

## Principal Research Results

# Evaluation of Biological Effects of Intermediate Frequency Magnetic Fields

## Background

The utilization of intermediate frequency (IF; 300Hz to 10MHz) electromagnetic fields (EMFs) is widely spreading in novel electric equipments. In contrast to radiofrequency and extremely low frequency EMFs, the biological effects of the IF EMFs have not been studied very well. Therefore, public concern over the health effects of exposure to the IF EMFs is increasing. Especially, carcinogenic and reproductive/developmental effects are the biggest concerns of equipment users. These toxicological issues should be clarified by known, reliable toxicological tests as soon as possible.

## Objectives

The aims of this research are to develop an exposure system of IF magnetic fields (MFs) for *in vitro* research, and to evaluate the effect of the IF MFs on mutagenicity\*<sup>1</sup> by bacterial mutagenicity test and on developmental toxicity in chick early embryogenesis.

## Principal Results

### 1. Development of exposure system

We developed a Helmholtz type exposure system for the *in vitro* research. The system can generate a vertical and sinusoidal MF in the frequency range from 2 to 60 kHz. The maximum field strength varies as the MF frequency, and 0.91mTrms (146 times greater than the strength of ICNIRP guideline\*<sup>2</sup>), 1.1mTrms (176 times) and 0.11mTrms (18 times) at 2 kHz, 20 kHz and 60 kHz, respectively. This system can provide a large and uniform MF environment (20 x 20 x 20cm-cube, field variation ranged less than 2.5% to the targeted mean).

### 2. Evaluation of mutagenicity

Four strains of *Salmonella typhimurium* (TA98, TA100, TA1535, TA1537) and two strains of *Escherichia coli* (WP2 *uvrA*, WP2 *uvrA/pKM101*) were chosen to cover a wide point mutation spectrum. Mutagenicity tests of three MF exposure conditions, such as 0.91mTrms at 2kHz, 1.1mTrms at 20kHz and 0.11mTrms at 60kHz, were carried out. In statistical analysis, neither significant nor reproducible difference was found between exposed and unexposed control groups in all exposure conditions with six test strains. These results indicate that the strong IF MFs exposure could not affect the mutation frequency in each strain.

### 3. Developmental toxicity evaluation in chick early embryogenesis

Chick embryos were exposed to 20 kHz sinusoidal wave, 1.1 mTrms vertical MF for the first 2 days of their embryogenesis. Pretreated embryos with a teratogen to induce abnormalities were also exposed to the same MF. After the MF exposure, embryos were macroscopically observed and their total abnormal ratio that includes morphological abnormalities and early death were evaluated. Results showed no statistical differences between MF exposed and unexposed control embryos indicating that the IF MF employed in this study did not induce teratogenicity in the early development of chick embryo.

## Future Developments

Genotoxic evaluation other than mutagenicity and reproductive/developmental toxicity tests using rodents will be carried out for the accumulation of further scientific knowledge.

### Main Researchers:

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### Reference

S. Nakasono, et.al., 2005, "Biological Effects of Intermediate Frequency (IF) Magnetic Fields -Evaluation of mutagenicity of IF magnetic fields by bacterial mutation assay-", Technical Report V04008 (in Japanese)

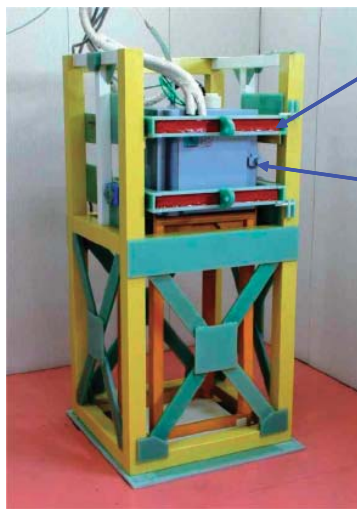
I. Nishimura, et.al., 2005, "Biological Effects of Intermediate Frequency Magnetic Fields -Developmental toxicity evaluation in chick early embryogenesis-", Technical Report V04018 (in Japanese)

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\* 1 : One of the DNA damage effects, which could initiate the tumor development.

\* 2 : The reference level is 0.00625mTrms for MFs exposure to the public set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

## 2. Environment - Environmental risk assessments



### Coils (HelmholtzType)

Field Generation	; vertical and sinusoidal MF
Max. field strength	; 1.1mTrms (at 20kHz)
MF variation	; below $\pm 2.5\%$
Stray field	; low 0.03 $\mu$ Trms at control system neglectable vibration and harmonic component

### Incubator (Water-Jacketed Type)

Exposure space	; 20 x20 x 20 cm
Temperature variation	; below $\pm 0.4^\circ\text{C}$
Humidity variation	; below $\pm 10\%$

Output frequency	Max. field strength	Comparison with ICNIRP reference level*
2kHz	0.91mTrms	146 times
20kHz	1.1mTrms	176 times
60kHz	0.11mTrms	18 times

\*; ICNIRP reference level for public is 0.00625mTrms

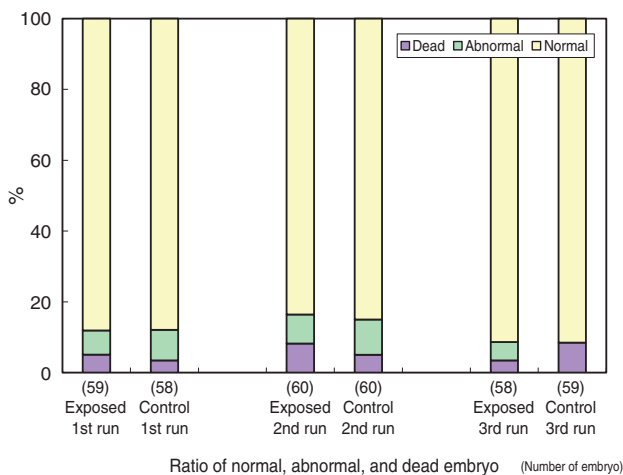
**Fig.1** Exposure system of intermediate frequency magnetic fields for *in vitro* research

**Table 1** Results of bacterial mutagenicity test

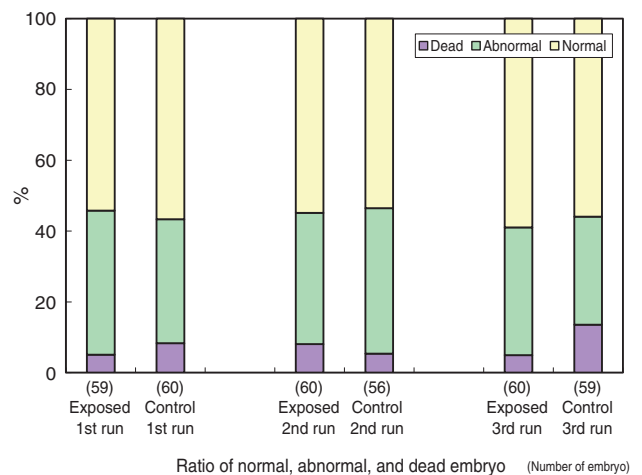
Test Strain	Type of Mutation	Control	Exposure Condition		
			2kHz 0.91mTrms (146 times)	20kHz 1.1mTrms (176 times)	60kHz 0.11mTrms (18 times)
<i>Salmonella typhimurium</i>	TA98	1/10	0/5	0/5	1/5
	TA100	1/10	0/5	2/11	0/6
	TA1535	0/10	0/5	2/11	0/6
	TA1537	0/10	1/6	1/11	0/6
<i>Escherichia coli</i>	WP2 <i>uvrA</i>	1/10	1/6	0/11	0/5
	WP2 <i>uvrA</i> /pKM101	3/10	0/6	0/10	0/6

Denominator shows the number of tests, and numerator shows the number of statistically significant results (P<0.05) by

In statistical analysis, neither significant nor reproducible difference was found between exposed and unexposed control groups in all exposure conditions with six tester strains.



**Fig.2** MF exposure experiment with normal chick embryos



**Fig.3** MF exposure experiment with chick embryos pretreated with a teratogen