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# Effects of Mobile Phone Radiation on Brain Using Statistical Parameters and Its Derivatives

C. K. Smitha[1], N. K. Narayanan[2]

Department of Electronics & Instrumentation Engineering College of Engineering, Vadakara, Kerala, India.[1]

Department of Information Technology, Kannur University, Kerala, India.[2]

**ABSTRACT:** The electroencephalogram (EEG) is a record of the oscillations of brain electric potentials, reveals the synaptic action that strongly co-relate with brain state. In this paper we tried to understand the changes in brain by analyzing statistical and Hijroth parameters of single channel EEG, mean and standard deviation of signal's derivatives while using mobile phone. EEG of 10 volunteers was recorded at rest and on exposure to radiofrequency (RF) emissions from two mobile phones having different SAR values. Student's paired t- test is used to analyze the data set with average values of feature parameters; null hypothesis is rejected in all the cases. The samples from different conditions act as they were from different population; this shows the changes in feature parameter while using mobile phone**.**

**KEYWORDS:** EEG, Statistical Parameters, Hijroth parameters, Mobile phone radiation, Student's paired t –test.

## I. INTRODUCTION

In recent years usage of mobile phone has increased drastically**.** There is an increased concern about adverse effects of mobile phone radiation on the nervous system. A large number of investigations were conducted to study the effects of mobile phone radiation [1-9]. Mobile phones generate a modulated radio frequency electromagnetic field (RF-EMF), which is a form of non-ionizing radiation. However, it is unknown whether mobile phone radiation could affect cellular and physiological activities by other mechanisms. The changes in the electrical potential of brain can be easily measured by EEG, hence we choose EEG signal for the analysis to find the effects of radiation on the brain.

Thermal effects are based on energy absorption from the field to the tissue, which causes the oscillation of molecules. The rate at which radiation is absorbed by the human body is measured by the Specific Absorption Rate (SAR). The maximum power output from a mobile phone is regulated by the mobile phone standard and by the regulatory agencies in each country. The SAR limit permitted over a volume of 1 gram of tissue is fixed as 1.6 W/kg, in India.

In the previous work by the same authors, signal complexity of single channel EEG with radiation from mobile phone was analyzed using various fractal methods [10-14]. The variation in the energy level of single channel EEG at various frequency bands were analyzed using normalized wavelet energy and wavelet power [15, 16]. The result showed that, there were some changes in fractal dimension, wavelet energy and wavelet power while using mobile phone.

EEG signal is treated as random stochastic process. The characteristic of random process can be characterized by probability distribution [17] of their moments such as mean, variance, skewness and kurtosis which serves as feature parameters. Hijroth parameters namely activity, mobility and complexity describe the properties of EEG signals were also used as features. Other feature parameters used are mean and standard deviation of 1st order and second order derivatives which provides a constant characteristic of the signal. Due to chaotic characteristics, behaviors of EEG signals become unpredictable for relatively long periods. The lengths of samples were taken as 128 points, equivalent

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to sampling rate, to get almost constant characteristics. From the review of literature, it is learned that these features were not used earlier, for the analysis of the effects of radiation due to mobile phone.

The paper is outlined as follows: Methods of feature extraction and analysis are briefed in section 2. Results obtained in section 3 and the interpretation of the result is detailed in section 4. Section 5 comprises conclusion and scope of further work.

## II. MATERIALS AND METHODS

### *A Data Acquisition*

Ten healthy individuals of different age groups were participated in the study. EEGs were recorded from EEG Lab under Neurology Department of Malabar Institute of Medical Sciences Hospital, Calicut using Galelio N.T machine. EEG of the volunteers is recorded by keeping mobile phones at two different positions of head for 5 minutes each. This procedure is repeated using two types of mobile phones in 5 conditions i) At rest, ii) Phone 1 at right ears, iii) Phone-1 at Cz, iv) Phone-2 at right ears and v) Phone -2 at Cz. During the procedure the volunteers were instructed to lie down and relax; EEGs were taken initially at rest and the phone is switched on (in talking mode) and kept at the above described positions. The volunteers were unaware of the instant of switching of mobile phone. This procedure is repeated using two different mobile phones with different SAR values. SAR for the phone 1 is 1.3W/Kg and for phone 2 is 0.987 W/Kg.

### *B. Preprocessing*

Unwanted signals or artifacts (noises) can be removed by visual inspection and by filtering. A notch filter is used to remove 50 Hz line frequency. Wavelet algorithm [18] using threshold filtering is used to de-noise the signal.

### *C .Feature Extraction*:

*i) Statistical Parameters :* The digitized EEG signal values $x(t_I)$ can be considered as realizations of one stochastic variable $(t_i)$. Consider the discrete random variable, x can take any set of value, from 1 to M, the mean (μ) or average of the sample function is given as follows.

$$E[x(t_i)] = \frac{1}{M}[\sum_{s=1}^{M}(x(t_i)] = m_1 = \mu \tag{1}$$

The variance or $\sigma^2$ of $x(t_i)$ Is a second central moment or the moments around the mean is

$$m_2 = E[(x(t_i) - E(x(t_i))^2] \tag{2}$$

'σ' is the standard deviation . The third $(m_3)$ and fourth $(m_4)$ central moments are defined as follows is

$$m_3 = E[(x(t_i) - E(x(t_i))^3 ] \tag{3}$$

And

$$m_4 = E[(x(t_i) - E(x(t_i))^4] \tag{4}$$

The skewness can be derived from this as

$$\beta_1 = {m_3}/{(m_2)}^{3/2} \tag{5}$$

The kurtosis can be derived as

$$\beta_2 = {m_4}/{(m_2)}^2 \tag{6}$$

Skewness is the indicator of asymmetry. Kurtosis is the measure of the flatness of the distribution.

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ii*) Hijroth Parameters:* Hijroth parameters namely activity, mobility and complexity is nothing but the derived values of statistical parameters which can be used for describing the properties of EEG signals. They are derived as follows :

$$\text{Activity} = VAR(x(t)) \quad (7)$$

$$\text{Mobility} = \sqrt{\text{Activity}\left(\frac{dx}{dt}\right) / \text{Actvity}(x(t))} \quad (8)$$

$$\text{Complexity} = \sqrt{\text{Mobility}\left(\frac{dx}{dt}\right) / \text{Mobility}(x(t))} \quad (9)$$

*D. Methods of Analysis*

*Statistical analysis:* In general, the two samples come from a population have same variance if same measurement method was used. Hypothesis testing [19, 20] is used for depicting inferences about a population, based on statistical evidence. The null ($H_o$: $\mu_1 = \mu_2$ ) and alternative hypothesis ($H_a$: $\mu_1 \neq \mu_2$) were selected for the two-sided paired t-test and analyzed using the traditional logic. The null hypothesis is rejected if $|t_{calc}| >| t_{crit}|$, or $P_{value} < \alpha$. The null hypothesis is rejected at the 95% level of confidence since α is fixed as 0.05.

## III. RESULTS

*A. Statistical Parameters and Hijroth parameters*

Hundred samples of length of 128 points are selected randomly from each data set. Statistical parameters namely, mean, standard deviation, skewness, kurtosis, mean and standard deviation of 1$^{st}$ and 2$^{nd}$ derivatives, Hijroth parameters namely activity, mobility and complexity are calculated and shown in Table-1.

TABLE -1
MEAN VALUES OF FEATURE PARAMETERS

| Parameters | Rest (Cz) | Ph-1 (Cz) | Ph-2 (Cz) | Rest (Au) | Ph-1 (Au) | Ph-2 (Au) |
|---|---|---|---|---|---|---|
| Mean | 13.62 | 1.71 | -8.45 | -10.44 | 9.02 | -4.21 |
| Std.Dev | 7.64 | 8.66 | 8.87 | 8.49 | 8.83 | 8.97 |
| Skewness | -0.03 | 0.01 | -0.08 | -0.01 | -0.03 | -0.01 |
| Kurtosis | 2.67 | 2.65 | 2.58 | 2.44 | 2.53 | 2.48 |
| Activity | 92.29 | 122.74 | 116.94 | 103.74 | 533.29 | 328.78 |
| Mobility | 0.12 | 0.11 | 0.12 | 0.08 | 0.1 | 0.08 |
| Complexity | 5.68 | 5.36 | 4.74 | 6 | 7.44 | 6.9 |
| mean 1st Derivative | 0.0017 | -0.0019 | -0.0024 | 0.0011 | 0.0037 | -0.0026 |
| SD of 1st Derivative | 0.95 | 0.99 | 1.03 | 0.64 | 0.93 | 0.66 |
| mean 2nd Derivative | 0.0002 | 0 | 0.0002 | 0.0001 | -0.0003 | 0.0001 |
| SD of 2nd Derivative | 0.47 | 0.51 | 0.6 | 0.29 | 0.66 | 0.37 |

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The data is grouped as 6 specifically, at rest with data from auricle electrodes, using phone 1 at Auricle, Phone -2 at auricle, at rest with data from Cz electrodes, using phone 1 at Cz position, Phone -2 at Cz position. Data set prepared using average value of the feature parameters at different conditions were analyzed using Student's t-test. The table 2 shows the result obtained while using t-test.

TABLE -2
RESULT OF STUDENT'S T-TEST WHILE KEEPING PHONE AT CZ POSITION AND AURICLE POSITION

| Para meters | Phone at Cz Position | | | | Phone at Auricle Position | | | |
|---|---|---|---|---|---|---|---|---|
| | Ph-1 (Cz) | | Ph-2(Cz) | | Ph-1 (Au) | | Ph-2(Au) | |
| | $\lvert t_{stat}\rvert$ | $P_{value}$ | $\lvert t_{stat}\rvert$ | $P_{value}$ | $\lvert t_{stat}\rvert$ | $P_{value}$ | $\lvert t_{stat}\rvert$ | $P_{value}$ |
| Mean | 1.06 | 0.32 | 1.14 | 0.28 | 1.02 | 0.33 | 0.54 | 0.61 |
| Std. Dev | 1.33 | 0.22 | 2.25 | 0.05 | 0.21 | 0.84 | 0.3 | 0.77 |
| Skewness | 1.83 | 0.1 | 2.2 | 0.06 | 0.45 | 0.66 | 0.26 | 0.8 |
| curtosis | 0.43 | 0.68 | 1.05 | 0.32 | 2.16 | 0.06 | 0.81 | 0.44 |
| Activity | 0.85 | 0.42 | 0.99 | 0.35 | 0.93 | 0.38 | 0.91 | 0.39 |
| Mobility | 0.97 | 0.36 | 0.35 | 0.74 | 1.92 | 0.09 | 0.15 | 0.88 |
| Complexity | 0.79 | 0.45 | 1.27 | 0.24 | 1.28 | 0.23 | 0.6 | 0.57 |
| mean of 1st Derivative | 1.17 | 0.27 | 0.92 | 0.38 | 0.8 | 0.45 | 1.3 | 0.23 |
| SD of 1st Derivative | 0.36 | 0.73 | 0.58 | 0.58 | 1.17 | 0.27 | 0.23 | 0.82 |
| mean of 2nd Derivative | 0.76 | 0.46 | 0.1 | 0.92 | 1.25 | 0.24 | 0 | 1 |
| SD of 2nd Derivative | 0.68 | 0.51 | 1.24 | 0.25 | 1.31 | 0.22 | 1.16 | 0.27 |

## IV. DISCUSSION

### *A. Analysis of Feature parameters*

Values of Activity increases while placing phone at both positions namely at Cz position and at Auricle position. But complexity decreases while keeping hone at Cz position and increases at auricle position. Values of mobility are almost constant. From Table-1 it is evident that the average values for different conditions are different, which indirectly shows the changes in EEGs while using mobile phones. Here measured average value is the sum of potential of a group of neurons comes under a particular electrode which we considered here. The change in the value shows that, either state of some of the neurons in that group changes from polarized to depolarized or vise versa or some new neurons from nearest region starts to contribute to the potential to this particular region. While analyzing the values of skewness and kurtosis, from table 1, it is evident that the distribution of data is not symmetrical and normal. Skewness is equal to 0 for symmetric probability distributions and Kurtosis is equal to 3 for normal distribution. Here low kurtosis shows the distribution has a more rounded peak and shorter thinner tails. The Figure-1a) to 1d) shows $\mu \pm \sigma$ values of sample data and plot of Hijroth parameters. Figure 1 a) shows the difference in range of mean $\pm$ Std. Deviation for different conditions. The average values of Hijroth parameters (Figure 1 b to d) shows the differences at different conditions.

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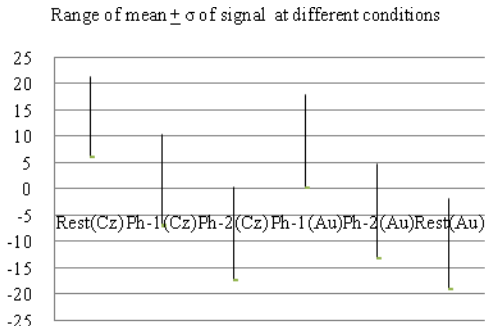


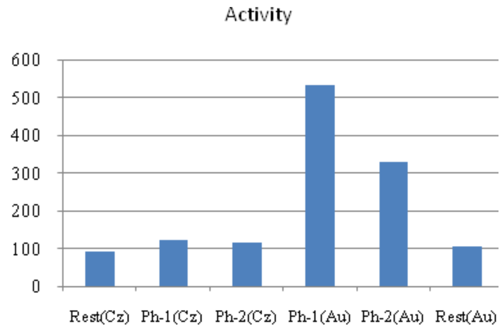
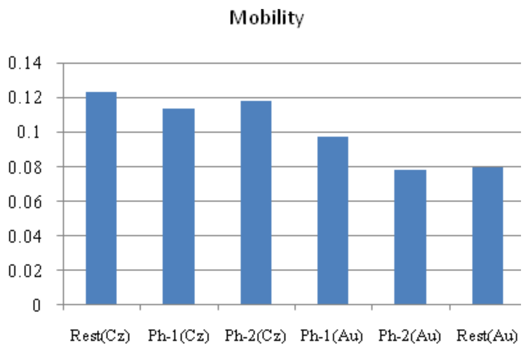




Fig 1 a) Plot of range of values of mean± standard deviation parameter - Activity for

Fig -1b) Plot of average value of Hijroth different conditions



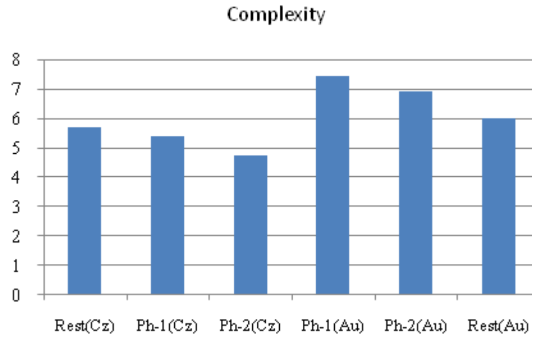




Fig - 1 c) Plot of average value of Hijroth parameter – parameter
Mobility for different conditions

Fig - 1 d) Plot of average value of Hiroth
- Complexity for different conditions

*B. Analysis of t-test result*

As per the result of t-test, the null hypothesis is rejected in all the cases with 95% confidence level. It is evident that there are some effects in the brain due to mobile phone radiation. For eg. Take the first three values in the 1st raw of the Table – 2. Here mean value of data set at rest is compared with data set for phone 1 at Cz position. Here $|t_{stat}|$ (1.06) is less than $|t_{crit}|$ (2.62) and $P_{value}$ (0.32) is greater than confidence interval (0.05). Since $|t_{stat}| < |t_{crit}|$, $1.06<2.62$ and $P_{value}$ $0.36>0.05$, Null hypothesis is rejected i.e. Mean of values at rest and phone one at Cz are different. From the Table -2, it is clear that even though critical value of $|t_{crit}|$ (2.62) is very much greater than $|t_{stat}|$, all values of $P_{value}$ are very much less than confidence interval ($\alpha=0.05$), so null hypothesis is rejected in all cases.

## V. CONCLUSION

From Table -1 it is obvious that, most of the feature parameters are comparatively less with phone-2 having less SAR value than phone-1. The result of t test (Table-2) shows 100% rejection of the null hypothesis, while analyzing the data obtained by keeping phone in Cz position and in auricle position, it is evident that the sample means are different. The changes in statistical and Hijroth parameter shows the variations in EEG signal while using mobile phone, which demonstrate transformation in the activities of brain due to radiation.

This analysis is done with single channel EEG of 10 volunteers. Moreover the data set is prepared with an EEG machine meant for clinical purposes. Data set from highly accurate EEG machine may give more prominent result. Further investigation must be conducted with increased data set with EEGs of more volunteers. The effect of radiation may vary; due to gender difference, age difference, and mode of usage of phone (frequent or occasional

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usage) etc has to be further investigated. Data from more channels can be used for further investigation especially while keeping the phone in auricle position.

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