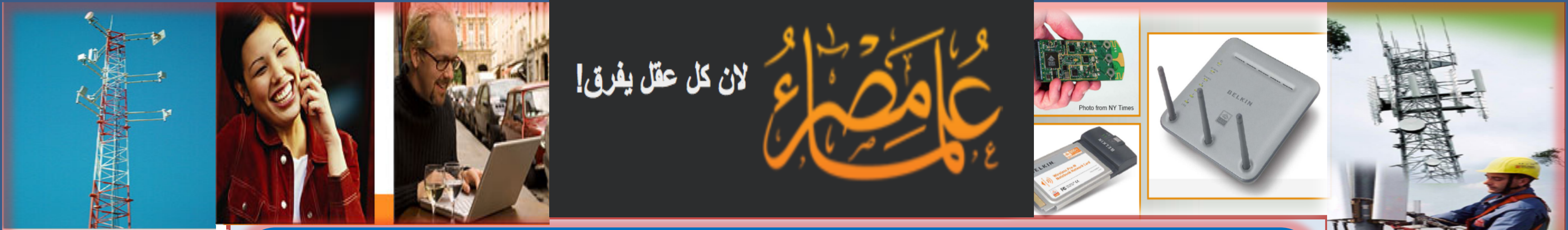

Part II

Electromagnetic Waves Radiation and Health Effects

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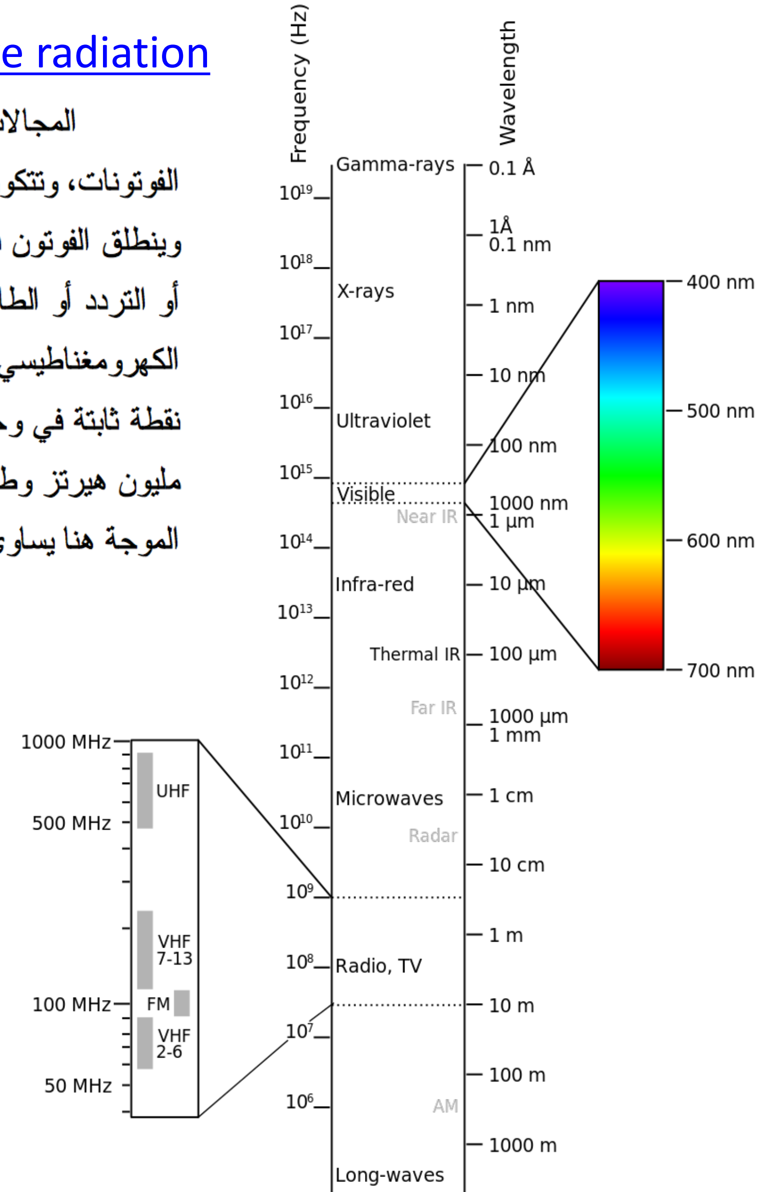
Electromagnetic spectrum "الطّيف

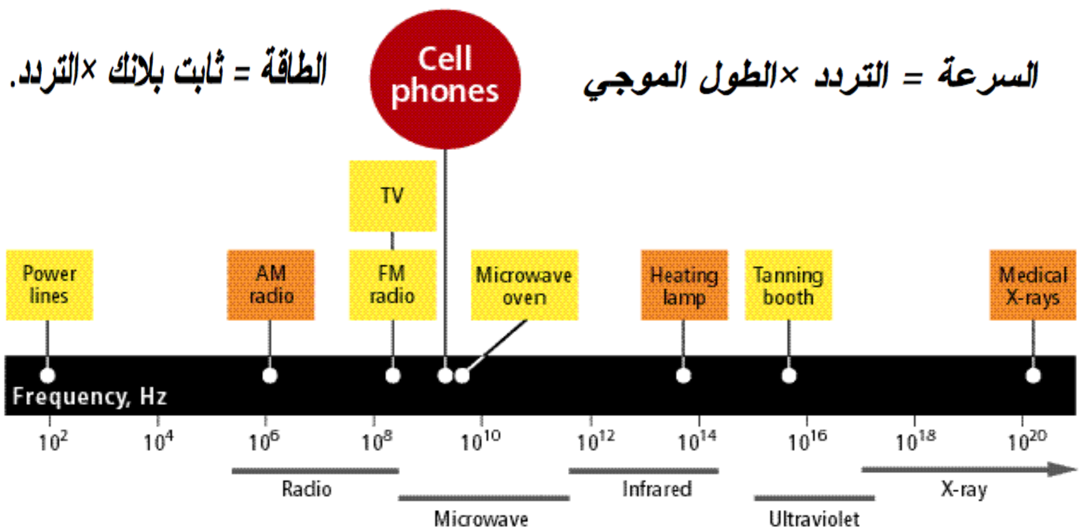
Range of all possible frequencies of electromagnetic wave radiation

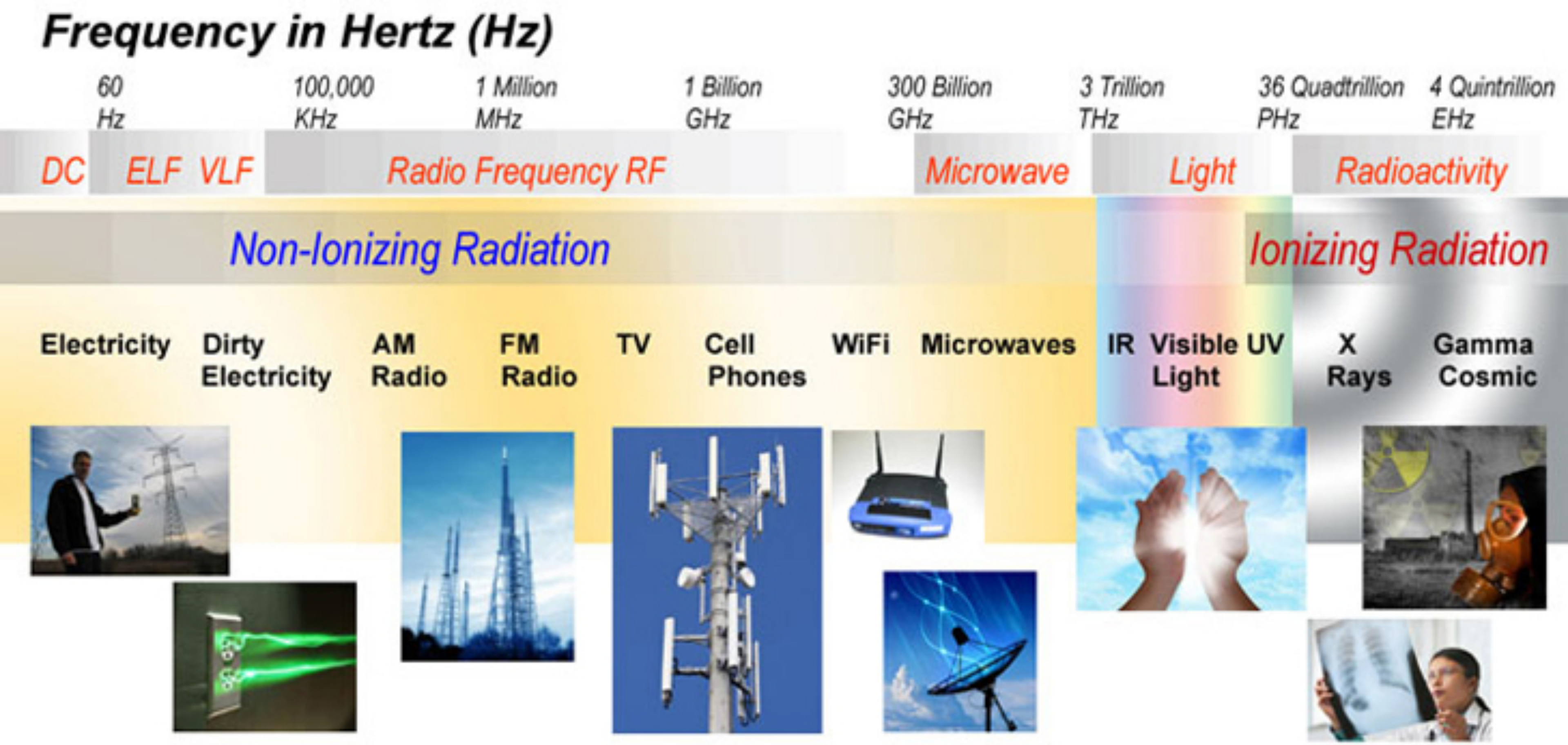
المجالات الكهرومغناطيسية هي موجات تنطلق بسرعة 300 ألف كيلومتر في الثانية وتحمل طاقة يطلق عليها الفوتونات، وتتكون هذه المجالات من مجالين ينتشران في اتجاهين متعامدين هما المجال الكهربائي والمجال المغناطيسي وينطلق الفوتون في الاتجاه المتعامد على الاتجاهين، ويمكن أن نصف الموجات الكهرومغناطيسية بواسطة طول الموجة أو التردد أو الطاقة. وترتبط هذه العوامل الثلاثة بعلاقات فيما بينها, ويلعب كل منها دورا معينا في تأثير المجال الكهرومغناطيسي على النظام البيولوجي. يعرف تردد الموجه الكهرومغناطيسية على انه عدد الذبذبات التي تمر خلال نقطة ثابتة في وحدة الزمن. كلما كانت الموجة قصيرة, زاد التردد. فمتوسط بث محطات المذياع AM يعمل بتردد مليون هيرتز وطول موجة البث حوالي 300 متر, أما أفران الميكروويف فتستخدم تردد 2.45 غيغا هيرتز وطول الموجة هنا يساوي 12سم (3).



السرعة = التردد × الطول الموجي

الطاقة = ثابت بلانك × التردد.





Non-ionizing Radiation: the photon energy is insufficient to knock electrons from atoms in living tissue

ionizing radiation has the ability to alter matter, including human cells. It has very high energy which can change a molecule's structure. This can have serious consequences – ionizing radiation can cause changes in the structure of DNA, leading to mutations and in some cases cancer.

Cell phone radiation: Harmless or health risk?

Biological hazards of electromagnetic fields

Thermal effects

Nonthermal Effects

↓

SAR and Exposure guidelines ?

The most apparent biological effects of RF energy at cell phone frequencies are due to heating. (increase in the temperature of the tissues)

EM radiation Non-thermal effects

- Worms raise safety concerns over mobile phone radiation. Nottingham University UK found that female nematode worms exposed to mobile phone radiation produced stress hormones, grew 10% larger, and produced more eggs.
New Scientist 7 Feb 2002

- Pigeons get lost near radio masts. research shows that the prized birds, able to find their way from 700 miles away, get confused near radiation-emitting masts. Exposure also makes pigeons fly much lower than usual. Now pigeon fanciers are demanding curbs on the number of mobile phone masts to protect their birds. Research by the Swiss Bird Study Organisation. Sunday Mirror 18 June 2000

- Mobile phone radiation causes birth defects in chickens - 10,000 chicks exposed in eggs to mobile phone radiation. Result = doubled number of birth defects. Dr Theodore Litovitz, Catholic University of America found research confirmed earlier French findings last year. Sunday Telegraph (Australia) 2 May 1999

- RF radiation IMPROVES brain function. Tiny study - only 36 people for 30 minute bursts. Bristol University Dr Alan Preece. Lloyds Product Liability International 5 April 1999

- Mobile phone radiation disturbs sleep patterns. Electromagnetic fields from mobile phone use in bed significantly increases brain activity during early, non-rapid-eye-movement sleep.

EM radiation Non-thermal effects

1. Brain cancer in rats after RF radiation exposure

Researchers, dates[a]	Exposure to RF radiation: Frequency, MHz	SAR, W/kg	Duration, months	No. of rats: RF exposed	Unexposed	Cancer: Tumor generation
Brain tumor generation						
C.K. Chou et el., 1992	2450 PM	0.15–0.4	25	100	100	None
J.C. Toler et al., 1997	435 PM	0.32	21	200	200	No significant difference between groups
M.R. Frei et al., 1998	2450 FM	0.3	18	100	100	None
M.R. Frei et al., 1998	2450 FM	1.0				

Brain tumor generation PLUS promotion of chemically induced tumors

Researchers, dates[a]	Frequency	SAR	Duration	RF exposed[b]	Unexposed[b]	Tumor generation	Tumor promotion
W.R. Adey et al., 1999	837 PM	0.3–2.3	25	60[b]	60	Insignificant decrease in RF-exposed rats	None
W.R. Adey et al., 2000	837 FM	0.3–2.3	26	90	90	No sig diff.	
B.C. Zook et al., 1999	860 FM	1	22	60	60	No sig diff.	
B.C. Zook et al., 1999	860 PM						

Source: http://infoventures.com/emf/spectrum.htm.

EM radiation Non-thermal effects

- Alterations in cellular growth
- DNA damages
- Effects on embryo development
- cancer promotion.

On animals and where mainly concerned with the study of possible

- effects on DNA in brain cells,
- on the blood-brain barrier,
- on the central nervous system.

1. vast majority has given a negative answer (non thermal effects)
2. some positive findings, but, generally, not been replicated
3. Needs long term studies

http://en.wikipedia.org/wiki/Mobile_phone_radiation_and_health

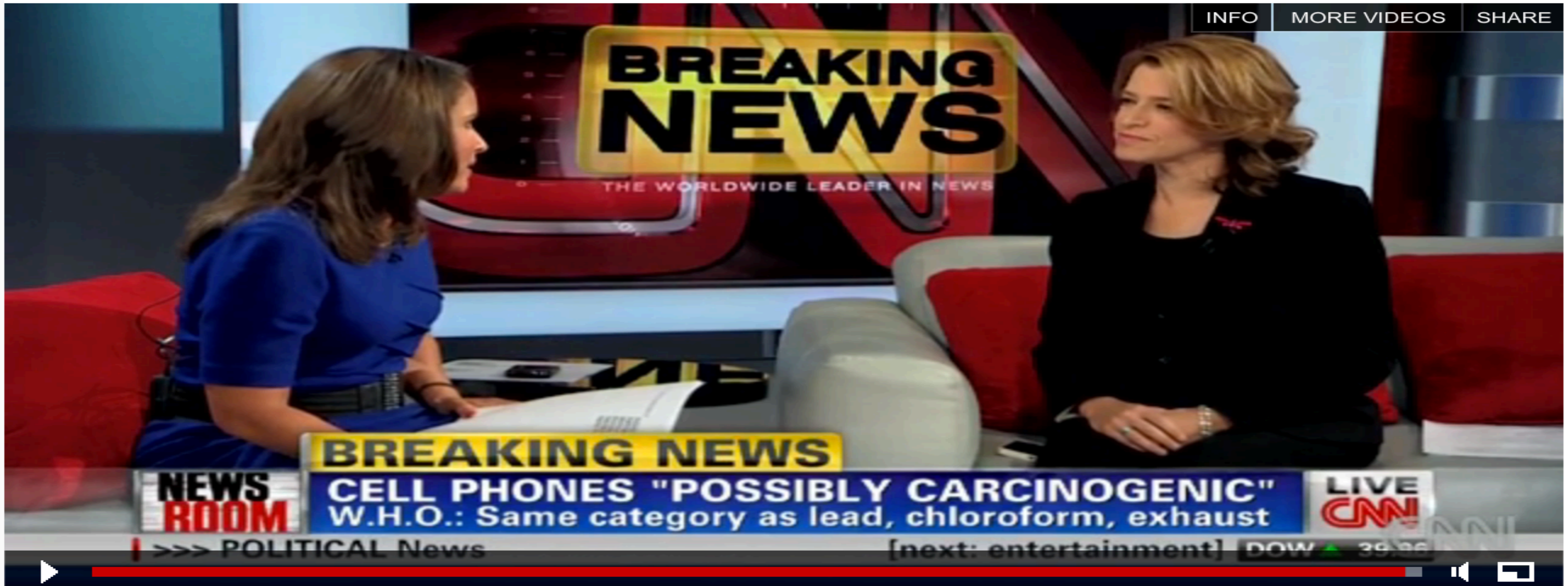
http://www.kecbu.uobaghdad.edu.iq

دراسة موسعة حول مدى تأثير الموجات الكهرومغناطيسية على صحة الانسان

WHO: Cell phone use can increase possible cancer risk

By Danielle Dellorto, CNN
May 31, 2011 -- Updated 1749 GMT (0149 HKT)

http://edition.cnn.com/2011/HEALTH/05/31/who.cell.phones/



Cell phone use 'possibly carcinogenic' Source: CNN

The Telegraph

May 31, 2011

Mobile phones 'possibly carcinogenic' say World Health Organisation experts

Mobile phones may increase the risk of developing brain cancer, an influential health organisation has said admitted for the first time.

International Agency for Research on Cancer

World Health Organization

A Working Group of 31 scientists from 14 countries met at IARC in Lyon, France

PRESS RELEASE
N° 208

31 May 2011

IARC CLASSIFIES RADIOFREQUENCY ELECTROMAGNETIC FIELDS AS POSSIBLY CARCINOGENIC TO HUMANS

Lyon, France, May 31, 2011 -- The WHO/International Agency for Research on Cancer (IARC) has classified radiofrequency electromagnetic fields as possibly carcinogenic to humans (Group 2B), based on an increased risk for glioma, a malignant type of brain cancer[1], associated with wireless phone use.

Group 2B - possibly carcinogenic (not Group 2A - probably carcinogenic).
That means that there **"could be some risk" of carcinogenicity**,
so additional research into the long-term, heavy use of mobile phones needs to be conducted.

http://www.iarc.fr/en/media-centre/pr/2011/pdfs/pr208_E.pdf

INTERPHONE **Project (WHO)**

- This is the largest study of the risk of brain tumours in relation to mobile phone use conducted to date. It included substantial numbers of subjects who had used mobile phones for at least ten years.

- **Overall, no increase in risk of glioma or meningioma was observed with use of mobile phones.** There were suggestions of an increased risk of glioma at the highest exposure levels, but biases and error prevent a causal interpretation.

- The subjects of the INTERPHONE-study were adults
- Users in the study were not heavy users by today's standards.
- Today it is not unusual for teenagers usages !!
- require further investigation

http://www.iarc.fr/en/media-centre/pr/2010/pdfs/pr200_E.pdf

Radiation from WiFi connections can reduce sperm activity in up to a quarter of men, study finds

By DAILY MAIL REPORTER
UPDATED: 09:50 GMT, 1 December 2011

EWG's Guide to Safer Cell Phone Use: Cell Phone Radiation Damages Sperm, Studies Find

AUGUST 27, 2013

EWG Science Review

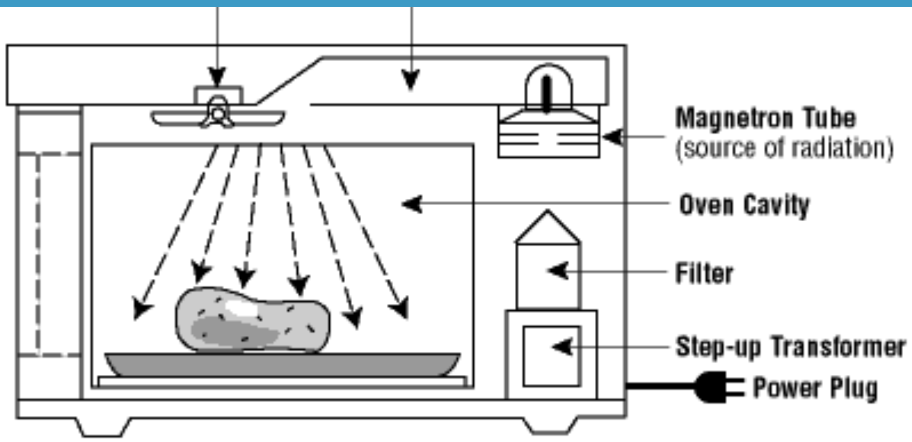
Cell Phone Radiation Damages Sperm, Studies Show

Phones Carried on Belt or in Pants Pocket May Harm Reproductive Health

Although most scientific and public attention on the issue of the safety of cell phone radiation has focused on evidence suggesting an increased risk of brain tumors (Baan 2011), a little-noticed but growing body of research points to a new concern – sperm damage (La Vignera 2012).

http://www.ewg.org/cell-phone-radiation-damages-sperm-studies-find

Thermal effects



radiation. Most household microwave ovens operate on a frequency of 2450 megahertz in a continuous wave (cw) mode.

- Typical levels of radiation leakage from microwave ovens is max about 0.2 mW/cm2

- This level of leakage cannot be sensed by the body.
- The power density decreases rapidly with increasing distance.

Thermal effects

- Dielectric heating, in which any dielectric material (tissue) is heated by rotations of polar molecules.

- cell phone: heating effect: at the surface of the head, causing its temperature to increase by a fraction of a degree. (less than sunlight effect).

- The brain's blood circulation is capable of disposing of excess heat by increasing local blood flow.

- However, the cornea of the eye does not have this temperature regulation mechanism. (cataracts disease of engineers who work on high power radio transmitters at similar frequencies).

Thresholds for the induction of thermal effects to the human body

Target	Effect	Threshold
Whole body	Various physiological effects	1.0 °C
Eye lens	Cataract	3 ÷ 5 °C
Skin	Warmth sensation	0.02 ÷ 1 °C
	Pain sensation / Burns	10 ÷ 20 °C
Brain	Neuron damage	4.5 °C

Experiment on thermal effects of the rabbit eye

Exposure of the rabbit eye (very similar to human eye) to incident power densities higher than (100 mW/cm^2) applied for at least half an hour is able to induce lens opacification (cataract), appearing after a latency period of a few days. Temperature of the lens is increased by at least 3 °C. note: GL (1 mW/cm^2).

Temperature elevations induced, after 15 minutes, in the user's head by a phone equipped with helical antenna kept in "touch-cheek" position

$f = 835$ MHz; $P_{rad} = 250$ mW

Heating cause	**ΔT_{ear} [°C]**	**ΔT_{brain} [°C]**
SAR	0.08	0.02
Phone contact	0.90	0.01
Phone contact + power dissipation in the amplifier	0.94	0.01
Phone contact + power dissipation in the amplifier + SAR	0.98	0.02

International Safety Guidelines and SAR definition

Main Safety Guidelines

- **WHO - World Health Organization**. Extremely low frequency fields. Environmental Health Criteria, Vol. 238. Geneva, World Health Organization, 2007.

- **ICNIRP – International Commission on Non-Ionizing Radiation Protection (1998).** Guidelines for limiting exposure to time varying electric, magnetic and electromagnetic fields (up to 300 GHz). Health Physics 74(4), 494-522.

- **IEEE Standards Coordinating Committee 28. IEEE standard** for safety levels with respect to human exposure to electromagnetic fields, 0-3 GHz. New York, NY, IEEE - The Institute of Electrical and Electronics Engineers, 2002 (IEEE Std C95.6-2002).

- National standards : EC + FCC + Canada + Italy + UK standards

Exposure guidelines

the two basic dosimetric parameter to establish if the exposure is safe or not are :

- 1. PFD, “S” (Reference Level, Free space measurements)

- 2. SAR (basic restriction,EM inside biological tissues)

Power density , “S”
(Free space measurements)

$$PD = \frac{P}{S} = |\vec{E} \times \vec{H}|,$$

where P is the incident power, S is the exposed surface area, and $\vec{E}$ and $\vec{H}$ are the electric and magnetic field vectors, respectively.

The Specific Absorption Rate (SAR) (EM inside biological tissues)

معدل الامتصاص النوعي

SAR is defined as the rate at which energy is absorbed per unit mass of the body tissue, (power absorbed per unit mass) W/kg

$$SAR = \frac{P}{m} = \frac{\sigma|\vec{E}|^2}{\rho} = C\frac{dT}{dt}\bigg|_{t=0}$$

E : the magnitude of the measured or computed rms electric field.
σ : the tissue conductivity , ρ: the tissue mass density.
m: the tissue mass , C : the heat capacity T : the temperature

- is a quantitative measure of power absorbed per unit of mass and time. In contrast to the PD, it also takes into account the physical properties of exposed samples:
- is a measurement of how much electromagnetic radiation is absorbed by body tissue whilst using a mobile phone.
- The higher the SAR the more radiation is absorbed.

Basic restrictions issued by the most recognised exposure guidelines

		Workers Controlled	General public Uncontrolled	
ICNIRP	Whole-body SAR	4 W/kg	0.08 W/kg	
	Local SAR trunk (10 g averaging)	10 W/kg	2 W/kg	0.2 °C
	Local SAR limbs (10 g averaging)	20 W/kg	4 W/kg	
EC	Whole-body SAR	–	0.08 W/kg	
	Local SAR trunk (10 g averaging)	–	2 W/kg	
	Local SAR limbs (10 g averaging)	–	4 W/kg	
IEEE	Whole-body SAR	4 W/kg	0.08 W/kg	
	Local SAR trunk (1 g averaging)	8 W/kg	1.6 W/kg	0.09 °C
	Local SAR limbs (10 g averaging)	20 W/kg	4 W/kg	
FCC	Whole-body SAR	4 W/kg	0.08 W/kg	
	Local SAR trunk (1 g averaging)	8 W/kg	1.6 W/kg	
	Local SAR limbs (10 g averaging)	20 W/kg	4 W/kg	

Reference levels for general public (uncontrolled env.) exposure

	Frequency range	$\lvert\mathbf{E}\rvert_{rms}$ (V/m)	$\lvert\mathbf{H}\rvert_{rms}$ (A/m)	S (W/m^2)
ICNIRP EC	10 – 400 MHz	28	0.073	2
	400 – 2000 MHz	$1.375 \cdot f^{1/2}$	$0.0037 \cdot f^{1/2}$	f/200
	2 – 300 GHz	61	0.16	10
IEEE	3 – 30 MHz	823.8/f	16.3/f	–
	30 – 100 MHz	27.5	$158.3/f^{1.668}$	–
	100 – 300 MHz	27.5	0.0729	2
	300 – 3000 MHz	–	–	f/150
	3 – 15 GHz	–	–	f/150
	15 – 300 GHz	–	–	100
FCC	1.34 – 30 MHz	824/f	2.19/f	–
	30 – 300 MHz	27.5	0.073	2
	300 – 1500 MHz	–	–	f/150
	1.5 – 100 GHz	–	–	10

Guidelines for Limiting Exposure to Radiofrequency Radiation

Comparison between different Reference Levels for general public exposure for frequency band of **GSM 900 (925 – 960 MHz):**

	E-field strength (V/m)	H-field strength (A/m)	Power density (W/m^2)
ICNIRP	41.82 – 42.60	0.113 – 0.115	4.63 – 4.80
NRPB	115.63 – 120.00	0.305 – 0.317	35.08 – 37.79
IEEE	----	----	6.17 – 6.40
FCC	----	----	6.17 – 6.40
ARPANS	41.67 – 42.45	0.111 – 0.113	4.63 – 4.80
CANADA	48.21 – 49.11	0.128 – 0.130	6.17 – 6.40
ITALY	6	0.016	0.1

Guidelines for Limiting Exposure to Radiofrequency Radiation

Comparison between different Reference Levels for general public exposure for frequency band of GSM 1800 (1805 – 1880 MHz):

	E-field strength (V/m)	H-field strength (A/m)	Power density (W/m^2)
ICNIRP	58.42 – 59.62	0.157 – 0.160	9.03 – 9.40
NRPB	194	0.52	100
IEEE	----	----	12.03 – 12.53
FCC	----	----	10
ARPANS	58.20 – 59.40	0.155 – 0.158	9.03 – 9.40
CANADA	61.4	0.163	10
ITALY	6	0.016	0.1

Guidelines for Limiting Exposure to Radiofrequency Radiation

Comparison between different Reference Levels for general public exposure for frequency band of UMTS (2110 – 2170 MHz):

	E-field strength (V/m)	H-field strength (A/m)	Power density (W/m^2)
ICNIRP	61	0.16	10
NRPB	194	0.52	100
IEEE	----	----	14.07 – 14.47
FCC	----	----	10
ARPANS	61.4	0.163	10
CANADA	61.4	0.163	10
ITALY	6	0.016	0.1

International PD Guidlines

GSM-900: 4.63 W/m2 = 0.463 mW/m2

GSM-1800: 9 W/m2 = 0.9 mW/m2

UMTS-2110 : 10 W/m2 = 1 mW/m2

International Specific Absorption Rate (SAR) Guidelines

The US FCC : 1.6 W/kg averaged over 1g

ICNIRP: 2 W/kg averaged over 10g

Important Notes on Exposure guidelines

1. Exposure in the near field of an antenna, where localized peaks can occur in power absorption. although whole-body averaged SAR is below the basic restriction, potentially hazardous local heating could occur in the tissues around the SAR hot spot. (phones near head case)

2. The highest frequency at which SAR is still considered:
   10 GHz for the ICNIRP guideline and European Recommendation,
   6 GHz for the IEEE standard and the FCC regulation.
   Because the millimeter-wave frequency range absorption is extremely superficial power density (S) is used.

3. Basic restrictions and reference levels are intended as time-averaged values, with averaging times varying, for the different guidelines considered, from 6 to about 30 minutes. (6 minutes, adopted by ICNIRP, 30 mins IEEE)

Peak Power Levels

- GSM handset can have a peak power of **2 watts**
- US analog phone had a maximum transmit power of **3.6 watts.**
- Other digital mobile technologies, such as CDMA and TDMA, use lower output power, typically below **1 watt.**

http://www.s21.com/sar.htm

Main characteristics of a GSM hand-held terminal transmitter

	GSM 900	DCS 1800
Frequency band	890 – 915 MHz	1710 – 1785 MHz
Channel width	200 kHz	200 kHz
Peak radiated power	2 W	1 W
Multiple access technique	FDMA + TDMA	FDMA + TDMA
Modulation scheme	GMSK	GMSK
Maximum average radiated power	250 mW	125 mW

Main characteristics of a GSM base-station transmitter

	GSM 900	DCS 1800
Frequency band	935 – 960 MHz	1805 – 1880 MHz
Channel width	200 kHz	200 kHz
Peak radiated power (typical)	30 W	30 W
Multiple access technique	FDMA + TDMA	FDMA + TDMA
Modulation scheme	GMSK	GMSK

Dosimetry Techniques

Analytical

❖ available for simple geometries and handsets

❖Problem: These are rather restricted in their application to real life models.

Measurments

❖ Real radiating structure to expose anatomically shaped phantoms of the human body.

❖ Problem: rather simplified models of the human body, not able to represent the complexity of a biological subject.

Numerical

❖Very accurate and realistic models of the human body

❖Problem: The difficulty in modelling complex radiating structures

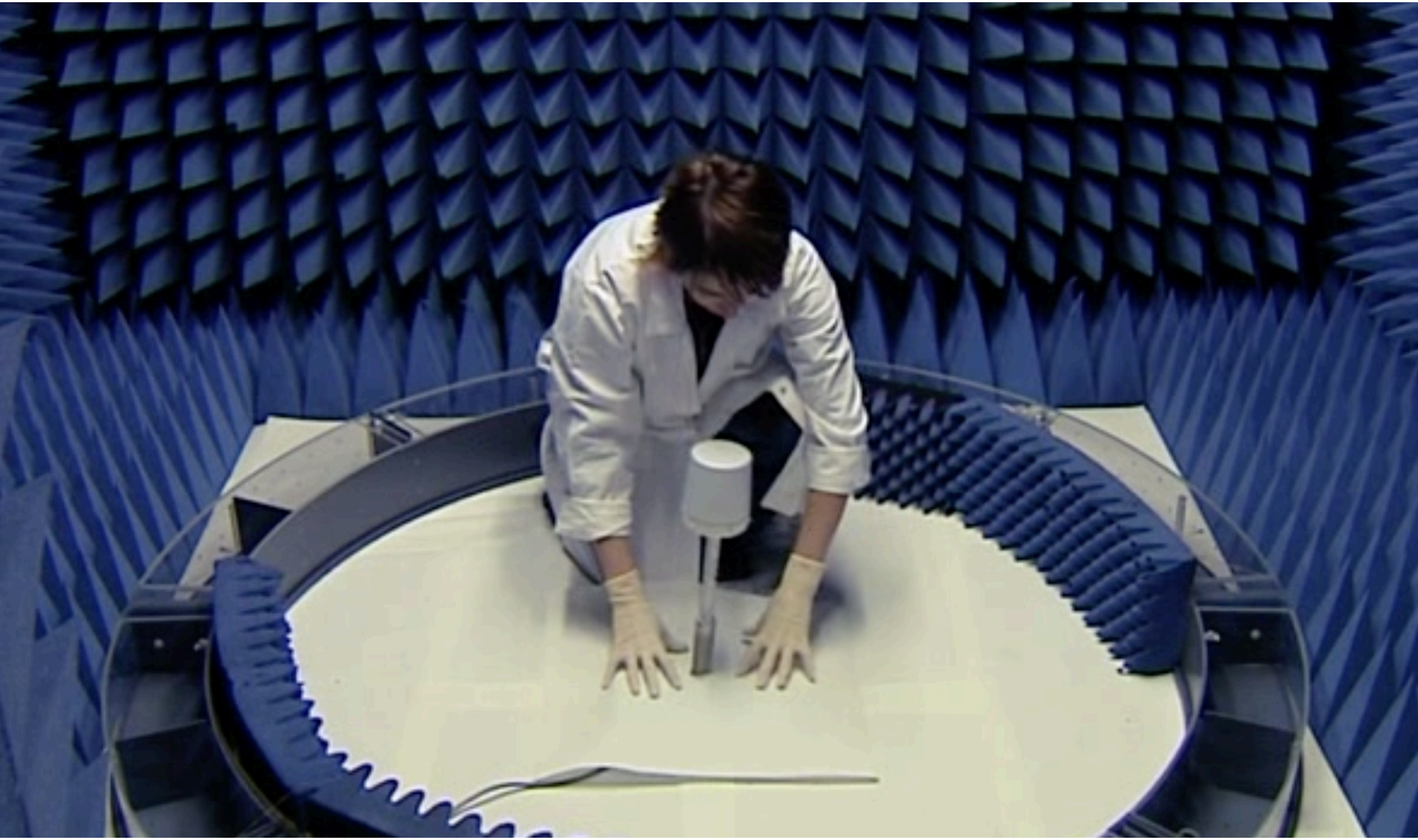
Can be overcame by adopting appropriate numerical techniques.

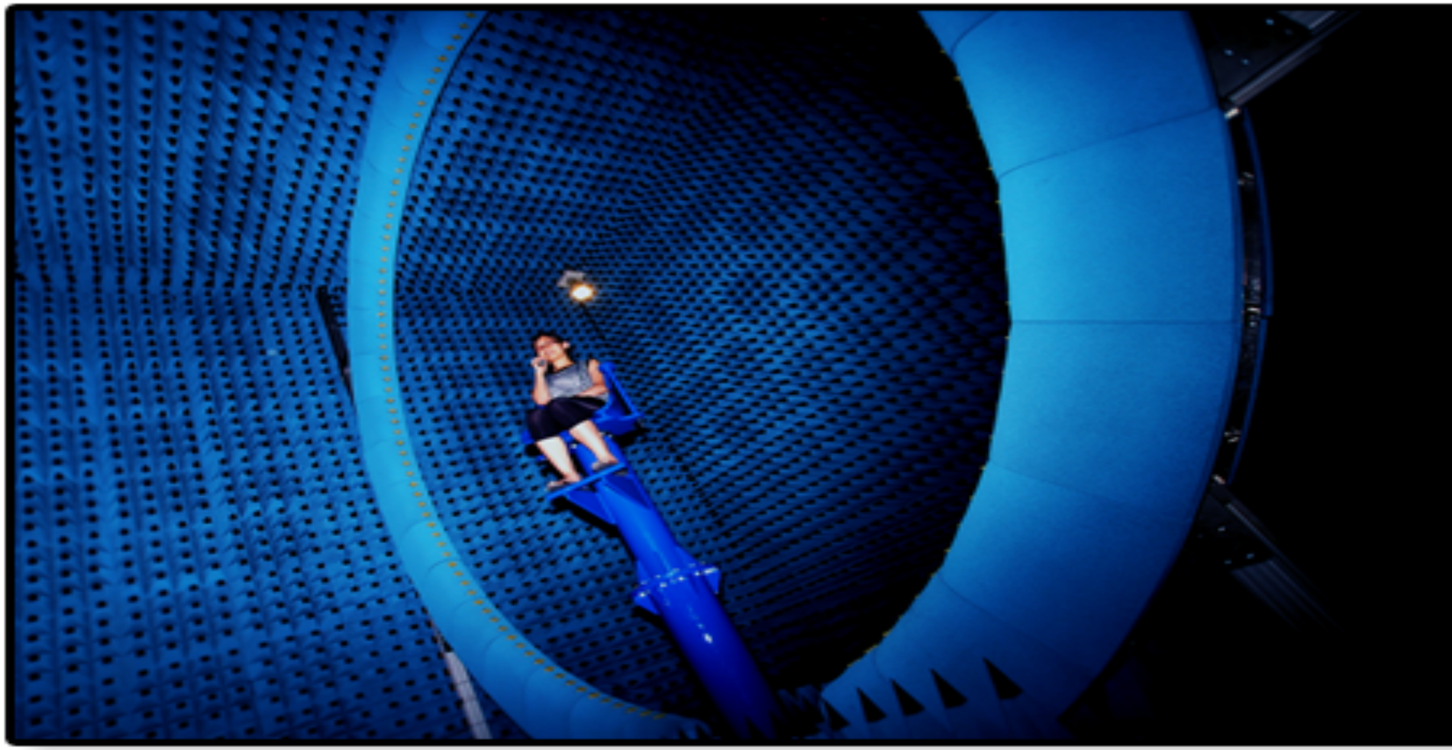
SAR Measurments

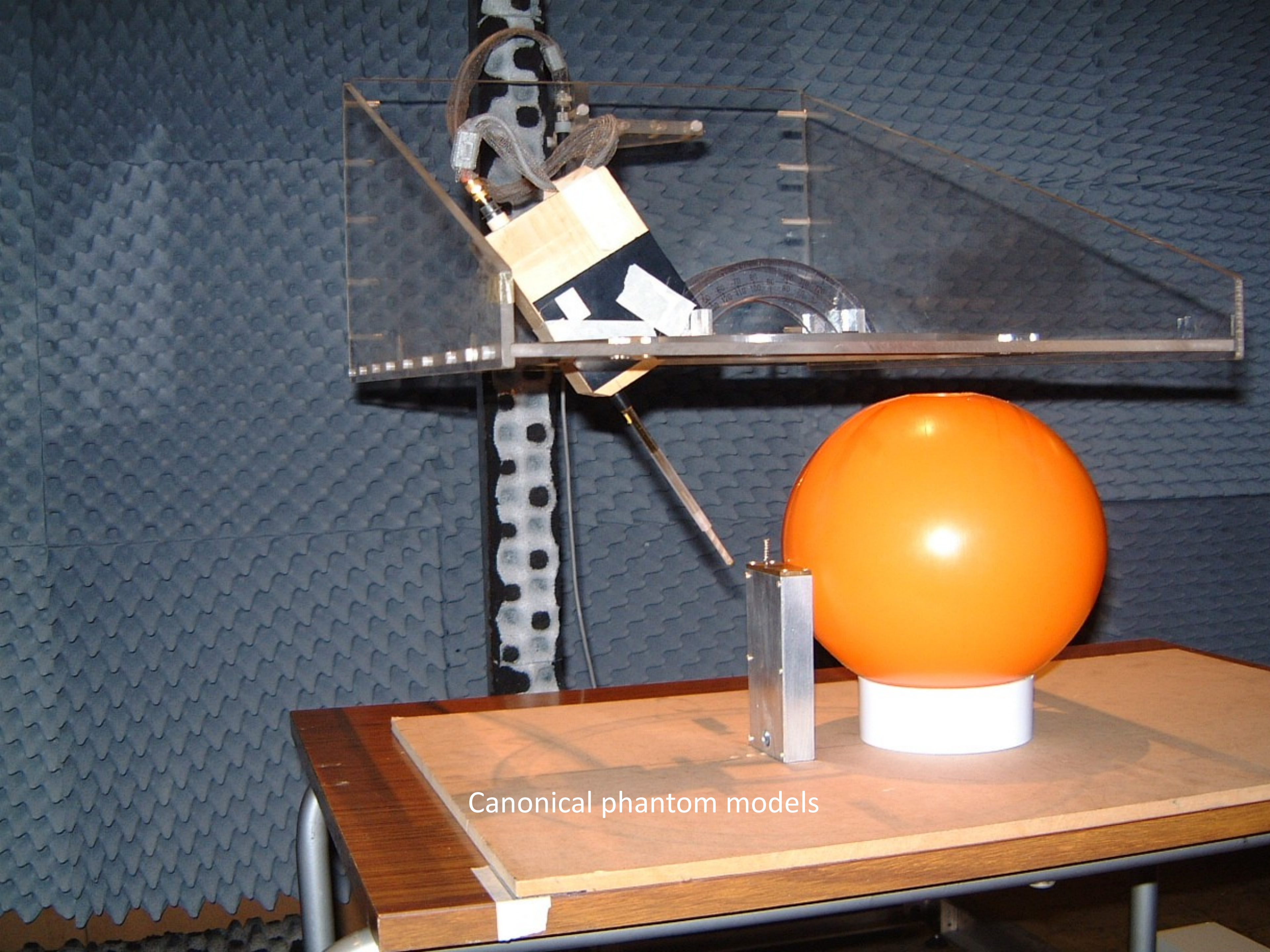
performs a direct measure of the induced electric field in canonical and realistic phantom models filled with tissue simulating liquid using

1. **Temperature-sensing probes**

2. **E-field probes**







Canonical phantom models

Phantom models

- a phantom has been produced that is based upon the dimensions of a large adult male head

  (larger head = higher SAR).

- This phantom has been **constructed with compressed thin ears** to simulate users with small ears.

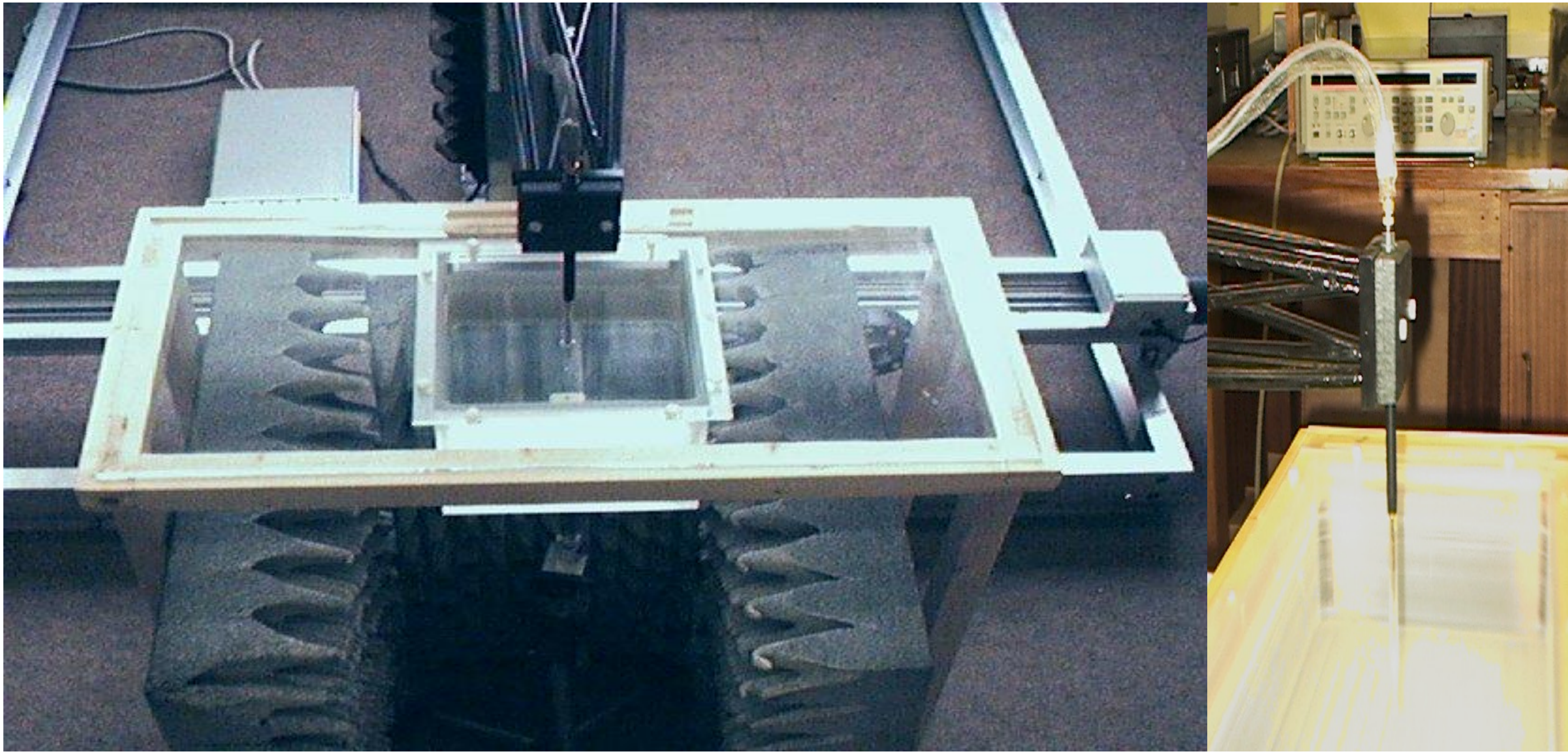
- In addition – right and left model heads are used to ensure that the different exposure areas caused by the asymmetric location of the antenna in many phones are being measured.

The Liquid

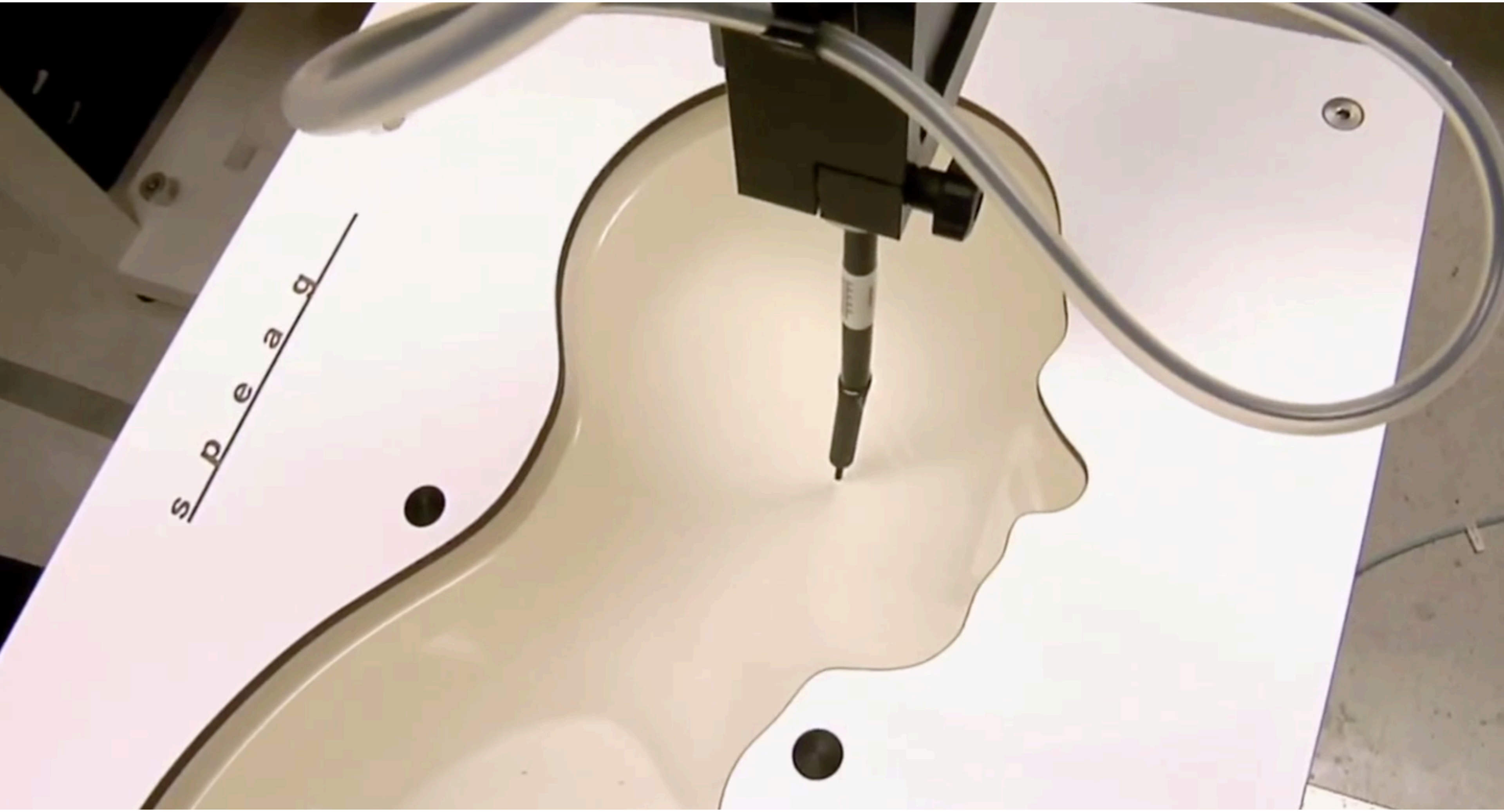
- The phantom is filled with a liquid that correlates with the dielectric properties of human head tissue.
- The dielectric properties of 'head tissue' have been calculated taking into account the properties of human brain tissue and the matching effects of the outer tissue layers of the head (e.g., skin and skull) to provide a conservative overestimate of the values.
- Different 'recipes' are used for tests on different frequencies.

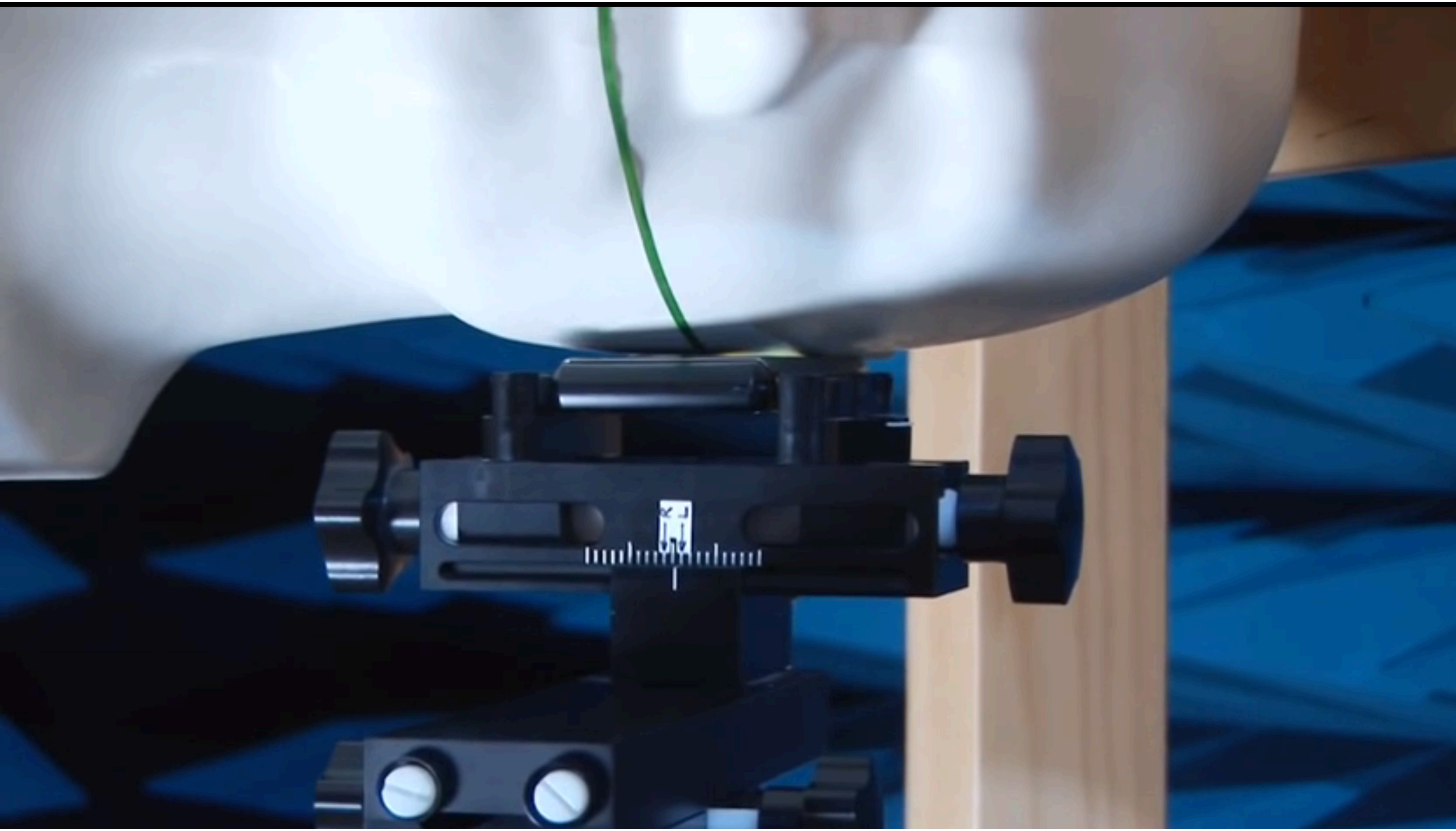
The Robot

- consists of a mechanical arm
- A special probe is then used to derive the actual SAR measurements.
- The measurements are carried out by establishing a reference point in the phantom and then scanning a specified area in and around the phantom
- while the phone is operating at its maximum certified power level.

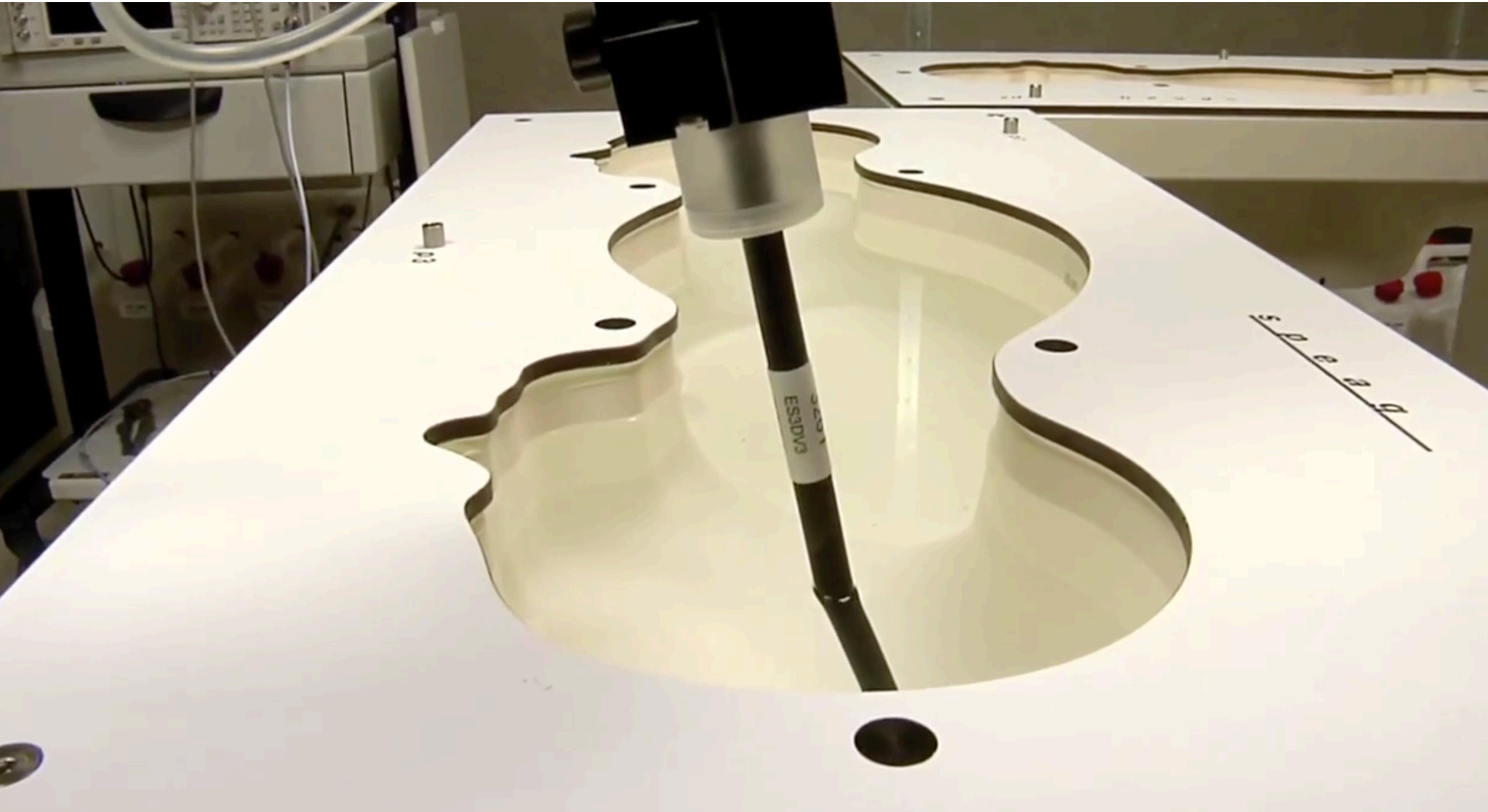


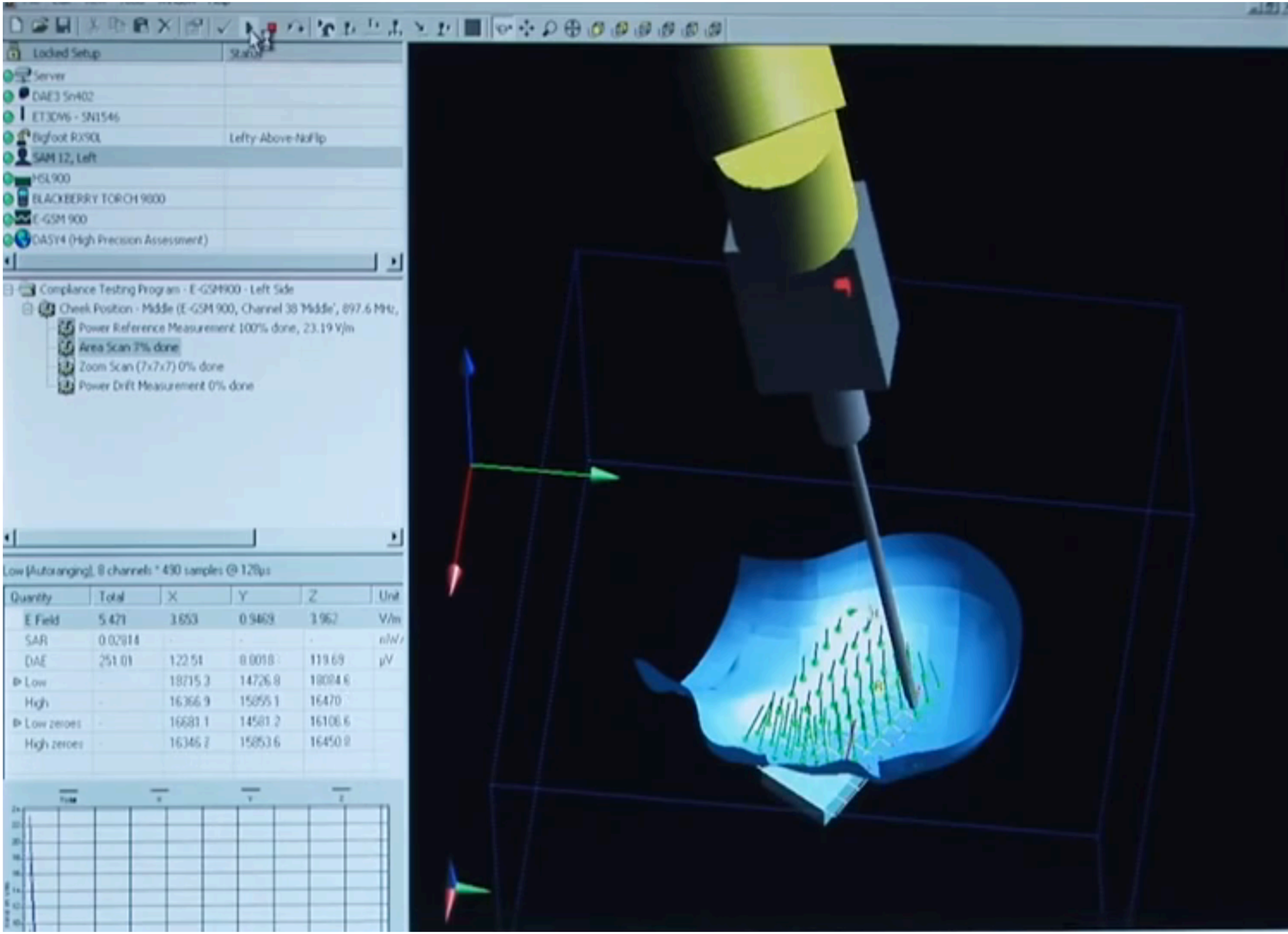
Near field measurement setup. This shows a dielectric tank to contain phantom brain liquid (not used in this test). Probe and positioner above and behind tank; test handset partially obscured below.

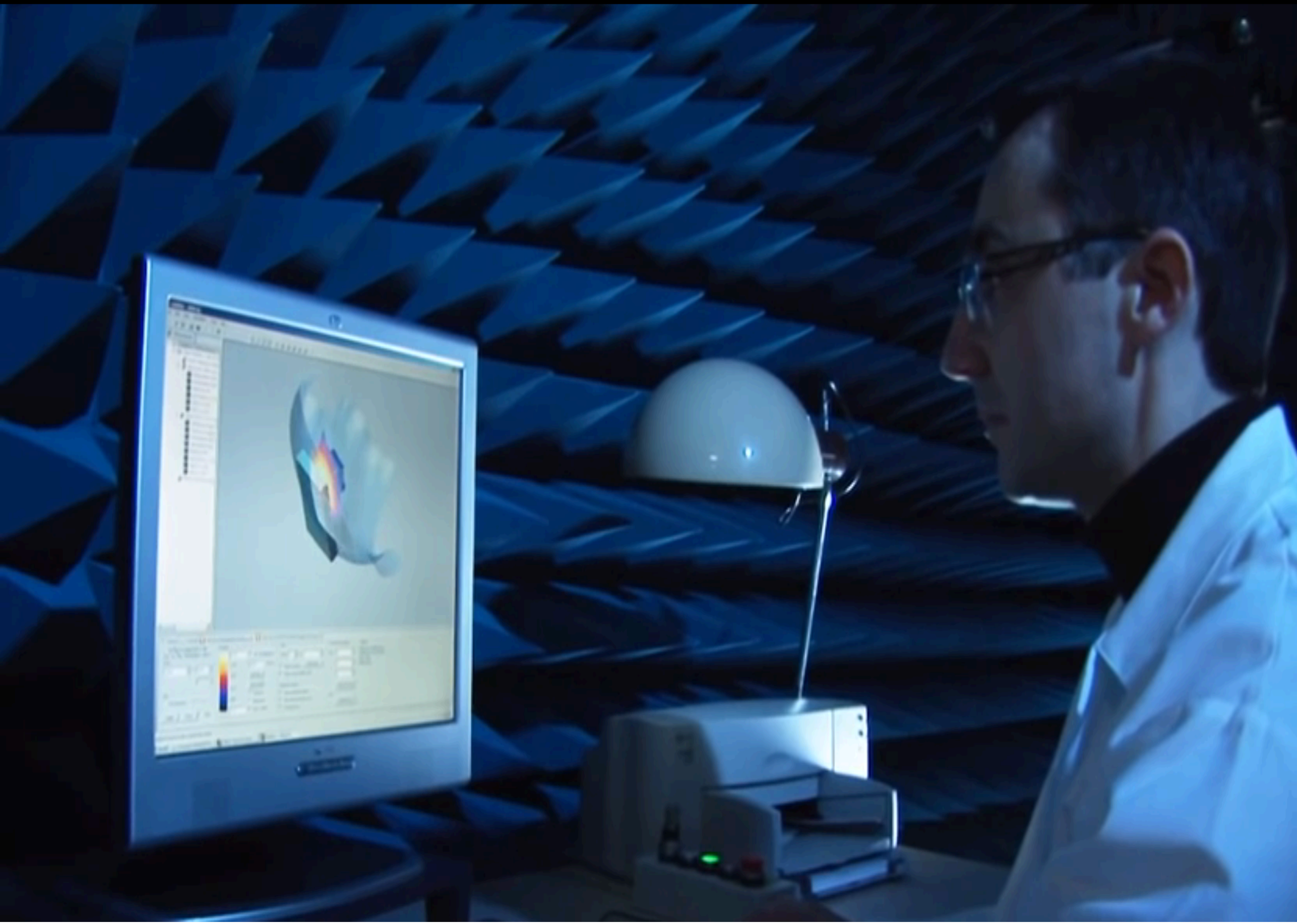

speag



http://www.youtube.com/watch?v=eH_awIiDRxU


ES3DV3


Locked Setup
Server
DAE3 Sn402
ET3DV6 - SN1546
Bigfoot RX90L
Lefty-Above-NoFlip
SAM 12, Left
MSL900
BLACKBERRY TORCH 9800
E-GSM 900
DASY4 (High Precision Assessment)
Compliance Testing Program - E-GSM900 - Left Side
Cheek Position - Middle (E-GSM 900, Channel 38 'Middle', 897.6 MHz,
Power Reference Measurement 100% done, 23.19 V/m
Zoom Scan (7x7x7) 0% done
Power Drift Measurement 0% done
Quantity
Total
X
Y
Z
Unit
E Field
SAR
DAE
Low
High
Low zeroes
High zeroes



Numerical Method and Computer Modeling

Computational Electromagnetics Classifications

Time domain methods and Frequency domain methods

Differential formulations and Integral formulations

Hybrid Methods involving Method of Moments

- Finite Element method (FE) / MoM
- Hybrid Ray-based and MoM: GTD/MoM, UTD/MoM and PO/MoM
- FDFD/GTD/MoM: GEMACS

Hybrid Methods with Finite Difference Time Domain Method

- Finite Element and Finite Volume methods /FDTD
- + Some MoM and FDTD hybrid proposals (either Time domain MoM or non iterative frequency domain MoM)
- Ray tracing / FDTD method

Method of Moments (MoM)
Frequency Domain-Integral Method

$$\boldsymbol{E}^{sct}(\boldsymbol{r}) = -j\omega\mu \oiint_S [\boldsymbol{J}_s(\boldsymbol{r}')g(R) + \frac{1}{k^2}(\nabla' . \boldsymbol{J}_s(\boldsymbol{r}'))\nabla g(R)]\, ds'$$

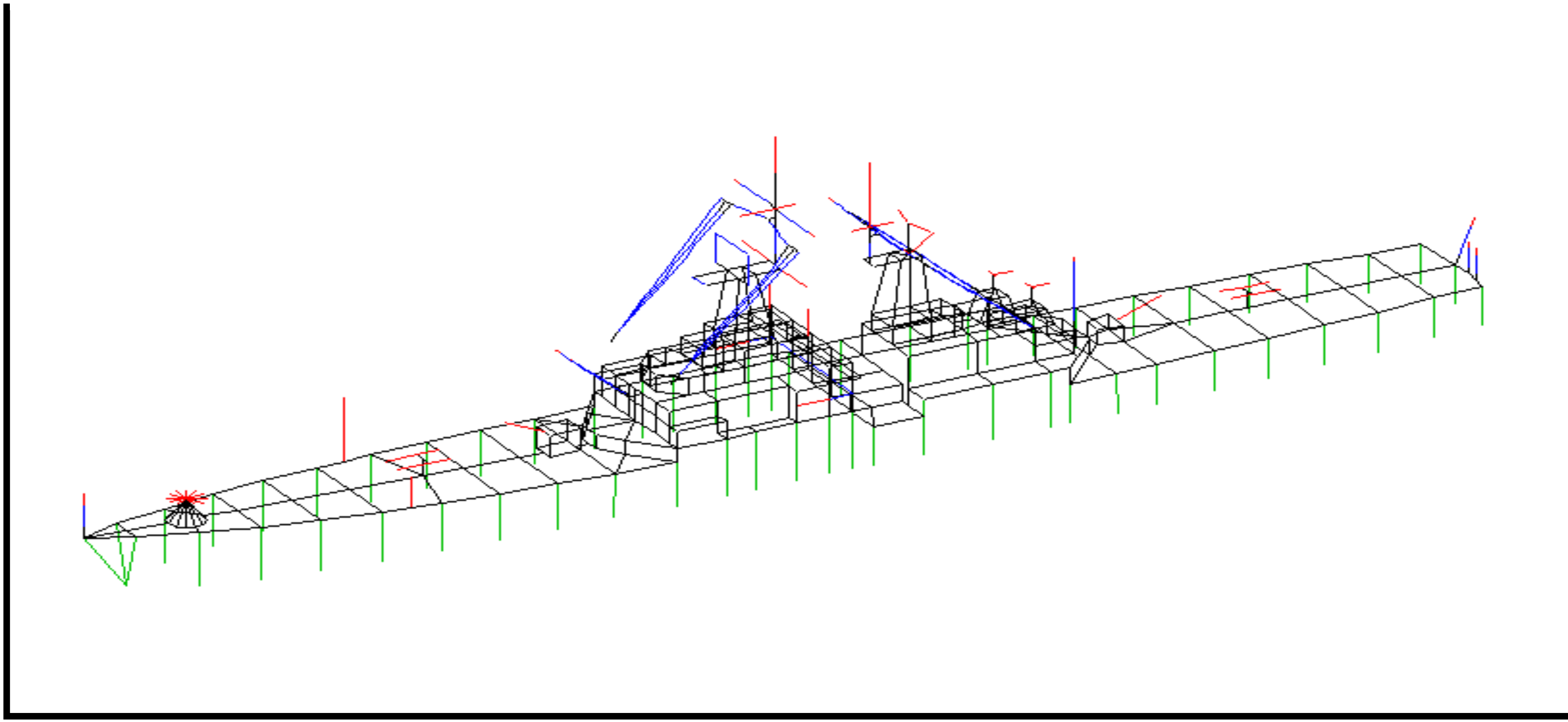
$$I(l') = \sum_{s=1}^{N} I_s f_s(l')$$

$$< J_m, E_s >= \mathrm{j}\omega\mu \mathrm{I_s} \int_{\mathrm{l'}}\int_{\mathrm{l}} [\mathrm{f_m}(\mathrm{l})\mathrm{f_s}(\mathrm{l'})(\hat{a}_m \cdot \hat{a}_s)\mathrm{g(R)} + \frac{1}{\mathrm{k}^2}\mathrm{f_m}(\mathrm{l})\frac{\partial}{\partial \mathrm{l'}}\mathrm{f_s}(\mathrm{l'})\,(\hat{a}_m \cdot \nabla \mathrm{g(R)})]\,\mathrm{dl\,dl'}$$

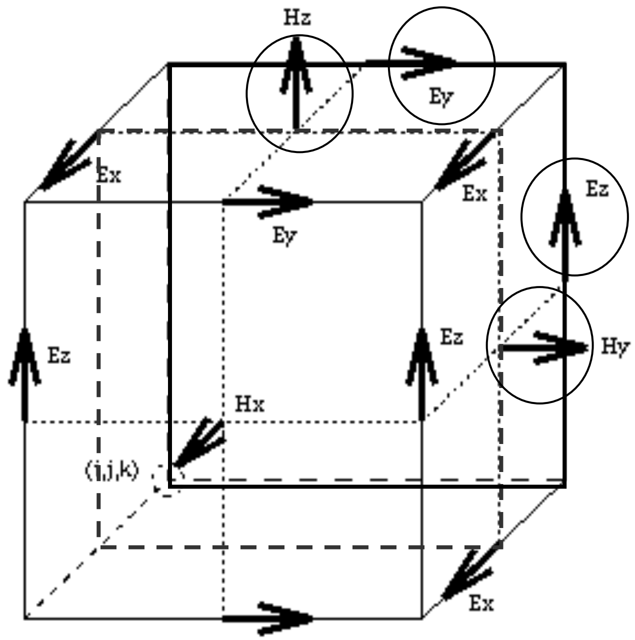
$$\left[V_m\right] = \left[Z_{ms}\right]\left[I_s\right]$$

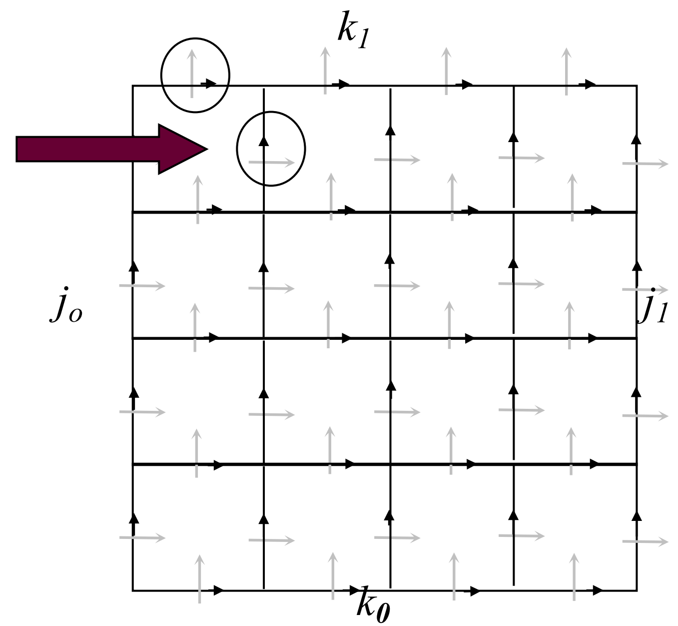
FAN ANTENNA ON MILIITARY SHIP OVER A LOSSY GROUND PLANE
THE EXCITATION IS PLACED AT 403 TAG SEGMENT NUMBER

OPERATING FREQUENCIES ARE
1.8MHz AND 3.2MHz AND 3.7MHz



Implementation of Huygens Surface





Location of E_y ($\rightarrow$) and E_z($\uparrow$) components in planes $i=i_o$
Location of H_z ($\uparrow$) and H_y($\rightarrow$) components in planes $i=i_o-1/2$

E_y components at cells referenced ($i=i_o$, $j=j_o+{}^1/_2, \ldots, j_1-{}^1/_2$; $k=k_o, \ldots, k_1$)

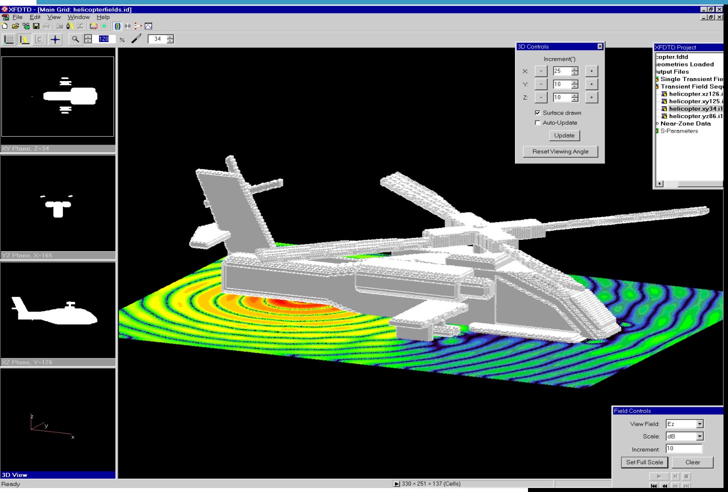
Modified Updating equations:

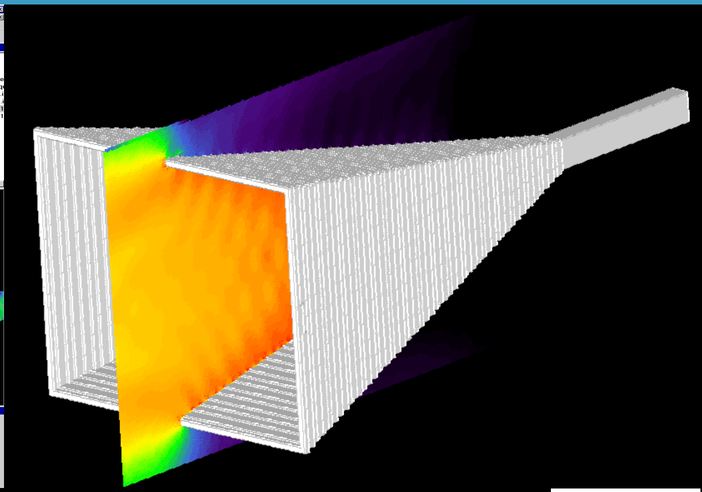
$$E_{y\,i_o,j,k}^{\;n+1} = \{E_{y\,i_o,j,k}^{\;n+1}\}_{(3.19)} - C_{b,Ey}\Big|_{i_o,j,k} . H_{z,mom\,i_o-1/2,j,k}^{\;n+1/2}$$

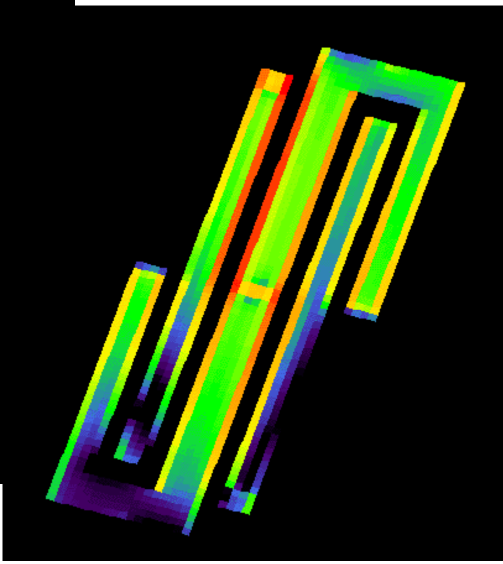
E_z components at cells referenced ($i=i_o$; $j=j_o, \ldots j_1$; $k=k_o+{}^1/_2, \ldots ,k_1-{}^1/_2$):

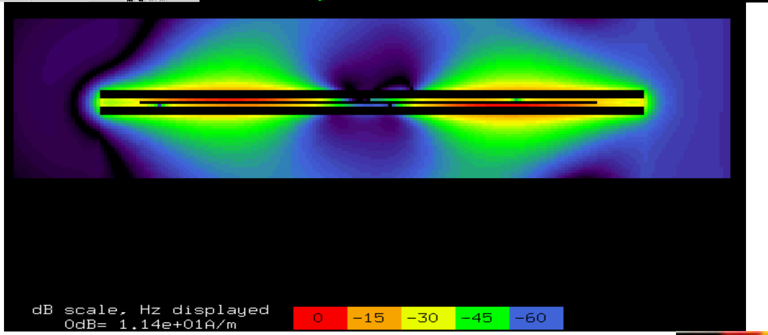
$$E_{z\,i_o,j,k}^{\;n+1} = \{E_{z\,i_o,j,k}^{\;n+1}\}_{(3.20)} + C_{b,E_z}\Big|_{i_o,j,k} H_{y,mom\,i_o-1/2,j,k}^{\;n+1/2}$$

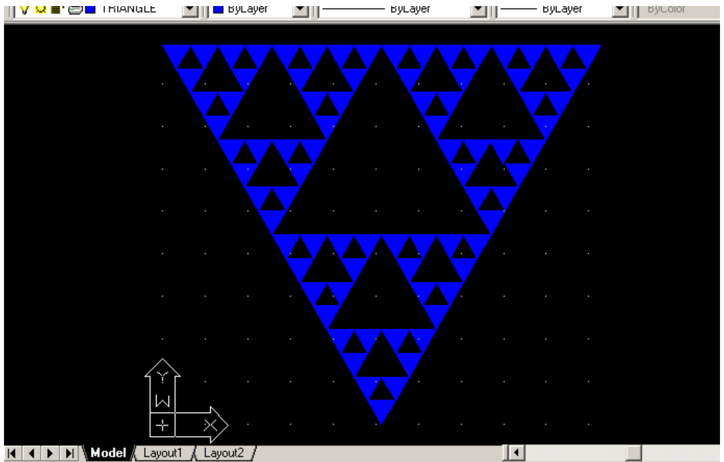
Finite Difference Time Domain (FDTD)

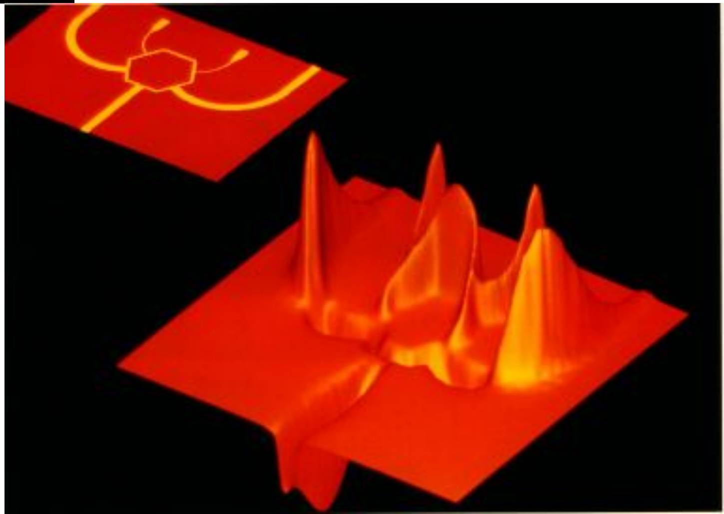




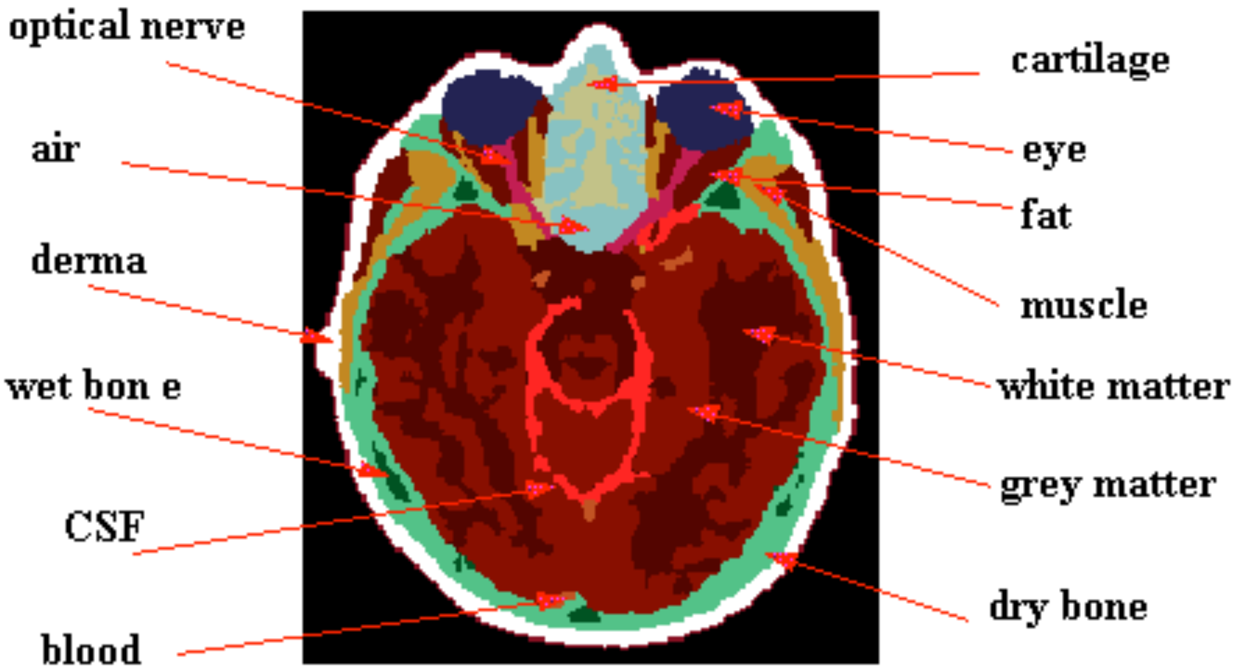








From (MRI) scan of a human head that was created within the IBREHT project. The MRI data was obtained (with permission) from Siemens Medical Systems Inc., of Iselin NJ, USA: the person depicted is anonymous.



The original unclassified image was made freely available to the world-wide computer graphics community as a canonical example for experimental purposes and hence it has acquired an 'industry-standard' status. This head dataset consists of 15 tissue types (only 13 of which have distinct electrical properties).

Table 6.3 Head model types and properties

Type ID	ε_r 900	σ(S/m) 900	ε_r 1800	σ(S/m) 1800	ρ(kg/m^3)	Number of cells	Mass weight	Type
1	1	0	1	0	1	1280248	0.009914563	Air
2	44.5	0.77	42.3	1.11	1100	20966	0.360353125	Skin
3	17.4	0.25	16.5	0.43	2200	28054	0.96435625	Bone
4	44.5	0.77	46.2	1.43	1100	4342	0.074628125	Dura
5	68.3	2.42	67.4	2.83	1020	1667	0.026567813	Cerebro-Spinal Fluid (CSF)
6	53.8	1.17	51.5	1.57	1030	13736	0.22106375	Grey Matter
7	34.5	0.59	33.1	0.84	1030	36036	0.579954375	White Matter
8	48.2	1.57	48.2	1.57	1000	0	0	Fat
9	51.8	1.11	49.6	1.58	1040	37966	0.6169475	Muscle
10	48.2	1.57	48.2	1.57	1000	0	0	blood
11	40.7	0.82	38.3	1.23	1100	3217	0.055292188	Cartilage
12	67.9	1.68	67.2	2.08	1000	308	0.0048125	Ocular Humour
13	44.1	0.71	42.1	1.1	1100	10	0.000171875	Lens of eye
14	54.9	1.17	52.7	1.67	1100	155	0.002664063	Sclera of eye
15	32.6	0.82	33.1	0.84	1040	1556	0.025285	Spinal cord
16	41.6	0.83	40.1	1.15	1030	1867	0.030047031	Cerebellum
Total head mass = 2.962143594 kg								

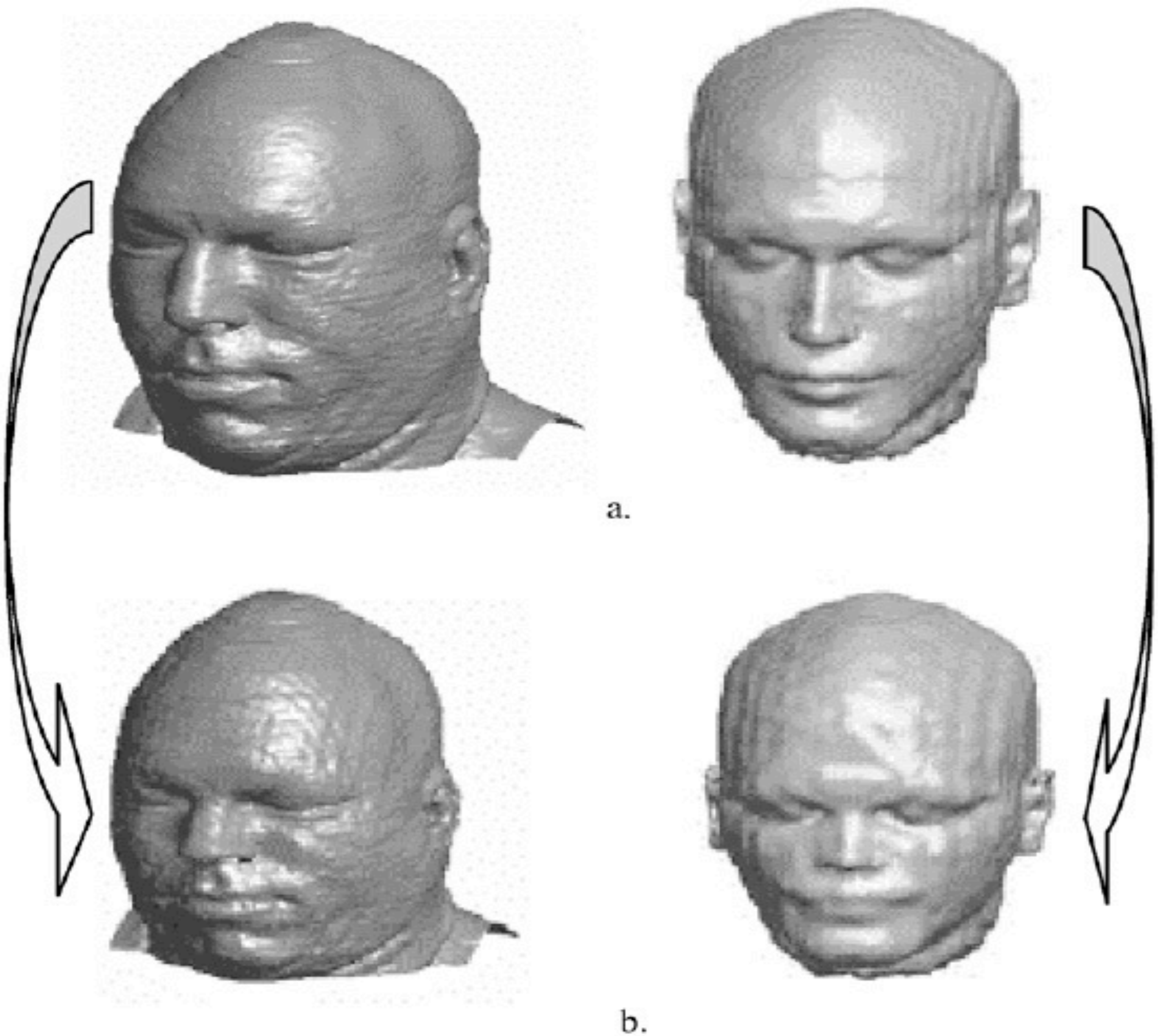
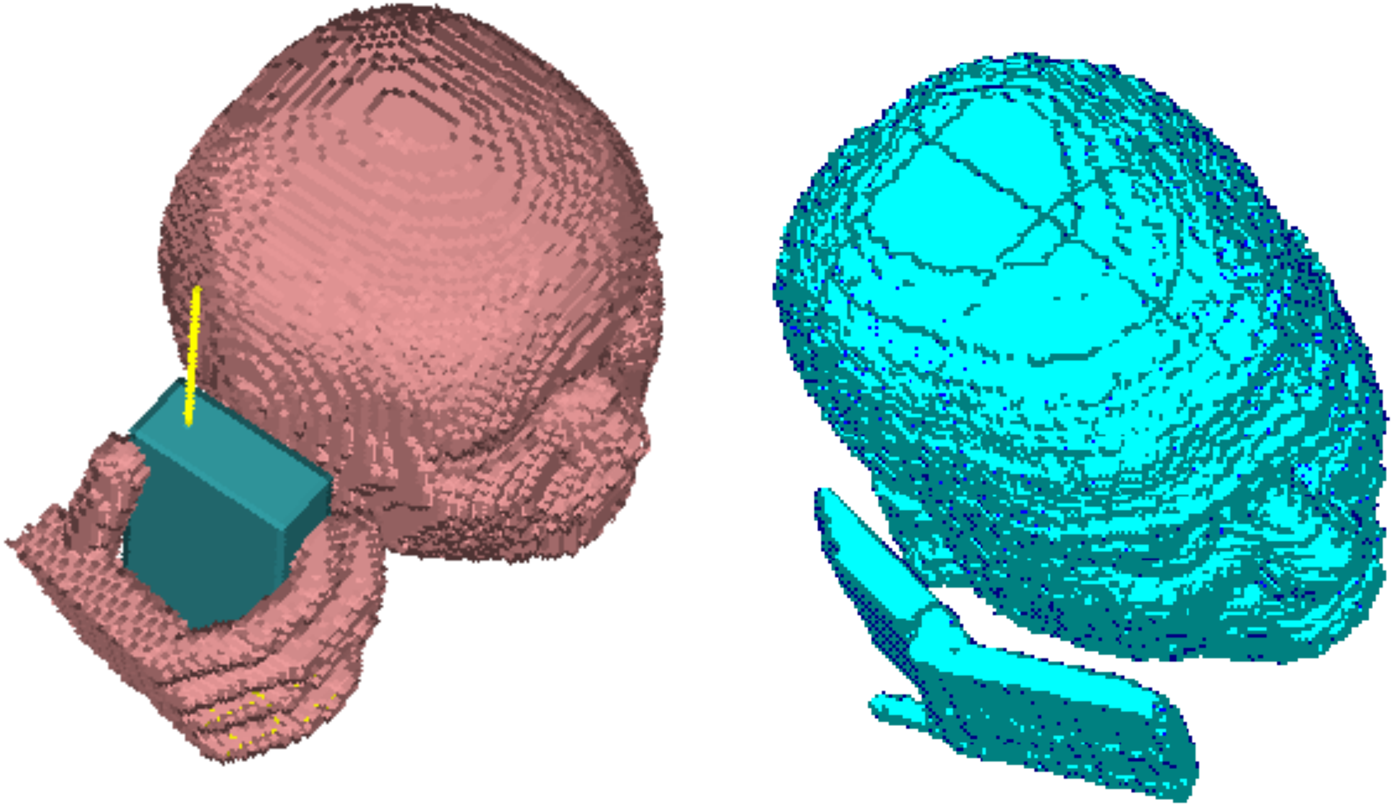


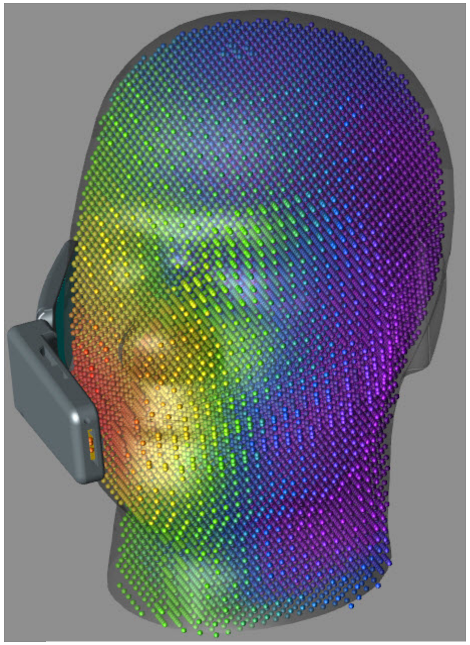
Fig. 4. Morphological description of the human head. (Adult and “CL”). (a) Adult head. (b) Five-year-old CL head.

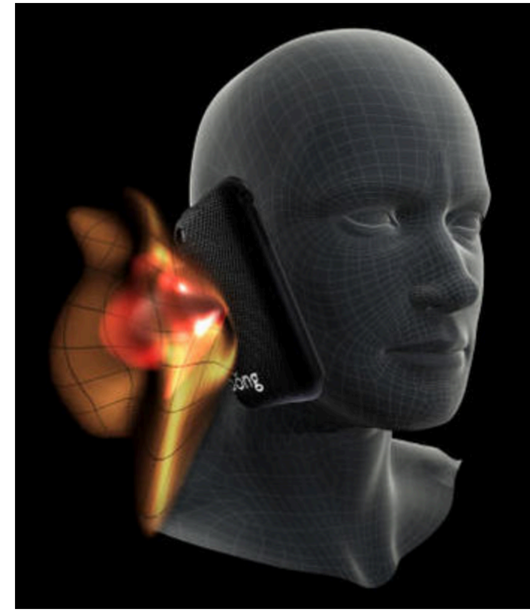
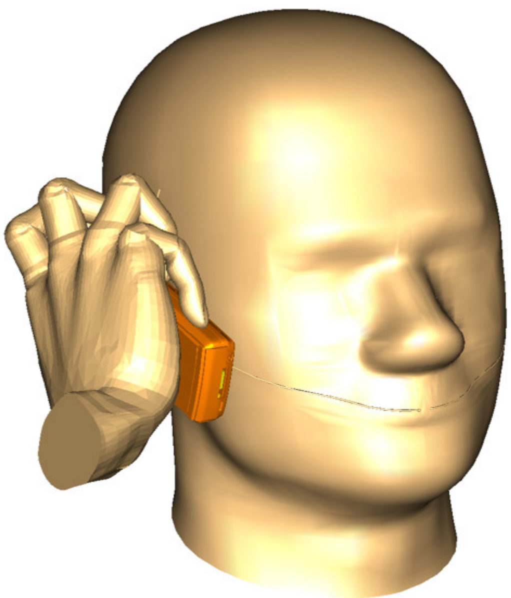
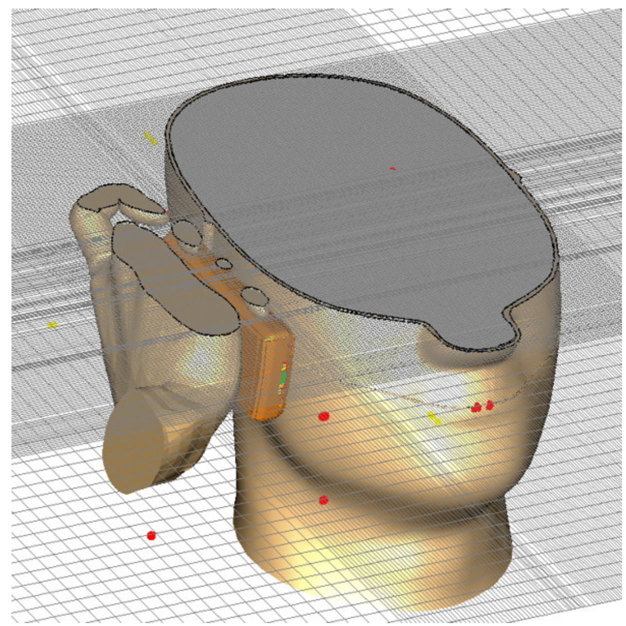


$$SAR(i,j,k) = \frac{\sigma(i,j,k)}{2\rho(i,j,k)} |\boldsymbol{E}(i,j,k)|^2$$

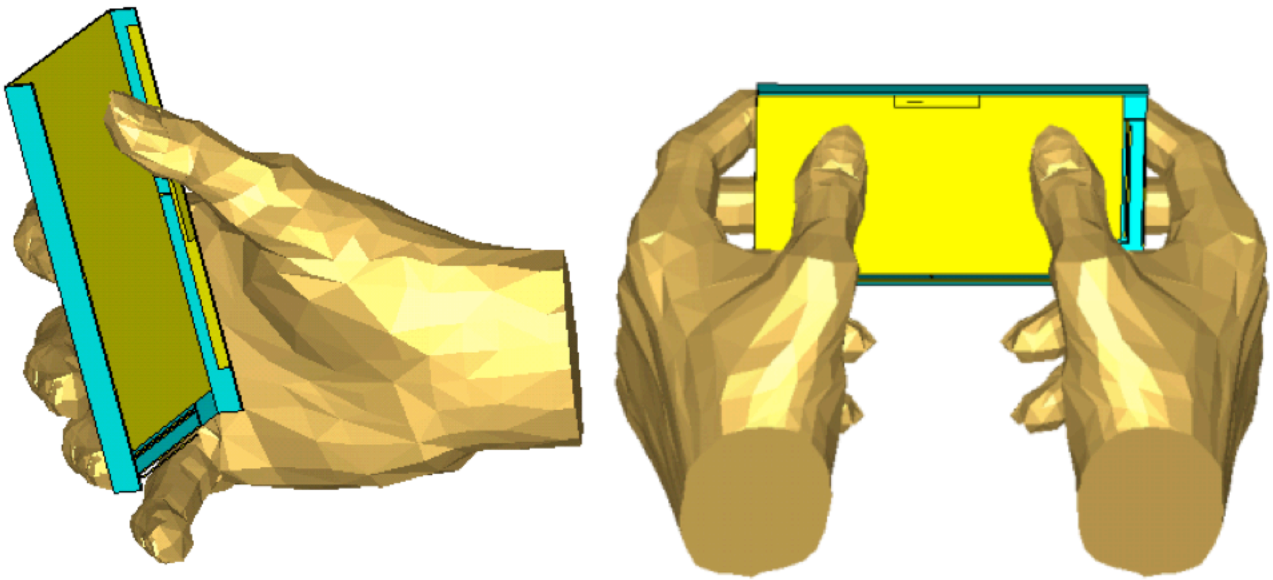
$$P_{abs} = \sum_{i,j,k} SAR(i,j,k)\, \rho(i,j,k)\, \Delta^3$$

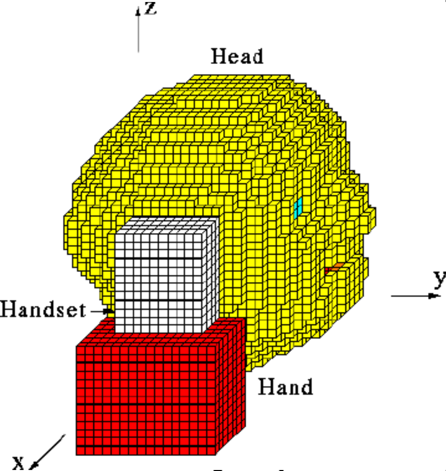
Source: CEPHOSE



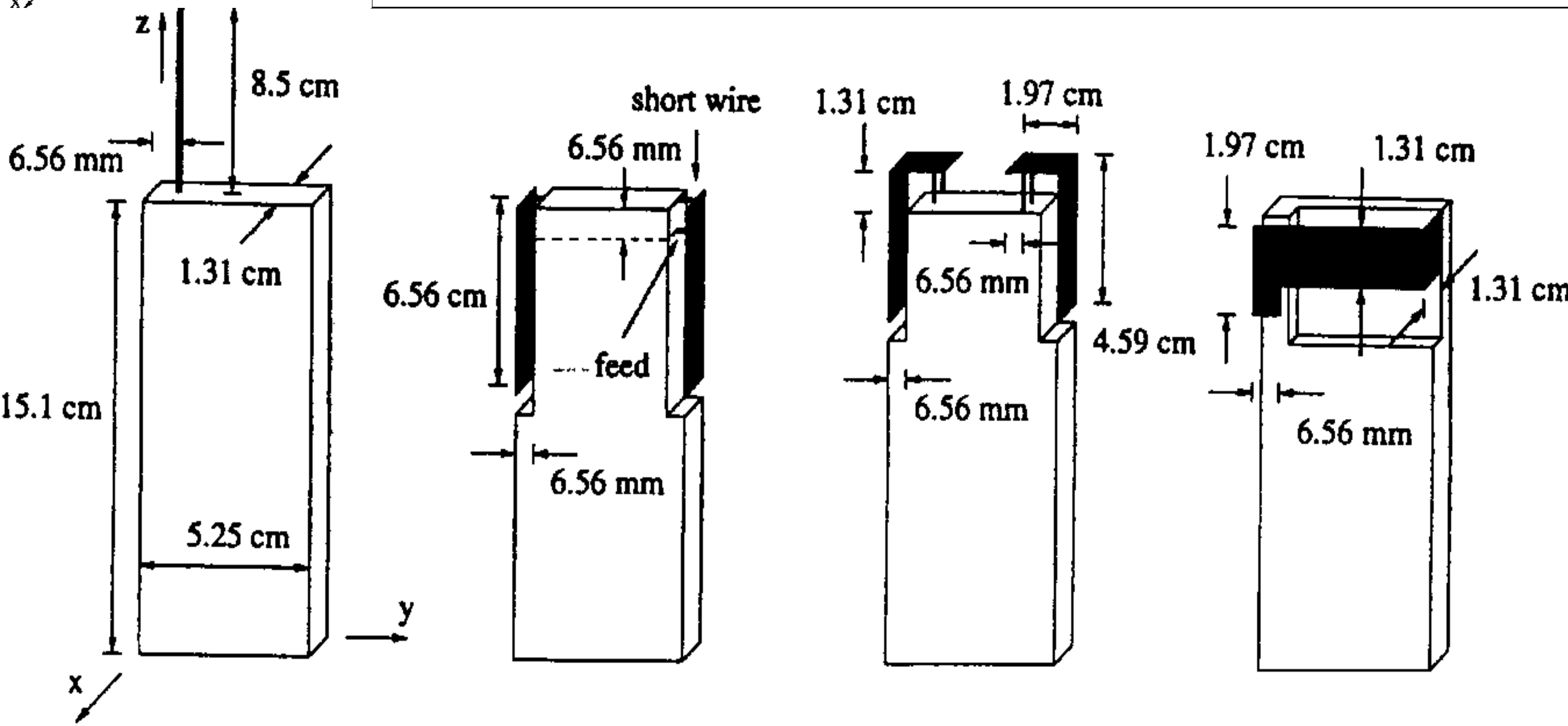




Source: CST MICROWAVE STUDIO®





Four 916 MHz handset antenna geometries (a) monopole, (b) side-mounted dual PIFA (c) top-mounted dual PIFA (d) back-mounted PIFA



CEPHOS

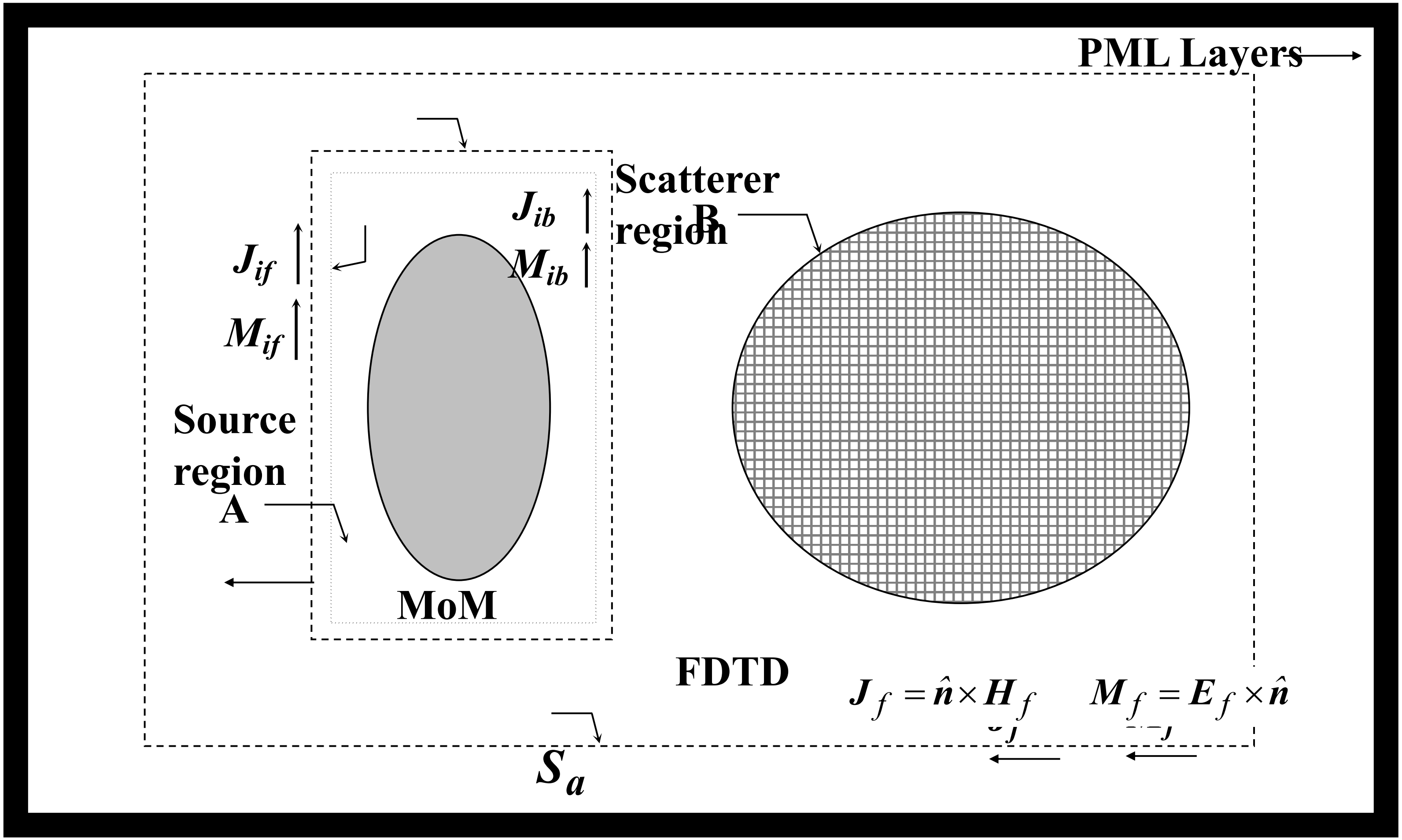
CEllular PHOnes Standard

ICCS:	Institute of Communication and Computer Systems, National Technical University of Athens and University of Thessaloniki, Greece.
Rome:	Department of Electronic Engineering, University of Roma "La Sapienza", Rome-Italy
CNET:	National Centre for Telecommunications studies, Paris-France.
Ancona:	Department of Electronics and Automation, University of Ancona, Ancona – Italy.
Bradford:	Department of Electronic & Electrical Engineering, University of Bradford, UK (Note: this refers to pure FDTD studies undertaken by a colleague of the present author).
Green/MAS:	Hybrid Green's function and method of auxiliary sources analytical technique, implemented by ICCS (see above).

Simulation of human interaction with mobile telephones using hybrid techniques over coupled domains

MA Mangoud, RA Abd-Alhameed, PS Excell

Microwave Theory and Techniques, IEEE Transactions on 48 (11), 2014-2021

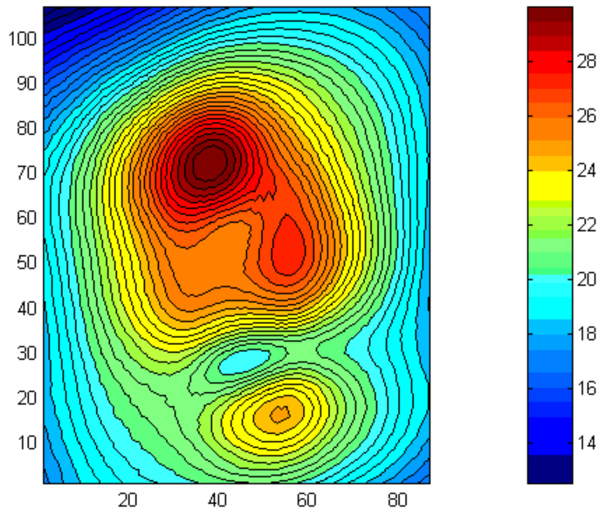


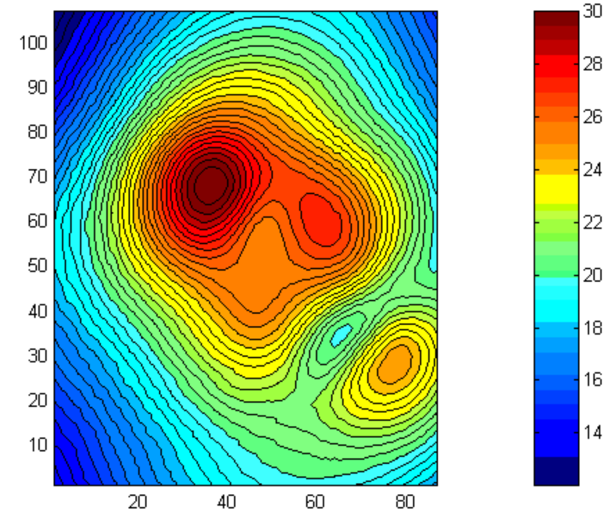
$$J_{if} = \hat{n} \times H_{if} \qquad M_{if} = E_{if} \times \hat{n} \qquad V_b = \int_{S_c^-} (J_{ib} . E_{ms} - M_{ib} . H_{ms}) ds_c^-$$

$$\nabla \times E = -\frac{\partial B}{\partial t} - M_{if} \qquad \nabla \times H = \frac{\partial D}{\partial t} + J_{if} \qquad V_b = \sum_{k=1}^{n_{s_c^-}} (J_{ib_k} . E_{ms}(r, r_k') - M_{ib_k} . H_{ms}(r, r_k')) a_k$$

CEPHOS

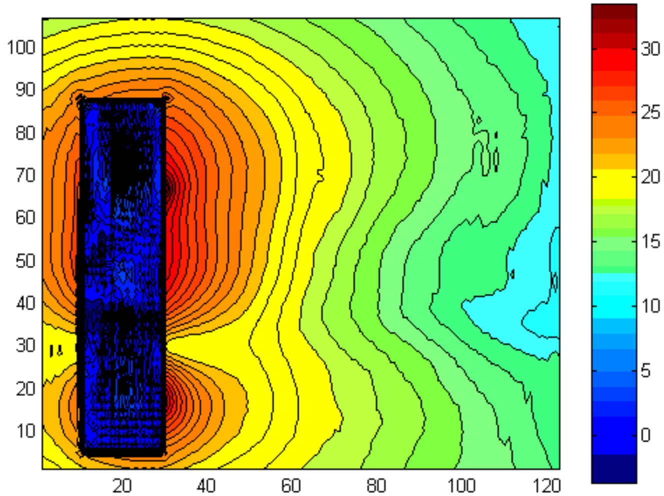
Results for Free Space Simulation of Handset

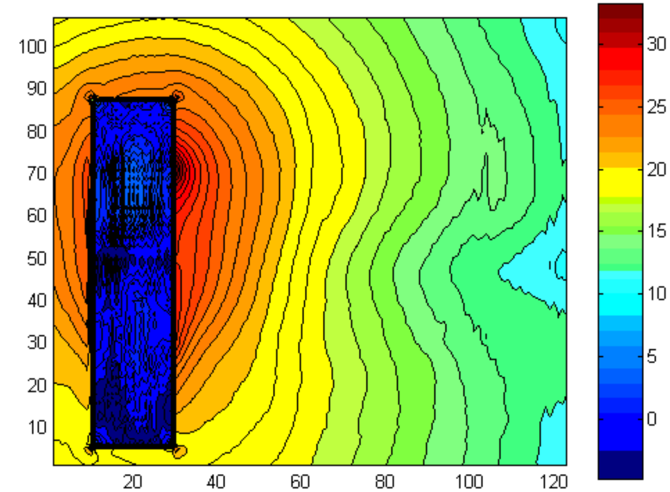




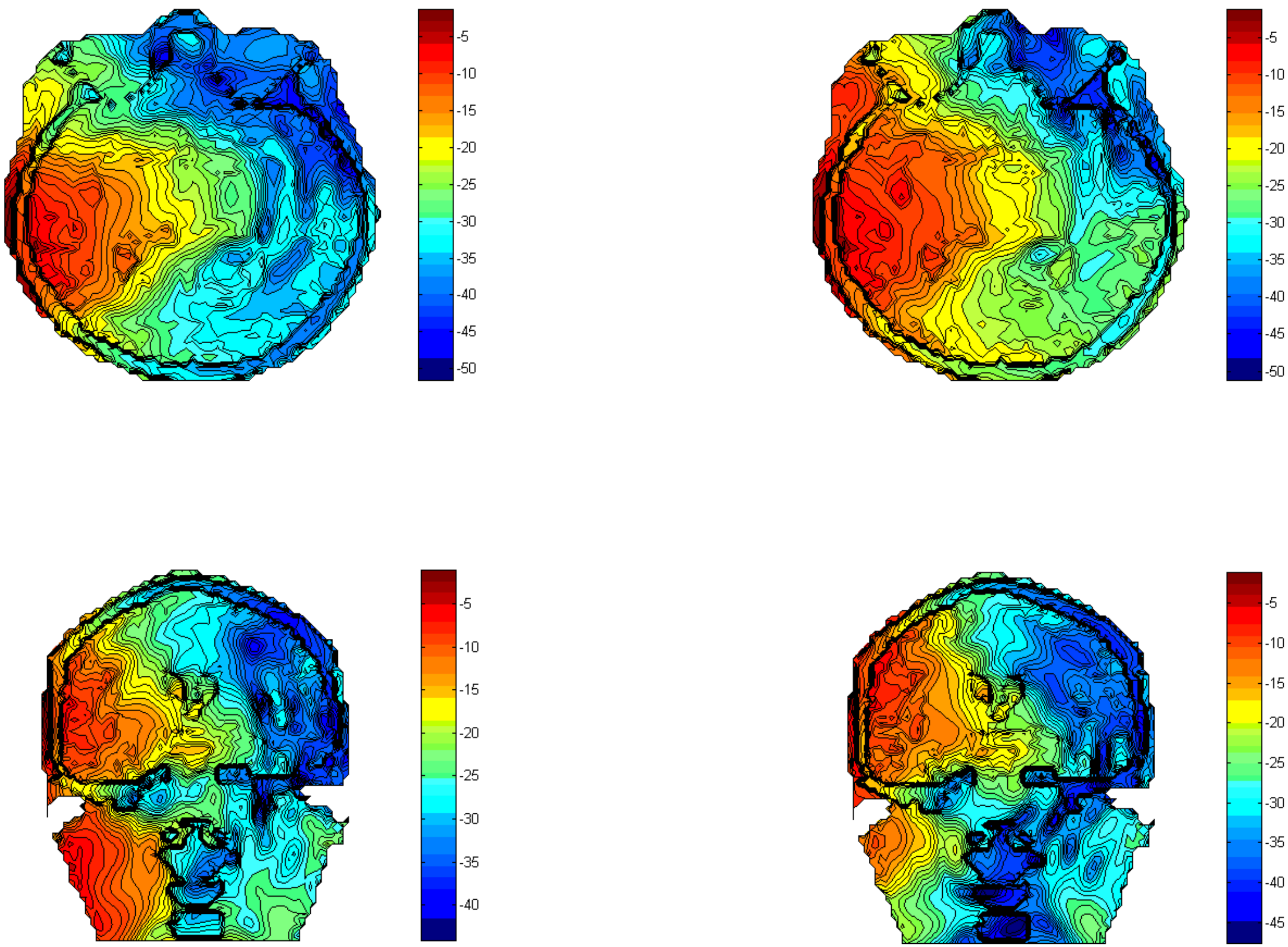
Near field 1 cm from the point *E* on the helix handset (vertical case)

Near field 1 cm from the point *E* on the helix handset (rotated 30 degrees)

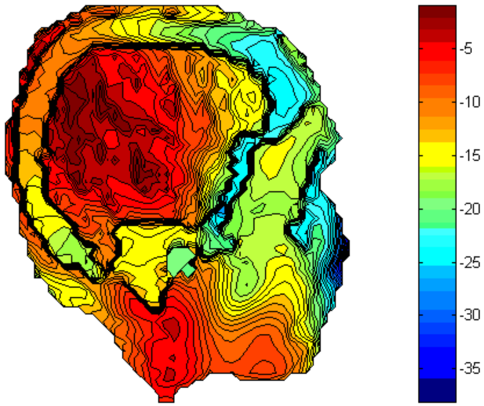




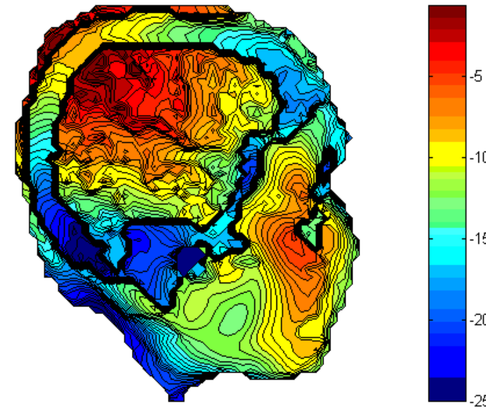
Unaveraged MAX SAR, for the realistic head image adjacent to the helical antenna handset, as modelled by the hybrid method.



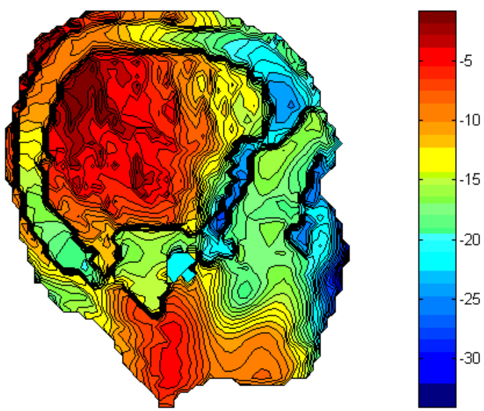
Unaveraged SAR, normalised to its maximum value, for the realistic head image adjacent to the helical antenna handset



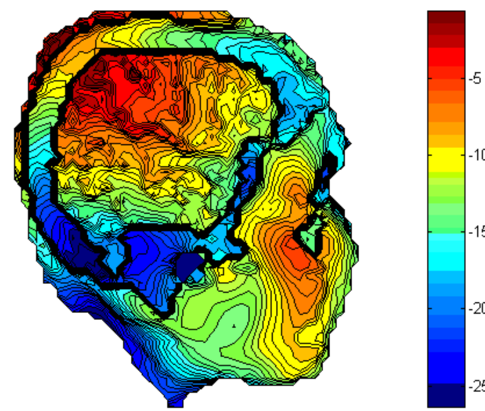
Vertically positioned helix handset at vertical *y-z* plane 2.5 cm from ear canal of head model



Helix handset rotated by 30 degree at vertical *y-z* plane 2.5 cm from ear canal of head model

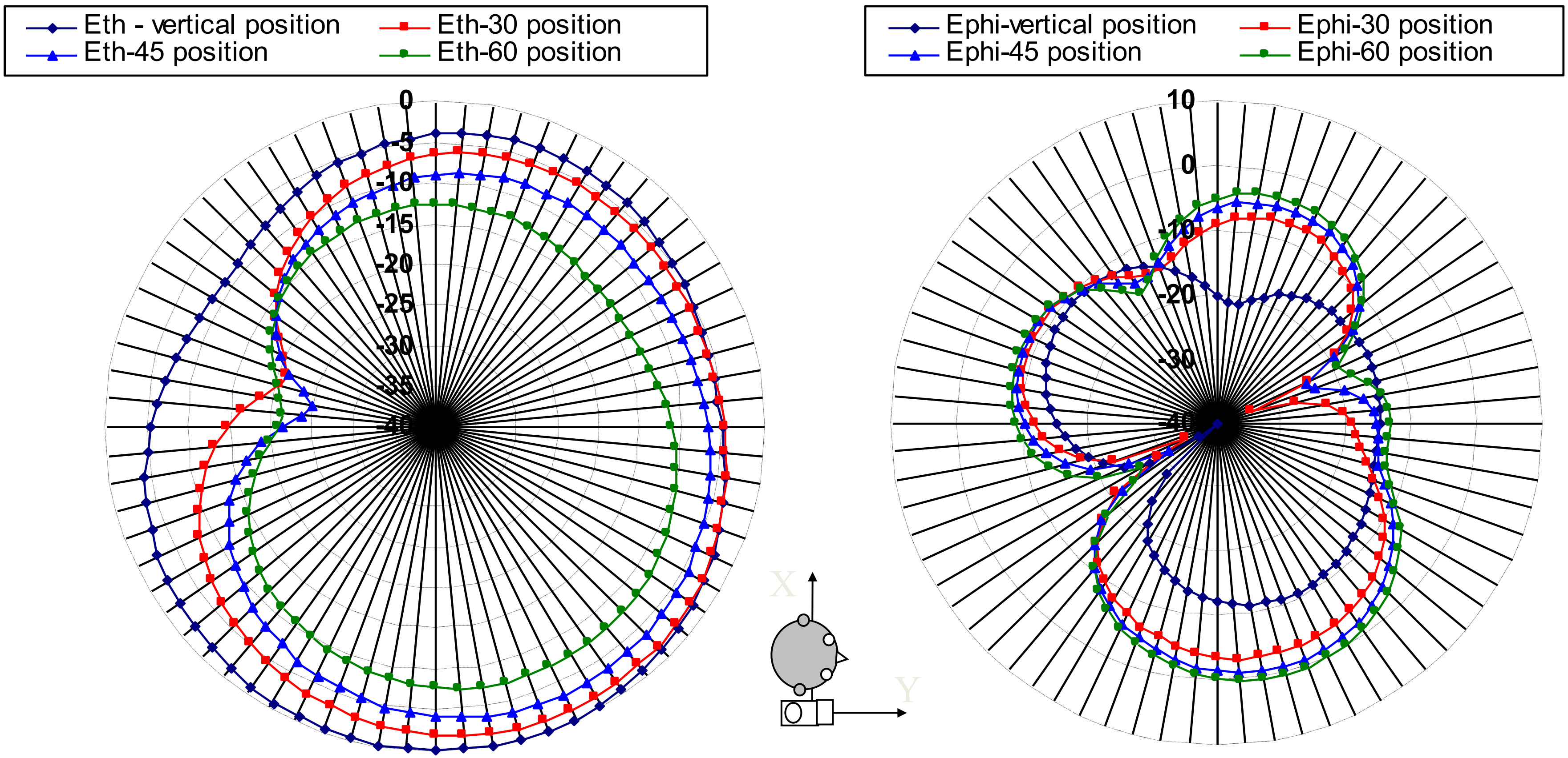


Vertically positioned monopole handset at vertical *y-z* plane 2.5 cm from ear canal of head model



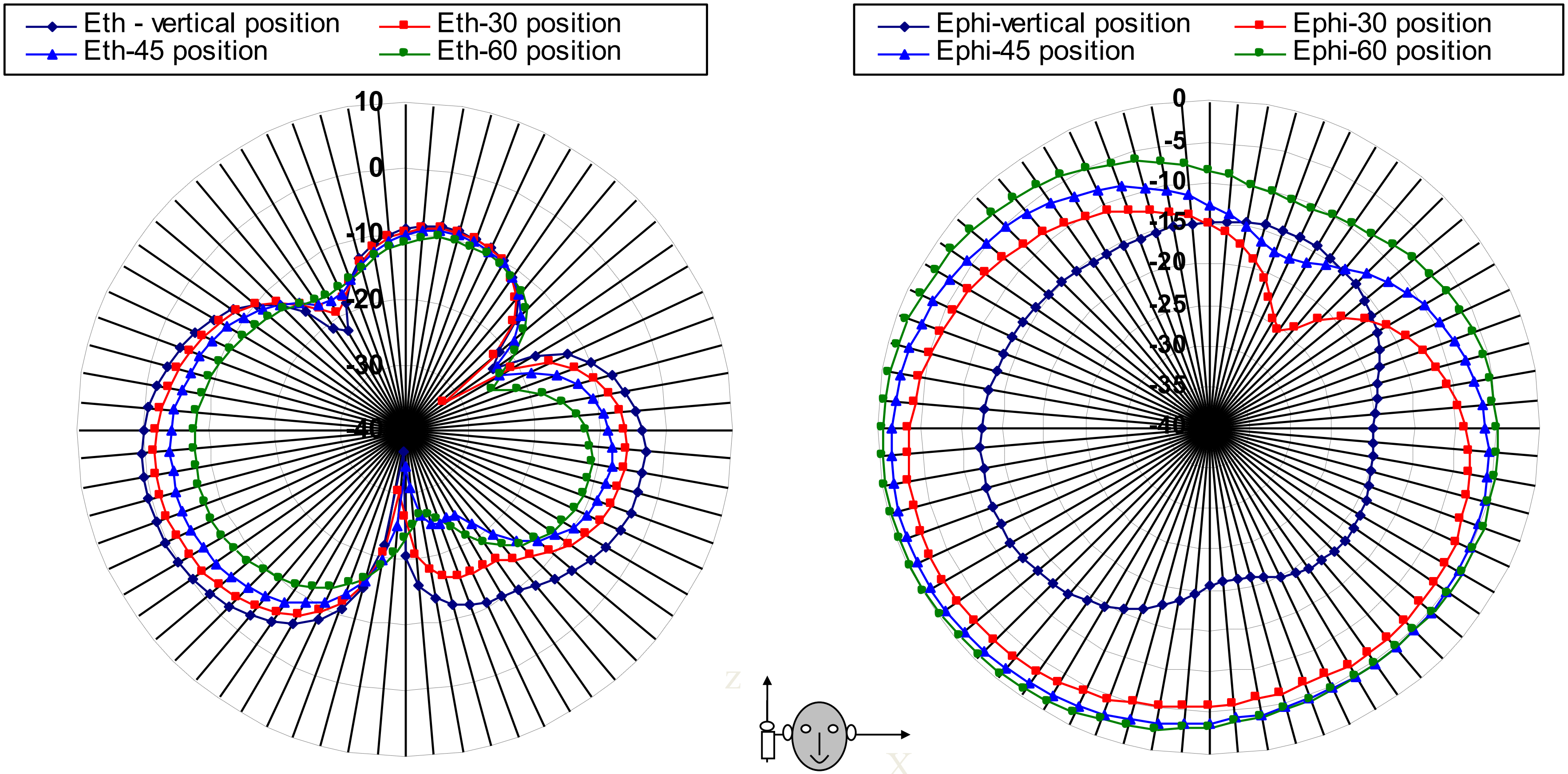
Monopole handset rotated by 30 degree at vertical *y-z* plane 2.5 cm from ear canal of head model

Gain patterns (dBi) computed using the hybrid for CNET handset ('Telephone A') adjacent to the head at four tilt angles.

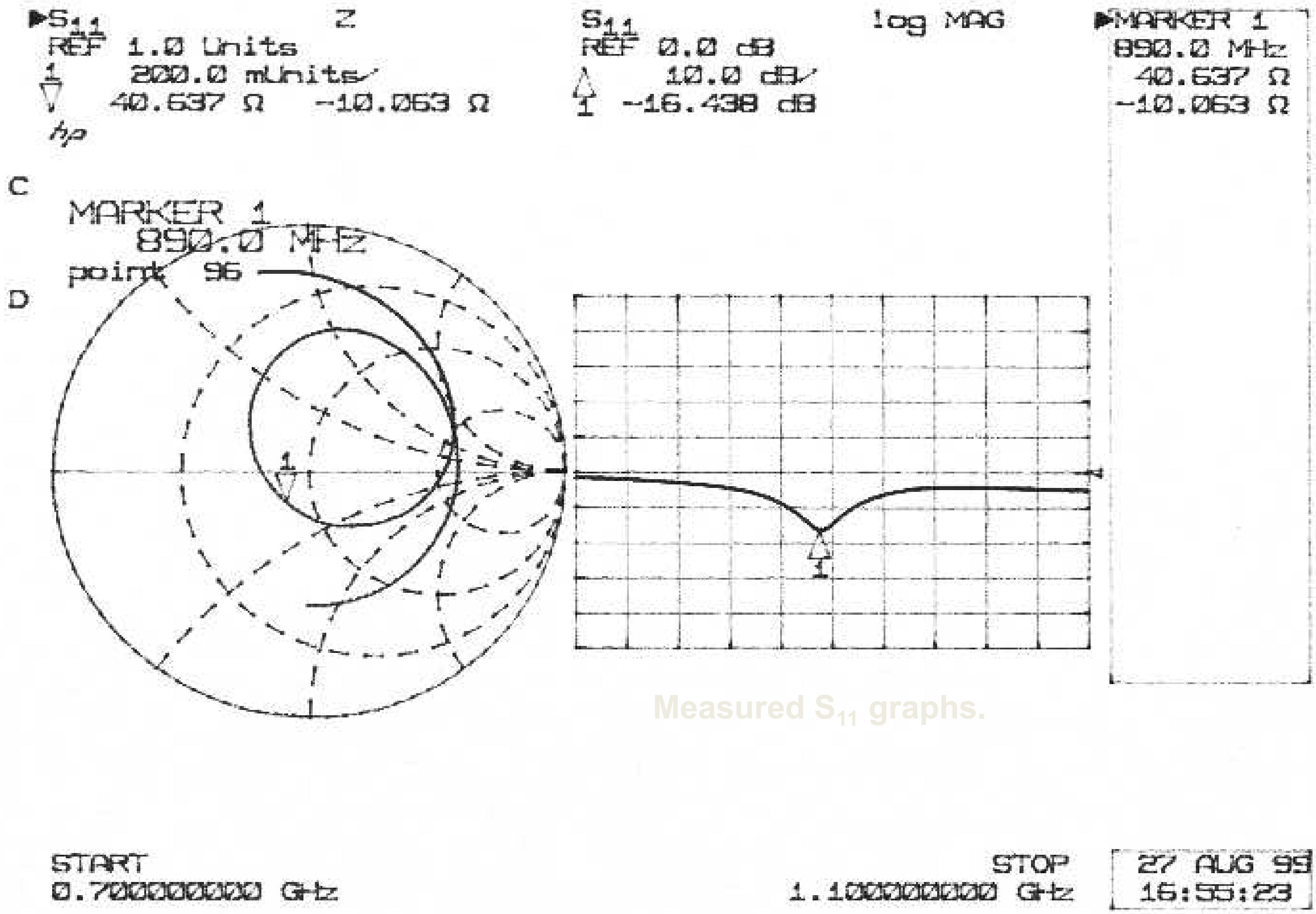


Azimuth pattern.

Gain patterns (dBi) computed using the hybrid for CNET handset ('Telephone A') adjacent to the head at four tilt angles.

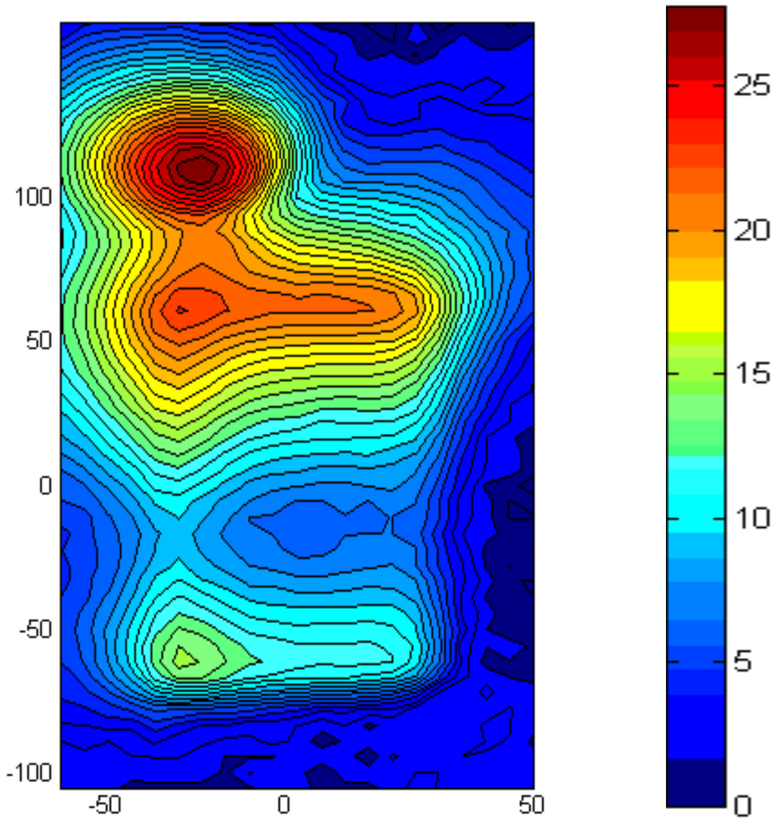


Elevation ($\phi=0^o$) pattern

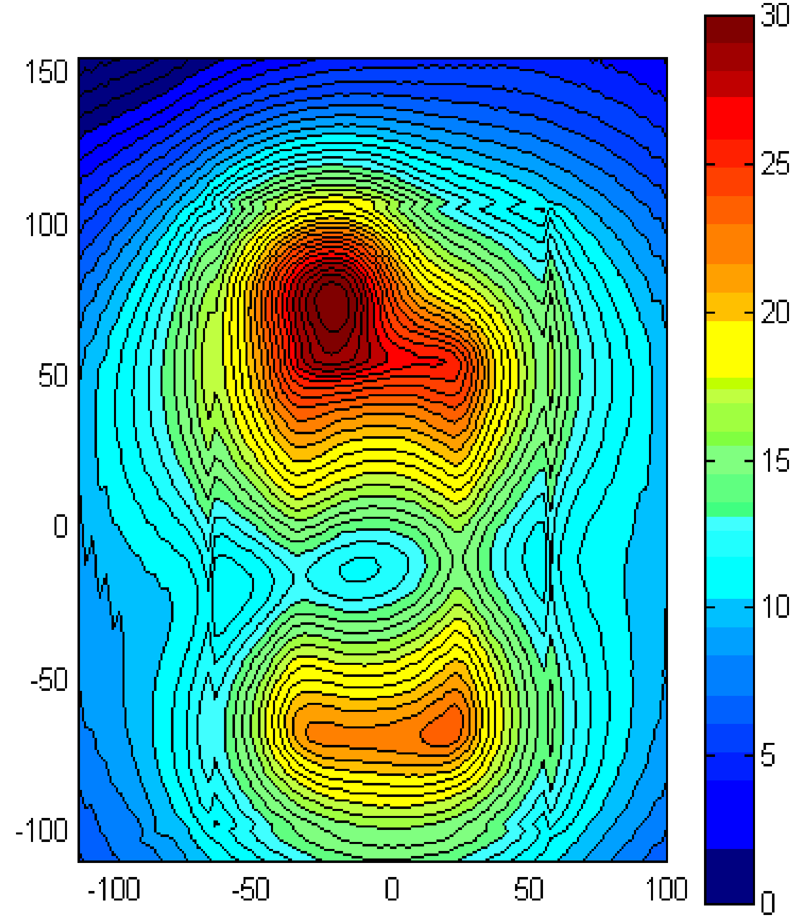


Handset with CNET-type (A) antenna (air dielectric) around 900 MHz band.

Near field contours (in dB) over a plane 1cm from the handset surface.

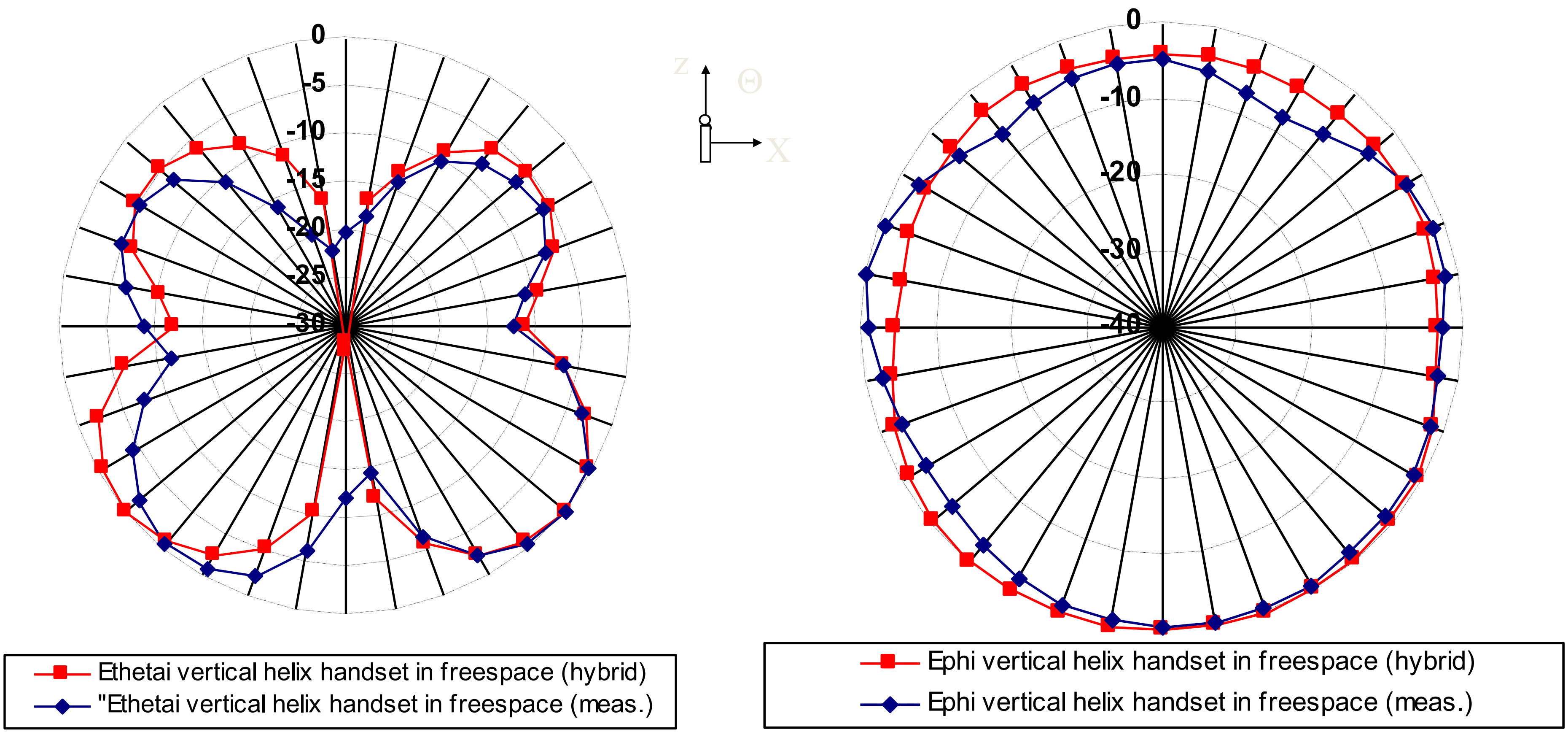


(a) measured



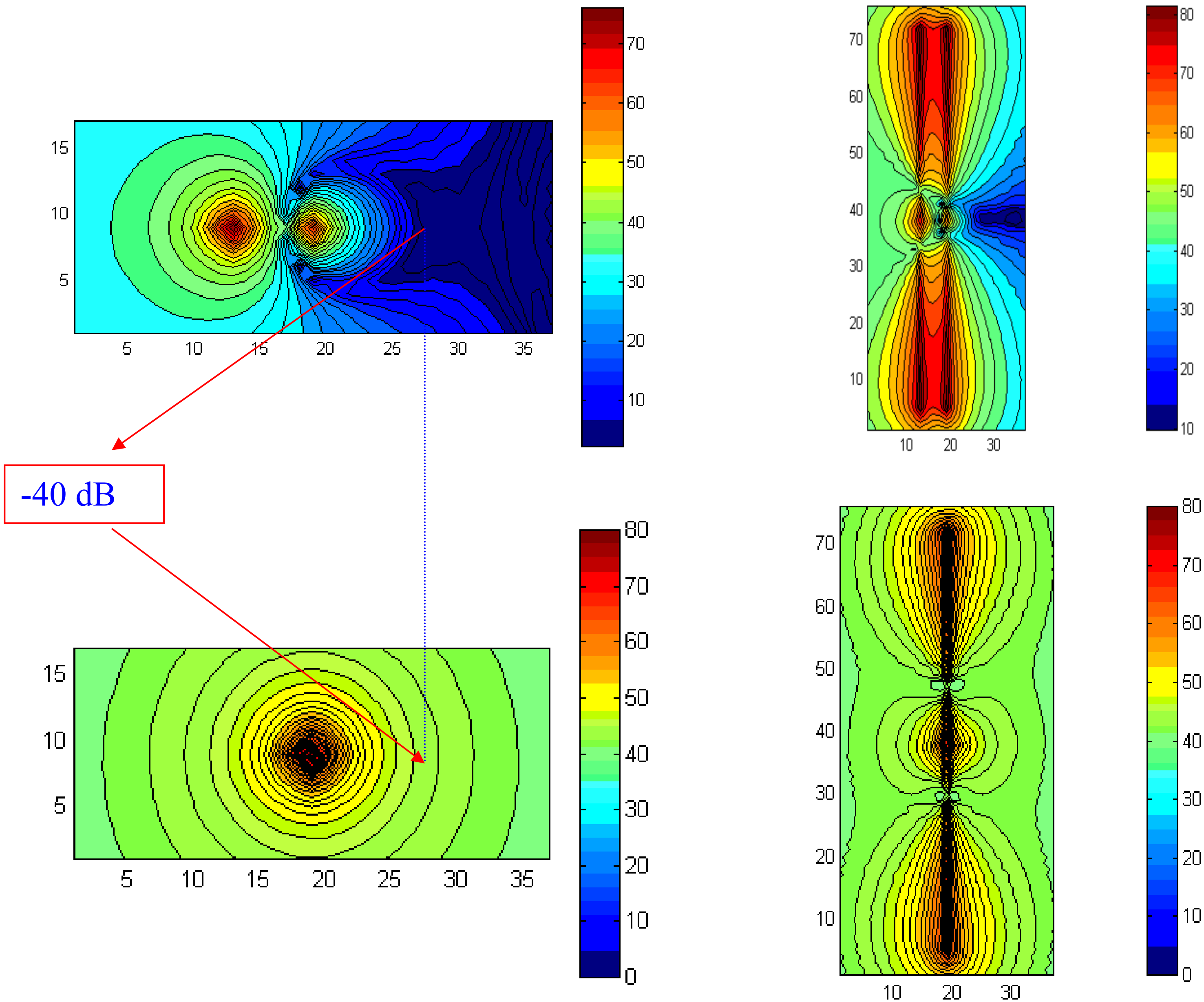
(b) Simulated (hybrid method)

Far Field Measurements

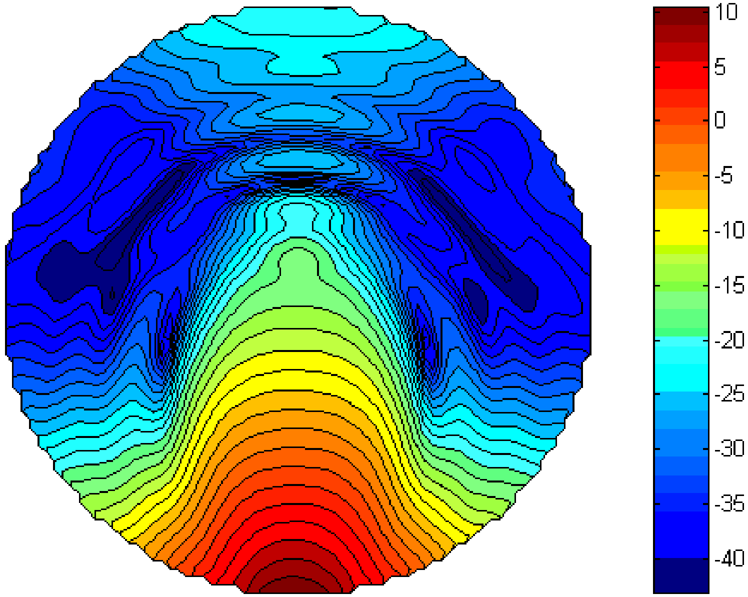


Hybrid method computed and measured radiation patterns (in dB) normalised to maximum for 1710 MHz telephone in free space

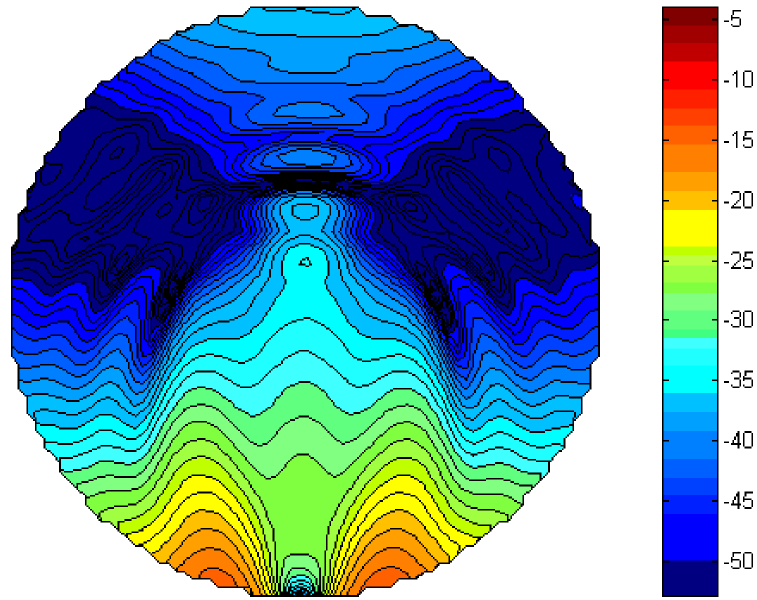
Two-Dipole Array in Free Space Using Pure FDTD Code



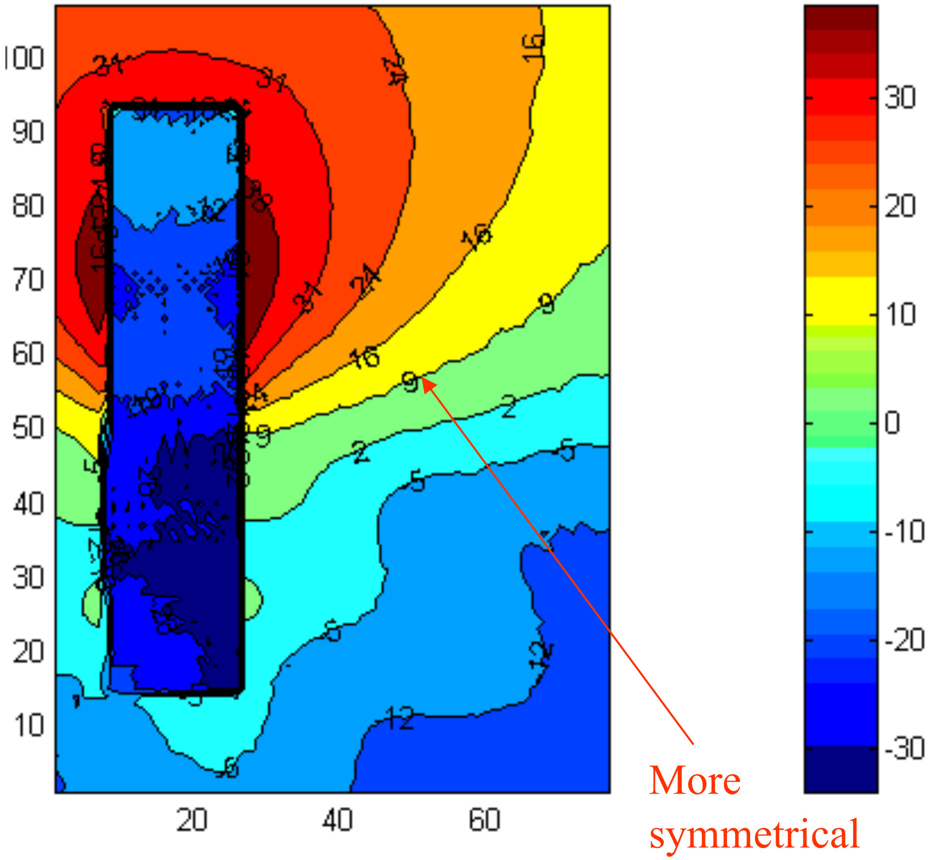
Resultant electric field in dB through central problem space



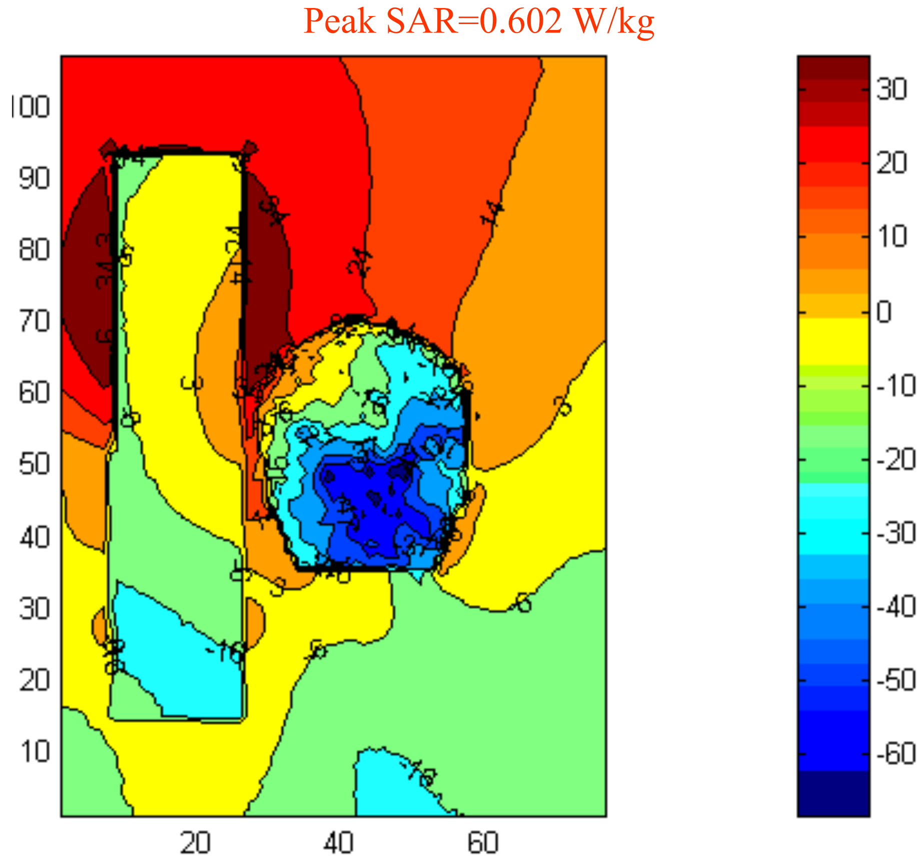
SAR Distribution in dB for a central horizontal slice ($z = 0$) across the spherical head for single dipole case, normalised to 1 watt input power



SAR Distribution in dB for a central horizontal slice ($z = 0$) across the spherical head for 2 element dipole array case, normalised to 1 watt input power



Electric field distribution (in dB) for satellite QHA handset in free space (input voltage of 1 volt for each of the four feed sources) using hybrid method

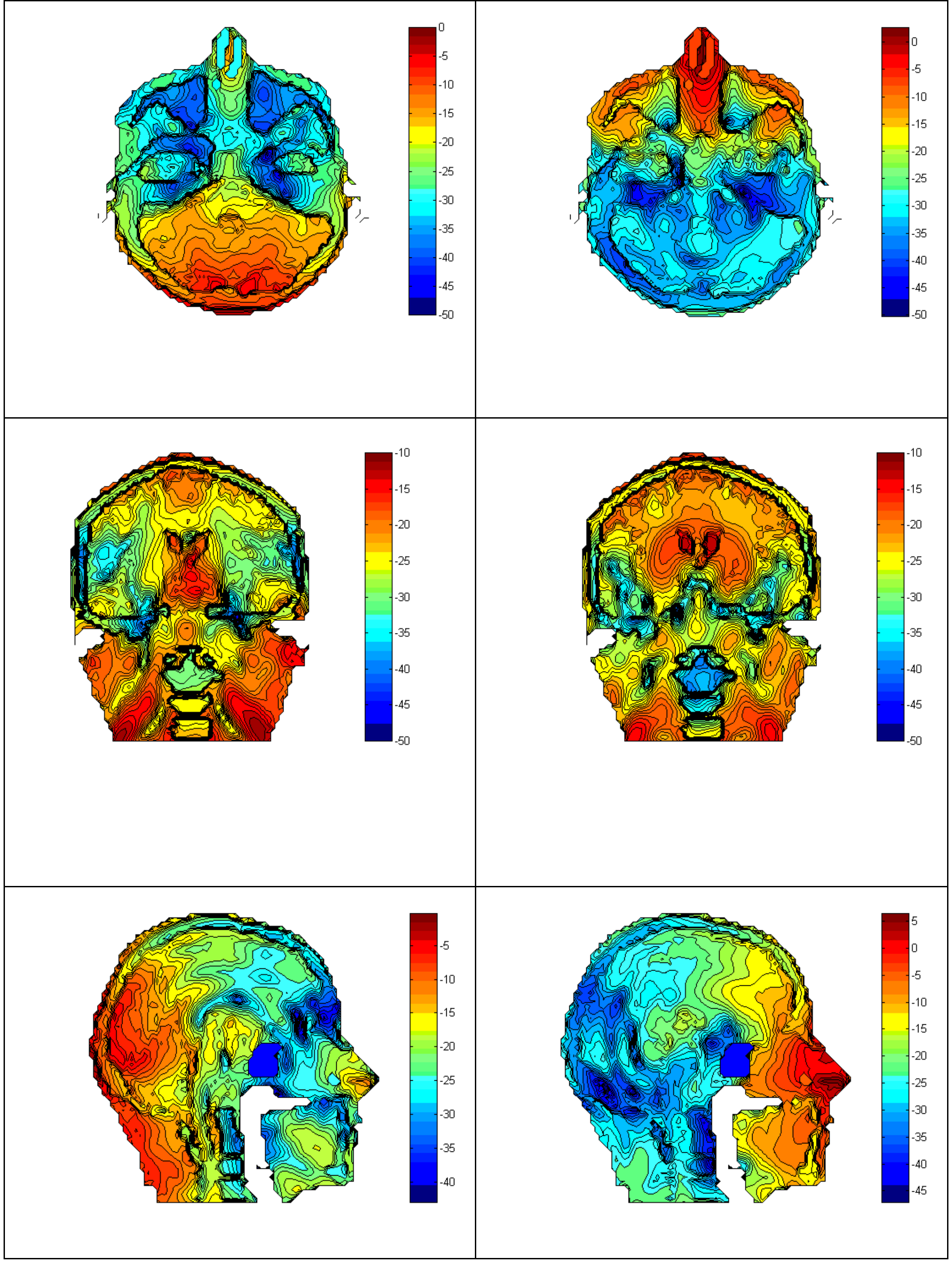


Electric field distribution (in dB) at central vertical slice of a simulated biological head interacting with satellite QHA handset, with separation distance of 2cm, using hybrid method

Microcells Radiation Head only interaction Study (vodafone , UK)

A comparison between the safety distances of a micro cell antenna using electromagnetic field and the specific absorption rate (SAR) assessment is made.

The input power in the antenna is determined such that the electromagnetic fields and the SAR equal the reference levels and the basic restrictions, respectively, at a certain distance.

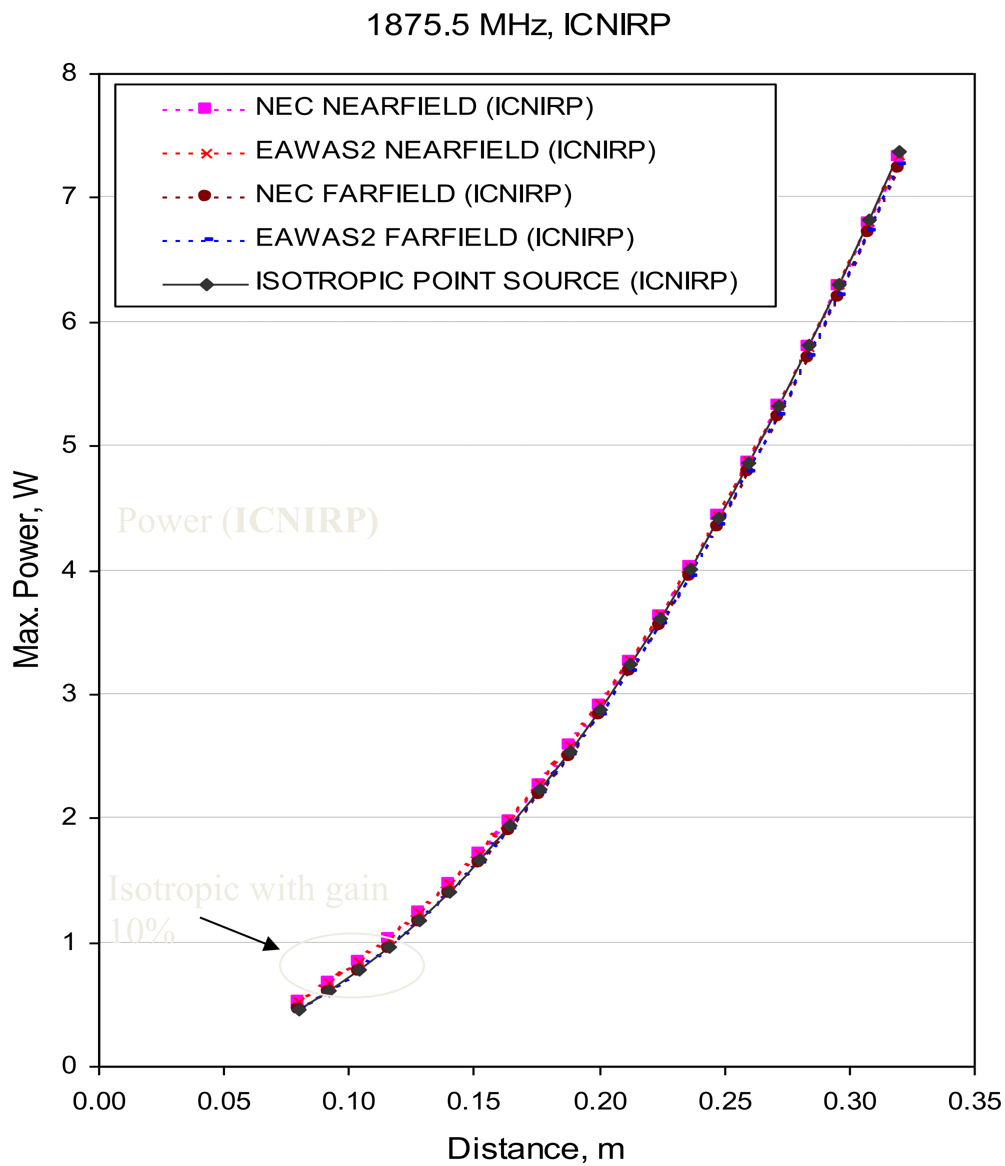


(Notes):

- The local field concentration in the nose

<u>Peak SAR</u> calculations (in dB) for the three main median planes for half wavelength dipole antenna **behind (left column)** and **in front of (right column)** the head. Frequency **<u>1875.5 MHz,</u>** distance **<u>0.5 wavelength</u>** from nearest point of head. Radiated power normalised to **1W**.

Maximum power that may be radiated from a half-wavelength dipole at **1875.5**, according to **ICNIRP** 'investigation level' **PFD criteria**.

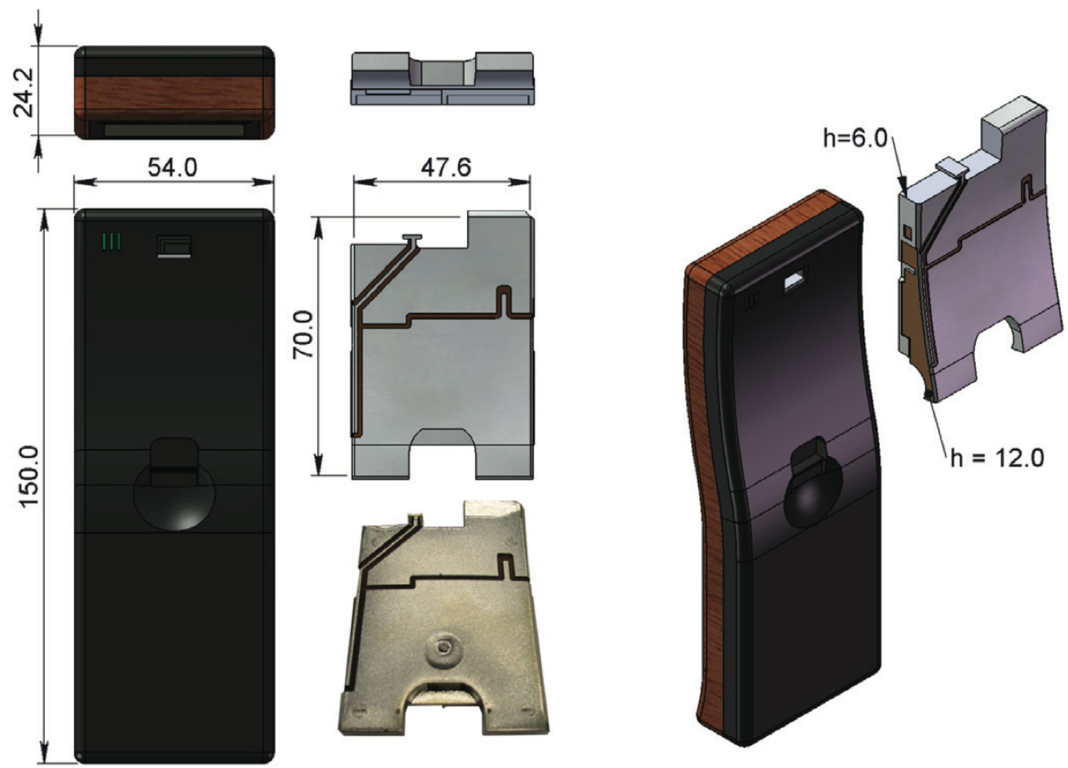


Mobile-Phone Antenna Design

IEEE Antennas and Propagation Magazine, Vol. 54, No. 4, August 2012

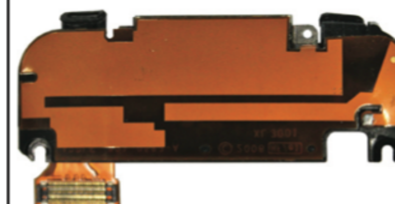
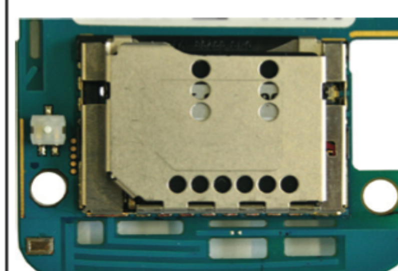
Corbett Rowell[1,2] and Edmund Y. Lam[2]

A survey of internal antennas in mobile phones from 1997 to 2010. It covers almost 60 GSM and 3 3G handsets



Hagenuk GlobalHandy

Table 7. A comparison of manufacturing technologies.

Type	Theory	Advantages	Disadvantages	Examples
Stamped metal	Stamped steel part integrated together with plastic piece	Easy assembly, versatile, spring clip contacts can be integrated into antenna	Long lead times for patterns, minimum line width, cannot utilize layered antennas or 3D curves	
Flex-film	Copper etched flexible film glued onto plastic piece	Copper has high conductivity, can contain air gap (between antenna and back cover) or mounted on inside of cover to maximum volume	Requires several parts- more logistics, glue and mechanical tolerances	
Hot stamp	Uses heat and pressure to place a metal part to a surface (no 2-D curves to bend over)	Stable pattern, no pealing, similar performance to copper flexfilm	Flat pattern only, no 3D curves	
PCB trace	Antenna trace on PCB	In-expensive, no assembly	Design limited to flat surface, worse performance due to proximity of antenna to PCB components	

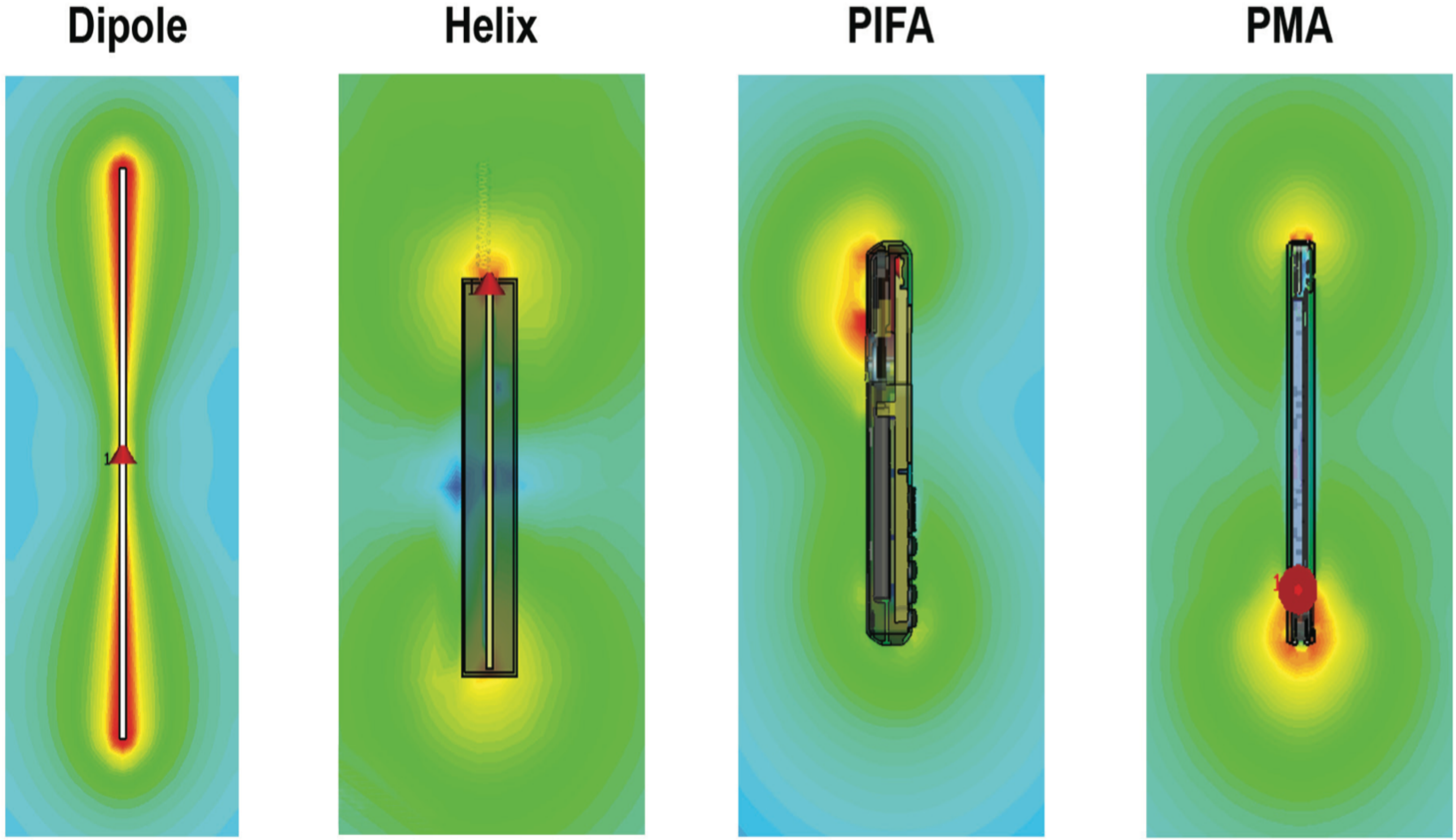


Figure 5. A comparison of the electric-field distributions: The PMA (planar monopole antenna) and the helix both have dipole-type electric-field distributions. The PIFA electric-field distribution is more similar to that of a microstrip antenna.

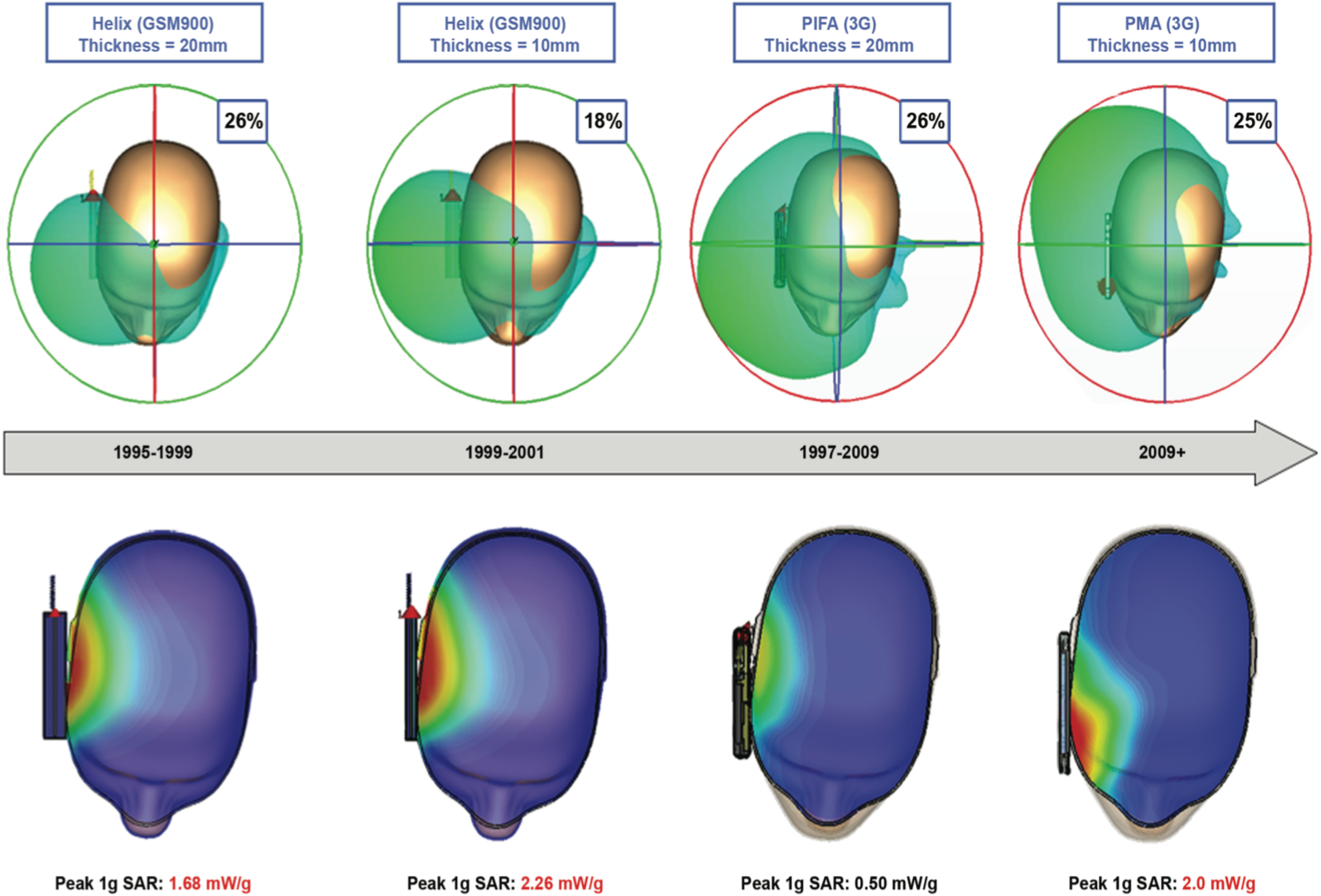


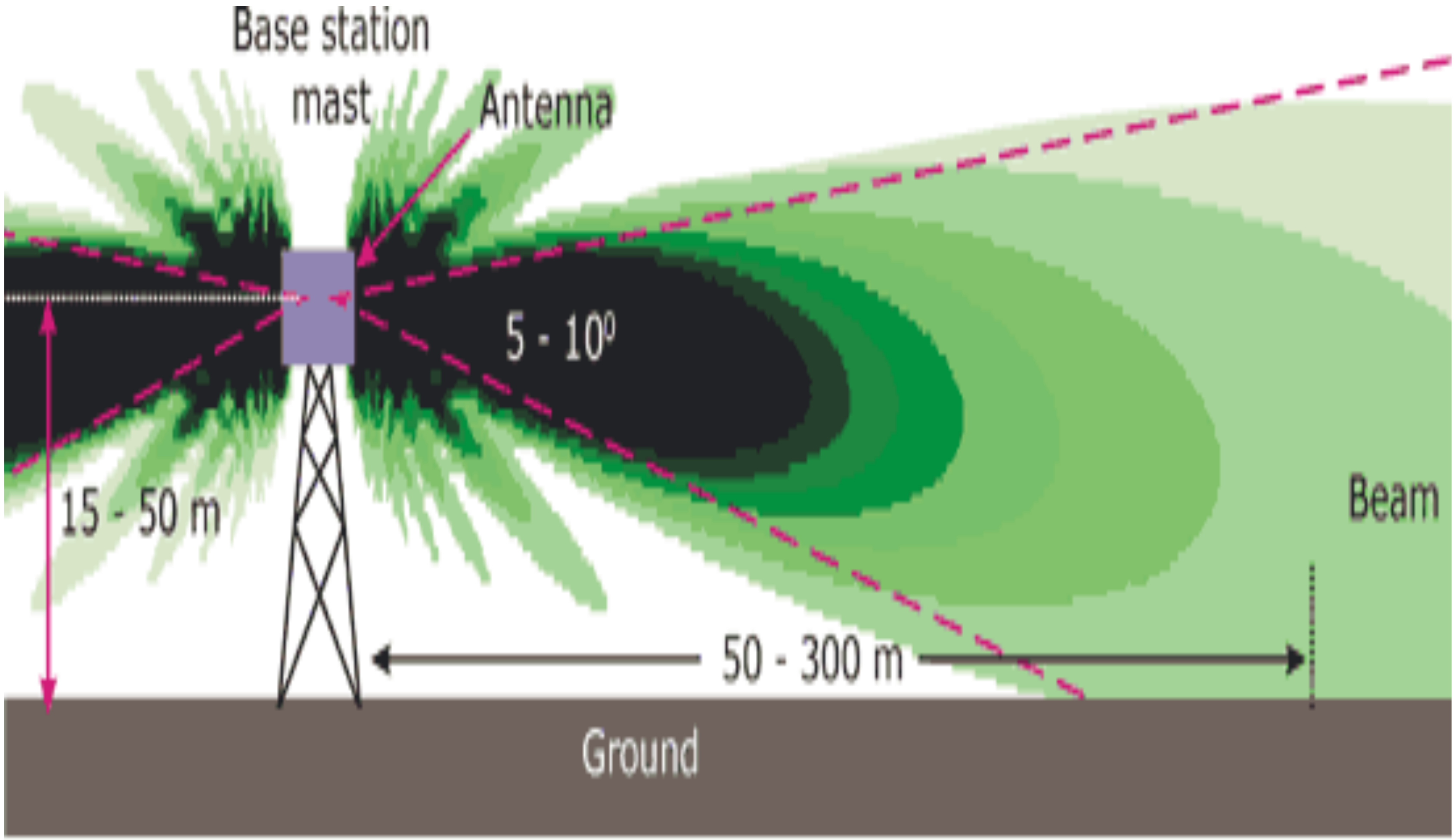
Figure 4. The evolution and performance of GSM antenna types from 1995 to 2011. As the thickness of the phone decreases, the helix antenna has poorer SAR and radiation efficiency. The PCB reduces the effect of the near fields for the PIFA, resulting in better SAR and radiation efficiency.

النطاق	تردد الإرسال	حد SAR لـ FCC هو 1جرام(واط/كجم)1	الجسم	الرأس
GSM 850 UMTS 850 (CDMA 800 (BC 0 LTE Band 5	849-824	1.6	1.19	1.13
GSM 1900 UMTS 1900 (CDMA 1900 (BC 1 LTE Band 2	1910-1850	1.6	1.18	1.18
LTE Band 13	777-787	1.6	0.93	0.54
LTE Band 17	704-716	1.6	0.83	0.58
LTE Band 4	1710-1755	1.6	1.14	1.17
LTE Band 20	860 - 834	1.6	0.83	0.47
LTE Band 25	1850-1915	1.6	1.10	1.18
LTE Band 26 (CDMA 800 (BC 10	849 - 819	1.6	0.61	0.58
GHz Wi-Fi 2.4	2483.5-2400	1.6	0.51	0.56
GHz Wi-Fi 5	5150-5250 5250-5350 5500-5700 5725-5850	1.6 1.6 1.6 1.6	0.42 0.45 0.59 0.58	0.34 0.38 0.56 0.43

أعلى مستويات النقل وتم وضعها في مواقع محاكاة الاستخدام جانب الرأس، مع عدم وجود فاصل، وبالقرب من الجسم، مع الفصل ٥ مم.

Base stations Radiation

RF Beam from the Base Station



there is a difference between antennas and towers. It is the antennas that you need to keep your distance from and not the towers that hold the antennas.

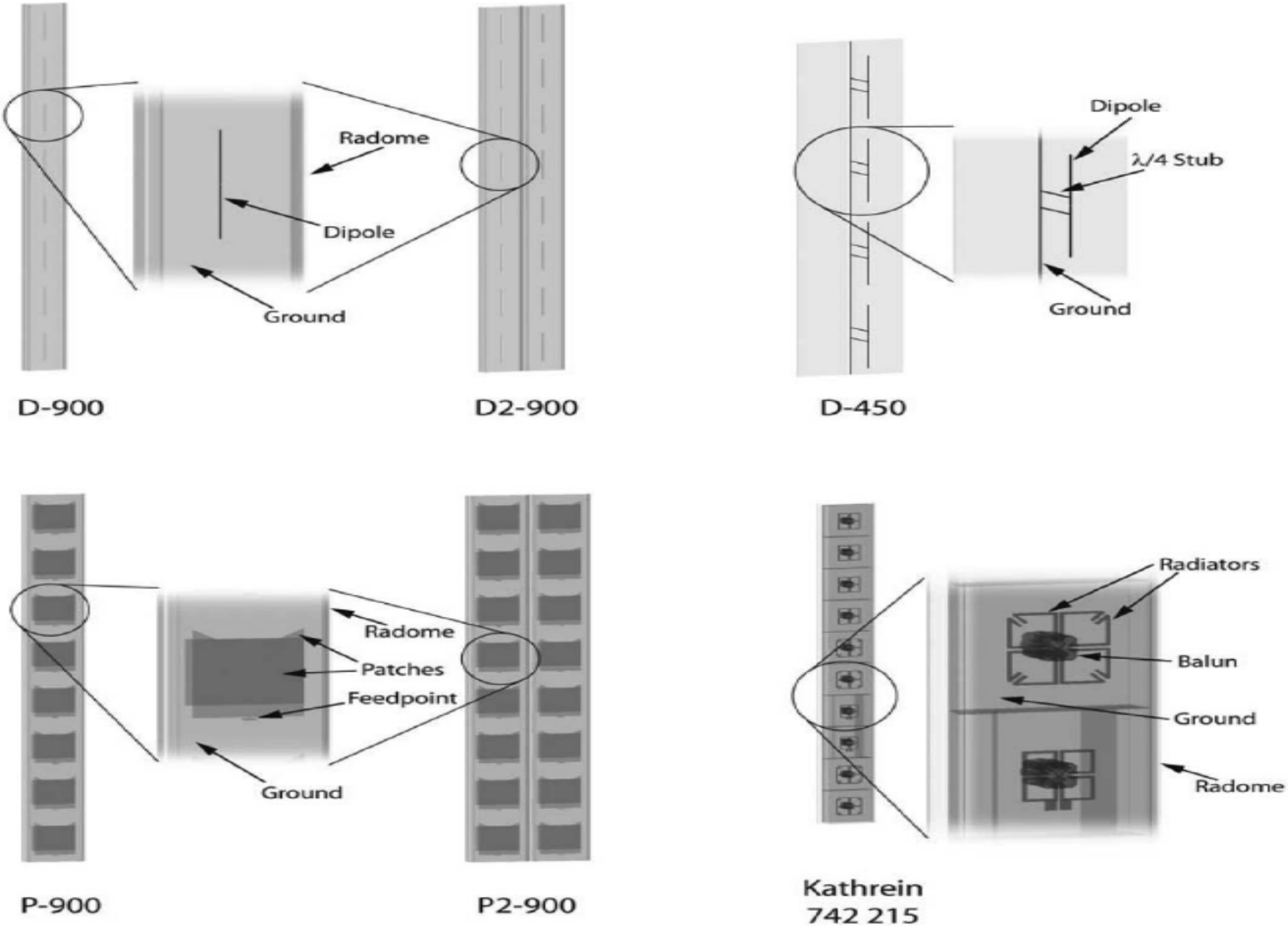



900 MHz PCS & GSM Base Station 6 Sector Antennas

Frequency Range	870-960 MHz
Gain	16.1 dBi
3dB Beamwidth Vertical Plane	14°
3dB Beamwidth Horizontal Plane	60°
F/B Ratio	≥ 30 dB
VSWR	≤ 1.35
Nominal Impedance	50 ohm
3dB Beamwidth	Vertical
Maximum Input Power	500 W
Lightning Protection	All metal parts grounded
Connector	N Female or 7/16 DIN Female
Dimension	1219mm × 305mm × 127mm / 3.20 ft × 1.0 ft × 0.42 ft
Weight	6.4 kg / 14.11 lb
Rated Wind Velocity	216 km/h / 135 mph
Radiating Elements Material	Brass
Back Panel Material	Aluminum Alloy Passivated Plane
Radome Material	Fiberglass
Mounting Mast Diameter	φ 40 – 89 mm / φ 1.57 – 3.50 in
Intermodulation	≤ 110 dB

1800 MHz PCS & GSM Base Station 3 Sector Antennas

Frequency Range	1710-1990 MHz
Bandwidth	170 MHz
Gain	12.5 dBi
VSWR	≤ 1.5
Nominal Impedance	50 ohm
Polarization	Vertical
Maximum Power	100 W
Connector	N Female
3dB Beamwidth Horizontal Plane	120°
3dB Beamwidth Vertical Plane	16°
F/B	> 25 dB
Dimension	600 × 100 × 80 mm
Weight	6 kg / 13.23 lb



Base station antenna models.

Main characteristics of a GSM hand-held terminal transmitter

	GSM 900	DCS 1800
Frequency band	890 – 915 MHz	1710 – 1785 MHz
Channel width	200 kHz	200 kHz
Peak radiated power	2 W	1 W
Multiple access technique	FDMA + TDMA	FDMA + TDMA
Modulation scheme	GMSK	GMSK
Maximum average radiated power	250 mW	125 mW

Main characteristics of a GSM base-station transmitter

	GSM 900	DCS 1800
Frequency band	935 – 960 MHz	1805 – 1880 MHz
Channel width	200 kHz	200 kHz
Peak radiated power (typical)	30 W	30 W
Multiple access technique	FDMA + TDMA	FDMA + TDMA
Modulation scheme	GMSK	GMSK

Conclusions of exposure in close proximity of the base-station antenna (study 2)

the approach suggested in exposure guidelines of using the PFD might be not conservative for locally averaged SAR values

very close to the antenna (2-m distance), not for general population, technical personnel working near the antenna, Occupational (workers) exposure should be applied. (8 w/kg) not (1.6 w/kg).

Prof. Paolo Italo Bernardi group study @ Università degli Studi "La Sapienza" di Roma
Dipartimento di Ingegneria Elettronica

Exposure to radio base stations

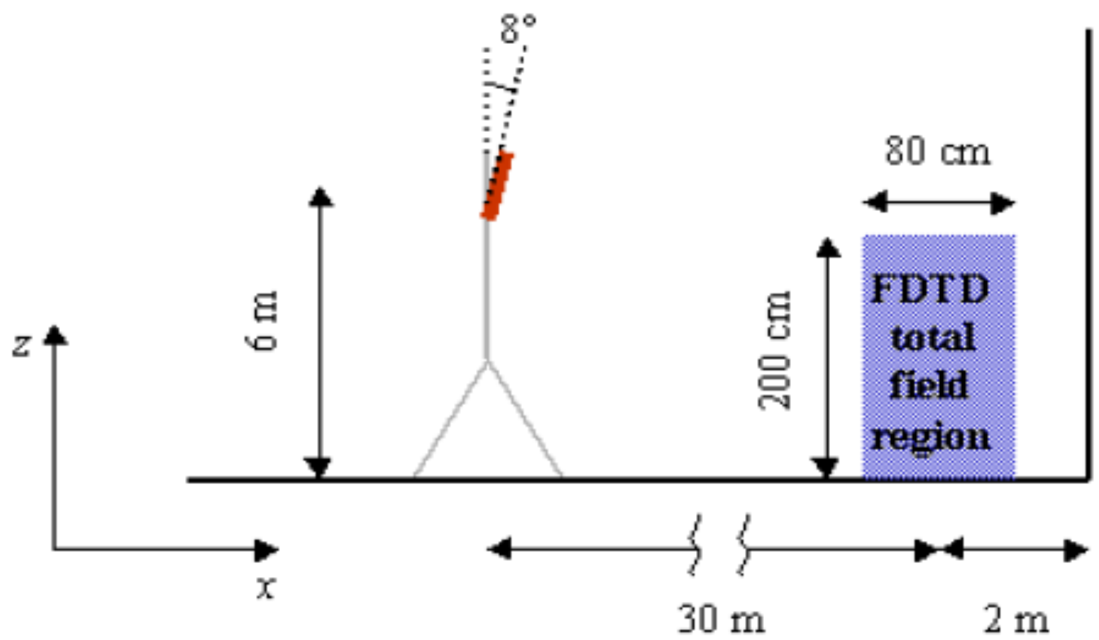


Figure II.17 - Geometry of the problem considered for the validation of Ray-Tracing / FDTD matching

1 mm,

41tissues

586 x

340 x

1868

cells).

1/10 of the wavelength in the tissues with the highest permittivity

(5mm) 118 x 68 x 360 cells)

(see the Visible Human (Brooks Air Force Base Laboratories, Texas) site at *http://www.nlm.nih.gov/research/visible/visible_human.htm*l).

TABLE I
CHARACTERISTICS OF THE HUMAN BODY MODELS

Human model	Mass kg	CM ratio m^2/kg	Height m	BMI kg/m^2	Age years
Visible Human	101	6.0×10^{-3}	1.80	31.2	38
Japanese Male	71	7.7×10^{-3}	1.73	23.7	22
Japanese Female	55	8.8×10^{-3}	1.60	21.5	22

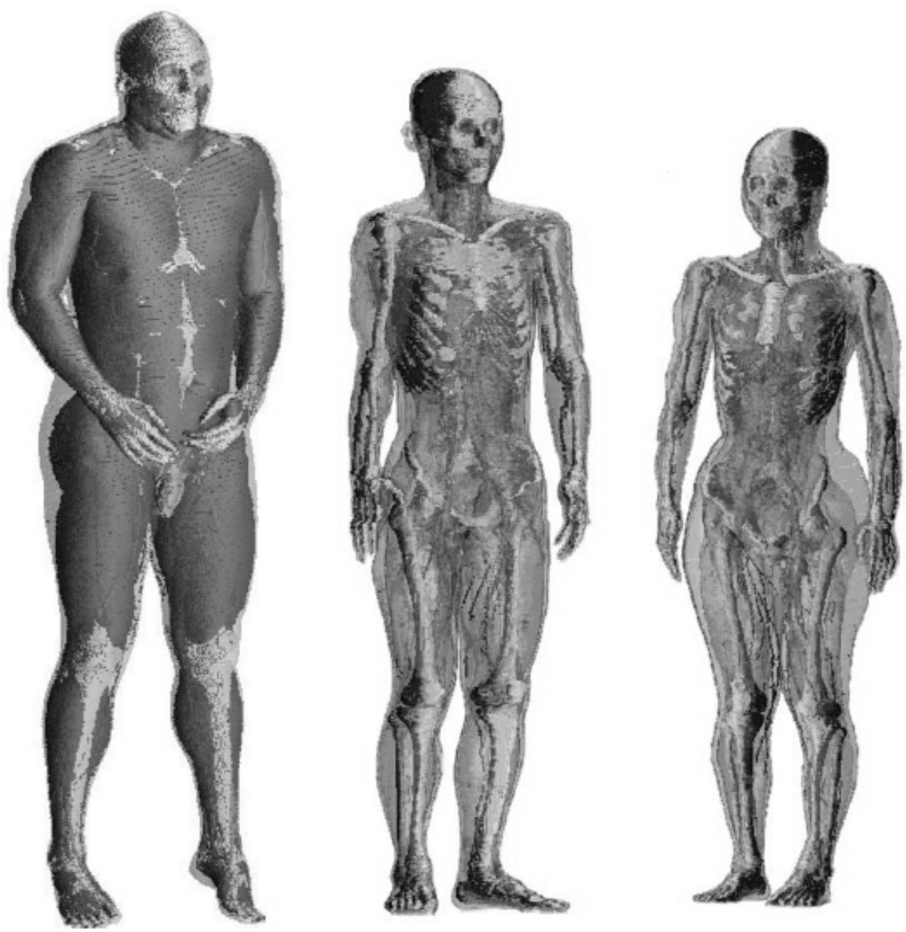


Fig. 1. Anatomical body models: Visible Human (left), Japanese Male (center), Japanese Female (right).

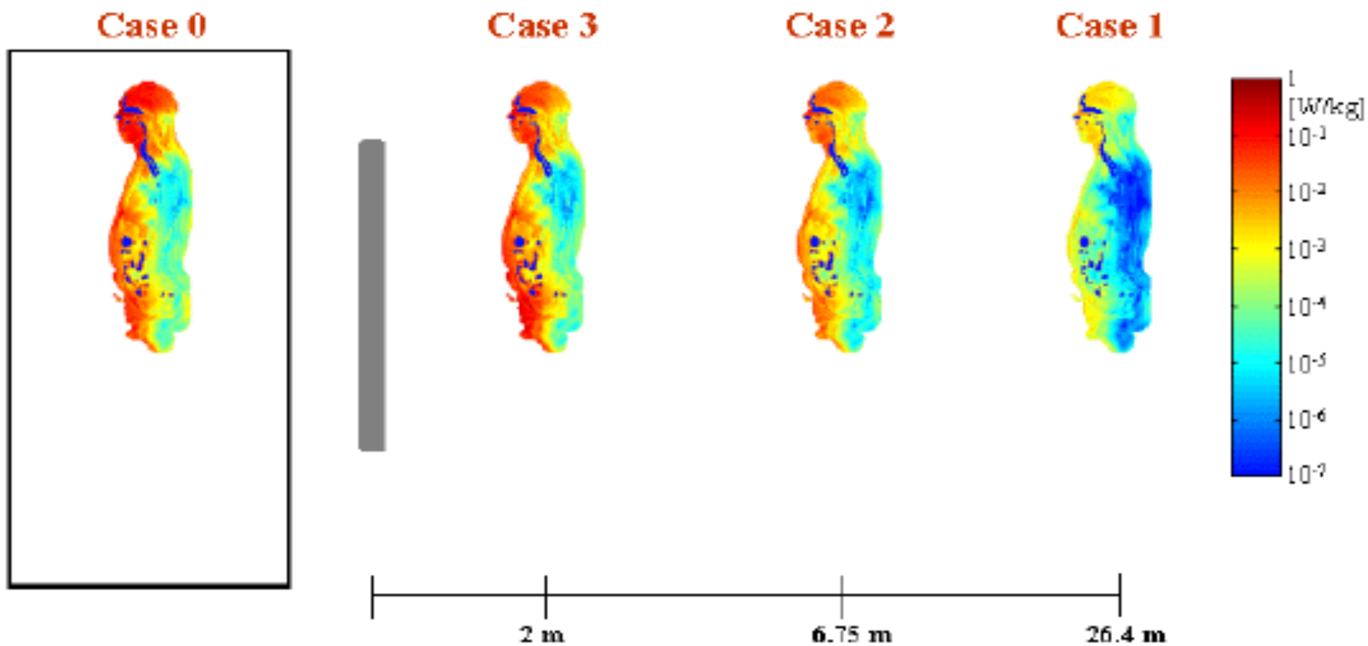
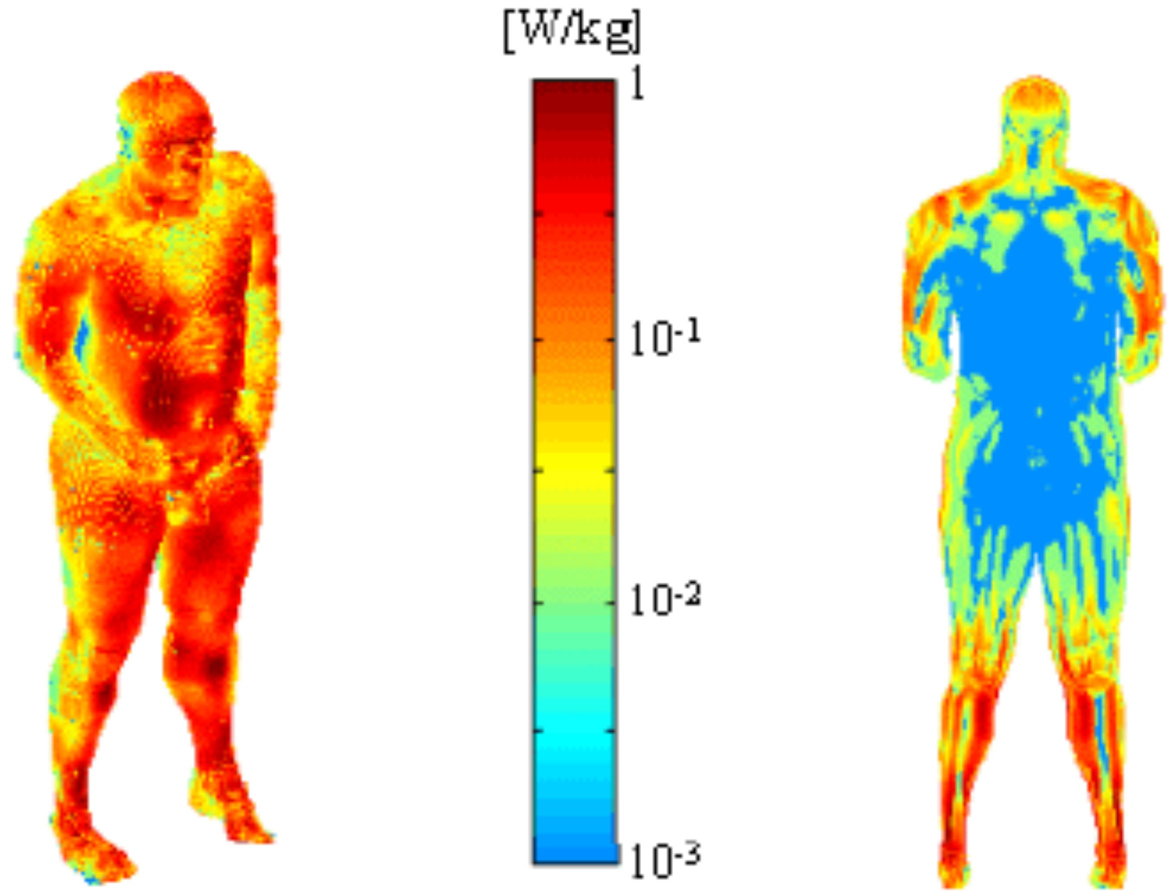


Figure III.18 - SAR distributions in a central sagittal section of the exposed subject for the examined situations

Table III.6 - SAR inside the exposed subject for the examined situations

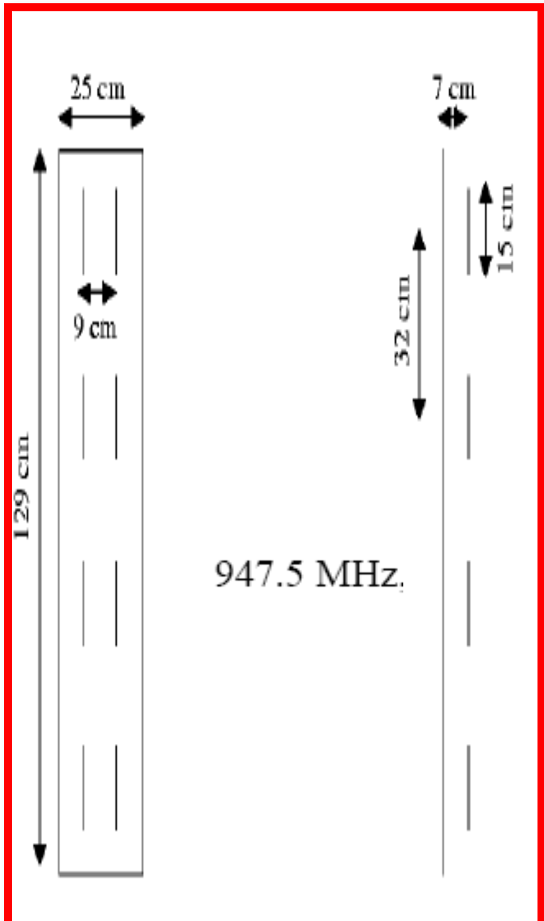
	SAR_{WB} [W/kg]	SAR_{1g} [W/kg]	SAR_{10g} [W/kg]
Case 0	0.024	0.75	0.47
Case 1	0.00055	0.017	0.011
Case 2	0.0064	0.25	0.16
Case 3	0.026	1.9	1.2



(a) (b)

- **SAR distribution: (a) over the body surface; (b) in a coronal section**

$f = 900$ MHz; $P_{inc} = 1$ mW/cm^2



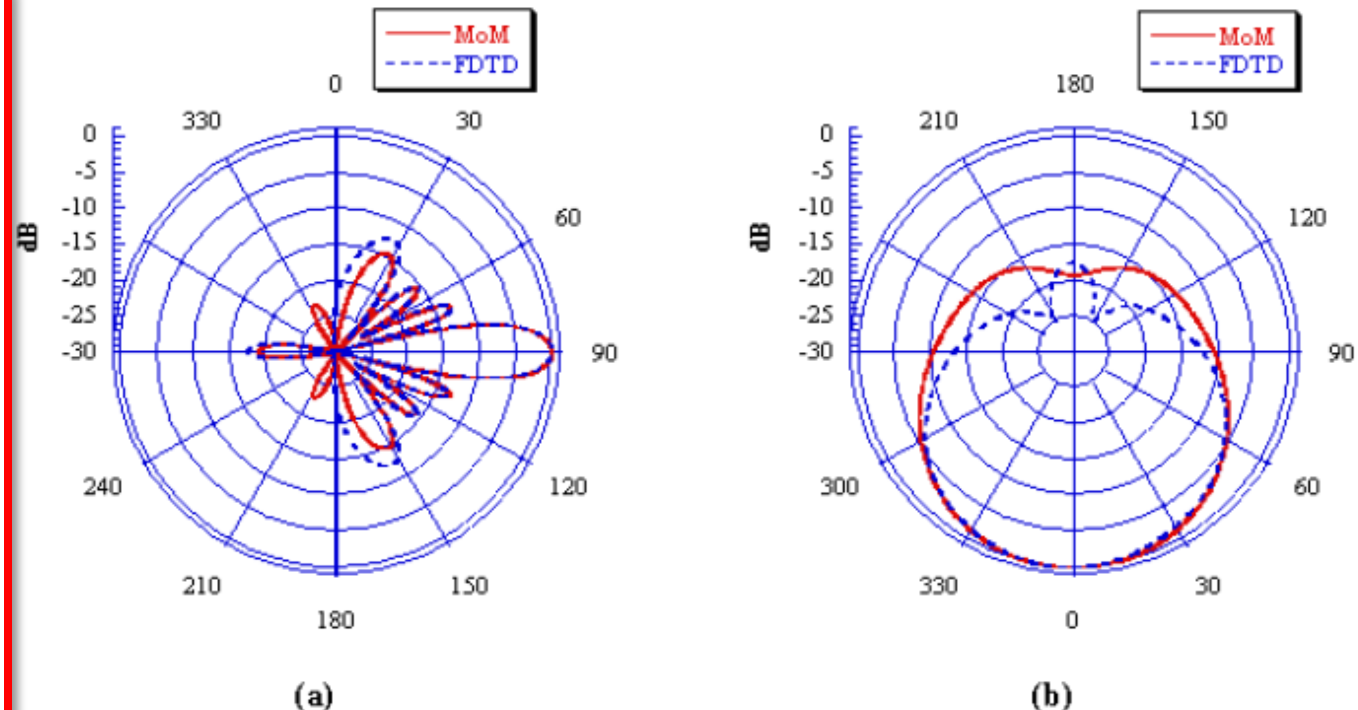
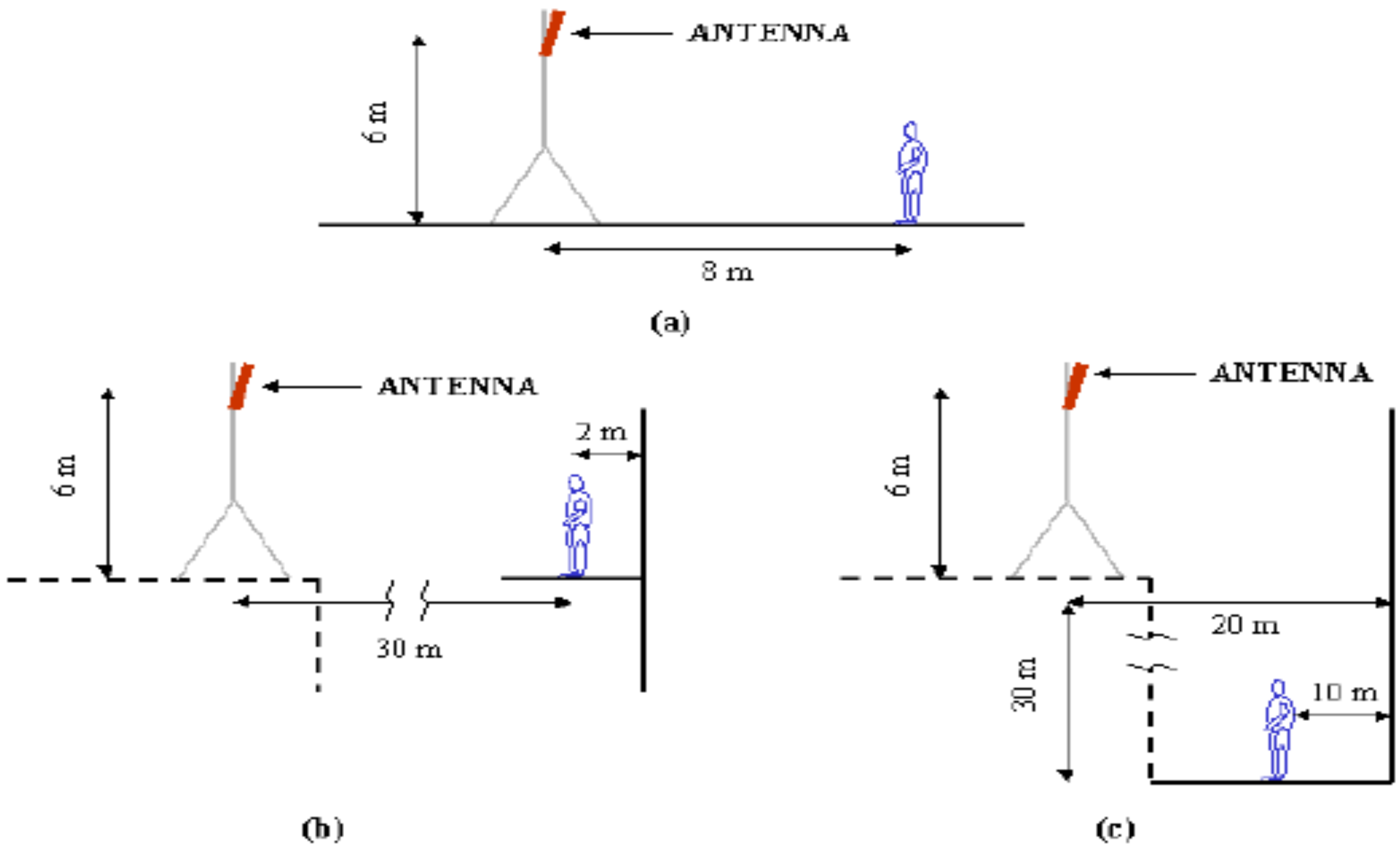
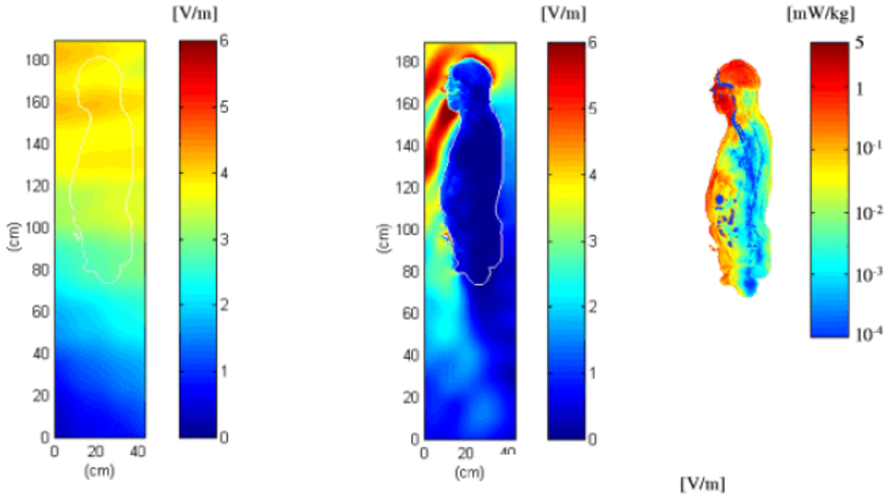


Figure II.9 - Normalised radiation patterns of a GSM base station antenna computed with MoM and FDTD analysis: (a) E-plane; (b) H-plane

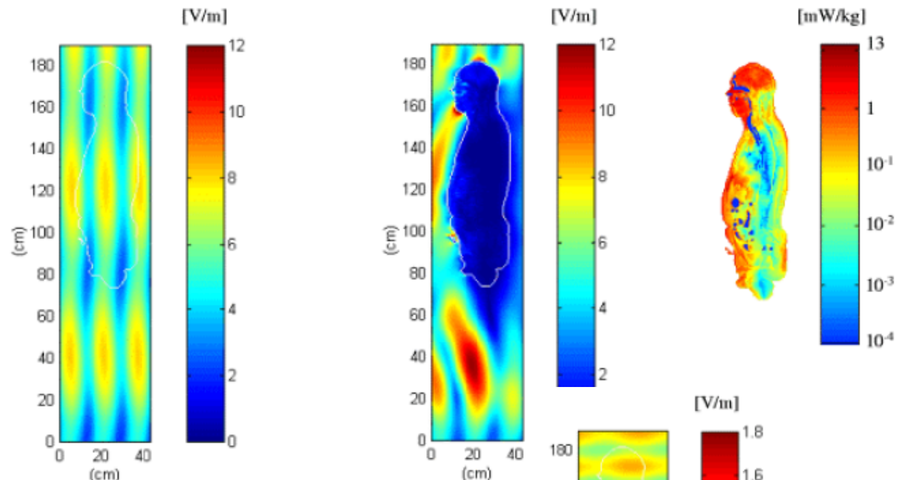
-3 dB Horizontal BW= 80°,
-3 dB Vertical Plane= 13°;
gain = 14.7 dBi.

SAR in urban environment

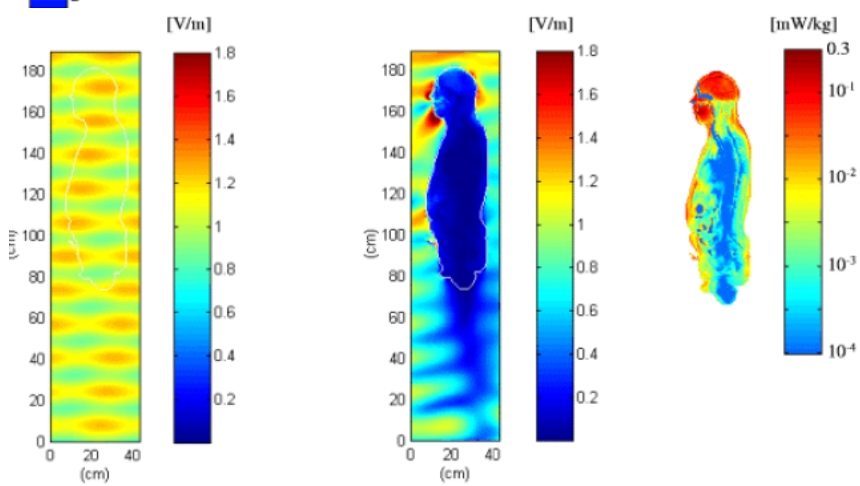




(a) (l



(a) (b)



(a) (b) (c)

Conclusions of realistic urban-environment exposure (study 1)

environment exposure situations studied

	Unperturbed exposure field levels				
	E_{Imax} [V/m]	E_{Iav} [V/m]	SAR_{1g} [mW/kg]	SAR_{10g} [mW/kg]	SAR_{WB} [mW/kg]
Case 1	4.2	2.8	5.3	3.0	0.12
Case 2	8.1	5.5	13.2	8.5	0.46
Case 3	1.3	1.1	0.26	0.17	0.01

- The exposure levels (<<) are below the recognized reference levels

The field values (EImax and EIav) are well Below standard values at the frequency of 947.5 MHz are 48.7 V/m and 42.3 V/m. As concerns SAR, a glance at Table III.3 shows that all the computed SAR values are at least two order of magnitude lower than basic restrictions valid for general public exposure.

- **These results are dependent upon the dielectric characteristics of the building walls. That give rise to rather low reflections(<0.4). Considering a reflection coefficient of 0.7, the presence of walls results in 40% increase in the average field levels with a doubling in the SAR_{WB} value wrt free space conditions.**

Research project@ UOB : Environmental Measurement

The Capital Governorate (24 base stations)

Far field measurements

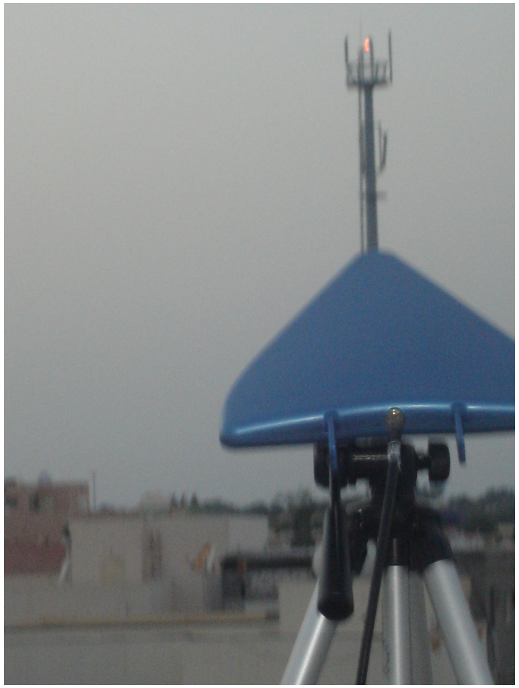
Equipments and Software:

- spectrum analyser (SPECTRAN® HF-6080)
- The antenna (HyperLOG® 6080)
- tripod, adopter and 5 meters extension cable.
- Microsoft® Office Excel
- "Google Earth"
- SPECTRAN spectrum analyser software “LCS”

Long term (24 hours) measurement of RF radiation

2-Long-term measurements:

- The antenna was fixed and connected to the spectrum analyser.
- The number of readings was set 240 and the time between readings is 360 seconds.
- After 24 hours the data were downloaded using spectrum analyser software "LCS".



Street Mapping of Power Density

- The levels of RF radiation from mobile phone base stations in the Kingdom of Bahrain was much less than exposure limits issued by ICNIRP or by PCPMREW.

- Max. RF radiation levels for GSM900:

0.003400 W/m² (**E=**1.133 V/m and H=3.007 mA/m)

- → 0.073% of ICNIRP limit (4.63 W/m²) :: 1362 times less

Max. RF radiation levels for GSM1800:

0.001440 W/m² (**E** = 0.737 V/m and **H** = 1.958 mA/m).

→ 0.016% of ICNIRP limit

- Max. RF radiation levels for UMTS:

0.00064739 W/m² (**E** = 0.494 V/m and **H** = 1.311 mA/m)

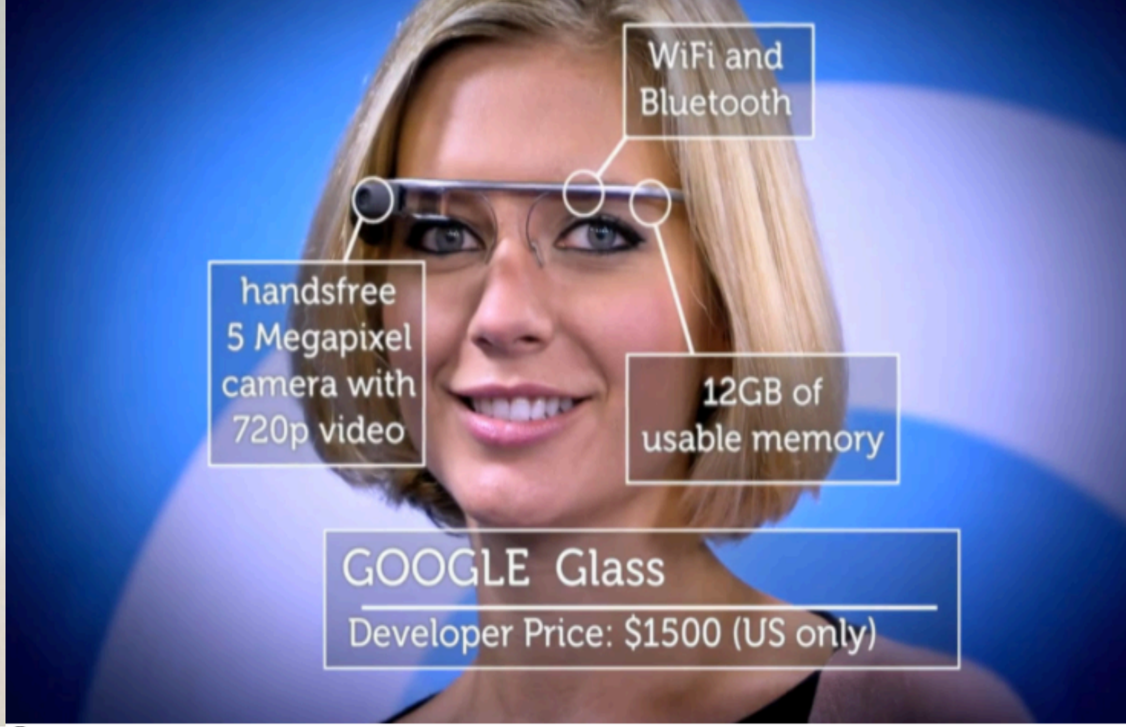
→ 0.016% of ICNIRP limit

ICNRP statement

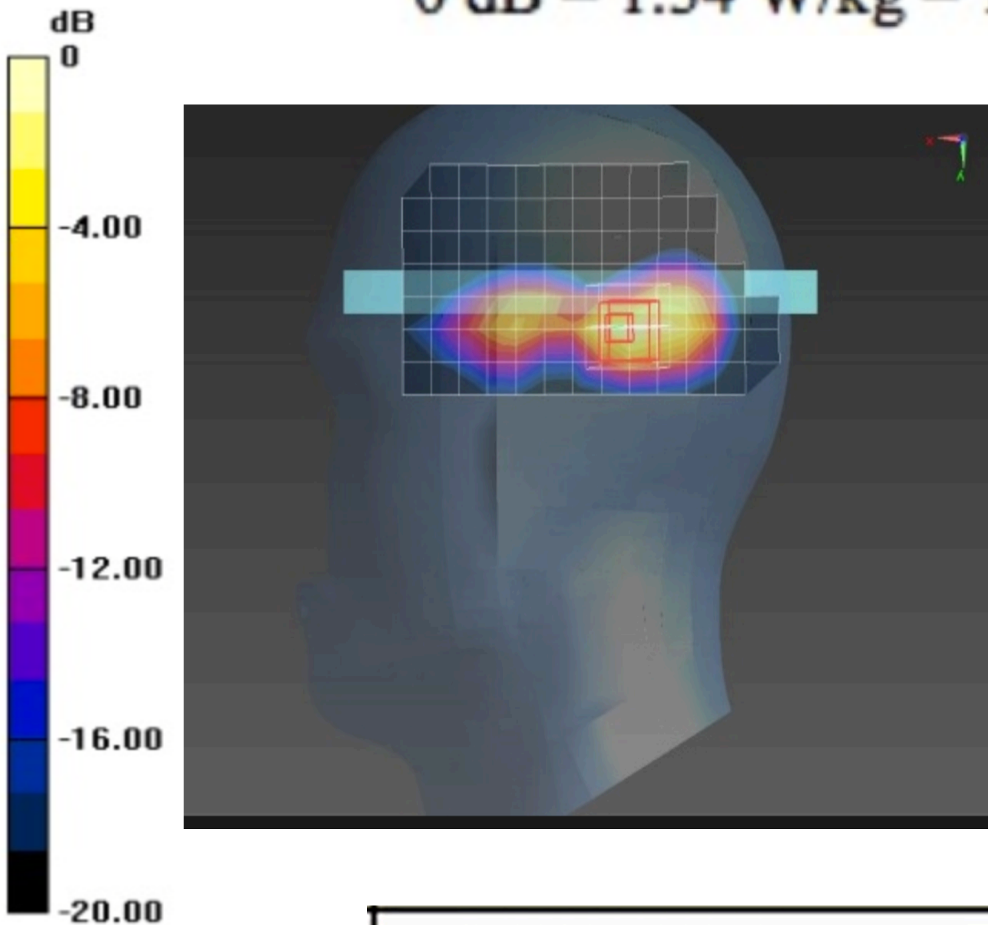
Recent surveys have shown that the RF exposures from base stations range from 0.002% to 2% of the levels of international exposure guidelines

Wearable and mm waves Radiation

"millimeter waves" (mmw) refers to extremely high-frequency (30 – 300 GHz)


WiFi and Bluetooth
handsfree 5 Megapixel camera with 720p video
12GB of usable memory
GOOGLE Glass
Developer Price: $1500 (US only)

0 dB = 1.34 W/kg = 1.27 dBW/kg



Head: 1.42 W/kg (Ear Side)

"We've studied design comfort and safety very closely, and we haven't found cause for concern. It's something we'll continue to watch carefully."

http://www.geek.com/mobile/google-glass-fcc-docs-uncovered-1538216/
http://blog.cellphone-health.com/2013/05/is-google-glass-radiation-cause-for-concern.html/

International Journal of Microwave and Wireless Technologies, page 1 of 11.
doi:10.1017/S1759078711000122

Millimeter-wave interactions with the human body: state of knowledge and recent advances

MAXIM ZHADOBOV[1], NACER CHAHAT[1], RONAN SAULEAU[1], CATHERINE LE QUEMENT[2] AND YVES LE DREAN[2]

60-GHz exposures, It is shown that 26–41% of power is reflected at the air/skin interface for the normal incidence, and this value deviates significantly for illuminations under oblique incidence.

Bioelectromagnetics 29:65–70 (2008)

Millimeter Wave Dosimetry of Human Skin

S.I. Alekseev, A.A. Radzievsky, M.K. Logani, and M.C. Ziskin*

Center for Biomedical Physics, Temple University Medical School, Philadelphia, Pennsylvania

the deeper fat layer had little effect on the PD and SAR profiles. We observed the appearance of a moderate SAR peak in the therapeutic frequency range (42–62 GHz) within the skin at a depth of 0.3–0.4 mm. Millimeter waves penetrate into the human skin deep enough (d=0.65 mm at 42 GHz) to affect most skin structures

Precaution & Conclusions

منها: شروط تركيب محطات الهاتف الخليوي

- ان يكون ارتفاع المبنى المراد إقامة المحطة فوق سطحه في حدود من 15-50 متر.
- ان يكون ارتفاع الهوائي أعلى من المباني المجاورة في دائرة نصف قطرها 10 أمتار.
- أن يكون سطح المبنى الذي يتم تركيب الهوائي فوقه من الخرسانة المسلحة.
- ان لا تقل المسافة بين أي محطتين علي سطح نفس المبنى عن 12 متراً
- ان يكون الهوائي من النوعية التي لا تقل نسبة الكسب الأمامي مقارنة بالكسب الخلفي عن 20 ديسبل.
- لا تقل المسافة بين الهوائي والجسم البشري عن 12 متر في اتجاه الشعاع الرئيسي ويتم وضع حواجز من جميع الاتجاهات.
- لا يسمح بتركيب الهوائي فوق أسطح المباني المستغلة بالكامل كالمستشفيات والمدارس -يجب عدم توجيه الهوائيات في اتجاه أبنية مدارس الأطفال
- إلزام الشركات بالمواصفات الخاصة بالإشعاع ICNERP , FCC, IEEE, WHO (مثلا : أن لا تتجاوز 0.4 ملي واط/سم2 علي أن تقدم الشركة شهادة بذلك

شهادة قياس محطة للتليفون المحمول (ماكروسيل)

موضوع الشهادة : قياس مدى مطابقة المحطة لبروتوكول تركيب محطات التليفون المحمول .	الشركة المالكة :
عنوان المحطة:	

مسلسل	البند والمعايير	نتيجة المعاينة	مدى المطابقة
1	ارتفاع الهوائيات من سطح الأرض (15 50م) .		مطابق
2	المسافة بين الهوائيات والعنصر البشرى في اتجاه الشعاع الرئيسي (6م) .		مطابق
3	عدد الهوائيات المرسلة (واحد على كل صاري) (3 على برج) .		مطابق
4	المسافة بين برجين لمحطتين على نفس المبنى (12م) .		مطابق
5	وجود شرفات بدون سقف تحت الهوائيات .		مطابق
6	قياسات كثافة القدرةالكهرومغناطيسية (أقصى قيمة 0.4 مللي وات/سم2). في اتجاه الهوائي الأول . في اتجاه الهوائي الثاني . في اتجاه الهوائي الثالث . أماكن متفرقة حول المحطة .	0.0000 مللوات/سم2 0.0000 مللوات/سم2 0.000 مللوات/سم2 0.0000 مللوات/سم2	مطابق
7	المسافة بين أقرب مدرسة أو مستشفى والمبنى .		مطابق

ملاحظات : يوجد طبق ميكروويف للربط مع سنترال الشركة .

النتيجة : المحطة مطابقة لاشتراطات بروتوكول تركيب محطات التليفون المحمول .

www.tra.gov.eg

Stewart Report Recommendations

1. the Expert Group recommends that the **beam of greatest intensity should not fall** on any part of the school grounds or buildings without agreement from the school and parents.

2. Particular attention should be paid to the **auditing of emissions** from base stations sited near schools. **(Source of more info: http://www.notowersnearschools.com/health.html)**

3. The information on **SAR from phones** should be available to **consumers** at the point of sale, and on a national web site + a leaflet to every household

4. Exclusion zones:
   - Establishment of clearly defined **physical exclusion zones** around base station antennas
   - The design of **warning signs logo** should be taken forward by the British standards.

5. The need for further **research**:
   - Effects on brain function
   - The consequences of exposure to pulsed signals
   - **Improvements in dosimetry.**
   - Psychological studies related to individual well-being and human volunteer.

What precautions can I take to reduce exposure to cell phone radiation? (http://www.cnet.com/)

 Don't put your cell phone right next to your body. Moving a cell phone even an inch from the body can greatly reduce radiation exposure. Signal strength falls off as the square of the distance to the source. At 10 times the distance between the cell phone and your head, the signal strength is 100 times less, and at 100 times the distance, it would be 10,000 times less.

 Keep conversations short. The less you talk on your cell phone, the less exposure to radiation you will have. So by keeping voice conversations short, you're limiting your exposure.

 Use a headset. Experts recommend using either a wired headset or a Bluetooth headset. While you may still be exposed to some radiation using either type of headset, it's still a lot less than holding the phone to your ear. If you do use a Bluetooth headset, I'd recommend taking it out of your ear when you're not using it. There's no need to continue to expose yourself to low levels of electromagnetic radiation when you don't need to, since we still don't know the long-term effects of radiation exposure at these low levels.

 Use the speaker phone function of the cell phone. For the same reason you'd use a headset, using a speaker phone is another good option. It keeps the cell phone away from your body, and you don't have to worry about using a headset. Of course, the downside is that everyone around you will hear your conversation, so this may only be something you do when you're at home or somewhere private.

Turn your cell phone off when you are not using it. For example, turn off your phone when you go to sleep at night. Or at the very least turn off the cellular radio in your phone. Many smartphones, such as the iPhone, allow you to put your phone in "airplane mode." This shuts down the cellular radio portion of your phone. You can also turn off the Wi-Fi radio, too, just to be safe.

 Avoid using your cell phone in places where you get a poor signal. Many consumers also don't realize that cell phones emit different amounts of radiation depending on where they are with respect to a wireless operator's cell phone tower. Cell phones are constantly communicating with cell phone towers, but the further away the subscriber is from the cell tower, the weaker the signal. In order to connect to the cell tower, the device must boost its power, which increases the amount of radiation emitted. This means that if you get poor reception in your basement, you should move upstairs to your living room, where you have better reception, to talk on your cell phone. **Radiation Apps claims that** a minute of talk time in a "red zone," bad reception = amount of exposure you'd get talking on the phone for three hours in a "green zone," where reception is good and the radiation emitted from a cell phone is much less.
Apps: Tawkon, radiation monitor, RT radiation

 Text, IM, or use the Net more than talking on your phone. When you're texting or using your phone to access the Internet, you aren't holding it up to your head the same way you would if you were talking on it. So texting and using other forms of communication that don't require you to put the phone to your head or right next to your body are good ways to reduce exposure.

 Carry your cell phone in your purse or backpack instead of in your pocket. Again, it's all about creating distance between you and your cell phone. So if you carry your phone away from your body, then you are reducing your exposure.

References

[1] Rohde & Schwarz Basics of LTE / LTE-Advanced and latest in wireless telecom Webinars & Videos :
http://www.rohde-schwarz.com/en/solutions/wireless-communications/lte/lte-webinars/webinars-overview_53570.html (HIGHLY RECOMMENDED)

[2] LTE Encyclopedia (https://sites.google.com/site/lteencyclopedia)

[3] WHO
http://www.who.int/peh-emf/publications/en/mcmcradiationmobilephonebk.pdf

[4] Icnerp :
http://www.icnirp.de/documents/emfgdl.pdf

Thanks for your attention ☺
Q&A

and it turns out that ancient Egyptians worshipped wifi.

Thank you

Comments, Questions and Discussions

Dr. Mohab Abd-Alhameed Mangoud

http://mangoud.com

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