Development of a Wireless embedded system to reduce the influence of Gaussian noise and 50 Hz Power line noise in Electromyography (EMG)

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Abstract: - Electromyography (EMG) is a technique for evaluating and recording the activation signal of muscles. In EMG, the electrical source is the muscle membrane potential of about -70mV. Measured EMG potentials vary depending on the muscle under observation. The typical repetition rate of the muscle unit firing is about 7-20 Hz, depending on the size of the muscle, previous axon damage and other factors. EMG signals are influenced by electrical environmental noise. The main sources of these noise signals are the noise from the differential amplifier circuit that is normally included in data logger devices and 50 Hz power line noise. In this paper a development of a Wireless data acquisition system is presented. The system uses an embedded system and the commercial ZigBEE protocol to reduce the influence of white Gaussian noise and 50Hz Power line noise from EMG measurements signals.

Key-Words: - Index Terms, Electromyography, White Gaussian noise, embedded systems, ZigBee, LabVIEW

1 Introduction

Electromyography (EMG) is a technique for evaluating and recording the activation signal of muscles. EMG signals are used in many clinical and biomedical applications. It is used clinically for the diagnosis of neurological and neuromuscular problems, and also by gait laboratories for use in biofeedback or ergonomic assessment.

EMG is measured using similar techniques to that used for measuring EKG, EEG and other electrophysiological signals. Electrodes are placed on the skin overlying the muscle. Alternatively, wire or needle electrodes are used and these can be placed directly in the muscle. For maximum benefit users need to acquire the EMG signal with a minimum of interference.

2 Problem Definition

In common with other electrophysiological signals, EMG signals are small and need to be amplified by a specially designed circuit designed to measure physiological signals. These amplifiers include a differential amplifier circuit designed to reject the common mode power line noise present on the surface of the body.

A common source of interference in any electronic circuit and most especially in biomedical systems is the 50 Hertz main power-line frequency and its harmonic components. In addition to the electrodes this interference enters the biomedical system from the power supply and other devices connected to the mains supply. The interference can be magnetic or more commonly capacitive. The capacitance connecting the patient to the mains supply is 0.2pF. The capacitance between patient and ground is about 2pF – this gives rise to a leakage current and a corresponding surface potential on the body. The 50Hz noise has amplitude of tens of volts and is much larger than the EMG signal. The described application of a Wireless embedded system using ZigBEE protocol reduces the effects of these noise sources by reducing the common mode noise present at the amplifier inputs – reducing the gain needed to extract a clean signal.

3 System Hardware

The hardware part of this application includes a

microcontroller for each pad-unit and a micro RF modem for wireless transmission of EMG signals.

For the wireless embedded system, we used ZigBEE/IEEE 802.15.4 protocol. This protocol was chosen for the following reasons:

- One ZigBee network can contain more than 65,000 nodes (active devices). The network they form in cooperation with each other may take the shape of a star, a branching tree or a net (mesh). The ZigBee protocol does not require a host/slave configuration like many similar technologies, allowing for more flexibility in networking topologies such as mesh networking, broadcast mode, and packet rerouting. For this reason further embedded systems-pads can be added.

- The low-power model of ZigBee, offers a wireless transmission range of 100 meters.

- Zigbee protocol offers low transmission bandwidth, high frequency transmission 2,4 GHz and low rate errors that are unaffected from electromagnetic fields.

- Zigbee provides low-power electricity consumption during data transmission. No extra power source is required for the transmission module.

- For reliable and secure data transmission in wireless networks, ZigbEE offers a security toolbox including access control lists, data freshness timer and 128-bit encryption.

As we can see, the block diagram of fig1. presents a completed ZigBee system, which contains microcontroller, MAC Layer, Network Layer, security (if needed) and the application profile with the sensors drivers that will be connected.
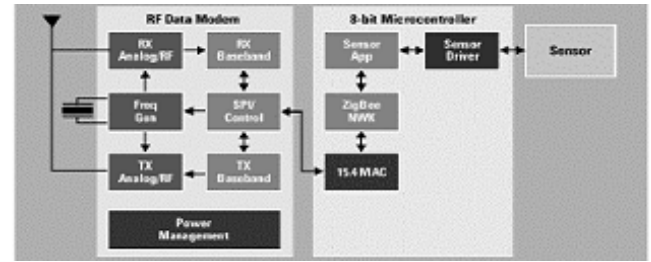

Fig.1: ZigBee system

For wireless transmission of EMG signals, one embedded Reduced Function Device (RFD) was used for each pad-unit as shown in Fig. 2. One Full Function Device acts as Coordinator to collect all data from RFD modules (Fig2). Each FFD and RFD unit includes a programmable microcontroller with stack architecture which is made up of blocks called layers: the Medium Access Control (MAC) layer, the Network Layer, the Secure layer and the Application layer which defines the application profiles in software for the sensors and the actuators to be connected.
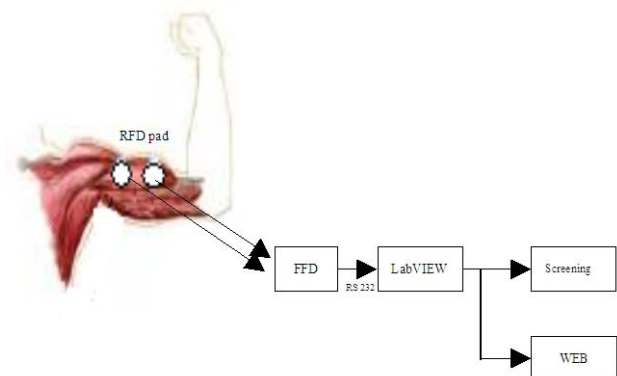

Figure 2: Wireless Embedded system pad (Pad Sensors and Reduce Function Device (RFD pad) and Coordinator (FFD))

The software is running in the memory of a microcontroller with the support of IEEE 802.15.4 protocol. In the present study, for the handling of FFD and RFD units the PIC18LF4620 microcontroller was selected, because of it's:

1. Low power consumption
2. Low input voltage for operation (nanowatt Technology),
3. Support of synchronous and asynchronous communication gates with sensors and integrated ZigBee radio transceivers.

The transmitter and receiver circuit of ZigBee

signals was built on an independent board from that of the microcontroller, so that it can support RF data modems from different manufacturers. The integrated RF modem chosen here is the CC2420, (2.4GHz) Fig. 3, because of its special functions in handling data packets and the link quality indication. These functions reduce the operational load of the microcontroller which leads to selecting a model of smaller size and cost. The communication between microcontroller and RF modem takes place through a Serial Peripheral Interface (SPI).
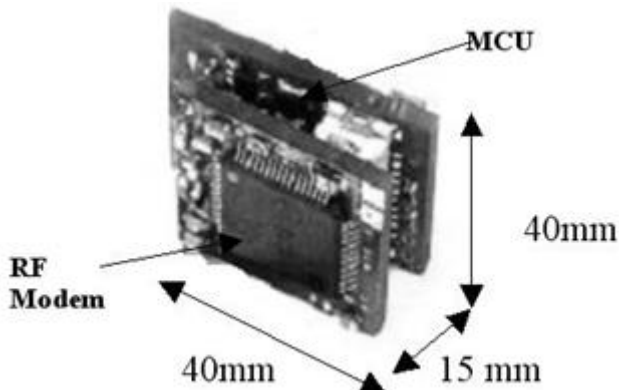
Figure 3: RF Modem CC2420 and main board of embedded system.

The connection of the coordinator unit (FFD) of the wireless network with the main computer is via a serial RS232 port. All control and measurement information are grouped into ASCII strings.

4 Experimental results

During the experiments scenario comparison was made:-Wireless Embedded System Pads vs Wire Pads for EMG Screening (WESpWp)
Every measurement was viewed using LabVIEW code as shown in Fig4. Also the monitoring and control can be observed via the web using LabVIEW.
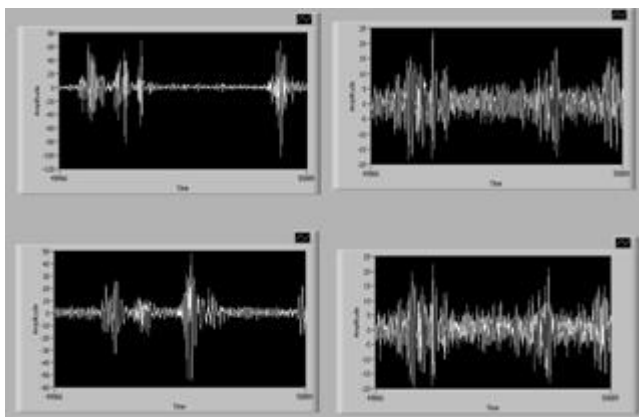

Figure 4: LabVIEW front panels of EMG screening

In this scenario the EMG signal was screened. Every pad had an active electrode booster. The level of the electrical signal from the skin surface (typically in the range of 0.00001 to 0.001 Volt) to levels closer to 0.01 to 1.0 volts, depending on the degree of amplification (gain). Each active pad was wired into the EMG Data Logger that was placed on the left foot. We used three points which collected EMG signals (Fig5).
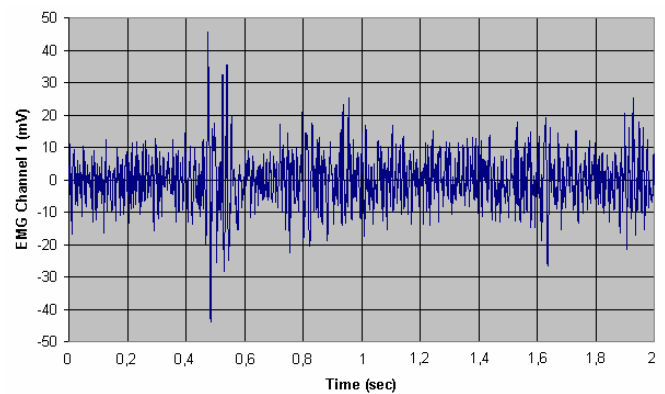

Figure 5: EMG by wire connection

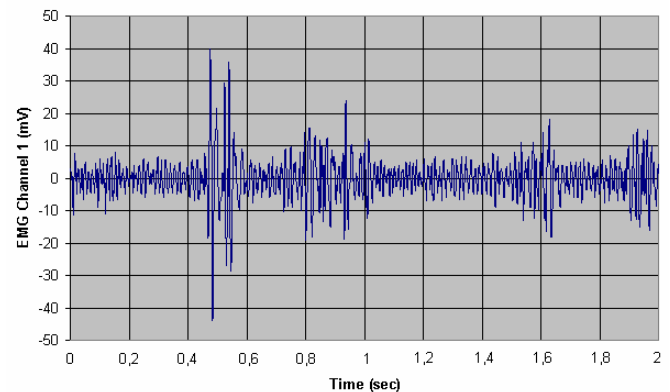After screening, each sensor pads was connected wirelessly to the EMG Logger (Fig 6).

Figure 6: EMG by wireless connection

A method of sample compression was used to hold the maximum average value (peak level) of signal for observation and calculation of the amplitude level error of signal. By this method the signal shows the peak ripple levels at the time. In this case the amplitude level of the error signal was calculated at 10% by wire connection from one environment without noise parameters. The result of wireless embedded system connection is showed with zero error. (In figures the wireless signal and the ideal signal are identically) (Fig 7a, Fig 7b and Fig 7c).
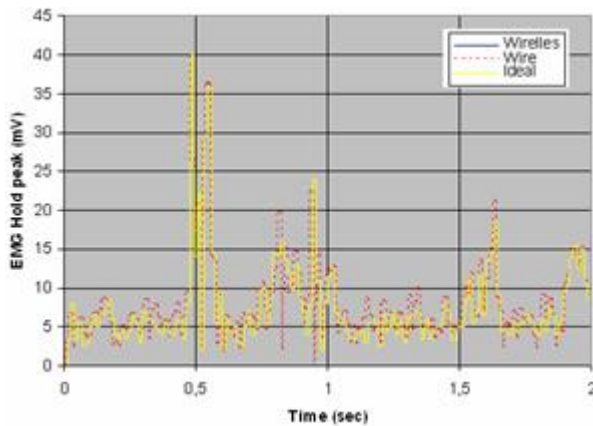
Figure 7a: Holding peak levels on EMG channel 1 by wire, wireless and ideal environment without noise
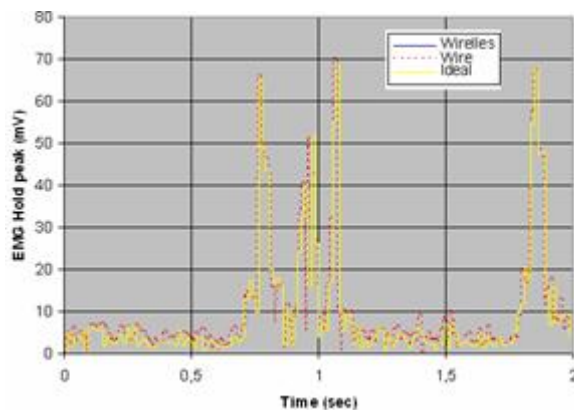

Figure 7b: Holding peak levels on EMG channel 2 by wire, wireless and ideal environment without noise
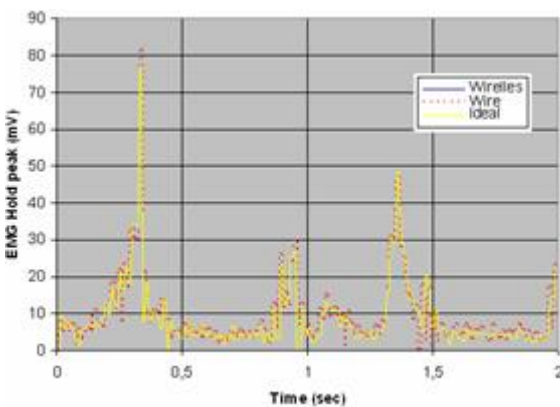

Figure 7c: Holding peak levels on EMG channel 3 by wire, wireless and ideal environment without noise

5 Conclusions

From the above results we conclude that with the use of a wireless embedded system the important problem of white Gaussian noise and 50 Hz Power line noise from EMG via wire pads-sensors is reduced. The wireless connection between embedded system pads showed no signal errors. A topic of future research includes the research of

electromagnetic field by mobiles near EMG.

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