Moving One Dimensional Cursor Using Extracted Parameter from Brain Signals

Siti Zuraimi Salleh missxeetea_z@yahoo.com
Department of Electronic Eng.
Faculty of Electrical Engineering
University Technology of Malaysia (UTM)
81310 Skudai, Johor, Malaysia

Norlaili Mat Safri norlaili@fke.utm.my
Department of Electronic Eng.
Faculty of Electrical Engineering
University Technology of Malaysia (UTM)
81310 Skudai, Johor, Malaysia

Siti Hajar Aminah Ali aminahh@uthm.edu.my
Department of Telecommunication
Faculty of Electrical Engineering
University Technology of Tun Hussein Onn Malaysia (UTHM)
86400 Batu Pahat, Johor, Malaysia

Abstract

This study focuses on developing a method to determine parameters to control cursor movement using noninvasive brain signals, or electroencephalogram (EEG) for brain-computer interface (BCI). Two conditions were applied i.e. Control condition where subjects relax (resting state); and Task condition where subjects imagine a movement. In both conditions, EEG signals were recorded from 19 scalp locations. In Task condition, subjects were asked to imagine a movement to move the cursor on the screen towards target position. Fast Fourier Transform (FFT) was used to analyze the recorded EEG signals. To obtain maximum speed and accuracy, EEG data were divided into various interval and difference in power values between Task and Control conditions were calculated. As conclusion, the present study suggests that difference in delta frequency band between resting and active imagination may be use to control one dimensional cursor movement with parietal region produces the optimum output.

Keywords: Brain-computer interface (BCI), electroencephalogram (EEG), extracted parameter, Fast Fourier Transform (FFT)

1. INTRODUCTION

For normal people, communication is a need to undergo their daily activities. Communication is a process to transmit or transfer information, thought or feeling by or to or between people or groups. It is a connection allowing access between persons by either verbal contact or action.
But some people suffer from “locked-in syndrome”, meaning they are completely unable to control any muscle, preventing them from communicating with their caregivers or environment [1]. For such users, a brain-computer interface or BCI is the only hope for even communicating with loved ones, controlling even simple devices like televisions or lamps or otherwise expressing oneself. BCI is a novel augmentative communication system that translates human intentions into a control signal for an output device such as a computer application [2] or a mobile robot [3], in which users send information using brain activity alone without conventional peripheral nerves and muscles [3].

BCI can be divided into two general categories i.e. invasive and noninvasive [3]. Most noninvasive BCI systems use electroencephalogram (EEG) signals; i.e., the electrical brain activity recorded from electrodes placed on the scalp. The main source of the EEG is the synchronous activity of thousands of cortical neurons. Measuring the EEG is a simple noninvasive way to monitor electrical brain activity, but it does not provide detailed information on the activity of single neurons (a few µVolts) and noisy environment (especially if recording outside shield rooms) [3]. In invasive BCI systems, the activity of single neurons (their spiking rate) is recorded from microelectrodes implanted in the brain. Such systems are being studied mainly in nonhuman primates [4]. These invasive BCIs face substantial technical difficulties and entail significant clinical risks as they require that recording electrodes be implanted in the cortex and function well for long periods, and they risk infection and other damage to the brain [5]. For human, therefore, noninvasive BCI systems are applied due to the clinical risks and ethics [3].

2. DATA COLLECTION AND ANALYSIS

In BCI studies, the foremost important element is data collection and analysis whereby the recorded and collected data will be used as an input to the system. The input referred here is EEG signal; it was digitized, analyzed and processed for extracting important and useful information [6].

2.1 Participants

Six normal healthy subjects aged 20-26 years old gave informed consent to participate in these experiments.

2.2 Condition

Subjects sat on a chair facing a monitor screen that was placed one meter in front of the subjects. Two conditions were applied, i.e. Control condition and Task condition. In Control condition, subjects were asked to relax (resting) while in Task condition, subjects were asked to imagine voluntary movement, e.g. imagine moving a cursor to a target location on a computer screen. In Control condition, subjects were instructed to fix their eyes on the centre of the screen. No image was displayed on the screen during the entire experiment. In Task condition, subjects were asked to imagine a movement to move the cursor on the screen towards the target. Cursor moving towards the target was displayed on the screen during the entire experiment to imitate real application.

2.3 Data Acquisition

EEG signals were obtained from 19 scalp electrodes, placed on the scalp based on 10-20 electrode placement system (Figure 1). Signals were recorded with passbands of 0.5 -120 Hz and stored in a personal computer with a sampling frequency of 1 kHz. A single trial lasted for 10 seconds and four trials, as illustrated in Figure 2, were conducted for each condition with intervening rest period to avoid fatigue.

The 10-20 electrode placement system is a method used to describe the location of scalp electrodes. These scalp electrodes are used to record the EEG using a machine called an electroencephalograph. The system is based on the relationship between the location of an electrode and the underlying area of cerebral cortex. Each electrode site has a combination of a letter and a number (or another letter) to identify the lobe and the hemisphere location, respectively. The letters F, T, C, P and O stand for Frontal, Temporal, Central, Parietal and Occipital. Even numbers 2, 4, 6 and 8 indicate the electrodes at right hemisphere while electrodes at the left hemisphere are indicated by odd numbers 1, 3, 5 and 7. Other than that, small letter 'z' refers to an electrode placed in the midline. The '10' and '20' are referred to the 10% or 20% inter-electrode distance [7].

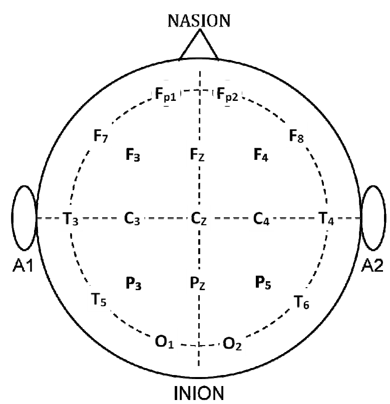


FIGURE 1: Scalp Locations Based On 10-20 Electrode Placement System.

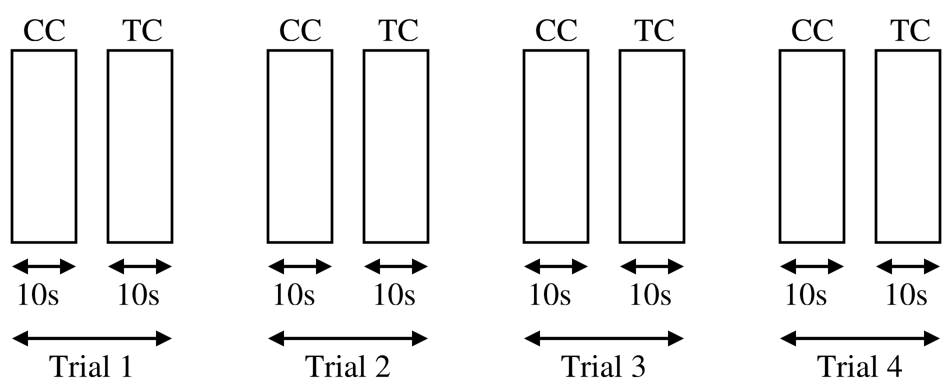


FIGURE 2: The Sequence of Condition. CC and TC represent Control condition and Task condition, respectively.

2.4 Data Analysis

10 seconds of EEG data of Control and Task conditions were divided into ten frames so that each frame consists of one second data. The EEG data were divided into various time intervals, i.e. 1024 ms and 512 ms, as depicted in Figure 3, to investigate time interval that provide optimum speed and accuracy. Data in frequency domain were obtained by applying Fast Fourier Transform (FFT) with butterfly operation for each time interval in a frame [8]. Frequency was divided into six groups, i.e. delta band (0 to 4 Hz), theta band (4 to 7 Hz), alpha band (8 to 12 Hz), beta band (13 to 30 Hz), gamma band (31 to 50 Hz) and high gamma band (>51 Hz). Each frequency band in Task condition was compared to the Control Condition. Differences between

these two condition were obtained and observed, i.e. difference in power *(f)* (DP) = power in Task *(f)* – power in Control *(f)*.

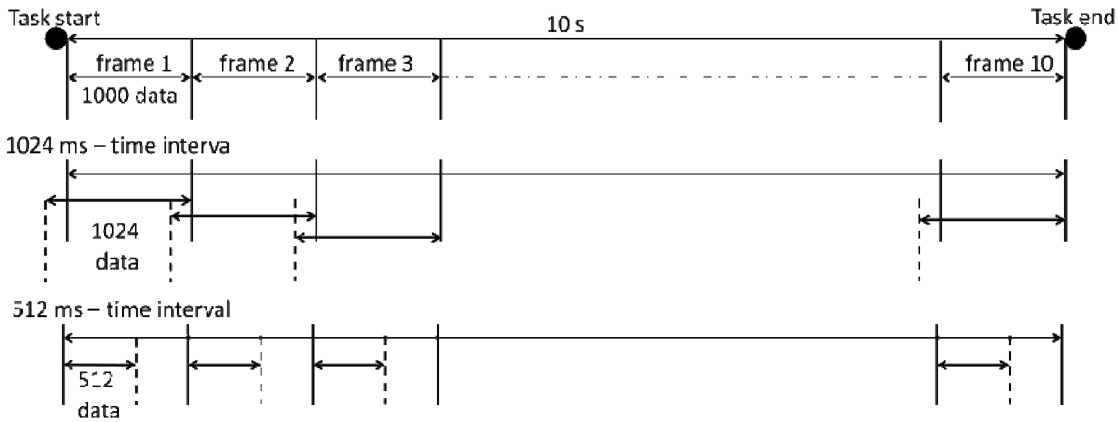
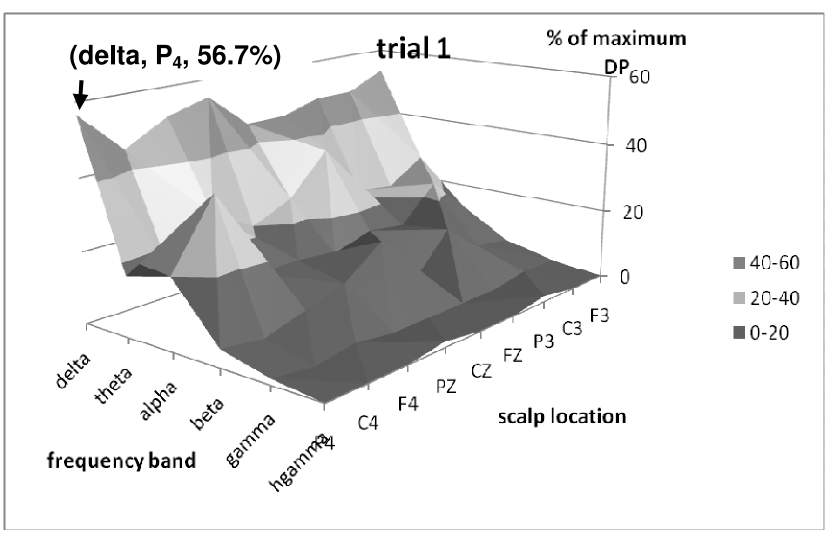


FIGURE 3: Division of Data at 1024 ms and 512 ms Time Interval.

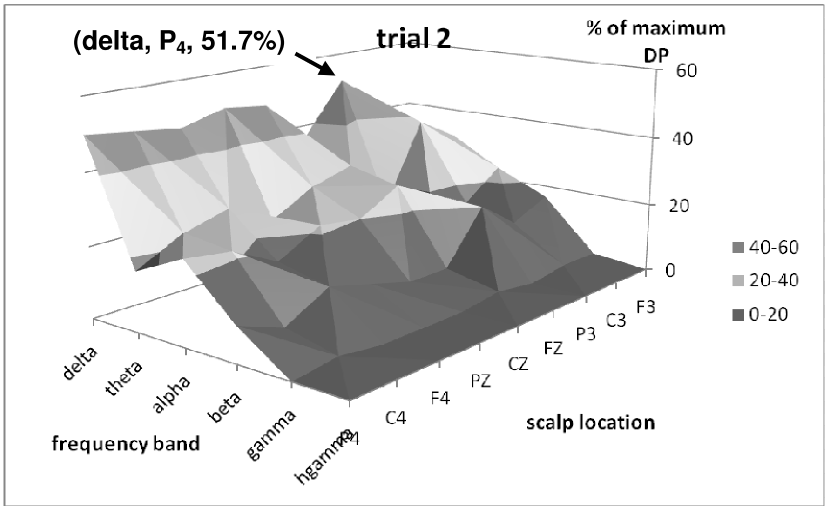
3. PARAMETER EXTRACTION RESULT

3.1 Time Interval: 1024 ms

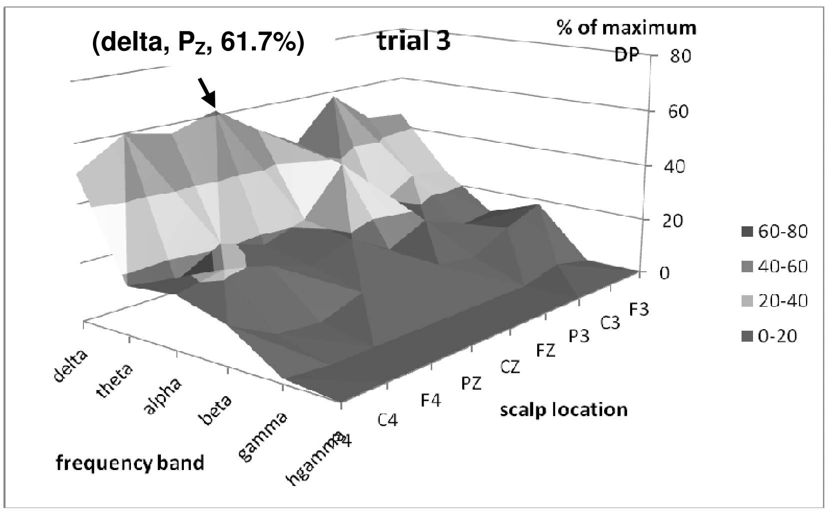
Figure 4 shows the result of percentage of maximum DP using 1024 ms time interval for all trials (6 subjects x 10 frames). For trial 1 (Figure 4(a)), maximum DP was found at P_4 site with 56.7% occurrence. For trial 2 (Figure 4(b)), maximum DP was observed at another site i.e. P_3 with 51.7% occurrence. For trials 3 and 4 (Figure 4 (c) and (d)), both maximum DP was found at P_Z site with 61.7% and 60.0% occurrences, respectively. Generally, the maximum DP occurred at delta band, which ranged 0-4 Hz, for all trials.



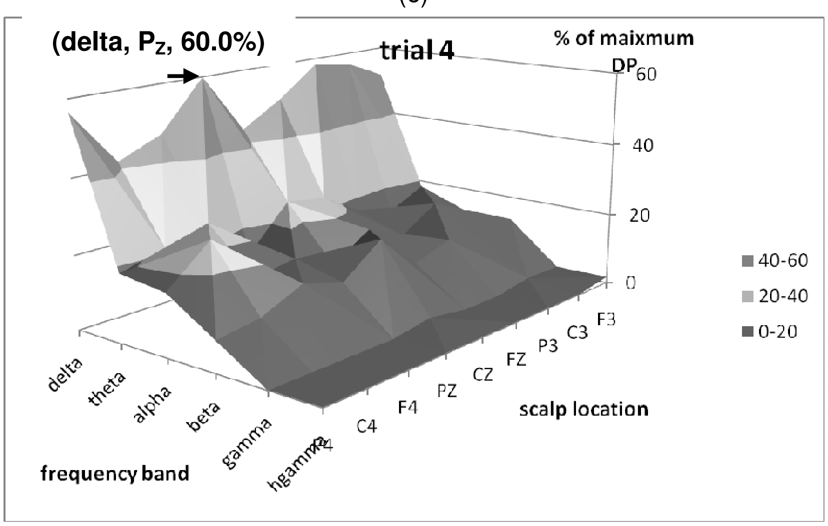
(a)



(b)



(c)

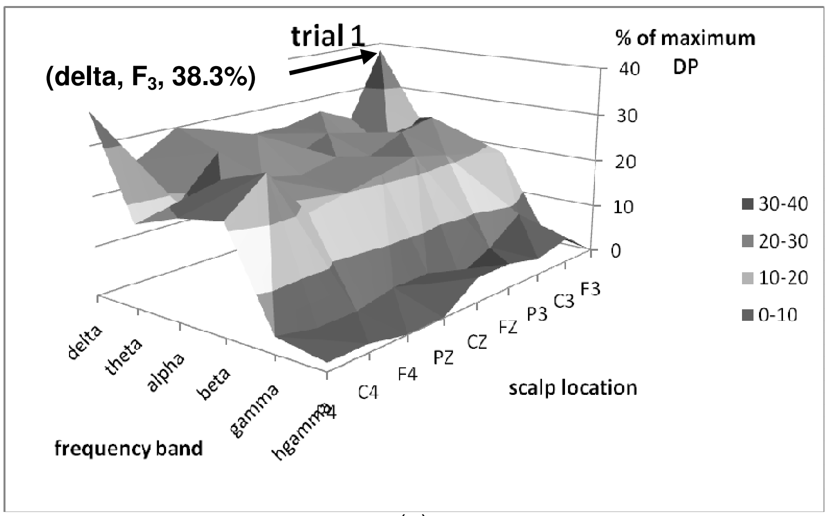


(d)

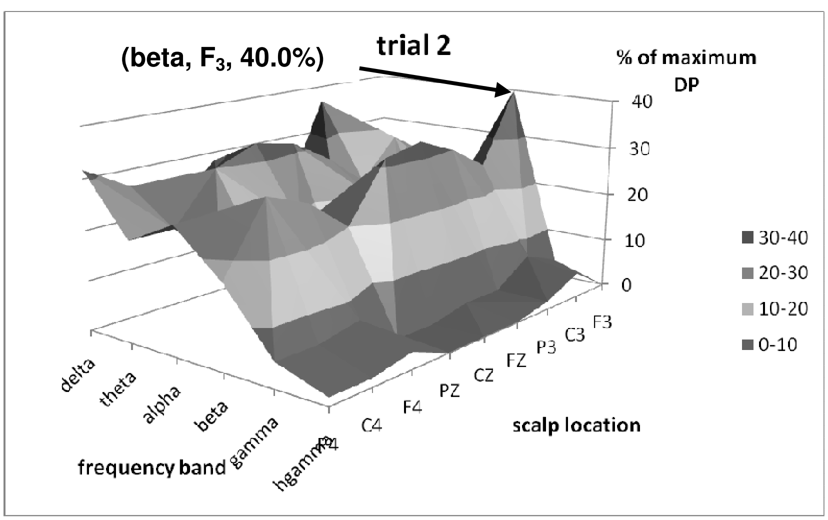
FIGURE 4: Result for Trial 1, 2, 3 and 4 Using 1024 ms Sampling Interval.

3.2 Time Interval: 512 ms

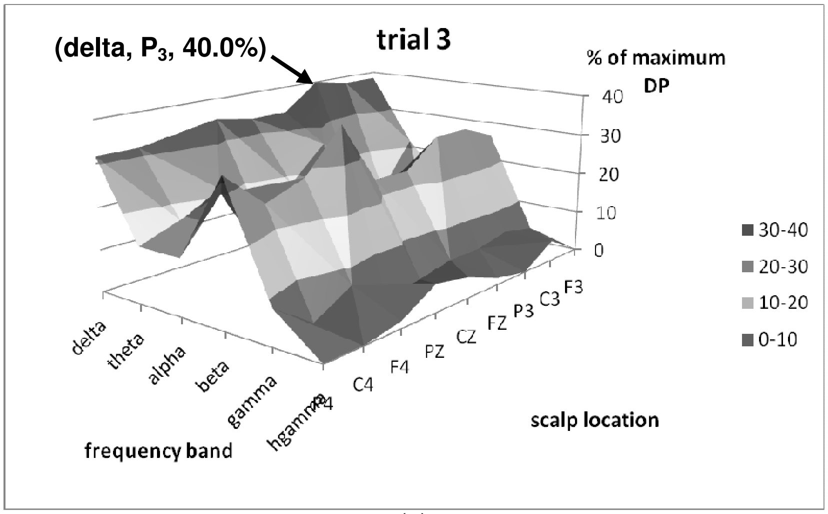
Maximum DP for all trials (6 subjects x 10 frames) using 512 ms time interval are shown in Figure 5. In section 3.1, the frequency range for maximum DP was constant for all trials i.e. in delta band. However, there were two different frequency band observed in time interval 512 ms. For trials 1 and 2 (Figures 5(a) and (b)), both maximum DP occurred at F_3 site with 38.3% and 40% occurrences, respectively. However, the frequency band in which the maximum DP occurrence appeared was different. For trial 1, maximum DP occurrence was obtained in delta band whereas for trial 2, it was obtained in beta band. For trials 3 and 4 (Figures 5(c) and (d)), the frequency range in which maximum DP was found was seen constant but not the scalp location. The maximum DP occurred in delta band for both trials 3 and 4. In trial 3, the maximum DP was found at P_3 site with 40% occurrence. Meanwhile, in trial 4, there were three different sites assembled the maximum DP awith similar occurrence percentage, 38.3%, i.e. F_3, P_3 and P_4.



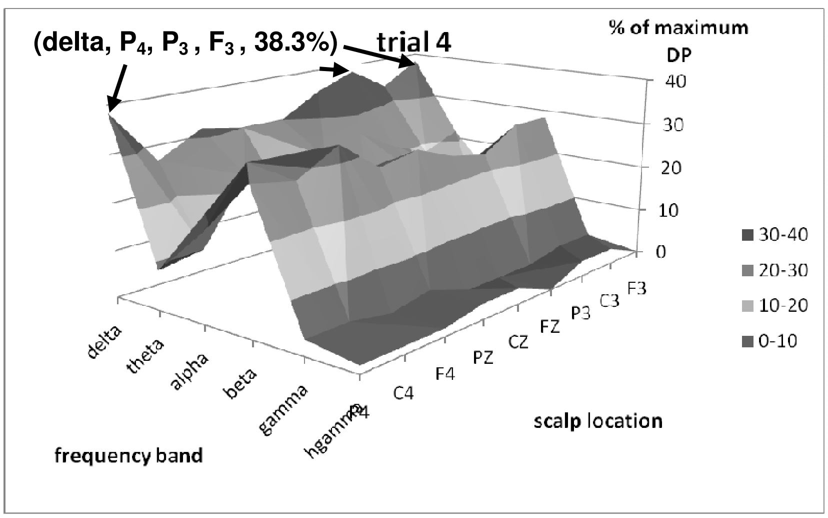
(a)



(b)



(c)



(d)

FIGURE 5: Result for Trial 1, 2, 3 and 4 Using 512 ms Time Interval.

3.3 Averaging for All Trials

Initially, it is expected that every trial will produce similar result to determine the parameters. However, it was not the case here. The maximum DP was found at various scalp locations for all the trials. To overcome these distinctions, averaging process based on location was done for all the trials. Results are shown in Figures 6 and 7 for time interval 1024 ms and 512 ms, respectively.

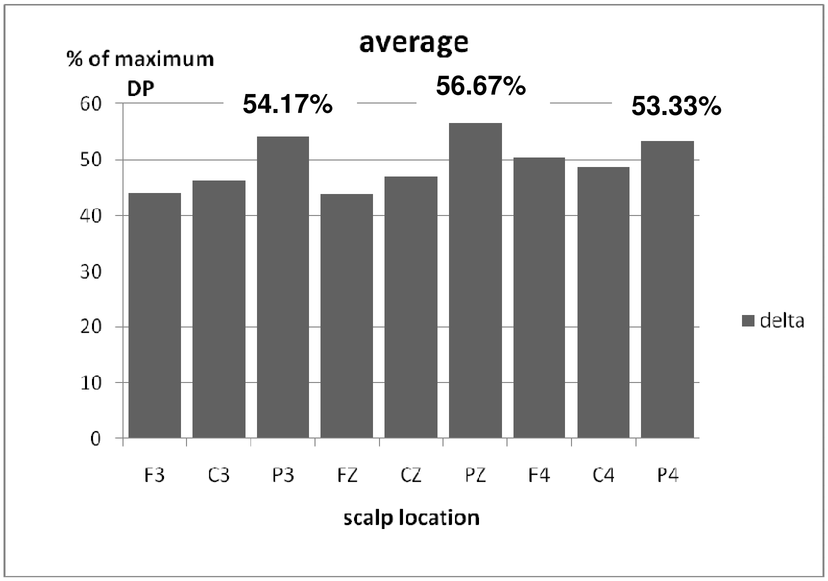


FIGURE 6: Percentage of Averaged Maximum DP in Delta Band for Time Interval 1024 ms.

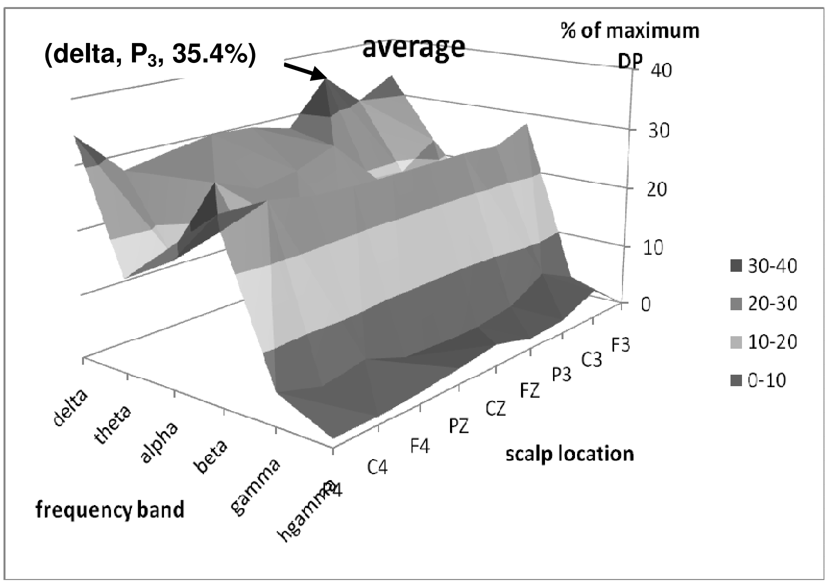


FIGURE 7: Percentage of Averaged Maximum DP for Time Interval 512 ms.

Figure 6 shows that the scalp location with highest percentage of averaged maximum DP using time interval 1024 ms was P_Z (56.67%), followed by P_3 (54.17%) and P_4 (53.33%).
For time interval 512 ms, the highest percentage of averaged maximum DP occurred at P_3 site within delta frequency range with 35.4% occurrence. The other two locations were P_4 and F_3, with 34.6% and 33.3% occurrences, respectively, also in the delta frequency band (Figure 7).

4. DISCUSSION AND CONCLUSION

In this study, we were interested to observe the maximum difference in power between resting and active imagination, i.e. at which scalp location and frequency band it occurred. The two features (scalp location and frequency band) are similarly identified by Leuthardt et al. (2004) in their BCI study using electrocorticographic (ECoG) [9]. However, they focus on r^2 value instead of maximum difference in power.

From our findings, the maximum different in power (DP) between the two conditions occurs in delta band at posterior area, i.e. P_Z for 1024 ms time interval and P_3 for 512 ms time interval. Comparing the two time intervals, delta band at central posterior area (P_Z) provided higher percentage of difference in power, hence, can be use to control one dimensional cursor movement [10] for future study of online BCI. By selecting the power difference of delta frequency band (< 4 Hz) in central posterior area, it is expected that the cursor can move further and faster in one dimensional direction towards targeted location. It is also expected that no training is required to obtain optimum results. Many researches have shown that BCI training must be conducted many times to achieve best performance for each subject. For example, Wolpaw et al. (2004) had conducted over twenty sessions per subject, at a rate of two to four per week [5]. In this study, the result was based on a single session of an experiment; hence, it is believed that the extracted feature can be used to control a one dimensional cursor movement without prior training. However, further study is needed to delineate this speculation.

Although it is always been reported that BCI researchers use mu and beta rhythm which is associated with actual movement or imagination of movement, in this research, the values in the delta band are used instead to convert EEG signals to cursor movement. Wolpaw et al. (2002) reported that movement or preparation for movement is typically accompanied by a decrease in mu (8-12 Hz) and beta (13-30 Hz) rhythm amplitudes [1], therefore, minimizing their different amplitude values in power. In this study, we found maximum difference in power occurs in delta frequency band even though the slow rhythm is always being associated with sleep wave in adult.

In the study, the maximum power difference in the delta frequency band was found at posterior area that contains primary and association cortices for somatosensation [11]. The region can be divided into two functional regions, one that involves sensation and perception and the other that concern with integrating sensory input, primarily with the visual system [12]. Since the subject was provided with the vision of targeted location and the cursor location, the posterior area probably constructs a spatial coordinate system to represent the two locations. Further study is needed in this aspect.

In conclusion, the present study suggests that difference in delta power at posterior area between resting and active imagination may be use to control a one dimensional cursor movement.

5. REFERENCES

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