Birla Vishwakarma Mahavidyalaya

*(An Autonomous Institution)*

Vallabha Vidhyanagar


A Project Report

# "Automation System using BCI"

Project-1 (EC-441)


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BIRLA VISHVAKARMA MAHAVIDYALAYA
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***(An Autonomous Institution)***

## Electronics and Communication Department

# *Certificate*

This is to certify that the project entitled, “Automation using BCI" submitted by A**nkit Jha (15ET006)** in partial fulfilment of the requirements for the B. Tech Degree in "**Electronics and Communication**" at the "**Birla Vishwakarma Mahavidyalaya**" has done an authentic work, carried out by them under my supervision and guidance.

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# Acknowledgement

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# Content

# Abstract

A system which switches the home appliances with the intensity control using EEG signals. EEG(Electroencephalography) or Brain Waves are the most complex and feeble signals which can be extracted and worked to attain different objectives. A Brain Computer Interface(BCI) acts as an interconnection between the signal generated from human gazes, and other senses which leads to a thought process for any action through transmitting that signal to the computer for further processing to attain a desirable output. Home automation using BCI is an advanced version of Automation where the devices would be considered as a type virtual human organ which reacts whenever body wants a change and can be switched whenever the human brain generates a control signal, due to the nearby conditions. The feeble signals received by the Non-Invasive BCI unit is amplified and classified using CNN algorithms and processed to get the desired signal to make the swap or change the current mode as per the intensity of the extracted wave. The development in home automation is moving forward towards the future in creating the ideal smart homes environment. Optionally, home automation system design also been developed for certain situation which for those who need a special attention such as old age person, sick patients, and handicapped person. A brain–computer interface (BCI), often called a mind-machine interface (MMI), or sometimes called a brain–machine interface (BMI), it is a direct communication pathway between the brain and an external device. A brain–computer interface (BCI) is a device that enables severely disabled people to communicate and interact with their environments using their brain waves. Most research investigating BCI in humans has used scalp-recorded electroencephalography or intracranial electrocorticography. The use of brain signals obtained directly from stereotactic depth electrodes to control a BCI has not previously been explored. In this paper, we present a smart home automation system using brain–computer interface.

# Problem Statement

The main objective in system is to Detection of electric signal near eye area and using electrodes system will try to identify the changes in electric pulse in order to conclude the motion to be taken. As a proof of concept system will be enabled to control different platform and devices like computer or the hardware system as per mentioned below.

**Appliances control**: This module will deal with the controlling of hardware appliances using the electronic relay based switching circuit. Actual home appliances are connected to this circuit and the circuit will be then connected to the computer. It works as a middle ware between actual appliances and the computer.

**Computer cursor and application control**: Likewise, user can control the computer cursor and the applications using electric signals. This will enable disabled patients to have good access over computer system. To implement this there will be a microcontroller to USB interfacing circuitry which will convert microcontroller signals in to computer understandable signals which will then get processed by software program.

**Sensor based security alerts**: As a part of the security module proposed system will having the motion detection, gas sensor, heat sensor which will alert user in critical condition. If configured then it can send a SMS based alert to assistant user.

**Web based**: As all these modules work together and to make these modules accessible through the web interface, the proposed system will have a web service which can be accessed through any web client or the web browser.

# Introduction

Brain Computer Interface(BCI) sometimes called Direct Neural Interface converts neural electric signals to digital signals which help us to analyze the signal pattern and those patterns are classified for a certain processing done by human brain. The method of recording brain signals is called Electroencephalography(EEG). EEG is an electrophysiological monitoring method through Non-Invasive sensors placed over the scalp of the human head, which records the brain signals which is very weak as the electric pulse generated by brain are very feeble, these weak signals are converted to more discernable signal. After the conversion these signals are amplified to make it readable for the available devices, the amplified signal is modulated and transmitted to the local computer, where the signal is further demodulated. The demodulated signal is further quantized and a further digital signal is attained for further, signal processing. After the signal is consolidated and classified these digital neural waves are further used for a variety of purpose. These purposes serve in better understanding of human brain behaviour or better say Human behaviour on many different situations. The received EEG signals are used in many medical remedies like, communication system for severe disabilities like paralysis, locked in syndrome, prosthetic control, neurorehabilitation after neurological injuries etc. Other applications include gaming, entertainment, lie detection, brain fingerprinting, mood monitoring etc.

These applications lead to many other areas contributing to the development in the technologies, the era of automation is turning to its next era with IOT (Internet of Things), future robotics etc. In this era Automation using Brain waves will be another big advancement in the filled of automation. In this era, Automation using Brain waves will be another big advancement in the filled of automation. Automation using these derived waves will help the paralyzed personnel or the people who are suffering from any neural disorder or are unable to mobilize. Those people can directly take care of themselves using these BCI automation system. The whole system would run directly from brain without any other movable settings therefore it can be used in the cases where the person is unable to move or communicate either

The project discussed about is a BCI (Brain Computer Interface) which would be used to automate appliances remotely to automate home based appliances. The ultimate purpose of a direct brain computer interface (BCI) is to allow an individual with severe motor disabilities to have effective control over devices. Bio potentials generated from brain is known as EEG signal. Electroencephalogram or EEG signals are related to the electrical activity of our brain and it tracks the brain wave pattern. Our brains generate 16 different amounts of voltage signals at different states of our mind. There are different mind states like Concentration, Meditation, Attention and etc. Our project is mainly focused on measuring the Concentration, Meditation and Attention level using Emotive Insight 5. We are able to manipulate those signals levels of concentration, meditation and attention to control electronic devices.

Different brain states are the result of different patterns of neural interaction. These patterns lead to waves characterized by different amplitudes and frequencies. This neural interaction is done with multiple neurons. Every interaction between neurons creates a minuscule electrical discharge. This project dealing with the signals from brain. Different brain states are the result of different patterns of neural interaction. These patterns lead to waves characterized by different amplitudes and frequencies. The signal generated by brain was received by the brain sensor and it will divide into packets and the packet data transmitted to wireless medium (blue tooth). the wave measuring unit will receive the brain wave raw data and it will convert into signal using MATLAB GUI platform. Then the instructions will be sending to the home section to operate the modules (bulb, fan). The project operated with human brain assumption and the on off condition of home appliance is based on changing the muscle movement with blinking.

# Brain Waves

Brainwave is a kind of traceable neurophysiological energy in a living brain. Invisible to human eyes, it is only detectable using electroencephalography (EEG), electrocorticography (ECoG) and magnetoencephalography (MEG). The waves or oscillations or rhythms are produced mainly by the oscillatory networks of the brain. Three main oscillatory networks are thalamocortical, extrathalamic-cortical and cortical-cortical networks. Greater limbic system (reticular system, hypothalamus, thalamus, basal forebrain nuclei, limbic system) has a great influence on these oscillatory networks. This system which is in microgravity position lies deep inside and surrounded by the ventricles of the brain. It receives all information from inside and outside of our body and then projects to all areas of the brain (from all to one and from one to all—nearly similar concept to "from God back to God"). Therefore, the greater limbic system could be regarded as "a core of the neuroaxis" which lies in microgravity compartment and in microgravity position ("T"-shape or curving shape; whilst gravity position is "I"-shape or vertical shape). By knowing the origin of the brainwaves and methods to detect them, one may study seizure networks, normal and abnormal brain networks and arguably, even to explore the relationship between the "invisibles": "invisible" brainwaves and "invisible" soul. Oscillation with synchronisation does exist inside and outside of our brain. Neural oscillation can be stratified into microscale-oscillation (activity of a single neuron), mesoscale-oscillation (activity of local group of neurons or vertices) and macroscale-oscillation (neural activity of different brain regions/networks) [1]. Neurons can generate action potentials or spike trains (multiple action potentials in sequence) at microscale oscillation and can be studied using intracellular single-unit recordings. When a group of neurons fire action potentials, synaptic interactions play a major role to synchronise the input to other brain regions. Synchronised firing patterns give rise to large-amplitude mesoscale oscillations of local field potentials which can be detected as brainwaves by using electroencephalography (EEG), electrocorticography (ECoG) or magnetoencephalography (MEG). Neural oscillations which arise from interactions between or among brain regions are known as macroscale-oscillation and form various brainwaves network loops or circuits inside our brain [2]-[5]. This article describes the principles for the brainwaves, their anatomical origin and relationship with microgravity, and our experience in using them to study brain and seizure networks, mapping the region of the brain and lately to explore the relationship between body, mind and soul.

### 4.1 <u>Principles of Brain Waves</u>:

Brainwaves can be detected using EEG, ECoG and MEG. There are five major brainwaves distinguished by their different frequency ranges from high to low frequency. Slow waves are waves frequencies of less than 8 Hz, including theta and delta waves whilst fast waves are waves of more than 13 Hz. Hertz is a unit of frequency which equals cycle per second (Hz: cycle/sec). Amplitude of brainwaves is normally measured using microvolt unit (µV). Low amplitude falls within less than 20 µV, medium amplitude between 20 - 50 µV and high amplitude, more than 50 µV. Pertaining the types of brainwaves, alpha waves (8 - 13 Hz; 20 - 60 µV) mainly appear in the posterior half of the head and are usually found over the parieto-occipital region of the brain. It may appear as round, sinusoidal or sometimes as sharp waves and regarded as the most prominent rhythm in brain activity. It normally indicates a relaxed awareness without any attention or concentration. Concerning beta wave (13 - 30 Hz; 2 - 20 µV), it is the usual waking rhythm of the brain associated with active thinking or active attention (fast wave). In adults, it is normally found at frontal and central region. The slow wave theta (4 - 8 Hz; 20 - 100 µV) is thought to originate from the thalamus. It appears as consciousness slips towards drowsiness. Theta waves therefore have been associated with sleep, deep meditation, creative inspiration and unconsciousness. Another slow wave is delta wave (0.5 - 4 Hz; 20 - 200 µV). It is associated with deep sleep and unconsciousness. Both slow waves can play normal role in newborn, infancy and childhood. Lastly, the gamma wave (above 30 Hz; approximately 5 - 10 µV) which were reported by Galambos et al. in 1981 occurs at certain occasion when sensory stimuli such as auditory clicks or flashes of light were given. Recently, it was reported as a good indicator of event-related synchronization of the brain and therefore can be used to demonstrate the locus for the activity. Other types of brainwaves are: a) Kappa waves—found at 10 Hz and associated with thinking; b) Lambda waves—occurring at occipital region which associated with visual exploration; c) Mu waves—recorded at Rolandic fissure (vertex of scalp) in alpha frequency (8 - 13 Hz) but it is independent of alpha, blocking not with eye opening but with movement or intended movement; d) Rho waves—are positive transient sharp waves at occipital region; and e) Spindle (sigma) waves—waxing and waning spindle waves at 7 - 14 Hz, that indicates EEG synchronization recorded during quiescent sleep.

## 4.2 Origin:

The origins of brainwaves or EEG/MEG/ECoG detected brainwaves are mainly from pyramidal postsynaptic potentials which are in oscillations with:

a) The thalamus, therefore known as thalamocortical networks (modulated by the reticulo-thalamo-cortical circuits. It is part of greater limbic system: dorsal pathway).
b) The extra thalamic-cortical circuits (mainly involve the reticular system, hypothalamus, hippocampus, amygdala, basal forebrain nuclei—they are part of the greater limbic system too: ventral pathway).
c) Other cortex, known as cortical-cortical networks . Moruzzi and Magoun in 1949 had shown the involvement of the reticular system inside the brainstem for its crucial role in generating pattern of brainwaves.

This anatomical region (classical reticular system inside the brainstem) has vast networks with other structures in the diencephalon (thalamus, hypothalamus, basal forebrain nuclei, Para hypothalamic nuclei, pineal and pituitary glands, limbic system) and even with the telencephalon (insula, basal ganglia and neocortex). It is also the centre regarded by most to be responsible for consciousness, sleep and dreams and in integrating behavior, endocrine, autonomic and somatomotor systems . Since it has vast connections with hypothalamus, thalamus, parahypothalamic nuclei, basal ganglia, spinal cord, cerebellum, limbic structures, neocortex (all areas), Nieuwenhuys and colleagues have expanded the definition of classical limbic system caudally and named “greater limbic system” which includes also this classical reticular system which lies inside the brainstem. The greater limbic system forms cores and paracores for the neuroaxis which is in microgravity (curving/flexure/bowing/sujood/antigravity/astronaut like) position and generally can be divided into two:

a) Reticular activating system (RAS)
b) Reticular inhibitory system (RIS).

They are extraordinarily rich in neuromediators, such as: a) locus coeruleus (noradrenergic); b) raphe nuclei (serotoninergic/5-HT); c) reticular junction (cholinergic), tuberomammilary nucleus (histaminergic) and d) gamma-aminobutyric acid for reticular inhibitory system (GABA).

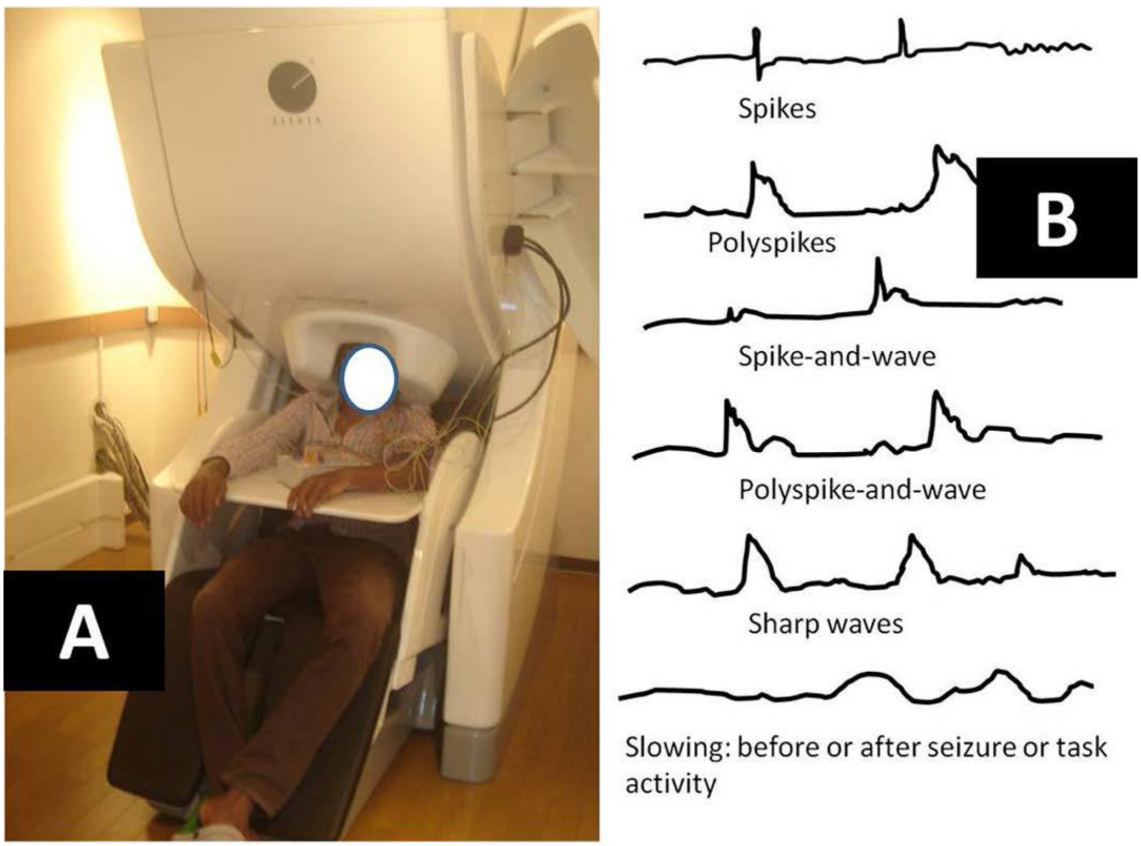


**Figure 1.** (a) The magnetoencephalography examination. (b) Brainwaves pattern in detecting seizure

The dendrites of the cells in this area are arranged in mosaic. In summary, this greater limbic system forms a centre or core for the neuroaxis (? seat of the soul). All information from inside (self) and outside of our body (i.e. universes) goes to this region and from here it projects out to all areas of the brain (all to one and one to all concept). One of the proofs for this area getting involved in generating brain rhythms is the effectiveness of left vagal nerve stimulation in treating refractory epilepsy. The afferent fibres of the vagal nerve have broad projections to the reticulo-hypothalamic-centromedian thalamic-limbic systems or better known as “greater limbic system” via the nucleus of the solitary tract and locus coeruleus. Greater Limbic System and Microgravity When further anatomical observation is made at this region, its shape is in “T” shape. The diencephalon and telencephalon are in horizontal position whilst the brainstem is in vertical position. This feature is mainly because of the presence of main cephalic fissure during central nervous system (CNS) development. This curving or flexure position looks like similar to the astronaut-position while in the outer space or in microgravity chamber. The microgravity position (T-shape) of this region is believed to result from the presence of buoyancy inside the CNS. The buoyancy or weightlessness is provided by the CSF and maintained by the anchoring effects of the spinal cord and brainstem nerve roots, ligaments, and by the vascular pulsation provided via Wind- Z. Idris et al. 439 kessel effect. This position is similar to the fetus at early gestation while in the uterus (during CNS development) and also similar to all the animals (from invertebrates to vertebrates animals) either from ocean (the largest buoyancy environment on earth) or on land (they are in flexure position or microgravity or horizontal position; but humans are in vertical or “I” gravity position). Considering this Archimedes concept, the inclusion of reticular system into the greater limbic system as advocated by Nieuwenhuys et al. seems valid mainly because, when microgravity (weightlessness) is eliminated, the anatomy of this region is actually form one single vertical connecting core or in gravity position which could be the center or the seat of the soul.

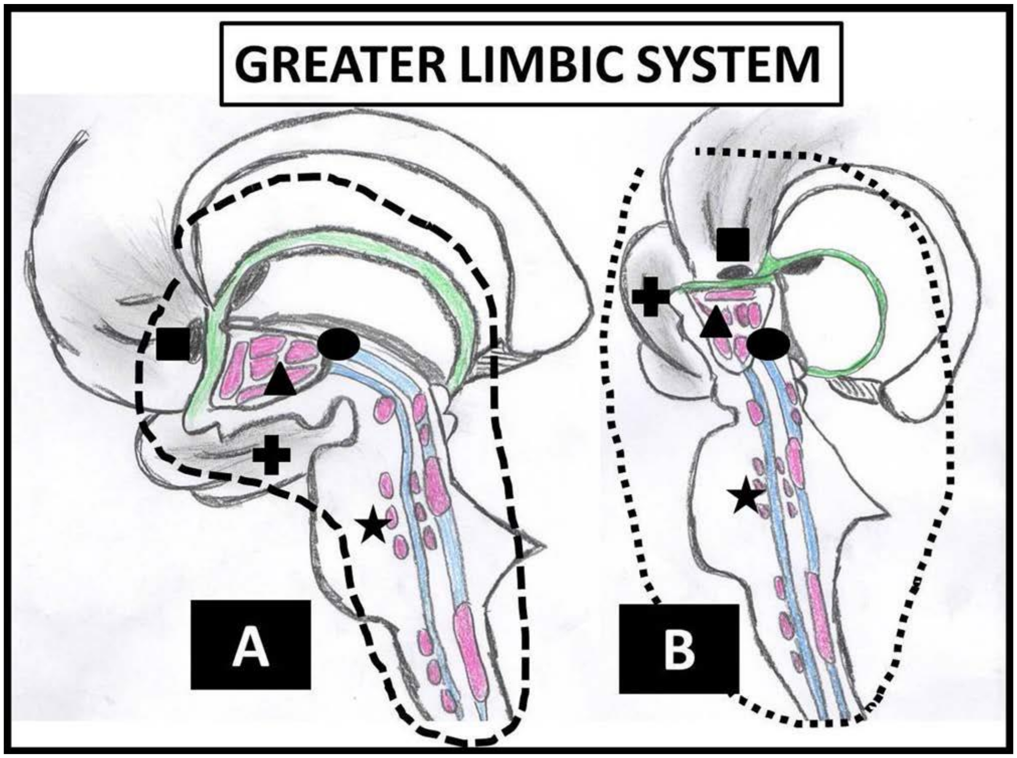


**Figure 2.** The effect of the microgravity onto the reticular system and brainstem-diencephalic region. (a) Microgravity position and (b) The gravity position. The limbic-hypothalamic-Para hypothalamic system extends caudally to the brainstem reticular system when viewed especially in gravity position (which corresponds to Nieuwenhuys and colleagues' idea of greater limbic system). Annotations: squared black—basal forebrain nuclei area; triangle—the hypothalamus; round—the thalamus; star—the mesopontine nuclei/ reticular system (locus coeruleus, pedunculopontine nucleus, raphe nucleus); and crossed—the amygdala and hippocampus located lateral to the midbrain area.

### 4.3 Application:

In our Centre, brainwaves were recorded for routine and research purposes. Currently at our Centre, brainwaves were recorded using scalp EEG, MEG, ECoG and EEG-fMRI. This is mainly done for epilepsy, brain mapping, and study on brain networks and soul searching. Examples are given below.

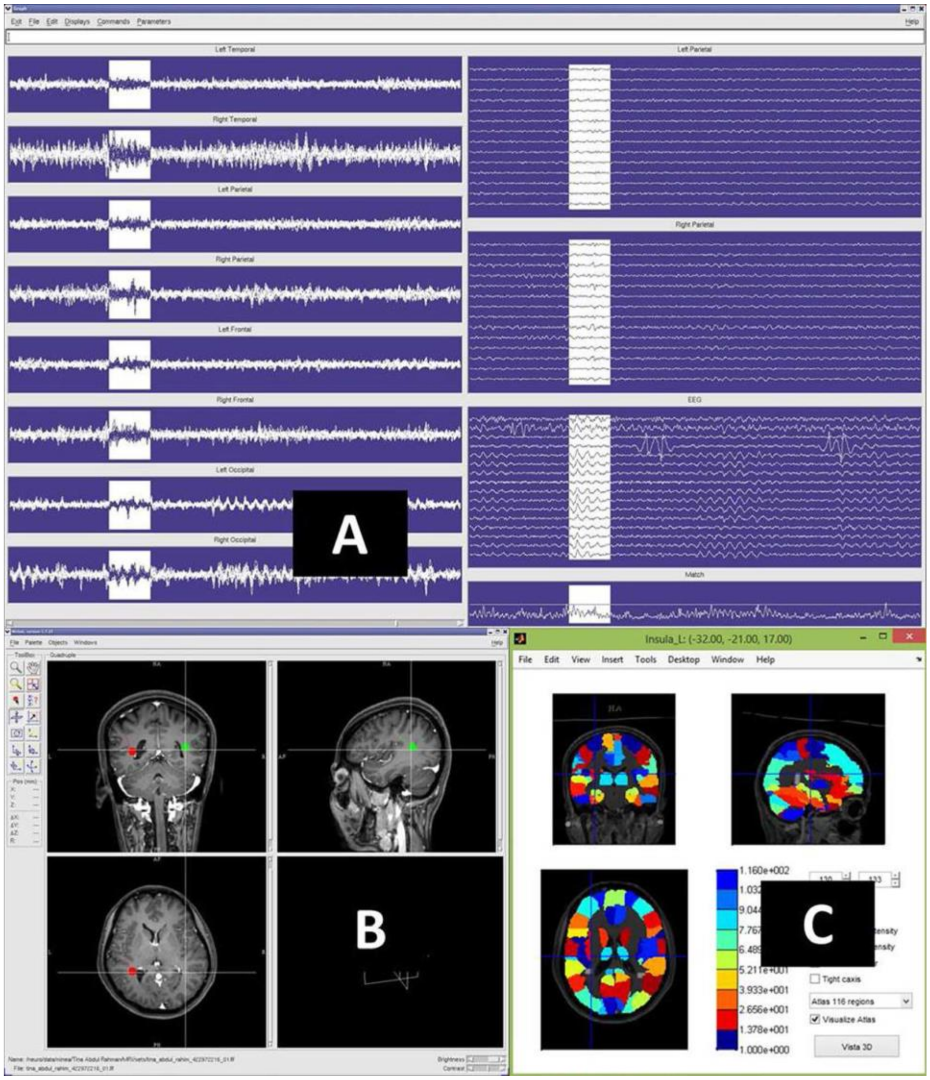


**Figure 3.** (a) Brainwaves for patient suffering from insular epilepsy. (b) The magnetic source imaging localizes the abnormal waves using equivalent current dipole technique (red and green dipoles). (c) The brain atlas fused to the brainwaves data to know exactly the location for abnormal waves (left insular).

### 4.3.1 Epilepsy (Seizure Disorders) and Brain Mapping

Epilepsy is a seizure disorder that occurs when there is a sudden, brief change in how the brain works and commonly manifested in form of alteration in consciousness, abnormal movements or sensations. Brainwaves features can be slowing waves, spikes, spike-and-wave, polyspikes, polyspike-and-wave and sharp waves. Figure shows MEG recordings from a patient suffered from insular epilepsy. She had poor memory, frequent sudden attacks of unable to breath and imbalance. The abnormal brainwaves noted were slowing and sharp waves. The MEG source localization using ECD technique localizes the abnormal waves at periatrial area on both sides which correspond to the lesions inside the ventricles. Mapping this area with the atlas revealed the dipoles for abnormal waves are adjacent to the insular and limbic system. Another refractory epilepsy patient, the epileptic foci were detected using ECoG. The patient suffered from focal seizure which involved his right upper limb. The MSI localized the epileptic spikes at the left sensorimotor cortex which tallied with the intraoperative EEG (iEEE or ECoG) findings. The nearby lesion was removed and eloquent areas with spikes were treated with multiple subpial transections.

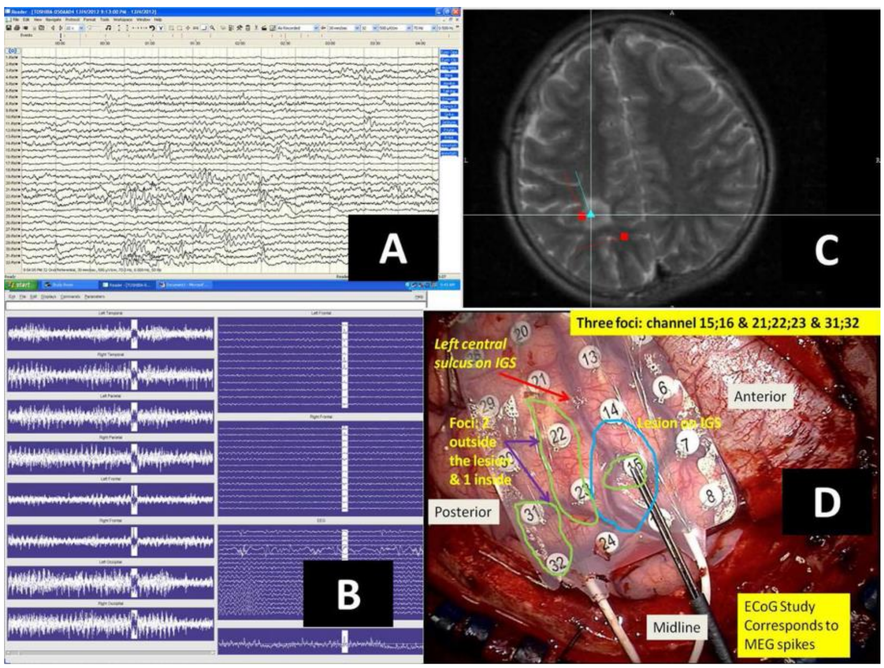


**Figure 4.** Brainwaves with the seizure spikes detected using ECoG (a) and MEG (b). (c) Source localization identifies the seizure foci near the area of brain lesion at left motor cortex (red squares and blue triangle). (d) Intraoperative EEG localization (iEEE or ECoG) of seizure foci (base on electrode numbers— in A image) correspond with the MEG findings (drawn in green).

### 4.3.2 Brain Networks (Networks for the Pain)

An army trainee suffers from complex regional pain syndrome (CRPS) after being hit at the left shoulder. His symptoms persist despite various therapies given. His spontaneous resting state MEG with eyes open disclosed abnormal brainwaves or. Neuromag collection of events software was utilised to analyse the spontaneous brainwave data (brainwave threshold-amplitude was set at above 10% from normal brainwave activity for brain networks analysis involving high amplitude and abnormal brainwaves morphology. Figure shows the brainwaves collections of events which were localized to the MRI (known as magnetic source imaging or MSI). Multiple activated dipole areas were noted:

a) Sensorimotor cortices
b) Insula cortices (operculum)
c) Cingulate
d) Amygdalo-piriform-hippocampal area

These areas corresponded to the pain networks or areas identified in various studies.

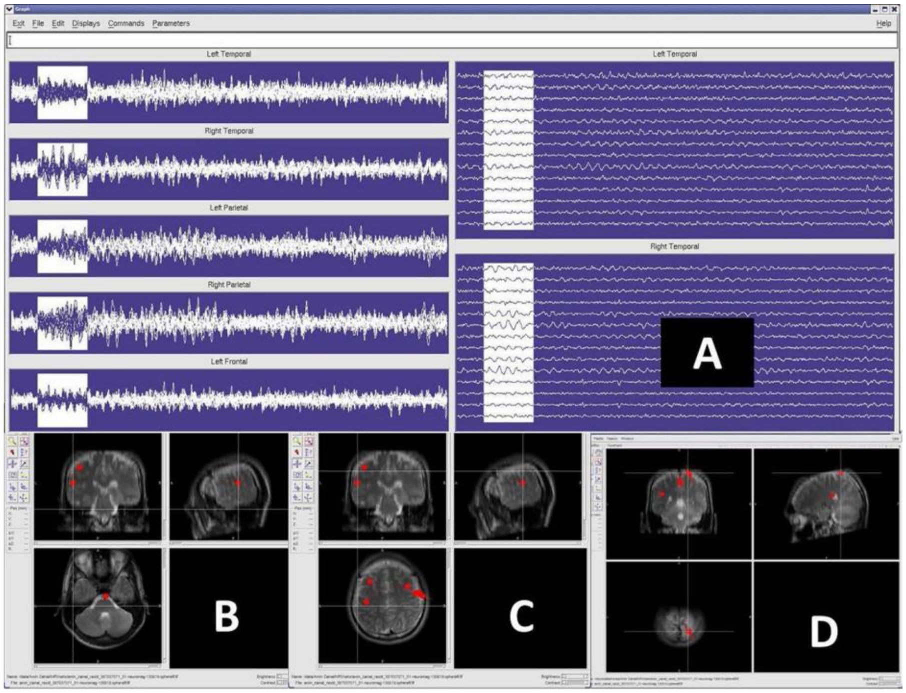


**Figure 5.** (a) The abnormal brainwaves for a patient suffering from complex regional pain syndrome. (b), (c) and (d) Collection of events analysis disclosed sensorimotor, insular, cingulate and amygdala-piriform-hippocampal areas are the networks for the neuropathic pain.

### 4.3.3 Brainwaves and the Soul (Spirit)

Soul or spirit cannot be seen by our eyes. Various texts and manuscripts had described the concept of "behind a living body there is likely a soul". This soul is commonly related to: a) breathing; b) heart; c) lungs; d) brain; e) immortal; f) from God; g) at the anterior portion of the ventricle as described by Leonardo da Vinci; h) related to CSF containing ventricles; i) knowing the soul, knowing the God better; j) non-substance soul; k) material for the body and immaterial for the soul and last; l) soul is related to an infinite spirit . Following deaths, the physical bodies can no longer function. Those that cannot be noted anymore after death (most are oscillatory items) we can regard as “soul indirect manifestations”. Those (soul manifestations) are heart rate, blood pressure, peristalsis, vascular pulsation, breathing movements and “brainwaves”. Manifestation of soul in the various forms can easily be understood as an analogy to the light (as soul) and the rainbow (as items in oscillations). Rainbow is the one that can be noted by us, but not the bright light. During ECoG mapping of the brain under awake state for the seizure spikes at right sensorimotor cortex and at the same time patient was given the option to listen to religious text of the patient’s faith, the seizure spikes and the brainwaves were noted to have changed in their morphology . The finding is interesting because it may suggest that the greater limbic system (origin of the brainwaves) is also the spiritual area of the brain (? seat of the soul—where all signals arising from human activities are concentrated/modulated/ processed here). Similar observation on another patient after removal of the lesion at left auditory (dominant hemispheric) area appeared to again show brainwave changes during listening to the religious text.

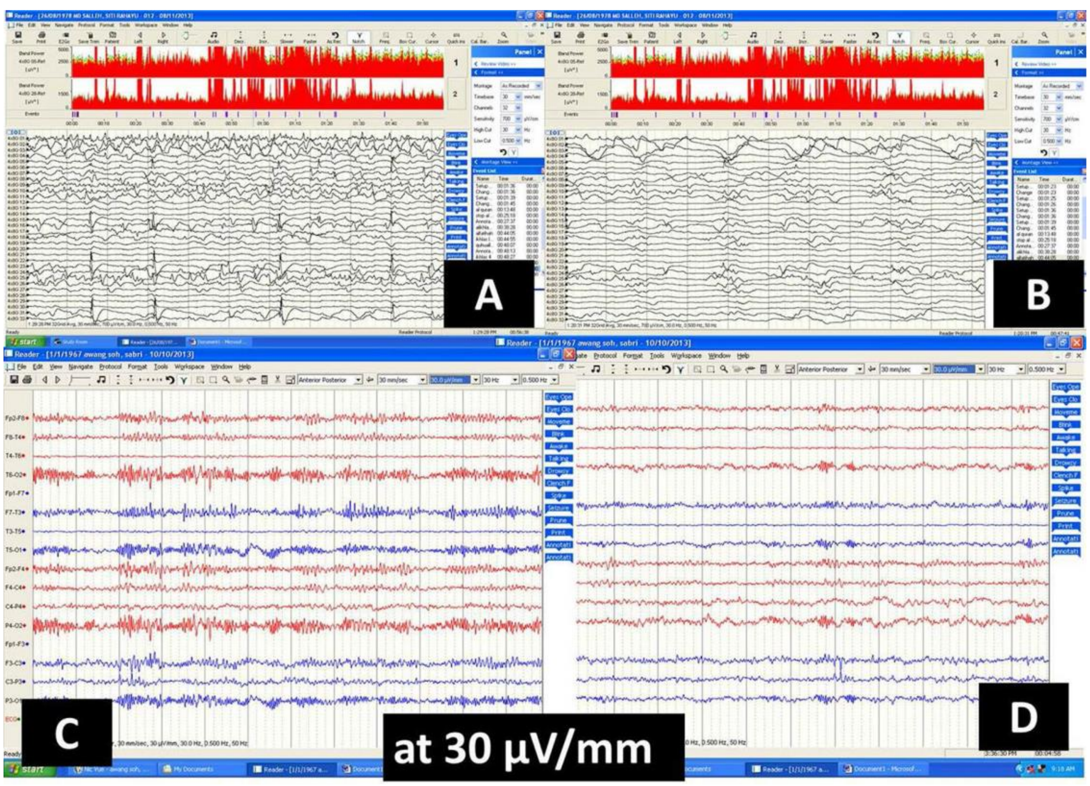


**Figure 6.** (a) Before and during (b) listening to religious text of the patient’s faith who suffers from focal epilepsy arising at sensorimotor cortex. (c) Before and during (d) listening to the religious text of the patient’s faith who suffers from convexity meningiomas at left auditory area.

# Electroencephalography (EEG)

**Electroencephalography** (**EEG**) is an electrophysiological monitoring method to record electrical activity of the brain. It is typically noninvasive, with the electrodes placed along the scalp, although invasive electrodes are sometimes used such as in electrocorticography. EEG measures voltage fluctuations resulting from ionic current within the neurons of the brain.[1] In clinical contexts, EEG refers to the recording of the brain's spontaneous electrical activity over a period of time, as recorded from multiple electrodes placed on the scalp. Diagnostic applications generally focus either on event-related potentials or on the content of EEG. The former investigates potential fluctuations time locked to an event like stimulus onset or button press. The latter analyses the type of neural oscillations(popularly called "brain waves") that can be observed in EEG signals in the frequency domain.

EEG is most often used to diagnose epilepsy, which causes abnormalities in EEG readings. It is also used to diagnose sleep disorders, depth of anesthesia, coma, encephalopathies, and brain death. EEG used to be a first-line method of diagnosis for tumors, stroke and other focal brain disorders, but this use has decreased with the advent of high-resolution anatomical imaging techniques such as magnetic resonance imaging (MRI) and computed tomography(CT). Despite limited spatial resolution, EEG continues to be a valuable tool for research and diagnosis. It is one of the few mobile techniques available and offers millisecond-range temporal resolution which is not possible with CT, PET or MRI.

Derivatives of the EEG technique include evoked potentials (EP), which involves averaging the EEG activity time-locked to the presentation of a stimulus of some sort (visual, somatosensory, or auditory). Event-related potentials (ERPs) refer to averaged EEG responses that are time-locked to more complex processing of stimuli; this technique is used in cognitive science, cognitive psychology, and psychophysiological research.

## 5.1 History

The history of EEG is detailed by Barbara E. Swartz in *Electroencephalography and Clinical Neurophysiology*. In 1875, Richard Caton (1842–1926), a physician practicing in Liverpool, presented his findings about electrical phenomena of the exposed cerebral hemispheres of rabbits and monkeys in the *British Medical Journal*. In 1890, Polish physiologist Adolf Beck published an investigation of spontaneous electrical activity of the brain of rabbits and dogs that included rhythmic oscillations altered by light. Beck started experiments on the electrical brain activity of animals. Beck placed electrodes directly on the surface of brain to test for sensory stimulation. His observation of fluctuating brain activity led to the conclusion of brain waves.

In 1912, Ukrainian physiologist Vladimir Vladimirovich Pravdich-Neminsky published the first animal EEG and the evoked potential of the mammalian (dog). In 1914, Cybulski and Jelenska-Macieszyna photographed EEG recordings of experimentally induced seizures.

German physiologist and psychiatrist Hans Berger (1873–1941) recorded the first human EEG in 1924. Expanding on work previously conducted on animals by Richard Caton and others, Berger also invented the electroencephalogram (giving the device its name), an invention described "as one of the most surprising, remarkable, and momentous developments in the history of clinical neurology".[9] His discoveries were first confirmed by British scientists Edgar Douglas Adrian and B. H. C. Matthews in 1934 and developed by them.

In 1934, Fisher and Lowenback first demonstrated epileptiform spikes. In 1935, Gibbs, Davis and Lennox described interictal spike waves and the three cycles/s pattern of clinical absence seizures, which began the field of clinical electroencephalography. Subsequently, in 1936 Gibbs and Jasper reported the interictal spike as the focal signature of epilepsy. The same year, the first EEG laboratory opened at Massachusetts General Hospital.

Franklin Offner (1911–1999), professor of biophysics at Northwestern University developed a prototype of the EEG that incorporated a piezoelectric inkwriter called a Crystograph (the whole device was typically known as the Offner Dynograph).

In 1947, The American EEG Society was founded and the first International EEG congress was held. In 1953 Aserinsky and Kleitman described REM sleep.

In the 1950s, William Grey Walter developed an adjunct to EEG called EEG topography, which allowed for the mapping of electrical activity across the surface of the brain. This enjoyed a brief period of popularity in the 1980s and seemed especially promising for psychiatry. It was never accepted by neurologists and remains primarily a research tool.

In 1988, report was given on EEG control of a physical object, a robot.

In October 2018, scientists connected the brains of three people to experiment with the process of thoughts sharing. Five groups of three people participated in the experiment using EEG. The success rate of the experiment was 81%.

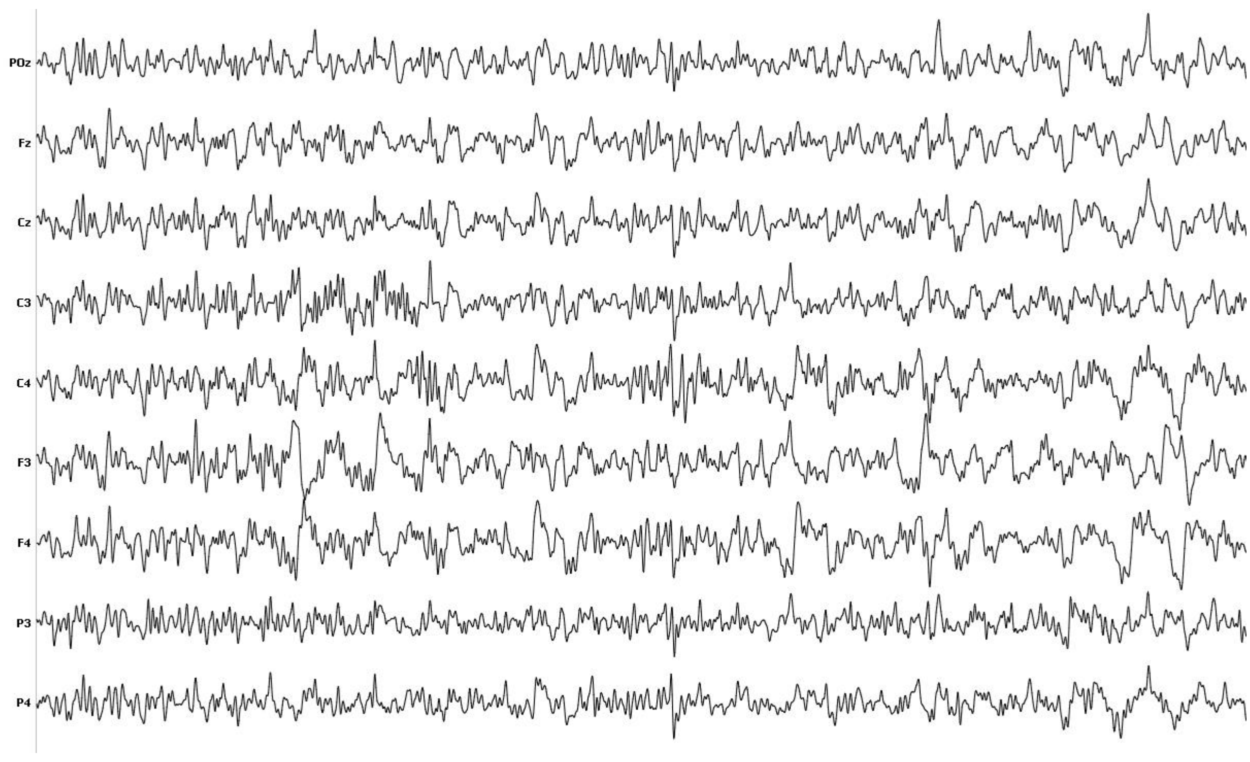


**Figure 7.** EEG waves.

## 5.2 Usage:

### 5.2.1 Medical Use:

A routine clinical EEG recording typically lasts 20–30 minutes (plus preparation time) and usually involves recording from scalp electrodes. Routine EEG is typically used in clinical circumstances to distinguish epileptic seizures from other types of spells, such as psychogenic non-epileptic seizures, syncope (fainting), sub-cortical movement disorders and migraine variants, to differentiate "organic" encephalopathy or delirium from primary psychiatric syndromes such as catatonia, to serve as an adjunct test of brain death, to prognosticate, in certain instances, in patients with coma, and to determine whether to wean anti-epileptic medications.

At times, a routine EEG is not sufficient to establish the diagnosis and/or to determine the best course of action in terms of treatment. In this case, attempts may be made to record an EEG while a seizure is occurring. This is known as an ictal recording, as opposed to an inter-ictal recording which refers to the EEG recording between seizures. To obtain an ictal recording, a prolonged EEG is typically performed accompanied by a time-synchronized video and audio recording. This can be done either as an outpatient (at home) or during a hospital admission, preferably to an Epilepsy Monitoring Unit (EMU) with nurses and other personnel trained in the care of patients with seizures. Outpatient ambulatory video EEGs typically last one to three days. An admission to an Epilepsy Monitoring Unit typically lasts several days but may last for a week or longer. While in the hospital, seizure medications are usually withdrawn to increase the odds that a seizure will occur during admission. For reasons of safety, medications are not withdrawn during an EEG outside of the hospital. Ambulatory video EEGs therefore have the advantage of convenience and are less expensive than a hospital admission, but the disadvantage of a decreased probability of recording a clinical event.

Epilepsy monitoring is typically done to distinguish epileptic seizures from other types of spells, such as psychogenic non-epileptic seizures, syncope (fainting), sub-cortical movement disorders and migraine variants, to characterize seizures for the purposes of treatment, and to localize the region of brain from which a seizure originates for work-up of possible seizure surgery.

Additionally, EEG may be used to monitor the depth of anesthesia, as an indirect indicator of cerebral perfusion in carotid endarterectomy, or to monitor amobarbital effect during the Wada test.

EEG can also be used in intensive care units for brain function monitoring to monitor for non-convulsive seizures/non-convulsive status epilepticus, to monitor the effect of sedative/anesthesia in patients in medically induced coma (for treatment of refractory seizures or increased intracranial pressure), and to monitor for secondary brain damage in conditions such as subarachnoid hemorrhage (currently a research method).

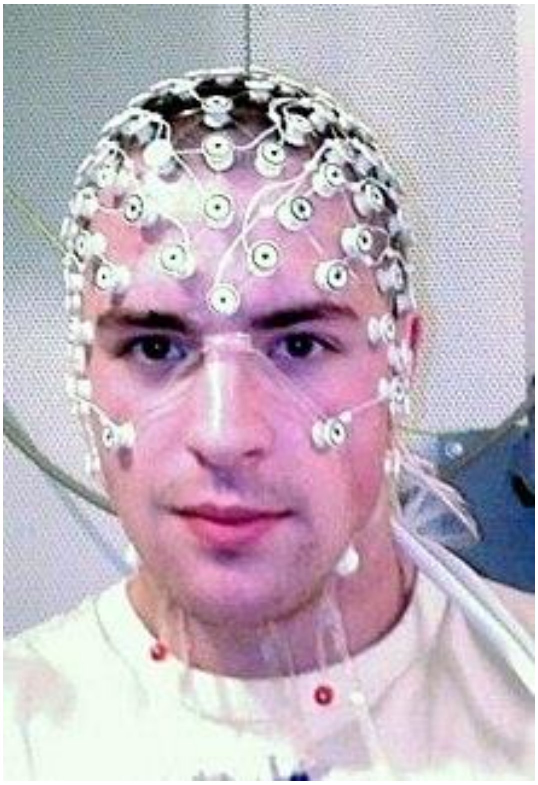

**Figure 7.** An Electroencephalography Recording Setup.

If a patient with epilepsy is being considered for resective surgery, it is often necessary to localize the focus (source) of the epileptic brain activity with a resolution greater than what is provided by scalp EEG. This is because the cerebrospinal fluid, skull and scalp *smear* the electrical potentials recorded by scalp EEG. In these cases, neurosurgeons typically implant strips and grids of electrodes (or penetrating depth electrodes) under the dura mater, through either a craniotomy or a burr hole. The recording of these signals is referred to as electrocorticography (ECoG), subdural EEG (sdEEG) or intracranial EEG (icEEG)--all terms for the same thing. The signal recorded from ECoG is on a different scale of activity than the brain activity recorded from scalp EEG. Low voltage, high frequency components that cannot be seen easily (or at all) in scalp EEG can be seen clearly in ECoG. Further, smaller electrodes (which cover a smaller parcel of brain surface) allow even lower voltage, faster components of brain activity to be seen. Some clinical sites record from penetrating microelectrodes.

Recent studies using machine learning techniques such as neural networks with statistical temporal features extracted from frontal lobe EEG brainwave data has shown high levels of success in classifying mental states (Relaxed, Neutral, Concentrating) and mental emotional states (Negative, Neutral, Positive).

EEG is not indicated for diagnosing headache. Recurring headache is a common pain problem, and this procedure is sometimes used in a search for a diagnosis, but it has no advantage over routine clinical evaluation.

### 5.2.2 Research Use:

EEG, and the related study of ERPs are used extensively in neuroscience, cognitive science, cognitive psychology, neurolinguistics and psychophysiological research, but also to study human functions such as swallowing. Many EEG techniques used in research are not standardized sufficiently for clinical use. But research on mental disabilities, such as auditory processing disorder (APD), ADD, or ADHD, is becoming more widely known and EEGs are used as research and treatment.

## 5.3 Mechanism:

The brain's electrical charge is maintained by billions of neurons. Neurons are electrically charged (or "polarized") by membrane transport proteins that pump ions across their membranes. Neurons are constantly exchanging ions with the extracellular milieu, for example to maintain resting potential and to propagate action potentials. Ions of similar charge repel each other, and when many ions are pushed out of many neurons at the same time, they can push their neighbours, who push their neighbours, and so on, in a wave. This process is known as volume conduction. When the wave of ions reaches the electrodes on the scalp, they can push or pull electrons on the metal in the electrodes. Since metal conducts the push and pull of electrons easily, the difference in push or pull voltages between any two electrodes can be measured by a voltmeter. Recording these voltages over time gives us the EEG.

The electric potential generated by an individual neuron is far too small to be picked up by EEG or MEG. EEG activity therefore always reflects the summation of the synchronous activity of thousands or millions of neurons that have similar spatial orientation. If the cells do not have similar spatial orientation, their ions do not line up and create waves to be detected. Pyramidal neurons of the cortex are thought to produce the most EEG signal because they are well-aligned and fire together. Because voltage field gradients fall off with the square of distance, activity from deep sources is more difficult to detect than currents near the skull.

Scalp EEG activity shows oscillations at a variety of frequencies. Several of these oscillations have characteristic frequency ranges, spatial distributions and are associated with different states of brain functioning (e.g., waking and the various sleep stages). These oscillations represent synchronized activity over a network of neurons. The neuronal networks underlying some of these oscillations are understood (e.g., the thalamocortical resonance underlying sleep spindles), while many others are not (e.g., the system that generates the posterior basic rhythm). Research that measures both EEG and neuron spiking finds the relationship between the two is complex, with a combination of EEG power in the gamma band and phase in the delta band relating most strongly to neuron spike activity.

### 5.4 Method:

In conventional scalp EEG, the recording is obtained by placing electrodes on the scalp with a conductive gel or paste, usually after preparing the scalp area by light abrasion to reduce impedance due to dead skin cells. Many systems typically use electrodes, each of which is attached to an individual wire. Some systems use caps or nets into which electrodes are embedded; this is particularly common when high-density arrays of electrodes are needed.

Electrode locations and names are specified by the International 10–20 system for most clinical and research applications (except when high-density arrays are used). This system ensures that the naming of electrodes is consistent across laboratories. In most clinical applications, 19 recording electrodes (plus ground and system reference) are used. A smaller number of electrodes are typically used when recording EEG from neonates. Additional electrodes can be added to the standard set-up when a clinical or research application demands increased spatial resolution for a particular area of the brain. High-density arrays (typically via cap or net) can contain up to 256 electrodes more-or-less evenly spaced around the scalp.

Each electrode is connected to one input of a differential amplifier (one amplifier per pair of electrodes); a common system reference electrode is connected to the other input of each differential amplifier. These amplifiers amplify the voltage between the active electrode and the reference (typically 1,000–100,000 times, or 60–100 dB of voltage gain). In analog EEG, the signal is then filtered (next paragraph), and the EEG signal is output as the deflection of pens as paper passes underneath. Most EEG systems these days, however, are digital, and the amplified signal is digitized via an analog-to-digital converter, after being passed through an anti-aliasing filter. Analog-to-digital sampling typically occurs at 256–

512 Hz in clinical scalp EEG; sampling rates of up to 20 kHz are used in some research applications.

During the recording, a series of activation procedures may be used. These procedures may induce normal or abnormal EEG activity that might not otherwise be seen. These procedures include hyperventilation, photic stimulation (with a strobe light), eye closure, mental activity, sleep and sleep deprivation. During (inpatient) epilepsy monitoring, a patient's typical seizure medications may be withdrawn.

The digital EEG signal is stored electronically and can be filtered for display. Typical settings for the high-pass filter and a low-pass filter are 0.5–1 Hz and 35–70 Hz respectively. The high-pass filter typically filters out slow artifact, such as electrogalvanic signals and movement artifact, whereas the low-pass filter filters out high-frequency artifacts, such as electromyographic signals. An additional notch filter is typically used to remove artifact caused by electrical power lines (60 Hz in the United States and 50 Hz in many other countries).

The EEG signals can be captured with opensource hardware such as OpenBCI and the signal can be processed by freely available EEG software such as EEGLAB or the Neurophysiological Biomarker Toolbox.

As part of an evaluation for epilepsy surgery, it may be necessary to insert electrodes near the surface of the brain, under the surface of the dura mater. This is accomplished via burr hole or craniotomy. This is referred to variously as "electrocorticography (ECoG)", "intracranial EEG (I-EEG)" or "subdural EEG (SD-EEG)". Depth electrodes may also be placed into brain structures, such as the amygdala or hippocampus, structures, which are common epileptic foci and may not be "seen" clearly by scalp EEG. The electrocorticographic signal is processed in the same manner as digital scalp EEG (above), with a couple of caveats. ECoG is typically recorded at higher sampling rates than scalp EEG because of the requirements of Nyquist theorem—the subdural signal is composed of a higher predominance of higher frequency components. Also, many of the artifacts that affect scalp EEG do not impact ECoG, and therefore display filtering is often not needed.

A typical adult human EEG signal is about 10 µV to 100 µV in amplitude when measured from the scalp[46] and is about 10–20 mV when measured from subdural electrodes.

Since an EEG voltage signal represents a difference between the voltages at two electrodes, the display of the EEG for the reading encephalographer may be set up in one of several ways. The representation of the EEG channels is referred to as a *montage*.

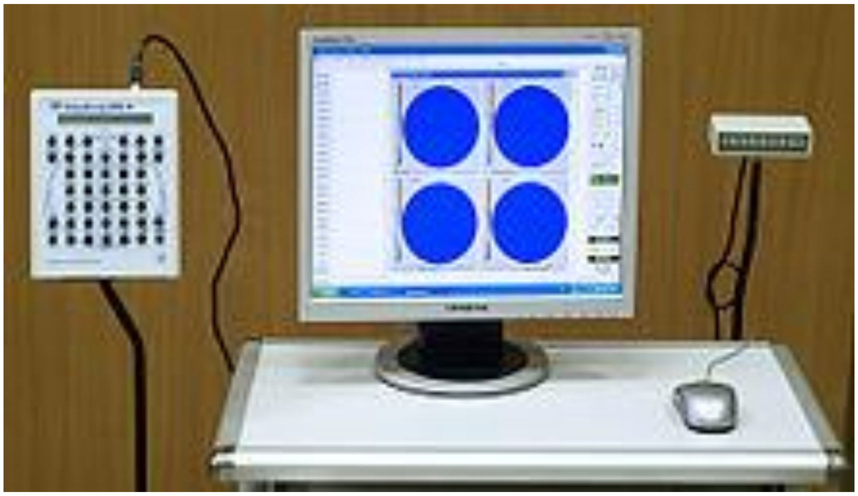

**Figure 8.** A Computer Electroencephalograph *Neurovisor-BMM 40*.

**Sequential montage**

Each channel (i.e., waveform) represents the difference between two adjacent electrodes. The entire montage consists of a series of these channels. For example, the channel "Fp1-F3" represents the difference in voltage between the Fp1 electrode and the F3 electrode. The next channel in the montage, "F3-C3", represents the voltage difference between F3 and C3, and so on through the entire array of electrodes.

**Referential montage**

Each channel represents the difference between a certain electrode and a designated reference electrode. There is no standard position for this reference; it is, however, at a different position than the "recording" electrodes.

```
Midline positions are often used because they do not amplify the signal
in one hemisphere vs. the other, such as Cz, Oz, Pz etc as online
reference. The other popular offline references are:

REST reference:which is an offline computational reference at infinity
where the potential is zero. REST (reference electrode standardization
technique) takes the equivalent sources inside the brain of any a set of
scalp recordings as springboard to link the actual recordings with any
an online or offline( average, linked ears etc)  non-zero reference to
the new recordings with infinity zero as the standardized reference. A
free software can be found at (Dong L, Li F, Liu Q, Wen X, Lai Y, Xu P
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and Yao D (2017) MATLAB Toolboxes for Reference Electrode Standardization Technique (REST) of Scalp EEG. Front. Neurosci. 11:601. doi: 10.3389/fnins.2017.00601),and for more details and its performance, pls ref to the original paper (Yao, D. (2001). A method to standardize a reference of scalp EEG recordings to a point at infinity. Physiol. Meas. 22, 693–711. doi: 10.1088/0967-3334/22/4/305)

```
"linked ears": which is a physical or mathematical average of electrodes
attached to both earlobes or mastoids.

Average reference montage: The outputs of all of the amplifiers are summed
and averaged, and this averaged signal is used as the common reference
for each channel.

Laplacian montage: Each channel represents the difference between an
electrode and a weighted average of the surrounding electrodes.
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When analog (paper) EEGs are used, the technologist switches between montages during the recording in order to highlight or better characterize certain features of the EEG. With digital EEG, all signals are typically digitized and stored in a particular (usually referential) montage; since any montage can be constructed mathematically from any other, the EEG can be viewed by the electroencephalographer in any display montage that is desired.

The EEG is read by a clinical neurophysiologist or neurologist (depending on local custom and law regarding medical specialities), optimally one who has specific training in the interpretation of EEGs for clinical purposes. This is done by visual inspection of the waveforms, called graphoelements. The use of computer signal processing of the EEG—so-called quantitative electroencephalography—is somewhat controversial when used for clinical purposes (although there are many research uses).

### 5.4.1 Dry EEG Electrodes:

In the early 1990s Babak Taheri, at University of California, Davis demonstrated the first single and also multichannel dry active electrode arrays using micro-machining. The single channel dry EEG electrode construction and results were published in 1994.[48] The arrayed electrode was also demonstrated to perform well compared to silver/silver chloride electrodes. The device consisted of four sites of sensors with integrated electronics to reduce noise by impedance matching. The advantages of such electrodes are:

(1) No electrolyte used

(2) No skin preparation

(3) Significantly reduced sensor size

(4) Compatibility with EEG monitoring systems.

The active electrode array is an integrated system made of an array of capacitive sensors with local integrated circuitry housed in a package with batteries to power the circuitry. This level of integration was required to achieve the functional performance obtained by the electrode. The electrode was tested on an electrical test bench and on human subjects in four modalities of EEG activity, namely:

(1) Spontaneous EEG

(2) Sensory event-related potentials

(3) Brain stem potentials

(4) Cognitive event-related potentials.

The performance of the dry electrode compared favorably with that of the standard wet electrodes in terms of skin preparation, no gel requirements (dry), and higher signal-to-noise ratio.

In 1999 researchers at Case Western Reserve University, in Cleveland, Ohio, led by Hunter Peckham, used 64-electrode EEG skullcap to return limited hand movements to quadriplegic Jim Jatich. As Jatich concentrated on simple but opposite concepts like up and down, his beta-rhythm EEG output was analysed using software to identify patterns in the noise. A basic pattern was identified and used to control a switch: Above average activity was set to on, below average off. As well as enabling Jatich to control a computer cursor the signals were also used to drive the nerve controllers embedded in his hands, restoring some movement.

In 2018, a functional dry electrode composed of a polydimethylsiloxane elastomer filled with conductive carbon nanofibers was reported. This research was conducted at the U.S. Army Research Laboratory. EEG technology often involves applying a gel to the scalp which facilitates strong signal-to-noise ratio. This results in more reproducible and reliable experimental results. Since patient dislike having their hair filled with gel, and the lengthy setup requires trained staff on hand, utilizing EEG outside the laboratory setting can be difficult. Additionally, it has been observed that wet electrode sensors’ performance reduces after a span of hours. Therefore, research has been directed to developing dry and semi-dry EEG bioelectronic interfaces.

Dry electrode signals depend upon mechanical contact. Therefore, it can be difficult getting a usable signal because of impedance between the skin and the electrode. Some EEG systems attempt to circumvent this issue by applying a saline solution. Others have a semi dry nature and release small amounts of the gel upon contact with the scalp.[52] Another solution uses spring loaded pin setups. These may be uncomfortable. They may also be dangerous if they were used in a situation where a patient could bump their head since they could become lodged after an impact trauma incident.

ARL also developed a visualization tool, Customizable Lighting Interface for the Visualization of EEGs or CLIVE, which showed how well two brains are synchronized.

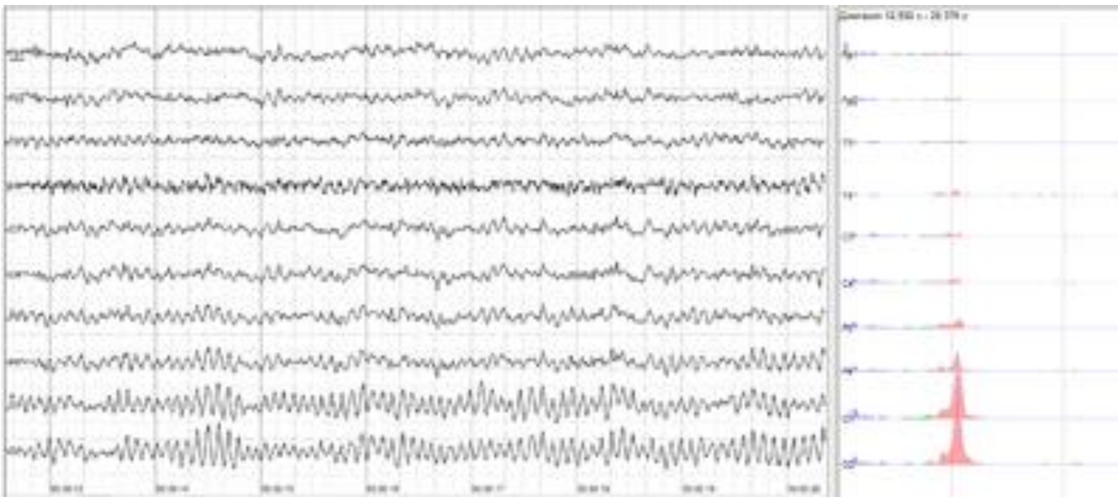

**Figure 9.** The sample of human EEG with prominent resting state activity – alpha-rhythm. Left: EEG traces (horizontal – time in seconds; vertical – amplitudes, scale 100 μV). Right: power spectra of shown signals (vertical lines – 10 and 20 Hz, scale is linear). Alpha-rhythm consists of sinusoidal-like waves with frequencies in 8–12 Hz range (11 Hz in this case) more prominent in posterior sites. Alpha range is red at power spectrum graph.

## 5.5 Advantages:

Several other methods to study brain function exist, including functional magnetic resonance imaging (fMRI), positron emission tomography (PET), magnetoencephalography(MEG), nuclear magnetic resonance spectroscopy (NMR or MRS), electrocorticography (EEG), single-photon emission computed tomography (SPECT), near-infrared spectroscopy (NIRS), and event-related optical signal (EROS). Despite the relatively poor spatial sensitivity of EEG, it possesses multiple advantages over some of these techniques:

- Hardware costs are significantly lower than those of most other techniques
- EEG prevents limited availability of technologists to provide immediate care in high traffic hospitals.

- EEG sensors can be used in more places than fMRI, SPECT, PET, MRS, or MEG, as these techniques require bulky and immobile equipment. For example, MEG requires equipment consisting of liquid helium-cooled detectors that can be used only in magnetically shielded rooms, altogether costing upwards of several million dollars; and fMRI requires the use of a 1-ton magnet in, again, a shielded room.
- EEG has very high temporal resolution, on the order of milliseconds rather than seconds. EEG is commonly recorded at sampling rates between 250 and 2000 Hz in clinical and research settings, but modern EEG data collection systems are capable of recording at sampling rates above 20,000 Hz if desired. MEG and EROS are the only other noninvasive cognitive neuroscience techniques that acquire data at this level of temporal resolution.
- EEG is relatively tolerant of subject movement, unlike most other neuroimaging techniques. There even exist methods for minimizing, and even eliminating movement artifacts in EEG data
- EEG is silent, which allows for better study of the responses to auditory stimuli.
- EEG does not aggravate claustrophobia, unlike fMRI, PET, MRS, SPECT, and sometimes MEG
- EEG does not involve exposure to high-intensity (>1 tesla) magnetic fields, as in some of the other techniques, especially MRI and MRS. These can cause a variety of undesirable issues with the data, and also prohibit use of these techniques with participants that have metal implants in their body, such as metal-containing pacemakers
- EEG does not involve exposure to radioligands, unlike positron emission tomography.
- ERP studies can be conducted with relatively simple paradigms, compared with IE block-design fMRI studies
- Extremely antiinvasive, unlike Electrocorticography, which actually requires electrodes to be placed on the surface of the brain.

EEG also has some characteristics that compare favorably with behavioral testing:

- EEG can detect covert processing (i.e., processing that does not require a response)
- EEG can be used in subjects who are incapable of making a motor response
- Some ERP components can be detected even when the subject is not attending to the stimuli.
- Unlike other means of studying reaction time, ERPs can elucidate stages of processing (rather than just the final end result)
- EEG is a powerful tool for tracking brain changes during different phases of life. EEG sleep analysis can indicate significant aspects of the timing of brain development, including evaluating adolescent brain maturation.
- In EEG there is a better understanding of what signal is measured as compared to other research techniques, i.e. the BOLD response in MRI.

## 5.6 Disadvantages:

- Low spatial resolution on the scalp. fMRI, for example, can directly display areas of the brain that are active, while EEG requires intense interpretation just to hypothesize what areas are activated by a particular response.
- EEG poorly measures neural activity that occurs below the upper layers of the brain (the cortex).
- Unlike PET and MRS, cannot identify specific locations in the brain at which various neurotransmitters, drugs, etc. can be found.
- Often takes a long time to connect a subject to EEG, as it requires precise placement of dozens of electrodes around the head and the use of various gels, saline solutions, and/or pastes to keep them in place (although a cap can be used). While the length of time differs dependent on the specific EEG device used, as a general rule it takes considerably less time to prepare a subject for MEG, fMRI, MRS, and SPECT.
- Signal-to-noise ratio is poor, so sophisticated data analysis and relatively large numbers of subjects are needed to extract useful information from EEG.

## 5.7 With other Neuroimaging Techniques:

Simultaneous EEG recordings and fMRI scans have been obtained successfully, though successful simultaneous recording requires that several technical difficulties be overcome, such as the presence of ballistocardiograph artifact, MRI pulse artifact and the induction of electrical currents in EEG wires that move within the strong magnetic fields of the MRI. While challenging, these have been successfully overcome in a number of studies.

MRI's produce detailed images created by generating strong magnetic fields that may induce potentially harmful displacement force and torque. These fields produce potentially harmful radio frequency heating and create image artifacts rendering images useless. Due to these potential risks, only certain medical devices can be used in an MR environment.

Similarly, simultaneous recordings with MEG and EEG have also been conducted, which has several advantages over using either technique alone:

- EEG requires accurate information about certain aspects of the skull that can only be estimated, such as skull radius, and conductivities of various skull locations. MEG does not have this issue, and a simultaneous analysis allows this to be corrected for.
- MEG and EEG both detect activity below the surface of the cortex very poorly, and like EEG, the level of error increases with the depth below the surface of the cortex one attempts to examine. However, the errors are very different between the techniques, and combining them thus allows for correction of some of this noise.
- MEG has access to virtually no sources of brain activity below a few centimeters under the cortex. EEG, on the other hand, can receive signals from greater depth, albeit with a high degree of noise. Combining the two makes it easier to determine what in the EEG signal comes from the surface (since MEG is very accurate in examining signals from the surface of the brain), and what comes from deeper in the brain, thus allowing for analysis of deeper brain signals than either EEG or MEG on its own.

Recently, a combined EEG/MEG (EMEG) approach has been investigated for the purpose of source reconstruction in epilepsy diagnosis.

EEG has also been combined with positron emission tomography. This provides the advantage of allowing researchers to see what EEG signals are associated with different drug actions in the brain.

## 5.8 Normal Activity:

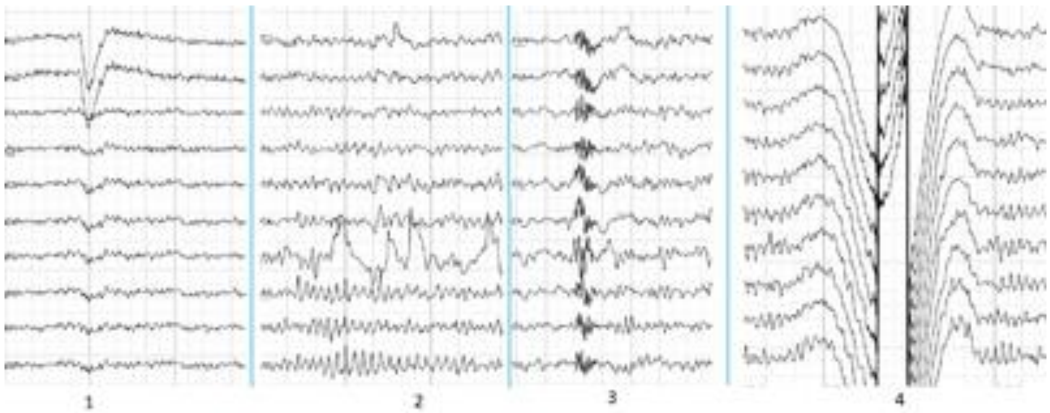


**Figure 10.** The samples of main types of artifacts in human EEG. 1: Electrooculographic artifact caused by the excitation of eyeball's muscles (related to blinking, for example). Big-amplitude, slow, positive wave prominent in frontal electrodes. 2: Electrode's artifact caused by bad contact (and thus bigger impedance) between P3 electrode and skin. 3: Swallowing artifact. 4: Common reference electrode's artifact caused by bad contact between reference electrode and skin. Huge wave similar in all channels.

The EEG is typically described in terms of (1) rhythmic activity and (2) transients. The rhythmic activity is divided into bands by frequency. To some degree, these frequency bands are a matter of nomenclature (i.e., any rhythmic activity between 8–12 Hz can be described as "alpha"), but these designations arose because rhythmic activity within a certain frequency range was noted to have a certain distribution over the scalp or a certain biological significance. Frequency bands are usually extracted using spectral methods (for instance Welch) as implemented for instance in freely available EEG software such as EEGLAB or the Neurophysiological Biomarker Toolbox. Computational processing of the EEG is often named quantitative electroencephalography (qEEG).

## Comparison of EEG bands

| Band | Frequency (Hz) | Location | Normally | Pathologically |
|---|---|---|---|---|
| Delta | < 4 | Frontally in adults, posteriorly in children; high-amplitude waves | • adult slow-wave sleep<br>• in babies<br>• Has been found during some continuous-attention tasks | • subcortical lesions<br>• diffuse lesions<br>• metabolic encephalopathy hydrocephalus<br>• deep midline lesions |
| Theta | 4–7 | Found in locations not related to task at hand | • higher in young children<br>• drowsiness in adults and teens<br>• idling<br>• Associated with inhibition of elicited responses (has been found to spike in situations where a person is actively trying to repress a response or action).[63] | • focal subcortical lesions<br>• metabolic encephalopathy<br>• deep midline disorders<br>• some instances of hydrocephalus |
| Alpha | 8–15 | posterior regions of head, both sides, higher in amplitude on dominant side. Central sites (c3-c4) at rest | • relaxed/reflecting<br>• closing the eyes<br>• Also associated with inhibition control, seemingly with the purpose of timing inhibitory activity in different locations across the brain. | • coma |
| Beta | 16–31 | both sides, symmetrical distribution, most evident frontally; low-amplitude waves | • range span: active calm → intense → stressed → mild obsessive<br>• active thinking, focus, high alert, anxious | • benzodiazepines<br>• Dup15q syndrome |
| Gamma | > 32 | Somatosensory cortex | • Displays during cross-modal sensory processing (perception that combines two different senses, such as sound and sight)<br>• Also, is shown during short-term memory matching of recognized objects, sounds, or tactile sensations | • A decrease in gamma-band activity may be associated with cognitive decline, especially when related to the theta band; however, this has not been proven for use as a clinical diagnostic measurement |
| Mu | 8–12 | Sensorimotor cortex | • Shows rest-state motor neurons.[67] | • Mu suppression could indicate that motor mirror neurons are working. Deficits in Mu suppression, and thus in mirror neurons, might play a role in autism.[68] |

The practice of using only whole numbers in the definitions comes from practical considerations in the days when only whole cycles could be counted on paper records. This leads to gaps in the definitions, as seen elsewhere on this page. The theoretical definitions have always been more carefully defined to include all frequencies. Unfortunately there is no agreement in standard reference works on what these ranges should be – values for the upper end of alpha and lower end of beta include 12, 13, 14 and 15. If the threshold is taken as 14 Hz, then the slowest beta wave has about the same duration as the longest spike (70 ms), which makes this the most useful value.

## 5.9 <u>Wave Patterns:</u>

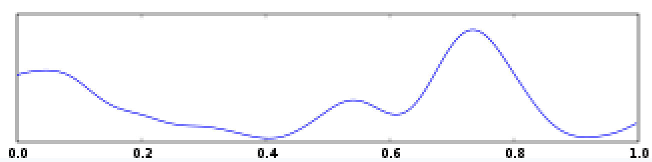


**Figure 11.** Delta waves

- Delta is the frequency range up to 4 Hz. It tends to be the highest in amplitude and the slowest waves. It is seen normally in adults in slow-wave sleep. It is also seen normally in babies. It may occur focally with subcortical lesions and in general distribution with diffuse lesions, metabolic encephalopathy hydrocephalus or deep midline lesions. It is usually most prominent frontally in adults (e.g. FIRDA – frontal intermittent rhythmic delta) and posteriorly in children (e.g. OIRDA – occipital intermittent rhythmic delta).

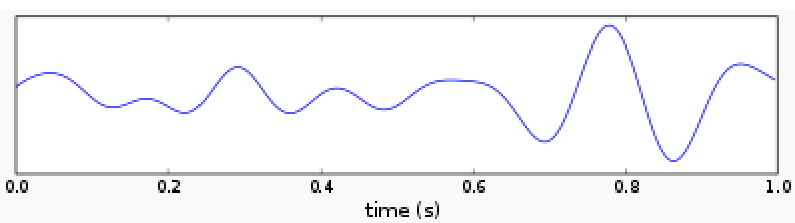


**Figure 12.** Theta waves

- Theta is the frequency range from 4 Hz to 7 Hz. Theta is seen normally in young children. It may be seen in drowsiness or arousal in older children and adults; it can also be seen in meditation.[70] Excess theta for age represents abnormal activity. It can be seen as a focal disturbance in focal subcortical lesions; it can be seen in generalized distribution in diffuse disorder or metabolic encephalopathy or deep midline disorders or some instances of hydrocephalus. On the contrary this range has been associated with reports of relaxed, meditative, and creative states.

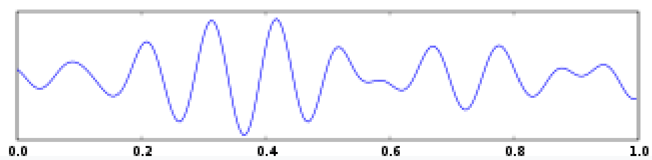


**Figure 13.** Alpha wave

- Alpha is the frequency range from 7 Hz to 13 Hz.[71]Hans Berger named the first rhythmic EEG activity he saw as the "alpha wave". This was the "posterior basic rhythm" (also called the "posterior dominant rhythm" or the "posterior alpha rhythm"), seen in the posterior regions of the head on both sides, higher in amplitude on the dominant side. It emerges with closing of the eyes and with relaxation, and attenuates with eye opening or mental exertion. The posterior basic rhythm is actually slower than 8 Hz in young children (therefore technically in the theta range).

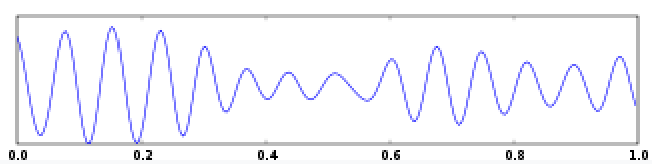


**Figure 14.** Sensorimotor rhythm aka mu rhythm

In addition to the posterior basic rhythm, there are other normal alpha rhythms such as the mu rhythm (alpha activity in the contralateral sensory and motor cortical areas) that emerges when the hands and arms are idle; and the "third rhythm" (alpha activity in the temporal or frontal lobes).[72][73] Alpha can be abnormal; for example, an EEG that has diffuse alpha occurring in coma and is not responsive to external stimuli is referred to as "alpha coma".

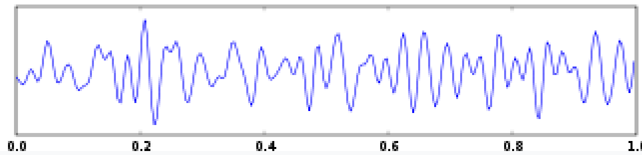


**Figure 15.** Beta waves

- Beta is the frequency range from 14 Hz to about 30 Hz. It is seen usually on both sides in symmetrical distribution and is most evident frontally. Beta activity is closely linked to motor behavior and is generally attenuated during active movements.[74] Low-amplitude beta with multiple and varying frequencies is often associated with active, busy or anxious thinking and active concentration. Rhythmic beta with a dominant set of frequencies is associated with various pathologies, such as Dup15q syndrome, and drug effects, especially benzodiazepines. It may be absent or reduced in areas of cortical damage. It is the dominant rhythm in patients who are alert or anxious or who have their eyes open.

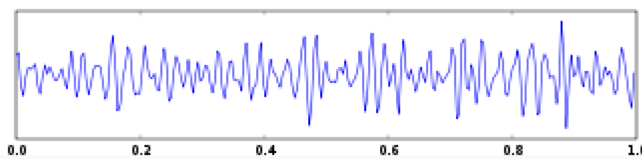


**Figure 16.** Gamma waves

- Gamma is the frequency range approximately 30–100 Hz. Gamma rhythms are thought to represent binding of different populations of neurons together into a network for the purpose of carrying out a certain cognitive or motor function.[1]
- Mu range is 8–13 Hz and partly overlaps with other frequencies. It reflects the synchronous firing of motor neurons in rest state. Mu suppression is thought to reflect motor mirror neuron systems, because when an action is observed, the pattern extinguishes, possibly because of the normal neuronal system and the mirror neuron system "go out of sync" and interfere with each other.[68]

"Ultra-slow" or "near-DC" activity is recorded using DC amplifiers in some research contexts. It is not typically recorded in a clinical context because the signal at these frequencies is susceptible to a number of artifacts.

Some features of the EEG are transient rather than rhythmic. Spikes and sharp waves may represent seizure activity or interictal activity in individuals with epilepsy or a predisposition toward epilepsy. Other transient features are normal: vertex waves and sleep spindles are seen in normal sleep.

Note that there are types of activity that are statistically uncommon, but not associated with dysfunction or disease. These are often referred to as "normal variants". The mu rhythm is an example of a normal variant.

The normal electroencephalogram (EEG) varies by age. The prenatal EEG and neonatal EEG is quite different from the adult EEG. Fetuses in the third trimester and newborns display two common brain activity patterns: "discontinuous" and "trace alternant." "Discontinuous" electrical activity refers to sharp bursts of electrical activity followed by low frequency waves. "Trace alternant" electrical activity describes sharp bursts followed by short high amplitude intervals and usually indicates quiet sleep in newborns[75]. The EEG in childhood generally has slower frequency oscillations than the adult EEG.

The normal EEG also varies depending on state. The EEG is used along with other measurements (EOG, EMG) to define sleep stages in polysomnography. Stage I sleep (equivalent to drowsiness in some systems) appears on the EEG as drop-out of the posterior basic rhythm. There can be an increase in theta frequencies. Santamaria and Chiappa cataloged a number of the variety of patterns associated with drowsiness. Stage II sleep is characterized by sleep spindles – transient runs of rhythmic activity in the 12–14 Hz range (sometimes referred to as the "sigma" band) that have a frontal-central maximum. Most of the activity in Stage II is in the 3–6 Hz range. Stage III and IV sleep are defined by the presence of delta frequencies and are often referred to collectively as "slow-wave sleep". Stages I–IV comprise non-REM (or "NREM") sleep. The EEG in REM (rapid eye movement) sleep appears somewhat similar to the awake EEG.

EEG under general anesthesia depends on the type of anesthetic employed. With halogenated anesthetics, such as halothane or intravenous agents, such as propofol, a rapid (alpha or low beta), nonreactive EEG pattern is seen over most of the scalp, especially anteriorly; in some older terminology this was known as a WAR (widespread anterior rapid) pattern, contrasted with a WAIS (widespread slow) pattern associated with high doses of opiates. Anesthetic effects on EEG signals are beginning to be understood at the level of drug actions on different kinds of synapses and the circuits that allow synchronized neuronal activity

## 5.10 Economics:

Inexpensive EEG devices exist for the low-cost research and consumer markets. Recently, a few companies have miniaturized medical grade EEG technology to create versions accessible to the general public. Some of these companies have built commercial EEG devices retailing for less than $100 USD.

- In 2004 OpenEEG released its ModularEEG as open source hardware. Compatible open source software includes a game for balancing a ball.
- In 2007 NeuroSky released the first affordable consumer based EEG along with the game NeuroBoy. This was also the first large scale EEG device to use dry sensor technology.
- In 2008 OCZ Technology developed device for use in video games relying primarily on electromyography.
- In 2008 the Final Fantasy developer Square Enix announced that it was partnering with NeuroSky to create a game, Judecca.
- In 2009 Mattel partnered with NeuroSky to release the Mindflex, a game that used an EEG to steer a ball through an obstacle course. By far the best selling consumer based EEG to date.
- In 2009 Uncle Milton Industries partnered with NeuroSky to release the *Star Wars* Force Trainer, a game designed to create the illusion of possessing the Force.

- In 2009 Emotiv released the EPOC, a 14 channel EEG device. The EPOC is the first commercial BCI to not use dry sensor technology, requiring users to apply a saline solution to electrode pads (which need remoistening after an hour or two of use).
- In 2010, NeuroSky added a blink and electromyography function to the MindSet.
- In 2011, NeuroSky released the MindWave, an EEG device designed for educational purposes and games.[102][103] The MindWave won the Guinness Book of World Records award for "Heaviest machine moved using a brain control interface".
- In 2012, a Japanese gadget project, neurowear, released Necomimi: a headset with motorized cat ears. The headset is a NeuroSky MindWave unit with two motors on the headband where a cat's ears might be. Slipcovers shaped like cat ears sit over the motors so that as the device registers emotional states the ears move to relate. For example, when relaxed, the ears fall to the sides and perk up when excited again.
- In 2014, OpenBCI released an eponymous open source brain-computer interface after a successful kickstarter campaign in 2013. The basic OpenBCI has 8 channels, expandable to 16, and supports EEG, EKG, and EMG. The OpenBCI is based on the Texas Instruments ADS1299 IC and the Arduino or PIC microcontroller, and costs $399 for the basic version. It uses standard metal cup electrodes and conductive paste.
- In 2015, Mind Solutions Inc released the smallest consumer BCI to date, the NeuroSync. This device functions as a dry sensor at a size no larger than a Bluetooth ear piece.
- In 2015, A Chinese-based company Macrotellect released BrainLink Pro and Brain Link Lite, a consumer grade EEG wearable product providing 20 brain fitness enhancement Apps on Apple and Android App Stores.

## Literature Survey

Integration of Bluetooth and Wi-Fi technology in Controlling home appliances can help and improve lifestyle of all user groups especially to the disabled and elderly people in term of safety and comfortable. The implementation of combined wired and wireless systems would be of most practical in designing a smart home system especially in cutting the system's installation cost for conventional home.

The smart elderly home monitoring system (SEHMS) is divided into three different modules which are safety monitoring system, telehealth system and telecare system. The smart phone is then connected to the monitoring system by using the TCP/IP networking method via Wi-Fi. A graphical user interface (GUI) is developed as the monitoring system which exhibits the information gathered from the system. The GUI opens an option to the user to examine the fall as well as making the confirmation or cancellation. A remote panic button has also been tested and implemented in the same android based smartphone. In addition, the monitoring system can also answer the call automatically after the emergency alarm has started.

The SunSPOT development kit will be used to simulate smart home devices. In this paper, the functionalities of a digital home temperature reader, as well as light switches will be demonstrated on the SunSPOTs. Possibilities of remote access to the SunSPOTs can be breakdown into two alternatives that can be either through the Internet cloud or through the GSM cloud.

Appliance control subsystem enables the user to control home appliances remotely whereas the security alert subsystem provides the remote security monitoring. The system is capable enough to instruct user via SMS from a specific cell number to change the condition of the home appliance according to the user's needs and requirements. The second aspect is that of security alert which is achieved in a way that on the detection of intrusion the system allows automatic generation of SMS thus alerting the user against security risk. In addition, the monitoring system can also answer the call automatically after the emergency alarm has started. This project will also not be a research or analytic based system to monitor human behavior. It will only provide ease of access to control house appliances and also monitor certain areas of the house. In terms of connection variant, this project proposed mixture of wired and wireless connection, where wired connection will run from the home appliances to the main control board while wireless connection will only exist in between the main control board and the UI platform, which is the phone or PC connected via Bluetooth. A concept on smart home application and development includes various implementation techniques and is never limited. Smart homesystems are created based on analysis on client needs and budget to cater for the system. With technologies available today, efficient integration of this system could be achieved. Home automation, also referred to as smart home concept, it is not new to consumers. It encompasses the ability to control electrical and electronic devices at home remotely thus providing ease of access to home users. This concept may be applied in various manners to fit the requirement of a smart home. Now, advancement in wireless technology introduced new ideas such as Bluetooth and Internet linking; Wi-Fi, which has been slowly replacing the conventional wired technology which requires wire bonded interconnection between electrical devices. The main advantage of wireless interlinking includes diminishing the need of wires for connection.

# Block diagram

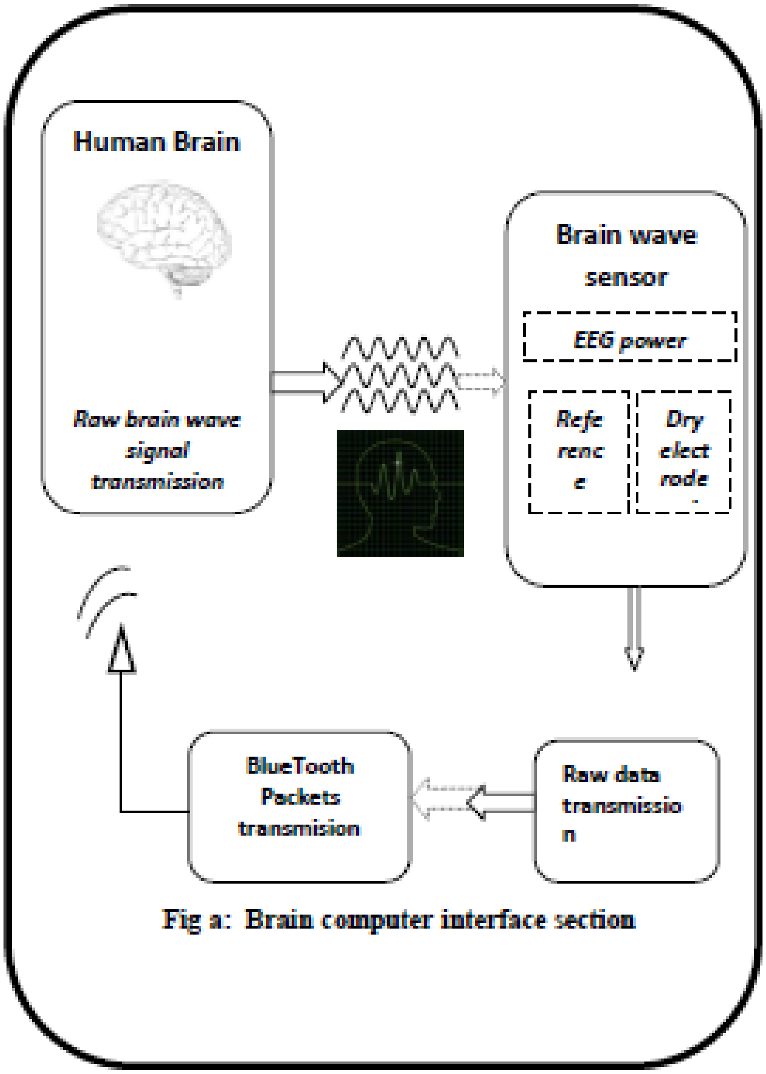


**Figure 17.** **Block Diagram 1**

The whole system comprises of two parts i.e., Data Processing unit and the other part is home controlling unit.The block diagram clearly show the process of the evenyt being occurred top autmate the home appliacnces with our thinking capability. The very first process is to intercept the brainwave signal using Emotiv Insight 5 wing the dry electrodes within it. Then this raw data is further trasmitted over to the controlling unit through Bluetooth module and the module at the receiving side receives the raw data from the brain using Emotiv Insight 5. Here the data is received using a serial Data receptor

# Block diagram

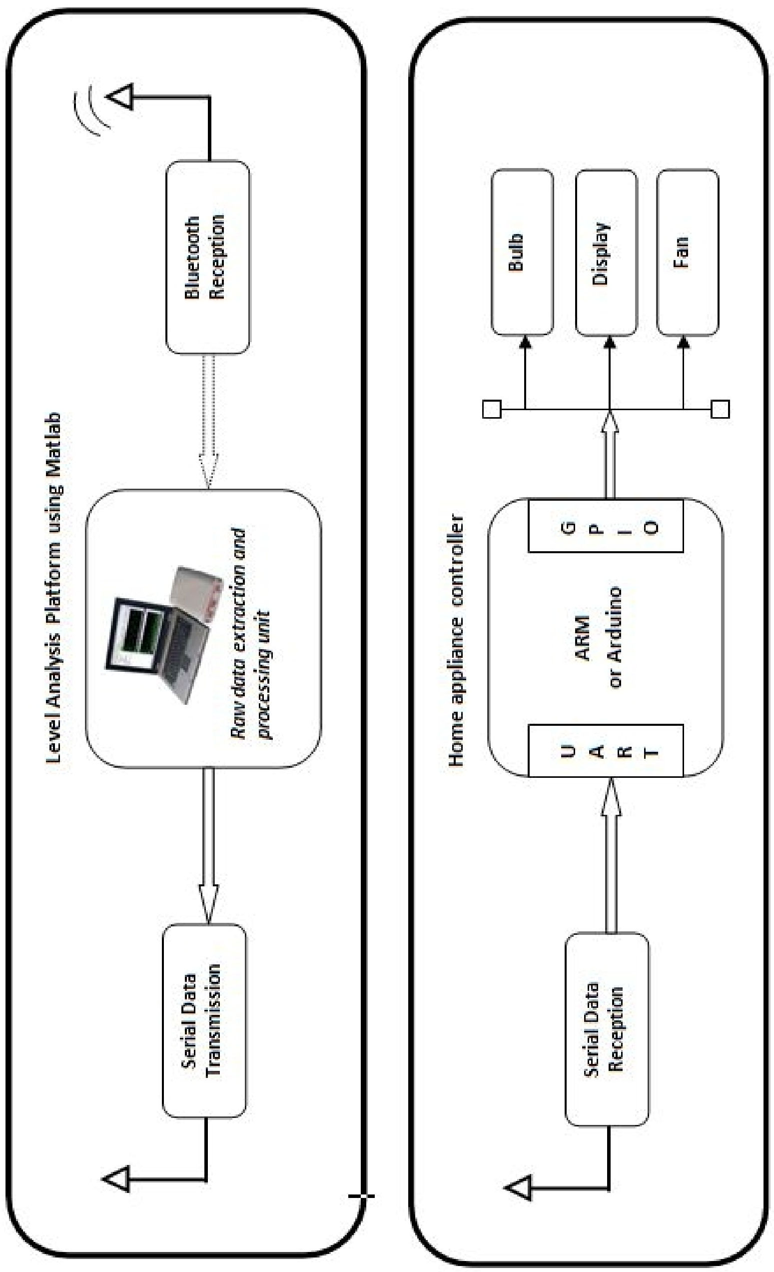


**Figure 18.** Block Diagram 2

and is further given to the controller here using the UART protocol and as the brain signal is defined and as per that the controller gives commands to the home appliacnes to ON-OFF as per the frequency variation of the mindwave and these commands can be given directly using GPIO pins available onboard.

# BCI (Brain Computer Interface)

B**rain–computer interface** (**BCI**), sometimes called a **neural-control interface** (**NCI**), **mind-machine interface** (**MMI**), **direct neural interface** (**DNI**), or **brain–machine interface** (**BMI**), is a direct communication pathway between an enhanced or wired brain and an external device. BCI differs from neuromodulation in that it allows for bidirectional information flow. BCIs are often directed at researching, mapping, assisting, augmenting, or repairing human cognitive or sensory-motor functions.

Research on BCIs began in the 1970s at the University of California, Los Angeles (UCLA) under a grant from the National Science Foundation, followed by a contract from DARPA. The papers published after this research also mark the first appearance of the expression *brain–computer interface* in scientific literature.

The field of BCI research and development has since focused primarily on neuroprosthetics applications that aim at restoring damaged hearing, sight and movement. Thanks to the remarkable cortical plasticity of the brain, signals from implanted prostheses can, after adaptation, be handled by the brain like natural sensor or effector channels. Following years of animal experimentation, the first neuroprosthetic devices implanted in humans appeared in the mid-1990s.

## 8.1 Invasive BCIs:

**8.1.1 Vision: I**nvasive BCI research has targeted repairing damaged sight and providing new functionality for people with paralysis. Invasive BCIs are implanted directly into the grey matter of the brain during neurosurgery. Because they lie in the grey matter, invasive devices produce the highest quality signals of BCI devices but are prone to scar-tissue build-up, causing the signal to become weaker, or even non-existent, as the body reacts to a foreign object in the brain in *vision science*, direct brain implants have been used to treat non-congenital (acquired) blindness. One of the first scientists to produce a working brain interface to restore sight was private researcher William Dobelle.

**8.1.2 Movement:** BCIs focusing on *motor neuroprosthetics* aim to either restore movement in individuals with paralysis or provide devices to assist them, such as interfaces with computers or robot arms.

Researchers at Emory University in Atlanta, led by Philip Kennedy and Roy Bakay, were first to install a brain implant in a human that produced signals of high enough quality to simulate movement. Their patient, Johnny Ray (1944–2002), suffered from ‘locked-in syndrome’ after suffering a brain-stem stroke in 1997. Ray’s implant was installed in 1998 and he lived long enough to start working with the implant, eventually learning to control a computer cursor; he died in 2002 of a brain aneurysm.

## 8.2 Partially Invasive BCIs:

Partially invasive BCI devices are implanted inside the skull but rest outside the brain rather than within the grey matter. They produce better resolution signals than non-invasive BCIs where the bone tissue of the cranium deflects and deforms signals and have a lower risk of forming scar-tissue in the brain than fully invasive BCIs. There has been preclinical demonstration of intracortical BCIs from the stroke perilesional cortex.

*Electrocorticography* (ECoG) measures the electrical activity of the brain taken from beneath the skull in a similar way to non-invasive electroencephalography, but the electrodes are embedded in a thin plastic pad that is placed above the cortex, beneath the dura mater. ECoG technologies were first trialled in humans in 2004 by Eric Leuthardt and Daniel Moran from Washington University in St Louis.Light reactive imaging BCI devices are still in the realm of theory. These would involve implanting a laser inside the skull. The laser would be trained on a single neuron and the neuron's reflectance measured by a separate sensor. When the neuron fires, the laser light pattern and wavelengths it reflects would change slightly. This would allow researchers to monitor single neurons but require less contact with tissue and reduce the risk of scar-tissue build-up.

## 5.3 Non-Invasive BCIs:

There have also been experiments in humans using non-invasive neuroimaging technologies as interfaces. The substantial majority of published BCI work involves noninvasive EEG-based BCIs. Noninvasive EEG-based technologies and interfaces have been used for a much broader variety of applications. Although EEG-based interfaces are easy to wear and do not require surgery, they have relatively poor spatial resolution and cannot effectively use higher-frequency signals because the skull dampens signals, dispersing and blurring the electromagnetic waves created by the neurons. EEG-based interfaces also require some time and effort prior to each usage session, whereas non-EEG-based ones, as well as invasive ones require no prior-usage training. Overall, the best BCI for each user depends on numerous factors.

| Brain Wave Type | Frequency range | Mental states and Condition |
|---|---|---|
| Delta | 0.1Hz to 3Hz | Deep, Dreamless sleep, non-REM sleep, unconscious |
| Theta | 4 Hz to 7 Hz | Intuitive, Creative, recall, fantasy, imaginary, dream |
| Alpha | 8 Hz to 15 Hz | Relaxed, but not drowsy, Tranquil, conscious |
| Low Beta | 12 Hz to 15 Hz | Formerly SMR, Relaxed yet focused, integrated |
| Midrange Beta | 16 Hz to 20 Hz | Thinking, aware of self and surrounding |
| High Beta | 21 Hz to 30 Hz | Alertness, agitation |

# P300 (Event related potential)

The **P300** (**P3**) wave is an event related potential(ERP) component elicited in the process of decision making. It is considered to be an endogenouspotential, as its occurrence links not to the physical attributes of a stimulus, but to a person's reaction to it. More specifically, the P300 is thought to reflect processes involved in stimulus evaluation or categorization. It is usually elicited using the oddball paradigm, in which low-probability target items are mixed with high-probability non-target (or "standard") items.

When recorded by electroencephalography (EEG), it surfaces as a positive deflection in voltage with a latency (delay between stimulus and response) of roughly 250 to 500 ms.[2] The signal is typically measured most strongly by the electrodes covering the parietal lobe. The presence, magnitude, topography and timing of this signal are often used as metrics of cognitive function in decision making processes. While the neural substrates of this ERP component still remain hazy, the reproducibility and ubiquity of this signal makes it a common choice for psychological tests in both the clinic and laboratory.

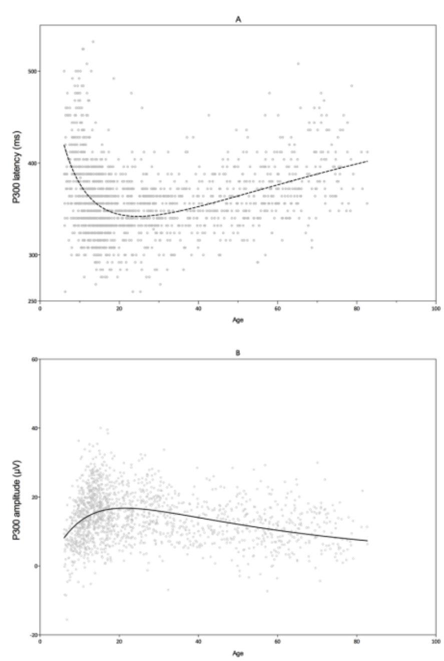


**Figure 18.** P300 latency and amplitude trajectories across the lifespan as obtained from the cross-sectional dataset. Dots represent scores from individual participants. From *From P300 Development across the Lifespan: A Systematic Review and Meta-Analysis*.[1] The latency and amplitude of the P300 response may vary as a function of age.

## Flowchart and Working

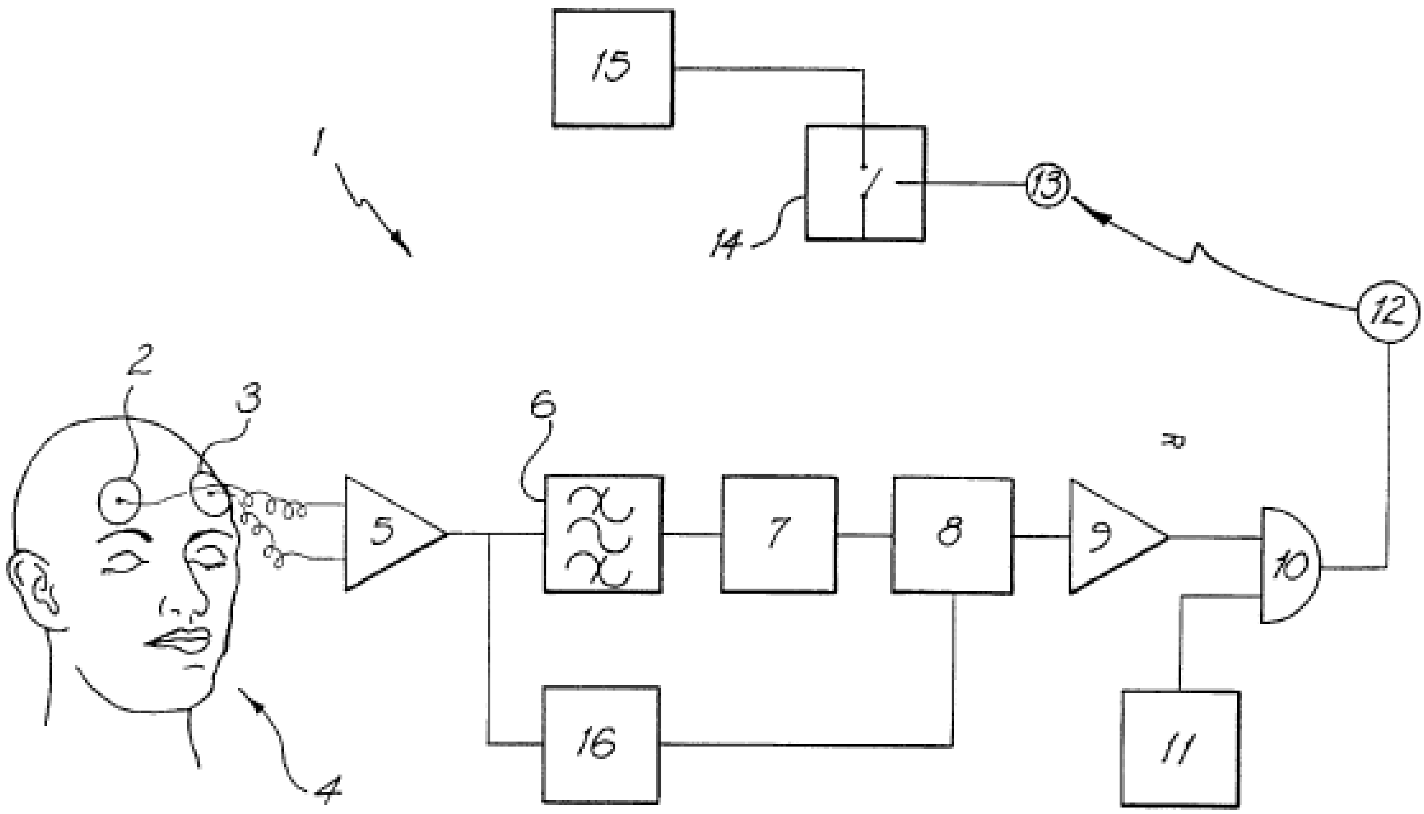


**Figure 19.** Block diagram of an EEG based activation System embodying the present invention

Referring to the figure 19, the system 1 comprises two conventional silver-silver chloride electrodes 2 and 3 configured in differential (bipolar) mode. The electrodes Smeared with conducting gel are pressed against the Scalp of a Subject 4, for instance, in the O1-T5 positions, as given by the international 10-20 position classification system. A differential EEG signal is produced and then amplified using an amplifier 5 with gain of 74 dB. The next stage consists of an analogue bandpass filter 6 centered in the alpha band, with a centre frequency of 10 Hz and a bandwidth of 2 Hz. The bandlimited signal is converted to DC using an RMS to DC converter 7.

A signal averager 8 follows the RMS to DC converter 7 to Smooth out the rapid variations caused by the aperiodic nature of the alpha activity. The averager consists of a signal integrator that delivers a ramping up output when an input signal is received in the pass-band of filter 6. When the input Signal is removed, the output of the averager slowly falls. FIG. 20 shows the amplified output of the Signal average 8 for three characteristic time constants T, namely where T is 1 Second, 2.2 Seconds and 4.7 Seconds. The rapid varia tions likely to cause Spurious Switching are not transferred from the input to the output of the averager 8. A 2.2 Second time constant offers an acceptable compromise between rapid Switching (less than 3 S) while effectively eliminating rapid variations at the output. The output from the averager 8 is further amplified by amplifier 9, having again of 34 dB, and is then presented to one input of a comparator 10. The other input to comparator 10 is connected to a predetermined DC threshold voltage 11. The threshold voltage V is between 0.5V and 1 V higher than the nominal Voltage at the other input of the comparator when a Subject has his eyes open. The noise immunity provided by the comparator 10 prevents Spurious Switching that might be caused by natural variations in the alpha Signal amplitude. The EEG signals generated in, for instance, the occipital temporal regions of the brain are continuously monitored by the apparatus described. When the signal amplitude at 10 Hz (bandwidth of 2 Hz) increases beyond the predetermined threshold Set by comparator 10, during eye closure, an infra-red transmitter 12 is activated. An infra-red receiver 13 responds by toggling a Switch 14 attached to an electrical appliance 15.

The Switch 14 is toggled only when the signal from amplifier 9 rises up above the predetermined threshold 11 and not as it falls below the threshold from above. It follows that the State of the Switch is not altered when a person opens his/her eyes.
Most EEG signals suffer from artefacts, which can be caused, for example, by muscle or eye movement, generally referred to as electromyograph (EMG) or electrooculogram (EOG) respectively. AS long as the spectral components of Signals that would interfere or corrupt the EEG spectrum, lie outside the 9 to 11 Hz frequency interval of interest here,

high order low or high pass filters can be used to attenuate the interference. EMG artefact has most of its energy concentrated above 15 Hz. Nevertheless, the artefact does affect the complete EEG spectrum. FIG. 19 shows a Switching protection module 16 connected between the output of amplifier 5 and the Signal averager 8, to address the problem of Signal artefacts.

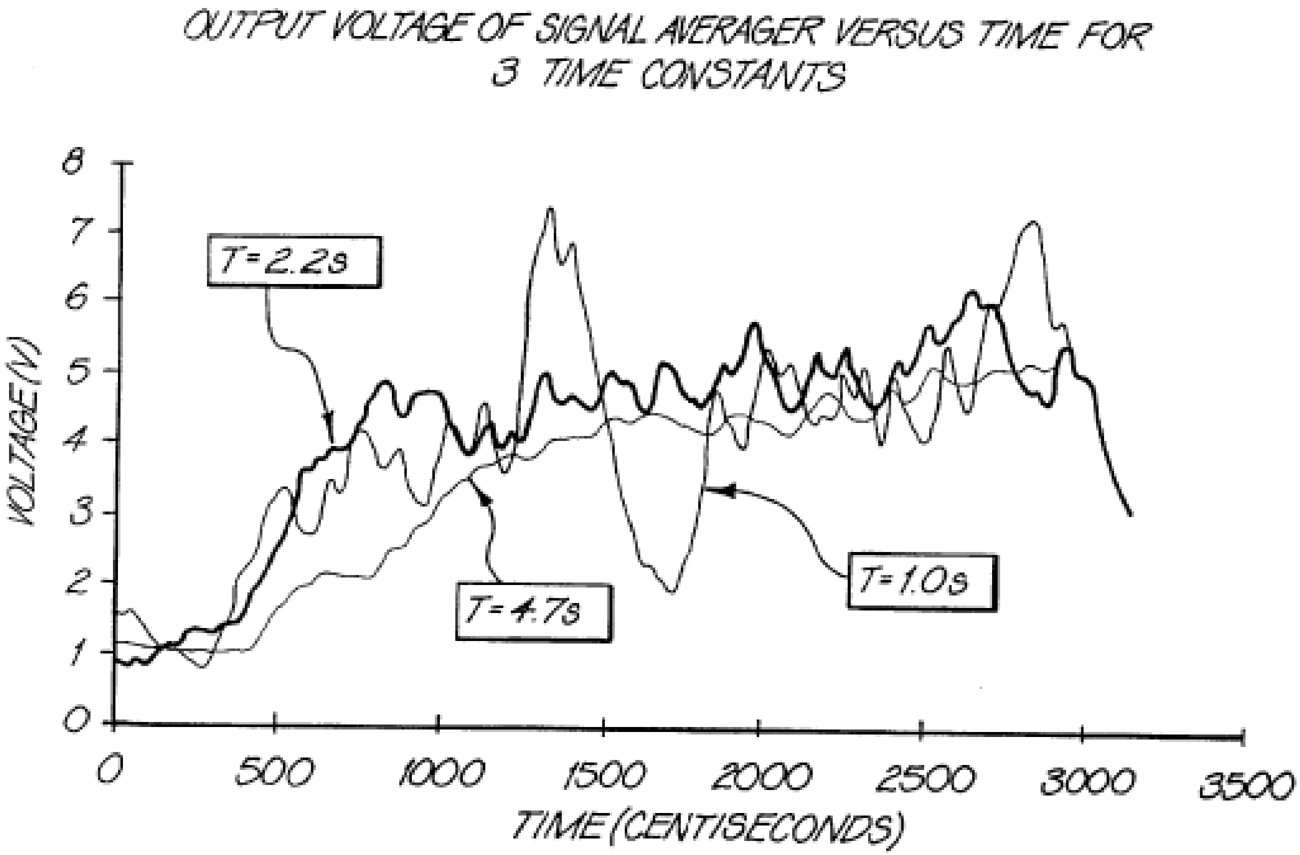


**Figure 20.** graph showing the amplified output of a signal averager within the system of FIG. 1, for three different time constants, 1 S, 2.2 S and 4.7 S;

The Switching Suppression module 16 monitors the Signal amplitude at the output of amplifier 5, at a frequency known to be dominant when interfering Signals, such as those due to EMG, occur. While the signal amplitude exceeds a predetermined threshold, the output of the comparator 10 is prevented from changing State. In effect the output is frozen until the amplitude of the noise component relaxes below the threshold level, at which time the comparator 10 is again responsive to changes in the EEG signal amplitude.

FIG. 21 shows the noise protection module 16 in greater detail. The output of the amplifier 5 of gain 74 dB shown in FIG. 1 is fed to a bandpass filter 17 with a center frequency of 28 Hz and a bandwidth of 2 Hz. The bandlimited signal is converted to DC using an RMS to DC converter 18. A signal averager 19 follows the RMS to DC converter 18 to smooth the signal. After AC to DC conversion and time averaging, the noise Signal is fed to one input of a comparator 20. The other input to the comparator 20 is set to a noise threshold value 21. The threshold value is chosen by trial and error So that it is effective in Suppressing Switching when EMG levels are large enough to cause Spurious Switching. When wideband noise exists, the amplitude of the 28 Hz component of the Signal Sensed by the electrodes increases. When the noise signal exceeds the noise threshold, the comparator 20 Switches States and in doing So forces the output of the Signal averager 8 appearing in FIG. 19 to go low. This effectively prevents the output of the comparator 10 in FIG. 19 from going high, thereby Suppressing further on-off toggling of an appliance or device 15. The output remains frozen until the noise Signal presented to comparator 20 drops below the noise threshold value. Experimental Results In order to establish the capability of the system, all experiment was conducted in which a male Subject was asked to Successively activate a Switch by closing his eyes.

The time taken between issuing the command and the Switch activation was recorded. The quiescent eyes open Voltage for the subject was 0.7 V and the Switching threshold of the comparator was Set to 1.2 V. The Subject was asked to remain as Still as possible for the duration of the experiment. FIG. 4 is a histogram of the results of one hundred Successive activations of the Switch. The histogram shows the frequency of the times taken to exceed the threshold and activate the Switch. In this experiment the minimum activation time is 1.3 Seconds and the maximum 3.2 Seconds. The mean-activation time is 2.0 Seconds with a Standard deviation of 0.4 seconds

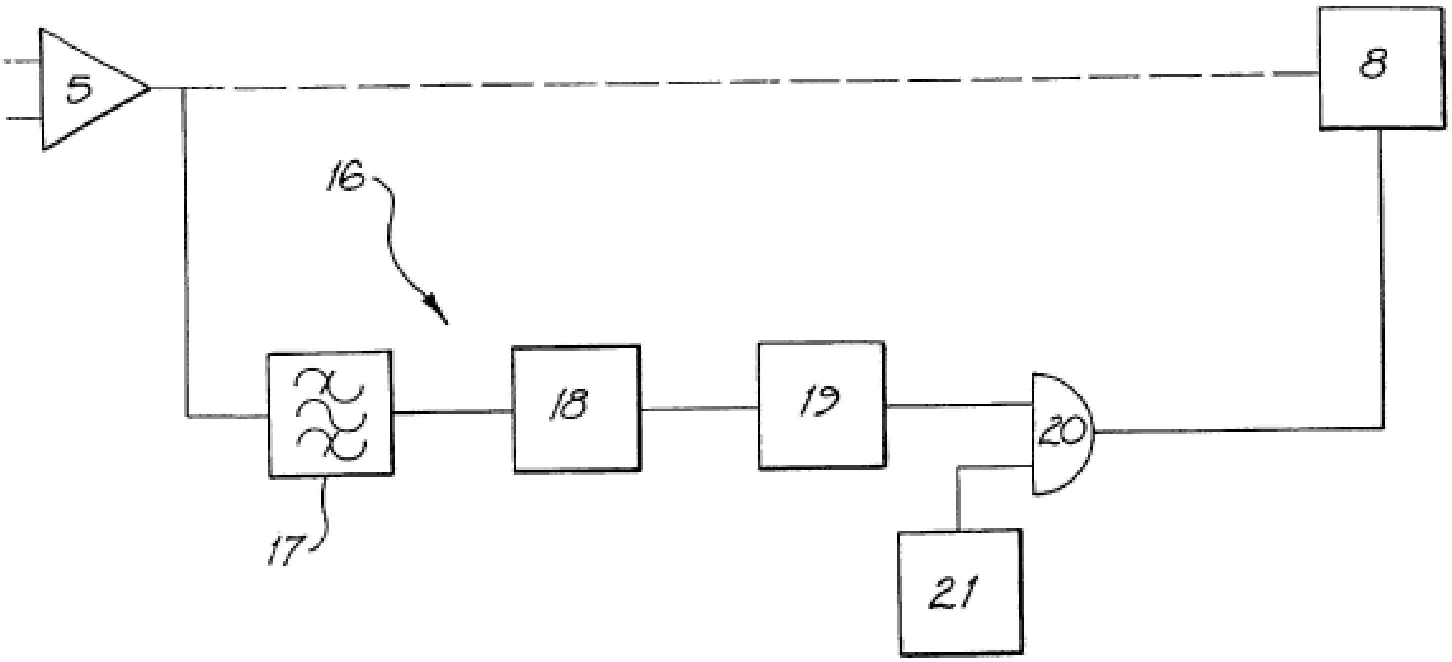


Figure 21. Block diagram of a noise protection module used with an embodiment of the present project

FIG. 23 shows the time for Switch activation as a function of trial number. Trend analysis of the data, which was gathered over a period of 30 minutes, suggests that, over the duration of the experiment, the activation time is marginally improved by repeated attempts to activate the Switch. The correlation between Switching time and trial number is -0.21, with the improvement Statistically Significant at the 5% level. It was observed during this experiment and others carried out Subsequently with other Subjects, that eye motion or blinking are not causes of Spurious Switching.

A longitudinal Study with this Subject was carried out over a period of 18 months to determine the quiescent Voltages. The quiescent eyes open Voltage, at the input to the com parator varied in the range 0.7 V to 1.1 V. The quiescent eyes closed voltage varied from 3 V to 4 V. This suggests that the comparator threshold Voltage for this Subject should be Set at around 1.6 V to 2 V.

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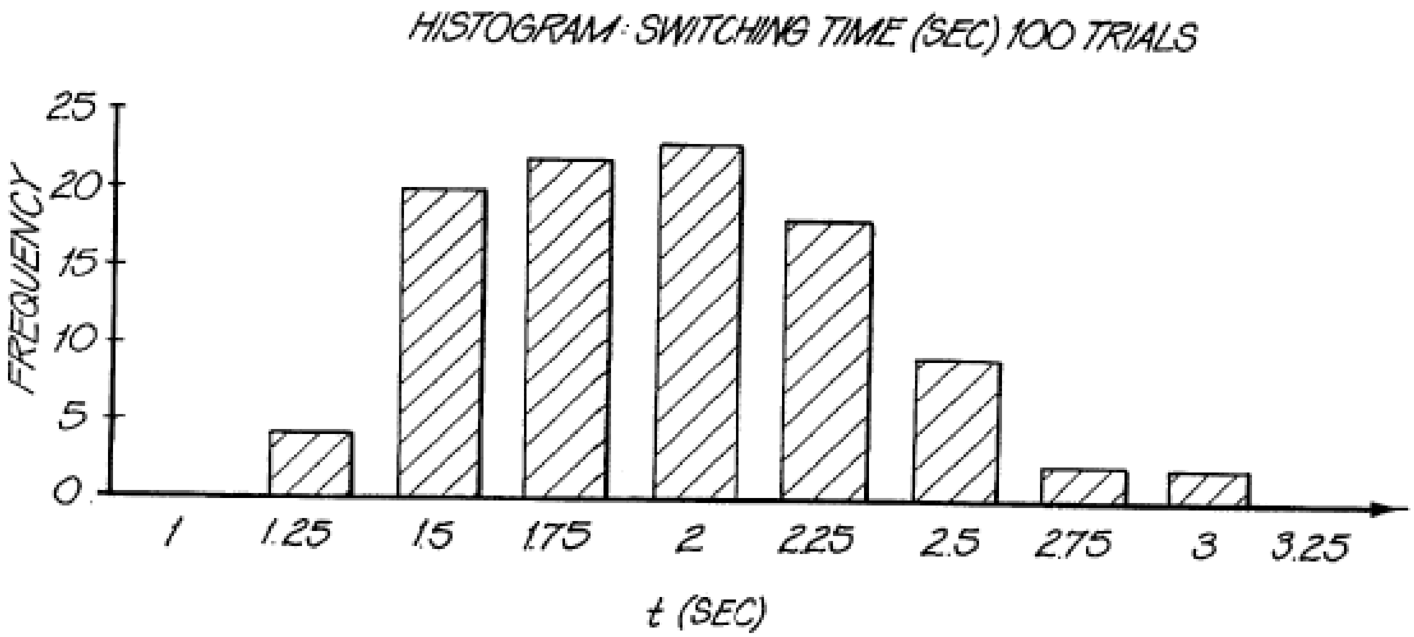



**Figure 22.** Histogram of Switching time in seconds in 100 Trials

The average time for Switching to occur after eye closure is related to the difference between the comparator threshold voltage, V., and the quiescent eyes open voltage, V. The mean time for Switching to occur can be considered as a function of V, where,

$$V = V_{th} - V_{qeo}$$

To a first approximation, the Voltage V and the time taken to reach that Voltage with the eyes closed t, may be related by:

$$V = V_{max}(1 - \exp(-t/\tau))$$

Where, V, is the maximum time averaged voltage above V. that a Subject can generate; and T is the time constant for the Voltage rise that depends on both the time constant of the Signal averager as well as the characteristic rise time of the alpha Signal amplitude upon eye closure.

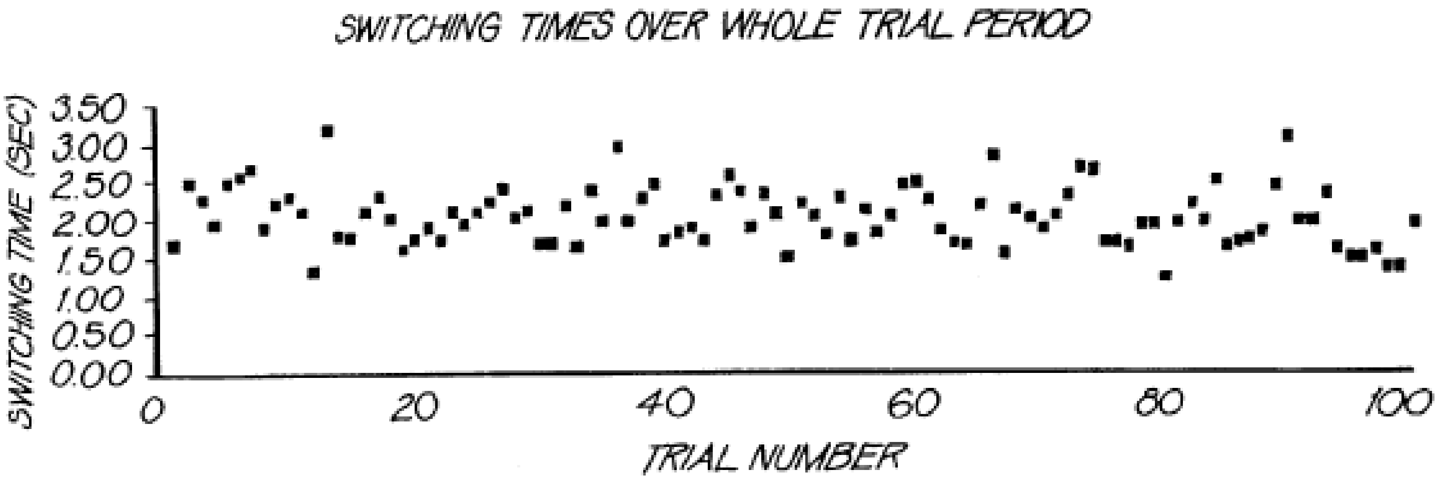



**Figure 23.** Switching Times over whole trials number graph

There is some delay, or offset, to between the Subject being instructed to close his eyes and the alpha Signal amplitude beginning to rise.

Rearranging Equation 1 and including the offset we get,

$$t=-\tau \ln(1-(V/V_{max}))+t_{offset}$$

Fitting Equation 2 to experimentally recorded data using a weighted nonlinear least Squares fitting routine gives:

$$\tau=(3.1\pm0.4)s,\ V_{max}=(3.16\pm0.9)V,\ t_{offset}=(1.52\pm0.19)s$$

For any preferred Switching time, t, it is possible to establish to what value of threshold voltage V, must be set for this subject by using equation 2 to find V. The threshold voltage V, is set to V+V. The effectiveness of the noise protection module 16 was established in two ways. First, a Schedule of movements and actions likely to cause Spurious Switching was devised. This consisted of a Sequence of 10 Second intervals of, for example, grinding teeth followed by remaining Still and followed by head nodding. Proper operation of the system was confirmed before and after the Sequence by the Subject remaining Still and activating the Switch through eye closure. Table shows the Sequence of actions as well as the occurrence (or otherwise) of Spurious Switching with the noise protection module both active and inactive:

SPURIOUS SWITCHING: OCCURENCE = 1, NONE = 0

| ACTION | SUPPRESSION OFF | SUPPRESSION ON |
|---|---|---|
| none | 0 | 0 |
| grinding teeth | 1 | 0 |
| none | 1 | 0 |
| nodding head | 1 | 0 |
| none | 0 | 0 |
| rotating head | 1 | 0 |
| none | 0 | 0 |
| yawning | 1 | 0 |
| none | 0 | 0 |
| rapid blinking | 1 | 0 |
| none | 0 | 0 |
| raising eyebrows | 1 | 0 |
| none | 0 | 0 |
| jiggling cable | 1 | 0 |
| TOTAL | 8 | 0 |

The threshold 11 for Switching on the system was set to 2 V. With the noise protection module active no spurious Switching occurred. With the module inactive, several false positives, Such as Switching not caused by eye closure, were recorded.

The behaviour of the system and the module was also assessed in a Situation closer to that which might be encountered in use, for example in an office environment. The Subject was asked to engage in normal behaviour for 15 minutes, that is, no defined tasks were prescribed. During this time the Subject Spoke, turned his head, wrote, and answered the telephone. With the noise protection module inactive, 34 false positives were recorded in the 15 minutes period. With the module active, no false positives were recorded in the next 15-minute period and the number of occasions the noise threshold of the module was exceeded was 77. It should be noted that not all artefacts large enough to trigger the noise protection module will necessarily cause Spurious Switching of the System.

It should be appreciated that, although the project has been described with reference to a particular embodiment, it could be embodied in many other forms. In particular it should be understood that the invention is not limited to merely providing a Single pulse output, and the ramping output of the Signal averager may be used to activate a Selective Series of outputs as it ramps through different levels.

Individual eye closed to eye open Signal variation ranges from 2:1 to 13:1, however, 3:1 is of Sufficient magnitude to permit an individual to effect proportional control over external devices by deliberately varying the magnitude of their EEG signal; that is, turn on, Speed up (or change channel), Slow down, and turn off. The Voltage generated upon eye closure (after amplification, filtering at 10 Hz, and averaging of the "raw EEG signal) is found to increase approximately linearly from about 1 V to 4 V. By setting other comparator levels between 1 V and 4 V, it is possible to offer multi-Switching options. A person can activate one of six options in around 10-12 seconds. The 10-12 seconds needed to Switch in the Six Option System is due to the cycling through the Six options. After eye closure, the Voltage increases to an upper threshold level at which point a Sequence of options is activated and presented to the person in a step by Step manner. The person now opens them eyes and waits for the device to be activated to be offered. When this occurs, the person closes their eyes and the Voltage increases until it reaches a lower threshold level at which point the desired device or appliance is activated. Typically, the upper threshold level will be set at 3 V and the lower threshold at 2 V. In order to test the effectiveness of this System, two persons (one male and one female) were required to Select an appliance from the Six options 30 times (random Selection of a fan, a television, a radio, a light, a computer and an air conditioner). The time taken to Select the option and the number of errors (selecting the wrong option) were recorded. Both persons were given a brief introduction and 15 minutes experience with the System before the trials. The first subject (male) correctly selected 27 of the 30 options in a mean time of 12 seconds per Selection (Standard deviation=2.1, minimum=8.5, maximum=16.3 seconds). The results demonstrate that repeated exposure improves the Switching skills involved.

Repeated practice should improve the error rate and reduce the time down to around 10 seconds, and the time could be reduced to around 5 Seconds to Select an option. It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the Specific embodiments without departing from the Spirit or Scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

What is claimed is:

1. An EEG based activation System for providing an activation for equipment, comprising:

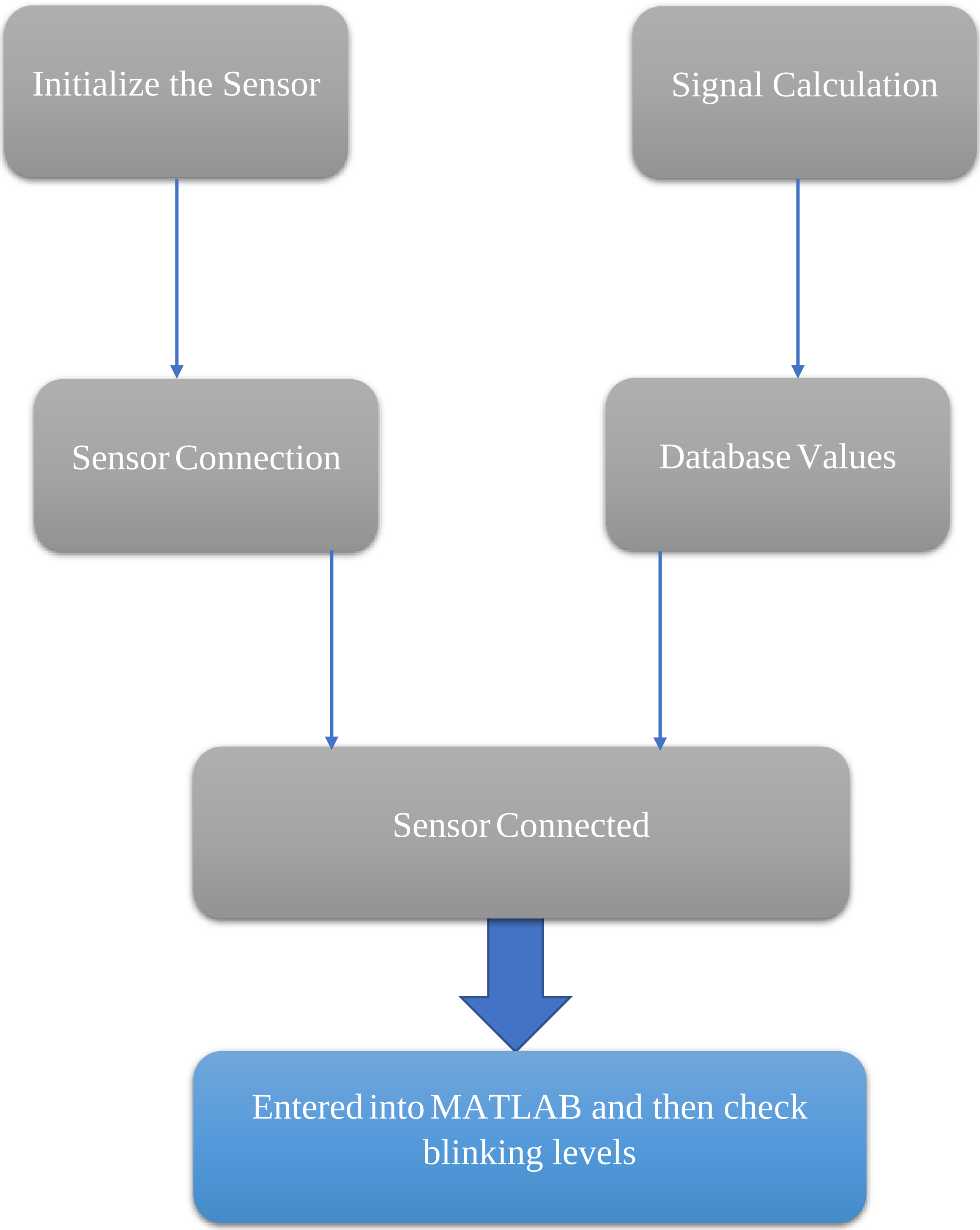
- An input port to receive electrical Signals from Scalp electrodes,
- an amplifier for amplifying the Signals received at the input port;
- a bandpass filter for filtering Signals from the amplifier;
- a signal averager for Smoothing Signals from the filter;
- a comparator for receiving a signal from the Signal averager,

  wherein the Signal averager integrates the Signals in a passband from the bandpass filter and provides a ramp ing output, the Signal averager has an integrating time constant of between one and five Seconds, and the comparator compares the Signal from the Signal aver ager with a reference and provides an output Signal that changesState whenever the Signal from the Signal averager exceeds a predetermined threshold in order to provide Such activation in response to changes in the electrical Signals received at the input port from the Scalp electrodes.

2. The EEG based activation System according to claim 1 wherein the integrating time constant is around 2 Seconds.

3. The EEG based activation system according to claim 1wherein the bandpass filter passes the Signals from the amplifier in the alpha-band, between 8 and 13 Hz.
4. The EEG based activation system according to claim 3 wherein the bandpass filter passes the Signals from the amplifier in the range 9 to 11 Hz.
5. The EEG based activation system according to claim 1 wherein the reference is derived through trial and error.
6. The EEG based activation system according to claim 1 wherein the ramping output from the Signal averager increases approximately linearly with time, and the System is adapted for multi-level Switching proportional control.
7. The EEG based activation system according to claim 1 further comprising a noise protection module receiving the electrical signals from the Scalp electrodes and extracting a noiseband Signal using another bandpass filter, the noise band Signal is averaged by the Signal averager, and used to freeze the output of the activation System when the averaged noise band Signal exceeds a predetermined threshold.
8. The EEG based activation system according to claim 7 wherein the noise band signal is between 27 to 29 Hz.
9. A method of activating equipment using the System of claim 1 comprising the Step of the Subject wearing the Scalp electrodes closing their eyes So that changes in the electrical Signals received at the input port from the Scalp electrodes cause a chance of State in the output signal to provide Such activation.
10. A method of activating equipment using the System of claim 1 comprising the Step of the Subject wearing the Scalp electrodes opening their eyes So that changes in the electrical Signals received at the input port from the Scalp electrodes cause a change of State in the output Signal to provide Such activation.
11. A method of activating equipment using the System of claim 1 comprising the Step of the Subject wearing the Scalp electrodes closing and opening their eyes

So that changes in the electrical Signals received at the input port from the Scalp electrodes cause a change of State in the output Signal to provide Such activation



# Hardware & Software Used

The Emotiv Insight is a sleek, multi-channel, wireless headset that monitors your brain activity and translates EEG into meaningful data you can understand. At some point, if your aim is to use this headset for research purposes, like me, you would want to be able to analyze the raw EEG data with ease. Furthermore, if time and Financial constraints are possible limitations in the course of your project, the need for a quicker and much easier way to accomplish this task exists. This document will explain how to record your EEG data in real-time, export it to EEGLAB and analyze the data accordingly. It stems from a research project that was done as part of the Biomedical Engineering Research Group (BERG) in the Department of Mechanical and Mechatronic Engineering at the University of Stellenbosch, South Africa.

**Required Facilities**

Apart from the laboratory space, the following tools were available to me and were used for the export and analysis of the data:

**MATLAB$^{R}$ :** This Mathematical Software will be used in order to stream and process the EEG raw data. General data-analysis will be executed using built-in functions, like EEGLAB.

**EEGLAB:** Interactive Matlab toolbox for processing continuous and event- related EEG data incorporating independent component analysis (ICA), time/frequency analysis, artifact rejection, event-related statistics, and several useful modes of visualization of the averaged and single-trial data. Since it is an open-source platform.

**EmotivR software:** The software pertaining to the EEG headset used in order to generate algorithms used for the feedback training. Extensions of this software, the Emotiv Xavier Testbench and Emokey, can also be used to capture real-time raw EEG data and send serial data.

# Preparation

Before you export EEG data, you should ensure that you are prepared and that you are aware of the steps involved to capture the EEG data in the first place.

The following may act as a checklist for you to read through in order to prepare for your recording session:

1. Emotiv EEG headset
2. Windows 7 compatible Laptop / Computer
3. Emotiv Xavier Controlpanel 3.1.19 (build 200): The Emotiv Control Panel is a software that allows the user to monitor the status and features of the Emotiv Insight. After cognitive detections during training

are mapped to keystrokes using Emokey, users calibrate their focus and training with each of four different driving commands.

4. Emotiv Xavier Testbench 3.1.19: Data collection will take place in real time, while the subject wears the Emotiv Insight. Emotiv Testbench receives EEG data packets in JSON format from the Insight's USB dongle.

The Emotiv Testbench runs as a background process on your computer and is responsible for directing headset data from the serial port to an open network socket. Any language or framework that contains a socket library should be able to communicate with it. Any EEG recorded data will then be exported to Excel compatible csv. format.

## Device Setup

### Battery Check

Before starting the recording of EEG data, the Emotiv Insight headset must be switched on and it should be veri_ed that the built-in battery is charged and is providing power. If the headset battery needed charging, the power switch must be set to the o_ position and plugged into the laptop / computer, usingthe mini-USB cable provided with the headset.

### Setting up the Device

The device can now be set up for each the user. The following steps should be followed before recording an EEG session:

**STEP 1:** Before putting on the EPOC Neuroheadset, ensure that each of the 16 electrode sockets are fitted with a sensor unit with a moist felt pad. If the pads are not already moist, wet them with saline solution before inserting into the neuroheadset using the procedure outlined above.

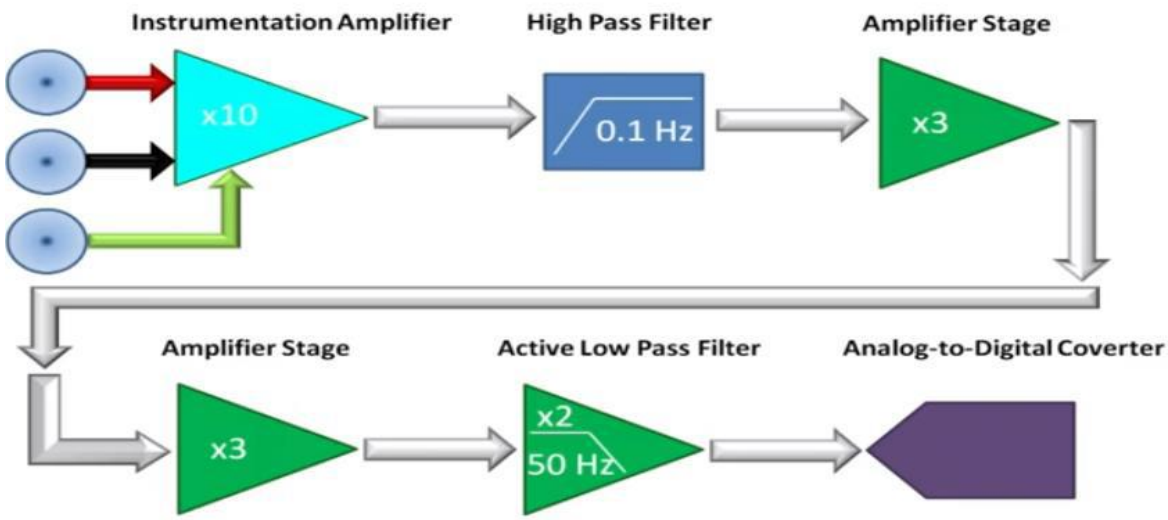
**STEP 2:** Switch on the EPOC Neuroheadset, and verify that the built-in battery is charged and is providing power by looking for the blue LED located near the power switch at the back of the neuroheadset. If the neuroheadset battery needs charging, set the power switch to the off position, and plug the neuroheadset into the Emotiv battery charger using the mini-USB cable provided with the EPOC Neuroheadset, or alternatively through a spare USB socket on your PC using a USBMiniB cable. Allow the EPOC Neuroheadset battery to charge for at least 15 minutes before trying again. A fully discharged neuroheadset will take up to 6 hours to reach full charge.

**STEP 3:** Verify that the *Wireless Signal* reception is reported as "Good" by looking at the *Engine Status* area in the EmoEngine Status Pane (described in Section 2.6). If the *Wireless Signal* status is reported as "Bad" or "No Signal", then make sure that the Emotiv Wireless USB Receiver is inserted into a USB port on your computer and that the bright LED and dim flickering data transfer LED on the top half of the receiver are visible. If the LED is blinking slowly or is not illuminated, then remove the receiver from the computer, reinsert it, and try again. Remove any metallic or dense physical obstructions located near the receiver or the EPOC Neuroheadset, and move away from any powerful sources of electromagnetic interference, such as microwave ovens, large motors, or high-powered radio transmitters. You may also attach the USB Transceiver to the end of a USB extension cable in order to position the Transceiver prominently in the space, away from potential sources of interference such as monitors and wireless routers.

**STEP 4**: Put on the EPOC Neuroheadset by gently pulling apart the headband and lowering the sensor arms onto your head from the top down, near the rear of the skull. Next, slide the neuroheadset forward until the sensors closest to the neuroheadset pivot points are located directly above your ears and as close to your hairline as possible. Adjust the fit so that the rectangular.

# Methodology

Human brain mainly works on electric signals transmitting all over the body to send the information in order to operate the body parts. Even while rotating eye ball body increases or decreases the resistance near eye area. This variation in electric signals can be measured using electrodes or the myoelectric sensors. By implementing these signals processor, we can interface different devices to control on demand. Hence proposed system is designed to control computer and hardware system using brain waves electric signals. Proposed systems will detection the variations in electric signal strength through voltage level near the eye area and generates a wireless radio frequency signals in order to control the home automation prototype model. By implementing this system, we can further extend it to bio enabled human body parts to control through brain waves. Electroencephalography (EEG) is the most studied potential non-invasive interface, mainly due to its fine temporal resolution, ease of use, portability and low set-up cost. But as well as the technology's susceptibility to noise, another substantial barrier to using EEG as a brain–computer interface is the extensive training required before users can work the technology. For example, in experiments trained severely paralyzed people to self-regulate the slow cortical potentials in their EEG to such an extent that these signals could be used as a binary signal to control a computer cursor. (Birbaumer had earlier trained epileptics to prevent impending fits by controlling this low voltage wave.) The experiment saw ten patients trained to move a computer cursor by controlling their brainwaves. The process was slow, requiring more than an hour for patients to write 100 characters with the cursor, while training often took many months. Proposed System will incorporate temperature sensor, fire sensor, motion (obstacle) sensor, Light detector sensor, Water sensor. These sensors are connected to the central system and once any of the sensors gets activated then system will send alert message. Multiple Sensor Based Home Security System is very practical. It can be used not only in the home environment but also in a business environment too. It can monitor the surrounds to not only protect our properties but our lives.




Besides, it can be highly customized to suit each one's need and preference. So Multiple Sensor Based Home Security System is very useful for us as well as other people. After successful implementation of the system it is expected that outcome of the system should be able to identify the human brain wave to control the home appliances with fast reaction and it is also expected that system should react at highest priority in case of critical conditions. The system will sense the signal from brain sensor of disabled person and follow the commands accordingly and he can comfortably operate or handle the home appliances.

Complete system can be monitored externally by the person using android system as well as alert signal will also be provided.

# Application/Scope

A concept on smart home application and development includes various implementation techniques and is never limited. Smart home systems are created based on analysis on client needs and budget to cater for the system. With technologies available today, efficient integration of this system could be achieved. Home automation, also referred to as smart home concept, it is not new to consumers. It encompasses the ability to control electrical and electronic devices at home remotely thus providing ease of access to home users. This concept may be applied in various manners to fit the requirement of a smart home. Now, advancement in wireless technology introduced new ideas such as Bluetooth and Internet linking; Wi-Fi, which has been slowly replacing the conventional wired technology which requires wire bonded interconnection between electrical devices. The main advantage of wireless interlinking includes diminishing the need of wires for connection.

Smart Homes, also known as automated homes, intelligent buildings, integrated home systems or domestics, are a recent design development. Smart homes incorporate common devices that control features of the home. Originally, smart home technology was used to control environmental systems such as lighting and heating, but recently the use of smart technology has developed so that almost any electrical component within the house can be included in the system. Moreover, smart home technology does not simply turn devices on and off, it can monitor the internal environment and the activities that are being undertaken whilst the house is occupied. The result of these modifications to the technology is that smart home can now monitor the activities of the occupant of a home, independently operate devices in set predefined patterns or independently, as the user requires. Smart home technology uses many of the same devices that are used in assistive technology to build an environment in which many features in the home are automated and devices can communicate with each other.

# Conclusion

Hereby, I conclude that Greater limbic system and cortical-cortical networks seem crucial in generating brainwaves. These systems cover the whole part of the brain and therefore are important in inducing various functions of the brain via "oscillations" or brain rhythms. Therefore, brainwaves (sinusoidal oscillations) can be further classified based on their frequency. These classified frequencies have different properties and gives a definite pattern for every activity. Monitoring those waves and working on those waves will help us to control the whole system of automotive network, resulting in better and non-mobilize control of the unit. The device is very helpful for the class of people who are totally unable to move they can even stay at home alone without depending on any one else to take care. The era of mobilization and self-dependency will rise again for those set of people using these devices.

Even the future prospect for these devices watches a novel and effective cause to be sustainable for the further development. These developments can include IoT in it which will enhance the range of these devices.

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