

## Remote ECG Signal Monitoring Via Internet

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### Abstract

In this paper the Internet was used as a media for transmission an ECG (Electro-Cardio-gram) signal from a patient directly to a remotely reside doctor or consultant who will respond via the same media directly. The ECG signal (at patient side) has been compressed in a manner to achieve low bandwidth requirement by using Matlab capabilities. Also, at consultant side the original signal is reconstructed using the same capabilities of Matlab. The Internet works as the center of communication between the two sides. A database was used to store the patient information which can be handled easily by consultant. Respecting the internet no more than a simple rented web site was required as a file storage shared between the consultant and patient. The results show that the received signal at the doctor side after reconstruction had the complete and compatible to the signal used for diagnosis.

**Keywords:** ECG Monitoring , Via Internet, FTP

### مراقبة اشارة نبضات القلب عبر الانترنت

#### الخلاصة

في هذه البحث ، إستعملت شبكة الإنترنت كوسيلة لإرسال إشارة (إي سي جي) من المريض مباشرة إلى الطبيب أو الاستشاري عن بُعد والذي سيرد عن طريق نفس المنظومة مباشرة. صُغِّتْ إشارة ال (إي سي جي) في جانب المريض بأسلوب للحصول على متطلب ذو المجال المنخفض بإستعمال قابليات الـ Matlab ، أيضاً في جانب الطبيب أو الاستشاري فان الإشارة الأصلية سيعاد بناءها باستخدام نفس قابليات Matlab. الإنترنت تعمل كمرکز الإتصال بين الجانبين. هنالك قاعدة بيانات قد انشأت لخرن معلومات المريض والتي من الممكن الوصول اليها بسهولة من قبل الاستشاري. كذلك بالنسبة الى الانترنت لم نحتاج الى اكثر من موقع بسيط تم استأجاره ليعمل كواسطة لخرن الملفات ويتم استخدامه من قبل الاستشاري والمريض. أظهرت النتائج بان الإشارة المستلمة من قبل الطبيب كاملة المواصفات بعد اعادة بنائها ومطابقة للإشارة المرسله لاستخدامها للاغراض التشخيصية

### 1. Introduction

Recently, many systems has been developed or proposed using the Internet as a backbone for communication, because of it's availability over local and wide area. There are several published literature and papers about advanced remote monitoring, Kathy J. Liszka, et al.[1] in 2004 described a real time remote arrhythmia monitoring system developed at NASA collects ECG

signals from mobile or homebound patients, combines GPS ( Global Positioning System) location data, and transmits both to a remote station for display and monitoring. Fensli, R, et al.[2] in 2005 published a paper about New wireless technology for Tele-home-care , that gives new possibilities for monitoring of vital parameters with wearable biomedical sensors, and give the patient the freedom to be mobile and

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still be under monitoring. Mohammed Al-Rousan, et. al. [3] in 2006 published an article presents a remote healthcare patient monitoring system, called Virtual Eye (VI) that utilizes the world wide web infrastructure to monitor, collect, analyses and record patients health status. M. Blount, et. al.[4] in 2007 described a Personal Care Connects (PCC), that had been designed to facilitate the remote monitoring of patients. Malcolm Clark, et. Al.[5] in 2007 published a paper which describes the impact of a Remote Patient Monitoring (RPM), the system allows vital signs to be transmitted to a central server, the medical professional may then observe the data and provide advice to the staff on optimum management.. Most of the previous works has been severed from the problem which is its need for a public IP address. In this research we investigated the ability to reduce the complexity required, and hence reducing the cost, to acquire and transmit the ECG signal via Internet. In general there are two parts in the project accompanying this research, first one is the design and implementation of simple Holter device benefited from the digital processing provided by MATLAB software like( acquisition, filtering, compression, etc.) . The second one is the web part which is required for communicating the ECG signal via Internet, This part also being simple and not expansive due to using the FTP( file transfer protocol) which is provided simply by the server which hosts the rented web site. Comparing to other methods which are expensive because of using host with public IP or Virtual private Network(VPN).

In this research, the need of a public IP address is not necessary, since only a public Internet server is used. This will make the system very easy to implement any where without requiring a special server with public IP.

Moreover, the implementation of such a system can be regarded low cost compared to others like those in [6,7].

## 2 .The Overall Proposed System Description

The proposed system consists of three parts which are:-

- a. The patient part.
- b. The consultant part.
- c. The Internet server part.

These three parts are communicated with each other through the Internet as a transmission media. Figure (1) shows these parts.

### 2.1 Patient Part

In this part the Microsoft Internet Explorer (IE) acts as the user interface through which the patient can communicate to both the Internet server and the Matlab software, The connection to Matlab software is done through the automation server commands available in VBscript [8] .

#### i) ECG circuit .

This circuit consists an instrument amplifier (IA-AD524) then its output signal enters two first order high pass filters the first one cutoff frequency is at 0.05 Hz and the second at 0.5 Hz. The right leg technique is used in this circuit to reduce the noise, where the negative source (-9) volts is connected to the right led of the patient through 44K $\Omega$  resistance, after passing through a buffer that is designed with OP-741.

#### ii) Matlab software at the patient part .

The Matlab script file, which consists many Matlab functions, is used to get the patient ECG signal then processes this signal to produce the polynomial coefficient which is then stored in a file to be transmitted to Internet server, the whole process can

be shown in figure (2), and a summary of them is given bellow:-

1. Signal enters to PC from microphone of sound card, using microphone jack .
2. Use Matlab to get the signal & convert it to vector, By using the following Matlab commands:

```
AI = aloginput('winsound');
start(AI)
trigger(AI)
data = getdata(AI);
```

Process the converted signal with SW notch filter, the notch filter is a second-order (IIR) filter designed to suppress the 50Hz interference this filter has a notch frequency of 50Hz and -3dB width 10Hz, the transfer function of this filter is:-

$$h(z) = \frac{1 - 1.618z^{-1} + z^{-2}}{1 - 1.516z^{-1} + 0.873z^{-2}} \dots\dots 1$$

The reference equation of this filter has been implemented using matlab software .

3. Process the output signal from the previous step with software (SW) digital Butterworth filter in 4 steps two for low pass filter and two for high pass filter , The low pass filter has cutoff frequency at 50Hz and has the following transfer function:-

$$h(z) = \frac{0.0675(1 + 2z^{-1} + z^{-2})}{1 - 1.143z^{-1} + 0.413z^{-2}} \dots 2$$

The high pass filter has cutoff frequency at 0.5Hz and has the following transfer function:-

$$h(z) = \frac{0.956(1 - 2z^{-1} + z^{-2})}{1 - 1.9z^{-1} + 0.915z^{-2}} \dots 3$$

-It is essentially designed for file transferring.

## 2.2 Consultant part

- i) In this part the Microsoft Internet Explorer (IE) is also used as the interface between the consultant and both the Internet server and the Matlab software. The Matlab software is installed in both the patient and consultant clients. The interaction between the (IE) and Matlab is done

These filters were implemented using Matlab software.

4. Recognize if the abnormality has occurred, Since there are standard measurements for ECG signal that determine the correct interval and amplitude.
5. Treat the resulting signal mathematically to get polynomial equation, calculate the coefficients of the polynomial equation for each 40 elements of the ECG data vector by using the matlab command (polyfit), The polynomial generated is a 6<sup>th</sup> order has the following form:-

$$p_6 x^6 + p_5 x^5 + p_4 x^4 + p_3 x^3 + p_2 x^2 + p_1 x^1 + p_0 \dots\dots\dots 4$$

### iii) Connecting Patient's part to Internet Server.

The patient part communicates with the Internet server using HTTP(Hyper Text Transport Protocols) protocol used by the Internet Explorer( IE) to get the patient page, but the compressed ECG data will be transferred to the Internet server using FTP (File Transfer Protocol), which has the following advantages:-

- It is fast than HTTP in this type of applications.
- It is a secure protocol by using authentication.

by using the Automation commands available in VBscrip .

### ii) Matlab software for consultant part.

In this part the reconstruction of the original signal is done by Matlab script file consists many functions carried upon the received data from the patient part, the diagram shown in figure(3) summarizes this process. These function can be summarized as:-

1. *Download the files of the patient in sequence*, All patient files are downloaded one after the other from the specified directory within the web site at the server.
2. *Check if new information is found*, this means there is a change with patient files if not no action has been taken .
3. *Reconstruct & plot the polynomials equation*, this means regenerating the 40 data vector for each 7 elements(p6..p0)which is the coefficients of the 6<sup>th</sup> order polynomial, using Matlab command (polyval).
4. *Send the reply to the patient*, according to the current patient information the doctor will send a reply.
5. *Insert the notes of doctor in Access database*, the notes of the doctor will be inserted into a database which was constructed using Access database in this database there are two tables, one includes patient's personal information like :-

( *name, sex, age, family history, diabetes, blood pressure, others*)

The second table contains the doctor *notes* and *date* of that notes there is a table for each patient see figures(11,12) .

### **iii) Consultant connection with Internet server.**

1. we use simple hardware consists of an ECG preamplifier ( 1000 gain) , a high pass filter ( to remove noise artifacts ), and a digital Notch and Butterworth filters that were built with Matlab. The signal was entered using the "microphone" jack built in the sound card of a PC to minimize the electronic circuits that led to reduce the cost and power consumption.

The consultant part retrieves the ECG data from the Internet server Using FTP and sends the responses to the Internet server using FTP too, but the consultant Page is retrieved using HTTP protocol used by the (IE), as described in figure (1).

### **2.3 Internet Server Part**

Here, a general purpose Internet server with HTTP and FTP services is provided, the data files as well as the interfacing pages are reside in this server at a leased site, No additional work is required more than using the site as a meeting point for the patient part and the consultant part.

### **3.Results:-**

The obtained results can be demonstrated in the figures (4-13), figure (4) is the original ECG signal and figure (5) is the ECG obtained from the polynomial parameters ( i.e the compressed signal), the other figures demonstrate the web part.

### **4.Conclusions:**

A continuous monitoring of the ECG signal and the patient's current heart activity are necessary for people suffering from the cardiac diseases. In this we describe an internet based remote real time Holter ECG monitoring system which characterized by the following features:-

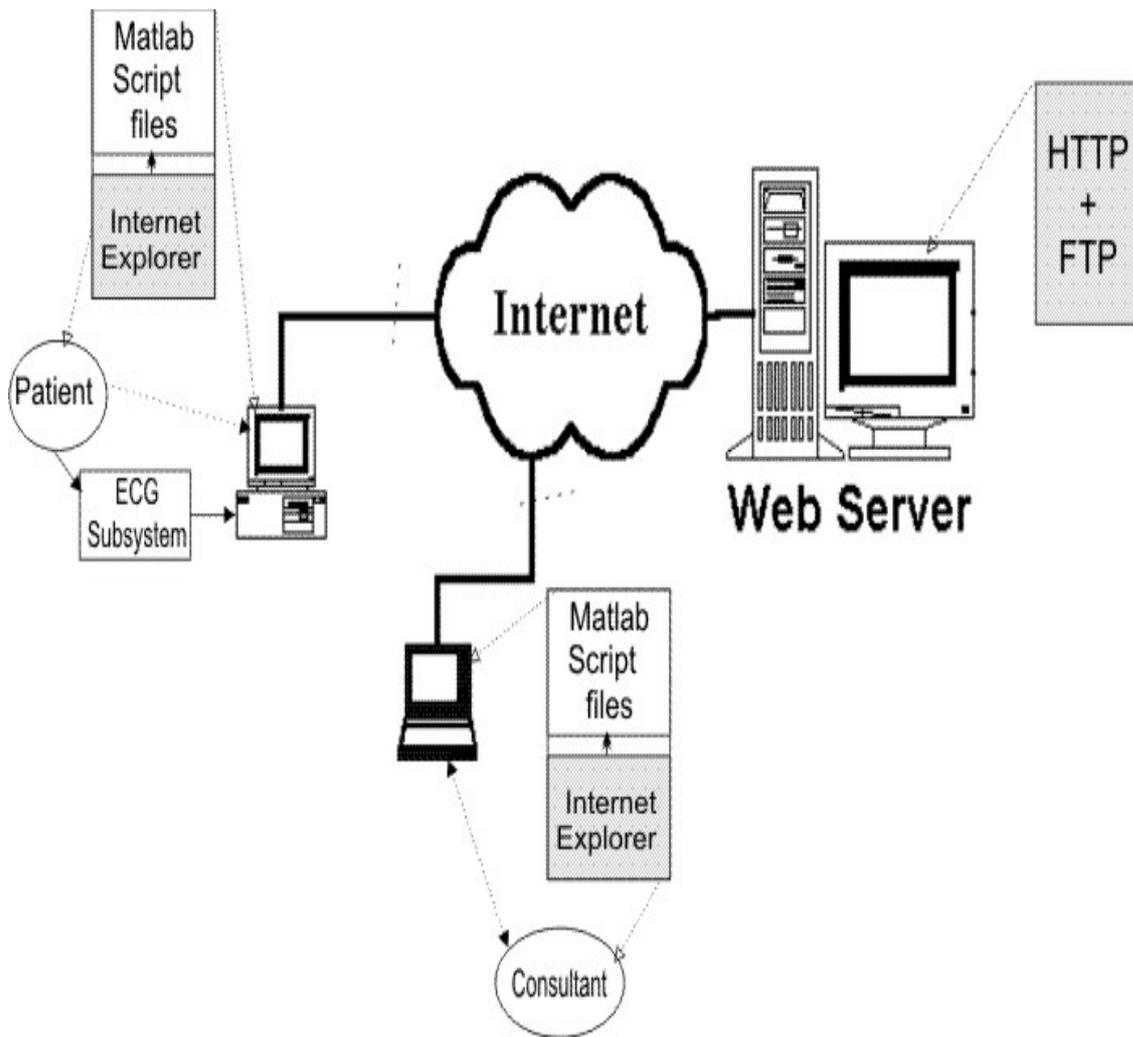
- 2.The MATLAB was used for local signal analysis then using the MATLAB capabilities to transmit and receive files using FTP over the internet so only a website was rented in a size of 250 KB which leads to a great reduction in the cost.
- 3.The reliability of the communications in this system is good because of using the Internet as a communication medium , since the Internet has the ability to communicate in case of

connection failure because almost (with internet) there are an alternative connection to carry the communications.

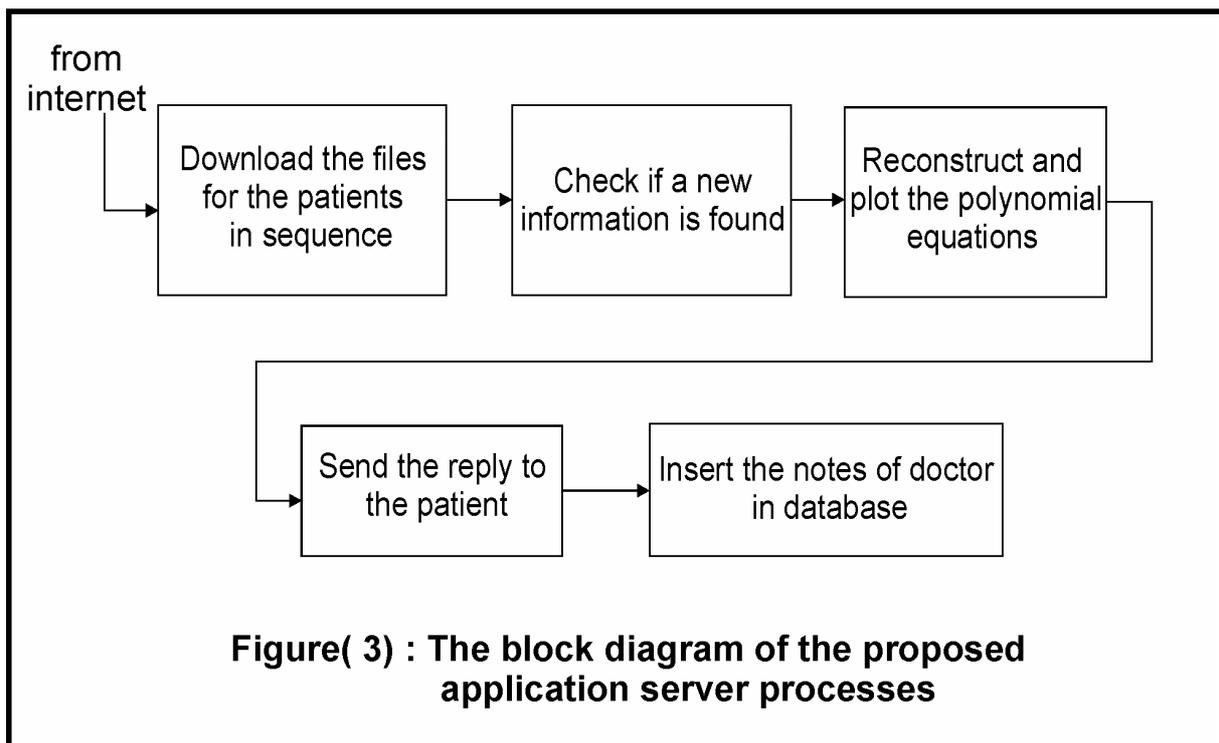
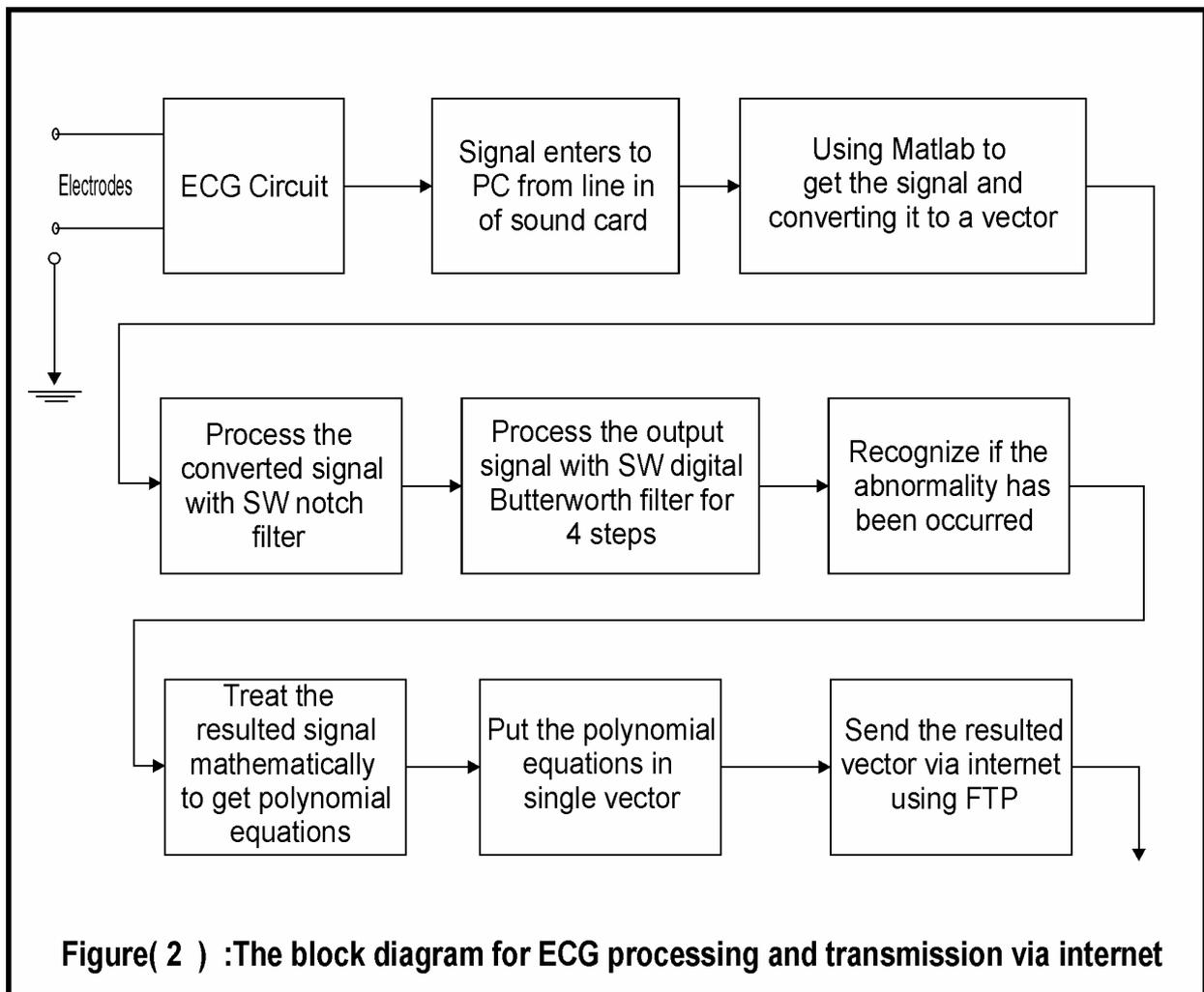
Comparing this approach with other systems we were pointed to in the survey which are lack of the local analysis and most of them required server with public IP address which is not easy to realize and costly.

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Figure(1) The Overall ECG Monitoring System



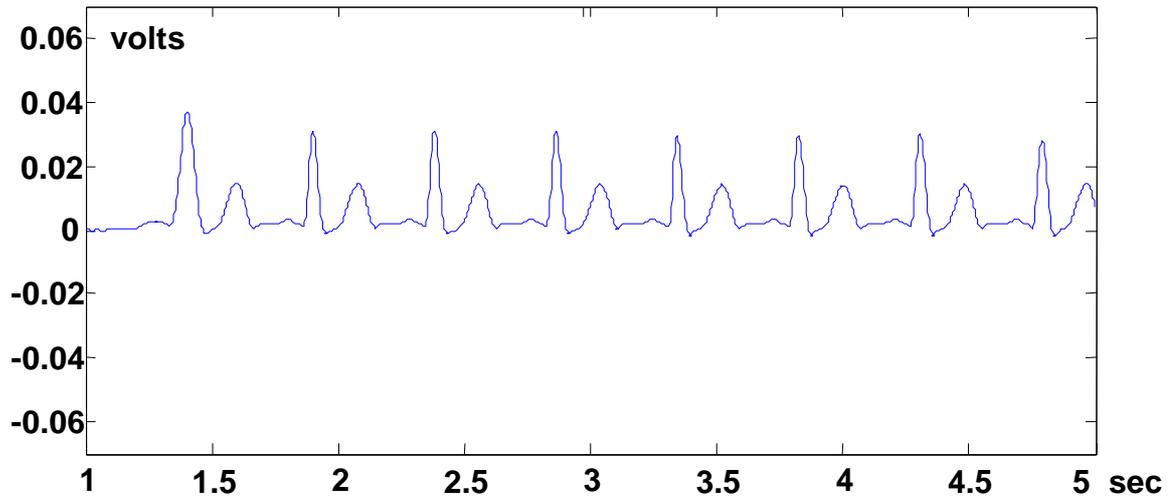


Figure (4) ECG original signal

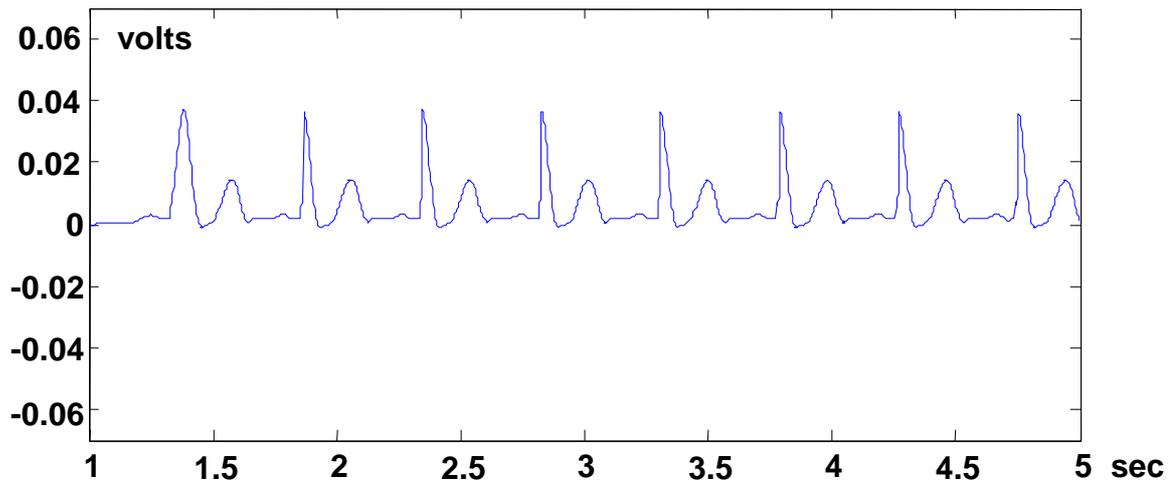


Figure (5) Manipulated ECG signal

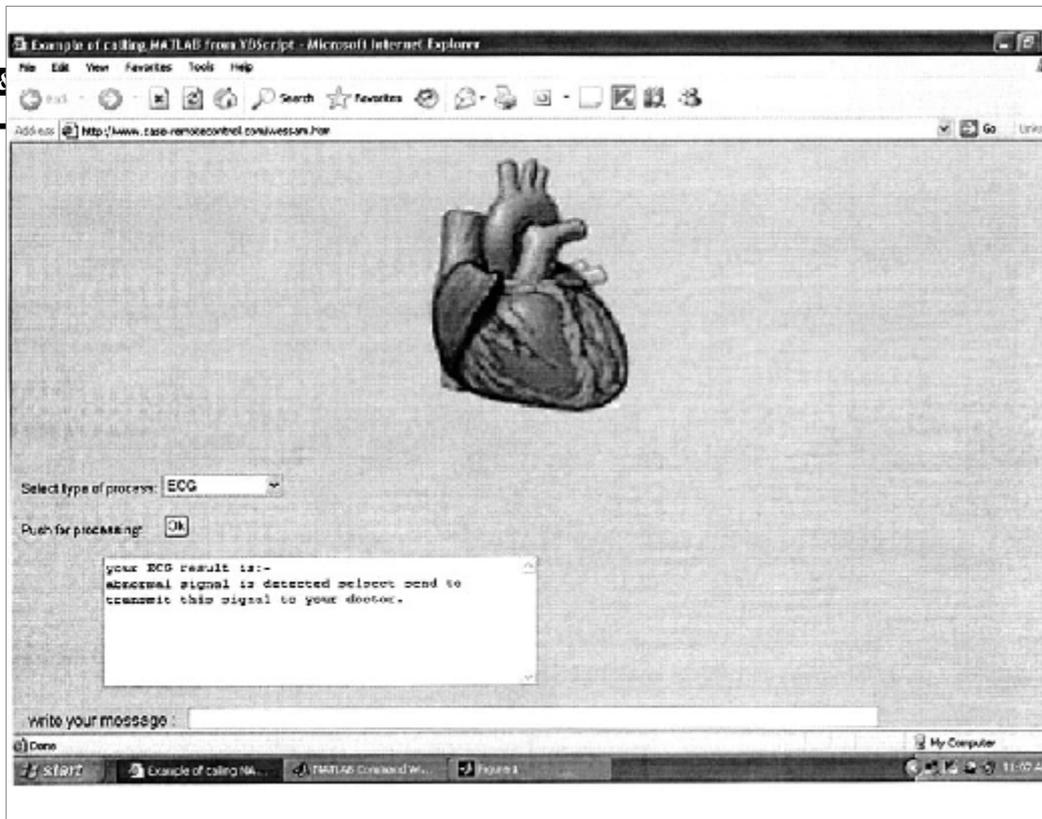


Figure (6): An abnormal signal was detected and ready for send

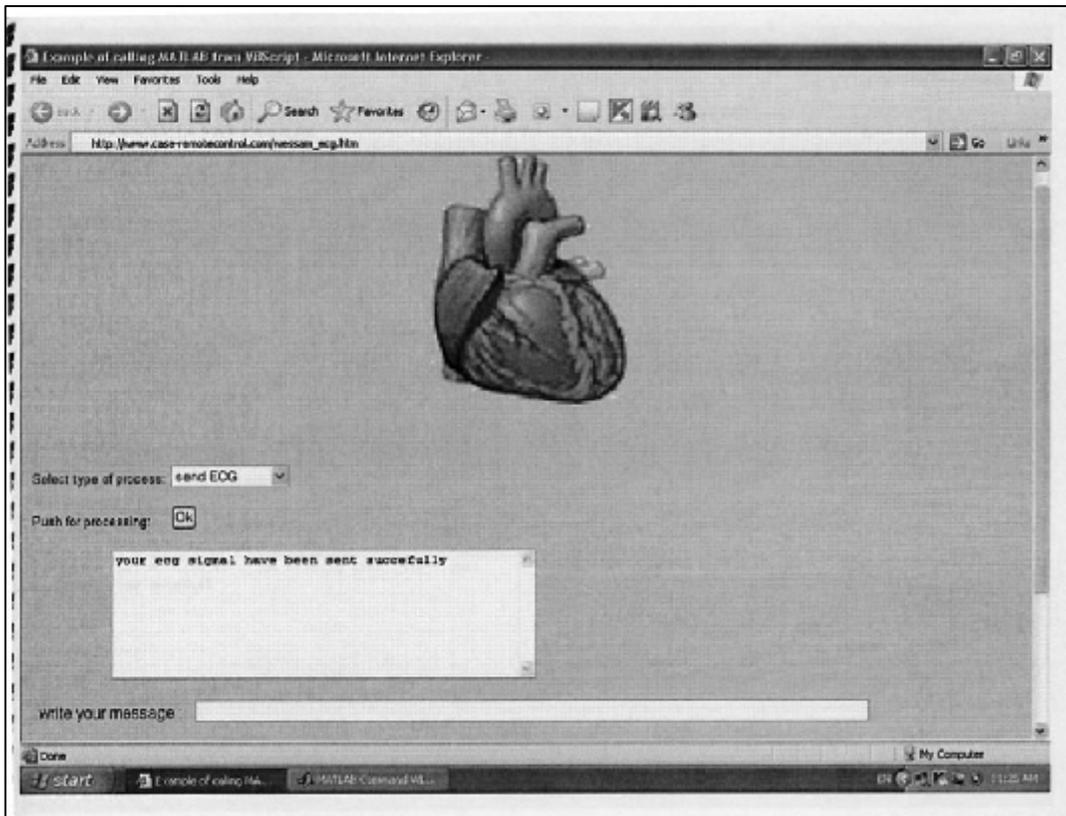
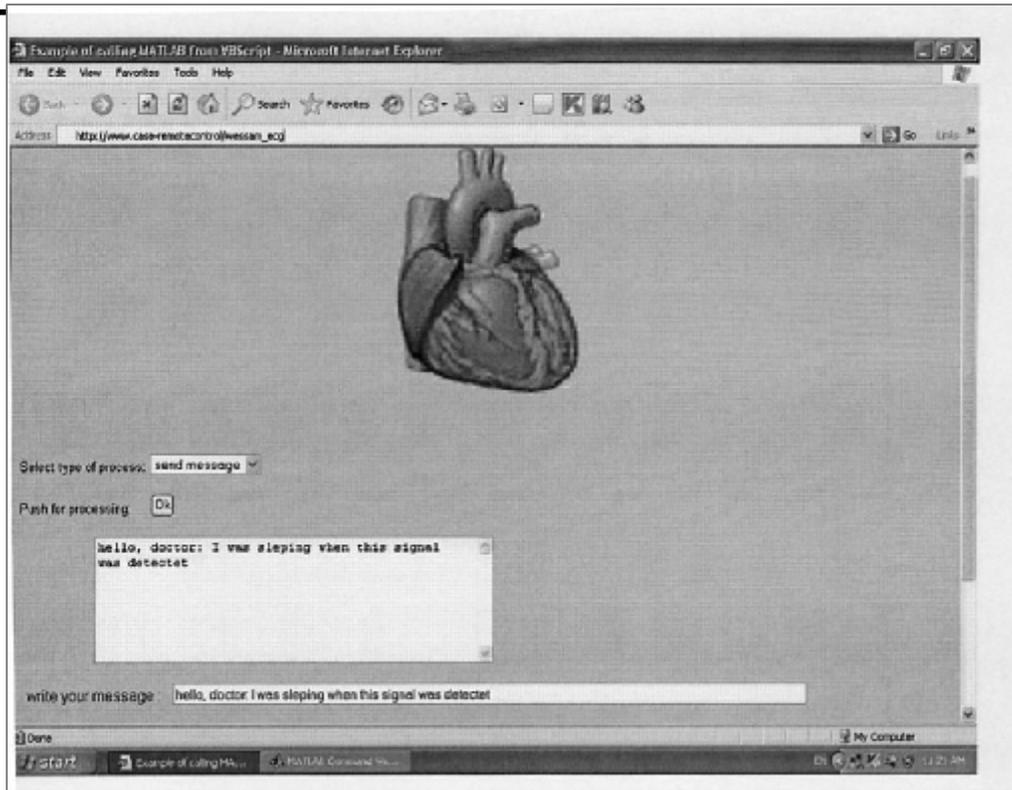
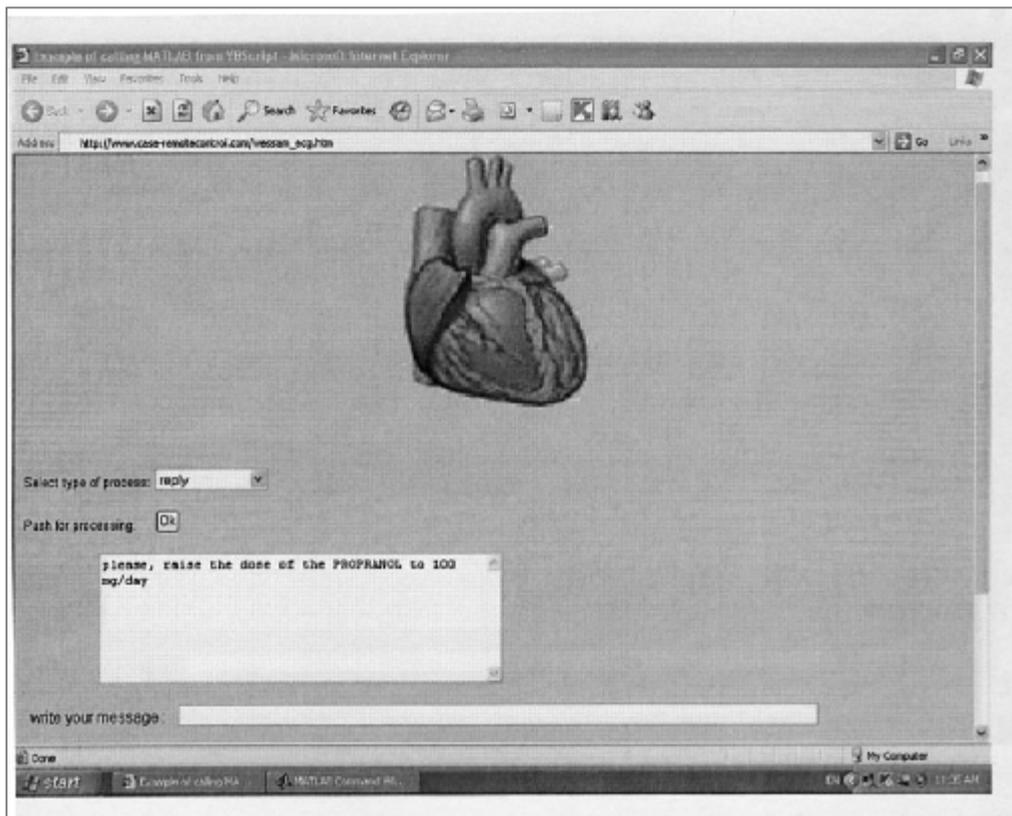


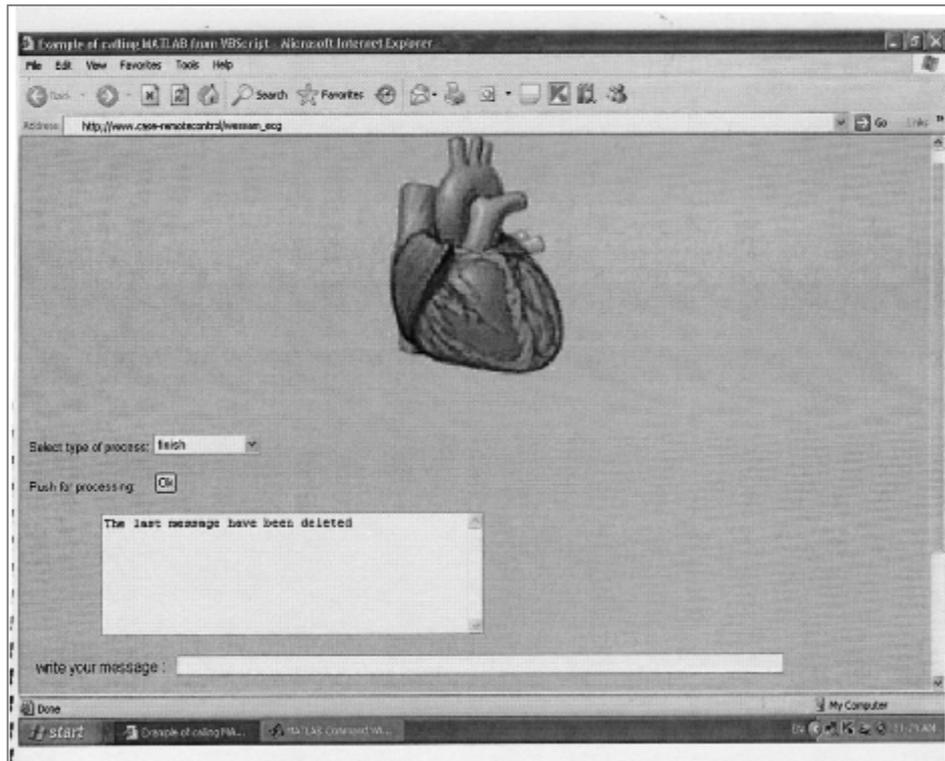
Figure (7): ECG signal was sent



Figure(8):sending a message



Figure(9):Reply from the Doctor



Figure(10):Finishing The connection

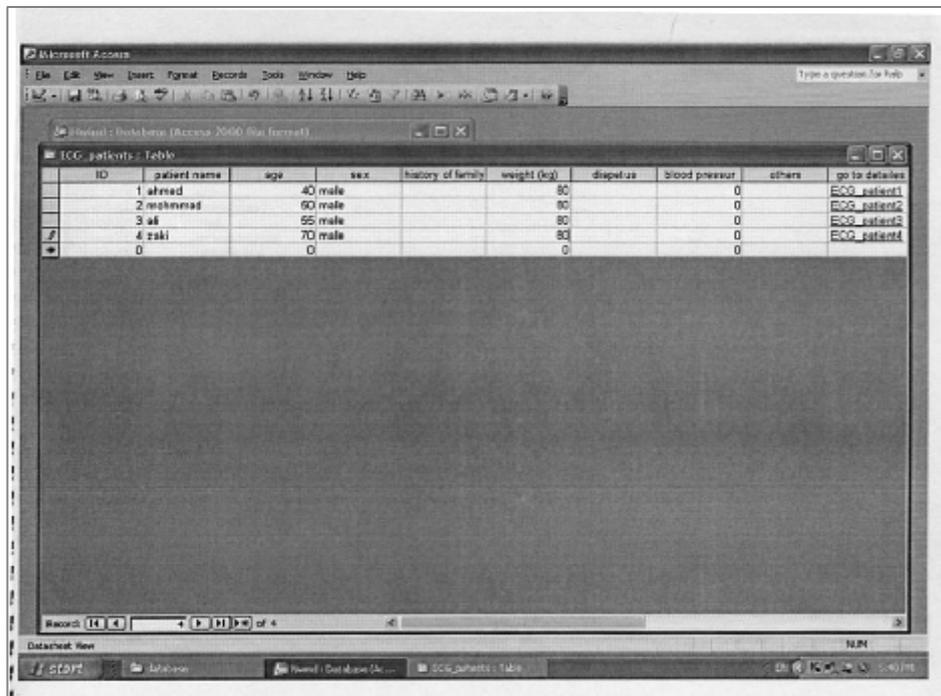
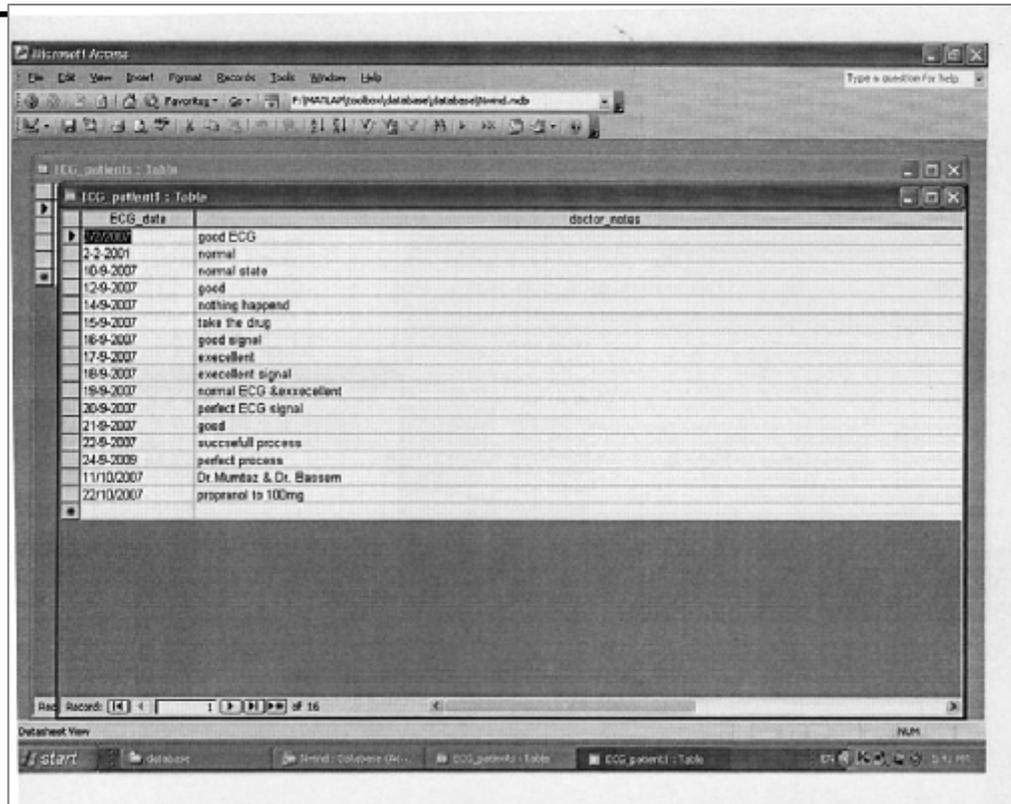
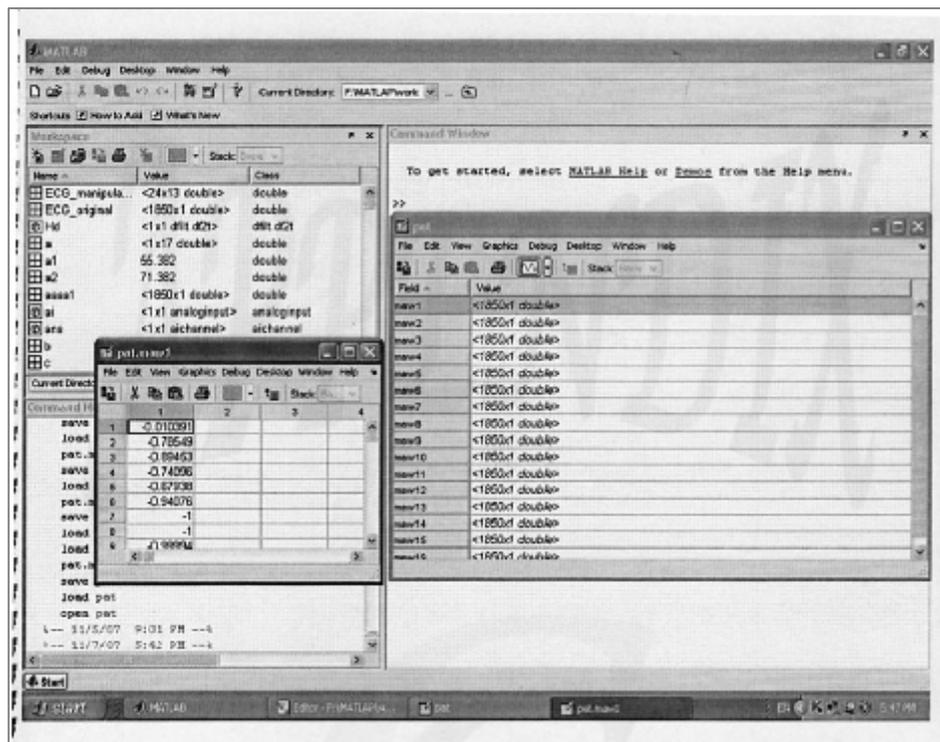


Figure (11):Patient Database



Figure(12):Patient1 database since every patient has its own database



Figure(13):Stored normal ECG Signal Database That is used in Analysis and detection process