RESEARCH ARTICLE OPEN ACCESS

A Novelty of Electroencephalogram Signal and Assessment of Sub Band Data Distribution for Brain Balancing Application.

N. Fuad[1, 2], M.N.Taib[2], R.Jailani[2], M.E.Marwan[3]
[1] (Department of Computer Engineering, Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Johore, MALAYSIA)
[2] (Faculty of Electrical Engineering, Universiti Teknologi MARA, 40450 Selangor, MALAYSIA)
[3] (Kolej Poly-Tech MARA Batu Pahat, 83000 Johor, MALAYSIA)

ABSTRACT
The 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 EEG models involves pre-processing 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. The Shapiro-Wilk test has been used to check the normality of data distributio and the correlation between sub band has been analized using Pearson correlation. Results indicate that the proposed maximum PSD from 3D EEG model were able to distinguish the different levels of brain balancing indexes.
Keywords - *power spectral density; 3D EEG model; brain balancing*

I. INTRODUCTION

A normal human brain contains a hundred billions of neurons. About 250,000 neurons are connected to a single neuron. The information will be processed by brain and sent signal to whole human body. An electrical power will be generated and this signal is named wave [1-4]. Brain is consisted of pair parts known as left hemisphere and right hemisphere. The left hemisphere controlled language, arithmetic, analysis and speech activities. The right side of hemisphere is dominant in the cognitive tasks such as understanding, emotion, perceiving, remembering and thinking [5-8].

The happiness and good health is affected by healthy lifestyle [9]. The stress feeling and faces mental illness is caused by disability of mind balance control. Imbalance lifestyles will be affected by physical and psychology [11]. The happiness, satisfaction and healthy condition are achieved when human mind in balanced condition [10-12]. Previous studies proved the healthier life can be improving human potential. Nowadays, the interests to find the methods for balancing of brain have been increased [13-15]. The auditory and visual methods in brainwave entrainment gave positive results in balance thinking [14-16]. There are other methods namely Transcranial Magnetic or Electric Stimulation. This traditional method included massages, meditation and acupunctures [13-15]. From 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 [1, 17]. Recently, there is no a scientific proves of brainwave balancing index using EEG. Just some techniques or devices are found to help human felling clam and brain balancing.

The electroencephalogram (EEG) is a device to collect brainwave signal named theta-θ, delta-δ , alpha-α and beta-β bands are produced [19]. The EEG raw data is produced in spectral pattern. The power for each spectral powers has the frequency bands: theta-θ (4–8 Hz), delta-δ (0.5–4 Hz), alpha-α (8–13 Hz) and beta-β (13–30 Hz) [20]. These components are utilized and hypothesized to produce the variation of neuronal assemblies [1, 21]. In theoretical, 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 [3].

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. Fourier Transform (FT) is implemented to produce frequency domain. 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 [22]. Discrete Fourier Transform (FFT) is used to estimate the smoothed periodograms by the power spectral density [23]. There are several methods to perform time-frequency analysis and Short Time Fourier Transform (STFT) is one of the method to produced two dimension (2D) EEG outcome named 2D EEG image [24]. 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 [25]. There are another research done in 3D implementation such as crystal surfaces [26], brain-computer interface (BCI) [27] and assessment some parameters for 3D acoustic scattering; constant, linear and quadratic [28].

In this research, some methods are proposed to produce 3D EEG model. The resultant of 3D model for EEG is shown and the results used to find the correlation between left and right brainwaves using features extraction of maximum PSD from 3D model. The normality is tested using Shapiro-Wilk and Pearson Correlation in Statistical Package for Social Science (SPSS).

II. METHODOLOGY

The flow diagram in figure 1 shows the methodology of the research. Some processes have been carried out; data collection, signal pre-processing, 2D and 3D development, features extraction and data analysis on maximum PSD for evaluation.

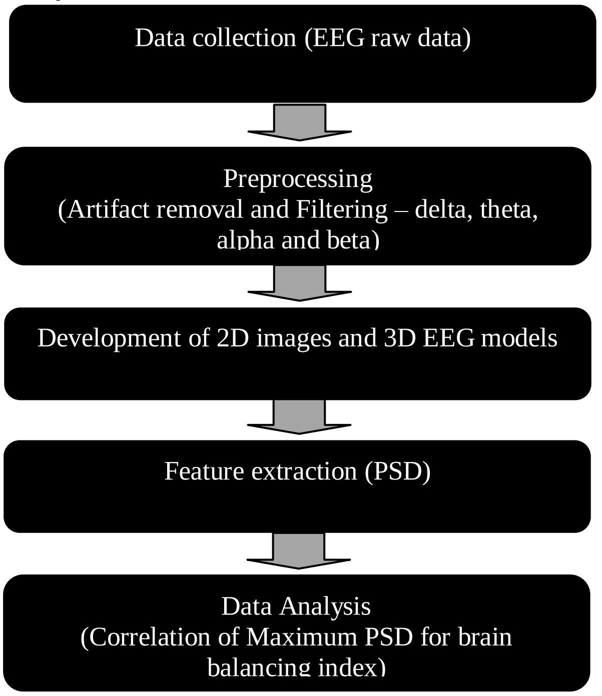

Figure 1. Flow diagram of methodology

2.1 DATA COLLECTION

This research involved 51 volunteers of samples 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 (UiTM) Malaysia. 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 recording. The EEG data were recorded using 2-channels (gold disk bipolar electrode) and a reference to two earlobes. The electrodes connections comply to 10/20 International system with the sampling rate of 256Hz. Channel 1 positive was connected to the right hand side (RHS), Fp_2. The left hand side (LHS), Fp_1 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 5kΩ. The MATLAB and SIMULINK are used to process the data with the intelligent signal processing technique.

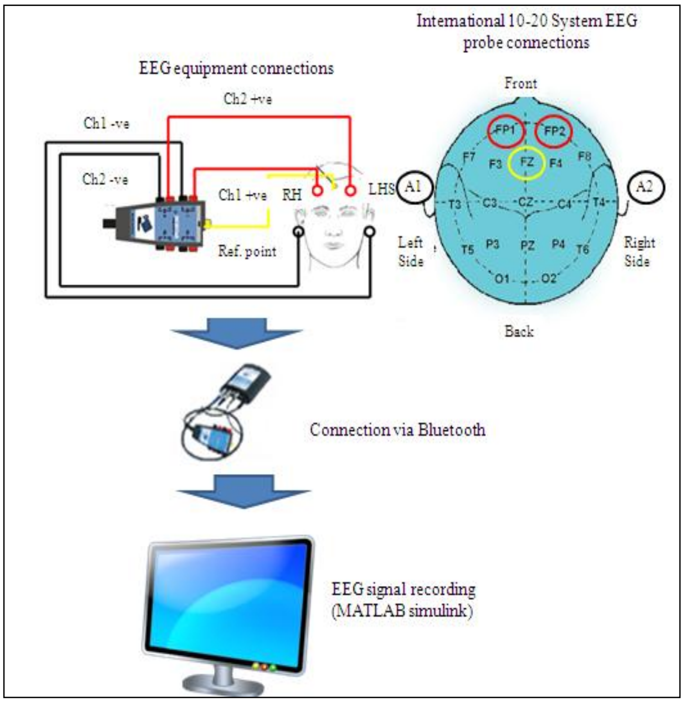

Figure 2. Experimental setup

2.2 PRE-PROCESSING

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 artifacts may be produced when the eyes of volunteers blink. The artifacts can be removed by setting a threshold value in MATLAB tools. The setting of threshold values were below than -100µV and greater than 100µV. Only the meaningful and informatics signal were occurred within -100µV to 100µV. The Hamming windows was used to design the band pass filter with the rate of overlapping of 50% for the frequency 0.5Hz to 30Hz which were theta-θ (4–8 Hz), delta-δ (0.5–4 Hz), alpha-α (8–13 Hz) and beta-β (13–30 Hz).

2.3 2D IMAGES USING STFT

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 beta band was set from 13Hz to 30Hz; delta band was set from 0.5Hz to 4Hz, alpha band (8Hz to 13Hz) and theta band (4Hz to 8Hz). Therefore, the analysis of time frequency (equation 1) using STFT was performed. 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.

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

2D EEG image named spectrogram is in time frequency domain.

2.4 3D EEG MODELS

3D EEG models have been developed from EEG spectrogram using image processing techniques. Color conversion, gradient, optimization and mesh algorithms were integrated to developed this model, while the spectogram images are represented in RedGreenBlue (RGB) color. Color conversion was implemented to transform spectogram of RGB to spectogram 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, length(x) = n and length(y) = m where [m, n] = 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 using MATLAB's array mathematics features.

2.5 EEG ANALYSIS

A spectral of PSD was produced from 3D EEG model, then the maximum PSD was choosed as features to analyze. Using Shapiro-Wilk technique in Statistical Package for Social Science (SPSS) software, the normality is tested. Shapiro-Wilk is selected because of the small size of samples. If the value of p is small enough which is less than 0.05 ($p < 0.05$), the data is considered as significant but not in normal distribution. Pearson Correlation showed the correlation between sub band for left and right brainwaves. The correlation is calculated using the formula as shown by (equation 3).

$$Pearson\_Correlation = \frac{\sum (x_i - x)(y_i - y)}{(N-1)s_x s_y} \quad (3)$$

where the mean of the sample is represent by and and xi and yi is the data point and N is the number of samples. Correlation is the linear relationship between two variables. Zero correlation indicates that there is no relationship between the variables. Correlation of negative 1 indicates a perfect negative correlation, meaning that as one variable goes up, the other goes down. Correlation of positive 1 indicates a perfect positive correlation, meaning that both variables move in the same direction together.

III. RESULTS AND DISCUSSION

An example of raw EEG signal showed in figure 3. 2D EEG image named spectrogram is in time frequency domain. An example of the image is generated using STFT and the algorithm has explained previously. The outcome showed in figure 4. The developments of 3D EEG models have been successful using optimization; gradient and mesh algorithms as shown in figure 5 (a)-(h). The 3D model is spectral of PSD and a different maximum PSD produced by each frequency band. Eight 3D models for channels Fp1 and Fp2 are produced by EEG sample. The 3D model produced as depicted in Table I.

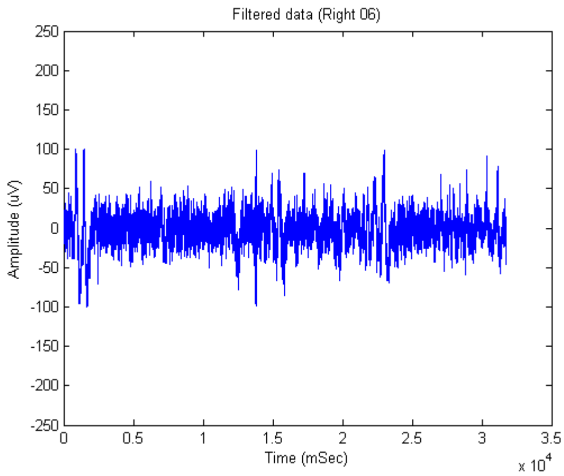

Figure 3. Raw EEG signal in time domain

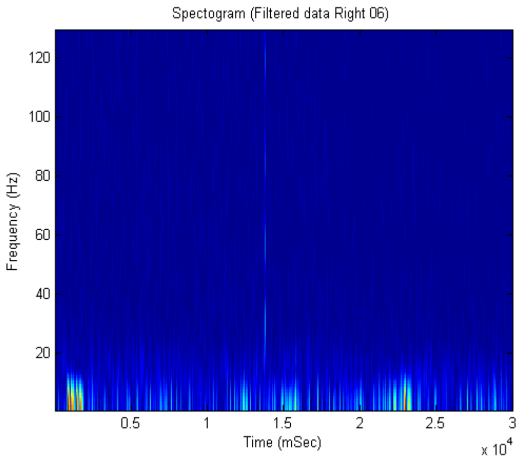

Figure 4. 2D EEG image or spectrogram

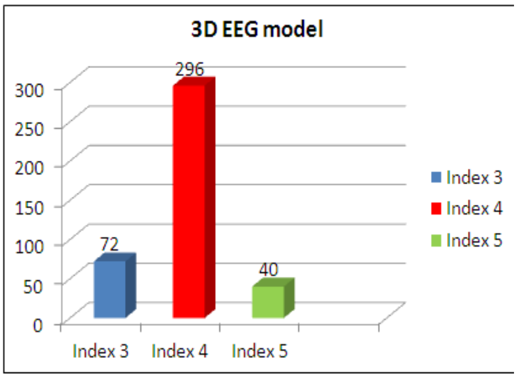

Figure 6. Data Sample Per Index

3.1 BRAIN BALACING INDEX

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 (4). Figure 6 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).

$$\text{Percentage of asymmetry} = 2x\frac{\sum left - \sum right}{\sum left + \sum right}x100\% \quad (4)$$

TABLE II BRAIN BALANCING INDEX WITH RANGE OF BALANCE SCORE

Balanced group/index	Percentage difference between left and right	Subjects
Moderately Balanced - 3	40.0%-59.9%	9
Balanced - 4	20.0%-39.9%	37
Highly Balanced - 5	0.0%-19.9%	5

3.2 NORMALITY TEST

Significant level, *p* which is the confidence interval for mean is 95%. Table III shows Shapiro-Wilk test for checking normality of the dependent variables which is maximum PSD data for each sub bands left and right.

TABLE III SHAPIRO-WILK TEST OF MAX PSD FOR EACH SUB BAND

	Shapiro-Wilk	
Sub band	Statistic	Sig.
Delta Left	0.956	0.054
Delta Right	0.954	0.047
Theta Left	0.966	0.152
Theta Right	0.950	0.030
Alpa Left	0.946	0.022
Alpa Right	0.910	0.001
Beta Left	0.855	0.000
Beta Right	0.884	0.000

It shows that $p < 0.05$ for certain data in bands, so that the data distributed not in normal pattern (blue color). In the other hand, the delta right, theta right, alpha (left and right) side and beta (left and right) side of the brain fulfill the hypothesis. Some data can be seen that $p > 0.05$ and this is true for delta left side and theta left side. The data is normally distributed (red color). Therefore the result showed that mixing between normal distribution and not normal distribution, resulted to nonparametric types of data.

3.3 CORRELATION

The confidence interval (significant level, p) for mean is 95%. Figure 7 depict the Pearson Correlation to analyze the correlation between sub band for left and right brainwave. There was a strong positive relationship between right and left side of brain for all sub bands with $r > 0.5$ for all sub bands at left and right side. For Index 3, alpa band is the highest correlation values (r=0.960), Index 4 theta band is the highest (r=0.622) and for Index 5 beta band is the highest value (r=0.946).

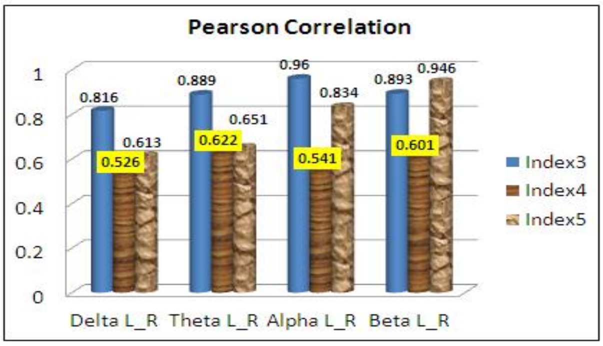

Figure 7. Pearson Correlation Value of Maximum PSD for Each Sub Band

IV. CONCLUSION

3D EEG model is generated using signal processing and image processing. The artifact removal and band pass filter are implemented for preprocessing signal stage. The resultant images which are two-dimensional (2D) EEG image or spectrogram were constructed via Short Time Fourier Transform (STFT). Optimization, color conversion, gradient and mesh algorithms are image processing techniques have been implemented to produce this model. Results indicate that the proposed maximum PSD from 3D EEG model were able to distinguish the different levels of brain balancing indexes. All bands from the left and right side of the brain are positively correlated.

REFERENCES

[1] Y.M. Randall and C. O'Reilly, Computational Exploration in Cognitive Neuroscience: Understanding the Mind by Simulating the Brain, *MIT Press London*, 2000.

[2] D. Cohen, *The Secret Language of the Mind*, Duncan Baird Publishers, London, 1996.

[3] M. Teplan, Fundamentals of EEG Measurement, *Measurement Science Review, vol. 2,* pp. 1-11, 2002.

[4] E. R. Kandel, J. H. Schwartz, T. M. Jessell, *Principles of Neural Science*, Fourth Edition, McGraw-Hill, 2000.

[5] E. Hoffmann, *Brain Training Against Stress: Theory, Methods and Results from an Outcome Study*, version 4.2, October 2005.

[6] R. W. Sperry, *Left -Brain, Right Brain*, in Saturday Review:speech upon receiving the twenty-ninth annual Passano Foundation Award, 1975, pp. 30-33.

[7] R. W. Sperry, *Some Effects of Disconnecting The Cerebral Hemispheres*, in Division of Biology, California Institute of Technology, Pasadena. California, 1981, pp. 1-9.

[8] Zunairah Haji Murat, Mohd Nasir Taib, Sahrim Lias, Ros Shilawani S.Abdul Kadir, Norizam Sulaiman, and Mahfuzah Mustafa. Establishing the fundamental of brainwave balancing index (BBI) using EEG, presented at *the 2nd Int. Conf. on Computional Intelligence, Communication Systems and Networks* (CICSyN2010), Liverpool, United Kingdom, 2010.

[9] P. J. Sorgi, *The 7 Systems of Balance: A Natural Prescription*.

[10] R. W. Sperry, Some Effects of Disconnecting the Cerebral Hemispheres, in *Division of Biology California Institute of Technology, Pasadena*. California, 1981, pp. 1-9.

[11] P. J. Sorgi, *The 7 Systems of Balance: A Natural Prescription for Healthy Living* in a Hectic World Health Communications Incorporated, 2002.

[12] E. R. Braverman, *The Edge Effect: Archive Total Health and Longevity*: Sterling Publishing Company, Inc.,2004.

[13] Z. Liu, L. Ding, Integration of EEG/MEG with MRI and fMRI in Functional Neuroimaging, *IEEE Eng Med Biological Magazine*, vol. 25, pp. 46-53, 2006.

[14] U. Will and E. Berg, Brain Wave Synchronization and Entrainment to Periodic Acoustic Stimuli, *Neuroscience Letters*, vol. 424, pp. 55-60, 2007.

[15] B.-S. Shim, S.-W. Lee, Implementation of a 3 –Dimensional Game for Developing Balanced Brainwave, presented at *5th International Conference on Software Engineering Research, Management & Applications*, 2007.

[16] Rosihan M. Ali and Liew Kee Kor, Association Between Brain Hemisphericity, Learning Styles and Confidence in Using Graphics Calculator for Mathematics, *Eurasia Journal of Mathematics, Science and Technology Education,vol. 3(2),* pp127 -131, 2007.

[17] M. Hutchison, *Mega Brain Power: Transform Your Life with MindMachines and Brain Nutrients*: Hyperion, 1994.

[18] Zunairah Hj. Murat, Mohd Nasir Taib, Sahrim Lias , Ros Shilawani S. Abdul Kadir, Norizam Sulaiman and Zodie Mohd Hanafiah, Development of Brainwave Balancing Index Using EEG, *2011 Third International Conference on Computational Intelligence, Communication Systems and Networks*, pp.374-378, 2011

[19] Jansen BH, Cheng W-K. Structural EEG analysis: an explorative study, *Int J Biomed Comput* 1988; 23: 221-37.

[20] L. Sornmo, and P. Laguna, *Bioelectrical Signal Processing in Cardiac and Neurological Applications. Burlington*, MA: Elsevier Academic Press, 2005.

[21] N. Hosaka, J. Tanaka, A. Koyama, K. Magatani, The EEG measurement technique under exercising, Proceedings of the *28th IEEE EMBS Annual International Conference*, New York City, USA, Sept 2006, pp. 1307-1310.

[22] A. Delorme, and S. Makeig, "The EEGLAB," Internet http://www. sccn.ucsd. edu/eeglab, vol. 2, no. 004, pp. 1.2.

[23] C. Babiloni, G. Binetti, E. Cassetta, D. Cerboneschi, G. D. Forno, C. D.Percio, F. Ferreri, R. Ferri, B. Lanuzza, C. Miniussi, D. V. Moretti, F. Nobili, R. D. Pascual-Marqui, G. Rodriguez, G. L. Romani, S. Salinari, F. Tecchio, P. Vitali,O. Zanetti, F. Zappasodi, P. M. Rossin., Mapping distributed sources of cortical rhythms in mild Alzheirmer's disease. A multicentric EEGstudy, *NeuroImage, vol. 22,* pp. 57-67, 2004.

[24] K. N. Diaye, R. Ragot, L. Garnero, V. Pouthas , What is common to brain activity evoked by the perception of visual and auditory filled durations? A study with MEG and EEG co-recordings, *Cognitive Brain Research,vol. 21,* pp. pp. 250-268, 2004.

[25] C. Babiloni, R. Ferri, G. Binetti, F. Vecchio, G. B. Frisoni, B. Lanuzza, C. Miniussi, F.

Nobili, G. Rodriguez, F. Rundo, A. Cassarino, F. Infarinato, E. Cassetta, S. Salinari, F. Eusebi, and P. M. Rossini, Directionality of EEG synchronization in Alzheimer's disease subjects, *Neurobiology of Aging, vol. 30*, pp. 93-102, 2009.
[26] A. Piryatinska, G. Terdik, W. A. Woyczynski, K. A. Loparo, M. S. Scher, and A. Zlotnik, Automated detection of neonate EEG sleep stages,*Computer Methods and Programs in Biomedicine*, In Press, Corrected Proof.
[27] M. T. Pourazad, Z. K. Mousavi, and G. Thomas, Heart sound cancellation from lung sound recordings using adaptive threshold and 2D interpolation in time-frequency domain, in Proceedings of the *25th Annual International Conference of the IEEE*, 2003, pp. 2586-2589.
[28] Ohbuchi.R, Incremental 3D ultrasound imaging from a 2D scanner , *Conference in Biomedical Computing*, Atlanta, 1990.

Appendix A

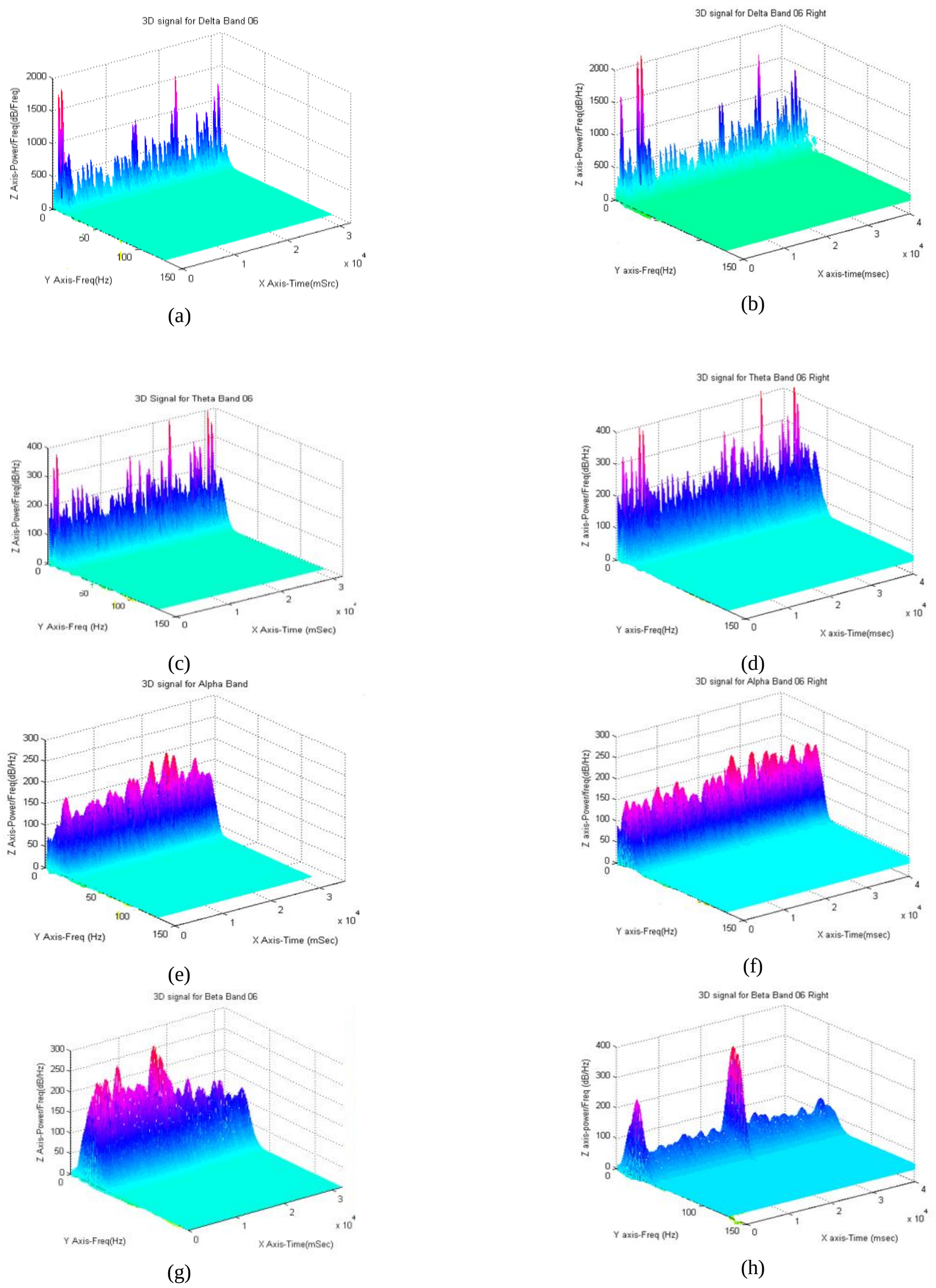

Figure 5. Three Dimension (3D) model for (a) Delta band from Fp1 channel (b) Delta band from Fp2 channel (c) Theta band from Fp1 channel (d) Theta band from Fp2 channel (e) Alpha band from Fp1 channel (f) Alpha band from Fp2 channel (g) Beta band from Fp1 channel (h) Beta band from Fp2 channel