Effect of Wireless Network Radiation on Heart Rate Variability

Barjinder Singh Saini and Anukul Pandey

Abstract—**The health risk associated with the increased exposure to wireless network devices like Mobile Phones, Wi-Fi etc, had been area of concern. In this paper, the effects of wireless network radiations (WNR) on Heart Rate Variability (HRV) had been investigated. The two non-linear indices namely i) Approximate Entropy (ApEn) ii) Detrended Fluctuation Analysis (DFA) had been used for deciphering the hidden dynamics of HRV. The study comprised of 19 healthy male subjects in the age group of 23±4.3 (mean ± std dev) years. The Electrocardiogram (ECG) of each subject obtained under three different WNR exposure modes namely i) Least or minimum exposure: when WNR level is 0.49±0.12 mW/m^2 ii) Moderate exposure: when WNR level is 2.08±0.27 mW/m^2 iii) Maximum or calling mode exposure: when WNR level is 1.65±0.32 W/m^2. The results indicate that there is a significant increase in DFA scaling exponent when the WNR level changed from minimum to maximum value, as p-value <0.05, whereas the change in mean value of ApEn was not significant due to higher standard deviation among all the subjects. The WNR exposure caused changes in HRV indices and it varied with WNR level, but all the changes cannot be considered as p values were higher.**

Index Terms—**HRV, DFA, ApEn, electromagnetic radiation exposure.**

I. Introduction

The wireless devices such as mobile phones, Wi-Fi, Bluetooth enabled devices etc use electromagnetic radiations for transmission and reception purpose. The potential health risk associated with electromagnetic radiations emitted by mobile phones and base transceiver system (BTS) are still in debate. Their wireless network radiations are of non-ionization type and are having low electromagnetic power density. Exposure to high-power RF energy may have negative thermal effects on eye, skin and pregnancy [1]-[5]. Wireless network radiations are widespread in the living environment. The mobile phone essentially carries very low power (~µW) when it in standby mode but when user communicate, the pulsed electromagnetic wave moves to a value of 250mW [6]. There were subjective complains like headache, short term memory loss, fatigue, dizziness, irritation etc. among wireless device users. The biological, wild life and human physiology were affected by the non-ionization radiation reported by previous studies [7]-[10]. In contrast the few studies showed no correlation establishment between neurological and non-ionization radiation exposure [11], [12].

Heart rate variability (HRV) is a non-invasive clinical tool to measure status of physiological, cardiac and autonomic nervous system (ANS) [13], [14]. The ANS modulates the cardiac pacemaker and provides beat-to-beat regulation of the cardiovascular rhythm. Linear and non-linear techniques can be used to analyze HRV [15], [16]. The present study attempts to find cardiovascular effect of wireless network radiation emitted by mobile phone and BTS in healthy young male volunteer easy chair sitting position.

II. Materials and Methods

In this study 19 healthy male subjects in the age group 23±4.3 (mean ± standard deviation) years have been participated. The electrocardiogram (ECG) of each subjects of 20 minutes duration was obtained using Zephyr Bioharness^{TM} physiological monitoring system under three different WNR exposure modes namely (i) approximately 800 meters from nearest BTS without mobile phone (where radiation level is 0.49±0.12 mW/m^2 and is referred to as least exposure mode) (ii) Approximately 50 meters from nearest BTS without mobile phone (where radiation level is 2.08±0.27 mW/m^2 and is referred as moderate exposure mode) (iii) Approximately 800 meters from nearest BTS with mobile phone near chest in calling mode (where radiation level is 1.65±0.32 W/m^2 and is referred as calling mode exposure).

A. Experimental Setup

All the recordings were obtained on easy chair sitting mode position. The subject first made to relax for 10 minutes before taking every reading. The mean heart rate during ECG recording of subjects was also measured. Experiment were done in quite surrounding and prior to ECG recording all volunteers were asked to maintain their steadiness and do less of bodily and mental activity in order to improve quality of ECG [17]-[19].

The same environmental conditions were observed along with same mobile phone used for experimentation having specific absorption rate (SAR) 1.2 W/kg [18], which is within the ICNIRP[7] limit used during recording.

The radiofrequency radiation (RFR) were measured at the testing sites using Radio Frequency Electromagnetic Field (RF EMF) strength meter (50MHz to 3.5GHz) in watt per square meter. However, the cardiovascular effect may depend on the degree of acceptance of RFR exposure by the living body species not on the RFR that exist in space [20].

B. Nonlinear HRV Measures

The Approximate Entropy (ApEn) and Detrended

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Fluctuation analysis (DFA) measure were used to quantify the heart rate variation in above defined three different test conditions.

C. Approximate Entropy

Entropy represents the degree of randomness, when it is applied to quasi-stationary RR time series. ApEn provides the degree of regularity, the low value of regularity and predictability of the time series leads to high value of ApEn. Pinacus introduces ApEn for analysis of physiological time series processing for complexity evaluation [21].

ApEn (*m, r, N*) is the negative natural logarithm of the conditional probability that the time series length of *N* that are similar for *m* points remain similar for *m*+1 points, within a tolerance of *r* [21]. ApEn requires each template to add on nonzero conditional probability. ApEn was used to quantify HRV complexity in healthy groups for different age groups at different times of the day [22].

D. Detrended Fluctuation Analysis (DFA)

If the non-stationary signal such as ECG is integrated directly without any special consideration then the level of non-stationarity may be increased [23]. So, the DFA is applied on non-stationary time series which calculates root mean square fluctuation of time series and provide intrinsic self similarity in non-stationary time series [24]. In the DFA method the total length N of RR time series is integrated as equation 1 and then vertical characteristic scale was measured.

$$y(k) = \sum_{i=1}^{k} [RR(i) - RR_{avg}] \quad (1)$$

For measurement of vertical characteristics the time series was divided in boxes of equal length *n* which represents the trend in that box and local trend are removed by subtraction of RR_{avg} [23]. In each box a least square fit to data is used to represent the trend, $y_n(k)$ represent the straight line in particular box. The root mean square of integrated fluctuation and detrended RR times series is given by equation 2, which will be calculated for every window [25].

$$F(n) = \sqrt{\frac{1}{N} \sum_{k=1}^{N} [y(k) - y_n(k)]^2} \quad (2)$$

$F(n)$ will increase with the box size. The slope of line relating $\log(F(n))$ to $\log(n)$ give the value of scaling exponent (α). An α of 0.5 corresponds to white noise, $\alpha = 1$ represents l/f noise and $\alpha = 1.5$ indicates Brownian noise or random walk. Scaling exponent having potency for diagnostic and prognostic abilities with various type of cardiac diseases. DFA method gives superior results with respect to spectral analysis for the analysis of HRV in patient with sleep apea.

III. Result and Discussion

The subjective symptoms like headache, short term memory loss, fatigue, dizziness, irritation etc. were informed by volunteers through oral communication with calling mode exposure. The mean heart rate does not significant change during three experimental conditions. The result obtained through quantification of nonlinear HRV in three different experimental conditions are shown in Table I. The results were given in the form of mean standard deviation for all the 19 male subjects. The variation in approximate entropy and scaling exponent (α) under three different exposure modes for all the 19 subjects are also shown in Fig. 1 and Fig. 2 respectively. Further, the statistical comparison among data were made based on t-test for calculation of p-value.

A. Detrended Fluctuation Analysis

The mean value of scaling exponent (α) in Table I is low in case of least exposure case, highest in the case of maximum WNR exposure and low in moderate case as well. The study indicates that α value increases with statistical significance, when mobile phone placed near chest in calling mode with respect to least radiation and also α value of HRV is not significant if the volunteers got exposed by wireless transmitter station this may due to the ambient (temperature, humidity, pollution level, air flow direction etc.) conditions in moderate exposure changes with respect to least exposure. This can be well justified by statistical analysis as *p*-value is <0.05 for calling mode exposure condition with respect to least exposure. The scaling exponent increases in 10 volunteers when moderate exposure was experienced compared to least exposure (Fig. 1). Also scaling exponent increases in 16 volunteers when calling exposure was experienced compared to least exposure (Fig. 1).

TABLE I: HRV Parameters in Three Conditions

Parameters	Exposure modes			*p*-value 1	*p*-value 2	*p*-value 3
	Least exposure	Moderate exposure	Calling mode exposure			
Scaling exponent	0.92±0.088	0.92±0.091	0.97±0.09	0.41	0.02	0.18
Approximate Entropy	0.57±0.29	0.61±0.31	0.56±0.26	0.79	0.42	0.36

n.u- normalised unit, *p*-value1-statistical comparison between least and moderate exposure,
p-value2- statistical comparison between least and calling mode exposure
p-value3- statistical comparison between moderate and calling mode exposure

B. Approxumate Entropy

The mean value of approximate entropy in Table I was low in 7 subjects in case of moderate radiation exposure and was high in 10 subjects in calling mode exposure when it was compared with the least radiation exposure (Fig. 2). The statistical significance of approximate entropy value was not made because of higher *p*-value.

Scaling exponent value is highest in case of calling mode exposure and lowest in least exposure. This result indicates that HRV increases when higher WNR is experienced by volunteers and decreases when least exposure is experienced shown in Table I.

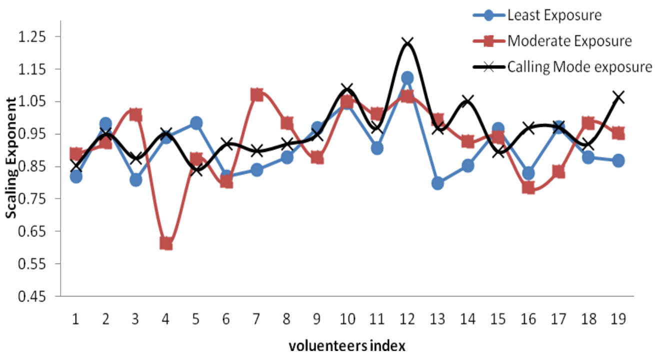

Fig. 1. Variation in scaling exponent.

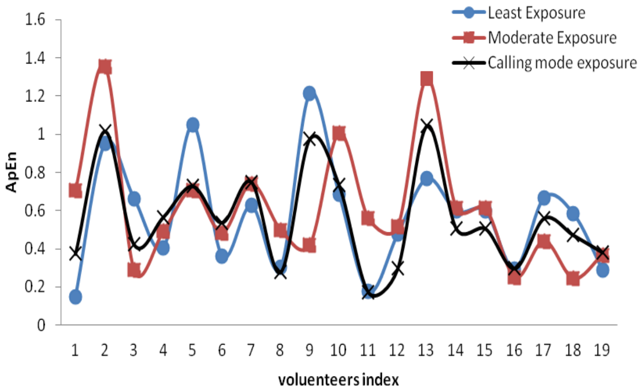

Fig. 2. Variation in approximate entropy.

IV. Conclusion

Cardiovascular effect of wireless network radiation by use of HRV parameters is evaluated. The p-value was calculated using *t*-test. The low *p*-value suggests that the difference in average of two groups is significant. The HRV measure namely approximate entropy and scaling exponent changes with insignificance in all the experimental conditions as high *p*-value except from least exposure to calling mode exposure on scaling exponent is significant as *p*-value is <0.05. This might be because sensitivity of human body towards WNR is different at different WNR level which may be unpredictable.

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