

A DISSERTATION
On
**GENERATION AND COMPARISON OF ECG SIGNAL
USING MATLAB**

Submitted in partial fulfillment of the requirements for the award of the degree
Of
MASTER OF TECHNOLOGY
In
VLSI DESIGN & EMBEDDED SYSTEMS

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CERTIFICATE



It is certified that **Tarun Pratap Singh (2k11/VLS/09)**, student of Master of Engineering, VLSI Design & Embedded Systems, Department of Electronics & Communication Engineering, Delhi Technological University (Formerly Delhi College of Engineering), have submitted the dissertation entitled '**Generation and comparison of ECG signal using Matlab**' under my guidance towards partial fulfillment of the requirements for the award of the degree of Master of Engineering (VLSI Design & Embedded Systems).

This dissertation is a beneficent record of project work carried out by him under my guidance and supervision during the academic session **2011-2013**. His work is found to be excellent and his discipline impeccable during the course of the project. I wish him success in all his endeavors. The content of this thesis, in full or in parts, have not been submitted to any other institute or University for award of any degree.

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ABSTRACT

The Scarcity of Experienced Doctors in rural areas is very common and hence the medical facility provided in rural areas is not better as compared to urban areas. This project emphasizes the heart diseases and studies the various different vital parameters of an ECG signal i.e. P, Q, QRS, S, T & U waves. In the Existing Methods like Probabilistic Models, McSharry's Model, Wavelet Transform, the whole ECG signal was transmitted from rural areas to urban areas for diagnosis. ECG being a continuous signal the reception may be erroneous. This project proposes a novel method of retrieving vital parameters and regeneration of ECG signals from the retrieved vital parameters. The vital parameters can be retrieved after digitizing the continuous ECG signal. The decimal values of retrieved signals can be send to urban areas accurately.

We also propose abnormality identification using auto & cross correlation, impulse response and step response methods. Experiments are carried out on various database carried from hospitals for validation of the proposed method. The results show that the proposed method is very effective and an efficient method for fast diagnosis of heart diseases.

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CHAPTER 1: INTRODUCTION

Largest-ever study of deaths shows heart ailments have replaced communicable diseases as the biggest killer in rural & urban India. Mortality rates for coronary heart disease are higher outside capital cities. The difference between rural and urban areas accounts for approximately 5000 excess deaths per year.

If some of the increased mortality in rural people is the result of under prescribing for cardiovascular disease, then doctors can make a difference by addressing the issue of appropriate prescribing and compliance.

Access problems probably account for much of the rural-urban gap. We know that rural patients see their general practitioners, on average, 1-2 fewer times per year than city dwellers. Additionally, rural patients have less access to cardiologists, who are more likely to be aggressive with cardiac therapies and do not have to pay attention to the patient's many other needs. Timely access to technical intervention in acute coronary syndromes is a problem, for example if patients have to travel for hours before even being considered for thrombolytic, pacemakers or percutaneous coronary intervention.

Rural areas have a disproportionately high and increasing percentage of elderly patients who are more likely to have cardiovascular disease, and are also likely to have other medical problems. Legitimate concerns about drug interactions and adverse effects in this vulnerable group may increase the reluctance to prescribe. However, studies looking at hypertension treatment and anticoagulation show that, generally, older patients should have the same goals (for example blood pressure < 130/80) as younger patients.



TOP TEN CAUSES OF DEATH IN INDIA				
(Ages 25 to 69 as percentage)				
RANK	CAUSE OF DEATH	MALE	FEMALE	TOTAL
1	Cardiovascular diseases	26.3	22.5	24.8
2	Respiratory diseases	10.1	10.4	10.2
3	Tuberculosis	11.4	8.3	10.1
4	Malignant and other tumours	7.8	11.8	9.4
5	Ill-defined conditions	4.8	6.0	5.3
6	Digestive diseases	6.1	3.5	5.1
7	Diarrhoeal diseases	4.0	6.6	5.0
8	Unintentional injuries	5.0	4.1	4.6
9	Intentional self-harm	3.3	2.6	3.0
10	Malaria	2.4	3.4	2.8

(All ages as percentage)				
RANK	CAUSE OF DEATH	MALE	FEMALE	TOTAL
1	Cardiovascular diseases	20.3	16.9	18.8
2	Respiratory diseases	9.3	8.0	8.7
3	Diarrhoeal diseases	6.7	9.9	8.1
4	Perinatal conditions	6.4	6.2	6.3
5	Respiratory infections	5.4	7.1	6.2
6	Tuberculosis	7.1	4.7	6.0
7	Malignant and other tumours	5.4	6.0	5.7
8	Senility	4.0	6.5	5.1
9	Unintentional injuries	5.2	4.5	4.9
10	Ill-defined conditions	4.6	5.0	4.8

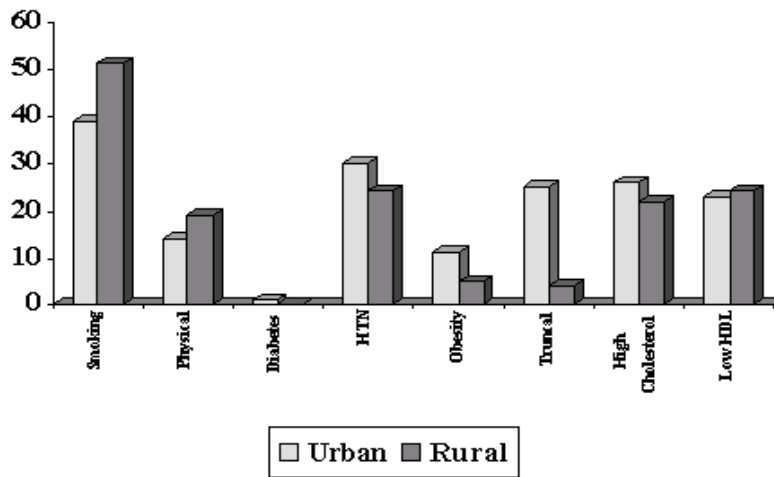


Table 1 & bar chart of represents figures of diseases

1.1 RELATED WORK

ECG has been attraction of researchers for more than 2 decades. ECG acquisition, filtering & processing using Lab view & Matlab is proposed in [1]. Authors of [3] carried out use of Matlab & lab view for analysis of ECG signal. Feature Extraction of ECG is



proposed using Wavelets Transform [2], Digitization of ECG signal [4 & 5]. For rural areas the Schemes of Medical facilities are provided by Tele-Medicine, E-health, m-Health, Tele-Diagnosis Technologies defined in [7-11]. Our proposed method also supports Tele-diagnosis Methodology by regenerating ECG from its vital parameters. Unlike existing methods, we analyzed ECG signals using auto & cross correlation and impulse and step response methods

1.2 RESEARCH GOALS

The focus of this thesis is to regenerate the ECG signal from its vital parameters (P, Q, QRS, S, T, and U) by using built-in functions in Matlab and analyze it. The decimal values of vital parameters are retrieved after digitizing the ECG signal. We used STEM function of MATLAB for digitizing ECG and further modified ECG simulation code for generating user defined ECG signal. We have also done a rigorous ECG signal analysis using auto & cross correlation methods and step and impulse response methods.

1.3 THESIS ORGANISATION

In this thesis regeneration of the ECG signal from its vital parameters (P, Q, QRS, S, T, and U) by built-in functions in Matlab & Comparison of that signal with the standard ECG signal is presented. The organization of the proposed work is presented in this section.

Chapter 2 presents the background of ECG signal & its Acquisition & features. The ECG Standards, its features and electrodes are discussed.



Chapter 3 Characteristics of ECG signal are discussed. Different types of abnormalities & its characteristics features related with heart disease are discussed with respect to standard ECG signal. Various types of abnormalities & its characteristics feature shown in a table.

Chapter 4 Retrieval of vital parameters & Regeneration of ECG signal is explained. The original ECG signal is first converted into digital domain. The vital parameters are retrieved from the digitized ECG. Using these values user defined ECG signal is simulated which is actually the regenerated ECG signal.

Chapter5 Analysis of regeneration of ECG signal is carried out by using values of vital parameters. Comparison of Normal ECG with User defined Regenerated ECG signal is done successfully by using Auto & Cross Correlation and Impulse & Step Responses.

Chapter 6 Presents the conclusions, Future Scope and summarizes the research work done in the thesis.



CHAPTER 2: ACQUISITION OF ECG SIGNAL

The electrocardiogram (ECG) provides a physician with a view of the heart's activity through electrical signals generated during the cardiac cycle, and measured with external electrodes. Its clinical importance in cardiology is well established, being used for example to determine heart rate [1], investigate abnormal heart rhythms, and causes of chest pain. As shown in Figure 1.1, the most important ECG signal features in a single cardiac cycle are labelled (along with the physiological cause of that feature):

- "P" wave - due to depolarization of the atria
- "Q" wave - due to activation of the anterioseptal region of the ventricular myocardium
- "R" wave - due to depolarization of the ventricular myocardium
- "S" wave - due to activation of the posterio basal portion of the ventricles
- "T" wave - due to rapid ventricular repolarization

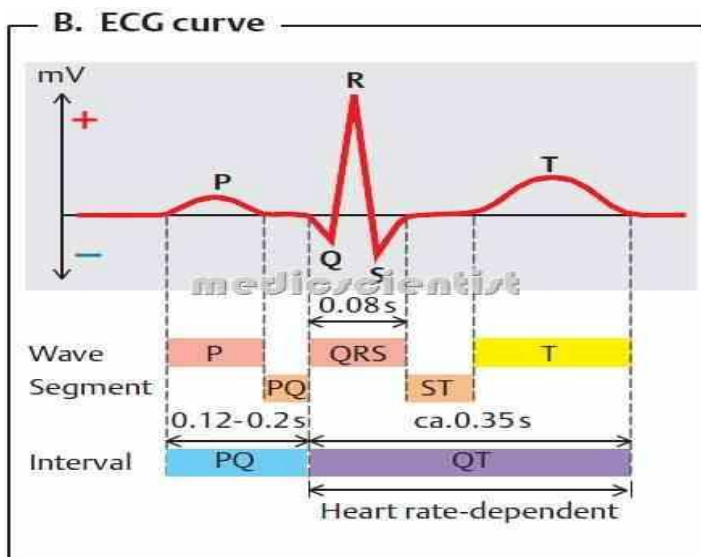


Figure 2.1 ECG curve

An ECG is generated by a nerve impulse stimulus to a heart. The current is diffused round the surface of the body surface. The current at the body surface will build on the voltage drop, which is a couple of μV to mV with an impulse variation. Usually, this is very small amplitude of impulse, which requires a couple of 1000 times of amplification.

A typical ECG tracing of a normal heartbeat (or cardiac cycle) consists of a P wave, a QRS complex and a T wave. A small U wave is normally visible in 50 to 75% of ECGs. The baseline voltage of the electrocardiogram is known as the isoelectric line. Typically the isoelectric line is measured as the portion of the tracing following the T wave and preceding the next P wave. The electrical activity of the heart can be recorded at the surface of the body using an electrocardiogram. Therefore the electro-cardio-gram (EKG) is simply a voltmeter that uses up to 12 different leads (electrodes) placed on designated areas of the body. Figure 1 shows the typical ECG trace [2]. The electrical activity of the heart is generally sensed by monitoring electrodes placed on the skin surface. The electrical signal is very small (normally 0.0001 to 0.003 volt). These signals are within the frequency range of 0.05 to 100 Hertz (Hz.) or cycles per second.

2.1 FEATURES OF ECG SIGNAL

The paper upon which the ECG is recorded is ruled in lines one mm both horizontally and vertically. Five lines in both directions complete one block. The vertical axis represents voltage. With normal standardization, each 1mm represents 0.1mV. The horizontal axis represents time with normal speed, 1mm represents 0.04s i.e. each 5mm represents 0.2s and in one minute the ECG paper moves by 300 thick lines or 1500mm.

Electrocardiogram (ECG) provides evidence for early diagnosis of the coronary heart disease and the myocardial infarction in an invasive and accurate way and has been one of the most popular diagnostic procedures in primary care. It's quite natural to consider that many benefits would emerge if a patient bearing cardiac angina is provided with timely services of ECG examination in a nearby point of care instead of undergoing a fussy flow within hospitals or other facilities, especially where access to facilities and



expert advice requires travelling over long distances [3]. However, even in many communities equipped with some kind of ECG machines, quality of ECG interpretation is much far away from sufficient satisfaction, and sometimes even only automatic diagnostic report without detail description of ECG waveform could be provided, especially in countries with uneven distribution or chronic shortages of physicians and health technicians [4].

2.2 NORMAL ELECTROCARDIOGRAM

The basic ECG waveform consists of three recognizable deflections. The deflections are termed as 'P wave, 'QRS complex ' and 'T Wave [5].

P Waves:

The P wave represents the spread of electrical activation through the atrial myocardium. In the normal ECG it is a small, smooth, rounded deflection preceding the QRS complex. A P wave is formed when right depolarization starts and terminates before left atrial depolarization termination. In normal circumstances atrial depolarization begins as soon as depolarization of the SA node spreads to activate the adjacent right atrial myocardium. Depolarization then spreads simultaneously in all available directions through the right atrial myocardium. The direction in which the greatest amount of atrial myocardium is available determines the direction in which the right atrial comp. of P wave is best seen.

QRS Complex:

The QRS complex represents the spread of electrical activation through the ventricular myocardium. It is usually, but not always, the largest deflection of the ECG. It is always spiky in shape. The QRS complex is the electrical manifestation at the body surface of the ventricular myocardial depolarization. Ventricular activation begins on the left side of



inter-ventricular septum. It then spreads from the left to the right within the septum and later, from endocardium to Epicardium in the free walls of the two ventricles. The full sequence of ventricular depolarization can be simplified into three phases, viz.

1. Depolarization of the inter-ventricular septum.
2. Depolarization of the free wall of the right ventricle.
3. Depolarization of the free wall of the left ventricle.

T Wave:

The T wave represents the electrical recovery of the ventricular myocardium. This must inevitably follow electrical activation and must be accomplished before any repeat electrical activation is possible. A T wave follows each QRS complex and is separated from it by an interval which is constant in any given ECG.

U Wave:

The U wave is a small rounded, upright wave occurring immediately at the end of the T wave. It is part of the repolarization process. The U wave is normally 5-25% of the height of the preceding T wave. Its exact genesis is still uncertain.

2.3 STANDARDS OF NORMAL ECG

P wave:

1. It should not exceed 0.12s in duration.
2. Its height should not exceed 25mm in lead 2.
3. Any negative component visible in lead VI should not have a greater area than that of the positive component.

QRS Complex:

1. R wave in lead aVL must not exceed 13mm.
2. R wave in lead aVF must not exceed 20mm.



3. Any Q wave present in leads aVL, aVF, must not have a depth greater than one-fourth height of the ensuing R wave and must not have a duration equal to or in excess of 0.04s.

T wave:

Normality of T waves in the limb leads is analyzed as follows:

1. Using soft criteria:

When QRS is upright, T wave should upright. When QRS is negative, T wave should be negative. When QRS is close to zero, T wave should small, but may be positive or negative.

2. Using reliable criteria:

The angle between mean frontal plane QRS axis and the mean frontal plane T axis must not exceed 45 degrees.

U wave:

1. The normal U wave is upright in all leads in which the T wave is upright. It should also be upright in the right precordial leads even if the T waves are inverted here.

2. Its average amplitude is less than 0.5mm. The U wave is normally 5- 25% of the height of the preceding T wave. Hence it tends to be the largest in V2 and V3 where it may occasionally reach 2mm in height.

3. It is definitely abnormal when it is taller than preceding T wave.

S-T segment:

The S-T segment in the precordial leads must not deviate from the

Iso-electric line by more than +1mm or -1mm.

PR interval:

It is defined as the measure of the total transmission from the beginning of the atrial myocardial depolarization to the beginning of the ventricular myocardial depolarization.



Criteria for normality:

1. PR interval is 0.11s or less.
2. Total QRS duration is 0.11s or more.

QT interval:

QT interval is the time interval from the first recognizable part of the QRS complex to the final recognizable part of the T wave in the same lead.

Ventricular activation time (VAT):

It is the time interval between the starting q wave with the peak of R wave. It can only be measured in leads showing a 'QR' type of QRS complex.

Criteria for normality:

It should not exceed 0.04s.

2.4 Introduction to Transducers:

Transducers are defined as devices capable of converting signals from one form of energy to another, without loading the source. The bioelectric potentials generated in the body are ionic potentials, produced by the ionic current flow. Efficient measurement of these ionic potentials requires that they be converted into electronic potentials before they can be measured by conventional methods. Devices that convert ionic potentials into electronic potentials are called electrodes [8].

Electrode theory:

The interface of metallic ions on solution with their associated metals results in an electrical potential that is called the electrode potential. This potential is the result of the difference in diffusion rates of ions into and out of the metal. Equilibrium is produced by the formation of a layer of charge at the interface. Another source of an electrode potential is the unequal exchange of ions across a membrane that is semi-permeable to a given ion when the membrane separates liquid solutions with different concentrations of



that ion. The equation relating the potential across the membrane and the two concentrations of the ion is the ‘Nernst’ equation. In electrodes used for the measurement of bioelectric potentials, the electrode potential occurs at the surface of a metal and an electrolyte. It is impossible to measure the absolute electrode potential of a single electrode, for measurement of the potential across the electrode and its ionic solution would require that another metallic interface be placed inside the solution. Therefore all electrode potentials are given as relative values and must be stated in relation to some reference. By international agreement, the normal hydrogen electrode was chosen as the reference standard and arbitrarily an electrode potential of zero volts.

2.4.1 Types of electrodes:

A wide variety of electrodes can be used to measure bioelectric events but nearly all can be classified as belonging to one of three basic types:

1. Microelectrodes: Electrodes used to measure bioelectric near or within a single cell.
2. Skin Surface Electrodes: Electrodes used to measure ECG, EEG and EMG potentials from the surface of the skin. These are discussed further in the next section.
3. Needle electrodes: Electrodes used to penetrate the skin to record EEG potentials from a local region of the brain or EMG from a specific group of muscles.

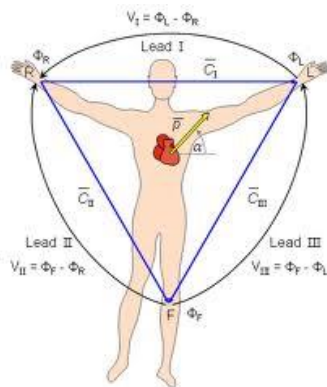


Figure 2.2 types of electrodes used for measurement of ECG

All three types of bio-potential electrodes have the metal-electrolyte interface described in the earlier section. In each case, an electrode potential is developed across the interface. The double layer of charge at the interface acts as a capacitor. Thus, the equivalent circuit of a bio-potential electrode in contact with a body consists of a voltage in series with a resistance capacitor network [10].

2.4.2 Electrode Characteristics:

The resistance-capacitance networks represent the impedance of the electrodes both electrode potential and impedance are valued by polarization. Size and type of the electrode are also important in determining the electrode impedance. The larger surface electrodes have impedances of 2 to 10 k, whereas small needle electrodes and microelectrodes have much higher impedances. For best results in reading and recording the potentials measured by the electrodes, the input importance of the amplifier must be several times that of the electrodes..

2.4.3 Skin Surface Electrodes:

These are also known as Body surface electrodes. These are found in many sizes and forms. Although any type of surface electrode can be used to sense ECG, EEG or EMG potentials, the larger electrodes are usually associated with the ECG where localization of electrodes is not important, unlike the other two.

The earliest bio-potential measurements used immersion electrodes, which were merely buckets of saline into which the patient placed the hands and feet one bucket for each extremity. This had problems of maintenance, spillage and inconvenience of position. A great improvement over the immersion electrodes was the plate electrodes. Originally separated from the subject's skin by cotton or felt pads soaked in a strong saline solution, later versions used a conductive electrolyte jelly or paste.

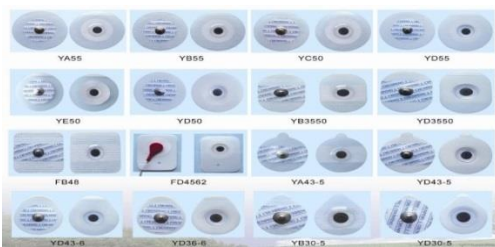


Figure 2.3 skin electrodes

Both these electrodes suffer from sensitivity to movement. Even the slightest movement changes the thickness of the thin film of electrolyte between the metal and skin and thus causes variance in electrode potential and impedance. Floating electrodes remove this problem. To eliminate the need for cleaning and caring of the electrodes after each use, disposable electrodes have been introduced. These are of floating type with simple snap connectors.



Chapter 3: ECG Signal Characteristics

Given below are parameters for major biomedical signals in terms of frequency content and amplitude

3.1 Abnormalities:

The four categories of diseases are considered

1. Heart blocks:

- a. RBBB
- b. 1st degree AV block

2. Rhythms:

- a. Sinus Tachycardia
- b. Sinus Bradycardia
- c. Sinus Arrhythmias

3. Myocardial Infarcts:

- a. Anterior lateral wall myocardial infarct
- b. Inferior wall myocardial infarct

4. Left Ventricular Hypertrophy

3.2 Normal ECG

The heart rate of a normal person is 72 per min. & the range is 60-120 per minute.

P wave: amplitude duration about 0.25mv 0.12 sec.

PR interval 0.12- 0.2Sec

QRS Complex 0.04 – 0.10 Sec

ST Segment is isoelectric.

T wave is usually upright except in lead aVR and V1.



QT interval: - The normal Qt interval is 0.32-0.45.

U wave: Normally U wave is absent or it may be just present. Its amplitude & duration are less than that of the T wave.

3.3 Abnormal ECG

1. Heart blocks:

A. Right Bundle Branch Block:

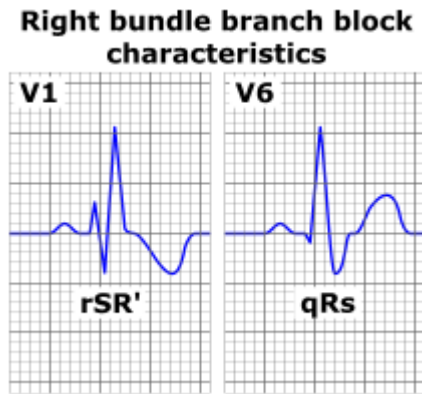


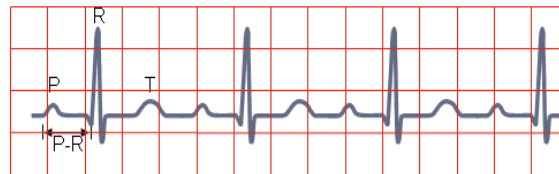
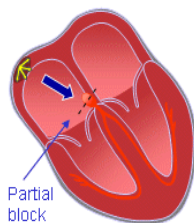
Figure : 3.1 right bundle branch block

1. A wide slurred QRS Complex with rSR pattern in leads V1, a wide “S” & inverted “T”
2. QRS Complex is wide more than 0.12s.
3. ST depression & T wave inversion may be present in leads V1 & V2.

B. 1st Degree AV Block:

A-V BLOCK, FIRST DEGREE

Atrioventricular conduction lengthened



P-wave precedes each QRS-complex but interval is > 0.2 s

Figure 3.2 1st Degree A V Block

Delay in Conduction of impulse through AV node. This results in prolongation of RR

Interval to above 0.2 seconds Rhythm is regular & no beat is dropped.

2. Rhythms:

A. Sinus Tachycardia:

Cardiac rate > 100 times/min RR is less than 15 small squares with normal PQRST Complexes occurring at regular intervals.

B. Sinus Bradycardia:

Cardiac SA node discharges < 60 -times/ min Pulse rate less than 60/min RR interval is more than 25 small squares with normal PQRST Complexes occurring at regular intervals

C. Sinus arrhythmia:

It is alternate period of Tachycardia & Bradycardia, which occur due to irregular discharge of the SA node associated with phase of respiration.

Tachycardia occurs towards the end of inspiration and Bradycardia occurs towards the end of the expiration. PQRST Complexes are normal but occur irregularly in relation to Phase of respiration so that PR interval varies.

3. Myocardial Infarct:

A) Anterolateral wall myocardial infarct.

- a. ST elevation found in lead 2, 3, avF.
- b. ST depression in leads V2-V6 & T inversion.

B) Inferior wall myocardial infarct.

ST elevation found in leads V2-V6 & T inversion in leads 2,3, avF.

There are three stages of myocardial infarct:

- i. Initial stage: - ST elevation and T inversion found.
- ii. Developing stage: - No inversion of T found.
- iii. Chronic stage: - Q wave amplitude $> \frac{1}{4}$ (R wave amplitude).



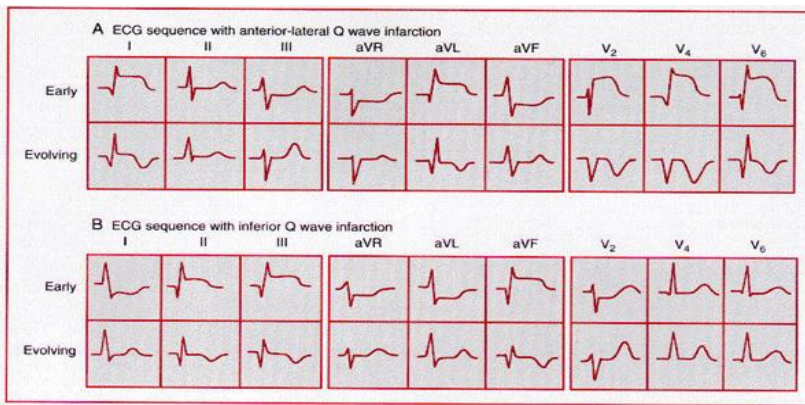


Figure 3.3 Myocardial Infarct

4. Left Ventricular Hypertrophy:

ST – T Charges – Without digitalis QRS interval 0.09sec or more Causes of LVH: -

- 1) Hypertension
- 2) Coronary artery disease.
- 3) Mitral insufficiency.
- 4) Aortic Valvular disease.
- 5) Congenital heart disease
- 6) Cardio myopathies.

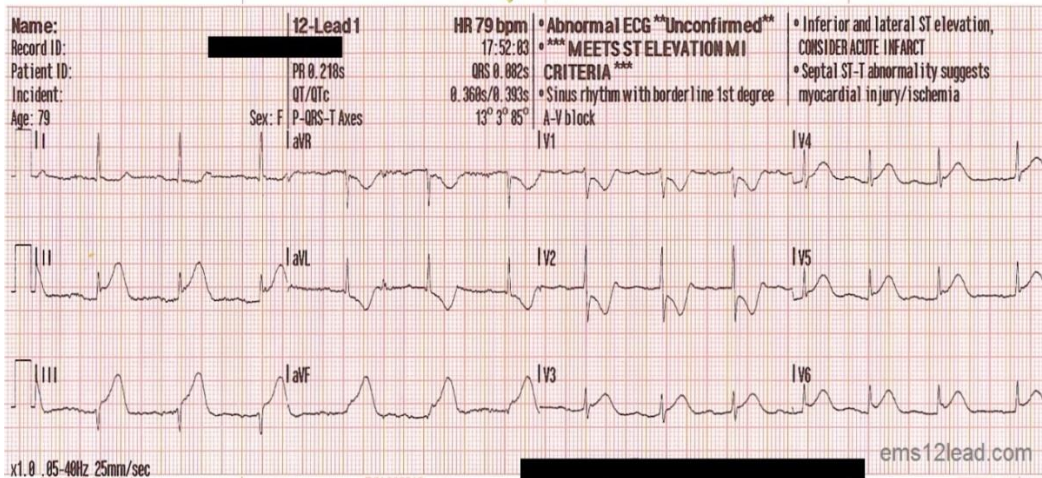


Figure 3.4 Left Ventricular Hypertrophy

Sr. No	Name of abnormality	Characteristic features
1	Dextrocardia	Inverted P-wave
2	Tachycardia	R-R interval < 0.6 s
3	Bradycardia	R-R interval > 1 s
4	Hyperkalemia	Tall T-wave and absence of P-wave
5	Myocardial	Ischaemia Inverted T-wave
6	Hypercalcaemia	QRS interval < 0.1 s
7	Sinoatrial block	Complete drop out of a cardiac cycle
8	Sudden cardiac death	Irregular ECG.

Table 2: Various diseases (abnormalities) of human being



CHAPTER 4: RETRIEVING OF VITAL PARAMETERS & REGENERATION OF ECG SIGNAL

4.1 METHODOLOGY

We use De-noise, Data acquisition & Signal Processing Toolboxes in Matlab for removing noise from ECG signal taken from an ECG machine. The ECG signal received from a machine in the MATLAB environment is shown in Fig. 4.1. This signal is further digitized using STEM function of MATLAB tool box. From the digitized version, one can read the vital parameters of ECG.

For simulation of ECG signal using MATLAB, we take heartbeat as 72, amplitude of P, R, Q, T waves as 25mV, 1.6mV, 0.025mV, 0.35mV respectively while the duration of P-R interval, S-T interval, P interval, QRS interval as 0.16s, 0.18s, 0.09s, 0.11s respectively. Instead of using these values, the retrieved parameters can be used as follows.

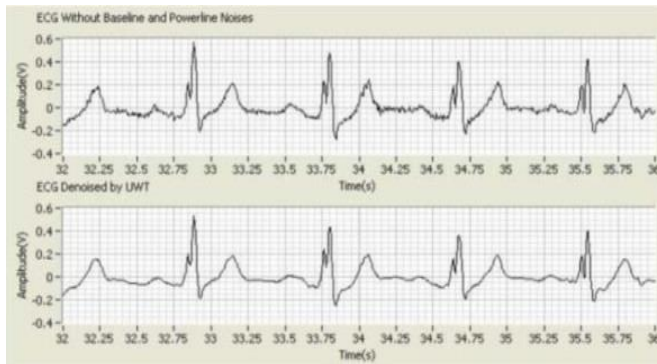


Figure 4.1 ECG wave taken from machine into MATLAB

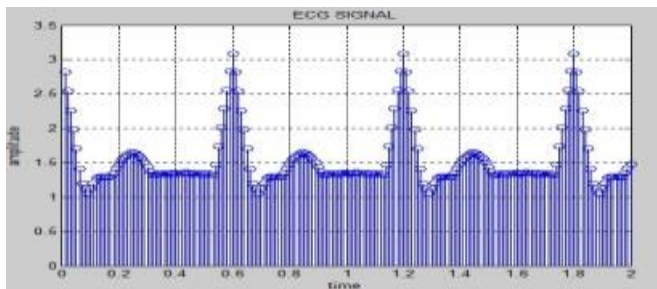


Figure 4.2.1 Discrete ECG wave in MATLAB

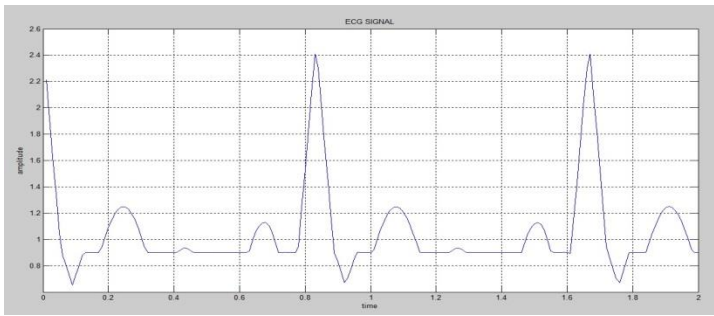


Figure 4.2.2 ECG waveform generated in MATLAB

4.2 ECG SIGNAL FROM MACHINE

Generally, the recorded ECG signal is often contaminated by noise and artifacts that can be within the frequency band of interest and manifest with similar characteristics as the ECG signal itself. In order to extract useful information from the noisy ECG signals, we need to process the raw ECG signals.

In MATLAB, the *Data Acquisition Toolbox* provides Simulink blocks for acquiring live data into Simulink models and for outputting live signals to the physical hardware, it uses the *Analog Input* block to acquire live analog data from a data acquisition device into Simulink. The acquired data is processed in Simulink and uses the Analog Output block to output data to an analog data acquisition device. The acquired ECG data by Simulink is shown in Fig. 4.3.



Fig4.3 This simulink Scope shows an acquired ECG signal with a sampling frequency of 1200 Hz

Removing Wideband Noise & Baseline Wandering

Baseline wandering usually comes from respiration at frequencies wandering between 0.15 and 0.3 Hz, and we can suppress it by a high pass digital filter. We also can use the Wavelet transforms to remove baseline wandering by eliminating the trend of ECG signal

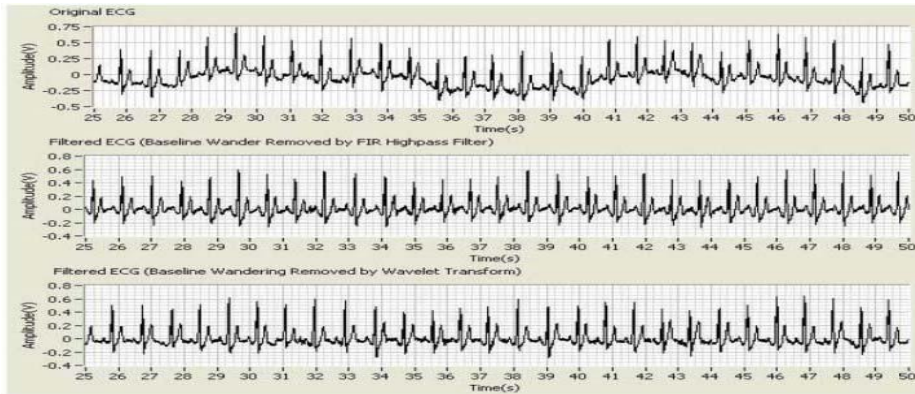


Fig.4.4 Comparing the digital filter-based and wavelet transform-based approaches

After we remove baseline wandering, the resulting ECG signal is more stationary and explicit than the original signal [10]. However, some other types of noise might still affect feature extraction of the ECG signal. The noise may be complex stochastic processes within a wideband, so you cannot remove them by using traditional digital filters. To remove the wideband noises, we can use the Wavelet De-noise Express VI. This Lab-VIEW based higher-level Express VI first decomposes the ECG signal into several sub-bands by applying the wavelet transform, and then modifies each wavelet coefficient by applying a threshold or shrinkage function, and finally reconstructs the de-noised signal. The following figure shows an example of applying the un-decimated wavelet transform (UWT) to the ECG signal.

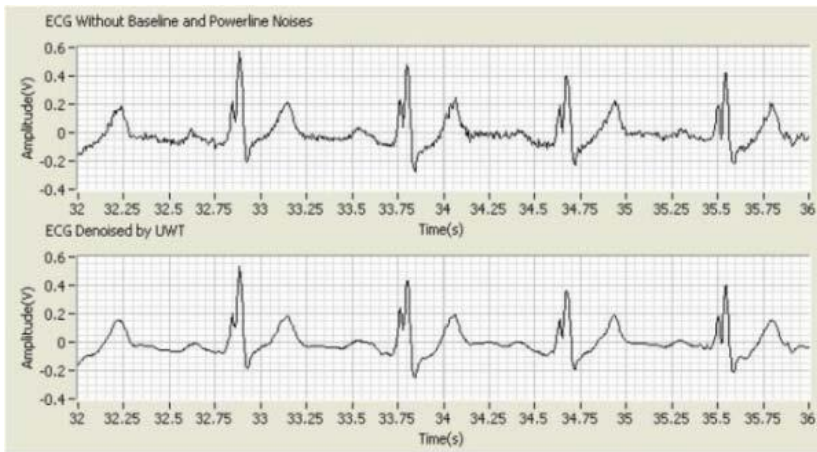


Fig.4.5 ECG signals before and after UWT de-noising

4.3 REGENERATION OF ECG SIGNAL

ECG Generated from its parameters

The normal value of heart beat lies in the range of 60 to 100 beats/minute. ECG Signal comprises various parameters such that by adding P, Q, QRS, S, T, U waves, we get the ECG signal. Figure (4.6-4.8) shows how the regeneration of ECG takes place. Similarly one the same graph we can plot another ECG wave with different parametric values.

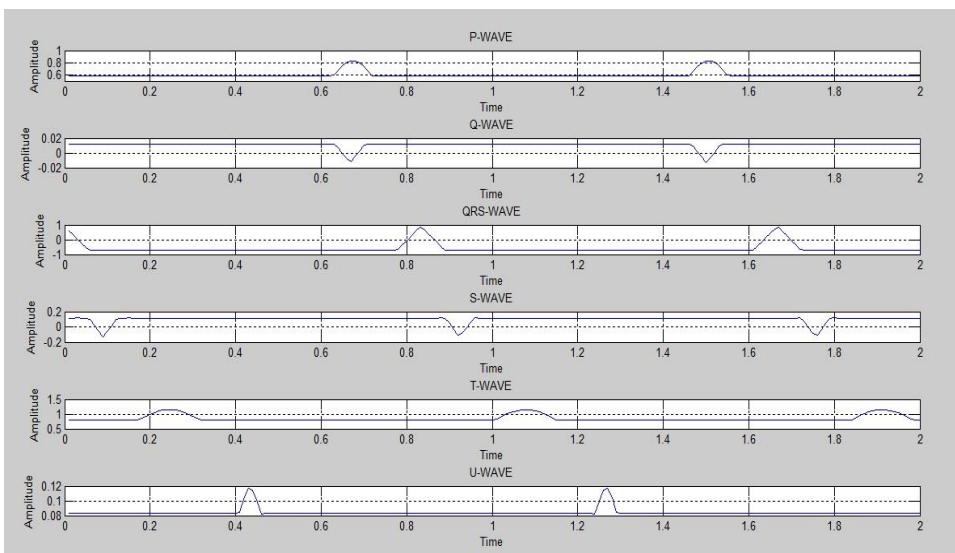


Fig.4.6 Generating P, Q, QRS, S, T, U waves separately

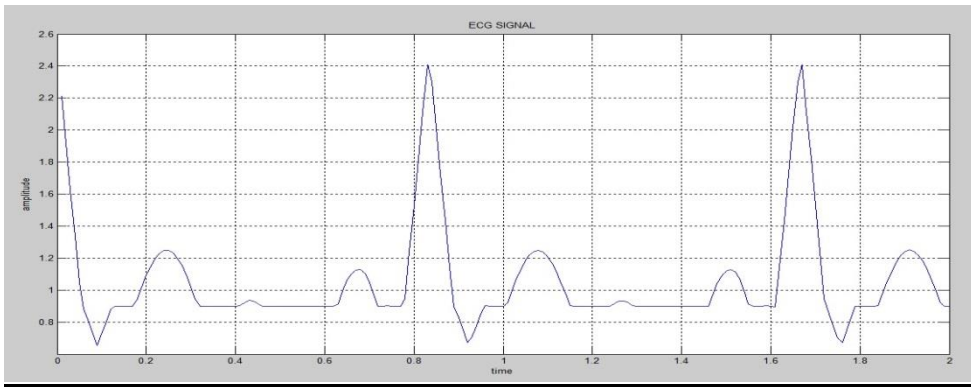


Fig.4.7 Generating ECG wave by adding those waves

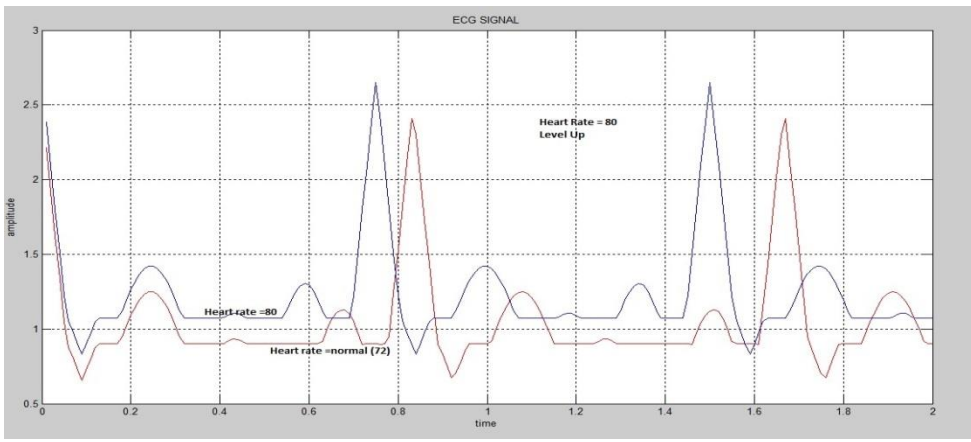


Fig.4.8 plotting of 2 different ECG waves

4.4 Comparison With Different Techniques

Though, the non-adaptive filtering is faster than the adaptive filtering methods but the adaptive filtering after tuning the taps to some optimum value gives the best results [11]. Adaptive filtering in some cases though amplified the S-peaks, but it does not give any serious distortion effects onto the signal. However, the wavelet approach is more convenient than the conventional filtering techniques, which highlights the details of the ECG signal with optimal time-frequency resolution. If we analyze the ECG signal by both conventional FFT and Wavelet transform, then we have found Wavelet is to be superior to the conventional FFT method in finding the small abnormalities in ECG signals. We use correlation functions which gives better accurate comparisons.



4.5 Auto- Correlation & Cross-Correlation

AUTOCORRELATION

it is the similarity between observations as a function of the time separation between them. It is a mathematical tool for finding repeating patterns, such as the presence of a periodic signal obscured by noise, or identifying the missing fundamental frequency in a signal implied by its harmonic frequencies. It is often used in signal processing for analyzing functions or series of values, such as time domain signals.

CROSS CORRELATION

Cross-correlation is a measure of similarity of two waveforms as a function of a time-lag applied to one of them. This is also known as a *sliding dot product* or *sliding inner-product*. It is commonly used for searching a long-signal for a shorter, known feature. It also has applications in pattern recognition, single particle analysis, electron tomographic averaging, cryptanalysis, and neurophysiology.

Calculations

- 1) Given a signal $f(t)$, the continuous autocorrelation $R_{ff}(\tau)$ is most often defined as the continuous cross-correlation integral of $f(t)$ with itself, at lag τ .

$$R_{ff}(\tau) = (f(t) * \bar{f}(-t))(\tau) = \int_{-\infty}^{\infty} f(t + \tau) \bar{f}(t) dt = \int_{-\infty}^{\infty} f(t) \bar{f}(t - \tau) dt$$

where \bar{f} represents the complex conjugate and $*$ represents convolution. For a real function, $\bar{f} = f$.

The discrete autocorrelation R at lag j for a discrete signal x_n is

$$R_{xx}(j) = \sum_n x_n \bar{x}_{n-j}$$



2) For continuous functions, f and g , the cross-correlation is defined as:

$$(f \star g)(t) \stackrel{\text{def}}{=} \int_{-\infty}^{\infty} f^*(\tau) g(t + \tau) d\tau,$$

where f^* denotes the complex conjugate of f .

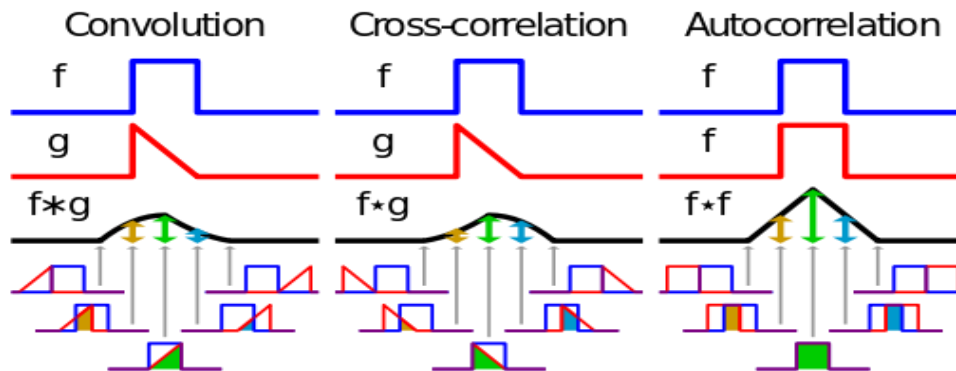


Fig.4.9 Relation between Convolution & Correlations

4.6 IMPULSE & STEP RESPONSES

IMPULSE RESPONSE

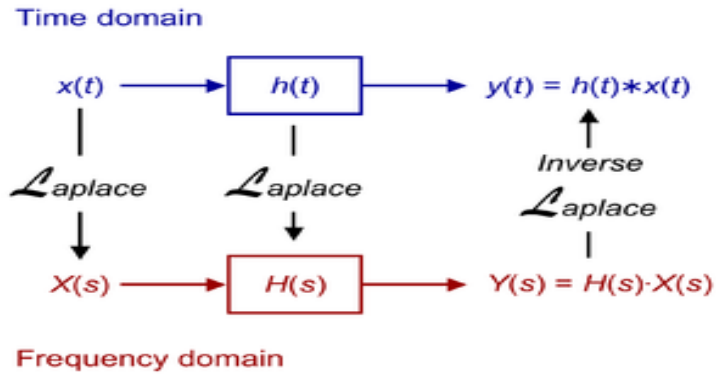
Impulse response, or **impulse response function (IRF)**, of a dynamic system is its output when presented with a brief input signal, called an impulse. More generally, an impulse response refers to the reaction of any dynamic system in response to some external change. In both cases, the impulse response describes the reaction of the system as a function of time (or possibly as a function of some other independent variable that parameterizes the dynamic behavior of the system).

STEP RESPONSE

The **step response** of a system in a given initial state consists of the time evolution of its outputs when its control inputs are Heaviside step functions. In electronic

GENERATION AND COMPARISON OF ECG SIGNAL USING MATLAB

engineering and control theory, step response is the time behavior of the outputs of a general system when its inputs change from zero to one in a very short time. The concept can be extended to the abstract mathematical notion of a dynamical system using an evolution parameter.



Here $h(t)$ is known as Unit impulse response if $x(t)$ is train of impulses & if $x(t)$ is Step Function then it is known as Unit Step Response.



CHAPTER 5: RESULTS & ANALYSIS

5.1 Analysis

Retrieval of vital parameters & Regeneration of ECG signal is explained. Before a reasonable and acceptable design is given, a general flow of ECG Tele-diagnosis service is analyzed and described as follows:

- An ECG machine should be authorized and communicate with the RDC successfully through network after being started.
- When a patient requiring a service of ECG examination have arrived at the care point, the patient demographic information (described as patient information below) is gathered. Then a collection of ECG trace is started. A complete ECG record including patient information, ECG waveform and automatic measurement information is created and represented in a standard format supported by the ECG information system (EIS) in the RDC.
- ECG record is transmitted to RDC for storage and accessibility. RDC should register the patient and archive the ECG record. (Figure 5.1 shows an overall description of the flow)



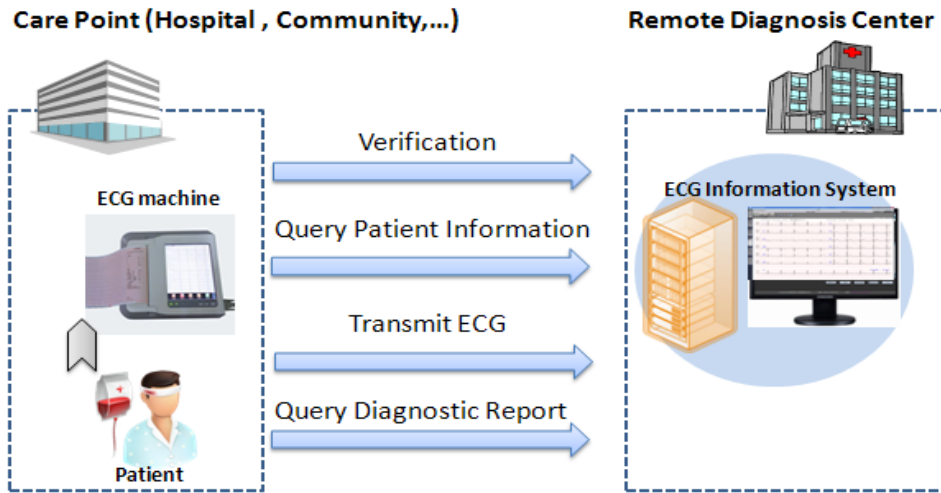


Figure 5.1 Flow of ECG Tele-diagnosis

5.2 Model Design

Based on the above analysis and the key objectives emphasized in last section, several interactive transactions required, namely Verification, Query Patient Information, Transmit ECG, and Query Diagnostic Report, are defined.

5.2.1 Different Waveforms

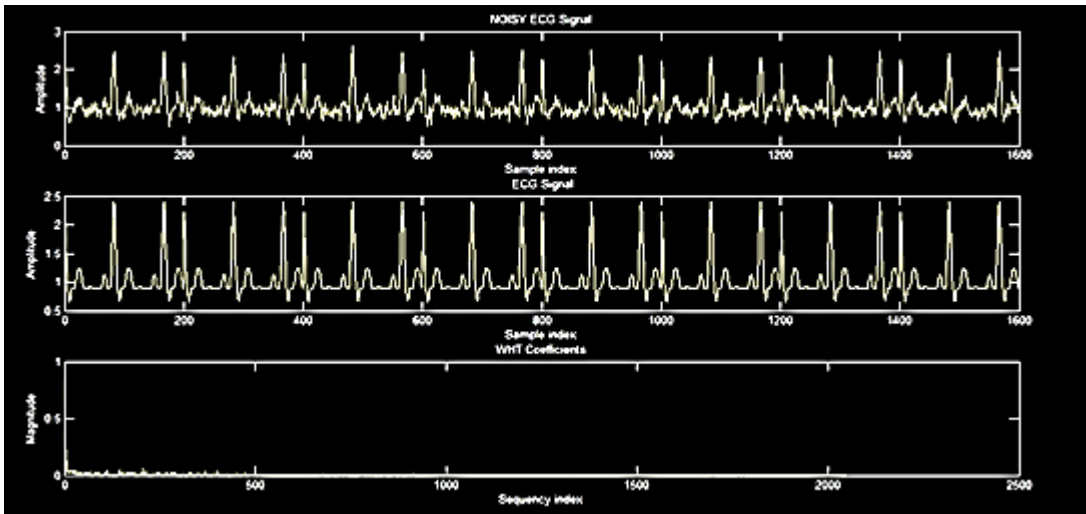


Fig. 5.2 Typical ECG Waveforms with noise & without noise

The discrete values of P, Q, QRS, S, T, and U are retrieved from the digitized ECG signal as shown in Figure 5.3

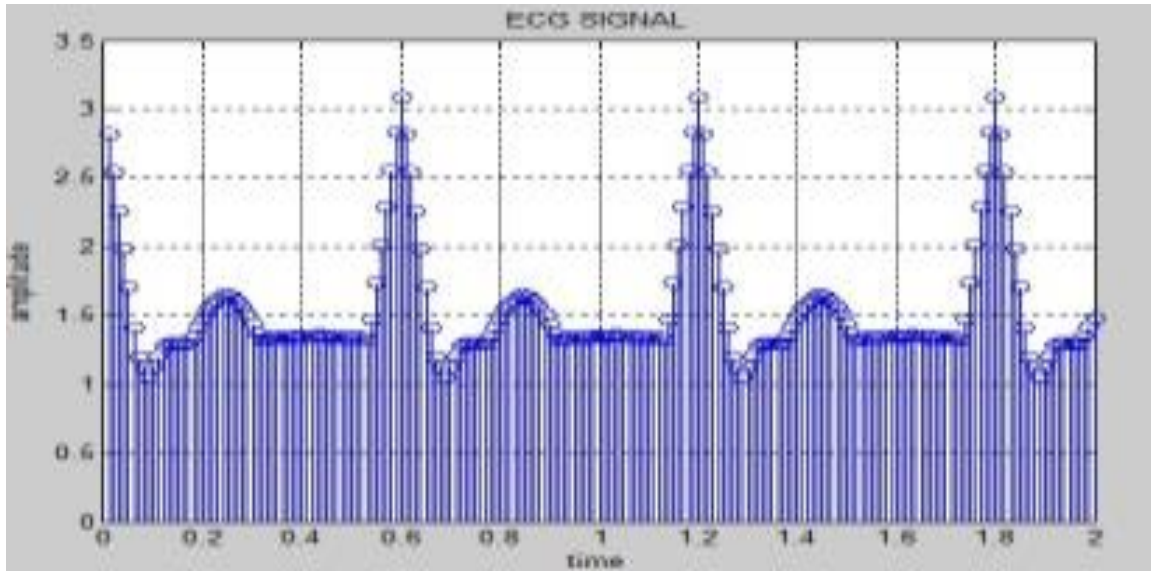


Fig.5.3 Converting analogue ECG into Discrete Domain

Using these values, ECG signal is simulated. Different screenshots of MATLAB has been shown below in figures (5.4- 5.6).

GENERATION AND COMPARISON OF ECG SIGNAL USING MATLAB



Fig.5.4 Entering the input values for 1st ECG signal

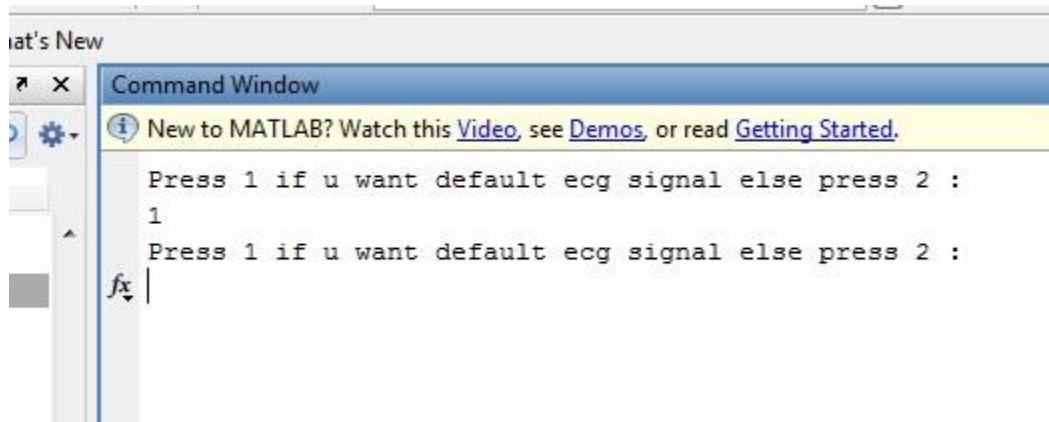


Fig.5.5 Entering the input values for 2nd ECG signal

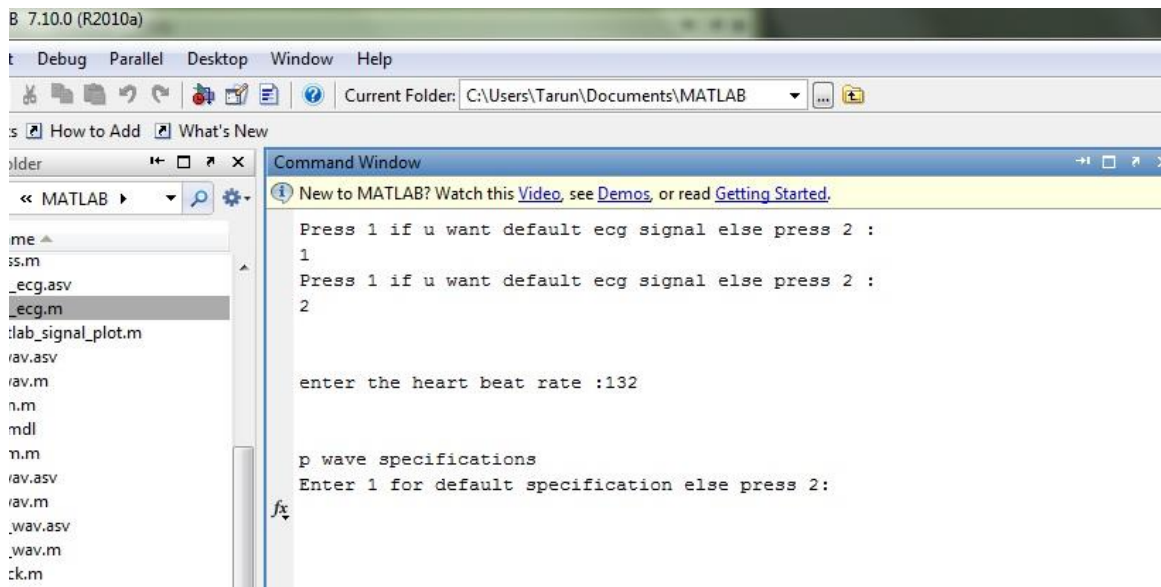
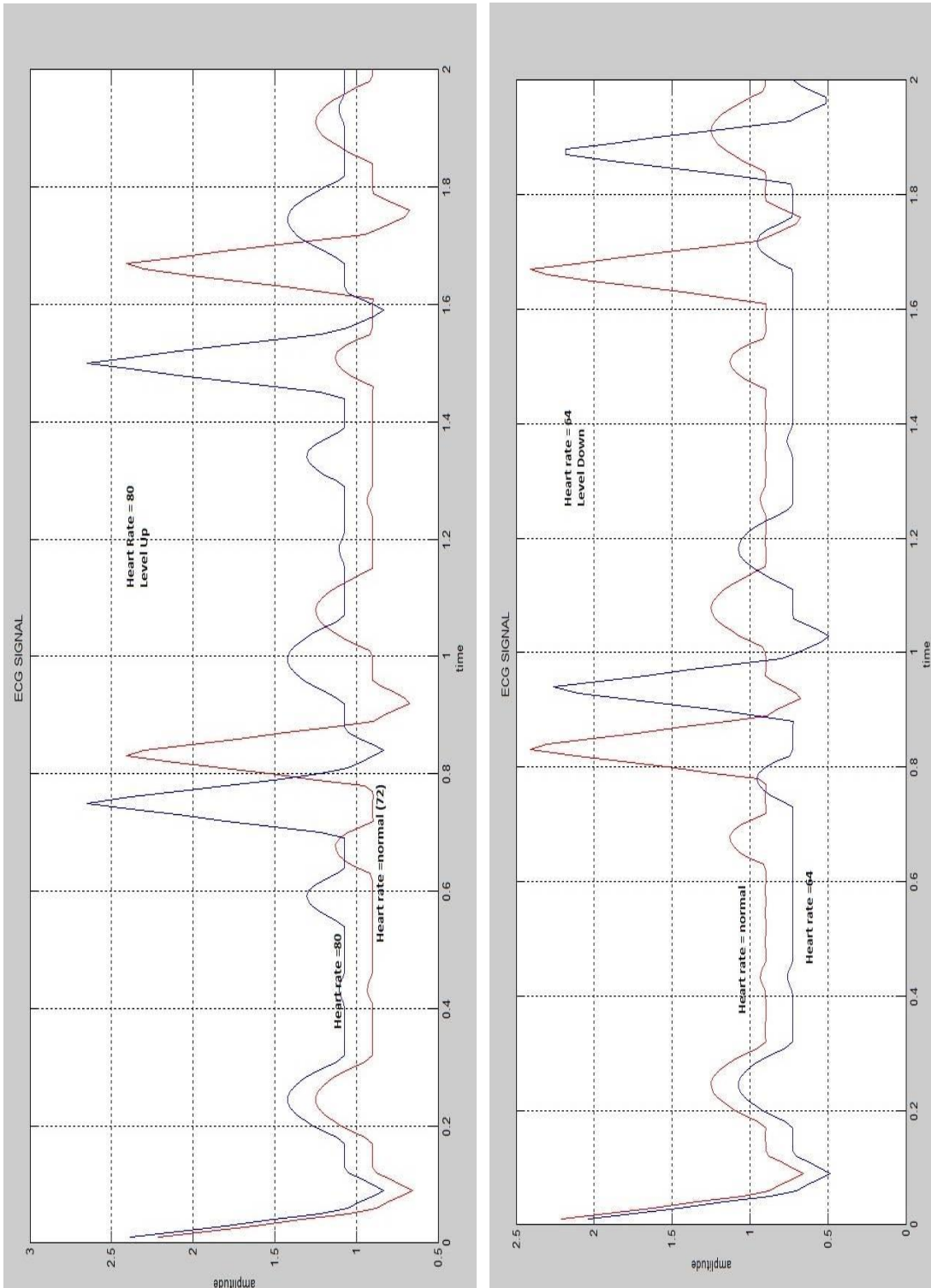


Fig.5.6 Entering the input values for 2nd ECG signal with different input values of vital parameter



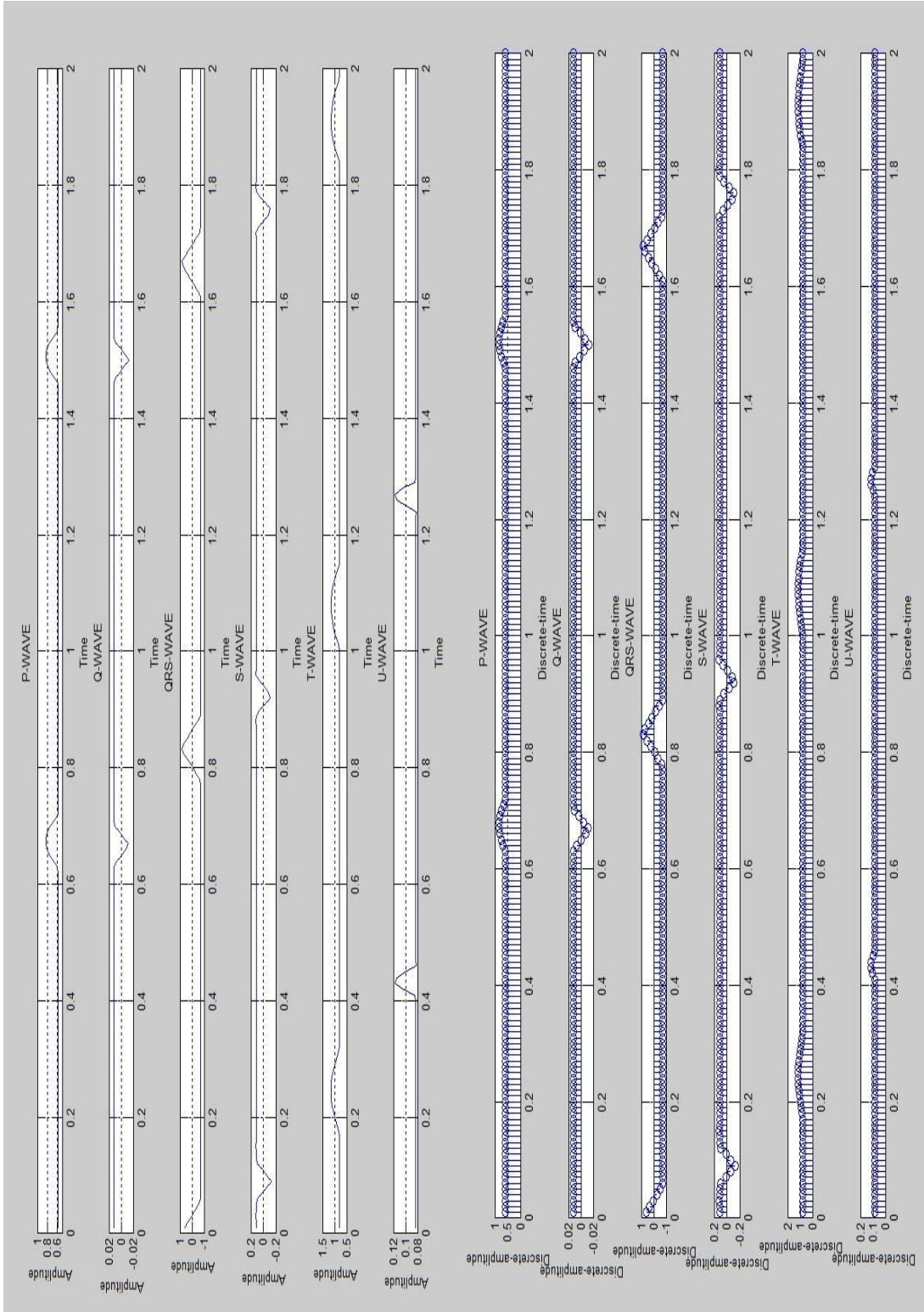
ECG WAVEFORM BY VARYING HEART RATE BEAT



When heart rate increases → level up (DC level of wave increases upwards)

When heart rate decreases → level down (DC level of wave increases downwards)

CONTINUOUS & DISCRETE FORMS OF VARIOUS PARAMETRES OF ECG WAVE

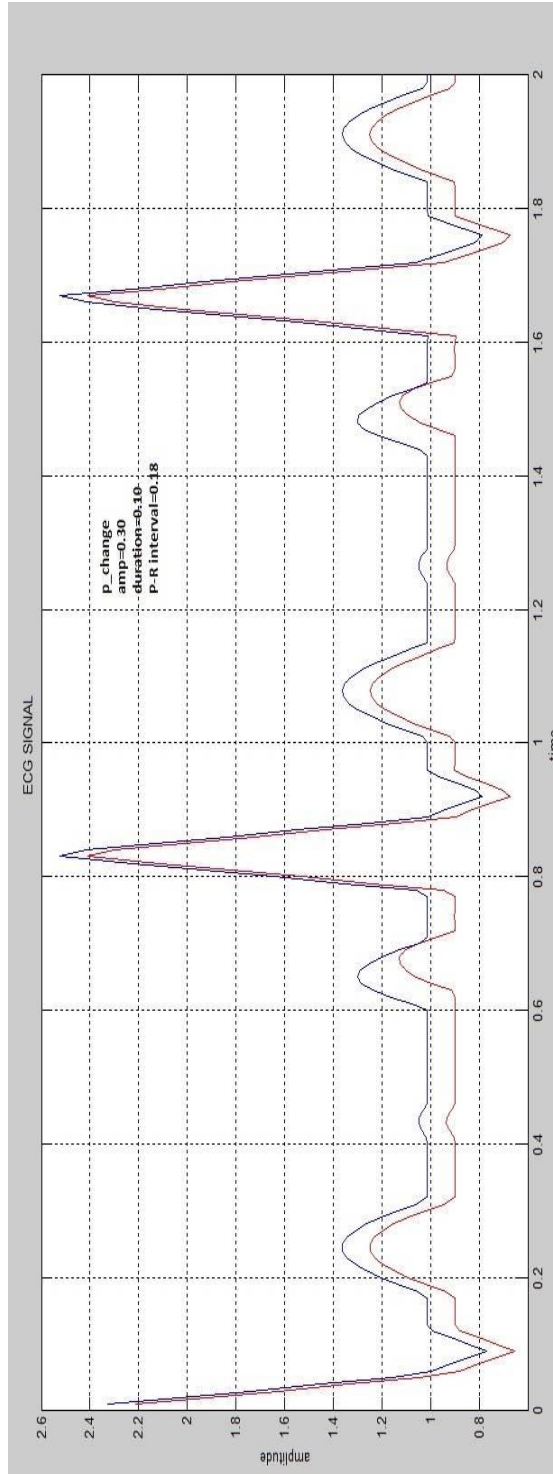
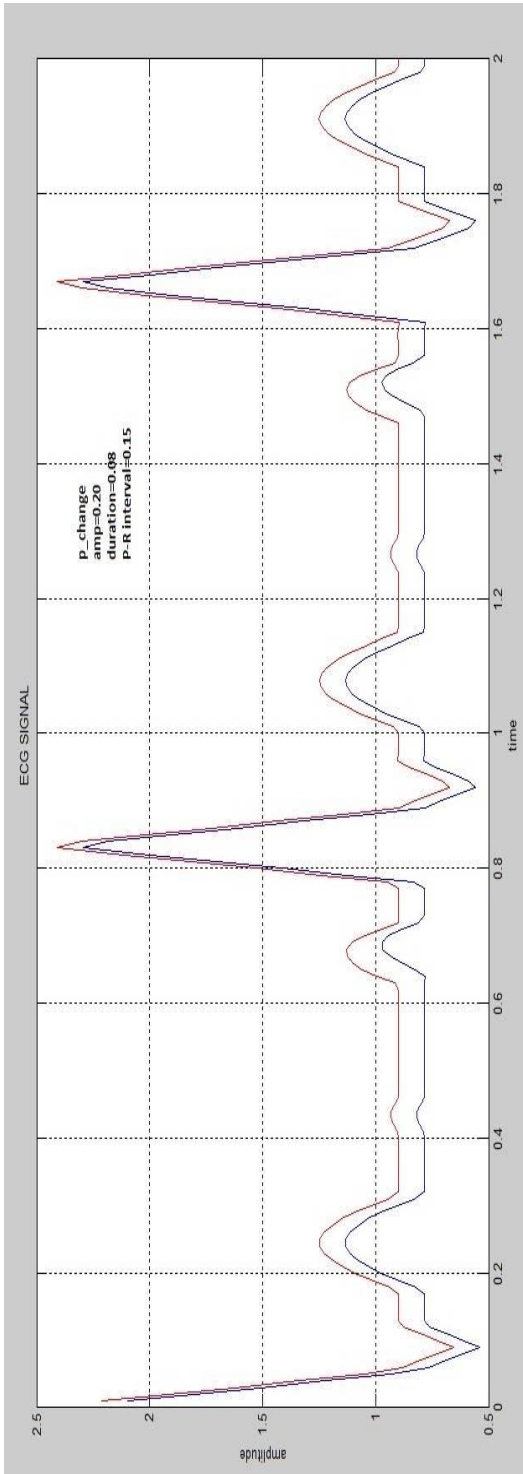


Using stem(x,y) function in Matlab we calculate Discrete co-efficients of parameters



STUDYING THE VARIOUS CO-EFFICIENTS OF THOSE VARIOUS WAVES

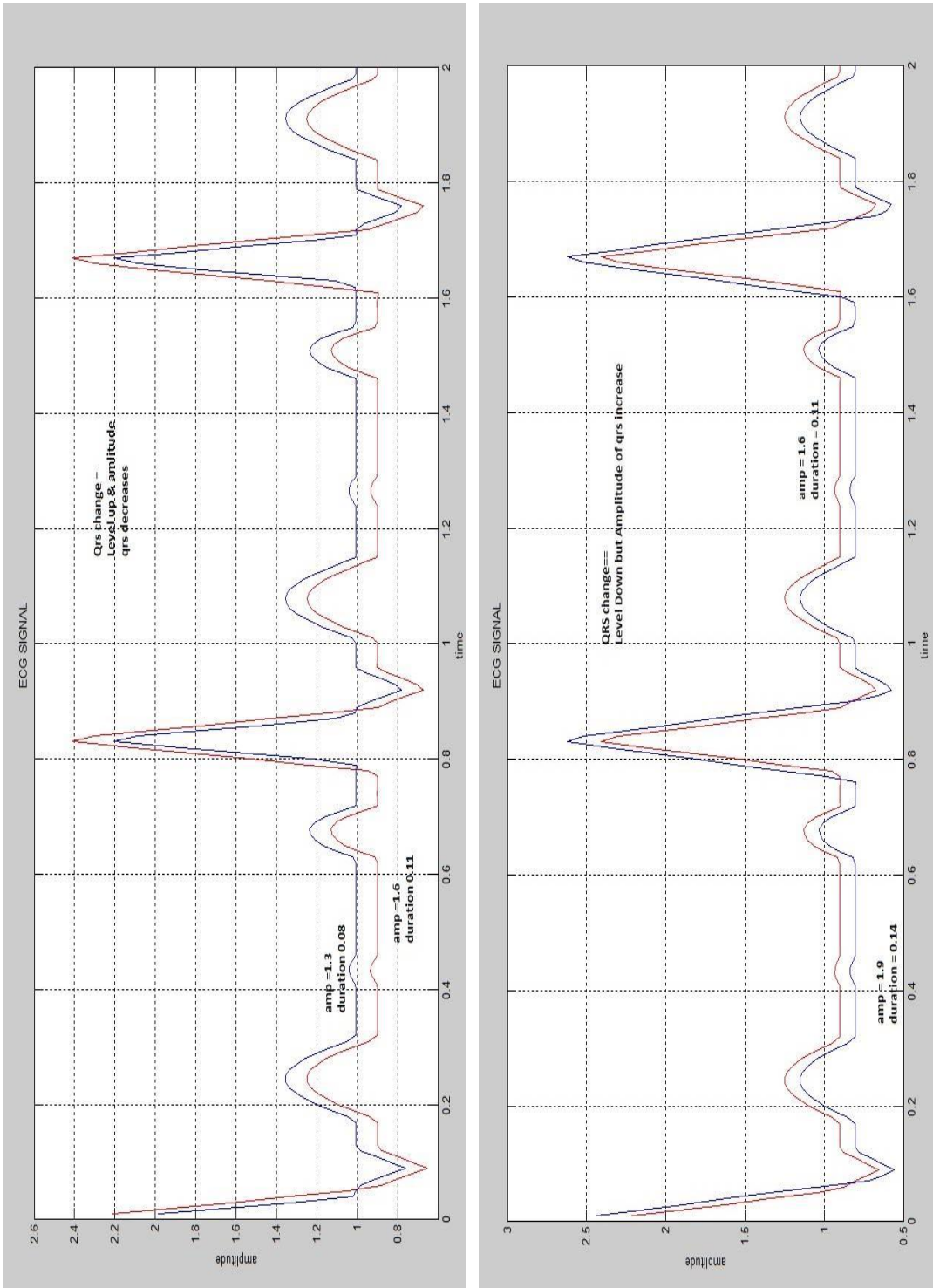
P-Wave change



According to change in the value of p-parameter we have this type of curve of ECG



QRS Wave Change

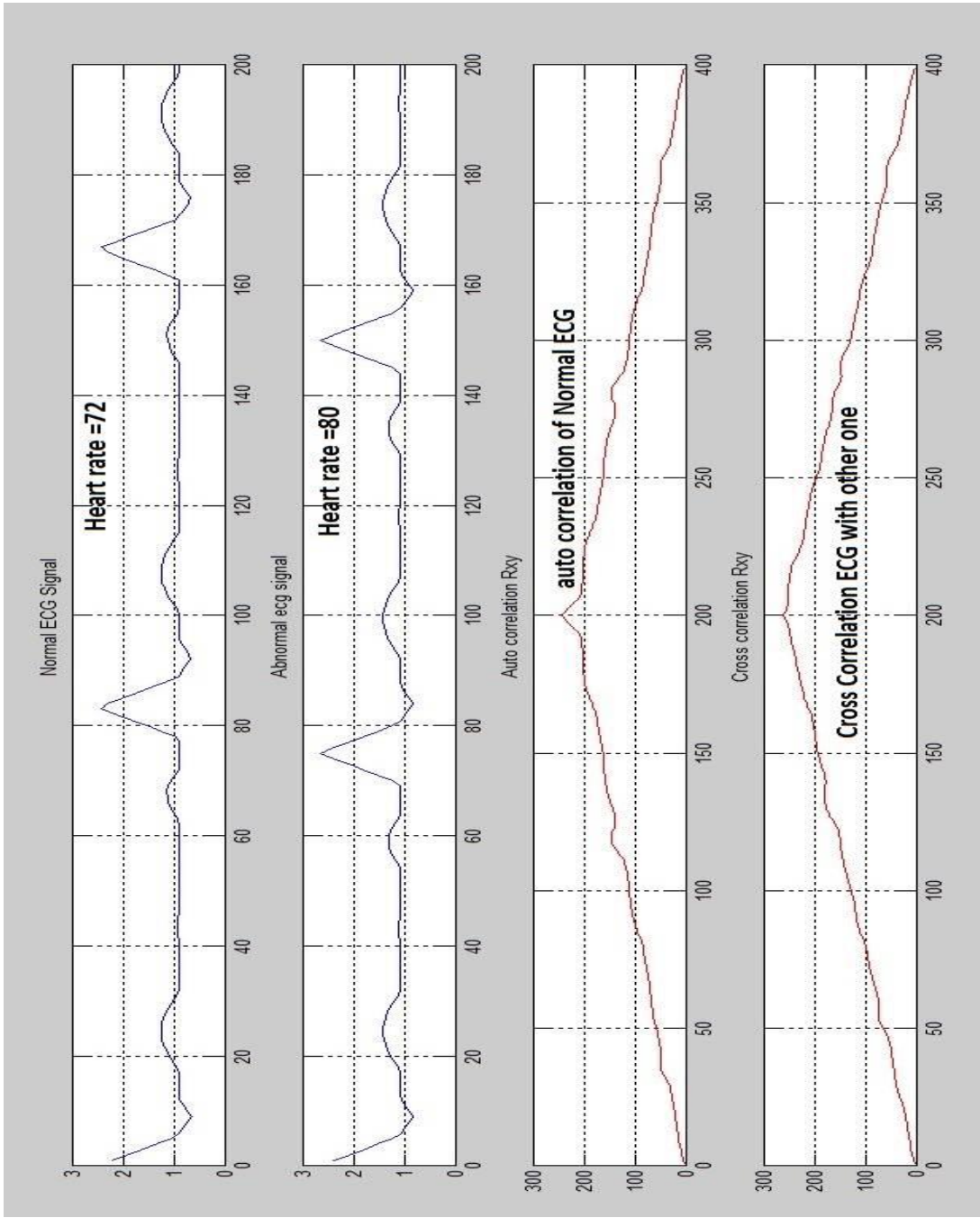


According to change in the value of p-parameter we have this type of curve of ECG

Here it has been noticed that the dc level of ecg was changed.



Auto & Cross-Correlation

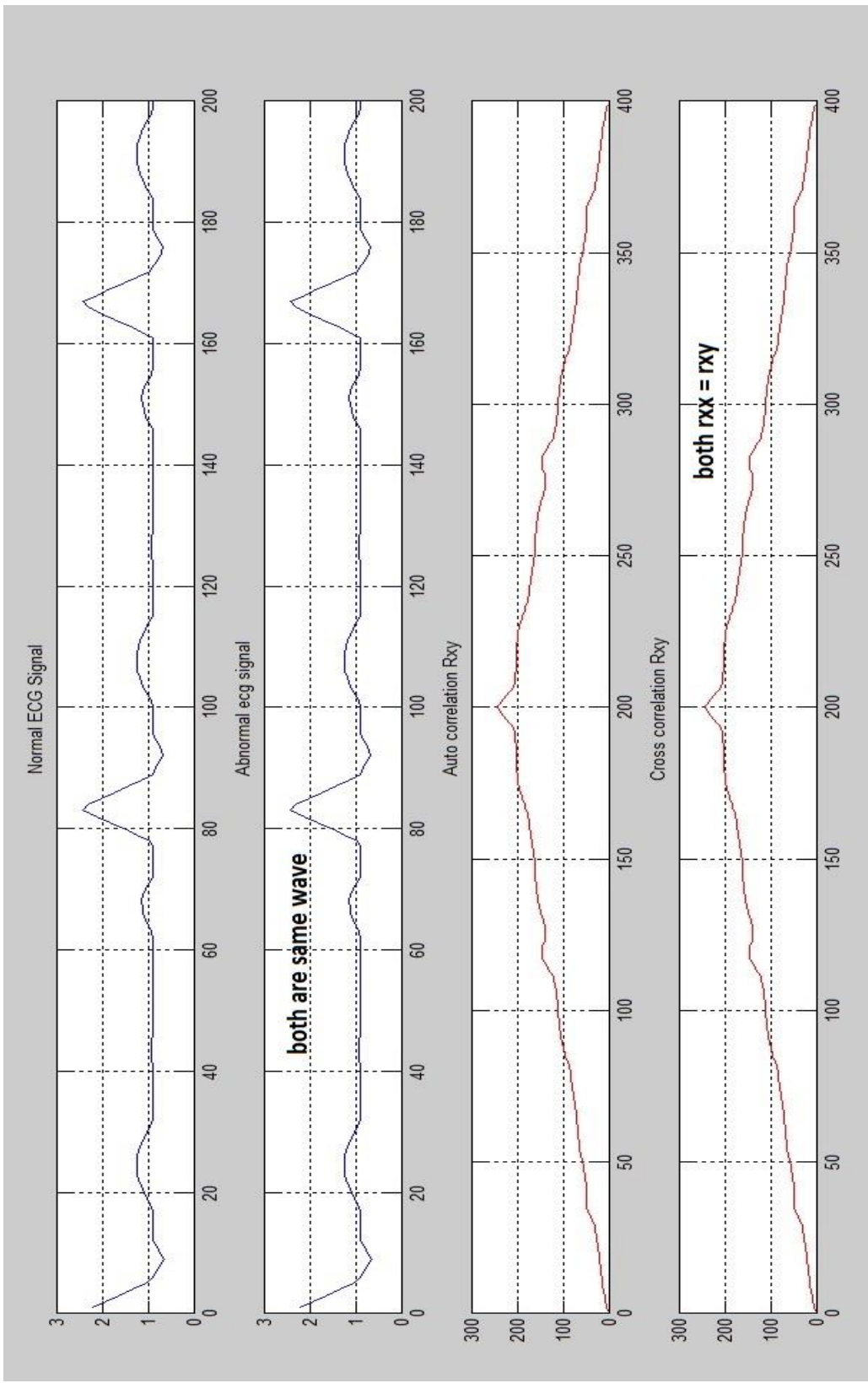


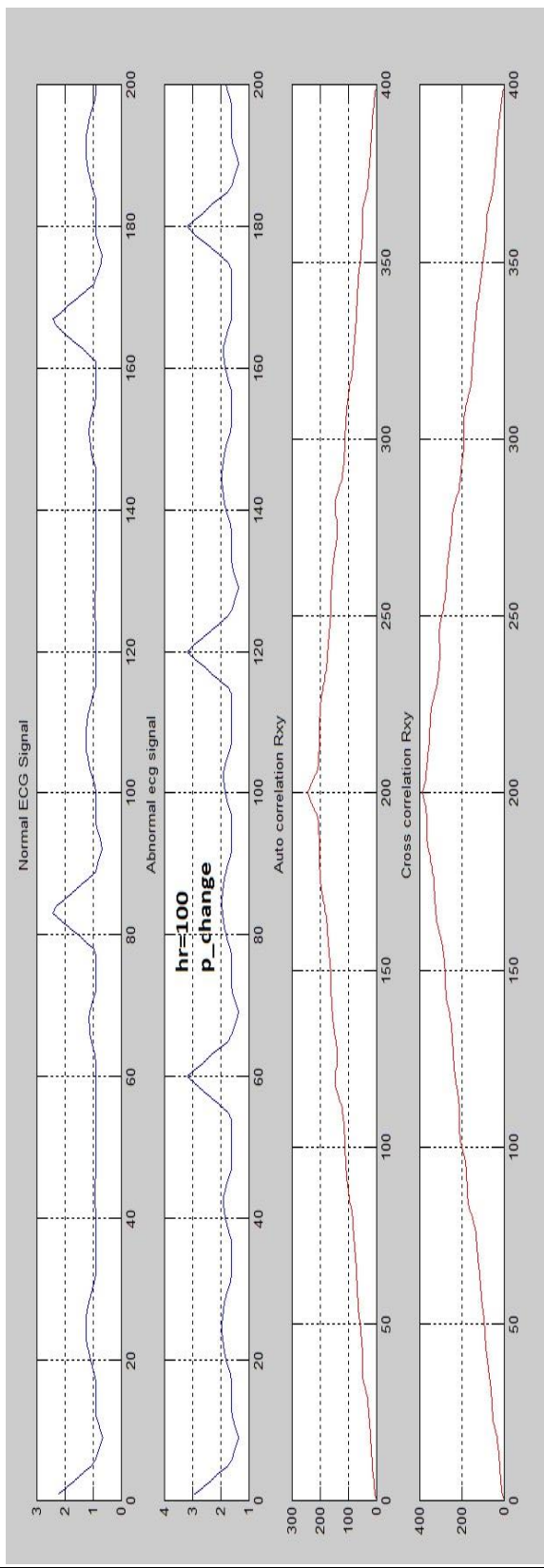
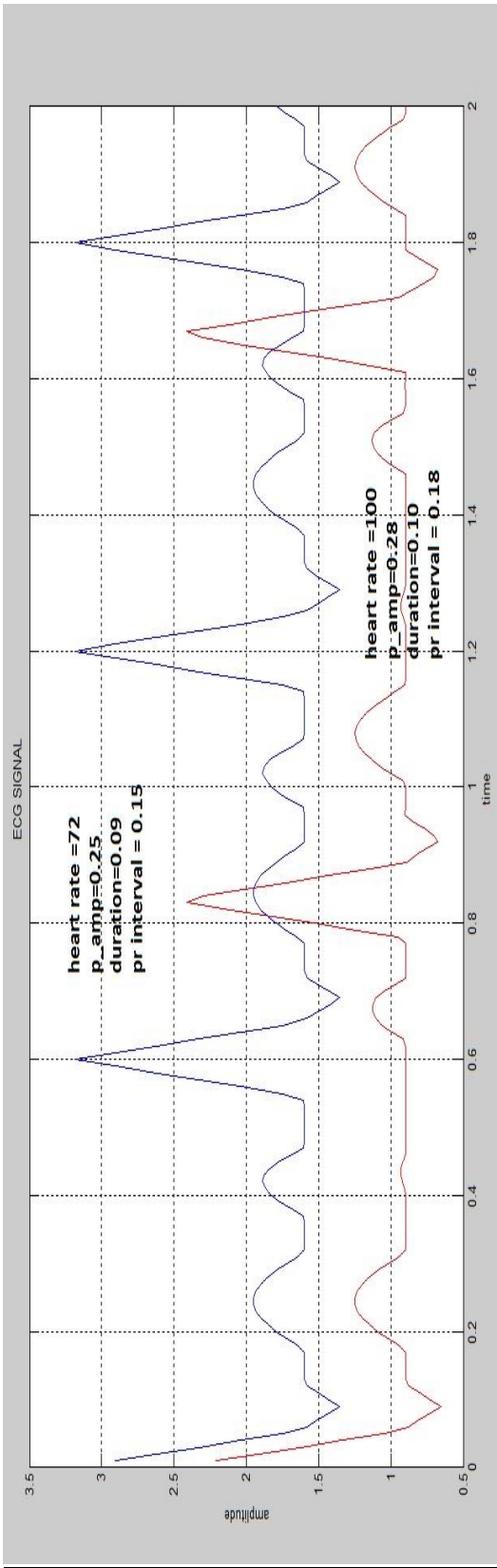
Here, The tolerable limit is 10% when compare to above result of co-relations.

Here, By Comparing Auto & cross-Correlation within the limits of 0-100 & 300-400 on time axis we conclude any one of the disease that belong to the serial no(s) 1-3 of table no 1. While 150-250 shows the disease of serial no 6 of the table.

While the remaining portion shows the rest of the abnormalities showed in table 2.

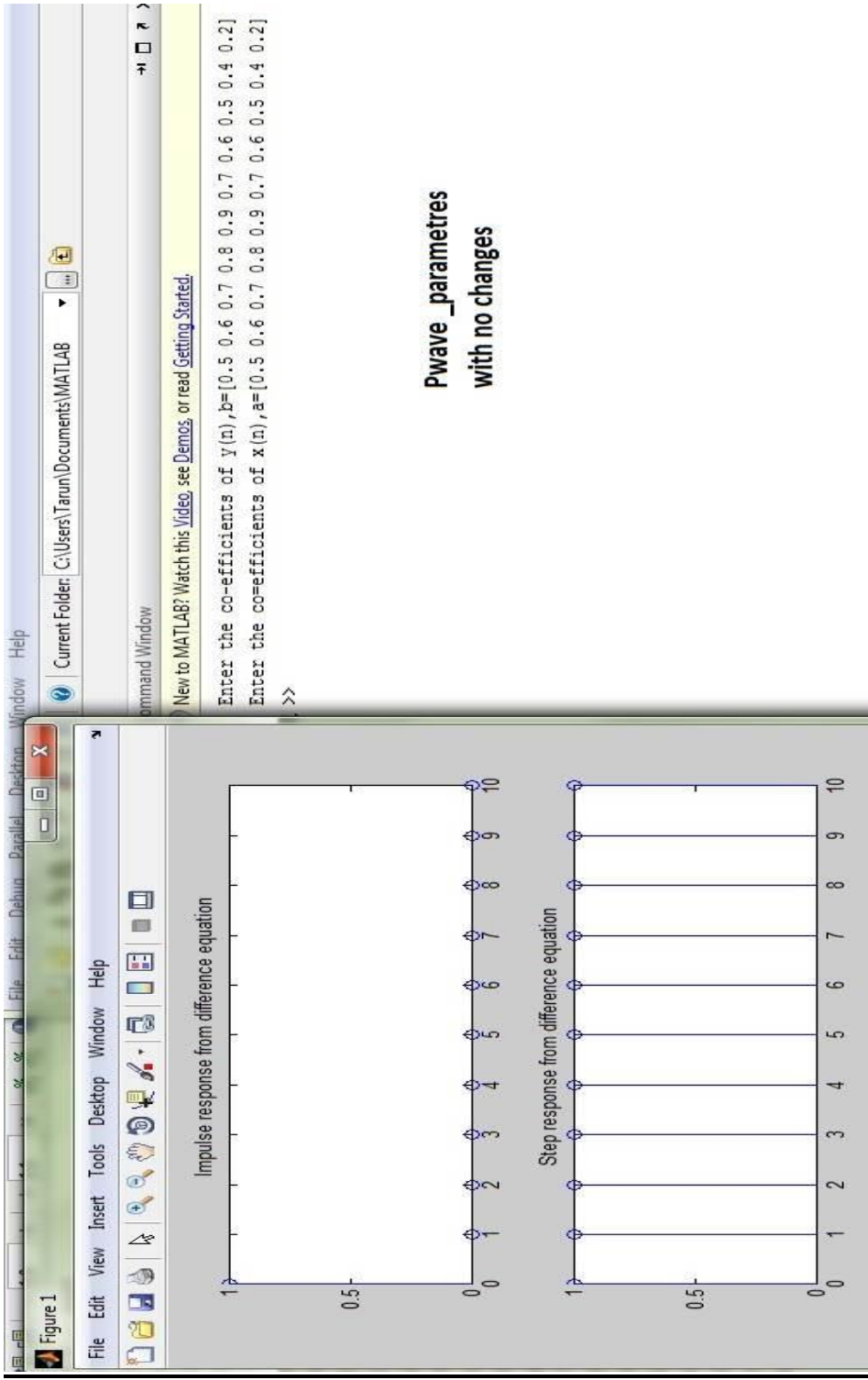


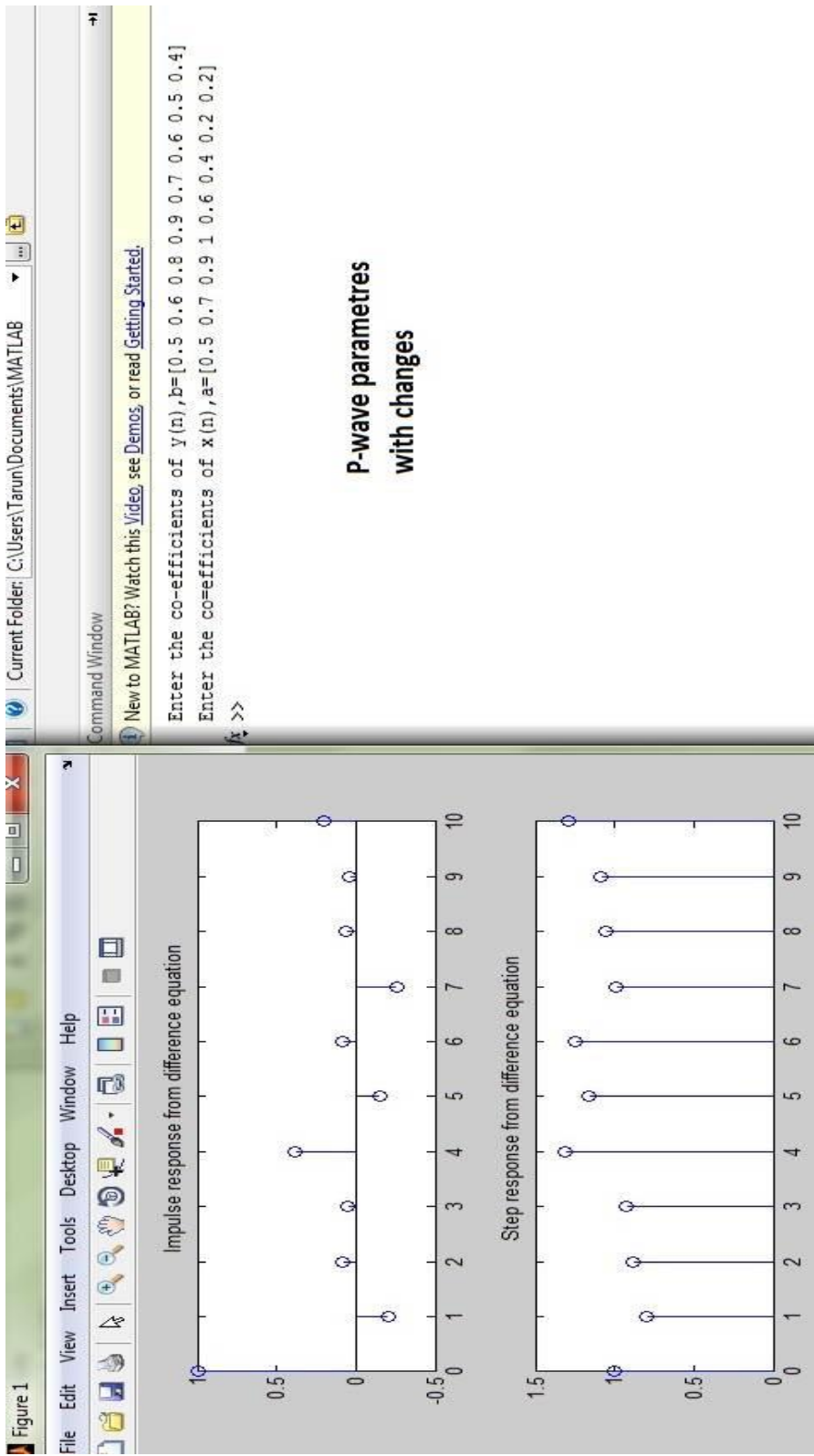




STEP RESPONSES OF THE CO-EFFICIENTS

If we need more clarity about the abnormalities we do those comparison through Impulse & step Responses where the point to point comparison of those vital parameters takes place.

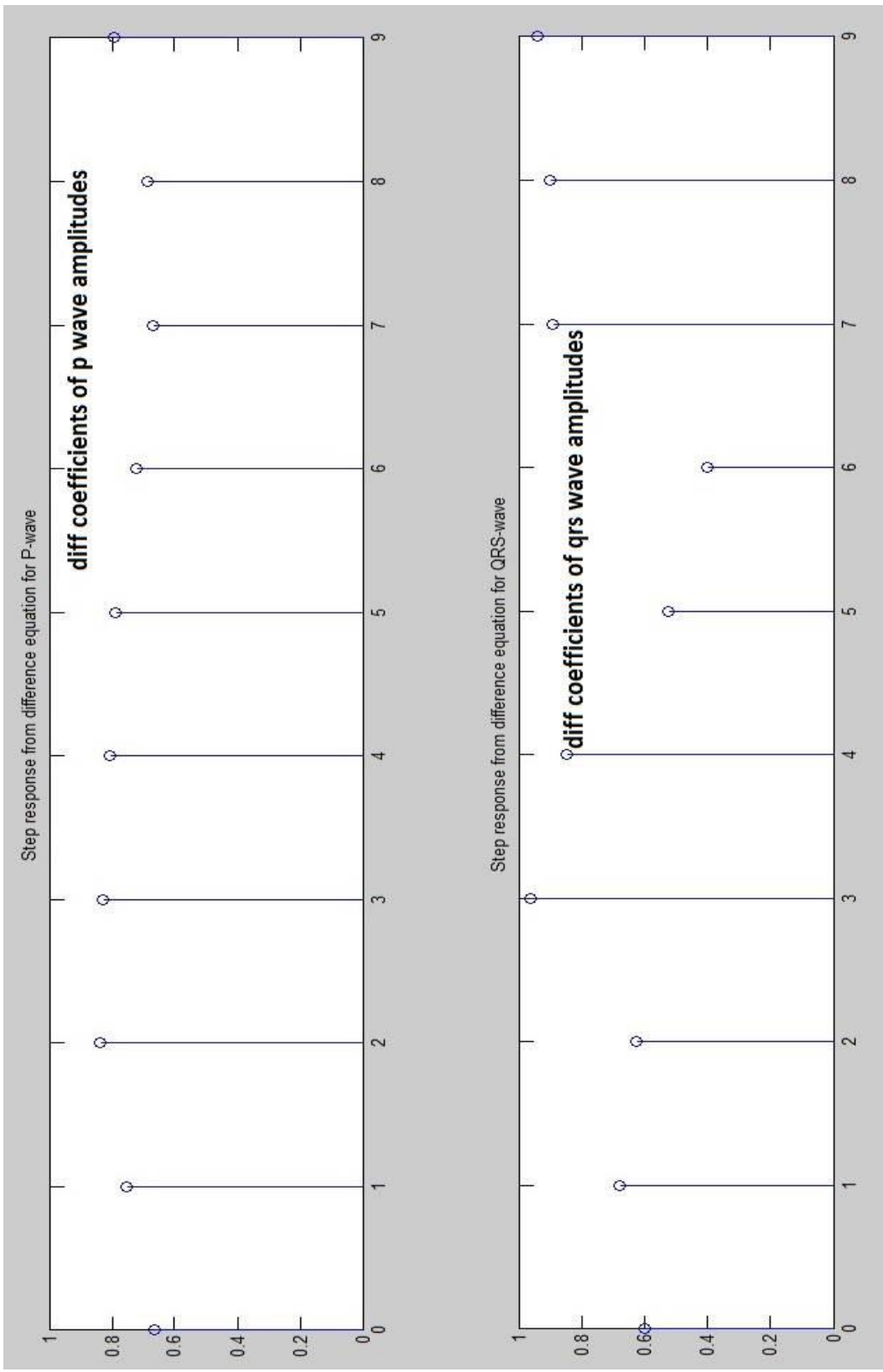




P-wave parametres with changes

Responses @ different Co-efficient(s) of regenerated ECG





These are the ratio of co-efficient(s) of normal & user defined regenerated ECG



CHAPTER 6: SUMMARY & CONCLUSION

6.1 SUMMARY & CONCLUSION

- The Regeneration of ECG has successfully done using MATLAB Environment by using different parameters of ECG Waveform & we successfully examined the various heart diseases by studying those parameters.
- We successfully studied Auto- correlation & Cross-correlation (also impulse & step responses) for comparison of the normal & abnormal ECG.
- The permissible limit for auto correlation and cross-correlation are given in the result section give a group of abnormalities shown in that table which shows how critical the waveform is.
- Step response & Impulse response is further studied for deep analysis of the individual abnormalities rather than group of abnormalities.



6.2 FUTURE SCOPE

- We can say that if we convert ECG signal from analog signal value into digital bits by some algorithm based on ADC's, then it is easier to check the coded bits
- If we have a code that represents a Normal ECG signal then we can compare it with that code which would be generated using different values of the ECG parameters.
- It is easier to compare or check the Bit Error & we can easily conclude that if an error occurs in a particular bit that will show which type of disease related with human being.
- We can assume a bit code for a certain fixed level of an analog signal value & such that if signal alters its position with respect to the threshold value the bits would changes.
- The digital domain would be having best results & those results would much better than previous one as sending/ receiving Bits is very easy rather than sending the values of the different parameters of any signal.



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