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# Embedded Based Wireless ECG System

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**Abstract**— The aim of the paper is to design an embedded based wireless ECG system using IEEE 802.11G. With the emerging application of embedded systems in all the fields, the use of microcontrollers can be applicable to the field of medical sciences. In the conventional ECG system, the system is complex due to the higher number of wires from patient's body to the monitoring section. And one more disadvantage is that a cardiac specialist cannot monitor all emergency ward patients ECG. At a time, he can monitor only one patient in the hospital. In this paper, we present a design by which the specialist can monitor all patient's ECG sitting in his room using IEEE 802.11G as main communication between devices and also designed a EMI filter to remove power line interference on ECG signals.

**Index Terms**— Cardiac specialist, ECG, EMI filter, IEEE 802.11G, Microcontroller, Medical science, power line interference.

## 1 Introduction

MOBILE telemedicine systems are becoming more important all the time, especially in the care of patients that are isolated or traveling, far from a reference hospital. These systems must be embedded in low cost, small devices with low power consumption, and should have an interface that is usable by the patient. Incorporating technologies such as Bluetooth, GPRS, GSM or IEEE 802.11G (Wi-Fi) to these systems allows the wireless transmission to health or control centers. This paper describes a low cost, portable system with wireless transmission capabilities for the acquisition, processing, storing and visualization in real time of the electrical activity of the heart to a PC.

In our paper, we have used embedded systems to acquire the signal from patient using two paste electrodes and amplify the signal using an instrumentation amplifier. The amplified signal is filtered using an RC network. Then it digitized using PIC microcontroller and given as serial port input as PC.

In today's modern world, as everything goes wireless, in our paper ECG also goes wireless. The digitized ECG signal is transmitted using IEEE 802.11G. The transmitted signal is received and viewed in MATLAB. The wireless networking is controlled by NETBEANS which is a java application IDE. In MATLAB, it is filtered from power line interference by designing an EMI filter.

## 2 General Block Diagram

### 2.1 Transmitter

The Transmitter block consists of electrodes, signal conditioning, filter, and controller and IEEE 802.11G system.

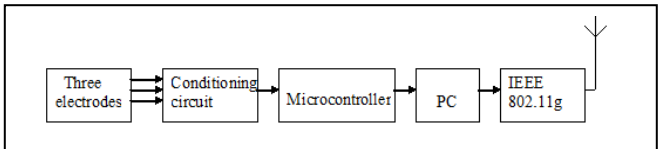


Fig. 1. Block diagram of transmitter

### 2.2 Receiver

The receiver consists of IEEE 802.11G interfaced to computer by the software Netbeans which has MATLAB.

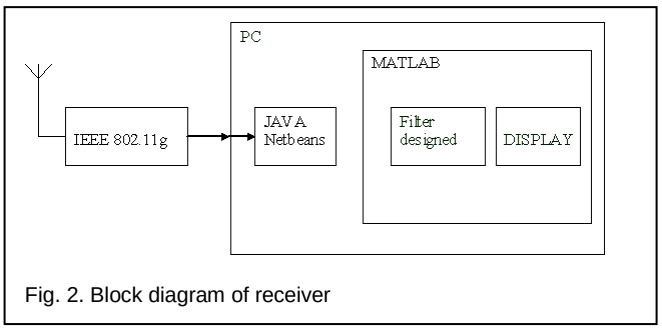


Fig. 2. Block diagram of receiver

## 3 Explanation Of The Block Diagram

### 3.1 Sensors

In our ECG we use two paste electrodes which are meant for acquiring ECG signals. By convention, the positive electrode lead on the left arm (LA), and the negative electrode lead on the right arm (RA), and therefore measure the potential difference between the two arms.

### 3.2 Signal Conditioning

This module consists of a high pass filter to eliminate very low frequency noise. This is also used to remove the phase shift problem occurring in the acquisition of ECG signal. The ECG signal which is of very low amplitude has to be amplified as well as filtered from the noise signal. The signal conditioning circuit should consist of the two stages an amplifier using AD620 and a high pass filter of 0.05 Hz critical frequency.

### 3.3 ECG Signal Digitizing

A PIC16F877A microcontroller is used for analog to digital conversion. The input from the signal conditioning circuit is given as input to RA0 of port A. Then it is digitized using the AD conversion module in the device. The output is taken from USART module and given as serial port input to PC.

### 3.4 Wireless Transmission

The digitized data is received through serial port using java platform pc and transmitted via IEEE 802.11G USB adapters to remote desktop. The java platform has to be run for transmission over wireless networks.

### 3.5 Receiver

Using the java (NETBEANS platform), the data received as text file and it is viewed in the MATLAB software. The data is converted back into analog value and the values are updated from time to time. In MATLAB this signal is removed from power line interference using an EMI filter.

This EMI filter is based upon core algorithm. In this algorithm, the sinusoid of power line signal is obtained and subtracted from the original ECG signal with noise to obtain refined ECG signal. The output is compared with output of RLS algorithm designed for the removal of 50Hz power line interference. Thus the signal graph is viewed in MATLAB.

In our experimentation, two ECG transmitters are used and the signal is viewed in single receiver using java platform. By programming, it has been done to select the desired transmitter using either IP address or host name of the personal computer. By this we can demonstrate that all the patients can be monitored round the clock and database can be maintained.

## 4 EMI Filter Design

Power line interference coupled to signal carrying cables is particularly troublesome in medical equipment such as electrocardiograms (ECGs). Cables carrying ECG signals from the examination room to the monitoring equipments are susceptible to electromagnetic interference(EMI) of power frequency (50 Hz or 60 Hz) by ubiquitous supply lines and plugs so much so that sometimes the ECG signal is totally masked by this type of noise.

Filtering such EMI signal is a challenging problem given that the frequency of the time-varying power line signal lies within the frequency range of the ECG signal, there are some other technical difficulties involved. The most important of which is the low sampling frequency at which the ECG signals are taken and the low computational resources available at the level of the apparatus.

This problem was one of the first to attract the attention of developers of adaptive filtering theory. Although classical adaptive filtering provides a partial solution to the problem, the problem is still considered open und research continues to find an ultimate solution. A recently developed signal processing algorithm, introduced in has been found promising in construction of an EMI filter with all desirable features while complying with technical constrains such as low computational resources & low sampling frequency.

The proposed EMI filter employs the core algorithm as its main building block and constitutes a universal narrow-band EMI filter for elimination of quasi-periodic interference. The proposed EMI filter offers a robust structure and is shown to have a high degree of immunity with respect to external noise.

## 5 Shortcomings of the Existing Model

Notch filter cannot be used since the frequency can vary about fractions of hertz in power lines. Wide band stop filter also cannot be used since it can distort the ECG signal itself. Use of external reference power line signal also cannot used since it is impossible to implement.

## 6 Requirements of an EMI Filter

The EMI filter should act as a sharp notch filter to eliminate only the undesirable power line interference. It should automatically adopt itself to variations in the frequency & level of noise and also the adaptation must be done very quickly to keep the signal clean. It must be robust with respect to variations in internal & external conditions and also be able to work in low information conditions.

$$y(t) = \sum_{k=1}^{N} [A_k \cos \emptyset_k + n(t)]$$

## 7 Description of the Developed Algorithm

In this section we shall review the mathematical structure & properties of the core unit employed to construct the proposed EMI filter. Let u(t) denote a signal comprising of number of individual sinusoidal components & noise expressed by

(1)

And $\emptyset_k = \omega_k t + \theta_k$. Where $\emptyset_k$ the total phase and n(t) is denotes the total noise which is imposed on the signal.

The objective is to find a scheme for estimating a certain component of such input signal as fast & accurate as possible. It should not be sensitive to the noise and potential time variations of the input signal.

Let M be a manifold containing all the signals defined as

$$M = \{y(t, \theta) = \theta_1 \sin(\theta_2 t + \theta_3 | \theta_i \epsilon [\theta_{i_{min}}, \theta_{i_{max}}])\}$$

(2)

where $\Theta = \{[\theta_1, \theta_2, \theta_3]^T | \theta_i \epsilon [\theta_{i,min}, \theta_{i,max}]\}$ is the matrix of parameters which belongs to the parameter and T denotes matrix transposition .to extract sinusoidal component of u(t) ,the solution has to be an orthogonal projection of u(t) onto the manifold M ,or equivalently has to be an optimum which minimizes aa distance function d between and i.e.,

$$\theta_{opt} = arg \max_{\theta \to \theta} d[y(t,\theta), u(t)] \quad (3)$$

In the least squares method d is the instantaneous distance function by

$$d^2(t,\theta) = [u(t) - y(t,\theta)]^2 \triangleq e(t)^2 \quad (4)$$

The error function e(t) is the totality of the components present in the input signal other than the component of interest, plus the error incurred in the estimation process. The parameter matrix is estimated by using the gradient descent method as follows:

$$\frac{d}{dt}\theta(t) = -\mu\frac{\partial}{\partial\theta}[d^2(t,\theta)] \quad (5)$$

## 8 Structure of The Proposed EMI Filter

One single unit of the core algorithm can be employed to extract the power line signal mixed with the ECG signal. This unit can efficiently follow the variations in amplitude, phase, and frequency of the interfering signal. Once it is extracted it is subtracted from the input signal to yield a clean ECG signal. In order to further enhance the performance of the filter in applications in which the sinusoidal component to be extracted constitutes a small portion of the signal, the use of a BPF to filter out non power line signal components. It is a second order filter. Its use is to improve the signal to noise ratio [signal here means the power line EMI and noise means all the other component].

At the input of the core unit whatever is not removed by BPF will be effectively removed by the core unit so as to produce a pure sinusoid which is the power line interference. This interference is to be subtracted from the input to provide the clean ECG signal. The BPF characterized by its transfer function $H(f)$ which causes attenuation $|H(f)|$ and phase delay is $\angle H(f)$ are the functions of frequency. Since the core generates the value of the frequency in real time, the attenuation & phase delays are known & can be restored. In practice the filter does not have to band pass & a high pass filter may be sufficient.

A more general configuration may then be employed to eliminate the fundamental & significant harmonics of the power line EMI if it is severely distorted. One of the issues to be considered in the design of the proposed EMI filter is setting of its parameters. As long as the frequency of the input signal is close to its nominal value [e.g.: 50 Hz], it does not introduce any significant constraints. It has been observed that the proposed EMI filter is very insensitive with respect to the variations of parameters. This feature renders the adjustment of the filter fairly simple. All initial conditions of integrators are set to zero except that of frequency which is taken to be 50 Hz

## 9 SAMPLED SIGNALS

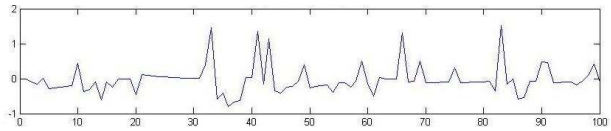

Fig. 5. Output from CORE Algorithm

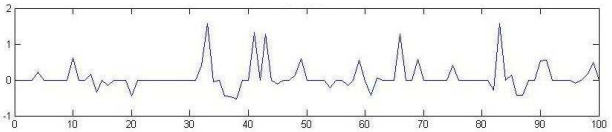

Fig. 3. Input signal

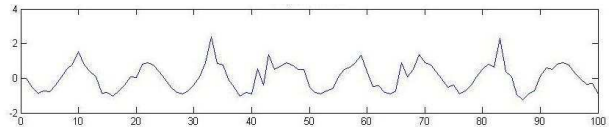

Fig. 4. Output from RLS

## 10 Main Features And Comparison With Existing Method

The main features of the proposed EMI filter can be summarized as follows:

1. Effectiveness in tracking large variations in the parameters of the interfering power signal such as its level & frequency.
2. Obviating the need for interference reference signal
3. Obviating the need for synchronization.
4. Robustness & noise immunity.
5. Simplicity of structure.

## 11 Software Used For Building This Method

### 11.1 MPLAB

MPLAB for programming the PIC microcontroller.

### 11.2 NETBEANS

NETBEANS is a java application platform for wireless networking.

### 11.3 MATLAB

MATLAB for filtering the signal using EMI filter designed and displaying the filter.

## 12 Enhancement

The system designed in the paper is complex due to use of PC at each side .It has been done due to the lack of time and lost. As an enhancement, we make use of an integrated WI-FI chip with a

microcontroller, and also in the patient side, we can make use of 12 lead electrodes to acquire the ECG signal. Thus the patient monitoring side becomes compact whose size is of a mobile phone. The 3G mobiles can be used as receiver using in-built WI –FI in the mobiles. The software can be implemented in J2ME language. Similarly it can be connected to any LAN network using the WI-FI access point. Using GPS, we can also track the patients suffering from severe heart problems (or sudden arrhythmias). This utilizes the mobile phone platform. We can also program the transmitter side processor to alarm the doctor if the patient's ECG becomes abnormal and automatically it can be transmitted to the doctor's PC.

## 13 ADVANTAGES

1. It allows the specialist to monitor the patients' ECG by sitting in his room.
2. The ECG can be transferred to anywhere in the world using WLAN and can get the advice from specialists from all over the world
3. It reduces the complexity of the system by reducing the number of wires.
4. It can be used to store the information in the head doctor personal computer for future references.
5. With WLAN, it provides the WLAN based telemedicine.
6. The ECG signal is removed from the power line interferences by using the EMI filter.

## 4 CONCLUSION

Thus, in our paper, we have designed a wireless ECG system using three most competing technologies by embedded systems using PIC microcontroller, IEEE 802.11G and digital signal processing .The system given here is simple, easier to construct. ECG can be transferred to anywhere in the world using WLAN and can get the advice from specialists from all over the world. In commercial use .it can be made compact form in the size of a mobile phone. Because of reduction in wires, the complexity of system is reduced. Further enhancements can be made easily. With the filter designed, we can eliminate the power line interference without distorting the ECG signal.

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