

Evaluation of Left and Right Frontal Sub-Band via Three Dimensional EEG Model in Brain Balancing Application

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Abstract: Human Brain produces four bands of frequency such as delta, alpha, beta and theta. Every frequency bands have different range delta (0.2- 3 Hz), theta (3- 8 Hz), alpha (8-12 Hz) and beta (12-30 Hz) can be used for analyzing brain activities. Additionally, the brain is also divided into two hemispheres; right and left and every part has their own function of activities for human. Electroencephalogram (EEG) is a technique to measure signal by studying and evaluating the pattern of the brainwaves. Nowadays, there is not found a scientific prove of brainwave balancing index using EEG. But there are some techniques or devices to help human felling clam and brain balancing. This paper presents power spectral density (PSD) characteristics extracted from three-dimensional (3D) electroencephalogram (EEG) models in brain balancing application. There were 51 healthy subjects contributed the EEG dataset. Development of 3D models involves preprocessing of raw EEG signals and construction of spectrogram images. The resultant images which are two-dimensional (2D) were constructed via Short Time Fourier Transform (STFT). Optimization, color conversion, gradient and mesh algorithms are image processing techniques have been implemented. Then, maximum PSD values were extracted as features and further analyzed using mean relative power (MRP) and difference mean relative power (DMRP) technique for left frontal (LF) and right frontal (RF). Some patterns can be observed when MRP technique implemented which is the gap among LF and RF for theta, alpha and beta become smaller when the number of index increases. Although, DMRP technique shows the difference between LF and RF for alpha is decrease when the number of index increase. These patterns means that the signal for LF and RF alpha became more balance in index 5 (highly balanced) compared index 3 (moderately balanced). Results indicate that the proposed maximum PSD from 3D EEG model were able to distinguish the different levels of brain balancing indexes. Some patterns are indicates between index 3, index 4 and index 5 for brain balancing application. (323 words)

Key words: power spectral density; 3D EEG model; brain balancing; mean relative power

INTRODUCTION

A normal human brain contains a hundred billions of neurons as have been figured out by the scientists. About 250,000 neurons are connected to a single neuron. The information will be processed and sent by a normal brain to whole human body. An electrical power will be generated and this signal is named wave (Randall, Y.M. and C. O'Reilly, 2000; Cohen, D., 1996; Teplan, M., 2002; Kandel, E.R., *et al.*, 2000). Brain is consisted of pair parts known as left hemisphere and right hemisphere. The language, arithmetic, analysis and speech are performed in the left side of the brain. The right side of hemisphere is dominant in the cognitive tasks such as understanding, emotion, perceiving, remembering and thinking (Hoffmann, E., 2005; Sperry, R.W., 1975; Suresh Kanna, J.H., 2009; Zunairah Haji Murat, *et al.*, 2010).

The brain hemispheres are not exactly symmetrical, but the degree of asymmetry between the two hemispheres is insignificant (Suresh Kanna, J.H., 2009). Brain asymmetry means that both brain hemispheres have to work closely to ensure a smooth operating and having an overly dominant hemisphere is invariably not a good thing on human brainwave. When a person is relaxed the functions of both the brain hemispheres will be symmetrical (Suresh Kanna, J.H., 2009). Asymmetry technique can identify which brain hemisphere will be activated at a certain time and condition.

The happiness and good health is affected by healthy lifestyle (Sorgi, P.J.). Referring to a psychiatrist, Dr. Paul Sorgi, the stress feeling and faces mental illness is caused by disability of mind balance control and imbalance lifestyles will be affected by physical and psychology (Sorgi, P.J., 2002). In contrast, the happiness, satisfaction, healthy and free to communicate with each other are achieved by manage the mind balance (Sperry, R.W., 1981; Sorgi, P.J., 2002; Braverman, E.R., 2004). Many studies proved that longer and healthier life can be obtained to ensure the human being live in balance in order to improve human potential. Recently, the interests

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to find the methods for balancing of the brain have been increased (Liu, Z., L. Ding, 2006; Will, U. and E. Berg, 2007; Shim, B.-S., S.-W. Lee, 2007) by using auditory and visual methods in brainwave entrainment that results in more waves that are similar to the frequency following response (Will, U. and E. Berg, 2007; Shim, B.-S., S.-W. Lee, 2007; Rosihan, M., Ali and Liew Kee Kor, 2007). There are other methods to perform the test namely Transcranial Magnetic or Electric Stimulation. This traditional method included massages, meditation and acupunctures (Liu, Z., L. Ding, 2006; Will, U. and E. Berg, 2007; Shim, B.-S., S.-W. Lee, 2007). From the previous researches and the review of literature, most of the human want to feel happy and healthy. While, a balance life is become from balance thinking or mind from the brain (Randall, Y.M. and C. O'Reilly, 2000; Hutchison, M., 1994).

The electroencephalogram (EEG) is a device to collect brainwave signal and the frequency of theta- θ , delta- δ , and alpha- α and beta- β bands are produced (Jansen, B.H., W-K. Cheng, 1988). The EEG raw data is produced in spectral pattern. The power for each spectral power has the frequency bands: 0.5-4 Hz is delta- δ band, 4-8 Hz (theta- θ band), 8-13 Hz (alpha- α band) and 13-30 Hz (beta- β band) (Sornmo, L. and P. Laguna, 2005). These components are utilized and hypothesized to produce the variation of neuronal assemblies (Randall, Y.M. and C. O'Reilly, 2000; Hosaka, N., *et al.*, 2006). Referring to the theory, beta band is the lowest amplitude but the highest frequency band while delta band is opposite to beta band. High beta is occurred when human is inactive, not busy or anxious thinking but the low beta is occurred in positive situations. Human activities such as closing the eyes, relax/reflecting mode and all activities with inhibition control are affected by alpha band. The theta band is occurred when human in stress mode and light sleep also it has been found in baby activities. When human is in profound sleep mode, the delta band is produced (Teplan, M., 2002).

However, EEG topography is produced by several software or toolboxes such as EEGLAB in Matlab embedded module (Delorme, A. and S. Makeig, 2004). LORETA is an electromagnet tomography in low resolution used for Alzheimer patients to produce EEG spectrogram or topography (Babiloni, C., *et al.*, 2004). MEG and EEG signal are normally displayed by using the brainstorm approach (Diaye, K.N., *et al.*, 2004). Normally, EEG signals are represented by time domain and the plot of domain is displayed in time-amplitude. In the same time, some additional information can be found from frequency domain signal (Teplan, M., 2002). The artifact in EEG can be re-referenced in average of EEG power density spectrum analysis. The result is analyzed using an algorithm of Fourier Transform (FT) algorithm (Babiloni, C., *et al.*, 2006). Discrete Fourier Transform (FFT) is used to estimate the smoothed periodograms by the power spectral density (Piryatinska, A., *et al.*). There are several methods to analyze EEG signal in time-frequency domain and Short Time Fourier Transform (STFT) is a method to convert an EEG signal become a two dimensional (2D) image (Pourazad, M.T., *et al.*, 2003). However, some differences are recognized among 3D and 2D in term of implementation in technology field. For examples, parameters for 2D baby scanning are height and width and 3D baby scanning are height, width and depth (Ohbuchi, R, 1990). There are another research done in 3D implementation such as crystal surfaces (Kochae, A.I., R.A. Brazhe, 2011), interfacing computer to the brain (Dongmei Hao, *et al.*, 2006) and three dimensional acoustic assessments (Tadeu, A.J.B., *et al.*, 2001).

Hence, this paper shows the results of 3D model for EEG. The features namely PSD is extracted from 3D EEG model. Then the features extraction patterns of maximum PSD are analysed by mean relative power (MRP) and difference of mean relative power (DMRP) technique. MRP and DMRP is proven can implemented to recognise difference index of brain balancing.

2. Methods:

Figure 1 shows the flow diagram of methodology. Initially, EEG signals were collected from 51 volunteers. Then, the EEG signals were pre-processed to produce clean signals and filtering into four band frequencies delta, theta, alpha and beta. Next, the 2D image was produced from clean EEG signals and 3D EEG model have been developed from EEG spectrogram using image processing techniques.

The samples are among 51 volunteers which are 28 males and 23 females with an average age of 21.7. The data are collected from Biomedical Research and Development Laboratory for Human Potential, Faculty of Electrical Engineering, Universiti Teknologi MARA Malaysia (UiTM). All volunteers are healthy and not on any medication before the tests. These are performed and have fulfilled the requirement provided by ethics committee from (UiTM). Figure 2 shows the experimental setup for EEG signal recording. There were two channels and one reference to two earlobes used to collect or record EEG signal. These channels connected to gold disk bipolar electrode that complied with 10/20 International System. The sampling rate is 256Hz. Channel 1 positive was connected to the right hand side (RHS), Fp₂. The left hand side (LHS), Fp₁ was connected to channel 2 positive. Fp_z is the point at the center of forehead declared as reference point. MOBILab was used in wireless EEG equipment and the EEG signal was monitored for five minutes. The Z-checker equipment was used to maintain the impedance to below than 5k Ω . The MATLAB and SIMULINK are used to process the data with the intelligent signal processing technique

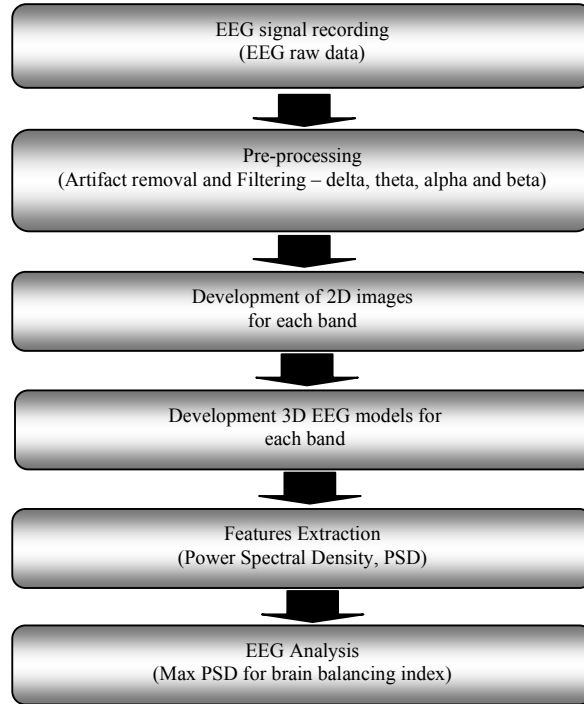


Fig. 1: Flow diagram of methodology

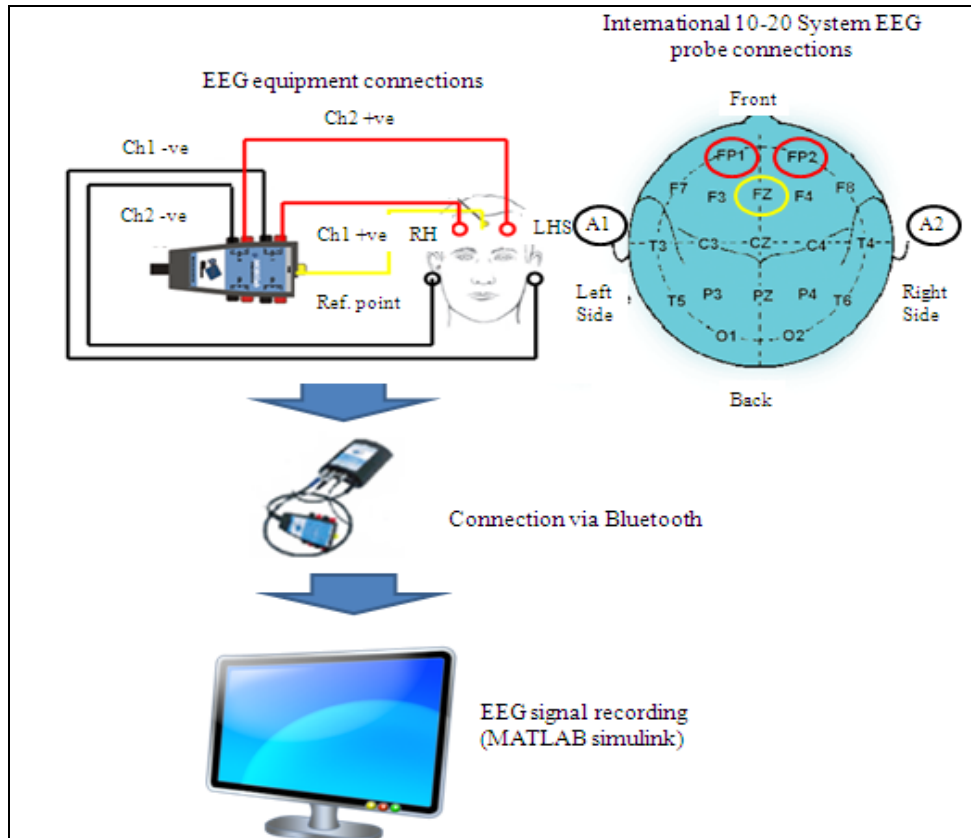


Fig. 2: Experimental setup

The EEG raw data was processed separately after data collection. The filter of band pass and artifact removal was included in EEG signal pre-processing. The artefacts may be produced when the eyes of volunteers blink. The artefacts can be removed by setting a threshold value in MATLAB tools. The setting of threshold values were below than $-100\mu\text{V}$ and greater than $100\mu\text{V}$. Only the meaningful and informatics signal were occurred within $-100\mu\text{V}$ to $100\mu\text{V}$. The Hamming windows were used to design the band pass filter with the rate of overlapping of 50% for the frequency; 4-8 Hz is theta- θ band, 0.5-4 Hz (delta- δ band), 8-13 Hz (alpha- α band) and 13-30 Hz (beta- β band).

The STFT was used to produce the spectrogram image in 436x342 pixels of image size for Fp1 and Fp2 channel. Each band of frequency was set in a spectrogram image. The theta- θ band was set from 4Hz to 8 Hz, 0.5-4 Hz (delta- δ band), 8-13 Hz (alpha- α band) and 13-30 Hz (beta- β band). This method was used for motor imagery EEG signal classification (Delorme, A. and S. Makeig, 2004; Babiloni, C., *et al.*, 2004) and epileptic seizures detection using EEG signal. (Diaye, K.N., *et al.*, 2004; Babiloni, C., *et al.*, 2006). Equation 1 was implemented to analysis the signal in time frequency domain. The EEG signal, $x(t)$, the window function, $w(t)$ and signiture of complex conjugate, $*$ are stated in STFT. The signal changed in time and performed using STFT. The small window of data in one time was used to map the signal to 2D function of time and frequency. Then the Fourier Transform (FT) would be multiplied with window function to yield the STFT.

$$STFT_x^{(w)}(t, f) = \int_{-\infty}^{\infty} [x(t).(t - t').e^{-j2\pi ft} dt] \quad (1)$$

3D EEG models have been developed from EEG spectrogram using image processing techniques. Some techniques or algorithms such as gradient, color conversion, optimization and mesh algorithms were integrated to developed this model, while the spectrogram images are represented in RedGreenBlue (RGB) color. Color conversion was implemented to transform spectrogram of RGB to spectrogram of gray scale. Gray scale images were used in a data matrix (I) which the values represent intensity within some range which are 0 (black) and 255 (white). Gray scale is the most commonly used images within the context of image processing. Equation 2 is implemented to RGB values of the pixels in the image to gray scale values of pixels.

$$P = C \times R \quad (2)$$

where C is the column value of the pixel, R is the row value and P is gray value. Then, Optimization Options Reference (OOR) was implemented to gray scale pixels image for optimization technique. There were severals options in OOR using MATLAB software but for this research, DiffMaxChange(Maximum change in variables for finite differencing) option have been chosen. The natural shape can be found from pixels value. This shape related to the maximum of certain energy function computed from the surface position and squared norm. A finite number of points were generated for the height of the optimized surface. Then the matrices of pixels value were resized using Gradient and Mesh algorithm into vectors. Two vector arguments replaced the first two matrix arguments, $\text{length}(x) = n$ and $\text{length}(y) = m$ where $[m, n] = \text{size}(z)$. A vectors x is included matrix X (rows) and a vectors y is for matrix Y (columns). Matrix X and Y can be evaluated as features using array module in MATLAB's software.

3. Data Analysis:

Three Dimensional (3D) EEG Model produces spectral of power spectral density (PSD), then the maximum PSD is chosen as features to analyze. Equation 3 and 4 are implemented to calculate the mean relative power (MRP) for sub band left frontal (LF) and right frontal (RF) using Statistical Analysis Microsoft Excel 2010.

$$LF\ k\ MRP = \frac{\sum LF\ k\ power}{N} \quad (3)$$

$$RF\ k\ MRP = \frac{\sum RF\ k\ power}{N} \quad (4)$$

k corresponded to δ , θ , α and β band, where δ band is 0.5-4 hz, θ band (4-8 hz), α band (8-13 hz) and δ (13-3hz). N is the number of the sample. The difference of mean relative power (DMRP) sub band are done for LF and RF as equation 5 using Statistical Analysis Microsoft Excel 2010.

$$k\ DMRP = \sum LF\ k\ MRP - \sum RF\ k\ MRP \quad (5)$$

k corresponded to δ , θ , α and β band, where δ band is 0.5-4 hz, θ band (4-8 hz), α band (8-13 hz) and δ (13-3hz).

The brain balancing index was analyzed offline from previous work [18]. The percentage difference between left and right brainwaves was calculated from PSD values of EEG signals using the asymmetry formula

as shown by (6). Table I shows the respective index and range of balance score. There were three groups; index 3 (moderately balanced), index 4 (balanced) and index 5 (highly balanced).

$$\text{Percentage of asymmetry} = 2x \frac{\sum \text{left} - \sum \text{right}}{\sum \text{left} + \sum \text{right}} \times 100\% \quad (6)$$

Table 1: Brain Balancing Group With Range Of Balance Score

Index level	Percentage difference between left and right	Samples
Index level 3	40.0%-59.9%	9
Index level 4	40.0%-59.9%	37
Index level 5	0.0%-19.9%	5

Result And Discussion

Three Dimensional (3D) EEG models were produced using optimization; gradient and mesh algorithms as depict in Figure 3 (a)-(h) (Appendix A). These show each of frequency bands for Fp1 and Fp2 channels. The 3D signal is spectral of PSD and a different maximum PSD produced by each frequency band. Eight 3D signals for channels Fp1 and Fp2 are produced by EEG sample. The 3D EEG model produced as depicted in Table II.

Table 2: Data Sample Per Index

Index level	Samples	3D EEG model
Index level 3	9	72
Index level 4	37	296
Index level 5	5	40

4.1 Mean Relative Power Pattern (MRP) for Left Frontal (LF) and Right Frontal (RF):

Normally, samples are in calmness and not stress when their brain in balance. This could be due to the theory that alpha is dominant during relaxing, close eyes but not sleep. From the observation in figure 3 (a-c) the gap for LF and RF alpha for index 3 (moderately balanced) is bigger compared to index 4 (balanced). The gap between LF and RF alpha become smaller and decrease. Because of small difference value between LF and RF alpha for index 5 (highly balanced), the curve is overlapped each other. Based on the results, there is evidence that the gap between LF and RF alpha decrease when the number of index increase.

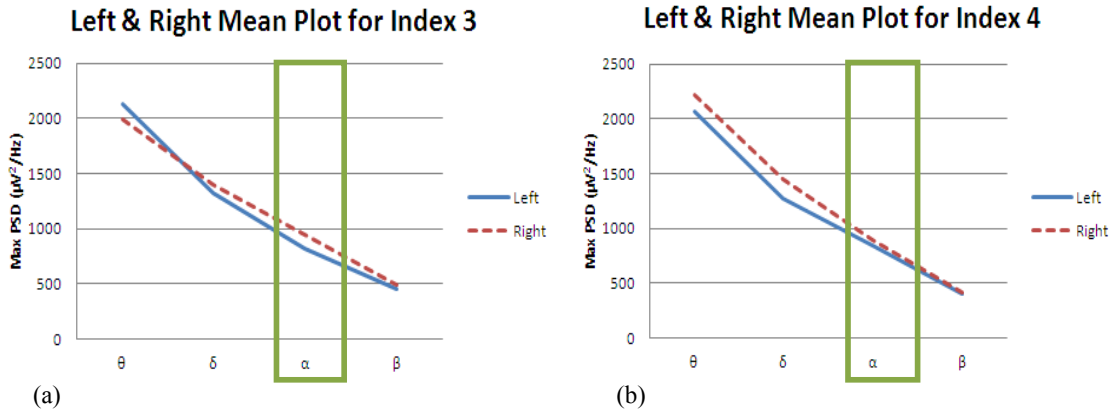




Fig. 3: Mean relative plot for Left Frontal (LF) and Right Frontal (RF) (a) Index 3 (b) Index 4 (c) Index 5

4.2 Difference Mean Relative Power Pattern (DMRP) for Left Frontal (LF) and Right Frontal (RF):

Some patterns can be observed from figure 4(a-c). The mean relative for maximum PSD in LF group shows lower value compared to RF group because the samples were calmness and not stress or tension. The theta-alpha in LF and RF group show the same pattern for three indexes. In contrast, beta signal in the same group shows opposite pattern caused of the samples were in relax (alpha) or deep relax (theta)). The mean relative value for LF and RF for alpha is higher than LF and RF beta showed that the samples were relax, not sleep and not in thinking mode when EEG data recording. The difference of mean relative between LF and RF for alpha decrease when the no. of index increase means that the signal for LF and RF alpha became more balance in index 5 compared index 3.



Fig. 4: Mean Relative plot for Left Frontal (LF) and Right Frontal (RF) and Difference Mean Relative (a) Index 3 (b) Index 4 (c) Index 5

Figure 5 shows the difference of mean relative between LF and RF for alpha decreases when the number of index increases. This pattern reflected to signal for LF and RF alpha become more balance from index 3 (moderately balanced), index 4 (balanced) and index 5 (highly balanced). The samples are relax, not sleep and thinking mode.

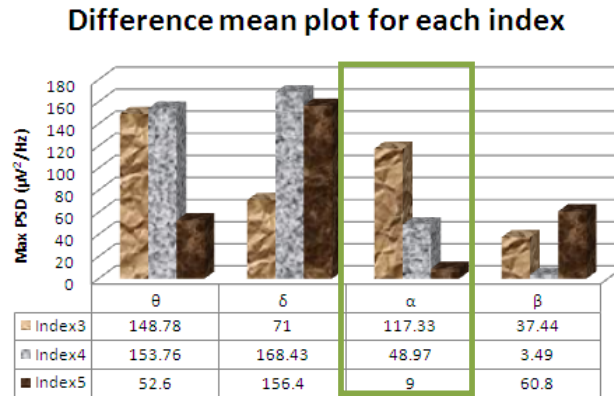


Fig. 5: Difference of mean relative power plot for difference indexes

Conclusion:

Experimental results revealed that maximum power spectral density from three dimensional signals can be used as a characteristic to recognize the pattern of brain balancing groups. The statistical analysis for sub bands right and left side shows that the data is significant. The results of an analysis depicted some of the dependent variables are not distributed in normal pattern which caused by the outliers. The slope pattern becomes decrease when the number of index is increase. The index 5 is highly balance compared to index 3, meaning the signal for LF and RF must equally same. The gap pattern becomes decrease when the number of index is increase. The index 5 is highly balance compared to index 3, meaning the difference between LF and RF must small. It is mean the signal for LF and RF become more balance for index 5 compared to index 3. Theta and alpha band showed the same pattern that RF signal is higher than LF signal but beta signal in the same group shows opposite pattern.

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Appendix A

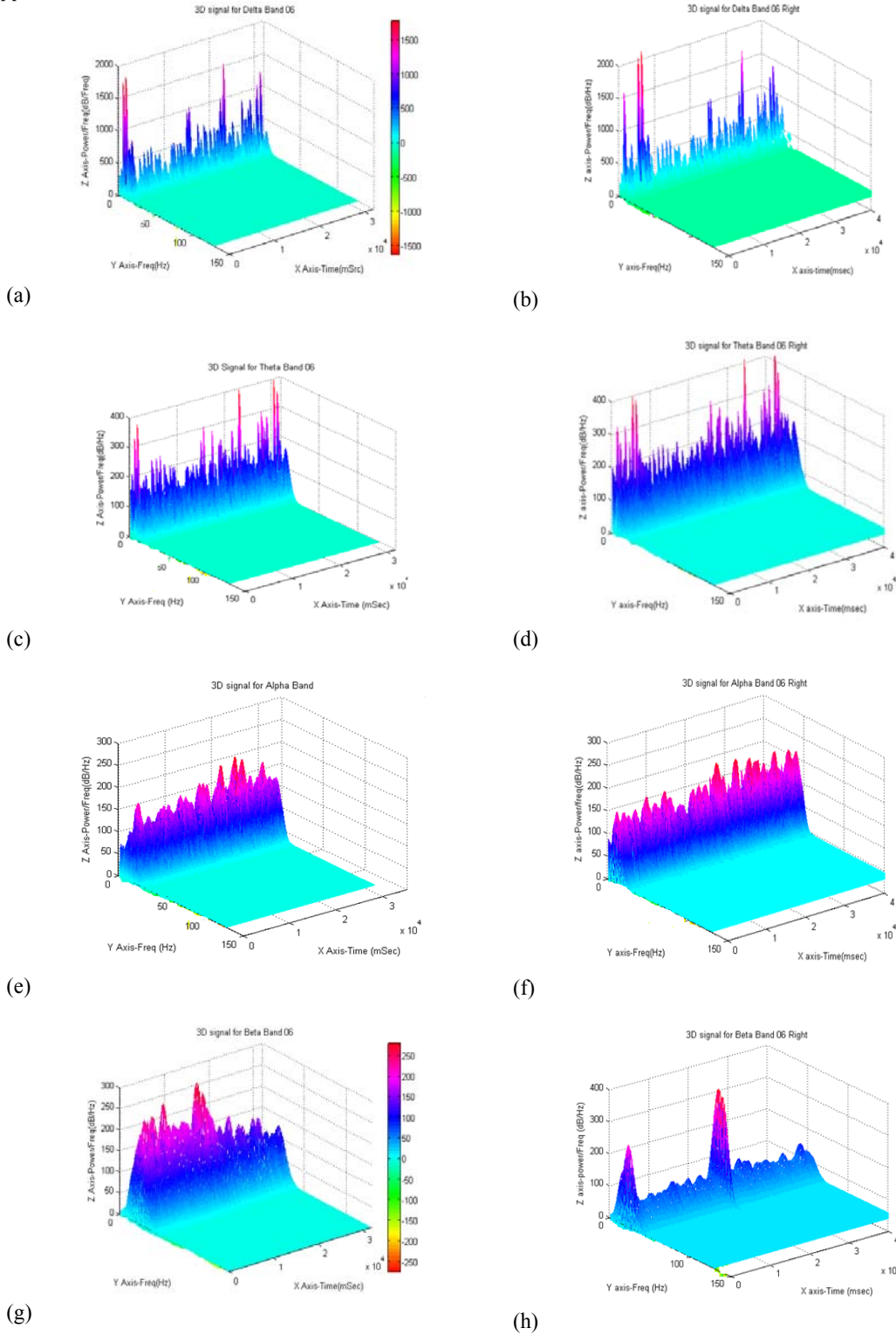


Fig. 3: Three Dimensional (3D) EEG model for (a) Delta band from Fp1 channel (b) Delta band from Fp2 channel (c) Theta band from Fp1 channel (d) Theta band from Fp2 channel (e) Alpha band from Fp1 channel (f) Alpha band from Fp2 channel (g) Beta band from Fp1 channel (h) Beta band from Fp2 channel