International Journal of the Physical Sciences Vol. 6(36), pp. 8097 - 8104, 30 December, 2011
Available online at http://www.academicjournals.org/IJPS
DOI: 10.5897/IJPS11.240
ISSN 1992 - 1950 ©2011 Academic Journals

Full Length Research Paper

Thermographic analysis of Wi-Fi frequencies exposed to unrestrained Swiss albino mice

A. D. Usman[1]*, W. F. Wan Ahmad[1], M. Z. A. Ab Kadir[1], M. Mokhtar[2] and R. Ariffin[3]

[1]Department of Electrical and Electronic Engineering, Faculty of Engineering, University Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.
[2]Department of Computer and Communication Engineering, Faculty of Engineering, University Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.
[3]Faculty of Electrical Engineering, Universiti Teknologi Mara (UiTM) Pulau Pinang, 13500 Permatang Pauh, Pulau Pinang, Malaysia.

Accepted 15 July, 2011

Effects of electromagnetic field exposure due to Wi-Fi frequency were presented. A total of 72 unrestrained Swiss albino mice were used as surrogate and were divided into two groups of sham exposed and 2.46 GHz exposure group. The exposure duration was for 7 h/day, 7days/week for 4 consecutive weeks. Thermographic pictures of both groups were taken to obtain the body temperature of the mice before and after the exposure. A Signal generator was connected to an omnidirectional antenna to generate average field strength of 1.1 × 10^{-3} mW/cm^2 and specific absorption rate (SAR) of 1.82 × 10^{-4} for the exposure purpose. A statistical analysis performed shows a significant difference at α = 0.05 for the temperatures before and after exposure. The mice body mass was found to decrease with prolonged exposure in the 2.46 GHz exposure group. This however, is contrary for mice in sham exposed group. The death rate for exposure group was found to be 28% as compared to 6% of the sham exposed group.

Key words: Electromagnetic exposure, radio frequency-electromagnetic field (RF-EMF), thermography, far field, radiation.

INTRODUCTION

One of the recent technological advancement in today's world is in Wireless Fidelity (Wi-Fi). This technology was developed on IEEE 802.11 standards operating in 2.4 and 5 GHz bands. It provides wireless access to applications and data across a radio network. Wi-Fi enables users to communicate to internet from any place such as offices, homes, in space and any place without the hassles of plugging wires. Locations where users are able to connect to wireless networks are called Wi-Fi hotspot. The most popular Wi-Fi technology, such as IEEE 802.11b operates at frequency range of 2.40 to 2.4835 GHz. The network devices that provide the Wi-Fi air interface between the broadband network and the user terminal is called Wi-Fi access point (Wi-Fi AP), which is a radio transceiver itself. The use of Wi-Fi services for private purposes is covered by an exemption order, but the provision of it to public in some countries is permissible under a class of license, provided that the services do not cross the public streets. For these public purposes, a fixed carrier license is required (Ross, 2008).

Regulations were given by international bodies and scientific communities in terms of maximum exposure allowed (Australian Radiation Protection and Nuclear Agency (ARPANSA), 2002; Institute of Electrical and Electronics Engineering (IEEE), 2005; International Commission on Non-Ionizing Radiation Protection (ICNIRP), 1998). However, with these regulations, people exercise fears on the possible effects that might be associated with usage of these technologies with time. To date, studies on effect of exposure to Wi-Fi frequency were scanty, but similar studies on the frequencies

*Corresponding author. E-mail: aliyu_d_usman@yahoo.com. Tel: +60126627419.

around the frequencies of operation of Wi-Fi results in complicated results as in (Charles and Elliot, 1995; Fritze et al., 1997; Golberg, 2002; Lai and Sing, 1995, 1996, 1997; Malyapa et al., 1997; Michaelson and Lin, 1987; Moulder et al., 1999, 2005; Narayanan et al., 2009; Norton et al., 1992; Philips et al., 1998; Sakar et al., 1994; Sareesh et al., 2010; Usman and Wan Ahmad, 2008; Usman et al., 2011; Valberg et al., 2007). Yet attempts were made by some countries to turn some of their cities to e-cities with Wi-Fi technologies thereby exposing greater population to more radio frequency radiation (RFR).

In frequency range of mobile communication, universal mobile telecommunication system (UMTS) as well as Wi-Fi, one of the relevant interactions of radio frequency-electromagnetic field (RF-EMF) with biological tissue is the absorption and conversion of EMF energy into thermal energy. Thermal effects are those caused by rise in temperature produced by the energy absorbed from oscillating electric field. The force produced by an electric field on charged objects, such as mobile ions in the body causes them to move, resulting in electric currents and resistance of the materials in which the currents are flowing result in heat. This heat input causes temperature to rise and may result in damaging molecules and altering metabolic function. According to ICNIRP guidelines, as long as the exposure is below the recommended level of 0.98 mW/cm^2, no adverse biological effects can be expected. The basis for the exposure guidelines is thermal effects and does not guarantee for long term exposure. Hence, in order to address the possible health risk associated with long term EMF exposures from Wi-Fi technologies a number of approaches are possible. In this study, thermal effect due to long term exposure to Wi-Fi frequencies were investigated using infrared thermo graphic camera (IRTC). The IRTC was found suitable, because it is non invasive and can be used to detect temperature increase in both human and animal without being in contact with the subject.

MATERIALS AND METHODS

The study was designed to measure the whole body surface temperature of mice after exposure to RF-EMF at the typical Wi-Fi frequency of 2.46 GHz for four weeks.

Animal care and handling was carried out according to Malaysian animal handling code of conduct adopted from National Research Council guide for the care and use of laboratory animals (National Research Council (NRC), 1996). The RF-EMF design and exposure set-up were done according to Electronic Communication Commission (ECC) protocol (EEC, 2003). A total of 72 male Swiss albino mice (*Musmusculus*) about 4 weeks age on arrival and weighing between 34 to 45 g were obtained from Veterinary Research Institute (VRI) Ipoh, Perak, Malaysia. The mice were grouped into sham exposed and 2.46 GHz exposed group. The sample size in each group is made up of 36 mice. The mice in each group was randomly selected and housed in 2 cages of 18 mice each and were then allowed to acclimatize for a week before the exposure started (Shahryar et al., 2009; Warn et al., 2003; Weinert and Waterhouse, 1999). The cages were made of metal with plastic coating and the dimensions were 0.6 × 0.42 × 0.24 m. The floors of the cages are made of removable plastic cover and are covered with wooden chips. One cage is capable of accommodating 25 unrestrained mice (NRC, 1996). Hence, with only 18 mice in each cage the mice are able to move around freely. Both the sham exposed and the 2.46 GHz exposure group's ambient temperature and humidity were maintained throughout the experiment at 27 ± 2°C and 65 ± 5%, respectively. The experiments were conducted in an environment shielded from EMF sources. The water bottle and the food container were made of plastics and assorted mixed food and water were available to the mice *ad libitum*. Wooden chips beddings were used to supply comfort and absorb mice waste. The beddings were changed regularly to avoid infection.

Pulse modulated direct sequence spread spectrum (DSSS) RF-EMF in the range of 2.46 GHz with duty factors of ~1% and pulse rates ~10 Hz frequency were generated and exposed to one group, while similar arrangement were made for the sham exposed group with RF-EMF generator turned off. A signal generator (R & S SMB1000A) with frequency range of 9 kHz to 6 GHz was used in generating the required Wi-Fi signal. This signal was set at +13 dBm power to provide the required exposure. An omni-directional antenna is used to transmit the signal to the mice in 2.46 GHz exposed group. A spectrum analyzer (R & S FSL6) with a frequency range of 9 kHz–6 GHz was used to measure the received signal strength at different position inside the cage as well as to make sure that the signal received is free from dominant unwanted signal. RF-EMF monitoring meter (portable measurement system (SMP) wave control) in the frequency range of 3 kHz to 3 GHz was used to validate the electric field strength generated inside each cages. The cages were placed at far field distance using far field equation parameters given by Equation 1, where *R* is the distance (m) from the source to the far field, *D* is the largest dimension (m) of the source antenna and *λ* is the wavelength (m) of the transmitted signal (Saunders et al., 1991). The far field distance was calculated to be 2 m from the source.

$$R = \frac{2D^2}{\lambda} \tag{1}$$

The average field strength generated by the signal generator and transmitted by the omni-directional antenna measured at several points inside the cages using both the spectrum analyzer and SMP electric field meter was averaged as 1.1 × 10^{-3} mW/cm^2. This correspond to the typical field strength obtained during the Wi-Fi base stations and their access point (APs) site surveys conducted at far field distances previously by our group (Usman et al., 2011).

An empirical formula for calculating the average specific absorption rate (SAR) of an irradiated object over broad range for prolate spheroidal models of human and animals (Durney et al., 1986) developed was used to calculate the average SAR. The average SAR for incident power density of 1 mW/cm^2 and E polarization with semi major axis a, and semi minor axis b, in meters is shown in Equation 2, where A_1, A_2, A_3 and A_4 are functions of a and b, A_5 is a function of ε, the permittivity of muscle and ε_{20} is the permittivity at 20 GHz. The average length is 2a, and b is defined in Equation 3, where V is the volume and the resonant frequencies f_0, f_{01} f_{02} and A_1, A_2, A, A_4 and A_5 are defined in the work of Durney et al. (1986) in Equation 5.2 to 5.9.

$$SAR(W/kg) = \frac{A_1 f^2/f_0^2\,[1 + A_3\,(f/f_0)u(f - f_{01}) + A_4 A_5 (f^2/f_0^2)u(f - f_{02})]}{10^3 f^2/f_0^2 + A_2(f^2/f_0^2 - 1)^2} \tag{2}$$

The unit function $u(f-f_{01})$ is defined by:

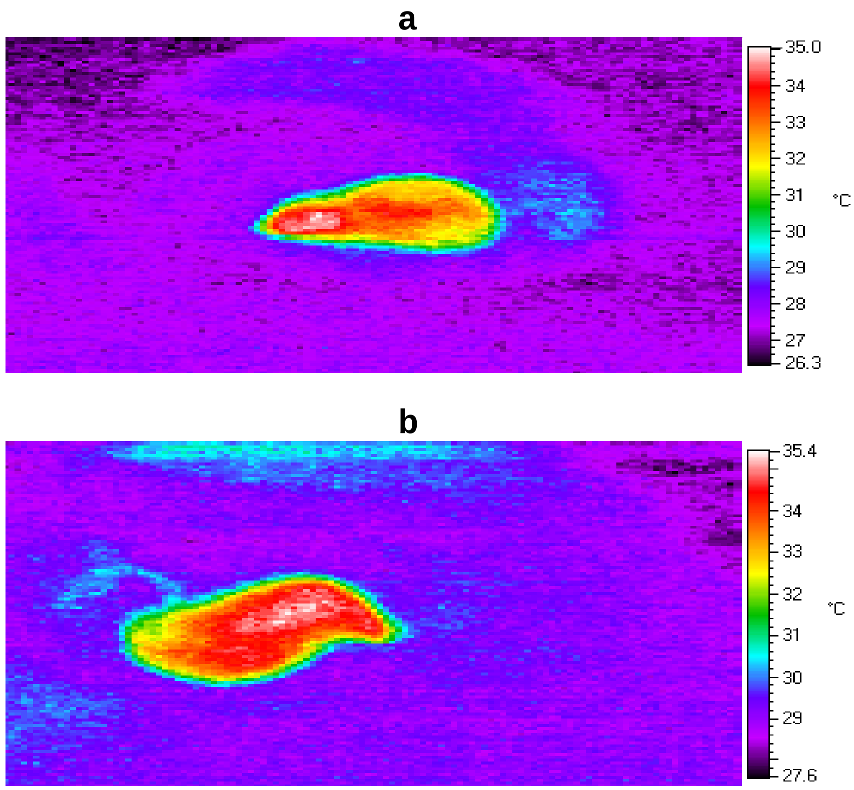

Figure 1. Thermographic pictures of the mice in 2.46 GHz exposed group taken (a) before and (b) after the EMF exposure.

$$u(f - f_{01}) = \begin{cases} 0, & f < 0 \\ 1, & f_{01} \geq 0' \end{cases} \qquad u(f - f_{02})$$ is similarly defined.

$$b = \sqrt{\frac{3V}{4\pi a}} \qquad (3)$$

These equations allowed computation of the frequency dependant normalized SAR of mouse appropriate for estimating the average SAR for free moving mouse. The average SAR for an incident power density of 1.1 $\times 10^{-3}$ mW/cm^2 at 2.46 GHz was calculated to be 1.82 $\times$ 10^{-4} W/kg.

The exposure was conducted for 7 h daily for 4 weeks including weekends and public holidays. Measurements of temperature rise in the body of the mice were done each day before and after the 2.46 GHz exposure using IRTC (IR Snap shot Model 525). One thermographic image was taken per sample for all the samples in each group. The camera resolution is 0.1°C and Snap View pro 2.1 software is used for the thermographic analysis. This infra-red camera has a wavelength of 8 to 14 µm which is quite suitable for measurements of mice temperatures (Holst, 2000). In this band, molecular absorption process from water or carbon dioxide is not distinctive and the transmission coefficient of normal atmospheric air is high. Wien's law stipulated that peak radiation of 37°C back body lies at 9.3 µm and this can be detected with this high sensitivity infra red sensor. In this wide band range the emissivity is related to the object, black body and ambient temperature given by Stefan's Boltzmann law (Holst, 2000) in Equation 4, where T_m is the black body temperature, T_0, is the object temperature, T_{amb} is the ambient temperature and ε_m is the emissivity coefficient of the object in the wave band use for the measurement.

$$T^4 = \varepsilon_m T_0^4 + [1 - \varepsilon_m] T_{amb}^4 \qquad (4)$$

RESULTS

The IRTC was used to capture the temperature of all mice from each group before the exposure (in the morning) and after the 7 h exposure (in the evening). The body mass of all the mice in each group were taken on day 1 and subsequently on weekly basis. The sample of the color coded temperature maps obtained from IRTC is as shown in Figure 1. The IRTC gives an integrated measurement of color temperature and volume/area of a body, the white area is the point of the highest temperature on the mice body. Average mice temperatures taken on each day before and after exposure as well as the average weights taken on weekly basis were presented in Figures 2 to 5. The mice death recorded during this study were sent for postmortem examination.

The thermography of the sham exposed group is shown in Figure 2. In this group, there is no definite pattern for temperature changes, the average thermo-graphic result fluctuates. The mice average temperature increases, decreases or even shows no change in some

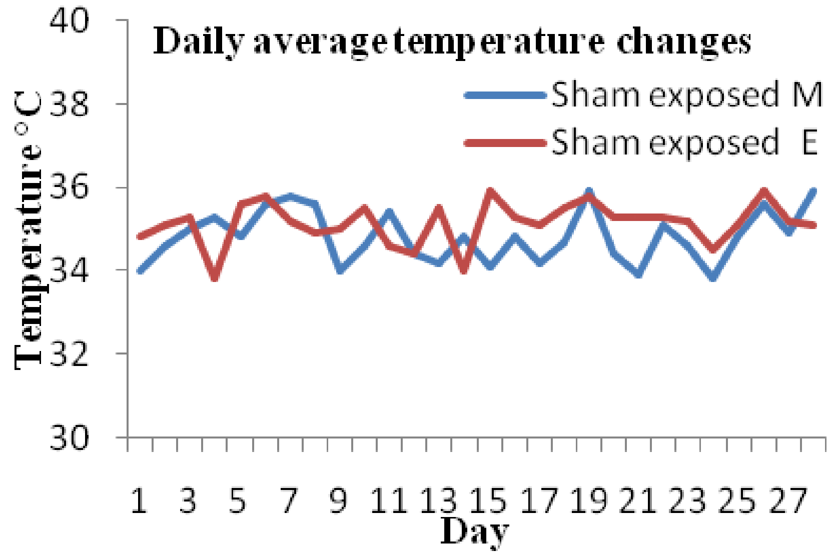

Figure 2. Average temperature variations for sham exposed group.

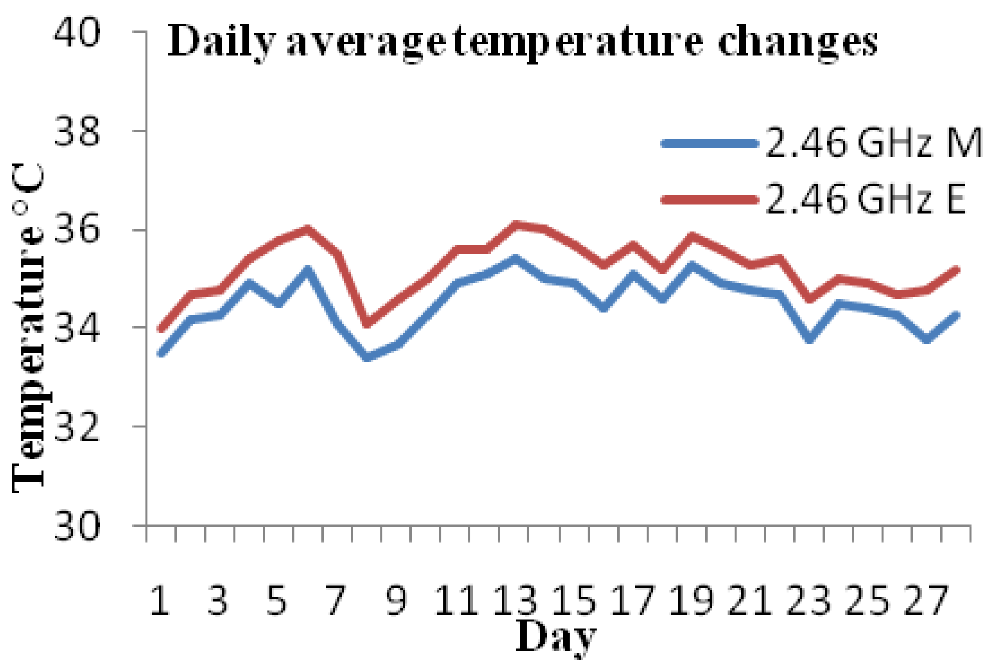

Figure 3. Average temperature variation with prolong exposure for 2.46 GHz exposed group.

instances after the 7 h duration. The average highest temperature of 35.9°C recorded in the sham exposed group was on day 15 and 26, and the lowest average temperature of 33.8°C was recorded on day 4.

The average temperature change of mice in 2.46 GHz exposed group where measurements are taken both before the exposure in the morning (M) and after 7 h of exposure in the evening (E) for four weeks were shown in Figure 3. From the graph, the average highest temperature of 36.1°C was observed on day 13 and the lowest average temperature recorded was 34.0°C on day 1 immediately after the exposure (in the evening). The high difference in daily temperature before and after the exposure is 1.4°C on day 7 and the temperature difference with respect to the average ambient temperatures were within the range of 6 to 7.1°C. It was observed from week 3, that there is small increment in temperature with prolong exposure. This small increment

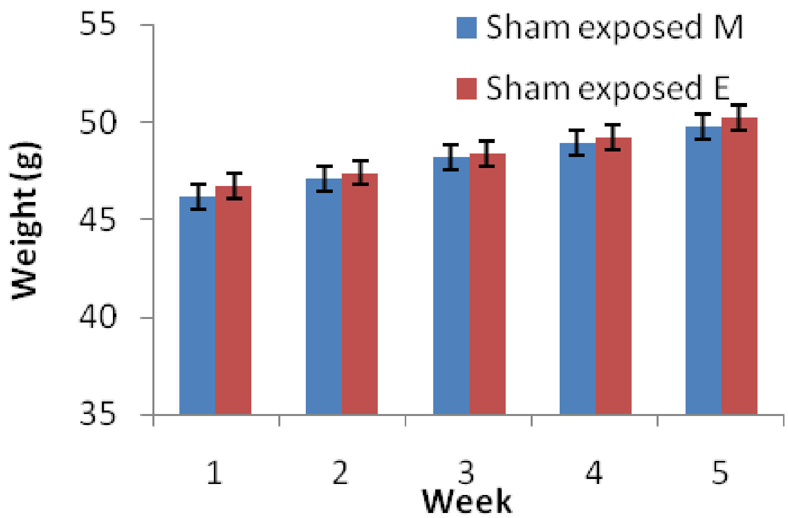

Figure 4. Average body mass of mice for sham exposed group.

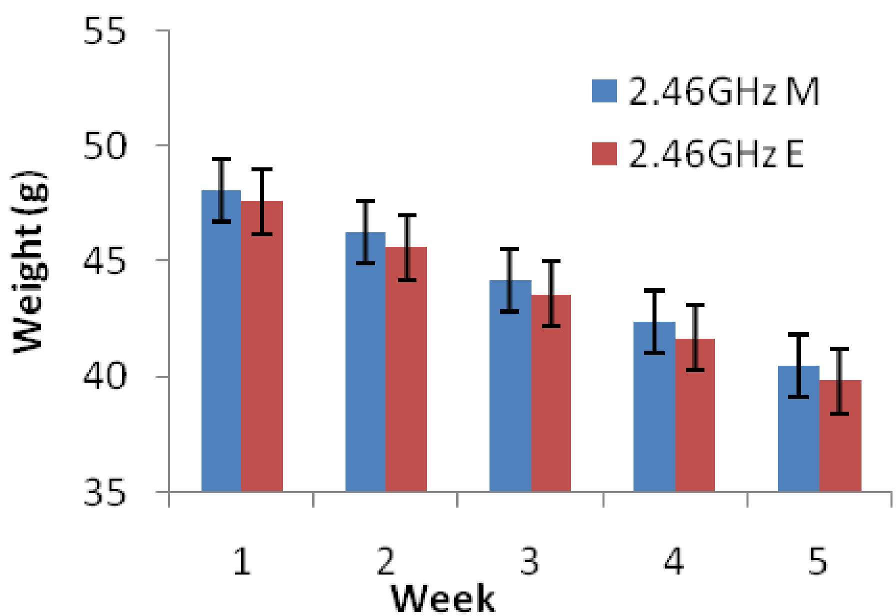

Figure 5. Average body mass variation with prolong exposure for 2.46 GHz exposed group.

may likely be due to decrease in metabolic activities of the mice.

The mice average body mass measured before the exposure in the morning on day 1 and subsequently at the end of every week after the exposure in the evening were shown in Figures 4 and 5 for both sham exposed and 2.46 GHz exposed groups, respectively. For the sham exposed group in Figure 4, the average weight of the mice increases. The average weight measured on day 1 is 46.2 g and at the end of week four, the average weight was measured to be to 50.2 g. This however, is contrary to 2.46 GHz exposed group as shown in Figure 5. RF-EMF exposure effect was evident as the average weight of the mice in 2.46 GHz exposed group on day 1 is 48.1 g and a decrease in weight was observed after each week measurement. At the end of week four, the mice average weight decreases to 39.8 g. Note that after the four weeks exposure, the average weight of the mice in the 2.46 GHz exposed group is 10.4 g less than the average weight of the mice in sham exposed group. The death recorded may also be another indicator as a result of prolonged exposure to Wi-Fi frequency. In the 2.46 GHz

Table 1. Paired sample T-test for mice in 2.46 GHz exposed group.

Temperature	n	Mean	SD	t	p
Post test (Evening)	28	35.2321	0.55914	15.315	0.000
Pre test (Morning)	28	34.5143	0.54141	-	-

Table 2. Independent sample T-test for mice in 2.46 GHz and sham exposed group.

Group	n	Mean	SD	t	p
2.46 GHz	28	35.2321	0.55914	0.596	0.553
Sham exposed	28	35.1464	51531	-	-

exposed group, the death recorded was 10 equivalents to 28% as against 2 death recorded from the sham exposed group which is equivalent to 6%. A postmortem examination of the dead mice from the sham exposed and exposed groups were taken to VRI Ipoh. The postmortem examination of the sham exposed group was found to be normal while that of the 2.46 GHz exposed group shows a sign of dehydration and cell degeneration.

A statistical analysis carried out using SPSS software also corroborated the results obtained in Figure 3. The paired sample t-test shown in Table 1 for 2.46 GHz exposed group shows t (27) = 15.315 and p = 0.000. Therefore, since sig-t (0.000) < α (0.05), it shows that the difference in temperature observed after the exposure in the evenings is significant as compared to the temperature before the exposure in the morning at 0.05 level of significance. However, the independent sample t-test results shown in Table 2 were on the contrary with sig-t (0.553) > α (0.05). The repeated measure analysis using Turkey honestly significant difference (HSD) for 2.46 GHz exposed group shows Wilk's Lamda value as 0.103, p-value as 0.000 (< 0.05), the effect size as 0.897 and the statistical power is 100%.

DISCUSSION

Previously, a number of studies were conducted to determine the effect of temperature rise as a result of exposure either to heat or electromagnetic field to human or animal using infra red thermal imaging (Alla et al., 1998; Christian, 2005; Ivana et al., 2007; Ludwig et al., 2007; Mikokajczyk et al., 1991). These studies however, are either for short term exposure, long term with short exposure duration or using restrained mice as the surrogate. On the other hand, this study was designed to expose unrestrained Swiss albino mice to Wi-Fi frequency for 7 h mimicking the average hour's people spend in the office or school children spent in schools with Wi-Fi facility.

Though, the incident power density of 1.1×10^{-3} mW/cm^2 used in this study is less than the ICNIRP recommended value of 0.98 mW/cm^2, sharp temperature increase were noticed after the exposure in each day for mice in 2.46 GHz exposed group. The differences observed after the exposure was found to be significant. However, contrary results were obtained when comparing 2.46 GHz exposed group and sham exposed group. Temperature compensation was noticed within the period before the next exposure start. But in most cases temperature did not revert back to the previous readings.

Temperature increase is related to metabolic activities of the body; for the 2.46 GHz exposed group, it was observed that the metabolic activities decrease with increase in the number of days for the exposure. Naturally, the cells of living organisms maintain an electrical charge across their membrane that are essential for normal functioning of human tissues which are sensitive to microwave energies. Microwave induced stress is capable of rearranging and altering metabolic function of molecules. This may result to changes in hormonal activity, interference of flow of substances and leads to eventual cell damage. The decrease in body weight with prolong exposure noticed in 2.46 GHz exposed group during the course of this study may likely be as a result of lack of appetite as well as some other hidden effects. While mice in sham exposed group gained weight as the days goes by, with the highest records in week 4. An increase urine secretion, clustering of the mice in one place and non free movement of the mice in 2.46 GHz group are observed while this is in the contrary to the mice in sham exposed group. This result is quite comparable to the study (Ludwig et al., 2007; Mikolajczyk et al., 1990), which demonstrate heating effect as a result of induce stress on animals exposed to microwave frequencies and differences in water content in salivary, kidney and peripheral bloods of rats subjected to different kind of EM fields, respectively. Also, findings of Ray and Behari (1990) reported that animals exposed to microwaves tended to eat and drink less and thus, showed a smaller gain in body weight corroborated the findings of this work.

Some of the limitations of this study are largely due to complicating requirements of RF-EMF researches, that is, seeking compromise between the biological and the engineering requirements. Difficulties in ensuring uniform field distribution, interference, uniform temperatures and humidity especially when dealing with unrestrained animals is paramount. A reasonable homogeneous field distribution was obtained by optimizing the design to obtain average field strength. Absorbers were used to prevent possible interference and a humidity and temperature meter was used in monitoring the room temperature and humidity. The experimental rooms were dimly lighted so as to reduce the clustering of the mice in one place.

Conclusion

Long term exposure of RF-EMF in the range of Wi-Fi frequency on unrestrained Swiss albino mice was investigated. An increase in body temperature was observed and recorded using IRTC. Despite the thermoregulatory mechanism of animal body when subjected to heat stress, it is evident that the temperature effect is cumulative as this gives rise to manifestation of some changes in both physiological and eating habit. This action leads to loss of weight and increased urine secretion as well as non active nature of the animal as compared to the sham exposed group. The death rate is another pointer to likely secondary effect caused by the long term RF-EMF exposure. A statistical analysis conducted shows that the temperature rises as a result of exposure where Wi-Fi frequencies is significant. From the results, it is demonstrated that, the pattern of energy absorption inside irradiated body is non uniform and the biological responses are dependent on the exposure durations.

REFERENCES

Alla Z, Samuel D, Oleg V, Rafeal B (1998). Dyanamic Thermography: Analysis of Hand Temperature during Exercise. *Annals Biomed. Eng., 26*: 988-993.

Australian Radiation Protection and Nuclear Agency (ARPANSA) (2002). *Maximum Exposure Levels to Radiofrequency Fields-3 kHz to 300 GHz*. from http://www.arpansa.gov.au/pubs/rps/rps3.pdf.

Charles P, Elliot P (1995). *Handbook of Biological Effects of Electromagnetic Fields* (2nd ed): *CRC Press*, Florida.

Christian K (2005). Infrared thermal imaging to measure local temperature rises caused by handheld mobile phones. *IEEE Transaction on Instrumentation and Measurement, 54*(4): 1513-1519.

Electronic Communication Commission ECC (2003). Measuring nonionizing electromagnetic radiation (9kHz-300GHz), Recommended practice (02)04 C.F.R.

Fritze K, Sommer C, Schmitz B, Mies G, Hossmann KA, Kiessling M, Wiessner C (1997). Effect of global system for mobile communication (GSM) microwave exposure on blood-brain barrier permeability in rat.*ActaNeuropathol, 94:* 465-470.

Golberg BR (2008). Literature Resources for Understanding Biological Effect of Electromagnetic Fields Retrieved 9/13/2008, from http://infoventures.com/emf/top/lit-rev.html

Holst GC (2000). Common Sense Approach to Thermal Imaging.

Institute of Electrical and Electronics Engineering (IEEE) (2005). *Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz*. New York NY.

International Commission on Non-Ionizing Radiation Protection. (ICNIRP) (1998). Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic field (up to 300GHz) *Health Phys., 74*: 494-522.

Ivana K, Petr K, Gurkan AKG, Yunus P, Kemal CS (2007). Application of infrared thermography in animal product. J. Fac. Agric., *22*(3): 329-339.

Lai H, Sing NP (1995). Acute low-intensity microwave exposure increases DNA single-strand breaks in rat cells. *Bioelectromagnetics, 16*: 207-210.

Lai H, Sing NP (1996). Single and double strand DNA breaks in rat brain cells after acute exposure to radiofrequency electromagnetic radiations *In.*t J. Radiat Biol., 69: 513-521.

Lai H, Sing NP (1997). Melatonin and a spin-trap compound block radiofrequency electromagnetic radiation -induced DNA strand break in rat brain cells *Bioelectromagnetics, 18*: 446-454.

Ludwig N, Gargano M, Luzi F, Carenzi C, Verga M (2007). Applicability of Infra-red Thermography as a non-invasive Measurement of stress in Rabbit. *World Rabbit Science, 15*: 199-206.

Malyapa RS, Ahern EW, Straube WL, Moros EG, Pickard WF, Roti RJL (1997). Measurement of DNA damage after exposure to 2450 MHz electromagnetic radiation. *Radiat Res., 148*: 608-617.

Michaelson SM, Lin JC (1987). *Biological Effects and Health Implications of Radio-Frequency Radiation* (1st ed). New York: Springer.

Mikolajczyk H, Kameduka M, Ruppe I, Eggert S (1990). Thermal Effect in Rats Exposed to Heat at 40^0 C or to Electromagnetic Fields. *J. Therm. Bio.l, 16*(2): 115-119.

Moulder JE, Erdreich LS, Malyapa RS, Meritt J, Pickard WF, Vijayalaxmi (1999). Cell Phones and Cancer: What is the evidence for connection? *Radiat Res., 151*: 513-531.

Moulder JE, Foster KR, Erdreich LS, McNamee JP (2005). Mobile phones base stations and cancer: A review. *Int. J. Radiat. Biol., 81*: 189-203.

Narayanan SN, Kumar RS, Potu BK, Nayak S, Mailankot M (2009). Spatial memory performance of Wistar rats exposed to mobile phone. *Clinics, 64*: 231-234.

National Research Council (NRC) (1996). Guide for care and use of laboratory animals. Institute of Laboratory Animal Resources, Washington DC: National Academic Press.

Norton WT, Aquino DA, Hozumi I, Chiu FC, Brosnan CF (1992). Quantitative aspects of reactive gliosis: review. *Neurochem Res., 17*: 877-885.

Philips JL, Ivaschuk O, Ishida-Jones T, Jones RA, Campbell-Beachler M, Haggren W (1998). DNA Damage in Molt-4T lymphoblastoid cells exposed to cellular telephone radiofrequency fields in vitro. *Bioelectrochem. Bioenergetics, 45*: 103-110.

Ray S, Behari J (1990). Physiological changes in rats after exposure to low levels of microwaves, *Radiat. Res.,* 123: 199-202.

Ross J (2008). *A painless guide to Wi-Fi and broadband wireless* (2 ed.). USA: Nostarch Press Inc.

Sakar S, Ali S, Behari J (1994). Effect of low power microwave on the mouse genome: A direct DNA analysis. *Mutation Res., 320*: 141-147.

Sareesh NN, Raju SK, Bhagath KP, Satheesha N, Gopalakrishna PB, Maneesh M (2010). Effect of radio-frequency electromagnetic radiations (RF-EMR) on passive avoidance behaviour and hippocampal morphology in Wistar rats. *Ups J. Med. Sci.*, 1-6.

Sienkiewicz ZJ, Saunders RD, Kowalczuk CL (1991) Biological Effects of Exposure to non-ionising Electromagnetic Fields and Radiation: Radiofrequency and Microwave Radiation. London: NRPB.

Shahryar HA, Lotfi A, Ghodsi MB, Bonary ARK (2009). Effect of 900 MHz Electromagnetic Fields emitted from cellular phone on the T3, T4, and cortisol levels in Syrian Hamsters. *Veterinary Institue in Pulawy, 53*: 233-236.

Usman AD, Wan- Ahmad WF (2008). *RF EM exposure: The issues, the debate and the realities.* Paper presented at the IEEE International RF and Microwave Conference, Kuala Lumpur, Malaysia.

Usman AD, Wan -Ahmad WF, Ab- Kadir MZA, Mokhtar M, Zainal Abidin (2011). Densitometry of Electromagnetic Field Exposure Due to Wi-Fi Frequency. Progress in Electromagnetic Research Symposium, Marrakesh, Morocco, Mar. 20-23, 1385.

Valberg PA, van Deventer TE, Repacholi MH (2007). Workgroup Report: Base stations and wireless networks-Radiofrequency (RF) exposures and health consequences. *Environ. Health Phys., 115*: 416-424

Warn PA, Brampton MW, Sharp A, Morrissey G, Steel N, Denning DW, Priest T (2003). Infrared body temperature measurement of mice as an early predictor of death in experimental fungal infections. *Laboratory Animal, 37*: 126-131.

Weinert D, Waterhouse J (1999). Daily activity and body temperature rhythms do not change simultaneously with age in laboratory mice. *Physiol. Behaviour, 66*(8): 605-612.