International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 04 | Apr -2017 www.irjet.net p-ISSN: 2395-0072

ANALYSIS OF DIFFERENT TYPES OF IIR AND FIR FILTERS IN ECG SIGNAL USING VARIOUS TRANSFORMS FOR DIFFERENT ORDERS AND TIME CONSUMPTION

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Abstract - *Electrocardiogram (ECG or EKG) is the process of recording the electrical activity of the heart over a period of time placing electrodes on the skin. The spikes and dips within the tracings are referred to as waves. In this project ECG signal is taken as the input signal. AWGN noise is mixed with the ECG signal. Then various transforms like DFT, DCT, FWHT and DWT are applied to the noisy ECG signal. Then IIR and FIR filtering techniques are applied to the coefficients of various transforms. Then comparisons are made based on time consumption and order of the filter.*

Key words: **ECG signal, Transforms, IIR Filter, FIR Filter, AWGN Noise, Windowing techniques.**

1. INTRODUCTION

An electrocardiogram (EKG or ECG) is an instrument that is used to check the electrical activity of the heart. The electrical activity of the heart is in the form of line tracings. The spikes and dips in the tracings are called waves. It consists of 10 electrodes and 12 leads placed on the chest of the patient. The main purpose of ECG is to find the proper functioning of heart. The electrodes present are RA, LA, RL,LL, V_1, V_2, V_3, V_4, V_5, V_6. In a normal heart, the rhythm is called Normal Sinus Rhythm (NSR). This produces P wave, QRS complex and T wave. The various types of transforms that are used are DCT, DWT, FFT, FWHT. The various IIR filtering techniques used are Butterworth filter, Chebyshev type 1, Chebyshev type 2 and FIR filtering technique used is Windowing technique. The various Windowing techniques are Kaiser window, Hamming window, Chebyshev window.

2. SYSTEM OVERVIEW

ECG signal is taken as the input signal. Then AWGN noise is added with the input ECG signal. Then various transforms like DCT, FFT, FWHT, DWT are applied to this noisy input ECG signal. After applying transforms various filtering techniques like IIR and FIR filtering are applied to this transform applied noisy signal. Then comparisons are done based on time consumption and order of the filter.

2.1 Block Diagram

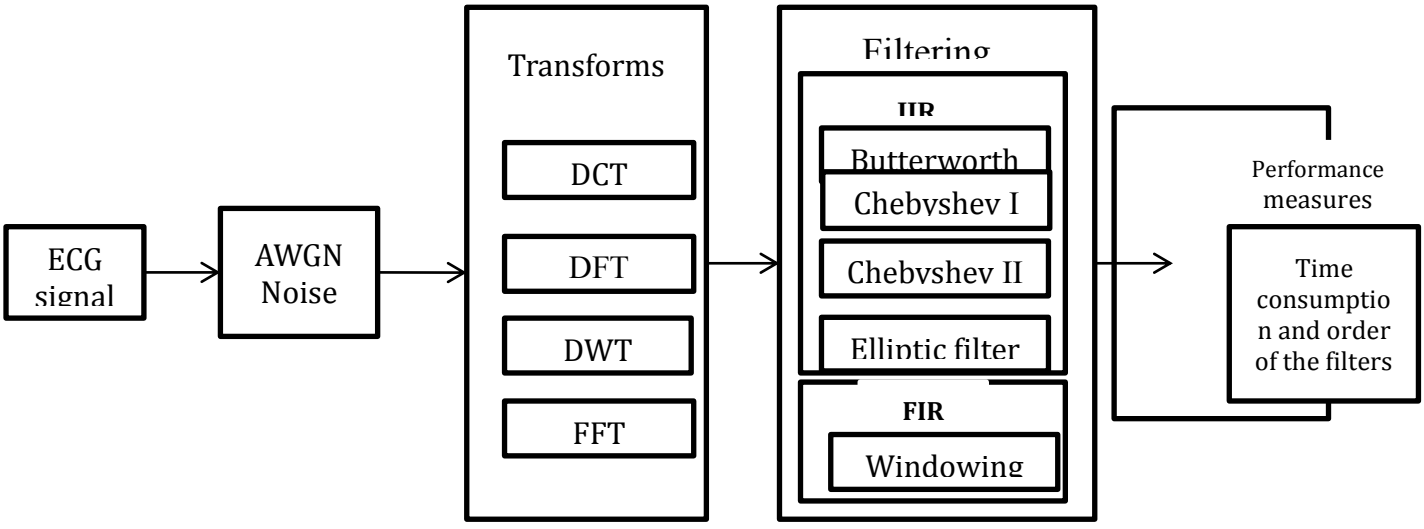

Fig-1: Block diagram of different types of IIR and FIR filters in ECG signal using various transforms.

2.1 Transforms

The various types of transforms are explained below briefly.

2.1.1 DCT (Discrete Cosine Transform)

A discrete cosine transform (DCT) expresses a series of finitely many data points in terms of a sum of cosine functions oscillate at different frequencies. DCT has the applications of solving partial differential equations,Chebyshev approximation, audio compression.

A discrete Cosine Transform of N sample is defined as

$$y(k) = w(k)\sum_{k=1}^{N} x(n)\cos(\pi / 2N(2n-1)(k-1)).....3.1$$

Where,

$$w(k) = 1/\sqrt{N}; k = 1$$
$$w(k) = \sqrt{2/N}; 2 \le k \le N.....3.2$$

2.1.2 FFT (Fast Fourier Transform)

A fast Fourier transform (FFT) is an resourceful algorithm to calculate the discrete Fourier transform (DFT) and it's inverse. The applications of FFT are fast large integer and polynomial multiplication, solving differential equations and fast Chebyshev approximation. The u th FFT coefficient of length N sequence is defined as

$$X_k = \sum_{n=0}^{N-1} x_n e^{-i2\pi nk/N}; k = 0,1,....N-1.....3.3$$

AWGN (Additive White Gaussian Noise)

Additive White Gaussian Noise is the noise which is intrinsic to the information system where white refers to the color that has uniform emissions at all frequencies. It is Gaussian because it has normal distribution in the time domain.

2.3 Filters

A filter is a device which is used to remove the unwanted noise present in the signal.

Filters may be:

- Linear or non-linear
- Time-invariant or time-variant
- Causal or non-causalAnalog or digital
- Discrete-time (sampled) or continuous-time
- Passive or active type of continuous-time filter
- Infinite impulse response (IIR) or finite impulse response (FIR) type of discrete-time or digital filter.

2.3.1 IIR Filters

IIR filters are digital filters with unlimited impulse retort. There are four types of IIR Filters. They are as follows,

- Butterworth filter
- Chebyshev Type I filter
- Chebyshev Type II filter
- Elliptic filter

2.3.2 FIR Filter

The different types of windowing techniques are

2.3.2.1 Hamming Window

The hamming window is defined as

$$w(n) = .54 - .46\cos(2\pi n|N-1)$$

Where,

N is the order of the filter
M is the window length.

So the impulse response of the FIR low pass filter designed using the hamming window is

$$h(n) = w(n).d(n-M)$$

The Hamming window is defined mathematically as

$$w(n) = .5 - .5\cos(2\pi n|N-1)$$

2.3.2.2 Kaiser Window

The other name of Kaiser Window is Kaiser Bessel Window. It is defined by the formula

$$w(n) = \begin{cases} \dfrac{I_0(\pi\alpha\sqrt{1-\left(\frac{2n}{N-1}-1\right)^2})}{I0(\pi\alpha)}, & 0 \le n \le N-1 \\ 0 \quad \text{, otherwise} \end{cases}$$

Where,

N is the length of the sequence

I_0 is the zeroth-order modified Bessel function of the first kind
α is an arbitrary, non-negative real number that determines the shape of the window.

3. RESULTS

The following are the results that are obtained by using MATLAB software. ECG signal is taken as the input signal and then it is mixed with AWGN noise. Then various transforms like DCT, DWT, FFT, FWHT are applied to the noisy ECG signal. Then IIR and FIR filtering techniques are applied to the transformed noisy ECG signal of different orders. Then comparisons are made based on time taken, SNR and cross correlation.

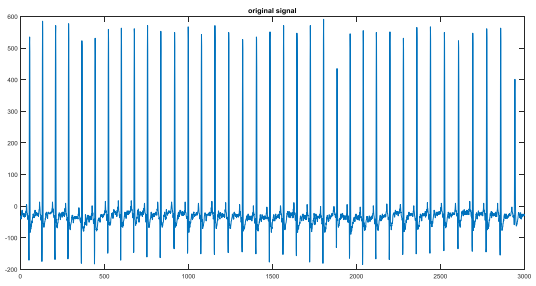

Fig-2: ECG signal

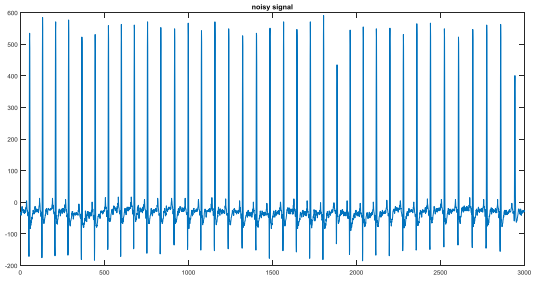

Fig-3: ECG signal with AWGN noise

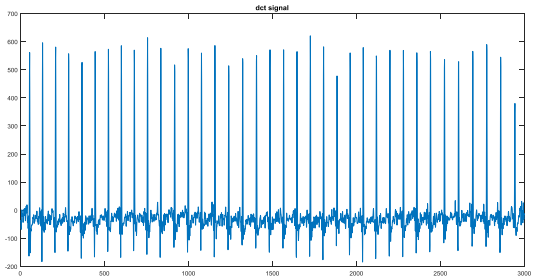

Fig-4: DCT applied ECG signal with noise

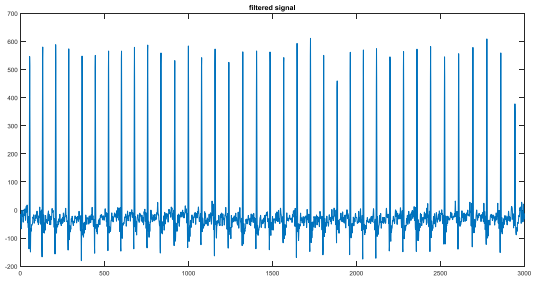

Fig -5: DCT applied ECG signal with noise filtered by Butterworth filter (low pass) of order 2

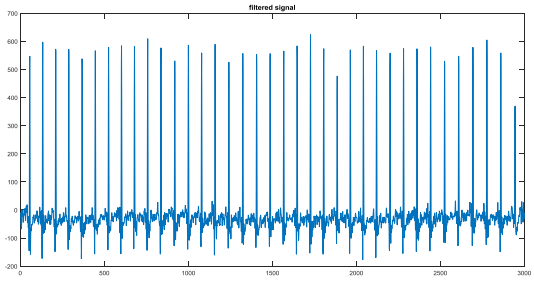

Fig-6: DCT applied ECG signal with noise filtered by Butterworth filter (low pass) of order 3

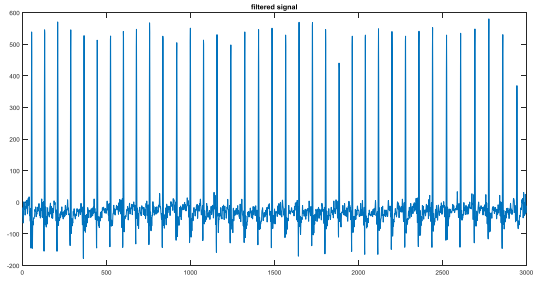

Fig-7: DCT applied ECG signal with noise filtered by Chebyshev Type I filter (low pass) of order 2

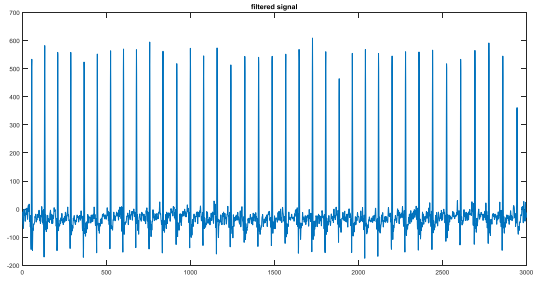

Fig-8: DCT applied ECG signal with noise filtered by Chebyshev Type I filter (low pass) of order 3

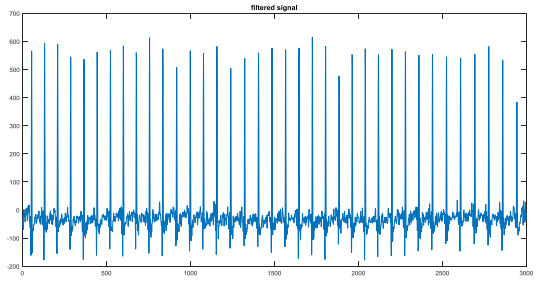

Fig -9: DCT applied ECG signal with noise filtered by Chebyshev Type II filter (low pass) of order 2

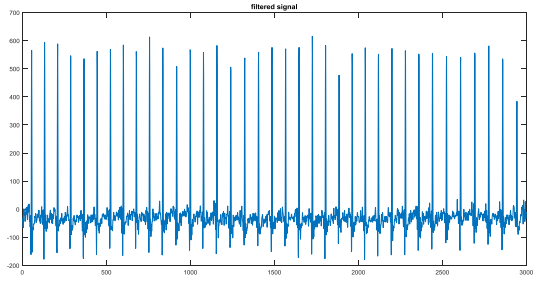

Fig-10: DCT applied ECG signal with noise filtered by Chebyshev Type II filter (low pass) of order 3

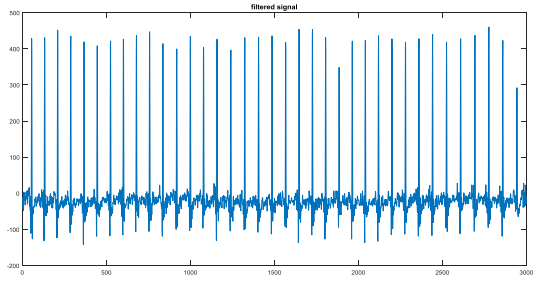

Fig-11: DCT applied ECG signal with noise filtered by Elliptic filter (low pass) of order 2

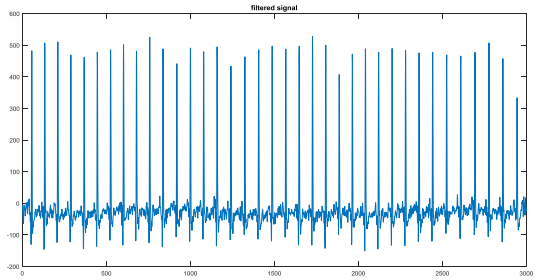

Fig -12: DCT applied ECG signal with noise filtered by Elliptic filter (low pass) of order 3

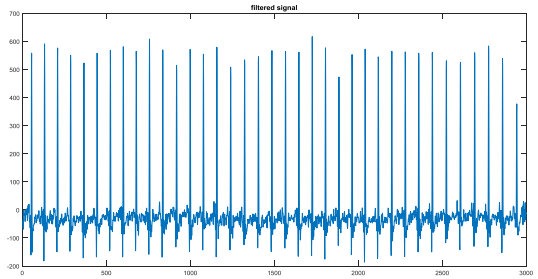

Fig-13: DCT applied ECG signal with noise filtered by Kaiser window of order 10

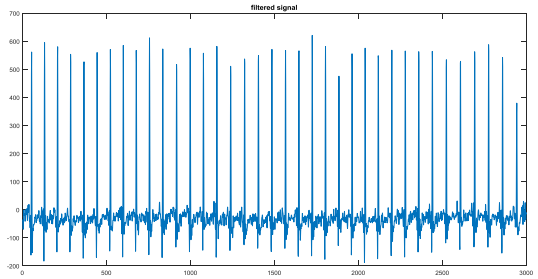

Fig-14: DCT applied ECG signal with noise filtered by Hamming window of order 34

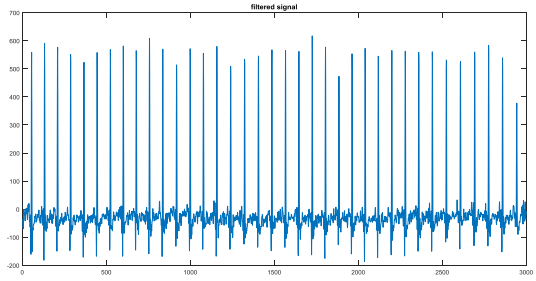

Fig-15: DCT applied ECG signal with noise filtered by Chebyshev window of order 34

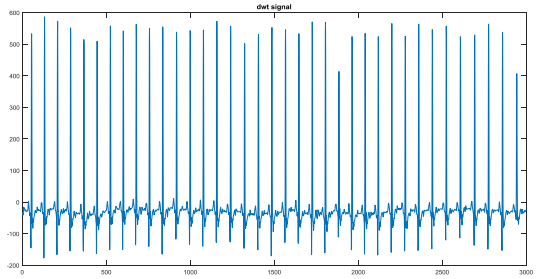

Fig-16: DWT applied ECG signal with noise

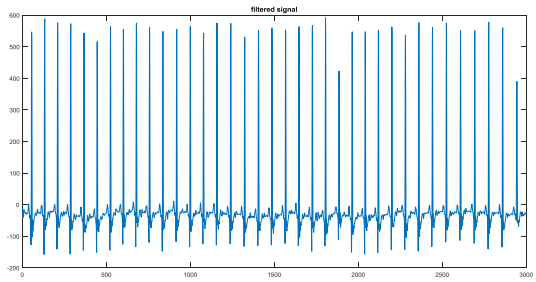

Fig -17: DWT applied ECG signal with noise filtered by Butterworth filter (low pass) of order 2

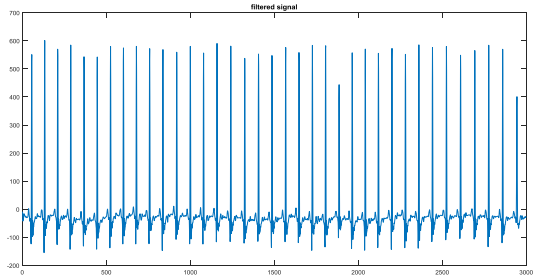

Fig-18: DWT applied ECG signal with noise filtered by Butterworth filter (low pass) of order 3

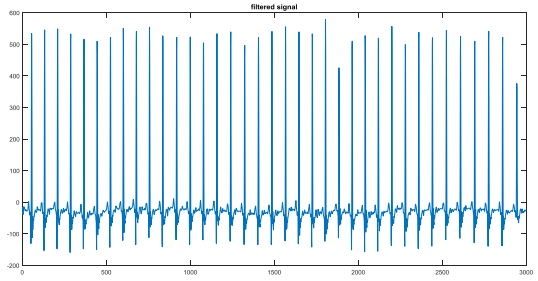

Fig-19: DWT applied ECG signal with noise filtered by Chebyshev Type I filter (low pass) of order 2

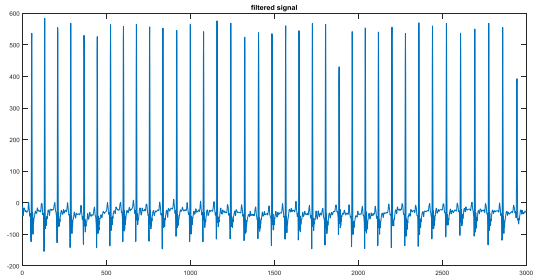

Fig-20: DWT applied ECG signal with noise filtered by Chebyshev Type I filter (low pass) of order 3

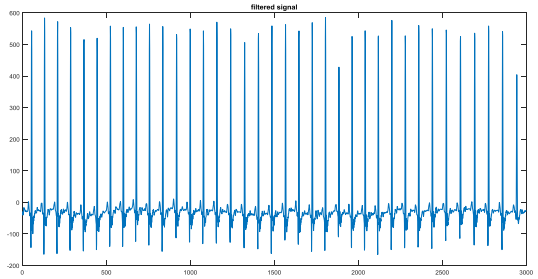

Fig-21: DWT applied ECG signal with noise filtered by Chebyshev Type II filter (low pass) of order 2

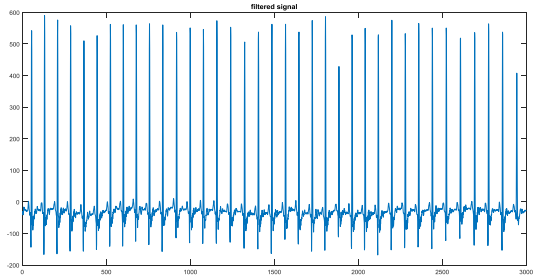

Fig-22: DWT applied ECG signal with noise filtered by Chebyshev Type II filter (low pass) of order 3

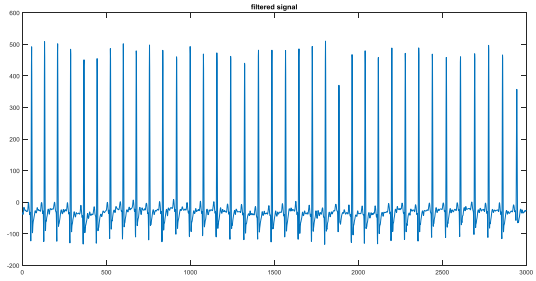

Fig-23: DWT applied ECG signal with noise filtered by Kaiser window of order 10

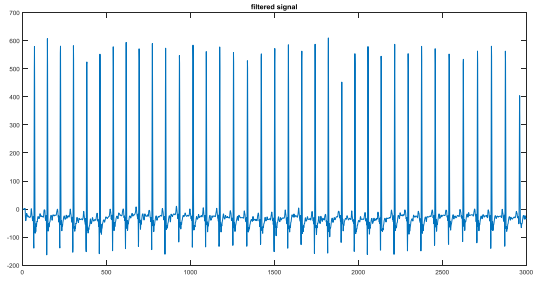

Fig-24: DWT applied ECG signal with noise filtered by Hamming window of order 34

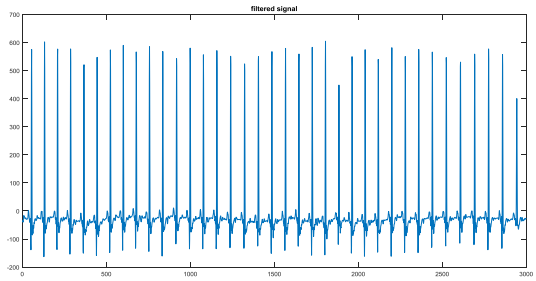

Fig-25: DWT applied ECG signal with noise filtered by Chebyshev window of order 34

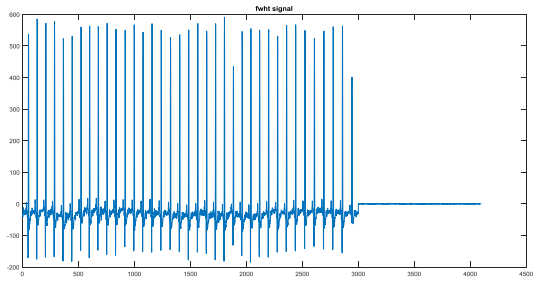

Fig-26: FWHT applied ECG signal with noise

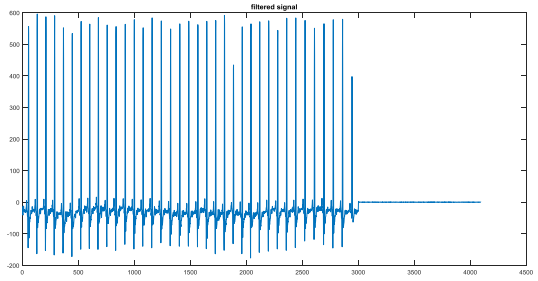

Fig -27: FWHT applied ECG signal with noise filtered by Butterworth filter (low pass) of order 2

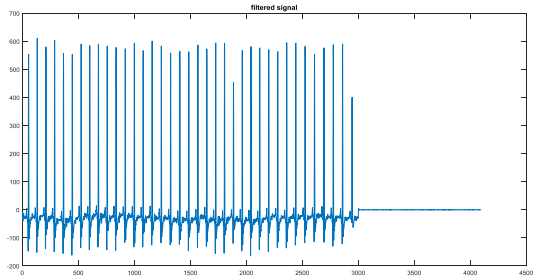

Fig -28: FWHT applied ECG signal with noise filtered by Butterworth filter (low pass) of order 3

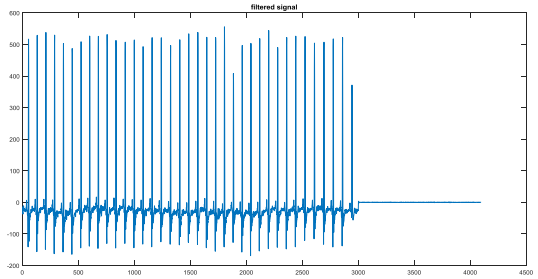

Fig -29: FWHT applied ECG signal with noise filtered by Chebyshev Type I filter (low pass) of order 2

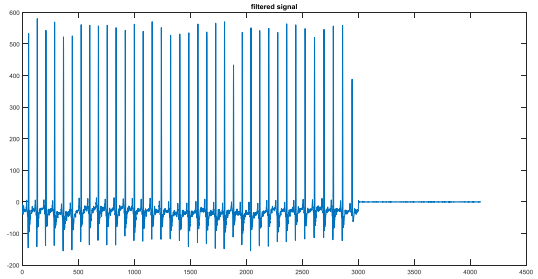

Fig -30: FWHT applied ECG signal with noise filtered by Chebyshev Type I filter (low pass) of order 3

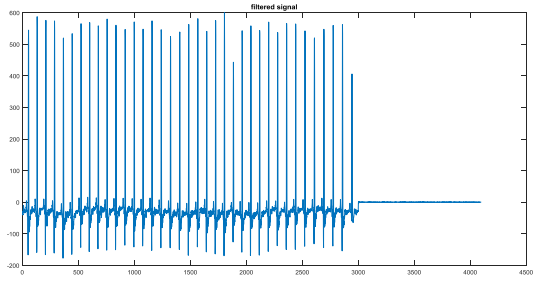

Fig -31: FWHT applied ECG signal with noise filtered by Chebyshev Type II filter (low pass) of order 2

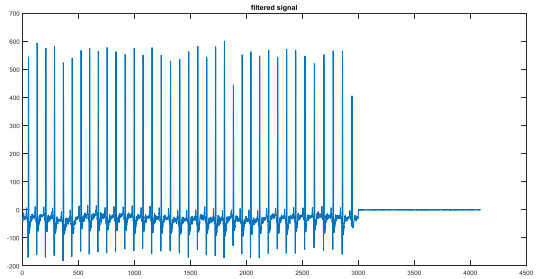

Fig -32: FWHT applied ECG signal with noise filtered by Chebyshev Type II filter (low pass) of order 3

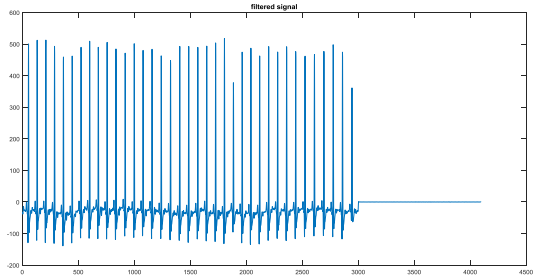

Fig-33: FWHT applied ECG signal with noise filtered by Kaiser window of order 10

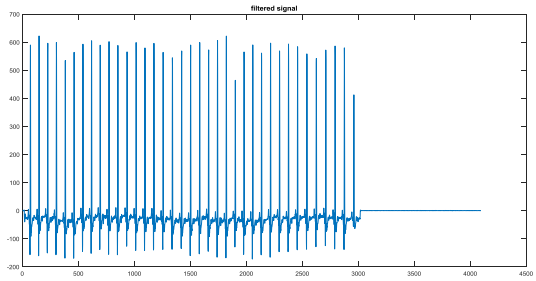

Fig-34: FWHT applied ECG signal with noise filtered by Hamming window of order 34

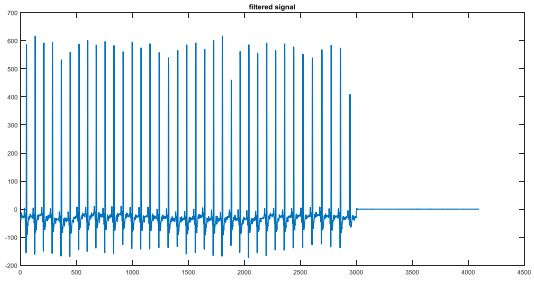

Fig-35: FWHT applied ECG signal with noise filtered by Chebyshev window of order 34

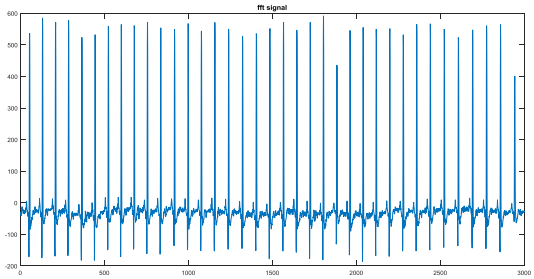

Fig-36: FFT applied ECG signal with noise

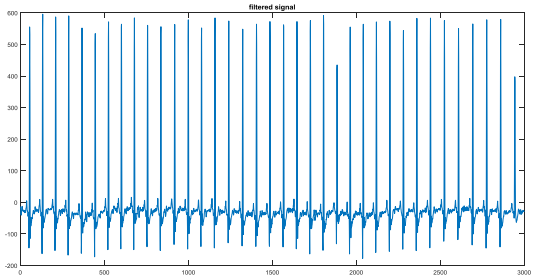

Fig -37: FFT applied ECG signal with noise filtered by Butterworth filter (low pass) of order 2

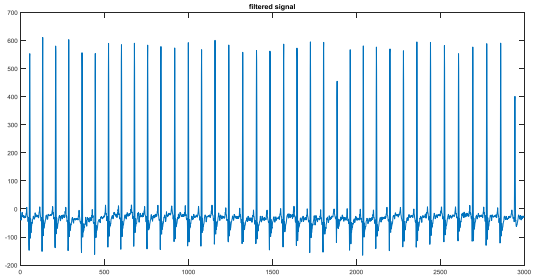

Fig -38: FFT applied ECG signal with noise filtered by Butterworth filter (low pass) of order 3

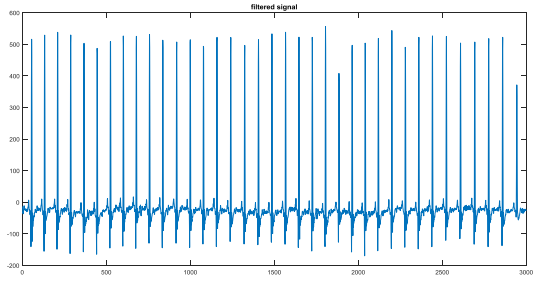

Fig -39: FFT applied ECG signal with noise filtered by Chebyshev filter Type I (low pass) of order 2

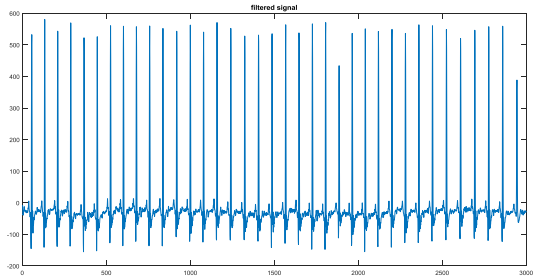

Fig -40: FFT applied ECG signal with noise filtered by Chebyshev filter Type I (low pass) of order 3

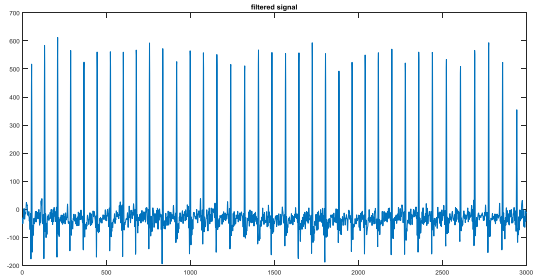

Fig -41: FFT applied ECG signal with noise filtered by Chebyshev filter Type II (low pass) of order 2

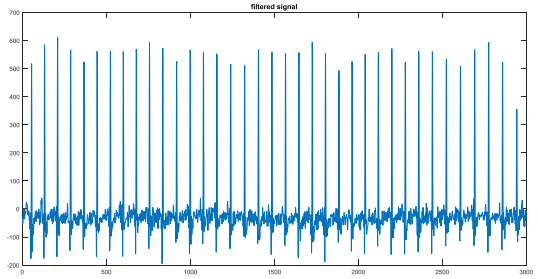

Fig -42: FFT applied ECG signal with noise filtered by Chebyshev filter Type II (low pass) of order 3

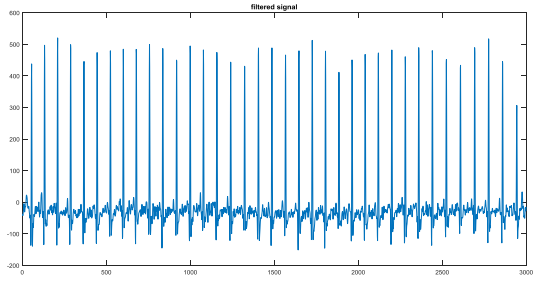

Fig-43: FFT applied ECG signal with noise filtered by Kaiser window of order 10

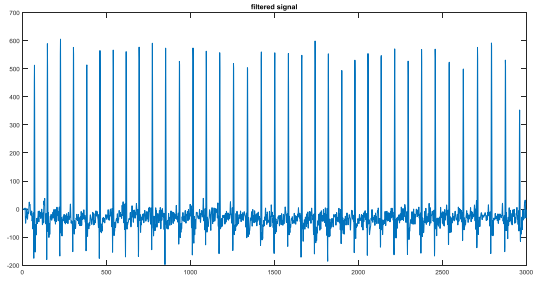

Fig-44: FFT applied ECG signal with noise filtered by Hamming window of order 34

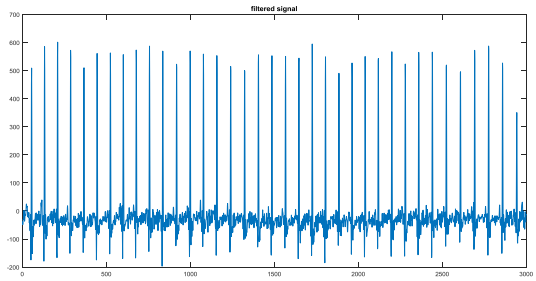

Fig-45: FFT applied ECG signal with noise filtered by Chebyshev window of order 34

Table-1: Tabulation of IIR Filtering techniques (order-2) applied DCT and DWT based on various parameters

Transform	Parameters	Butterworth filter(Low)	Chebyshev Type I(Low)	Chebyshev Type II(Low)
DCT	Time taken	0.5084	0.5145	0.5848
	PSD after filtering	4.2133	3.7780	4.2145
	PSD before filtering	4.2096	4.2095	4.2095
	SNR	0.1313	0.5201	0.1080
	Cross correlation	3.5218e+07	3.2202e+07	3.5407e+07
DWT	Time taken	2.9427	1.2787	0.8043
	PSD after filtering	4.2073	3.7729	4.2087
	PSD before filtering	4.2095	4.2096	4.2094
	SNR	0.01825	0.5654	0.1508
	Cross correlation	3.48e+07	3.18e+07	3.51e+07

Table-2: Tabulation of IIR Filtering techniques (order-2) applied FFT and FWHT based on various parameters

Transform	Parameters	Butterworth filter(Low)	Chebyshev Type I(Low)	Chebyshev Type II(Low)
FFT	Time taken	0.5132	0.5169	0.4720
	PSD after filtering	4.2079	3.807	4.1158
	PSD before filtering	4.2096	4.2095	4.2095
	SNR	0.0461	0.8360	0.1412
	Cross correlation	3.59e+07	2.99e+07	3.51e+07
FWHT	Time taken	3.5801	0.5638	0.5634
	PSD after filtering	3.0823	2.2461	3.0828
	PSD before filtering	4.2096	4.2094	4.2095
	SNR	0.0462	0.8361	0.0095
	Cross correlation	5.59e+07	2.99e+07	3.62e+07

Table-3: Tabulation of IIR Filtering techniques (order-3) applied DCT and DWT based on various parameters

Transform	Parameters	Butterworth filter(Low)	Chebyshev Type I(Low)	Chebyshev Type II(Low)
DCT	Time taken	0.6554	0.7845	0.5364
	PSD after filtering	4.2137	4.1536	4.2144
	PSD before filtering	4.2094	4.2096	4.2094
	SNR	0.1111	0.2745	0.1072
	Cross correlation	3.5381e+07	3.4076e+07	3.5414e+07
DWT	Time taken	0.0768	0.7156	0.7103
	PSD after filtering	4.2076	4.1476	4.2081
	PSD before filtering	4.2095	4.2096	4.2096
	SNR	0.1633	0.3167	3.1490
	Cross correlation	3.49e+07	3.37e+07	3.5e+07

Table-4: Tabulation of IIR Filtering techniques (order-3) applied FFT and FWHT based on various parameters

Transform	Parameters	Butterworth filter(Low)	Chebyshev Type I(Low)	Chebyshev Type II(Low)
FFT	Time taken	0.5121	0.5116	0.4614
	PSD after filtering	4.2080	4.0825	0.1158
	PSD before filtering	4.2094	4.2095	4.2095
	SNR	0.0248	0.3572	0.1404
	Cross correlation	3.61e+07	3.34e+07	3.51e+07
FWHT	Time taken	3.5703	0.5679	0.5759
	PSD after filtering	3.0828	2.9909	3.0828
	PSD before filtering	4.2095	4.2094	4.2095
	SNR	0.0250	0.3573	0.0075
	Cross correlation	3.61e+07	3.34e+07	3.62e+07

Table-5: Tabulation of FIR Filtering techniques applied DCT and DWT based on various parameters

Transform	Parameters	Kaiser	Hamming	Chebyshev
DCT	Time taken	0.3423	0.5126	0.5166
	PSD after filtering	4.294	0.4197	4.1963
	PSD before filtering	4.2096	4.2096	4.2096
	SNR	0.8594	0.1032	0.1639
	Cross correlation	2.98e+07	3.54e+07	3.51e+07
DWT	Time taken	0.4168	0.5787	0.5616
	PSD after	4.2765	4.2136	4.1908

	filtering			
	PSD before filtering	4.2096	4.2095	4.2095
	SNR	0.8718	0.1705	0.2272
	Cross correlation	2.97e+07	3.49e+07	3.44e+07

Table-6: Tabulation of FIR Filtering techniques applied FFT and FWHT based on various parameters

Transform	Parameters	Kaiser	Hamming	Chebyshev
FFT	Time taken	0.1756	0.1481	0.187
	PSD after filtering	4.1921	4.1362	4.098
	PSD before filtering	4.2096	4.2095	4.2095
	SNR	0.8709	0.14	0.195
	Cross correlation	2.97e+07	3.51e+07	3.47e+07
FWHT	Time taken	0.4399	0.4594	0.5262
	PSD after filtering	3.1408	3.0846	3.0697
	PSD before filtering	4.2095	4.2095	4.2095
	SNR	0.8045	0.0357	0.0929
	Cross correlation	3.02e+07	3.60e+07	3.55e+07

4. CONCLUSIONS

In this project, ECG signal with AWGN noise is taken as input signal. Then various transforms like Fast Fourier Transform (FFT), Fast Walsh Hadamard Transform (FWHT), Discrete Wavelet Transform (DWT), and Discrete Cosine Transform (DCT) are applied to the noisy ECG signal respectively. Then IIR and FIR filtering techniques are applied to these transformed noisy ECG signal. Then based on the tabulated parameters DWT applied noisy ECG signal filtered by Kaiser window of order 10 produces better result with limited distortions as it has SNR value of 0.8718, cross correlation of 2.97e+07 and time taken as 0.4168.

ACKNOWLEDGEMENT

The author would like to thank her guide Dr.P.Kannan, Head of the Department, Department of ECE, PET Engineering College.

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