Current trends in health and safety risk assessment of work-related exposure to EMFs
Milan, February 14-16, 2007

Evaluation of compliance with SAR limits on the basis of external RFEM- field and induced current measurements

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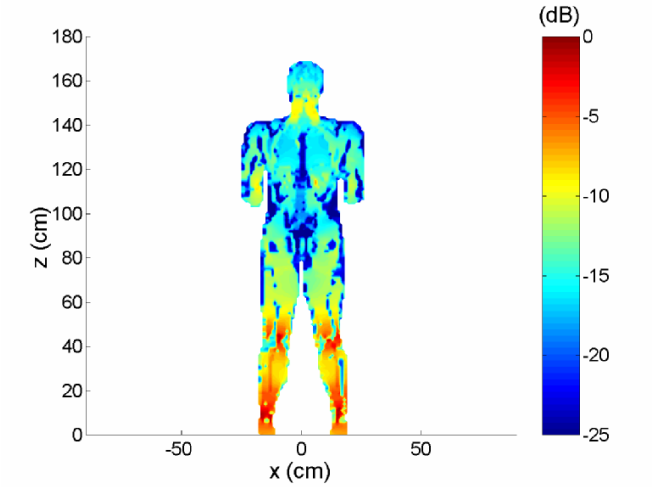


Content

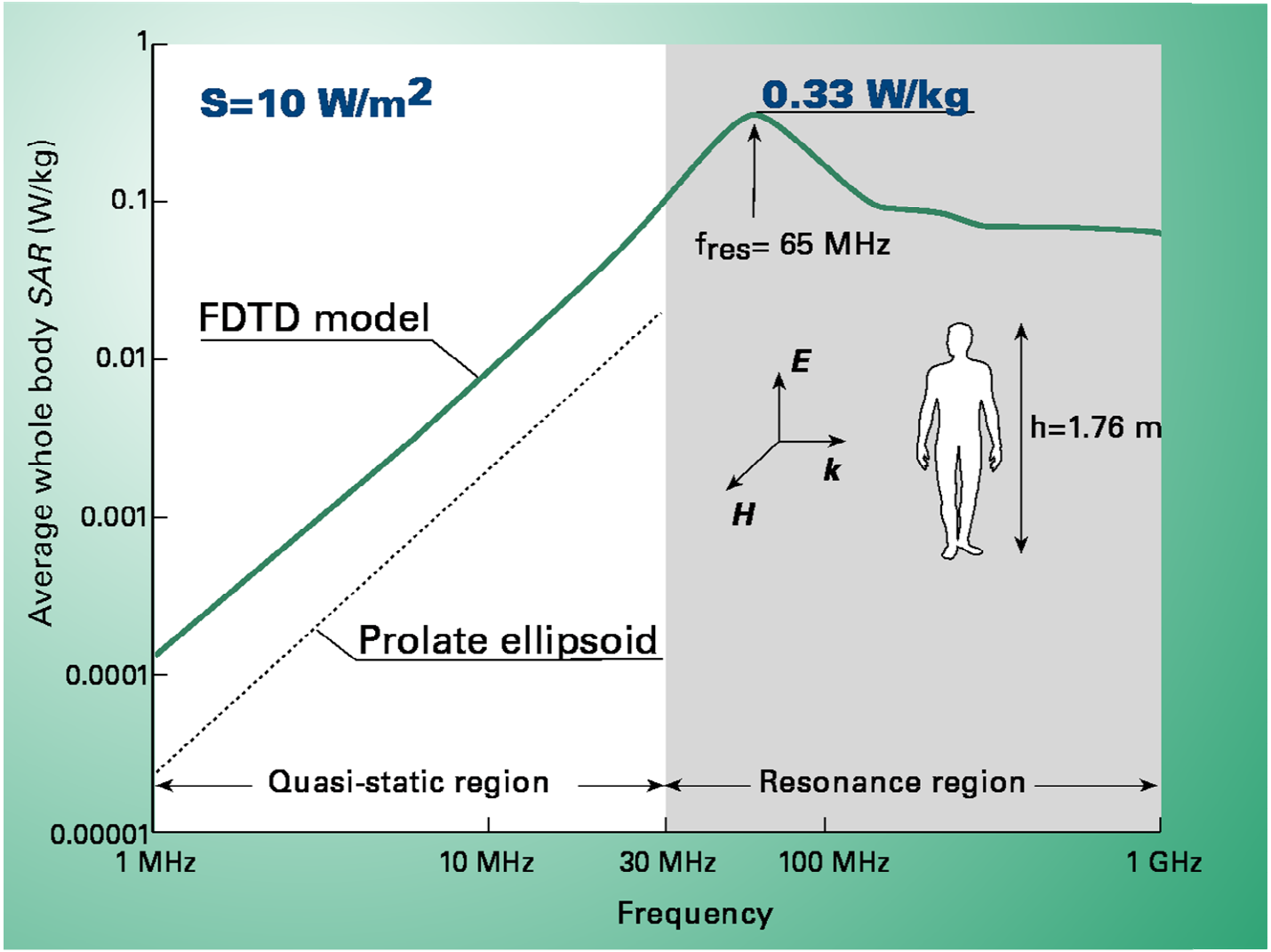
- Exposure limit values and action values
- Exposure assessment for non-homogeneous RF-fields in broadcast tower
- Exposure assessment for non-homogeneous RF fields in the vicinity of microwave antennas
- Assessment of SAR and induced body current in a reactive near field of a dielectric heater
- Localized exposure from a small source near the body

Exposure limit values for RF fields (Directive 2004/40/EC)

Frequency range	Current density for head and trunk (mA/m^2,rms)	Whole body average SAR (W/kg)	Localised 10 g average SAR for head and trunk (W/kg)	Localised 10 g average SAR for limbs (W/kg)	Power density (W/m^2)
0.1 - 10 MHz	f/100 (f in kHz)	0.4	10	20	-
0.01 - 10 GHz	-	0.4	10	20	-
10 - 300 GHz	-	-	-	-	50

SAR values are 6 min time averages

SAR in uniform plane wave



Action values for RF-fields (Directive 2004/40/EC)

Frequency range	Electric field strength E (V/m)	Magnetic field strength H (A/m)	Equivalent plane wave power density S_{eq} (W/m^2)	Contact current I_C (mA)	Limb induced current I_L (mA)
0.1 - 1 MHz	610	1.6/f	-	40	-
1 - 10 MHz	610/f	1.6/f	-	40	-
10 – 110 MHz	61	0.16	10	40	100
110 - 400 MHz	61	0.16	10	-	-
400 - 2000 MHz	$3f^{½}$	$0{,}008f^{½}$	f/40	-	-
2 - 300 GHz	137	0.36	50	-	-

ICNIRP Guidelines 1998

The reference levels (action values) are spatially averaged values over the body with the important proviso that the basic restrictions (exposure limit values) on localized exposure are not exceeded

Flow chart for exposure assessment (EN 50392)

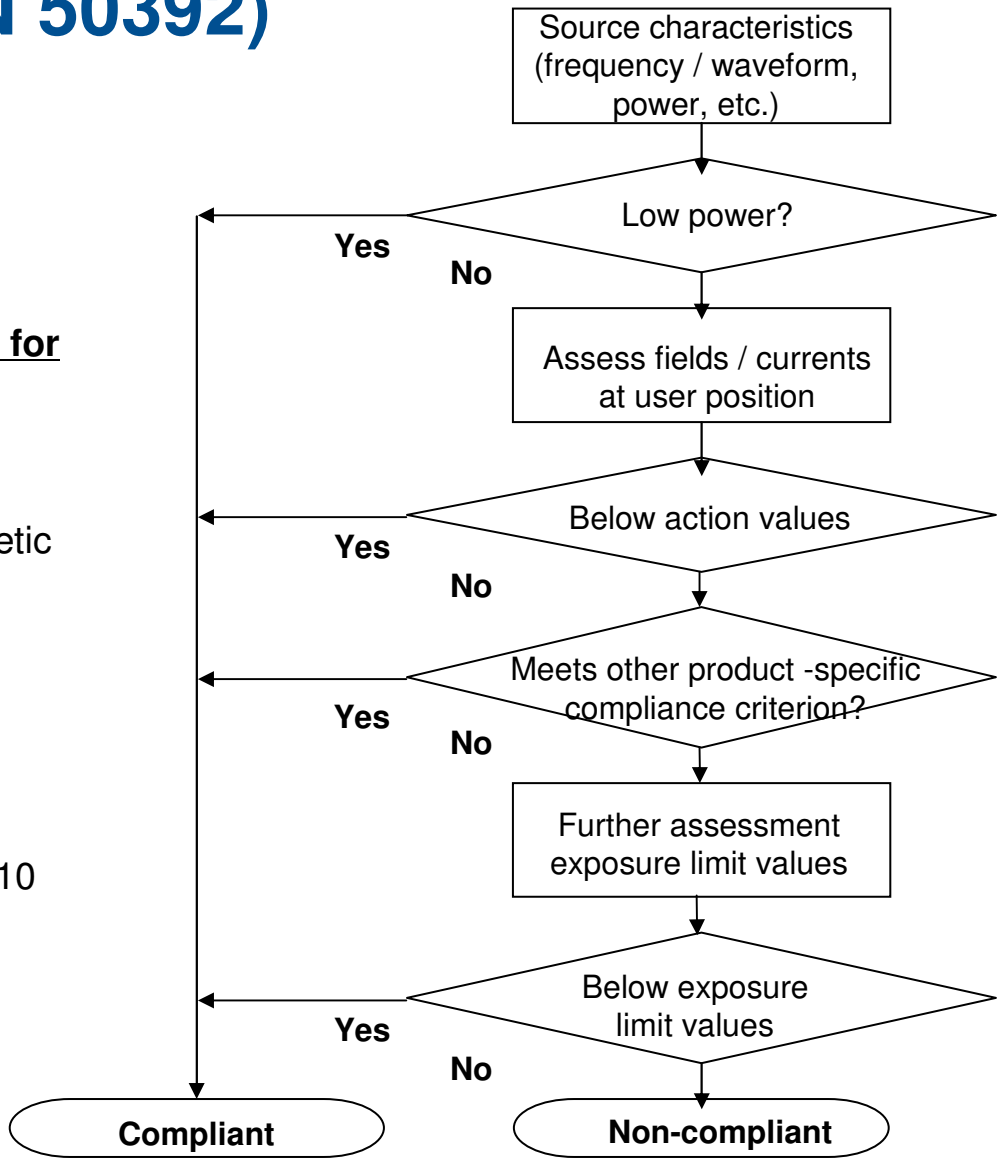
Occupational exposure limits for RF Fields

Action values

- External electric and magnetic field strength
- Induced body current

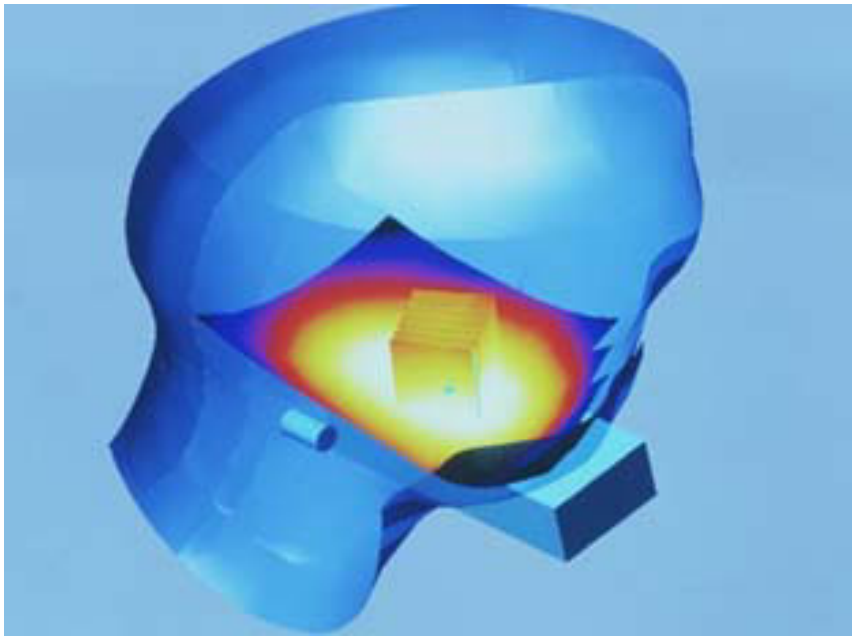
Exposure limit values

- Peak SAR (10 g)
- Whole body average SAR
- Induced current density (< 10 MHz)

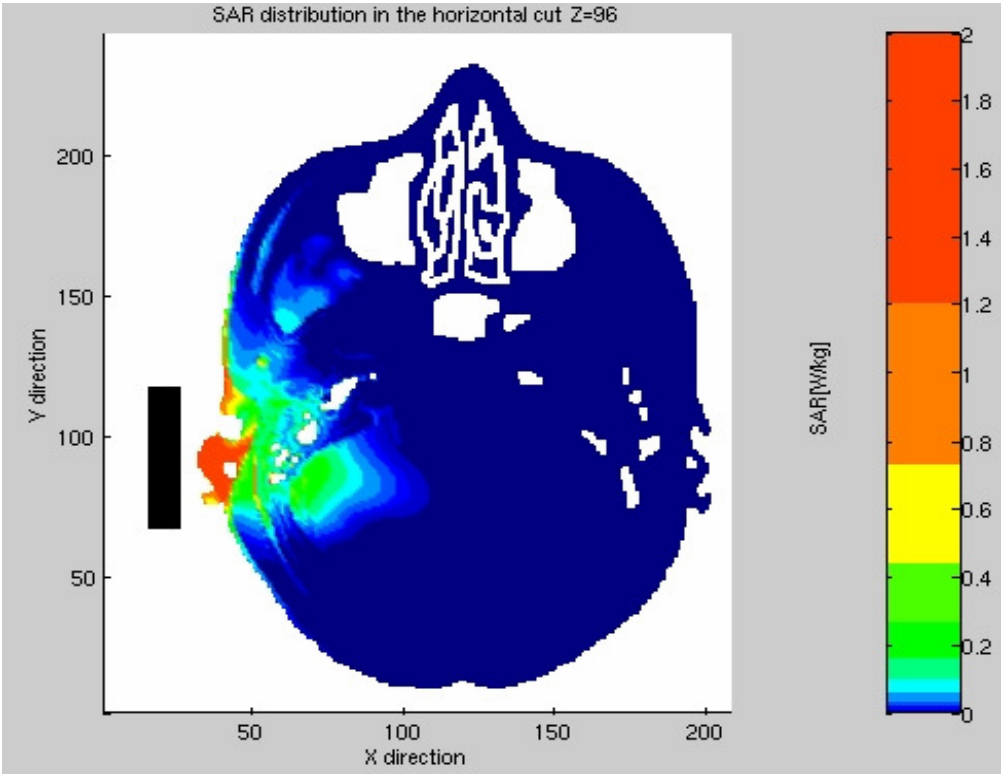


SAR assessment for a localized exposure from a mobile phone

measured in homogeneous liquid phantom



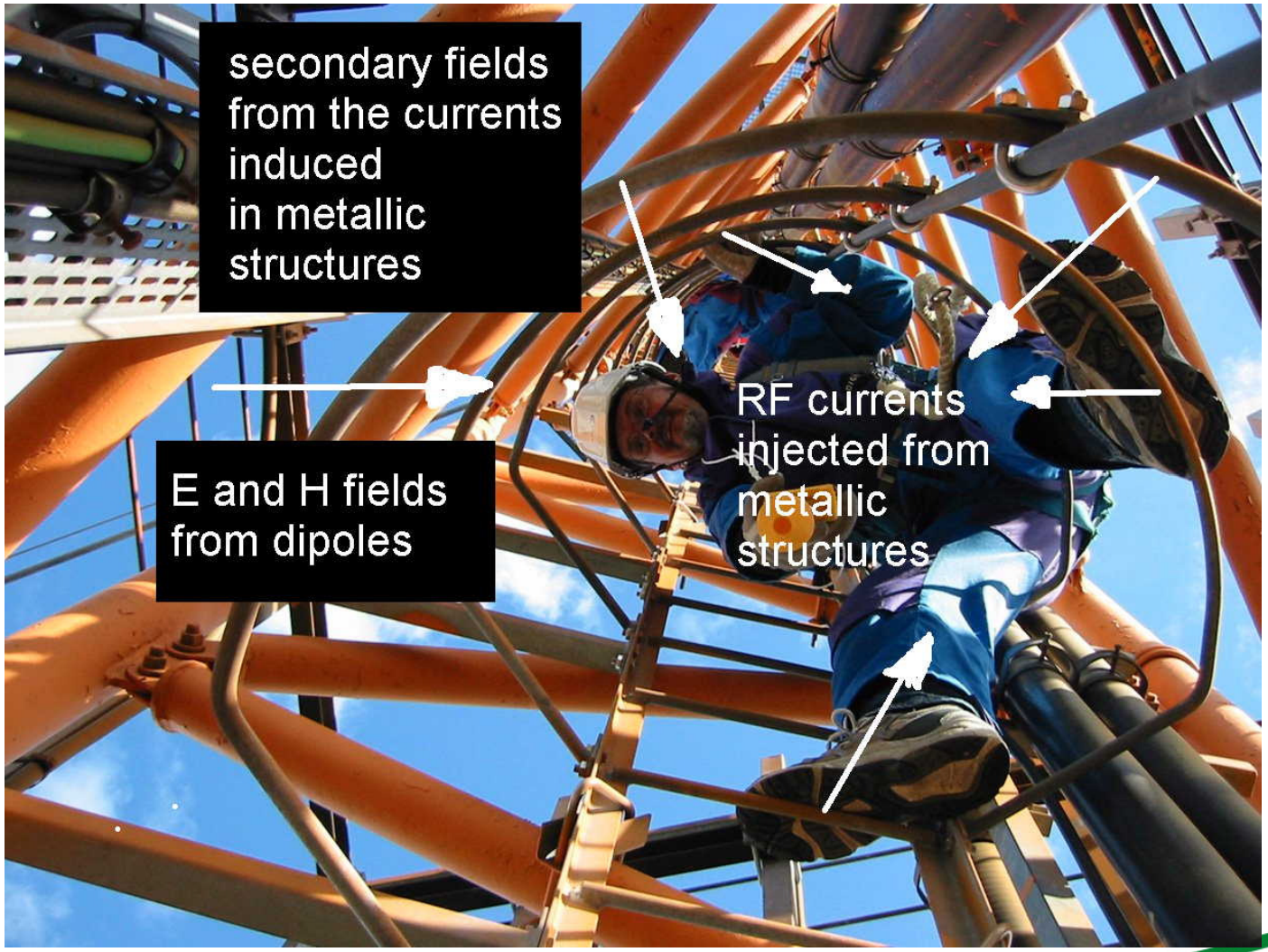
computed in realistic head model



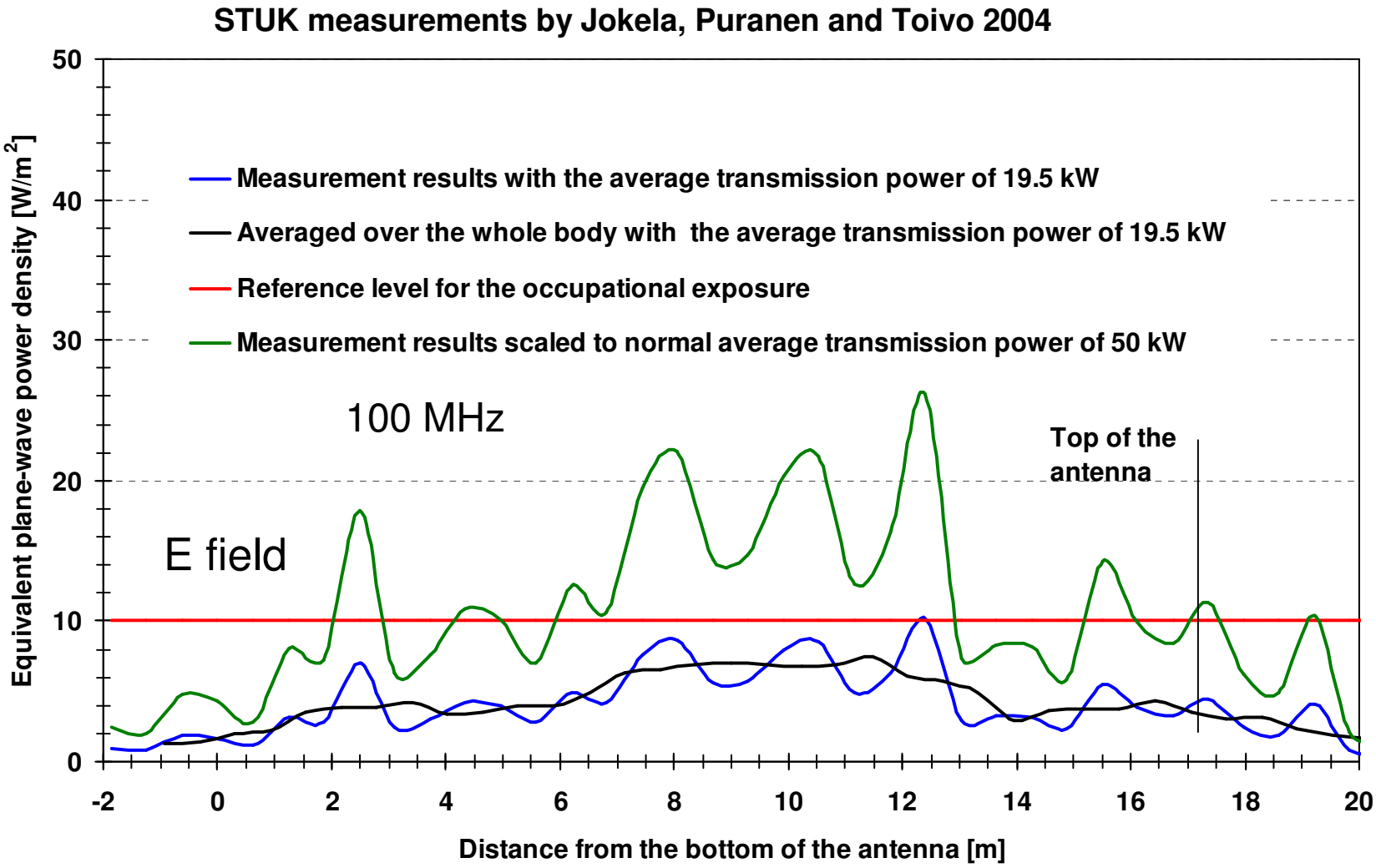
Tim Toivo and Tommi Toivonen, STUK

http://www.elmagn.chalmers.se/~elfrk/work/dosimetry/dosimetry.html

RF exposure sources in a FM/TV mast



E-field measurement in FM-radio antenna



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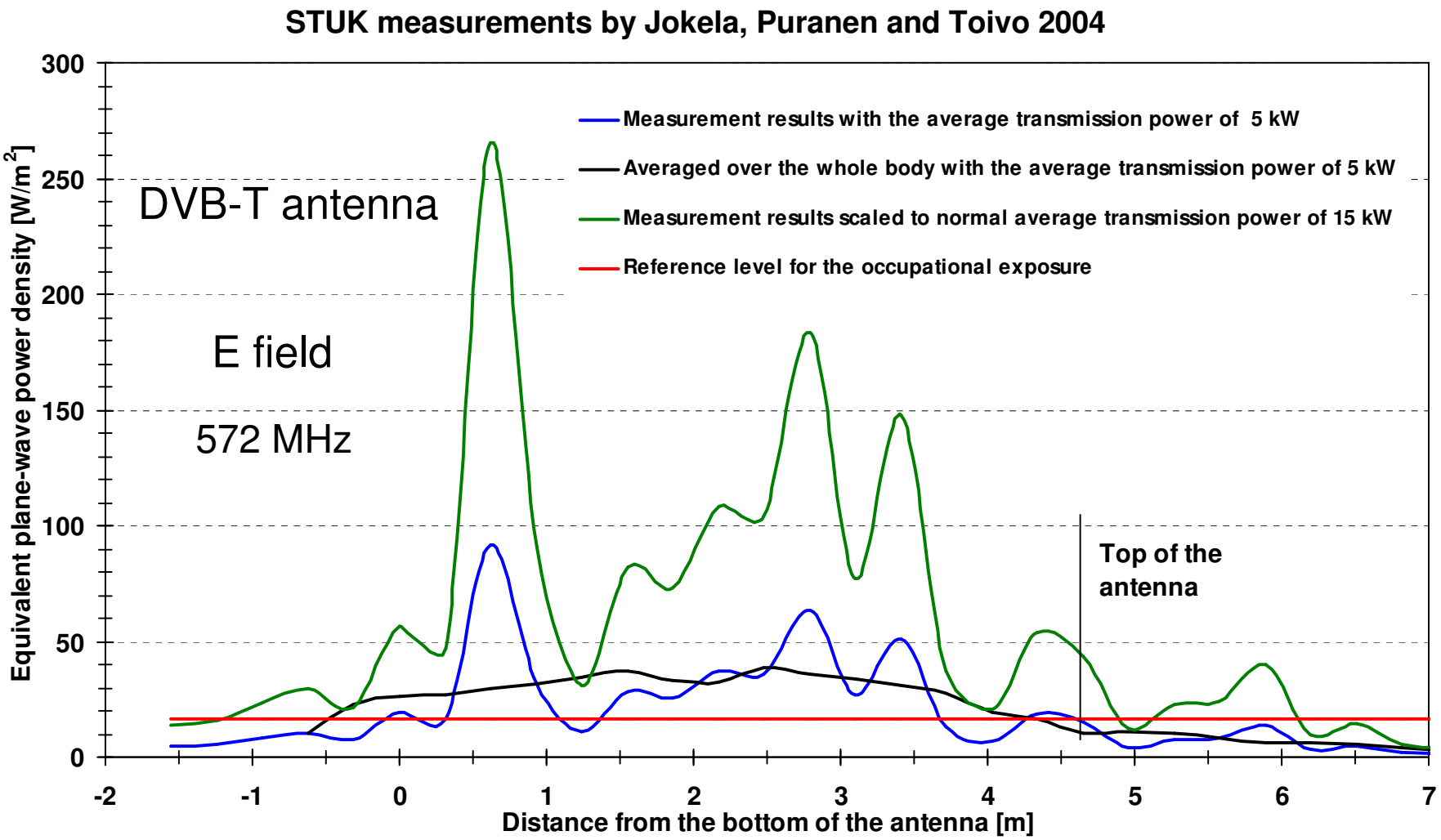
E-field measurement in Digi TV antenna



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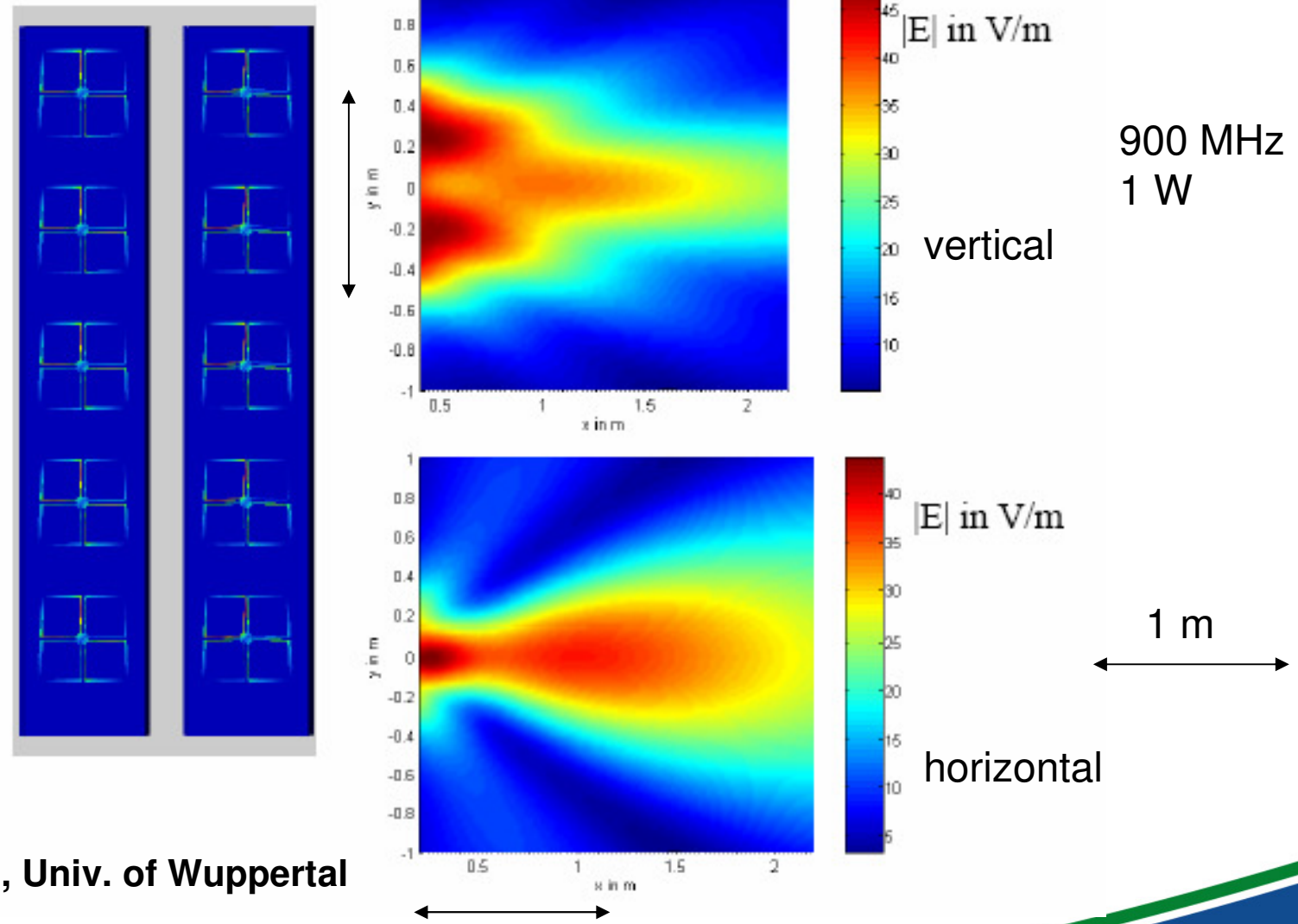
RF EXPOSURE ASSESSMENT IN THE FM/TV MAST

- Routine SAR assessment impossible in so complex exposure environment
- Technical problems with body current measurements
- Electric and magnetic field measurements with isotropic broadband probes at distances **not less than 20 cm** from the metallic structures
- **Body average of E^2, or S_E is a good exposure indicator.**

Near field of a base station antenna



900 MHz
1 W

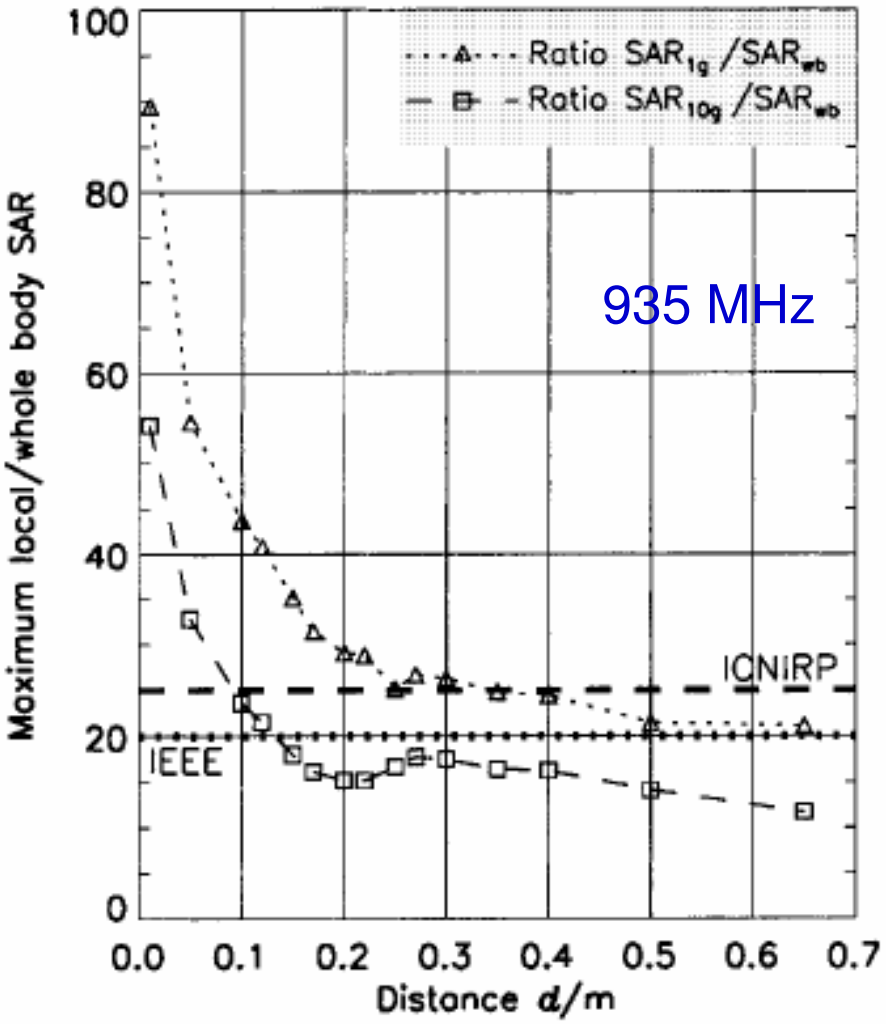
vertical

1 m

horizontal

Hansen et al., Univ. of Wuppertal

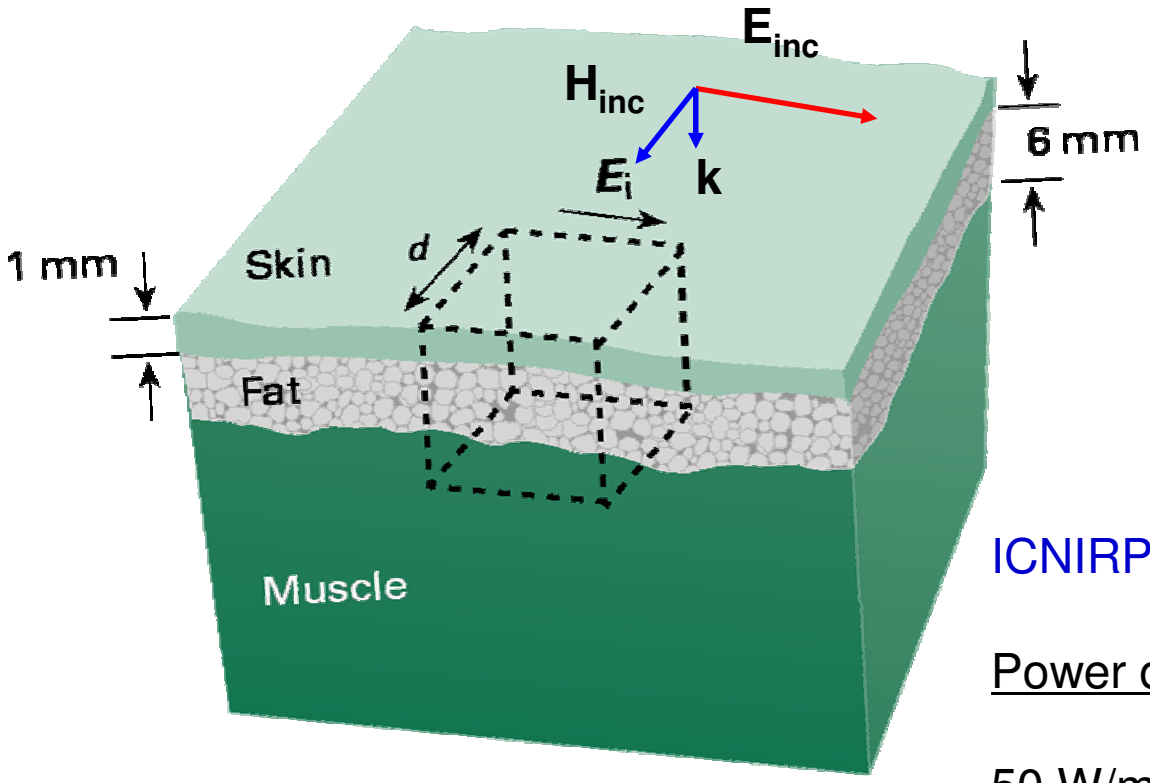
Computed SAR near a base station



Cooper et. al. Bioelectrom. 23:429-443, 2002

- For distance exceeding 30 cm exposure is limited by the whole body average (WBA) SAR.
- At GHz range WBA-SAR is correlated with body average power density

Planar layer model for calculation of SAR in surface absorption range



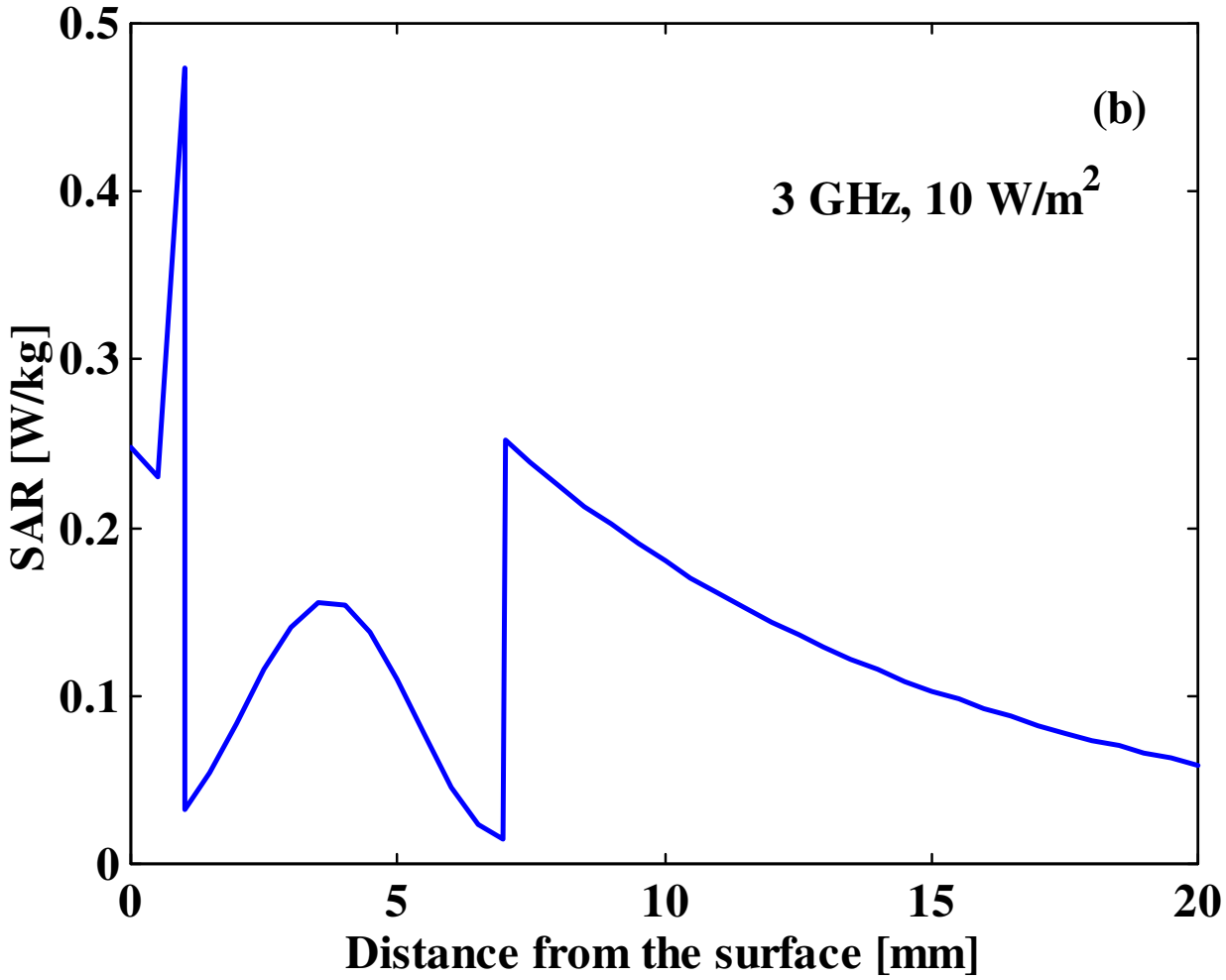
for 10 g tissue cube
d=2.2 cm

ICNIRP guidelines 1998

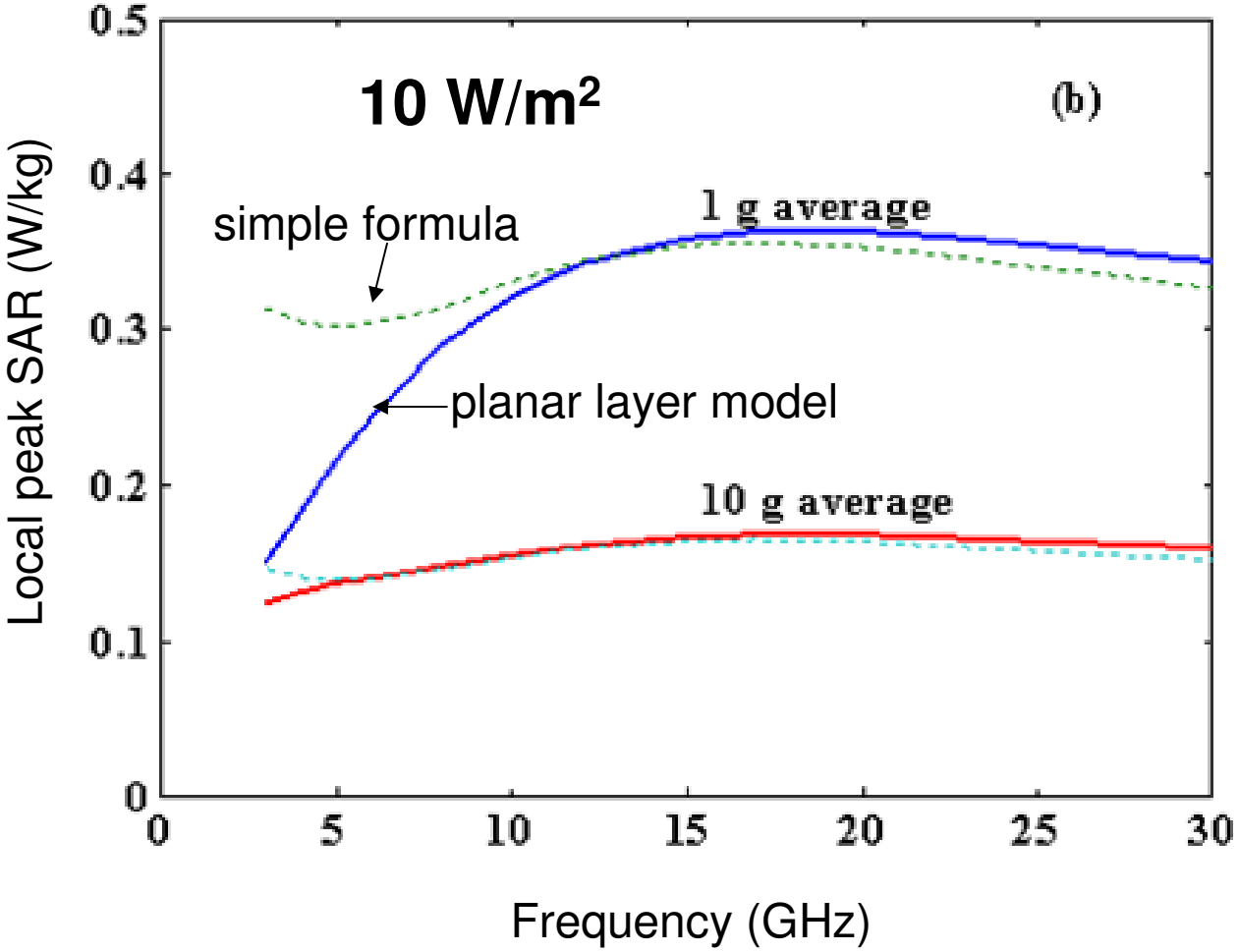
Power density limit from 10 to 300 GHz

50 W/m^2 averaged over 20 cm^2
1000 W/m^2 averaged over 1 cm^2

Concentration of SAR in the surface of the body at microwave frequencies



Effect of averaging of local peak SAR in the body surface



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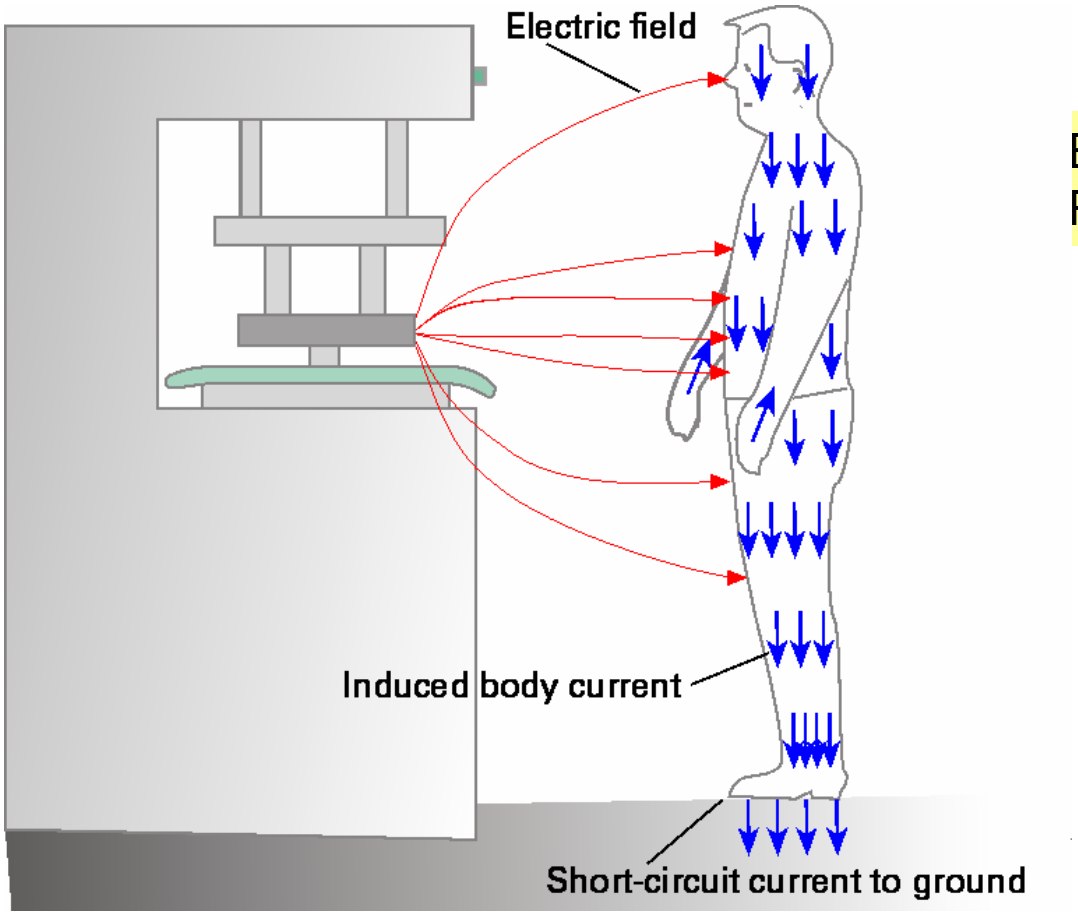
Jokela K. EMC & SAFETY OF MULTIMEDIA COMMUNICATION TERMINALS Standard Evaluation Report, report 2000

Relaxation of the reference level for spatial peak power density above 1 GHz.

Peak power density may exceed at least 6 dB the body average power density, if the distance to the antenna exceeds 30 cm

Non-uniform exposure near an industrial dielectric heater



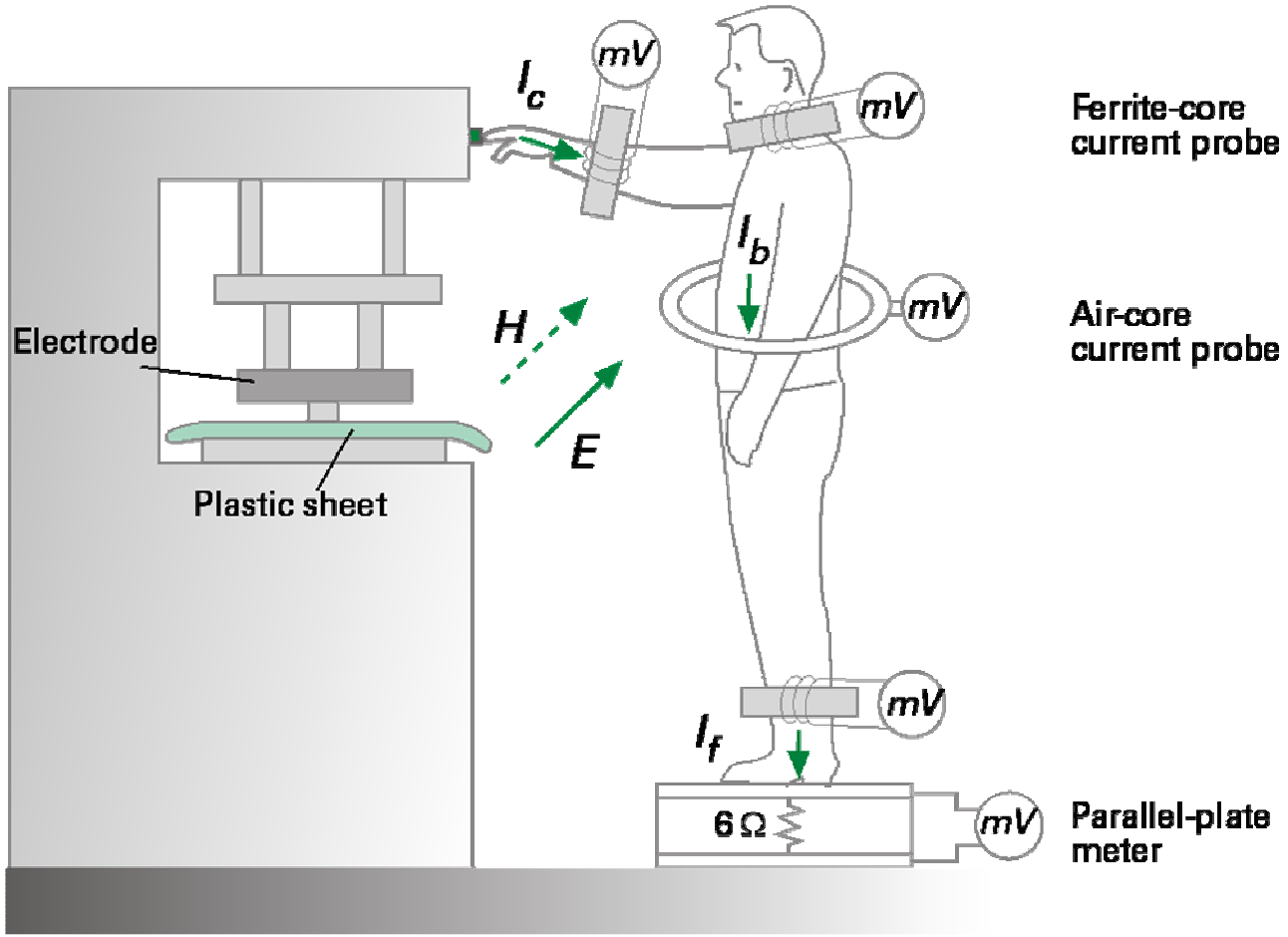
Electric field induces longitudinal RF-currents in the body

27 MHz

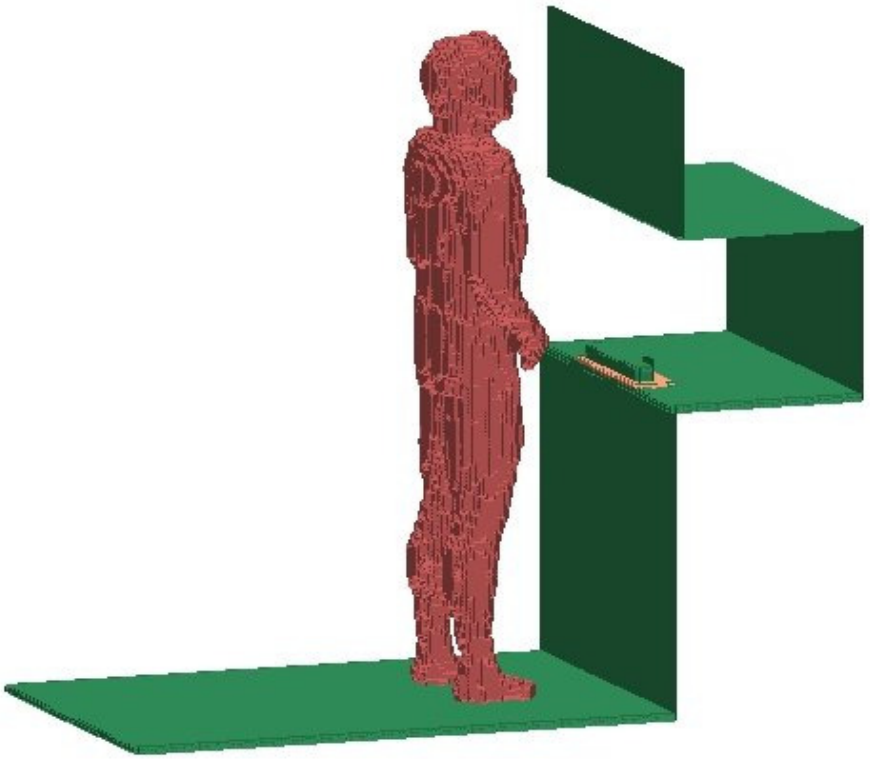
Research problem

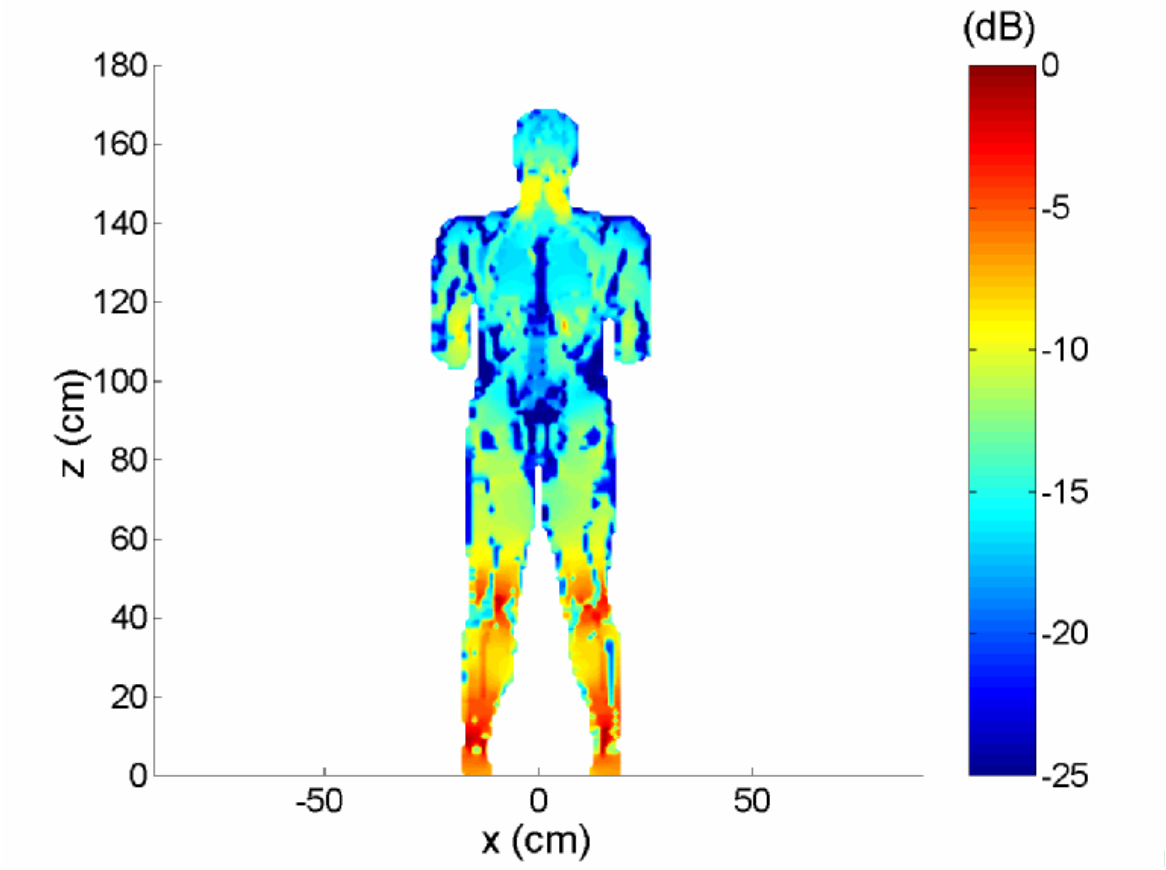
Estimate the whole body average and local maximal SAR from the measured RF current

Measurement of induced current



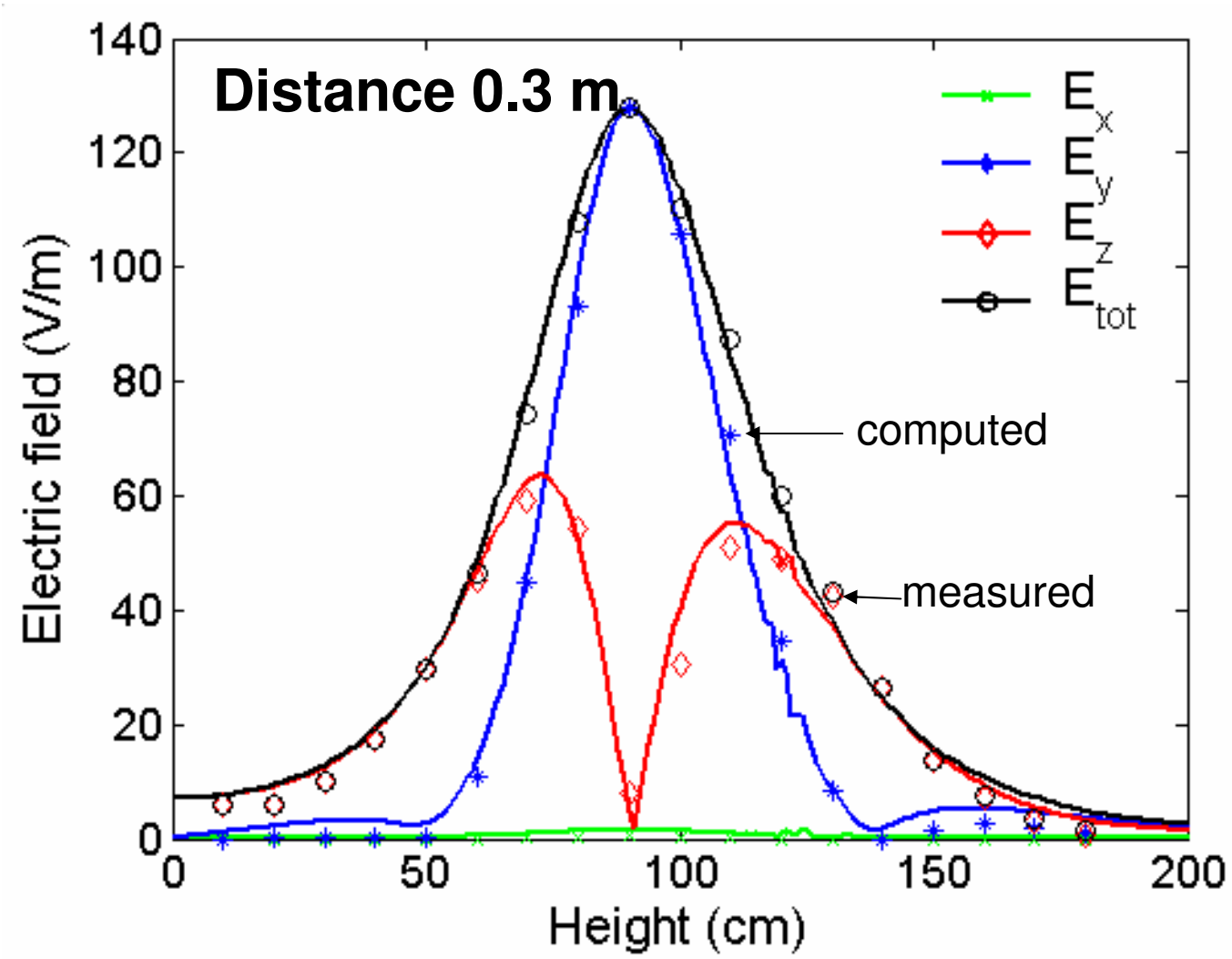
SAR simulation



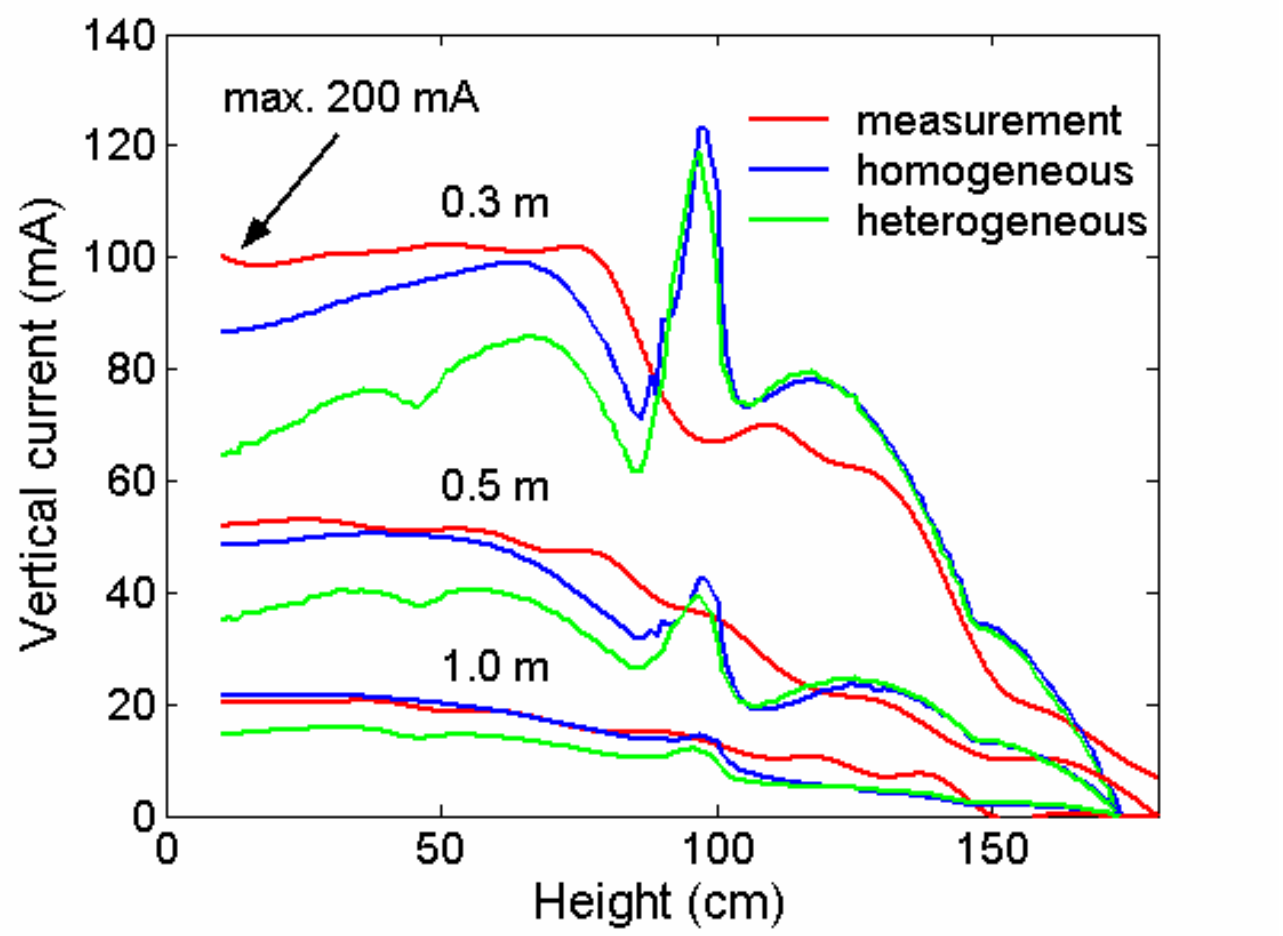


Kännälä et al. 2006

Electric field



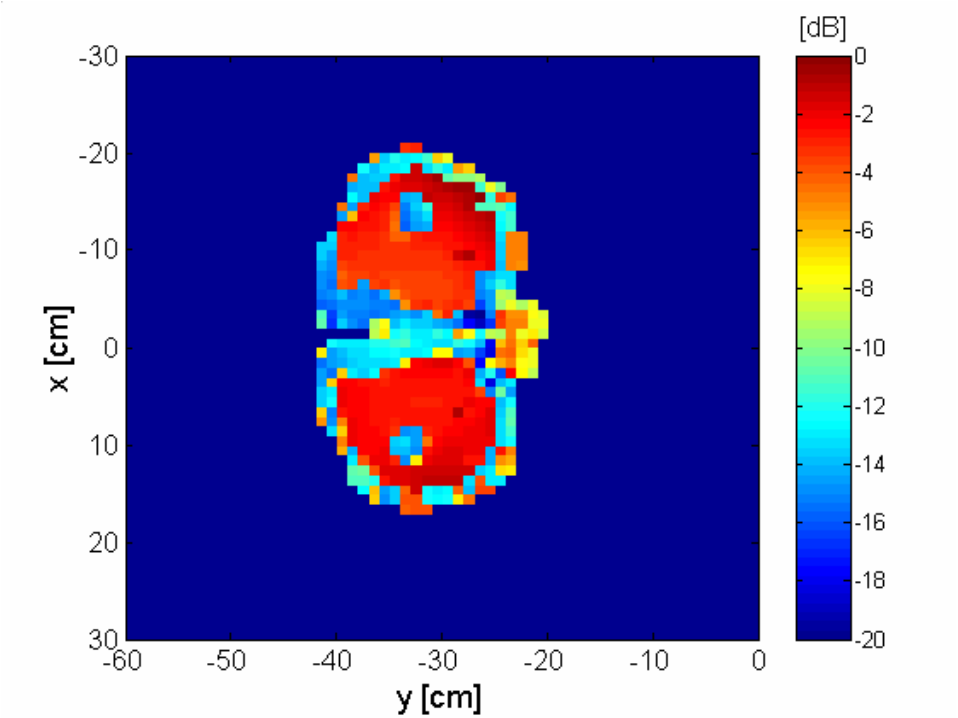
Measured and computed body current



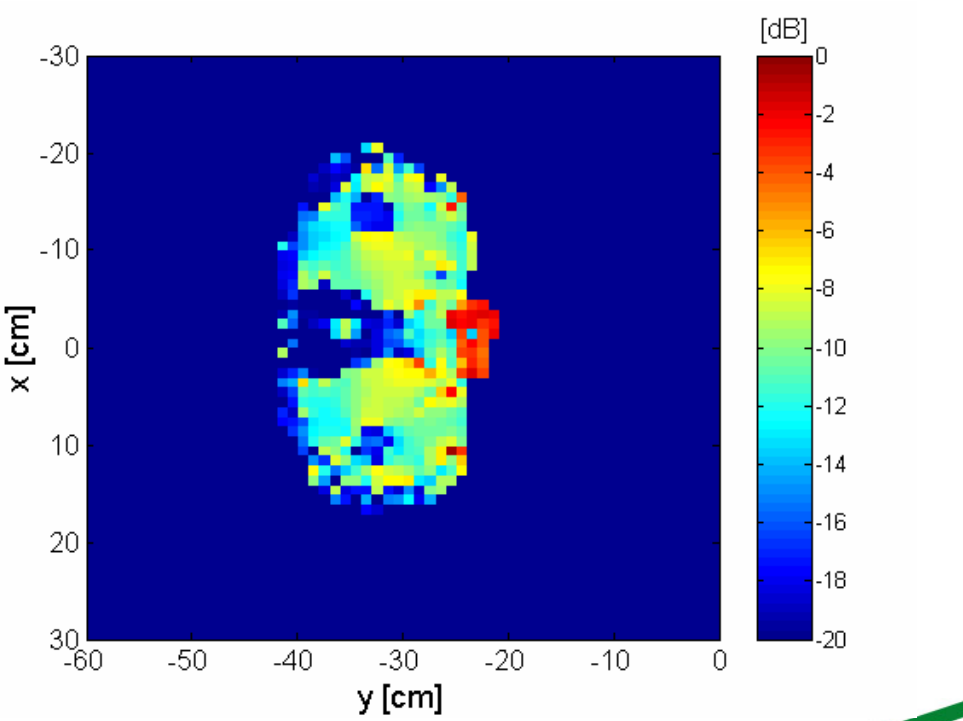
Current density in pelvic cross-section (heterogeneous model)

distance 0.3 m

vertical (longitudinal)



horizontal



Relation of SAR to current and electric field

Current in the ankle = 100 mA

Distance [m]	$E_{tot,max}$ [V/m] (60)	SAR_{wba} [W/kg] (0.4)	SAR_{10g} [W/kg] (20)
0.3	378	0.130	7.3 (in arm)
0.5	212	0.079	5.2 (in ankle)
1.0	93	0.062	5.3 (in ankle)

For non-uniform exposure to near electric field from a dielectric heater

- induced body currents are longitudinal and distributed evenly along the high conducting tissues below the skin,
- currents depend on the body average electric field E,
- hot spots in the ankles and wrists are most critical,
- whole body and local peak SAR can be estimated from the measured current for electrode distance > 0.3 m,
- for distance <0.3 m, critical hot spot may arise in the tissue most adjacent to the electrode,
- SAR limits are not exceeded when current < 100mA and distance >0.3 m.

CONCLUSIONS

- Below 30 MHz the measurement of induced body currents and body average electric field is a good practice for assessing exposure to electric field (high impedance sources).

- From 100 to 1000 MHz the equivalent electric field averaged over the whole body is probably sufficient exposure indicator in the FM/TV mast where the fields are relatively evenly distributed over the whole body.

- Above 1 GHz the local power density may exceed 6 dB the whole body average.

- At distance less than 20 cm determination of SAR is necessary for realistic exposure assessment.

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