SFAAS – Smart Fetal ECG Acquisition and Analysis System

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Abstract- 833.5 million or about two-thirds of Indian population still lives in rural areas which are mostly devoid of sophisticated medical technologies accessible by their urban counterparts [1]. One of the most important of these are the medical facilities which are still considered a luxury in the remote rural landscapes. Unlike cities, the process of childbirth and other pregnancy-related issues are largely handled by midwives [2] which are often not accurate and completely safe. Pertaining to this problem, we propose a Smart Fetal ECG (FECG) Acquisition and Analysis System – SFAAS. The main objective of SFAAS is developing fully robust, automatic ECG equipment which can acquire ECG from the abdomen of a pregnant woman and separate the convoluted mixtures obtained indicating the defects in the ECG recording thus showing the health of the fetus. In this paper NI LabVIEW is being used for acquisition and filtering of the ECG signals. The convoluted mixture of MECG and FECG signals were separated and filtered using adaptive filtering algorithms like LMS (Least Mean Square) to remove the baseline wandering, powerline interference, EMG noise, patient–electrode motion artifacts and contact noise. These recordings can then be transferred to the nearest health center via an automated generated email for immediate treatment and diagnosis and peak detection is used for possible detection of diseases. An auto-generated SMS(Short message system) is also generated in indicate the status of the fetus to the particular patient.

Keywords— FECG, MECG, LabVIEW, DAS, Biomedical Instrumentation, Biotelemetry, LMS algorithm

I. INTRODUCTION

Biomedical signals are fundamental observations for analyzing the body functions and for diagnosing a wide spectrum of diseases . ECG analysis has been widely used for diagnosing many cardiac diseases and is a . The ECG or elctro-cardiogram is a graphic record of the duration and magnitude of the electrical activity that is generated by depolarization and repolarization of the atria and ventricles. One cardiac cycle in an ECG consists of the P-QRS-T waves. Most of the clinically useful information in the ECG is found in the intervals and amplitudes defined by its features (characteristics wave peaks and time durations). The development of accurate and quick methods for automatic ECG feature extraction is of major importance.[3]

Producing an algorithm for the detection of the P wave, QRS complex and T wave in an ECG is a difficult problem due to the time varying morphology of the signal subject to the physiological conditions and presence of noise. There are various algorithms that adapt a range of different approaches to yield a procedure leading to the denoising and identification of the waves. These approaches are mainly based on wavelet [4], matched filters[5], Poisson transform [6], mathematical morphology [7], fuzzy logic [8], LabVIEW [9]. From the literature survey,it is seen that LabVIEW can be used effectively for QRS detection and throught the font panl we could actually visualise the ECG report pretty well. In the work presented here an algorithm is proposed with low computational complexity using LabVIEW for filtering ECG signals and detection of P wave, T wave, QRS wave and their onsets and offsets using adaptive based filtering concept on Least Mean Square(LMS) filters.

The whole aim of this paper is to create a robust yet simple Virtual instrument to acquire the foetal ecg, analyse it and then send it to the patients regarding the health of their foetuses against the possible checkup of few heart diseases like long QT, Bradycardia, Tachycardia, Wolff Parkinsons disease. The diseases if generated will be notified by the doctor and the patient will be urged to seek medical attention.

II. LITERATURE SURVEY

The condition of infrastructure of pregnant women in India is pretty bleak with maternity mortality rate(MMR) is exponentially higher than acceptable limits. The reasons of infant mortality rate due to congenitive heart diseases is pretty common. A following table shows the percentage of infants dying due to congeital heart diseases in India.[10]

S. No.	India/States		Pneumonia	Anaemia	Diarrhoea and Gastroenteritis	Typhoid and Paratyphoid	Influenza	Congestive and Other Heart Diseases	Drowning	Convulsions	Dysentery	Malaria	Total
		ICD Code	J 18	D 50-64	A 09	A 01	J 10-11	151	X 71	G 40	A 06	B 50-54	
	India		**19.0**	**9.0**	**6.3**	**5.1**	**3.8**	**3.5**	**3.4**	**3.3**	**3.1**	**2.6**	**59.2**
1	Andhra Pradesh		6.3	7.9	3.2	3.2	0.0	7.9	7.9	6.3	1.6	0.0	44.4
2	Bihar		22.0	22.0	2.4	7.3	2.4	0.0	2.4	2.4	7.3	0.0	68.3
3	Gujarat		1.7	11.9	1.7	5.1	0.0	1.7	3.4	5.1	0.0	1.7	32.2
4	Haryana		26.0	4.0	6.0	6.0	4.0	0.0	6.0	2.0	2.0	2.0	58.0
5	Karnataka		14.7	13.3	8.0	1.3	6.7	2.7	2.7	0.0	5.3	0.0	54.7
6	Kerala		0.0	0.0	0.0	0.0	0.0	60.0	20.0	20.0	0.0	0.0	100.0
7	Madhya Pradesh		22.1	6.2	1.6	2.3	0.0	8.1	3.3	7.5	0.3	0.0	51.5
8	Maharashtra		26.2	13.9	7.5	6.5	7.8	0.0	1.0	1.4	2.4	10.2	76.9
9	Orissa		25.0	21.4	7.1	0.0	0.0	3.6	3.6	3.6	3.6	7.1	75.0
10	Punjab		20.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	60.0
11	Rajasthan		39.1	15.2	0.0	3.3	3.3	0.0	4.3	1.1	3.3	0.0	69.6
12	Tamil Nadu		2.4	3.2	7.1	0.0	4.8	8.7	8.7	2.4	4.0	0.0	41.3
13	Uttar Pradesh		25.9	6.5	7.3	14.6	2.8	1.2	2.0	3.2	5.7	2.0	71.3

Source: India, Registrar General, Vital Statistics Division. (2002). Survey of Causes of Death (Rural), India : Annual Report 1998. New Delhi. p. 28.

Figure 1: Statistical data representing death of congenital heart diseases of infants

*All the authors have equal contribution in the work presented here.

During the last 3 decades, several techniques and instruments have been available to provide reasonably reliable information and data instantaneously about the foetus during its intraauterine life or at the time of delivery. But the development of foetal instrumentation has been a difficult task because of the complex nature of problems involved.The only information available is picked up from the maternal abdominal wall are the electrical potential of the foetal heart activity.The isolation and and interpretation of the mixed up foetal signals require expert handling as the separation puts to a hurdle for many instruments.[11]

The disease identified for detection in the system are:-

Diseases	**Symptoms**	**Effects**
Long QT	Male(QT>440ms) Female(QT>460ms)	Fainting, Seizures
Bradycardia	Bpm<100(first trimester)	Fatigue, Weakness, Dizziness
Tachycardia	Bpm>180(first trimester)	Fever, Hypovolemia, Hyperthyroidism
Wolff-Parkinson's Syndrome	Short PR, Long QRS(>120ms)	Palpitations, Dizziness, Shortness of breath

Figure 2: Target diseases and its symptoms and effects

III.METHODOLOGY

The main objective of SFAAS is developing fully robust, automatic ECG equipment which can acquire ECG from the abdomen of a pregnant woman and separate the convoluted mixtures obtained indicating the defects in the ECG recording. These recordings can then be transferred to the nearest health center via email for immediate treatment and diagnosis.

A variety of techniques [12] have been developed for acquiring FECG such as:

1. Fetal Electrocardiography (FECG) using abdominal surface electrodes,

2. Photoplethysmography (PPG) using Near Infrared (NIR) light,

3. Ultrasound based Cardiotocography (CTG) known as electronic fetal

monitoring and

4. Fetal Magnetocardiography (FMCG).

The method used here is abdominal foetal cardiogram where the ecg is recorded by suitably placing electrodes on mother's abdomen and recording theecg using surface electrodes.The maximum amplitude of FECG (R wave) is around 100 to 300 µv. The magnitude is much smaller than an average adult.The foetal heart rate ranges around 110 to 180 bpm.The main problem faced is the signal to noise ratio which should be high to get good reading. The methodology of the system is further divided into two parts:-

The basic block diagram of the entire system is shown here:-

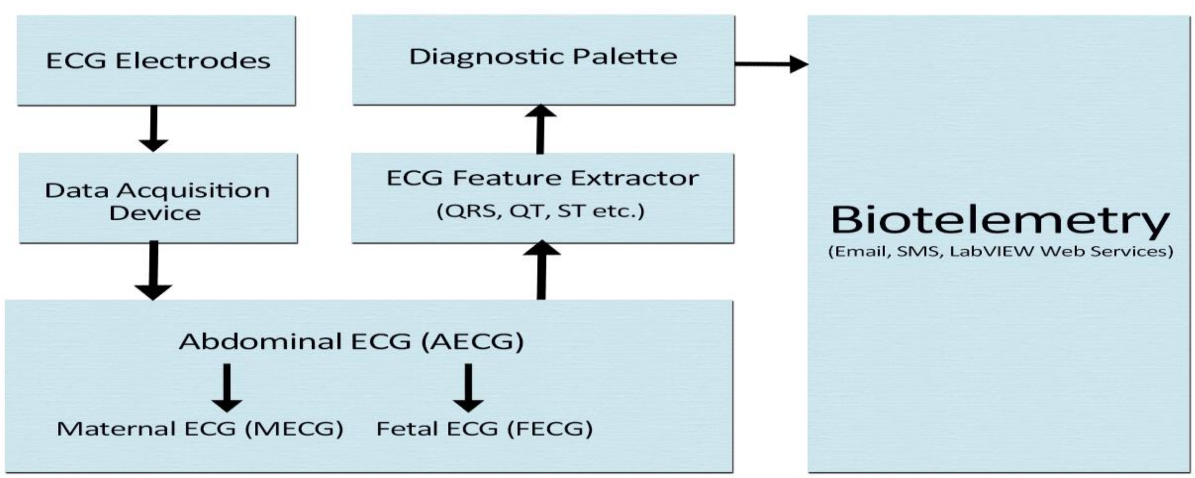


Figure 3: Block Diagram of the system

III.I Acquisition and Analysis of FECG:

In our proposed system, abdominal surface electrodes are being used to acquire the FECG. This is achieved by placing the electrodes on the abdomen of the pregnant woman as shown in [fig.1]. The ECG thus obtained from the abdomen is called abdominal ECG (AECG) and it consists of the convoluted mixture of Maternal ECG (MECG) and Fetal ECG (FECG). This mixture is then separated in order to analyze the fetal ECG.

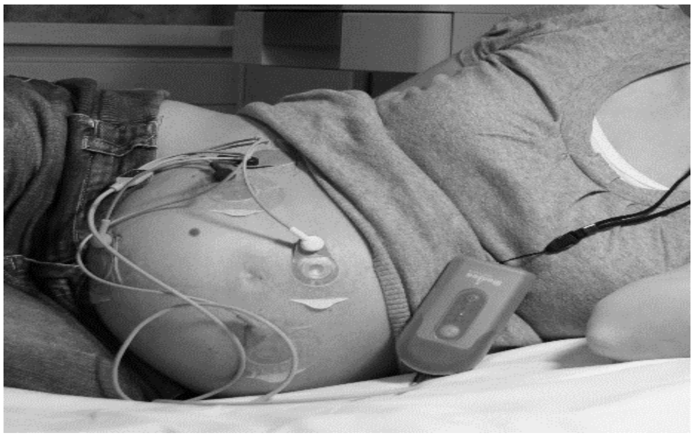


Figure 4: Placement of electrodes on pregnant woman

NI LabVIEW is being used for acquisition and filtering of the ECG signals. Here in the .vi file, the entire process is systematically segmented through the LabVIEW Event Structure. We are using a LabVIEW measurement file (.lvm) of an abdominal ECG taken from Physionet database. This .lvm file is opened through the 'Read Measurement File', the convoluted mixture is separated using 'Split Signal' tool and the corresponding raw waveforms of AECG, MECG and FECG are shown on the front panel [fig.2].

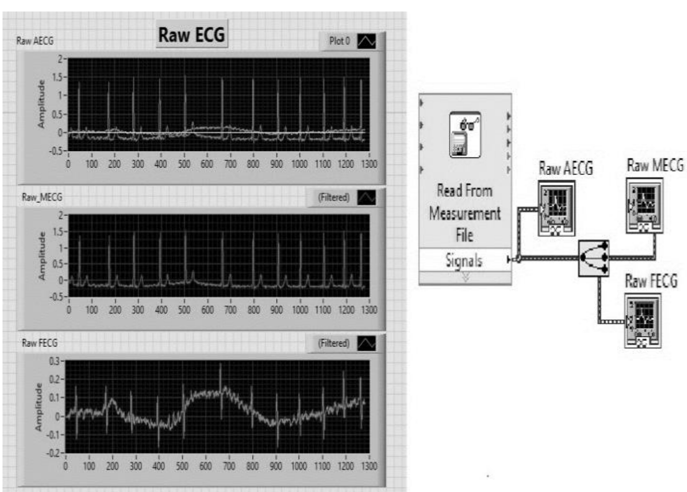


Figure 5: Raw ECG Front panel and Block Diagram

The next step is to filter the ECG signals for baseline wandering, powerline interference, EMG noise, patient–electrode motion artifacts and contact noise. Among these, baseline wandering and powerline interference are the most significant ones. There are various techniques to suppress them such as using a digital high pass filter and wavelet transform. In our approach, we are using the adaptive LMS filter noise filtering and improved detection of the QRS complex.

LMS filters are a class of adaptive filters that are able to "learn" an unknown transfer function. They use a gradient descent method in which the filter coefficients are constantly updated based on the instantaneous error signal. The standard LMS filter in LabVIEW takes in two inputs – x(n), d(n) and produces an output y(n) along with an error signal e(n) [fig. 3] by performing the following operations:

1. Calculates the output signal y(n) from the adaptive filter.
2. Determines the error signal e(n) through: e(n) = d(n)–y(n).
3. Updates the filter coefficients by using the following equation:

$$\omega(n+1) = \omega(n) + \mu.e(n).u(n)$$

where μ is the step size of the adaptive filter, $\omega(n)$ is the filter coefficients vector and u(n) is the filter input vector.

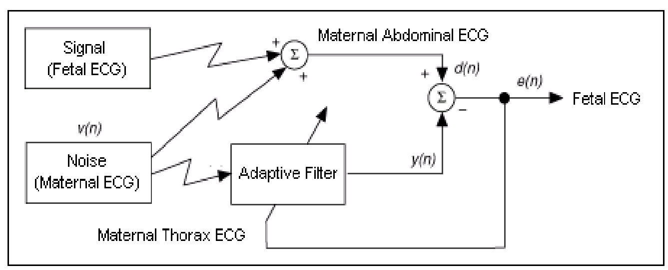


Figure 6: LMS Algorithm for separation of raw ecg

Based on this, a FIR LMS filter with a filter length of 40 and step size of 0.45 is created from which the filtered ECG signals are produced for further analysis of the QRS complex [fig. 7].

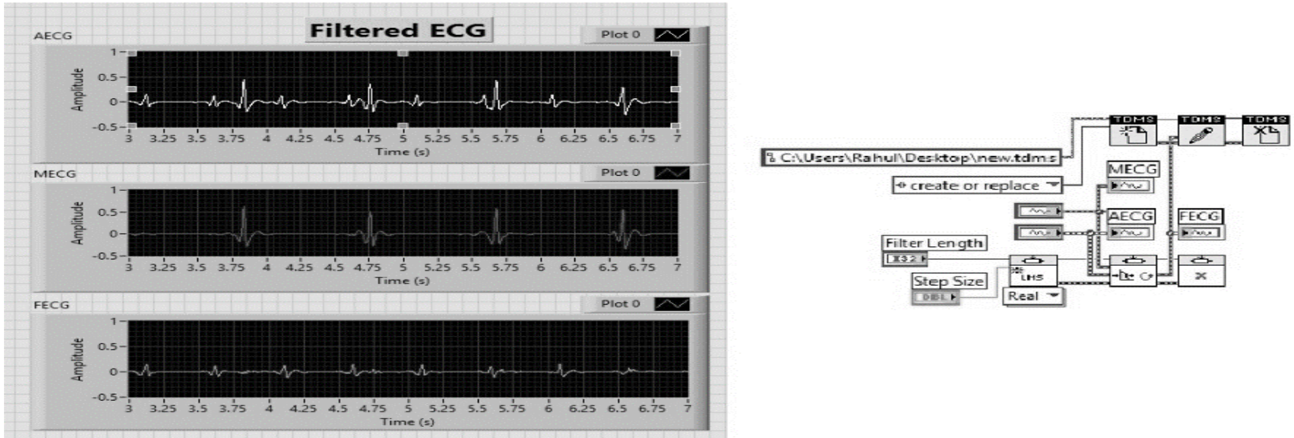


Figure 7: Filtered ECG Front Panel and Block Diagram

The filtered FECG waveform is then converted into a .tdms file for feature extraction using LabVIEW Biomedical Toolkit. It analyzes the FECG and produces several features such as QRS amplitude, QRS width, ST level, PR interval, QT interval and heart rate. These parameters are then compared against the normal standards and a diagnostic report is produced. If there is any abnormality detected, the .vi files sends report to the nearest hospital through e-mail and SMS.

III.II SFAAS BIOTELEMETRY

For the telemetry and telemedicine part, we are generating an email consisting of the patient details along with the ECG values like PR,QR,ST intervals etc which will be mailed to the doctors in the city hospitals for further detailed analysis. Also, we are sending an SMS using GSM module to the patient,i.e,the mother, informing them about the condition of the foetus and whether there exist any abnormality so that further check up is required or not. Also NI web-services are used so that main city hospitals central station can monitor the real time patient foetus ECG which are being acquired at the rural centres.

EMAIL G-CODE:- The email VI uses .NET connectivity tools of NI LabView to setup SMTP client server access using telnet services of the system with port 587 and and SSL encryption standard. It implements constructor nodes to get the sender and receiver email credentials, property nodes are used to to generate the mail message and add attachments if required and invoke nodes are used to interact with the smtp client using telnet port 587 and SSL(Secure socket Layer) encryption standard over the internet.

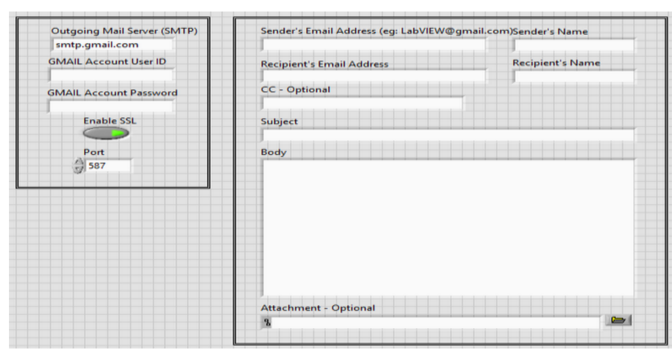


Figure 8: Front panel

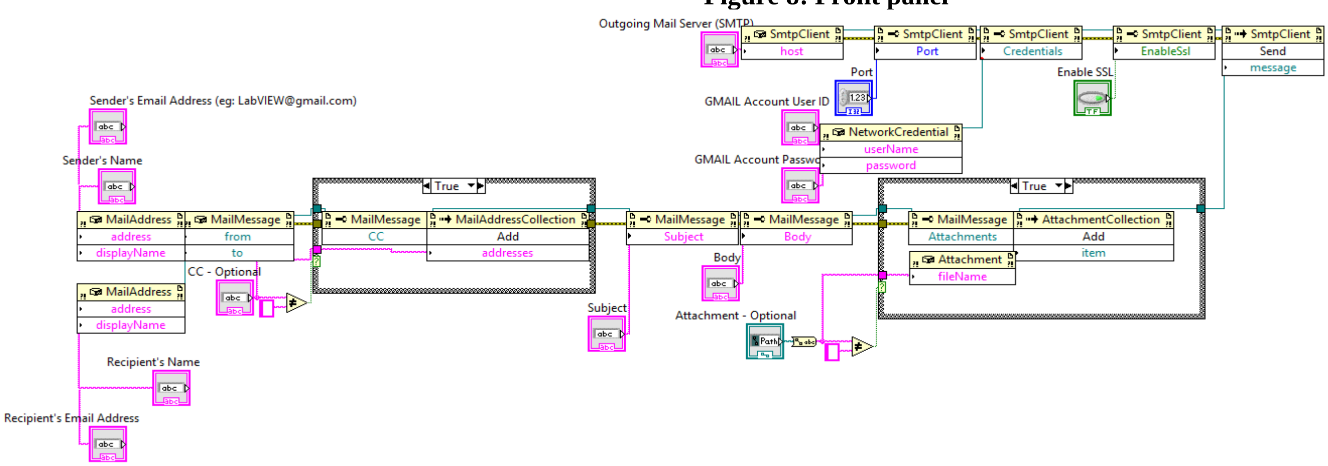


Figure 9: Block Diagram

SMS G-CODE:- we have used GSM module to interface with NI LabView using a RS232-USB connector and NI VISA serial resources. Baud rate is set as 9600 and AT(attention) commands are used to communicate with the module. “AT+CMGF” is used to check for the modem availability and “AT+CMGS” is used to get the mobile number and text message. Commands are executed using command execution sub-VI. Error terminals are connected to display any error of delivery failure.

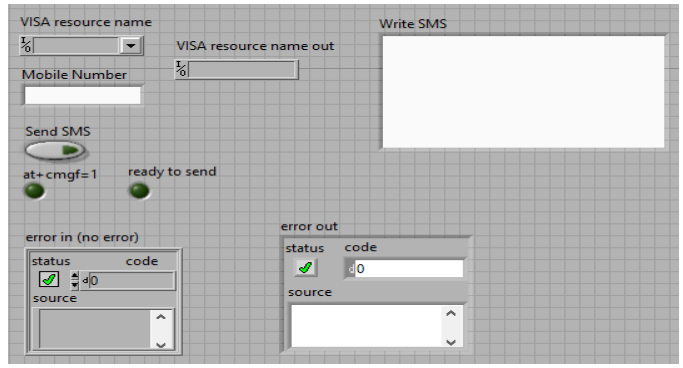


Figure 10: Front Panel

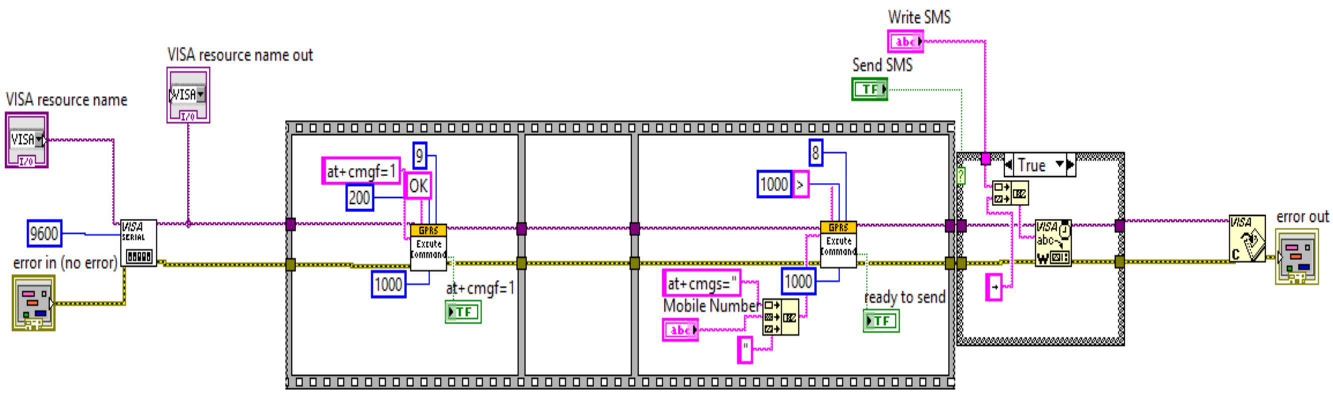


Figure 11: Block Diagram

The entire setup is shown below:-

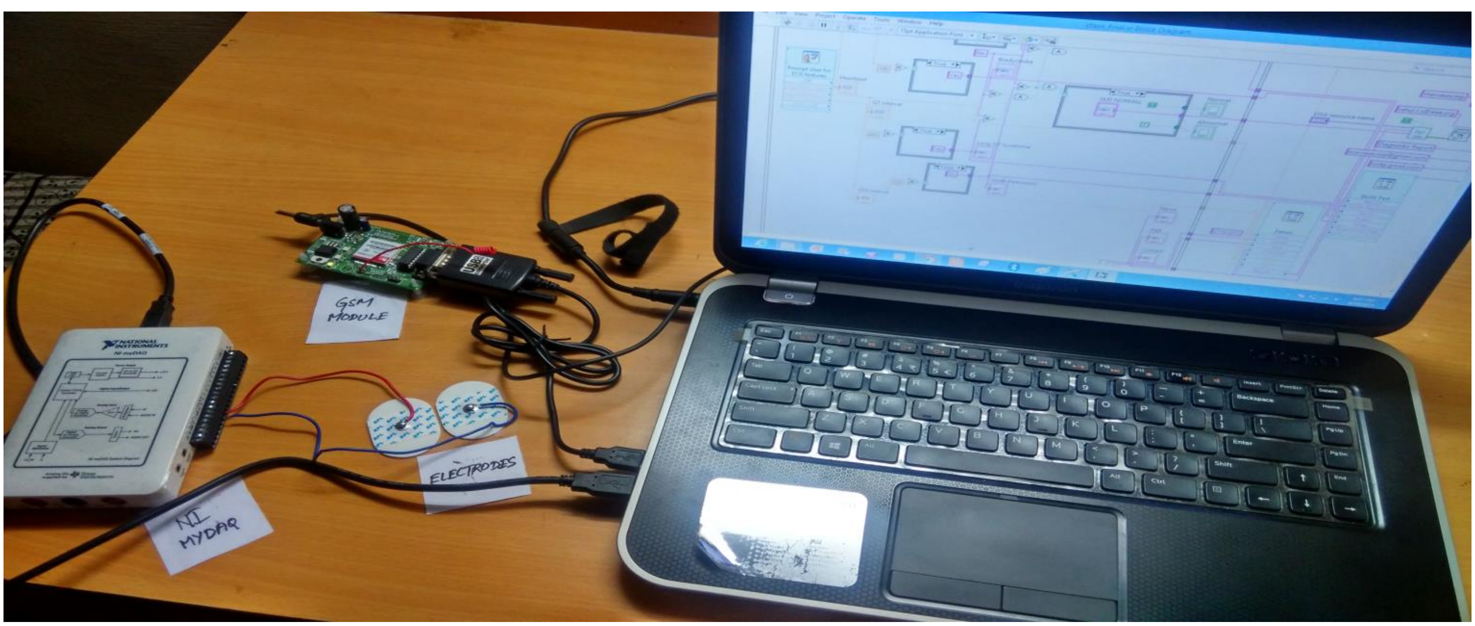
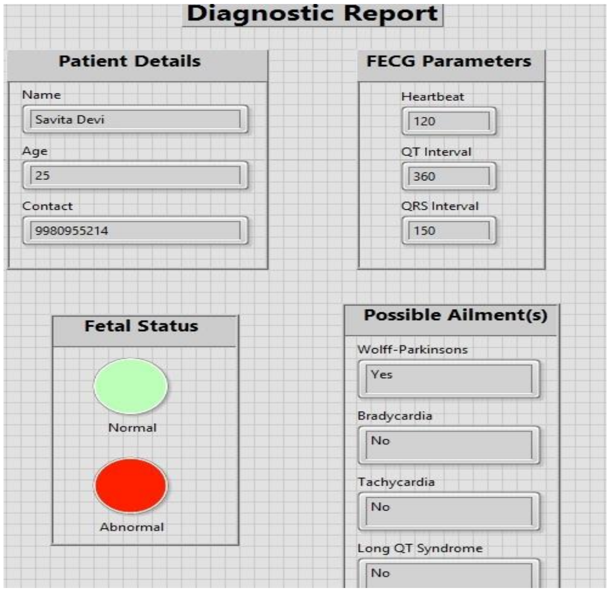
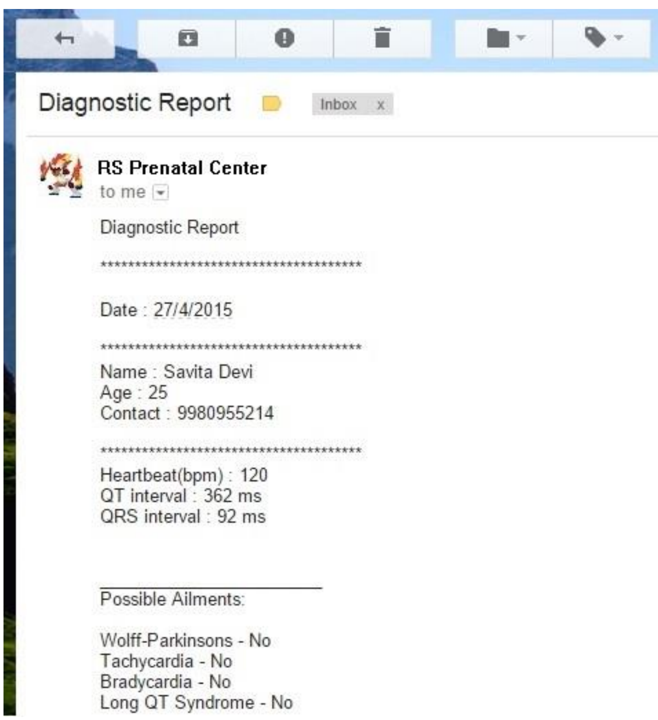


Figure 12: System setup

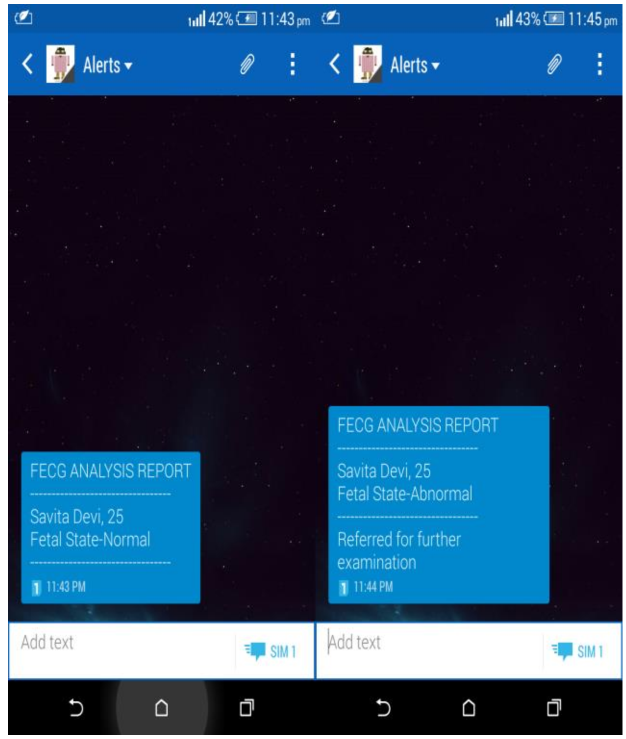
IV. RESULTS



Next we extracted the values and published the diagnostic report on the front panel of Labview.



An email is sent to the doctor where the three parameters are shown and the possible ailments marked and if there is any abnormality noticed then the patient is referred for further examination.



A screenshot of the sample message is shown which is generated from the gsm module configured by the sms vi. Thus it can be seen that the telemetry system was succesful in sending results of the state of the foetus.

Next we used the web publishing tool to show the ecg signals for the doctor to analyse and send the feedback back to the patients.

V. CONCLUSION

The equipment design aims at building a robust yet simple system to acquire the abdominal ecg to fetal and maternal ecg. The system simulated on a sample data taken from MIT BIH database for the detection of diseases. The VI contains LMS algorithm which successfully removed the noise and filtered the signal. This data received is used as a .tdms input for the ecg feature extractor which detect the peaks and calculates the intervals. Once they are detected it is given as a input in the user prompt box which triggers to vis namely the sms and the email vi. Experimental results show encouraging success in telemetry as the gsm module works successfully. Also the email was received stating the condition of the diseases. As the results show, if this system is implemented in the rural areas, it can be a huge beneficiary for the health of the foetus and the pregnant women.

VI. ACKNOWLEDGEMENT

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