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Removal of Power-Line Interference from Biomedical Signal using Notch Filter

[1]L. Thulasimani and [2]M. Dhivya

[1]Assistant Professor ,Department of Electronics and Communication Engineering, PSG College of Technology, Coimbatore, India.
[2]PG scholar ,Department of Electronics and Communication Engineering, PSG College of Technology, Coimbatore, India.

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ABSTRACT

Bio-signal recordings are often contaminated by residual power-line interference. Filtering of power-line interference is very meaningful in the measurement of biomedical events recording, particularly in the case of recording signals as weak as the ECG(Electrocardiogram). The available filters for power-line interference either need a reference channel or record the frequency as 50/60Hz fixed. Basically traditional analogue and digital filters are known to suppress ECG components near to the power-line frequency. In this paper, a filter prototype is designed to cancel out the power-line interference(50Hz) from biomedical signals like ECG and EEG(Electroencephalogram) using a filtering technique of the signal type chosen. The tool used for digital signal processing is MATLAB2012a.

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INTRODUCTION

In biomedical signal processing, the aim is to extract clinically, biochemically or pharmaceutically relevant informant in order to enable an improved medical diagnosis. All living things, from cells to organism, deliver signals of biological origin. Such signals can be electric, mechanical, or chemical. All such signals can be of interest for diagnosis, for patient monitoring and biomedical research. The main task of processing biomedical signals is to filter the signal of interest out of from the noisy background and to reduce the redundant data stream. Biomedical signal processing is mainly about the innovative applications of signal processing methods in biomedical signals through various creative integrations of the method and biomedical knowledge. There are a number of medical systems include ultrasound, electrocardiography and plythesmography are widely used for this purpose (Muhammad Ibn Ibrahimy, 2010).

Real-time acquisition of data directly from the source by direct electrical connections to instruments avoids the need for people to measure, encode, and enter the data manually. Sensors attached to a patient convert biological signals, like blood pressure, pulse rate, mechanical movement, and electrical activity, e.g., of heart, muscle and brain into electrical signals, which are transmitted to the computer. These signals are then sampled periodically and are converted to digital representation for storage and processing. Automated data-acquisition and signal processing techniques are particularly important in patient monitoring settings (Van Bemmel, J. and M. Musen, 1997). The sampling rate(sampling frequency) is too low relative to the rate at which a signal changes value will produce a poor representation (Gardner, R.M. and M.M. Shabot, 2006). On the other hand, oversampling increases the expense of processing and storing the data (Camm, A.J., 1996).

The paper is organized as follows: Section II defines the objective to reveal the necessity of biomedical signal processing and filtering technique. Section III describes about the importance of cancelling out the power-line interference in biomedical signal processing. Section IV discusses the simulation results. Section V gives the conclusion and future scope of this paper.

Biomedical Signal Processing:

The term “bio-signal” is defined as any measured and monitored from a biological being. Electrical bio-signals (bio-electrical signals) are the electrical currents generated by electrical potential differences across a tissue, organ or cell system like the nervous system. Most naturally occurring signals are analogue signals. i.e., signals that vary continuously. A digital computer stores and processes value in discrete unit. Before processing is possible, analogue signals must be converted to discrete units. For example, a change in a signal that varies between 0.1 and 0.2 volts will be undetectable

Corresponding Author: L. Thulasimani, Department of Electronics and Communication Engineering, PSG College of Technology.
E-mail: ltm@ece.psgtech.ac.in

if the instrument has been set to record changes between 0.0 and 1.0 in 0.25volt steps. For instance, looking at an ECG, we find that the basic repetition frequency is at most a few per second, but that the QRS complex contains useful frequency components at the order of 150Hz (Webster, J.G., 1998). Thus, the sampling rate should be at least 300 measurements per second. This rate is called the Nyquist frequency.

The different types of biological signals can be classified into two main groups mainly the deterministic and the stochastic (or statistical) signals. Heart beat and respiration generates signals that are also repetitive. The deterministic group is defined as the signal wave shape repeated periodically and is further classified as periodic such as sine wave, quasi-periodic such as ECG, and transient such as cell response. The stochastic group is defined as the statistical properties either change or do not change in time which includes stationary signals such as alpha waves and non-stationary signals such as EEG (Tierney, J., 1971).

The electrical characteristics of bio-signal in a typical adult human has an ECG signal bandwidth ranges between 0.01-300Hz with amplitude range of less than 50µV-10mV, EEG signal bandwidth ranges between 0.01-150Hz with amplitude range of less than 10-100µV in scalp and less than 10µV-20mV in subdural electrodes, and EMG signal bandwidth ranges less than 100µV-100mV for external EMG and less than 1µV-5mV for internal EMG.

The important aspects that influence the biomedical signal processing include:

1) Noise: The component of the acquired data that is not due to the specific phenomenon being measured is known as noise. A primary source of noise is the electrical or magnetic signals produced by nearby devices and power-lines. Filtering algorithms can be used to reduce the effect of noise (Hwang, I. and J. Webster, 2008).

2) Precision and Accuracy: Precision refers to the fidelity of the measurement and is also limited by the accuracy of the instrument that converts and transmits the signal. Accuracy refers to the tendency of measured values to be symmetrically grouped around the variability of medical data.

3) Abstraction and Analysis: Once the data have been acquired and filtered, they typically are processed to reduce their volume. Often the data are analysed to extract important parameters or features of the signal. For example, The duration or intensity of the ST segment of an ECG.

Filtering Process:

The notch filter is a digital filter which provides programmable gain and anti-aliasing by exploiting oversampling. Moreover, it is applicable to filter out a single frequency signal and is employed to remove the 50Hz power-line interference from the biomedical signal. Modern biomedical system usually digitizes the signal using ADC (analogue to digital converter). Since sharp digital filters are typically optimised in area and power, it is not necessary to use analogue filters to eliminate all aggressors before sampling.

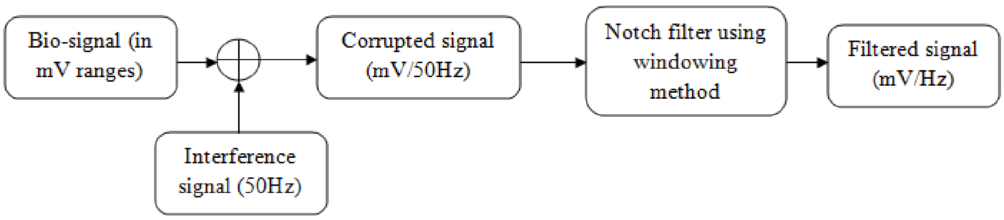

Fig. 1: Block diagram of bio-signal interference cancellation using notch implementation.

The block diagram of interference cancellation from biomedical signal using notch filter is proposed in figure1.The bio-signal is given as input to the system and is contaminated with frequency of 50Hz considered to be the PLI. It is then mixed with the input signal to give the corrupted signal in mV range and then sampled and filtered out using notch filter by windowing method to achieve the interference free signal output.

Interference Cancellation:

Power-line interference (PLI) is a challenging task in digital signal processing especially in biomedical field. The power consumption can be determined by the dynamic range which is thereby increased due to PLI. The dynamic range is defined as the measure of the ratio between the largest signal that can be handled by the system without significant distortion and the minimum detectable signal set by the input-referred noise. The specifications for the minimum detectable signal are typically set by the signal being measured and the largest signal is often set by the interference (Jose L. Bohorquez, 2011).

From various artifacts contaminate ECG recording, the most common is the PLI and baseline drift which is easily recognised by the interfering frequency of 50Hz(as per Indian standard) in ECG. The interference may be due to stray effect of the alternating current fields due to loops in the patient's cables and loose contacts of the cable. When the machine or the patient is not properly grounded, PLI may even completely obscure the ECG waveform.

The most common cause of 50Hz interference is the disconnected electrode resulting in a very strong signal, and therefore needs quick action. PLI can be as large as 5µVp-p differently. This corresponds to the required dynamic range of almost 25dB, resulting in unnecessary power consumption.

Simulation Results:

This section discusses about the interference cancellation from the biomedical signals in low amplitude range. The ECG data analysis is done by matlab M-File program designed using notch filter. Figure2. Shows the response of the filter whose impulse response is unity at n=50th sample out of 100samples sampled according to nyquist rate. The designed notch filter eliminates the sample with the frequency 50Hz. Figure3. Shows the corresponding magnitude and phase response of the notch filter designed having normalised frequency 0.1rad/sample.

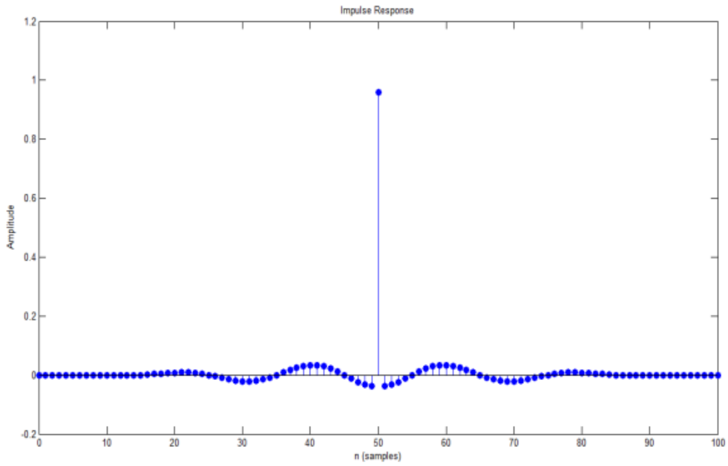

Fig. 2: Impulse response of the filter design.

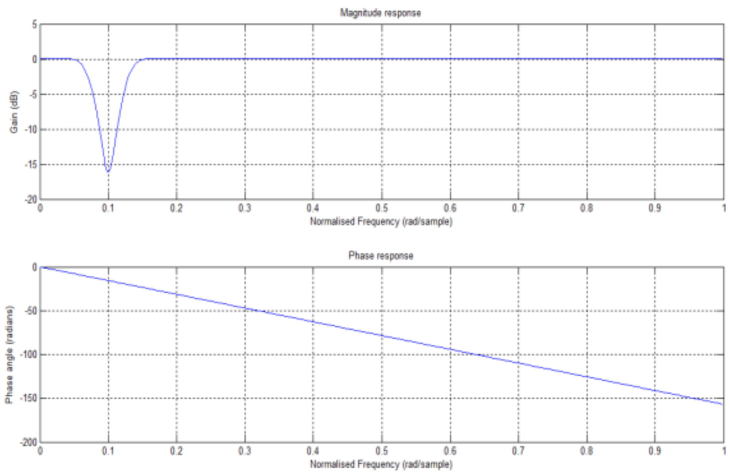

Fig. 3: Magnitude and phase response of the notch filter.

The figure 4. shows the generation of ECG signal of PQRSTU peaks with 3000 samples which is sampled with 3.5mV amplitude range. Then it is contaminated with the 50Hz power-line interference signal throughout 3000samples. It is then filtered out using the notch filter designed. The figure 5. shows the power spectral density of the ECG signal samples created. Then these samples at 50Hz or 0.1rad/sample normalised frequency is filtered by notch filter design.

Conclusion:

Thus, these observations concludes that the power/frequency spectrum of the contaminated signal of 0.2dB/rad/sample at 0.1rad/sample normalised frequency is reduced to filtered signal of -12dB/rad/sample at 0.1rad/sample normalised frequency of the total samples thereby cancelling interference from the biomedical signals generated. The filter specification includes notch filter design with 3000samples. The order of the filter and the number of taps used is 100 and 101 respectively. The filter frequency ranges from 40-60Hz using hamming window method. This can be further developed by performing various algorithms to design a notched filter at two or more frequencies to eliminate 50/60Hz interference in the system. And also can be implemented in hardware such as FPGA (Field Programmable Gate Array) satisfying the optimising constraints such as low power, low area and high speed. Also, real time data can be taken for interference cancellation analysis.

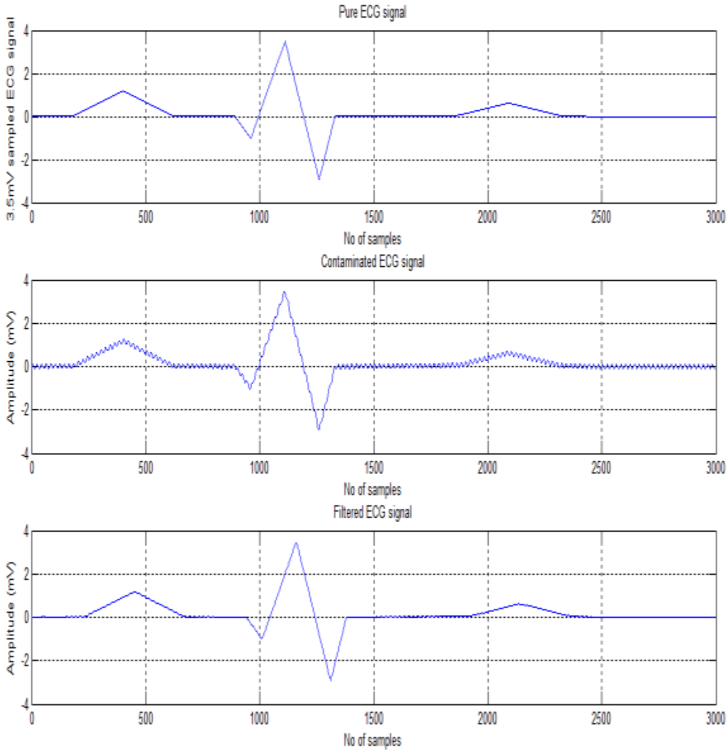

Fig. 4: Generating contaminated and filtered ECG signal.

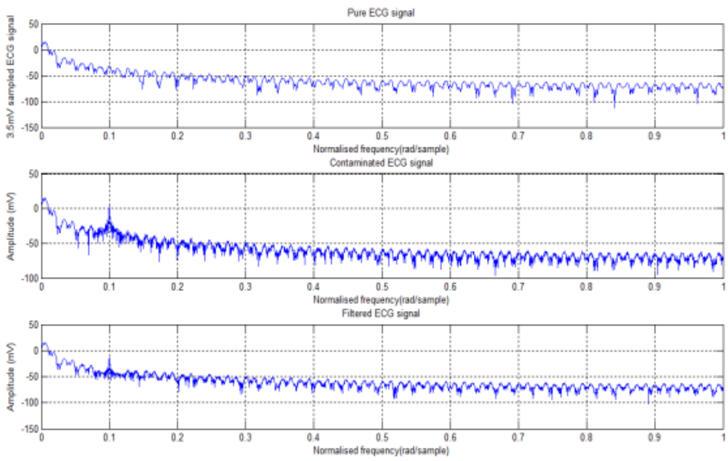

Fig. 5: Power/frequency spectrum of ECG signal.

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