Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: Exposure assessment for BAN devices

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Abstract: [Provide needs of exposure assessment for BAN devices]

Purpose: [To provide exposure assessment safely to use BAN devices]

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Exposure assessment for BAN devices

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Contents

- EMF Safety Standards
- EMF Assessment Standards
- Biological Tissues and Human Phantom Models
- Preliminary Results for Exposure Assessment (Body-Mounted and Implanted Devices)
- Conclusions
International EMF Standards

- International EMF Safety Standards
  - ICNIRP: Endorsed by WHO
  - IEEE ICES TC95

- Exposure Assessment Standards
  - IEC TC106
  - IEEE ICES TC34
Frequency Spectrum

- Non-ionizing
  - Low induced currents
    - No proven effect
  - High induced currents
    - Heating
  - Electronic excitation
    - Photochemical effects
  - Ionizing
    - Broken bonds
      - DNA damage

Frequency, Hz:
- AM radio
- FM radio
- Microwave oven
- Heating lamp
- Tanning booth
- Medical X-rays
Exposure Limits

- **Basic restriction**
  - Induced currents
  - SAR
  - Power density

- **Reference level or MPE**
  - Electric field, Magnetic field
  - Power density
## SAR Limits

<table>
<thead>
<tr>
<th>Division</th>
<th>ICNIRP</th>
<th>IEEE</th>
<th>CENELEC</th>
<th>FCC</th>
<th>JAPAN</th>
<th>KOREA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency (Hz)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10^5~10^10</td>
<td>10^5~3×10^9</td>
<td>10^4~3×10^11</td>
<td>3×10^5~6×10^9</td>
<td>10^5~3×10^9</td>
<td>10^5~10^10</td>
<td></td>
</tr>
<tr>
<td><strong>Whole body</strong></td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>-</td>
</tr>
<tr>
<td><strong>Local-ized</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Limb</strong></td>
<td>4</td>
<td>4 (also for pinnae)</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Head</strong></td>
<td>2</td>
<td>1.6</td>
<td>2</td>
<td>1.6</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>Body</strong></td>
<td>2</td>
<td>1.6</td>
<td>2</td>
<td>1.6</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>Tissue mass (g)</strong></td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>1(head, body)</td>
<td>10</td>
<td>1</td>
</tr>
</tbody>
</table>
WG 1: Measurement and calculation methods for low frequency (0 to 100 kHz) electric and magnetic fields and induced currents
WG 2: Characterization of low frequency electric and magnetic fields produced by specific sources
WG 3: Measurement and calculation methods for high frequency (100 kHz to 300 GHz) electromagnetic fields and SAR
WG 4: Characterization of high frequency electromagnetic fields and SAR produced by specific sources
WG 5: Generic product standard

IEEE ICES TC34
WG1: Measurement methods (3 – 6 GHz)
WG2: Calculation methods (30 MHz – 6 GHz)
CENELEC TC 106x

- WG 1: Mobile phones and Base stations
- WG 2: EAS & RFID
- WG 3: Basic Standards
- WG 4: Generic Standards
- WG 7: Broadcasting
- WG 9: Inductive and dielectric heaters
- JWG 10/TC26/TC106x: Welding
- JEG13/TC61/TC106x: Domestic appliances
- WG 15 Active Implants
- WG 16 Electrolysis
- WG 17 Electricity supply industry
- TC 9x WG10: Railways and EMF
Relevant Assessment Standards

- **IEC TC 106 WG4**
  - IEC 62209: Hand-held and body-mounted wireless communication devices
  - IEC 62369: Short Range Devices (SRDs) in various applications (EAS, RFID, Monitoring and detection, Telemetry, etc.)

- **CENELEC TC 106x WG15**
  - Pr 16681 EMF assessment with respect to active implantable medical devices in electric, magnetic and electromagnetic fields -- Part 1: General
  - Pr 16682 EMF assessment with respect to active implantable medical devices in electric, magnetic and electromagnetic fields -- Part 2-1: Cardiac pacemakers
Exposure Assessment for Medical BAN Devices

- **Location**
  - In-body
  - On-body
  - Out-body

- **Assessment standards**
  - Numerical methods
  - Measurement techniques
# Biological Tissues - FCC

<table>
<thead>
<tr>
<th></th>
<th>1. bladder</th>
<th>16. fat (mean)</th>
<th>31. Skin (dry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>blood</td>
<td>17. Gall bladder</td>
<td>32. Skin (wat)</td>
</tr>
<tr>
<td>3</td>
<td>bone canaliculus</td>
<td>18. gall Blad bile</td>
<td>33. small intestine</td>
</tr>
<tr>
<td>4</td>
<td>bone cortical</td>
<td>19. gray matter</td>
<td>34. spleen</td>
</tr>
<tr>
<td>5</td>
<td>bone marrow Infiltrated</td>
<td>20. heart</td>
<td>35. stomach esop duodenum</td>
</tr>
<tr>
<td>6</td>
<td>bone marrow not Infiltr</td>
<td>21. kidney</td>
<td>36. tendon</td>
</tr>
<tr>
<td>7</td>
<td>breast fat</td>
<td>22. Lens_Cortex</td>
<td>37. testis prostate</td>
</tr>
<tr>
<td>8</td>
<td>cartilage</td>
<td>23. Lens_Nucleus</td>
<td>38. thyroid thymus</td>
</tr>
<tr>
<td>9</td>
<td>cerebellum</td>
<td>24. liver</td>
<td>39. tongue</td>
</tr>
<tr>
<td>10</td>
<td>cerebro_spinal_fluid</td>
<td>25. lung (inflated)</td>
<td>40. trachea</td>
</tr>
<tr>
<td>11</td>
<td>colon(Large intestine)</td>
<td>26. Lung(Deflated)</td>
<td>41. uterus</td>
</tr>
<tr>
<td>12</td>
<td>cornea</td>
<td>27. muscle (parallel fiber)</td>
<td>42. vitreous_Humour</td>
</tr>
<tr>
<td>13</td>
<td>dura</td>
<td>28. muscle (transverse_fiber)</td>
<td>43. white matter</td>
</tr>
<tr>
<td>14</td>
<td>eye_tissue(sclera)</td>
<td>29. nerve (Spinal chord)</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>fat</td>
<td>30. ovary</td>
<td></td>
</tr>
</tbody>
</table>

- Website: [http://www.fcc.gov/fcc-bin/dielec.sh](http://www.fcc.gov/fcc-bin/dielec.sh)
Dispersive Characteristics of Biological Tissues

The tissue parameters provided here are derived from the 4-Cole-Cole Analysis in "Compilation of the Dielectric Properties of Body Tissues at RF and Microwave Frequencies" by Camelia Gabriel, Brooks Air Force Technical Report AL/OE-TR-1996-0037

\[
\varepsilon_r(\omega) = \varepsilon_\infty + \sum_{n=1}^{4} \frac{\Delta\varepsilon_n}{1 + (j\omega \tau_n)^{1-\alpha_n}} = \varepsilon_\infty + \chi(\omega)
\]

4th Cole-Cole model
VHP Model

- Height: 187 cm, Weight: 105.4 kg, Black(USA)
- Voxel size: 1 mm x 1 mm x 1 mm, Number of tissues: 110
Korean Whole-Body Model

- Standard – Height: 171.4 cm, Weight: 63.9 kg
- Volunteer – Height: 176.0 cm, Weight: 67.0 kg
- Voxel size: 3 mm x 3 mm x 3 mm, Number of tissues: 29
Head-Mounted Display

- Modeling of head-mounted display (Frequency : 2.4 GHz)

Ref. US Patent No.6,091,546

<table>
<thead>
<tr>
<th></th>
<th>Conductivity</th>
<th>Dielectric constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display</td>
<td>0.01</td>
<td>4.5</td>
</tr>
<tr>
<td>Frame</td>
<td>0.02</td>
<td>3.5</td>
</tr>
</tbody>
</table>
Down-Scaled VHP Model

- Size of VHP adult model and standard 13 year-old Korean boy

<table>
<thead>
<tr>
<th></th>
<th>VHP model</th>
<th>13 year-old Korean model</th>
<th>Scale factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest thickness</td>
<td>313.6</td>
<td>178.7</td>
<td>0.56</td>
</tr>
<tr>
<td>Chest width</td>
<td>549</td>
<td>260.9</td>
<td>0.48</td>
</tr>
<tr>
<td>Height</td>
<td>1870</td>
<td>1582.4</td>
<td>0.85</td>
</tr>
<tr>
<td>Head thickness</td>
<td>240</td>
<td>178.3</td>
<td>0.74</td>
</tr>
<tr>
<td>Head width</td>
<td>165</td>
<td>154.7</td>
<td>0.94</td>
</tr>
<tr>
<td>Head length</td>
<td>250</td>
<td>227</td>
<td>0.91</td>
</tr>
</tbody>
</table>
Simulation Results

Antenna in the side frame (VHP adult)

Antenna in the front frame (VHP adult)

Antenna in the side frame (VHP child)

Antenna in the side frame (Korean adult)
Wristwatch-Type Phone

- Modeling of wristwatch-type phone (Frequency : 2.4 GHz)

Ref. US Patent No.6,757,390 B2/ No.6,801,476 B2

<table>
<thead>
<tr>
<th></th>
<th>Conductivity</th>
<th>Dielectric constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone body</td>
<td>0.04</td>
<td>4.0</td>
</tr>
<tr>
<td>Strap</td>
<td>0.0007</td>
<td>2.25</td>
</tr>
<tr>
<td>display</td>
<td>0.01</td>
<td>4.5</td>
</tr>
</tbody>
</table>
Simulation Results

Wristwatch phone in front of the mouth (VHP adult)

Wristwatch phone in front of the heart (VHP adult)

Wristwatch phone on the thigh (inside pocket) (VHP adult)
Dosimetric Measurement

- SAM phantom was used for measurement (Frequency : 1.8 GHz, 2.4 GHz)
- Measurement system and liquid phantom

<table>
<thead>
<tr>
<th></th>
<th>1.8 GHz</th>
<th></th>
<th>2.4 GHz</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dielectric const.</td>
<td>Conductivity</td>
<td>Dielectric const.</td>
<td>Conductivity</td>
</tr>
<tr>
<td>Target value</td>
<td>40.0</td>
<td>1.4</td>
<td>39.2</td>
<td>1.8</td>
</tr>
<tr>
<td>Measurement</td>
<td>38.7</td>
<td>1.4</td>
<td>40.32</td>
<td>1.87</td>
</tr>
</tbody>
</table>
Measurement Results

- System validation

<table>
<thead>
<tr>
<th>Frequency</th>
<th>1.8 GHz</th>
<th>2.4 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAR value</td>
<td>1 g SAR</td>
<td>10 g SAR</td>
</tr>
<tr>
<td>Target value</td>
<td>38.1</td>
<td>19.8</td>
</tr>
<tr>
<td>Measurement</td>
<td>36.7</td>
<td>20.7</td>
</tr>
</tbody>
</table>

- Comparison of the maximum 1g-averaged SAR

<table>
<thead>
<tr>
<th>Frequency</th>
<th>1.8 GHz</th>
<th>2.4 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement</td>
<td>22.89</td>
<td>29.24</td>
</tr>
<tr>
<td>Simulation</td>
<td>20.14</td>
<td>25.50</td>
</tr>
<tr>
<td>Diff[M-S] (%)</td>
<td>+13.65</td>
<td>-14.66</td>
</tr>
</tbody>
</table>
Summary of SAR Values

- Summary of the maximum 1 g averaged SAR values for body-mounted devices

<table>
<thead>
<tr>
<th>Classification</th>
<th>Head-mounted display</th>
<th>Wristwatch-type phone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Side</td>
<td>Front</td>
</tr>
<tr>
<td>VHP Adult</td>
<td>13.15</td>
<td>23.82</td>
</tr>
<tr>
<td>Child (VHP down-scaled by 0.74)</td>
<td>17.44</td>
<td>35.79</td>
</tr>
<tr>
<td>Korean Adult</td>
<td>15.00</td>
<td>31.60</td>
</tr>
</tbody>
</table>
In-Body Simulation Results

- **Source: neck**
  - Body average SAR $1.21 \times 10^{-2}$ (W/kg/W)
  - Max 1g SAR $5.27 \times 10^2$ (W/kg/W)
  - Max 10g SAR $1.20 \times 10^2$ (W/kg/W)

- **Source: heart**
  - Body average SAR $1.44 \times 10^{-2}$ (W/kg/W)
  - Max 1g SAR $6.37 \times 10^2$ (W/kg/W)
  - Max 10g SAR $1.45 \times 10^2$ (W/kg/W)

Frequency: 403.5 MHz
Conclusions

- Exposure levels from body-mounted and implanted devices were analyzed.
- More comprehensive analysis is underway, and will be reported to WG.
- Body-mounted devices are turned on most of the time, and eyes or reproductive organs are relatively weak to EMF exposure.
- Accurate dosimetric assessment is required in designing and developing stages of such devices to prevent possible biological effects.
- Assessment standards need to be prepared.