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# Effects of ultra-high frequency electromagnetic field at 28 GHz on micronucleus formation in human cells

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## Abstract

The relationship between exposure to electromagnetic fields (EMF) and health risks is of increasing interest. Although general concern regarding the potential hazards of exposure to an EMF has led to many epidemiological investigations, the effects of EMF exposure on human cells are still controversial [1, 2]. In this study, we developed a new exposure system that generates an ultrahigh frequency EMF of 28 GHz, and confirmed the device retains a normal culture environment without any artefact by cell proliferation test. We then investigated the effects of the ultrahigh frequency EMF by micronucleus (MN) formation test which is internationally recognized method of safety evaluation test. Our results showed that the exposure to ultrahigh frequency of 28 GHz at power density of 0.5-2.5 mW/cm$^2$ for 24 hours has no significant effect on MN formation in CCD32Sk, XP2SA, XP2OSSV and AT2KY cells.

## 1 Introduction

The 5th generation wireless technology for digital cellular communication networks and ultrahigh-speed wireless LAN system are expected to spread globally in the near future, although no clear data has been evaluated the effects of ultrahigh frequency on human body. The introduction of mobile telecommunication devices is a public concern regarding the potential health risks associated with radiofrequency (RF) radiation emitted in use of these devices and by their base station antennas. The possible relationship between exposure to an electromagnetic field (EMF) and human health is very important, and urgent response to research on safety to the human body is required. To investigate the non-thermal effects of ultrahigh frequency radiation, we developed a device to expose human cells to 28 GHz electromagnetic fields and assessed the frequency of micronucleus (MN) formation.

## 2 Materials and Methods

We used a specially designed exposure apparatus that employs a transmitting antenna of ultrahigh frequency radio wave as shown in Figure 1. A uniform radio wave of 28GHz is emitted from a horn antenna at the top of the applicator and penetrates culture medium and cells adhering to the bottom of culture dishes placed on cooling water jacket. The inside of incubator, where the exposure system is placed, was maintained under controlled conditions of an atmosphere of 95% air and 5% $CO_2$ at a relative humidity of >95% and a temperature of 37℃. A continuous 28 GHz signal was produced by a signal generator (Keysight Technologies N5173B, CA, USA) through a power amplifier (Exodus Advanced Communications AMP6034-40, NV, USA). The dosimetry of RF field is performed with both numerical and experimental approaches. The results agreed fairly well with an exposure intensity of up to 2.5 mW/cm$^2$ at the bottom of the medium, where cells were located. The temperature of the medium in the culture dishes was maintained at 37°C using a constant temperature water bath (Sansyo SA-100, Tokyo, Japan).

The MN formation test was performed after exposure to the 28GHz EMF at 0.5, 1.0 and 2.5 mW/cm$^2$ for 24 hours using CCD32Sk (normal skin of a newborn infant), XP2SA, XP2OSSV (hereditary disease with xeroderma pigmentosum) and AT2KY (hereditary disease with ataxia telangiectasia) cells. Cells were exposed to UV at 1.0 J/m$^2$ or X-ray at 1.0 Gy, or treatment with bleomycin (10 μg/mL) for 1 hour as positive controls. A total of 500 binucleated cells were counted, and the frequency of MN formation was determined using a fluorescence microscope (Olympus AX-70, Tokyo, Japan) according to the criteria described previously [3]. At least three independent tests were performed.

## 3 Results and Discussion

The frequencies of MN formation in CCD32Sk, XP2SA, XP2OSSV and AT2KY cells are shown in Figure 2. MN frequency increased significantly following bleomycin treatment, whereas no significant difference was observed between incubator control, sham-exposure, and the 28 GHz EMF exposed cells. These results suggest that 24-hour exposure to an ultrahigh frequency of 28 GHz with 0.5 mW/cm$^2$ have no significant effect on MN frequency in CCD32Sk, XP2SA, XP2OSSV and AT2KY cells.

## 4 Conclusions

The data observed in the present study suggest that the exposure to 28 GHz at 0.5 mW/cm2 for 24 hours have no significant effect on MN formation in any of the cells derived from a physically unimpaired person (CCD32Sk)

or in the cells derived from a genetic disease patient (XP2SA, XP2OSSV, AT2KY). However, the possibility of epigenetic effects of the ultrahigh frequency EMF wave in human cells remains, and further studies are required.

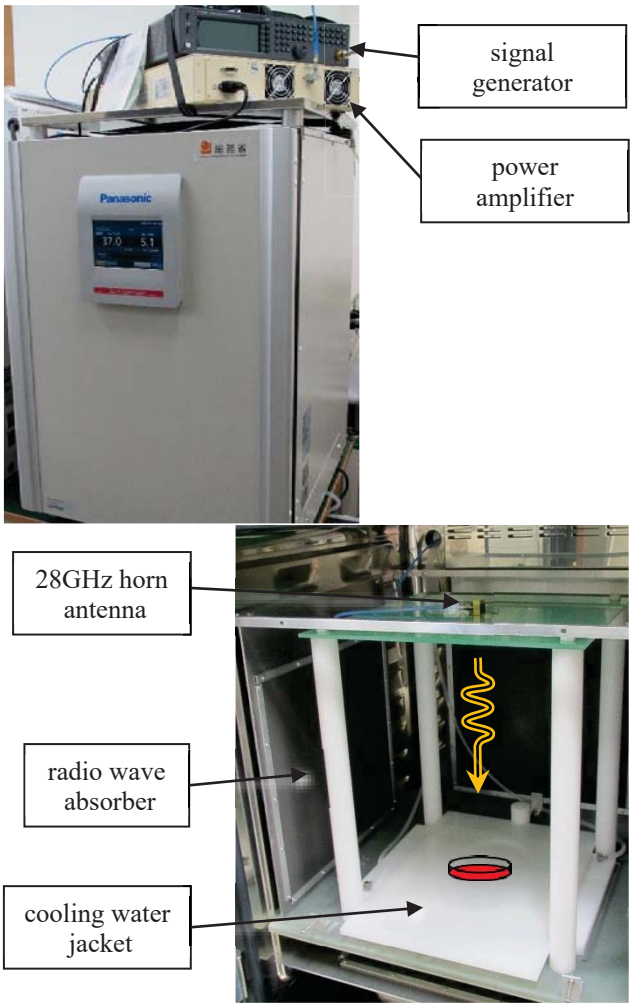
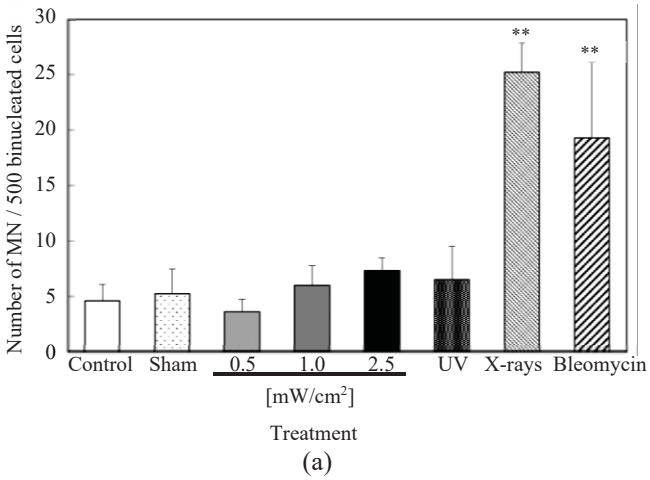
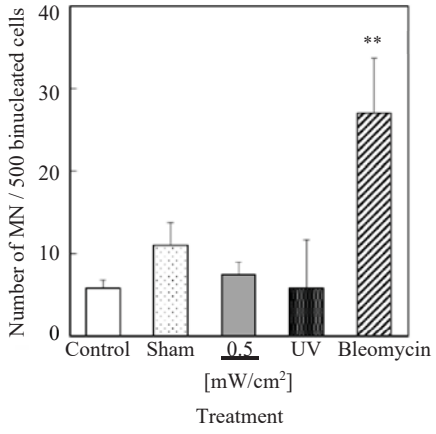



**Figure 1.** Newly developed exposure system that generates an ultrahigh frequency of 28 GHz EMF.




(a)

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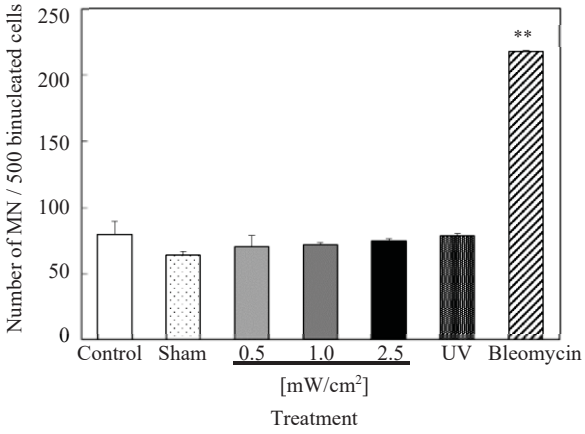
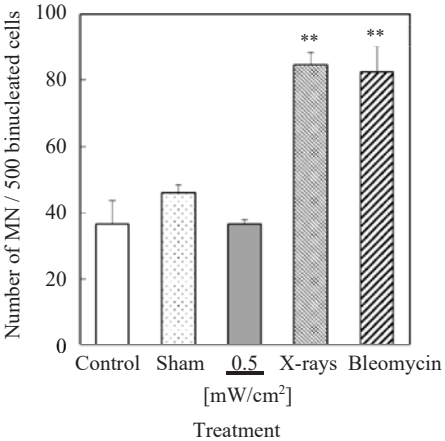



(c)




(d)

**Figure 2.** Micronucleus frequency in CCD32Sk (a), XP2SA (b), XP2OSSV (c), and AT2KY (d) cells exposed to 28GHz EMF at up to 2.5 mW/cm$^2$ for 24h. Treatment with UV (1.0 J/m$^2$), X-ray (1.0 Gy), and bleomycin (10 μg/mL) served as positive controls. (Asterisks ** indicate $p<0.01$)

## 5 Acknowledgment

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## 6 References

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