Dosimetry of Human Exposure to the Real Telecommunication Network

Tongning Wu
wutongning@catr.cn
China Academy of Telecommunication Research of Ministry of Industry and Information Technology
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Introduction

- Public concerns on the safety of the electromagnetic fields (EMF) exposure introduced the calls to limit the EMF emission

- Unnecessarily low EMF emission may reduce the link quality

- China has the largest population and the most conservative EMF standards world-wide

- Lawsuits on the EMF exposure from the base stations were not sparse at the beginning of the 21st century

- Need to conduct dosimetric studies to evaluate the results of the human exposure to the real EMF
Chinese national EMF standards

- GB 9175-88 Hygienic standard for environmental electromagnetic waves
- GB 8722-88 Regulations for electromagnetic radiation protection
Materials and methods

- Mapping the real EMF level according to various safety standards
- Numerically reconstructing the specific EMF exposure
- Modeling the Chinese human body
- Analyzing the results
- Communicating the risks
A large scale measurement campaign for the base station EMF (I): geographic information

**Guangxi Province**

A: Baise  
B: Chongzuo  
C: Fangchenggang  
D: Laibin  
E: Nanning  
F: Beihai  
G: Liuzhou  
H: Guigang  
I: Yunlin  
J: Guilin  
K: Hezhou  
L: Wuzhou

The number in the parenthesis indicates the number of the measured GSM base stations.

**GSM 900/1800 MHz, 821 stations and 6207 measurement points**
A large scale measurement campaign for the base station EMF (I): Protocols

• The measurement was performed between 9:00 am to 5:00 pm. No measurement on the rainy days

• Temporal variation of the measured power density was maximum 9 dB

• All the measurement points located between 10 and 70 m to the antenna mast. The averaging time was 3 min

• The measurement points were deployed in priority along the directions to the main lobes of the base station antennae

• At least 1 m was kept between the measurement antenna and the domestic electronics (which were powered off at the time of measurement). The distance between the measurement antenna and the operators was no less than 0.5 m. All the measurements points were 1.5 m higher than the ground (separated by wooden tripod)

• For each measurement point, the 900 MHz and the 1800 MHz frequency band power density were recorded as well as the wide frequency band power density (10MHz-3GHz). The compliance with the standards was calculated with:

\[ \sum_{i=1}^{n} \frac{S_i^{\text{meas}}}{S_i^{\text{ref}}} = \frac{S_1^{\text{meas}}}{S_1^{\text{ref}}} + \frac{S_2^{\text{meas}}}{S_2^{\text{ref}}} + \cdots + \frac{S_n^{\text{meas}}}{S_n^{\text{ref}}} < 1 \]
A large scale measurement campaign for the base station EMF (II): situ categorization

<table>
<thead>
<tr>
<th>Location Type</th>
<th>Measured Base stations: 80</th>
<th>Measurement points: 629</th>
<th>GPS: 22°28<del>22°37N, 109°87</del>110°55E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential area (46/238)</td>
<td>0.05 ± 0.07_{0.01} (15%)</td>
<td>0.12 ± 1.25_{0.03}</td>
<td>0.46 ± 0.00_{0.10}</td>
</tr>
<tr>
<td>Office (12/57)</td>
<td>0.04 ± 0.07_{0.01} (14%)</td>
<td>0.11 ± 1.35_{0.03}</td>
<td>0.43 ± 0.40_{0.10}</td>
</tr>
<tr>
<td>Primary school and kindergarten (0)</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>School (9/30)</td>
<td>0.03 ± 0.3_{0.01} (2%)</td>
<td>0.07 ± 0.43_{0.03}</td>
<td>0.26 ± 1.70_{0.10}</td>
</tr>
<tr>
<td>Commercial area (10/15)</td>
<td>0.03 ± 0.03_{0.01} (18%)</td>
<td>0.07 ± 0.40_{0.03}</td>
<td>0.29 ± 1.50_{0.10}</td>
</tr>
<tr>
<td>Hospital (0/0)</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Tourist area (2/16)</td>
<td>0.14 ± 0.25_{0.02} (20%)</td>
<td>0.36 ± 1.30_{0.03}</td>
<td>1.43 ± 3.20_{0.10}</td>
</tr>
<tr>
<td>Industrial area (1/5)</td>
<td>0.01 ± 0.01_{0.01} (21%)</td>
<td>0.04 ± 0.05_{0.03}</td>
<td>0.14 ± 0.20_{0.10}</td>
</tr>
</tbody>
</table>
A large scale measurement campaign for the base station EMF (III): Instrumentations

(a) EMF meter measurement setup
(b) Spectrum analyzer measurement setup
Chinese human anatomical models (I): standing models

- Female: 26y, 160 cm; 54kg, 90 different tissues
- Male: 32y, 170, 62kg, 87 different tissues
- Infant: 12mo, 74 cm, 9.6 kg, 31 different tissues
- 1 cubic mm
Chinese human anatomical models (II): postured models
Simulation methods (I): plane wave exposure

- Plan wave simulation
Simulation methods (II): multi-reflection

<table>
<thead>
<tr>
<th></th>
<th>Rayleigh fading</th>
<th>Rician fading</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Real}(E_{x,y,z})$, $\text{Img}(E_{x,y,z})$</td>
<td>central normal distribution</td>
<td>noncentral normal distribution</td>
</tr>
<tr>
<td>$</td>
<td>E_{x,y,z}</td>
<td>$</td>
</tr>
<tr>
<td>$</td>
<td>E_{\text{total}}</td>
<td>$</td>
</tr>
</tbody>
</table>

\[
\overline{E(r)} = \sum_{i=1}^{n} A_i \cdot \exp(j \cdot \overline{k_i} \cdot \overline{r} + \overline{\varphi}_i) \cdot \overline{v_i} + \sum_{i=1}^{N} A_i \cdot \exp(j \cdot \overline{k_i} \cdot \overline{r} + \overline{\varphi}_i) \cdot \overline{v_i}
\]

\[
\overline{E(r)} = A_{1x} \cdot \exp(j \cdot \overline{k_{1x}} \cdot \overline{x} + \overline{\varphi}_{1x}) + A_{1y} \cdot \exp(j \cdot \overline{k_{1y}} \cdot \overline{y} + \overline{\varphi}_{1y}) + A_{1z} \cdot \exp(j \cdot \overline{k_{1z}} \cdot \overline{z} + \overline{\varphi}_{1z}) + \sum_{i=1}^{N} A_i \cdot \exp(j \cdot \overline{k_i} \cdot \overline{r} + \overline{\varphi}_i) \cdot \overline{v_i}
\]

\[
A_1 = \sqrt{K \cdot 2 \cdot \text{var}(A)}
\]

\[
\overline{E_m(r)} = A_m \exp(j \cdot \overline{k_m} \cdot \overline{r} + \overline{\varphi}_m) \cdot \overline{v_m}
\]

\[
\overline{E_n(r)} = A_n \exp(j \cdot \overline{k_n} \cdot \overline{r} + \overline{\varphi}_n) \cdot \overline{v_n}
\]
Simulation methods (III): other used methods

- FDTD-MoM hybrid simulation
Results (I): Measurement

- All the measured GSM downlink EMF results complied with the reference levels of ICNIRP guidelines and GB 8702-88

- The repartition of the power density for the GSM 900 MHz and 1800 MHz accounted only about 20% of the total environmental EMF level for 10 MHz to 3 GHz

- Concerning with GB 9175-88, very few measured points (14 out of 6207) exceed the Level I of GB 9175-88

- Adjusting the direction of the antenna can effectively reducing the E-field values
Results (II): Simulation

- Two different numerical methods provide consistent results.
- SAR results were marginal compared with the safety limits under the realistic wireless network.
- Minors were not significantly overexposed compared with the adult.
Results (III): different EMF environments

- Exposure with same E-field strength but different fadings will not introduce higher whole body averaged SAR compared with the plane wave exposure.

- The tissue specified SAR may change due to the different incident directions.

Rayleigh fading

Plane wave
Results: Risk communications

- A small scale trial on risk communication has been conducted:
  - randomly selected 50 people in Beijing
  - questionnaire for attitudes on the environmental EMF exposure:
    - negative opinion to environmental EMF (45/50)
    - no idea on safety limits and the basic EMF conceptions (42/50)
  - by showing the in-situ measured data and the calculated results:
    - neutral or positive to environmental EMF (38/50)
    - knew safety limits and the basic EMF conceptions (36/50)
Conclusions

• Realistic E-field strength often complies with even the most conservative reference levels

• Measurement and simulation can effectively reflect the EMF power absorption in the human body using the anatomical model

• SAR is marginal compared to the basic limits for all the studied human models

• Realistic EMF environment could promote communication without posing excessive risk if being properly managed (the specific fading patterns due to modern EMF environments is not a factor contributing to high SAR)

• Risk communication could effectively reduce the unnecessary worry on the EMF exposure
to read:

- 李从胜等, 基于MOM/FDTD法评估人体暴露于向基站电磁场的组织SAR, 微波学报, 28, 303-6, 2012.
Thank you