PROJECT REPORT

Entitled

‘’Smart Wheelchair for Differently-Abled People Using Bio-Signals”

Submitted In the Fulfilment of Summer Project

: Presented& Submitted:

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Certificate

This is to certify that Mr.Umang Yadav (Roll no.: U12EC030), Ms.Kesha Bodawala (Roll no.: U12Ec004), Mr.Alok Sheth (Roll no.: U12EC142) has satisfactorily completed a summer research project on **"Smart Wheelchair for Differently-abled People Using Bio-Signals**" during the year JULY-2014.

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ABSTRACT

Rehabilitation devices have been an integral part of the differently-abled people's life since time immemorial. Various mechanical rehabilitation devices have been developed so far and this project is an attempt to computerise the quintessential rehabilitation device-wheelchair. We aim to construct a wheelchair which would be controlled by eye winking and would enable those unable to move their limbs to control and manoeuvre their wheelchair.

This project is one small step forward in the vast avenue of “Human Machine Interface” a.k.a HMI. There are various biological signals emitted from the human body viz. EEG, EOG, EMG etc. In this project our main focus is on the acquisition and analysis of EEG waves so that it can be used as an input to drive a D.C motor which in turn drives the subject’s wheelchair.

The idea is based on the fact that whenever we wink or close our eyes, our eyeball moves in the upward direction in the socket and thus a substantial potential difference is obtained in our EEG pattern thereby making the data set computable for further calculations.

One point to be noted here is that the project deals with the sheer control of wheelchair in the four cardinal directions i.e. forward backward right and left and does not endeavour to develop any other sort of motions.

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Abbreviations	Definition
LED	Light Emitting Diode
EMG	Electromyography
EOG	Electrooculography
EEG	Electroencephalography
HCI	Human Computer Interface
HMI	Human Machine Interface
BCI	Brain Computer Interface
CNS	Central Nervous System
MPF	Mean Power Frequency

Chapter - 1.Introduction

1.1 Motivation

There are thousands of people in India, who are facing disability in movement. They face discrimination on regular basis which takes many forms. These people are considered more as a liability than an asset to the society. Since they encounter discrimination, they tend to alienate themselves from the society as they feel unwanted and rejected. According to census 2001, in India there were around 0.6% of population had disability in movements that is around 6 million people!

In addition, most of our public infrastructure, public transport and government buildings are not disabled-friendly. There has to be a concerted effort to ensure the disabled have access to these places and not feel hampered in anyway.

Our mind-set has to change and accept these people and integrate them into our society. For this reason, we are building a special type of wheelchair which would be helpful to these people for being self-dependent and would be helpful to integrate them in our society.

Apart from these reasons we as 2nd year electronics students had this technical itch to learn something new which gave us a further impetus to carry this out.

1.2 Current Rehabilitation Techniques

With improvement in technology, there is a vast development in the field of rehabilitation Techniques. Researchers are going on to develop reliable, low cost and easy to use devices. Out of all the rehabilitation techniques, HCI (Human Computer Interface) and HMI (Human Machine Interface) are the latest and most effective techniques. Researches in these fields are being carried out extensively. The main objective of the HMI system is conversion of signals generated by humans through various gestures to control some electromechanical devices. While in HCI system some key strokes or cursor movements on the screen are controlled by using these signals. In HCI and HMI both bio signals and non biosignals are used as a medium of control [1].

The chief bio signals used in the Interface are Electromyography (EMG), Electroencephalography (EEG) and Electrooculography (EOG). HMI is commonly used by motor impaired patients to control wheelchair [1].

Rehabilitation devices are broadly classified into two categories; the first category includes all those devices which are bio signal and the second category includes non biosignal based devices. Non bio signal rehabilitation aids provide 100% accuracy and require less training for patients but the usage of these devices is limited to patients with partial or complete flexibility in their body parts. Bio signal based rehabilitation devices mainly use bio signals like EEG, EOG or EMG as control signals. The advantage of using bio signal approach is that when patients become completely paralyzed, the only resource available to them then is bio signals [1].

However it usually needs user training and has lesser accuracy than non biosignal approaches. The biosignal approach usually requires machine learning because biosignals produced by each individual are unique due to difference in individual physiological properties and skin conductance [1] .

1.2.1 Non biosignal approach

In general non biosignal based rehabilitation devices include techniques which make use of sip-n-puff response, tongue control, eye tracking, head movement tracking and chin control.

The sip-n-puff technology is an old technique which is used to control motorized wheel chair by quadriplegic patients. In this method, control signals are given to a device using air pressure by "sipping" (inhaling) or "puffing" (exhaling) on a pneumatic tube. SNP technology generally makes use of four control signals which are produced by hard sip, hard puff, soft sip and soft puff. Typical application of Sip-and-Puff devices is the control of motorized wheelchair. Control typically consists of four different inputs from the user. An initial hard puff will enable the wheelchair to move forward, while a hard sip will stop the wheelchair. Conversely, an initial hard sip will enable the wheelchair to move backward, while a hard puff will stop the wheelchair. A continuous soft sip or soft puff will enable the wheelchair to move left or right respectively depending on the duration of sipping or puffing. The mouth-controlled input provides users a simple and effective way to control mouse movement. However, the basic disadvantage of the sip and puff technique is that muscles of many paraplegics and other paralyzed patients are not capable of sip and puff action.

Another common technique is the Head Movement Tracking technique. In this, head movements are transformed into cursor movements on the screen. Cursor movements are proportional to head movements. Head movements are calculated by different methods like accelerometer placed in a patient's cap or by capturing video of head movements. But the problem with this technique is that differentially abled people of certain categories such as cerebral palsy patients cannot even move their head comfortably [2, 3]. Another problem of this technique is that forehead always needs to face the camera [3].

In the chin control technique, the chin sits in a cup shaped joystick handle and is usually controlled by chin movements. This system is applicable only for patients with good head control. It provides more flexibility than head control.

1.2.2. Bio Signal Approach

1.2.2.1 EEG based methods

The Electroencephalography (EEG) records electrical brain signals from the scalp, where the brain signal originates from post-synaptic potentials, aggregates at the cortex, and transfers through the skull to the scalp. BCI is a device that extracts EEG data from brain and converts it into device control commands using signal processing techniques. The cerebral electrical activities of the brain are recorded via the EEG, through electrodes that are attached to the surface of the skull. The signals measured by the electrodes are amplified, filtered and digitized for processing in a computer where feature extraction is performed. This is followed by classification and a suitable control command is generated [5].

This is one of the most important technologies for patients with paralysis who suffer from severe neuromuscular disorders, since BCI potentially provides them the means of communication, control, and rehabilitation tools to help compensate for or restore their lost abilities [3]. EEG techniques are non-invasive and low cost. But it brings great challenges to signal processing and pattern recognition, since it has relatively poor signal-to-noise ratio and limited topographical resolution and frequency range [6].

1.2.2.2 EMG based methods

EMG measures electrical currents that are generated in a muscle during its contraction. A muscle fibre contracts when it receives an action potential. The EMG observed is the sum of all the action potentials that occur around the electrode site. In almost all cases, muscle contraction causes an increase in the overall amplitude of the EMG.EMG signals can be used for a variety of applications including clinical applications, HCI and interactive computer gaming. They are easy to acquire and of relatively high magnitude than other bio signals. On the other hand, EMG signals are easily susceptible to noise. EMG signals contain complicated types of noise that are caused by inherent equipment noise, electromagnetic radiation, motion artefacts, and the interaction of different tissues. Hence pre-processing is necessary to filter unwanted noise in EMG. The EMG signals also have different signatures depending on age, muscle development, motor unit paths, skin fat layer, and gesture styles. The external appearances of two individuals' gestures might look identical, but the characteristic. EMG signals are different [4].

1.2.2.3 EOG based methods

The Electrooculogram (EOG) is the electrical signal that corresponds to the potential difference between the retina and the cornea of the eye. This difference is because of the fact that occurrence of metabolic activities in the cornea region is higher than that in the retinal region. Usually the cornea maintains a voltage of +0.40 to +1.0 millivolts which is higher than the retina. When the eyes are rolled upward or downward, positive or negative pulses are generated. As the rolling angle increases, the amplitude of the pulse also increases and the width of the pulse is in direct proportion to the duration of the eyeball rolling process.

The EOG is the electrical recording corresponding to the direction of the eye and makes the use of EOG for applications such as HCI very attractive. EOG-based techniques are very useful for patients with severe cerebral palsy or those born with a congenital brain disorder or those who have suffered severe brain trauma [2].

1.3 Path of action:

It has indeed been a long path traversed before we concluded something concrete for our project.so it is important to describe it here.

Initially, we had our focus on controlling the wheelchair by mere thought process. But later on, as experiments followed, we found out that thought is more of a cognitive process which is distributed in a way that human mind has yet not grasped, its localisation is just not possible. We also had a meagre amount of data sets to work on. Also the EEG acquisition techniques that are available as of now are not up to the mark so as to record the thoughts emitted by a system as complex as human mind. Further, even more complex analysis techniques would have been needed to compute these data sets which also proved to be a major obstacle in this path.

So we changed our line of thought and further focussed on mu waves and its properties. But the major hurdle here was that mu waves are a rare type of waves found in only 17-18% of the adults. And thus a system designed on something so sparsely distributed would be rather vague and useless.

So finally, we gave our last shot to wheelchair control using eye movements. During this phase also, we initially went bit off-track as we focused on eyeball movements in spite of using the apparatus used or EEG recording and thus it delivered no clear results. Then we focused on eye closure activities and it was during these experiments, that we had a ray of hope. Eye closure experiments were the first experiments of all to give a clear line of demarcation between left and right directions. Further we narrowed down the fact that for designing a system of our requirements, we only need the instantaneous change during the eye closure and so we further experimented more on eye 'winking' rather than eye 'closure'.

1.4 Objectives

We aim at developing a fully functional electronically controlled wheelchair which is robust at usage, simple, responsive and error immune. Also, we intend to make it as affordable so that it can be used by everyone suffering from this disability. The main aim of the work presented in this thesis is to develop a reliable and easy to use biosignal acquisition system and rehabilitation technique: a controlled motorized prototype wheelchair model developed as a rehabilitation aid. This work includes:

1. Developing a data acquisition system for acquiring EEG signals.

2. Developing a new algorithm for detecting basic eye movements and blinking.

3. Implementing rehabilitation devices which can be controlled using EEG.

1.5 Problem Statement:

To design a wheelchair which is controlled with the help of biological waves, in our case we chose the cornea-retinal potential as an input signal. Our aim is to build a smart wheelchair controlled by eye wink of the driver.

To drive the wheelchair, particular pattern for the winking is as below:

Left + Left ⟶ Left turn

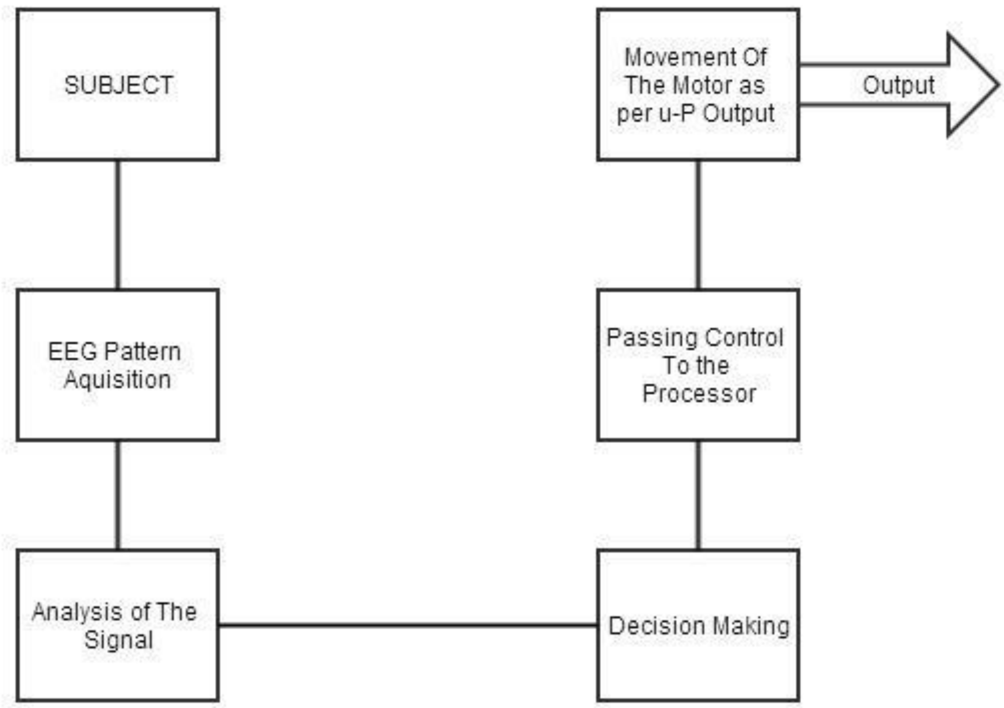
Right + Right ⟶ Right turn

Right + Left ⟶ Backward

Left + Right ⟶ Forward

Both eyes closed forcedly ⟶ Stop

1.5.1 The Model:



[Block Diagram of the System]

Brief Working

From the above block diagram, we get a brief idea of the working of the system.

Step 1- Acquire the EEG signal of the subject with the help of necessary hardware.

Step 2- Continuous real time analysis of the system by the controller for any particular erroneous changes in the signal.

Step 3- If something in particular is detected; a decision is made by the controller.

Step 4- This decision is then transferred as an input the the motor driving the wheelchair.

Step 5- Thus the required output is obtained.

1.6 Application Areas

A system as such would be useful to large criteria of people that suffer from extremely limited peripheral mobility diseases like paraplegia and quadriplegia. Further using the analysis as a backbone many other systems can be developed which would use these biological signals as inputs and thus this project opens up many more avenues in the area of biological control and EEG pattern based design.

1.7 Design Constraints

We faced quite a few problems while designing the system especially with the hardware. First of all, the EEG analyser machine had 20 electrodes to be placed at the subject's scalp which required a lot of precision as the electrodes were much vulnerable to the slightest of jerks and thereby creating a discontinuity in the electrode system.

Secondly we still face the problem of real time processing and analysis of the acquired EEG signal as we are unknown to the working of DSP processors etc.

1.8 Flow of the Work

We started with the experimentation phase first which underlined the collection of EEG signals from various subjects as they were asked to perform certain tasks. The tasks moved from very simple left and right directional thinking to further limb movements and then to the relevant winking and eyeball movements tasks.

In the meanwhile, we analysed the EEG channels of the subjects and tried to find a particular trend or pattern in all these subjects. Analysis revealed some common features related to the subjects and some specific features as well.

Further we quantised our data sets using a freeware named Acqknowledge and then further imported the data to MATLAB© to calculate mean powers and frequencies.

1.9 literature survey

There are numerous interfaces and communication methods between human and machines. A typical human–machine interface is to utilize input devices such as keyboards, a mouse, or joystick. Recently, a number of biological signals such as electromyogram (EMG) [7] and electroencephalogram (EEG) [8] have been employed as hands-free interfaces to machines (e.g., see [9]–[11]). In particular, the so called brain computer interface (BCI) [12]–[16] has received significant attention. The BCI is a system that acquires and analyses neural (brain) signals with the goal of creating a direct high-bandwidth communication channel between the brain and the computer. Such systems are envisioned to have huge potentials for a wide ranging areas of research and applications such as brain (neural) signal acquisition and processing, bioengineering, and understanding the underlying neuroscience, to name a few. For systems and controls research, advances on brain–machine interfaces offer intriguing opportunities and challenges, for instance, brain control of machines.

One such project was developed by K. S. Ahmed, Department of Bio-electronics, Faculty of Engineering, MTI, Modern University for Technology and Information, Katamia, Egypt which comprised of a model based to detect the four movements (turn right – turn left – forward -stop) of wheelchair based on the eye blinks (right wink, left wink, single/double blinks). The WT coefficients were used as the best fitting input vector for classifier. Radial Basis Function network was used to classify the signals. The weighted energy difference between electrodes pairs F7 and F8 were used as features. Signals were recursively decomposed into high and low passed sub-bands, and the resolution of the spectrum was determined by the chosen decomposition level. The sub-band energy from the last decomposition level was used to construct features from EEG signals. The sensitivity and specificity were calculated for 20 cases and there were 80% and 75% respectively [17].

Apart from this a scheme for controlling the wheelchair using EEG waves and eye blinking pattern was developed by Jzau-Sheng Lin, Kuo-Chi Chen and Win-Ching Yang which was very much similar to Mr. Ahmed’s Methods, differing only in the hardware used for EEG acquisition and the control commands[18].

Eye wink control which consisted of a non biosignal approach was developed by Robin Shaw, Everett Crisman, Anne loomis and ZofiaLaszewski which basically consisted of a wearable eye-frame which had two infra-red eye wink detectors in front of both the eye sockets [19].

Similarly, DjokoPurwanto, Ronny Mardiyanto and Kohei Arai used a digital camera setup in front of the user to capture the eye information and to interpret the gaze direction, thereby controlling the movement of the wheel chair [20].

Several endeavours have been made in the direction of developing a system driven by both, the EEG and the EMG signals. One such project was developed by A Ferreira, R L Silva, W C Celeste, TF BastosFilhoand M SarcinelliFilho which added an interactive PDA along with the entire wheelchair assembly where several movement options were continuously flashed in front of the subject and for selection of a particular option, the subject had to close his/her eye[21].

To avoid artefacts from EMG (and also EOG), they had used the band- pass filter with a pass band of0.53–30 Hz in the EEG detection. However, it was very difficult to perfectly reject the artefacts from EMG (and also EOG) even with the utility of the band pass filter [21].

Another brilliant paper on the control of wheelchair using biosignals is published by R. Barea, L. Boquete, M. Mazo and E. Lopez which discusses the Wheelchair Guidance Strategies Using the EOG waves. This paper describes an eye-control method, based on electrooculography (EOG), for Guiding and controlling a wheelchair; the control is actually effected by eye movements within the socket [22].

Dandan Huang, KaiQian, Ding-Yu Fei, WenchuanJia, Xuedong Chen, and OuBaihad developed a 2-D virtual wheelchair based on the multi-class discrimination of spatiotemporally distinguishable phenomenon of event-related desynchronization/synchronization (ERD/ERS) in electroencephalogram signals associated with motor execution/imagery of right/left hand movement [23].

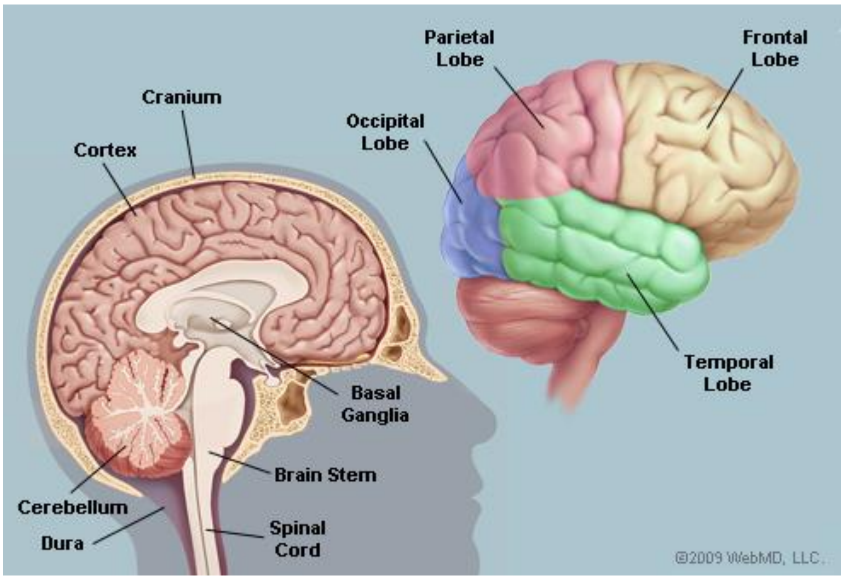
Chapter - 2. - A Brief Introduction about Biological Facts

2.1 HUMAN BRAIN

The human brain has been called the most complex object in the known universe, and in many ways, it's the final frontier of science. This three-pound organ is the seat of intelligence, interpreter of the senses, initiator of body movement, and controller of behaviour. The brain is the crown jewel of the human body. The brain is like a committee of experts. All the parts of the brain work together, but each part has its own special properties.

FACTS:

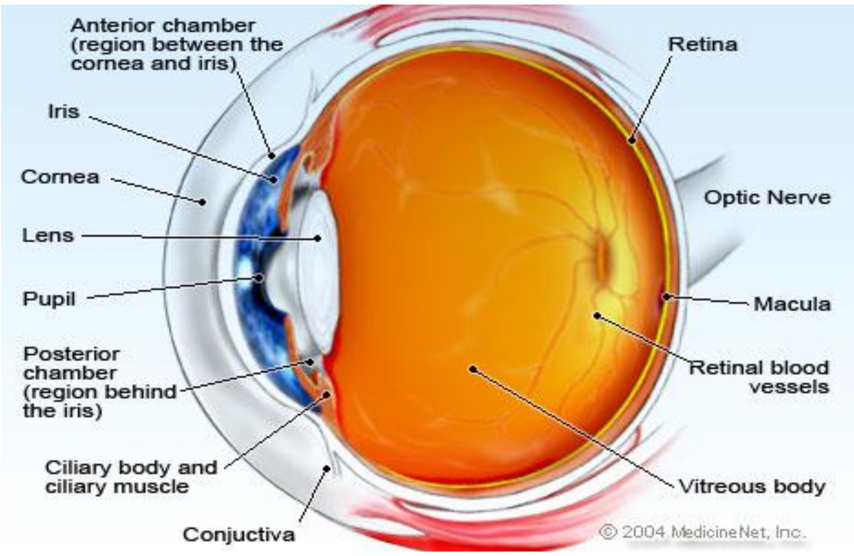
- The brain is a part of central nervous system (CNS).
- The CNS is made up of spinal cord, the medulla, the pons, the cerebellum, the midbrain, the diencephalon and the cerebral hemispheres.
- The brain is divided in 2 hemispheres: the left and the right; which are not functionally symmetrical .both are connected to each other by a bunch of fibres called corpus callosum.
- Brain contains 10^11 nerve cells or neurons and their synaptic connections that is around 10^15!!
- In each of the brain's two hemispheres the overlying cortex is divided into four anatomically distinct lobes: frontal, parietal, temporal, and occipital, originally named for the skull bones that encase them.



[Fig.1.Cross sectional view of brain and different lobs of brain] [Courtesy of [24]]

During our experimentation phase in which we analysed thought related EEG experiments, we found out that no trend in particular is found as the subject has to focus very hard which was impractical. This line of thought gave us a paradigm shift and we shifted our focus to motor control using "eye movement" rather than control using simple thought. That's the reason to study the anatomy of eye to have a heads-up of further discussion.

2.2 Anatomy of EYE



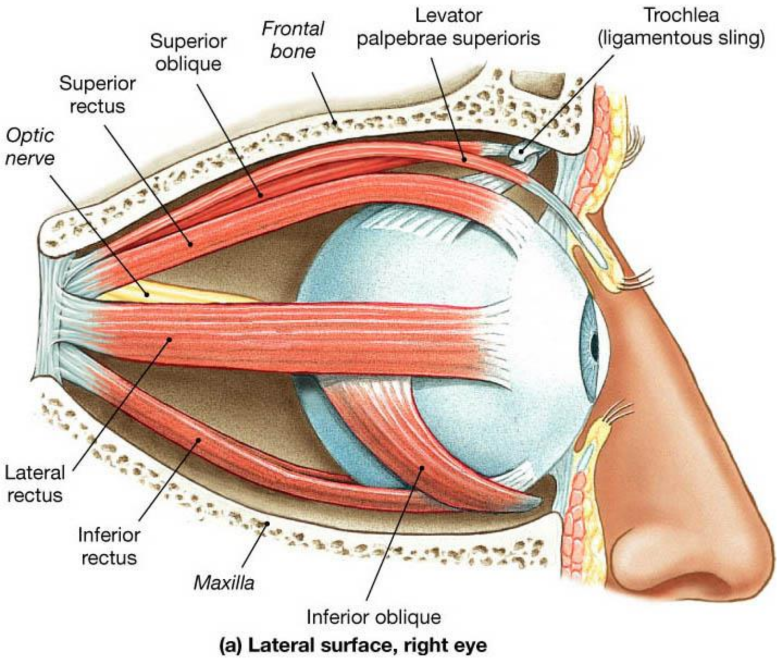
[Fig.2.Structure of human eye][Courtesy of Medicine Net, Inc.]

The eye is our organ of sight. The eye has a number of components which include but are not limited to the cornea, iris, pupil, lens, retina, and macula, optic nerve, choroid and vitreous [25].

- Cornea: clear front window of the eye that transmits and focuses light into the eye.
- Iris: coloured part of the eye that helps regulate the amount of light that enters.
- Pupil: dark aperture in the iris that determines how much light is let into the eye
- Lens: transparent structure inside the eye that focuses light rays onto the retina.
- Retina: nerve layer that lines the back of the eye, senses light, and creates electrical impulses that travel through the optic nerve to the brain.
- Macula: small central area in the retina that contains special light-sensitive cells and allows us to see fine details clearly.
- Optic nerve: connects the eye to the brain and carries the electrical impulses formed by the retina to the visual cortex of the brain.
- Vitreous: clear, jelly-like substance that fills the middle of the eye [25].

2.2.1 Eye Movement

Extra ocular muscles



[Fig.3.Lateral surface of human right eye showing different muscles used for eye movements][Courtesy of [26]]

The stabilization of eye movement is accomplished by six extra ocular muscles that attach to each eyeball and perform their horizontal and vertical movements and rotation. These muscles are controlled by impulses from the cranial nerves that tell the muscles to contract or to relax. When certain muscles contract and others relax, the eye moves [27].

The six muscles and their function are listed here [27]:

- Lateral rectus–moves the eye outward, away from the nose
- Medial rectus–moves the eye inward, toward the nose
- Superior rectus–moves the eye upward and slightly outward
- Inferior rectus–moves the eye downward and slightly inward
- Superior oblique–moves the eye inward and downward
- Inferior oblique–moves the eye outward and upward

There are five different types of eye movements [27]:

- Saccades–looking from object A to object B
- Pursuit–smoothly following a moving object
- Convergence/divergence–both eyes turning inward/outward simultaneously
- Vestibular–eyes sensing and adjusting to head movement via connections with nerves in the inner ear
- Fixation maintenance–minute eye movements during fixation

2.3 Signals and behaviour:

2.3.1 Origin of EOG:

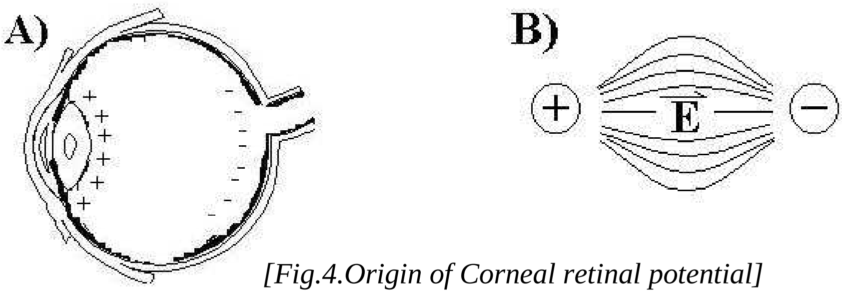
So what is the exact physical mechanism responsible for generating the EOG signal we measure?

We are not measuring the EMG from the extra ocular muscles. Though the exact origin of the EOG has not been conclusively determined; there are several theories that have been proposed as The mechanism behind it [28].

The first is the cornea-retinal dipole theory. It states that an electric dipole is formed through the eye because the cornea is positively charged, while the retina is negatively charged. As you may remember from physics, a dipole creates an electric field that can be measured. This is the potential that is being measured by the EOG. As the eye changes direction, so does the dipole and thus, the detected signal [28].

The second school of thought is similar to the one described above, but instead of the dipole being created by the cornea and the retina, the dipole is believed to be the potential difference across the retina itself [28].

The third theory states that it is the eyelid movement that creates a sliding potential source, which is responsible for the potential recording. The cornea-retinal theory is most widely accepted [28].



[Fig.4.Origin of Corneal retinal potential]

2.3.2 EEG

Electroencephalography (**EEG**) is the recording of electrical activity along the scalp. EEG measures voltage fluctuations resulting from ionic current flows within the neurons of the brain. In clinical contexts, EEG refers to the recording of the brain's spontaneous electrical activity over a short period of time, usually 20–40 minutes, as recorded from multiple electrodes placed on the scalp. Diagnostic applications generally focus on the spectral content of EEG, that is, the type of neural oscillations that can be observed in EEG signals [29].

Intensity of the brain waves recorded from the surface of the scalp range from 0 to 200 microvolts, and their frequencies range from once every few seconds to 50 or more per seconds. The character of the waves is independent on the degree of activity I respective parts of the cerebral cortex and the waves change markedly between the states of wakefulness and sleep and coma [30].

2.3.2.1 Why does Brain emit waves?

The electrical activity of the EEG is an attenuated measure of the extracellular current flow from the summated activity of many neurons. However, not all cells contribute equally to the EEG [31].

When a nerve is stimulated the resting potential changes. Examples of such stimuli are pressure, electricity, chemicals, etc. Different neurons are sensitive to different stimuli (although most can register pain). The stimulus causes sodium ion channels to open. The rapid change in polarity that moves along the nerve fibre is called the “ACTION POTENTIAL."

The surface EEG predominantly reflects the activity of cortical neurons close to the EEG electrode. Thus deep structures such as the hippocampus, thalamus or brain stem do not contribute directly to the surface EEG [31].

Because the electrical activity originates in neurons in the underlying brain tissues, the waveform recorded by the surface electrode depends on the orientation and the distance of the electrical source with respect to the electrode [31].

The EEG signal is inevitably distorted by the filtering and attenuation produced by intervening layers of tissue and bone, which act like resistors and capacitors in an electrical circuits .thus the amplitude of EEG potentials is much smaller (microvolts) than the voltage changes in a single neuron (millivolts) [31].

2.3.2.2 Classification of EEG waves

EEG waveforms are generally classified according to their frequency, amplitude, and shape, as well as the sites on the scalp at which they are recorded. The most familiar classification uses EEG waveform frequency (e.g., alpha, beta, theta, and delta) [30].

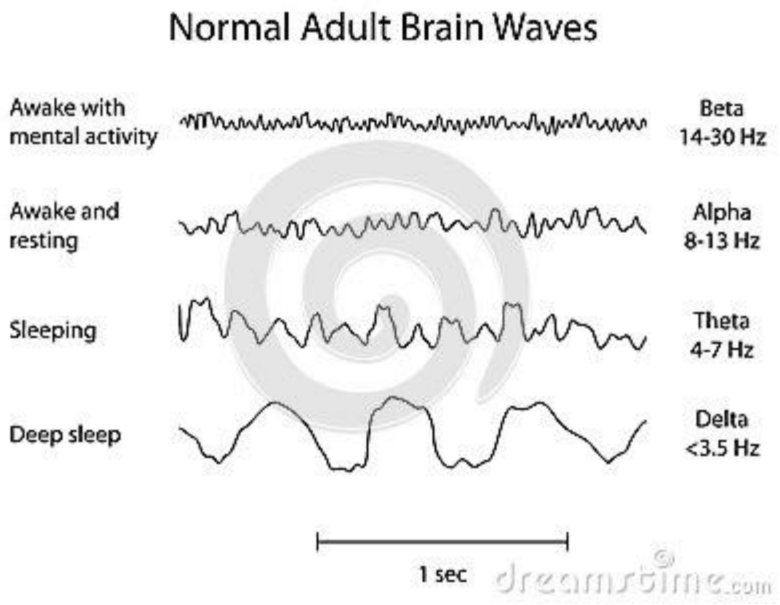
Alpha waves are rhythmical waves that occur at frequencies between 8 and 13 cycles per second and are found in the EEGs of almost all normal adult people when they are awake and in a quiet, resting state of cerebration. These waves occur most intensely in the occipital region but can also be recorded from the parietal and frontal regions of the scalp. Their voltage usually is about 50 microvolts. During deep sleep, the alpha waves disappear [30].

When the awake person's attention is directed to some specific type of mental activity, the alpha waves are replaced by asynchronous, higher-frequency but lower-voltage *beta waves [30]*.

Beta waves occur at frequencies greater than 14 cycles per second and as high as 80 cycles per second. They are recorded mainly from the parietal and frontal regions during specific activation of these parts of the brain [30].

Theta waves have frequencies between 4 and 7 cycles per second. They occur normally in the parietal and temporal regions in children, but they also occur during emotional stress in some adults, particularly during disappointment and frustration. Theta waves also occur in many brain disorders, often in degenerative brain states [30].

Delta waves include all the waves of the EEG with frequencies less than 3.5 cycles per second, and they often have voltages two to four times greater than most other types of brain waves. They occur in very deep sleep, in infancy, and in serious organic brain disease [30].



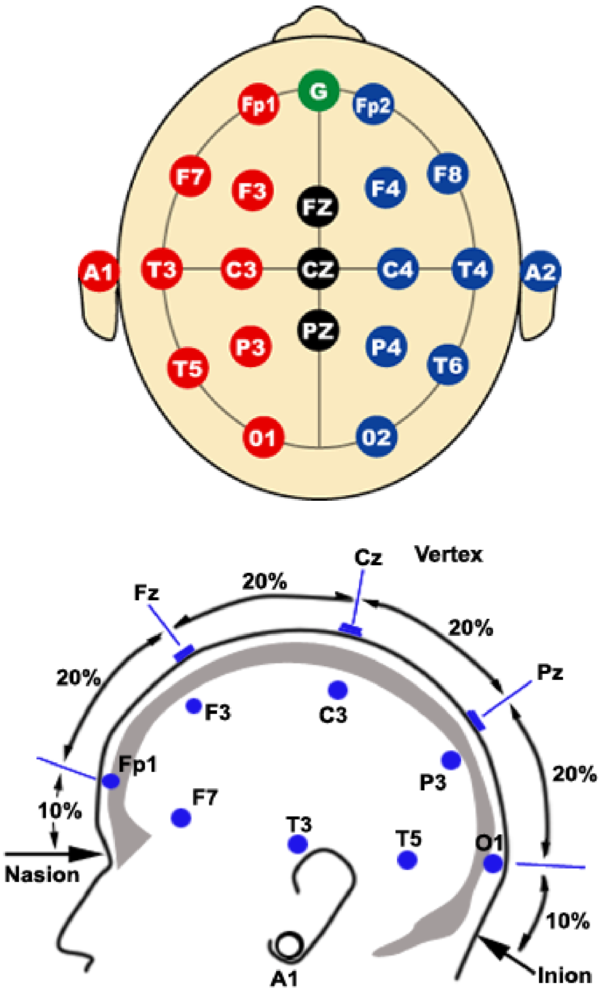
[Fig.5.Occurrence of different brain waves during different states of mind][Courtesy of dreamstime.com]

2.3.2.3 Electrode placements and experiments

Our aim was to record the signals from forehead whenever subject wink his eye.

In our experiments to get the signals, we set the electrodes according to standard 10-20 systems for electrode placement used for EEG tests as we weren't aware of exact origin of corneal-retinal potential signals initially!

The standardized placement of scalp electrodes for a classical EEG recording has become common since the adoption of the 10/20 system. The essence of this system is the distance in percentages of the 10/20 range between Nasion-Inion and fixed points. These points are marked as the Frontal pole (Fp), Central (C), Parietal (P), occipital (O), and Temporal (T). The midline electrodes are marked with a subscript z, which stands for zero. The odd numbers are used as subscript for points over the left hemisphere and even numbers over the right [32].



[Fig.6.10-20 system of electrode placement for EEG][Courtesy of [32]]

Chapter -3. Experimentation and Analysis

In order to get a proper grasp of the working of EEG we framed certain sets of experiments we intended to perform on a varied range of subjects. We wanted to see if we could find any kind of patterns or trends in the EEG while performing simple actions like limb movements, facial expressions or the movement of the eyes.

The recording was done on clinical Neurosoft EEG acquisition machine at Dr.Ritesh Shah's clinic. The electrodes were closely arranged on the scalp above the motor strip. One of the earliest experiments were done on Alok and Umang and thereafter we performed various experiments on 13 subjects and recorded 25 data sets in total. All the subjects comprised of males and females and were under the age group of 19-23.Most of them were right handed.

3.1 Format of experiments:

Every test starts from subject resting on chair with his hands and legs set in comfortable manner to him. Subject is restricted from any kind of movements of his hands or legs, speech and even smile!!

Terms regarding the tests:

Baseline:

Every experiment was started with baseline, baseline is nothing but the time given to the subject to get ready for the test and get acquainted with the equipment.

Relax:

During the relaxation period subject has to relax his mind and focus on a particular thought and also restricted from any kind of limb movements. Relaxation time was given between any two activities to differentiate the pattern.

Alert tone:

To instruct the subject we used to make beep sound from the mobile phone, after this beep sound only subject had to react.

[Fig.7.EEG acquisition machine]

[Fig.8.Alok performing EEG experiment]

3.2 Experiment 1:

Task	Time
Baseline Recording	0:00 to 4:00

[Table.1.Baseline Timing of Experiment 1]

1) Simple Left Right- Subject had to think about left or right direction with utmost attention.

Think Left	4:00 to 4:30
Relax	4:30 to 5:00
Think Right	5:00 to 5:30
Relax	5:30 to 7:30

[Table.2.Simple Left Right Test Timings of Experiment 1]

2) Tapping- We tapped the subject's either right or left hand and subject had to make a decision in his mind accordingly

Right	7:30 to 7:40
Right	7:40 to 7:50
Right	7:50 to 8:00
Relax	8:00 to 8:30
Left	8:30 to 8:40
Left	8:40 to 8:50
Left	8:50 to 9:00
Relax	9:00 to 9:30
Left	9:30 to 9:40
Right	9:40 to 9:50
Right	9:50 to 10:00
Left	10:00 to 10:10
Right	10:10 to 10:20
Left	10:20 to 10:30
Relax	10:30 to 12:30

[Table.3.Tapping Test Timings of Experiment 1]

3) Number Line: subject was given a number during the task that he had to tell either is on the right or the left of the zero on the number line.

-3	12:30 to 12:40
-2	12:40 to 12:50

+5	12:50 to 13:00
+11	13:00 to 13:10
-7	13:10 to 13:20
+3	13:20 to 13:30
+15	13:30 to 13;40
-11	13:40 to 13:50
Relax	13:50 to 16:00

[Table.4.Number Line Test Timings of Experiment 1]

4) Imagination- The subject is supposed to imagine that he is doing some activity with his specified limb. For e.g. when the direction right is given to the leg he can think of kicking a ball with his leg or so.

Right Leg	16:00 to 16:30
Relax	16:30 to 16:40
Left Leg	16:40 to 17:10
Relax	17:10 to 17:20
Right Hand	17:20 to 17:50
Relax	17:50 to 18:00
Left Hand	18:00 to 18:30
Relax	18:30 to 21:00

[Table.5.Imagination Test Timing of Experiment 1]

5) Movement- The subject is actually supposed to MOVE the specified limb.

Left Leg	21:00 to 21:10
Relax	21:10 to 21:20
Right Leg	21:20 to 21:30
Relax	21:30 to 21:40
Left Hand	21:40 to 21:50

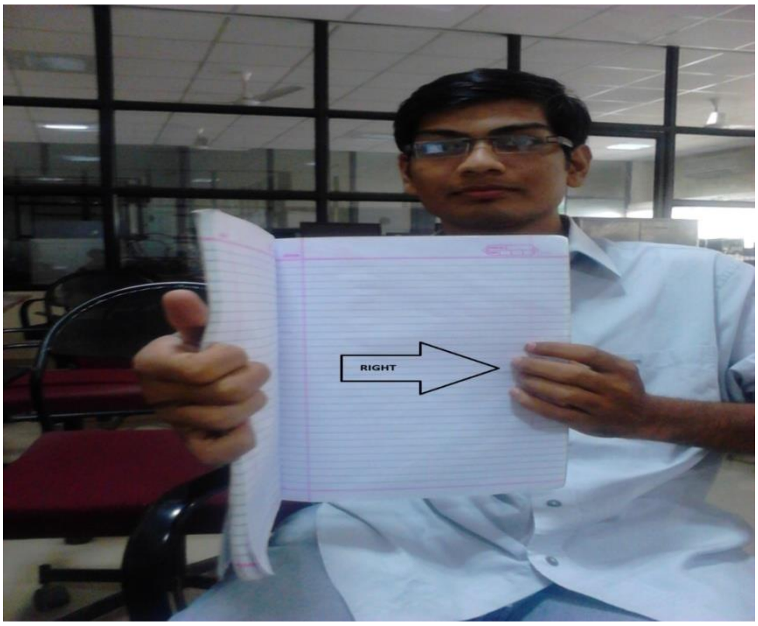
Relax	21:50 to 22:00
Right Hand	22:00 to 22:10
Relax	22:10 to 22:20

[Table.6.Limb Movements Timings of Experiment 1]

3.2.1 Observations of Experiment 1:

As this was the first experiment in the series, it was very much thought-centric and we wanted to know whether mere "thinking" gives any substantial EEG patterns or not. Unfortunately nothing correlating was observed as it was very difficult to focus just on thinking directions keeping all other thoughts at the bay. Apart from this, we noticed that the number line test did not contribute anything in particular and so we shifted our line of thought and introduced another replacement for that test in the next experiment.

PS: The test that we introduced instead of the number line test was the corner test. This comprised of determination of a particular corner by the subject as and when he was shown a folded book.



[Fig.9.Umang conducting corner test]

3.3 Experiment: 2

Time	Activity
0:00-1:00	Relax
1:00-1:05	Left
1:05-1:10	Relax

1:10-1:15	Left
1:15-1:25	Relax
1:25-1:30	Right
1:30-1:35	Relax
1:35-1:40	Right
1:40-1:50	Relax
1:50-1:55	Left
1:55-2:00	Relax
2:00-2:05	Right
2:05-2:15	Relax
2:15-2:20	Right
2:20-2:25	Relax
2:25-2:30	Left
2:30-2:40	Relax
2:40-2:45	Both
2:45-2:50	Relax
2:50-2:55	Both
2:55-4:00	Relax
4:00-4:30	Right wrist
4:30-5:00	Relax
5:00-5:30	Left wrist
5:30-6:00	Relax

[Table.7.Timings & Activities of Experiment 2]

Instructions to the subjects:

At the end of the first minute, we instruct the subject that he has to close his left eye forcefully and at the moment of first minute we make beep sound from mobile phone and then only subject has to close his eye for 5 seconds at the end of the 5 seconds we instruct to open eye and accordingly whole test is performed. From 2:40th minute onwards subject has to close his both eyes for 5 seconds as per the beep sound.

We had also included wrist movements in this test. From 4th minute onwards subject had to move his wrist as per the instruction given for the time duration of 30 seconds.

3.3.1 Observation of Experiment 2:

When we switched to experimentation in this way we finally could see a silver lining as the eye closing tests clearly gave us a line of demarcation between the relaxed state of mind and the closing of the eye. The difference in the EEG pattern was very much crude in nature and one could make out by observing the mere waveform when the eye was closed. One point we noted here was that the peaks obtained did not really depend on the time interval for which the eyes were closed but rather were obtained at the very instant when the eye was closed or opened. Further delving into this topic, we found out that the peaks were obtained due to a phenomena called corneal retinal potential. This experiment was performed on 3 subjects, twice on each thereby acquiring 6 data sets in total.

3.4 Experiment 3:

Time(in minutes)	Activity
0:00-1:00	Relax
1:00	Left
1:20	Left
1:40	Right
2:00	Right
2:20	Left
2:40	Right
3:00	Left
3:20	Right
3:40	Right
4:00	Left
4:20	Right
4:40	Left
5:00	Left
5:05	Left
5:20	Right
5:25	Right
5:40	Left
5:45	Right
6:00	Left
6:05	Right
6:20	Right
6:25	Left
6:40	Right
6:45	Left
7:00	Both eyes
7:20	Both eyes
7:40	Both eyes
8:00	Both eyes
8:15-8:40	Noise

[Table.8.Timings & Activities of Experiment 3]

Instruction to the subject:

At the end of the first minute, we instruct the subject that he has to wink his left eye forcefully and at the moment of first minute we make beep sound from mobile phone and then only subject has to wink eye and accordingly whole test is performed. From 5th minute onwards subject has to wink eye two times within the time interval of 5 seconds as per the instruction. From 7th minute onwards subject has to wink both his eyes forcefully and in the last we take the reading of noise!

In that we instruct the subject to move his neck, speak some words, hands and legs movements or any kind of activity through which noise can occur.

3.4.1 Observation:

Once we obtained a particular trend in eye closure exercise, we further gave it a shot to eyeball movements and eye winking as even blinking can be attributed to closure by a machine. On analysing eye movements nothing substantial was observed as the test that we were performing was an EEG test and thus eyeball movements could not be recorded well. When we switched to the winking experiment though, we found out that the frontal electrodes responded to these changes really well- The left sided electrodes producing a peak during the left wink and the right sided giving a similar peak during the right eye wink. Further, our observations were reinforced when we asked the subject to blink both his eyes and on doing so, both the electrodes responded in the way we had expected. On getting strong trends on the first subject we were further motivated to perform similar experiments on different subjects and in our endeavour to do so, we tested 7 subjects and acquired 13 data sets in total.

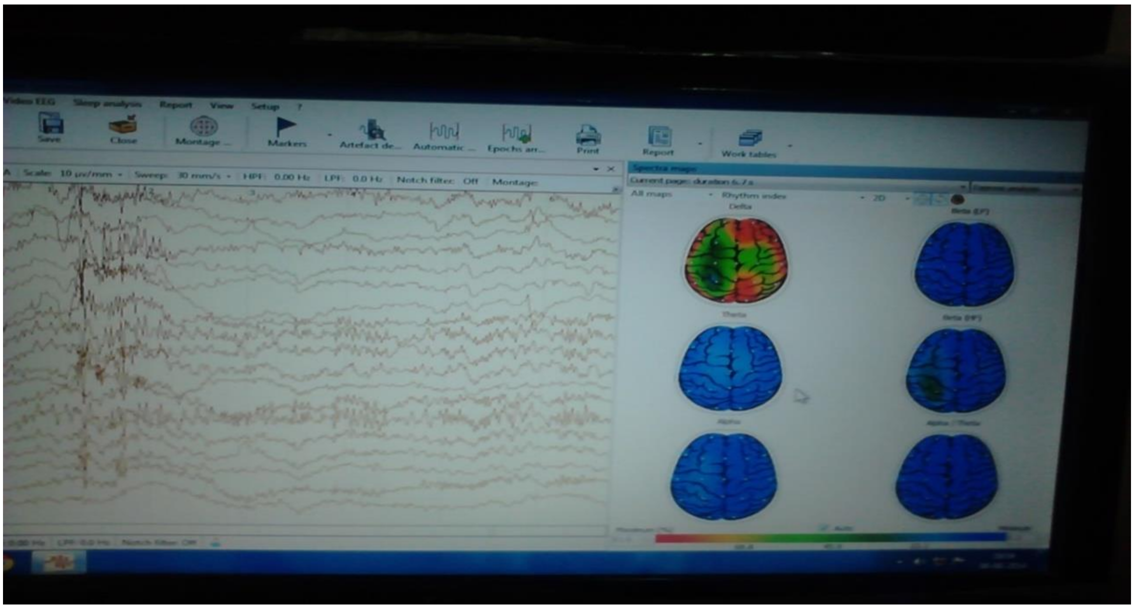
3.5. A Brief Introduction about Analysis

EEG signals can be analysed by using various methods such as frequency analysis method, power spectral density method etc.

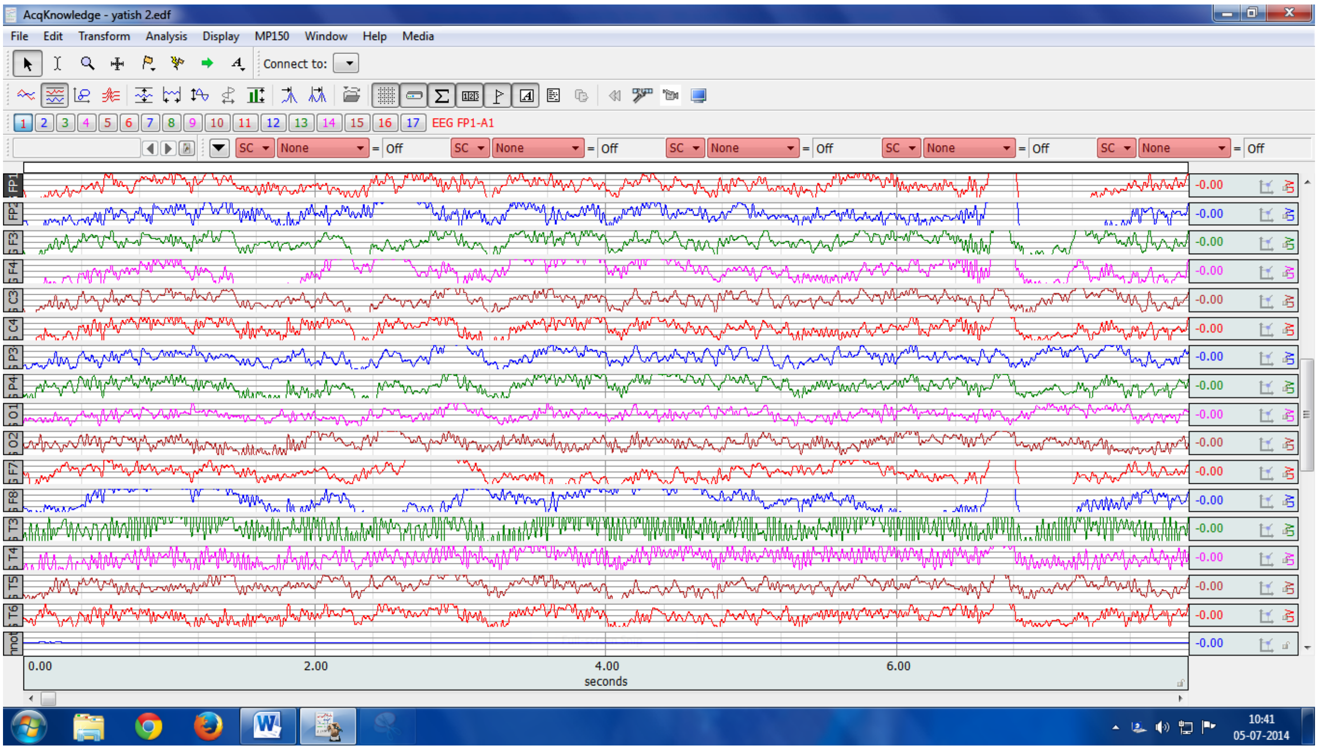
There are many open source soft wares are also readily available for analysis such as ACQKNOWLEDGE.

EEG signals can also be analysed by breaking it into its components like alpha, beta, gamma, theta, delta waves. Mostly EEG signals are analysed in the manner of epochs. Epochs are nothing but the short time intervals. In epoch analysis signals is divided into pieces of finite the time duration.

After dividing the signals into epochs, for each epoch various parameters are computed. In our analysis we set the epoch for one second and computed Mean power and Mean power frequency for that interval.



[Fig.10.Topographic analysis of brain waves in Neurosoft software]



[Fig.11.Acqknowledge software]

3.6 Analysis:

3.6.1 Experiment 1:

1) Simple left and simple right thinking:

Analysis:

As per the theory of EEG, when a person is awake and in thinks deeply about something, we get beta waves from Frontal lobe and some effect can also be seen as mu waves over central sensory motor strip area, so we started analysing from frontal channels FP1, FP2, F7, F8, F4, F3 then central channels C4 and C3, we derived mean power and mean frequency as per the theory but we could not get any particular trend in this experiments through these channels. So, also examined remaining channels but in that also we could not get any pattern.

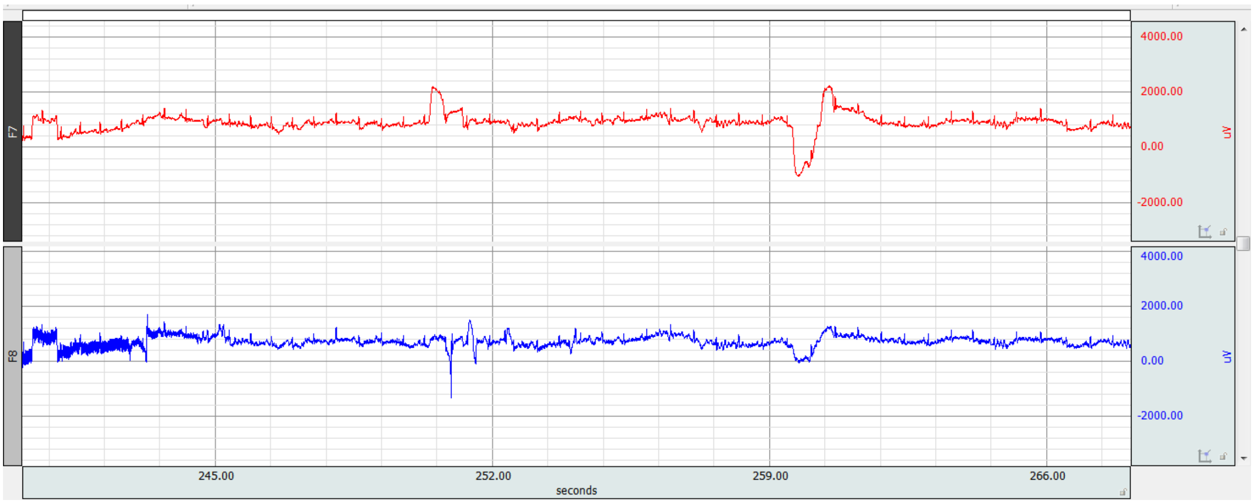
It is due to fact that, it is too hard for the subject to concentrate on any particular direction for a sufficiently long period. Besides this, the accuracy of surface EEG was not up to the mark. In our case EEG electrodes were placed on to the scalp by just electrode gel so, they were subject to high impedance due to hair, it was difficult to keep them steady against some disturbances like windblown by FAN, head movements of subject, electrical disturbances etc.

This type of experiment requires a lot practice for subject to keep it mind concentrate against surrounding environment and a good EEG acquisition technique and large number of datasets to get trend and very deep knowledge of advance frequency analysis techniques such as wavelet theory etc. as we had just completed our second year so weren't much aware about some concepts related to these theories.

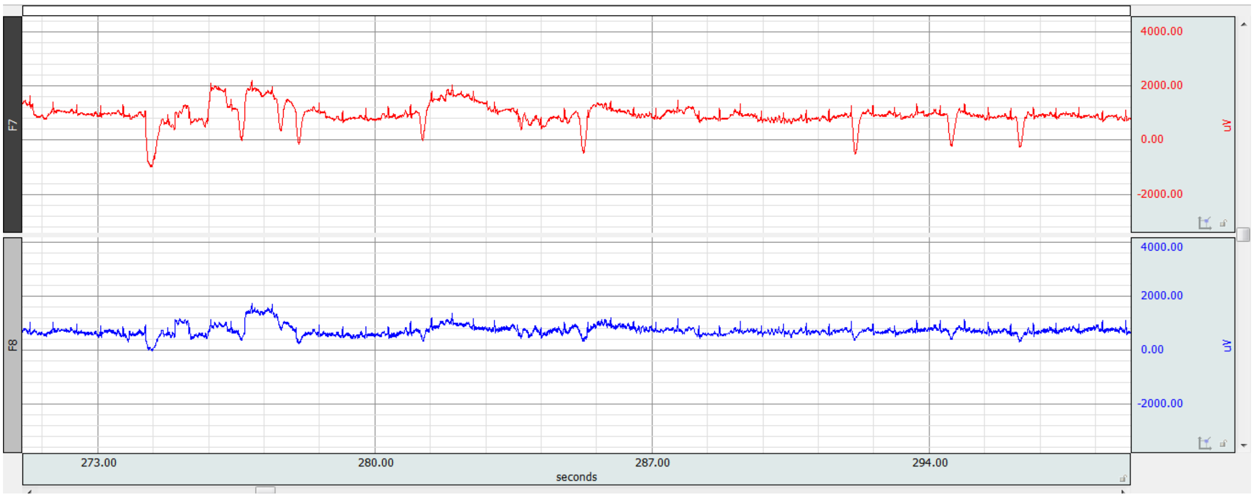
As a result we dropped this idea and concentrated on controlling wheelchair through EYE movements.

As you can see from the waveforms, that it is too noisy, if you compare waveforms for the left, right and relax mode, you can see that there is any distinguishable changes in any of the signal parameters, we also computed various parameters for these signals using the ACQKNOWLEDGE and NEURONSOFT.NET, but we could not get any required results from that.

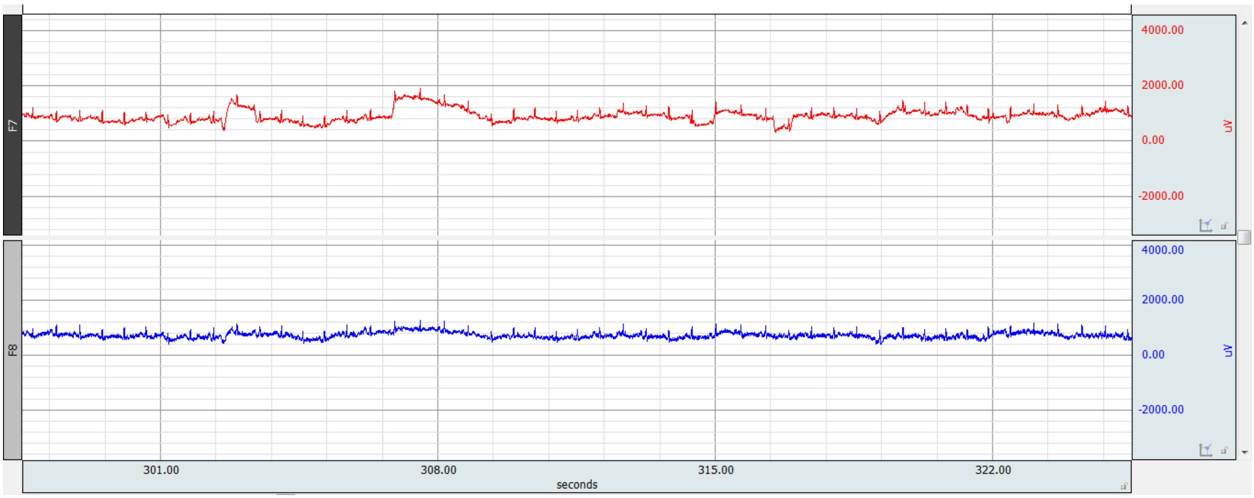
We filtered EEG signal in alpha, beta, gamma etc. and did the same computation for them also, but at last we could not get anything.



[Fig.12.Waveforms of channels F7 and F8 during left thinking]



[Fig.13. *Waveforms of channels F7 and F8 during relax position]*



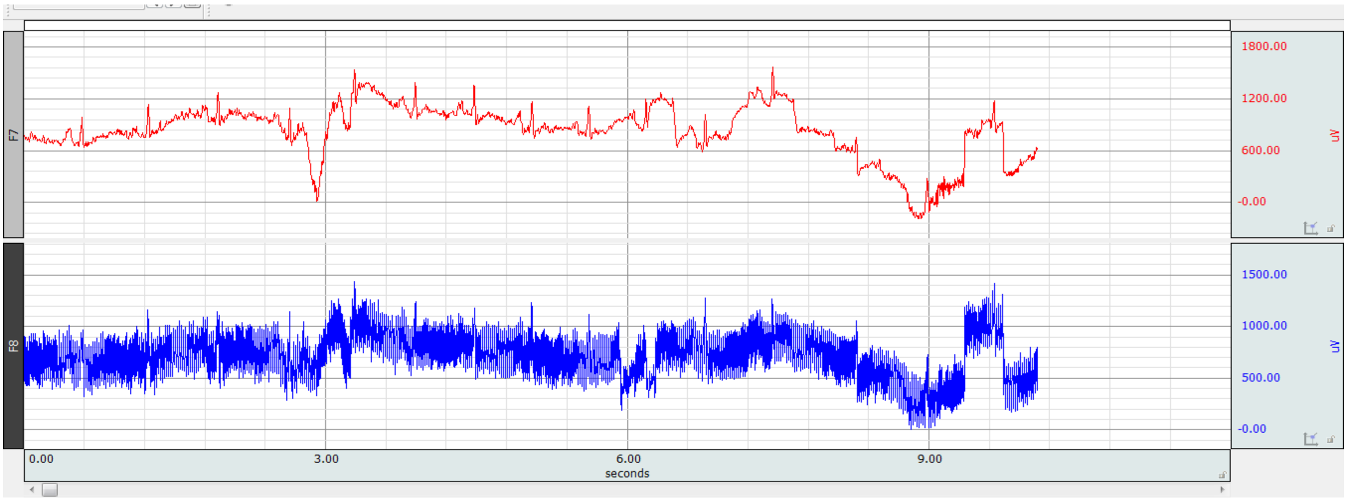
[Fig.14. *Waveforms of channels F7 and F8 during right thinking]*

2) Tapping:

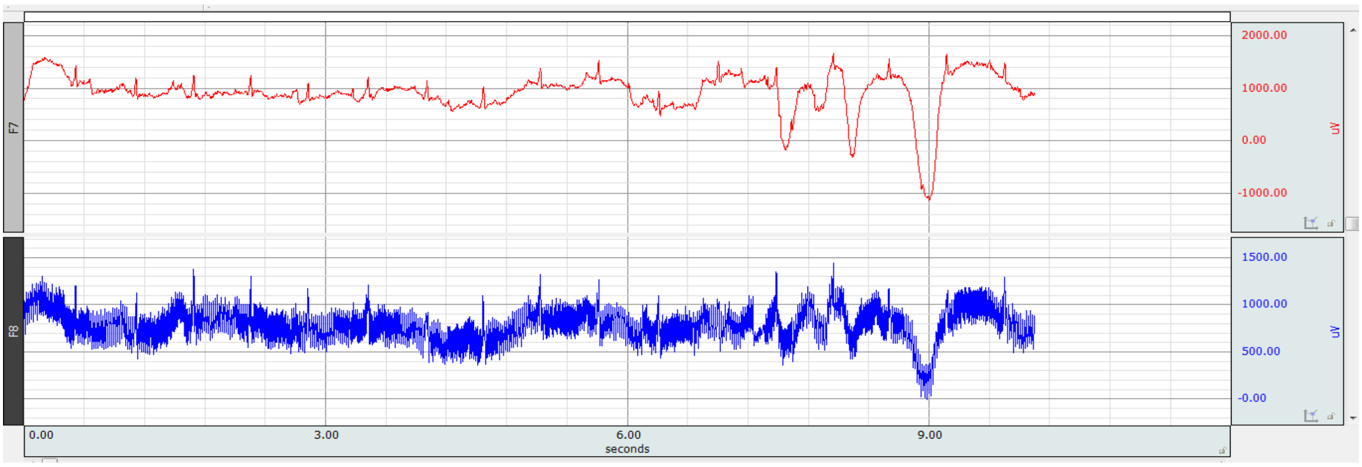
Analysis:

This test forces the subject to think in a particular direction through tapping on either left or right hand. So this is just a similar to thinking test. So as pointed out earlier also it is too hard to get the subject's mind focus over a particular direction .so, we got the same result as first test!!

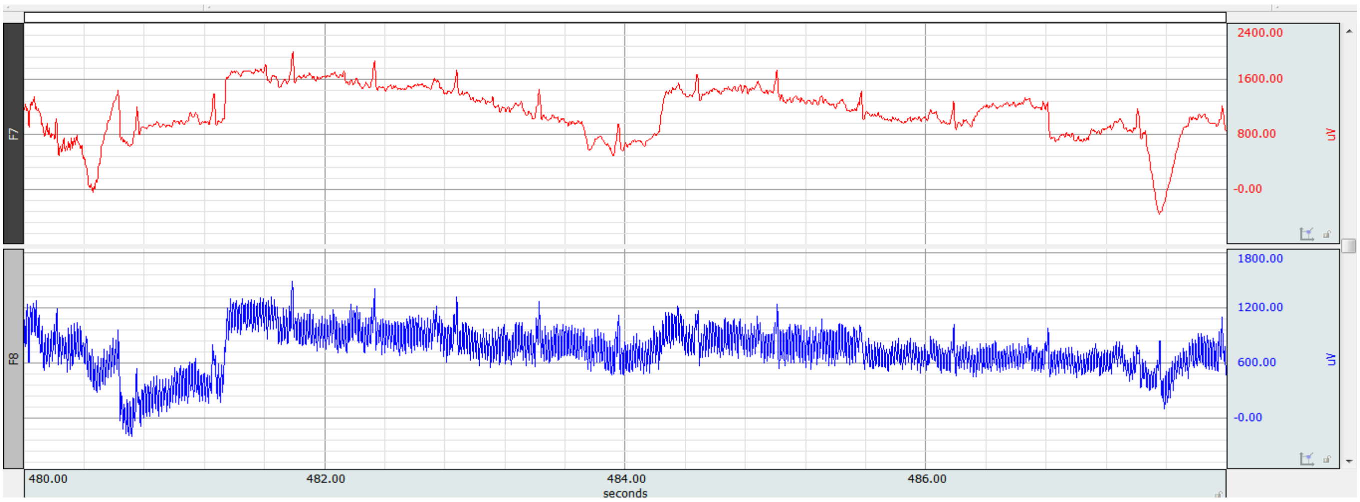
And if you compare waveforms given below, you will get to know they are too random in nature, so it is too difficult to extract the pattern. Though, there are some peaks in F7 channels, they do not contribute to any trend, they may be due to eye the blink. As a result we dropped this test in experiment 2.



[Fig.15. *Waveforms of channels F7 and F8 during left tapping]*



[Fig.16. *Waveforms of channels F7 and F8 during right tapping]*



[Fig.17.Waveforms of channels F7 and F8 during relax position]

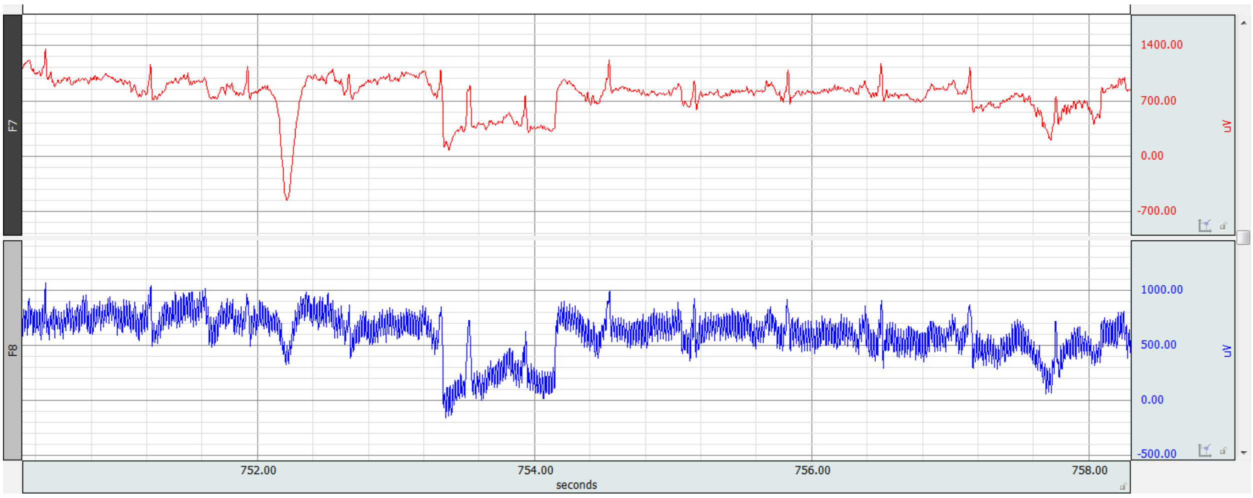
3) Number line:

This is also a just another way in our endeavour of getting trend through the just thinking process .In this test person was told a signed number during test and he has to think over its direction, means whether it is on the left or right side of the zero on the number on the number line.

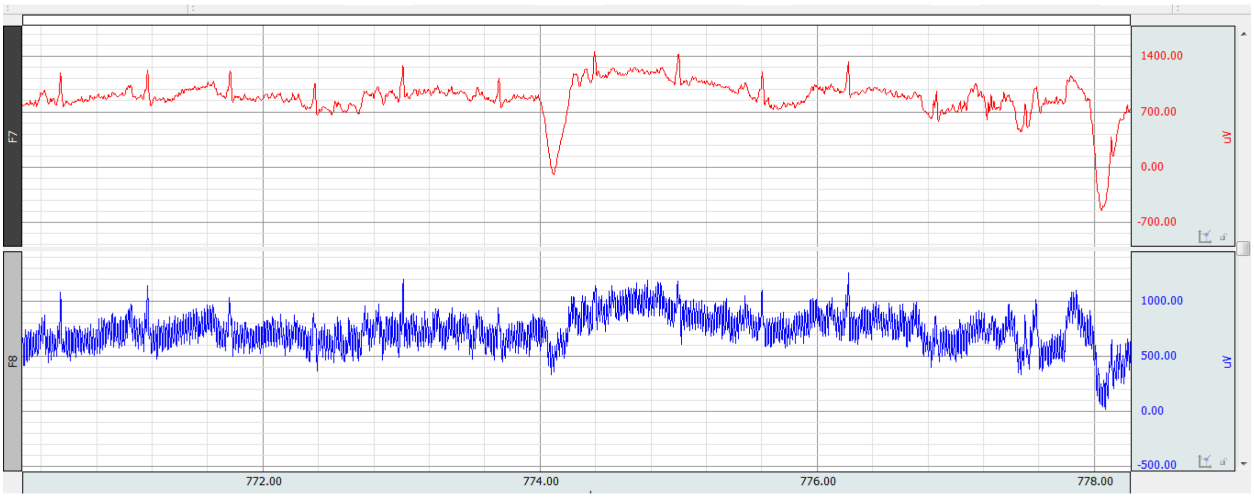
Analysis:

For this test also we firstly concentrated on analysing the frontal channels. If you refer the waveforms given below, you will get to know, in this test also there is not any substantial changes in waves during thinking.

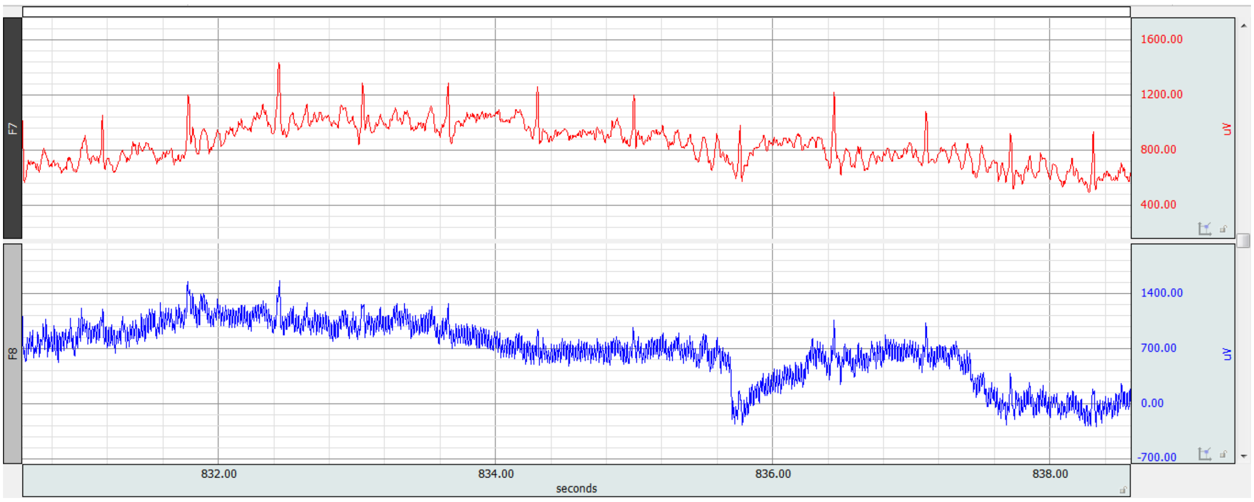
We also gone through the same computational procedure as done for the earlier test, but we failed to get any kind of trend. Various reasons can be there for not getting results, some of them are mentioned in first test.



[Fig.18. Waveforms of channels F7 and F8 for negative numbers (left)]



[Fig.19.Waveforms of channels F7 and F8 for positive numbers (right)]



[Fig.20.Waveforms of channels F7 and F8 during relax position for number-line test]

4) Imagination task:

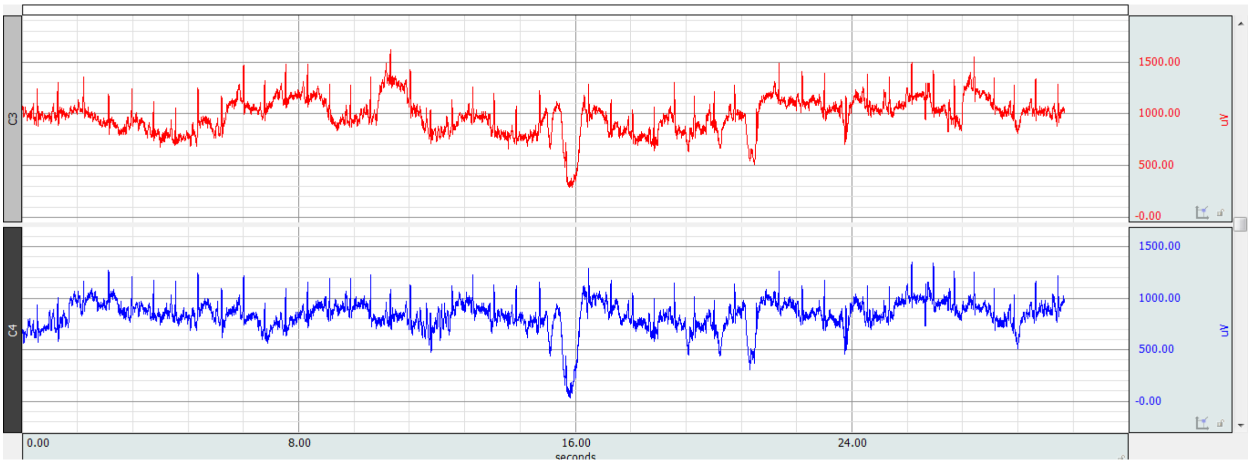
According to a theory when you try to move your limbs or just imagine of moving it, mu waves (9 Hz to 11 Hz) disappear from the central lobe. When right limbs are moved, mu waves from left lob gets disappeared and when left limbs are moved, mu waves from right lob gets disappeared. This can be the good criteria to detect left and right movement. So we had decided to add imagination task and limb movements.

Analysis:

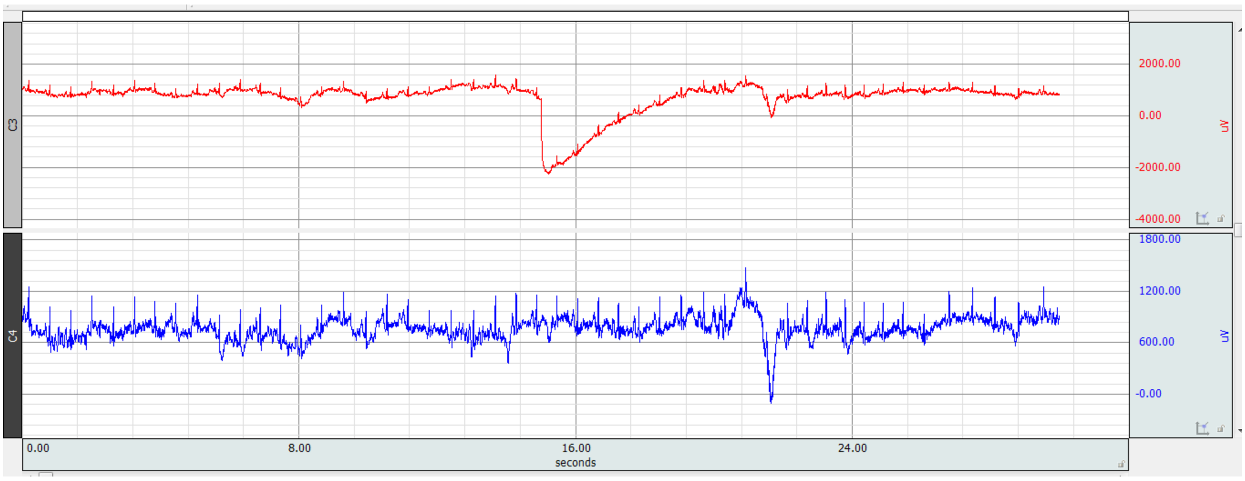
Mu waves originates from the sensory motor cortex area, which fall in the range of channels C3 and C4. So, we have shown waveforms of those channels as reference. If you see the waveforms given below, you will get to know that, they are quite random, we get some spike somewhere randomly, amplitude is not any particular range and frequency is also not in range of 9 to 11 which is quite opposite to the characteristics of the mu waves. And also if you go by theory, these waves are not suppressed by the imagination of movements.

After going deeply for reason, we came to know that mu possibility of getting mu waves in adults is too less which around 17% only. There are some other reasons also, such as concentration of mind, noise etc.

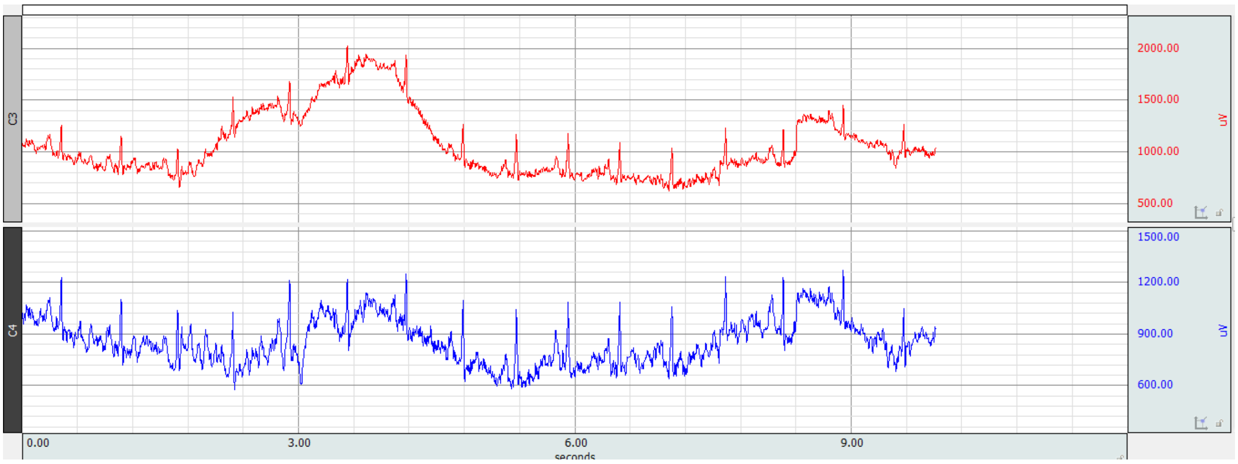
So we could not get the required result from this test, also.so we dropped this idea for further test.



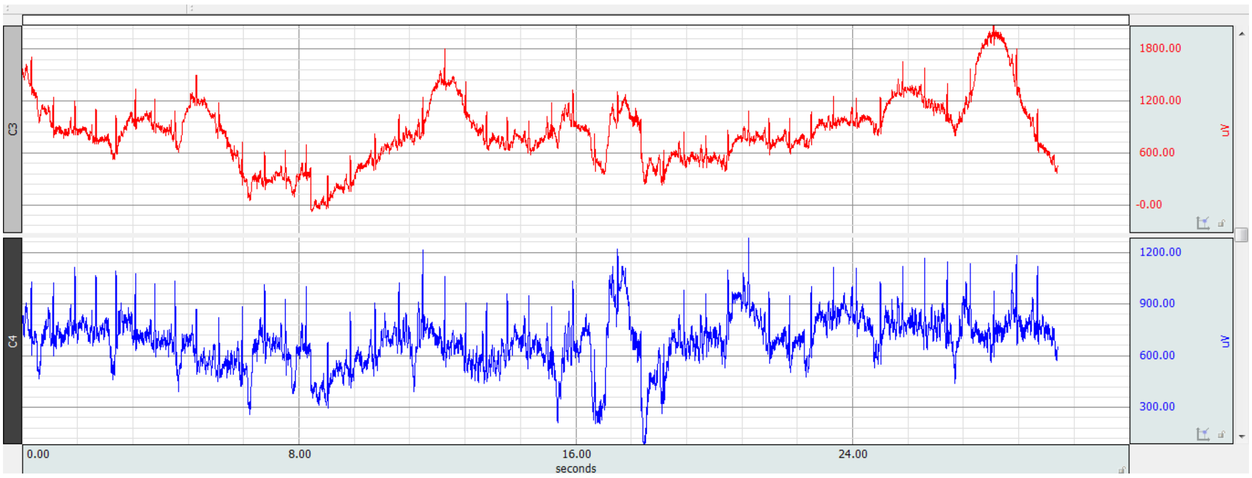
[Fig.21.Waveforms of channels C3 and C4 during right leg movement imagination]



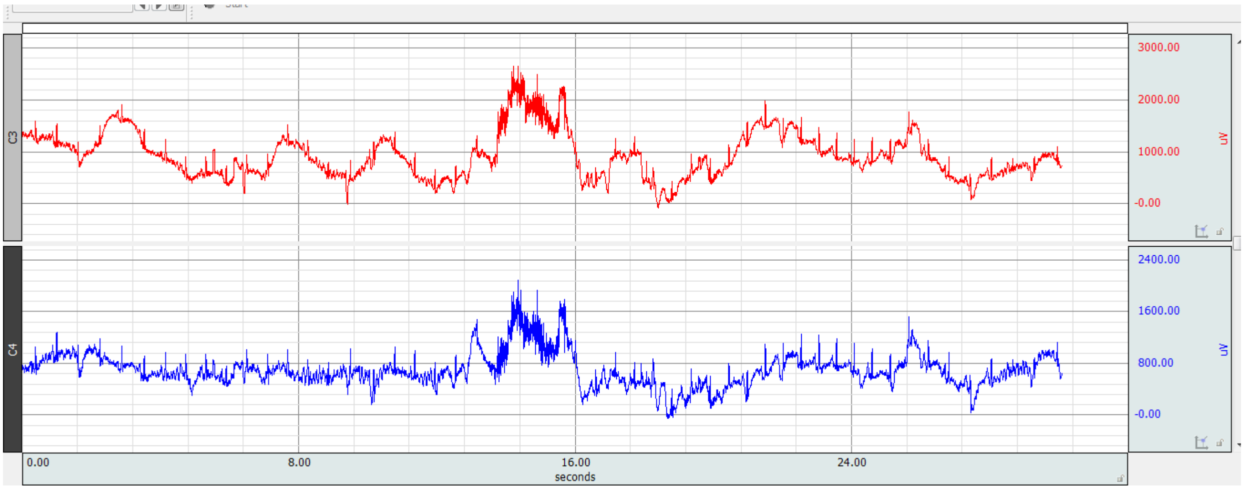
[Fig.22.Waveforms of channels C3 and C4 during left leg movement imagination]



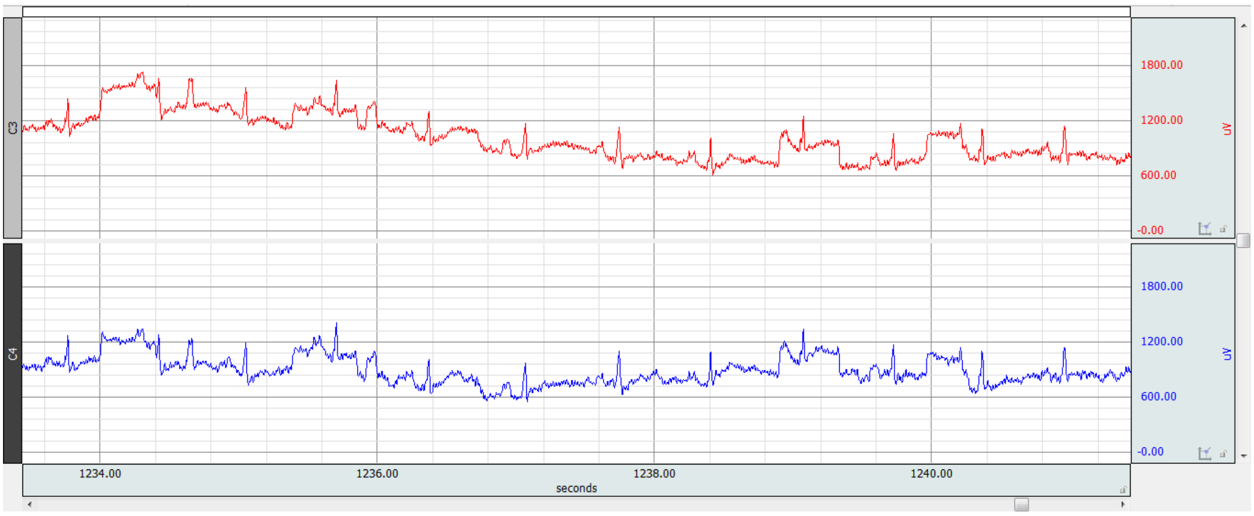
[Fig.23. Waveforms of channels C3 and C4 during relax position]



[Fig.24.Waveforms of channels C3 and C4 during right hand movement]



[Fig.25.Waveforms of channels C3 and C4 during left hand movement]



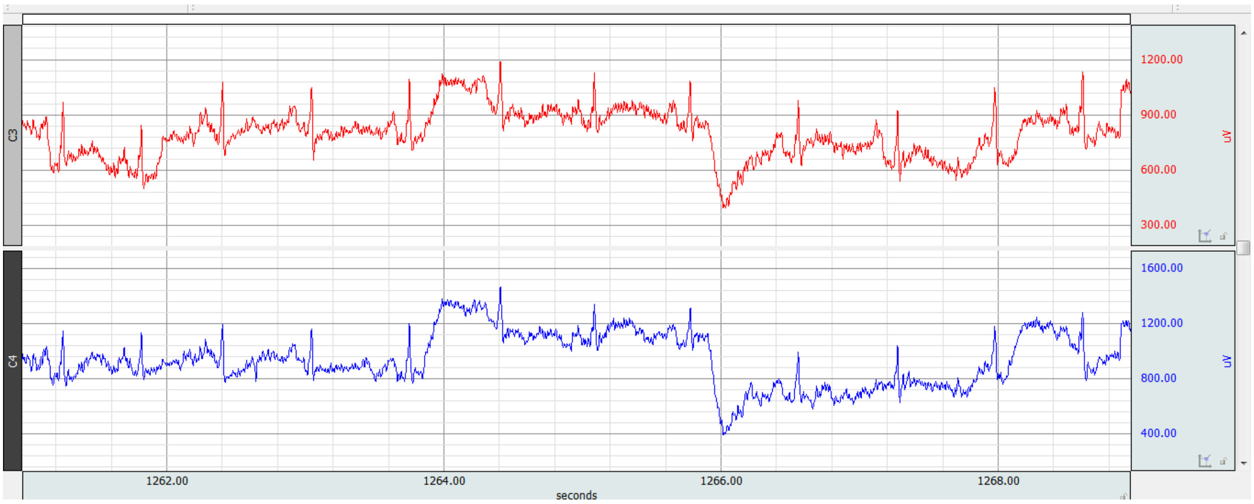
[Fig.26.Waveforms of channels C3 and C4 during relax position]

5) Limb movements:

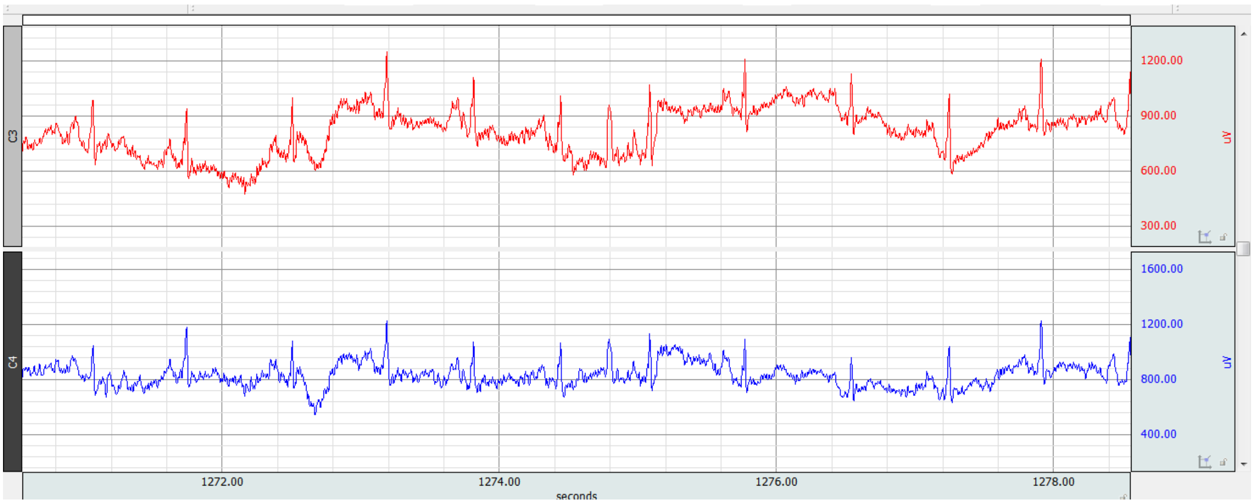
This is just a another type of test for the possibility of driving the wheelchair by using mu waves .In this test subject was asked to move his limbs for finite duration for timing refer the table given in chap 3.

Analysis:

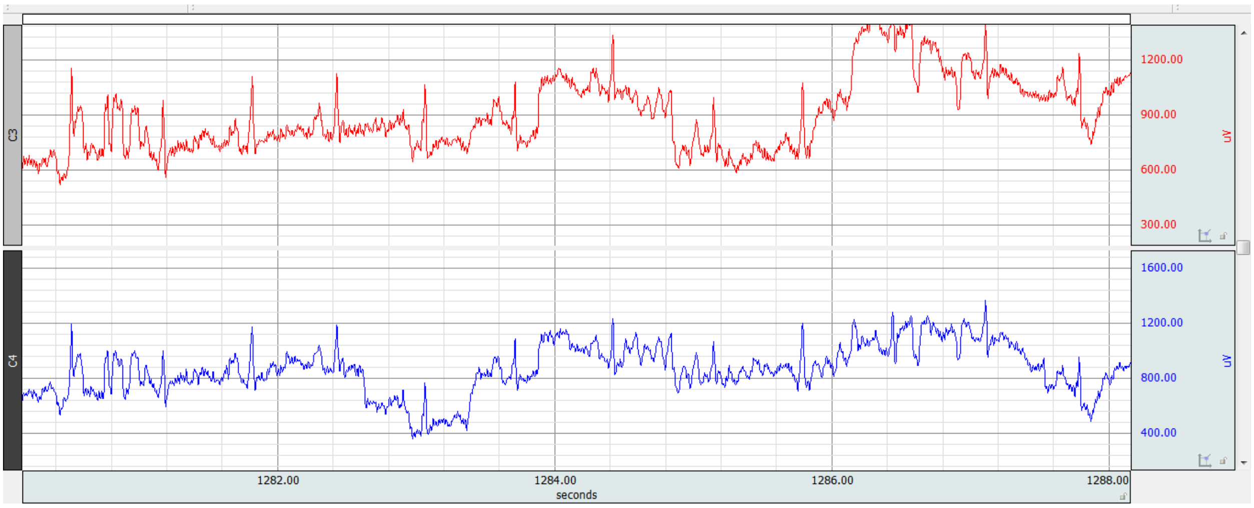
We failed to get the results in this test also, reasons are same as the imagination task. We did a lot mathematical computation but in the end, it was all worthless. Though we tried one more time and included this test in experiment 2.



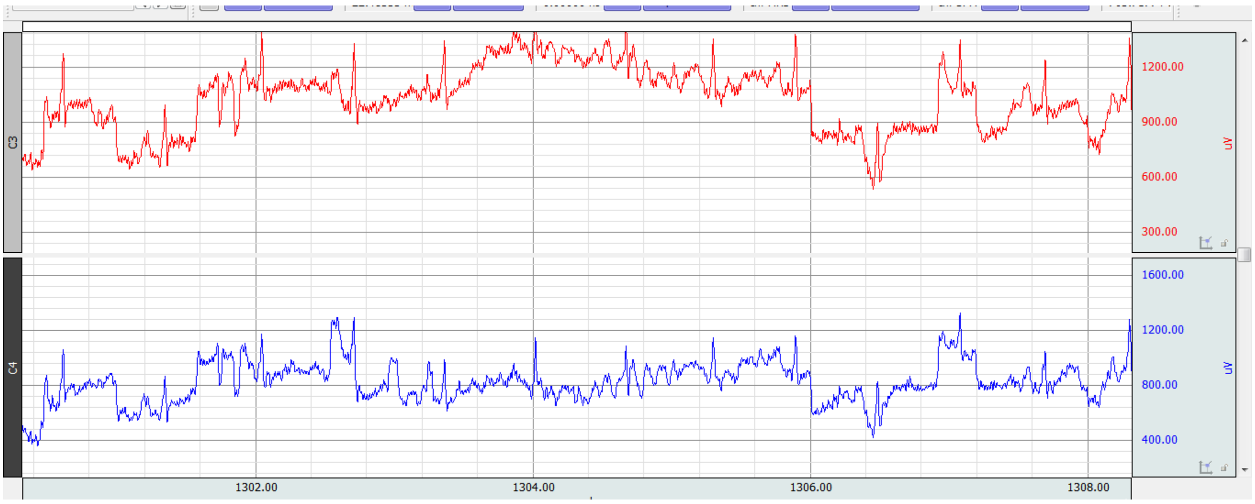
[Fig.27.Waveforms of channels C3 and C4 during left leg movement]



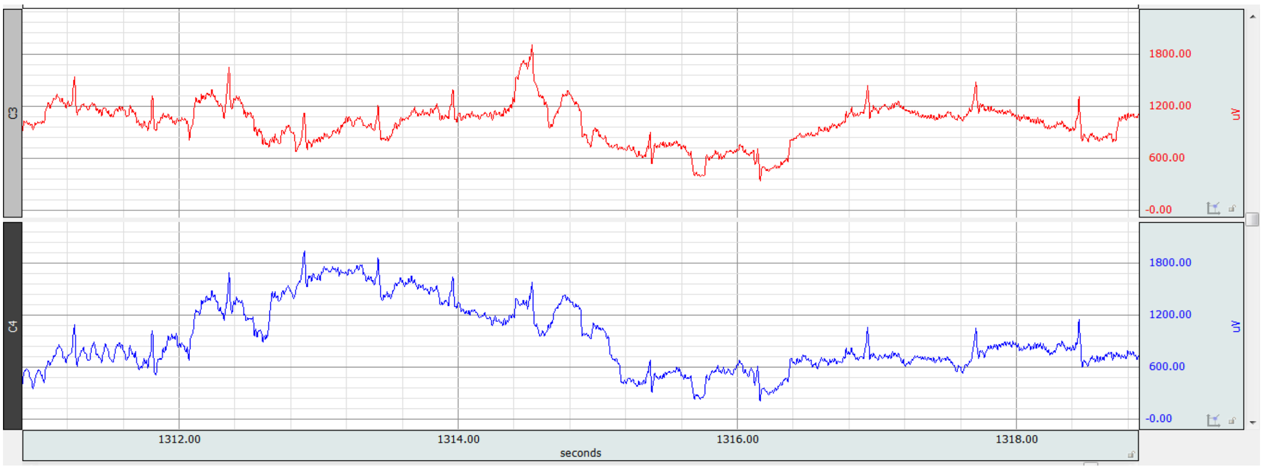
[Fig.28.Waveforms of channels C3 and C4 during relax position]



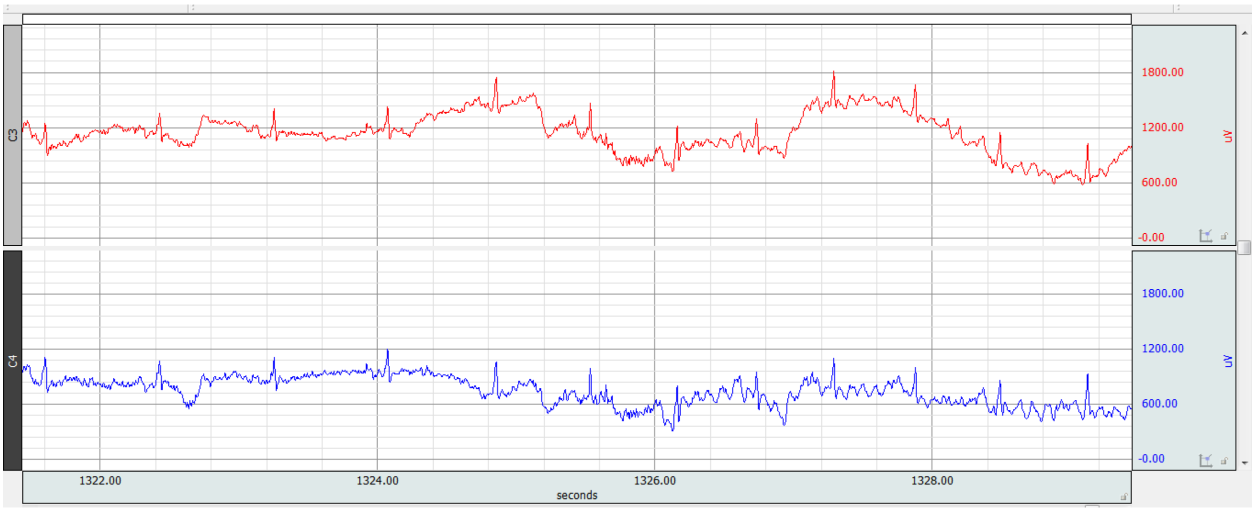
[Fig.29.Waveforms of channels C3 and C4 during right leg movement]



[Fig.30 .Waveforms of channels C3 and C4 during left hand movement]



[Fig.31.Waveforms of channels C3 and C4 during relax position]



[Fig.32.Waveforms of channels C3 and C4 during right hand movement]

3.6.2 Experiment 2:

Eye Controlled Wheelchair:

As we decided to control over wheelchair using eye movements, we found two different ways:

1) Eye ball movements:

Due to the cornea-retinal potential we get the potential difference in electrode placed near eye whenever person moves his eyes. We did some experiments using this format.

but there are some big disadvantages of this idea. Like person driving wheelchair can be distracted by surrounding and in that case due to the eye ball movements false detection can occur!

The second reason is that we had done experiments so far using EEG test, this idea requires EMG test for exact readings, though we did some experiments using EEG.

Third reason is in EMG test we requires total 5 electrodes to get the signals, but as per our research and pattern later on, you will come to know that by using only two frontal channels EEG , we can run wheelchair.

In EEG based experiments, we got some power difference but it was too less and there was not any particular pattern of occurring it for different movements. So, we dropped this idea and concentrated on eye closing, blinking and winking.

2) Eye closing

We found that eyeball movements are not much efficient as compared to eye closing as it is very hard to detect eyeball movements. Further it is hard to keep your eyeballs controlled throughout the motion of the wheelchair. The user needs deep training for that. So we concentrated mainly on eye winking.

In early experiments we had very little idea how exactly brain waves changes with eye movements. So we asked subjects to keep their eyes closed for 5 secs as per the instruction and we analysed the waves.

As you can see, the waveforms have certain peaks during left and right closing time.

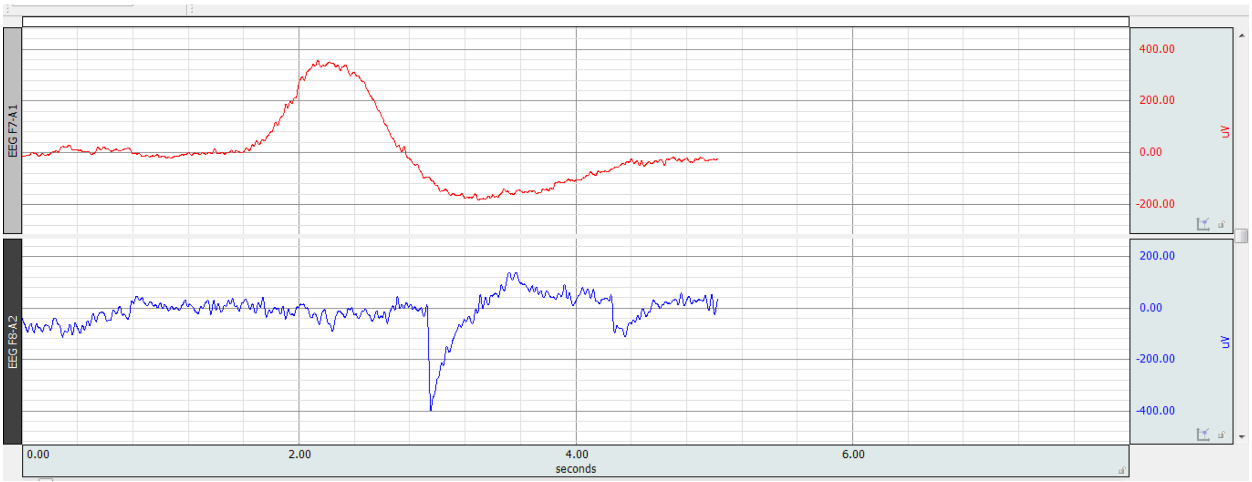
We analysed different parameters like frequency, amplitude, power and amplitude of different waves such as alpha and beta waves during this time period. we could find some kind of pattern based on power in this experiment but it was not good enough to run the wheelchair.

In fig. 2.1 ,F7 has large peak for left eye closing and F8 also has peak but of negligible amplitude as compared to F7.in right eye closing waveform is distorted , but you can see that in that case F8 has larger amplitude than F7 and in relax mode both channels get suppressed.

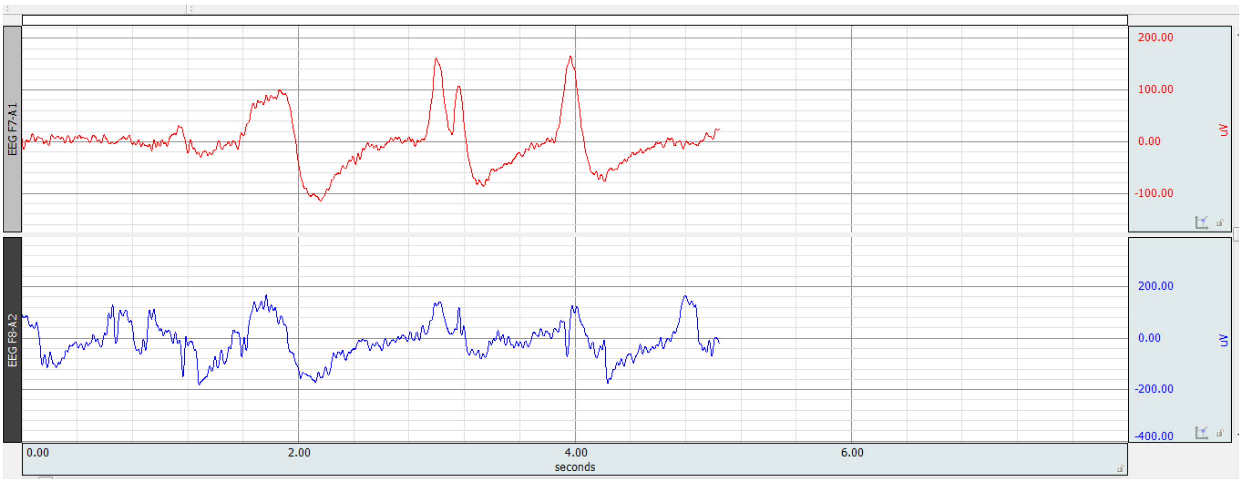
We came to know that whenever subject closes or opens his eye only at that instance we are getting power difference. Hence in later experiments we focused on eye winking rather than eye closing.

3) Wrist movements:

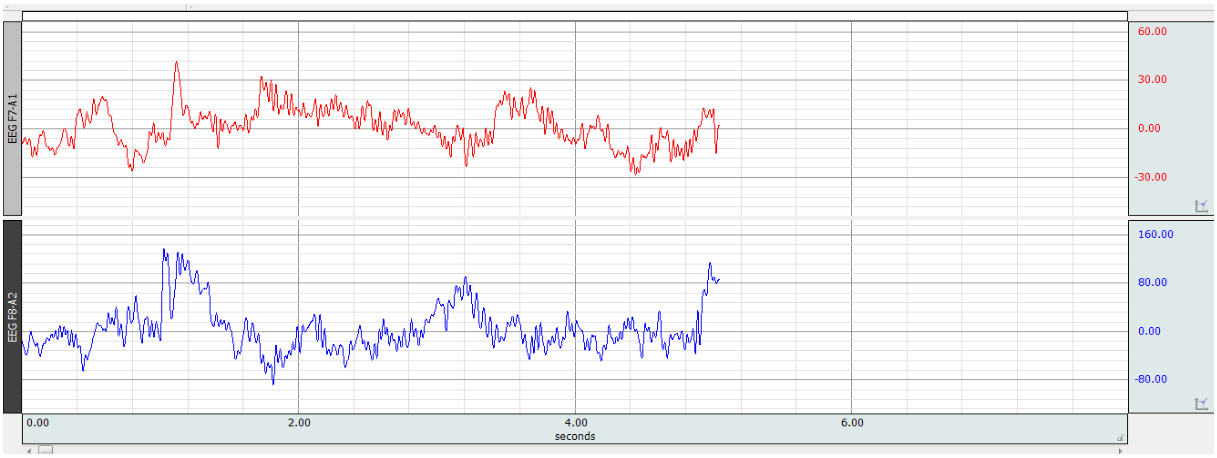
In second experiment we had also included wrist movements as possibility of driving wheelchair using mu waves, but we could not get any trend in this test also, reasons are same as given in experiment 1. For reference and continuity we have shown waveforms here



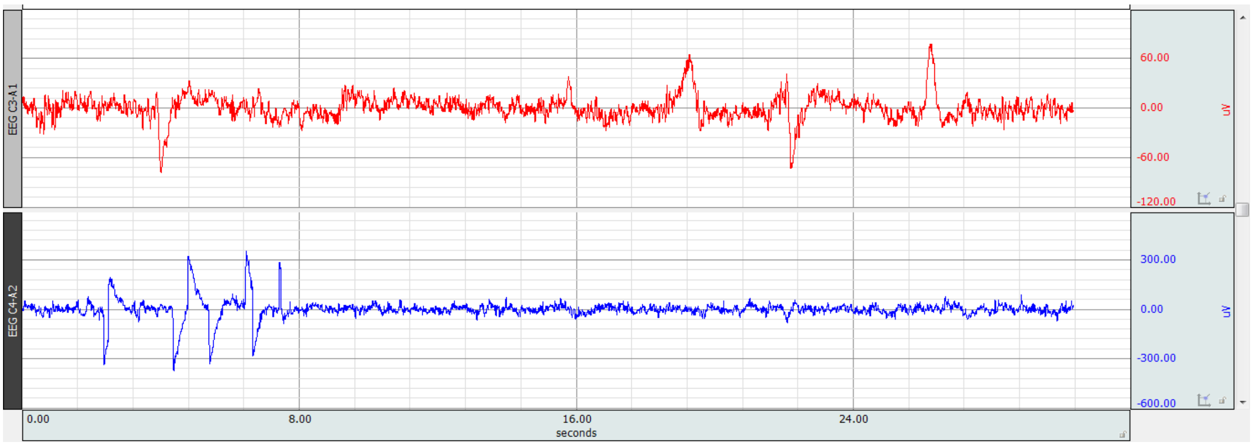
[Fig.33.Waveforms of channels F7-A1 and F8-A2 during left eye closing]



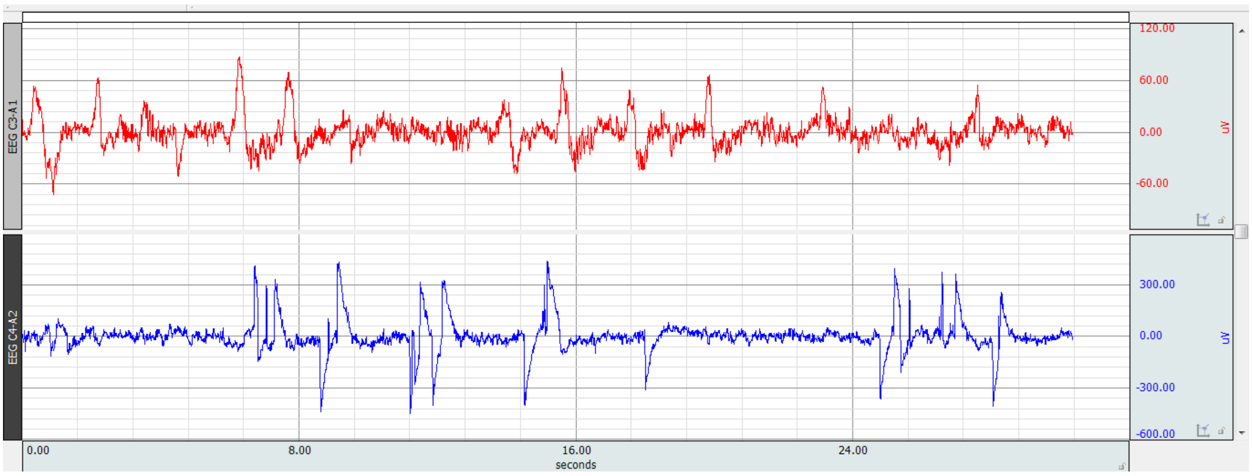
[Fig.34.Waveforms of channels F7-A1 and F8-A2 during relax position]



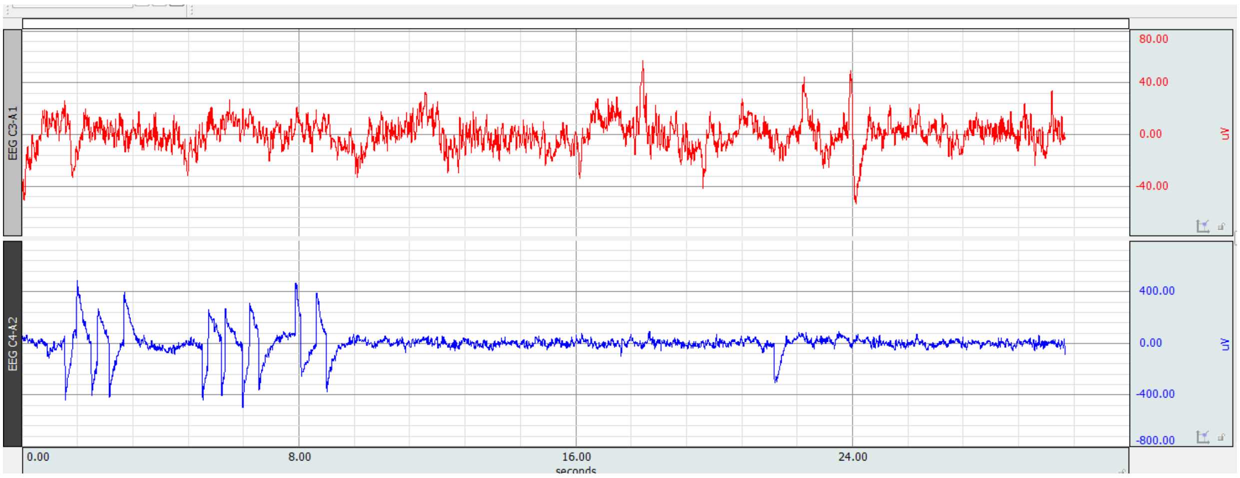
[Fig.35.Waveforms of channels F7-A1 and F8-A2 during right eye closing]



[Fig.36.Waveforms of channels C3-A1 and C4-A2 during left wrist movements]



[Fig.37.Waveforms of channels C3-A1 and C4-A2 during relax position]



[Fig.38.Waveforms of channels C3-A1 and C4-A2 during right wrist movements]

3.6.3 Experiment 3:

3.6.3.1 Subject: Alok

Analysis:

The last series of experiments were the most accurate ones which gave us a tunnel-vision in further development. As shown in all these figures it can be clearly seen even by mere observation of the waveforms that winking gives the most sure shot changes when it comes to EEG patterns. Without any need of applying mathematical transforms on these waves we can design a system based on these results by just considering power spectral density and the frequency of the waves as two parameters required for system design. Delving ourselves into further step-by-step analysis which follows as below:

Exercise-1: Single wink exercise

As said earlier, in this test the subject was asked to wink a particular eye as per the instruction. For the test pattern refer the table above.

- From Fig 3.1 it is quite evident that whenever a person winks his/her left eye, there is a substantial change obtained in the F7 and F8 electrodes. A crest is formed in the F7 wave which is of a considerably higher amplitude and at the same time some activity takes place in the F8 electrode but its amplitude is negligible. This was indeed a major breakthrough for us as we now got some clear line of demarcation between the left and the right side.
- Similarly from Fig 3.2 it can be observed that the behaviour of the waves emitted from F7 and F8 are exactly opposite when it comes to right eye winking, viz. activities are observed in both the waveforms but the amplitude of F8 is considerable while that of F7 is negligible in comparison to F7. We can say that for right eye winking the roles of F7 and F8 are interchanged.
- During the end of the exercise, the subject was allowed to relax and it can be observed from Fig 3.3 that as soon as the subject relaxed himself, the activities in the F7 and F8 channel suppressed and during the entire relax session, no particular spike or erroneous behaviour was detected in the waveform.

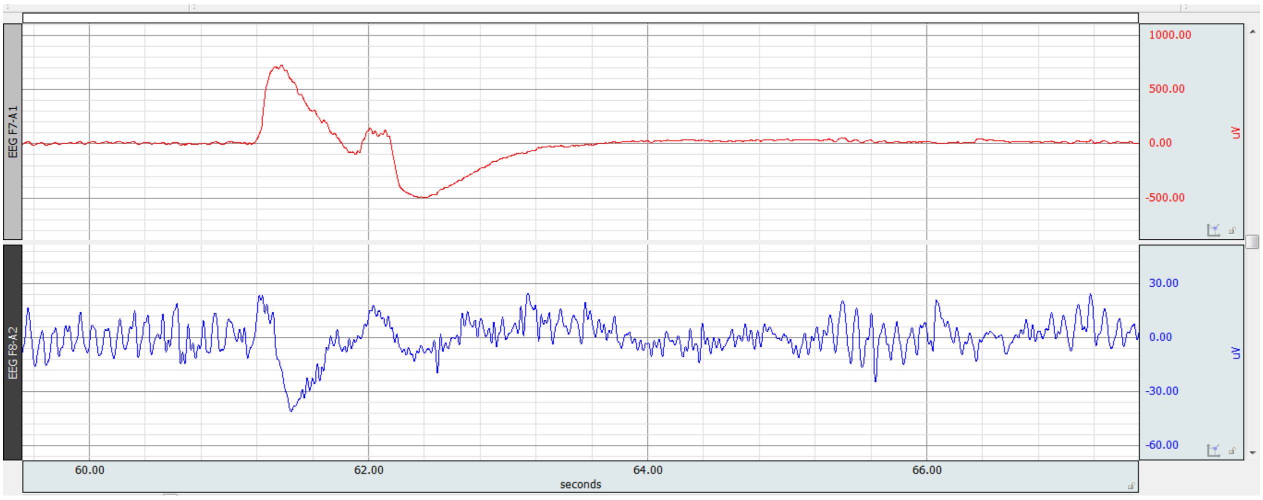
Exercise-2: Simultaneous winking exercise

As mentioned earlier, in this exercise, the subject was supposed to wink twice at an interval of 5 seconds in between two winks. For more details, please refer the table given above in the document.

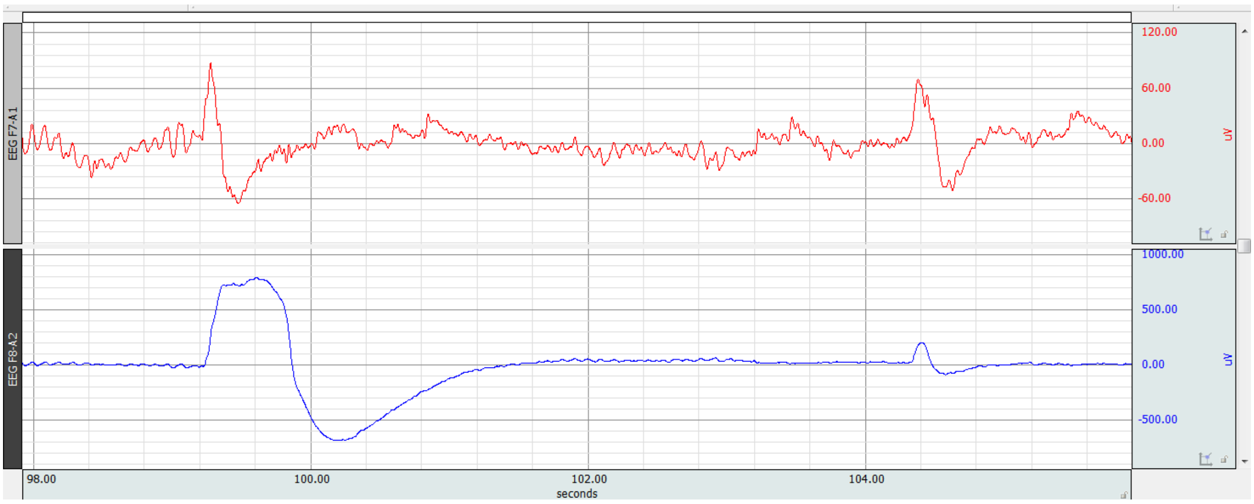
- It can be clearly seen in Fig 3.4 that the analysis of our first exercise is consistent here also when the subject was asked to wink his left eye twice. During both the winks one can clearly see how the F7 channel produces a spike with amplitude in the range of 1000s while the F8 produces a similar spike but its amplitude is not even in the range of three digits!!]
- Similar parallels can be drawn out from Fig 3.5 when the subject was asked to wink his right eye twice.
- Also when combinations were made which involved the right-left or the left-right winking, one can clearly see from the figures that the analysis is consistent i.e. when the subject winked his left eye first, there was a spike in the F7 channel and no such activity in the F8 channel.
- Similarly as soon as he winked his right eye just after an interval as short as 5 seconds, the F8 channel shown spike while the F7 was almost at rest.
- If you see the computation given in spread sheet ahead, it is quite evident from that we get a large power difference between two channels.

Addendum:

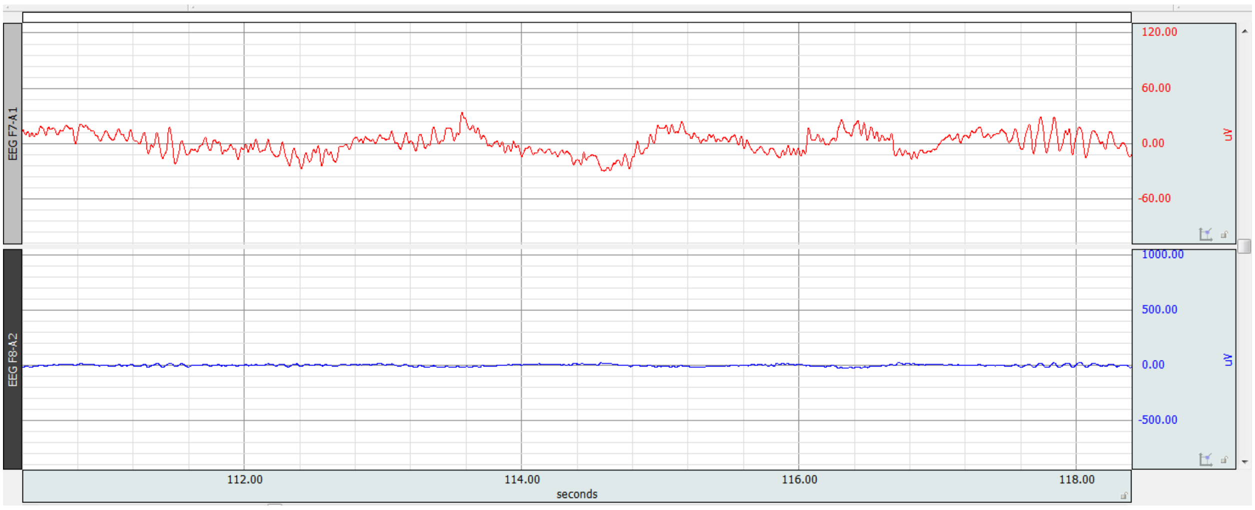
For checking the vulnerability of our system towards minor movements and jerks which can be experienced on a common wheelchair, we allowed the subject to move his neck and limbs up to a certain extent to see whether these movements hamper the EEG patterns required for analysis or not. And the result was quite positive as the F7 and F8 channels were virtually unchanged by these jerks and motions and so we can say that this path of design is more or less noise and jerk immune.



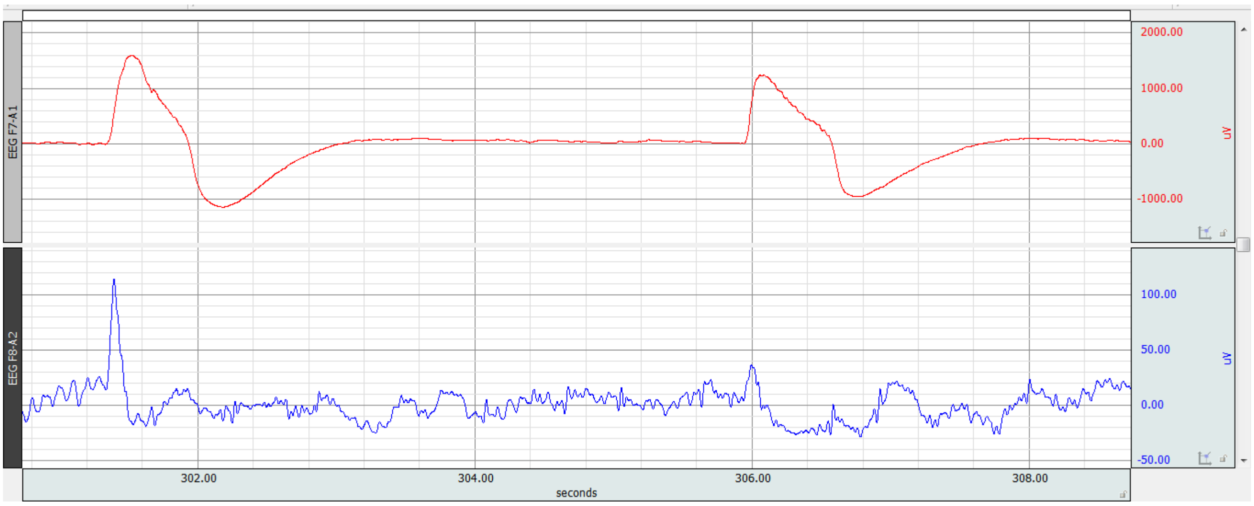
[Fig.39.Waveforms of channels F7-A1 and F8-A2 for left eye wink at 60th second]



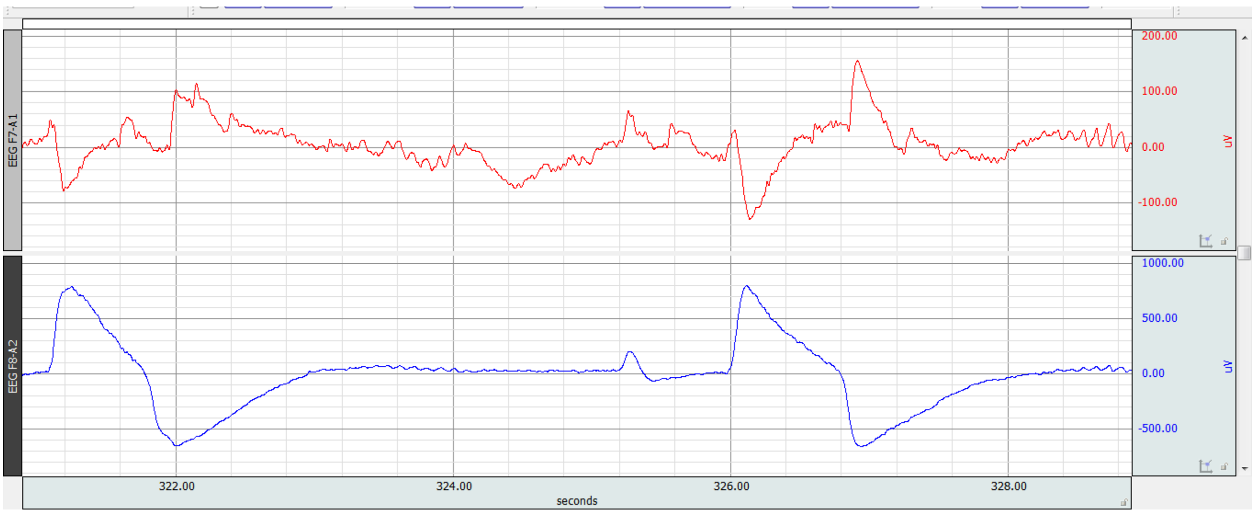
[Fig.40.Waveforms of channels F7-A1 and F8-A2 for right eye wink at 100th second]



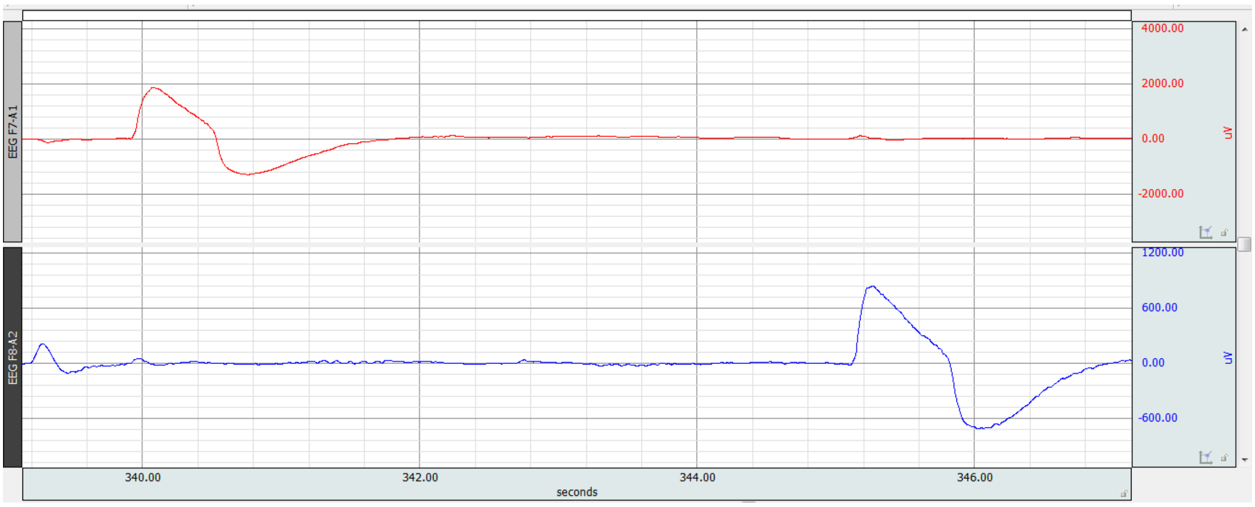
[Fig.41.Waveforms of channels F7-A1 and F8-A2 during relax position]



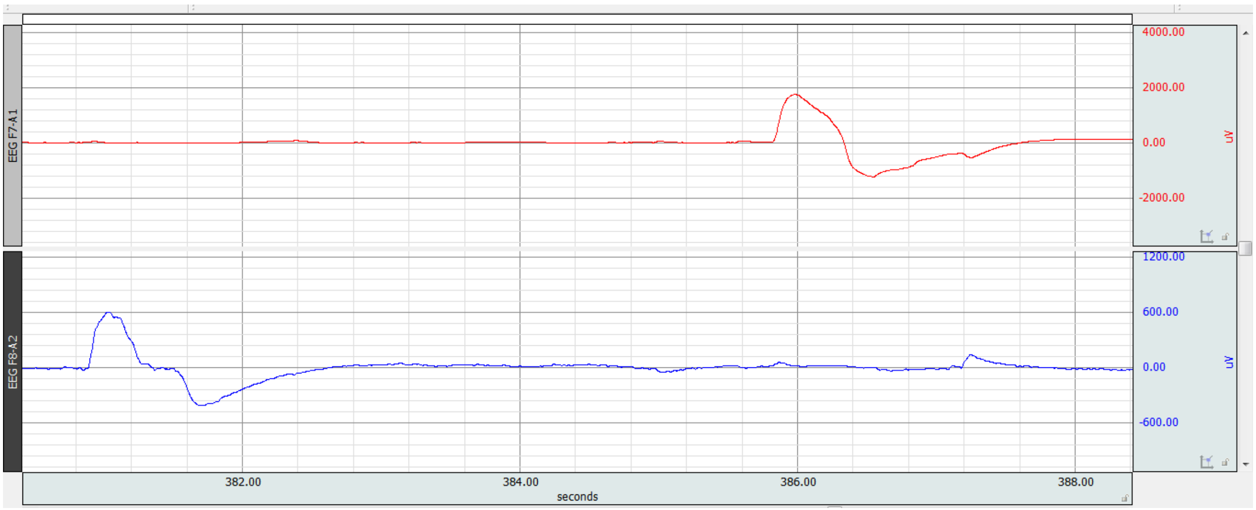
[Fig.42. Waveforms of channels F7-A1 and F8-A2 for two times left eye wink at 300th and 30th seconds]



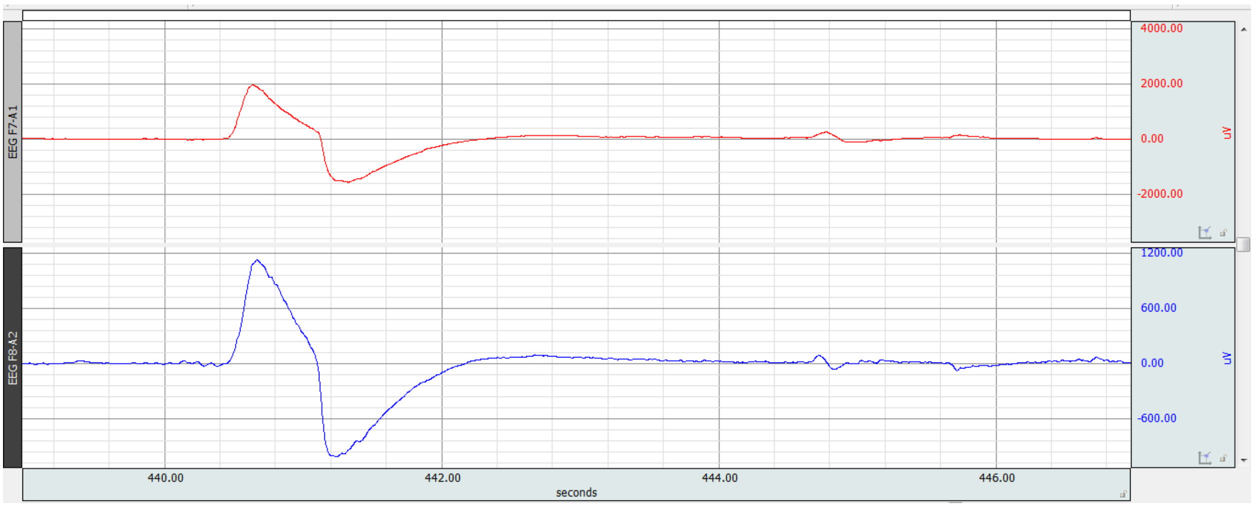
[Fig.43. Waveforms of channels F7-A1 and F8-A2 for two times right eye wink at 320th and 325th seconds]



[Fig.44.*Waveforms of channels F7-A1 and F8-A2 for* successive left and right eye winks at 340th and 345th seconds]



[Fig.45.*Waveforms of channels F7-A1 and F8-A2 for* successive right and left eye winks at 380th and 385thseconds]



[Fig.46.Waveforms of channels F7-A1 and F8-A2 for both eyes closed at 440th second]

We have also shown the spread sheet of showing mean power and mean frequency of channels F7 and F8.

You can see that at the time of winking F7 crosses the threshold, it is high lighten by pink colour and at the time of the right eye winking F8 crosses threshold and is high lighten by the yellow colour, during simultaneous two wink, we get the threshold crossed in corresponding channel, when both eye were closed we get the threshold crossed in both channels, during relaxation time power is quite low in the range of thousands and at he moment of winking it goes up to certain lakhs.

We can also see the changes in mean power frequency. At the moment of left eye winking MPF of F7 is always less than that of the F8 and in the range of the 1.8-2.3 Hz. Exactly opposite is true for right winking. During both eyes closed frequency in both channels is in range of 1.8 to 2.3 Hz and difference between these two is quite low up to 0.1 Hz.

	A	B	C	D	E	F	G
1	activity	time(s)	f7	f8		meanF f7	mean f8
2		1	361.9756	7.079854		1.840236	1.840236
3		2	3937.155	772.7241		3.033422	4.086655
4		3	745.8789	393.9476		2.957168	3.236701
5		4	1260.869	227.8784		2.099564	2.506913
6		5	8972.787	5456.409		2.684784	2.495316
7		6	351.439	577.7768		3.421539	2.807713
8		7	887.8079	615.6826		2.869096	2.385839
9		8	1925.597	2624.694		2.398962	2.36042
10		9	4320.15	3895.228		2.645916	2.010301
11		10	181.1516	531.9477		3.23768	2.312122
12		11	184.6433	41.87168		3.007564	6.788335
13		12	2228.725	263.9086		1.923027	2.329629
14		13	266.814	114.3214		4.278384	6.19185
15		14	3960.849	3643.695		2.282355	2.954979
16		15	1745.602	787.4224		2.064218	2.46574
17		16	87.45358	188.3811		5.787374	4.460837
18		17	87.97216	61.33847		4.952004	7.442894
19		18	400.2329	70.54081		3.890017	7.812
20		19	1106.953	130.9243		2.524392	5.282671
21		20	523.5672	269.0419		2.075241	2.935164
22		21	303.2146	287.0696		2.903802	2.857214
23		22	184.3198	73.53745		3.351557	10.30209
24		23	205.3368	96.06035		2.881966	6.218274
25		24	11.18829	45.09924		11.60516	3.929924

Sheet1 Sheet2 Sheet3

	A	B	C	D	E	F	G
61	left	60	84.28587	108.5435		10.32325	10.20328
62		61	77.47851	59.50967		7.120152	11.71731
63		62	121635.2	320.7399		2.033552	2.820171
64		63	110140.1	66.22915		1.966694	4.841506
65		64	2037.223	85.49163		2.042829	5.423372
66		65	667.2981	19.92783		2.078478	11.95501
67		66	622.9545	72.02164		2.428776	10.37978
68		67	323.7157	42.78743		2.610514	6.189104
69		68	1512.124	4690.112		4.881698	4.717996
70		69	8355.799	3658.731		2.187365	2.022394
71		70	124.1527	482.7627		3.305316	2.264554
72		71	92.63865	121.4241		3.550981	3.252207
73		72	85.46538	86.36856		8.701398	9.506354
74		73	121.0005	105.6238		5.684975	7.732227
75		74	65.73584	33.32893		5.830265	9.014569
76		75	2162.964	210.777		3.075989	2.834139
77		76	64.03106	46.97628		5.178569	4.97436
78		77	134.2317	106.8836		8.208293	9.838482
79		78	184.8593	112.2898		4.687077	5.986021
80		79	665.7428	670.0897		4.738507	5.143116
81	left	80	1036.536	1172.344		2.463146	2.908175
82		81	704577.1	1395.04		1.997667	2.949942
83		82	657943.7	81.52685		1.939005	3.868176
84		83	20009.62	494.5778		1.886157	2.225487
85		84	[illegible]92.149	441.8479		1.996673	2.823374

Sheet1 Sheet2 Sheet3

	A	B	C	D	E	F	G
101	right	100	1048.793	281593.6		3.0502	1.964991
102		101	171.5191	236201.2		3.551283	1.855276
103		102	42.59274	2063.805		4.981023	2.058216
104		103	154.36	1815.287		4.14489	2.038078
105		104	105.2374	715.2882		4.995148	2.082943
106		105	704.6903	4367.006		2.906131	2.98329
107		106	228.8544	107.0816		2.469479	3.699219
108		107	78.43345	188.9871		5.98015	5.233689
109		108	10094.53	1691.819		2.171447	2.469023
110		109	21057.98	7594.17		2.054156	2.35903
111		110	889.8157	460.9479		2.046015	2.233138
112		111	148.1472	62.41794		3.552986	3.597108
113		112	74.5449	54.45185		8.08697	10.88148
114		113	119.3828	60.75747		4.251656	8.475346
115		114	108.0203	97.13404		4.577007	3.876152
116		115	246.1703	94.75059		2.490338	3.643107
117		116	96.54688	83.8413		3.40165	4.539189
118		117	125.4446	157.4163		4.295	3.293464
119		118	121.3198	76.91661		5.874399	10.68675
120		119	101.3069	155.2315		9.902222	10.02731
121	right	120	178.1142	101.1472		4.62638	8.275762
122		121	104.7772	223.6964		7.157245	5.533011
123		122	1473.158	250766.5		2.582825	2.0718
124		123	798.0006	223042		2.522403	1.940574
125		124	[illegible]0.6846	1922.674		2.435772	1.993867

Sheet1 Sheet2 Sheet3

	A	B	C	D	E	F	G
141	left	140	2372.865	281.8852		3.629839	4.021257
142		141	1059925	515.8156		1.994611	2.951498
143		142	806560.4	231.879		1.906149	2.368945
144		143	19501.57	96.39919		1.879976	3.735856
145		144	2958.744	92.69258		1.927747	5.99621
146		145	3253.892	156.9181		2.02775	8.538321
147		146	1099.107	96.31992		2.066334	5.709565
148		147	403.2168	30.45365		2.249553	7.036252
149		148	229.3165	165.6856		3.04166	4.045156
150		149	577.5844	144.7528		2.821773	4.813354
151		150	173.9774	71.12332		2.514858	3.01183
152		151	1232.084	175.227		2.628653	3.697858
153		152	13740.52	2134.382		2.352469	2.828282
154		153	1007.074	79.07701		2.410032	4.245053
155		154	89.04287	34.00091		5.910907	5.89716
156		155	351.4018	42.51283		2.374612	5.312787
157		156	104.202	59.80213		4.48671	7.641339
158		157	195.4793	52.26094		2.725245	4.292262
159		158	44.81204	15.0898		5.138713	12.66155
160		159	125.746	172.1826		9.32476	9.328502
161	right	160	62.83021	33.46907		5.764949	7.293892
162		161	1770.696	207732.4		2.725677	2.049043
163		162	260.174	212109.8		3.265972	1.951878
164		163	186.1467	3525.335		4.007302	2.086622
165		164	[illegible]1.6976	680.3991		5.292971	3.174335

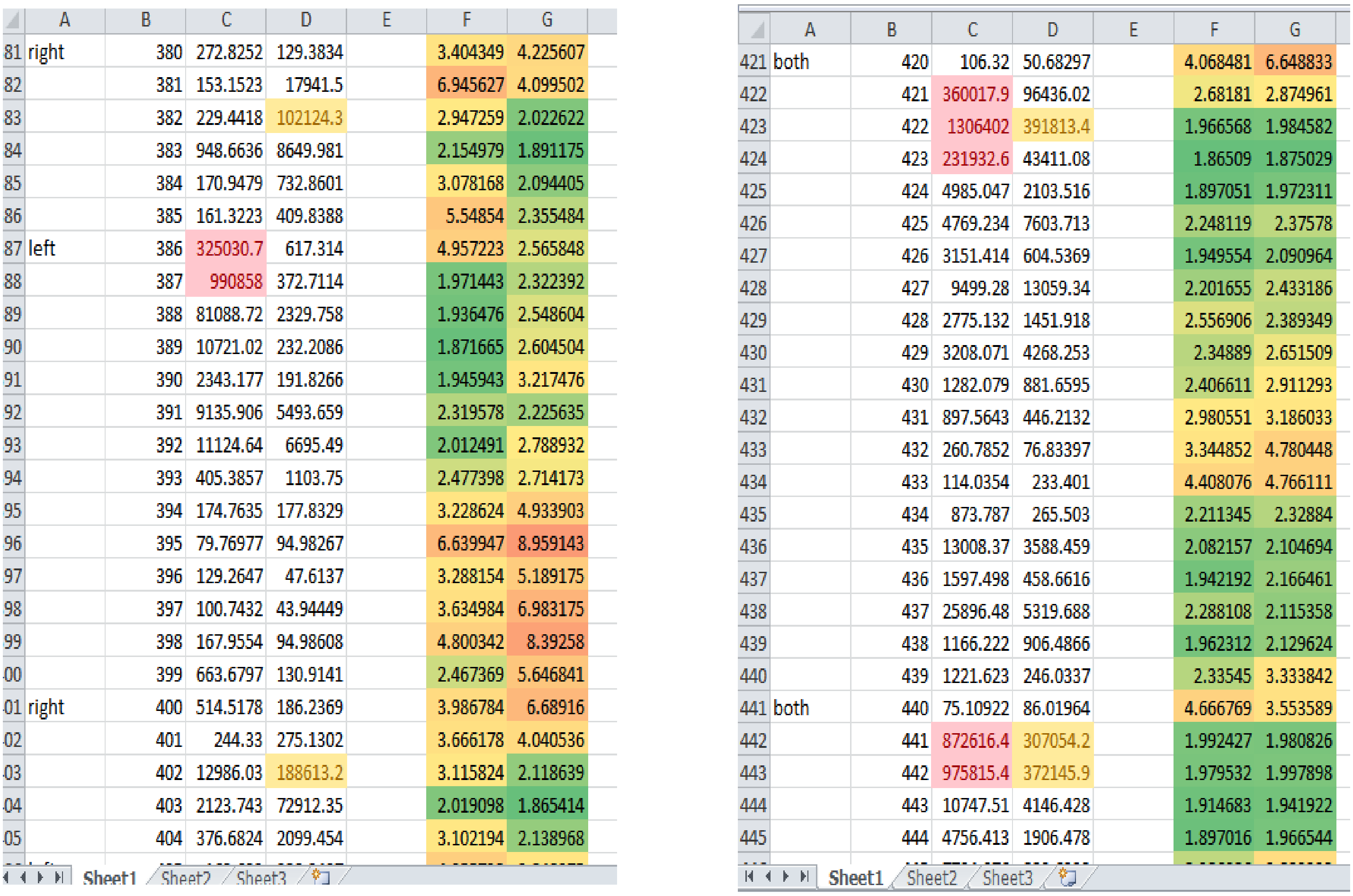
Sheet1 Sheet2 Sheet3

	A	B	C	D	E	F	G
301	left	300	151.1115	180.3215		5.062826	4.505783
302		301	186.7044	108.3432		3.042569	3.860898
303		302	593313	815.8766		2.009629	3.300856
304		303	551766.6	31.07404		1.862029	7.478804
305		304	4102.979	138.0861		1.908893	2.64456
306	left	305	2002.434	65.43178		2.026087	6.00634
307		306	12353.15	113.7504		2.097799	4.403283
308		307	649798	355.2576		1.958453	2.433571
309		308	83677.31	150.7977		1.862628	3.291829
310		309	3158.497	327.9012		1.92675	2.496919
311		310	10081.25	6710.578		2.131547	2.337133
312		311	9788.991	7202.663		2.087365	2.019597
313		312	1388.39	409.7235		2.365698	3.654159
314		313	2678.202	2652.715		2.437851	2.15938
315		314	9192.076	1379.192		2.585513	2.908256
316		315	400.2672	250.8363		2.682062	2.375115
317		316	304.4488	230.5325		4.295765	3.46743
318		317	564.6579	97.9214		2.471541	5.223092
319		318	208.4606	127.5511		4.730857	6.988743
320		319	398.9416	86.20625		2.945213	7.220508
321	right	320	196.0718	357.6256		2.566595	2.443873
322		321	2058.085	2285.792		2.545457	2.708925
323		322	1240.117	224020.1		3.027649	2.024218
324		323	2701.822	134319.6		1.994071	1.850792
325		324	[illegible]9.7524	2596.016		3.895733	1.966912

Sheet1 Sheet2 Sheet3

	A	B	C	D	E	F	G
341	left	340	46059.39	5238.033		2.453995	2.823036
342		341	1464653	124.7531		1.956251	3.406533
343		342	186728.1	222.0451		1.861085	4.561528
344		343	3808.642	154.3355		1.991478	3.367506
345		344	5696.733	259.3158		1.90001	2.859409
346	right	345	1010.328	45.0238		2.107998	4.800169
347		346	1174.888	242889.7		2.923864	2.020349
348		347	491.842	178810.8		3.037462	1.860563
349		348	199.6874	2077.344		2.930679	1.958779
350		349	2810.142	9642.597		2.353052	2.3877
351		350	1326.019	3171.06		2.592624	2.626356
352		351	3740.21	3110.741		2.044191	2.467391
353		352	11146.94	13759.13		2.114245	2.300253
354		353	4122.795	2879.38		2.108821	2.114505
355		354	1781.91	790.9316		2.31736	2.632187
356		355	940.2252	113.8814		2.33751	5.061513
357		356	4308.013	1582.52		2.938636	3.320704
358		357	2567.855	167.0998		2.91144	3.311747
359		358	6883.423	1222.57		2.158037	2.373698
360		359	905.4646	492.406		2.480639	3.010194
361	left	360	4706.405	6965.403		2.573701	2.681541
362		361	729.6438	264.995		2.461819	2.805538
363		362	1162867	182.8014		2.017576	3.272039
364		363	49586.42	100.523		1.88521	3.73743
365		364	[illegible]80.734	191.3815		1.923758	8.659859

Sheet1 Sheet2 Sheet3



	A	B	C	D	E	F	G
81	right	380	272.8252	129.3834		3.404349	4.225607
82		381	153.1523	17941.5		6.945627	4.099502
83		382	229.4418	102124.3		2.947259	2.022622
84		383	948.6636	8649.981		2.154979	1.891175
85		384	170.9479	732.8601		3.078168	2.094405
86		385	161.3223	409.8388		5.54854	2.355484
87	left	386	325030.7	617.314		4.957223	2.565848
88		387	990858	372.7114		1.971443	2.322392
89		388	81088.72	2329.758		1.936476	2.548604
90		389	10721.02	232.2086		1.871665	2.604504
91		390	2343.177	191.8266		1.945943	3.217476
92		391	9135.906	5493.659		2.319578	2.225635
93		392	11124.64	6695.49		2.012491	2.788932
94		393	405.3857	1103.75		2.477398	2.714173
95		394	174.7635	177.8329		3.228624	4.933903
96		395	79.76977	94.98267		6.639947	8.959143
97		396	129.2647	47.6137		3.288154	5.189175
98		397	100.7432	43.94449		3.634984	6.983175
99		398	167.9554	94.98608		4.800342	8.39258
00		399	663.6797	130.9141		2.467369	5.646841
01	right	400	514.5178	186.2369		3.986784	6.68916
02		401	244.33	275.1302		3.666178	4.040536
03		402	12986.03	188613.2		3.115824	2.118639
04		403	2123.743	72912.35		2.019098	1.865414
05		404	376.6824	2099.454		3.102194	2.138968

Sheet1 Sheet2 Sheet3

	A	B	C	D	E	F	G
421	both	420	106.32	50.68297		4.068481	6.648833
422		421	360017.9	96436.02		2.68181	2.874961
423		422	1306402	391813.4		1.966568	1.984582
424		423	231932.6	43411.08		1.86509	1.875029
425		424	4985.047	2103.516		1.897051	1.972311
426		425	4769.234	7603.713		2.248119	2.37578
427		426	3151.414	604.5369		1.949554	2.090964
428		427	9499.28	13059.34		2.201655	2.433186
429		428	2775.132	1451.918		2.556906	2.389349
430		429	3208.071	4268.253		2.34889	2.651509
431		430	1282.079	881.6595		2.406611	2.911293
432		431	897.5643	446.2132		2.980551	3.186033
433		432	260.7852	76.83397		3.344852	4.780448
434		433	114.0354	233.401		4.408076	4.766111
435		434	873.787	265.503		2.211345	2.32884
436		435	13008.37	3588.459		2.082157	2.104694
437		436	1597.498	458.6616		1.942192	2.166461
438		437	25896.48	5319.688		2.288108	2.115358
439		438	1166.222	906.4866		1.962312	2.129624
440		439	1221.623	246.0337		2.33545	3.333842
441	both	440	75.10922	86.01964		4.666769	3.553589
442		441	872616.4	307054.2		1.992427	1.980826
443		442	975815.4	372145.9		1.979532	1.997898
444		443	10747.51	4146.428		1.914683	1.941922
445		444	4756.413	1906.478		1.897016	1.966544

Sheet1 Sheet2 Sheet3

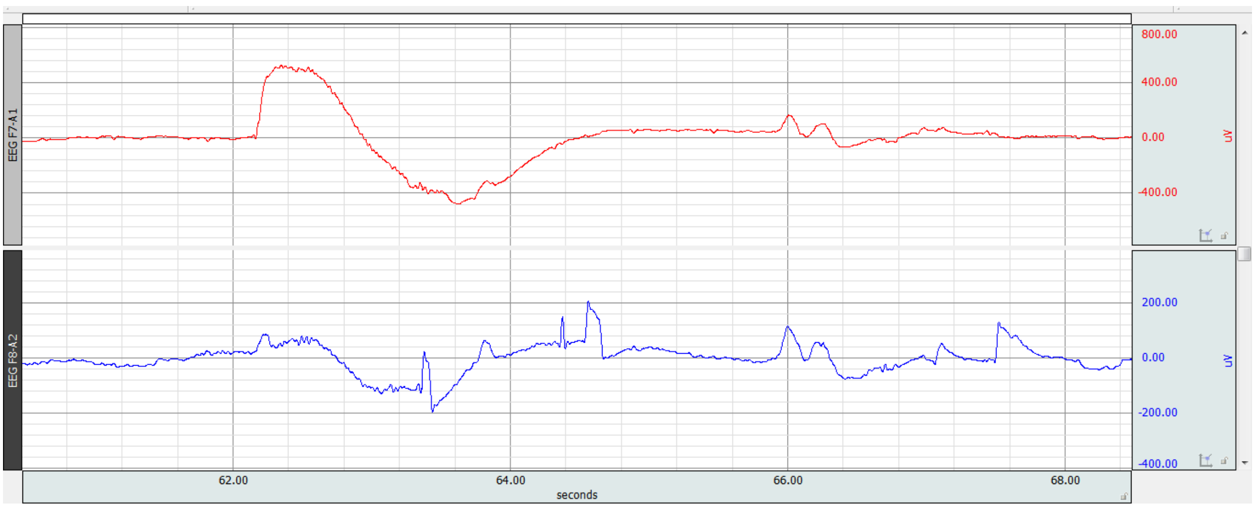
[Fig.47.Analysis using spreadsheets]

3.6.3.2 Subject: Parth

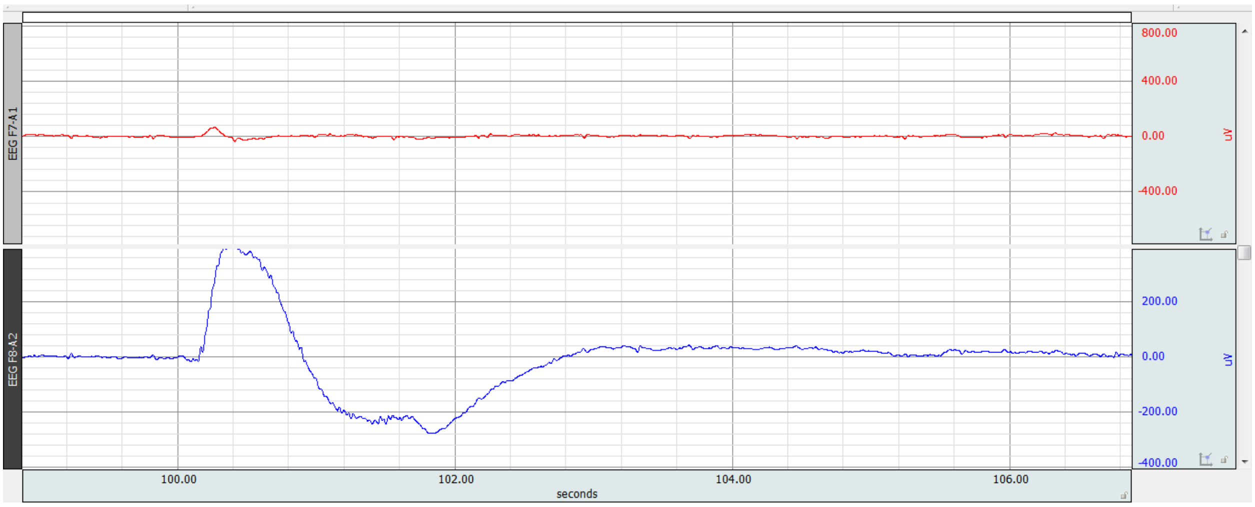
As we are getting a good enough trend to drive the wheelchair we are showing one more example here.

Analysis:

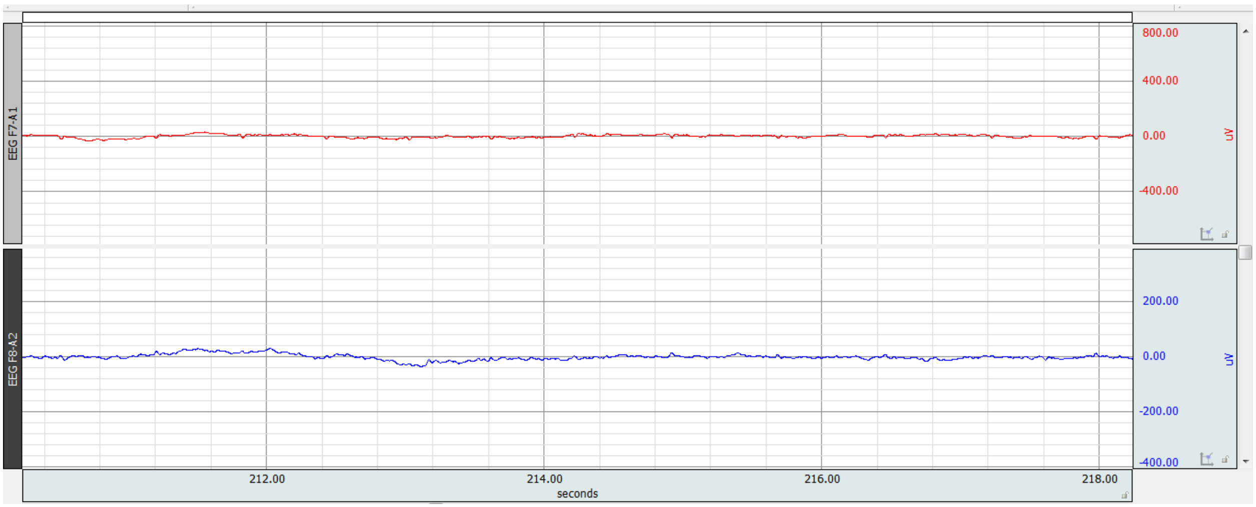
The same pattern we are getting as were in earlier example. we are getting the peaks during left wink in F7 and in F8 during right eye wink. Spread sheet screenshots are also included here. As you can see here threshold is different for this subject and it has to be actually due to various reasons.



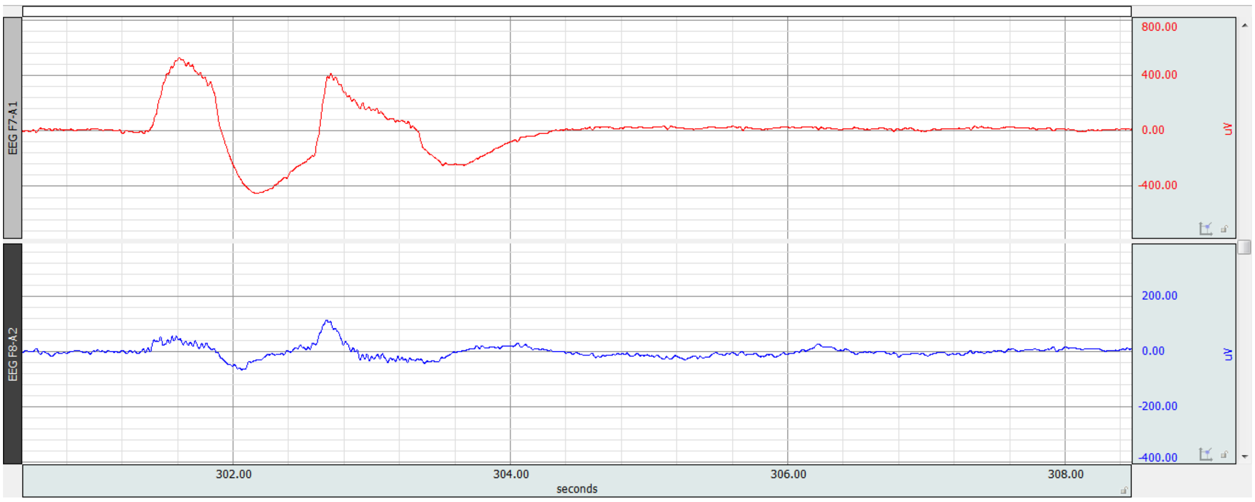
[Fig.48.Waveforms of channels F7-A1 and F8-A2 for left eye wink at 60th second]



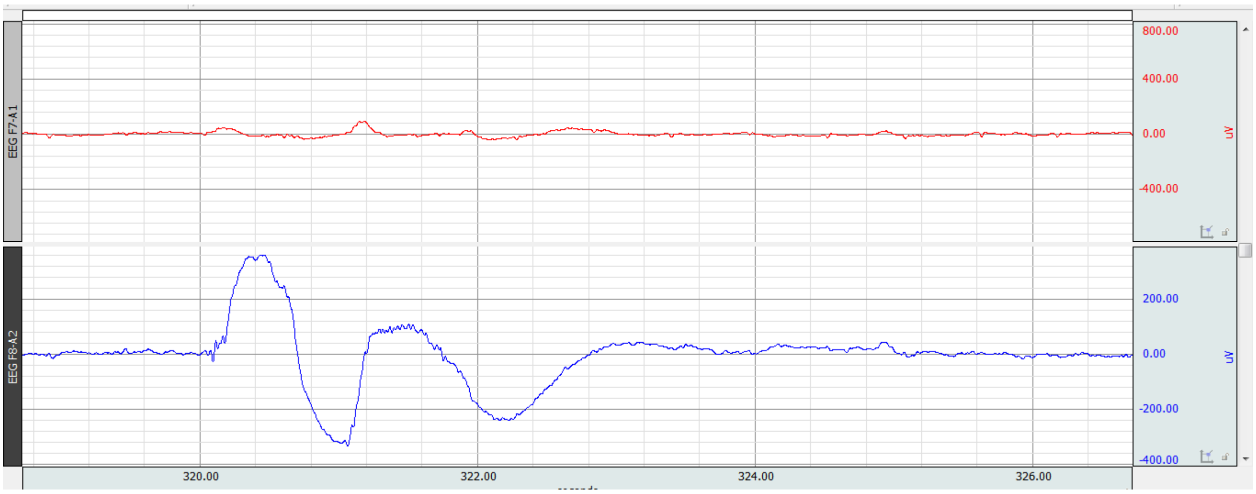
*[Fig.49.Waveforms of channels F7-A1 and F8-A2 for right eye wink at 100*th second]



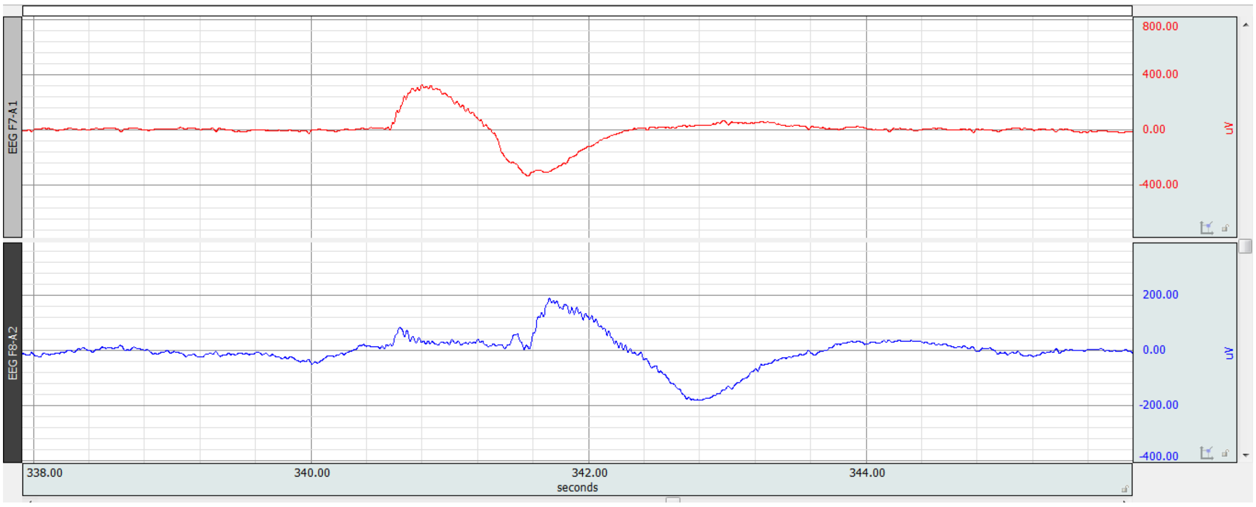
[Fig.50.Waveforms of channels F7-A1 and F8-A2 during relax position]



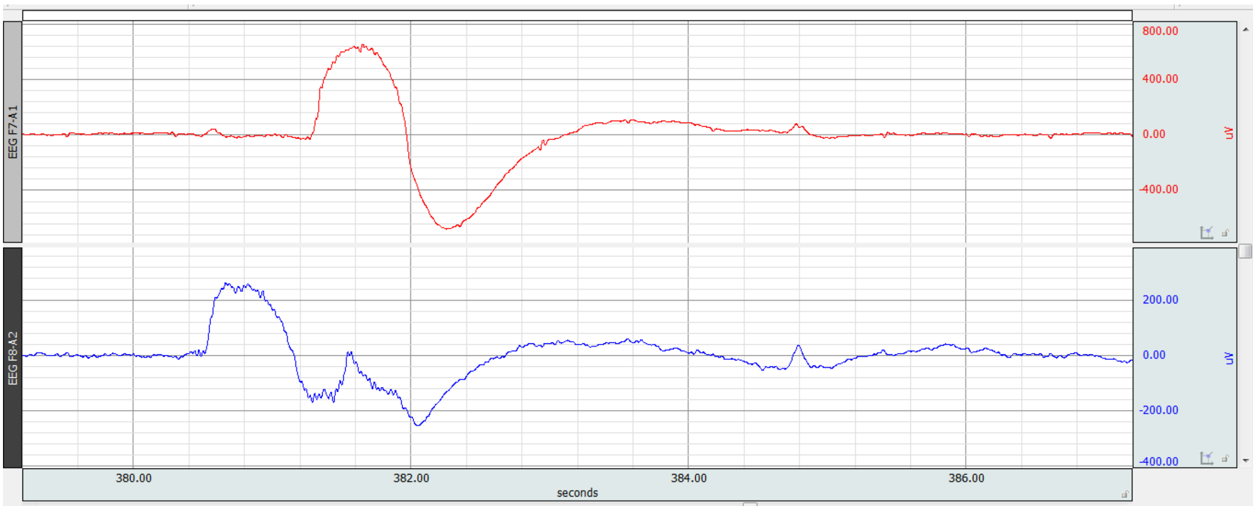
[Fig.51.Waveforms of channels F7-A1 and F8-A2 for two times left winks at 300th second]



[Fig.52.Waveforms of channels F7-A1 and F8-A2 for two times right winks at 320th second]



[Fig.53.*Waveforms of channels F7-A1 and F8-A2 for successive left and right winks at 340th seconds]*



[Fig.54.Waveforms of channels F7-A1 and F8-A2 for successive right and left winks at 380th seconds]

61		59	6861.787	2489.984	2.287132	2.279036
62	left	60	2450.966	1182.914	2.016595	1.999801
63		61	939.5889	915.9306	3.278788	3.19385
64		62	66.56552	384.1793	6.30682	2.306975
65		63	119872.4	3225.681	1.958726	2.305029
66		64	122403.9	9127.063	1.860742	2.556004
67		65	10466.26	4863.796	1.935157	3.138902
68		66	2989.159	647.2862	1.907512	2.162972
69		67	3325.261	2281.385	2.849367	2.485474
70		68	886.1297	1862.158	2.358659	2.942117

241		239	67.7946	28.90571	6.885497	6.645867
242	left	240	57.85654	87.20392	5.788326	3.358099
243		241	45511.14	242.2886	2.050204	4.599994
244		242	58194.59	412.6722	1.869594	2.273818
245		243	2072.963	309.5917	2.007232	2.326925
246		244	1004.829	367.7567	1.993639	2.486411
247		245	247.4831	205.788	3.103221	2.509048
248		246	140.2835	92.76813	3.623923	2.798036
249		247	89.5168	18.43661	4.593014	6.977706

81		79	47.79182	85.03511	6.218569	3.181213
82	left	80	52.24143	75.9537	5.783512	3.06214
83		81	30561.49	6494.989	2.062645	2.178299
84		82	23600.96	612.243	1.994358	2.476875
85		83	2896.11	3933.045	3.090099	2.453983
86		84	893.9045	135.8055	2.202708	2.71455
87		85	74.98685	1118.054	5.432358	1.949653
88		86	133.5069	923.6857	3.201082	2.088088
89		87	75.45451	3612.452	5.767403	2.469771
90		88	26.86052	342.7093	6.284744	2.143943

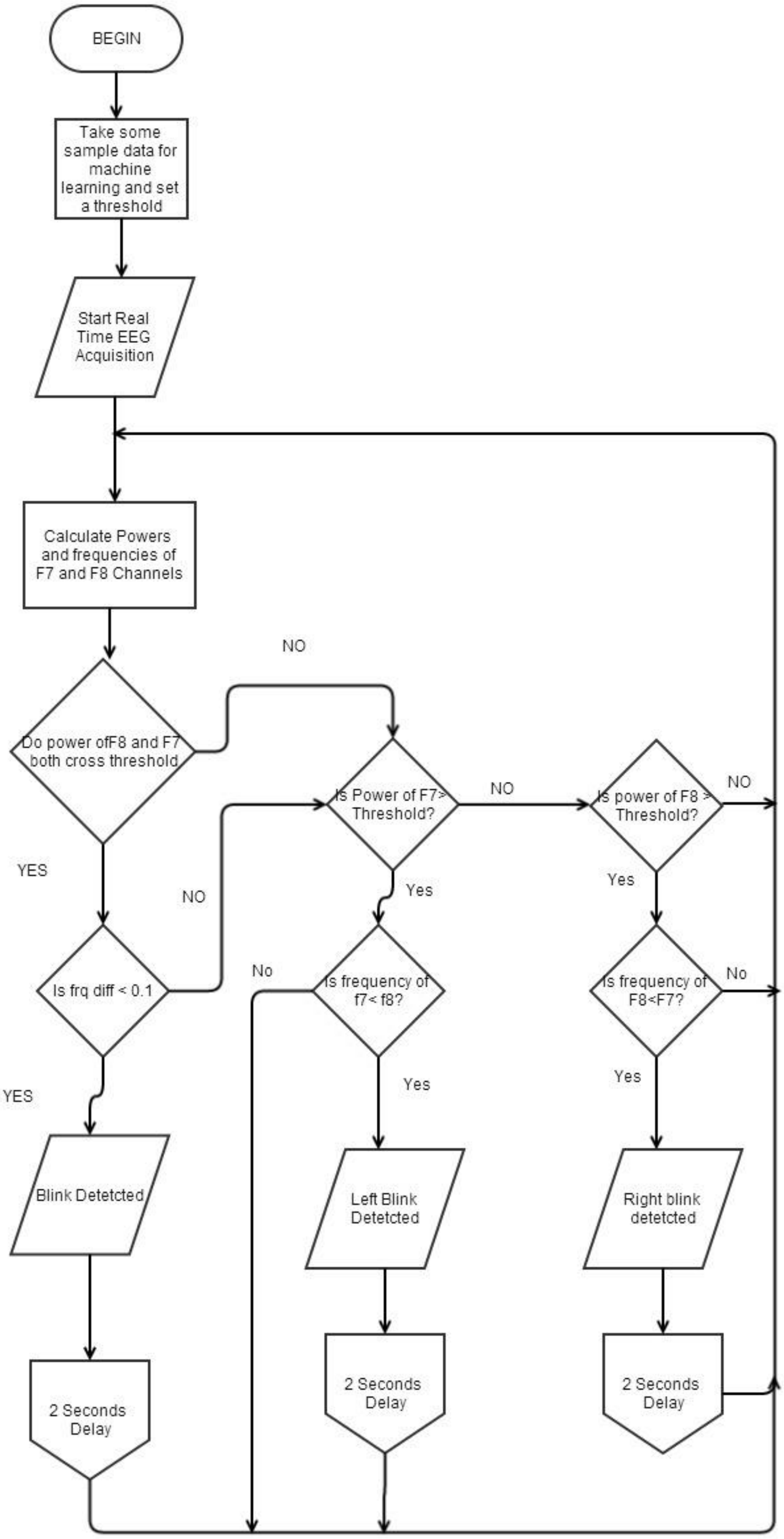
260		258	112.3357	99.25006	3.797622	3.272787
261		259	49.63279	40.62878	7.266219	5.149094
262	right	260	64.38682	66.13643	5.457692	3.693318
263		261	160.865	82852.25	4.298648	1.904534
264		262	478.3784	67357.95	3.60541	1.891065
265		263	186.6357	3860.426	2.836748	1.968529
266		264	71.20075	1154.35	3.514302	2.016824
267		265	83.6626	513.29	3.968565	2.058549
268		266	132.8297	62.40249	2.984192	4.142659

102	right	100	38.57164	14.59494	7.762699	11.21363
103		101	405.8207	64835.43	3.180414	1.943441
104		102	98.38186	49334.64	4.817457	1.856687
105		103	41.93715	10180.57	7.946967	1.876752
106		104	20.92279	1136.484	8.063401	2.011816
107		105	47.39678	860.9716	4.588555	1.924897
108		106	43.51167	274.3433	5.423798	2.30129

121		119	31.07203	36.17535	6.881815	5.862661
122	right	120	41.64244	47.42309	6.734588	4.333005
123		121	148.64	25245.15	4.301369	2.02376
124		122	79.87109	23178.07	5.917706	1.891207
125		123	35.37576	2268.478	7.156624	1.950409
126		124	37.15584	877.4464	8.136926	1.944711
127		125	42.049	282.8745	4.513433	2.158062
128		126	1747.91	1455.221	3.036908	2.99112
129		127	50.25944	26.95676	6.284302	4.461552

[Fig.55.Analysis using spreadsheets]

4.1 Flowchart for Wink Detection



Flowchart Description:

As shown in the flowchart above, the system consists of some decision making structures running in an infinite loop. This is because our system is a real time system and has to continuously acquire the data from the user until the power button is pressed off. The conditions we have incorporated for the flowchart design are

	Left Wink	Right Wink	Both Eyes Closed
Power Conditions	Power(F7)>Threshold	Power(F8)>Threshold	Power(F7,F8)>Threshold
Frequency Conditions	F7<F8 In the range of 1.8-2.3 Hz	F7>F8 In the range of 1.8-2.3 Hz	Freq. Diff should be less than 0.1

[Table.9.Wink Detection Conditions]

Based on these requirements, the flowchart was developed which is self-explanatory.

4.2 Programming:

A program was to be written for extracting the signal parameters, viz. power spectral density and frequency from the signal itself. This was done in MATLAB using the MATLAB files available and some coding from our side. The program logic used is as follows:

Program Algorithm:

> The program algorithm is based on the theory of mean power and mean power frequency. Detailed theory is given in appendix.

4.3 Designing a test apparatus:

Instead of realizing the entire system, we intend to make a small test system as we faced a shortage of resources as none of us possessed the EEG acquisition system and also, we did not have computing systems powerful enough to compute the entire data set in real time without many minutes of time lag. So we intend to make a small system comprising of two LEDs namely the right one and the left one which would be connected with the MATLAB code and would glow as per the behavior of the subject keeping in terms with the MATLAB program.

4.4 Future Work:

The technique we have developed so far, is quite good taking count of complexity of algorithm and number of electrodes it uses, we are going to develop a prototype showing the feasibility of the developed algorithm , we aim to build a fully robotic chair based on EEG signals. We hope to develop this smart chair accommodating the paralyzed or handicapped people and helping them to move freely. The technique we have developed requires some more time to take decision about driving direction, In future, we aim to build more time efficient, speedy and more accurate technique using more complex signal processing methods and by using DSP processors. We aim to optimize current techniques and to make many new equipment to help the differently abled people.

Conclusion

- Thought is a process which is distributed across the brain and is not localized to a particular region of it. Thus using the EEG acquisition techniques, it is extremely difficult to build a system.
- Eye winking provides an incredible trend for various subjects and thus delivers a framework which can be used further for system design.
- Any system based on biological signals requires an initial phase of MACHINE LEARNING as the thresholds and levels vary from person to person.

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Appendix

Theory:

1. Mean power:

1 Analog signals:

For analog signals we define power as energy per time interval.

$$\boldsymbol{Pa = \frac{1}{T0}\int_{-T0/2}^{T0/2} |(x(t)|^2 \ dt}$$

2. Discrete signals:

For time discrete signals we define power as energy per sample.

$$\boldsymbol{Pd = \frac{1}{N}\sum_{n=N1}^{N1+N-1} (|x(n)|)^2}$$

To get the mean power for 1 second of data epoch of recorded EEG signals, we just made a function in MATLAB, which by definition squares the amplitude of the samples in that time interval and takes the mean of that.

2. Power Spectral Density - the basics

Power Spectral Density (PSD) is the frequency response of a random or periodic signal. It tells us where the average power is distributed as a function of frequency.

- The PSD is deterministic, and for certain types of random signals is independent of time[1]. This is useful because the Fourier transform of a random time signal is itself random, and therefore of little use calculating transfer relationships (i.e., finding the output of a filter when the input is random).

- The PSD of a random time signal x(t) can be expressed in one of two ways that are equivalent to each other.

    1. The PSD is the average of the Fourier transform magnitude squared, over a large time interval

$$S_x(f) = \lim_{T\to\infty} E\left\{ \frac{1}{2T} \left| \int_{-T}^{T} x(t) e^{-j2\pi ft} dt \right|^2 \right\}$$

2. The PSD is the Fourier transform of the auto-correlation function.

$$S_x(f) = \int_{-T}^{T} R_x(\tau) e^{-j2\pi ft} dt$$

$$R_x(\tau) = E\{x(t)x^*(t+\tau)\}$$

- The power can be calculated from a random signal over a given band of frequencies as follows:

1. Total Power in x(t): $P = \int_{-\infty}^{\infty} S_x(f) df = R_x(\mathbf{0})$

2. Power in x(t) in range f_1 - f_2: $P_{\mathbf{12}} = \int_{f_1}^{f_2} S_x(f) df = R_x(\mathbf{0})$

[Source: faculty.etsu.edu/Blanton/lab_3_psd.doc]

3. Spectral Estimation Method

The various methods of spectrum estimation available, categorized as follows:

- Nonparametric methods
- Parametric methods
- Subspace methods

Nonparametric methods are those in which the PSD is estimated directly from the signal itself. The simplest such method is the *periodogram*. Other nonparametric techniques such as *Welch's method*, the *multitaper method* (*MTM*) reduce the variance of the periodogram.

Parametric methods are those in which the PSD is estimated from a signal that is assumed to be output of a linear system driven by white noise. Examples are the *Yule-Walker autoregressive* (*AR*) *method* and the *Burg method*. These methods estimate the PSD by first estimating the parameters (coefficients) of the linear system that hypothetically generates the signal. They tend to produce better results than classical nonparametric methods when the data length of the available signal is relatively short. Parametric methods also produce smoother estimates of the PSD than nonparametric methods, but are subject to error from model misspecification.

Subspace methods, also known as *high-resolution methods* or *super-resolution methods*, generate frequency component estimates for a signal based on an Eigen analysis or Eigen decomposition of the autocorrelation matrix. Examples are the *multiple signal classification* (*MUSIC*) *method* or the *eigenvector* (*EV*) *method*. These methods are best suited for line spectra — that is, spectra of sinusoidal signals — and are effective in the detection of sinusoids buried in noise, especially when the signal to noise ratios are low. The subspace methods do not yield true PSD estimates: they do not preserve process power between the time and frequency domains, and the autocorrelation sequence cannot be recovered by taking the inverse Fourier transform of the frequency estimate.

Periodogram

In general terms, one way of estimating the PSD of a process is to simply find the discrete-time Fourier transform of the samples of the process (usually done on a grid with an FFT) and appropriately scale the magnitude squared of the result. This estimate is called the *periodogram*. The Periodogram estimate of the PSD of a length-L signal $x_L[n]$ is

$$\boldsymbol{Pxx(f) = \frac{1}{LFs} |\sum_{n=0}^{L-1} x(n) * e^{-\frac{j2\pi fn}{Fs}} |^2}$$

Where F_s is the sampling frequency.

In practice, the actual computation of $P_{xx}(f)$ can be performed only at a finite number of frequency points, and usually employs an FFT. Most implementations of the Periodogram method compute the *N*-point PSD estimate at the frequencies

$$f_k = \frac{kF_s}{N} \quad k = 0,1,\ldots,N-1$$

In some cases, the computation of the Periodogram via an FFT algorithm is more efficient if the number of frequencies is a power of two. Therefore it is not uncommon to pad the input signal with zeroes to extend its length to a power of two.

The Modified Periodogram

The *modified periodogram* windows the time-domain signals prior to computing the DFT in order to smooth the edges of the signal. This has the effect of reducing the height of the side lobes or spectral leakage. This phenomenon gives rise to the interpretation of side lobes as spurious frequencies introduced into the signal by the abrupt truncation that occurs when a rectangular window is used. For nonrectangular windows, the end points of the truncated signal are attenuated smoothly, and hence the spurious frequencies introduced are much less severe. On the other hand, nonrectangular windows also broaden the main lobe, which results in a reduction of resolution.

Welch's Method

An improved estimator of the PSD is the one proposed by Welch. The method consists of dividing the time series data into (possibly overlapping) segments, computing a modified periodogram of each segment, and then averaging the PSD estimates. The result is Welch's PSD estimate. Welch's method can be in MATLAB by pwelch function.

The averaging of modified periodogram tends to decrease the variance of the estimate relative to a single periodogram estimate of the entire data record. Although overlap between segments introduces redundant information, this effect is diminished by the use of a nonrectangular window, which reduces the importance or *weight* given to the end samples of segments (the samples that overlap).

However, as mentioned above, the combined use of short data records and nonrectangular windows results in reduced resolution of the estimator. In summary, there is a trade-off between variance reduction and resolution. One can manipulate the parameters in Welch's method to obtain improved estimates relative to the periodogram, especially when the SNR is low.

Mean Power Frequency (MPF):

MPF is a weighted average frequency in which each frequency component, f, is weighted by its power, P. Thus Equation

MPF = (f1*P1+f2*P2+ ... + fn*Pn) / (P1 + P2 + ... + Pn)

i.e. the MPF is obtained by summing the (frequency times power) of the components and dividing by the sum of the powers.

To get the MPF for 1 second of data epoch of recorded EEG, we first found the power spectral density and corresponding frequency using Welch's method in MATLAB and then used the equation mentioned above.

For reference used formula is as under,

[pxx,f] = pwelch(x,window,noverlap,nfft,fs)

Which returns the two-sided Welch PSD. The frequencies in f are in cycles per unit time. The sampling frequency, fs, is the number of samples per unit time. Window is either integer or vector used to divide signal in sections, by default MATLAB uses hamming window. No overlap suggests samples that must overlap from section to section.nfft is no of fft points used to calculate PSD.

[Source: http://www.mathworks.in/help/signal/ug/spectral-analysis.html]