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Abstract: [Provide needs of exposure assessment for BAN devices]
Purpose: [To provide exposure assessment safely to use BAN devices]

Exposure assessment for BAN devices

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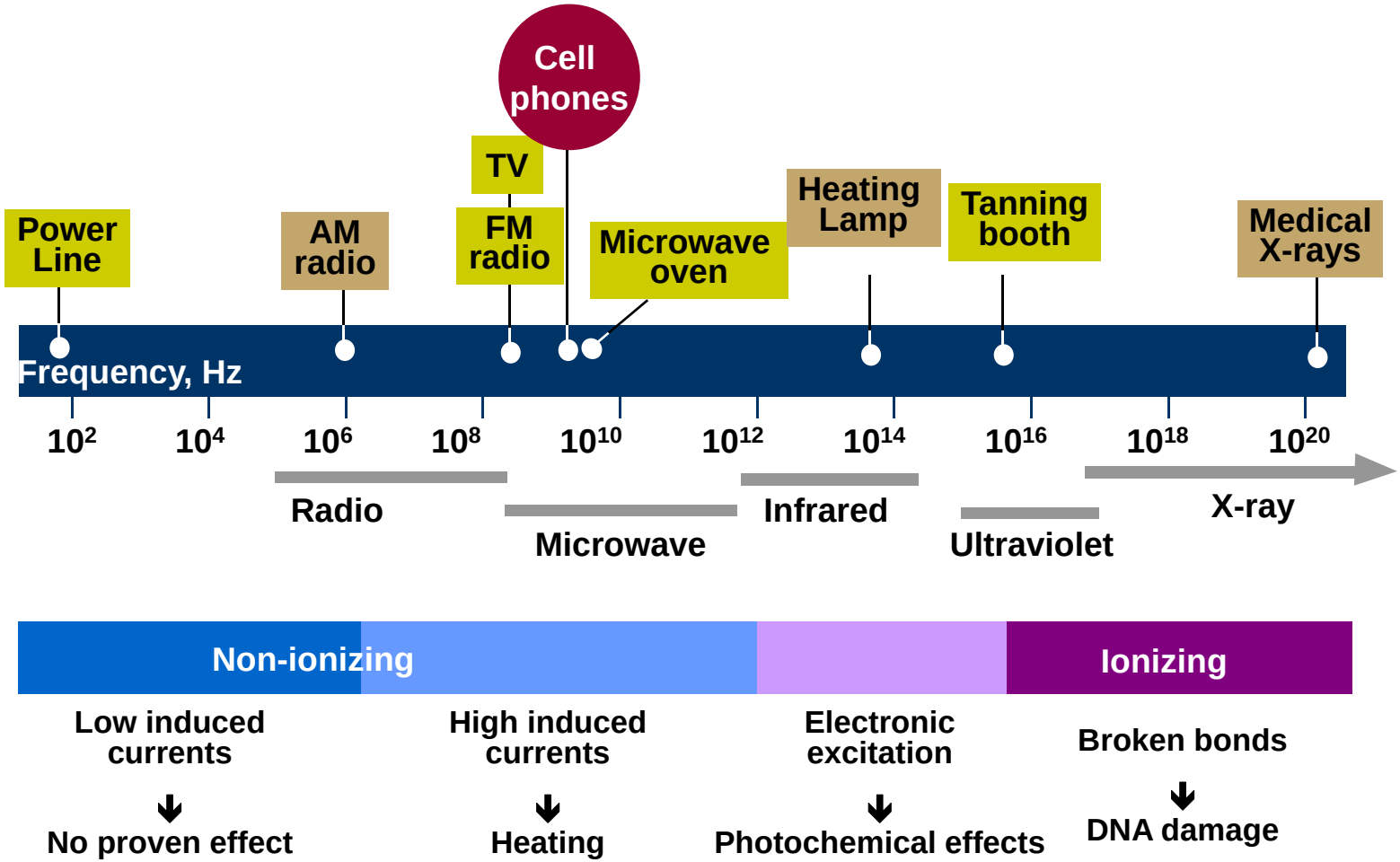
Contents

- 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



Exposure Limits

- Basic restriction
  - Induced currents
  - SAR
  - Power density
- Reference level or MPE
  - Electric field, Magnetic field
  - Power density

SAR Limits

Division		ICNIRP	IEEE	CENELEC	FCC	JAPAN	KOREA
Frequency (Hz)		10^5~10^{10}	10^5~3×10^9	10^4~3×10^{11}	3×10^5~6×10^9	10^5~3×10^9	10^5~10^{10}
Whole body		0.08	0.08	0.08	0.08	0.08	-
Local-ized	Limb	4	4 (also for pinnae)	4	4	4	1.6
	Head	2	1.6	2	1.6	2	
	body	2	1.6	2	1.6	2	
Tissue mass (g)		10	10	10	1(head, body) 10(limb)	10	1

WGs for Assessment Standards

- IEC TC 106
  - 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

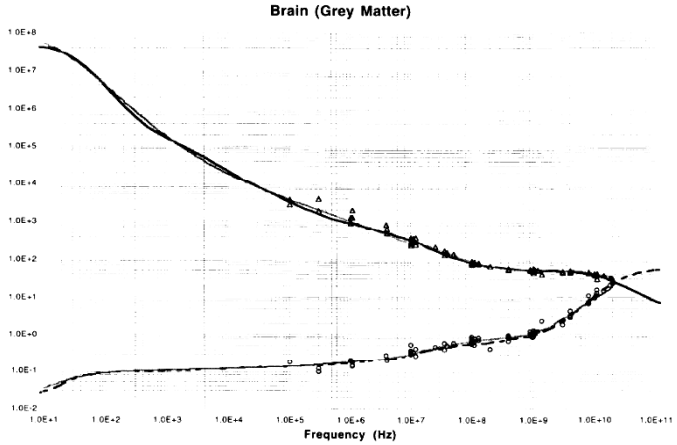
- Location
  - In-body
  - On-body
  - Out-body
- Assessment standards
  - Numerical methods
  - Measurement techniques

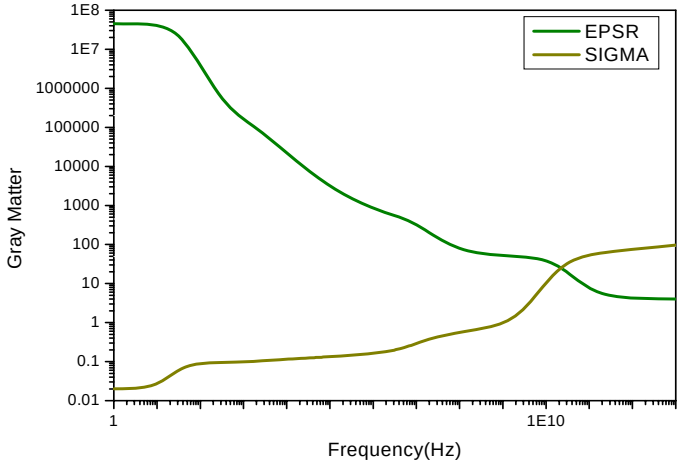
Biological Tissues - FCC

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

- Website : http:// www.fcc.gov/fcc-bin/dielec.sh

Dispersive Characteristics of Biological Tissues





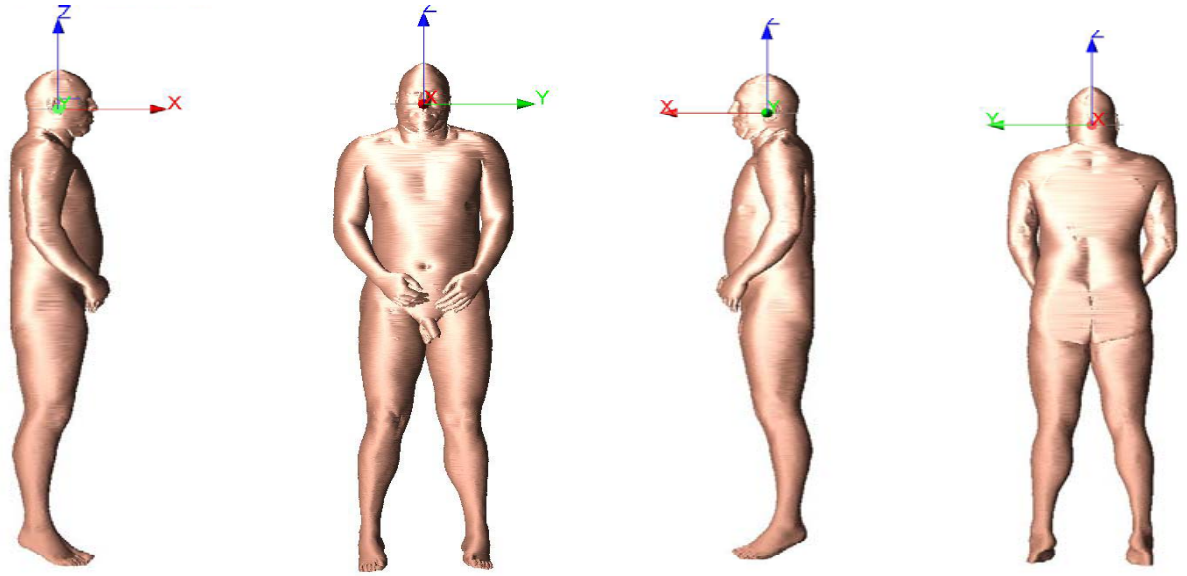
The tissue parameters provided here are derived from the 4-Cole-Cole Analysis in "Compilation of the Dielectric Properties of Body Tissues at RF and Microwave Frequencies" by Camelia Gabriel, Brooks Air Force Technical Report AL/OE-TR-1996-0037

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

4th Cole-Cole model

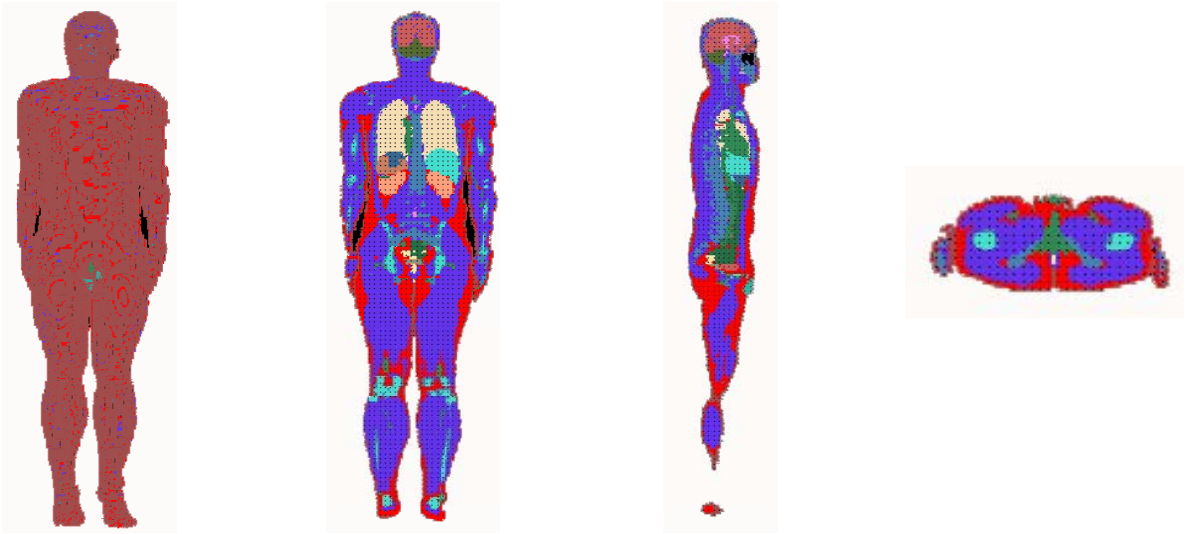
VHP Model

- 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

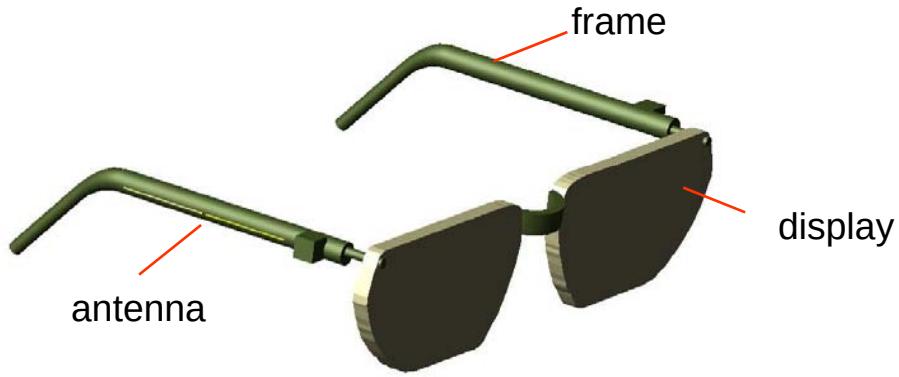
- Standard – Height : 171.4cm, Weight : 63.9 kg
- Volunteer – Height : 176.0 cm, Weight : 67.0 kg
- Voxel size : 3 mm x 3 mm x 3 mm, Number of tissues : 29



Head-Mounted Display

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

Ref. US Patent No.6,091,546



	Conductivity	Dielectric constant
Display	**0.01**	**4.5**
Frame	**0.02**	**3.5**

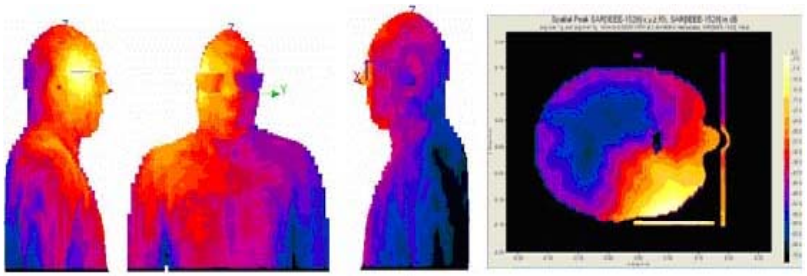
Down-Scaled VHP Model

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

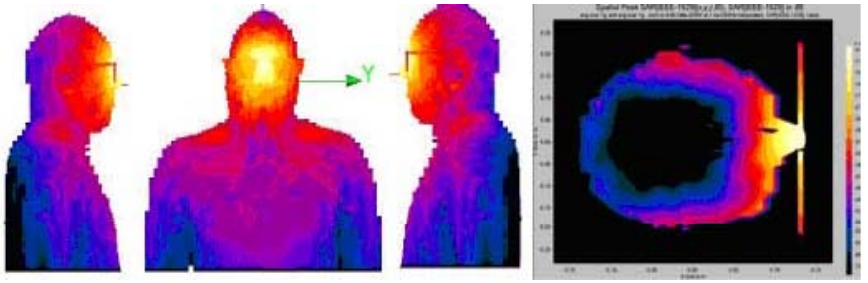
[mm]

	VHP model	13 year-old Korean model	Scale factor
Chest thickness	**313.6**	**178.7**	**0.56**
Chest width	**549**	**260.9**	**0.48**
Height	**1870**	**1582.4**	**0.85**
Head thickness	**240**	**178.3**	**0.74**
Head width	**165**	**154.7**	**0.94**
Head length	**250**	**227**	**0.91**

Simulation Results

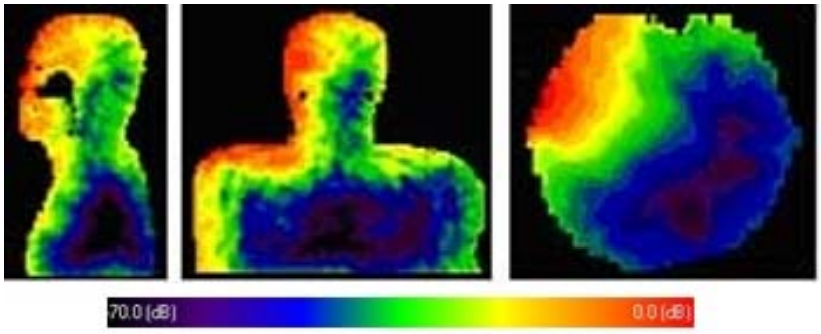


Antenna in the side frame (VHP adult)



Antenna in the front frame (VHP adult)

Antenna in the side frame (VHP child)

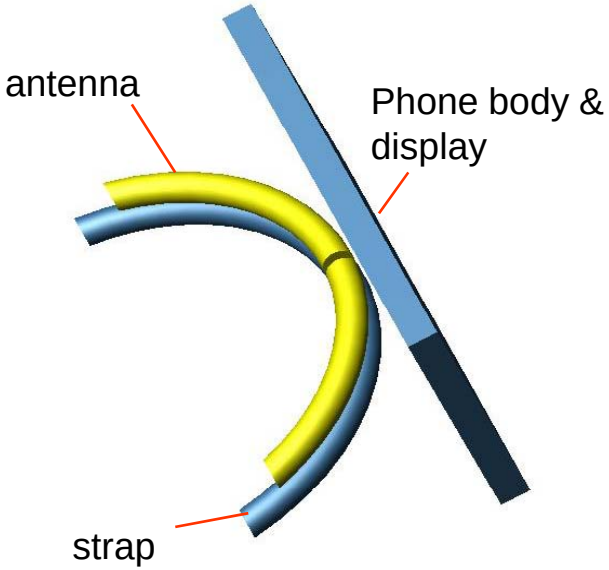


Antenna in the side frame (Korean adult)

Wristwatch-Type Phone

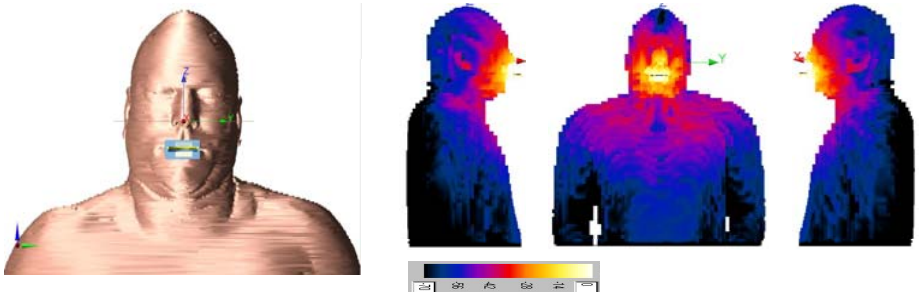
- Modeling of wristwatch-type phone (Frequency : 2.4 GHz)

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

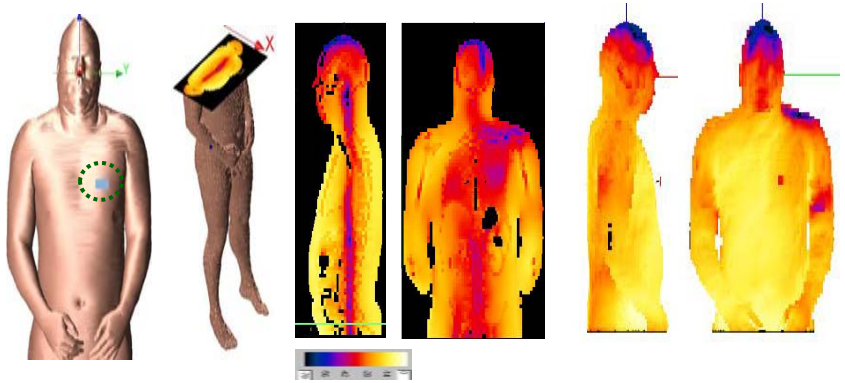


	Conductivity	Dielectric constant
Phone body	0.04	4.0
Strap	0.0007	2.25
display	0.01	4.5

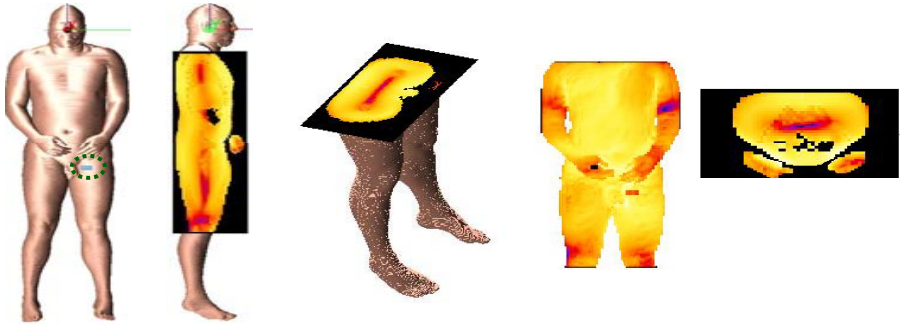
Simulation Results



Wristwatch phone in front of the mouth (VHP adult)



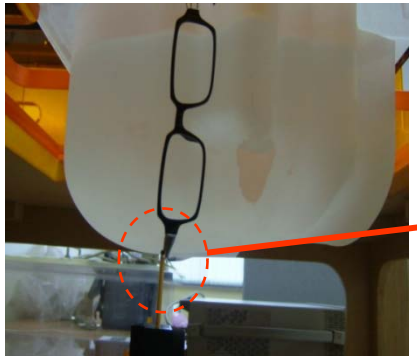
Wristwatch phone in front of the heart (VHP adult)

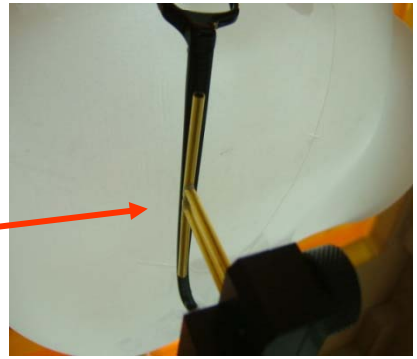


Wristwatch phone on the thigh (inside pocket) (VHP adult)

Dosimetric Measurement

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





	1.8 GHz		2.4 GHz	
	Dielectric const.	Conductivity	Dielectric const.	Conductivity
Target value	40.0	1.4	39.2	1.8
Measurement	38.7	1.4	40.32	1.87

Measurement Results

- System validation

Frequency	1.8 GHz		2.4 GHz	
SAR value	1 g SAR	10 g SAR	1 g SAR	10 g SAR
Target value	38.1	19.8	52.4	24.0
Measurement	36.7	20.7	51.9	26.0

- Comparison of the maximum 1g-averaged SAR

Frequency	1.8 GHz	2.4 GHz
Measurement	22.89	29.24
Simulation	20.14	25.50
Diff[M-S] (%)	+13.65	-14.66

Summary of SAR Values

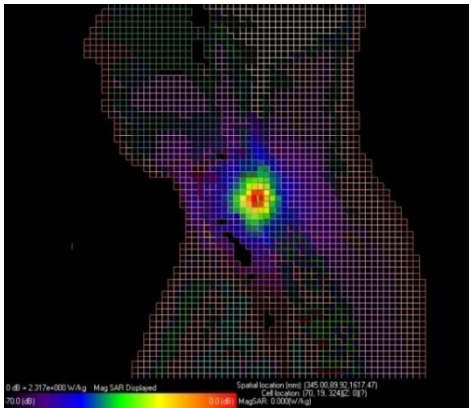
- Summary of the maximum 1 g averaged SAR values for body-mounted devices

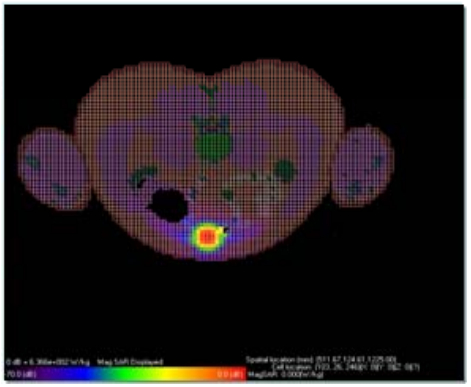
[W/kg/W]

	Head-mounted display		Wristwatch-type phone			
Classification	**Side**	**Front**	**Mouth**	**Heart**	**Waist**	**Thigh**
VHP Adult	**13.15**	**23.82**	**5.23**	**2.33**	**6.38**	**2.49**
Child (VHP down-scaled by 0.74)	**17.44**	**35.79**	**6.24**	**6.29**	**5.01**	**6.38**
Korean Adult	**15.00**	**31.60**	**7.97**	**4.24**	**5.03**	**4.18**

In-Body Simulation Results

Frequency : 403.5 MHz





- Source : neck
  - Body average SAR 1.21x10^{-2} (W/kg/W)
  - Max 1g SAR 5.27x10^{2} (W/kg/W)
  - Max 10g SAR 1.20x10^{2} (W/kg/W)
- Source : heart
  - Body average SAR 1.44x10-2 (W/kg/W)
  - Max 1g SAR 6.37x10^{2} (W/kg/W)
  - Max 10g SAR 1.45x10^{2} (W/kg/W)

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.