agarwala, M.D. Uplane, "Design and Implementation of Digital FIR Equiripple Notch Filter on ECG Signal for removal of Power Line Interference," *WSEAS Trans. Signal Processing*, issue 4, vol. 4, April 2008.

[16] M.S. Chavan, Ra. Agarwala, M.D. Uplane, " Interference Reduction in ECG using Digital FIR Filters based on rectangular window," *WSEAS Trans. on Signal Processing*, issue 5, vol. 4, May 2008.

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