Non-Invasive Extraction of Fetal ECG using Differential Algorithm and Analysis using LabVIEW

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Abstract—

Early detection of a fetal Heartbeat can be important in many cases, where monitoring the development of the fetal heart is necessary. Studies have shown that Electrocardiogram (ECG) signal can play a significant role in investigating the obstetric state during pregnancy and labor. By means of fetal ECG, the disturbances of cardiac activity can be determined. In this paper by using Differential technique fetal extraction is done from two ECG signals recorded at thoracic and abdominal area of mother's skin. The thoracic ECG is assumed to be almost complete maternal ECG while abdominal ECG is considered to be composed of both mother and fetal ECG signals. Extracted fetal ECG is studied along with Sonographic report for continuous comparison. The user interface is designed using LabVIEW tool. The output is connected to the personal computer, for analysis and display of result on screen.

Index Terms—Thoracic ECG, Abdominal ECG, Fetal ECG, Differential algorithm, LabVIEW.

I. INTRODUCTION

During the last decade, several techniques, devices and instrument have become available which provide reasonably reliable information and data instantaneously about the fetal during its intrauterine life or at the time of delivery. Nevertheless, the development of fetal instrumentation has been a difficult task because of the complex nature of the problem involved [1]. The fetal while in the uterus is mechanically shielded from the outside world so that it can safely develop there. This means that only a limited amount of information can be obtained directly about the fetal condition. The only information which is readily available about the fetal and which can be picked up from the maternal abdominal wall is the electrical potential of the fetal heart activity and the fetal heart sound signals. Fetal Heart Rate (FHR) monitoring is a technique that can give the substantial message about the condition of fetus it is being performing by detecting ECG signal that is generated by the heart of the fetus [1].

The feature of Fetal ECG (FECG) such as pulse rate, wave shape and real time changes are convenient in defining fetal life and existence of abnormal condition of fetus or congenital cardiopathy [2]. FHR can recognize condition, which may extend to fetal and or maternal mortality or morbidity. From these conditions, the status of the fetus can be found along with the irregularity of cardiac rhythm, cardiac arithmia and the activity of the Automatic Nervous System (ANS) [3]. An unnatural pattern may mean that the fetus is not getting enough oxygen or there are other problems. Sometimes an abnormal pattern also may mean that an emergency or abdominal delivery is needed. However, FECG abnormalities are unpredictable and it may occur at any time. To monitor such abnormalities, ambulatory monitoring has been established a useful approach with use of long-term monitoring of FECG, where, the mother can perform normal daily activities, work and keep away the unnecessary hospital stays [3].

Accurate finding of the QRS complex, in particular, accurate detection of the R-peak, is essential in computer-based FECG signal analysis especially for a correct measurement of FHR and Fetal Heart Rate Variability (FHRV). However, this is often hard to achieve, since several sources of existing noise contraction are frequently found, such as baseline drifts, power line interferences, motion artifacts and muscular activity [3].

II. SYSTEM DESCRIPTION

Figure 1 shows the system block diagram for extraction and analysis of FECG.

Electrodes are placed on thoracic and abdominal region of pregnant subject for extraction of thoracic and abdominal ECG using recording system. Thoracic ECG is

assumed to be completely maternal ECG whereas abdominal ECG is composite signal i.e. combination of maternal ECG and Fetal ECG. The maternal ECG of thoracic region is non linear transform version of maternal ECG of abdominal region. For further analysis of signal we use LabVIEW tool. By using Stereo pin the extracted signal is interfaced with LabVIEW software.
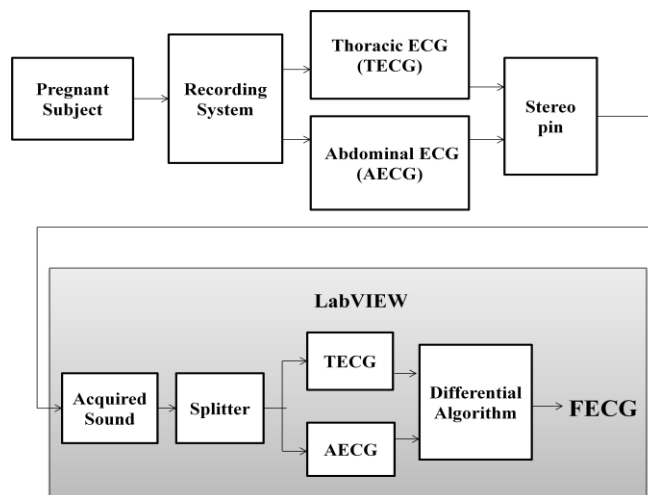

Figure 1 System Block Diagram.

In LabVIEW the TECG and AECG signals of pregnant subject are acquired. These signals are merged together, so we split them to obtain them individually and then apply the Differential Algorithm on them for the extraction of FECG.

III. DETAILS OF SYSTEM

The hardware and software components used for designing the described in this paper are:
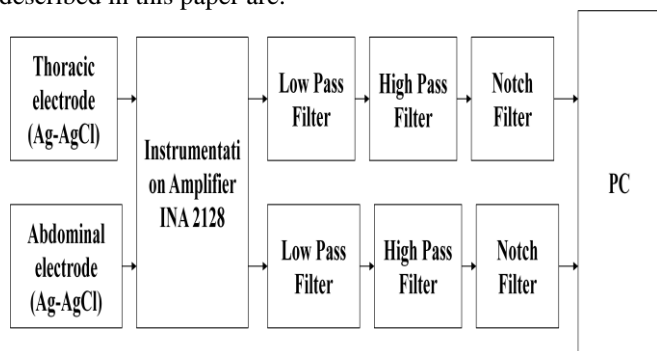

Figure 2: Block diagram of ECG Acquisition Circuit.

Hardware component used for design system is such as shown in figure 2.

1) Ag-AgCl Electrode

Ag-AgCl electrodes are easily available in medical shop with low cost. Disc of electrode can easily fill with conducting jelly to increase conductivity and reduce the noise

[4]. Leads are also very important because improper leads may be another source of noise so we created l meter leads with low impedance coaxial cable with good quality disc 12mm connector.

2) Instrumentation amplifier

The INA2128 is a dual, low power, general purpose instrumentation amplifier offering excellent accuracy. Its versatile 3-op amp design and small size make it ideal for a wide range of applications [5]. Current-feedback input circuitry provides wide bandwidth even at high gain (200kHz at G = 100).

3) Filters

High pass, low pass and notch filters has been designed using OPA4227 op amps low noise and wide bandwidth with high precision to make them the ideal choice for applications [6] requiring both ac and precision dc performance. The OPA4227 is unity gain stable and features high slew rate (2.3V/μs) and wide bandwidth (8MHz).

The softwares used for designing the system described in this paper are:

1) LabVIEW

LabVIEW is licensed software. LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a highly productive graphical programming language for building data acquisition and instrumentation systems [7]. It is a graphical programming language that uses icons to create applications instead of lines of text to create applications. LabVIEW programs are called virtual instruments, or VIs, because their appearance and operation imitate physical instruments, such as oscilloscopes and multimeters [8]. Although there are many different softwares in market for building virtual instruments such as LabWindows/CVI (C for Virtual Instrumentation), HP VEE (Hewlett-Packard's Visual Engineering Environment), TestPoint and Measurement Studio, LabVIEW has superseded all of these due to its unique features.

i) GUI Implementation using LabVIEW

A LabVIEW front panel of the entire system has five tabs. In 1st tab options are provided to the user for performing different tasks like entering patient's data, acquire and store signal, Retrieving stored signal and analysis and acquire sound and their analysis as shown in Figure 3.

1. 'Enter Patient's information' gives pop up window for entering patient's data as shown in figure (b).
2. The TECG and AECG signals of subject can be acquired and stored as a .wav file by clicking on 'acquire ECG and store' button. Figure (c) shows the front panel result window of acquired and stored signal.
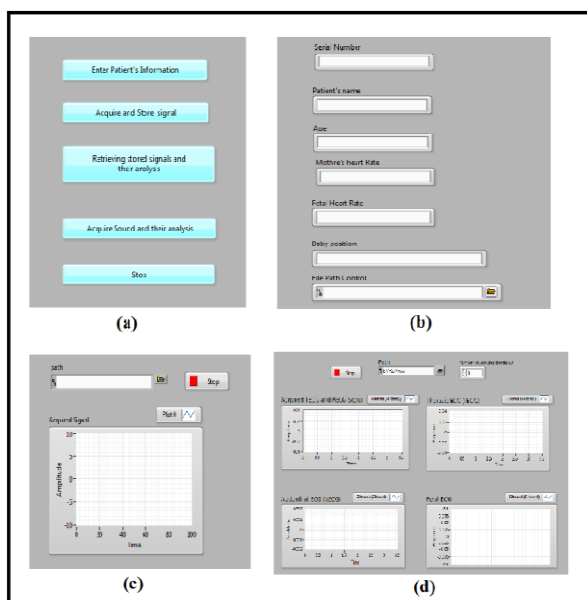
Figure 3: (a) Front Panel showing Options for User. (b) Front Panel window for entering patient's data. (c) Front panel result window of acquired and stored signal. (d) Front panel result window of retrieving stored signal and their analysis

3. The stored ECG signal (.wav file) of various subjects can be retrieve and analysis part of signal can be take place by clicking on 'Retrieving stored ECG signal and their analysis' button. Figure (d) shows the front panel result window of retrieving stored signal and their analysis.

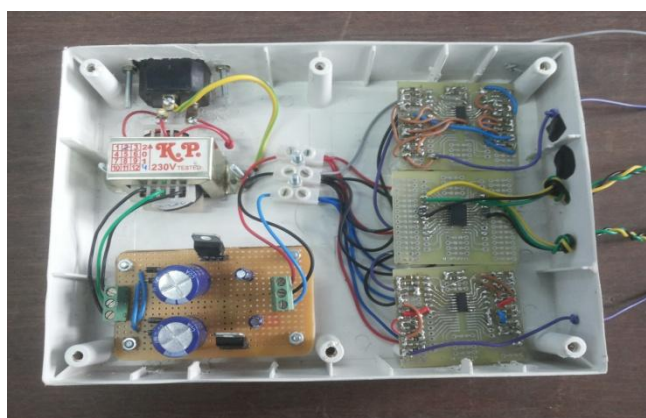## IV. DESIGNED SYSTEM AND RESULTS

Figure 4: Internal View of Complete hardware Circuit.

Figure 4 shows internal view of complete hardware circuit of the project. The main goal is to make the entire system light, compact and portable the proposed kit was scaled down in size

so that it could be easily transported anywhere. Surface Mounted Devices (SMD) resistors, capacitors and IC's were used because it occupies very less space and hence were advantageous for reducing the size of the kit. The entire circuit was placed inside a box, drilled with screws and the wires were kept in place with the help of industrial glue so that the connections between the IC's, resistors and the capacitors were permanently fixed. Six holes were drilled outside the side of the box for the three inputs of the TECG amplifier and the three inputs of the AECG amplifier. The input to the ECG amplifier circuit was give through the ECG leads attached to the thoracic and abdominal surface of the pregnant subject.

The acquired thoracic ECG and abdominal ECG signal has been displayed on LabVIEW waveform graph as shown in figure 5.
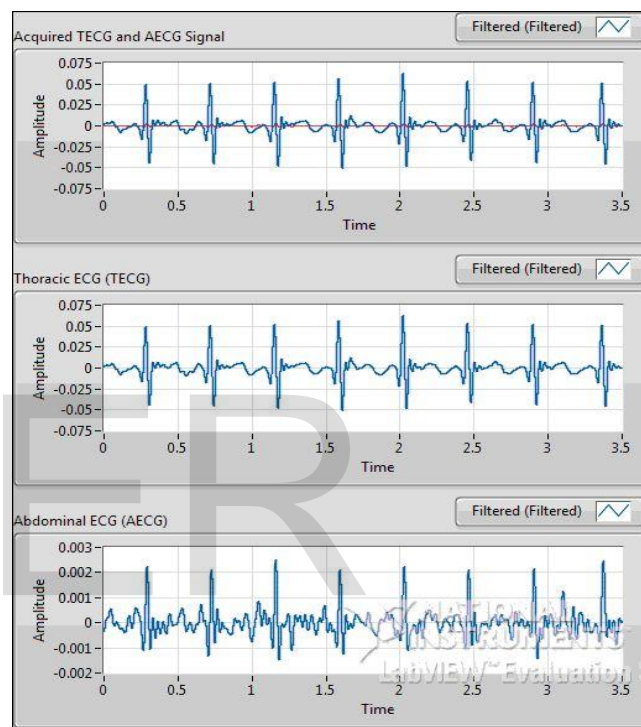

Figure 5: Acquired thoracic ECG and abdominal ECG signal on LabVIEW

The following figures show the acquired and processed TECG, AECG and FECG signals in LabVIEW. The waveform graph first shows the acquired TECG and AECG signal. The abdominal ECG signal is not clearly visible because the signal extracted from the abdominal ECG is little away from the heart as compare to signal extracted from the thoracic region, so the amplitude of abdominal ECG signal is small as compare to thoracic ECG signal. In LabVIEW by using splitter we separated the thoracic and abdominal ECG signal such as shown in 2 and 3 waveform graph. The software filter use for the thoracic ECG are LPF (Bessel) and HPF (Butterworth) and for the abdominal ECG are LPF (Inverse chebyshiv) and HPF (Butterworth) such as shown in waveform graph 4 and 5. And

waveform graph 6 shows the Fetal ECG signal which extracted using differential algorithm.
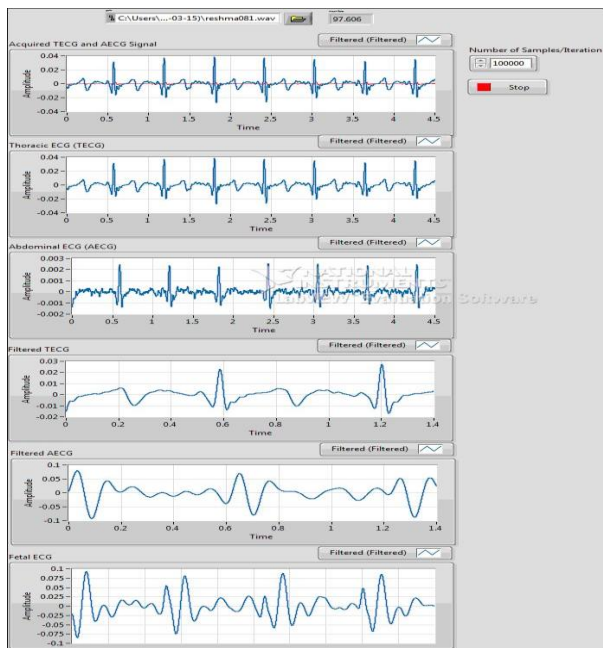

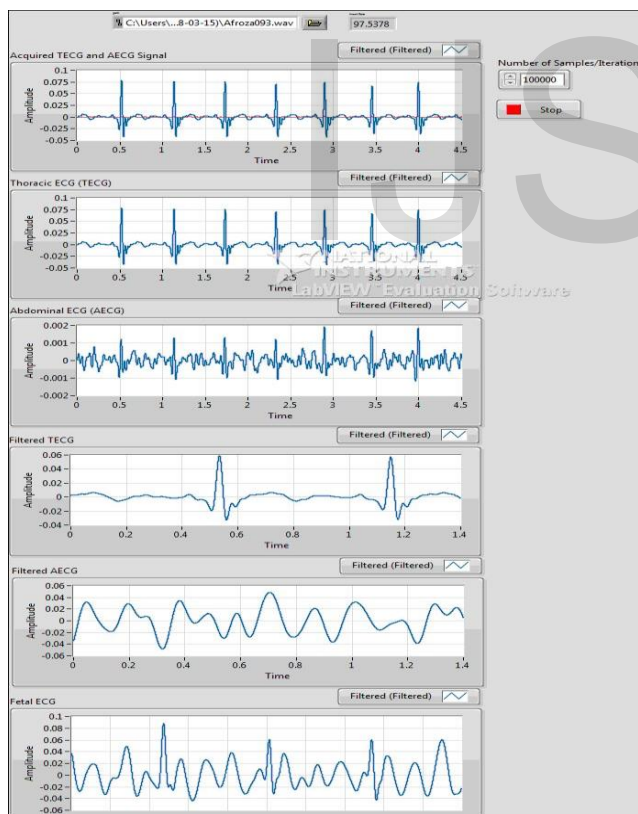Figure 6: Extracted (TECG, AECG, FECG) signals of 8 month pregnant subject

Figure 7: Extracted (TECG, AECG, FECG) signals of 9 month pregnant subject

Table 4.1: Extracted ECG parameter of various pregnant patients

Sr. No	Name	Amplitude of FECG μV	Beats/ minute (Fetal HR)	Gestation of average age	Baby position as per the sonographic al report
1	Asha Mishra	0.40	171.42	31 weeks 6 days	Presentation-Cephalic, Placenta-Posterior, Grade II maturity.
2	Pooja Shah	0.75	127.65	30 weeks 2 days	Presentation-Cephalic, Placenta-Right Lateral, Grade III maturity.
3	Sarita Varma	0.60	200	39 weeks 1 days	Presentation-Cephalic, Placenta-Anterior, Grade III Maturity.
4	Savita Patil	0.56	153.32	37 weeks	Presentation-Cephalic, Placenta-Anterior, Grade II Maturity.
5	Aafrabi	0.30	187.5	32 weeks 6 days	Presentation-Cephalic, Placenta-Fundo Posterior, Grade III Maturity.
6	Gausiya	0.20	127.37	36 weeks 4 days	Presentation-Cephalic, Placenta-Posterior, Grade III Maturity.
7	Reshma	0.24	157.89	32 weeks 5 days	Presentation-Cephalic lie, Placenta-Posterior, Grade II Maturity.

V.   Conclusions

For the detection of FECG from the composite AECG signal, the differential algorithm with FFT plays a significant role. For the analysis purpose LabVIEW has been used as the GUI

tool. Time analysis, frequency analysis, and differential Algorithm are the different ways to eliminate maternal QRS complex and we have acquired a significant level of FECG waveform. Many TECG and AECG signals of pregnant subjects were taken and analyzed. These signals have significant information about the fetal and its cardiac health. Even though the amplitude of FECG is very small, by using high gain amplifier and LabVIEW tools, significant information about positioning of fetus at different trimesters is extracted. In this method we got clear picture of heart rate as well as distinct QRS complex. Using this device, a pregnant subject can monitor the ECG of fetus without stepping out of home in case if she is trained. It's small, portable and provides good SNR monitoring features. Hence "Non–invasive Extraction of Fetal ECG using Differential Algorithm and Analysis using LabVIEW" is low cost and easy to use for pregnant subjects.

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