Risk Evaluation of EMF and What is Limiting Exposure Protects People from

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Outline

1. Nature of Electromagnetic field
2. Experience in low freq. EMF
3. Health Risk Evaluation
4. Response of Japanese Authority
5. What is Necessary for Bridging a Gap among Authority, Operators, Society and Community?
We have over 350 researchers and cover all over the field of Railway technology.
Nature of interaction between biological organism and EMF

<100kHz sinusoidal wave
EMF (mainly magnetic field) induces electric field because of conductivity of tissues.
The induced field cause nerve stimulation.

>100kHz sinusoidal wave
EMF is absorbed in molecule in tissues as energy.
The energy cause temperature elevation.
Reference level of the current ICNIRP Guideline (1998 and 2010)

Induced electric field

Energy absorption

- ICNIRP1998(Public)
- ICNIRP2010(Occup.)
- ICNIRP2010(Public)

- Ventricular fibrillation (t=1ms)
- TMS (t=0.1ms)
- Hyperthermia
  - IC-card, RF-ID*
- Mobile telephony*

*: Description of frequency bands and not represent flux density

- MRI, Geomagnetic field
- Power line, Home appliances
- IH cooker, Etc*

- Levitation, Mose’s effect, Orientation
- Magnetophosphen

- 100kHz

Magnetic flux density (μT)

Frequency (Hz)
Our experience in Low Frequency EMF
Magnetic fields (MFs) with several frequencies exists simultaneously in our environment (such as train)

Sources
- Inverter/converter, reactor, catenaries, rails, substations, etc.

We exposed to various frequencies, waveforms, strengths of MFs.

Static, Extremely Low Frequency (ELF), Intermediate frequency, etc.

Guidance in guidelines.

Simple summation of waves or powers
No consideration of combination effects

Prior studies in biological effects of combination MFs reported,

using very weak field such as several tens μT of each components, but not in strong fields.
There are not solid evidences from many studies dealing with environmental level

- To examine single component strong MFs as strong as possible
  - static (up to 14T), 50Hz (up to 40mT), 20kHz (up to 4mT)

- To examine frequency range which actual biological experiments has not done, so far
  - Intermediate frequency such as several kHz (New national project)

- Estimation of biological effects by exposure to complex MFs using environmental condition and also extreme condition.
  - Static 1mT and 50Hz 0.5mT, static 5T and 50Hz 1mT, etc
Mutation assay systems

- Ames’ test
- Yeast mutation assay
- *In vitro* micronucleus test
- Hprt gene mutation assay
- MLA (mouse lymphoma assay)
- WST (wing spot test of fruit fly)
- *In vivo* micronucleus test
Exposure Systems of MFs

Static magnetic field: Max. 14 Tesla
→ 200,000 times of geomagnetic field

Extremely Low Frequency magnetic field
Max. 40 mTesla (50Hz)
→ 100-10,000 times than those found in environment
Effect on Recombination of exposure to Strong Static Magnetic Field in *D. malanogaster mei-41*

- Normal
- *mwh*
- *flr*

**Graph:**
- Ratio of mutation frequency of exposure to control in large spots
- Magnetic field (T)
- Exposure time: 24 hr

Part of this result from Takashima et al., (J. Rad. Res.)
### Results of our mutation studies in various MFs

<table>
<thead>
<tr>
<th>Exposure condition</th>
<th>Bacteria</th>
<th>Ames' Test</th>
<th>Yeast mutation assay</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>E. coli</strong> (SOD) Ames' Test</td>
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<tr>
<td>Static magnetic field</td>
<td></td>
<td></td>
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<tr>
<td>20mT</td>
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<td>100mT</td>
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<tr>
<td>2T</td>
<td>NS</td>
<td>↑*</td>
<td>NS</td>
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<tr>
<td>5T</td>
<td>NS</td>
<td>↑*</td>
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<tr>
<td>13T</td>
<td>NS</td>
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<tr>
<td>Time varying magnetic field</td>
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<td></td>
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<tr>
<td>50Hz</td>
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<tr>
<td>20mT</td>
<td>NS</td>
<td>NS</td>
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</tr>
<tr>
<td>40mT</td>
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<tr>
<td>2kHz</td>
<td>0.4mT</td>
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</tr>
<tr>
<td>0.8mT</td>
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<tr>
<td>0.9mT</td>
<td>NS</td>
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<tr>
<td>20kHz</td>
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<td>21kHz</td>
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<td>3.9mT</td>
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<tr>
<td>Combined magnetic field</td>
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<tr>
<td>Static 1mT + 50Hz · 0.5mT</td>
<td>NS</td>
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<tr>
<td>Static 20mT + 50Hz · 1mT</td>
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<td>NS</td>
</tr>
<tr>
<td>Static 5T + 50Hz · 1mT</td>
<td>NS</td>
<td>NS</td>
<td>↑*</td>
</tr>
<tr>
<td>Static 0.5mT + 50Hz · 0.5mT + 2kHz · 0.5mT</td>
<td>NS</td>
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</table>
## Results of our mutation studies in various MFs (Cont.)

<table>
<thead>
<tr>
<th>Mouse lymphoma</th>
<th>Cultured cell</th>
<th>Drosophila melanogaster</th>
<th>Mice</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPRT mutation assay</td>
<td>in vitro micronucleus test</td>
<td>Wing spot test</td>
<td>in vivo micronucleous test</td>
</tr>
<tr>
<td>assay</td>
<td>NS</td>
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<td>NS</td>
<td>NS</td>
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</tbody>
</table>
Numerical analysis of dosimetry

High magnetic flux density
Low magnetic flux density

Numerical analysis
Evaluation of human dosimetry

- 2mm resolution
- Composition including over 50 tissues
- Each tissue is able to assign independent conductivity
- Conductivity of each tissue was assigned by parametric model†
- Male, Female, Child, Pregnant models are available.

(†S. Gabriel et al. (1996))

*This model was developed by Kitasato University, Keio University, Tokyo Metropolitan University, and NICT.

http://www2.nict.go.jp/mt/b186/bio/bio_human_model_E.html

male model (Taro)
Japanese human voxel model*
Numerical analysis using the impedance method

Induced current within voxels are evaluated using magnetic flux density and conductivity.

Averaging: Induced electric fields were averaged over a cross-section of 1 cm² perpendicular to the current direction. Because of electrical inhomogeneity of the body. (ICNIRP protocol)

99%tile value is picked up as Maximum induced electric field.
Example of passenger positions
Evaluation of dosimetry in variety positions

Standing with CNS horizontal plane

Grab a handle

Sitting

Prone

Railway Technical Research Institute
Health Risk Evaluation of EMF
Health Risk Evaluation

- Lethal, Cancer
- Cancer, Infection, Teratogenesis, others
- Stimulation, Poisoning
- Stimulation, other
- Biological load by exposure chemical/physical agents

Carcinogenicity (genotoxicity)
Hormonal effect, teratogen, Differentiation
Process of risk evaluation of EMFs

- Hazard identification
- Risk evaluation
- Set limit exposure

International Agency of Research on Cancer (IARC)
World Health Organization (WHO)
International Committee of Non Ionizing Radiation Protection (ICNIRP)
Risk evaluation by international organizations
Hazard vs. Risk

- Hazard is character whether the agent is harmful or not.
- Risk is action. It includes facts such as extent of hazard effect, dose, chance, susceptibility (genetic background), etc...

### Hazard (IARC)
- Alcohols in liquor shop
- Cigarette at tobacco shop
- Cars in a showroom
- Guns in a gunshop
- Dynamite

### Risk (WHO)
- Taking alcohol
- Smoking cigarette
- Driving a car
- Using Gun
- Ignition of dynamite
Agents Classified by the IARC Monographs

It is not classified extent of the effect but classified **strength of scientific evidence**.

Group 1 Carcinogenic to humans 119 agents (processed meat, alcohol beverage)
Group 2A Probably carcinogenic to humans 81 (Drinking coffee, Red meat)
Group 2B Possibly carcinogenic to humans 292 (ELF-MF, RF-EMF, pickles)
Group 3 Not classifiable as to its carcinogenicity to humans 505 (Static MF)
Group 4 Probably not carcinogenic to humans 1
ELF Electric/Magnetic fields (factsheet No.322)

Guidance of the WHO

A. Policy-makers should establish guidelines for ELF field exposure for both the general public and workers for preventing acute effects.

B. National authorities should implement EMF protection programs that includes exposure measurements from sources where exposures might be expected to exceed limit values.

C. Regarding long-term effects, given the weakness of the evidence for a link between exposure to ELF magnetic fields and childhood leukemia, the benefits of exposure reduction on health are unclear.
EMF Above 100kHz

- Prevention of temperature elevation is primary target of protection

Body core temperature
- Mean body core temperature (app. 37 °C) typically varies over the day by 0.5 °C
- ΔT > 1 °C in body core temperature is defined as potentially harmful
- RF modelling predicts:
  - 3-4 W/kg WBA SAR over 2 hours induce ΔT = 0.5 °C
  - 6-7 W/kg WBA SAR may results in ΔT = 1 °C (consistent with the limited human measurement research)
Local temperature

• Excessive localized heat can cause pain and damage cells. There is a substantial body of literature showing that tissue damage can occur at temperatures > 41-43 °C (time dependent)
• Thermonormal brain and abdomen temperature is typically < 38 °C, and that of the extremities (including skin and pinna) < 36 °C
• Local temperatures > 40 °C should be avoided
• ΔT > 2 °C in the head, torso, testes, eyes considered potentially harmful
• ΔT > 4 °C in the extremities (limbs, skin, pinna) considered potentially harmful
Risk Evaluation and Revised Guideline (100kHz – 300GHz)

Risk Evaluation by WHO
- Task group meeting may be organized in 2017
- EHC and factsheet may publish in 2019-2020?

Revision of Guideline by ICNIRP
- Basic Philosophy and Review of RF Dosimetry has been discussing.
- No practical schedule is shown.
- At least revision will be published after risk evaluation by WHO.
Response of Japanese Authority
Radio-Radiation Protection Guidelines PDCA Cycle

Radio-Radiation Protection Guideline

Plan

Radio Regulatory Council

Ministerial Ordinances of Radio Law
- Enforcement Regulations
- Regulations for Radio Equipment

Do

Information and Communications Council

Committee on the Possible Adverse Health Effects of RF-EMF

Check

- Introduction of Advanced Wireless Systems
- Updated Research Results
- Risk Communication

Act

- Revision of the International Guideline (ICNIRP/IEEE-ICES)

Source from Ministry of Internal Affairs and Communication (MIC), Japan
The RRP Guideline

- To harmonize RRP Guideline to the ICNIRP 1998 and 2010 guideline.
  (Practically harmonized to ICNIRP from 10 kHz to 6GHz)

Source from MIC, Japan

Railway Technical Research Institute
Enforcement of the RRP Guidelines

• Enforcement Regulations of Radio Law
  - Article 21-3: Safety facilities for electromagnetic field strength
    Radio stations should be so built as not to be easily accessed by the public, where the strength of radio waves emitted from the radio station exceeds the maximum values. (For Broadcasting Stations, Mobile Base Stations, etc.)

• Regulations for Radio Equipment
  - Article 14-2: SAR limit value
    Radio equipment which is used close to the human body must make SAR (absorbed energy in any 10 grams of tissue over 6 minutes period) value below values. (2W/kg except for limbs, 4W/kg for limbs)(For Mobile Terminals and Handheld Equipment, etc.)
  - Article 46-2: Type Specification
    The Minister shall specify the Industrial electromagnetic facility, if it meets the following requirements.
    --It is so settled that EMF strength exposed to the human body satisfies the value as shown in the Ministerial Notification. (For Wireless Power Transfer Systems)

Source from MIC, Japan
What is Necessary for Bridging a Gap among Authority, Operators, Society and Community? (my own opinion)
Establishment of Mutual Trust

• Risk communication
  - Integrity, transparency
  - to communicate with people using correct information and correct knowledge to help people from incorrect judgement from incorrect information and incorrect knowledge which are from media and internet sources without solid evidence sometime.
  - achievement of dialogue

• Education
  - Literacy
  Life is beautiful and meaningful but also full of risk taking.
  - Responsibility
Encourage Research to Reduce Uncertainty (e.g. Non-thermal effect?)


• They investigated possible health effects of mobile phone use, with mobile phone related symptoms (MPRS). They recruited 11 subjects with MPRS and 43 controls.

• Subjects were exposed to EMF of 2.14 GHz, 10 V/m (W-CDMA), in a shielded room to simulate whole-body exposure to EMF from base stations.

• The MPRS group did not differ from the controls in their ability to detect exposure to EMF; nevertheless they consistently experienced more discomfort, regardless of whether or not they were actually exposed to EMF, and despite the lack of significant changes in their autonomic functions. Thus, the two groups did not differ in their responses to real or sham EMF exposure according to any psychological, cognitive or autonomic assessment.

• They concluded no evidence of any causal link between hypersensitivity symptoms and exposure to EMF from base stations.
Limitation of Science

• Science is not omnipotent.
  - However in Japan, people tend to think Science is the foundation of
    the world.

• The logic of **Natural Science** is basically not able to prove “nothing”
  or “no-effect” because Science works to find “difference” and seek
  why the difference happen. Thus, to find effect and determine
  threshold is need to establish limit values. On the other hand, to
  prove “no-effect”, we have to investigate all possibilities. Simply, it is
  impossible.

• Of course, we have **Regulatory Science** to examine safety of newly
  developed chemicals, drugs, etc. This regulatory science determine
  criteria of risk that allowed in the community. In most case, EMF is
  negative in the evaluation process in this procedure.
Seeking Overlap Zone between Realm of Science and Society

I mention several words in myself as a scientist of this field over 25 years.

- “What men really want is not knowledge but certainty.” by Bertrand Russell (British philosopher)

- “It is easy to be afraid too much or far less, but it is really difficult to be afraid precisely.”, by Torahiko Terada (Japanese physicist)
Thank you very much for your attention.

Bardzo chciałbym podziękować za możliwość zabrania głosu na ten temat.