ANALYSIS OF THE EFFECTS OF MOBILE PHONE RADIATION ON BRAIN USING APPROXIMATE ENTROPY

C. K. SMITHA
Department of Electronics & Instrumentation Engg.
College of Engineering, Vadakara, Kerala- 673105
smi_c_k@yahoo.com

N. K. NARAYANAN
Department of Information Technology Kannur University,
Kerala- 670567
nknarayanan@gmail.com

ABSTRACT: The concern about the adverse effects of mobile phone radiation on the nervous system has increased due to the drastic increase of mobile phone usage. The mean value of Approxiate entropies of EEG data set with and without phone is compared with mean entropy of data set prepared with EEGs of patients having brain function abnormalities namely epilepsy and slowing. Average value of the entropy for phone usage is found in between the mean value of the data set for epileptic and slowing abnormalities. ANOVA test is used to compare the features of different conditions in EEG data set with and without phone. The test result is significant only for some of the channels. We tried to relate the affected area of brain under significant electodes to the Brodmann's area in the cerebral cortex. Approximate functions and traits controlled by these Brodmann's area under significant electrodes are also described. The mean values of approximate entropies of signals at different conditions spans in the range of mean of the value of the feature set at rest ± std deviation.

KEYWORDS: Mobile phone radiation, Approximate Entropy, ANOVA test, Broadmann's area.

INTRODUCTION

In recent years usage of mobile phone has increased drastically**.** There is an increased concern about adverse effects [1-9] of mobile phone radiation on the nervous system since the phone is kept near to the brain. Investigation of the effect of mobile phone radiation on brain is made by means of different features like fractal dimension, entropy etc, which are generally used to characterize the non linear behavior.

The high frequency microwave field cannot make any regular change in the movement of ions due to their small absorption cross-section and inertia. But this can cause fluctuations and vibration of the charged particles and membranes. This phenomenon is similar to the effect caused by Brownion motion, initiated by temperature. So the high frequency EM field and temperature have analogous effects on biological structures.

There are several possibilities to change the threshold of the action potential initiation in brain. This can be done by the local heating of the membrane or by changing the selective ion permeability of the nerve fibers. The change in the density of ion channels within ten percent of the equilibrium state, can significantly alter the action potential. In certain conditions this increases the probability of the spontaneous formation of the action potential. The change in the electrical potential of brain can be easily measured by EEG, hence EEG signal is selected for the analysis of the effects of radiation on the brain.

The bio-phsycial process underlying the EEG generation is not necessarily random in nature, but it may have high degree of complexity. Non linear dynamical systems such as neuronal networks generating EEG signals can display chaotic behavior and EEG generation can be described using sets of non linear differential equations. The level of chaos can be measured using entropy of the system[10]. Entropy is a measure of uncertainty. Higher entropy represents higher uncertainty and a more chaotic system. Since EEG is non linear signal, entropy is one of the best feature to represent the characteristics. The approximate entropy (ApEn), a nonlinear measure is used to quantify the degree of complexity is taken as feature.

In the previous work by the same authors, signal complexity of single channel is measured using various fractal methods includes Higuichi's method [11-15]. The variation in the energy of single channel of the EEG signal at various frequency bands were analyzed using normalized wavelet energy and wavelet power[16,17] . Statistical and Hijroth parameters[18], a characteristic measure of random process of single channel is also analysed. The result shows that there are some changes in the Fractal Dimension, wavelet Energy, wavelet Power and statistical parameters while using mobile phone. So in this paper the effect of mobile phone radiation on brain is analyzed by using the feature parameter in all 21 channels of the data set prepared.

The 21 channels are placed at different positions on scalp spread in 4 lobes and two hermispheres of brain as per 10-20 system of electrode positioning. The cortex is divided into four anatomically distinct lobes: frontal, parietal, temporal, and occipital The frontal lobe is largely concerned with planning future action with the control of movement, the parietal lobe with somatic sensation, the occipital lobe with vision and the temporal lobe with hearing [19]. The prefixes in the names of the EEG electrodes shows their position in these four lobes. The brain is also divided into two hemispheres, right and left. The left hemisphere is dominant in behavior involving language, speech and analysis whereas the right hemisphere is superior in perceiving, thinking, remembering and understanding.

The feature parameters of EEG data set with and without phone is compared with EEG data set of two major abnormalities of brain. First abnormality is Epilepsy, a chronic neurological disorder generally characterized by the sudden and recurrent seizures. It is an indication of hyper synchronous activity of neurons in the brain. The second abnormality is slowing of brain which correlates with diminished mental function, grey matter disease.

Korbinian Brodmann distinguished 52 anatomically and functionally distinct areas called Brodmann's area [20]in the human cerebral cortex. The area under control of each electrode can be interpreted on superimposing the positioning of 10-20 system of EEG electrodes on the plots of Broadmann's area. We tried to correlate the position of significant electrode with Broadmann's area.

This paper is organized as follows : Methods of feature extraction and analysis included in section 2. Results and discussion in section 3 and section 4 comprised of conclusion and scope of further work.

METHODS

EEGs were recorded with 21 scalp electrodes placed as per conventional 10–20 system of electrodes, from EEG Lab under Neurology Department of Malabar Institute of Medical Sciences Hospital, Calicut using Galelio N.T machine.

Data Acquisition

Three group of data sets were prepared from the Lab. First group,the main data set contains EEG of 35 healthy individuals of different age groups (39.8$\pm$11.8) with and without phone. EEG of the volunteers were recorded at rest and by keeping 2 different types of mobile phones (GSM and CDMA) at two different positions of head. This data set containing record of 35 sbjects for 5 minutes each of 5 conditions : rest, GSM at ears, GSM at vertex or Cz, CDMA at ears and CDMA at vertex or Cz. The volunteers were instructed about the procedure of the study and all were participated voluntarily. 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. 2nd group containing data of 6 subjects for 20 minutes of 6 epileptic persons of different age groups. 3rd group containing data of 2 subjects for 20 minutes having the abnormality of slowing.

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 due to fault in grounding or imperfect balancing. To filter out random noise, the Stationary wavelet transform (SWT) is applied. Wavelet algorithm using threshold filtering [20] is applied to de-noise the signal. The SNR obtained using this method is 12 to 17 dB.

Feature Extraction

Behavior of EEG signals is unpredictable for relatively longer periods due to chaotic characteristics. The length of samples were taken as 128 points, equivalent to sampling rate, to get almost constant characteristics. Theoretical back ground of Approximate Entropy is discussed below:

The approximate entropy (ApEn) quantifies the complexity or irregularity of either deterministic or stochastic signals. ApEn is not sensitive to noise and interference [21, 22].

Step-1: For a given seris x(i), and for a given the embedding dimension 'm' , the m-vector $X_m(i)$ is defined as

$$X_m(i)=[x(i), x(i+1), \quad x(i+m-1)], \; i= 1, 2 \ldots.. N-m+1 \qquad (1)$$

where N is the number of data points

Step-2: The distance between any two of the above vector $X_m(i)$ and $X_m(j)$ is

$$d[X_m(i), \; X_m(j)] = \max_{k} \; |x(i+k) - x(j+k)|, \quad \text{for } k = 0 \sim m-1 \qquad (2)$$

Where $|.|$ denotes the absolute value.

Step-3 : Fix a threshold level 'r'. The number of times, $N^m(i)$, that the above distance satisfies d $[X_m(i), X_m(j)] < r$ is found. This is performed for all i. For the embedding dimension, m

$$C_r^m(i) = \frac{N^m(i)}{N-m+1} \text{ for i=1,2 ….. N-m+1.} \quad (3)$$

Step-4 : Then the average natural logarithm of $C_r^m(i)$ is found as

$$\Phi^n(r) = \frac{1}{N-m+1} \sum_{i=1}^{N-m+1} \ln C_r^m(i) \quad (4)$$

Step-5: By repeating the same method for an embedding dimension of m+1, the Approximate Entropy is given for N number of data points

$$\text{ApEn(m, r, N)} = \lim_{n\to\infty} \Phi^m(r) - \Phi^{m+1}(r) \quad (5)$$

Statistical Analysis (ANOVA test)

Analysis of variance (ANOVA) is a procedure for assigning sample variance to different sources to decide whether the variation arises within or among different population groups. In general, two samples from a population have same statistical parameters, if same measurement method were used. Hypothesis testing is used for depicting inferences about a population, based on statistical evidence [23, 24]. In ANOVA test, null hypothesis ($\mu_1 = \mu_2 = \mu_3 = \cdots \mu_n$) is to be rejected if Fcalc > Fcrit and P-value < α.

Neural Science

Franz Joseph Gall, a German physician and neuroanatomist, proposed that the cerebral cortex did not act as a single organ but was divided into at least 35 organs, each corresponding to a specific mental faculty [19]. Wernicke's work in particular showed that different behaviors are produced by different brain regions interconnected by specific neural pathways. According to the nineteenth- century doctrine of phrenology, complex traits such as combativeness, spirituality, hope, and consciousness are controlled by specific areas in the brain. Inspired by Wernicke, Korbinian Brodmann distinguished 52 anatomically and functionally distinct areas called Brodmann's area [19] in the human cerebral cortex.

We tried to link these areas to the position of channels/elctodes in 10 -20 system. The area under control of each electrode can be interpreted on superimposing the positioning of 10-20 system of EEG electrodes on the Brodmann's area .

RESULTS & DISCUSSION

Comparison of feature parameter of data set with abnormal data set

The entropy defined in the section 2c for measuring signal complexity is used to compare features for of all channels of the three groups of data set prepared. Length of data set used at a time is fixed as number of points equal to sampling frequency to get constant characteristics. During each computation, 'm' is fixed to 2 and the width of the boundary is set as 'r' multiplied by the standard deviation (SD) of the original data set for the calculation of approximate entropy. Average values of entropies are calculated for all channels and are plotted in figure-1.

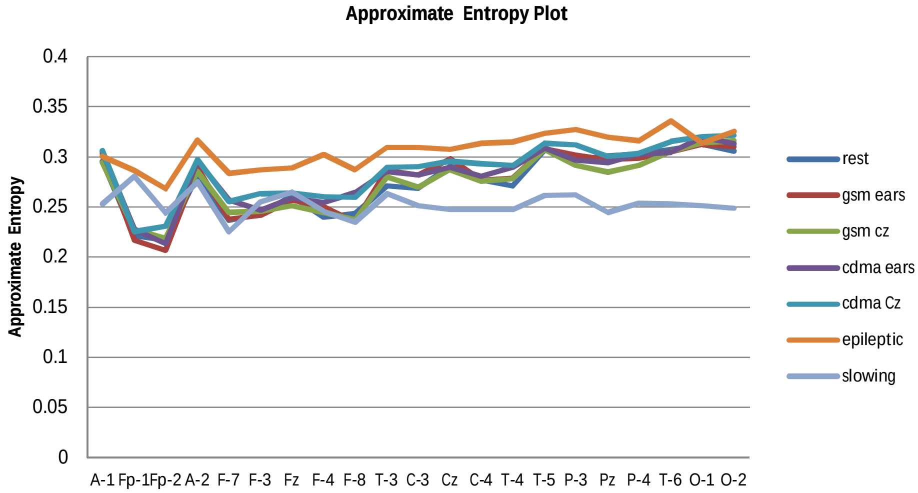

Fig 1 Plot of Approximate Entropy for different conditions of datasets

The entropy of the data set with phone lies in between that of data set with epileptic and slowing (fig-1). The value of entropy of EEG with phone is lesser than the entropy of EEG at rest. The complexity of signal can refer to the unpredictability of a signal, and it can also refer to difficulties one has in describing or understanding a signal. Here the entropy value is larger for the epileptic signals and less for slowing of brain.

Statistical analysis of feature paramenters

Feature parameters for the 1st group of data set (with and without phone) is analysed using ANOVA test and the result is shown in Table-1. The ANOVA test result is significant in channels F7, F8 and C3, p- value is less than the confidence level 0.05. The purpose of one-way ANOVA is to find out whether data from several groups have a common mean. The placement of electrodes on scalp are F7 on left hemisphere of frontal lobe, F8 on right hemisphere of frontal lobe and C3 on central part of the left hemisphere.

Table -1 ANOVA Test Statistics For Approximate Entropy As Feature

Channels	AppEn	Channels	AppEn	Channels	AppEn
A1	0.413	F4	0.108	T5	0.913
Fp1	0.66	F8	0	P3	0.099
Fp2	0.062	T3	0.164	Pz	0.202
A2	0.193	C3	0.033	P4	0.473
F7	0.042	Cz	0.599	T6	0.584
F3	0.067	C4	0.166	O1	0.697
Fz	0.583	T4	0.054	O2	0.323

Brodmann's area 22 and area 47 comes under the channel F7/F8 and area 40 comes under C3/C4 in which the ANOVA test is significant. Traits comes under the channels are constructiveness in F7, hope and consciousness at C3. On analysing the control of Brodmann's area, it is seen that when the lesions involve the left midtemporal sector (area 21 and 20) the patient has difficulty in recalling both unique and common names. Similarly area 22 controls left auditory tract. Area 40 is responsible for writing, retrievel of memory, music somasensory integration and calculation. Area 47 is responsile for working and episodic memory, familiar odour and motor inhibition. Area 20, 21 and 22 is responsible for language comprehension. Area 20 and 22 for attention and speech; Area 21 and 22 for complex sound processing etc.The damage /effect in a particular area will affect the controlling function related to that area.

CONCLUSION

The mean values of approximate entropies of signals at different conditions spans in the range of mean of the value of the feature set at rest + std deviation. The ANOVA test is significant in 3 number of channels out of 21 channels while using Approximate Entropy as feature parameter. This shows the variations in EEG signal while using the mobile phone, which demonstrate transformation in the activities of the brain due to radiation.

The change in complexity has to be taken into account in the view of right of brain will control left side and vise versa. As per the above discussions, it is seen that the difference in complexity is produced on the Left side of the brain in channels F7 and C3 and in channel F8 in right side of the brain. In the experiment the phone is kept next to right ear. The change in complexity in the channels next to phone, i.e. on right side of brain namely A2, F8 is a channel nearest to A2. So the change in F8 may be due to the noise in the electrode because of placing of phone. But changes in F7 and C3 has to be taken seriously. It can affect the controlling function of areas 22, 47 and 40.

The effect of radiation may vary due to gender difference, age difference, and mode of usage of phone (frequent or occasional usage) has to be further investigated. In this study two mobile phones with SAR values of 1.3W/Kg and 0.987 W/Kg is used, further investigations must be carried out to find the changes in brain while using phone with higher values of SAR.

ACKNOWLEDGMENT

The data set was prepared from MIMS hospital, Calicut solely for this research purpose, without any financial assistance. We thank Director, Management of the Hospital for the consent to use Lab facility and also thank Dr. Ashraf and staff members of Neurology department of Hospital, for helping with their EEG expertise.

REFERENCES

Hardell L, Hallquist A, Mild H, " Cellular and cordless telephones and the risk for brain tumors, Fur J Cancer Prev 11:377–386, 2002

Min Kyung Chu , Hoon Geun Song, Chulho Kim and Byung Chul Lee, " Clinical features of headache associated with mobile phone use: a cross-sectional study in university students", BMC Neurology 2011

Ashok Agarwal, Fnu Deepinder, Rakesh K.Sharma, Geetha Ranga, and Jianbo Li, "Effect of cell phone usage on semen analysis in men attending infertility clinic: an observational study", American Society for Reproductive Medicine, Published by Elsevier Inc. 124-128, 2008

IARC/A/WHO (2011) Classifies radiofrequency electromagnetic fields as possibly carcinogenic to humans. Press release.

James C Lin, "Cellular Telephone Radiation and EEG of Human Brain',IEEE Antennas and Propagation Magazine. Vol 45, No -5 October 2003.

Andrew A.Marino, Erik Nilsen,Clifton Frilot,"Nonlinear changes in Brain Electrical Activity due to Cell Phone Radiation", Bioelectromagnetics 24:339-346, 2003.

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

Eleni Nanou, Vassilis Tsiafakis, E. Kapareliotis, "Influence of the Interaction of a 900 MHz Signal with Gender On EEG Energy: Experimental Study on the Influence of 900 MHz Radiation on EEG" , Springer Science, The Environmentalist, 25, 173–179, 2005.

Hie Hinkirikus, Maie Bachmann, Ruth Tomson and Jaanus Lass,"Non-Thermal Effect of Microwave Radiation on Human Brain" , Springer Science, The Environmentalist, 25, 187–194, 2005

Saeid Sanei and J.A. Chambers, "EEG Signal Processing|", John Wiley and Sons, UK, 2007

C. K. Smitha, N. K. Narayanan" Effect of mobile phone radiation on brain using EEG analysis by Higuichi's fractal dimension method ", presented at the Proc. SPIE 8760, International Conference on Communication and Electronics System Design, 87601C (January 28, 2013); doi 10.1117/12.2012177

C. K. Smitha, N. K.Narayanan, "Study of Brain Dynamics under Mobile Phone Radiation Using Various Fractal Dimension Methods", presented at the proce. of International Conference on Signal processing, image processing and pattern recognition, ICSIPR, February 7 , p 288-292, 2013, doi 10.1109/ ICSIPR.2013. 6497942,

C. K. Smitha, N. K.Narayanan "Effect of Mobile Phone Radiation on EEG" at the proce. of third International Conference on Advances in Computing and Communications ACC, 29-31 August, 2013, DOI 10.1109/ICACC.2013.28

C. K. Smitha, N. K.Narayanan, " Effect of Mobile Phone Radiation on EEG Using Various Fractal Dimension Methods", International Journal of Advancements in Research & Technology, Volume 2, Issue5, May-2013 IJOART (ISSN 2278-7763)

C.K. Smitha, N. K. Narayanan "Brain Dynamics under Mobile Phone Radiation Using Various Fractal Dimension Methods", International Journal of Imaging and Robotics, Volume 13, Issue Number 2, 2014 (ISSN: 2231-525X) p 166-180

C. K. Smitha, N.K.Narayanan " Effect of Mobile Phone Radiation on Brain using Wavelet Energy", presented at the IFMBE Proceedings of the ICBME ,Singapore, Volume 43, 2014, pp 192-195, 2013, DOI :10.1007/978-3-319-02913-9_49, Print ISBN :978-3-319-02912-2 Series ISSN 1680-0737

C. K. Smitha, N. K.Narayanan " Effect of Mobile Phone Radiation on Brain – Wavelet Power Approach", presented at the proce. of the 18th World Multi-conference on Systemics, Cybernetics and Informatics WMSCI , Orlando , Volume 1, pp 213-218, 2014

C.K. Smitha, N. K. Narayanan," Effects of Mobile Phone Radiation on Brain Using Statistical Parameters and Its Derivatives", International Journal of Innovative Research in Computer and Communication Engineering ,Vol.2, Special Issue 5, pp 326-33, October 2014, ISSN(O): 2320-9801 ISSN (P): 2320-9798.

Eric R. Kandel, James H. Schwartz, Thomas M. Jessell et al,"Principles of Neural Science", 4th edition, McGraw-Hill, New York ,USA 0-8385-7701-6, 2000

Abdullah Al Jumah "Denoising of an Image Using Discrete Stationary Wavelet Transform and Various Thresholding Techniques" Journal of Signal and Information Processing, 2013, 4, 33-41 doi:10.4236/jsip.2013.41004 Published Online February 2013.

Yatindra Kumar, M.L Dewal, "Complexity Measures for Normal and Epileptic EEG Signals using ApEn, SampEn and SEN", International Journal of Computer & Communication Technology.

Weiting Chena, Jun Zhuang b et.al, "Measuring complexity using FuzzyEn, ApEn, and SampEn" , Medical Engineering & Physics 31, Elsveir. pp 61–68, 2009

Irwin Miller and John E Freund, "Probability and Statistics for Engineers" 4th Edition, Prentice Hall, 1985

Stuart and M G Kendall, "Statistical Inference and Statistical RelationshipThe advanced theory of Statistics vol-2', Hafers Press ,1986