Mobile Phone Handset Radiation Impact Study on Brainwave Signal Using EEG

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Abstract— There is ongoing discussion whether mobile phone usage has any effects on brainwave. The aim of this research is to investigate any effects of mobile phone handset radiation on human brainwaves using electroencephalograph (EEG). EEG signals were recorded from five healthy subjects that make calls from a mobile phone to another party without conversation. The EEG recording took place under three different conditions before, during transmitting and receiving the mobile phone calls for more than 10 minutes RF exposure. The spectral powers of the subjects were calculated using FFT and then statistical analysis is carried out using Paired sampled t-test to see the significant effect in the results obtained by FFT. In a nutshell, it has been observed that the RF radiation from mobile phone handset affects the Delta band, Theta band, Beta band significantly. Whereas, no significant effect has been observed for Alpha band and Gamma band as significant value is $p > 0.05$.

Key words: EEG, Brain waves, FFT, Radio frequency

I. INTRODUCTION

In recent years, the usage of mobile phone has increased drastically all over the world. The GSM and CDMA telecommunications system has been in use by the public for more than a decade. Now a day's wireless cellular telephony and other mobile phone communication services is the fastest growing field in the telecommunication world, a certain amount of energy radiated by mobile phone is absorbed by the body. Still, it is not clear yet whether any biological effects arise from the exposure to mobile phone radiofrequency electromagnetic fields (RF) emitted by GSM handheld devices. As per the world population clock the total world population is 7,012,000,000 and number of mobile users around the world are 6,800,000,000+ as evaluated in February 2013 [1]. Thus, there are 97 phones per 100 people. Also in India, there are 73.9 mobile phone Users per 100 people as per TRAI 30 November 2014 Press Release [2]. Mobile communication device are used in immediate vicinity of the body, producing high localized RF energy deposition. Frequency band used for mobile are GSM 900 or GSM 1800 or WCDMA 2100.The effect of mobile phone radiation on human health, especially on human brain activity is the subject of recent interest and study, as a result of the enormous increase in mobile phone usage throughout the world, People encounter various symptoms like sleepiness, dizziness, headache [3], fatigue, loss of mental attention, heart palpitations, disturbance of digestive system, burning and tingling sensations in the skin of the head, memory loss [4], brain tumors [5], [6] decrease in sperm count, decrease in mobility and many more after the use of mobile phone; still, there is no accepted measure with which we can prove these effects are due to RF radiation. Thus, researchers are still finding way to prove the presence of such affects. Thus, it is necessary to study the impact of mobile phone handset radiation on human brain.

Brain waves can provide information of mental state of the individual and the signal can be measured using Electroencephalograph (EEG). Brain waves oscillate, with rhythmic highs and lows, and can be measured with electroencephalograms, which use electrodes to record electrical activity. It is also used to diagnose sleep disorders, coma and brain death and cognitive processes such as memory, attention and consciousness. EEG is a non-invasive technique and, most commonly used for cognitive task related analysis [7]. The EEG provides a convenient window on the mind, revealing synaptic action that strongly co-relate with brain state [8]. EEG signals are the imprints of brain activity and changes according to the task performed by a person. These changes are reflected in different frequency bands of EEG waveform named as Delta (0.5-4Hz), Theta (4-8Hz), Alpha (8-13Hz), Beta (13-30Hz) and Gamma (>30Hz) [9-10]. Five brainwaves with the description are given below in the table1 that shows how these waves are associated with psychological facts of state of mind [11-12]. When more information is required about the neurophysiology of the electrical activity of the brain then the individual frequency bands in the EEG signals are analyzed in detail [13]. Power spectral analysis is a well-known standard method for the analysis of EEG signals [14]

Brain waves	Frequency (Hz)	Amplitude (µv)	Description
Delta	0.5-4	20-200	Associated with deep sleep
Theta	4-8	2-100	Associated with drowsiness
Alpha	8-13	20-60	Associated with relaxed and alert
Beta	13-30	2-20	Associated with active thinking or attention
Gamma	>30	5-10	Associated with event related synchronization of brain

Table 1: Brainwaves

II. MATERIALS AND METHODS

A. Participants

EEG data collection involved 5 subjects and they are the students from aging 18 to 27 year old. They were exposed under RF exposure from mobile phone for more than 10 minutes. Mobile phone was kept near right ear for all the subjects. All students were in healthy conditions and also not consuming any medicine or drugs prior to the EEG test.

Experimental setup in a biomedical lab has been shown in fig 1

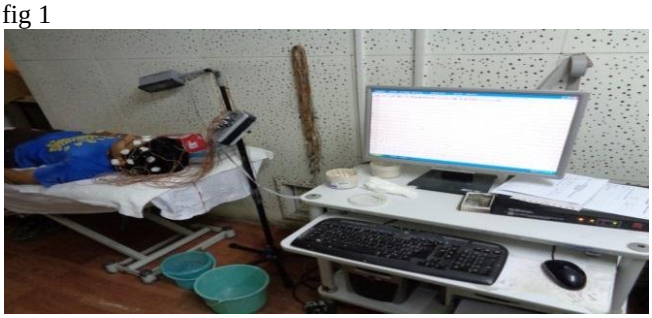

Fig. 1: Experimental setup

B. Exposure Equipment

Two mobile phone handsets used in the experiment was given below in the table 1 both handsets uses emission frequency of 900 MHz

Mobile phone model used	**SAR limit (Head) W/kg**	**SAR limit(Body) W/kg**
Samsung Ace Duos S6802	1.00 W/kg	0.84 W/kg
Xolo A600	0.82 W/kg	0.74/kg

Table 2: Mobile Phone Used in the Experiment

C. Time Frame Protocol of The Experiment

10 min or more	1 min	10 min or more	1 min	10 min or more
Before call (after 8 hrs sleep)	Rest	During call (Transmission mode)	Rest	During call (Receiving mode)
Closed eyes EEG recording		Closed eyes EEG recording		Closed eyes EEG Recording

Table 3: Time Frame Protocol

The above TABLE III shows the time frame protocol of the experiment involving two cases which were before and during calls (transmission and receiving mode) usage of mobile phone. Firstly the subjects will undergo the interview sessions to answer 6 item questioners related to the usage of mobile phones. The interview session is conducted between 2 to 4 minutes. The EEG recording duration is more than 10 minutes for each session with one minutes rest period in between, thus giving a total of approximately 36 to 40 minutes for each subject Different mobile phone was used and fixed to the left or right ear according to the subject whether he/she were left handed or right handed. During EEG recordings, subjects were asked to close their eyes and are not allowed to talk, to minimize artifacts in the EEG signals.

D. Data Acquisition

EEG recording is obtained by placing electrodes on the scalp with a conductive gel or paste, usually after preparing the scalp area by light scrap to reduce impedance. Electrode locations and names are specified by the International 10–20 system for most clinical and research applications. The 10–20 system or International 10–20 system is an internationally recognized method to describe and apply the location of scalp electrodes in the context of an EEG test or experiment [9]. In most clinical applications, 19 recording electrodes (plus ground and system reference) are used. The EEG data are recorded from Fp1, Fp2, F3, F4, C3, C4, P3, P4, O1, O2, F7, F8, T3, T4, T5, and T6 .The impedance of the scalp-electrode interface was adjusted to about 5KΩ by the injection of conductive gel into the electrodes. The EEG signals from all electrodes were recorded by RMS Maximus 32 EEG Super Spec machine Signal at each electrode were sampled at a rate of 256 s^{-1}, in a bandwidth of (1-100 Hz). Figure 2 shows the 10/20 international electrode system for EEG acquisition

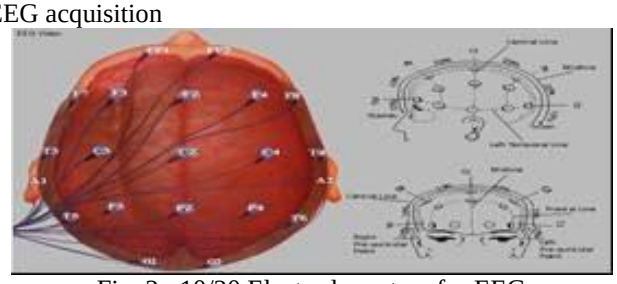

Fig. 2: 10/20 Electrode system for EEG Acquisition

E. Pre-Processing Of EEG Signal

In this the raw signal were filtered into the frequency ranges for each sub-bands, then the cut off data was done to get seconds recorded clean EEG data. We get clean EEG after applying notch filter at 50 Hz, and set LPF at 1.0 Hz and HPF at 70 Hz.

F. Fast Fourier Transform: Fft

Fast Fourier Transform (FFT) technique was used to convert the time domain signal to frequency domain before extracting meaningful information from the signals [15]. FFT was used to originate the power spectral in order to get Power Spectral Density (PSD) from the EEG time series data. Hamming Window used for FFT. The PSD is the extracted feature used to compare the three cases of EEG recording

The general equation to calculate FFT is given by equation

$$X(K) = \sum_{j=1}^{n} x(j) Wn^{(j-1)(k-1)} \qquad (1.1)$$

$$\text{where, } Wn = e^{-(2*pi*i)/N} \quad ; \text{ i, j are integers}$$

G. Data Analysis

Five physiological significant frequency bands from the EEG traces were considered in this study: Delta band, Theta band, Alpha band, Beta band and Gamma band. These frequency bands were selected and their powers were calculated for all channels using FFT. The spectral power for all the Channels were averaged separately. The spectral powers of the subjects were averaged and comparisons were made between different test conditions using paired student t-test with two-tailed significance to see any significant effect on brain waves. Statistical analysis is done with IBM SPSS 20.0 version software.

III. RESULTS AND DISCUSSION

A. Analysis of the EEG Signals

The EEG signals analysis is divided into three stages, which are the analysis before call, the analysis during transmitting call and the analysis during receiving call. The analysis was

performed using statistical tools, SPSS version 20.0. The analysis of the data from EEG test focused on the Comparison between the three stages.

The below TABLE IV show the mean value of delta, theta, alpha, beta and gamma band after. It can be observed that the mean value for all brain waves is more in case of Ideal mode (control case) as compared to Tx and Rx mode. However, mean value of brainwave (delta, theta and beta) decreases during call condition in transmitting mode as well as in receiving mode. Moreover, the mean value for Alpha band decreases from control case to Tx mode but small increment in mean value has been observed during receiving mode. For gamma band, the mean value remains the same for all three condition of exposure

Mean Value(µv/Hz)	Ideal case	Tx call	Rx call
DELTA POWER	47.56	31.896	29.01
THETA POWER	8.248	6.18	6.048
ALPHA POWER	14.84	10.90	11.26
BETA POWER	2.322	2.052	1.944
GAMMA POWER	0.08	0.084	0.08

Table 4: Mean Power Value for Three Different Brainwaves Under Three Conditions

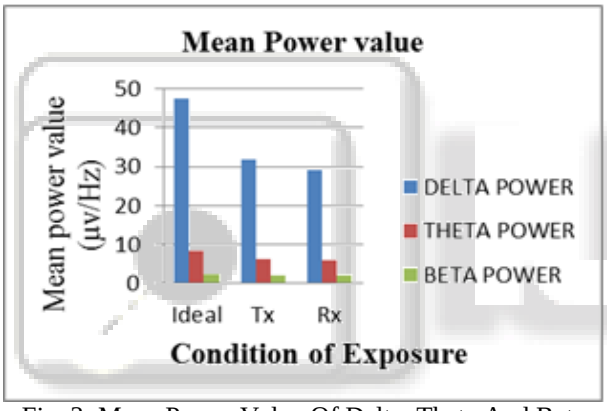

Fig. 3: Mean Power Value Of Delta, Theta And Beta Bands For Three Different Conditions Of Exposure

In the below TABLE V, the factor interaction between ideal-Transmitting mode for the delta, theta, and beta band and factor interaction between Ideal- Receiving mode for theta band are the only that reached statistically significance difference (p-value is < 0.05) and these were highlighted in the above table, and from Paired student sampled T-Test indicates that RF exposure certainly alter the brain wave activity. The Paired-Samples t- Test procedure is used to test the hypothesis of no difference between two variables. However, for alpha and gamma band the statistically significance difference (p-value is > 0.05), which indicates that there is no significant effect on these brain waves

Band	Factor interaction	Significance (p)
Delta	ideal - transmitting mode	**p = 0.042**
	Transmitting – Receiving	P = 0.716
	Ideal- Receiving	P = 0.076
Theta	ideal - transmitting mode	**p = 0.021**
	Transmitting – Receiving	p = 0.762
	Ideal- Receiving	**p = 0.023**
Alpha	ideal - transmitting mode	P = 0.202
	Transmitting – Receiving	P = 0.155
	Ideal- Receiving	P = 0.221
Beta	ideal - transmitting mode	**P = 0.038**
	Transmitting – Receiving	P = 0.537
	Ideal- Receiving	P = 0.126
Gamma	ideal - transmitting mode	P =0.862
	Transmitting – Receiving	P =0.85
	Ideal- Receiving	P = 1

Table 5: Results of Statistical Paired T-Test

IV. CONCLUSION

This study suggests that a change in human brain wave activity occurred in the delta (0-4 Hz), theta (4-8 Hz), and beta (13 – 32 Hz) EEG bands during exposure to a GSM mobile phone RF radiation more than 10 minutes. Alpha brain wave reflects relaxed state of mind and reduction in alpha power indicate increased demand of attention [16]. A small reduction in alpha power is observed during RF exposure from mobile phone in transmitting mode as seen in TABLE IV but, during receiving mode alpha power increases again. Decrease in theta band activity, decreases the ability of the brain to recall and store long term memory [18]. Hence, mobile phone radiation effects memory task and too much decrease in theta level give results in anxiety, poor emotional awareness, and stress. Beta waves tend to occur in people who are alert and focused [20]. Thus, related to the alert or working state. However, decrease in beta power has been observed after the usage of mobile phone in transmitting mode which implies that it will affect human alertness, decision making power and tends to increase the anxiety and stress if large reduction in beta power is observed.

Further research is recommended to understand whether more usage of mobile phone has some effect on neuronal activity associated with human brain function as the effect of radiation may vary, due to gender difference, age difference, mode of usage of phone, different time protocol etc.

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