RESEARCH ARTICLE OPEN ACCESS

Detection of an alpha rhythm of EEG signal based on EEGLAB

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Abstract
The electroencephalogram (EEG) is the electrical activity of brain that can be detected and measured by attaching some electrodes over the scalp according to international 10-20 system. There are five major frequency rhythms in EEG as delta, theta, alpha, beta and gamma. However EEG waves contain useful information of brain states, but we cannot extract all of these information by observing only in time domain directly. Hence we have to analyze these waveforms by signal processing techniques. Among of these EEG rhythms, alpha rhythm is very interested for us, because of its application in seizure suppression and for treatment of depression in biofeedback. Hence identification of location of the alpha band over the scalp can be very useful. In this paper, power spectrum density (PSD) is used as a powerful tool in order to detect alpha rhythm in subjects with open and closed eyes. Results of this paper are as a proper evidence of previous results which is concluded by other researchers on detection of place of alpha rhythm. It is observed that alpha rhythm is dominant wave over the back of head in awaken subject with closed eyes.
Keywords: Alpha rhythm, EEG, EEGLAB, PSD

I. Introduction

EEG is the electrical activity of brain that can be detected for monitoring of brain states in normal as well as abnormal infants, children and adult without any pain. These waves are measured by putting electrodes which usually are as small metal discs with thin wires over the scalp. Then these electrodes send signals to a computer for recording and displaying the results. Pattern of Normal EEG is recognizable by physicians. Hence, they can look for abnormal patterns that indicate seizures and other brain problems. The most common reason for usage of an EEG is diagnosis of seizure disorders.

EEGs can also help to identify causes of other brain problems such as sleep disorders, changes in behavior and etc. EEGs are sometimes used to evaluate brain activity after a severe head injury or before heart or liver transplantation [1].

Amplitude of EEG is in the range of microvolt up to 100 µV when it is taken over the scalp and in the range of milivolt when measured directly from surface of brain (in open operation) and its frequency is approximately up to 100Hz. There are five common frequency bands in EEG signals which their characteristics are shown in Table 1.

As is shown in Table1 amplitude of any rhythm has certain range. Intensity or value of amplitude is depended to some factor such as state of patient as well as location of electrode on the scalp. Alpha rhythm is one of these rhythms which is subject of this paper.

Table 1. Characteristics of EEG rhythms

State	Unconscious		conscious		
Rhythm	Delta	Theta	Alpha	Beta	Gama
Frequency (Hz)	0.5-4	4-8	8-13	13-30	>30
Amplitude (µV)	20-200	10	20-200	5-10	5–10

Amplitude of this rhythm varies from 14µv to 45 µv and its frequency is 8 to 13 Hz. Historically they were thought to represent the activity of the visual cortex in an idle state. More recent papers have argued that they inhibit areas of the cortex not in use, or alternatively that they play an active role in network coordination and communication [2]. Alpha wave biofeedback has gained interest for having some successes in humans for seizure suppression and for treatment of depression [3].

Electrical activity of brain is highly random in nature and may contain useful information about the brain state. They are basically non-linear and non-stationary in nature. However, it is very difficult to get useful information from these signals just by observing them directly in the time domain [4]. Hence, advanced signal processing techniques are necessary for investigation and feature extraction of brain states.
EEG can be analyzed using some methods in time domain, frequency domain and time_frequency domain. Many researchers have used PSD or spectral analysis for analyzing and feature extraction of EEG signals. This method determines power of the signal

which distributed in different frequency ranges. EEGLAB is an interactive MATLAB toolbox for processing continuous and event-related EEG, MEG and other electrophysiological data. EEGLAB provides an interactive graphic user interface (GUI) allowing users to flexibly and interactively process their high-density EEG and other dynamic brain data using independent component analysis (ICA) and/or time/frequency analysis (TFA), as well as standard averaging methods [5] which are freely available.

O. A. Padierna Sosa et al have developed an EEG signal processing program based on EEGLAB [6]. They concluded that EEGLAB is a program that provides an accessible solution to the EEG signal processing problem, its free distribution and great service variety allows inexperienced users to be able to acquire some knowledge experimenting with EEGLAB.

MD. Shahedul amin et al, have considered spectral analysis of human sleep EEG signals using EEGLAB. They have deduced that delta band more specifically, PSD at 1.8 ~ 2.0 Hz and at 2.7 ~ 2.9 Hz is good for finding whether a person is in sleeping or not. If the person is sleeping then there would be a sharp change at these positions [7]. S. Deivanayagi and her group have worked on spectral analysis of EEG Signals during Hypnosis. They have found the spectral analysis of EEG during hypnosis shows the frequency bands in theta and alpha ranges. From that analysis, they have derived that during hypnosis, the frequency bands acquired from the scalp falls in the higher theta and smaller alpha waves [8].

II. Power Spectrum Density(PSD)

PSD is the one of the most important tool for digital signal processing (DSP). It helps us to know how the strength of a signal is distributed in the frequency domain and its unit is energy per frequency. PSD demonstrates the strength of the variations of energy of a signal as a function of frequency. Hence, it gives us an idea about at which frequencies variations of energy are strong and at which frequencies they are weak. So calculating energy within a specific frequency range is possible by incorporating PSD within that frequency range.

PSD for a finite-power signal s(t) in operational terms can be defined as passing the signal s(t) through an ideal narrowband filter with transfer function as Eqn.1 [11].

$$H_{f_0}(f) = \begin{cases} 1, & f_0 - \frac{\Delta f}{2} < f < f_0 + \frac{\Delta f}{2} \\ 0, & else \end{cases} \quad (1)$$

The PSD evaluated at f_0, can now be defined to be the measured power at the filter output, divided by the filter width Δf (in the limit as $\Delta f \rightarrow 0$) [11].
Fast Fourier Transform (FFT) is a very helpful tool for computation of PSD. Matlab function as well as EEGLAB can be used for computation of PSD. In the case of EEG signal we know that, this signal is nonstationary signal, but investigation of this signal for less than 12 second can be assumed as a stationary signal [9]. Hence in this paper we have used 10sec of EEG signal for applying PSD.

III. Data collection

The EEG signals were downloaded from the EEG motor Movement /imagery dataset [in European data format (EDF)] [10]. Subjects performed different motor task while 64 channels EEG as international 10-20 system were recorded using the BCI2000 system. Each subject performed 14 experimental runs. Two one-minute baseline runs (one with eyes open and one with eyes closed which are our purpose), and three two-minutes runs of each of the four tasks with motor movement. In this paper we will discuss two tasks of subjects with open eyes and closed eyes (without motor movement) in first 10 second. EEGLAB software is used for taking PSD of these samples. Properties of these subjects are in Table.2. For these subjects sampling frequency is 160 Hz, number of sample is 1600, sampling time which is time interval between any two samples is 6 ms and duration of test is 10s.

Table 2. Characteristics of subjects

subject	s001r01	S001r02	S002r01	S002r02	S003r01	S003r02
Eyes state	open	close	open	close	open	close

IV. Result and discussions

For considering that in which part of scalp and what states of subject alpha rhythm is dominant, we have done some experiments in EEGLAB environment. In these experiments PSD of some channels such as P_Z, P_3, P_4, F_Z and C_Z for three subjects with open and closed eyes is taken out. In case of subject1, results have shown in Fig. 1 to Fig. 5 where left panel is related to subject with closed eyes and right panel is related to subject with open eyes. As it is mentioned in table 1, frequency of alpha wave is around **8** Hz to 13 Hz, so we highlighted this frequency range in mentioned figures with circles.

By simple observation in Fig.1 to Fig.5, we can say that alpha rhythm is dominant rhythm in awaken subjects with closed eyes in frontal, central and parietal lobes. But this rhythm will be canceled or attenuated with opening the eyes using any electrode over the scalp. Hence this method can be used for finding whether eyes of a person is closed or open.

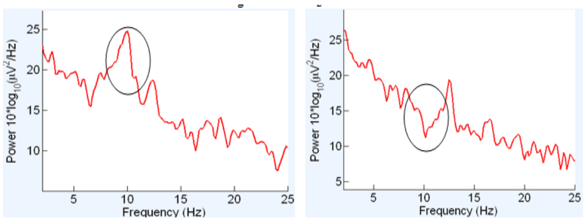

Fig.1 PSD of F_Z with closed eyes in left panel and with open eyes in right panel

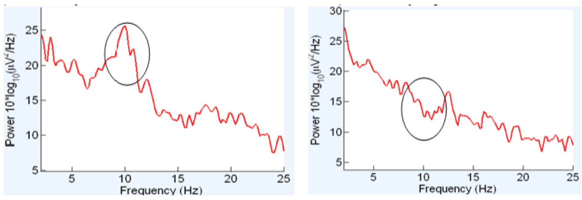

Fig.2 PSD of C_Z with closed eyes in left panel and with open eyes in right panel

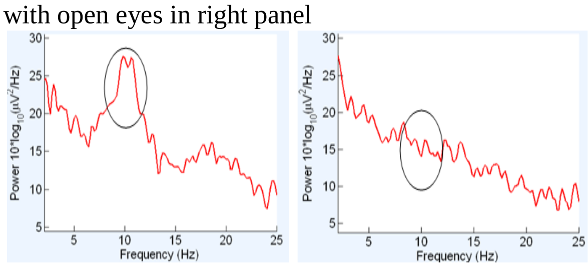

Fig.3 PSD of P_Z with closed eyes in left panel and with open eyes in right panel

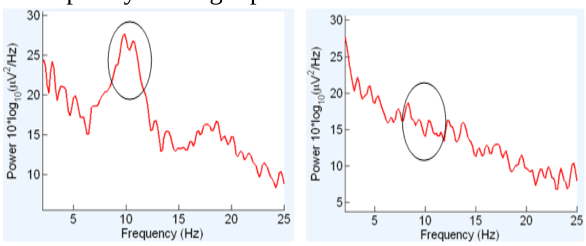

Fig.4 PSD of P3 with closed eyes in left panel and with open eyes in right panel

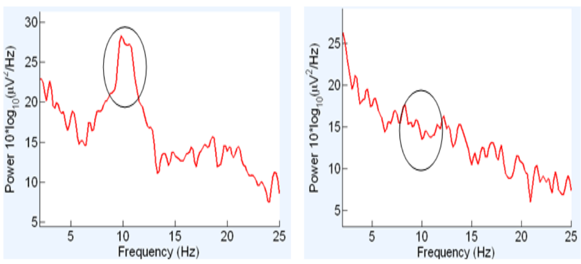

Fig.5 PSD of P4 with closed eyes in left panel and with open eyes in right panel

For two more subjects same results have observed. In Table 3 results of applying PSD on three mentioned subjects for five channels are displayed. In this table we have shown maximum amplitude or peak of the alpha rhythm with closed eyes for five mentioned channels. Bar graph related to this table, is shown in Fig. 6. for easy conclusion.

Table 3. Maximum amplitude of alpha wave with closed eyes for three subjects

Channel	Max α wave subject 1	Max α wave subject 2	Max α wave subject 3
Cz	26	23.5	25
Fz	25	21	24
Pz	27.7	29.5	29.5
P3	28	27.5	29.5
P4	29	29.5	27.5

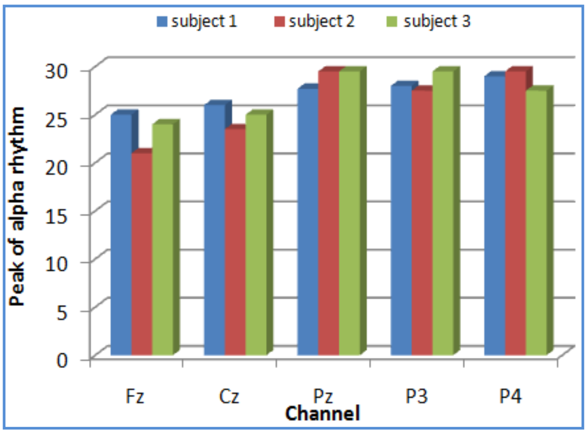

Fig. 6 Bar graph of peak (maximum) of the α rhythm

By focusing on Table 3 and graph of Fig. 6, we can say that for all three cases, maximum amplitude or peak of alpha wave is higher in Pz, P3 and P4 channels ratio to Cz and Fz. For all the cases, peak of the alpha rhythm reduces with changing the position of electrode from frontal to parietal lobes.

V. Conclusion

With analogy of 5 channels in 3 subjects, it is achieved that alpha band is dominant frequency rhythm in EEG signal in awaken subject with closed eyes, and with open eyes domination of this band is suppressed. As our results, this rhythm can be appears in any part of scalp but it is more dominant in channels which are located in back of head. Intensity of this band for any subject is different and that is depended to brain state of that subject. Hence we can conclude that alpha rhythm is dominant in alert person with closed eyes and back of head is good place for showing that. So it can be used in ambulatory or wireless EEG as a good symptom to detect whether eyes of a person were closed or open on the time of signal acquisition.

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