Safe Deep Brain Stimulator MR Imaging Experiments Using Fiber Optic Current Monitoring Feedback System

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INTRODUCTION

MRI has been used to image deep brain stimulator (DBS) lead and fMRI studies have been conducted in order to understand stimulation profiles of the electrodes (1-5). Both placement and functionality of the lead are vital. However, DBS leads may cause severe burns because of the RF induced currents during MRI (6,7). Previously, a fiber optic signal transmission system was presented by authors. In this study, an important extension is proposed in order to maximize safety profile of the system (8). Proposed feedback mechanism enables monitoring of the induced current to the brain. Any rise or fall of the current is a possible reason of changing conductivity due to RF heating. Therefore, monitoring this quantity provides opportunity for better safety profile. In this study, in-vivo and in-vitro safety experiments have been conducted.

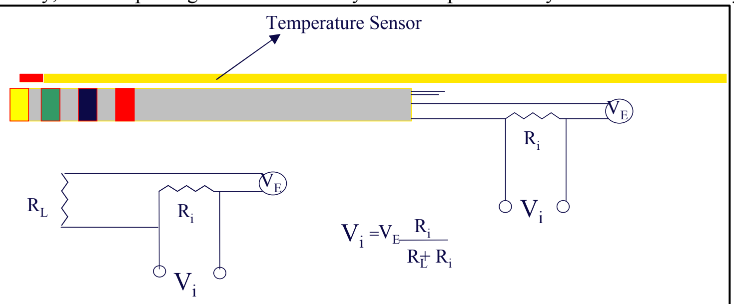

Figure 1: Principle of the system and temperature probe placement. Voltage on a series resistance provides impedance information of the subject. Monitoring V_i enables us to observe of the variation of temperature in the subject.

THEORY

Current induced by DBS system depends on impedance of the subject. Any increase or decrease can be monitored by placing series resistance to the electrodes. As a result, voltage on the series resistance is directly proportional to impedance of the subject, which is the brain tissue in this case. Previously proposed fiber optic system improved safety profile of the DBS experiments under MRI. This system is modified in order to monitor induced current to the subject.

METHOD

A 3 tesla Siemens TIM Trio MR scanner, four channel Medtronic 3387 DBS electrode (Medtronic Inc., Minneapolis, MN) were used in our experiments. Phantom and animal experiments were conducted in order to eliminate safety concerns of DBS studies in MRI. For phantom and animal experiments, following FLASH sequence was used: TE: 4 ms, TR: 234 ms, flip angle: 80 degrees, slice thickness: 10 mm, spacing: 0 mm, matrix: 128 X 256, FOV: 500 X 500 mm^2, 15 phases per location, measurements: 60, acquisition duration: 114 seconds. ReFlex model temperature sensors were used (Neoptix, Inc., Quebec City, Canada). The sensor tip touched the region between the first and the second electrodes from the tip of the probe. One other sensor was used to measure SAR (Figure 1).

In-vitro experiments, a sheep brain was used in order to compare measured heat and electrode current change. In-vivo experiments was conducted using a New Zealand rabbit. General anesthesia was induced by intramuscular injection of 5 mg/kg of ketamine and 40 mg/kg of xylazine.

3-cm portion of the lead was inserted into brains of rabbits.

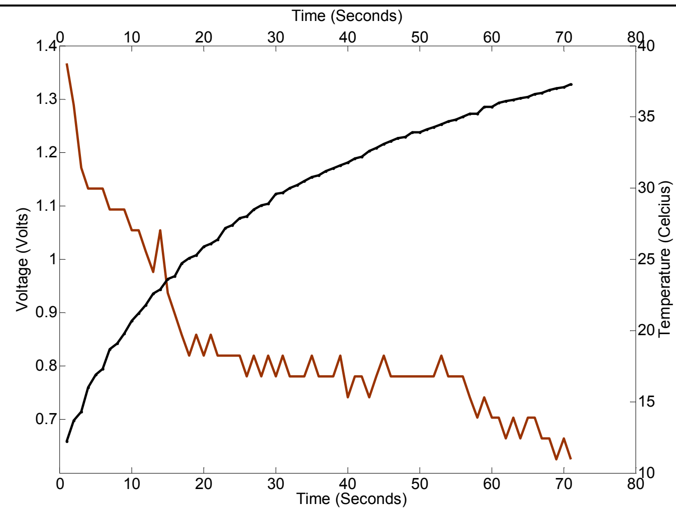

Figure 2: Phantom experiment. As heating experiment started, temperature rised rapidly and voltage on the series resistanve decreased significantly, which means, impedance of the subject increased due to temperature increment.

RESULTS

Both phantom and animal experiments showed that current on the DBS lead due to RF field can be monitored using a fiber optic feedback system, which was based on a 8051 microcontroller (Figures 2-3).

CONCLUSION

In this study, MR safe DBS system is introduced and possible applications are discussed.

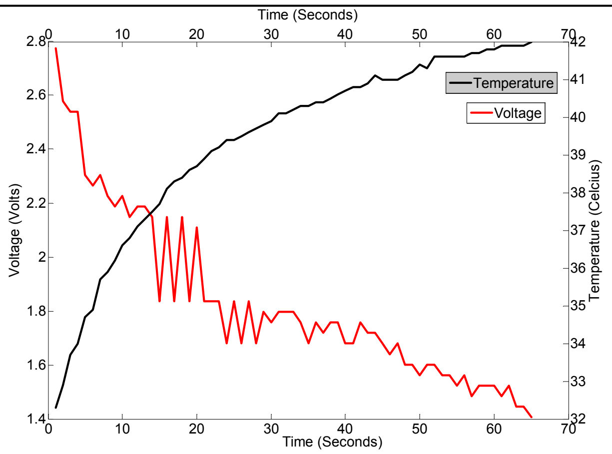

Figure 3: Rabbit experiment. Similar to phantom experiment, voltage decreased as the temperature increased in the brain.

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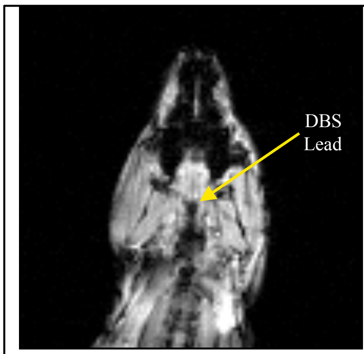

Figure 4: Image from rabbit experiment. DBS lead was placed in the brain of the rabbit.