ISSN 2229-5518

# Reconfigurable filtering using FFT/IFFT for PLI and High frequency artifacts removal in Real Time ECG Signal

Prajna K B, Padmavathi C

**Abstract**— Heart related problems are increasing, as the life style of people is improving. ECG signal is an explicit representation of activity of the heart. Different heart related diseases and unusualness in the heart are detected by ECG signal. ECG signals are altered by various noise and artifacts, which degrades the quality of the signal, that affect the proper diagnosis and monitoring. Hence obligatory measures have to be taken remove the noises. Here reconfigurable FFT/IFFT filter is used, that can work as a comb filter or as a band-pass filter that can supress PLI and high frequency artifacts respectively. The main focus is to de-noise the ECG signal; and analysing the performance of the reconfigurable FFT/IFFT filter in ECG de-noising applications. Correspondingly, MATLAB and Verilog simulation results are established.

**Index Terms**— Reconfigurable FFT filter, PLI, High frequency artifacts, ECG signal, bradycardia, tachycardia, Holter moniter;

## 1 Introduction

HEALTH care is leading to new trends as the life style of the people is improving. Much of equipment have come ,that can be handled at home, with basic knowledge of the equipment, as result the patient need not stay for long in the hospital and cost of staying in hospital can also be reduced. Long term ECG monitoring can also be done at done with the help of portable ECG device Holter monitor.

These days people are suffering from a lot of diseases, especially heart related problems, irrespective of age group. ECG means Electro-cardio-graphic signals. ECG monitoring is most widely used for detection of many congestive heart failure diseases/ problems. Electrical activity of the heart produces a characteristic wave shape, which is called ECG. ECG signal is composed of 5 peaks P, Q, R, S, and T. P wave being the first part corresponds to depolarization of the atria during atrial systole. QRS complex is the second part, where Q corresponds to slight drop in voltage, R corresponds to a large hike in voltage, and S corresponds to large drop in voltage. This process of QRS generation takes place during Ventricular depolarization. The last part is of ECG signal is T wave which corresponds to repolarization, i.e., the relaxation phase [8]. Fig. 1 and Fig.2 show normal ECG signal and Electrical activity of heart.

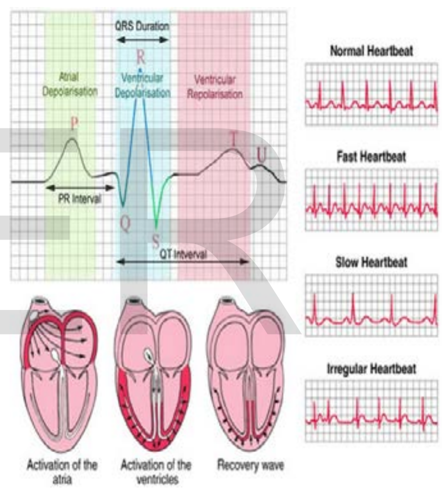



Fig.1 Normal ECG signal (*Source Google)*

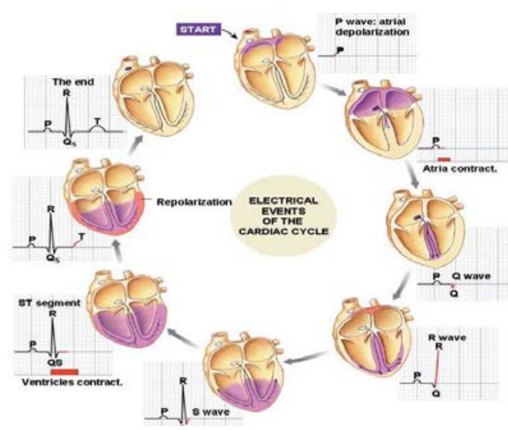



Fig.2 Electrical activity of the heart (*Source Google)*


- *Prajna K B is currently working as a Teaching Assistant in Alliance College of Enginerrring and Design ,Alliance University, Bangalore,India, PH-9886052528 E-mail: prajnakb295@gmail.com*
- *Padmavathi C is currently working as an Assistant Professor in Alliance College of Enginerrring and Design, Alliance University, Bangalore, India, PH-9066658565. E-mail: padmavathic87@gmail.com*

ISSN 2229-5518

## 2 PROBLEM DESCRIPTION

Unfortunately many noises get mixed to the ECG signal, which effects the proper identification of the problem in the heart. Electro-cardio-graphic signals (ECG) get corrupted by various kinds of noise. The various types are

1. Power line interference.
2. The noise due to locomotion of the body parts generally called as Base line drift.
3. If two or more electrodes come in contact it causes Electrode contact noise.
4. Noise due to movement of muscles in the arteries causes Muscle contraction,
5. The surgical electronic devices generate noise called as instrumental noise.

Baseline wandering, Power-line Interference, High frequency artifact, are the major types of disturbance in ECG signal. The power lines normally contain noise at 50 Hz, electromagnetic radiation produced by these power lines, is absorbed by the human body, which causes power line interference. Baseline wandering is caused due to locomotion of the human body parts during ECG monitoring. In ECG monitoring, high frequency artifacts are anomalous (interfering signals) that originate from external sources, other than the electrical activity of the biological structure being examined [8].

Due to these noises the doctors may misinterpret the problem which may lead even to death of the patient. It is very difficult to the doctor to give proper medical care. Hence it is obligatory to de-noise the ECG signal. In this project PLI and high frequency artifacts are de-noised.

There are many methods that are used to de-noise the ECG signal, but these methods remove only one type of noise. But many artifacts interrupt the ECG. Hence a method is necessary that detaches at least two or three types of noise from ECG signals.

## 3 METHODOLOGY

As demonstrated Mohammed Bahoura et al., discuss a wavelet-based de -noising technique, which is applied to detach power-line interference from ECG signal [2]. Yue-Der Lin et al., discuss method to remove Power Line Interference. Here a PLI presence is detected with the help of PLI detection module [3]. Mohammed Bahoura et al., say system output mean square error (MSE) can be minimized with help of least mean square algorithm. This algorithm is applied to an adaptive filter. An adaptive noise canceller was developed using sequential pipelined LMS and it was used to detach PLI from ECG signal [4]. Shubhajit Roy Chowdhury et al., say that at advanced stages of gestation heart rate tracking of the embryo is very essential. Here mainly base line wandering is seen. Daubechies algorithm is used for baseline wander correction [5]. Vinod K. Pandey discusses a method to see the heart's condition during pre-exercise or post-exercise mode. This method is usually used to check the presence of baseline wander, and it uses an adaptive filter scheme to detach this noise [6].

The methods discussed so far, detaches only one particular noise. But in general an ECG signal contains multiple types of noises. In my project two major types of noise, power line interference and high frequency artifacts are de-noised.

### 3.1 OBJECTIVE AND METHODOLOGY

The main objective is to de-noise the ECG signal and produce a noise free ECG signal. Now a day, ECG equipment can be handled at home with the help of portable system Holter monitor. In such system the results have to be very accurate, hence de-noising of the noises is very important.

Here a reconfigurable filter which is configured to work as bandpass and comb filter is used and it suppresses both high frequency artifacts and power line interference.

### 3.2 BLOCK DIAGRAM

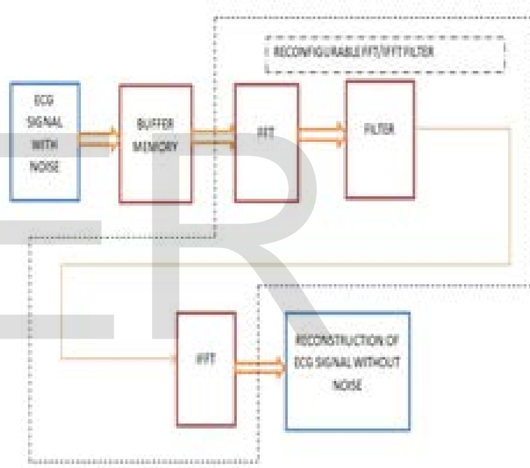



Fig.3 General Diagram (*Source ref [1]*)

Noise free ECG signal is obtained from matlab; high frequency noise and Powerline Interference noise are added to the signal. Normally 3000 samples of ECG are taken per person. Here 1024 samples are processed. The process is done by taking 256 samples at a time. Hence to de-noise 1024 samples of ECG signal, the process is repeated four times. The signal is converted to text format and the signal is saved in Buffer Memory.

### 3.2 DESCRIPTION OF VARIOUS BLOCKS

The different blocks of this project are

a. **Buffer Memory** where the ECG signal with noise is stored.
b. **FFT Block** that used in conversion of the ECG signal in time domain to frequency domain
c. **Filter Block** that is used to detach the noise component
d. **IFFT Block** that is used in obtaining the filtered ECG signal in time domain.

ISSN 2229-5518

a. **Buffer** is a temporary storage area for data from internal or external devices. Here the ECG signal with noise is stored in the Buffer. Here depending on the type of noise the signal values are stored in the Buffer. Buffer coding is done in Verilog. Each time 256 samples are saved in buffer, once these samples are de-noised next 256 samples are saved. The process is repeated 4 times in order to sample 1024 samples.

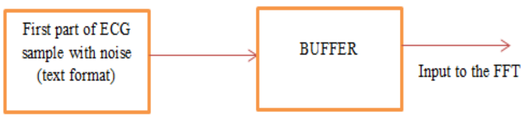



Fig.4 Buffer block

Fig.4 shows buffer where first part of the ECG sample with noise is saved in Buffer. Output of the Buffer is input to FFT block. Once the first part is de-noised, second part is saved; similarly third and fourth parts are saved and de-noised.

b. The input to **FFT** is ECG signal with noise stored in the buffer. Here decimation in frequency is used. 256 point FFT is applied to ECG signal, to convert from time domain to frequency domain. This is done because de-noising of noise is easier in frequency domain. Twiddle factors are obtaining by coding in Matlab, rest of the coding is done in Verilog. It is the first block of reconfigurable FFT/IFFT filter.

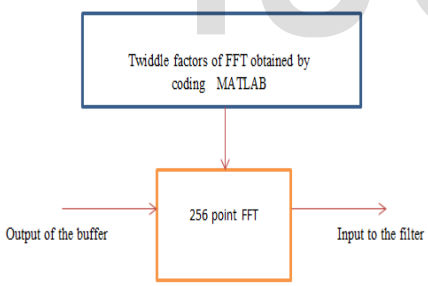



Fig.5 FFT block

The input for the FFT block is output of the Buffer. 256 Point FFT is performed on the data and the output is fed into the filter.

c. The frequency range of ECG signal is 0.5 Hz – 300 Hz. The filter coefficients are obtained with help of Matlab fdatool, rest of coding is done in Verilog. Here only signals in range of 10 Hz – 300 Hz are passed. Here Bandpass filter is used to detach high frequency artifacts. The upper and lower band cut-off frequency range is set in the fdatool. The Bandpass filter detaches the noise according to specifications in the fdatool.
   - PLI is a 50 Hz noise introduced by electromagnetic induction in the power lines. Hence noise at 50Hz has to be removed. Comb filter has a teeth structure which detaches noises at particular frequency interval. Hence it is used to detach the 50 Hz noise. The Comb filter detaches the noise according to specifications in the fdatool
   - The filter coefficients are obtained by designing the filter in matlab using fdatool and rest of the coding is done in Verilog. Fig.6 shows filter Block where depending upon the type of noise corresponding filter is activated.

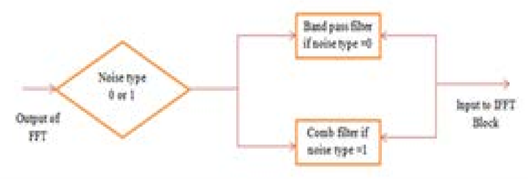



Fig.6 Filter block

d. Once the filtering process is completed the filtered signals are converted back to time domain using **IFFT**. Twiddle factors are obtaining by coding in Matlab, rest of the coding is done in Verilog. The result is saved in text file, once all the 1024 samples are de-noised, the text file is plotted in matlab and result is compared with the noise free ECG signal.

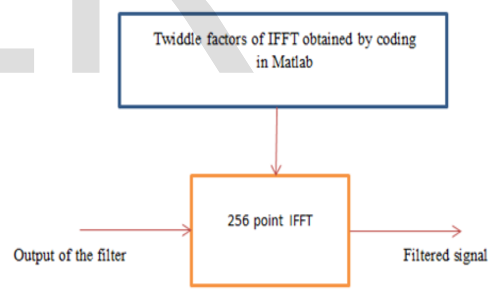



Fig.7 IFFT block

The input for the IFFT block is output of the Filter. 256 Point IFFT is performed on the filtered sample and the output is plotted in Matlab.

## 4 Results and Analysis

The ECG signal is plotted from the samples obtained from Matlab. Usually 3000 samples of ECG per person are taken, here 1024 samples are taken.

ISSN 2229-5518

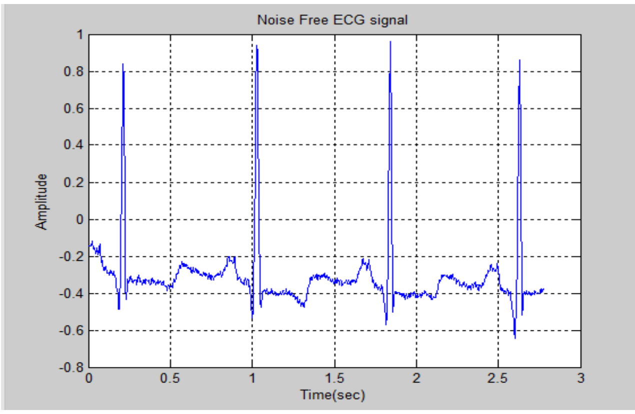



Fig.8 Noise free ECG signal

Power Line Interference and high frequency are added separately. The ECG samples in matlab are converted to text format and saved in buffer, depending on the type of noise, de-noising is done. Here 256 point FFT is applied, that is here there will be 8 stages, hence the 1024 samples of input are divided into 4 parts, each time one part is taken and de-noising is done. The twiddle factors for FFT and IFFT are obtained by writing code in matlab and it is saved in text file i.e., it is saved in a ROM and rest of the coding is done in Verilog and twiddle factors are used by calling the text file. Filter coefficients are obtained by designing the filter in matlab. Rest of the coding is done in Verilog.

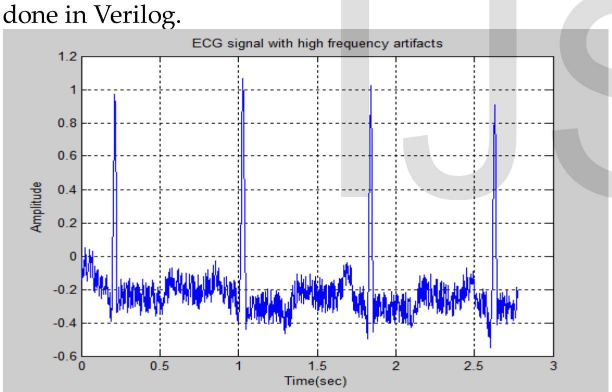



Fig.9 ECG signal with high frequency artifacts

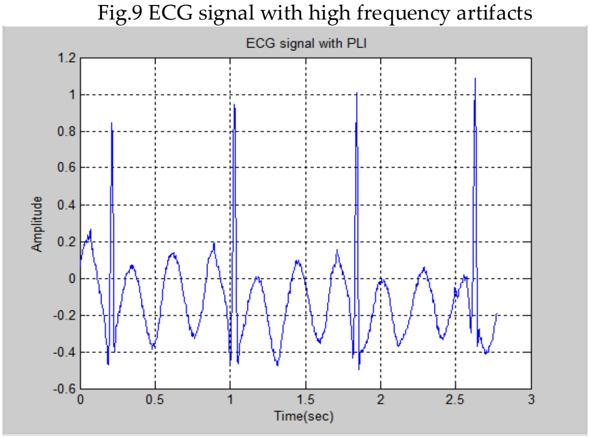



Fig.10 ECG signal with Power Line Interference

Depending on the type of noises corresponding filters are activated and de-noising operation is performed. Once the signals de-noised they are converted back to time domain using IFFT and the signals are plotted back in MATLAB.

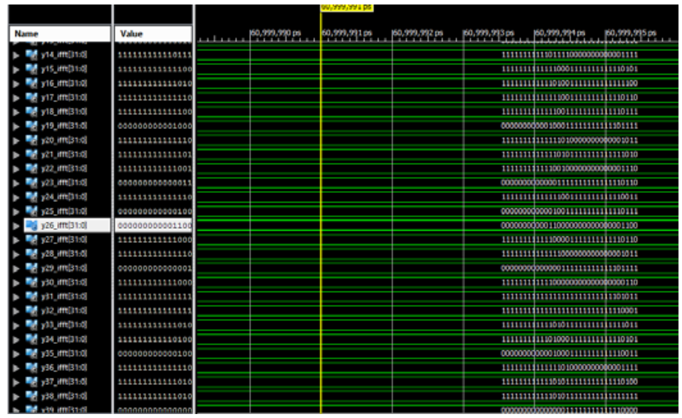


Fig.11 Timing Diagram of IFFT, after passing through Reconfigurable filter

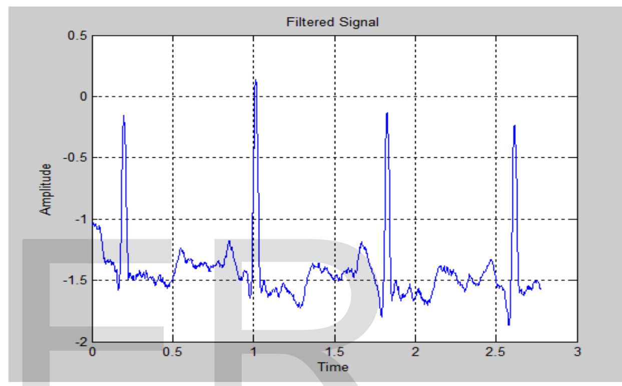



Fig.12 Filtered ECG signal

The filtered output in Fig 12 is similar to noise free ECG signal present in Fig.8.

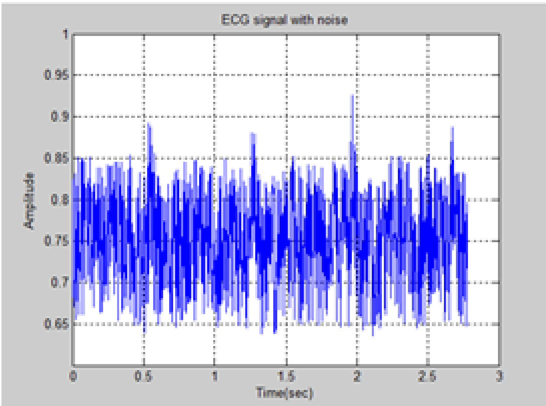
| NOISE TYPE | SNR BEFORE FILERING | SNR AFTER FILTERING | IMPROVE- PROVEMENT |
|---|---|---|---|
| PLI | 2.0694 | 14.0791 | 12.0097 |
| HIGH FRE- FREQUENCY ARTIFACT | 3.2567 | 16.2996 | 13.0429 |

**SNR value after filtering is greater than SNR value before filtering.**

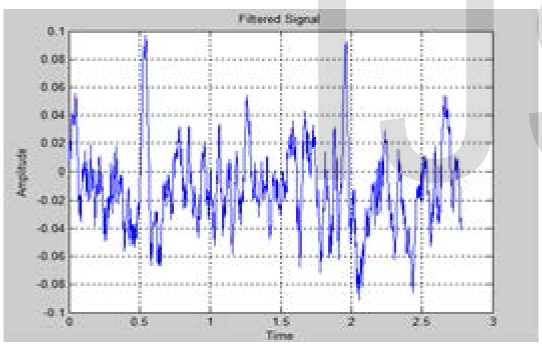
ISSN 2229-5518

### 4.1 Denoising of a Real time signal .

A real-time signal with patient suffering from Arrhythmia is taken from MIT data base. Arrhythmia is a disorder seen in heart beat i.e., there will be either too slow heart beat (brady-cardias) or too fast heart beat (tachycardia).




Since the real time is affected by noise and it would be difficult to predict the disease directly. So the signal is passed to the reconfigurable filter. After de-noising the signal a doctor can predict the exact disease.




When compared to the ideal noise free signal in fig 8, the filtered signal in fig 14 is different. A doctor by analyzing the filtered can predict the type of disease.

## 5 Conclusion

The new trends in medical fields as let to the invention of devices that can be handled at home like blood sugar level monitoring; even ECG can be monitored at home with portable device called Holter. But ECG signals are interrupted by many noises that affect proper identification of diseases. Hence detaching of these noises is obligatory. In this project mainly PLI and high frequency artifacts is detached using reconfigurable filter. The filtered signal is similar when compared to noise free ECG; hence in future it can be used for real time applications. In future it can be used for real time application. This method may be even used for de-noising of other bio medical signals like EEG, EMG.

## References

[1] Nannan Zhang, Zedong Nie, Yu Luo, Leilei Du, Xiaohui Wang, and Lei Wang Shenzhen "A Reconfigurable Overlapping FFT/IFFT Filter for ECG Signal De-noising", IEEE International Symposium on Bioelectronics and Bioinformatics ,April 2014.

[2] G. Bonneau, M. Bertrand, R. Guardo, M. Lafortune, and A. R. Lerlanc, "A preprocessor for on-line data reduction in accelerated playback of ECG's," IEEE Transactions on biomedical engineering, vol. BME-30, pp. 197 - 200, March 1983.

[3] Vrudhula K. Murthy, Thomas M. Grove, George A. Harvey and L. Julian Haywood, "Clinical Usefulness Of ECG Frequency Spectrum Analysis, " The Second Annual Syposposium on Computer Application in Medical Care, pp. 610- 612, November 1978.

[4] B. H. Calhoun, J. Lach, J. Stankovic, D. D. Wentzloff, K. Whitehouse, A. T. Barth, J. K. Brown, Q. Li, S. Oh, N. E. Roberts, and Y. Zhang, "Body Sensor Networks: A Holistic Approach From Silicon to Users," Proceedings of the IEEE, vol. 100, pp. 91–106, January 2012.

[5] Diana Albu, Johan Lukkien and Richard Verhoeven, "On-node Processing of ECG Signals," 2010 7th IEEE Consumer Communications and Networking Conference, pp. 1-5, January 2010.

[6] Mohammed Bahoura and Hassan Ezzaidi, "FPGA-Implementation of Wavelet-based De-noising Technique to Remove Power-Line Interference from ECG Signal, " 10th IEEE International Conference on Information Technology and Applications in Biomedicine, pp. 1-4, November. 2010.

[7] Yue-Der Lin and Yu Hen Hu, "Power-Line Interference Detection and Suppression in ECG Signal Processing, " IEEE Transactions on biomedical engineering, vol. 55, pp. 354 - 357, January 2008.

[8] Mohammed Bahoura and Hassan Ezzaidi, "FPGA-Implementation of a Sequential Adaptive Noise Canceller using Xilinx System Generator," 2009 International Conference on Microelectronics, pp. 213-216, December 2009

[9] Shubhajit Roy Chowdhury and Dipankar Chakrabarti, "Daubechies Wavelet Decomposition based Baseline wander correction of Trans-Abdominal Maternal ECG," 6th International Conference on Electrical and Computer Engineering, pp. 630 – 633, December 2010.

[10] Vinod K. Pandey, "Adaptive Filtering for Baseline Wander Removal in ECG," 10th IEEE International Conference on Information Technology and Applications in Biomedicine, pp. 1 - 4, November 2010.

[11] FREDRIC J. HARRIS, "On the use of windows for harmonic analysis with the discrete Fourier transform," Proceedings of the IEEE, vol. 66, pp. 51-83, January 1978.