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V-5.3 fMRI Classification Based on Analysis of Variance Combined with Support Vector Machine
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V-5.4 Client Selection for Coordinated IEEE 802.11ac Multi-user MIMO-enabled Access Points
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[Session V-6] Systems, Services and Applications for ICT Convergence

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V-6.1 Design of Active Dry Electrodes and its Evaluation for EEG acquisition
Seungchan Lee, Younghak Shin and Heung-No Lee (Gwangju Institute of Science and Technology, Korea)

V-6.2 Image Upsizing with Adaptive Wiener Filtering Method using Self-Prediction
Ilhong Shin, Hyun-Woo Lee (Electronics and Telecommunications Research Institute, Korea)

V-6.3 Dictionary Update based Adaptive EEG Classification for Real Time Brain-Computer Interface Applications
Younghak Shin, Seungchan Lee and Heung-No Lee (Gwangju Institute of Science and Technology, Korea)

V-6.4 Efficient architecture for circle detection using Hough transform
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[Session VI-1] Advanced Communication Networks and Future Internet Technologies

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Tomohiko Mizoguchi and Yoshihiro Ito (Nagoya Institute of Technology, Japan)

VI-1.2 Implementing SDN and Network-Hypervisor based Programmable Network using Pi Stack Switch
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VI-1.3 A Design of Cooperative Slotted ALOHA System with HARQ
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Jie Zhang, Guangjie Han (Hohai University, P.R. China); Yiqi Gui (Yangzhou University, P.R. China)

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VI-1.6 Impacts of Network Coding on End-to-End Packet Transport Performance

Design of Active Dry Electrodes and its Evaluation for EEG acquisition

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***Abstract*— In this paper, we aim to introduce a design of active dry electrodes for EEG based BCI systems. The proposed electrodes consist of dry probes and an active circuit for easy installation and higher quality of EEG recording. To verify the evaluation of the proposed electrodes, we tried to detect alpha rhythms as a typical EEG feature by using our own EEG acquisition boards and Matlab. Experimental results show that the power of alpha rhythm reaches over 50 percent after 10 seconds when the subject closes his eyes. We will verify the performance of the proposed electrodes through various analysis such as detection of visual evoked potential (VEP) and sensorimotor rhythm (SMR) in future research.**

Keywords—Brain computer interface (BCI), EEG acquisition, Active dry electrodes

I. INTRODUCTION

Brain-Computer Interface (BCI) systems can acquire user's intentions by analyzing the user's neurophysiological signals. The intentions are then translated into control signals which computer or external machines can understand. The BCI systems have possibilities as a new means of communications, many researchers and companies are developing the BCI systems for various applications related health care, entertainment, and communications.

In these systems, electrodes are the most important part because this part may affect the signal quality severely. Because amplitude of EEG signals is very small, the signals are sensitive and easy to be affected by various noise sources such as 60Hz power-line noise and physiological interference, i.e., Electrocardiogram (ECG) and Electrooculograms (EOG). Moreover, due to usage of conductive gels, electrode installation is also inconvenient and time-consuming. Therefore, development of improved EEG electrodes which provide high fidelity EEG signals and easy installation is one of the most important challenges.

Recently, researchers have studied about active or dry electrodes for solving these challenges. The dry electrodes are defined as those that do not require the use of conductive gels for installation process. Thus, a user can conveniently attach them to his/her scalp without any hair arrangement. Various materials and design such as spring-loaded fingers [1][2], bristle structures [3], and conductive foams [4] has been applied in design of dry electrodes. Active electrodes contain an amplifier or buffer circuits integrated to the electrodes themselves [5][6]. This amplifier or buffer circuits are located between the electrodes and the signal acquisition frontend for reduction of distortion of the measured signals.

In this paper, we aim to introduce our design of active dry electrodes for EEG signal acquisition, show detection of alpha rhythms for proof of functional qualification as the electrodes for EEG acquisition.

II. MATERIALS AND METHODS

A. Design of Active Dry Electrodes

Overall design of the active dry electrodes is a combination of dry probes and active circuits. The module of dry probes are equipped with six probes of spring loaded type. These probes contract their length up to a maximum of 2 mm when compressed. This structure provides flexibility and geometric adaptation between the sensors and the irregular scalp surfaces. Because the probes are easy to penetrate with the user's scalp through the hairs, any hair preparation is not needed in their installation process. The buffer circuits based on operational amplifier provide the robustness of acquired EEG signals by conversion of impedance characteristic from high input impedance into low output impedance. Fig. 1 is a picture of the proposed active dry electrode and a diagram showing the probe structures.

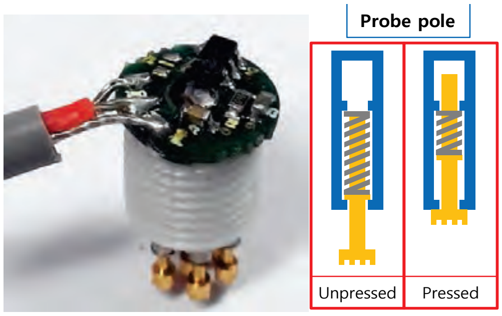

Figure 1. Picture of proposed active dry electrodes and diagram of dry probes

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B. *EEG Acquisition*

To acquire the detection of EEG signals, we designed a lab-made EEG acquisition system. This system is composed of a microcontroller (MSP430F5529, Texas Instruments, USA) and an analog front-end in for biopotential measurements (ADS1299 [7], Texas Instruments, USA). The analog front-end chipset integrated with eight analog to digital converters (ADCs), eight programmable gain amplifiers (PGAs) and digital low pass filters. Internal PGAs amplified the measured EEG signal with a gain of 24. And then, the amplified EEG signals digitized into 24-bit resolution of EEG data with a sampling rate of 250 Hz. The digitized EEG data sent to desktop computer by using universal asynchronous receiver transmitter (UART) protocol.

C. *Experimental Methods*

To verify the signal quality of the acquired EEG signals, we tried to measure the alpha rhythms of EEG signals using our proposed electrodes at a Fpz position based on international 10/20 system. Reference and ground electrodes are installed on the right and the left ear lobe respectively. One male subject participated in this experiment. The EEG signals measured by the proposed electrodes and monitored by Matlab (Matlab 2014a, Mathworks, USA) with a data acquisition toolbox. To filter the noises components of the measured signals, we applied digital low pass filter with 40 Hz cut off frequency. To eliminate the offset drift, we also utilized 20 points moving average filter after low pass filter. We monitored 11 seconds duration of the EEG signals and their spectrum using a data buffer and a fast Fourier transform(FFT) algorithm in real time. We also calculated the ratio of alpha rhythms based on the spectrum of acquired EEG signals for detection of the alpha rhythms compared to the total power of measured signals. The power of alpha rhythms is calculated as follows:

$$\text{Ratio of alpha rhythms} = \frac{bandpower(8 \sim 12Hz)}{bandpower(0 \sim 40Hz)}$$

III. RESULTS

Fig. 2 and Fig. 3 show the waveform, spectrum of acquired EEG signals and ratio of alpha rhythm when the subject opens the eyes. Fig. 4 and Fig. 5 also show the waveforms, the spectrums, and the ratio of alpha rhythm when the subject closes the eyes. Normally, the alpha rhythms from the acquired EEG signals tend to appear during wakeful relaxation when the users close their eyes. Compared to spectrums and graphs of alpha power ratio, we clearly observed the increasing power of alpha rhythms when the subject closes his eyes. The maximum power of alpha rhythm reaches 53 percent after around 10 seconds when the subject closes his eyes. On the contrary, the power of alpha rhythm records less than 20 percent when the subject open his eyes. We also observed a spectrum peak around 10 Hz in case of the closed eye state.

IV. CONCLUSION

We designed the proposed active dry electrodes to provide various advantages such as higher signal quality, convenient installation, feasibility of long-term monitoring compared to conventional wet electrodes. Through the spectral analysis of

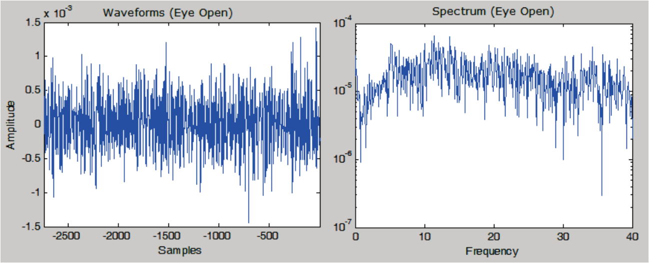

Figure 2. Waveform and spectrum of measured EEG signals when the subject opens his eyes.

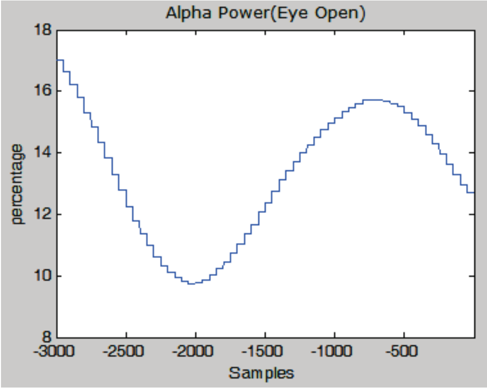

Figure 3. Alpha rhythm ratio of measured EEG signals when the subject opens his eyes.

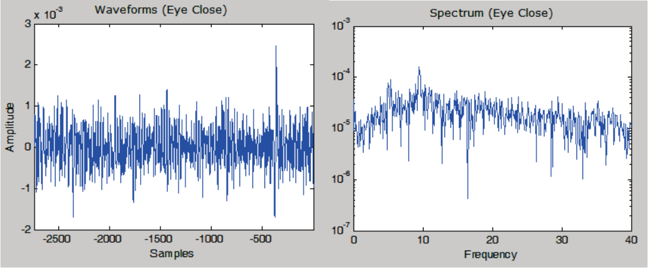

Figure 4. Waveform and spectrum of measured EEG signals when the subject closes his eyes.

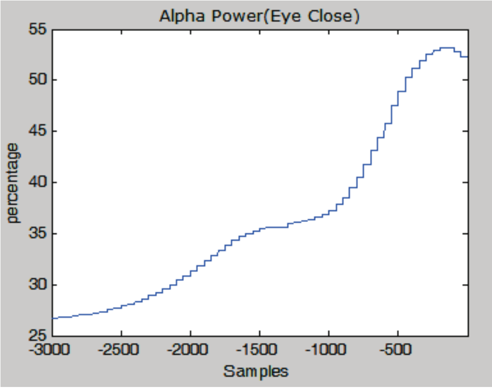

Figure 5. Alpha rhythm ratio of measured EEG signals when the subject closes his eyes.

the measured EEG signals in real time, we show that the proposed active dry electrodes are able to detect the typical EEG features likes alpha rhythms when the subject closed his eyes. We will verify the performance of the proposed electrodes through the analysis of electrical characteristics and detection of other EEG features such as visual evoked potential (VEP) and sensorimotor rhythm (SMR) in future research.

ACKNOWLEDGMENT

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