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主 論 文 の 要 旨

論文題目　**Development of Brain Activity Measurement System based on Highly Sensitive Magneto-Impedance Sensor**
（高感度 MI センサによる脳波計測の高度化とその応用に関する研究）

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論 文 内 容 の 要 旨

Human brain is considered as the most complex and important organ in the body and it is the key for perception of the world. Even though lots of brain research on both structure and function have get remarkable progresses, we still can not figure out all the secrets of our brains. With the development of technology, more and more new technique will be used in brain research to benefit the whole human beings.

With the development during the last two decades, the MI sensor has been improved and applied in several fields. Comparing with the conventional magnetic field sensor, MI sensor has a high sensitivity and a wide range of detection, which from milli-Tesla to pico-Tesla level. Also the MI sesnsor has a low power cost and compact structure and it makes the sensor could be easily integrated into other device, like wearable intelligent device.

In this study, based on the features of MI sensor talked above, we expect to develop a novel tool to measure and detect the magnetic activity of the brain, which could be used without magnetic shielding room and no need for cooling. To achieve this goal, I build the brain activity measurement system using highly sensitive MI sensor. Then we measured 3 brain activities in 4 kinds of tasks. Then with comparing our results to other research, the performance of this system is improved and new functions are added on for further measurement and development.

Chapter 1 is mostly about the background of brain research and related technologies used in monitoring and measuring brain activity. As the key technology, those methods play the most important roles in medical diagnosis and neuroscience research. Even though some of them have a quite high maintenance cost and limited in specific experimental environment, they can provide valuable and accurate data. Of these methods, some of them, such as Magnetic Resonance Imaging (MRI) and Computed Tomography (CT), are used to perform structural analysis. There are some other methods for proforming functional analysis, such as Positron Emission Tomography (PET), Electroencephalography (EEG), Magnetoencephalography (MEG) and functional Magnetic Resonance Imaging (fMRI), aimed to measure brain activity and locate the region related. There is also a introduction about the basic principles of magnetic field sensors wildly used in all kinds of applications like Hall effect sensor, Magnetoresistive sensor, Giant Magnetoresistive sensor, Fluxgate magnetometer and the Superconducting quantum interference devices. Also, a introduction of the brain activites I measured in this study is presented, such as the N100 auditory evoked field (AEF), the P300 event related field (ERF) induced by auditory stimuli, the alpha rhythm and the P300 ERF induced by visual stimuli.

Chapter 2 mostly describs the details of the MI sensor I used in this study, including the principle of MI sensor, functions of sensor circuits, detection characteristics and the noise level. The MI sensor used in this study is a novel highly sensitive micro magnetic sensor based on the Magnetoimpedance (MI) effect in amorphous wires and constituted with CMOS IC multivibrator circuits. The sensor head, which have two pico-Tesla resolution multi-core MI elements setting up in series, is designed to cancel out the background noise instead of using a magnetic shielding. With the analog amplifier and the digital processing module, the measurement system can get a 33kV/T sensitivity and the RMS noise of the whole system is lower than 4 pT in a laboratory environment. This system is designed to measure extremely weak brain magnetic field in multiple tasks.

Chapter 3 presents the study about the single-channel off-line system build for measuring N100 AEF and and P300 ERF (induced by auditory stimuli) brain activities. The N100 AEF was measured on the left temporal and right temporal regions simultaneously, and the P300 ERF was measured on the parietal region. Based on the features of those brain activites, I programmed a microcontroller to generate different auditory stimuli for inducing the brain activity. Then the measurement system recorded the signals. After processing the signals of different activities, results were compared with other brain activity relevant research that using EEG or MEG to confirm the performance of the measurement system. The results show similar characteristics to the most of results of other research.

Chapter 4 presents the study about the single-channel real-time system, which improved from the system discussed in chapter 3. It has integrated a stimuli generator, which can create multiple auditory / visual stimuli to induce the brain activities, and a real-time processing module that can process some brain activities in real-time (or just pre-process the data for later processing). It provides a possibility that MI sensor could be used in BCI application in the future. The system was used for measuring alpha rhythm and P300 ERF (induced by visual stimuli). The alpha rhythm was measured on the occipital regions, and the P300 ERF was measured on the frontal, parietal, left and right temporal region respectively. Also we used a calculation model to explain the reason why the amplitude of our results is bigger than that of SQUID.

Chapter 5 presents the study about the multi-channel system improved from the system discussed in chapter 4. It uses three highly sensitive MI sensors and a developed processing module based on Fast independent component analysis (FastICA) to separate the independent components, which a conventional frequency filter could not achieve that. The system was used for measuring P300 ERF (induced by visual stimuli) on the parietal region. It has been proved that the FastICA is a powerful tool to separate the mixed signals for reducing the noise that can not be easily done by a conventional frequency filter. But the system still need to be improved.

Chapter 6 presents the conclusions and the future work. In this study, the main goal was to develop a multi-function brain activity measurement system based on the MI sensors. We measured different types of brain activities in several positions using off-line processing, real-time processing and FastICA processing modules. Depending on the results, it presents the capabilities of the system for applications of brain activity measurement. But this system still need lots of improvement, such as making the circuit all into digital using a FPGA. I expect to obtain a lower noise level and a more integrated multi-channel system.