Design and Implementation of wireless heart monitor for expectant mothers in their 3rd trimester

Niyan Marchon[1], Dr. Gourish Naik[2]

[1](Electronics and Telecommunication Department, Padre Conceicao College of Engineering, India)
[2](Electronics Department, Goa University, India)

ABSTRACT: *A low cost Maternal & Fetal Heart Rate (MFHR) monitor is introduced in an attempt to reduce or eliminate hypoxic episodes well before the development of fetal asphyxia. MFHR monitoring is sensitive and detects fetal hypoxia early in the evolution to acidosis. The abdominal electrocardiogram (AECG) is the recording of the cardiac activity of both the mother and the fetus. The main challenge is to extract the fetal ECG, which is strongly distorted by maternal component of dominating energy and artifacts like baseline wander and power-line interference which were effectively preprocessed and filtered by using a Kaiser FIR filter having a SNR ratio of 13.68 , filter order of 298 and a Notch filter (fc = 50 Hz) with a bandwidth of 2 Hz respectively. Our endeavor has been to design this MFHR monitoring device using a smartphone. This system continuously monitors the patient's AECG data especially in the 3rd trimester. For the ongoing research work the maternal AECG signals were taken from the Physionet non-invasive ECG database. The AECG file is transferred from the PC to a microcontroller ATMEGA32A which is interfaced to a Bluetooth module. Data is then transferred wirelessly via Bluetooth to the phone. The smartphone contains an application that displays data received from the Bluetooth module interfaced with a plotter application. This Bluetooth Plotter application plots the ECG waveforms of the content on the phone. Various inferences were effectively made based upon the ECG graphs produced on the phone, thus giving the doctors an alert about the patient's and Fetal ECG information. Further research will examine the real time patient's data from the hospital assigned to us.*

Keywords: Maternal & Fetal Heart Rate (MFHR), asphyxia, Abdominal Electrocardiogram (AECG), baseline wander, power-line interference, Physionet, Bluetooth, smartphone.

I. Introduction

The intrapartum management of fetal distress is a challenge to obstetricians, compounded by difficulties in interpreting the fetal heart rate (FHR) pattern and confusion regarding the definition of asphyxia. Fetal asphyxia refers to acidosis resulting from progressive hypoxia in utero [1]. FHR monitoring is sensitive and can detect hypoxic episodes early in the evolution to acidosis. Electronic FHR monitoring was introduced in an attempt to reduce or eliminate the potentially disastrous consequences of fetal asphyxia. Enthusiasm for this new technology established the role of continuous FHR monitoring in labor before studies demonstrated its accuracy. Abnormal FHR patterns in the auscultation can be backed up by electronic fetal monitoring. Electronic FHR monitoring has other benefits over auscultation that are not always considered. These include an ability to understand the mechanism of developing hypoxia by pattern recognition and the ability to assess the fetal response to hypoxia by evaluating reactivity or variability. Reports shows in table I the total infant deaths occurred in the year 2012 in the medical hospitals in Goa, India, where 5 % of the infant deaths have occurred due to birth asphyxia.

TABLE I. CAUSE OF DEATH IN INFANTS AT THE MEDICAL HOSPITALS IN GOA

Total deaths	Congential Anomalies	Low birth Weight	Sepsis	Birth Asphyyxia	Others
249	81	69	66	12	21

Newspaper report, Heraldo (Insight) Friday, May 17 2013

FHR monitoring has several disadvantages, however. The most important is, increased cesarean sections (CSs) associated with overreaction to, or misinterpretation of, FHR patterns and a large increase in medicolegal malpractice litigation.

The ideal goals of fetal assessment in labor should be: 1) To detect and reverse hypoxia before it progresses. 2) Failing the ability to reverse hypoxia, monitoring should allow physicians to detect hypoxia and

determine when it leads to metabolic acidosis. 3) This allows for intervention by operative delivery before fetal death or damage occurs.

Electronic FHR monitoring is helpful in detecting hypoxia, but determining the precise point when metabolic acidosis occurs is difficult at best. The frequency of metabolic acidosis in labor is generally approximately 1% [1].

Despite disadvantages, the goal of protecting the fetus during this potentially dangerous 3rd trimester should and does supersede all other considerations. A thorough understanding of abnormal FHR patterns not only allows physicians to direct resuscitative efforts and prevent hypoxic damage but also prevents unnecessary interventions.

II.   Procedure For Denoising AECG

The Non-invasive abdominal ECG (AECG) taken from the online Physionet database as shown in figure 1 is the recording of the cardiac activity of both the mother and the fetus when several leads are placed on the abdomen of the mother. The motivation for monitoring the fetal heart rate through pregnancy is to recognise pathologic conditions, typically asphyxia, with sufficient warning to enable intervention by the clinician before irreversible changes set in. Fetal ECG is strongly distorted by the maternal component having a dominating energy and other artifacts such as baseline wandering and power line interference. An efficient way to remove the baseline wander is to use FIR Kaiser High pass filter. It also exhibits the highest SNR ratio, while all the IIR filters displayed a poor SNR ratios [2].
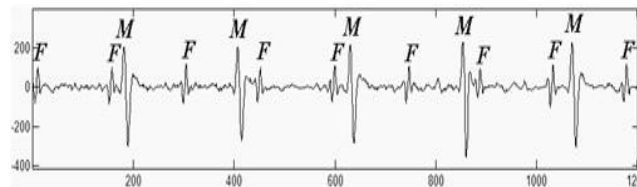

Fig 1 Composite Maternal Abdominal Signal; M- maternal QRS complex, F- fetal QRS complex

The Fast Fourier Transform (FFT) of the denoised signal shows that the 50 Hz frequency component has been effectively removed using the Notch filter. The combined methodology of using the Kaiser FIR high pass filter, Notch filter followed by the Savitzky Golay filter effectively denoises the abdominal Maternal ECG signal without destroying the fetal ECG information [2] as shown in figure 2.
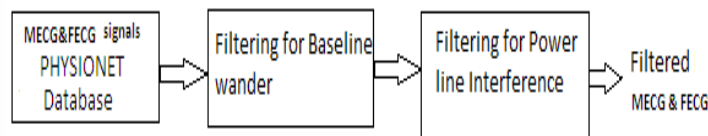

Fig 2 Combination method: Proposed Technique to filter AECG signals.

III.   Implementation Of The Wireless Heart Monitor

The wireless heart monitoring device consists of the Physionet non-invasive AECG database which is fed to the ATmega32 microcontroller, Bluetooth module and a smart phone as shown in figure 3. The physionet patient's recording was taken from a single subject between 21 to 40 weeks of pregnancy with a 10 second duration for each signal [3]. The signals sampled at a rate of 1 kHz, with 16 bit resolution which are sent to the Microcontroller via the HyperTerminal. The digital values are sent by the ATmega32 microcontroller to the smart phone via Bluetooth module as shown in figure 4. An Android application developed using the smart phone displays the ECG signal waveform using the digital values obtained from the Bluetooth module. The Android application also calculates the heart rate and checks whether it is above a threshold level. In case any abnormality is found the smart phone immediately sends a message to the doctor.

To test the proposed system, we imported data from Physionet and created our own database of three diseases for training the neural network. Each patient record, sampled at 1ms each contained 1000 values. This was further compressed using Debaushy's wavelet transform to 42 values. Three patient's records of each disease, of 10millisecond, were imported for each disease for training.
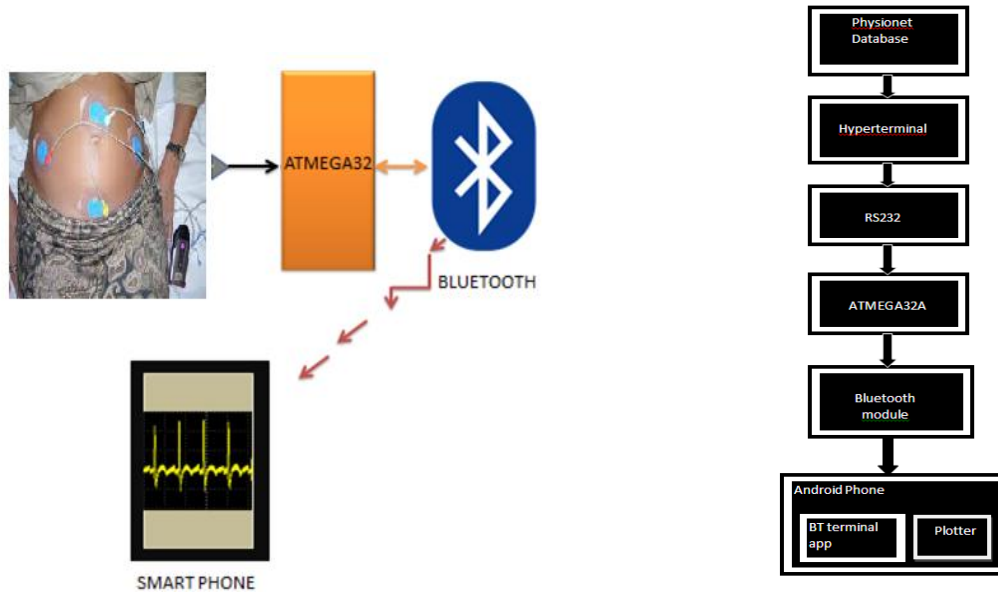
Fig 4 Flowchart of the proposed Wireless Heart Monitor   Fig 3 Proposed system of a Wireless Heart Monitor

3.1 . Initialization and Sending/Receiving data

The ATmega32 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, theATmega32 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

3.1.1 Baud Rate: The microcontroller does not accept the baud rate value. Instead, this value is used to calculate a value called Baud Number which is stored in a 16 bit register. This number signifies that value from which the counter has to go to zero so as to get/send the next bit. Hence, choosing a value of F_CPU = 8 MHz and a Baud Rate of 9600 bps, we get Baud   Number = 51. Therefore, each time before sending / receiving a bit, the CPU counts from 51 to 0.

3.1.2 Enable the receiver and/or transmitter: This is done by writing a '1' to the RXEN and/or TXEN bits of the register UCSRB.

3.1.3 Selecting mode of operation: You can use USART in synchronous as well as asynchronous mode.That is done by altering the UMSEL bit in the UCSRC register. Asynchronous mode is generally used (which is the default selection).

3.1.4 Registers and bits involved in sending data: We have to simply write data to a register named UDR to send the data serially. But before that, we have to check if the register is actually ready to receive data. That is done by checking the status of a bit named UDRE. If its status is '1', it means that UDR is at your service and if it is 0, wait for it to become '1' because it is already busy serving you.

3.1.5 Register and bits involved in receiving data: In order to receive data, we have to simply transfer the contents of UDR into a variable. But before this, we have to check if we have received the entire byte. This is done by checking the status of RXC bit. If RXC is '1', then there is an unread byte in UDR which needs to be emptied so as to receive the next byte of data.

3.2 USB2.0 to RS232 converter

As the baud rate is 9600 bits per second, hence one bit takes 1/9600 seconds or 104 micro sec. Our AVR ATmega32A will communicate with the computer through the RS-232 protocol. On the computer side we need to use the terminal emulation program that can communicate through the RS-232 protocol. For this ongoing research work, we used the standard windows communication program called HyperTerminal.

3.3. Bluetooth Module:

Serial Bluetooth RF Transceiver Module Interface JY-MCU BT_BOARD V1.3 was used. The power supply input of the module is 3.6 ~ 6V, and should not be more than 7V.This Bluetooth Module Baseboard can be compatible with master mode, slave mode and both master-slave mode. The key interface on the baseboard is

the master mode button and can be controlled by high level from external MCU, then this module will search again automatically.

Fig.5 Bluetooth Module: JY-MCU BT_BOARD V1.3

3.4. Neutral Networks to classify the heart diseases:

We have used the concept of neural networks to train a network, through supervised learning, to help classify an ECG into different heart diseases. For our present network, we used Physionet database and created a database of different patient records (taken over a period of 10 seconds each, with readings at an interval of 1ms each) for three different types of heart diseases viz. Atrial Fibrillation, Congestive Heart Failure and Ventricular Malignancy. The network helps classify which of the above disease, the test ECG belongs to.

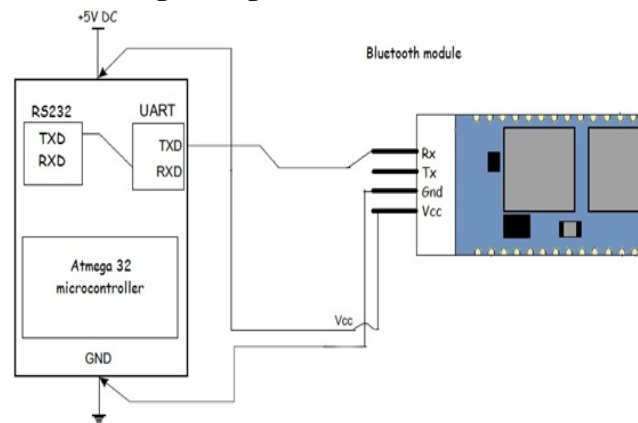## IV. Interfacing Atmega32 With The Bluetooth Module

Fig.6 Interfacing ATmega32 with the Bluetooth Module

For the interfacing, the TXD pin of Atmega32 is connected to the RX pin of the Bluetooth module. We have used 9600 bps as the baud rate for the serial communication and also for the communication between the Atmega32 and the Bluetooth module. By default the Bluetooth module transmits and receives at 9600/8/N/1.The power supply options are 3.6 to 5V.When powered up, the chip will blink red. Even after tethering, it will continue to blink. As soon as something initializes the connection by trying to send or get data, the light will switch to solid red.

V. Interfacing Atmega32 with the Bluetooth Module

An already present 'Bluetooth Terminal' application (that allows us to display the values received by a phone from another device, via Bluetooth, on the phone screen) and a coded application called 'Plotter' (that plots ECG graph) were interfaced with each other to provide our resultant application called, 'Bluetooth-Plotter'. It can be described as an Android application that asynchronously receives and plots graph data from an SPP (serial port profile) Bluetooth device using the RFCOMM protocol. The 'Bluetooth-Plotter' application consists of four codes: Bluetooth chat, Bluetooth chat service, Device list activity and the Graph view.

VI. Results

The physionet non-invasive AECG data was filtered and processed. The Bluetooth transmission module (JY-MCU BT_BOARD V1.3) was interfaced with the ATmega32 and successfully carried out the communication between them. The AECG was displayed on a smart phone using Android as shown in figure 7. The neural network correctly classified one of the three heart diseases which was fed to the module.
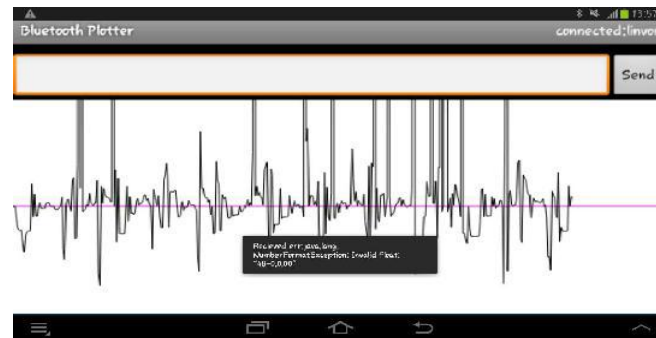
Figure 7: AECG plotted using Android application

VII. Conclusion

A low cost Maternal & Fetal Heart Rate (MFHR) monitor device using a smartphone was introduced in an attempt to eliminate hypoxic episodes well before the development of fetal asphyxia in the 3rd trimester. The AECG signals from the Physionet effectively filtered [2] the baseline wander and power-line interference using a Kaiser FIR filter having a SNR ratio of 13.68 , filter order of 298 and a Notch filter (fc = 50 Hz) with a bandwidth of 2 Hz respectively. The AECG file was transferred from the PC to a microcontroller ATMEGA32A which was interfaced to a Bluetooth module. Data was then effectively transferred wirelessly via Bluetooth to the phone. The Android smartphone's application 'Bluetooth plotter 'displayed the ECG waveform. Various inferences were effectively made based upon the ECG graphs produced on the phone, thus giving the doctors an alert about the patient's ECG information. Further research will examine the real time maternal and Fetal Heart rate to be alerted to the Hospital doctor.

Android being an open source allows future scope of adding enhanced functionality. GPS and GSM API's could be integrated in the application so that a patient's location could be tracked, and the doctor whose number has been already stored could be notified.

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