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Microcontroller -Based System for Electrogastrography Monitoring Through Wireless Transmission

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Electrogastrography (EGG) is a non-invasive method for recording the electrical activity of the stomach. This paper presents a system designed for monitoring the EGG physiological variables of a patient outside the hospital environment. The signal acquisition is achieved by means of an ambulatory system carried by the patient and connected to him through skin electrodes. The acquired signal is transmitted via the Bluetooth to a mobile phone where the data are stored into the memory and then transferred via the GSM network to the processing and diagnostic unit in the hospital. EGG is usually contaminated by artefacts and other signals, which are sometimes difficult to remove. We have used a neural network method for motion artefacts removal and biological signal separation.

Keywords: Electrogastrography, wireless, telemedicine

1. INTRODUCTION

TELEMEDICINE has been proposed as a means of improving the efficiency of the healthcare system, reducing the cost and stress caused by the hospital environment[1,2]. The traditional way of providing telemedicine services is to transmit biomedical signals from a patient to a hospital using “landlines,” such as the Public Switched Telephony Network and the Integrated Services Digital Network[3-5].

The development of mobile technology has led to new m-Health applications in healthcare provision[6]. Although face-to-face consultations between a clinician and a patient will never be replaced, there are medical cases that can be managed more efficiently by adopting wireless telemedicine. A wireless transmission is becoming increasingly popular in healthcare and biomedical engineering[6]. Modern data transmission wireless technologies give new possibilities to the designers of mobile medical equipment. In the last years a new device called Bluetooth wireless terminal has appeared on the market. In most cases it is a pair of tiny devices, mostly used for serial communication link RS-232 replacement. We have developed a small embedded EGG sensor system prototype using Bluetooth technology. This system is versatile and easily transportable.

Electrogastrography (EGG) is a method of recording gastric electrical activity from cutaneous electrodes placed on the abdominal surface[7]. The EGG provides information about the gastric myoelectric frequency and the amplitude or power of the EGG signal in the normal or abnormal frequency ranges. Recording of gastric myoelectrical activity was described by Alvarez[8] in 1921. In the mid 1970s electrogastrography gained renewed interest. Technical improvements and powerful computers made it possible to record and analyze gastric myoelectrical activity, using automated spectral analysis. The non-invasive nature of the technique makes it an attractive tool in both research and clinical settings. To date EGG has been used to study a wide variety of disorders associated with an altered gastric function [9-12]. The main component of gastric myoelectrical activity is called gastric slow wave or basic electrical rhythm (BER). This omnipresent slow wave is roughly sinusoidal and typically identified by its slow frequency and low amplitude (between 100 and 500 µV). The dominant frequency of EGG is 0.05 Hz or 3 cycles per minute (cpm) in healthy humans. Abnormalities in the regularity of the gastric slow wave have been frequently reported to be associated with gastric motor disorders and gastrointestinal symptoms, such as nausea and vomiting, anorexia, dyspepsia and eating disorders. Disturbances of the BER (gastric dysrhythmias) can occur in different patterns[13] as follows: an increase in the dominant frequency of the myoelectrical activity of the stomach from 3 cpm to 4–9 cpm regular activity is defined as tachygastria; a decrease in the dominant frequency of the myoelectrical activity of the stomach from 3 cpm to 1–2 cpm regular activity is defined as bradygastria.

EGG is very vulnerable to motion artefacts[14] which are not only strong, but also have a broadband spectrum, and their frequencies overlap with that of the gastric myoelectrical activity. This makes it difficult to separate them, and quantitative analyses of the EGG data are jeopardized. Therefore, an efficient solution for automated detection and suppression of motion artefacts in the EGG is required. A method using feature analysis and back propagation neural network was also developed to detect and then eliminate automatically motion artefacts in EGG recordings.

2. GENERAL PRESENTATION

Our system is represented by its block diagram in Fig.1. It consists mainly of three modules: The patient’s acquisition and processing board, the medical storage unit in the mobile phone and the medical control unit in the PC. The microcontroller receives the sensor signals from five inputs through the conditioning circuit and stores them temporarily in its EPROM memory. The data are then transferred to the mobile phone via the Bluetooth module and finally sent to the hospital unit via the GSM network. The other possibility is to store the data at home in a personal computer.

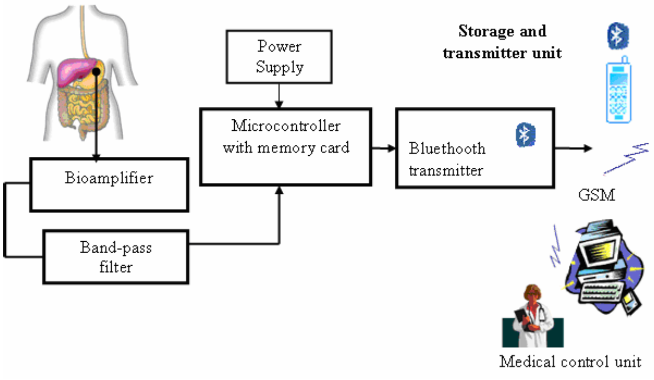

Fig.1 Block diagram of the data-acquisition system.

3. EGG MEASUREMENT SYSTEM

A. Conditioning circuits

A.1. EGG sensor

The electrogastrograph is constructed to measure the electrical potential between various points of the body. We use the Ag-Agcl electrode in a standard EGG acquisition system[7]. Depending on how the electrode pairs are connected to the EGG sensor, different waveforms and amplitudes can be obtained. Each pair contains unique information of the stomach activity.

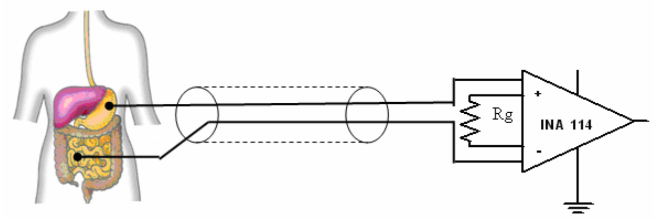

Fig.2 The EGG amplifier circuit

A.2. Instrumentation Amplifier

The instrumentation amplifier chosen for implementation is the INA114 from Burr-Brown (Fig.2). The signal amplitude at the output of the sensor is about 500µV; in this case the value of R_g is chosen to be 51, making the signal's gain close to one thousand.

A.3. Filtering

To remove the unwanted frequencies in this case requires a highly selective bandpass four order filter. The circuit used is made up with four similar stages based on OP 07 operational amplifiers mounted in cascade (Fig.3). The signal frequency components at 1.8 cpm and at 16.0 cpm have an attenuation of 3 dB or 71% in amplitude. Frequency components of interest in the EGG include normal 3.0 cpm slow waves, bradygastria of 0.5 to 2.4 cpm, and tachygastria of 3.7 to 9.0 cpm. From the frequency response of this filter one can see that normal gastric slow waves and abnormal tachygastrias will be recorded with the maximum amplification. The attenuation of low-frequency components is designed to remove the baseline (or DC) drift and obtain stable EGG recording. Bradygastria of below 2 cpm can also be recorded by this equipment.

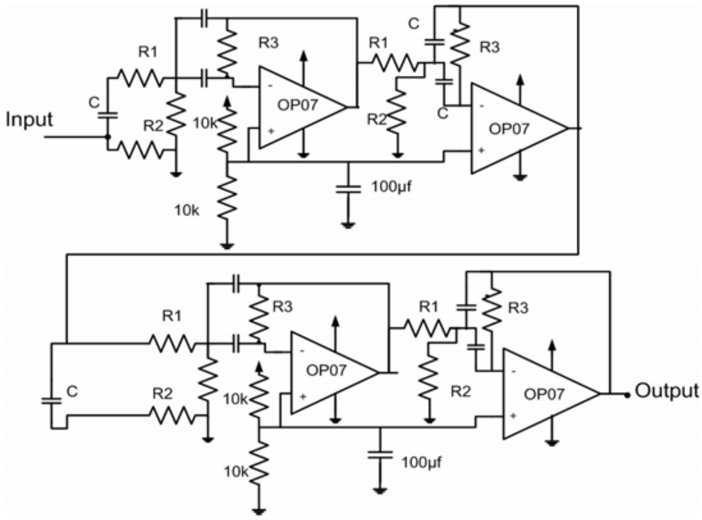

Fig.3 Band pass filter circuit

B. Central Processing Unit (CPU)

The Data Acquisition System is composed of two main subsystems: the programmable digital data acquisition system and transducers with their associated circuits. The requirement of data acquisition system dictated the use of the microcontroller. We adopted the 16 f 876 microcontroller. It is principally composed of 5 channels of 10 bit analog-to-digital converter (ADC), 3 timers and 2 hardware pulse-width modulation (PWM) generator modules, an universal synchronous asynchronous receiver transmitter (USART), an in circuit serial programming interface (ICSPI), 8K FLASH memory, and a 20MHz clock. This clock generator is very suitable for working together with the Bluetooth module to fulfil the wireless communication task.

C. The Bluetooth Transmission Module

Bluetooth technology is the wireless protocol used in the transmitter. Bluetooth has many advantages. First, it is available in a user-friendly modular form. There are many available Bluetooth devices which hide the Bluetooth stack and allow the user to interact with the device using simple modem commands. This reduces development time considerably. In addition, Bluetooth is a common technology on mobile phones, and this will expand the range of use for the transmitter. The Ezurio Bluetooth Intelligent Serial Module II (BISM II) is the device selected for the wireless module. This chip is in compliance with Bluetooth and provides USB and UART communication interfaces. As shown in Fig.4, this system can use UART interface to carry out the data transmission between the module and the microcontroller.

Any device connected via Bluetooth to the PAP-BT board can thus receive data in real-time. Having an excellent range of up to 300 meters with very low power consumption of less than 36 mA makes this module a true class leader.

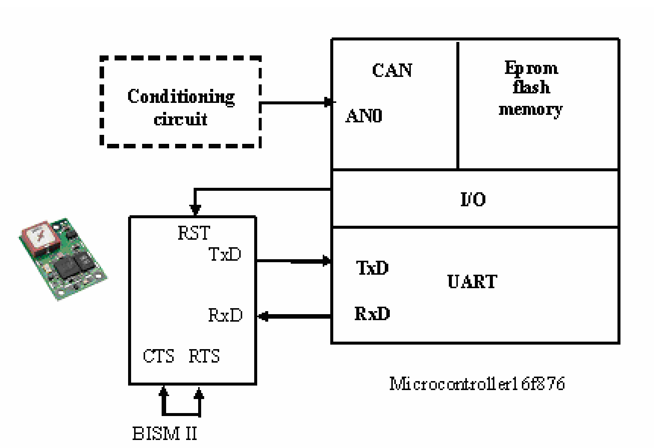

Fig.4 Central processing unit with Bluetooth transmission

4. EXPERIMENTATION AND EGG ANALYSIS

An acquisition has been carried out with the ambulatory system on a volunteer patient over a 4 hours time period. The sampling period chosen was 1 second. Thus, the number of samples acquired over 4 hours was 14.400. These data values were transmitted via the Bluetooth to the cell telephone where they were stored on a Secure Digital memory card using the FAT 16 format. After 24 hours the stored data were sent to the PC in the hospital via the web service.

Fig.5-a represents a slice of 250 samples of the received signal stored in the PC memory.

This interval has been chosen with artefacts peaks resulting from the volunteer's movement during the acquisition. These pulses with very short durations are therefore present inside the signal received by the PC. The spectral representation of the signal is given in Fig.5-b.

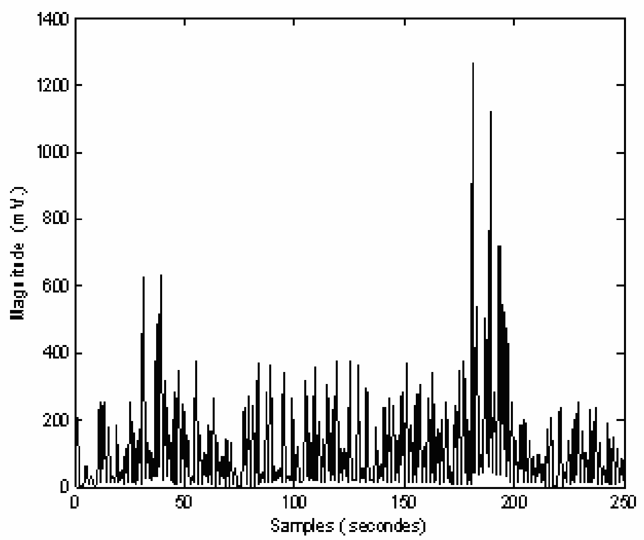

Fig.5-a Representation of 250 samples of the signal received by the PC

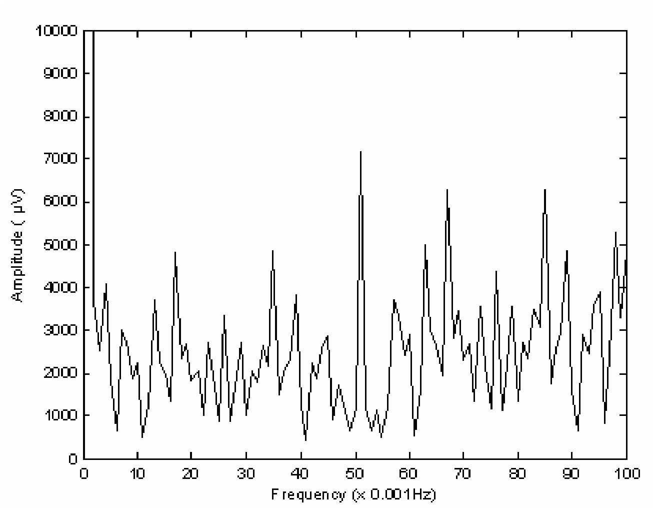

Fig.5-b Spectral representation of the network input signal.

In the part of our signal (Fig.5-a) we observe two pulse peaks around 40 seconds and 180 seconds. The suppression of the artefact peaks by filtering is to be avoided because of the presence of a frequency band common to the useful EGG signal and we have chosen to use neural nets to overcome this difficulty.

A . Motion artefact in EGG measurement

Up to a recent past, the deletion of EGG data with motion artefacts was performed by visual inspection. Unlike other electrophysiological recordings, the EGG is very vulnerable to motion artefacts in the ambulatory carried system. The artefacts are not only strong, but also have a broadband spectrum, and their frequencies overlap with that of the gastric myoelectrical activity. This makes it difficult to separate them, and quantitative analyses of the EGG data are jeopardized. Therefore, an efficient solution for automated detection and elimination of motion artefacts in the EGG is required.

B. Suppression of the artefacts by using the neural network methods

Neural networks have been widely used in pattern recognition due to their great potential of high performance, flexibility, cost-effective functionality, and capability for real-time applications. A number of successful applications of the neural network to biomedical signal detection and pattern recognition have been reported [14-15].

In this study, a method using feature analysis and backpropagation neural network is developed to detect and then eliminate automatically motion artefacts in EGG recordings. Special studies on motion artefacts of EGG are designed. The feature of the EGG is analyzed and used as the input of the detection system, which is realized by a backpropagation neural network. Performance of the neural networks using different features is compared to obtain an optimal selection of the features. The back propagation neural network is so powerful that it can learn a mapping of many complexities, and is used in perhaps 80 to 90% of practical applications. Fig.6 shows the network structure. The network has three layers: one input layer, one hidden layer, and one output layer. The output for the data with motion artefacts is set to one, whereas the output for those without motion artefacts is set to 0.

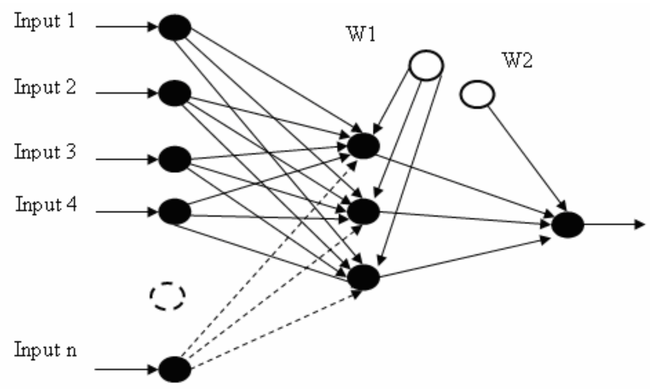

Fig.6 The network structure

The number of neurons in the hidden layer is one of the parameters to be designed, and experimental results show that three were optimal. The transfer function of the hidden layer is a tan-sigmoid function, whereas that of the output layer is a hard-limit function[8]. Because all transfer functions used in backpropagation network must be differentiable (derivatives of error are calculated at each learning step), a log-sigmoid function is used in the output layer.

C. Application to the EGG signal

After fixing and testing the parameters of the net with different simulations, we applied it to the case of an acquired EGG signal. For this purpose, we selected a pack of 250 samples that contained two artefact peaks. The obtained results are presented in the following diagrams (Fig.7-a and Fig.7-b).

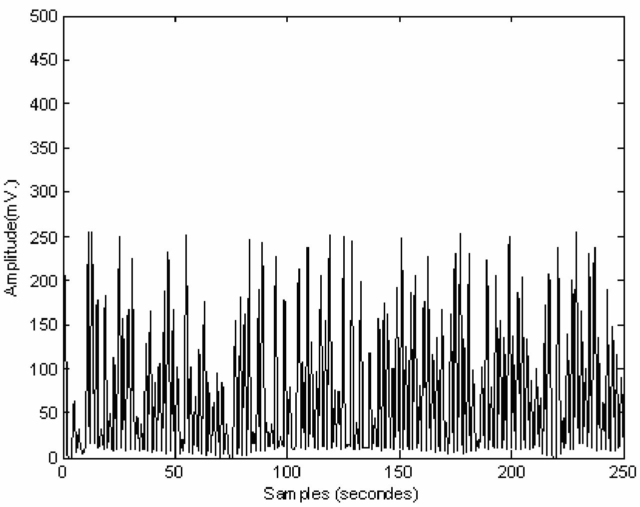

Fig. 7-a Output signal of the neural network.

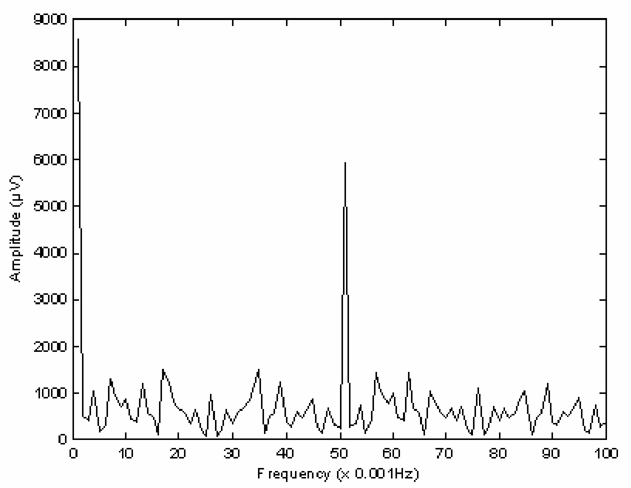

Fig.7-b Spectral representation of the network output signal

5. DISCUSSION

The previous result shows the quasi-suppression of the artefact peaks relatively to the shape of the acquired EGG signal. In the time-domain, Fig.5-a and 7-a above represent the input and output signals of the net, respectively. We have clearly verified the absence of the two artefact peaks that were present in the input signal of the net.

This result is confirmed in the spectral representation of the signal. Indeed, we observe, through Fig.5-b and 7-b a decrease of the frequency magnitude close to that of the fundamental gastric slow wave. These frequencies correspond to the artefact peaks that have been suppressed. The BER gastric wave of a frequency close to 0.05Hz appears clearly in the output signal of the net and the frequency components of the movement's artefacts are highly reduced.

This method overcomes the problem of non-adaptation of the classical filtering techniques in the case of this type of noise.

6. CONCLUSION

This study proposes and investigates the application of a GSM and the Bluetooth technology to a wireless-type EGG signal measuring system and the feasibility of the proposed system. According to our experimental results, the proposed system is proved to be feasible. The non-invasive nature of the technique makes it an attractive tool, in both the research and clinical settings. The use of an autonomous ambulatory system enables the patient to remain free in his movements during the signal acquisition. Our wireless transmission system permits to store the data acquired in the patient's mobile phone memory, and then to transmit them to the processing unit of the hospital through the GSM net. The presence of the patient in the hospital becomes no longer necessary and the distance separating the patient and the hospital is no longer a constraint.

Thanks to the ambulatory feature of the acquisition, the movement artefacts are unavoidable and disturb interpreting and analysis of the EGG signal. The application of an automatic processing method based on the use of neural networks enables a very important reduction of these artefact peaks.

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