Designing and Implementation of Digital Filter for Power line Interference Suppression

Manoj Sharma[1], Hemant dalal[2]

***Abstract*— This paper presents removal of noise from the ECG signal by using Digital filters designed with FIR and IIR technique. The analysis of ECG signal has great importance in the detection of cardiac abnormalities. The ECG signal is preserve of the electrical performance of heart versus time. ECG signal of a normal heart beat consists of a three parts P wave, QRS complex and T wave. The P wave reflects the activation of the right and left atria. The QRS complex shows depolarization of the activation of right and left ventricles. Results are obtained for the given order of the filter using windowing technique for the FIR filter. Powerline interference corrupts biomedical recordings. A Digital filter is one of the filters that are suggested to suppress the fundamental powerline interference and its harmonics in electrocardiographic recordings. The aim of this paper is to design and implement digital filter for suppressing the 50Hz powerline interference, with Different window function in electrocardiographic (ECG) signal recordings. The wavelet transform is used to reduce the effect of noise to get refined signal. The power spectral density and average power, before and after filtereration using different window techniques and wavelet utilization at 4 and 6 dB are compared. Order of the filter is also different. Filter with the Kaiser window shows the best result.

***Index Term*— ECG, FIR Filter, Windowing Technique, Wavelet Transform, power spectral density and average power

I. INTRODUCTION

Many times when ECG signal is recorded from surface electrode connected to the chest of patient, not tightly in contact with the skin as the patient breath the chest expand and contract producing a relative motion between skin and electrode, results in shifting of baseline known as low frequency baseline wander.

Manoj Sharma Electronics and communication department, CBS Group of institutions, Jhajjar, Haryana, INDIA.

Hemant Dalal, Electronics and communication department, CBS Group of institutions, Jhajjar, Haryana, INDIA.

The fundamental frequency of baseline wander is same as that of respiration frequency. It is required that baseline wander is removed from the ECG before extraction of any meaningful feature. Interference occurs in ECG signal is very common and serious problems. Digital filter are designed to remove this limitation. FIR with different windowing method is used. The results are obtained at low order. The input signals are taken from ECG database which includes the normal and abnormal waveforms. FDA tool is used in MATLAB to design these filters [1]. Baseline wander makes it difficult to analyze ECG, especially in the detection of ST-segment deviations. There are steps of designing filter which are: (a) Selection of standard ECG data and extraction of ECG signal. (b) Design and implementation of FIR and IIR filters for the removal of Baseline noise from ECG signal. (c) Implementation of Wavelet for overall noise removal [5]. (d) Design and implementation of adaptive filters for the removal of Powerline noise from ECG signal.

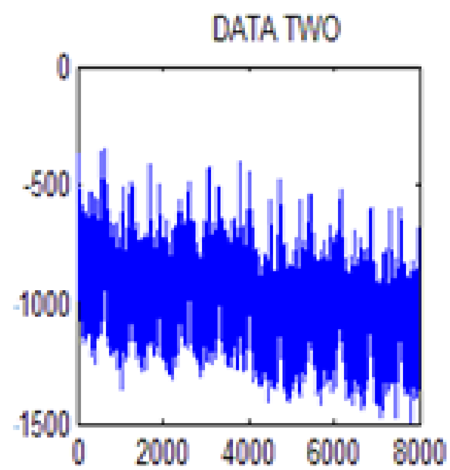

Fig. 1 EC G data two

II. SYSTEM DESIGN

FIR filters can also be designed using the windowing method. The ideal filter have infinite number of samples in time domain given in equation 3. Windows are performed in order to have finite number of samples in

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time domain for realiable filter design.

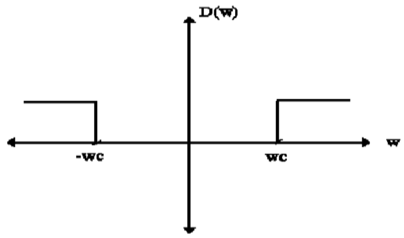

Fig. 2 Magnitude response of an ideal filter.

The cut-off frequency is w_c. The ideal high pass filter characteristic is given in Fig. 2. The continuous frequency response and the discrete-time impulse response are related by the equation 1. The aim is giving the relation between ideal frequency domain filter and its impulse response in time domain and to show the importance of windowing method [15].

$$D(w) = \sum_{k=-\infty}^{\infty} d(k).e^{-jkw} \quad \ldots(1)$$

$$d(k) = \int_{-\pi}^{\pi} \frac{D(w)}{2.\pi} e^{jwk} dw \quad \ldots(2)$$

The filter's impulse response can be obtained by using the inverse Fourier transform. The filter coefficients will simply be the impulse response samples. The desired low pass filter's response is given by equation 3.

$$D(w) = \begin{cases} 1, if|w| < wc \\ 0, elsewhere \end{cases} \quad \ldots(3)$$

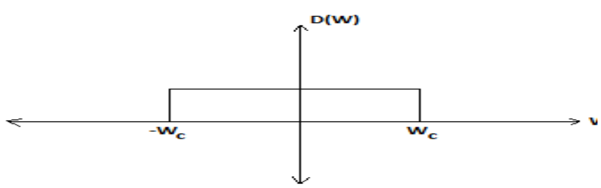

Fig 3 :Magnitude response of an ideal window.

A window function from –wc to wc is employed to show the windowing effect[15].

There are different windowing functions. The important window functions are rectangular window, Hamming, Hanning, Blackman windows[15].

- Rectangular Window

The filter is required to have finite number of values within a certain interval, from -M to M. This is equivalent to multiplying d (k) by a rectangular function given by

$$w(n) = \begin{cases} 1, if|n| < M \\ 0, otherwise \end{cases} \quad \ldots(4)$$

- Hamming Window

Discontinuities in the time function cause ringing in the frequency domain. The rectangular window is replaced by a window function ending smoothly at both ends which will cause reduction in ripples. The hamming window is an important window function. The hamming window is defined as:

$$w(n) = .54 - .46\cos\left(\frac{2\pi n}{N-1}\right)$$
$$n = 1,2,3,4\ldots\ldots N+1 \quad \ldots(5)$$

Where N is the order of the filter and M is the window length. This equation defines the window samples as already shifted (indices from 0 to 'N-1'). So the impulse response of the FIR low pass filter designed using the hamming window is [15]:

$$h(n) = w(n).d(n-M)$$
$$h(n) = \left(.54 - .46\cos\left(\frac{2\pi n}{N-1}\right)\right)\frac{\sin((n-M).wn)}{(n-M).\pi} \quad \ldots(6)$$

The ripples that occur in rectangular windowing in both the pass band and the stop band are virtually eliminated. Thus, the filtered data will have a wider transition width.

The Hanning window is defined mathematically as:

$$w(n) = .5 - .5\cos\left(\frac{2\pi n}{N-1}\right)$$
$$n = 0,1,2,3,4\ldots\ldots N-1 \quad \ldots(7)$$

The difference of Hanning window is performed window function. This function is quite similar to the Hamming window.

A wavelet [11] is a wave-like oscillation with amplitude that starts out at zero, increases, and then decreases back to zero. It can typically be visualized as a "brief oscillation" like one might see recorded by a seismograph or heart monitor. Generally, wavelets are purposefully crafted to have specific properties that make them useful for signal processing. Wavelets can be combined, using a "shift, multiply and sum" technique called convolution, with portions of an unknown signal to extract information from the unknown signal.

As wavelets are a mathematical tool they can be used to extract information from many different kinds of data, including - but certainly not limited to – audio signals

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and images. Sets of wavelets are generally needed to analyze data fully. This paper cover, all the steps that preceded project implementation. A major element of this stage was the extraction of ECG signals the standard database that chosen for the work. After extraction, the signals are subject to processing, using several tools available in the MATLAB [6].

III Results and conclusion

In this paper various noise removal techniques are applied to ECG signals [10], ECG database data sample, and the performance of these approaches are studied on the basis of spectral density and average power of signal. In the first step, the most simple approach which is linear trend or a piecewise linear trend to remove baseline drift is applied after that various digital filters are applied to the noisy ECG data having Baseline noise as shown in fig 4.1 then the wavelet approach is used for overall denoising of ECG signal and finally the digital filter is applied on the sample ECG signal to remove Power line noise. All of the above steps are performed using MATLAB software

Calculation of parameters

The two important parameters to check the suppression of Baseline noises are spectral density and average power of signal [6].

Power spectral density :

Table1 and 2 shows the comparison of different filters. The trade-off between spectral density and average power is best among all the filters. But it can also visualize that the waveform got distorted to some extend in case of rectangular window. The Kaiser Window and rectangular window is also showing better results at the expense of some more computational load as the order of the filter is large. But in case of remaining windows i.e. Hanning and Blackman windows, the order of filter easily grow very much high. It increases the number of filter coefficients which increases the large memory requirement and problems in hardware implementation. So, the Kaiser Window filter can be best choice for the removal of Baseline wandering among filters[2].

Table1 Comparison of various filters for Removal of noise at ECG sample input 2.

Filter	Filter Order	Spectral Density before Filtration	Spectral Dens after Filtratio	Wavelet output 4dB	Wavelet output 6dB
Hanning	450	59.8425	52.4935	52.4768	52.4774
Kaiser	450	59.8425	41.9062	41.7130	41.7188
Rectangular	450	59.8425	41.9377	41.7461	41.7518
Chebyshev	2	59.9737	41.440	41.271	41.280

Spectral density of data 2 using different filters is shown as

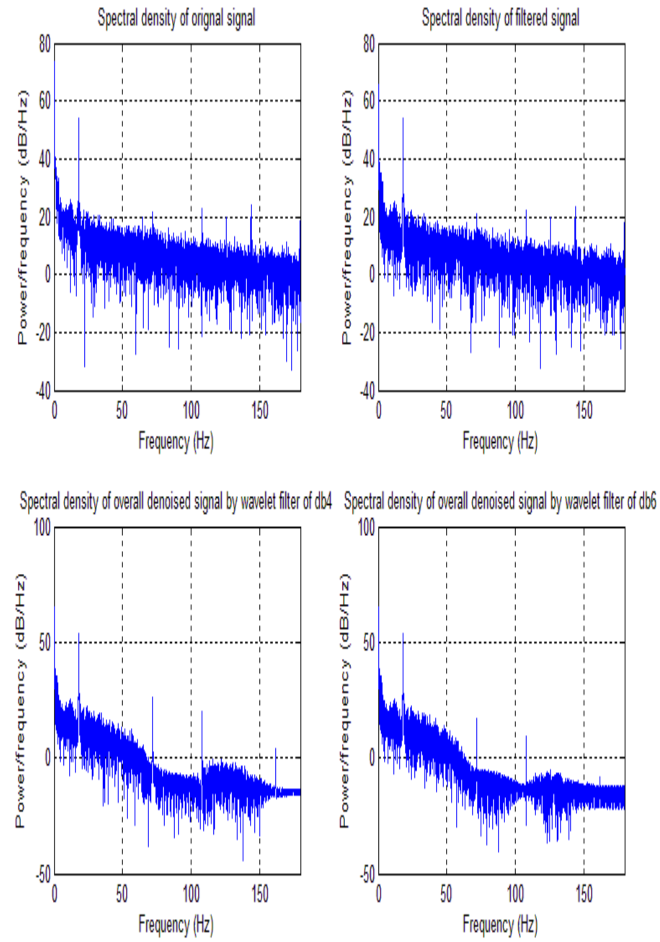

Fig.4 Spectral Density using Hanning filter

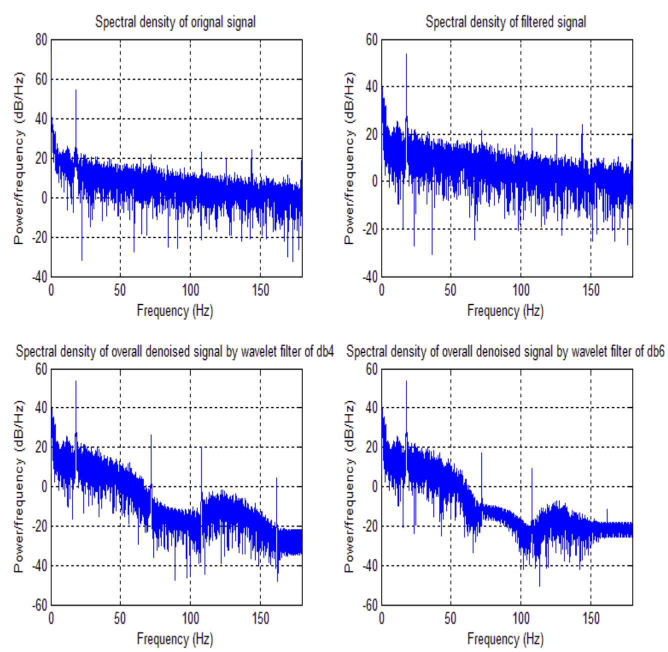

Fig.5 Spectral Density using Kaiser Filter

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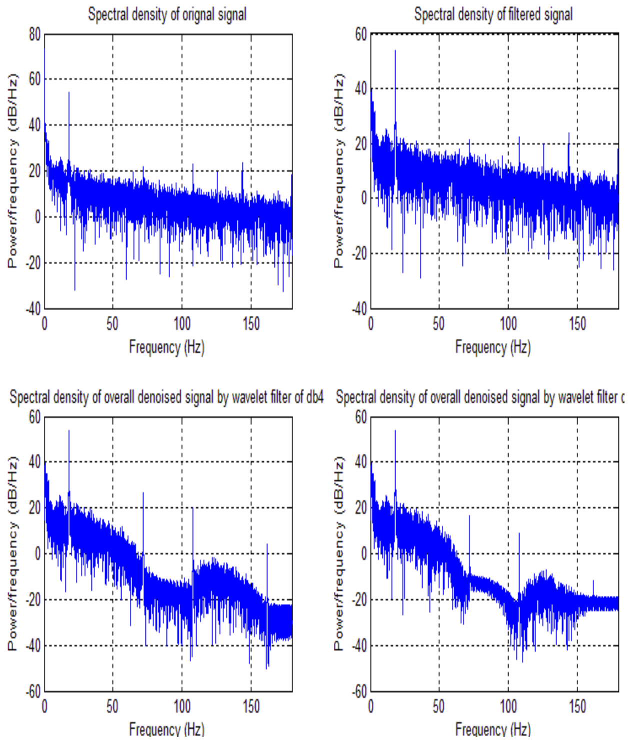

Fig.6 Spectral Density using Rectangular filter

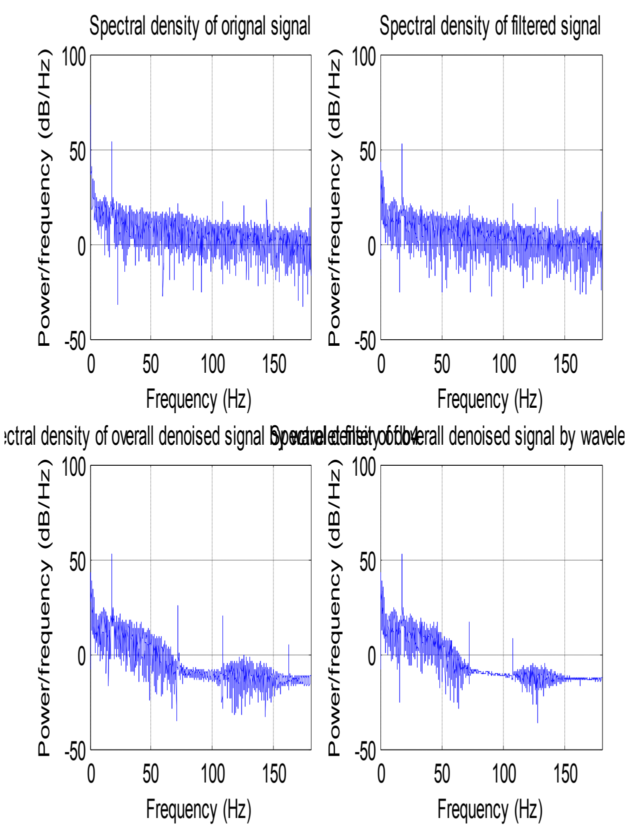

Fig.7 Spectral Density using chebyshev filter

Average power Comparison of various filters for Removal of noise at ECG sample input 2 in Table 2

IV CONCLUSION

This paper concludes the work in this thesis; digital FIR and IIR filter with wavelet for removal of Baseline noise were implemented in MATLAB. It is observed that the choice of the cut-off frequency is very important, a lower than required cut-off frequency does not filter the actual ECG signal component, however some of the noise successfully, but the ECG signal is distorted in the process. Cut-off frequency varies corresponding to heart rate and baseline noise spectra. Thus, constant cut-off frequency is not always appropriate for baseline noise suppression; it should be selected after a careful examination of the signal spectrum.

When FIR filter with wavelet is applied on signal it can be observe that the combination of Kaiser and wavelet yield the smallest phase delay among all the FIR filters combination. It can remove the Baseline noises without distorting the waveform. But the order of filter is 450.However, high filter orders are required to obtain this satisfactory result and this increases the computational complexity of the filter. Furthermore, there is significant delay in the filter result, thus this combination can be applied to long data window. Therefore, this combination is appropriate only for offline application, but for real time application, in which short intervals of data is filtered and fast implementation is important, FIR is not an appropriate filtering method.IIR and wavelet combination is more appropriate for real time filtering application due to its lower computational complexity, and its better trade-off between average power and spectral density. It completely eliminates the oscillations produced at the starting of the waveform called ringing effect. For performance analysis we use different baseline noise removal methods for the purpose of comparison. The results are presented in the tabulation form. From the table it can conclude that it outperform the other method.

Table 2 Average power Comparison of various filters for Removal of noise at ECG sample input 2

Filter	Filter Order	Average Power before Filtration	Average Power After Filtration	Wavelet Output at 4dB	Wavelet output at 6dB
Hanning	450	59.9737	52.9513	52.9213	52.9223
Kaiser	450	44.9132	44.7200	44.7258	59.9737
Rectangula	450	59.9737	44.9279	44.7354	44.7412
Chebyshev	2	59.9737	44.4556	44.2810	44.292

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Graphs for Avg power calculation are shown below:

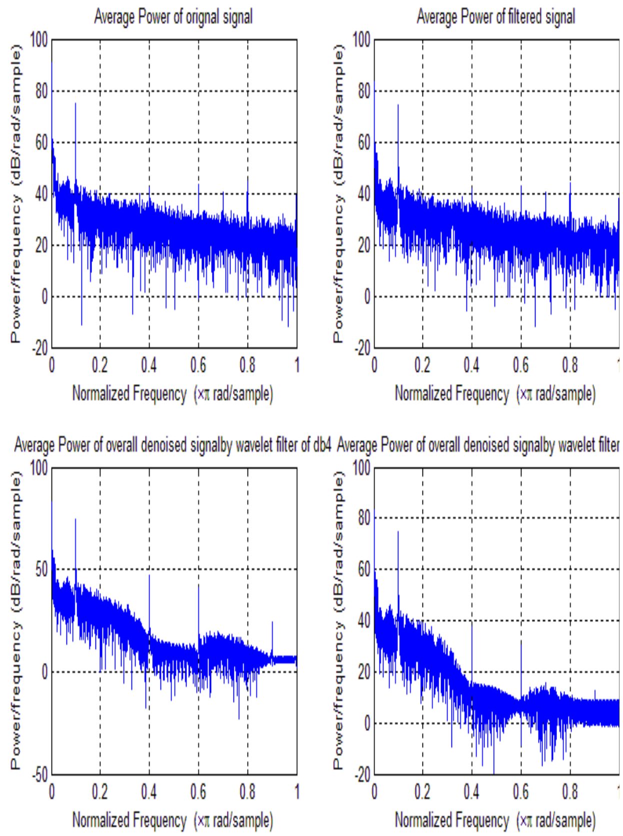

Fig.8 Avg power calculation for hanning window

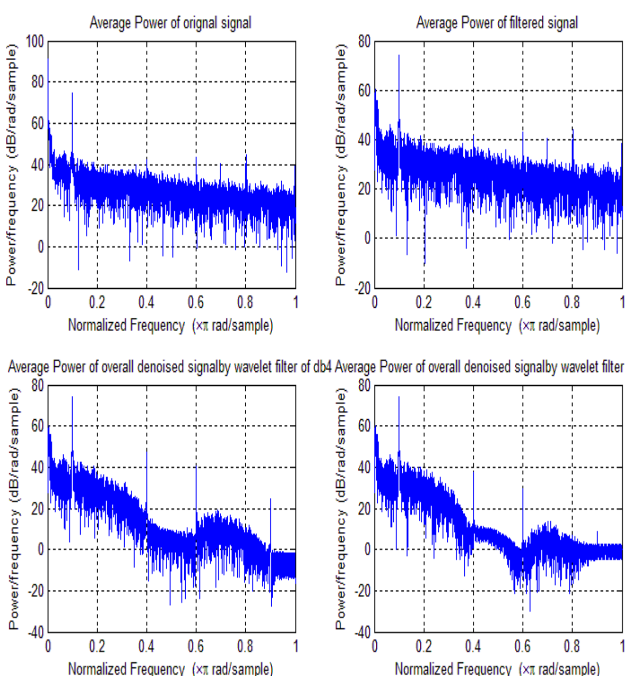

Fig.9 Avg power calculation for kaiser window

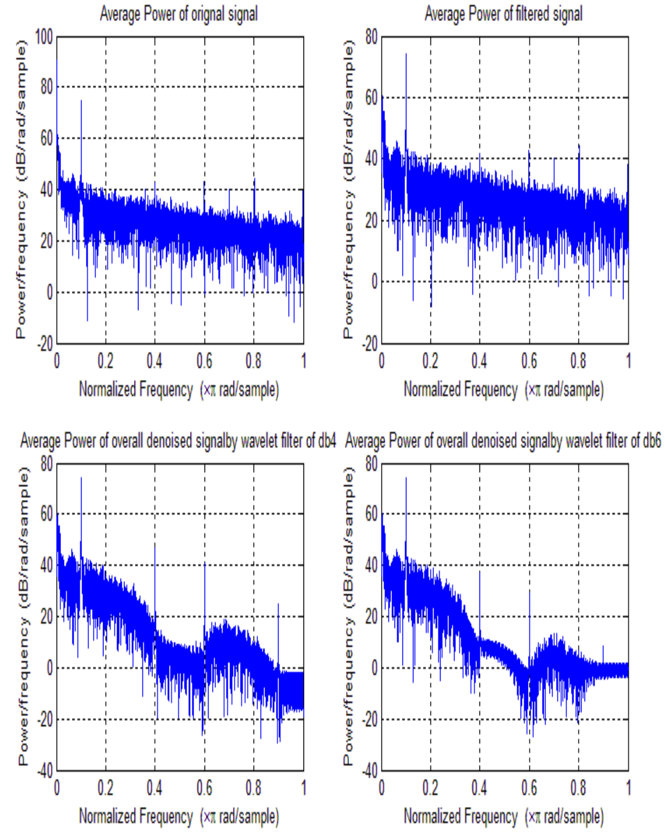

Fig. 10 Avg power calculation for rectangular window

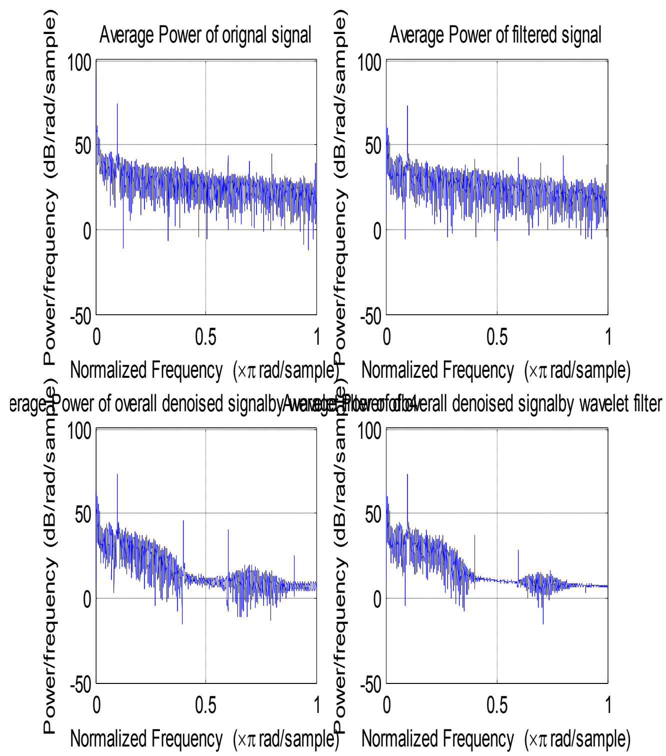

Fig.11 Avg power calculation for chebyshev window

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