ANALYSIS OF THE SIDE EFFECTS OF CELL PHONE ON THE BRAIN USING ELECTROENCEPHALOGRAM

By

TEIHISSANDE TINGOLFA 12267

FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronics Engineering
In Partial Fulfilment of the Requirements
For the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak DarulRidzuan

CERTIFICATION OF APPROVAL

ANALYSIS OF THE SIDE EFFECTS OF CELL PHONE ON THE BRAIN USING EEG

By

TEIHISSANDE TINGOLFA

A project dissertation submitted to the
Department of Electrical & Electronics Engineering
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

Approved by,

____
Dr. AAMIR SAEED MALIK
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
September 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

TEIHISSANDE TINGOLFA

ABSTRACT

Cell phone emits electromagnetic radiation which could be harmful to human brain after an extensive exposure. The number of cell phone users has drastically increased all over the world. In 2012, the number of cell phone subscribers went up to 6 billion and the majority of them are children and young adults. The main concern is the health risk involved with the cell phone usage. In this paper, the effects of cell phone on human brain are investigated. 16-channels EEG was used to record the brain signal from 24 healthy participants under six different conditions (before experiment, during experiment: right ear with distance, right ear without distance, left ear with distance, left ear without distance and after experiment). After data were pre-processed, the signal irregularity for all the six conditions was computed. Three parameters were used to measure the signal complexity for time series data: i) Composite Permutation Entropy Index (CPEI), ii) Fractal Dimension (FD) and iii) Hjorth complexity. Based on these three parameters, the results showed that the complexity level is high during experiment when the cell phone is at Right ear without distance compared to Left ear without distance for all the brain regions (frontal, central, parietal, temporal and occipital). However, the complexity level decreases with distance when the cell phone is either on right or left ear. The increase in the complexity level explains the presence of high frequency components due to the cell phone radiation. Participants are more exposed to the radiation during the call when the cell phone is without distance. For the frequency domain, absolute power and coherence were used for the analysis. It can be observed from the result that delta, theta and alpha brain waves are lower at both frontal and temporal lobes during cell phone usage. But beta wave is higher during and after call. This is due to the effect of radiation from the cell phone.

ACKNOWLEDGEMENTS

Praise to God, The Most Gracious and The Most Merciful for His endless blessings throughout my life and the success He granted me during this Final Year Project.

My deepest heart gratitude is to my parents who strived to get me where I am now and for their endless support and encouragement during this final year.

My utmost appreciation and gratitude towards my supervisor Dr. Aamir Saeed Malik, for the dedication of his time and effort, teaching, guiding and helping me in all my work-related tasks despite his many other obligations.

My gratitude is extended to the postgraduate students for help and giving advices whenever it was needed. Last but not least, I thank my friends and everyone who supported me throughout this project.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

EEG	Electroencephalography.
F	Frontal lobe.
T	Temporal lobe.
P	Parietal lobe.
O	Occipital lobe.

CHAPTER 1
INTRODUCTION

1.1 Background

The exponential increase in cell phone use around the world for the last decades has captured many scientists and researchers attention. Their concern is the health risk involved in using cell phone. The Central Brain Tumor Registry reported that the number of population in United Stated suffering from brain tumor (benign and malignant) had increased from 13.4 per 100,000 in 1995 to 18.2 per 100,000 in 2004 [1]. The real and clear cause of the brain tumor is still undetermined but scientists believed that cell phone has biological effects on human after a long term usage. These biological effects might be fatal because the cell phone subscriptions had increased drastically around the world. Teens and children are known to be very exposed to the cell phone effects because they start using it at a very young age. Furthermore, children around 12 years and above sleep with cell phone under their pillow. A recent study demonstrated that children exposed to cell phone electromagnetic radiation at 1800 MHz can have abnormities in cortical regions, hippocampus, hypothalamus and the eyes [1].

In order to investigate the possible health risk caused by the cell phone radiation, many experiments and researches have been done on animals (rat, rabbit, and cat), plants, or human beings. But in this research, our focus will be on human beings. One of the techniques used in human beings to determine the effect of radio frequency radiation caused by cell phone on brain activity is called electroencephalogram (EEG). EEG is the safest method of measuring brain electrical activity by placing electrodes on the scalp with a conductive gel. It was introduced since 1924 by Hans Berger. The conditions such as time and position of the EEG recording depend on the researchers. Some required subjects to open or close their eyes, to be asleep or awake.

Cell phone electromagnetic radiation is believed to be dangerous for the brain even though the researches and studies on that field are still inconclusive. The possible health risk of the cell phone includes cell damage, heating tissue, headache, brain tumors and etc… Therefore, this project aims to investigate and verify those possible health risks and the ways to prevent them.

1.2 Problem statement

Cell phone technology has evolved rapidly from 1G to 4G during the last decade. In line with this tremendous development, the frequency has gone from 450 to 2200 MHz which leads to higher electromagnetic radiation emission. Many scientists and researchers believed that the electromagnetic radiation emitted by the cell phone could harm human brain after an extensive exposure. The number of cell phone use has drastically increased all over the world. In 2012, the number of cell phone subscribers went up to 6 billion and the majority of them are children and young adults. Also, the number of brain cancers keeps increasing as reported by Central Brain Tumor Registry. Therefore, there is a need to investigate the effects of this radiation on the brain in order to confirm the beliefs and previous researches done.

1.3 Objective

This research intends to:

- Understand the brain waves and their functionalities
- Investigate the side effects of cell phone's electromagnetic radiation on human brain using electroencephalograph (EEG).

1.4 Relevancy & Feasibility

Relevancy: This research is more related to biomedical and neural engineering. Since engineering and medicine are working together to improve healthcare, this research will widen the knowledge about both fields.

Feasibility: The project can be achieved within two semesters according to the availability of the equipments that are needed for collecting and analyzing the data.

CHAPTER 2
LITERATURE REVIEW

This chapter covers some fundamental topics such as electromagnetic radiation, brain anatomy, electroencephalogram (EEG) in order to understand the project as well as the previous researches done.

2.1 Electromagnetic Radiation

The radio frequency emitted from cell phone is in the range of 800-2200 MHz, which is very dangerous for human brain. Figure 1 (a) is a demonstration of an electrical current that flows in a conductor (antenna or circuit inside cell phone) which generates both electric and magnetic fields. The combination of both magnetic and electric fields outputs Electromagnetic field (EMF) perpendicular to each other as shown in figure 1 (b). EMF is emitted by cell phone when there is reception, process, amplification of a signal and generation of a signal from built in antenna as shown in figure 1 (c). The EMF strength decreases exponentially according to the distance from the source. Due to the EMF strength, it is advised to keep the cell phone away from the body and the head to avoid and risk involved. [1]

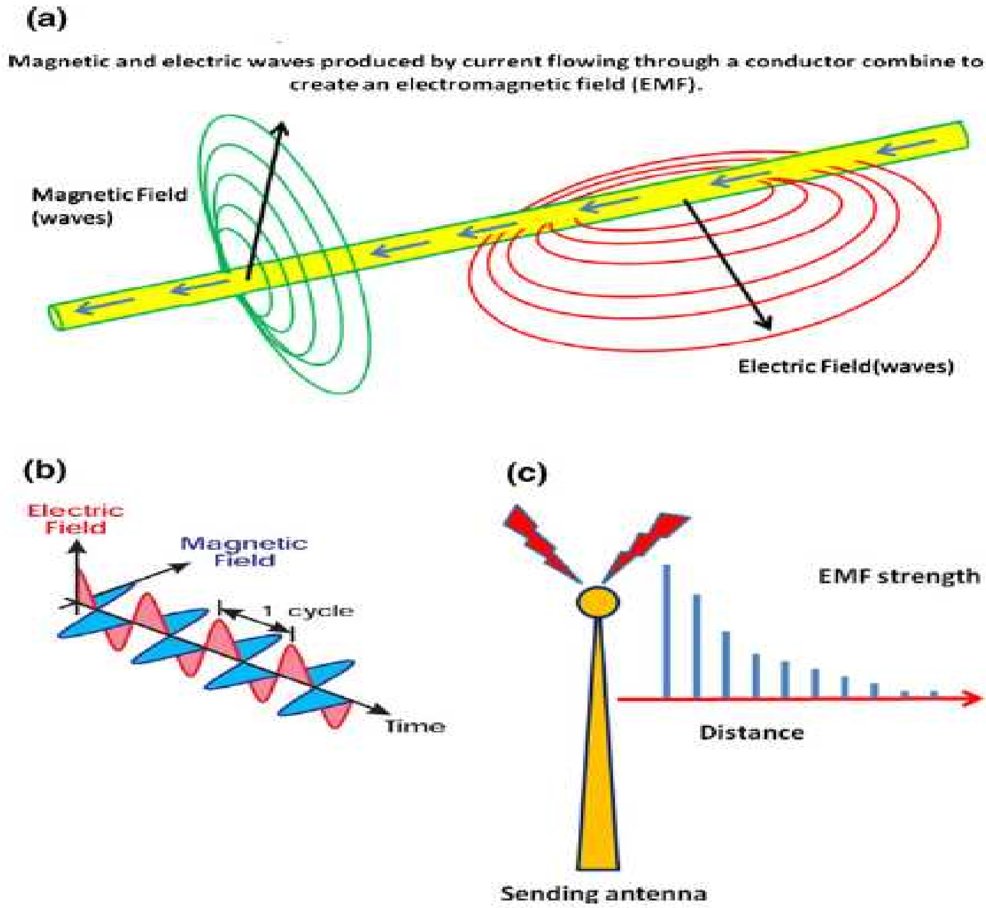

Figure 1: Electromagnetic field concept

The intensity of human brain magnetic field is 10^-13 Tesla. The intensity of cell phone's magnetic field is 750mT when the cell phone is idle, 0.015T when the cell phone is ringing and 0.03T during call.

2.2 Brain Anatomy

Known as the important part of our body, the brain coordinates all the activities that take place in our body. The brain consists of three mains parts which are cerebrum, cerebellum and brainstem as shown in figure 2 [2].

- The cerebrum is the biggest part of the brain .The cerebrum is responsible of interpreting any incoming information from the five senses which are smell, touch, vision, taste and hearing. It also has the ability to speech interpretation, reasoning, learning and control body movement. The cerebrum is composed of left and right hemispheres and is divided into three parts which are frontal lobe, parietal lobe, temporal lobe and occipital lobe.

- Frontal lobe deals with personality, behavior, emotions, judgment, planning, problem solving, speech (speaking and writing), body movement, intelligence, concentration and self awareness.
- Temporal lobe deals with memory, hearing, understanding language, sequencing and organization.
- Parietal lobe is in charge of language and words interpretation, signals from vision, hearing, motor, sensory and memory interpretation, spatial and visual perception, sense of touch, pain, and temperature.
- Occipital lobe interprets vision (color, light, movement).

➢ Cerebellum is the smaller part of the brain which is found under cerebrum as shown in the figure 2. It coordinates muscle movements, maintain posture and balance.

➢ Brainstem is the smallest part of the brain which connects cerebrum and cerebellum to the spinal cord. It contains midbrain, Pons and medulla. Brainstem is responsible of automatic functions such as coughing, vomiting, swallowing, heart rate, breathing, digestion, body temperature, sneezing, wake and sleep cycles.

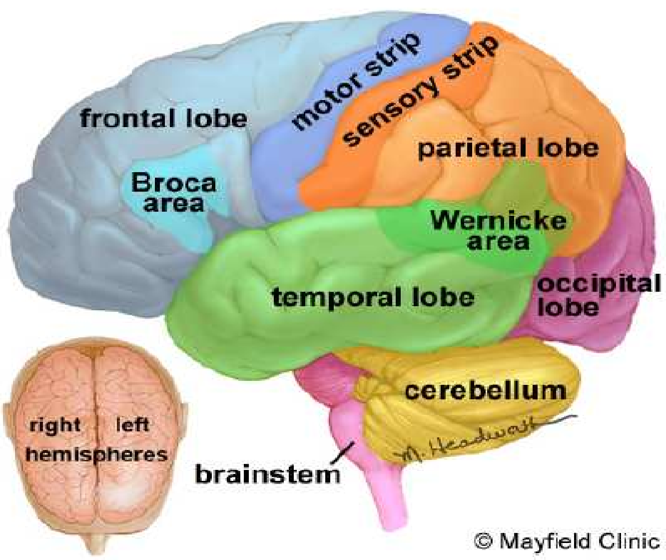

Figure 2: Brain anatomy

All the brain activities described above are done through neurons. The neurons convey information through electrical and chemical signals and they consist of cell body, dentdrites and axon as shown in figure 3 [2]. Neurons communicate to each other through a tiny gap called synapse. The arms of the neurons is called dendrites which act like antenna to receive message from other neurons. The received message from the dendrites are passed to the cell body which decide to pass the message or not. But the most important messages are passed to the end of axon where sacs containing neurotransmitter open into the synapse. The neurotransmitters channel out of the synapse and reach receptors on the receiving nerve cell, which stimulates the particular cell to pass on the message. The neurons are nourished, protected and given a structural support by glia cells. Glia cells are 10 to 50 times more than neurons and are the most commonly involved in brain tumors.

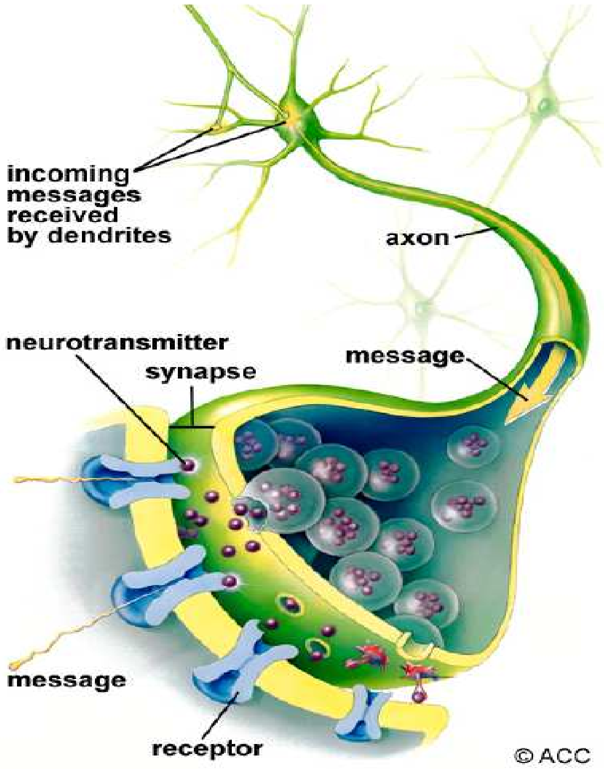

Figure 3: Neurons communication flow

2.3 Electroencephalogram

Most of the above studies are done using electroencephalogram (EEG). EEG is a tool to record any electrical activity that the brain generates by placing electrodes on the scalp with a conductive gel. The brain consists of millions of neurons that generate individually a little electric voltage field. The collection of these electric voltage fields produces an electrical signal which is detected by the electrodes placed on the scalp [3].

The international standard number of electrodes to be used in any experiment involving EEG is around 10 to 20 as shown in figure 4.

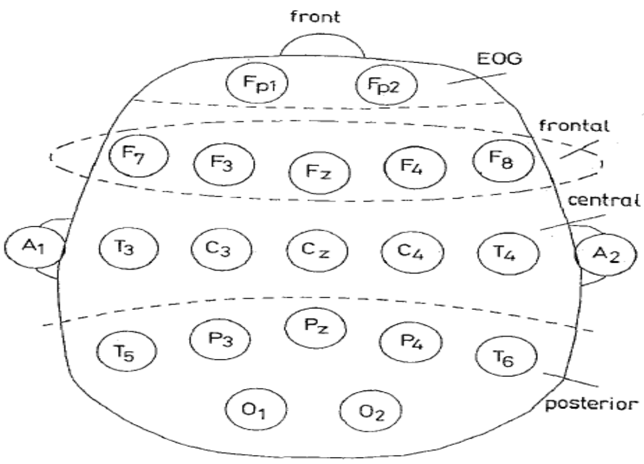

Figure 4: 10-20 standards electrodes disposition

1. Front left (FL): Fpl, F3, F7

2. Front midline (FM): Fz

3. Front right (FR): Fp2, F4, F8

4. Center left (CL): T3, C3, T5

S. Center midline (CM): Cz

6. Center right (CR): T4, C4, T6

7. Posterior left (PL): P3, O1

8. Posterior midline (PM): Pz

The electrical signal recorded from the brain is generally classified in frequency band known as alpha, beta, gamma, theta and delta. The corresponding brain wave of the different frequency band is shown in the figure 5 below.

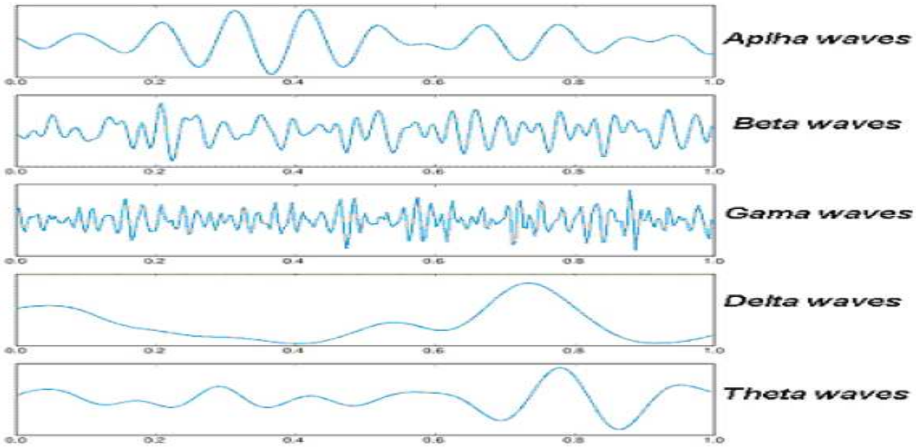

Figure 5: Brain waves

The different brain waves are summarized in the table 1 below according to their EEG band frequency and conditions.

Brainwave Type	Frequency range	Mental states and conditions
Delta	0.1Hz to 3Hz	Deep, dreamless sleep, non-REM sleep, unconscious
Theta	4Hz to 7Hz	Intuitive, creative, recall, fantasy, imaginary, dream
Alpha	8Hz to 12Hz	Relaxed, but not drowsy, tranquil, conscious
Low Beta	12Hz to 15Hz	Formerly SMR, relaxed yet focused, integrated
Midrange Beta	16Hz to 20Hz	Thinking, aware of self & surroundings
High Beta	21Hz to 30Hz	Alertness, agitation
Gamma	30Hz to 100Hz	Motor Functions, higher mental activity

Table 1: Summary of brain waves according to EEG band frequency and conditions

The amplitude of EEG signal ranges approximately from 1uV to 100uV which is very weak and it can easily be affected by other sources. Artifacts are EEG signal that the sources are different from brain; they can be physiologic or non-physiologic. Physiologic artifacts are caused by heart beat, eyes blink, muscle and tongue movements during EEG recording. However non-physiologic artifacts are caused by interference of equipment at 60Hz such as electrodes movement and body movement [3].

2.2 PREVIOUS STUDIES

A Swiss study conducted an experiment on human volunteers head by exposing the head to a cell phone electromagnetic radiation of 900 MHz, as a result, the cerebral blood flow in the side of the brain has increased enormously, demonstrating that there is a change of metabolism in the brain region. Furthermore, the increased in glucose metabolism on the side of the brain has been proven in a recent study after 50 minutes of cell phone use. [1]

Besides, an experiment was carried out by Reiser, et al., 36 participants were exposed to a radio frequency of a cell phone for 15 minutes, they were required to be awake and seated. The carrier frequency of the cell phone was 902.4 MHz, modulated at the frequency of 217 Hz. The power transmitted by the cell phone to the head was 8 W at a distance of 40 Cm. As a result of this experiment, there is an increase in EEG frequency of the brain wave after the 15 minutes exposure. The brain waves are in the range of 9.75 Hz – 12.5 Hz (Alpha 2), 12.75 – 18.5 Hz (Beta 1) and 18.75 – 35 Hz (Beta 2) [4]. Moreover, another similar experiment was done by Röschke and Mann on 34 men. The EEG condition was to be awake and closed eyes. The 34 men were exposed to GSM (Global System for Mobile Communication) mobile phone at a carrier frequency of 900 MHz modulated at a frequency of 217 Hz for about of 3.5 minutes. The peak power of the GSM mobile phone was 8 W transmitted at a distance of 40 Cm from the vertex. The statistical data was recorded from the EEG spectral power density at the frequency band of 1 – 3.5 Hz (Delta), 3.5 – 7.5 Hz (Theta), 7.5 – 12.5 Hz (Alpha), and 12.5 – 18 Hz (Beta) [5].

In order to clarify these two similar investigations, D'costa et al. had carried another investigation using two different types of cell phone (Nokia 6110 and Ericsson GH388) with different power output (full-power and standby modes respectively). The two cell phones operated at the carrier frequency of 900 MHz modulated at 217 MHz and they were configured to output 250 mW. The investigation was done on 10 participants with ages from 18 to 30 years. All the participants were required to be awake, seated and eyes closed. The EEG data was recorded for 5 minutes times ten for different conditions by placing the cell phone at the rear of the head at a distance of 2Cm as shown figure 2. The EEG data collected was set in frequency domain between 1-32 Hz by using software called Mindset EEG processing software (Wavelab).

The data was categorized into four main clinical EEG bands which are: delta (1 – 4 Hz), theta (4 – 8 Hz), alpha (8 – 13 Hz), and beta (13 – 32 Hz). D'Costa et al. found that there was a change in human brain wave activity when exposed to full radiated GSM mobile phone. The change appeared in alpha (8-13 Hz) and beta (13-32 Hz) of EEG bands [6]

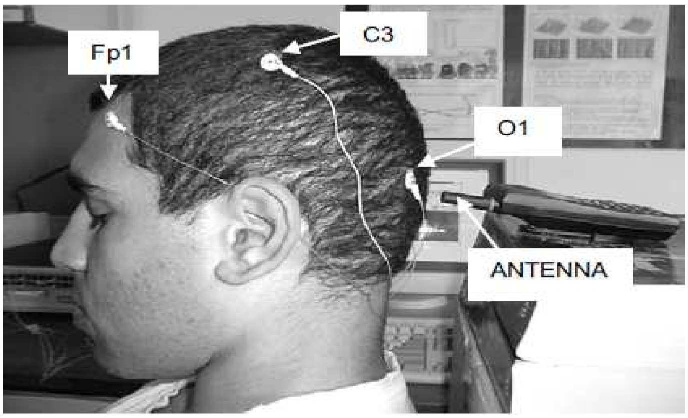

Figure 6: EEG experiment

In addition, Hinrikus et al. also conducted a study on 13 young volunteers with ages ranging from 21 to 30 years to investigate the non-thermal effects of microwave radiation on human brain. The subjects were exposed to 450 Hz microwave radiation of mobile communication located at 10 cm from skin on the left side of the head. This investigation helped in determining the increased in EEG energy level caused by microwave stimulation which is more intense in beta 1 and at higher modulation frequencies [7].

A German group conducted an experiment on the effects of mobile-phone EMFs on brain signals during sleep. A total of 12 volunteers were exposed at night (5 stages of sleep were considered) to radiofrequency (RF) emissions from a mobile phone. The brain signals were recorded using EEG. The data was analyzed and there was an increase in the spectral power during REM sleep but not in the other sleep stages [8].

In an experiment conducted on nine epileptic patients to prove whether the cell phone radiation affects their brain, had lead to almost consistent conclusion but the number of subjects were insufficient [9][20]. The nine epileptic patients were exposed to GSM Nokia 3310 at a carrier frequency of 900MHz modulated at 217 Hz with peak and mean power of 2W and 0.25 W respectively. They were in hospital for several days for supervision and were not under medication. The EEG recording lasted one hour for 6 different conditions, each 5min with eyes opened and closed periodically according to the instruction. The experiment used 10-20 electrodes standard. As a result, there is an increased in alpha, beta and gamma waves. The increase power in alpha wave in the epileptic patients are similar to the one reported for non epileptic. However, the increase power in beta and gamma wave may be due to the epileptic condition.

Similarly, E. Maby et al. investigated the effect of GSM mobile phone on nine healthy patients and six epileptic patients [10]. There was an influence in the brain activity precisely in the alpha wave of the nine healthy patients according to the decrease of correlation coefficient. However, for the six epileptic patients, the correlation coefficient increased. Both patients EEG brain signal were influence by the radio frequency.

Furthermore, a study was carried out to investigate the effect radio frequency emitted by cell phone on human brain activity [11]. Adults around the ages of 28 to 57 years old were exposed to radiation from five different mobile phones at a carrier frequency of 900MHz or 1800 MHz. they were required to close eyes and relax, the EEG recording was done for six 30munites. As a result, a change in brain activity (in delta frequency) was only found in one mobile phone [11]. Similarly, another study was done to investigate the effect of cell phone radiation brain. The experiment was done for 60mn session (before and after) exposure with eyes closed. Hence, there is a change observed in the brain [12].

James C. Lin conducted experiment on human EEG by exposing subjects to microwave radiation from cell phone [13]. The brain electrical signals were recorded using a large number of small, metallic electrodes placed on scalp. As a result, there were changes on the brain electrical activity but the result was inconclusive due to the artifacts from the electrodes and the inconsistency of the methodology.

However, in a study done to investigate brain cell damage in mammalian brain and blood-brain-barrier permeability has demonstrated that microwaves radiation influences brain's physiology insignificantly when exposed to low doses (Persson *et al.*, 1997; Salford *et al.,* 2003; Schirmacher *et al.*, 2000).

Children and youngster have the highest percentage of cell phone use which may be very dangerous to their health according to 2004 statistic by technology research. National Radio Protection Board in United Kingdom advised parents to not let their children below eight years old to use cell phone. Many laboratory studies have been done on youngster to demonstrate the effect of cell phone on children. Some studies have shown cell phone radiation can lead to short-term memory, delay in response time and brain cell damage [14][21]. However, recent investigations conducted by United Kingdom and Finland on 18 and 36 children of ages (10-14 years) respectively have shown no significant effect of cell phone. The two studies were inconclusive due to the small number of subjects and lack of ethical consideration [14].

CHAPTER 3
METHODOLOGY

This chapter covers the methodology of the project such as project activities, the timeline, key milestones, Gantt chart, and the tools that have been used in the project.

3.1 Project activities

The main flow of the project is shown in the figure 7 below. The project will be done using EEG recording. Firstly, EEG signal data need to be collected from volunteer participants which have not been under medication and are totally healthy. The EEG signals recorded will be processed in order to remove any artifacts caused by other source which is not brain. Once the artifacts are removed, the data will be analyzed using MATLAB.

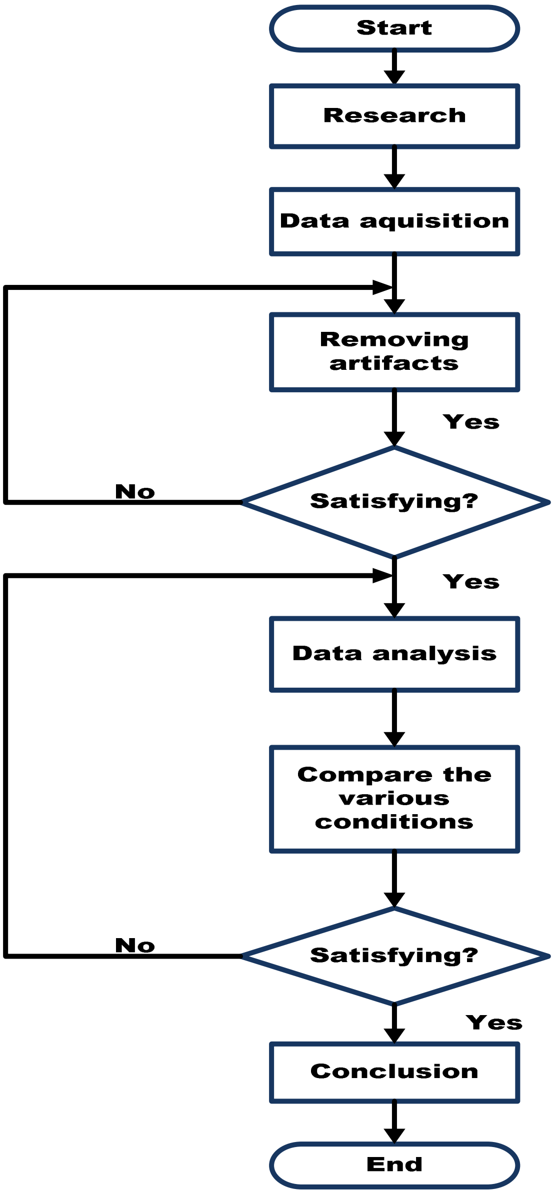

Figure 7: Project flowchart

3.2 Experiment procedure

3.2.1 Subjects & questionnaire:

Twenty four subjects both male and female are recruited from Universiti Teknologi PETRONAS students to participate in the experiment. The participants are asked about their health and cell phone usage. All of the selected subjects are healthy and have not been under any medication. Also, they have been using cell phone for more than 5 years.

Before the experiment, the experimenter briefs the subjects about the experiment procedure and requirements. Only participants that had washed their hair using only shampoo and not conditioner, cream or oil in their hair or skin have undergone the experiment because the latter would affect good connectivity. The participants are required to relax, be silent and steady to minimize artifacts and generate good EEG signal. Furthermore, before being assigned to the EEG experiment, the participants are asked to fill a consent form, as well as to complete a questionnaire. The questionnaire consists of 11 questions such as the amount of calls that they make daily, the mean duration of a call and the effect that they usually have while or after using the mobile phone in addition to some questions about their health condition. Please refer to Appendix A and B.

3.2.2 Experiment Design & Data Acquisition:

This experiment is carried out using EEG Emotive 16 channels as shown in figure 8 and 9 below. It is connected to a PC to show the brain signals.

Figure 8: Emotiv EPOC headset

Figure 9: Emotiv sub devices

A total of six conditions are performed for the EEG recording as shown in figure 10 below. The conditions are mentioned as i) Before Experiment: Eyes Open and relax ii) During experiment: Right ear with 5cm distance iii) During experiment: Right ear without distance iv) During experiment: left ear with 5cm distance v) During experiment: Left ear without distance vi) After Experiment: Eyes Open and relax. Each condition takes 5 minutes and participants can take break after each session.

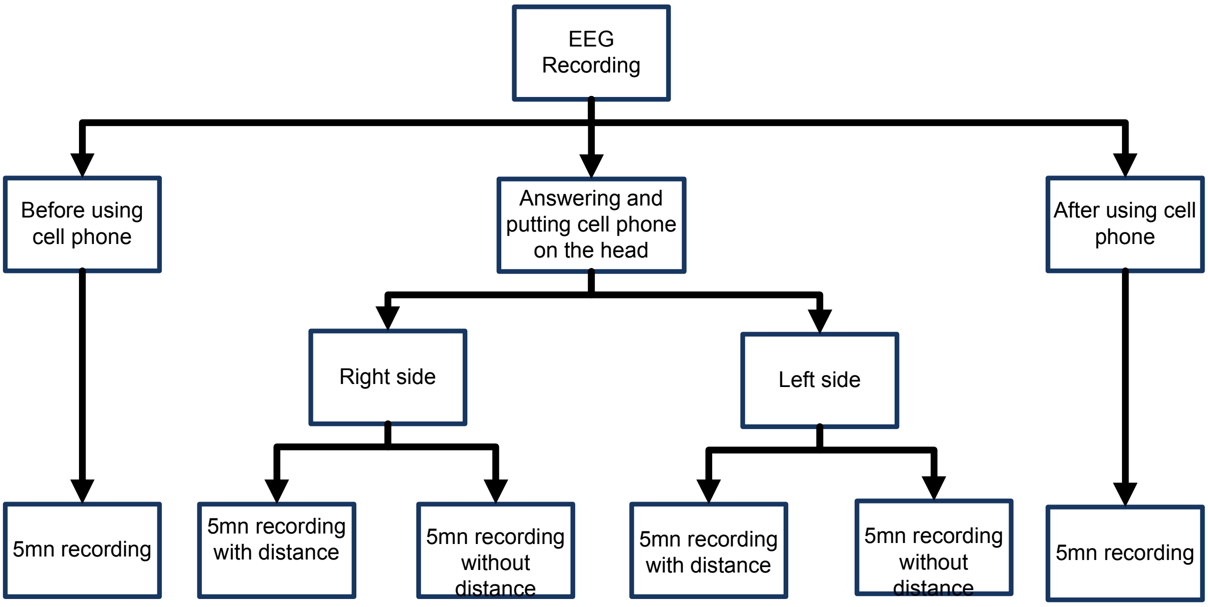

Figure 10: Block diagram for experimental protocol

The experimental setup is shown in figure 11 where the participant is undergoing the EEG recording for the six different conditions.

Figure 11: Experimental setup

3.3 Removing Artifacts:

The artifacts such as eye blink, muscles movement and DC are removed using EEG lab and Besa software. Following is the cleaning process.

1. Once the data was imported in EEG lab, a short IIR filter was used to remove and filter the signal from the DC artifacts, by designing Band Pass Filter BPF, LPF has a cutoff of 30.0 Hz, transition bandwidth of 0.3 Hz and its order is 13.0, HPF has a cutoff of 1.0 Hz, transition bandwidth of 0.3 Hz and its order is 6.0.
2. Eye blink and muscle artifacts were removed manually, having a Specific shape. Refer to the two following figures.

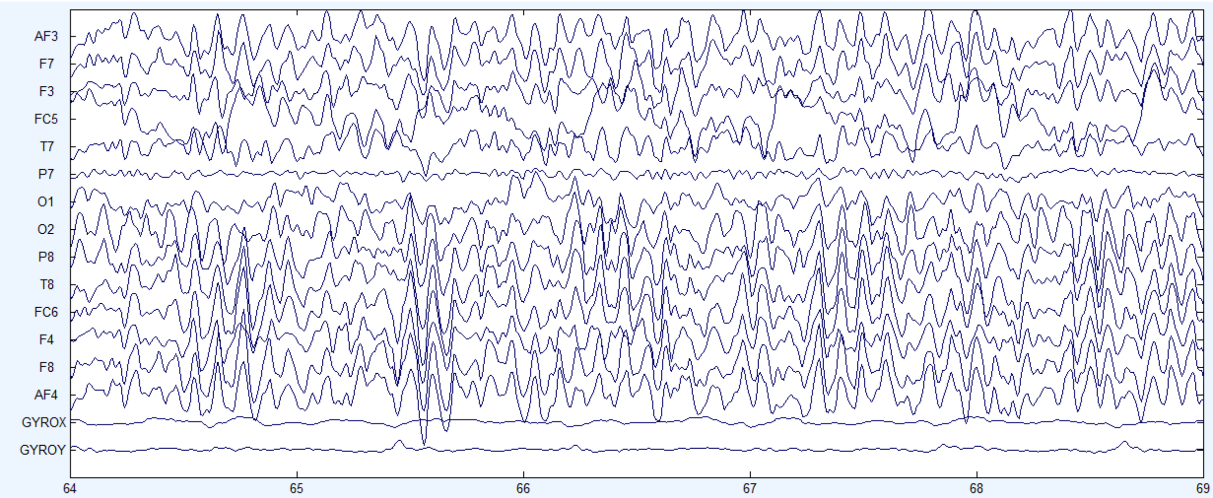

Figure 12: Row EEG signal recorded

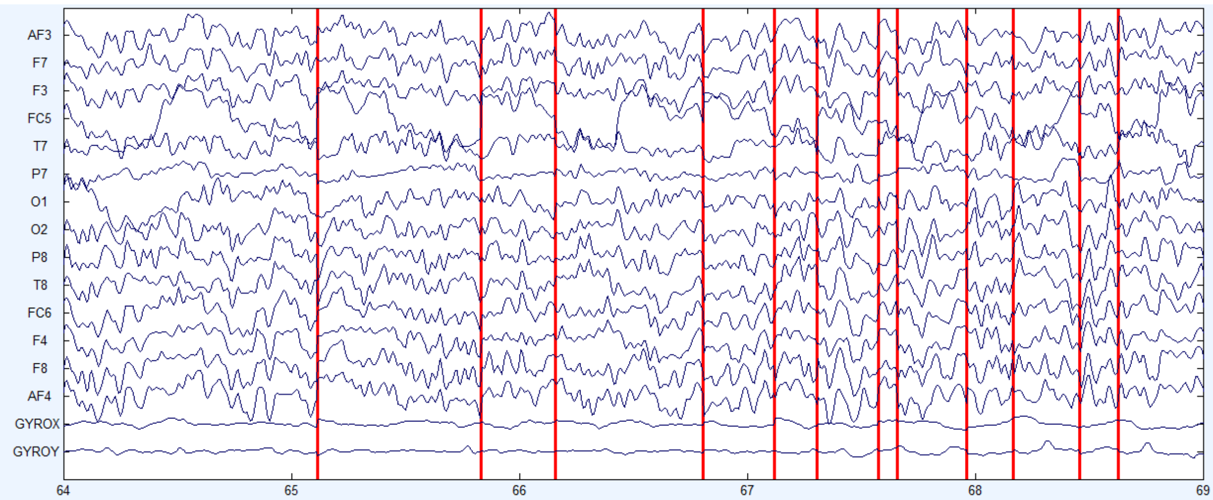

Figure 13: EEG signal after manually removing artifacts

3. Eye blink and muscle artifacts were removed automatically using Besa software by setting amplitude threshold to 100uV.

3.4 Data Analysis

3.4.1 Time Series Analysis

Three parameters are investigated in time series, Hjorth complexity, Composite permutation entropy index and Fractal dimension for Frontal, Temporal, Parietal, Central and Occipital lobes.

3.4.1.1 Hjorth Parameter

Hjorth introduced in 1970, three parameters which are activity, mobility and complexity to describe the EEG signal in time domain [15]. These three parameters are also called normalized slope descriptors because they can be defined by means of first end second derivatives. The activity of the signal is a measure of mean power. Mobility is an estimate of the mean frequency. The last parameter which is complexity gives an estimate of the bandwidth of the signal. The time domain analysis using Hjorth parameters is suitable for situations where the data is EEG recording. However, Hjorth parameters calculation is based on variance, hence; it is considered low compared to other methods.

By definition, activity (mo), mobility (m2) and complexity (m4), are given by the following equations:

$$m_0 = \int_{-\infty}^{\infty} S(\omega) d\omega = \frac{1}{T} \int_{t-T}^{t} f^2(t) dt$$

$$m_2 = \int_{-\infty}^{\infty} \omega^2 S(\omega) d\omega = \frac{1}{T} \int_{t-T}^{t} \left(\frac{df}{dt} \right)^2 (t) dt$$

$$m_4 = \int_{-\infty}^{\infty} \omega^4 S(\omega) d\omega = \frac{1}{T} \int_{t-T}^{t} \left(\frac{d^2 f}{dt^2} \right)^2 (t) dt$$

Where, *S(w)* the power density spectrum, *f (t)* the biosignal as a function of time and m_n is the spectral moment at order *n*. The discrete formulas used for the calculation of these parameters are based on the following derivations [15]:

$$m_0 = \sigma_a^2$$

$$m_2 = \frac{\sigma_d}{\sigma_a}$$

$$m_4 = \frac{\sigma_{dd}}{\sigma_d} / \frac{\sigma_d}{\sigma_a}$$

Where σ_a^2 is the variance of the biosignal a, σ_d the standard deviation of the first derivative of a, σ_{dd} the standard deviation of the second derivative of a.

3.4.1.2 Composite Permutation Entropy Index

Known as a non-linear method, Composite Permutation Entropy Index (CPEI) reflects the complexity of time series. The steps of computations are described as follow [16][17].

In the first step the continuous EEG signal are fragmented into a sequence of motifs. Secondly, the motifs are shaped and classified into one of the six different types which is either ‘peaks’, ‘slopes’, or ‘troughs’. Then, the probability of motifs to show in each type was calculated. Sequentially, Shannon uncertainty formula was used to compute the permutation entropy (PE) for the resultant normalized probability distribution of the motifs,

$$PE = -\frac{\sum p_i \times \ln(p_i)}{\ln(number\ \ of\ \ motifs)}$$

Finally, two permutation entropy parameters are added for the CPEI calculation, lag τ and noise threshold *tie*. Mathematically, the formula can be expressed as,

$$CPEI = -\frac{\sum p_i \times \ln(p_i), tie < 0.5,\ \ \tau = 1\ \ + \sum p_i \times \ln(p_i), tie < 0.5,\ \ \tau = 2}{\ln(49)}$$

Where the lag τ may be equal to 1 or 2 and the noise threshold (*tie* <0.5 uV). The above formula is the combination of PE of different lags (τ =1 and τ =2), to differentiate periods of delta waves and to distinguish mid-frequency waves from very slow delta oscillation respectively. This composite index is computed based on the summation of entropies and PEs. The six motifs for each PE_τ and one for PE_{ties}, hence a total of 49 (7×7) was used to normalize the denominator.

3.4.1.3 Fractal Dimension

Fractal dimension (FD) D_f determines the complexity and irregularity of time series signal such as EEG signal. It ranges from $D_f = 1$ for a simple curve to $D_f = 2$ for a curve which nearly fills out a whole plan. The algorithm constructs *k* new time series for a given time series: *X(1), X(2),…..,X(N),* described in [16][18].

$$X_m^k : X(m), \ldots, X(m + \mathrm{int}((N-m)/k) \times k)$$

Where *m=1,2,…,k* and *N* is total number of samples, *k* is interval time, *m* is initial time, *int(r)* is integer part of a real number *r*. The mathematical formula for length *L* (*k*) *m* , of each curve X_m^k is expressed as,

$$L_m(k) = \frac{1}{k}\left|\sum_{i=1}^{M}\left|X(m+i\times k) - X(m+(i-1)\times k)\right|\right|\left(\frac{N-1}{M\times k}\right)$$

Curve length, *L(k)*, for time interval *k*, is calculated as mean of the *k* values i.e., *L* (*k*) *m* where *m= 1, 2,…, k* as described below.

$$L(k) = \left(\frac{\sum_{m=1}^{k} L_m(k)}{k}\right)$$

The value of fractal dimension D_f is calculated by a least-square linear best-fitting procedure. It is equivalent to the slop coefficient of the linear regression of the *log/log* graph of $L(k) = k^{-D_f}$

3.4.2 Frequency Domain Analysis

In this section, two parameters are investigated, absolute power and coherent. MATLAB and Neuroguide software are used to extract the individual result. Excel sheet was used to plot the graph for frontal and temporal lobes only. As previously mentioned the Frontal lobe responsible for the memory, creating and mental processes. The Temporal lobe has the responsibility of the hearing sense, due to their relevancy to our topic; it is preferred to analyze the effects of the cell phone on only F – T lobes for frequency domain.

3.4.2.1 Absolute Power

Absolute Power is the distribution of the signal power over frequency. It has been commonly used for EEG signal analysis. Absolute power determines the activity of the brain in term of different brain waves i.e. Delta, Theta, Alpha, and Beta, in order to know the cell phone's effects.

The absolute power is computed with the aid of MATLAB for all the six conditions considering before using cell phone condition as baseline. It is important to classify the electrodes according to the brain regions such as frontal (Fp1, Fp2, F3, F4, F7 and F8); central (C3 and C4); temporal (T7 and T8), parietal (P7 and P8) and occipital (O1 and O2) before comparing the different conditions to the baseline. The absolute power analysis is done brain region by region to facilitate the comparison of the different conditions with respect to the band frequencies. The ratio of the absolute power is obtained by dividing each condition to the baseline. In other words, each of the conditions (During experiment: Right ear with 5cm distance, Right ear without distance, left ear with 5cm distance, Left ear without distance and After Experiment) is compared to the baseline (before experiment) for each brain regions and frequency band. The table below illustrates the comparison of the different conditions according to the brain region with respect to the frequency band.

Absolute power for the condition Before using the cell phone	Absolute Power for each of the other five conditions	Comparison value (ratio)	Description
Delta (base)	Delta	Delta / Delta (base)	-If the ratio = 1 , means that the condition's power has not changed from the base power -If the ratio > 1, (delta, theta, alpha or beta) power of the specific condition has increased than (delta, theta, alpha or beta) power of the condition before using the cell phone, and vice versa.
Theta (base)	Theta	Theta / Theta (base)	
Alpha (base)	Alpha	Alpha / Alpha (base)	
Beta (base)	Beta	Beta / Beta (base)	

Table 2 : Comparison between conditions in term of absolute power.

3.4.2.2 Coherence

Neuroguide software is used to analyze the coherence of the EEG signal for the six conditions focusing mainly of frontal and temporal lobe. Coherence determines the amount of phase stability between two different time series, the amount of shared information and the connectivity between brain regions. There are two types of coherence which are hyper coherence defined as the lack of functional differentiation and the lack of functional connectivity refer as hypo coherence. In this project, connectivity between electrodes values is obtained from the Neuroguide software for frontal and temporal brain regions with respect to the band frequency for all the six conditions. In order to know the changes in the connectivity, the ratio of the six conditions is performed with before experiment conditions as baseline. If the ratio is greater than 1 this means the connectivity between the two electrodes has increased and vice versa.

3.5 Tools and Equipment

1. Hardware

Emotiv EPOC 16 channels EEG cap (headset assembly with rechargeable, USB transceiver Dongle, Hydration sensor Pack with 16 sensor units, Saline solution and USB charger), cell phone device (Nokia C3) and personal computer (for recording purpose).

2. Software

Emotiv EPOC Software, EEGLAB, Neuroguide, Excel and MATLAB.

3.6 Gantt Chart

Table 3: FYP I

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project topic selection														
Research														
Extended proposal submission														
Proposal Defense														
Data acquisition														
Interim draft report submission														
Interim Report submission														

Table 4 : FYPII

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Data analysis															
Progress report draft submission															
Progress report submission															
PRE - EDX															
Draft report submission															
Dissertation submission (soft copy)															
Technical paper submission															
Oral presentation															
Dissertation submission (hard copy)															

CHAPTER 4
RESULT AND DISCUSSION

This chapter includes times series and frequency domain analysis' results and interpretations. CPEI, FD and Hjorth complexity parameter were used for times series analysis for all the brain regions (frontal, temporal, central, occipital and parietal). However, the frequency domain analysis focuses mainly on absolute power and coherence for only frontal and temporal lobes.

4.1 Time Series Analysis

The CPEI, FD and Hjorth complexity parameters were computed for all six conditions mentioned here as: i) Before Experiment: Eyes Open ii) During experiment: Right ear with distance iii) During experiment: Right ear without distance iv) During experiment: left ear with distance v) During experiment: Left ear without distance vi) After Experiment: Eyes Open.. The conditions and details are summarized in table 2. The mean values for CPEI, FD and Hjorth complexity parameter are plotted with respect to conditions for all brain regions (frontal, central, parietal, temporal and occipital).

No.	**CONDITIONS**	**DETAILS**
1	Before experiment: Eyes open	Eyes opened before cell phone usage and sitting relax for 5 minutes.
2	During experiment: Right ear with distance	Answering the phone call with right ear with a distance of 5cm for 5 minutes
3	During experiment: Right ear without distance	Answering the phone call with right ear without distance for 5 minutes
4	During experiment: Left ear with distance	Answering the phone call with left ear a distance (5cm) for 5 minutes
5	During experiment: Left ear without distance	Answering the phone call with left ear with a distance of 5cm for 5 minutes
6	After experiment: Eyes open	Eyes opened after cell phone usage and sitting relax for 5 minutes

Table 5: Conditions and details

4.1.1 Composite Permutation Entropy Index

CPEI is an index of the number of frequencies in the signal and is directly proportional to it. Higher CPEI values can be linked with the presence of more frequency components [16][17]. When high frequencies are dominant in the EEG signal, the number of each species of motif in each EEG segment will be almost equal. The CPEI value is maximum (PE=1.0) when there is an identical distribution of motifs between each of the six patterns. On the contrary, the CPEI value decreases when delta waves are slow in the signal.

From the figures below, during experiment: Right ear without distance, the CPEI complexity level is higher. However, the complexity level decreases when the cell phone is at Right ear with distance. The same trend is observed on the left ear during the experiment in all the brain regions. The level of complexity explains the presence of high frequency components in the signal caused by the cell phone radiation. Participants are more exposed to the radiation during the experiment when the phone is at Right ear without distance resulting in higher brain activity. By putting the cell phone 5cm distant from the ear, the radiation reduces in all the brain regions.

In addition, before the experiment, participants are more focus instead of being relaxed. This results in high brain activity which causes the complexity level to be high in all the brain regions. On the contrary, subjects become bored after the experiment and the complexity level is lower for all the brain regions.

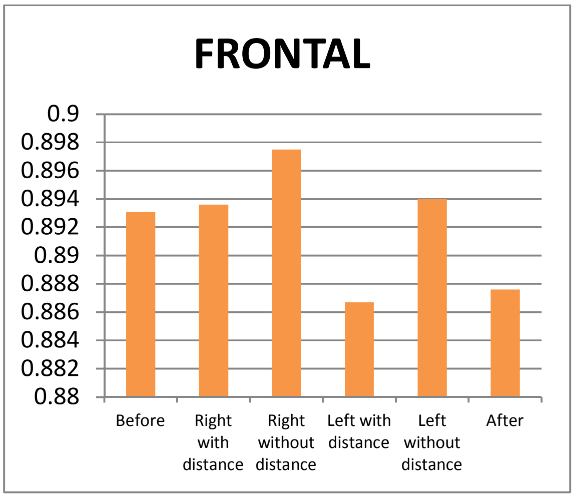

Figure14: CPEI with respect to conditions at frontal lobe

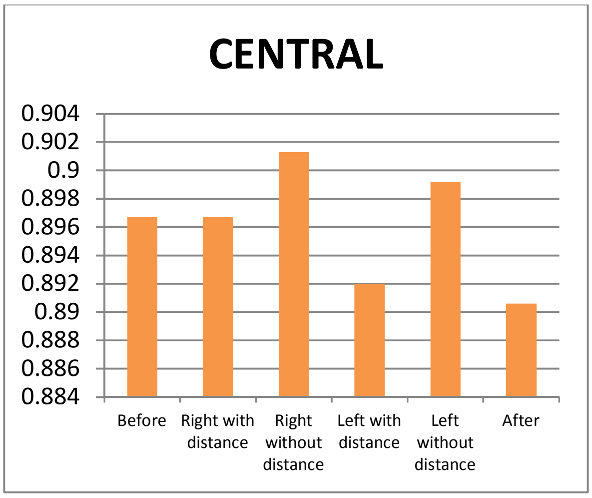

Figure15: CPEI with respect to conditions for central lobe

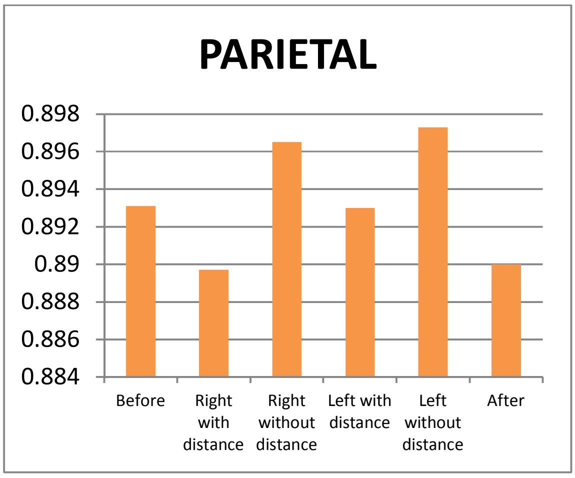

Figure16: CPEI with respect to conditions for parietal

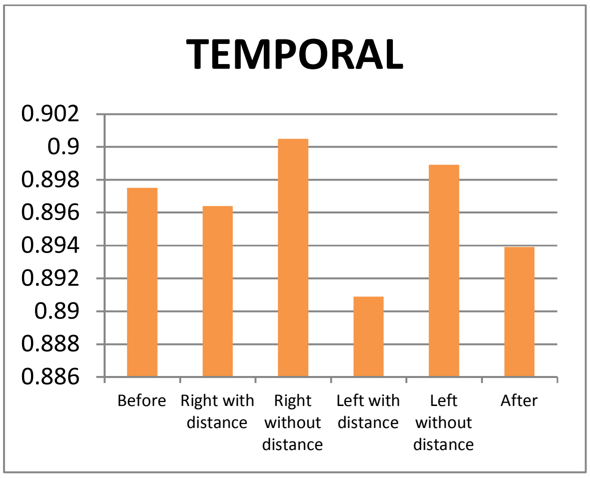

Figure17:CPEI with respect to conditions for temporal

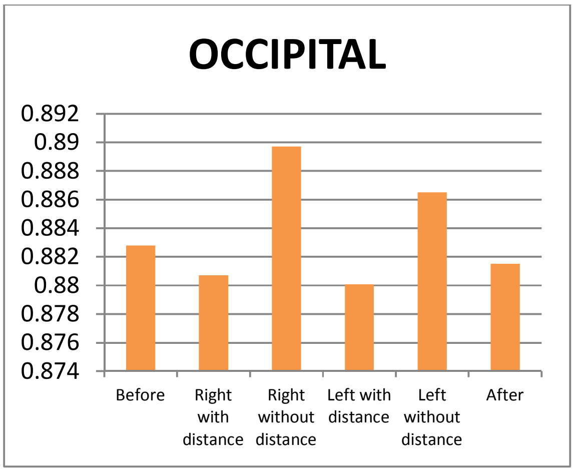

Figure 18: CPEI with respect to conditions for temporal

4.1.2 Fractal Dimension

Fractal dimension (FD) is a method to quantify the complexity of EEG signal. The figures below show the complexity level according to the conditions. The highest FD complexity level can be observed during experiment when the phone is at Right ear without distance in all the brain regions. In comparison to the left ear without distance, the complexity level is slightly lower. However, the complexity level decreases during the experiment when the cell phone is either on the right or left ear with distance. The complexity level increases with increase in frequency. Higher frequency components results in more brain activities which is due to the radiation. Participants are more exposed to the cell phone radiation when the cell phone is without distance on the right ear for five minutes. The radiation decreases with distance when the cell phone is either on right or left ear.

In addition, before the experiment, participants are more focus instead of being relaxed. This results in high brain activity which causes the complexity level to be high in all the brain regions. On the contrary, subjects become bored after the experiment and the complexity level is lower for all the brain regions.

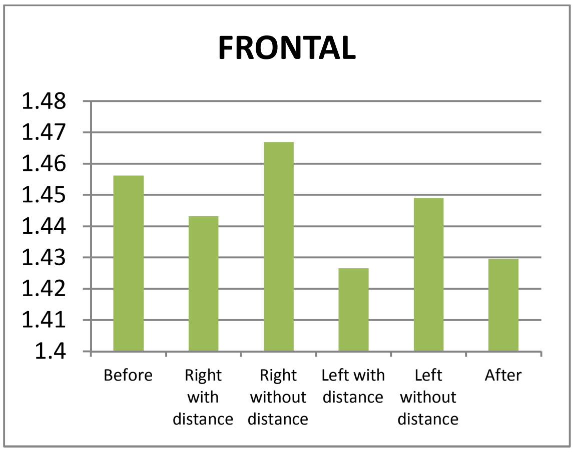

Figure 19: FD with respect to conditions for frontal

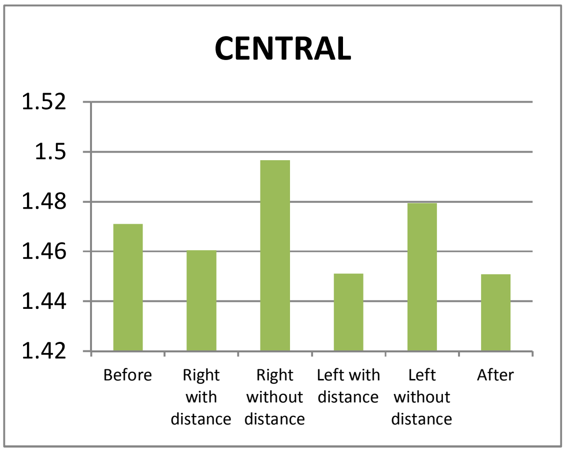

Figure 20: FD with respect to conditions for central

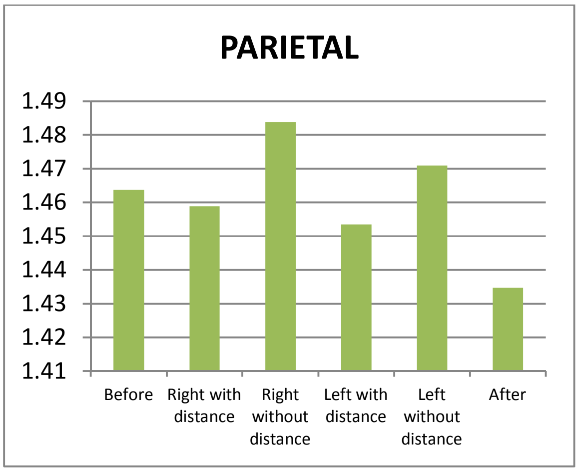

Figure 21: FD with respect to conditions for parietal

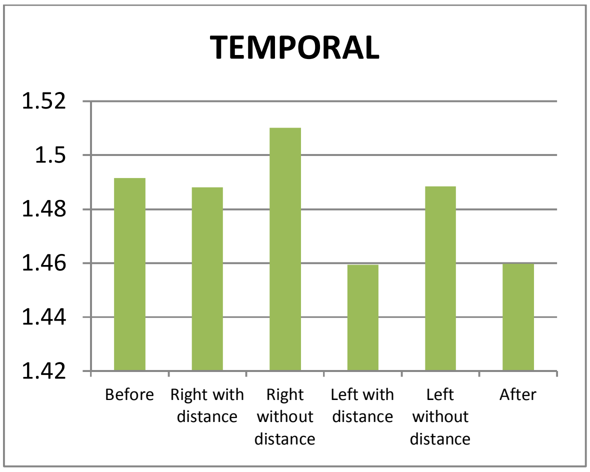

Figure 22: FD with respect to conditions for temporal

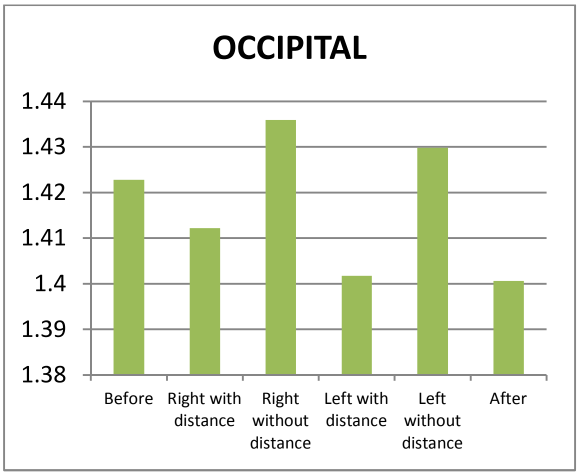

Figure 23: FD with respect to conditions for occipital

4.1.3 Hjorth Complexity Parameter

Hjorth complexity parameter is also a method to quantify the complexity of EEG signal. Looking at the trend of the figures below, it can be observed that in general, the complexity level is high during experiment when the phone is at Right or Left ear without distance in all the brain regions. However, the complexity level decreases with distance when the cell phone is either on right or left ear. The increase in the complexity level explains the presence of high frequency components due to the cell phone radiation. Participants are more exposed to the radiation during experiment when the cell phone is without distance.

In addition, before the experiment, participants are more focus instead of being relaxed. This results in high brain activity which causes the complexity level to be high in all the brain regions. On the contrary, subjects become bored after the experiment and the complexity level is lower for all the brain regions.

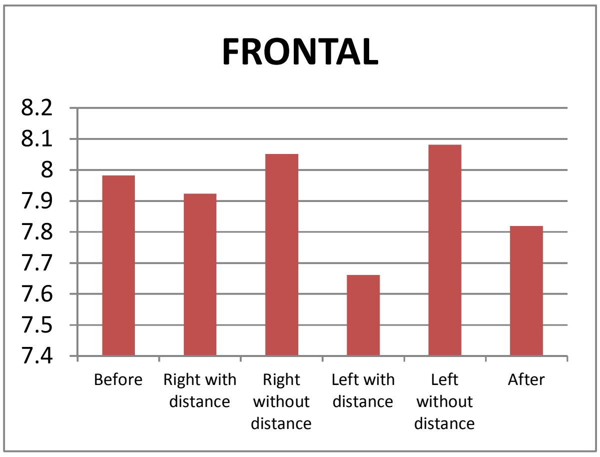

Figure 24: Hjorth complexity for frontal lobe

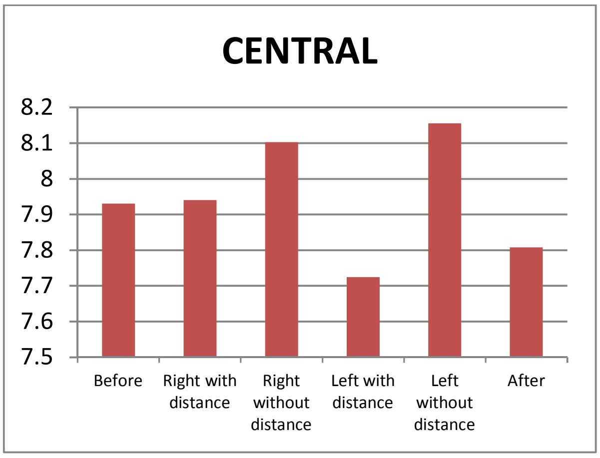

Figure 25: Hjorth complexity for central lobe

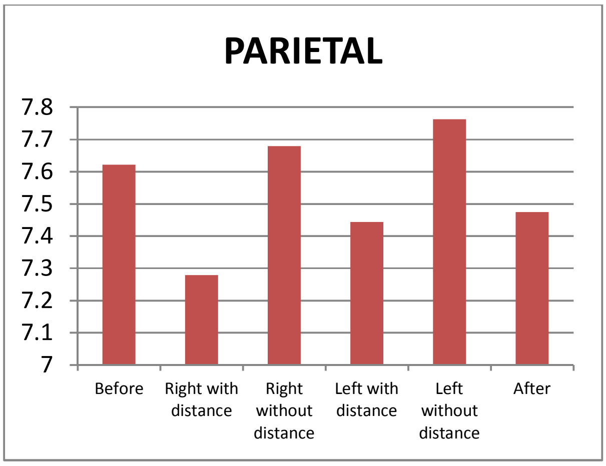

Figure 26: Hjorth complexity for parietal lobe

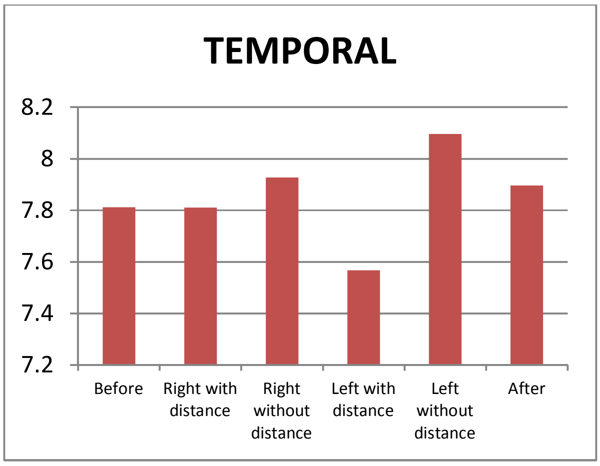

Figure 27: Hjorth complexity for temporal lobe

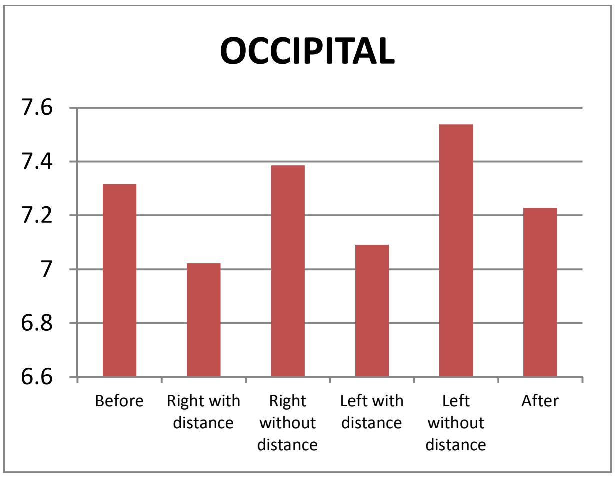

Figure 28: Hjorth complexity for occipital lobe

In summary, looking at this trend, we could say in general, that the CPEI results conformed to the FD method as well as Hjorth method. It can be observed that in general, the complexity level is high during experiment when the cell phone is at Right ear without distance compared to Left ear without distance. However, the complexity level decreases with distance when the cell phone is either on right or left ear. The increase in the complexity level explains the presence of high frequency components due to the cell phone radiation. Participants are more exposed to the radiation during the call when the cell phone is without distance.

There are limitations which should be mentioned here. The sample size (n=24) is very low. It is difficult to generalize the study. There is a need to replicate. The study participants are not evenly distributed between male and female participants (number of male participants=24, number of female participant =0). The electrodes used are only 16 which can be a constraint for source localization. We have focused our attention to three features and all of them are to quantify complexity in the time series signal as EEG in our case. Only complexity could not be the parameter to summarize the behavior of brain activations. In future work we would like to use other parameter based on frequency domain analysis e.g., wavelet analysis.

4.2 Frequency Domain Analysis

4.2.1 Absolute Power

The analysis is done for 20 healthy participants with a total of six conditions focusing mainly on frontal and temporal lobe. The simulations results are collected and plotted in excel to facilitate the analysis. From figure 29 to 32 below, it can be observed that delta and theta brain waves are lower at both frontal and temporal lobes during cell phone usage i.e. all four conditions and decrease within the period of the five minutes after the call. Delta and theta waves decreases when there are high brain activity and focus. Thus lower delta and theta brain waves means there is high radiation of the cell phone which can result in disruption and disorder in the brain. However, when the cell phone is slightly distant during the call for the four conditions at frontal and temporal lobe, delta and theta wave increase. This means there is less radiation.

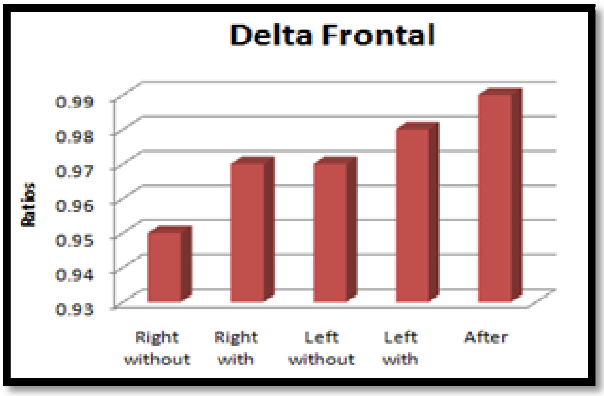

Figure 29: Absolute power ratios of Delta frontal

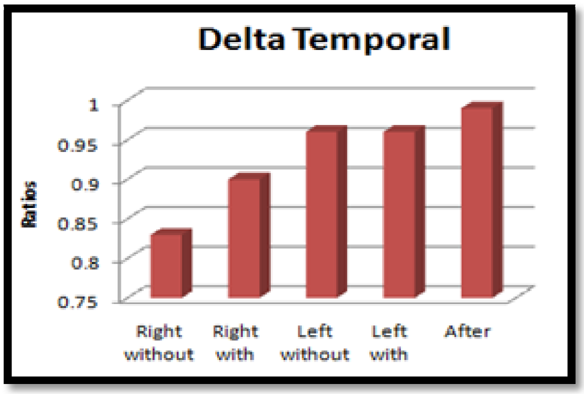

Figure 30: Absolute power ratios of Delta temporal

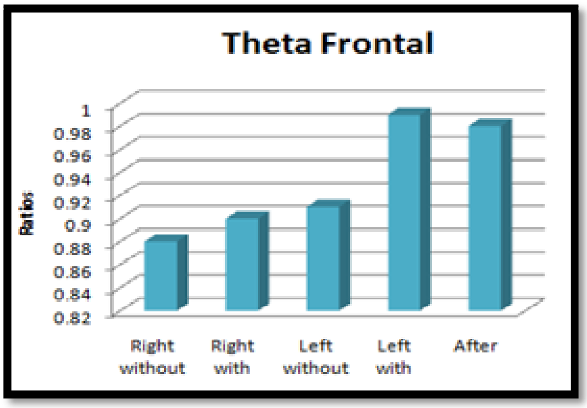

Figure 31: Absolute power ratios of theta frontal

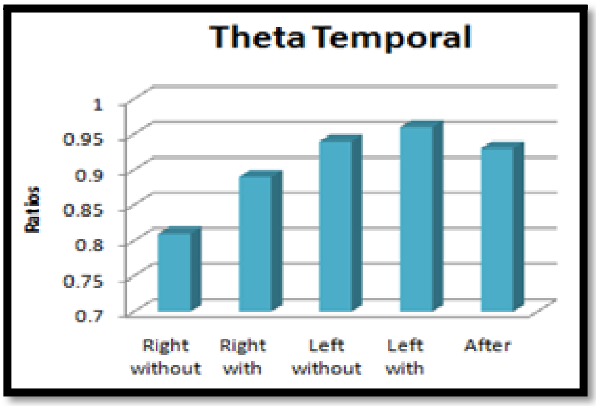

Figure 32: Absolute power ratios of theta temporal

In figures 33 and 36, alpha wave decreases during and after call on both frontal and temporal lobes. It is known that alpha wave increases during rest and relaxation moods. However, the result here shows lower alpha waves which means there was not relaxation. This is due to the radiation from the cell phone which causes some stress on the brain activity. On the other hand, alpha wave increases with distance on the left side of the brain.

In addition, beta wave increases with anxiety and mental stress. In figures 35 and 36, beta wave is higher during and after call which means the brain was under stress due to the radiation effect from the cell phone.

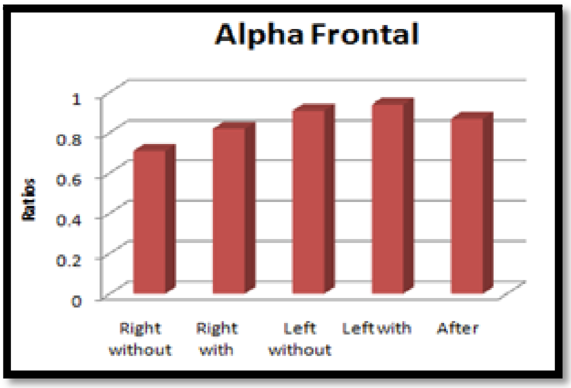

Figure 33: Absolute power ratios of alpha frontal

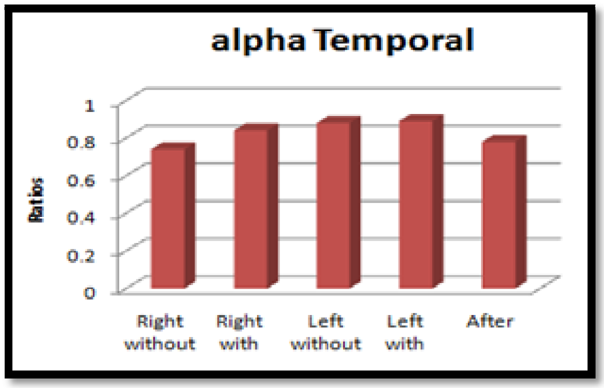

Figure 34: Absolute power ratios of alpha temporal

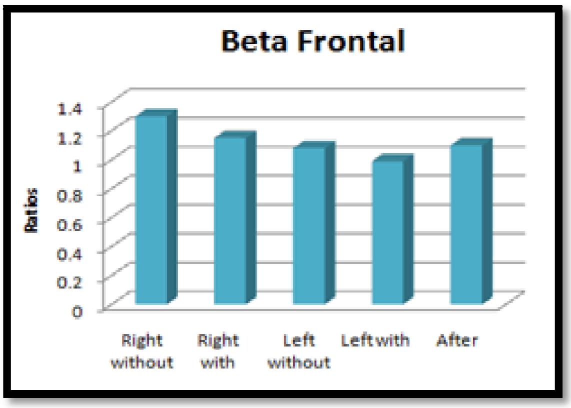

Figure 35: Absolute power ratios of beta frontal

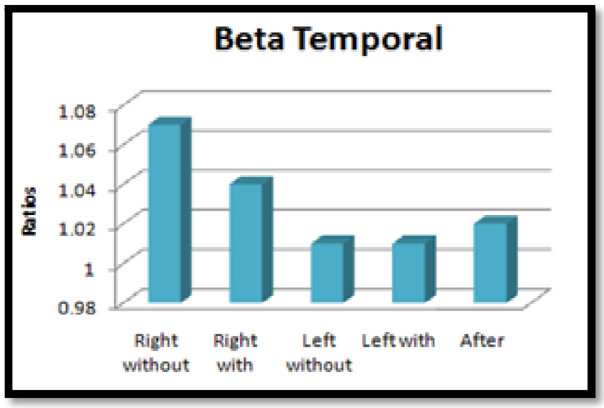

Figure 36: Absolute power ratios of beta temporal

4.2.2 Coherence

Neuroguide software is used to analyze the coherence of the EEG signal for the six conditions focusing mainly of frontal and temporal lobe. Coherence determines the amount of phase stability between two different time series, the amount of shared information and the connectivity between brain regions. The results of the coherence analysis are summarized in the table 6 below. Looking at figure 37, it can be observed that the theta and delta waves coherence are lower when the cell phone is at right side of the brain during call for both frontal and temporal. Delta and theta waves decreases when there are high brain activities. Thus lower delta and theta brain waves means there is low connectivity between electrodes due to high radiation of the cell phone. However, delta and theta waves coherence are higher when the cell phone is

5cm distant from the right side of the brain during call which means the participants are less exposed to the radiation and the connectivity is better. Similar trend is observed at the left side of the brain during call.

On the other hand, alpha wave coherence is lower when the cell phone is placed without distance during call but higher for beta wave under the same condition. Alpha wave increases during rest and relaxation moods but beta wave increases with anxiety and mental stress. This justifies that the participants are not relaxed and under stress when there is high radiation. However, alpha wave coherence is increases when the cell phone is 5cm distance during call but lower for beta wave under same condition. In this case, the radiation is lower therefore the brain is relaxed and less stress. The connectivity is improved. The same phenomenon is observed on the left side of the brain.

Table 6: The summary of the coherence ratio between the Frontal lobe and the Frontal lobe in terms of frequency bands

Frontal - Temporal					
Frequency bands	**Right side without distance**	**Right side with distance**	**Left side without distance**	**Left side with distance**	**After using the cell phone**
DELTA	**0.31**	**0.47**	**0.68**	**0.75**	**0.8**
THETA	**0.64**	**0.91**	**0.94**	**0.98**	**0.89**
ALPHA	**0.86**	**0.88**	**0.95**	**0.95**	**0.98**
BETA	**1.17**	**1.07**	**1.03**	**1.03**	**1.01**

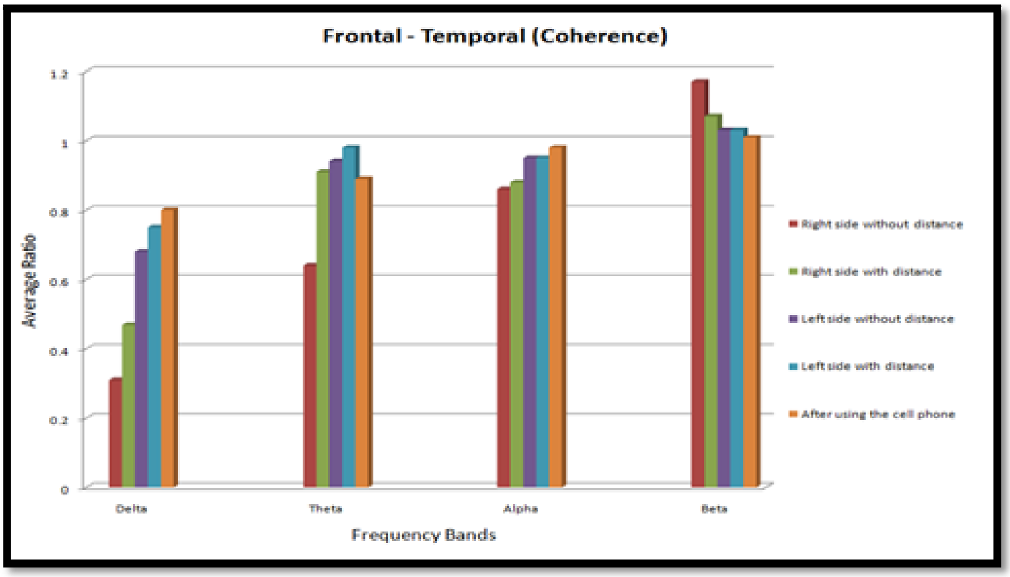

Figure 37: The summary of the coherence ratio between the Frontal lobe and the Temporal lobe in terms of frequency bands

CHAPTER 5
CONCLUSION & RECOMMENDATION

In this research, the effects of cell phone on human brain are investigated using electroencephalogram (EEG). The brain signals are recorded using 16-channels EEG for six different conditions for a total of 24 participants. After data were pre-processed, the signal irregularity for all the six conditions was computed.

Three parameters were used to measure the signal complexity for time series data: i) Composite Permutation Entropy Index (CPEI), ii) Fractal Dimension (FD) and iii) Hjorth complexity. Based on these three parameters, the results showed that the complexity level is high during experiment when the cell phone is at Right ear without distance compared to Left ear without distance for all the brain regions (frontal, central, parietal, temporal and occipital). However, the complexity level decreases with distance when the cell phone is either on right or left ear. The increase in the complexity level explains the presence of high frequency components due to the cell phone radiation. Participants are more exposed to the radiation during the call when the cell phone is without distance.

For the frequency domain, absolute power and coherence were used for the analysis. It can be observed from the result that delta, theta and alpha brain waves are lower at both frontal and temporal lobes during cell phone usage. But beta wave is higher during and after call. This is due to the effect of radiation from the cell phone.

There are limitations which should be mentioned here. The sample size (n=24) is very low. It is difficult to generalize the study. There is a need to replicate. The study participants are not evenly distributed between male and female participants (number of male participants=24, number of female participant =0). The electrodes used are only 16 which can be a constraint for source localization. We have focused our attention to three features and all of them are to quantify complexity in the time series signal as EEG in our case. In future work we would like to use other parameter based on frequency domain analysis e.g., wavelet analysis.

REFERENCES

[1]. C. Corle et al.. "Cell phones and glioma risk: a review of the evidence." J Neurooncol **106**(1):1-13, 2012

[2]. Anatomy of the Brain. http://www.mayfieldclinic.com/PE-AnatBrain.htm

[3]. Brain wave signal (EEG) of neurosky, Inc . pp 1-8 , December 2009.

[4]. H.-P. Reiser, W. Dimpfel, and F. Schober. "The influence of electromagnetic fields on human brain activity." European Journal of medical research, 1:27-32, 1995/96.

[5]. Röschke, J., and Mann, K.. "*No short-term effects of digital mobile radio telephone on the awake human electroencephalogram*". Bioelectromagnetics,18: 172-176, 1997.

[6]. H. D'Costa et al. "Human brain wave activity during exposure to radiofrequency field emissions from mobile phones." Australasian Physical & Engineering Sciences in Medicine 26: 4,2003

[7]. H. Hinrikus, M. Bachmann, R. tomson and J. Lass. "Non-Thermal Effect of Microwave Radiation on Human Brain." The Environmentalist, 25, 187–194, 2005

[8]. K. Mann, J. Roschke. "Effects of pulsed high-frequency electromagnetic fields on human sleep." Neurophysiology, 33: 41-47, 1996

[9]. James C. Lin. "Effects of Cell-Phone Radiation on the Electroencephalographic Spectra of Epileptic Patients". *IEEE Antennas and Propagation Magazine*, Vol. 52, No.6, December 2010

[10]. E. Maby et.al. "Short-term effects of GSM mobiles phones on spectral components of the human electroencephalogram". *Engineering in Medicine and Biology Society, IEEE Annual International Conference* , PP. 3751 – 3754, 2006

[11]. M. Hietanen, T. Kovala, and A.M. Hamalainen, "Human brain activity during exposure to radiofrequency fields emitted by mobile phones," *Scandinavian J. Work, Environment & Health*, vol. 26, pp. 87–92, 2000.

[12]. N.N. Lebedeva, A.V. Sulimov, O.P. Sulimova, T.I. Kotrovskaya, and T. Gailus, "Cellular phone electromagnetic field effects on bioelectric activity of human brain," *Crit. Rev. Biomed.Eng.*, vol. 28, pp. 323–337, 2000.

[13]. James C. Lin. "Human EEG and Microwave Radiation from Cell Phones". *IEEE Microwave magazine, vol.5, pp* 34 – 38,*June 2004*

[14]. James C. Lin. "*Cell Phone Microwaves and Cognitive Function in Children". IEEE Microwave magazine, vol.7, pp.* 32 - 35 *, February 2006*

[15]. M. Vourkas, G. Papadourakis, & S. Micheloyannis. "Use of Ann and Hjorth Parameters in Mental-Task Discrimination".

[16]. W. Mumtaz et al. "EEG Classification of Physiological Conditions in 2D/3D Environments Using Neural Network". 35th Annual International Conference of the IEEE EMBS, July, 2013

[17]. E. Olofsen1, J. W. Sleigh and A. Dahan. "Permutation entropy of the electroencephalogram: a measure of anaesthetic drug effect". British Journal of Anaesthesia, pp 1 – 12, 2008

[18]. A. Accardo , M. A¦nito , M. Carrozz, and F. Bouquet. "Use of the fractal dimension for the analysis of electroencephalographic time series". Biological Cybernetics, pp 339-350, 1997

[19]. J.Wu et al. "InteIIigent artefact identification in electroencephalography signal processing." *IEE Proceedings* ,144:5, September 1997.

[20]. J. L. Relova et al. "Effects of cell phone radiation on the electroencephalographic spectra of epilectic patients". IEEE Antennas and propagation Magazine, pp.173-179, 2010.

[21]. K. Lias et al. "Biological effect of 900MHz and 1800MHz mobile phones in SAR weight". IEEE Antennas and propagation Magazine, pp.422-425, 2009.

APPENDICES

APPENDIX A

QUESTIONNARE FORM

Participant Personal Information

Name:

Contact Number: **E-mail:**

Gender: Male ☐ Female ☐

Age:

Questionnaire

1. Have you ever experienced an EEG test before?

Yes ☐ No ☐

2. Are you taking any daily medications?

Yes ☐ No ☐

3. Do you have any current health problems of any sort (e.g.: diabetes, cancer, bed wetting, Etc.)?

Yes ☐ No ☐

4. Have you ever experienced any form of severe head injury/ sever fever?

YES ☐ NO ☐

5. Do you have skin allergy?

YES ☐ NO ☐

6. How many calls you normally have per day?

7. What is the average duration per call?

8. What are the effects that you usually have when using mobile phone?

9. How long these effects usually last?

10. Are you suffer from any permanent headache?

11. If yes, how many times you suffer from it? (Per week or per month)

APPENIX B

CONSENT FORM

Subject Information and Consent Form
(Signature Page)

Research Title: ***analysis of the side effects of cell phone on the brain using EEG***

Researcher's Name: ***Teihissande Tingolfa, Assoc. Prof. Dr. Aamir Saeed Malik***

To become a part this study, you or your legal representative must sign this page. By signing this page, I am confirming the following:

- I have read all of the information in this Subject Information and Consent Form including any information regarding the risk in this study and I have had time to think about it.
- All of my questions have been answered to my satisfaction.
- I voluntarily agree to be part of this research study, to follow the study procedures, and to provide necessary information to the doctor, nurses, or other staff members, as requested.
- I may freely choose to stop being a part of this study at anytime.
- I have received a copy of this Subject Information and Consent Form to keep for myself.

________________________________ ____________________
Subject Name (Print or type) Subject Initials and Number

________________________________ ____________________
Subject I.C No. (New) Subject I.C No. (Old)

________________________________ ____________________
Signature of Subject or Legal Representative Date (dd/mm/yy)
(Add time if applicable)

____
Name of Individual
Conducting Consent Discussion (Print or Type)

________________________________ ____________________
Signature of Individual Date (dd/mm/yy)
Conducting Consent Discussion

________________________________ ____________________
Name & Signature of Witness Date (dd/mm/yy)

Note: i) All subject/subjects who are involved in this study will not be covered by insurance.

Subject's Material Publication Consent Form
Signature Page

Research Title: ***analysis of the side effects of cell phone on the brain using EEG***

Researcher's Name: ***Teihissande Tingolfa, Assoc. Prof. Dr. Aamir Saeed Malik***

To become a part this study, you or your legal representative must sign this page.
By signing this page, I am confirming the following:

- I understood that my name will not appear on the materials published and there has been an effort to make sure that the privacy of my name is kept confidential although the confidentiality is not completely guaranteed due to unexpected circumstances.
- I have read the materials or general description of what the material contains and reviewed all photographs and figures in which I am included that could be published.
- I have been offered the opportunity to read the manuscript and to see all materials in which I am included, but have waived my right to do so.
- All the published materials will be shared among the medical practitioners, scientists and journalist worldwide.
- The materials will also be used in local publications, book publications and accessed by many local and international doctors worldwide.
- I hereby agree and allow the materials to be used in other publications required by other publishers with these conditions:
- The materials will not be used as advertisement purposes nor as packaging materials.
- The materials will not be used out of context– i.e.: Sample pictures will not be used in an article which is unrelated subject to the picture.
- There may be financial implications associated with the data or findings of this study. I agree that I will not be entitled to receive any financial compensation or claim any financial value except the already agreed honorarium for this study.

______________________________ ____________________

Subject Name (Print or type) Subject Initials or Number

_______________ _______________ _______________

Subject I.C No. Subject's Signature Date (dd/mm/yy)

______________________________ ____________________

Name and Signature of Individual Conducting Consent Discussion Date (dd/mm/yy)

Note: i) All subject/subjects who are involved in this study will not be covered by insurance.