ANALYZING THE EFFECTS OF CELL PHONE ON THE BRAIN USING EEG

By

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14126

FINAL PROJECT REPORT

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

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CERTIFICATION OF APPROVAL

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Approved by,

_____
Dr. NIDAL KAMIL
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
MAY 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.

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Eithar IsameldinAhmed Nouri

ABSTRACT

Cellular phones have become an integral part of modern telecommunications, however these mobiles communicate by transmitting high radio waves absorbed into the users' head during calls which could create health problems. For this reason, this research analyzes the effects of cell phones on the brain and attempts to find a way to reduce the direct radiation from the mobile. Brain signals are recorded using Emotiv16-electrode from 20 subjects, under different six conditions: before use; four sub conditions during use i.e. using the right ear without distance, right ear with distance, left ear without distance and left ear with distance; and finally after use of the cell phone. The collected data is analyzed using MATLAB and Neuroguide software. The findings show that the mobile phones could have an effect on the brain during the calls and five minutes after calls. These effects cause a decrease in Delta, Theta and Alpha power, and an increase of Beta power. Comparing the conditions of during and after calls to before calls, the coherence or the connection between the temporal and frontal lobe, are significantly lower in terms of Delta, Theta and Alpha, and greater in terms of Beta waves. There is then evidence that cell phones have side effects on the human brain. Keeping the cell phone away from the ear, or using the left ear instead of the right ear is recommended in order to reduce the side effects due to the radiation of the mobile phones.

ACKNOWLEDGEMENTS

Praise to Allah, 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. Nidal Kamil and my co- supervisor Dr. Aamir Saeed Malik, for the dedication of their time and effort, teaching, guiding and helping me in all my work-related tasks despite their many other obligations.

My gratitude is extended to the postgraduate students for 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 TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

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

CHAPTER 1
INTRODUCTION

1.1 Background of study

The brain is the most important part in the human body structure as it controls the movement, sensation, emotions and all bodily activities. It has a large number of cells called neurons and, as a result of any activity in the body, these cells produce electrical pulses. The combination of these electrical pulses of the brain is commonly called a Brainwave. Electroencephalography or EEG, a technique to record brainwaves, detects any changes or disease in the brain by placing certain electrodes on the scalp to sense and measure voltage fluctuations. EEG has created a revolution in Neuropsychology especially in the medical field to indicate various states or activity levels of the brain [1] [2].

As integral features of modern telecommunications, the use of cellular phones is growing rapidly worldwide and it is reported in most countries approximately 80% of the population owns a mobile phone. This information has influenced the present investigation to study the effects and changes that could occur to the human brain whilst using the cell phone, as mobiles transmit high frequency radio waves through their antennae and are connected to a wireless communications network via radio waves or satellite transmissions. The radiated radio frequency of a mobile phone is in the range of 450 – 2500 MHz. Moreover, the radiated power from the antenna is about 125mW and from the cell phone about 2 watts [3].

Normally, during the usage of mobile phone the human head absorbs the radio waves, and many users have reported feeling several unspecific symptoms during and after using the cell phones, such as headaches and dizziness. These problems have lead to the goals of this project which are to study the side effects of the cell phone on the human brain using electroencephalograph (EEG) technique, as well as to bring awareness to the

public about the effect of radiation from cell phones so that the users can take precautions.

1.2 Problem statement:

Cellular phones transfer signals via electromagnetic waves by emitting very high radio frequencies. When using the cell phone, electromagnetic waves are absorbed by the human head causing health problems especially at the place near the ear and skull regions where they are known to affect the neurons. The proof of this is from some users who have already reported headaches and dizziness during and after using their cell phone. Moreover, according to the World Health Organization, the radiation from cell phones could cause cancer. These reasons have triggered the interest of many scientists and researchers to investigate and monitor any potential public health impact. However, the scientific literature on this subject is wide apparently shows very inconsistent effects across studies. This research has therefore been carried out to investigate the side effects of the cell phone on brain activities.

1.3 Objectives and the scope of work:

The objectives of the project are:

- To investigate and study the side effects of the cell phone's electromagnetic field on the human brain using electroencephalographic (EEG).
- To find a way to reduce the side effects of the direct radiation from the cell phone on the human brain.

The scope of work for the first semester of this final year project (FYP1) concentrated on the literature review, theories, design of experiment and training on data collection. We concentrated on data collection, removing artifacts, analyzing and post processing the data in the second semester (FYP2).

1.4 Relevancy & Feasibility of the project:

Relevancy: This research is related to the biomedical and neural engineering field, as engineering and medicine fields are integrated to improve health care.

Feasibility: The project can be achieved within two semesters according to the availability of equipment required for collection of data, software and tools for data analysis.

CHAPTER 2
LITERATURE REVIEW

In order to understand the project results we should be familiar with some important points such as: the brain internal structure, brainwaves, EEG technique and the concepts of cell phone radiation. This chapter discusses these points and some previous researches related to our project.

2.1 Brain structure:

The brain is the most complex object in the known universe. It consists of a large number of cells called neurons which can reach up to 100 billion cells. A neuron is defined as a particle that consists of three main parts which are: **Soma** named as the cell body; it is the main cellular space of a neuron, in where the nucleus and the neuron's genetic information can be found. The second part is **The Axon** which is responsible for sending signals and messages to other neurons. Lastly **the dendrites** which is responsible for receiving messages from other neurons. The neurons are connected to each other through neural nets called synapses [1] [2] [4].

The neurons are responsible for sending and receiving the information, muscle movement, processing and controlling all our behavior and activities as well. As a result of any activity in the body, the neurons produce electrical pulses and currents are flow through the synapses. These electrical currents consist of some ions such as: K+, Na+, Ca++ and Cl-, it goes in and out the neuron through membrane channels using specific channel. So when these membrane channels are open, the ions diffuse through the membrane causing an increment of the positive electrical charge [1] [2] [5].

The surface area of the brain is called Cerebral Cortex, it has two hemispheres: right and left hemisphere, the communication between them is through the Corpus Callosum. Each one of the hemispheres plays a specific role;

The right hemisphere: named as representational hemisphere; it controls the left side of the body. Moreover it is responsible for emotion, doing the necessary processes that are needed for the nonverbal information and creativity as well [5].

Left Hemisphere: its function is controlling the right side of the body, thinking as well as analyzing and understanding languages [5].

Human brain has been divided into three main parts: Please refer to figure 1.

The Cerebrum

It is called the cerebral hemisphere that represented the most superior part of the brain, which is around 83% of total brain mass. It consists of gray surface layer and many convolutions, has three different functional areas: the motor areas, sensory areas and association area. The Cerebrum responsible for complicated analysis, movement initiation, conscious awareness of sensation, as well as the expression of emotion and behavior.

It is divided into four main parts or lobes: Please refer to figure 1.

Frontal Lobe: it occupies the front part of the brain which lies directly behind the forehead. Moreover, this area of the brain responsible for high cognitive functions, these functions can be concluded as controlling the responses and the reactions as input from the rest of the system, establishing relations between working memory representations, Behavior, critical thinking processes, creativity, problem solving, attention, some emotion, coordination of muscles movement, generalized and mass and skilled, some eye movements and sense of smell as well [2] [6][7] [8] [9].

Parietal Lobe: this lobe is located behind the motor area and before the occipital lobe, which associated with sensing functions and combination and comprehension. Responsible for language and functions, and some visual functions as well. It has fast response to detect any external or internal affects the body. Some of the researchers found that there is a direct relationship between the parietal lobe and episodic memory [2] [6] [7] [8] [10].

Temporal Lobe: it occupies the part above the ears, this area is more concerned about the Sense of hearing and hearing memories (such as music) , visual memories , some of speech, behavior, vision pathways and emotions and also the fear[2] [6] [7] [8].

Occipital lobe: it is located at the rear part of the brain which is above the cerebellum, Responsible for all the processes regarding the visualization, identifying the images and colors and linking that visual information with the memory. There is direct link between the occipital lobe and all other lobes to provide higher visual functions, such as reading, writing, and recognition. [2] [6] [7] [8] [11].

All the lobes are found on either side of the brain left and right side, in order to differentiate between the electrodes, for the right side the even numbers are used i.e. T2 , P2, F2 , but odd number in the left side i.e. T1, P5 , F3 .

The Cerebellum:

Small portion which lies upper the Brain stem. It controls the muscle movement and keeps and maintains the body's balance. It is considered as the smallest part of the brain. The main functions of this part are:

- Movement coordination as the cerebellum controls the synchronization of the muscle activation during movement.
- Maintain and regulate the balance of the body muscles while standing and moving.

The Brain stem:

The bottom end of the head part, it is responsible for the heart regulation, respiration, Neuro hormone and hormone secretion.

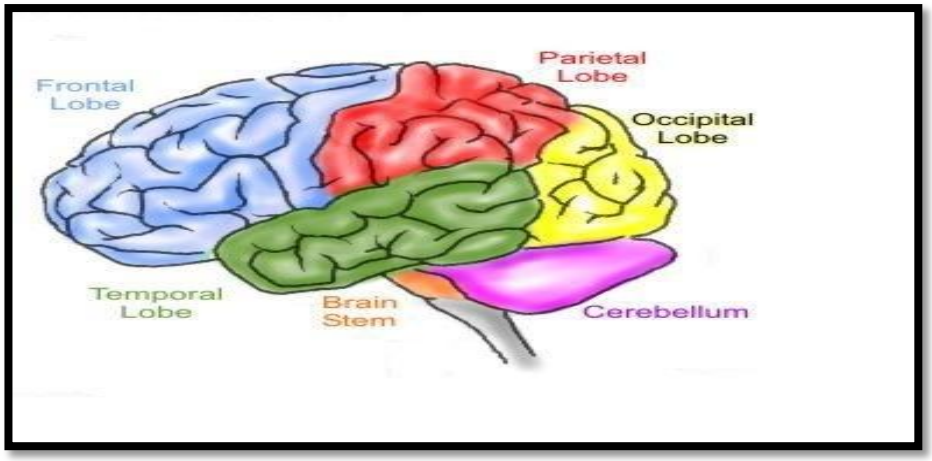

Figure 1: Regions of the human brain

The brainwaves:

The neurons communicate with each other through the electrical pulses language. The human activities will be translated and shown as frequencies and signals, which are called brainwaves, the brainwaves are very important criterion to know the human behavior and health status, all that can be done by measuring the electrical pulses and voltages of the brain signals, using the EEG, it is applied by placing electrodes on the scalp, amplifying the signals and displaying them on a PC screen.
Based on the frequency the brain waves had been classified into four basic groups:

-**Delta waves (0.5 – 4 Hz**): it has the highest amplitude (more than 100 micro volts) and the lowest frequency when it compares to the other waves. The area of these waves in Central cerebrum and parietal lobes. It can be found mainly in infants, during deep stages of sleep without dream and serious organic brain disease. The reactivity of delta wave is when the transactions of the upper brain stem separating the reticular activating system from the cerebral cortex delta will occur[1][12] [13].

-**Theta waves (4 – 8 Hz):** the amplitude 60 – 100μV available in the frontal, parietal and temporal regions. It can be found in the states of drowsiness and the first stages of sleep. People who have high rates from theta waves, suffering from the lack of focus. [1][12] [13].

-**Alpha Waves (8 – 13 Hz):** these waves were discovered in 1908 by Berger with amplitude 20 – 60 μV, it is concentrated in the occipital and parietal. Basically these waves decrease with the increase of age because of that the children have Abundance in Alpha waves. It appears when the brain's activity is inactive state, the cases of the relaxation and also when the eyes are closed. [1][12] [13].

-**Beta Waves (13 -30 Hz):** beta waves with very low amplitude (less than 20 μV), it is produced from the left hemisphere, there are three types of beta waves: Frontal beta blocked by movement widespread beta often un reactive Posterior beta shows reactivity to eye opening, so we can say that it induces in the cases of open eyes and wakefulness, active brain, consciousness and also the learning states thinking, calculating … etc. .[1][12] [13].

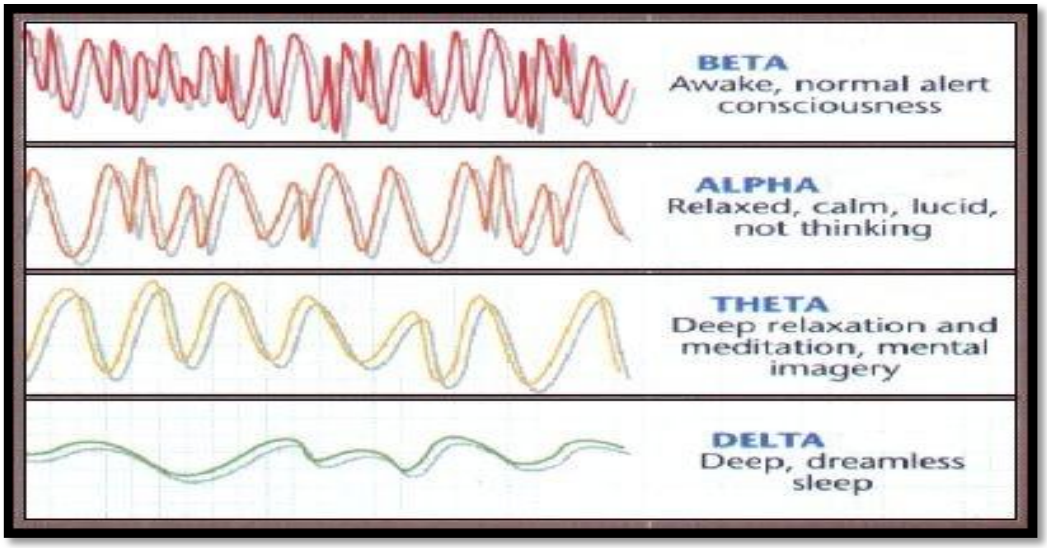

Figure 2: The Brainwaves

2.2 Electroencephalography EEG

In 1875 the English physician Richard Caton has studied the rabbits and monkeys brain and he found that there are electrical currents flowin the brain. In 1924, Hans Berger Continued the Caton's work, then he conducted the first EEG experiment; moreover he

recorded the electrical activities from the human's scalp by using the ordinary radio equipment [1].

Electroencephalography can be defined as a technique to read the electrical activities (current and voltage) that occur in the human brain by placing the measurement device on the human scalp. Actually it is a very advanced system in the field of biomedical as it has many uses, such as in monitoring alertness, development of the brain and brain death, Also it does Brain test whether there is a tumor, as well as the test drug addiction and other uses .The most important advantages of EEG that the test conducted in a short time (High temporal resolution), noninvasive, very cheap and easy to obtain the recorded data as well [1] [14]. The voltage amplitude of an EEG signal is about 40 to 100 V and the frequency varies from 0 to 100 Hz [15]. There are several types of EEG system for data acquisition such as Emotiv EPOC, Enobio and the net station (128 electrodes). Here we will focus on Emotiv EPOC.

Emotiv EPOC :(refer to figure 3 & 4)

The EEG hardware devices for Emotiv: **electrodes cap** to measure the signal from the head surface by transforming the ionic current on the skin to the electrical current in the electrode, electrodes need sub devices such as headset assembly with rechargeable, USB transceiver Dongle, Hydration sensor Pack with 16 sensor units, Saline solution and USB charger and we should get a **recording devices** such as personal computer. Refer to the following two figures [1] [14].

Figure 3: Emotiv EPOC headset

Figure 4: Emotiv sub devices

To capture the signals we should place the electrode cap in a certain way, using the international standardization system called 10-20 electrode placement system, "10" and "20" refer to the distances between adjacent electrodes [6].The 10 – 20 standardized system designed to pick up the electrodes on the head surface, mainly to get an appropriate and accurate results the scalp had been divided into many lobes F (frontal), T (temporal), P (posterior), and O (occipital), these letters with odd numbers refers to the left side of the head and with even numbers refer to the right side one [1] [2] . Please refer the following figure.

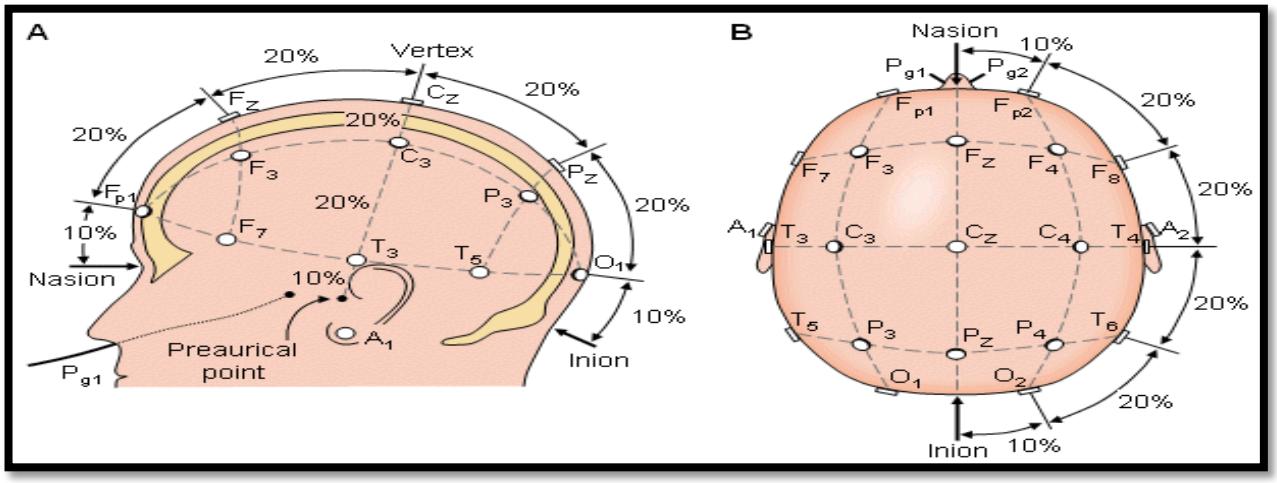

Figure 5 : 10 – 20 electrode placement system

2.3 Cellular Phones

A cell phone is an electronic telecommunication device, it connects to the wireless network through the radio waves using high frequency to transmit and receive the data. It radiates radio frequency in the range of 450 to 2500 MHz [3].

The intensity of human brain magnetic field is 10^-13 Tesla. As well as the intensity of cell phone's magnetic field when a cell phone switch off is (750mT), cell phone ringing is (0.015 T) and during calls is (0.03 T), the brain absorbs these electromagnetic waves which causing the health problems [16].

Mobile telephones are two-ways radios. When the sender talks into a mobile telephone, it converts the sound into radio frequency energy (or radio waves). The radio waves travel through the air until they reach a receiver at a nearby base station, the base station then sends your call through the telephone network until it reaches the receiving side.

When you receive a call on your mobile phone, the message travels through the telephone network until it reaches a base station close to your phone, the base station then sends out radio waves that are detected by a receiver in your telephone, where the signals are changed back into voice or data.

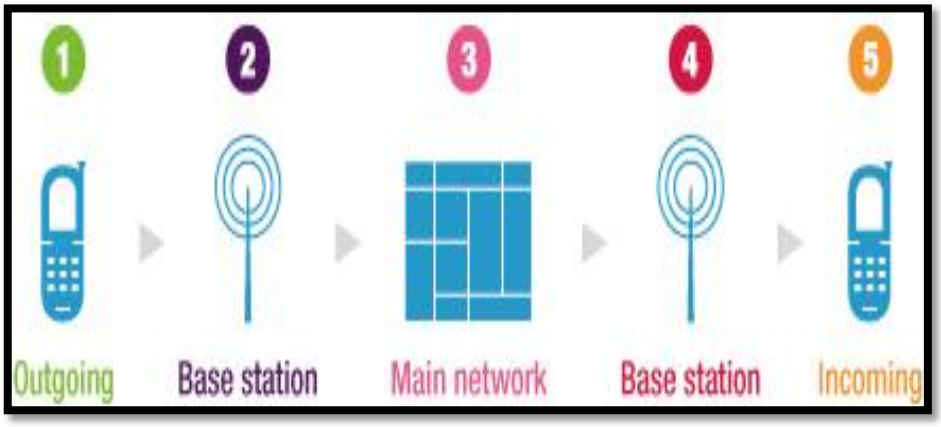

Figure 6 the mechanism of the cell phone

2.4 Previous Researches

Experiments have investigated the effects of mobile phone usage on human brain waves, particularly on alpha waves using electroencephalograph (EEG) technique [17]. The brain signals were recorded during a call between cell phones under different conditions i.e. right side and left side of the brain. These signals were analyzed using statistical analysis SPSS version 17.0 .The findings indicated that alpha levels decrease during the use of the cell phone with the right side but when the left side is used alpha waves remain stable and constant. The research outcome was that alpha waves decrease with the increment of cell phone radiation.

Further research examined the effects of electromagnetic radiation for two different types of cell phones: Global System for Mobile Communications (GSM) and Code Division Multiple Access (CDMA) as these two types have different power levels and frequencies. The experiments were conducted using 10 participants in three different statuses before using the phone i.e. in idle mode, using GSM and CDMA. The brain signals, which formed the data, were measured and collected using EEG. By applying digital signal processing techniques to analyze the data, the Fast Fourier Transform (FFT) was applied to find the power spectrum density of the brain electrical signals during emission of radiation from the mobile phone. The result was that the highest power spectral density happens when the GSM is used. The result also showed that the Global System for Mobile Communications (GSM) has the highest effect on the brainwaves than Code Division Multiple Access (CDMA) [18].

One study researched the effects of the mobile phone's electromagnetic field EMF on the human brain using EEG technique. Data was analyzed using a linear method to compute the spectral power, and it was found that 13 – 31% of the participants were affected by the field, which was dependent upon the modulation frequency [19].

A German group examined the effects of mobile-phone EMF on brain signals during sleep. The experiments were conducted with 12 volunteers at night during 5 stages of sleep and during exposure to radiofrequency (RF) emissions from a mobile phone. The signals were captured by EEG, and after analyzing the data, the result showed Spectral power during REM sleep was increased by 5% during EMF exposure but not in the other sleep stages [20].It should be noted that many cell phone users, especially teenagers, regard their units as replacement alarm clocks and sleep with the mobile underneath their pillow throughout their sleep. In this respect, this study raises concern about this practice.

Reiser and Dimpfel investigated the effect of radiation from a cell phone on the brain signals. Thirty six participants were assigned to the experiment under three conditions: before, during and after the call, with the researchers finding there is an increment in relative alpha power during and after field exposure [21].

Further experimentation studied the effect of mobile phone electromagnetic field emissions on the human brain using EEG, with 10 subjects during the presence and absence of radiofrequency (RF) that was generated by mobile phones under two conditions. In the first trial, RF was generated by GSM mobile phone and transmitted at fully – radiated power. In the second trial RF emissions were generated by a non-modified GSM mobile phone .Each case took five minutes. After collecting the data statistical analysis was applied, with the result indicating a difference in the full-power mode trial within the EEG alpha (8-13 Hz) and beta (13-32 Hz) bands [22].

CHAPTER 3
METHODOLOGY

This chapter includes the methodology that interprets the timeline, activities, Gantt chart, key milestones and the tools that have been used in the project.

3.1Procedure Identification:

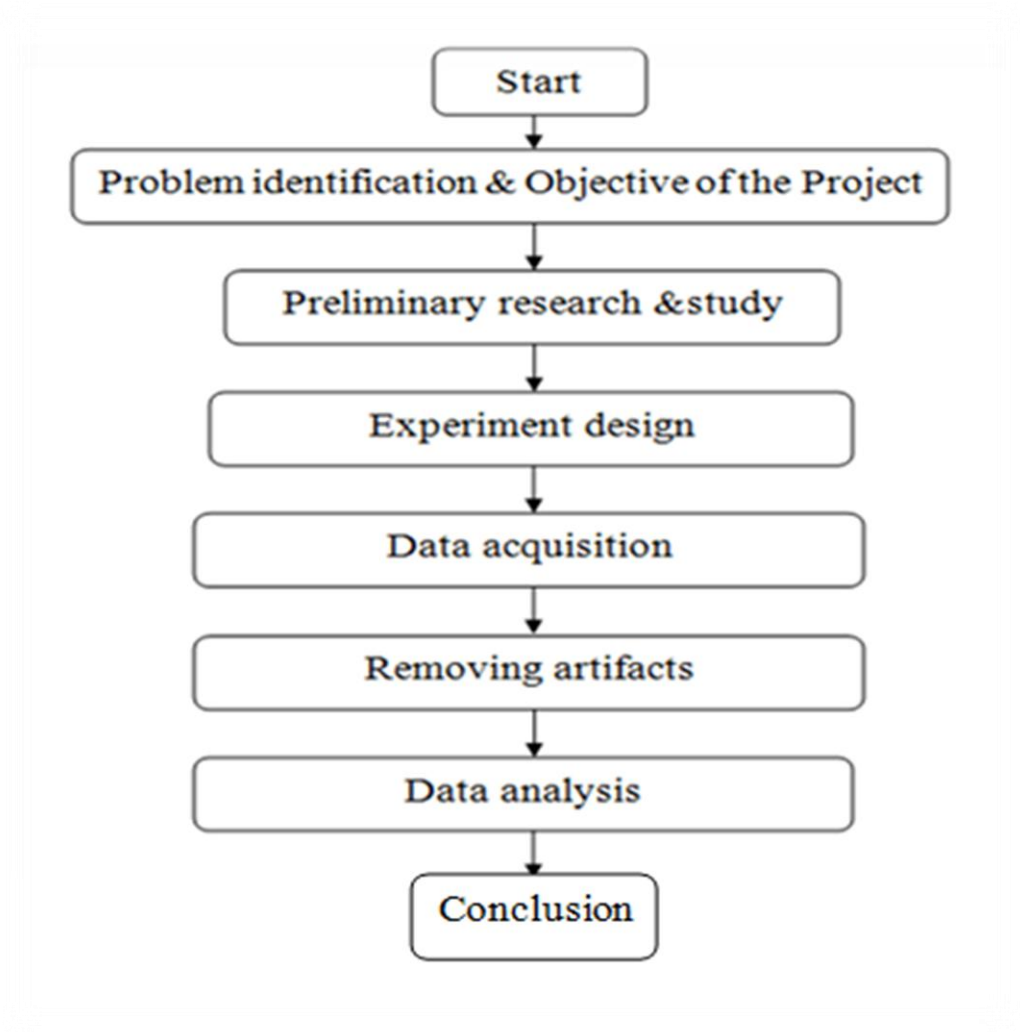

Figure 7 Project Flow Chart

As shown in the flow chart, the first stage was problem identification and definition of the objectives of the project, followed by preliminary research and studyto become familiar with the topic. Next was the design of the experiment, in addition to some training on collecting data. These steps were completed satisfactorily within FYP1.

Data collection, cleaning data i.e. removing artifacts and analyzing this collected data occurred mainly within FYP2.

3.2 Experiment procedure:

3.2.1 Subjects & questionnaire:

Twenty subjects are recruited from Universiti Teknologi PETRONAS students to participate in the experiment, both male and female and different nationalities. All participants are in good health therefore those taking any medication, having allergic skin, or having a history of head injury or chronic migraine, are excluded. Those who had headaches easily are also disqualified because these health conditions have an impact on the EEG signals, as data from the literature review had indicated. In addition all the participants are right handed, as the usage of right or left hand affects on the brain functions, due to that the participants are selected from the same category.

There is a briefing that has been delivered to the participants by the experimenter which isan overview as preparation for the experiment. The participants are advised to relax, to try to stop moving muscles as well as to keep silent to produce good signals with minimum artifacts. The participants are requested to attend the experiment after they had washed their hair, using only shampoo and not conditioner, cream or oil in their hair or skin that would affect good connectivity. The participant is asked to fill a consent form, as well as to complete a questionnaire before they are assigned to the EEG experiment. This comprised 11 questions such as the number 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:

The experiments are conducted using Emotiv EPOC 16 electrodes as shown in figure (8). It is connected to a PC to show the brain signals.

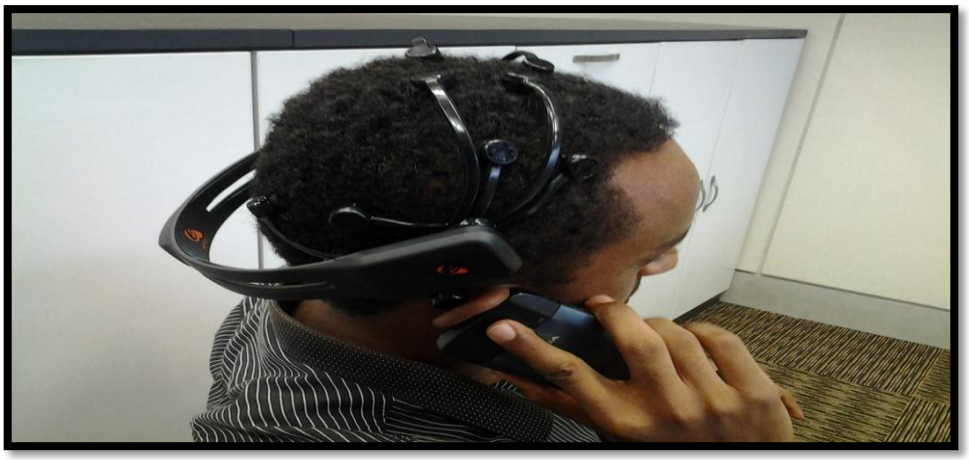

Figure 8Emotiv EPOC 16 electrodes

In order to assess the effect of cell phone, EEG recording is performed under six conditions or sessions: before using the cell phone; during the use of a cell phone (4 sub conditions) and after using the cell phone, please refer toFigure9 below.

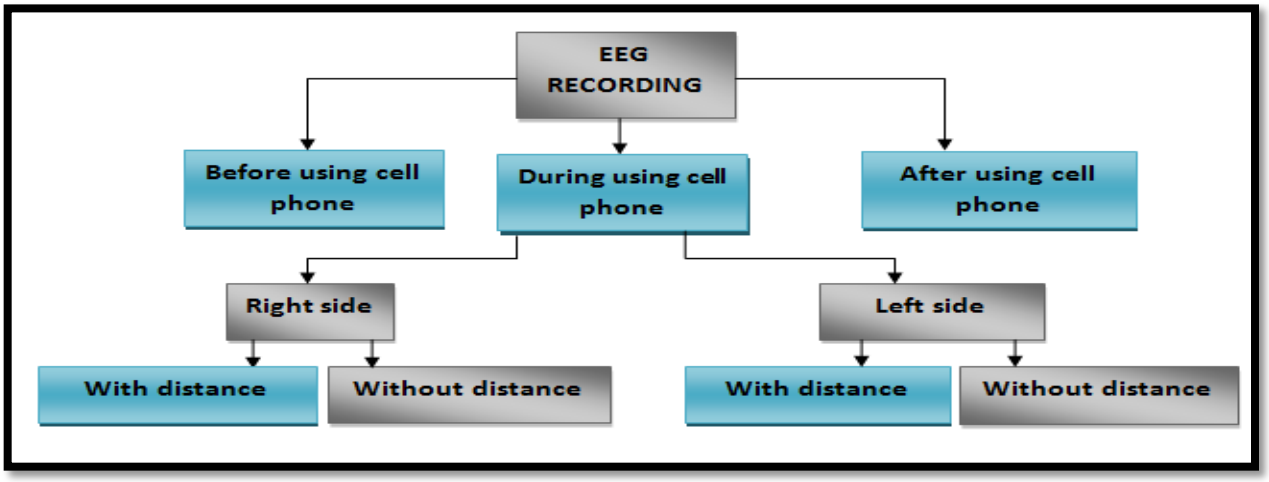

Figure 9 Block diagram for Experiment protocol

From the block diagram, the first case i.e. before using the cell phone, measures the normal brain signal. The participants are expected to be in a relaxed mode, and this condition is considered the baseline. All the other conditions are compared and analyzed based on this normal brain signal. In terms of the four sub conditions, the case of using cell phone (right side or left side) without distance means that the phone should be very close to the ear, but the case of using it with distance, means that the mobile phone should be a slightly distant from the ear, in our case the distance was about 2 cm. Finally the last condition is after using the cell phone to measure the brain signals and to detect whether headache or dizziness are experienced after the calls.

Each session takes 5 minutes, and after each session participants are allowed some minutes of rest. During all the sessions the participants are asked to remain silent to reduce the EEG artifacts. All of these tasks last approximately one hour.

3.3 Removing Artifacts:

Data acquisition is followed by the step of removing artifacts, which had been done using the EEG lab software to clean the data i.e. removing blinking and muscle movement artifacts, as well as the DC artifacts.

3.3.1 The steps of editing the data

1. After importing the data that we wanted to be cleaned, 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. From the setting, we can control the displayed time and the displayed channels of the signal.
3. Removal of eye movement and muscle artifacts was done manually, having a Specific shape. Refer to the two following figures.

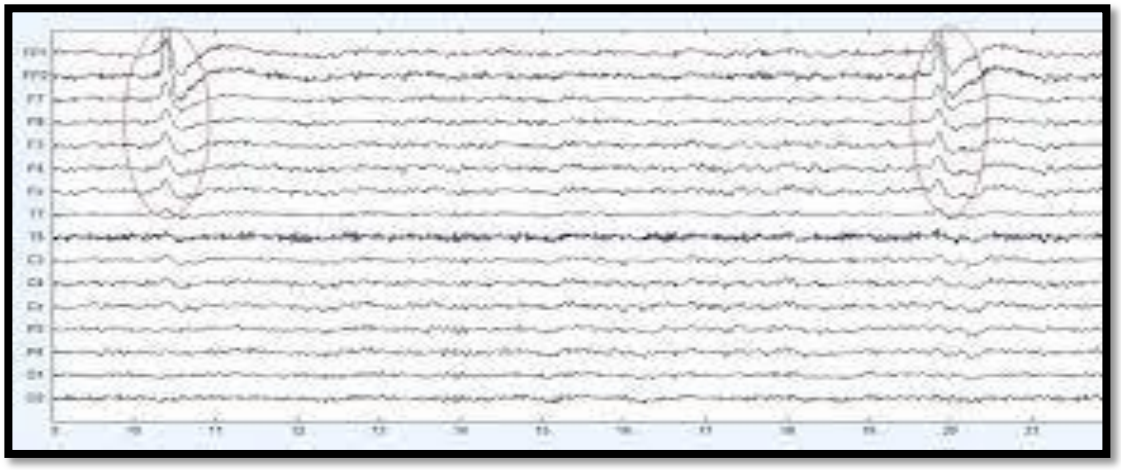

Figure10 eye movement artifacts, with a leap shape

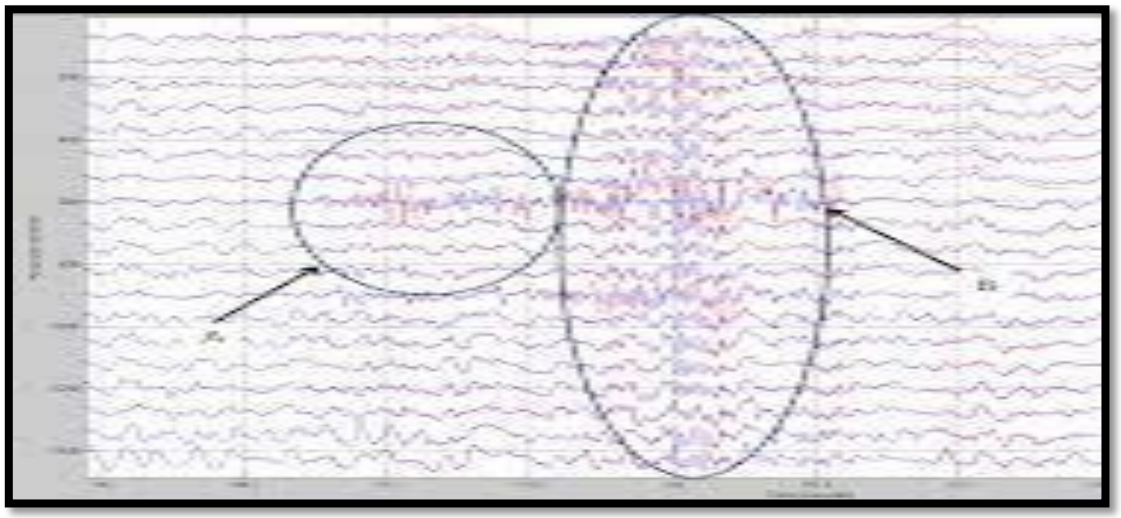

Figure11 muscles movement artifacts, with the compressed shape of signal

3.3.2 Type of artifacts:

The artifacts can generally be defined as the unwanted signals that appear in the EEG records, and are divided into two categories. The first is the External artifacts that are associated with the effects caused by equipment i.e. the EEG amplifier and the environment, as the surrounding atmosphere and the electrical wiring may produce electrical and magnetic fields which can address the faults in the electrical signals records. The second category is the internal artifacts which arise from body activities due either to movements or bioelectrical potentials e.g. blinking, rolling eyes or muscle movements. These artifacts can be detected and cleaned by the EEGLAB software as mentioned previously.

3.4 EEG Data Analyses:

In the research project we are interested in two sorts for EEG analysis which are Absolute power and Coherence.

MATLAB and Neuroguide software are used to extract the individual result in terms of absolute power and coherence respectively. The results are exported into an excel sheet for further computation such as: average results and results plotting. 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.

3.4.1 Absolute Power:

Absolute Power is a standard method that can be used for quantification of the EEG. It reflects the distribution of the signal power over frequency. Because of the importance of EEG power analysis, we evaluate the performance of each band i.e. Delta, Theta, Alpha, and Beta, in terms of absolute power to detect the cell phone's effects. We have used MATLAB code to extract the brain bands' power. This type of analysis focused on the comparison between the six conditions in terms of the band's power. The procedure will be described below for one participant:

1 Each subject has six conditions as mentioned before. Since the first condition i.e. before using the cell phone, represents the normal brain power, it is used as a baseline of comparison. Each of the other five conditions is compared to the baseline. Table 1 below shows the comparison between one of the conditions and the base condition. This is applicable for the other conditions.

Table 1 First step of abslute power analysis

condition of before using the cell phone (the base condition)					condition of using the cell phone (right side without distance)				
	delta	theta	alpha	beta		delta	theta	alpha	beta
AF3	15.66267	7.068267	8.185392	3.638958	AF3	6.076506	2.541181	2.317135	10.46938
F7	17.65857	5.507428	6.101699	3.26874	F7	6.925813	2.242716	1.916009	8.300717
F3	9.774345	6.108318	6.946033	3.057283	F3	4.115504	2.16616	1.885895	9.091987
FC5	8.034136	3.309138	3.846908	2.310027	FC5	3.736696	1.392938	1.215001	5.884821
T7	5.131841	2.814209	2.679011	2.336213	T7	2.646606	1.237504	1.040154	5.274704
P7	4.535037	2.796972	3.588493	2.102306	P7	2.595201	1.169146	0.987684	5.441625
O1	6.034183	3.037978	4.504864	1.755428	O1	2.86748	1.204431	1.017493	5.155644
O2	8.633856	5.746494	12.39477	3.646841	O2	4.032299	2.138643	2.129267	12.15455
P8	9.149043	6.918724	14.12864	4.160205	P8	4.714516	2.441454	2.412412	13.39639
T8	10.96473	7.103047	11.35416	4.205029	T8	6.577016	2.727482	2.550127	11.59527
FC6	14.64841	7.099801	10.97938	3.907294	FC6	5.386016	2.617727	2.669379	11.43824
F4	10.91197	6.91349	8.630216	3.633315	F4	4.621059	2.5017	2.30759	10.54824
F8	23.12144	8.10877	9.966695	4.259724	F8	9.260254	3.005718	2.692313	11.85377
AF4	16.2282	7.389892	8.982013	3.870181	AF4	7.549438	2.835582	2.489937	11.18209

2\ In terms of each condition the fourteen electrodes are classified into four lobes i.e. Frontal, Temporal, Parietal and Occipital. Table 2 presents this second step.

Table 2 second step of absolute power analysis

condition of before using the cell phone (the base condition)						condition of using the cell phone (right side without distance)				
		delta	theta	alpha	beta		delta	theta	alpha	beta
	Frontal	14.5	6.438	7.95	3.5	Frontal	5.95	2.4	2.2	9.8
	Temporal	8.04	4.96	7.01	3.27	Temporal	4.6	1.98	1.8	8.4
	Parietal	6.84	4.86	8.86	3.13	Parietal	3.65	1.8	1.7	9.4
	Occipital	7.33	4.4	8.45	2.7	Occipital	3.45	1.67	1.6	8.65

3\Each lobe now has four bands: delta, theta, alpha and beta. The analysis was done lobe by lobe. Table 3 shows the third step in relation to the Frontal lobe:

Table 3 third step of absolute power analysis

condition of before using the cell phone (the base condition)						condition of using the cell phone (right side without distance)				
		delta	theta	alpha	beta		delta	theta	alpha	beta
	Frontal	14.5	6.438	7.95	3.5	Frontal	5.95	2.4	2.2	9.8

4In this illustrative example the condition of using the cell phone on the right side without distance was compared to the base before using the cell phone condition by finding the ratio in terms of each frequency band as explained in Table 4.

Table 4 the comparison between the conditions in terms of the absolute power

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)	

5 Thesame applies to the other conditions of the frontal and temporal lobe.

6 The average result is calculated from all the ratios of the individual results.

3.4.2 Coherence:

Coherence is a measure of the amount of phase stability between two different time series that have the same wavelength, and it reflects the amount of shared information and the connectivity between brain regions.

There are two approaches to coherence in Neuroguide: (refer to figure 12)

1. **Hyper coherence:** is the lack of functional differentiation.
2. **Hypo coherence**: is the lack of functional connectivity.

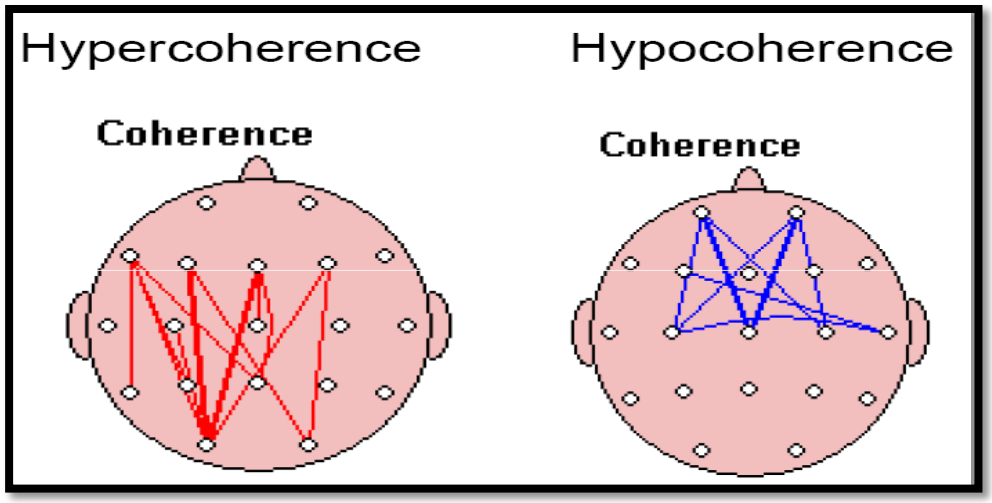

Figure 12 Representing the Hyper and the Hypo coherence

Since the project seeks to know the effects of the cell phone on the brain signals, we utilized the coherence measurement from Neuroguide software in order to compare the relation and the connection between electrodes of the temporal lobe and Frontal lobe.

As Emotiv is used for the data acquisition, since it only has 16 electrodes, and the Neuroguide provides the EEG topographic map only for devices over 19 electrodes, it is not possible to get the coherence as an EEG topographic map using Neuroguide. The coherence between the electrodes is expressed as values, and then the ratios were calculated between the six different conditions, using the initial cell phone condition as the baseline. This would indicate whether the connectivity had decreased or increased. For further explanation refer to Table 5 below.

Table 5 Illustrative example for coherence between Temporal - Frontal in terms of one condition compared to the initial condition

	Delta	Theta	Alpha	Beta
AF3 - T7	0.688866	0.71658	1.042252	1.058656
AF3 - T8	0.483059	0.96639	0.594803	1.493332
F7- T7	0.578779	0.833708	0.935948	1.304018
F7- T8	0.58602	1.026203	0.421115	0.596187
F3- T7	0.748625	0.946508	0.822887	0.966786
F3- T8	0.989761	0.931469	0.703251	1.303708
FC5- T7	0.872683	1.006956	1.086693	1.278017
FC5- T8	0.94122	0.580824	0.999469	0.753611
FC6- T7	1.285658	0.737376	0.978325	0.925343
FC6- T8	1.582019	0.6401	1.853701	1.249761
F4- T7	0.828007	0.952935	1.000359	0.94328
F4- T8	0.872558	0.747173	0.889689	0.473487
F8- T7	0.692122	1.36122	1.033006	1.049241
F8- T8	0.776371	1.8833	0.372208	0.992311
AF4- T7	0.425495	0.716275	1.134228	1.092643
AF4- T8	0.384254	1.079146	1.410536	1.000378

This is an example to show the steps for the analysis of coherence ratios between the four sub conditions of using the cell phone, after usage and before using the cell phone (the base of our comparison). If the ratio is less than 1 this means the connectivity between the two electrodes has decreased 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 for FYP I& FYP II

Table 6 FYP 1 Gantt chart

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Selection of the project topic														
Preliminary research work														
Preliminary report submission														
Proposal Defense (Oral Presentation)														
Experiment Design& training on data acquisition														
Submission of Interim draft report														
Submission of Interim Report														

Table 7 FYP II Gantt chart

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Data acquisition															
Data analysis															
Submission of progress report															
PRE - EDX															
Submission of draft report															
Submission of dissertation (soft copy)															
Submission of technical paper															
Oral presentation															
Submission of dissertation (hard copy)															

CHAPTER 4
RESULTS & DISCUSSION

This chapter discusses the results of the project and the ways that are used to interpret the data. As mentioned before, only Temporal and Frontal are chosen to analyze the effects of the cell phone on the brain in terms of absolute power and coherence.

4.1 Absolute Power:

The analysis focuses on the comparison between the six conditions of Frontal and Temporal lobe in terms of the bands absolute power. We obtain the results from the MATLAB codes. The results are exported into an Excel sheets for more statistical representation. The figures show the average results for the 20 subjects.

Delta brainwaves are known to increase with decreased levels of cortisol, a stress hormone, so Delta waves decrease when high performance and focus are required, also Theta waves decrease for the same reason. From the graphs below, the results show that Delta and Theta waves decrease significantly during the use of the cell phone i.e. all four sub conditions and further decrease within the period of the five minutes after the call for both regions (F & T). This takes place because the participants may have disruption and disorder in the brain which could be due to the high radiation from the cell phone. On other hand, comparing the four sub conditions during usage of the cell phone, Delta and Theta rate are found to be higher when the mobile phone is kept slightly distant from the ear, irrespective of whether it is the left or right side and when the mobile phone is used on the left side instead of the right side, as shown below.

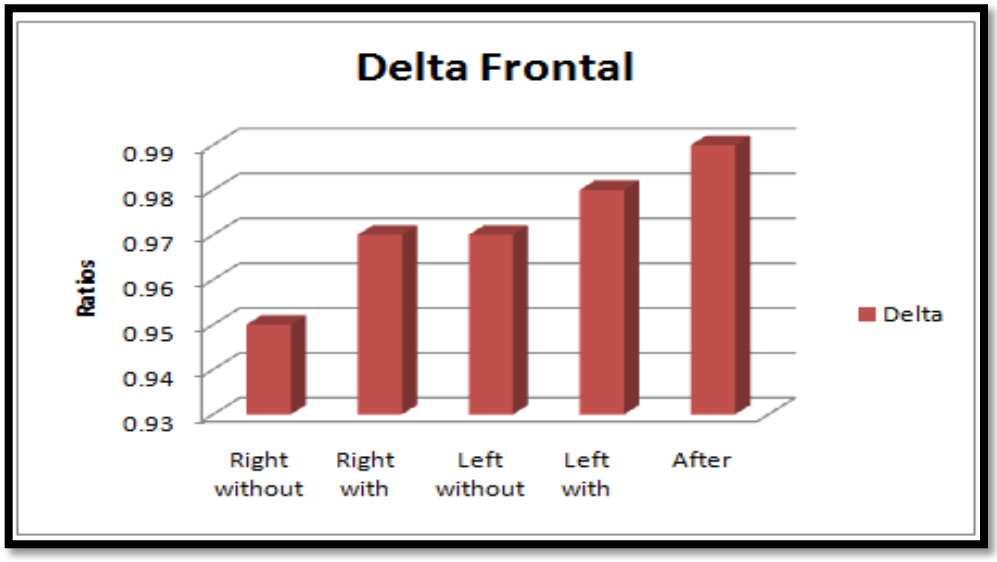

Figure 13 Absolute power ratios of Delta band at Frontal lobe

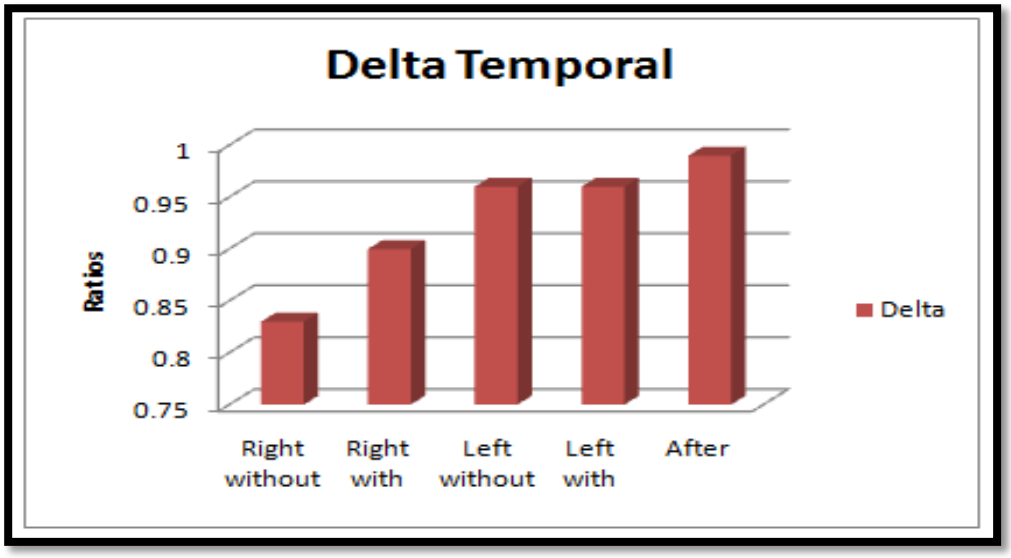

Figure 14 Absolute power ratios of Delta band at Temporal lobe

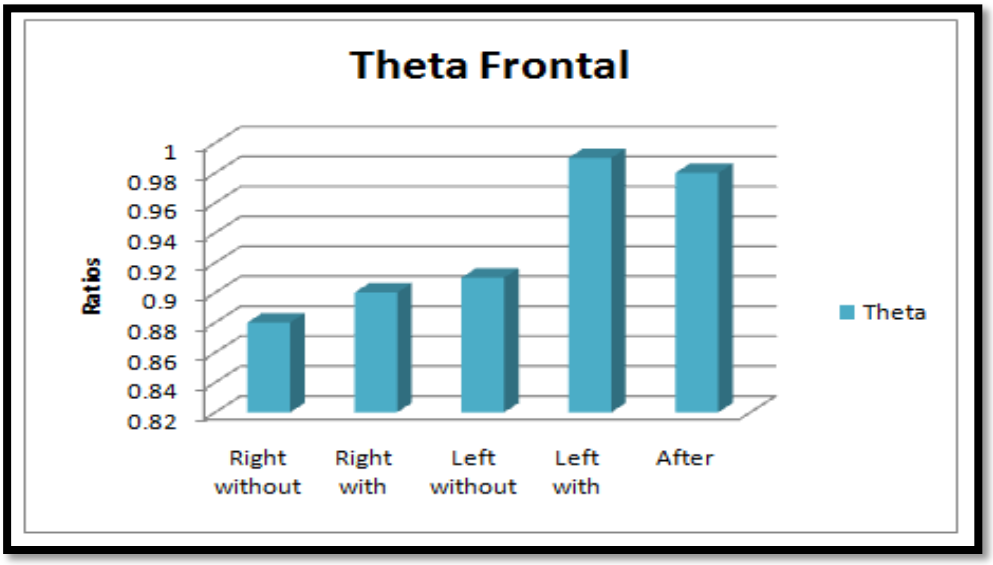

Figure 15 Absolute power ratios of Theta band at Frontal lobe

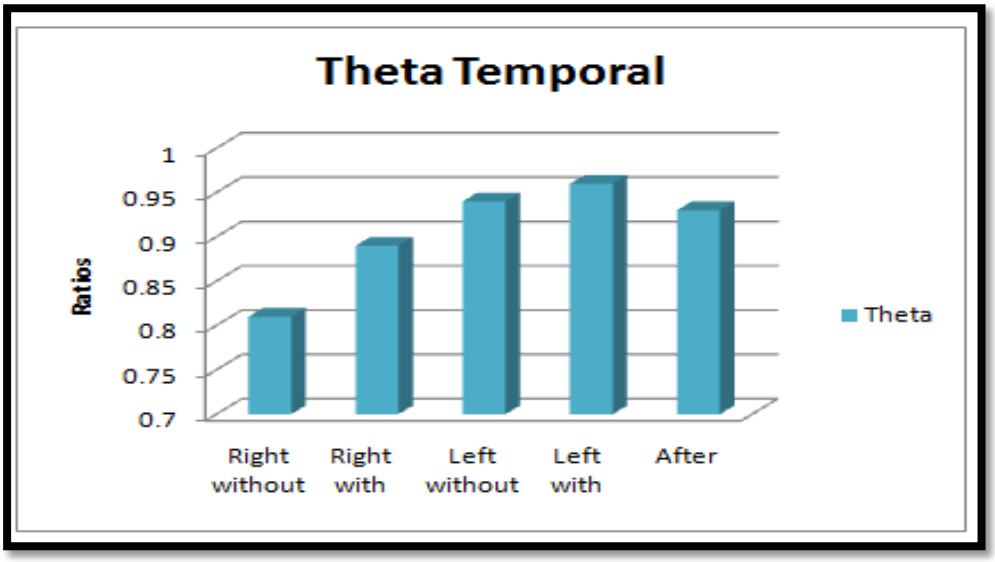

Figure 16 Absolute power ratios of Theta band at Temporal lobe

ALPHA waves are known to increase during rest and relaxation moods. The graphs show that Alpha power has decreased during the call i.e. during all four sub conditions and after the call within five minutes in both F & T lobes. This decrease of alpha shows that participants are not relaxed, due to exposure to the mobile phone. It can therefore be said that using the mobile phone affects the rest level in the brain. At the same time the results indicate that alpha level has improved when mobile is used at a slight distance or when the mobile is used on the left side. Please refer to the following figures.

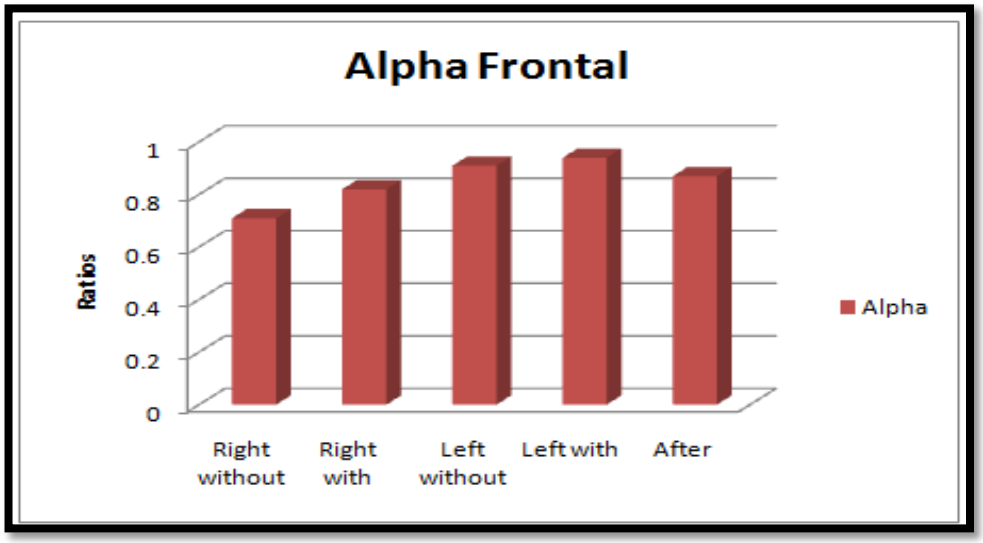

Figure 17 Absolute power ratios of Alpha band at Frontal lobe

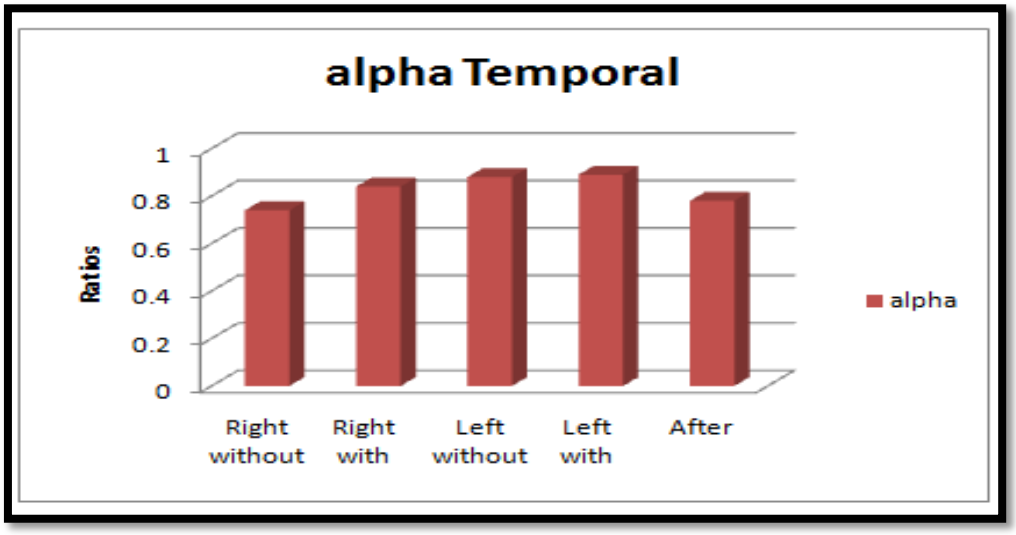

Figure 18 Absolute power ratios of Alpha band at Temporal lobe

The radiation could also affect Beta power. Beta waves increase with critical thinking, calculation and all other processes that can result in anxiety and mental stress. From the results it's found that using the mobile phone causes an increment in Beta level during and after the call, which means that the Subjects are under stress, and could be due to the high radiation from the cell phone. Refer to the following graphs.

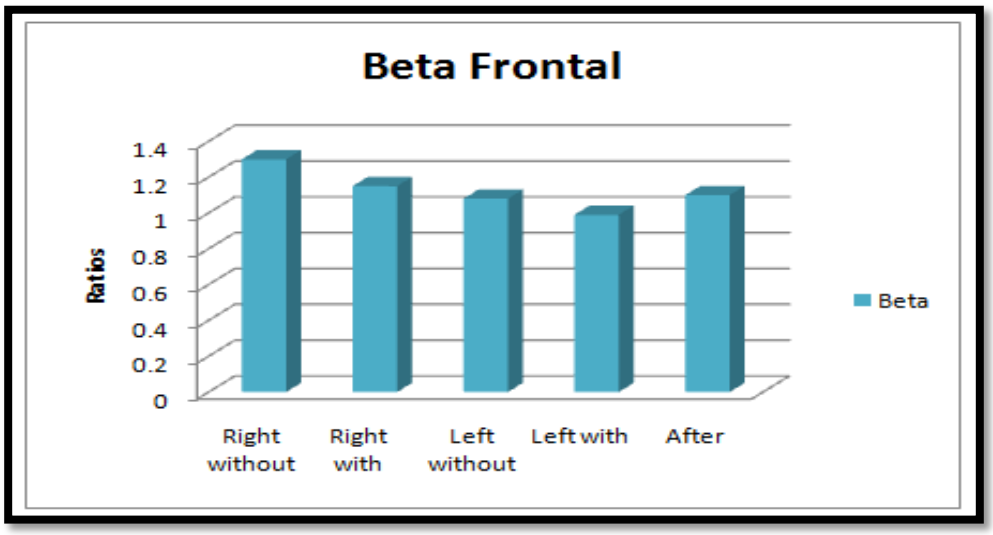

Figure 19 Absolute power ratios of Beta band at Frontal lobe

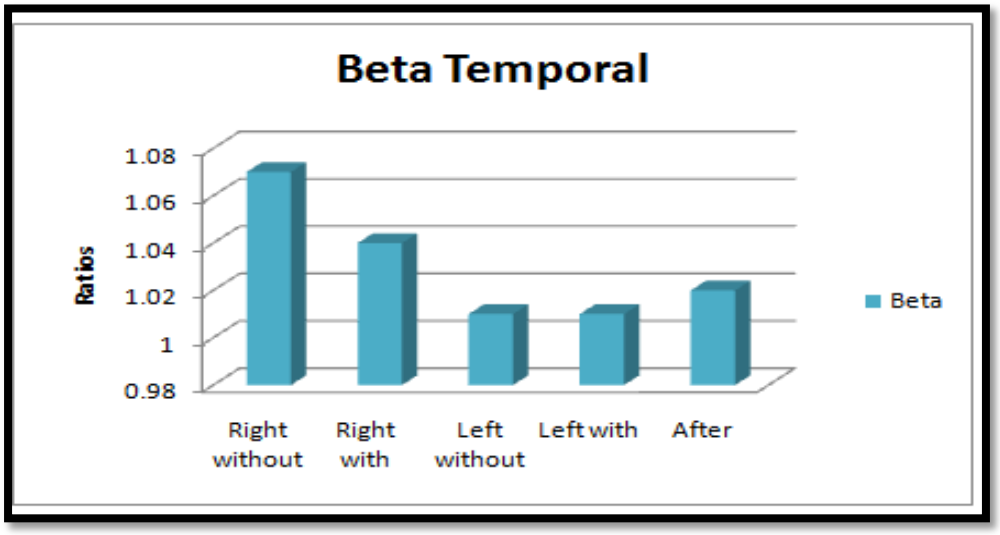

Figure 20 Absolute power ratios of Beta band at Temporal lobe

In a summary of analysis in terms of Absolute power, most of the high radiation affects the human ear and skull area during the calls and further within five minutes after using the cell phone. The results provided solutions to reduce the side effects which are keeping the mobile slightly away from the ear. Since the participants are right handed; their right brain (side) is more likely to be affected with the radiation than the left side, therefore using the left side is the second way to reduce the side effects.

4.2 Coherence:

Certain electrodes and regions are selected to interpret the data in terms of coherence, which are the temporal and frontal electrodes. As mentioned in the literature review, Theta and Delta waves increase when the participant's concentration decreases. From the results it is found that the coherence of Theta and Delta waves in the temporal-frontal regions during and after calls was lower compared to before making a call. This reduction in connectivity between the electrodes may have been due to anxiety about high radiation from the cell phone.

On the other hand, the results show that Beta coherence values are more dominant during and after calls compared to before calls, because Beta is associated with thinking and unrest cases which could be due to the high radiation from the mobile. It is also known that Alpha decreases when Beta increases, from the result, Alpha coherence is lower when the participants using the cell phone. They may have been exerted more mental effort because of the radio waves.

The results show the F – T electrodes verses the coherence ratio for each condition using the initial condition (before using the cell phone) as a baseline of comparison. Please refer to the following figures.

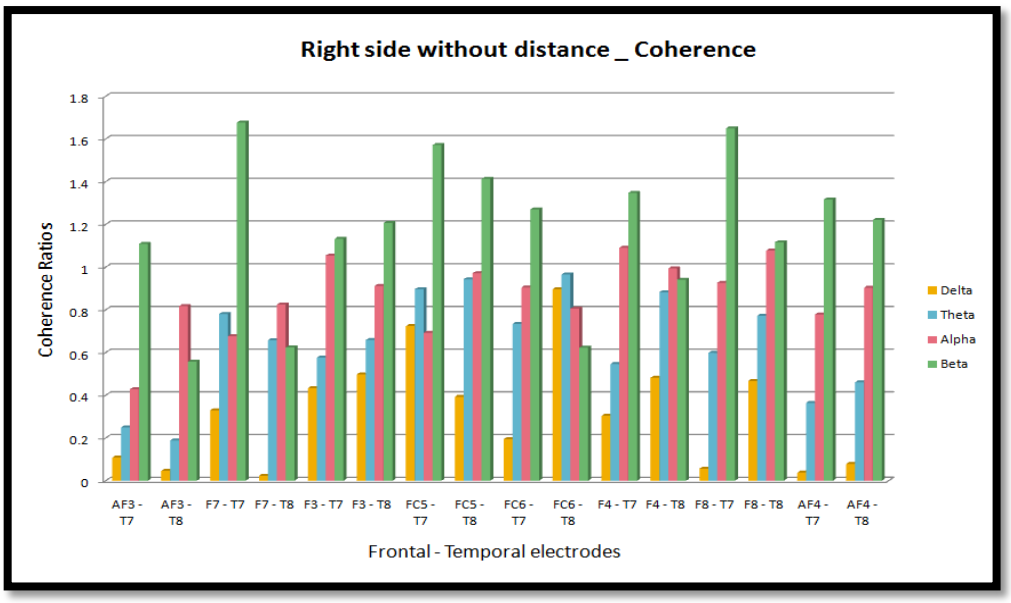

Figure 21 F - T coherence ratio of frequency bands when using a mobile at the right side without distance condition.

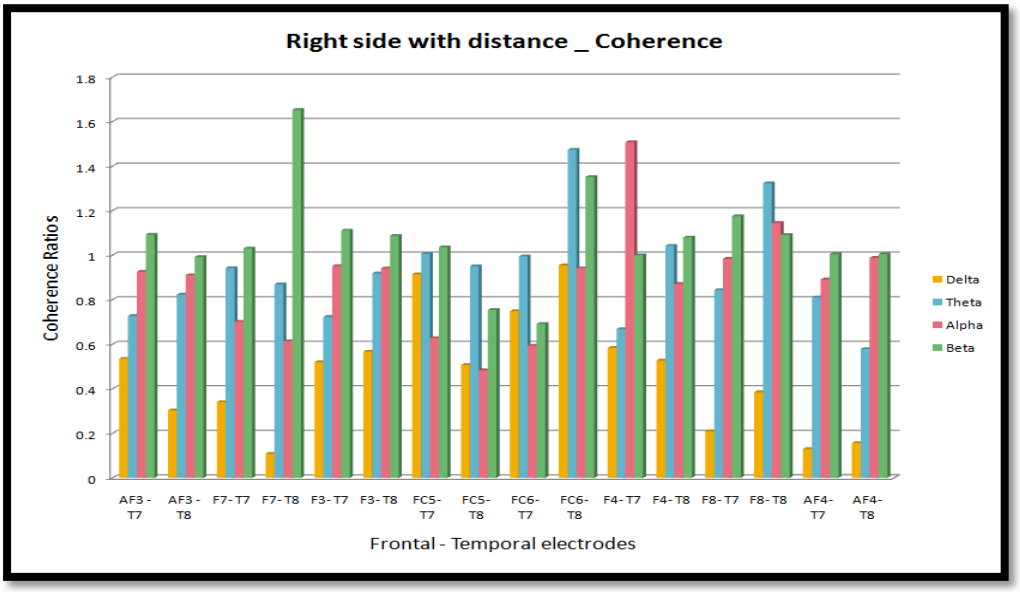

Figure 22 F - T coherence ratio of frequency bands when using a mobile at the right side with distance condition.

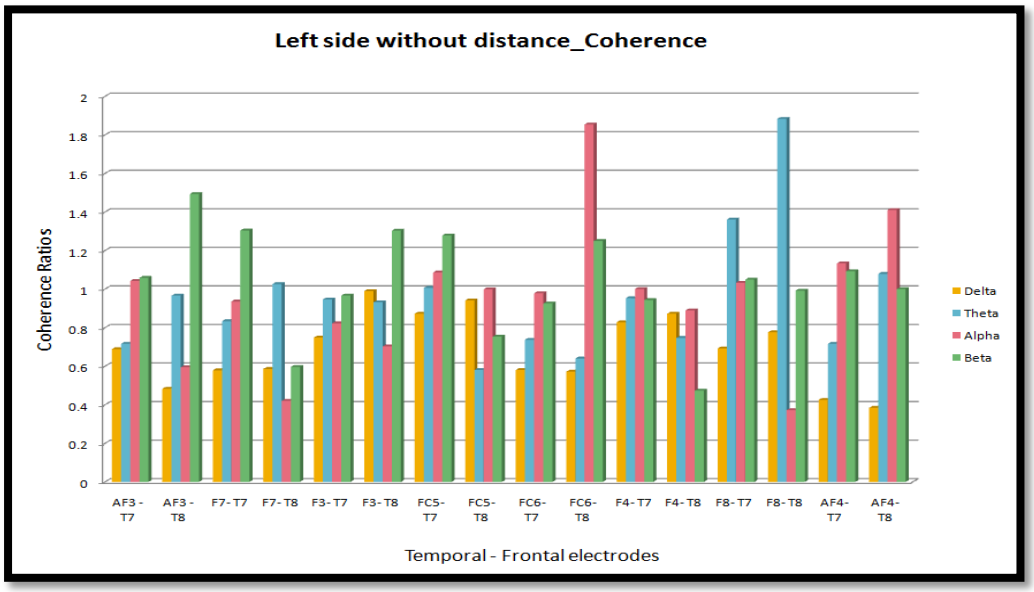

Figure 23 F - T coherence ratio of frequency bands when using a mobile at the left side without distance condition.

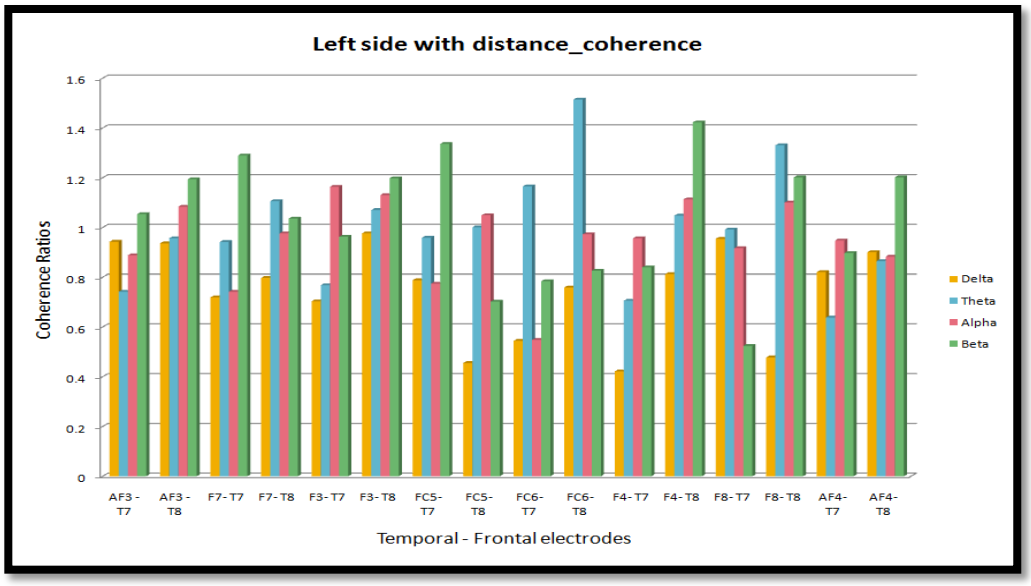

Figure 24 F - T coherence ratio of frequency bands when using a mobile at the left side with distance condition.

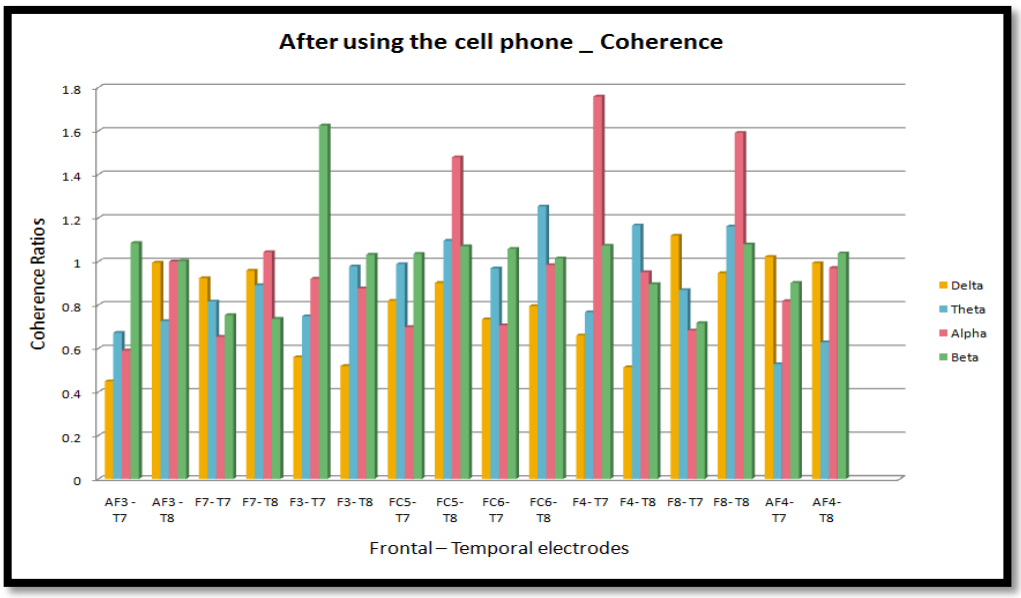

Figure 25 F - T coherence ratio of frequency bands After using the Cell phone.

In a summary of analysis in terms of Coherence, the connectivity and sharing information between F-T lobes is different from one condition to another. The results show that Delta and Theta coherence has decreased during and after usage within five minutes. By comparing the two conditions of using a mobile with right side (with distance and without distance) it's found that keeping the mobile slightly away from the ear is better than without distance which means the participants are more comfortable and low mental processes, the same thing happened when the cell phone is used with the left side.

Onthe other hand, it is found that Alpha coherence has decreased during and after usage, but Beta coherence has increased. The comparison shows that the connectivity between F – T electrodes in terms of Alpha has improved and increased when using the cell phone slightly distant from the ear when the right side is used, as well as using the left ear is another way to improve the connectivity. The opposite is true for Beta. The average result shows that there is no difference between left side (with distance and without distance) in terms of Alpha and Beta Coherence. Please refer to the table and the figure below.

Table 8 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**

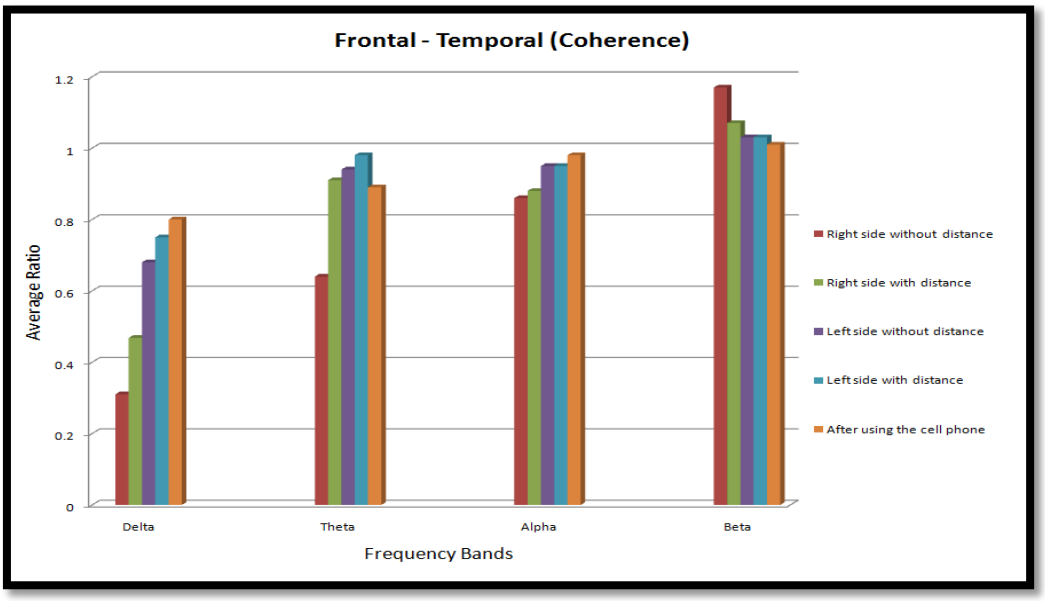

Figure 26 The summary of the coherence ratio between the Frontal lobe and the Temporal lobe in terms of frequency bands

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1 The Conclusion:

There are two objectives for this research project and they concerned: investigating and studying the side effects of the cell phone on the human brain using electroencephalographic (EEG), and finding a way to reduce the side effects of the direct radiation from the cell phone on the human brain.

It is found that the cell phone's effect on the brain is more obvious during and after usage within five minutes. In terms of bands power for Delta, Theta and Alpha levels appear much lower during and after usage, but Beta level is higher compared to the normal brain signal; and this is due to the high exposure from the cell phone.
In addition, Delta, Theta and Alpha coherence or connectivity between the Temporal and Frontal lobes is lower during and after calls, because the participants might be anxious. However, Beta is higher during and after calls due to the mental effort exerted during the call.

By comparing the different conditions whilst using the phone, there are two ways to reduce the side effects of direct radiation. These are: either keeping the mobile phone slightly distant from the ear, or by using the left side instead of the right side.

From these results we may say that the objectives of this research were successfully achieved.

5.2 The Recommendation:

In addition to use Emotiv EPOC 16 channels to record the EEG signals, we would like to suggest another EEG system for data acquisition e.g. the net station which consists of 128 electrodes. This would produce more accurate and reliable results. Moreover, it would be easier to obtain the EEG topographic map.

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.

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/ severfever?

YES ☐ NO ☐

5. Do you have skin allergy?

YES ☐ NO ☐

6. How many calls you normally have per day?

---

7. What is theaverage 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: ***analyzing the side effects of cell phone on the brain using EEG***

Researcher's Name: ***Eithar Isameldin Ahmed , Dr.Nidal Kamil , Dr. Aamir S. 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 Conducting Consent Discussion	Date (dd/mm/yy)
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 side effects of cell phone on the brain using EEG***

Researcher's Name: ***Eithar Isameldin Ahmed , Dr.Nidal Kamil , Dr. Aamir S. 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 contex – 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.