Experimental Assessment of Mobile Radio Modulated Microwaves Exposure Effects on Hydroxyl Radical Production within Human Leukocyte Cells

Takashi Hikage[1], Yoshihumi Kawamura[1], Toshio Nojima[1]

[1] Hokkaido University, Sapporo, Hokkaido 060-8628, Japan
{hikage, kawamura, nojima}@wtemc.ist.hokudai.ac.jp

Abstract

The purpose of this study was to investigate the non-thermal effects of microwave exposure on biological free-radical production, especially focusing on mobile radio frequencies. Experiments for the hydroxyl radicals that treat leukocyte cells were performed. In the experiments, six different sets of exposure conditions were used: continuous wave, GSM basic signal modulation, PDC signal modulation, and cdma2000 signal modulation. The exposure level was changed from cellular level to high SAR level. A fluorescent observation in which cells labeled with DCFH-DA was used to detect radicals within the cells. The obtained data was statistically analyzed to see if there was a significant effect on the radical production rates of the cells due to 900 MHz microwave.

1. Background

Biological free radicals are produced by systems within the human body and are beneficial in several ways. The biological free radicals, including some Reactive oxygen species (ROS) are electrophilic and highly reactive. The immune system is the main system utilizing free radicals. However, if undesired free radical production occurs in the body, since the free radical can transfer the radical form molecule to molecule causing damage at each encounter, it can trigger a chain reaction resulting in various unwanted effects on important cellular components such as DNA, or the cell membrane at the worst case. In some papers or reports, it has been suggested that DNA-damage due to electromagnetic fields (EMFs) exposure may occur as non-thermal effect at the frequencies below the high gigahertz spectral regions [1-7]. However, the repeatability and/or consistency of those experimental results are not clear. Generally, radio frequency (RF) microwave, which are in non-ionizing region, do not carry enough energy to generate free radicals. Up to this point however, there have not been any investigations conducted concerning the possibility of biological interactions due to the microwave exposure which may result in the production of free radicals. Hence, an experimental investigation of the RF microwave exposure's effects on the biological free-radical production should be performed using high sensitivity measurement equipments. In the experiments treating human leukocyte cells, the non-thermal effects of RF-EMF exposure on free radical productions are assessed. There are actually many types of free radicals formed within human body. Some examples are the superoxide anion (O2-), the hydroxyl radical (OH・), nitrogen radical (NO・), among others. Hydroxyl radicals produced in leukocyte cells are short-lived, but are the most reactive and damaging radicals. Therefore, in our experiments we use cells exposed to 900 MHz RF-EMF to estimate the effects on the activity of the hydroxyl radicals.

2. Methodology

Figure 1 shows the procedure of experiment. In the experiments, treating human leukocyte cells, the DCFH-DA (2', 7' - Dichlorodihydro- fluorescein diacetate) fluorescence method were employed to detect radicals within the cells. A rigid waveguide exposure setup was employed for the 900 MHz exposures (see Figure 2) [8]. The exposure equipment can achieve high intensity and a uniform exposure on the sample cells and it is available at the same time without special degradation of the impedance matching caused by the scattering waves from the samples. Under the 900 MHz condition, exposures were conducted using a range of SAR levels from average SARs of 2 W/kg to a maximum of 150 W/kg for each sample [9]. The exposure condition is shown in Table 1. For the radical productions within the cells, UV (<10 mW/cm^2, for 5 min) was used as a positive control. A Sham-exposure for the leukocyte cells experiment was carried out using a thermo control unit without microwave exposure. The inherent influence of microwave exposure on radical production within the cells was assessed by comparison with the sham-exposure. A large number of fractionated cell sample were used in this experiment. Statistical analysis using independent Student's t-test was performed to test

the differences between exposed and sham-exposed (thermal control) cells. A difference at $p<0.05$ was considered statistically significant.

3. Results

Data on the fluorescent intensities observed in the samples exposed to microwaves of 900 MHz and the control sample were obtained. As a result of a nonparametric test based on the data obtained from the control (sham exposure) sample, a correlation between the sample temperature and the radical production rate was found. It was found that as the temperature of the sample increased, the radical production also increased. Figure 3 shows statistical analysis result of fluorescence intensities of human leukocyte cells after 900 MHz microwave exposure. From the figure, no significant difference was found in the rates of radical production detected in the samples exposed to microwaves and control cells (non-microwave irradiation) in the same temperature.

4. Conclusion

The experiments described that the radical production in the cells was primarily induced by the temperature increase, and irrespective of the waveforms (modulated or not modulated), the nonthermal effects of microwaves found in the radical production possibly damaging DNA were undetected by the latest technology available.

Acknowledgments

This work is supported by Grant-in-Aid from the Ministry of Internal Affairs and Communications (MIC) of Japan.

References

[1]M.H. Repacholi and B. Greenebaum, “Interaction of Static and Extremely Low Frequency Electric and Mgnetic Fields With Living Systems: Health Effects and Research Needs,” Bioelectromagnetics, 20, pp.133-160 (1999).
[2]” MICROWAVE OVENS”, The Ecologist -November 2003, pp. 26-27 (2003)
[4]W.Ross Adey, “Potential Therapeutic Applications of Nonthermal Electromagnetic Fields: Ensemble Organization of Cells in Tissue as a Factor in Biological Field Sensing,” Bioelectromagnetic Medicine, New York:Mercel Dekker Inc. (2004).
[5] ”Risk Evaluation of Potential Environmental Hazards From Low Frequency Electromagnetic Field Exposure Using Sensitive in vitro Methods,” A project funded by the European Union under the program, (2004).
[6]M. Lantow, J. Schuderer, C. Hartwiga and M. Simko, ”Free Radical Release and HSP70 Expression in Two Human Immune-Relevant Cell Lines after Exposure to 1800 MHz Radiofrequency Radiation,” RADIATION RESEARCH 165, pp. 88–94 (2006).
[7] L.Traikov, G.Lawlor, A.Bocheva, V.Hajimitova, C.Shalamanova, M.Israel, H.Koshimizu, M.Markov, ” Acute Effects on Oxidative Stress Markers of High Frequency Electromagnetic Field 900 and 1800 MHz in Rats- Preliminary Experiments,” Proceedings of Biological Effects of EMFs 4th International Workshop, pp. 1215-1219 (2006).
[8]T. Hikage, T. Manabe, M Endo and T. Nojima, “Experimental Investigations on the Biological Free Radical Production in Human Fibroblasts Due To Microwave Exposure”, The Bioelectromagnetics Society the 28th Annual Meeting, P-B-78,(2006)
[9] T. Hikage, M. Endo, and T. Nojima, "A New 900 MHz Ridged-Waveguide Microwave Exposure Equipment to Achieve High Power Density Irradiation for In Vitro Experiments", Abstracts of EBEA 2007 8th International congress of the European BioElectromagnetics Association, p.28, (2007).

Table1. Conditions for Exposure

Frequency	900 MHz
Modulation schemes	CW, GSM, PDC half, cdma2000
Antenna Input power	CW, PDC, cdma2000: 44 dBm (max.) GSM: 50 dBm (max.)
Exposure time	5 minutes

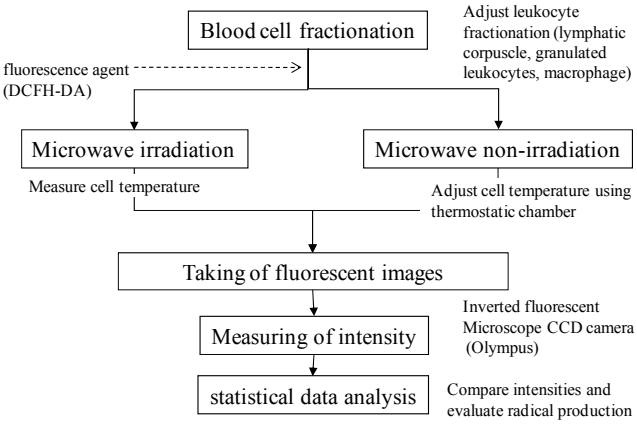


Figure1. Procedure for Experiment on Leukocyte Cells

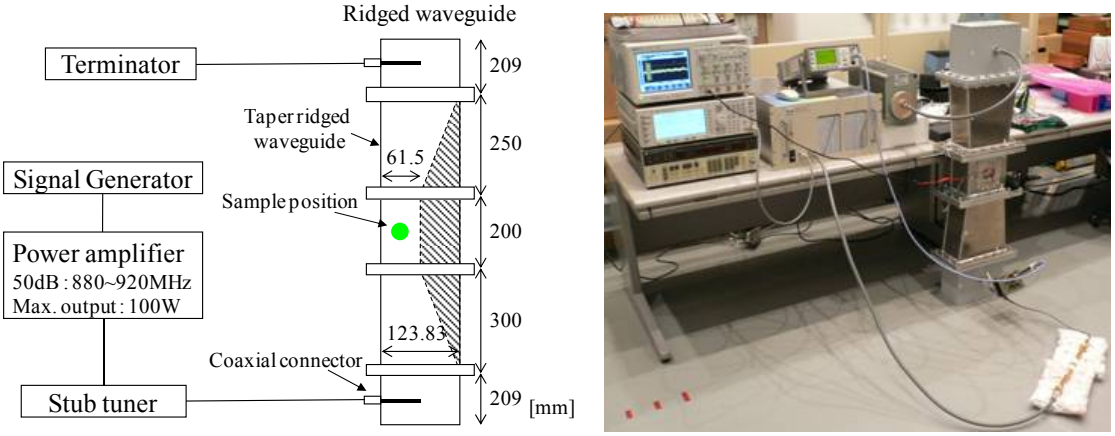
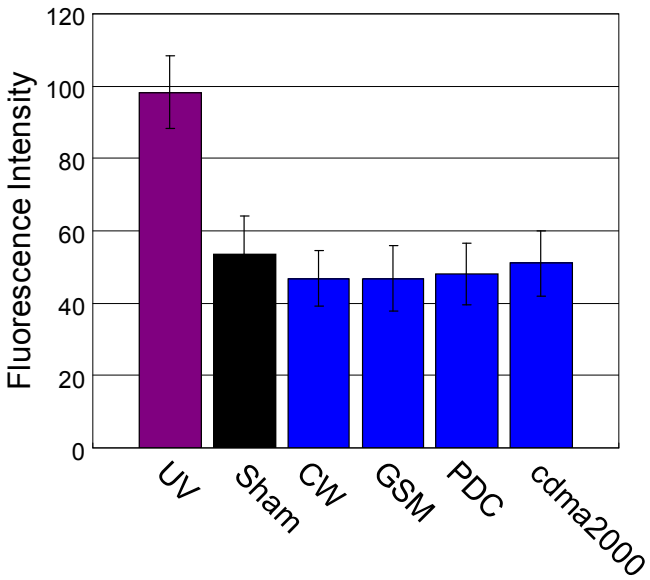


Figure2. 900 MHz ridged-waveguide exposure equipment



(error bar : standard deviation)

Figure3. Comparison of Fluorescence intensities of human leukocyte cells after 900 MHz microwave exposure