A NEW APPROACH FOR EVALUATING SNR OF ECG SIGNALS AND ITS IMPLEMENTATION

CH. RENUMADHAVI, Dr. S.MADHAVA KUMAR, Dr. A. G. ANANTH,
NIRUPAMA SRINIVASAN
Instrumentation Technology Department
Vishveshwariah Technological University
R. V. College of Engineering, Bangalore.
Jalappa Institute of Technology,Bangalore
INDIA

Abstract: During the process of recording, the Electro-Cardiogram (ECG) wave suffers from several noise and interferences. We have considered the 60Hz, power line interference component. These signals have been filtered using IIR, FIR and LMS Adaptive filters. The use of filters considerably improves signal quality during recording. The main objective is to analyze the Signal with Noise. A new approach for finding SNR which is used as a performance indicator for the comparison of filters and ECG has been developed. The Matlab simulated results are presented[10].

Key_Words : SNR (Signal to noise ratio), Digital filters, FFT, Power Spectrum, Interference Spectrum.

1. Introduction

The ECG or the electrocardiogram is a biological (Biomedical) signal. It is the electrical manifestation of the contractile activity of the heart. ECG is a quasi- periodical, rhythmically repeating signal, synchronized by the function of the heart, which acts as the generator of bioelectrical events. A typical ECG cycle is defined by the various features (P, Q, R, S, and T) of the electrical wave. The P wave marks the activation of the atria, which are the chambers of the heart that receive blood from the body. The activation of the left atrium, which collects oxygen-rich blood from the lungs, and the right atrium, which gathers oxygen-deficient blood from the body, takes about 90 msec. Next in the ECG cycle comes the QRS complex. The heart beat cycle is measured as the time between the second of the three parts of the QRS complex, the large R peak. The QRS complex represents the activation of the left ventricle, which sends oxygen-rich blood to the body, and the right ventricle, which sends oxygen-deficient blood to the lungs. During the QRS complex, which lasts about 80 msec, the atria prepare for the next beat, and the ventricles relax in the long T wave. It is these features of the ECG signal by which a cardiologist uses to analyze the health of the heart and note various disorders, such as atrial flutter, fibrillation, and bundle branch blocks .[1,2,3]

2. Problem Formulation

Figure1 shows a typical ECG signal

Figure1 Typical ECG signal

The ECG signal is a very weak time varying signal (about 10 microvolt) and has a frequency between 0.5Hz to 100Hz. The waveforms thus recorded have been standardized in terms of amplitude and phase relationships and any deviation from this would reflect the presence of an abnormality. Abnormal patterns of ECG may be due to undesirable artifacts Normally ECG is contaminated by powerline interference of 60Hz.So it is desired to eliminate this noise and to find how best the signal can be improved.

2.1 Signals to Noise Ratio

SNR is an engineering term for the power ratio between a signal (meaningful information) and the background noise. ECG signals normally have a wide dynamic range. SNRs are usually expressed in terms of the logarithmic decibel scale. In decibels, the SNR is 20 times the base-10 logarithm of the amplitude ratio, or 10 times the logarithm of the power ratio:
SNR=10 log (Es/En), where Es is a average signal amplitude and En is average noise amplitude measured within the system bandwidth. Further when using digital storage the number of bits of each value determines the maximum SNR. In this case the noise is the error signal caused by the quantization of the signal, produced during the analog-to-digital conversion. The noise level is non-linear and signal-dependent; different calculations exist for different signal models. The noise is modeled as an analog error signal being summed with the signal before quantization ("additive noise").

3. Problem solution

For the removal of 60Hz interference, various digital filters are designed and implemented [4,5, 7,8] .A new method for finding SNR has been evolved using ,
Noise Power = Mean Square difference between actual and expected signal.

3.1. Algorithm for calculating SNR

The following algorithm has been used for calculating SNR.

- Obtain the Original signal and the Filtered (Output) Signal.
- Find the length of the Signal.
- Obtain the Mean Power of both the Signals.
- Find FFT of the 2 sequences.
- Correlate the 2 sequences.
- Find Overlap.
- Calculate Signal to Noise Ratio.
- Convert to Decibel.

3.2. Results and Discussions

We have considered the following ECG signal as our inputs. An ECG contaminated with Power line interference of 60 Hz and an otherwise normal trace is considered as an input. The figure below Figure 2 shows an unfiltered ECG with 476 samples.

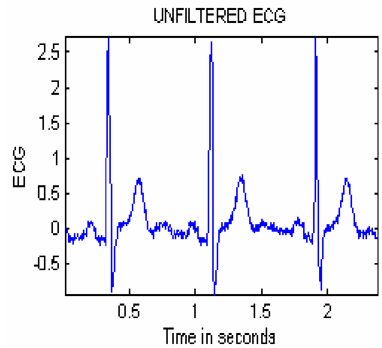

Figure 2: Plot of the unfiltered ECG

The frequency spectrum plot as shown in Figure 3 has a spike at a frequency of 60 Hz which is an indication of the interference at that frequency.

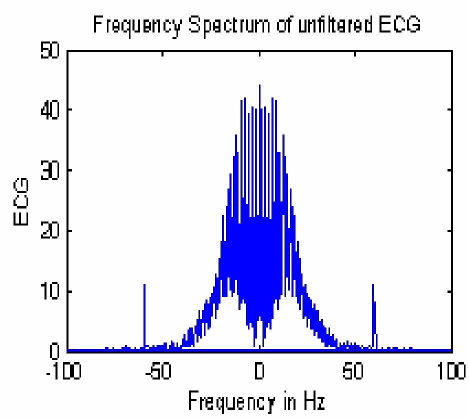

Figure 3: Plot of Frequency Spectrum of Unfiltered ECG

This noise was removed using the following filters;

- Butterworth Low Pass
- Butterworth Band Stop
- Chebyshev Low Pass
- Chebyshev Band Stop
- Moving Average
- Hamming Low Pass
- Hamming Band Stop
- Bartlett Low Pass

- Bartlett Band Stop
- LMS Adaptive

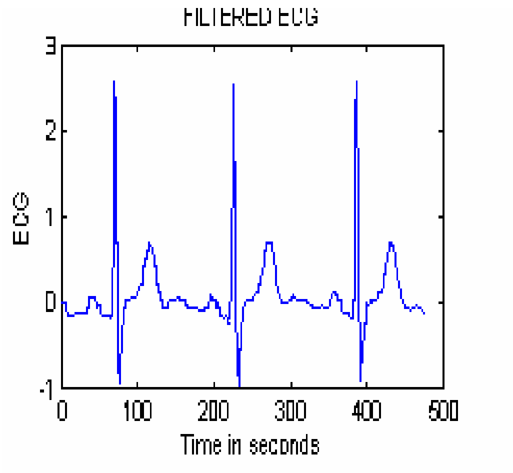

Figure 4: Plot of filtered ECG

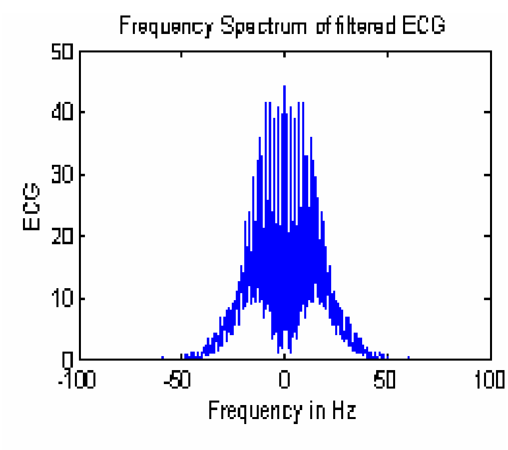

Figure5: Frequency Spectrum of filtered ECG

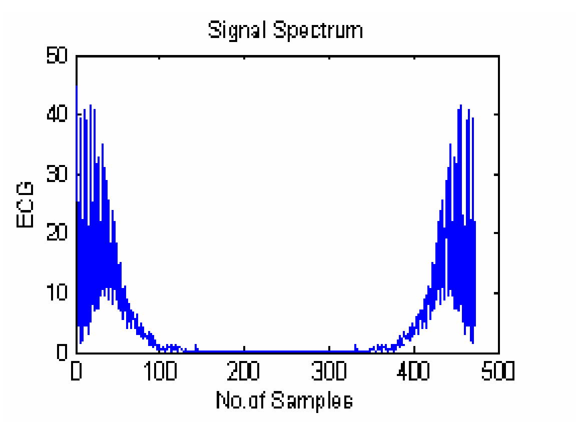

Figure 6: Signal Spectrum

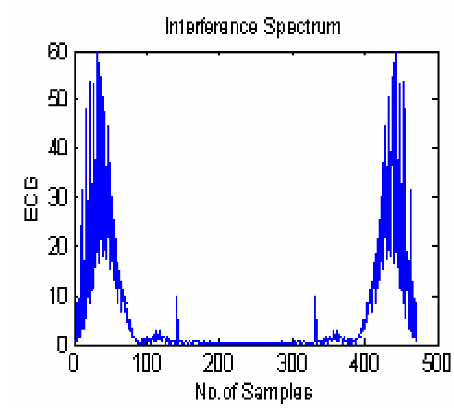

Figure 7: Interference Spectrum

3.3. Tabulation of Results

The results for the filters implemented are given in Table1 and Figure 8. It can be seen that the LMS Adaptive filter has the highest SNR of 22.52 dB.

Filter type	Order N	SNR (db)
Butterworth Low Pass	8	19.8714
Butterworth Band Stop	6	20.3785
Chebyshev Low Pass	5	20.0567
Chebyshev Band Stop	5	17.4962
Hamming Low Pass	54	21.6521
Hamming Band Stop	54	21.4968
Bartlett Low Pass	54	21.4146
Bartlett Band Stop	54	21.5906
Moving Average	4	12.4004
LMS Adaptive	2	22.5268

Table 1

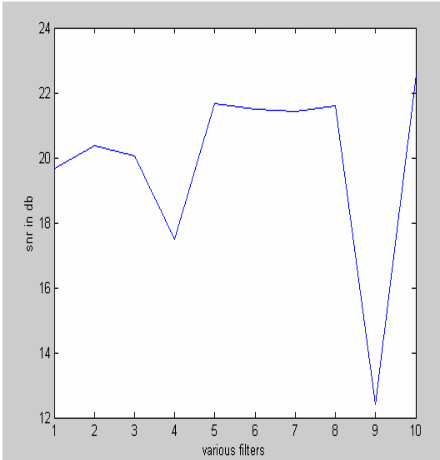

Figure 8: SNR Vs Various Filters

Digital filters with fixed cut off frequencies, like standard filters cannot eliminate the noise beyond the cut off frequency range. Notch filters remove the original 60 Hz component of the signal and have a slow roll off that unnecessarily attenuates other frequency bands. Adaptive filters have the advantage that they do not require a priori signal information or a cut off frequency.

4. Conclusions

- The analysis of the SNR is very essential for evaluating the ECG waves before interpreting the ECG of a subject.
- A number of filtering techniques have been adopted for processing the ECG signal for removing the 60 HZ power line noise component.
- It is found from the plot of SNR Vs various filters, LMS Adaptive filter has been found better noise filtering technique.

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