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FATIH UNIVERSITY
INSTITUTE OF BIOMEDICAL ENGINEERING

FREQUENCY ANALYSIS OF ELECTROENCEPHALOGRAPHY SIGNALS WHICH RECORDED FROM EPILEPTIC PATIENTS

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MSc. THESIS
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T.C.
FATİH ÜNİVESİTESİ
BİYOMEDİKAL MÜHENDİSLİK ENSTİTÜSÜ

EPİLEPSİ HASTALARINDAN KAYDEDİLEN ELEKTROENSEFALOGRAM SİNYALLERİNİN FREKANS ANALİZİ

MUHAMMED RUFAİ BATMANOĞLU

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BİYOMEDİKAL MÜHENDİSLİĞİ PROGRAMI

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Muhammed Rufai BATMANOĞLU, a **MSc** student of Fatih University **Institute of Biomedical Engineering** student ID520112015, successfully defended the **thesis** entitled "Frequency Analysis of Electroencephalogram Signals Which Recorded From Epileptic Patient", which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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Date of Submission: February 2016

Date of Defense: January 2016

To my lovely wife,

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January 2016 Muhammed Rufai BATMANOĞLU

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RESULTS AND DISCUSSION

LIST OF SYMBOLS

Hz	Hertz
μ	Mean
σ	Standart Deviation
Σ	Sum

ABBREVIATIONS

App : Appendix

D : Overlap

EEG : Electroencephalogram

N : Length of sliding window

Max : Maximum

Min : Minimum

PSD : Power spectral density

STD : Standart Deviation

WT : Wavelet transform

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SUMMARY

FREQUENCY ANALYSIS OF ELECTROENCEPHALOGRAM SIGNALS RECORDED FROM EPILEPTIC PATIENTS

Muhammed Rufai BATMANOĞLU

Biomedical Engineering Programme
MSc Thesis

Advisor: Asst. Prof. Şükrü OKKESİM

Epilepsy is the fourth most mutual neurological disorder and touches people of all ages. It generally means as seizure disorders. It can be categorized by changeable seizures and causes other health problems. A seizure is an unexpected, temporary deviation in the brain's electrical activity that produces disturbing signs. These symptoms can be collapse in attention or whole body convolution. According to the clinic and electroencephalogram (EEG) data, seizures can either be generalized or partial. Detection of seizure and normal condition from EEG signal take an important role for diagnosing the epilepsy.

In this thesis EEG signals are analysed by welch method between normal / healthy, seizure time and just before the seizure. That's why every patients EEG signals Power Spectral Density graphics and maximum power values are calculated. All results were statistically evaluated by student t -test. Maximum power of EEG signals, 17 number channels results we obtained for normal and seizure are giving the significant statistical result. Channel 1 and 23 are also statistical significant for normal and the onset moments ($P < 0.05$). Still there was no standard EEG signal analysis method for seizure detection in clinic. In this thesis analysis the EEG signal for seizure detection result can be helpful for researchers in the clinic work.

Keywords: Epileptic Seizure, Power Spectral Density, EEG Seizure Detection.

ÖZET

EPİLEPSİ HASTALARINDAN KAYDEDİLEN EEG SİNYALLERİNİN FREKANS ANALİZİ

Muhammed Rufai BATMANOĞLU

Biyomedikal Mühendisliği Programı
Yüksek Lisans Tezi

Danışman: Yrd. Doç. Dr. Şükrü OKKESİM

Epilepsi en çok karşılaşılan dördüncü nörolojik hastalıktır ve her yaşta insanda bulunabilir. Toplumda bilinen adı nöbet hastalığıdır. Nöbet çeşitlerine göre kategorize edilebilir ve farklı sağlık sorunlarına yol açabilir. Kişiyi rahatsız eden üreten nöbet beynin elektriksel aktivitesinde beklenmeyen geçici anomalidir. Bu semptomlar algıda ya da tüm vücut konvulsiyonunda çöküntü şeklinde olabilir. Klinik ve EEG verilerine göre nöbet genel veya bölgesel olabilir. EEG sinyallerinden normal ve nöbet anlarının tespit edilmesi Epilepsi tanısının konulmasında önemli rol oynamaktadır.

Tez çalışmasında normal/sağlıklı, nöbet anı ve nöbet anının hemen öncesi anlarına ait EEG sinyallerinin maksimum güç değerlerinin arasında farklılık olup olmadığı araştırıldı. Bu yüzden her bir kişiye ait EEG sinyallerin Güç spektral yoğunluk grafikleri elde edildi ve maksimum güç değerleri hesaplandı. Sonuçlar t testi ile istatistiksel olarak değerlendirildi. Elde edilen sonuçlar normal ve nöbet anları için 17. Kanaldan alınan EEG sinyallerinin maksimum güç değerleri arasındaki farklılığın istatiksel olarak anlamlı olduğunu göstermelidir. Normal ve onset anları için bu durum 1. ve 23. Kanallar için geçerlidir.($p<0,05$). Klinikte EEG sinyallerinden nöbet tespitinde kullanılan bir yöntem henüz bulunmamamktadır. Bu tez çalışmasında elde edilen sonuçlar EEG analizi ile nöbet tespiti çalışmalarına katkı sağlamaktadır.

Anahtar kelimeler: Epileptik nöbet, Güç Spectral Yoğunluğu, EEG nöbet tespiti.

CHAPTER 1

INTRODUCTION

Purpose of the Thesis

Epilepsy is a group of neurological diseases which is called epileptic seizures. The cause of epilepsy is unknown, although some people develop epilepsy as the result of brain injury, stroke, brain tumors, and substance abuse [1]. In epilepsy, the human neuronal activity becomes irregular that affecting in the aware of attitude, feeling, motion and sensitivity. Worldwide nealy 50 million people suffer epilepsy or Epilepsy related diseases [2, 3].

Epilepsy was come from Latin and Greek word which connotation “to seize upon” and one of the antique diseases that have seen the since 40000 years [4, 5]. In the 20th century knowledge about epilepsy is developed widely and very fast. For almost 40 years many studies were done to examine the detection of non-seizure, onset seizure and seizure conditions by using Electroencephalogram (EEG) signals. The EEG is a characteristic signal that containing knowledge about the condition of the brain. The analyses of the wave may contain useful information about the condition of the brain [6, 7]. Whatever, the human eye wount be able to detect them. Besides, since bio-signals are highly particular, the symptoms may appear at random in the time scale. Therefore, the EEG signal parameters, extracted using computers, are highly useful in diagnostics.

The purpose of this study is to detect the epilepsy disorder from the EEG signals. To achieve this goal we are going to detect epilepsy disorder patients EEG signals in three different situations (seizures moment, just before the seizure, normal state before the occurrence). Features are comparing to each other to get a statistical differences between this three conditions. This work discusses the effect on the EEG signal in this three condition by analyses the EEG signal. Results may give us opinion about the seizures moment, just before the seizure and normal state before the attack. All signals were collected from the Shoeb’s [4, 12] group recorded pediatric EEG signals and

created open source databank. Signals provided from open source: 21 patient’s EEG signal were examined. Power spectral density analysis was applied directly to the raw signal.

CHAPTER 2

2.1 THE MEDICAL BACKGROUND OF EPILEPSY

The word epilepsy first comes from by the Greek verb epilambanein, meaning to be seized, to be overwhelmed by surprise. Also a Greek physician Hippocrates wrote a book about epilepsy around 400BC. In that book he proved that epilepsy was a brain defect. In his book he wrote that epilepsy affected people have very prophetic powers and that was the curse from the god. In the past and todays behaviors have been empirical, typically reflecting the prevailing views of epilepsy. Some ancient history can help us to determine the origin of epilepsy. In past it was always found in the different corner of the world. . At the beginning of fifteen century epilepsy idea are more clearly but people had very strange idea. Like in in ancient Mesopotamia were recognized to “the hand of Sin,” the god of the moon even in The Hammurabi code, dated 1780 B.C. dictated that people with epilepsy could not marry [7,8].

In the 1930’s the first epilepsy analyzing method was invented by Hans Berger by using the EEG application and he proved that epilepsy origin was in the brain fact. Twelve years later the methods was developed. In 1985 epilepsy drug was invented by Jan, ET [9] Al. Now day’s different types of drugs and advanced technology are used to recover these diseases. Also people are very concern about this type of diseases.

2.1.1 The Human Brain

In our body all functions are controlled by brain. Its cover a huge quantity of information in an important capable way. Practically many people can do it without any trouble. Our body all functions are controlled by it as like: Breathing, heart rate and disease also fall asleep. Even with of numerous difficult responsibilities we can achieve it correctly without awareness and there are also positive effects that we have to conscious: in road we can see all condition of the road as like traffic jam also using statistics from feet, legs and hands, figure actions we can switch the way and speed of driving. Calculation to these we can pay attention music, sing a song or speaking with somebody on the mobile. So, in what way ensures our brain switch such a composite

multitasks at once? The answer is very easy. That the human body brain differences the big responsibilities into reduced ones. In our sample big task is driving car and smaller parts are achieved doings during driving the car like: sighted, moving, hearing testing and etc. Persons reduced parts also can be split into lesser tasks. So one part of human brain analyses sighted though, additional pars identify them. By responsibility that fragments of intelligence specify on some particular jobs. Another way we can say, if one part of brain injured, other parts of brain may possibly not perform proper actions. For example, at the back side of our brain has occipital lobe and damage to this lobe can cause blindness. Conversely, that damage is not affected the other part of body like hear or moving. Since the big duty: Seeing; divided into diverse sections in the intelligence, anybody who have lost one feature of vision like aptitude to see colors or to identify faces recognition, can still able to do other compartmented errands. We can simply conceive somebody's expression by enquiry their noises without sighted their expressions.

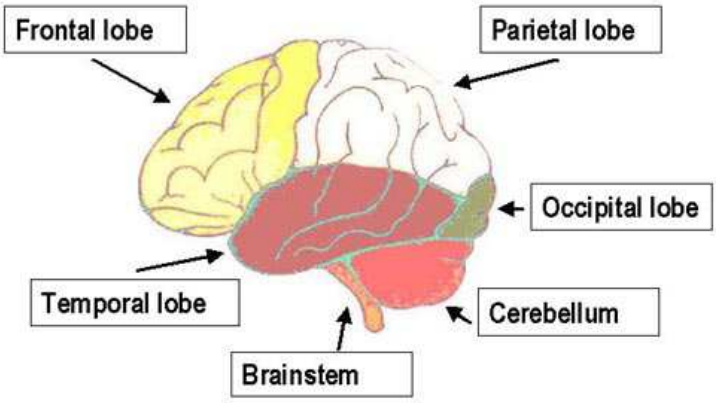

Figure 2.1. Major regions of the brain [5]

In human brain have very exact sections that are compulsory for essential actions for life. These are brainstem this part is attaches the brain and backbone cord as shown in Fig-2.1 and take a role in organizing numerous simple purposes such as breathing, eating heart rate and sleeping. The Cerebellum in Latin means "little brain" play key role in motor control and also in some other cognitive functions like fear and pleasure response, focusing. The Limbic system which is very complex system, occupied in two sides of the thalamus just under the right side of Cerebrum. It is not a discrete organization him self but the combination of different structures from telencephalon, diencephalon, and mesencephalon the limbic system takes role in

regulating motivations, emotions, and movement and also for memory. The diencephalon is also called Interbrain. It located between cerebrum and brain stem. The diencephalon has 4 different components:

I. Thalamus,
II. Subthalamus,
III. Hypothalamus
IV. Epithalamiums

Which take a role in directive of instinctual actions. At last Intellectual cortex is also named grey substance and covers the main part of the brain mass and lies over and around most of the other brain constructions. It receipts role in rational, observing, and creating and sympathetic language.

2.2 The Structure of a Neuron

For Information receiving and analyzing processes the human brain uses Conventional Electrical signal. But the Electrical signal itself are only symbols which do not imitate their real world representation and our important and necessary task is decoding their meaning [20]. Like other organs of body, brain is also composed of billions of cells. In the Nervous system there are two distinct classes of cells: neurons and glia. Unlike other cells of body, brain cells are geometrically is different.

A neuron is also the difference from other cells because of its property of electrically excitable. Human brain has contained around 100 billiard neurons and each nerve cells connection with other 50000-250000 neurons and also other sensory receptors, and muscle cells. They can process and transmit electrical excitation via electrical signals or chemical signals. The interactions between neurons enable people to think, move and feel emotions. While there are ten thousand specific types of neurons, generally there are three kinds of neurons:

1-Motor neurons: for conveying motor information.

2-Sensory neurons: for conveying sensory information.

3-Interneurons: for conveying information between different types of neurons.

Typically neurons has 4 main components: the cell body (soma), dendrites, axons, and presynaptic, or axon, terminals [10].

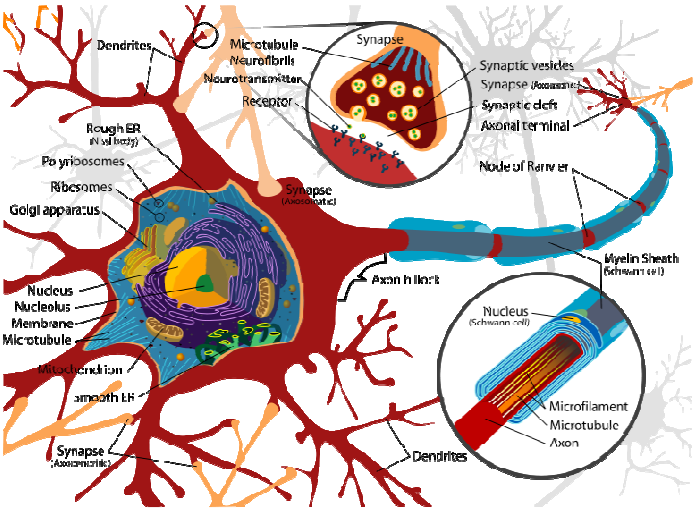

Figure 2.2: Complete neuron cell diagram [8]

2.2.1 Action Potential

The action potential is either an immediate increase or a decrease in the electrical cell membrane potential for a short moment. The action potential occurs caused by ion exchange which passes through the nerve cell membrane and it is a temporary change in the cell membrane transferred along the axon. It is generally started in the cell body and continues in a normal direction. The cell membrane is “depolarized” by producing a vertical attack, or it becomes positive. After the vertical attack, the cell membrane is repolarized, or it becomes negative. The action potential of most nerve cells continues 5-10 ms. The velocity of the action potential changes between 1-100m/s. the action potentials can be started by lots of different types of stimulus (chemical, electrical, optical, baric, and tactual). For example, the nerve cells in the central neuro system are activated chemically. In order for this stimulus to create an action potential, it should reach the threshold. Otherwise, it leads only to a local electrical defect and the action potential does not occur. Only when the stimulus reaches the threshold, an action potential is created and it starts to move from the nerve cell. The sharp point of the action potential occurs by opening of the Na^+ channels. The Na pomp produces both Na and K gradients. Each of them is used for producing the action potential. Na is more outside of the cell than the inside. Excitable cells have special Na^+ and K+ channel gates which can be opened or closed according to the cell membrane voltage. The open Na channel gates permit positive Na to pour inside the cell. It leads to depolarization and creates a vertical attack [12].

The processes are four steps:

1. The Na^+ channels are opened when the nerve cell dendrites receive a stimulus and if this opening is able to make the inner potential increase from -90 mV to -40 mV, the process continues.
2. After arriving to the threshold, more Na channels are opened. The Na^+ flow increases the inside of the cell membrane to about 50 mV. This process is called depolarization. Then Na^+ channels are closed and K+ channels are opened. Because of the fact that K+ channels open very slowly, the depolarization time gets full. When both channels are opened at the same time, it makes the system neutral and prevents the production of the action potential.
3. When K channels are opened, the cell membrane repolarizes itself towards the resting potential. Repolarization generally makes the resting potential -90 mV. This is called also as "hyperpolarization." The hyperpolarization prevents the nerve cell to take another stimulus during this stage or at least prevents it to reach the threshold. Another importance of hyperpolarization is that it guarantees the signal to continue in a mere direction.
4. After hyperpolarization, Na^+ and K+ pomps makes the cell membrane turn its resting potential -90 mV. In order for a nerve cell to receive another stimulus, it requires only1- 2 ms. During this stage, the action potential cannot be produced.

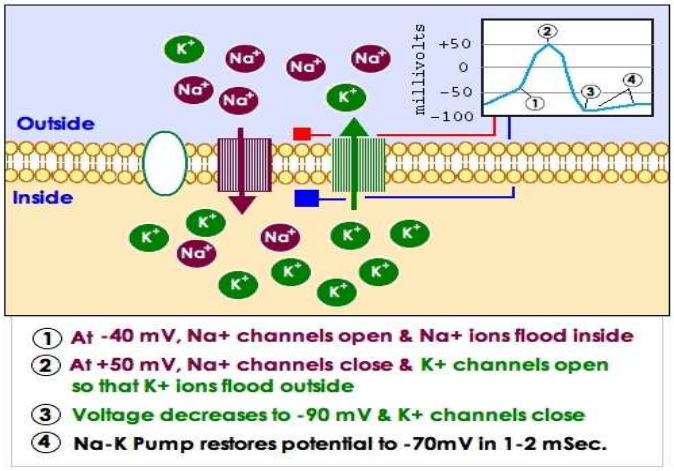

Figure 2.3: Action Potential [14]

2.3 Epilepsy Syndromes

Normally there are various types of epileptic syndromes. It is essential to think of that epilepsy is not an only illness it's a cluster of positions. To recognise of epilepsy conditions all should study wisely because any time it can be occur like occurrence time and situation, age at first time it happen, genetic family history. For more sure there are CT and MRI scan text can give more material. Experts classify seizures by in what way much of the brain is attack [13,14]. There are:

Focal seizures – when same small division of the brain is affected.

Generalized seizures – when extreme all of all the part of the brain is artificial. In the area of appropriations do not suitable into those groups these are known as random seizures.

2.3.1 Partial seizures

There are two chief types of partial seizure.

1. Simple partial seizures: This category of seizures are completely aware all the system through. Sign model are mutual bizarre feeling that is title into the belly an irritation feeling in arms also very quick solid sensation of anxiety or favorite feeling or trembling in part of the body. These seizures are infrequently documented as "notices" it can be a sign that extra kind of seizure is on its method [15].

2. Complex partial seizures: These types of seizures are happened when people lost their common sense of consciousness and won't be able to consider of at all occurred later final the seizure. The signs of a multifaceted partial seizure regularly take in untruthfully unequal and unforeseen physical behavior's, as like as: mouth flagellation, imprint their shots, creation always noises, cutting at clothes, insignificant with objects, positive an ignorant state, devastating or tolerating.

2.3.2 Generalized seizures

In the world there are total six types of general seizure.

- **Absences**

These types of seizures are called petit mal, classically affected by broods, it also happened in children. The reason of existence to find awareness of their locations, classically for up to 15 instants. The separate will appearance to stare vacantly into space, though some people will enthusiasm their sanities or blow their entrances. The

separate drives consume no memory of the seizure. Time off can happened frequent periods a day. It might disturb a child's show at school, and can be dangerous if they happen at a serious time, such as trip a full highway [16].

- **Myoclonic Seizures**

These types of seizures origin of ropes, centers or slight scheme to vibration or twitch,it also traditional an electrical shock. This are usually last for a little second, and you will typically last awake throughout it’s occur. Myoclonic shakes frequently occurred in the first few times after developing up and can occur in combination with other types of generalized seizures.

- **Clinic Seizures**

These origins the similar category of jolting as myoclonic jerks, except the signs will last longer, normally up to two minutes. Damage of awareness could also happen.

- **Atonic Seizures**

Atonic seizures cause of overall your controls to fast reduce, so there is an accidental it may failure to the crushed and there is a hazard for damage.

- **Tonic Seizures**

Tonic seizures source of all our muscles to arbitrarily development hard that can bad you lose reliability and drop over. As like atonic seizures, there is a threat of destruction.

- **Tonic-clinic Seizures**

Tonic-clonic seizures additional appellation is seizures, it has used to be documented as outstanding mal, have two phases. Our body will initially change stiff and then arms and legs will originate jerking. Missing consciousness and nearly many people will wet themselves. The seizure usually precedes a few notes, but can last little time. This type of seizure is what most people think of as an epileptic fit[17].

2.3.3 Global epilepsy rate in the world

In the world information about the epilepsy of certain disease population and help to development of the health organization. Occurrence is the proportion of population which had certain illness to the entire concerned population in given period. Occurrence

is the rate of occurring new illness in a given period in a concerned population. In the world the occurrence and incidence trainings had been held. Giving to the Who Epilepsy Atlas 2010, epilepsy affect 50 000 000 of peoples in worldwide [18]. The epilepsy percentages are more in the developing countries rather than industrialized countries and also social and ecological changes could be key factor but the important change is not detected between racial differences. In the figure we can see the world wide epilepsy map.

Some studies in the world occurrence rate of epilepsy is 8.2 per 1000 people and it means that at present 6 million people only in Europe affected by the epilepsy and 15 million people will have epilepsy at least once in their full life [19]. Also the occurrence of urban and rural states of Turkey had been done and the crude prevalence rate in rural place was 8.8/1000 and in urban areas was 4.5/1000 [20] and generation occurrence of epilepsy in rural state of Istanbul had been calculated and the rate was 8/1000 [21] and also the prevalence of epilepsy between children was again 8/1000 [22]. Ratios are different in different countries. Also age familiar occurrence rate also have been studied for dozen of ages and range from 18 to 69 [23-26]. The graph of occurrence to the exact ages for Europe and comparison for the global had been plotted in Figure 2.5

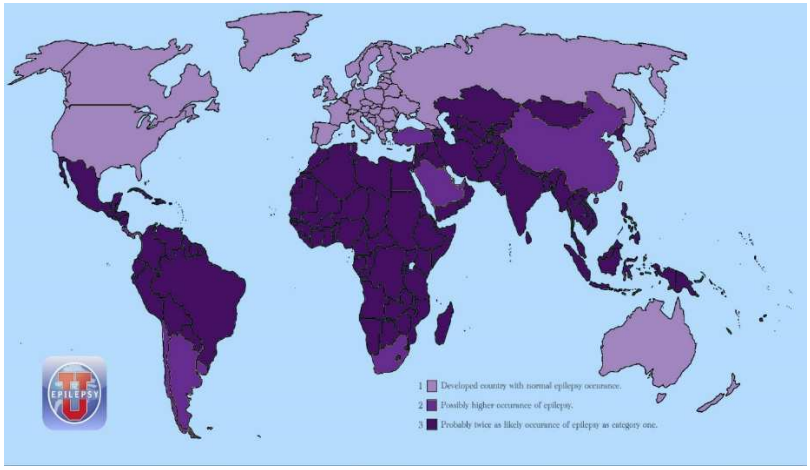

Figure 2.4: Global epilepsy rate population in WHO regions and in the world [27]

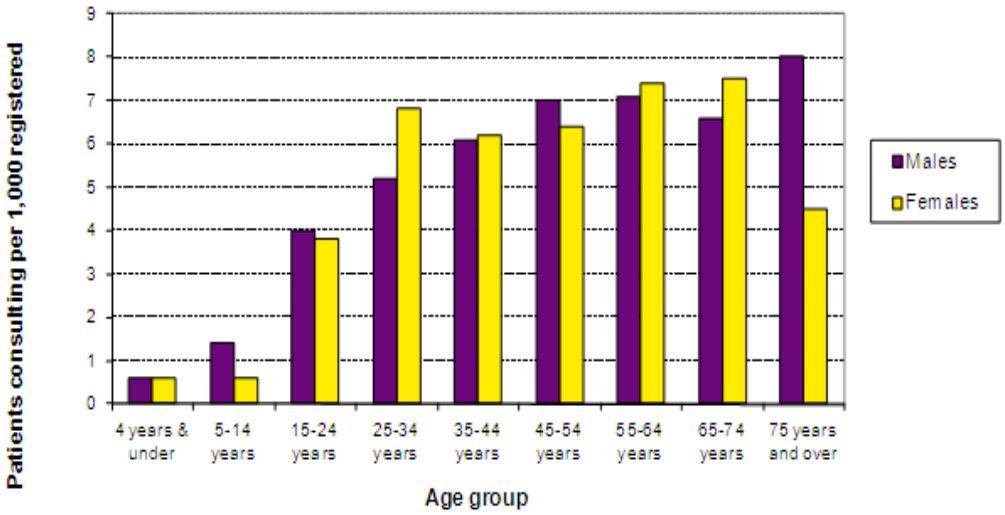

Figure 2.5: The age specific incidence of epilepsy in Europe [28]

As we can see in our lifetime the incidence is higher in only in two stages: Childhood and elderly. There is an indication lessening in children and increasing in elderly people. And also the occurrence rate of epilepsy in female is less than males. These data show that the seriousness of epilepsy in worldwide.

2.4 Electroencephalography

The brain usually produces small electrical signals that created from the brain cells and anxieties which send messages to each other. That electrical signals movement of the brain can be notable and documented by the electroencephalograph (EEG) machine. Hans Berger, who was a neuropsychiatrist, first invented the EGG device in 1929 of Jena in Germany. He defines the graphical signal image of the electrical currents produced in the brain. Ended of 1957 the EEG conductors, amps, and output procedures were established.

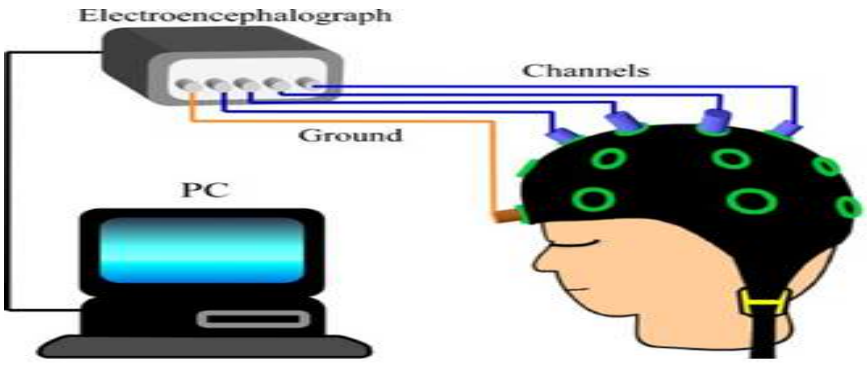

Figure 2.6: EEG signal analysis [29]

It is a non-invasive technique that measures by the surface electrodes .The EEG test is simple without pain and not harm full for body. When EEG recording are occurred it doesn't make any extra electricity into the human body or brain. An electroencephalogram (EEG) is an experiment that detects electrical activity in your brain using small, flat metal discs surface electrodes attached to the scalp [30,31]. Our brain cells communicate via electrical impulses all the time even in the sleeping time this electrical impulses potential differences between those electrodes are recorded in a processor and outcome of the result are given us important information about the conditions of epilepsy. An EEG is one of the main analytical experiments for epilepsy. An EEG may also performance a part in detecting other brain illnesses. Now, EEG application has different setups, processer storage celebrations, and generalised software can be producing an electrical map of the brain.

CHAPTER 3

MATERIALS AND METHODS

Demographic information about patients and disease, measurement system that used to recording signal and signal processing methods were explained. Total 22 subjects are counted in this thesis, the procedure of thesis, and the physiological signals that were examined in the thesis, the measurement system that used to collecting signal and signal processing methods was explained in this chapter.

All EEG signals in this study were delivered from open source database [1,14] which data collected at Children Hospital's Boston. It covers EEG signals which collected from Pediatric subjects with unyielding seizures. For describing their seizures and examination requirement for surgery interpolation, the subjects withdrawal from anti-seizure medication and checked for several days

3.1 Subjects information

Gender	**Male : 5 Female : 18**
Age	10.5 ± 5.47

Table 3.1. Subject Information.

23 different pediatric EEG signal package collected from 22 pediatric patients. Each Signals package represent with numbers. The data packet 21 obtained from the same patient numbered data packet 1 but 1.5 year later. The subject information is given the above Table-3.1.

The material and analyses of the EEG signal are very complex. The EEG complexity creates in the complex neural classification. Usually, the impulsive EEG is categorized as a linear stochastic procedure with great parallels to noise. EEG signal processing have some special properties such as:

- Noisy and pseudo-stochastic: The EEG is voltage difference is nearly 10 to 300 μV, that's why this signal can be affected easily by different artefacts as like electrocardiogram or electrooculogram ,electromyogram or other motion noises. Also EEG recording time EEG device can make some extra noise or signal. The EEG displays a great degree of uncertainty and non-stationarity.
- Time-varying and motionless: EEG is not a motionless procedure. It differs with the functional conditions. The waveforms could contain a fixed sinusoidal waves, unequal spikes, or Spindles. In peak neurotic situations, such as epilepsy seizures, the EEG may possibly to display unmistakable originality or nonstationary. In exercise, EEG as a fixed process concluded a fairly short period (~3.5 s for monotonous spontaneous EEG [33].
- High nonlinearity: old linear simulations of EEG signal processing are playing important characters in EEG investigation and analysis, EEG is a nonlinear procedure. In EEG this nonlinearity is dependent on time and state [34].

3.2 Electroencephalogram Signals

The circulation of EEG signals is same to a random procedure. A sequence of numerical procedures is established to calculate the EEG signals in different domains, such as time including, frequency, or time-frequency. One degree analyses the info of EEG signals in those three domains. There are a method Entropy is to measure the order or disorder of a time series. For this method different calculation are done by using various signal parameters. The most important parameters are power, frequency, amplitude, time domain, time frequency. From 9 to 42 .edf files included in each data package or case (chb01, chb02, etc.) from single subject. The 10 or less second gap during non-measuring time had been occurred due to the hardware limitations. In some cases this gap was much more than 10 seconds. For privacy of the subject protection, Protected Health Information (PHI) had been replaced with related information without losing their meaning in .edf files. Recorded dates had been replaced but the time relationship in each case was not changed.

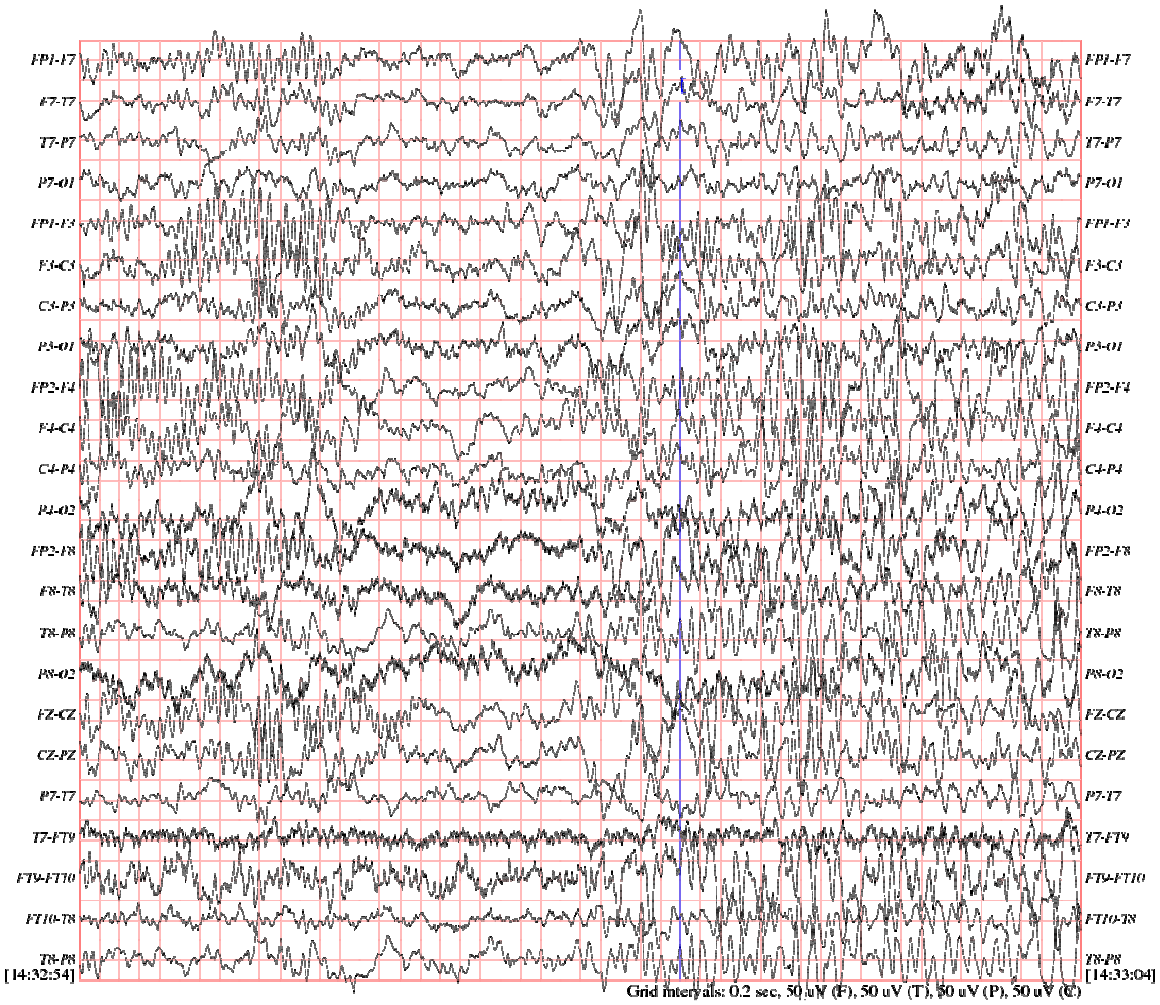

Figure 3.2: patient EEG signals [1]

Generally edf files cover 1 hour EEG signals, but sometimes as like chb10 contain 2 hours EEG signals and chb04, chb07, chb09 and chb23 contains 4 hours EEG signals. Generally in these cases seizures were too short. Signals collected with 256 Hz sample rate with 16-bit resolution. Expect a few cases with 24 and 26 channels, most recordings contain 23 channels. This source contained total 664 edf recorded files and 129 edf files contain between from one and four seizures. The standardized international 10-20 EEG system and nomenclature had been used.

Impulsive EEG records have some universally standard 10-20 structure is usually used. The electrodes are positioned on the surface of scalp in this system as shown in Fig-4.3 .1A, 3.1B and 3.1C.Reference points: Nasion and Inion used for causal orientation points. In the crosswise and median planes, from this reference points the skull boundaries are restrained. So this border divided into 10% and 20% intervals for

Electrode locations. Other three electrodes also placed equidistant from the points like in Figure 3.3.

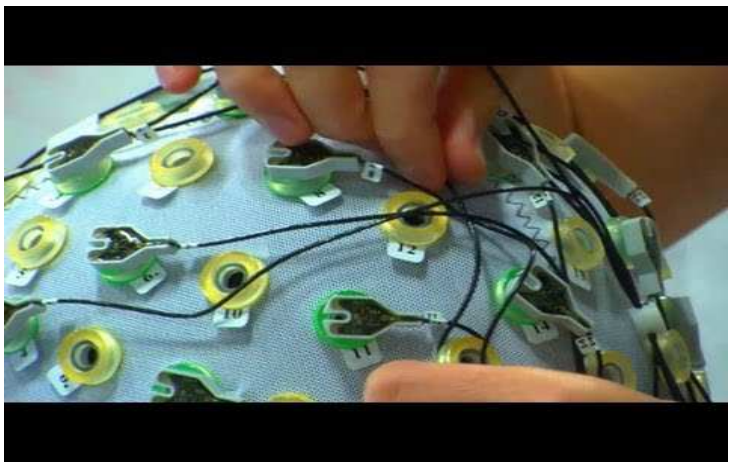

Figure 3.3: The Standardized International 10-20 System of EEG electrode position [30]

The purpose of the EEG electrodes placements is to get right EEG signals from the scalps. All electrodes are connected in an EEG device. From that device signals are going to a personal computer. In computer we defined the EEG signals from different peak frequency and give an output results. In clinic according to the results doctor are decided the patients conditions.

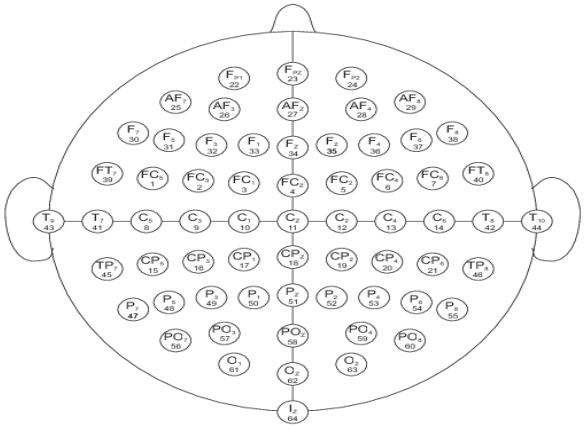

Figure 3.4. The international 10-20 system seen from location and nomenclature of the intermediate 10% electrodes, as standardized by the American Electroencephalographic Society [25].

3.3 Channels in EDF Files

In the EEG measurement, 2 kinds of measurements as bipolar or unipolar electrodes can be used. Bipolar: the potential difference among two pair of electrodes is measured As Shown in Fig-3.3. Unipolar: the potential difference between each electrode and neutral electrode (Reference) or Potential difference between each electrode and average value of all electrodes as shown in Fig-3.4. In these recordings first method-Bipolar measurement had been used. In this thesis we are using only 4 channels from the EDF files. All channels name are given bellow.

Channel number	Position
1	FP1-F7
2	F7-T7
3	T7-P7
4	P7-O1
5	FP1-F3
6	F3-C3
7	C3-P3
8	P3-O1
9	FP2-F4
10	F4-C4
11	C4-P4
12	P4-O2
13	FP2-F8
14	F8-T8
15	T8-P8
16	P8-O2
17	FZ-CZ
18	CZ-PZ

19	P7-T7
20	T7-FT9
21	FT9-FT10
22	FT10-T8
23	T8-P8

Table 3.2. Electrode placement.

In this chapter we will briefly explained the signals had been collected from 23 different channels from different parts of brain. Some of these channels could simply achieve from noise and some of them did not much. All studied three different areas of brain's channels to finding the most penetrating to the seizure:

- **Frontal central Channels**
  - ✓FP2-F4. Channel Number: 9;
  - ✓F4-C4. Channel Number: 10;
- **The right frontal and posterior Channels**
  - ✓FP2-F8. Channel number: 13;
  - ✓F8-T8. Channel Number 14;
  - ✓T8-P8. Channel Number 15;
  - ✓P8-O2. Channel number 16;
- **The central Channel**
  - ✓FZ-CZ. Channel number 17;

Establish that the most prominent activity region among them was frontal central channels, second one was central channels and third one was central and posterior channels. Conversely they are cast-off diverse method. Signals from total four channels: two from areas described above and other two from frontal and occipital regions would inspected for noticing the best channel. The examined channels are:

- ❖Channel 1: (Frontal Channel)
- ❖Channel 10: F4-C4 (Frontal Central)
- ❖Channel 17: FZ-CZ (The Central Channel)
- ❖Channel 23: (Occipital Channel)

This four channels from 4 different patient EEG had been observed.

3.4 Electroencephalogram Acquisition

The recording of EEG signal is very difficult task because it's very hard to catch the clear and useful signal from the brain. All process must be done very carefully. A clear signal can be provide us good acquisition. That's why Brain mapping modelling are very important for the electrode position on the scalp. EEG signal recording techniques are described in the bellow.

- ❖Electrode and head stage,
- ❖ Pre-processing and quantitative EEG
- ❖Data or results storage

The primary EEG signal recording process was very massive and composite. Extra major difficulty was signal can only verified in the EEG work room of a medical centre. But now a day's EEG data recording and signal processing are quite easier because of super computer and other electronic device.

Small metallic discs are used as electrodes for EEG recordings. The EEG electrodes are situated on the scalp in superior brain charting locations. In the scalp those places are accepted by the recordist who procedures the head by means of the Global 10/20 arrangement. Electrodes are originated in numerous systems and sizes depended on the provisional task or new method, as like as superficial, needle, sphenoid, subdural strip electrodes, and depth conductors. Now a day, normally surface electrodes are used for static clinical EEG signal recording. Capacities of electrodes settlement are among the certain stationary points on the head each points distance are 10% and 20%. Separately all electrode site is considered with a memo and a digit number. The letter symbolizes to the zone of brain unique the electrode. Even numbers indicate the right side of the head and odd numbers are signifying the left side of the head. Various type of electrodes that can be used. The most common are small discs of stainless steel, tin, gold or silver covered with a silver chloride coating. These usually have a lead attached. Other methods contain of a cap in which the electrodes are already fixed.

3.4.1 Amplifier

Usually amplifier is using to increase the currentor voltage of a signal. Generally little bit Weak-signal amplifiers are recycled principally in signal receivers. A weak-signal amplifier is calculated to arrangement with very small input signals, in some

circumstances calculating only a few Nan volts. This amplifiers must make negligible interior noise while collective the signal voltage by a great issue. The condition that signifies the efficacy of a weak-signal amplifier is compassion, sharp as the quantity of microvolts of signal response that makes a positive ratio of signal output to noise output. The method of EEG acquisition system is very developed. The EEG signal parameters are:

Frequency = 0.5–100.

Amplitudes = 10–300 μV.

To get the higher efficiency of EEG signal some particular features are required:

- Noise performance should be very good.
- Current leakage should be very small
- Common mode rejection ratio(CMRR) will be very high
- Input impedance will be very high
- Power source rejection ratio should be high
- Also isolation mode rejection ratio will be high

For digitized EEG signal recording, the digital noise, sensitivity regulator, and filter cut-off frequency control should also be considered.

3.4.2 Filtering

The routine EEG is usually sampled at a frequency of nearly 250 Hz, which in theory covers the band of 0 to 125 Hz. The EEG recording systems there are many artefacts that should be needed to very special filtering. Power line artefacts range are 50 to 60 Hz. EEG signal frequency bands are very different from to each other.

- Delta frequency 0.5–4 Hz
- Theta frequency 4–8 Hz
- Alpha frequency 8–12 Hz
- Beta frequency 12–30 Hz and
- Gamma frequency are grater then 40 Hz

3.4.3 EGG Data Storage

In previous time EEG was recorded with lettering liquid ink on a paper or kept on an analogue tape. But now day's researches found various storage and data analyses method. New generation EEG data storage system has totally computer based. First to last data collection, analogue digital converter and data analysis and data storage, data simulation everything were done by software. The digital storing is more appropriate for computer-based EEG study and following archiving and recovering.

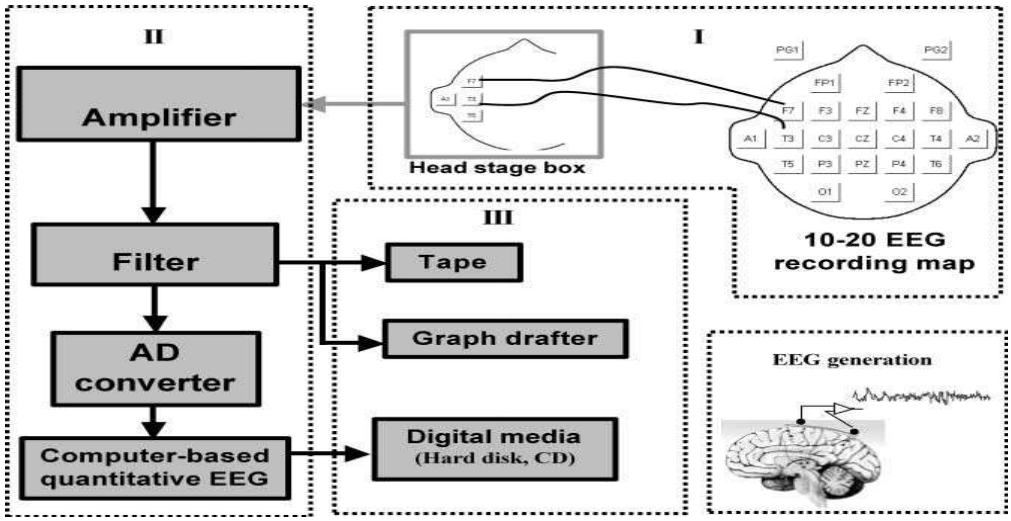

Figure 3.3 Diagram of EEG recording and quantitative system [32]

3.5 Electroencephalogram Pre-processing

EEG signal have several noise and artefacts. They are interfering the EEG signal. Sometimes it's really hard to identify the real signal of EEG from other signal. To get a good EEG data, signal needs a useable pre-processing to delete those extra noise and artifacts. The neural motion is at the close of between 10 - 100 μV. Nearly 10 to 300 μV neural motions can make a noise factors inside of the EEG signal by different internal and external way. There are some common factors that can make the noise and artefacts such as body motion artefacts of the patients through the EEG copy. As like talking or blinking or mouth and head movement. Also muscle artefacts can affect the EEG signal. Pulse wave or heartbeat, frequently appearing when wide inters conductor distance or the electrode pairs with the ear as the condition are used. Interferences contain the power line (50/60 Hz), TV locations; radio pager, mobile or telephone ring, or cardiac pacemakers, which frequently can be avoided by a score filter and by correctly preparation and protecting the footage structure.

3.6 Fast Fourier Transform

Fourier analysis is founded on the idea that real world signals can be approached by a sum of sinusoids, each at a changed frequency. The more sinusoids comprised in the sum, the better the estimate. The FFT, like greatest computer algorithms, creates an exponential Fourier series, instead of a Trigonometric Fourier Series. The two series are equal but that the magnitude produced by the exponential series is half the value of the trigonometric series. Most request software mechanically pays for this and presents the magnitude spectrum as a trigonometric series [35].

EEG signals aren't periodical and deterministic signals. In other words EEG signals' chosen in any time period arithmetical actions are not same exactly. Because these signals don't repeat themselves and they cannot characterize EEG signals found from all of a single mathematical expression recording time [36].

Some information can be gained from time domain in signal processing but it will be need frequency analysis for more information. For that reason the Fourier analysis can be exemplified to the used method. Fast Fourier Transform (FFT) is a frequently used method to identify saved signals' frequency spectrum during the contraction performed at certain times [36]. But EEG signals are non-stationary signals in terms of frequency, amplitude and wave form [37].

Several methods have been settled that enable a computer to calculate the Frequency Spectrum of a signal. The first step in all bags is to change the signal to a set of statistics for the computer to use. This is done by sample the signal at a regular intermission so that a table of values is created. Each sample value is detached from the next by a motionless period of time.

The number of points gotten and the time between examples combine to control the length of time we look at the signal. The resulting meanings apply:

Fs = sample rate in Hz

dT = 1/fs = interval between samples

N = number of samples taken

T = N x dT = total time period

f1 = 1/T = frequency of the first harmonic in Hz

So it's certain that by means of classic methods as the Fourier Transformation (FT) isn't suitable to process these signals. Short Time Fourier Transform (STFT) was developed in order to be applicable FT to the non-stationary signals. In STFT the signal is separated into small windows and each of the dived windows are acknowledged as stationary. The only problem in STFT is to achieve a good dissolvability in time-scale, in frequency scales the dissolvability is at poor heights at the end of the STFT realized with time-scale and thin windows. On the other hand when the window is extended it is experiential development in frequency dissolvability, in time-scale the dissolvability reductions. For that reasons the power spectral density (PSD) was applied to obtain feature from the EEG signals to make real the well-organized examination. PSD, which includes scale concept providing the time-frequency determination, is quite suitable for non-stationary signals [37]

Time-frequency analysis classifies the time at which different signal frequencies are present, generally by manipulative a signal range at fixed intervals of time. Generally time-domain analysis does not deliver any frequency info. But if the signals are EEG that are verify by time, the spectral analysis that deliver the frequency particulars, but unluckily, it's really hard to understand that what times the frequency changes happen. As defined above, the EEG signal is active, time variable, sometimes transient and frequently no stationary and sometimes despoiled by noise. In training, there was no need to know the frequency mechanisms but in this study it's very important to know about it. So the time-frequency analysis is mainly appropriate for this type of solution. Time-frequency analysis has been positively used to analyses the EEG signal analysis. There are various trace the seizure cause signal. The easiest technique uses a short time FT (STFT) to increase the time resolution focus on some specific wave rhythms. The spectra can be probable by another method.

3.7 The Power Spectral Density for Spectral Analysis

EEG frequency analysis generally called power spectral analysis. Power spectral analysis one of the useful applications for EEG analysis. The simple knowledge is to teach the EEG in numerous classic no overlapping frequency bands. In below various frequency band are showing.

Delta wave range is between 0.5 to 4 Hz.

Theta wave range is between 4 to 8 HZ

Beta 1 wave range is between 12 to 18 HZ

Beta 2 wave range is between 18 to 30 HZ

Sometimes gamma bands is greater the 30 Hz

Sometimes brain research are worked in the in event-related and cognitive brain research .The clinical specialist takes the EEG by the topographies or sizes of waves in each incidence band. However the surgeons couldn't calculate the spectrum, generally

Power spectral density function (PSD) demonstrations the strength of the variations (energy) as a function of frequency. Another way we can say that it shows at which frequencies variations are strong and at which frequencies variations are weak. So we can that Power Spectral Density is the Fourier Transform of the autocorrelation function of a signal. First compute the auto correlation function and then compute its Fourier Transform. The unit of PSD is energy per frequency (width) and we can get energy within a specific frequency range by integrating PSD within that frequency range. Computation of PSD is done directly by the method called FFT or computing autocorrelation function and then transforming it. The significant feature of this examination method, which is used frequently in analysing of bio signals, PSD is the most common function used in frequency domain analysis of the EEG and described as the Fourier transformation of autocorrelation function [36]. The Fourier transformation of a signal can give with equation below.

$$x(w) = \int_{-\infty}^{\infty} x(t) e^{-jwt} dt \tag{3.1}$$

Autocorrelation function R_x (t) was given in equation (3.2).

$$R_x(\tau) = \frac{1}{T} \int_{0}^{T} x(t).x(t+\tau) dt \tag{3.2}$$

The PSD of a signal is obtained to be get the Fourier transformation of the signal's autocorrelation function (Equation 3.3).

$$\Phi_x(w) = \int_{-\infty}^{\infty} R_x(\tau).e^{-jwt} d\tau \tag{3.3}$$

The Power spectrum shows power density in the “w” frequency and events the signal’s power constituent in each incidence. All of the frequency constituents’ PSD essential which are make the signal, deliver to be intended the total power (Equation 3.4).

$$P = R_x(0) = \frac{1}{2\pi} \int_{-\infty}^{\infty} \Phi_x(w) dw \tag{3.4}$$

The most well-organized way to compute a segment’s PSD would be gotten from a long-term data recording is increase the segments which reduction the data loss at least with the window functions [37,38]. For that reason in the study (by) 256- Hamming window and for each calculation 128 sample are made by instable.

CHAPTER 4

RESULTS

In this chapter, maximum points of PSD signals that computed ch1, ch4, ch10 and ch 14 EEG signals also statistical comparsion were done .The results of only test are given.

EEG signals recorded from 22 pediatric patients (5 males, ages 3–22; and 17 females, ages 1.5–19). Recording procedure was done at the Children's Hospital Boston. The owner of the dataset, Ali Shoeb, allows the analysing of the EEG signals for any research as seen in Physionet [4 - 12].

All patients have intractable seizures. This property is intensfy the valuableness of the data because up to 40% of epileptic patients have this kind of "uncontrolled," "intractable," "refractory," or "drug resistant seizure [37]. Intractable seizure do not controlled with special medications/drugs. Drug resistant or intractable seizure occur when a paitent do not get any beneficalness from the drugs that have special effect to prevent the seizure. Neorologist have to decide the drug types according to seizure type, tolerated by the person, and tried alone or together with other seizure drugs. Neorologist decided to the seizure types according to the following factors

4.1 Signal Processing

All the data processing and statistical analyzing was carried out using in-house programs developed under MATLAB R2009b Software (MathWorks Inc., Natick MA, USA). In here we selected sampled rate is 256 H

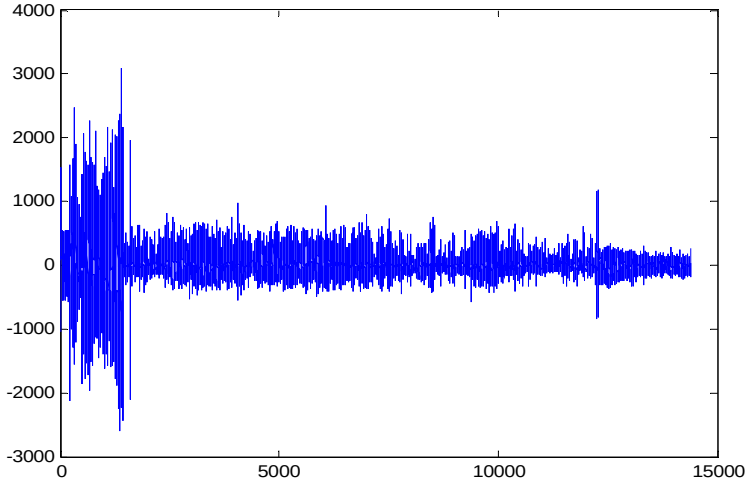

Figure 4.1 Raw EEG signal recorded from FP1-F7 Channel 1.

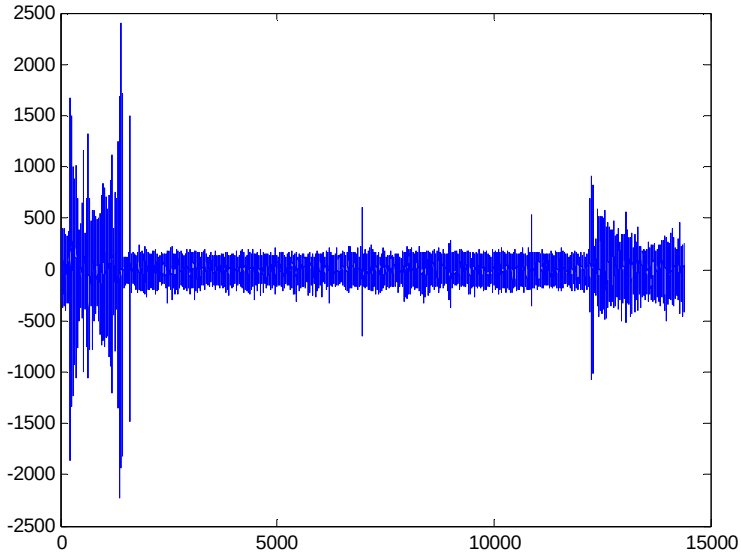

Figure 4.2 Raw EEG signal recorded from F4-C4 Channel 10

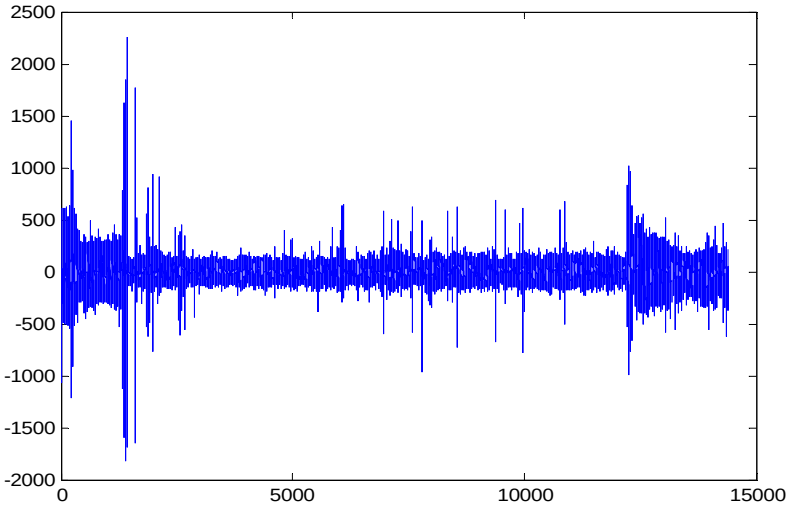

Figure 4.3 Raw EEG signal recorded from FZ-CZ Channel 17.

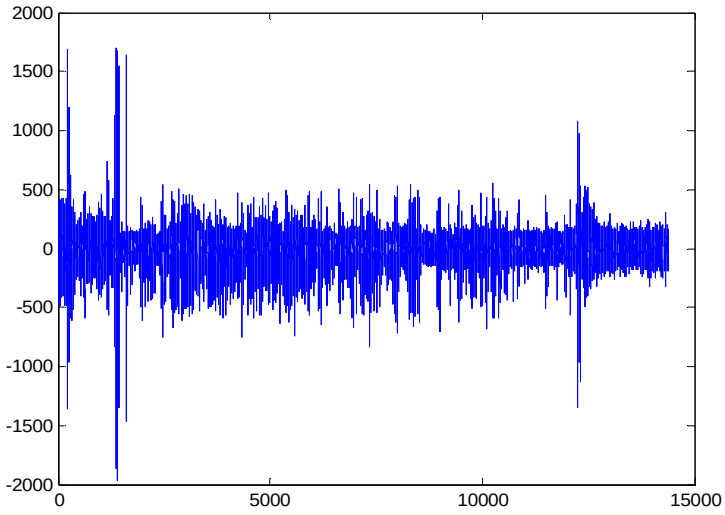

Figure 4.4 Raw EEG signal recorded from T8-P8 Channel 23.

Welch Method for Spectral Analysis of EEG Signals. The FFT based Welch method is defined as a classical (nonparametric) method. We made the spectral estimate with the Welch's Method, [42]

In this chapter, results are evaluated. Nonlinear EEG analysis is still at its beginning. So the results we obtained so far are promising and emphasize the high value of nonlinear EEG analysis techniques for both clinical practice and basic knowledge. To achieve this goal we observed the Epilepsy disorder patients EEG signals in three different situation first one is seizures moment then second one is just before the seizure and third one is normal state before the attack. Features were comparing to each other to get a statistical

differences between this three conditions. The differences between onset, normal and seizure were detailed briefly. All other signals and their file name, duration of recording are given it table 4.1. For a patients EEG signal more than one .edf file. And for each one are different codes were given as Chb01_03 which stay about 1 hour between 13:43:04 and 14:43:04 and raw EEG data was plotted in Fig 4.2.

The neurologists were examined each .edf file and detected seizure event . For example in Chb01_03 the seizure event occur between 2996 seconds and 3036 seconds.This area has quite changed as in amplitude and frequency in seizure port in EEG reflect high variation both amplifier and frequency as seen figure Fig. 4.5

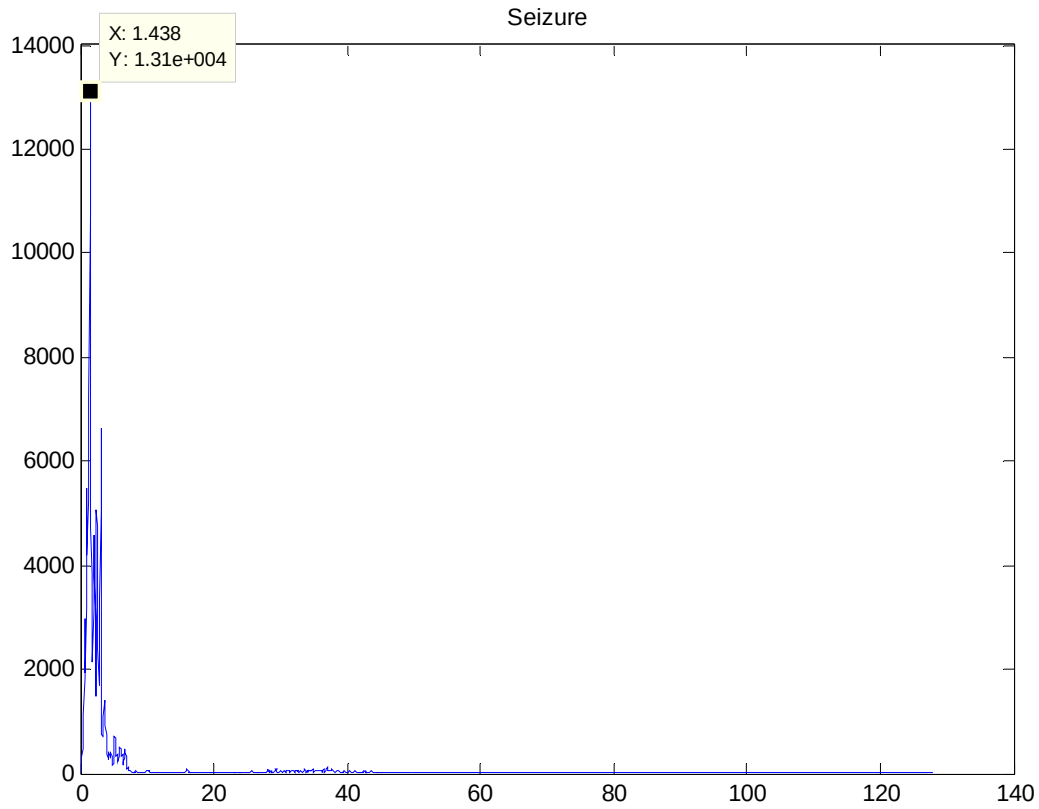

Figure 4.5 PSD graph of Seizure

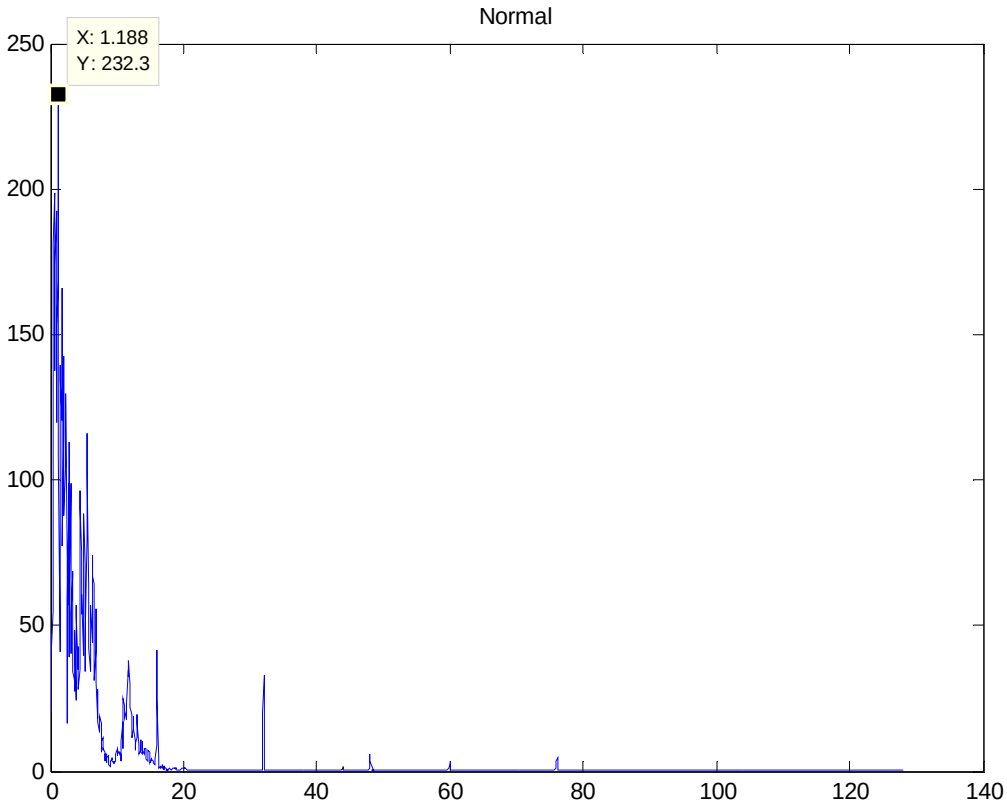

Figure 4.6: PSD graph of Normal

Then we applied welch method on each stage and compute maxium value of PSD as seen in Fig 4.6. Since each patient had several seizure included EEG, the only one measurement for each patient are selected one by one. Max value of PSD for each stage was given in table 4.1.

Table 4.1: Max value of PSD signal each selected channels

Peak Freq												
Patient No	Normal				Onset				Seizure			
	Ch 1	Ch10	Ch17	Ch23	Ch 1	Ch 10	Ch 17	Ch 23	Ch 1	Ch 10	Ch 17	Ch 23
1	1.2500	1.1250	1.1875	0.9375	1.1250	1.1875	1.1250	0.6250	1.6250	1.6875	1.5000	1.3750
2	3.000	2.000	4.5000	2.000	1.5000	1.5000	1.5000	1.5000	0.5000	0.5000	1.5000	0.5000
3	1.0625	0.9375	0.6875	1.000	0.6094	1.3750	0.8613	0.5313	0.9375	1.9375	0.9675	0.3125
4	1.8125	1.8125	1.8125	1.8125	0.5000	1.0625	1.0625	0.6250	0.8750	0.6875	1.5000	4.3125
5	5.1875	3.5000	5.1563	5.0625	1.3750	2.1875	2.000	0.6875	0.3438	1.3125	2.2500	1.1875
6	0.5000	1.000	1.000	1.2500	1.2500	4.7500	5.000	1.000	1.5000	1.5000	1.2500	2.2500
7	1.1875	1.9063	1.9063	1.4688	0.9375	1.2500	1.5938	0.4063	0.5938	1.0313	0.5625	0.8125
8	0.4219	2.5313	2.5313	1.8750	0.5625	0.5625	0.9063	0.5000	0.7344	0.5469	0.1719	0.4219
9	2.0625	6.1875	2.0625	5.5625	1.1250	6.5625	6.5625	6.4375	4.40625	4.0625	4.0625	4.5482
10	1.000	0.8750	0.8750	4.3750	0.1250	3.3750	3.2500	3.2500	1.2500	2.6250	1.2500	0.5000
11	2.000	2.000	2.000	0.0002	0.5000	0.5000	1.1250	0.0004	0.8750	0.8750	2.5000	0.00003
12	0.8750	0.0002	3.5625	0.0002	0.3125	0.0008	0.3750	0.0001	0.8750	0.0003	0.8750	0.0001
13	2.0625	0.0001	1.000	0.0001	0.8750	0.0001	1.1250	0.0003	0.4375	0.0001	0.2500	0.0003
14	0.6250	0.0004	1.7500	0.0004	1.7500	0.0002	0.8750	0.0001	1.5000	00004	0.8750	0.0004
15	2.8750	0.0001	3.7500	3.5000	0.1250	0.0004	1.2500	3.6250	0.2500	0.00005	3.1250	3.7500
16	1.000	0.0002	0.5000	0.0004	1.000	0.0001	2.000	0.0003	1.000	0.0001	0.5000	0.00001
17	2.4688	0.0001	3.1563	0.0002	0.8438	0.8438	0.0002	0.2813	0.8438	0.0004	0.2188	0.0001
18	1.1250	0.0004	4.0625	0.0003	1.6875	0.0001	1.1875	0.0003	0.4375	0.0001	1.1250	0.0003
19	0.6875	0,0007	2.6250	0.0001	0.7813	00001	0.5938	0.0007	1.0313	0.0002	1.000	0.0004
20	0.1250	0.0001	1.000	7.7500	0.3750	0.0004	0.8750	1.8750	0.5000	0.0004	1.6250	0.8750
21	1.000	0.0001	2.8750	0.0014	1.6875	0.0004	1.000	0.0002	0.8750	0.0006	0.8750	0.0001
22	0.5000	0.0001	9.5000	3.6563	0.2500	0.0005	9.5000	3.6563	1.6875	0.0003	0.6875	0.5625
23	1.8438	1.8750	1.8750	1.3750	0.4375	0.4375	2.8750	0.6875	0.6563	2.3750	1.0313	4.9688
STD	1.1258	1.5143	1.9799	2.1777	0.5106	1.6755	2.2139	1.6388	0.8414	1.0980	0.9410	1.6329
Mean value	1.4915	1.1361	2.556	1.8252	0.8435	1.1781	2.0350	1.1380	1.0243	0.8435	1.2763	1.1671

4.2 Statistical Analysis

A t-test is any statistical hypothesis test in which the test statistic follows a Student's t-distribution if the null hypothesis is supported. It can be used to determine if two sets of data are significantly different from each other, and is most commonly applied when the test statistic would follow a normal distribution if the value of a scaling term in the test statistic were known. In this study, we compare normal and seizure condition and normal and onset condition by using student t-test between channel 1, 10, 17 and 23. Student t-test condition by assigning the statistical significance as $p < 0.05$.

Table 4.2: Student t-test result

Channel no	**Normal vs seizure**	**Normal vs onset**
	p	p
1	0.1458	**0.0136**
10	0.1798	0.8878
17	**0.0091**	0.2355
23	0.1567	**0.005**

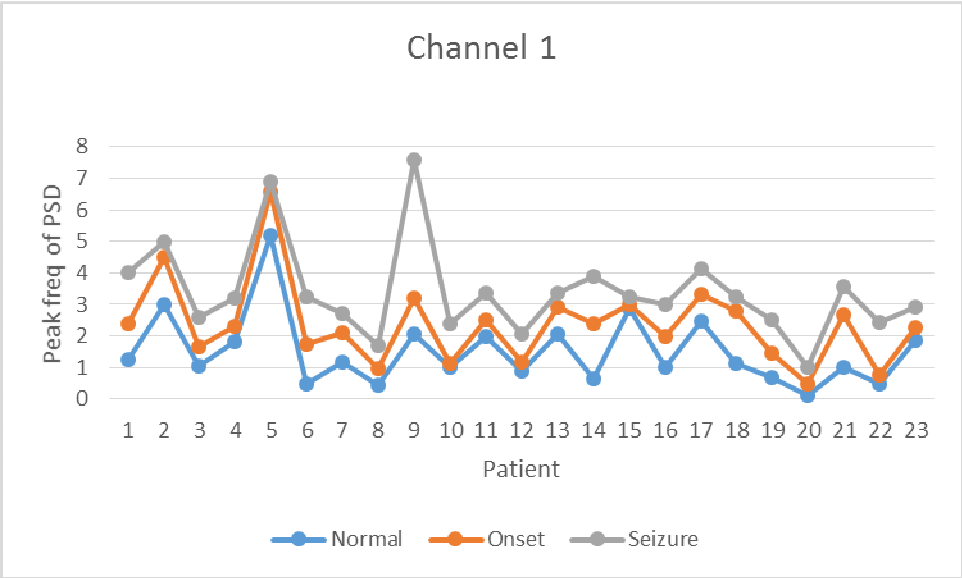

Figure 4.7: Result of channel 1 for Normal, Onset, and Seizure.

After applied PSD method, the new signal had been obtained and Figure 4.1 shows the Graph of new signal. By naked eye observation, it can easily observe that seizure part of EEG has higher value than rest one. But in patient 5 maximum point of seizure part is very high according to other values. Also in patient 9 onset value is higher than seizure and normal values. Also in patients 14 normal and onset values are higher than seizure value. From the table: 4.1 all signal's peak are seen into [0.5-2] range. Also seizure types can change by person to person sysmptoms of Epilepsy.

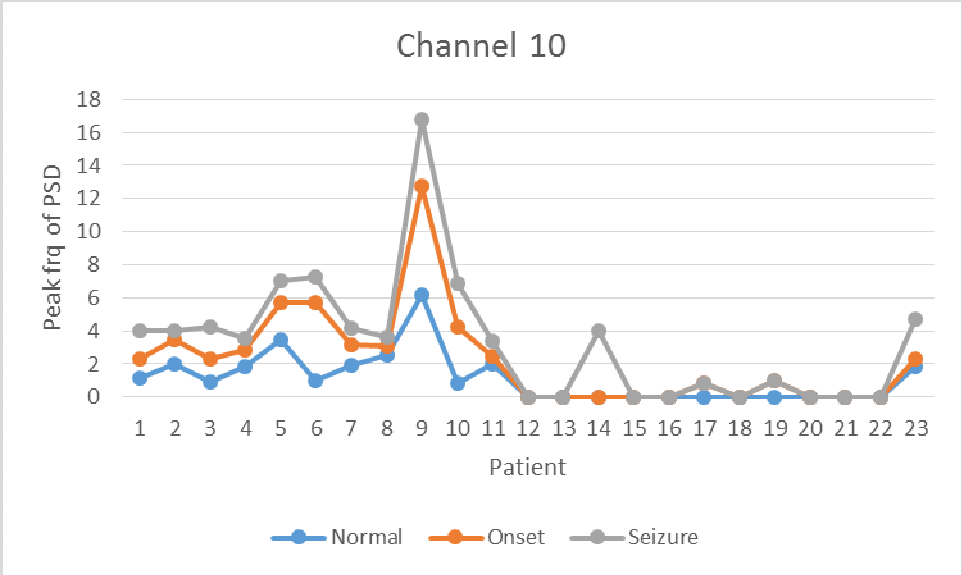

Figure 4.8: Result of channel 10 for Normal, Onset, and Seizure.

After applied PSD method, the new signal had been obtained and Figure 4.8 shows the Graph of new signal. By naked eye observation, it can easily observed that Seizure part of EEG has higher value than rest one. In patient 9 as we can see that the seizure value is very high according to others. Also in patients 17, 18, 19 we can see that the normal and onset value is very low. Also in 21 patient's seizure, normal and onset values are same. In Channel 10 the maximum peak of PSD value of seizure part of EEG signal is greater than normal contained part of signal's PSD value and also there value which is between 0.0001 and 2. The maximum value in this table is 4.1. In figure: 4.8 we can see that the seizure peak value is greater than the normal and onset.

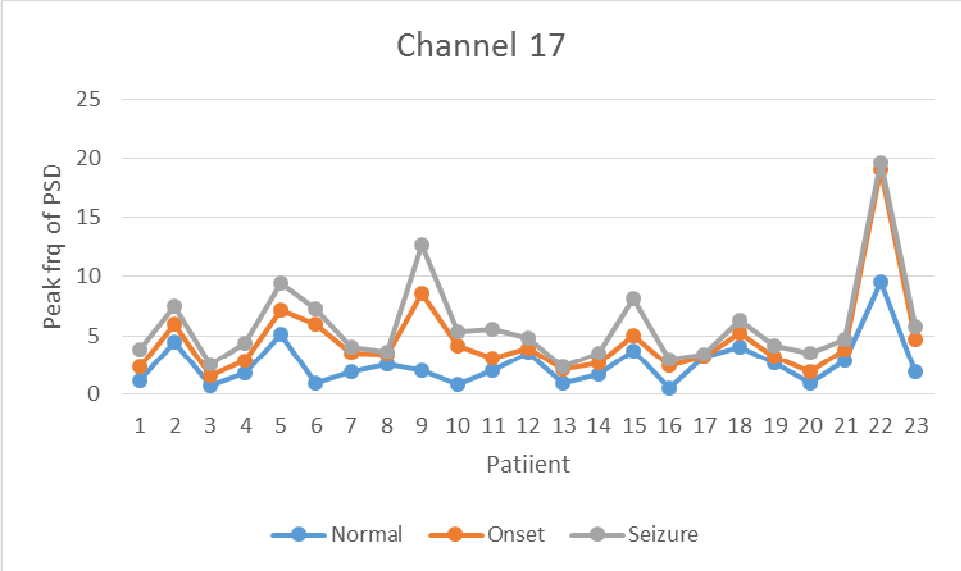

Figure 4.9: Result of channel 17 for Normal, Onset, and Seizure.

After applied PSD method, the new signal had been obtained and Figure 4.9 show the Graph of new signal. By naked eye observation, it can easily observed that Seizure part of EEG has higher value than rest one. In Channel 17 the PSD peak value of seizure part of EEG signal is greater than normal contained part of signal's peak value also there value which is between 0.01 and 1. The maximum value in this table is 7.6. In figure 4.9, we can see that the seizure peak value is very high in 22 patient's number according to others. Also the onset and normal value is also very high according to others peak value.

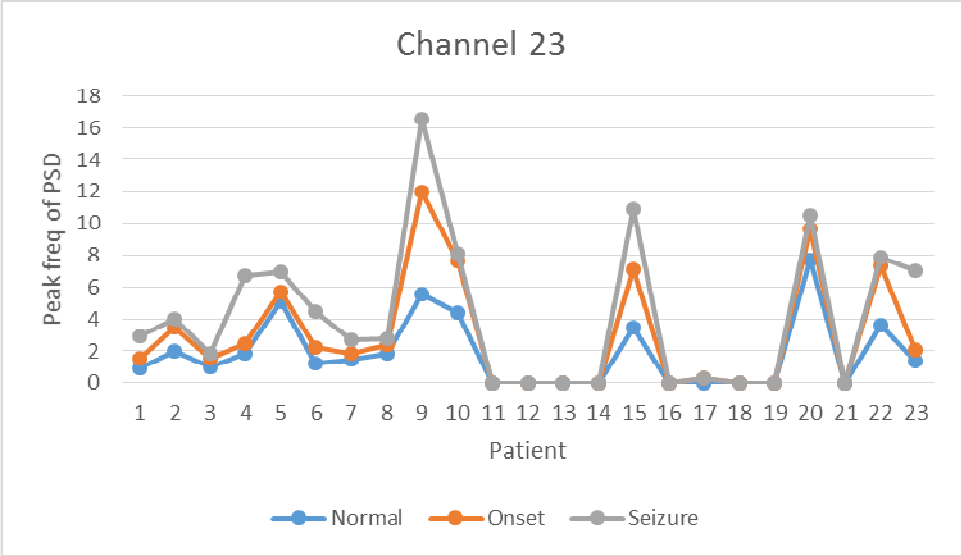

Figure 4.10: Result of channel 23 for Normal, Onset, and Seizure.

After applied PSD method, the new signal had been obtained and Figure 4.10 shows the Graph of new signal. By naked eye observation, it can easily observed that Seizure part of EEG has higher value than rest one. In Channel 23 the PSD peak value of seizure part is greater than normal and onset contained part of the signals. Also we can see that the patient 9 seizure peak values is very high according to other seizure values also in patient 9 normal and onset peak values are higher than other values. In patient 15 and 20 those patients peak value is also little bit high. But ın 22 patients number as we can see that the seizure and onset value are same. In table 4.1. In 23 channels values are between 0.0001- 1.3.and the maximum peak value is 6.56.

4.3 CONCLUTION

Epilepsy is the fourth most mutual neurological disorder and touches people of all ages. It known as seizure disorders. It is changes life quality very badly and it can be causes of other health problems. There are different and wide range of seizure types which varying person to person. These decrese in life quality like randomly movements, become angrier in predictable time else causes decrease in work performance and this costs more than treatment of epilepsy. Doctors are said that it is a chronic disorder. Numerous people with epilepsy have more than one type of seizure and might have other signs of nervous problems as well. Occasionally EEG testing, medical history, family history are similar among a group of people with epilepsy. These factors regulate the atmosphere of a seizure and its influence. Late diagnosis of epilepsy or unawareness

of signs and indications of illness are important reasons of high prevalence of epilepsy. In this case the investigates about epileptic seizures taking important role. In research there are mutual evidence among changed sections on the cortex, for understand the interdependence of another regions of the brain recently, many entropy methods are applying for EEG signal analysis, as like wavelet method ,time-dependent method are most common also time frequency or mutual information are used.

In this thesis, the recognition of seizure and normal and onset condition had been examined with PSD analysis method. As seen from results there are several peak frequency values which smaller than normal EEG. Since the signals are provided from open access source the deeply study about details of seizure could not promising.

On the other hand channel 1, 10, 17 and 23 has the maximum peak values are quite different As seen from results that the seizure maximum peak value is higher than other normal and onset peak values. All results were statistically evaluated by student t-test.Maximum peak values of 17^{th} channel EEG signal are giving the significant statistical results also channel 1^{st} and 23th are also satisfied for normal and the onset moments. Still there was no standard EEG signal analysis method for seizure detection. Moreover, these results also highlight that PSD are promising tools for the EEG signa analysis for seizure detection in clinic.All signals had been collected from children. But in the case of collecting signals from non-age justified patients, results could be more effective. Also we can compare this result in other method. So this power spectral density method performance can be seen. In future more accurate result can be found out

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