4th ITU **Green Standards** Week

Dosimetry of Human Exposure to the Real Telecommunication Network

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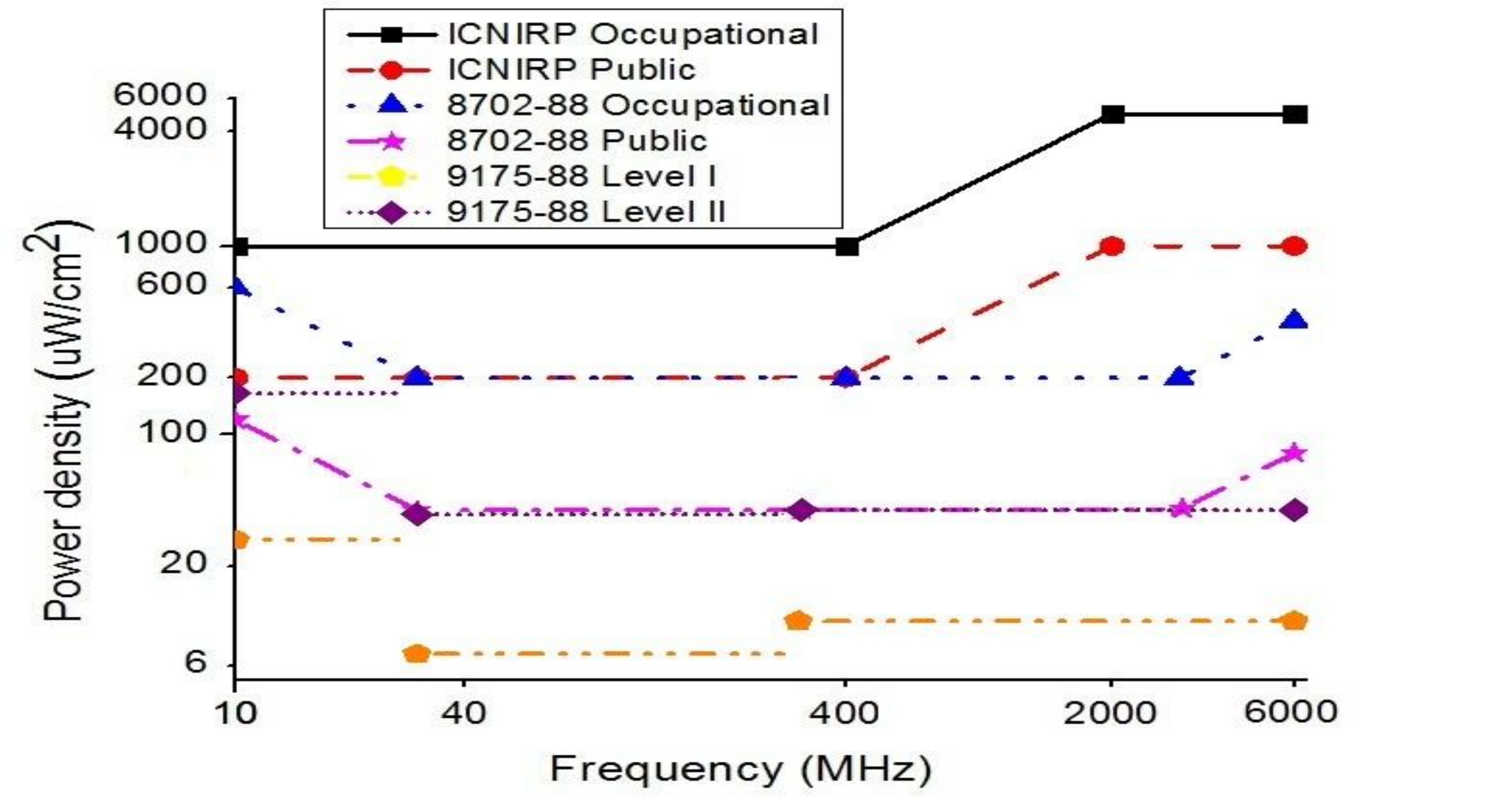
Introduction

- 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

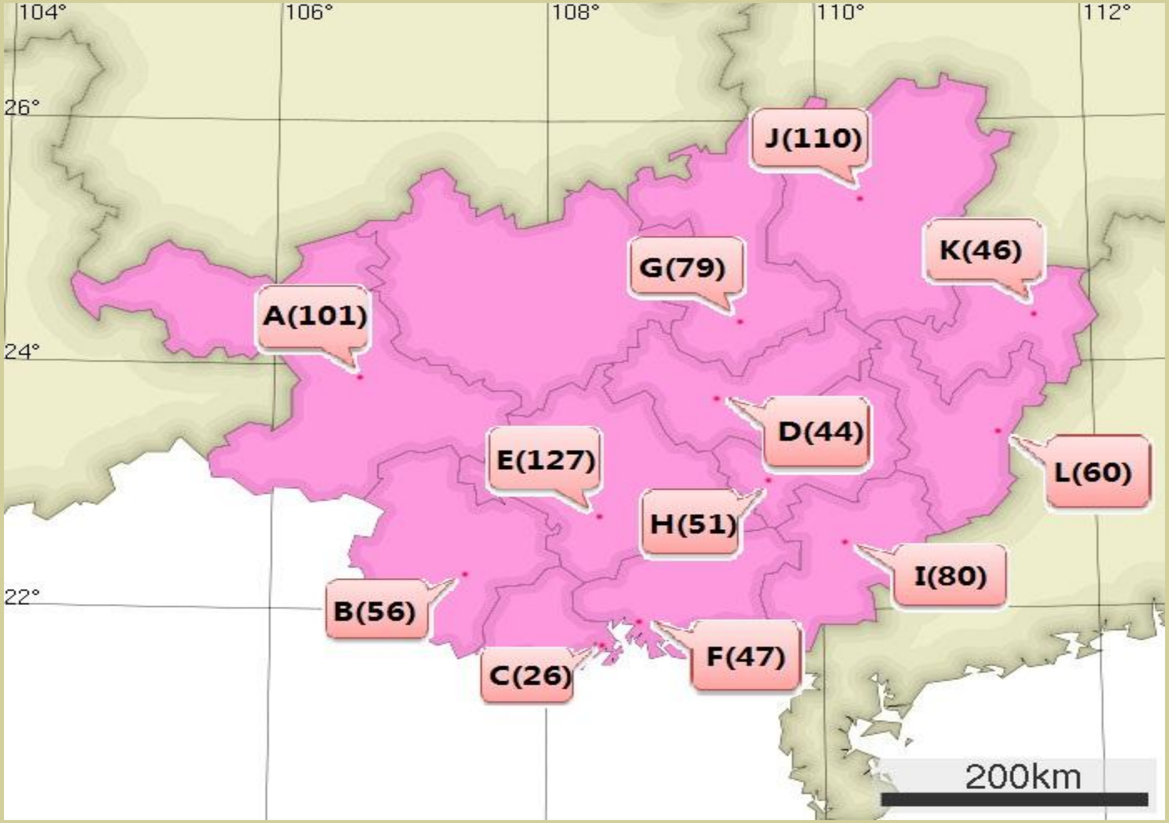
- Mapping the real EMF level according to various safety standards
- Numerically reconstructing the specific EMF exposure
- Modeling the Chinese human body
- Analyzing the results
- Communicating the risks

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

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



GSM 900/1800 MHz, 821 stations and 6207 measurement points

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

A large scale measurement campaign for the base station EMF (I): Protocols

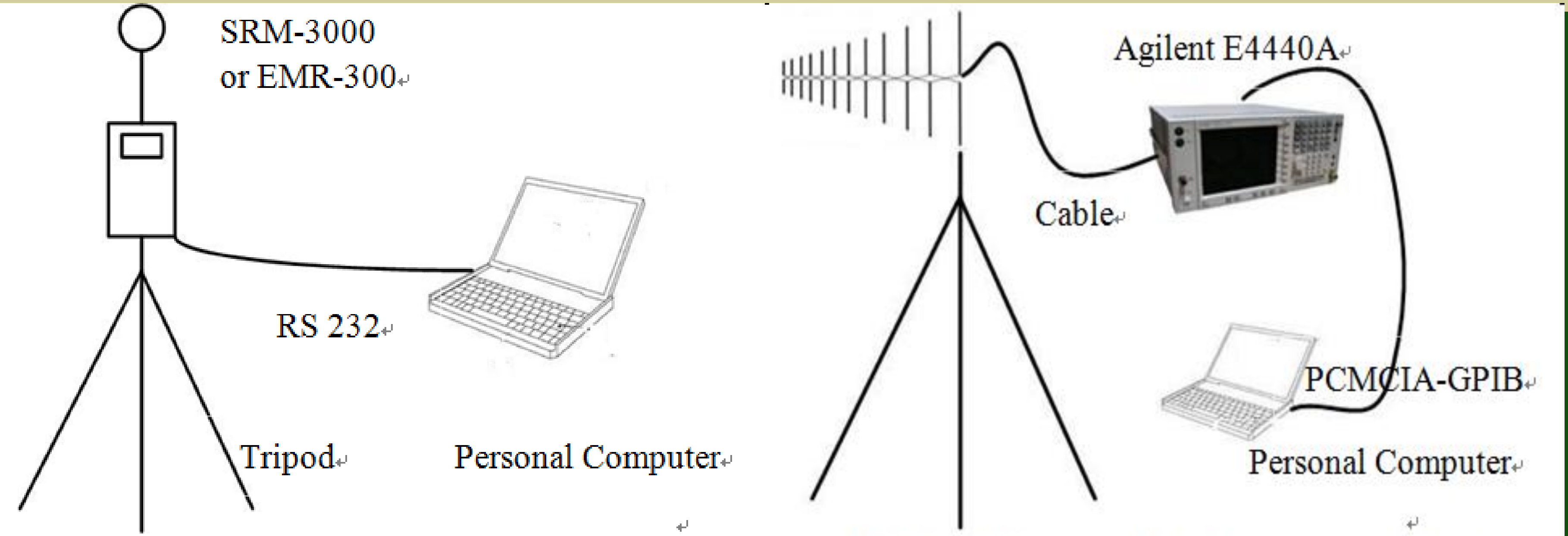
- **The measurement was performed between 9:00 am to 5:00 pm. No measurement on the rainy days**
- **Temporal variation of the measured power density was maximum 9 dB**
- **All the measurement points located between 10 and 70 m to the antenna mast. The averaging time was 3 min**
- **The measurement points 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:**

$$\sum_1^n \frac{S_i^{meas}}{S_i^{ref}} = \frac{S_1^{meas}}{S_1^{ref}} + \frac{S_2^{meas}}{S_2^{ref}} + \cdots + \frac{S_n^{meas}}{S_n^{ref}} < 1$$

A large scale measurement campaign for the base station EMF (II): situ categorization

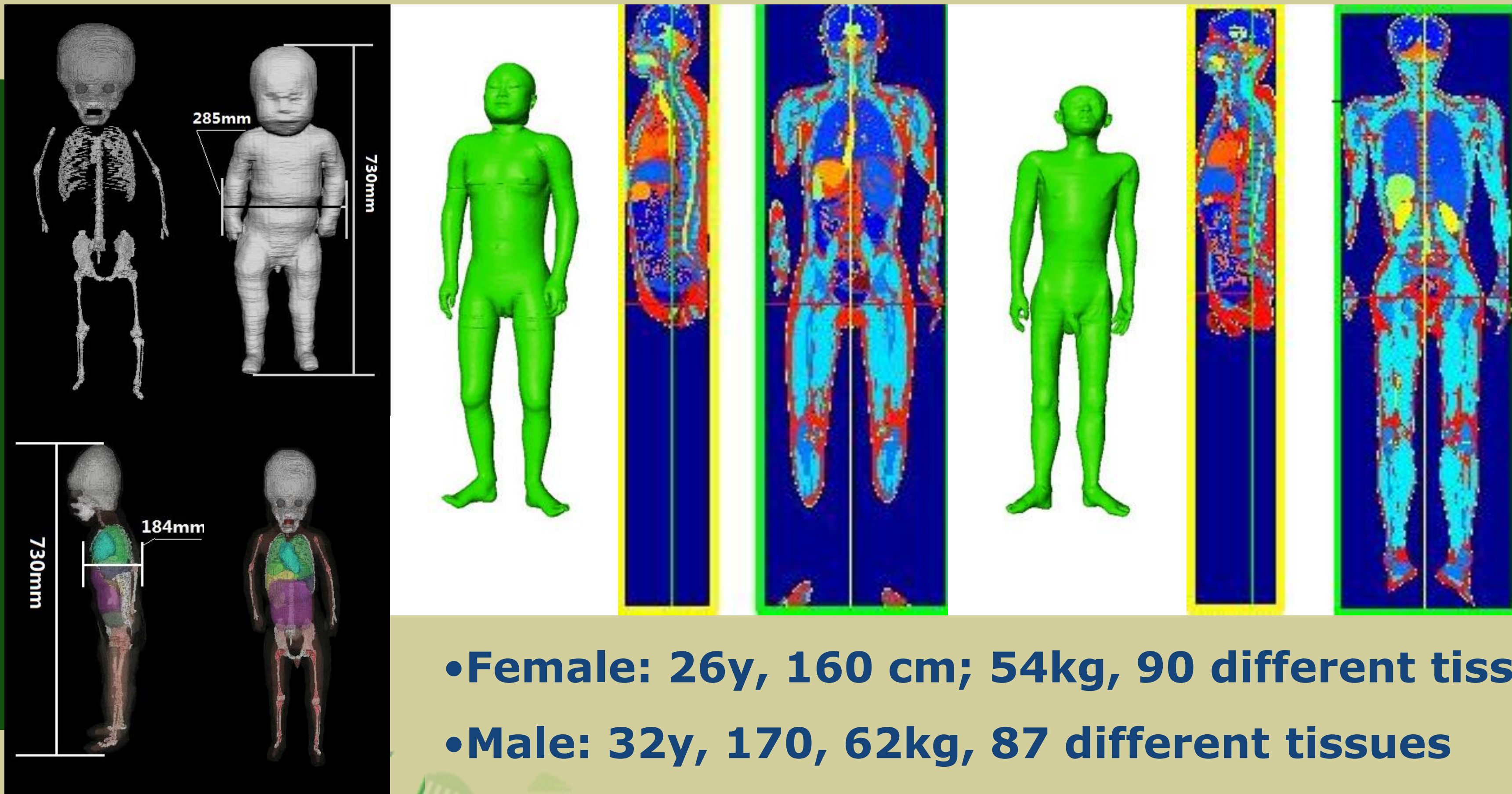
City: Yulin		Measured Base stations: 80		Measurement points: 629		GPS:22°28~22°87N 109°87~110°55E		
Location type	GSM 900 Results ($\mu W/cm^2$)	% 8702-88 (public)	% 9175-88 (Level I)	% ICNIRP (Public)	GSM 1800 Results ($\mu W/cm^2$)	% 8702-88 (public)	% 9175-88 (Level I)	% ICNIRP (Public)
Residential area (46/238)	$0.05\pm0.07_{0.01}^{0.50}$ (15%)	$0.12_{0.03}^{1.25}$	$0.46_{0.10}^{5.00}$	$0.02_{0.01}^{0.25}$	$0.02\pm0.04_{0.01}^{0.33}$ (5%)	$0.04_{0.03}^{0.83}$	$0.15_{0.10}^{3.30}$	$0.01_{0.01}^{0.17}$
Office (12/57)	$0.04\pm0.07_{0.01}^{0.54}$ (14%)	$0.11_{0.03}^{1.35}$	$0.43_{0.10}^{5.40}$	$0.09_{0.02}^{1.08}$	$0.02\pm0.01_{0.01}^{0.43}$ (7%)	$0.06_{0.03}^{1.08}$	$0.22_{0.10}^{4.30}$	$0.01_{0.01}^{0.22}$
Primary school and kinder-garden (0)	/	/	/	/	/	/	/	/
School (9/30)	$0.03\pm0.3_{0.01}^{0.17}$ (12%)	$0.07_{0.03}^{0.43}$	$0.26_{0.10}^{1.70}$	$0.01_{0.01}^{0.09}$	$0.01\pm0.02_{0.01}^{0.23}$ (5%)	$0.23_{0.03}^{0.58}$	$0.09_{0.10}^{2.30}$	$0.01_{0.01}^{0.12}$
Commercial area (10/156)	$0.03\pm0.03_{0.01}^{0.16}$ (18%)	$0.07_{0.03}^{0.40}$	$0.29_{0.10}^{1.60}$	$0.01_{0.01}^{0.09}$	$0.01\pm0.04_{0.01}^{0.24}$ (6%)	$0.03_{0.01}^{0.60}$	$0.1_{0.10}^{2.40}$	$0.01_{0.01}^{0.12}$
Hospital (0/0)	/	/	/	/	/	/	/	/
Tourist area (2/16)	$0.14\pm0.25_{0.01}^{0.52}$ (20%)	$0.36_{0.03}^{1.30}$	$1.43_{0.10}^{5.20}$	$0.01_{0.01}^{0.26}$	$0.04\pm0.10_{0.01}^{0.31}$ (5%)	$0.09_{0.03}^{0.78}$	$0.36_{0.10}^{3.10}$	$0.02_{0.01}^{0.15}$
Industrial area (1/5)	$0.01\pm0.01_{0.01}^{0.02}$ (21%)	$0.04_{0.03}^{0.05}$	$0.14_{0.10}^{0.20}$	$0.01_{0.01}^{0.01}$	$0.01\pm0.02_{0.01}^{0.25}$ (8%)	$0.01_{0.03}^{0.63}$	$0.05_{0.10}^{2.50}$	$0.01_{0.01}^{0.13}$

A large scale measurement campaign for the base station EMF (III): Instrumentations



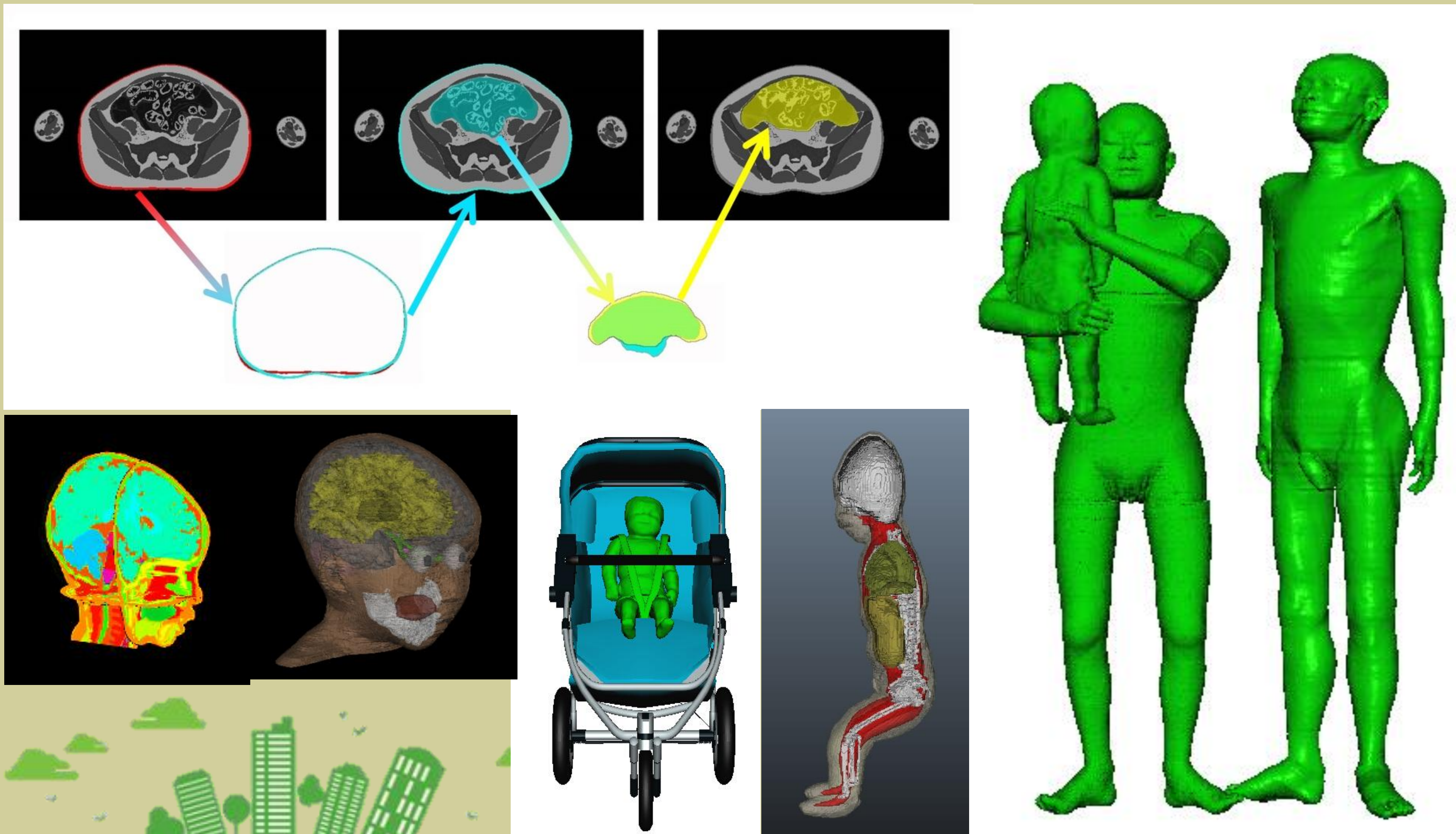
(a) EMF meter measurement setup (b) Spectrum analyzer measurement setup

Chinese human anatomical models (I): standing models



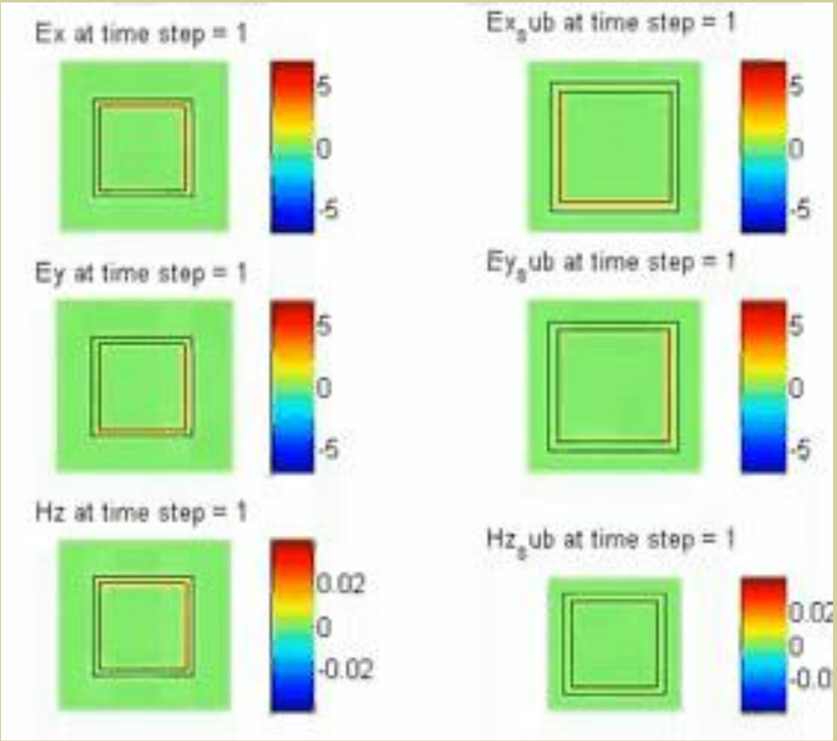
- Female: 26y, 160 cm; 54kg, 90 different tissues
- Male: 32y, 170, 62kg, 87 different tissues
- Infant: 12mo, 74 cm, 9.6 kg, 31 different tissues
- 1 cubic mm

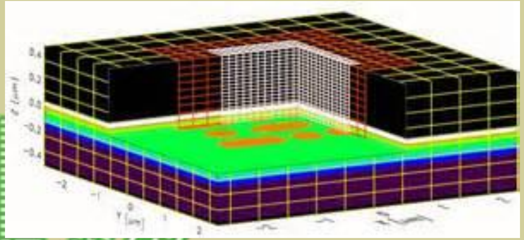
Chinese human anatomical models (II): postured models

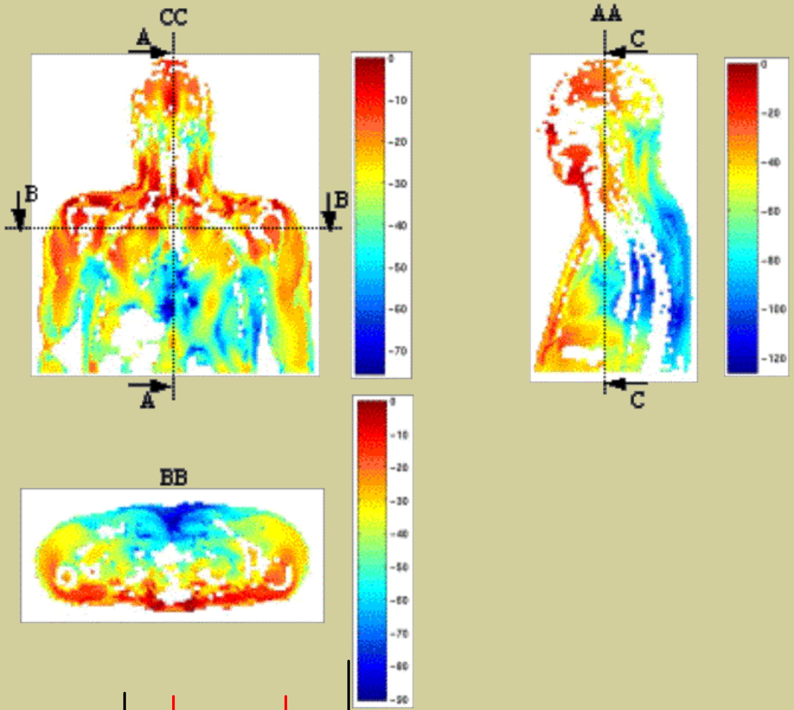


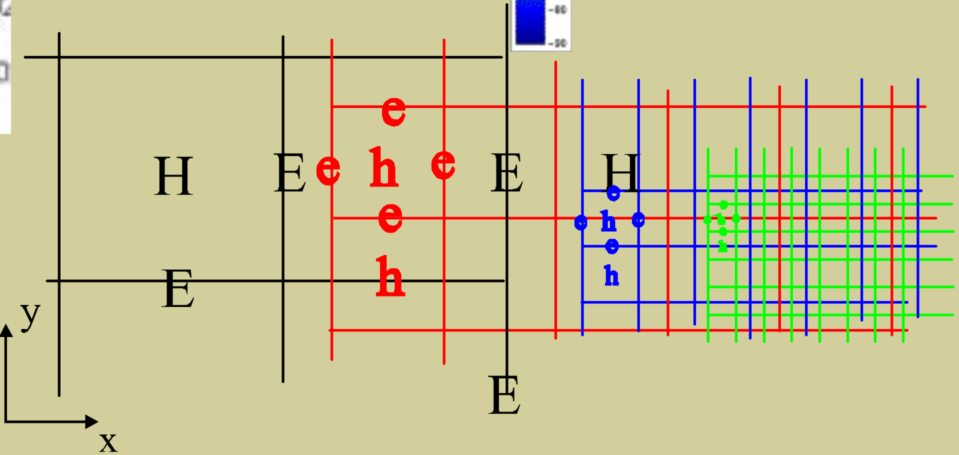
Simulation methods (I): plane wave exposure

- Plan wave simulation









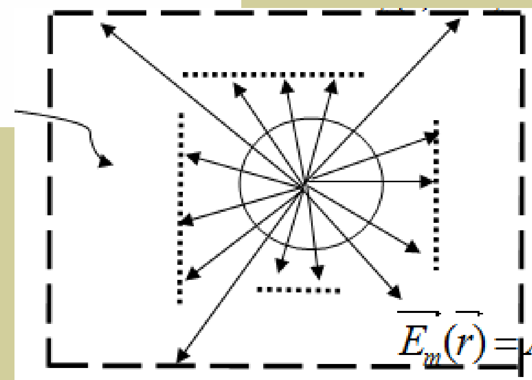
Simulation methods (II): multi-reflection

	Rayleigh fading	Rician fading
$Real(E_{x,y,z})$, $Img(E_{x,y,z})$	central normal distribution	noncentral normal distribution
$\lvert E_{x,y,z} \rvert$	central $\chi_{(2)}$ distribution	noncentral $\chi_{(2)}$ distribution
$\lvert E_{total} \rvert$	central $\chi_{(6)}$ distribution	noncentral $\chi_{(6)}$ distribution

$$\overline{E}(\overline{r})=\sum_{l=1}^{n} A_l \cdot \exp(j \cdot \overline{k_l}\,\overline{r}+\varphi_l) \cdot \overline{v_l}+\sum_{i=1}^{N} A_i \cdot \exp(j \cdot \overline{k_i}\,\overline{r}+\varphi_i) \cdot \overline{v_i}$$

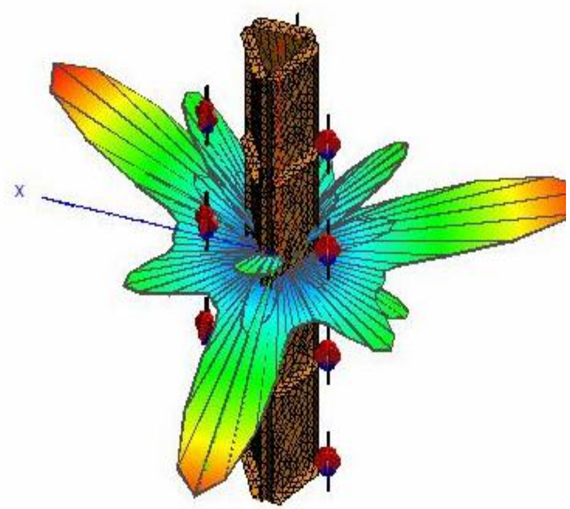
$$\overline{E}(\overline{r})=A_{l,x} \cdot \exp(j \cdot \overline{k_{l,x}}\,\overline{x}+\varphi_{l,x})+A_{l,y} \cdot \exp(j \cdot \overline{k_{l,y}}\,\overline{y}+\varphi_{l,y})+A_{l,z} \cdot \exp(j \cdot \overline{k_{l,z}}\,\overline{z}+\varphi_{l,z})$$
$$+\sum_{i=1}^{N} A_i \cdot \exp(j \cdot \overline{k_i}\,\overline{r}+\varphi_i) \cdot \overline{v_i}$$

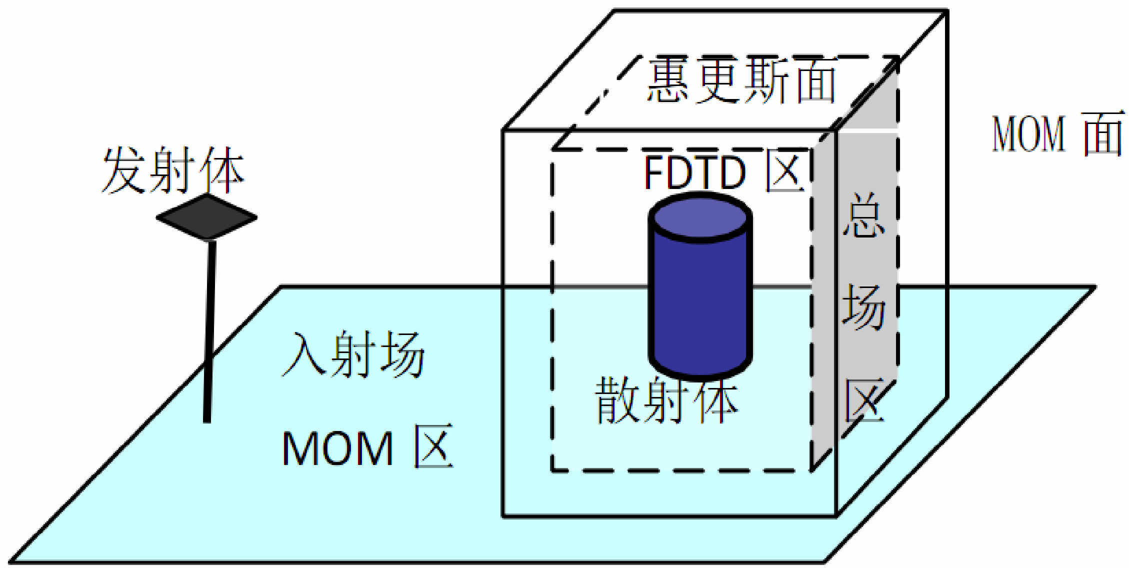
$$A_l = \sqrt{K \cdot 2 \cdot var(A_i)}$$



Simulation methods (III): other used methods

- FDTD-MoM hybrid simulation

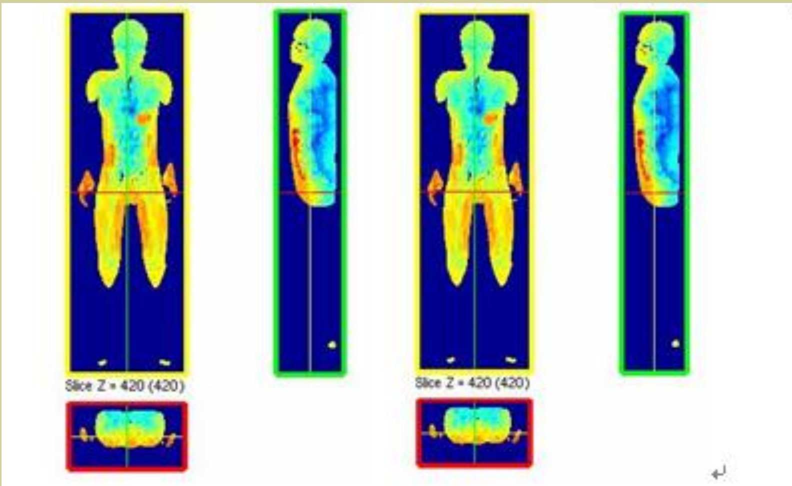




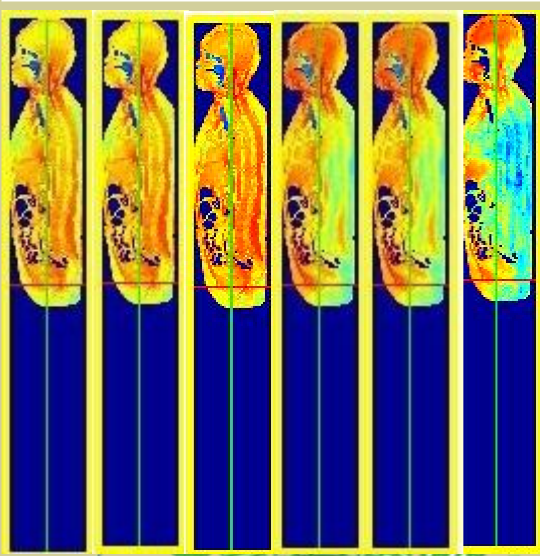
Results (I): Measurement

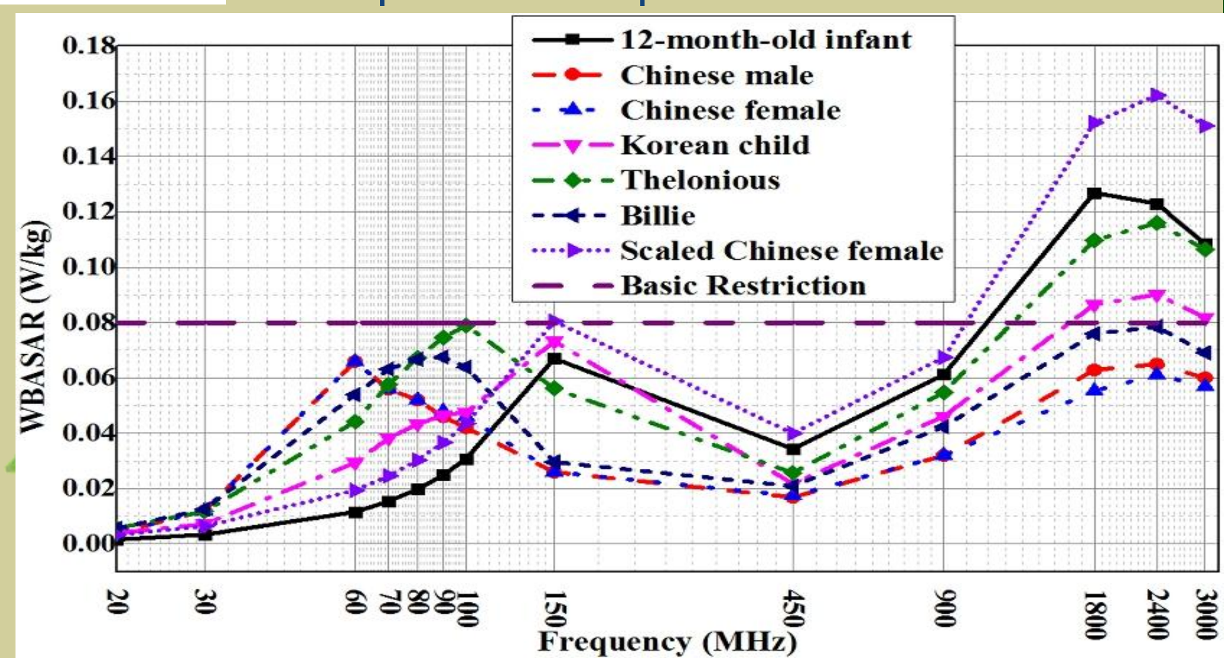
- All the measured GSM downlink EMF results complied with the reference levels of ICNIRP guidelines and GB 8702-88
- The repartition of the power density for the GSM 900 MHz and 1800 MHz accounted only about 20% of the total environmental EMF level for 10 MHz to 3 GHz
- Concerning with GB 9175-88, very 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 provides the consistent results
- SAR results was marginal compared with the safety limits under the realistic wireless network
- Minors were not significantly over-exposed compared with the adult





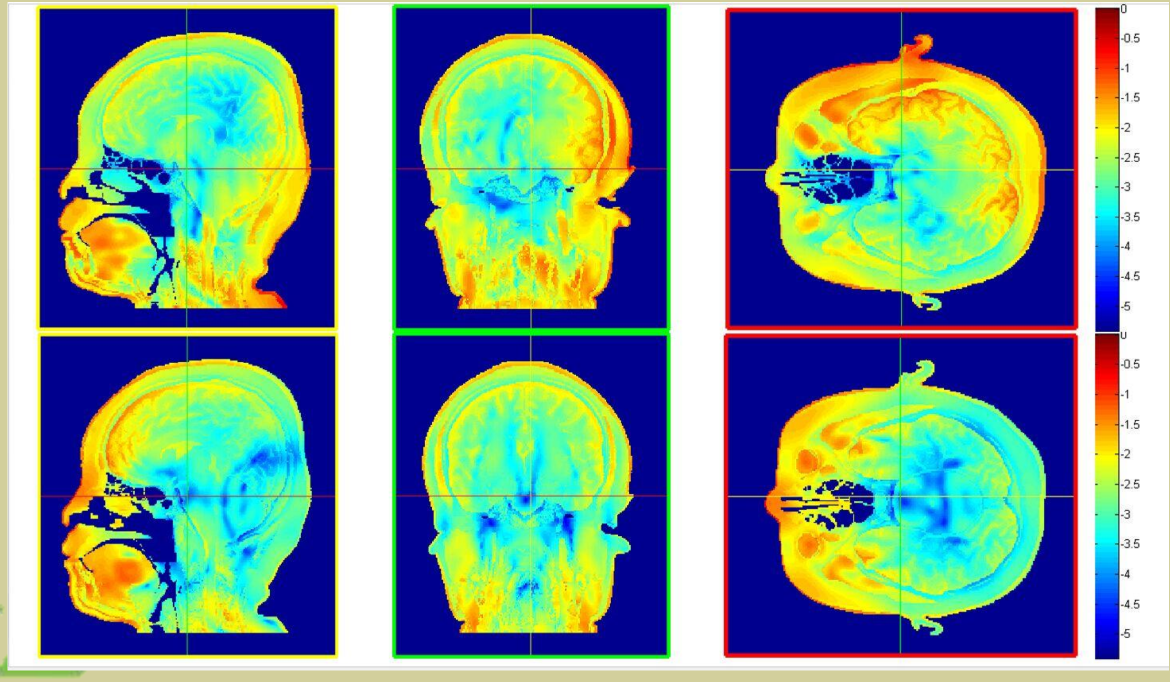
Results (III): different EMF environments

- **Exposure with same E-field strength but different fadings will not introduced 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:

- Wu et al., (2011). Chinese adult anatomical models and the application in evaluation of RF exposures. Physics in medicine and biology, 56(7):2075-89
- Wu et al., (2013). Simplified segmented human models for whole body and localised SAR evaluation of 20 MHz to 6 GHz electromagnetic field exposures. Radiation protection dosimetry, 153(3): 266-72.
- Wu et al.,(2013). Slice-based supine-to-standing posture deformation for Chinese anatomical models and the dosimetric results with wide band frequency electromagnetic field exposure: simulation. Radiation protection dosimetry, 154(1): 31-6.
- Wu et al., (2013). A large-scale measurement of electromagnetic fields near GSM base stations in Guangxi, China for risk communication. Radiation protection dosimetry, 155(1):25-31
- Li et al.,(2014). A Reverberation Chamber for Rodents’ Exposure to Wideband Radiofrequency Electromagnetic Fields with Different Small-Scale Fading Distributions, Electromagnetic biology and medicine, accepted.
- 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.

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Thank you