# The Analysis Study to Abnormal of Electroencephalogram for Suspects and Used as Forensic Science Evidence

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## ABSTRACT

This paper presents a analysis of mental disorder such as mentally deranged or mental deficiency using electrical activity of human brain, we study diagnose the abnormal brain waves to fine primary screen suspects, and use as forensic evidence by analyzing signal data from a persons brain thought to be guilty of a crime or offense. The electroencephalogram (EEG) signal, these can be used to interpret or analyze by certain level. It may be evidence of a suspect in the crime. Law enforcement authorities have to keep track of investigation arrested the culprit, by virtue of modern science and measuring EEG and software to develop their own has proven that the offender was quickly shortened to save time, the investigation and more identify the perpetrators accurate. The result was that EEG is a tested to that measures and records the electrical activity of human brain. And tested to compare the signals from my software using estimated value of the theory of least squares method, compared to the original signal is available. Then the trainer will be derived from the measured EEG brain waves of beta from 10 volunteers.


**Keywords**: Electroencephalogram, Mental disorder, Mentally deranged, Mental deficiency, Beta waves

## 1. INTRODUCTION

Mental disorders are so many different types of screening suspected to be a person of unsound mind or mental abnormalities that require special examination to make a diagnosis more accurate. The EEG is one type of special neurological examination that the appearance of abnormal EEG. In which medical profession has continued for a long time. Later on the information technology progressed. It has been used to analyze the EEG study, more can be seen by analyzing signals from the human body (Physiological signal processing). Which is the top of considered as the main branches being researched. So, my study analyzed abnormal EEG to screen suspects. And used as forensic evidence by measuring and recording of EEG signals from 10 volunteer patients in various subjects. These EEG signal in can be used to analyze and interpret a certain level. It may be evidence of a suspect in crime and in order to prevent or to resolve a problem clue or clues doubt. Tracking for, which is both reliable and accurate information on the impact on the public. We need to Tracking the investigation to arrest the culprit, by virtue of modern science has proven that the offender quickly save time by shortening the investigation by law enforcement authorities. And identify the culprit, more accurately, to achieve clarity is fair to all parties involved. The evidence will be used for verification, together with other evidence must be accurate and precise. To accomplish that will require scientific knowledge and processes in various fields with the introduction of new tools, techniques and analysis methods. Including modern information systems to assist in the operation. It held that forensic science application knowledge of technical aspects, integrated into law enforcement. For the purpose of investigating the evidence and the legal proceedings that lead to bringing the offender to criminal penalties. Because if no forensic evidence, the important complex cases would not be able to bring the offender to justice has made a bad effect on society because it is likely that he will commit the same again. In addition, the introduction of forensic science used in conjunction with this process effectively. It is a measure to prevent and suppress crimes with the other hand. This paper aims to analyze the screening suspect a mental disorder by measuring EEG for use as forensic evidence. The theory is that the EEG in physiological. Brain wave in left brain and right hemisphere are four types. In descending order of frequency from low to high frequency such as delta ($\delta$), theta ($\Theta$), alpha ($\alpha$) and beta ($\beta$) type. Delta waves are a type of brain waves with a frequency range from 0.1 to 3 Hz is shows in Figure 1.

Theta waves are a type of brain waves with a frequency range from 4 to 7 Hz is shows in Figure 2.

Alpha waves are a type of brain waves with a frequency range from 8 to 12 Hz is shows in Figure 3.

Beta waves are brain wave with frequencies above 12 Hz up to 18 Hz. There are three levels of subfrequency levels such as low beta brain waves with a frequency range of 12 - 15 Hz, mid rang beta brain

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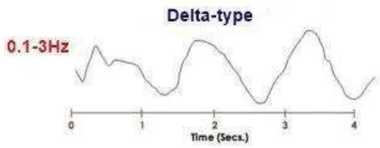


***Fig.1:***: Delta brain wave type.

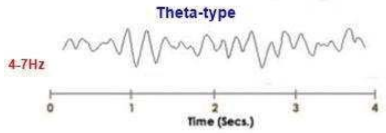


***Fig.2:***: Theta brain wave type.

waves with a frequency of 15-18 Hz, and a high beta brain waves with frequencies higher than 18 Hz as shown in Figure 4.

Measuring or recording EEG can be measured or recorded in several ways. Which in many ways is the method used to measure by fast fourier transform (FFT) spectrum by estimating the amount of energy at a given time by as much as one second, it would be the most accurate. By estimates of the total energy spectrum in-time as much as one second, it would be the most accurate.

**Estimation using the least squares method.**

Acquisition of the data set used functions that may be assigned by the thought that the best use of the data set. But given line may not be the best line. One methods that to find the best line for use the data set is needed is a method of least squares. The concept of this approach is to reduce the differences between each data point with the function. In this case the variable y is a linear function of several variables. The data set is represented by a straight line, called linear regression. As shown in equation (1).

$$\begin{aligned} y_i &= \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \cdots + \beta_k x_{ik} + \varepsilon_i \\ &= \beta_0 + \sum_{j=1}^{k} \beta_j x_{ij} + \varepsilon_i,\ i = 1, 2, ..., n \end{aligned} \tag{1}$$

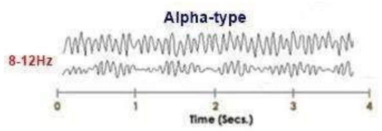


***Fig.3:***: Alpha brain wave type.

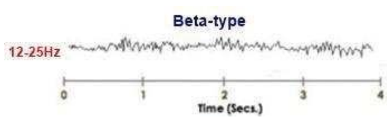


***Fig.4:***: Beta brain wave type.

Where,

$y_i$ is the dependent variable $i$

$x_{ij}$ is the independent variable $i$ in $j$ dimension

$\beta_0, \beta_i$ are coefficients shown intercept a slope.

$\varepsilon_i$ is the error between the value of the function and the actual data.

$k$ are all dimension

Least square function as shown in equation (2).

$$\begin{aligned} S = (\beta_0, \beta_1, ..., \beta_k) &= \sum_{i=1}^{n} \varepsilon_i^2 \\ &= \sum_{i=1}^{n} \left( y_i - \beta_0 - \sum_{j=1}^{k} \beta_j x_{ij} \right)^2 \end{aligned} \tag{2}$$

Where $S$ are total of square error. We can measure $S$ to a minimum by the differentiation coefficient $\beta$ making $S$ is the minimum value.

$$\begin{aligned} \left. \frac{\partial S}{\partial \beta_0} \right|_{\beta_0, \beta_1, ..., \beta_k} &= -2 \sum_{i=1}^{n} \left( y_i - \beta_0 - \sum_{j=1}^{k} \beta_j x_{ij} \right) \\ &= 0 \end{aligned} \tag{3}$$

and

$$\begin{aligned} \left. \frac{\partial S}{\partial \beta_j} \right|_{\beta_0, \beta_1, ..., \beta_k} &= -2 \sum_{i=1}^{n} \left( y_i - \beta_0 - \sum_{j=1}^{k} \right. \\ &\quad \left. \cdot \beta_j x_{ij} \right) x_{ij} \\ &= 0,\quad j = 1, 2, ..., k \end{aligned} \tag{4}$$

According to equation (3) and (4) the form of quadratic minimum are

$$\begin{aligned} n\beta_0 + \beta_1 \sum_{i=1}^{n} x_{i1} + \beta_2 \sum_{i=1}^{n} x_{i2} \\ + \cdots + \beta_k \sum_{i=1}^{n} x_{ik} = \sum_{i=1}^{n} y_i \\ \beta_0 \sum_{i=1}^{n} x_{i1} + \beta_1 \sum_{i=1}^{n} x_{i1}^2 + \beta_2 \sum_{i=1}^{n} x_{i1} x_{i2} \\ + \cdots + \beta_k \sum_{i=1}^{n} x_{i1} x_{ik} = \sum_{i=1}^{n} x_i \\ \vdots \quad \vdots \quad \vdots \\ \beta_0 \sum_{i=1}^{n} x_{i1} + \beta_k \sum_{i=1}^{n} x_{ik} x_{i1} + \beta_2 \sum_{i=1}^{n} x_{ik} x_{i2} \\ + \cdots + \beta_k \sum_{i=1}^{n} x_{ik}^2 = \sum_{i=1}^{n} x_i \end{aligned} \tag{5}$$

From equation (5), they can be expressed in the form of meta-matrix shown in Equation (6).

$$y = x\beta + \varepsilon \quad (6)$$

Given

$$\mathbf{y} = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix}, \quad \mathbf{x} = \begin{bmatrix} 1 & x_{11} & x_{12} & \cdots & x_{1k} \\ 1 & x_{21} & x_{22} & \cdots & x_{2k} \\ \vdots & \vdots & \vdots & & \vdots \\ 1 & x_{n1} & x_{n2} & \cdots & x_{nk} \end{bmatrix}$$

$$\beta = \begin{bmatrix} \beta_0 \\ \beta_1 \\ \vdots \\ \beta_k \end{bmatrix}, \quad \varepsilon = \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix}$$

The estimate for the inspired by the recession according to equation (7).

$$\hat{\beta} = (x'x)^{-1} x'y \quad (7)$$

From equation (7) when the coefficient used to estimate the model and make it function for linear estimation of equation (8).

$$y_i = x\hat{\beta} = (x'x)^{-1} x'y \quad (8)$$

From equation (8), when the desired function form can be applied to estimate the EEG signal by changing the model equations to the nature pairs of data model equations (9).

$$V_i = \sum_j a_{i,j} v_j \quad (9)$$

Where

- $V_i$ are implementation signals of $V_2$, $V_3$, $V_4$, and $V_5$
- $V_j$ are input signal from signal generator I, II, $V_1$, V
- $a_{ij}$ are the average form of the measured actual data measurement signals and 21 channels of EEG patterns as shown in Equation (10).

$$a_{i,j} = \left(v_j^T \cdot v_j\right)^{-1} v_j^T v_i \quad (10)$$

Given

$$V_i = V_{s,i}$$

$$V_j = V_{s,j}$$

Where

- $S$ are the average number of people.
- $J$ are EEG data I, II, $A_1$ and $A_6$
- $i$ are signal data of $A_2$, $A_3$, $A_4$ and $A_5$

## 2. METDULOGY OF WORK

First, frequency analysis algorithm study on brain wave to be used for data analysis. Secondary, records of 10 volunteer patient electrical physiology study. And since the brain of patients with Parkinson's disease, abnormal mental condition are susceptible to being induced by sleep deprivation and how to record electrical brain waves are a type called a spike up. Thirdly, the other observed disorders such as alpha wave decline, theta and delta waves increases. In addition, studies of brain waves that are similar to the epilepsy or abnormal mentioned in the left brain hemisphere or not. Fourthly, write program using matLAB version 9 or above for display and processing and interface between EEG recording devices and computers using Microsoft Windows 10 operating system. Finally, the list of suspects recorded EEG signals by comparison with a standard type beta.

### 2.1 System Design

The developed prototype device has two parts are including of hardware, software display and processing program is recorded EEG signals in two dimensions. Equipment hardware features are as follows.

- Measure the brain waves of a beta frequency of 13-25 Hz.
- Measure in 21EEG mode using six electrodes.
- Convert analog signals into digital 8-bits.
- A sampling rate of 500 Hz/channel.
- A USB interface types.
- 12VDC power supply.
- Maximum weight of 900 grams for easy portability.

2.1.1 Design of EEG device.

The design of the EEG device with 6 modules are shown in Figure 5 contains the measured signal using the detection signals from skin head of patients with electrodes, it is represented by the voltage coming out with differential amplifier circuit and the voltage of electricity that can be used to study the function of the brain wave, the signal that it is bandwidth in the range between 0.1-25Hz by selected. And then designed to amplify the signal noise reduction by using the signal of active device, such as the medical grad operational amplifier to reduce noise. The analog signal will be sent to PIC16F628A microcontroller, which is responsible for converting the signals into digital signals with a set of modules, and communication to transmit a signal to the computer is shows in Figure 5.

Figure 5 if the EEG signal from human brain is increased by EEG amplifiers (medical grade), and passed through a $3^{rd}$ order low-pass filter which minimizes distortion. When the signal is converted to digital signal, the EEG signal is picked up by the six electrodes and passed through the protection circuit in 6Chs preamplifier circuit. It serves two pur-

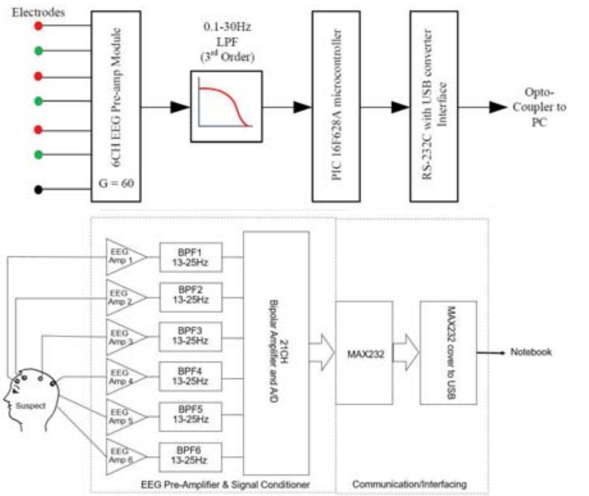


***Fig.5:***: The design of EEG block diagram.

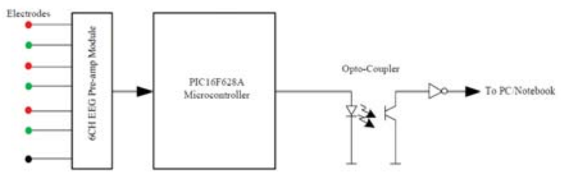


***Fig.6:***: Isolator circuit of EEG device

poses of protection circuit are: Firstly, it protects the circuitry from electrostatic discharge and secondly it protects the user from failing circuitry. In theory at least. After the filtering, the signal is ready for acquisition by the analog-to-digital converter which in our case is located inside a PIC16F628 microcontroller are shows in Figure 6. It will sends the digitized EEG to a PC/Notebook or mobile smart phone via a standard serial cable or wireless communication. To protect the user from electrical faults, the EEG device is electrically isolated from medical devices or external power sources. The block diagram is shows in Figure 6.

2.1.1.1 Protection circuit

After entering the printed circuit board trough EEG connectors, is the protection circuit. At the front circuit have 3 capacitors that are supposed to suppress RF signals entering the system through the electrode cable. They are followed by more transistors and resistors. The transistors are not actually used as such, instead they act as clamping diodes. When the voltage over one of these "diodes" exceeds about 0.5 volts, they start to conduct current. Below that level, they are basically open circuits, only conducting a few micro-amperes. If the voltage reaches about 0.9 volts, they begin to conduct in earnest. With the help of the resistors they prevent the voltage from ever going above 0.9 volts. They also limit the current going through a user, in case of short circuit between a power rail and an amplifier input pin.

***Fig.7:***: The EEG hardware prototype set.

2.1.1.2 Amplifiers and filters

Behind the protection circuit the INA (Instrumentation Amplifier). It has a lowers impedance, making it less sensitive to noise ratio. The gain of this circuit is set by two resister to G = 1 + 50K/Rg, where Rg = two resistor. In the junction between two it is possible to measure the common mode voltage. Integrate Circuit does this, and then passes the signal on to the DRL. After the INA, there is a high pass filter (HPF) made from capacitor and resistor, which is designed to remove direct current offsets. Its cut off frequency is about 0.10Hz. A standard, non-inverting amplifier circuit follows the HPF. Gain is set as G = (Ra +Rb)/Ra, where Ra = Pin+Rin = 1kOhm to 20k, and Ra=Rb=120k allowing the gain to be set to 60. Finally, there is a second high pass filter stage, identical to the first, and a $3^{rd}$ order low pass filter which also amplifies the signal another 18 times, with the op-amp at its centre.

Figure 7 is the EEG prototype hardware set of this research. They are include six EEG preamp module, Band Pass Filter (BPF) A-to-D converter, microcontroller and power supply etc.

2.1.1.3 RS232 Interface

The serial interface has three parts: A classic MAX232 that converts the serial port voltage levels usually to TTL levels by USB. Two opto- couplers electrically isolates the MAX232 from the rest of the board, for safety reasons. For someone who has used opto-couplers before, the circuitry around the opto-couplers may look a bit different. It allows higher transmission bitrates by reducing the voltage swing needed to change from zero to one or one to zero.

2.1.1.4 Microcontroller

The microcontroller is PIC16F628A by PIC family. It was selected for several reasons. It is quite fast. Most instructions only take one clock cycle to execute. It has a built in 6-Channel 8-bit A-to-D converter making it possible to measure 6 EEG signals at the same time, with 3 amplifier PCB. In the PIC16F628A, the last two channels are only 8 bits, which is not suitable for EEG, but should still work ok with ECG for example. It has a PWM-output. In the circuit it is used to generate a 10Hz square-wave signal. The signal is fed to the analog board where the amplitude is divided down to about 200 micro volt, suitable for testing and trimming the EEG amplifiers. It has a full-duplex serial port. Programming is very easy and does not require an expensive programmer. In other words, it does everything that

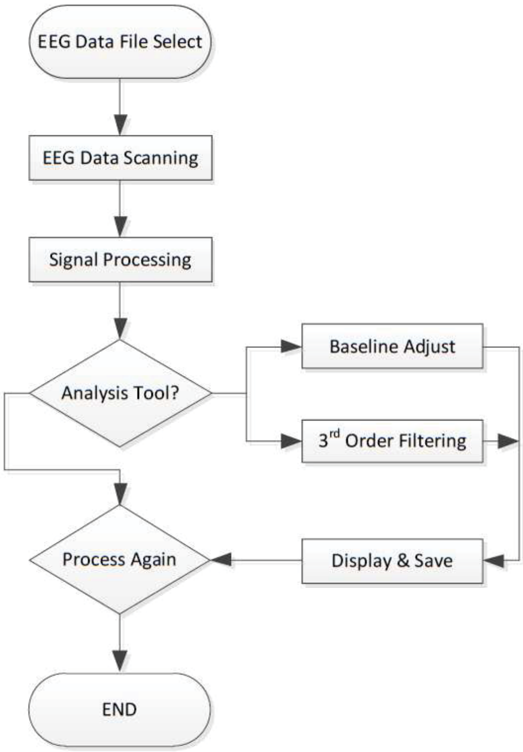


***Fig.8:***: Flowchart of data acquisition and the EEG signal processing.

is needed. The discrete parts to the left of the microcontroller are used for several things, but most of them are dedicated to creating a 4.0V DC signal for the A-to-D-converter.

2.1.1.5 Computer programs for processing.

The medical doctor's computer will act as a hub of information processing. Store and check for signs of each suspect. It can sending a EEG signal to physicians in an his/her computer. It consists of a set of program data for receive the software and data storage and processing of EEG signals. The display and signal processing applications, as shown in Figure 7 features as follows: -

– Displaying a list of suspects while recording EEG.
– EEG standard recording or equivalent.
– Display of EEG two dimension graph.
– List of suspects recorded EEG beta signals.
– The graph shows the area of interest and zoom-in / zoom the graph. etc.

Figure 8 is shown a flowchart of data acquisition and the EEG signal processing with HD two dimension graph. This principle we can creates a two-dimensional image, and took raw data to plot a graph by pulling data from the microcontroller by file format is a dot text (.txt) file, because this type with a capacity to store very low capacity. Then pick up programming txt is then plotted on a 2D graph.

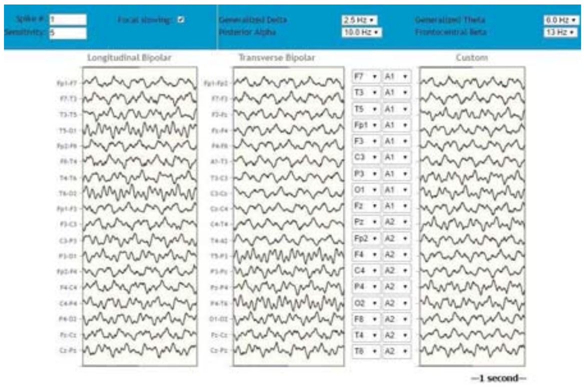

***Fig.9:***: PC screen displayed beta wave 13Hz of EEG recording.

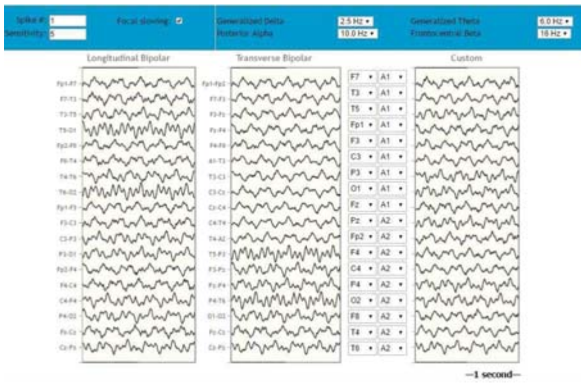

***Fig.10:***: PC screen displayed beta wave 16Hz of EEG recording.

## 3. RESULTS AND DISCUSSION

The results were that there was a master recording device signals EEG type beta program for visualizing and processing EEG out in a two-dimensional graphs and distribution of electrical atypical in the frequency range between 13-25. Hz. Figure 9-15 will display images in both normal subjects and individual aberrations of the mentally impaired. In this simulation, we take from the equation least squares.

However the EEG recording spatial resolution is low compared to Manetic Resonance Imaging (MRI) of the brain wave, we can determine whether any part of the activity. While we had recorded electrical brain that may be subject to interpretation of any part of the brain that are working on the assumption that by setting up a time. Therefore EEG recordings may be unable to measure activity in the brain that are deeper than the top, called the cerebral cortex as well. From EEG recordings trial of the beta is ideal for measuring symptoms of a mental infirmity and mental disabilities as a standard feature of the EEG. The meaning of EEG brain of beta is to be in working condition and unconscious. The EEG of the other three species that are not able to identify the symptoms of a mental infirmity because the properties of the wave itself. Such as EEG alpha type human brain is on vacation or meditation. While waves of how the human

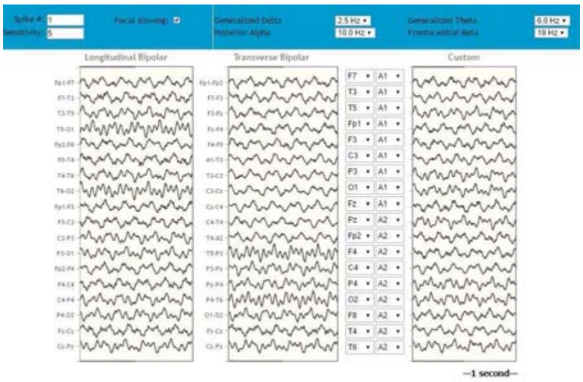


***Fig.11:***: PC screen displayed beta wave 19Hz of EEG recording.

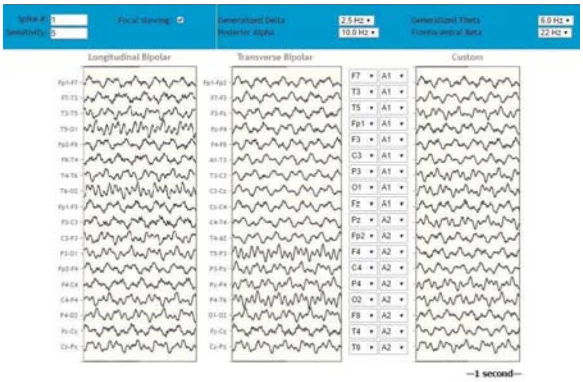


***Fig.12:***: PC screen displayed beta wave 22Hz of EEG recording.

brain is in the eye of deep meditation and EEG delta waves type in the human brain is fully asleep. Preparing to record EEG must take to install the placement of the electrodes, the electrodes are positioned to be conductive gel for EEG or other conductive solution. Or other methods Many species, to improve the efficiency of the electrical signals the human brain. This research compared with other methods, such as MRI, MRS and Ultrasound is then recorded EEG equipment takes a lot faster and more convenient. Again, Signal/Noise ratio is high, and how to analyze the data and try several times to get the correct data in the screening of suspects in the crime from EEG recordings the beta type.

### 3.1 Results and discussion of the estimates using Least Squares.

#### 3.1.1 The process of defining features.

To determine which features are used as input data for estimation using least squares (double moving average) have used all four features are features signs I, II, V1 and V6. The train data obtained from the measurements from the EEG recorder, and 21 channels using the electrode total of six electrodes. Therefore, data obtained from the measurements are so accurate and it can train and test to compare the signals

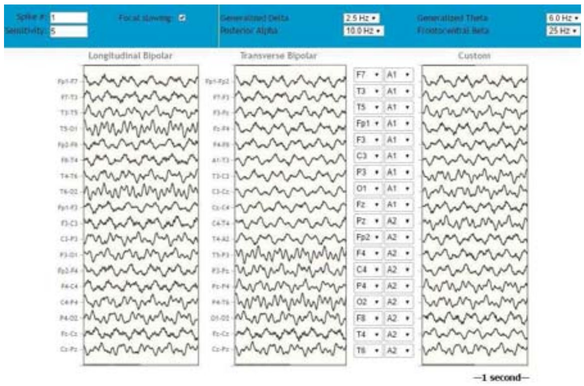


***Fig.13:***: PC screen displayed beta wave 25Hz of EEG recording.

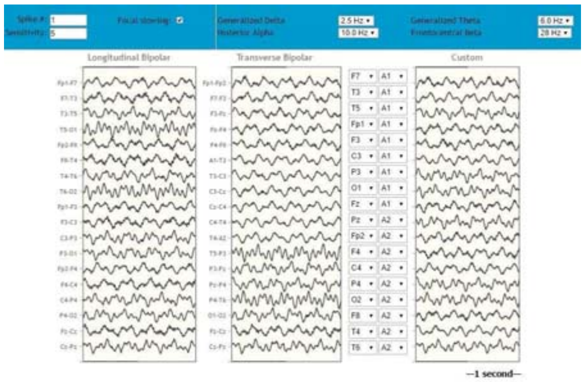


***Fig.14:***: Flowchart of data acquisition and the EEG signal processing.

from the build-up to the estimation theory of the least squares comparison signal to the brain that already. The data used to train those derived from the measured EEG data of volunteers male and 10 peoples make an informed choice in the best sign of all six were used for the train, which is a sign that there is many different forms. By the data will need to Normalize in the range of -1 to +1 at the same level and put all the information together to get the amount of data equal to 30,000. The data for the remaining four will be used for the test result after the train and taken all the tests. Data signals V2, V3, V4 and V5 from the test data input signal I, II, V1 and V6 data that must be taken to de-normalize in the range -1 to +1, and is converted back during the normal levels in the range 0 to +5 volt applications to display correctly.

#### 3.1.2 The replacement value estimates using least squares.

From equation $9^{th}$ we found that $V_i = \sum_j a_{i,j} v_j$

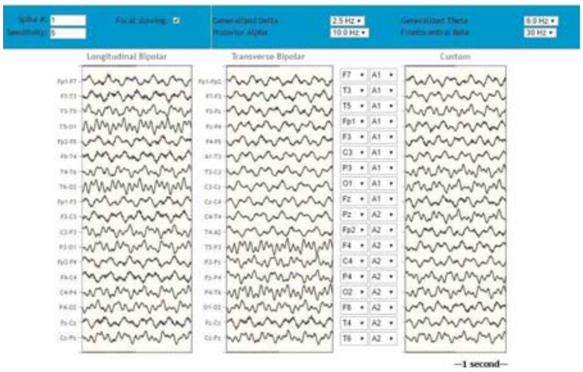


***Fig.15:***: Flowchart of data acquisition and the EEG signal processing.

***Table 1:***: The average absolute error of estimation signal V2-V5.

| **Suspects testing** | **Average absolute error MAPE (%) from the 1500 data.** | | | |
|---|---|---|---|---|
| | V2 | V3 | V4 | V5 |
| 1 | 4.8008 | 8.524 | 4.945 | 2.264 |
| 2 | 10.120 | 12.938 | 6.267 | 5.254 |
| 3 | 9.3429 | 9.845 | 5.459 | 4.243 |
| 4 | 7.1441 | 7.341 | 6.045 | 2.624 |
| Average error (%) | 7.8520 | 9.662 | 5.679 | 3.596 |

Where

$V_i$ are the $V_2$, $V_3$, $V_4$, $V_5$ is the desired signal generated.

$V_j$ are the I, II, V1 and V6 signal leading from the recorder.

$a_{ij}$ are the average of the measured data format from actual measurement signal.

After the results of the estimation method using the least square approximation method, it will have a coefficient obtained from the training data. Then the coefficients in the equation (11) was put to the test to determine the average absolute error. The results were as follows shows in table 1.

The result was that, the estimated value of the signal V2, V3, V4 and V5 is that the use of the method of least squares estimation, the absolute average error of less than 10%. Estimates show that by using the least squares method is more accurate than 90%. So, in this work, lead theme estimation signal V2, V3, V4 and V5, using the least squares method to use to design software to calculate the data from the hard disk recording with the display of the EEG signal and the part of the user interface, the next work.

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