DESIGN AND REALIZATION OF MEASURING DEVICE FOR TREMOR EVALUATION

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ABSTRACT

Tremor as an involuntary rhythmic oscillatory movement of a body part belongs to one of the most disabling features of multiple sclerosis. Our research presented in this paper deals with the developing of an evaluation system of tremor. The system which was designed and realized consists of the portable telemetry units with accelerometers and the base station. The system is able to store 3 axes accelerometry data in the dynamic range of $\pm$ 8 g and the sample frequency of 50 Hz. The system allows storing raw data for further processing in PC. The device was verified in the experiment with the gravitational acceleration. The illustration of results from pilot study are presented in the result section. These results show the system ability to trace various types of tremors and distinguish between them.

Index Terms— Tremor, multiple sclerosis, accelerometers, spectral analysis

1. INTRODUCTION

Multiple sclerosis (MS) is a disease that results in widespread damage to the nervous system. Tremor belongs to one of the most disabling features of multiple sclerosis. Although the epidemiology of the symptom has been studied extensively, it remains difficult to ascertain its prevalence. It is estimated that one third of MS people suffer from this very disabling sign that seriously impairs their activities of daily living and quality of life [1].

Tremor is an involuntary rhythmic oscillatory movement of a part of the body. Tremors are caused by derive from mechanical oscillations, mechanical reflex oscillations, normal central oscillators, and pathologic central oscillators [2]. In MS, tremor is frequently embedded in a complex movement disorder, which often includes dysmetria and other ataxic features [3]. Its cause cannot easily be linked to a single neuroanatomical site, because MS is a multifocal disease. From clinical observation, animal studies and some experimental evidence in humans it is apparent that the cerebellum and the thalamic nuclei connected to it play an important role in production of tremor in MS. Typical frequency band of tremor (2 - 10 Hz) was described in multiple sclerosis [1].

There is still some confusion in the nomenclature for the various types of tremor in MS. The different types of tremor are currently classified according to a working consensus of the Movement Disorder Society [4]. In MS, the two most prevalent tremor forms are postural tremor (tremor present whilst voluntarily maintaining a position against gravity) and intention tremor (tremor occurring during target directed movement where tremor amplitude increases during visually guided movements towards the target). True rest tremor (tremor present in a body part that is not voluntarily activated and is completely supported against gravity) is unusual in MS patients, and ”rubral” tremor is also very uncommon [5].

In general practice tests to examine and evaluate tremor are considerably subjective. However today the importance of evidence based medicine is emphasized, so it is necessary to objectify examination and evaluation of tremor as much as possible. We were interested in what kind of information could bring from objective examination using accelerometers.

An investigation of a tremor using accelerometers has been published many times in last years and a usefulness of this approach has been satisfactory proved – many of researches aims at study of a tremor in patients with Parkinson's disease, for example [6, 7, 8], but some of studies deal also with other types of tremors [9, 10].

The frequent approach to a tremor quantification using accelerometers is to acquire signals during pre-defined movements or exercising, but some studies acquire data also during long term activities or daily activities [9].

The examination using accelerometer could help to define subclinical manifestation of tremor in MS in the future. The aim of our research is to develop an evaluation system of

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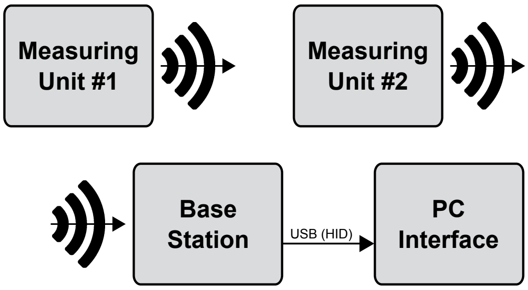

Fig. 1. General Concept of the Device

tremor in multiple sclerosis and potentially in other neurological diseases which allows recording of raw data for complex processing in PC.

2. CHARACTERISTICS OF TREMOR

As it was written above, the tremor is a rhythmic oscillatory movement. Thus, the most important characteristics of the tremor are a frequency range and an amplitude of the signal. The bandwidth and the highest frequency of tremor signal determine the sample frequency which is necessary for correctly acquired signals and the filters used for signal denoising. The amplitude of the tremor determines the necessary dynamic range of accelerometers used for tremor acquisition.

Approximate frequencies of human tremor in the upper limbs for patients with MS is 2 - 10 Hz, possibly up to 18 Hz for the other types of tremor [11, 12]. The similar values are showed also in [13] for physiological tremor or in [10] for Parkinsonian tremor and physiological tremor. The highest frequency of tremor mentioned in [14] (based on [15]) is 25 Hz.

The tremor signal is typically harmonic signal with amplitude lower than 2 g in most cases [7, 10], only in special cases such as bone vibration after vertical jump it could be over 2 g [16].

Based on these characteristics, for the accurate recording of MS tremor signal with possibility to investigate whole spectrum a sample frequency at least 25 Hz should be used.

3. DESIGN OF THE MEASURING DEVICE

Our approach was to design and realize the device both for measuring tremor on upper limbs and the noise of a background. The device consists of three main parts. Two modules with accelerometers, a base station (communication unit) and an application interface on PC. The general concept of the device is shown in figure 1.

Both measuring modules are fitted with the same accelerometer, LIS331DLH from STMicroelectronis. The data acquisition and the communication with the base station is served by PIC16F1827 microcontroller and by RF transceiver RFM12B (working on 433 MHz). Each module is supplied

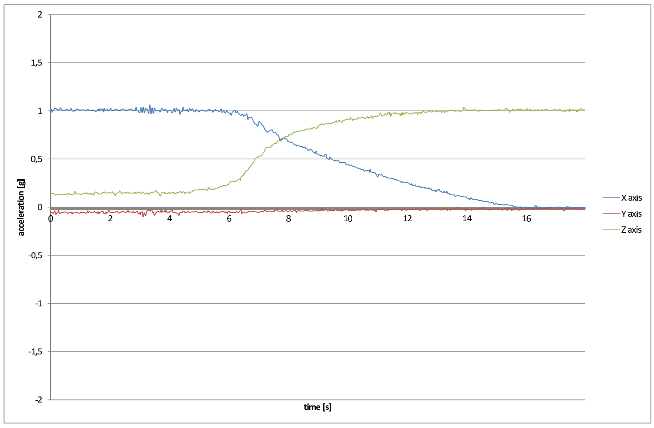

Fig. 2. Measuring of a gravitational acceleration during the rotation around the Y axis

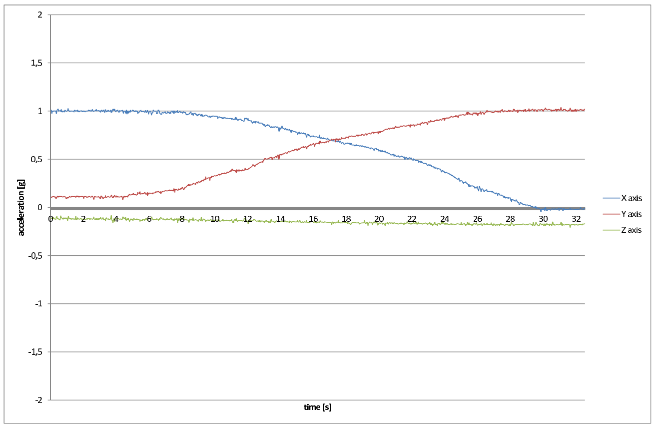

Fig. 3. Measuring of a gravitational acceleration during the rotation around the Z axis

by two AA batteries. The power consumption is maximally 2.6 mA during acquiring the data and 26 mA during transmitting the data.

The sampling frequency used for data acquisition is set to 50 Hz for all three channels (X, Y and Z), dynamic range is set to ± 8 g.

The modules could be used for measuring on two places simultaneously, for example on both upper limbs, on an upper limb and a back or – one accelerometer could be used for measuring of the tremor and the second one could be used for acquiring the background noise (for example vibrations of a building).

The base station operates the receiving data from both accelerometer modules and transmitting data to the PC. The station is connected to PC using USB connection in HID mode (no drivers are necessary).

Each data packet from accelerometer module consists from 11 bytes - module ID (1 byte), packet number (1 byte), low and high bytes for X, Y and Z axes (6 bytes), CRC (2 bytes) and terminational byte (1 byte).

The application interface on PC allow displaying of current data and storing them continuously to PC. The application is implemented in Visual Basic.

4. REALIZATION

Both measuring modules and base station are realized on double-sided PCBs in SMD technology. The dimension of PCB for accelerometer modules is 1.45 inch $\times$ 2.4 inch, the dimension of PCB for base station is 1.55 inch $\times$ 2.96 inch.

5. EVALUATION

An experiment which used the gravity as a source of acceleration was used for the verification of the device. The device was placed with X axis perpendicular to the ground (the axis was parallel to the gravitational acceleration) and consequently it was rotated around one of the horizontal axes. A corresponding decrease of measured value in X axis and an increase in one of the other axes were measured simultaneously. In the fist case, the device was rotated around the axis Y (see figure 2). In the second case, the device was rotated around the Z axis (see figure 3). The dynamic range of the device was set to $\pm$ 2 g for the verification (this range is fully sufficient for measuring of the gravitational acceleration and offers higher resolution than the full scale range $\pm$ 8 g).

6. RESULTS

During the pilot study, 31 patients with MS were measured. Each session consists of a rest tremor, a postural tremor and an intentional tremor measuring. The accelerometer sensor was placed as a ring on index finger. The rest tremor was measured on an arm in resting horizontal position, the postural tremor was measured on an arm in a calm standing position, and the intentional tremor was measured on an arm during stretching forward. Patients were measured more times usually with few weeks between the measurements. For each record the spectrogram of the signal was calculated (Hamming window length of 128 samples, overlap 121 samples). The typical results are show as an examples in figure 4.

In figure 4a, the spectrogram of the postural tremor on right arm (with open eyes) is shown. There is well recognizable and strongly bounded activity in frequency range from approx. 7 Hz to 9 Hz and an activity around approx. 2 Hz. The spectrogram belonging to postural tremor on right arm (with closed eyes) is shown in figure 4b. The significant activity in band around 2 Hz is well visible. In figure 4c, the spectrogram of the postural tremor on left arm (closed eyes) is shown. There is well recognizable activity in wide range around approx. 6 Hz. And finally, the figure 4d is an example of the spectrogram with an interupted wideband activity. The signal was measured as a postural tremor on left arm (patient with closed eyes).

7. CONCLUSION

The new device for measuring of tremor was designed and realized. The device consists from the portable telemetry units with accelerometers and the base station which is connected to PC via USB. The last part of the system is the PC based application which serves as an user interface. The system is able to store 3 axes accelerometry data with dynamic range $\pm$ 8 g and sample frequency 50 Hz. The device was verified in the experiment with the gravitational acceleration. The example results from pilot study are presented in the result section.

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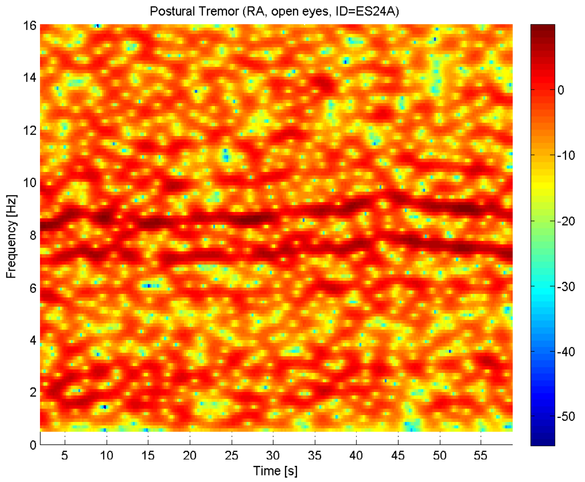
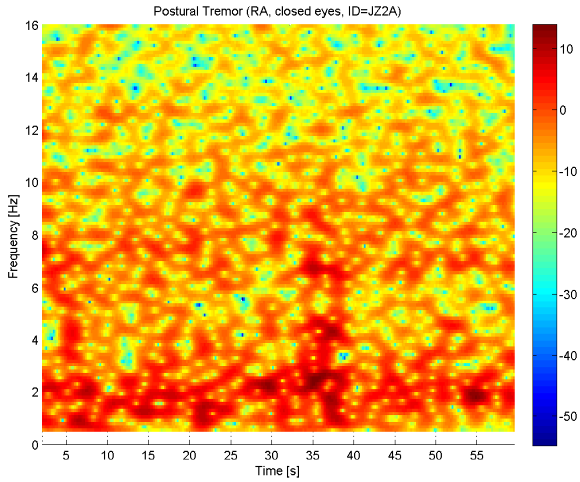
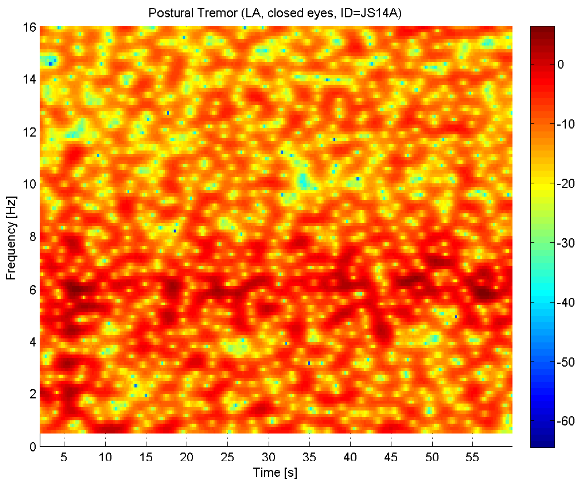


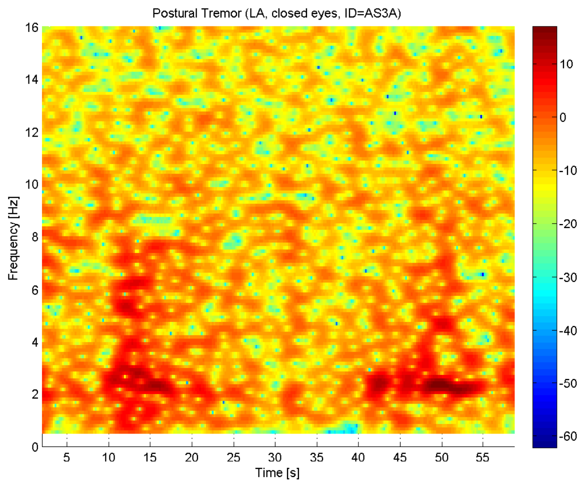
(a) Spectrogram with well bounded activity in band around 8 Hz



(b) Spectrogram with significant activity in band around 2 Hz



(c) Spectrogram with activity in wide range around 6 Hz



(d) Spectrogram with an interupted wideband activity

Fig. 4. Example of placing a figure with experimental results.

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