Diagnosis of Cardiovascular Diseases Based on R-R Interval Using ECG Signals

[1]A. Mahalakshmi [2]N. Nithya [3]P. Nandhini

[1,2,3]*Department Of Electronics and Communication Engineering,*
[1,2,3]*Akshaya College of Engineering and Technology, Coimbatore.*

Abstract

The electrocardiogram is a diagnostic tool that measures and records the electrical activity of heart in exquisite detail. This will get differ from the normal recordings, if there is any heart disease. We have taken into account the R-R interval based diseases. For this many methods are available to extract the information from the recorded ECG signal. Among them 'SO and CHAN' and 'PAN and TOMPKINS' are the most popular methods. From the 'PAN and TOMPKINS' method we have adopted certain steps and included our own ideas to diagnose the R-R interval based heart diseases. For this we have used the ECG signal from the physionet.org and MATLAB as a tool for the diagnosis purpose. We have written MATLAB programs and have executed them by using the signal obtained as mentioned above. By using our algorithm we have calculated the number of heart beats in a particular time interval, position of the R peaks and the R-R interval. By doing so for the normal and the abnormal signals, we have diagnosed the R-R interval based diseases like PVC.

Index Terms **-- ECG, R-R interval, PVC, No. of heart beats.**

1. Introduction

Electrocardiography (ECG or EKG) is a transthoracic interpretation of the electrical activity of the heart over time captured and externally recorded by skin electrodes. It is a noninvasive recording produced by an electrocardiographic device. The ECG works mostly by detecting and amplifying the tiny electrical changes on the skin that are caused when the heart muscle "depolarizes" during each heart beat. During each heartbeat a healthy heart will have an orderly progression of a wave of depolarization that is triggered by the cells in the Sino atrial node, spreads out through the atrium, passes through "intrinsic conduction pathways" and then spreads all over the ventricles. This is detected as tiny rises and falls in the voltage between two electrodes placed either side of the heart which is displayed as a wavy line either on a screen or on paper. This display indicates the overall rhythm of the heart and weaknesses in different parts of the heart muscle.

2.waves and their intervals

The ECG signal consists of five waves each with definite time period and amplitude. (Figure.1). [11],[12]

A. P wave

The P wave is the first wave of the electrocardiogram and represents the spread of electrical impulse through the atrial musculature (activation or depolarization). Its duration of not more than 0.11 seconds and amplitude of not more than 3mm in height and gently rounded, not pointed or notched

B. QRS complex

Probably the most important complex in the electrocardiogram is the QRS. It represents the spread of the electrical impulse through the ventricular muscle (depolarization).The first negative deflection is the Q wave. The first positive deflection is the R wave. The negative deflection following the R wave is the S wave. Its duration is from 0.08s to 0.12s.

C. ST segment and T wave

The S-T segment follows the QRS complex. Its level is relative to the baseline. The T wave represents the period of recovery for the ventricles (repolarization). The normal shape of the T wave is slightly rounded and slightly asymmetrical.

D. Intervals

The time period between the successive R peaks is the R-R interval. Its normal duration is from 0.6s to 1.2 s. The time period from the onset of P wave and onset of R wave is the P-R interval. Its duration is of 0.05s to 0.12s.

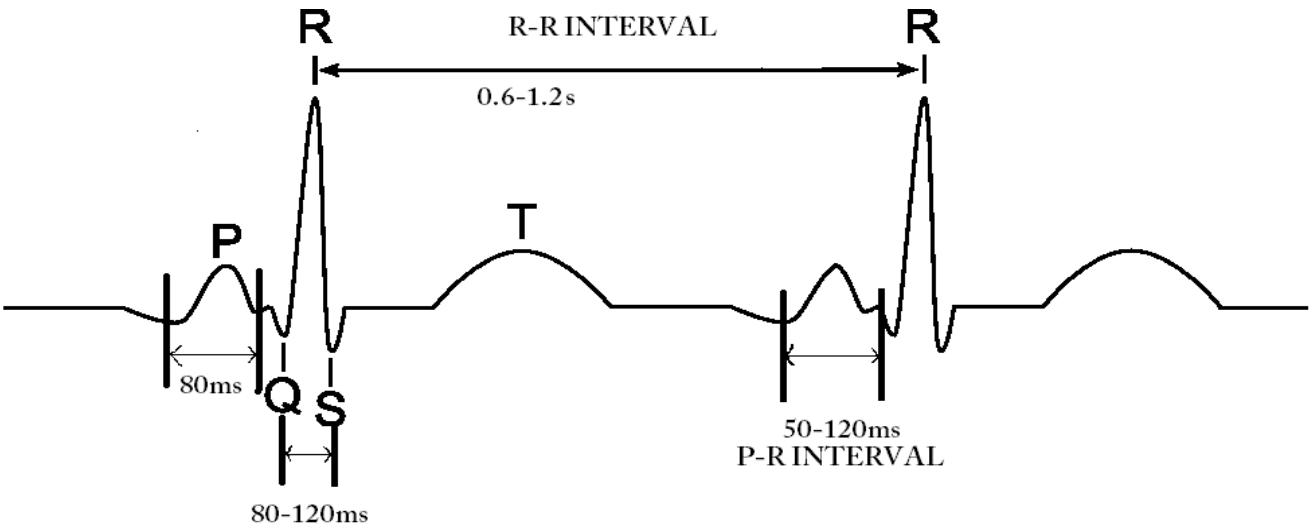

Figure.1 Waves and interval

3.Diseases due to disorders in electrical activity of heart

A. Bradycardia

Bradycardia often starts in the sinus node. A slow heartrate may occur because the sinus node discharges electrical impulses at a slower than normal rate. Due to the reduction in heart rate R-R interval becomes greater than 1.5s. and the p waves are found to be wider.

B. Tachycardia

Ventricular tachycardia is a pulse rate of more than 100 beats per minute, with at least three irregular heartbeats in a row. . The R-R interval is less than 0.5s. Because of this there won't be sufficient blood flow to heart.

C. Ventricular fibrillation

Fibrillation is an uncontrolled twitching or quivering of muscle fibers (fibrils). When it occurs in the lower chambers of the heart, it is called ventricular fibrillation. During ventricular fibrillation, blood is not removed from the heart. There may be lack of QRS complex in the ECG signal.

D. Atrial fibrillation

This is a rapid and irregular heart arrhythmia, caused by chaotic electrical impulses in the atria of the heart. In anatomical terms, the AV node and the ventricles (the two lower chambers) are therefore bombarded with frequent, irregular electrical impulses.

E. Bigeminy

This condition describes a state where your heart alternates one "normal" beat with one "premature" beat. Premature beats occur when either the atria or the ventricle initiate their own electrical impulse before receiving the impulse from the sinus node. This is identified by wide QRS complex.

F. Trigeminy

It's a form of cardiac arrhythmia characterized by the occurrence of three heartbeats in a repeating pattern: two normal beats coupled to an ectopic beat, or two ectopic beats coupled to a normal beat.

G. Premature ventricular contraction

It is a relatively common event where the heartbeat is initiated by the heart ventricles rather by the Sino atrial node, the normal beat initiator.The QRS and T waves look very different to normal readings. The spacing between the PVC and the preceding QRS wave is a lot shorter than usual and the time between the PVC and the proceeding QRS is a lot longer. However, the time between the preceding and proceeding QRS waves stays the same as normal due to the compensatory pause.

4.Basic principle

To study the characteristics of ECG signal many methods such as First derivative based method for QRS detection, Principle component analysis and the combined wavelet entropy etc.,[2]-[9].For finding the R-R interval based diseases we have obtained the basic idea from the Pan and Tompkins method. This method is known for it sensitivity.

A. Modified Pan and Tompkins method

In the first step the algorithm passes the signal through a low pass and a high pass filter in order to reduce the influence of the muscle noise, the power line interference, the baseline

wander and the T-wave interference. The low pass filter is given by,

$$y(n)=2*y(n-1)-y(n-2)+x(n)-2*x(n-6)+x(n-12) \quad (1)$$

and the high pass filter is given by,

$$y(n)=y(n-1)-1/32*x(n)+x(n-16)-x(n-17)+1/32*x(n-32) \quad (2)$$

After filtering the signal is differentiated using the formula below:

$$Y(n)=1/8*[2*(n)+x(n-1)-x(n-3)-2*x(n-4)] \quad (3)$$

This provides the QRS slope information. Then the signal is squared to make all the data points positive

$$y(n)=x(n)*x(n) \quad (4)$$

after this the signal is integrated using sliding window integration.

$$Y(n)=1/N*[x(n-(N-1))+x(n-(N-2))+\ldots+x(n)] \quad (5)$$

N=size of window.

This step is used to obtain waveform feature information. In the last step the peak of the signal is identified using thresholds. Thus by using this method the positions of the peak R can be identified.

5.Methodology and Materials

We have used MATLAB as our tool for the analysis purpose. Because it provides an interactive environment that enables you to perform computationally intensive tasks faster than with traditional programming languages such as C, C++, and FORTRAN.

A. Getting ECG signal

We acquired the required ECG signal from the physionet.org website (MIT-BIH Arrhythmia Database.). This website provides large collections of recorded physiological signals. We have downloaded it by using an ECG exporter program. (Figure.2,3) [10]

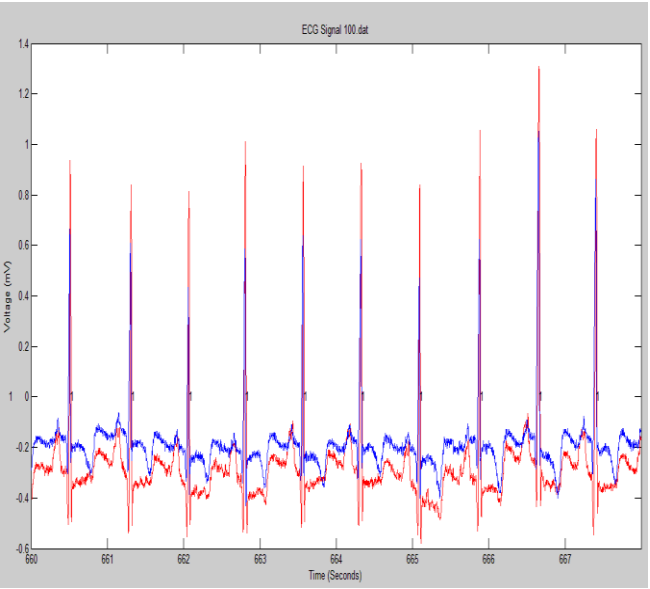

Figure.2 ECG wave obtained

B. Procedure

We have copied the data's of the ECG signal into the excel sheet. From the excel sheet we have brought the data's into our program through the command 'xlsread'. (Figure.4)Then the obtained signal is differentiated using the command diff ( ). (Figure.5) The signal is differentiated to avoid the problem with base line drift given that the low frequencies are then attenuated.

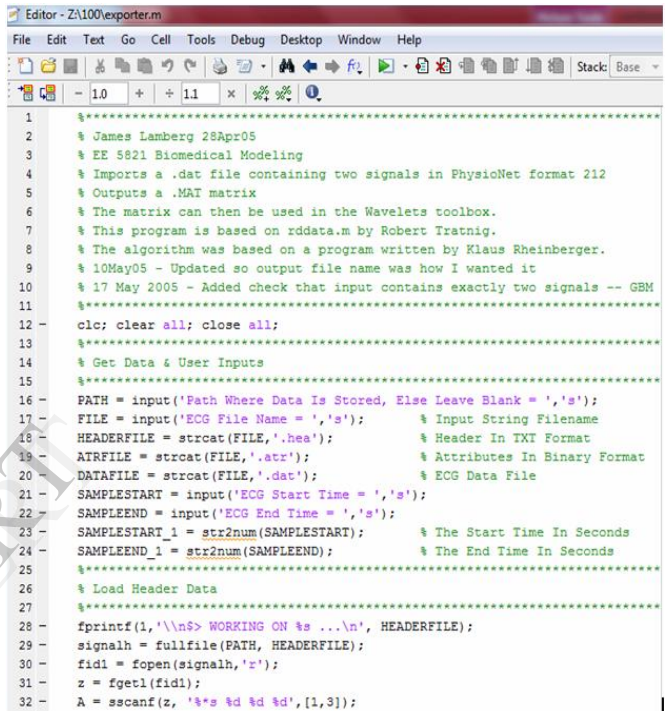

Figure.3 Exporter program

It is also done to get the information about the slope. Then the differentiated signal is squared to change all the values to positive. (Figure.6) In the next step the peak value and its position are obtained. For this the number of samples in each slot is copied to a matrix. Then the maximum value and its position is calculated using the command max( ).[1] The maximum values in each slot corresponds to the peaks and the position value corresponds to the corresponding peak position. Thus by finding the length of the variable containing the peak values of each slot will give the number of heart beats for the given time period. In the next step the R-R interval is obtained. The number of data's between two R peaks is obtained by subtracting the (n+1)th position value from the nth position value. From the number of values the R-R interval is obtained using the simple mathematical calculation. The values thus so far obtained are displayed using the command disp( ) and their corresponding waveforms are plotted. We have performed the above

procedure to the PVC affected signal and the normal signal. In reference to the annotations given by the physionet.org we have taken the data's around the PVC affected region and the normal sinus rhythm region for 10 seconds each.

Figure.4 Program

6.Results and Inference

For a normal sinus rhythm the R-R interval must be between 0.6s-1.2s. As seen earlier the ECG signal of PVC (Premature Ventricular Contraction) is characterized by wide PVC affected QRS proceeded and proceeded by normal QRS complex. Because of this the R-R interval is increased then usual. From the result we have obtained we found that the R-R interval for the normal ECG signal is within the specified range. For the PVC affected signal the R-R interval exceeds the prescribed time period. From this we have confirmed the presence of PVC in the given ECG data. (Figure.7,8) . In addition to this we have also analyzed the signal by finding the power spectral density and variance of the normal and abnormal ECG signal. Through PSD we have analyzed the power of the signal in terms of frequency (Figure.9,10).By taking the variance of the signal we have analyzed the variance between the successive PQRST in the ECG signal (Figure.11,12).

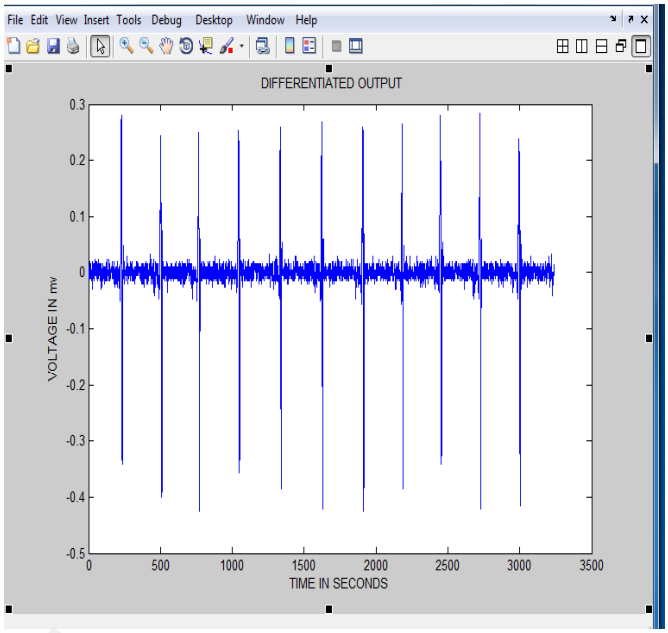

Figure.5 Differentiated output

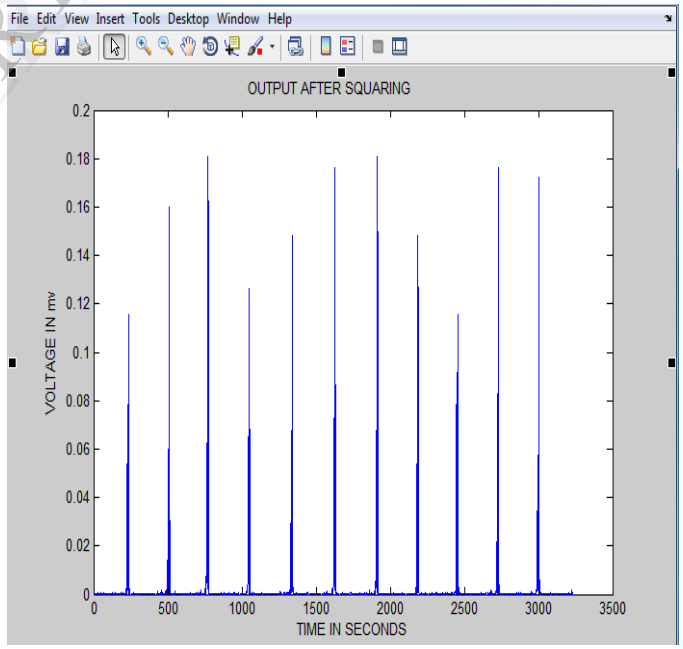

Figure.6 Squared output

7. Conclusion

Our algorithm is applied for the data's taken for 10 seconds an from this 1 minute calculation can be made. We have taken the PVC disease to explain the working of our algorithm. Similarly any R-R interval based diseases can be diagnosed using our algorithm.

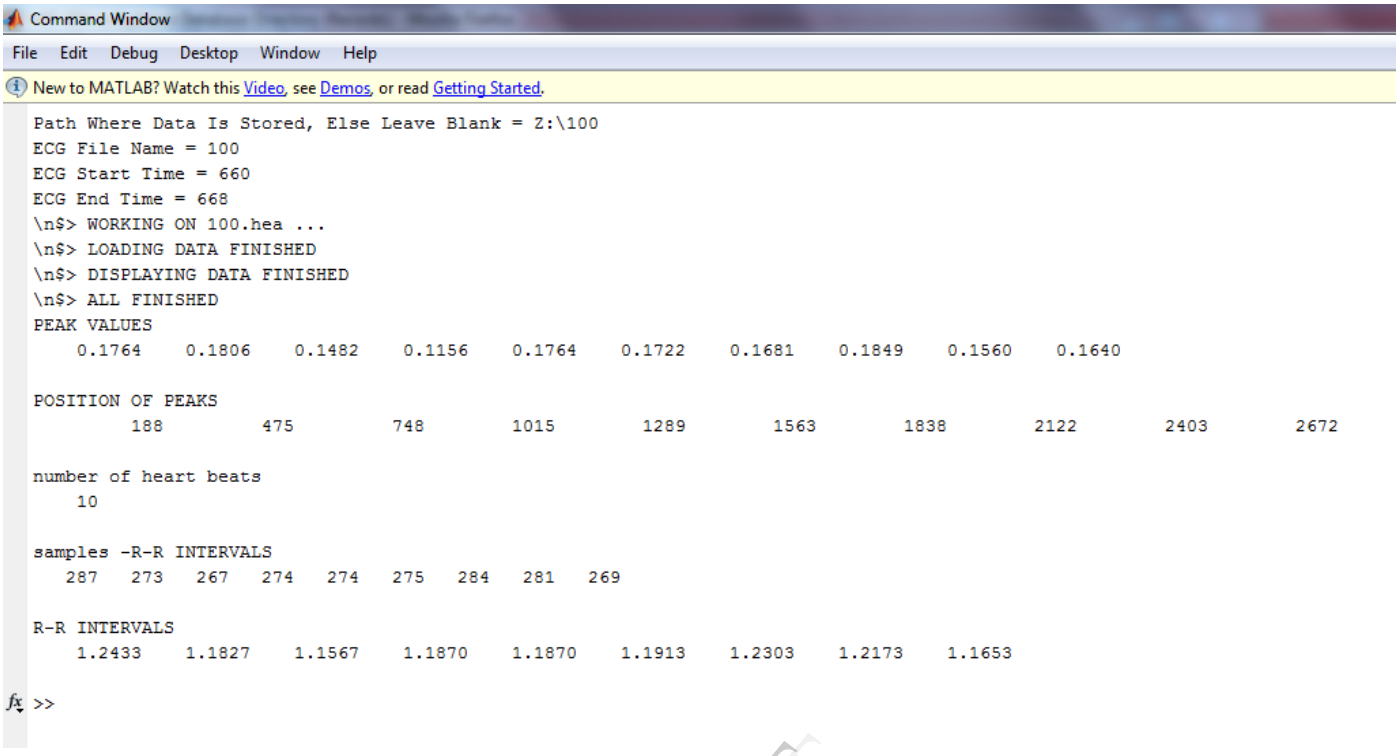

Figure.7 Result for normal data

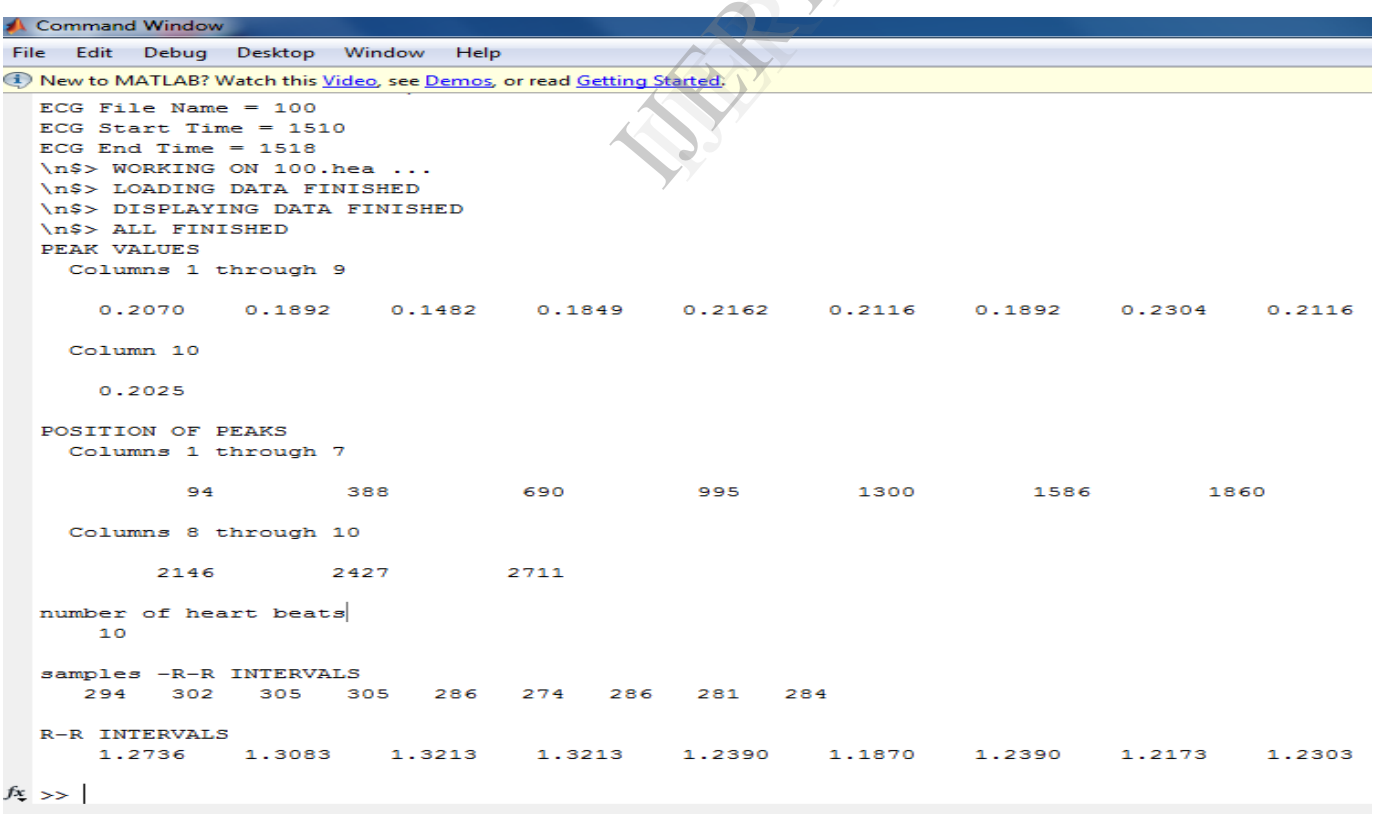

Figure.8 Result for abnormal data

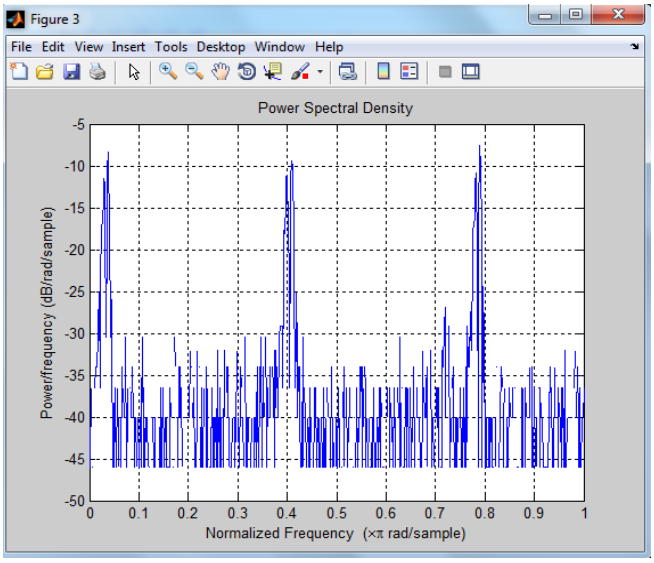

Figure.9 PSD of normal wave

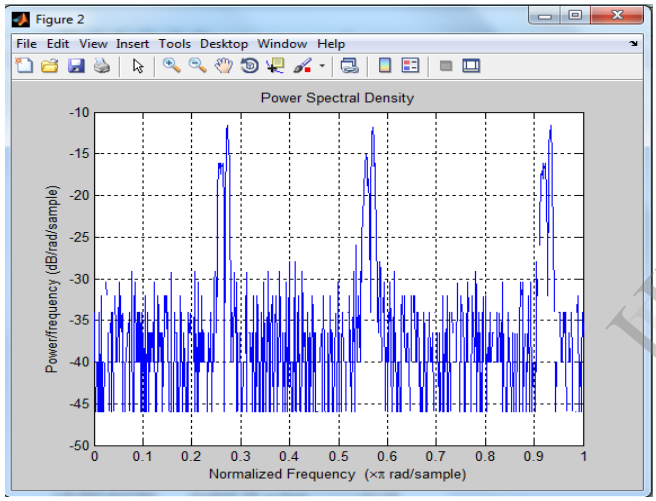

Figure.10 PSD of abnormal wave

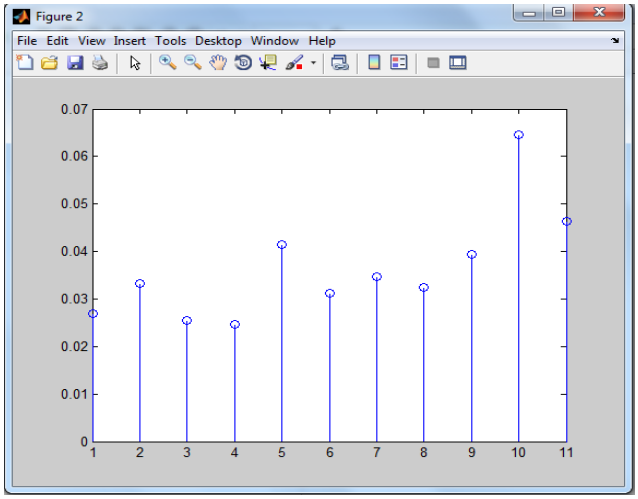

Figure11.Variance of normal signal

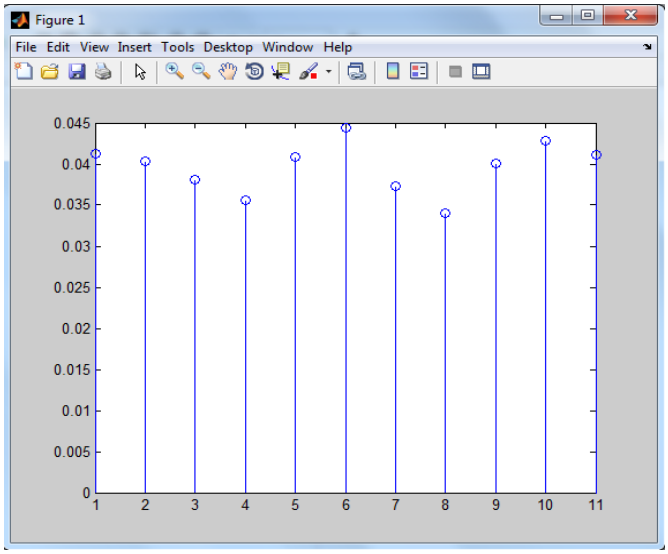

Figure12.Variance of abnormal signal

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