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Spectral and brain mapping analysis of EEG based on Pwelch in schizophrenic patients

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Spectral and brain mapping analysis of EEG based on Pwelch in schizophrenic patients

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Abstract. The aim of this study is to investigate and analyze the differences of power spectral distribution in various frequency bands between healthy subjects and schizophrenic patients. Subjects in this study were 8 people consisting of 4 schizophrenic patients and 4 healthy subjects. Subjects were recorded from 12 electrodes with Electroencephalography (EEG). EEG signals were recorded during a resting eye-closed state for 4-6 minutes. Data were extracted and analyzed by centering and filtering, then performed using Welch Periodogram technique for the spectral estimation with a Hamming window. The results of this study showed that delta power spectral in schizophrenic patients increased ten times from healthy subjects; theta power spectral in schizophrenic patients increased three times from healthy subjects; alpha power spectral in schizophrenic patients decreased with an increase of one third of healthy subjects. These results were confirmed by Kolmogorov-Smirnov test showing there were significant differences between schizophrenic and healthy subjects on delta, theta and alpha brain wave. Based on the results of Brain Mapping analysis showed that there was significant increasing in the activity of delta waves and theta waves in frontal lobe of schizophrenics, whereas the alpha waves indicated a decrease in the occipital lobe in all schizophrenic patients.

1. Introduction

Schizophrenia is conceptualized as a psychotic disorder with symptoms such as delusions (the belief in something that actually never happened or not real) and hallucinations (the belief that people see or hear us something that does not exist or is not real) [1]. One of the modalities that can observe the brain abnormalities in schizophrenia is EEG. EEG signals have characteristics to change each time (non-stationary) and random because of a very dynamic activity in the brain. Although the EEG signals is dynamic, but it can be classified based on certain characteristics, one of them through the power spectral analysis of several brain waves frequency range.

In the previous study, the power spectral analysis was used for classification of patients with brain damage asymmetric signal [2], the classification of EEG signals for automatic detection of epileptic seizure [3] also early detection of mild cognitive impairment and Alzheimer's disease [4]. In this study, EEG signals of schizophrenics analyzed and quantified using power spectral analysis through Welch periodogram approach with Hamming window, in an attempt to identify the components of the delta, theta, alpha, beta and gamma wave. Power spectral distribution of schizophrenia patients compared to power spectral distribution of normal subjects to analyze power spectral differences in both conditions. The representation of the power spectral distribution was displayed with brain mapping.

2. Method

The method used in this study was the experimental method with a direct measurement in normal subjects and patients with schizophrenia. Subjects in this study were 8 people consisting of 4 patients with schizophrenia (hereinafter referred SZ1, SZ2, SZ3, SZ4) who had been diagnosed based on the criteria of the Diagnostic and Statistical Manual of Mental Disorder, 4th edition (DSM-IV) and 4 healthy subjects (hereinafter referred to as H1, H2, H3, H4) as a control. Subjects were recorded from 12 electrodes with Electroencephalography (EEG) with a sampling frequency of 128 rps. EEG recording in schizophrenic patients was performed at the Mental Hospital of West Java province, Indonesia. While recording for healthy subjects was conducted at the Laboratory of Biophysics, Bandung Institute of Technology. The method of research that was conducted was depicted in the figure 1 below:

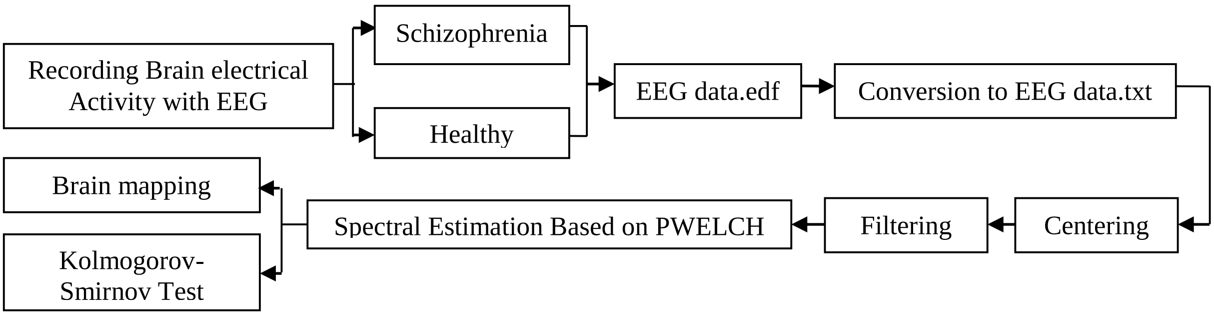

Figure 1. A block diagram of data processing.

Data recording results were in European Data Format (EDF) format. This data then were converted into American Standard Code for Information Interchange (ASCII) using TestBench software v.1.5.1.2. EEG data extraction was done by centering in order to remove the DC offset of each electrode. The principle of centering the data was done in order to averaging all the data and then each of the data was reduced by the average data. This was done so the the data which have a value above the average will have positive results and data which has a value below the average will have negative results. The data were then filtered from the noise and artifacts. This study used a band-pass filter that passes a signal at a frequency range above the lower limit frequency (2 Hz) and below the upper limit frequency (45 Hz).

Welch power spectral estimation was done by segmenting the data into the P part, the overlap segment length was D and one segment to the other segment displaced along the S Data (S ≤ D). Thus, the maximum length of P and the data obtained were [5]:

$$x^{(p)}(k) = w(k)x(k+pS), \quad 0 \le k \le D-1,\ 0 \le p \le P-1 \tag{1}$$

Furthermore periodogram estimate for each data-p to [5]:

$$U = T\sum_{k=0}^{D-1} w^2(k)\tilde{P}_{xx}^{(p)} = \frac{1}{UDT}\left|T\sum_{K=0}^{D-1} x^{(p)}(k)\exp(-j2\pi fkT)\right|^2 \tag{2}$$

Kolmogorov-Smirnov test (KS test) was applied to justify the power spectral differences between schizophrenic patients and healthy subjects. KS test principle showed compatibility between two cumulative distributions by taking into account the deviation between the two cumulative distributions [8]. Both sets of data were from the same distribution or there were no significant differences between both sets of data if the value of $p > 0.05$ at the 5% significance level. The representation of the power spectral distribution of each brain wave was displayed in 2D Brain mapping. The algorithm performed in conducting Brain mapping was as follows:

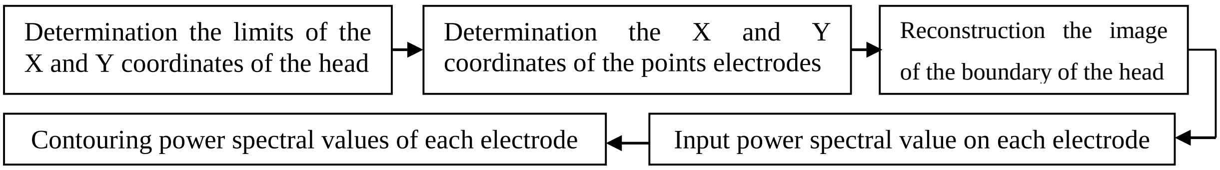

Figure 2. The algorithm of brain mapping.

3. Results

3.1. The results of spectral estimation

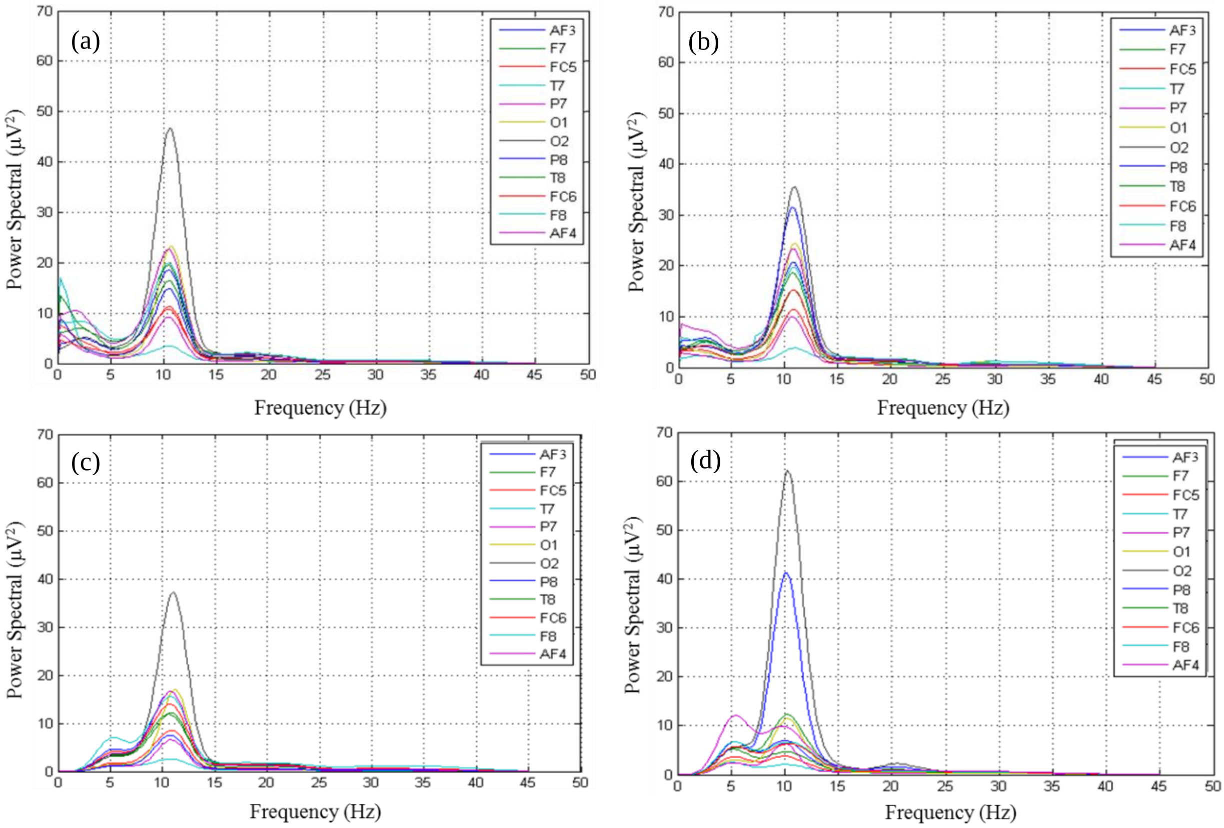

Figure 3. Results of spectral analysis in healthy subjects, (a) H1 (b) H2 (c) H3 (d) H4.

Figure 3 shows the results of spectral analysis using the Welch method in normal subjects with a resting state condition. The power spectral for normal subjects had varying values. The dominant power spectral distribution in healthy subjects was in the frequency 8-12 Hz. The highest value of power spectral was 62.11 μV^2 at the O2 electrode in the frequency 10.25 Hz. This indicated that the right occipital lobe had the highest alpha activity when recording a resting state. The results of the power spectral analysis for schizophrenics were shown in figure 4. The power spectral for schizophrenic patients had varying value. The dominant power spectral distribution in healthy subjects was in the range frequency of delta and theta. The highest value of power spectral was 263.3 μV^2 at the AF4 electrode in the frequency 3 Hz. This indicated that the right anterior frontal lobe experienced the highest alpha wave activity when recording the resting state.

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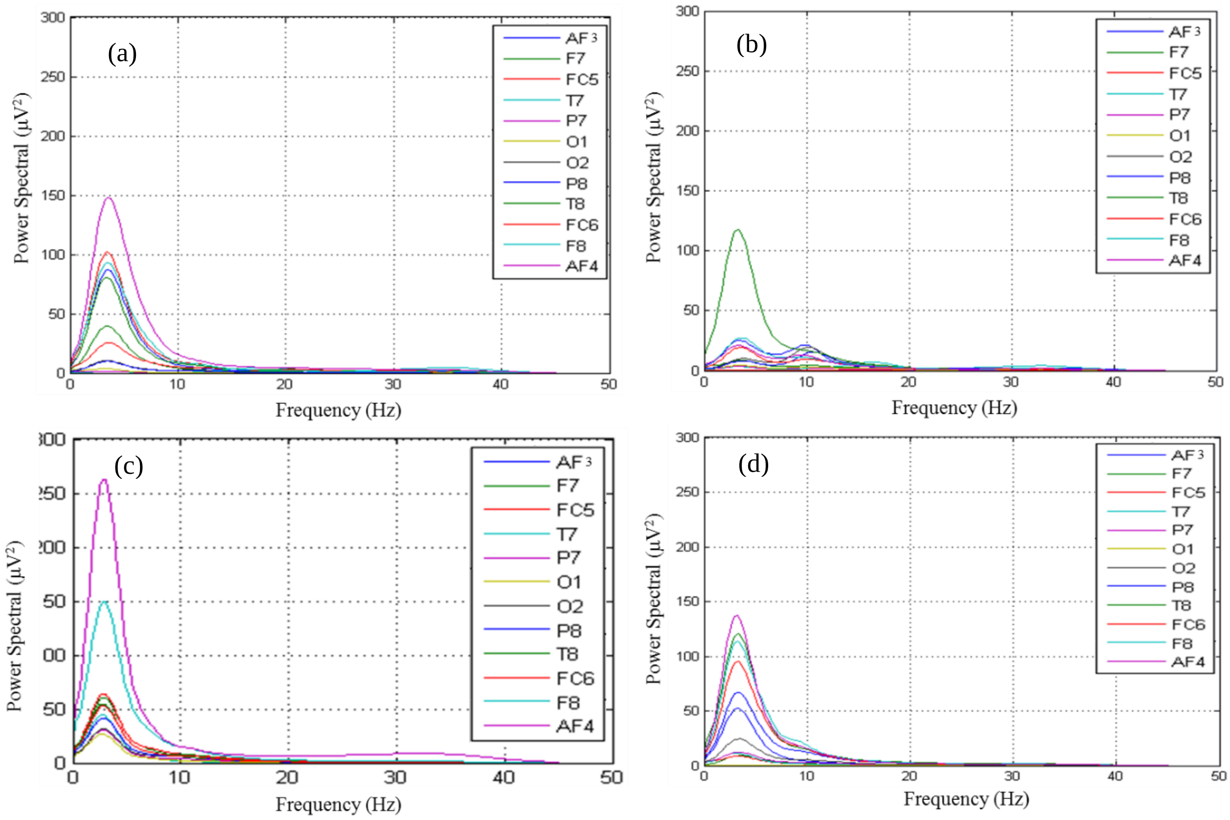

Figure 4. Results of spectral analysis in schizophrenic patients, (a) SZ1 (b) SZ2 (c) SZ3 (d) SZ4

These results were confirmed by Kolmogorov-Smirnov test which showed that there were significant differences between schizophrenic and healthy subjects on the delta ($p = 0.007$), theta ($p = 0.021$) and alpha ($p = 0.021$).

3.2. The results of brain mapping

Figure 5 shows the results of Brain mapping in healthy subjects and schizophrenic patients on the delta, theta, alpha beta and gamma. Based on these images it could be seen that there were significant differences between schizophrenic and normal subjects in the delta waves in the frontal lobe, theta waves in frontal lobe and in the alpha waves in the occipital lobe. There were no significant differences between schizophrenic and normal in the beta and gamma waves.

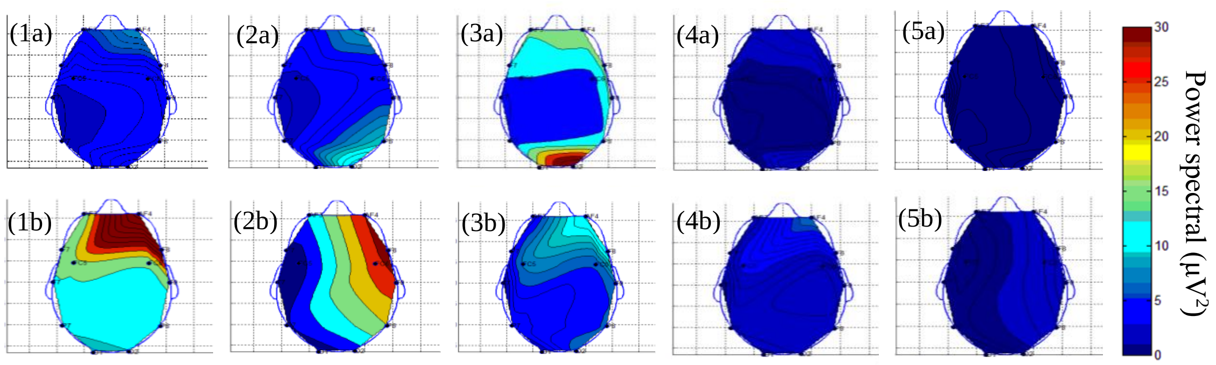

Figure 5. Results of brain mapping, (1) delta, (2) theta, (3) alpha, (4) beta, (5) gamma; (a) healthy subject, (b) schizophrenic patients

4. Discussion

Based on spectral analysis with Welch method, it could be seen some differences between healthy subjects and schizophrenic patients. The spectral power for normal subjects had the highest value on O2 electrode in the frequency range 10.25-11 Hz. The highest power spectral values of schizophrenics patients were contained in the AF4 electrode with a frequency range of 3 - 3.5 Hz. The lowest power spectral values were contained in the electrode electrodes O1. Electrodes O1 describe the electrical activity that occured in the occipital lobe which has a role in vision and visual processing. Power spectral value in the occipital lobe was low because the recording was done on resting state where schizophrenic conditioned at an eye-closed state. Based on the results of brain mapping, the most significant differences were in the delta and theta waves. This could be seen in the contour of the frontal lobe where the spectral power in the delta waves of schizophrenic patients increased. The frontal lobe is the area responsible for the process of thinking, emotions and behavior. Spectral value in the frontal of delta wave showed low levels of thinking in schizophrenic patients. It was suspected of being the cause of low levels of thinking and emotional responses. This finding was supported by Khan *et al.* (1993) [6], and Schellenberg *et al.* (1990) [7]. Unlike the case with delta and theta waves, the alpha waves decrease the occipital lobe activity in patients with schizophrenia. The contours of the spectral power in the beta and gamma waves did not show significant differences between schizophrenic and normal subjects. It could happen because the recording subjects were not in a state of full consciousness and did not experience high mental activity.

5. Conclusions

Spectral analysis of brain waves showed an increasing in delta power spectral (2-4 Hz) in schizophrenic patients with ten times increase from healthy subjects. The theta power spectral (4-8 Hz) in schizophrenic patients increased with three times increase from healthy subjects. Additionally, alpha power spectral (8-12 Hz) in schizophrenic patients decreased with one third increase of healthy subjects. Based on the results of Brain Mapping analysis showed that there were significant increasing in the activity of delta waves and theta waves in frontal lobe of schizophrenics, whereas alpha waves indicated a decreasing in the occipital lobe in all patients with schizophrenia.

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