Dosimetry of intermediate frequency region

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Outline

• Background
• Measurement of incident EMF in the vicinity of real systems
• Numerical simulation of induced quantities inside human in the vicinity of real systems
• Measurement of contact currents
Background

Recently, applications using intermediate frequencies (IF, 300 Hz – 10 MHz) are increasing.

Expansion of these technologies leads public concern about the biological effect of IF.
Background

In 2015, the Information and Communications Council of MIC, Japan, approved “Report on Technical Requirements for Rulemaking on WPT Systems”

<table>
<thead>
<tr>
<th></th>
<th><strong>EV</strong></th>
<th><strong>Home appliance</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System</strong></td>
<td>Magnetic coupling</td>
<td>Magnetic coupling</td>
</tr>
<tr>
<td><strong>Transfer power</strong></td>
<td>$\sim 3$ kW (Max $7.7$ kW)</td>
<td>$\sim 100$ W</td>
</tr>
<tr>
<td><strong>Frequency</strong></td>
<td>$79 \sim 90$ kHz</td>
<td>$6765 \sim 6795$ kHz</td>
</tr>
<tr>
<td><strong>Transfer distance</strong></td>
<td>$0 \sim 30$ cm</td>
<td>$0 \sim 30$ cm</td>
</tr>
<tr>
<td><strong>Approach distance for human</strong></td>
<td>$&gt; 20$ cm *</td>
<td>$&gt; 0$ cm</td>
</tr>
</tbody>
</table>

*Approach distance for humans refers to the distance at which the device is safe to use for humans.
ICNIRP Guideline for IF region

- Protection against known adverse health effects such as stimulus effect and thermal effect.

### Basic restriction

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>1 kHz - 3 kHz</th>
<th>3 kHz - 100 kHz</th>
<th>100 kHz - 10 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNS tissues of the head V/m</td>
<td>0.4</td>
<td>1.35 x 10^{-4} f</td>
<td>1.35 x 10^{-4} f</td>
</tr>
<tr>
<td>All tissues of head and body V/m</td>
<td>0.4</td>
<td>1.35 x 10^{-4} f</td>
<td>1.35 x 10^{-4} f</td>
</tr>
<tr>
<td>Whole-body SAR W/kg</td>
<td>0.08</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>10g SAR of head and body W/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10g SAR of limbs W/kg</td>
<td></td>
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</tr>
</tbody>
</table>

Guideline for stimulus effects

Guideline for thermal effects

- Instantaneous
- 6 minutes

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Dosimetry

- Experimental dosimetry
  - **Realistic exposure:** ○ (real exposure using actual sources)
  - **Human modeling:** △ (homogeneous phantom)
- Numerical dosimetry
  - **Realistic exposure:** △ (antenna modeling is required)
  - **Human modeling:** ○ (heterogeneous numerical model)

**Our approach:**
- ✓ Measure incident EMF experimentally
- ✓ Simulate induced field inside heterogeneous human model.
WPT System

- Number of turns: 13 turns
- Outer radius of spiral coils: 245 mm
- Inner radius of spiral coils: 120 mm
- Radius of loop: 250 mm
- Radius of copper wires: 1.6 mm (loops), 1.2 mm (coils)

![Diagram of WPT System](image)

![Graph of Transfer Efficiency vs Frequency](image)
Near-field Measurement System for Incident EMF

Amplitude and phase of electric and magnetic fields can be obtained.
Measured example (Spiral, 6.35 MHz)
Calculation of Induced Field in Human

- Induced fields in heterogeneous human are calculated using measured H field as incident field in impedance method.
Contact Current

In such a case of a human touching metal objects under EM fields, currents flowing through a human body may induce sudden pain or heat perception depending on their frequency and strength.

Contact current: Current passed into a biological medium via a contacting electrode or other source of current.
Contact Current

- Touch to ungrounded metal
  
  Currents flowing into a human touching an ungrounded metal under EM fields

- Touch to grounded metal
  
  Loop currents flowing through a human in contact with an electrode or current sources
Contact current due to magnetic field exposure

Contact current for incident H field of reference level (stimulus effect)

\[ I_C = \frac{2\pi f \mu_0 S}{Z} H \]

- f: frequency [Hz]
- S: loop size 1.5 m x 0.5 m
- Z: human impedance [Ω]
- I_C: Contact current [A]

- Size of loop: 1.5 m x 0.5 m
- Human impedance

Estimated contact current > Reference level of contact current

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Measurement of contact current

- Contact current meter
  - Narda 8870
  - TRC (equivalent circuit of human impedance of Japanese population)
Contact Current Measurement

Metal plate
- Distance to WPT system : 2 cm
- Size : 200 cm × 100 cm

WPT system
- Input power : 3 W

For grounded metal, contact loop
- Size: 150 cm × 50 cm
- Distance to WPT system: 2 cm

Contact current with ungrounded metal
- Distance to WPT system : 2 cm
- Size : 200 cm × 100 cm
- Flat-spiral type

Contact current with grounded metal
- Size: 150 cm × 50 cm
- Distance to WPT system: 2 cm
- Flat-spiral type (up-down)
- Flat-spiral type (left-right)
Contact currents vary depending on exposure situations; there was some case that contact currents for grounded condition was comparative to those of ungrounded condition.

Measurement of contact currents in both conditions is necessary.
Summary

• Two measurement systems are constructed in order to measure both amplitude and phase of electric and magnetic fields in the vicinity of WPT systems.

• For compliance, exposures evaluation from a real WPT system were done by combining experimental data of incident EMF and numerical analysis.

• Measurement of contact currents with both ungrounded and grounded conditions is needed.