ATTACHMENT 6

Skin SAR Enhancement for Body-Worn Devices

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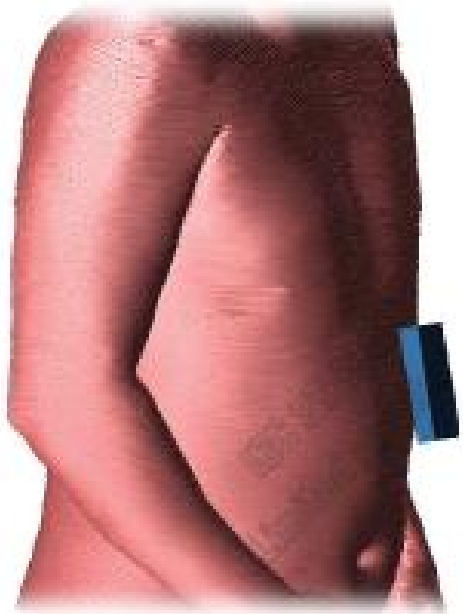
Outline

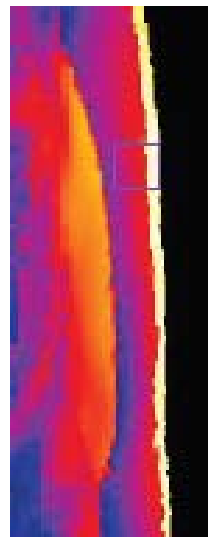
- **Background of the issue**
- **IEC task force project**
  - SAR analysis
  - Statistical modeling
- **Results**
  - Proposed SAR enhancement factors
- **Physiological relevance**
  - Comparison with temperature
  - Advice of ICES TC95.4

Background

Presentation by IT'IS on 5/2004

- SAR in people differs from SAR measured in phantom
- Tissue layering causes standing waves
  - **Certain fat thicknesses cause high SAR in skin**
- High SAR in the skin reported



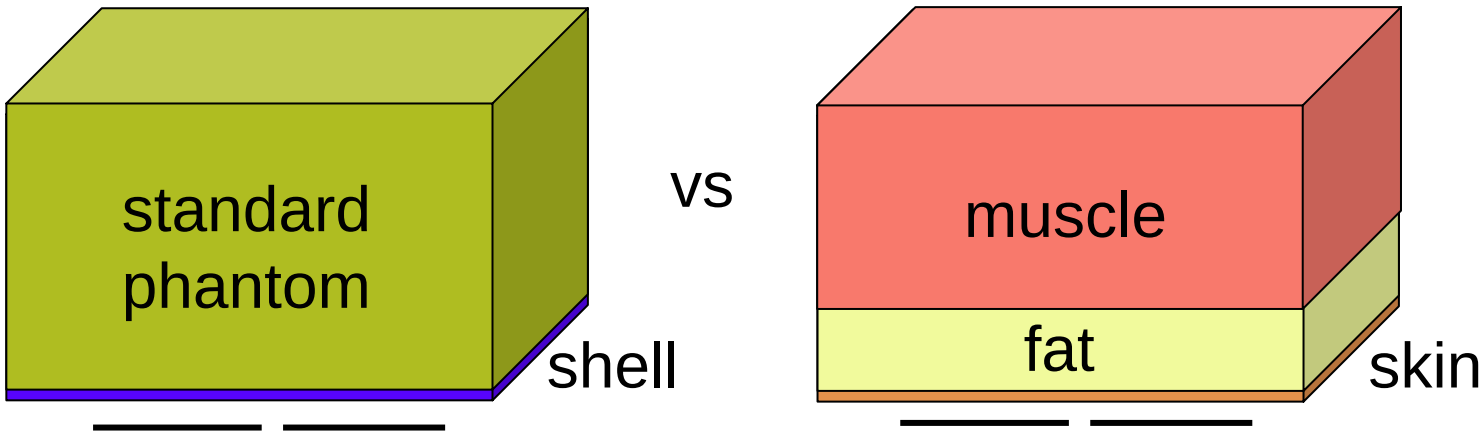


Task force established

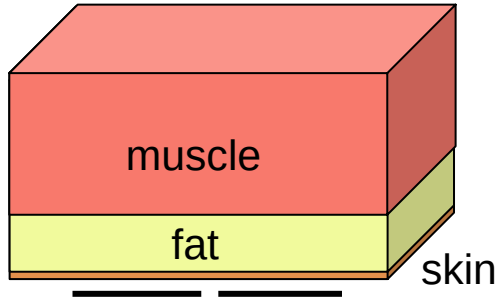
- Agree on appropriate methodology
- Make use of statistical techniques
- Compare with anatomical models
- Analyze results

Agreed-upon Approach (Feb 2005)

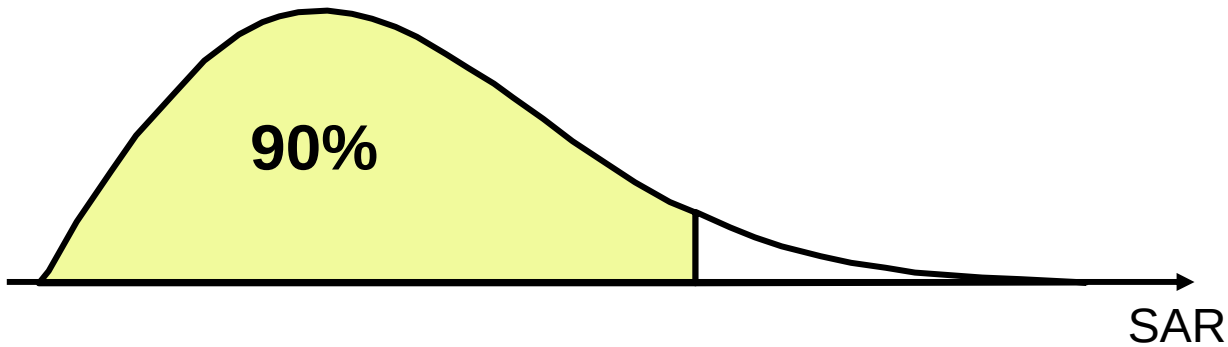
- **Study practical antenna types**
- **Validate with real models**
  - Wireless handsets against human models
- **Heterogeneous model: 3 layers: skin, fat, muscle**
  - Model tissue layers according to statistical distributions
- **Derive SAR enhancement factors for 1g and 10g avg SAR**



Statistical Approach



- **Statistical analysis of tissue thickness**
  - Not worst-case analysis
  - Consistent with IEC 62209-1 and IEEE 1528
  - Tissue thicknesses vary among population
  - Weigh SAR values by skin and fat thickness probability
- **Approach is robust**
  - Extremely unlikely cases become insignificant



Body worn device locations

Carnegie Mellon University - 1998

***Dynamic wearability* confined to body locations such as:**

arm - triceps

forearm

upper chest

back - subscapular

back – suprailiac

ankle

leg - calf

thigh - front

waist - lateral

Literature review by Anderson *et al.*

14 papers identified

Example distributions

Body location	Skin thickness	Fat thickness
Back – subscapular	1.58 – 2.37 mm	4.72 – 22.03 mm
Back – suprailiac	1.58 – 2.37 mm	0.72 – 30.58 mm
Thigh – front	0.99 – 1.30 mm	3.96 – 33.72 mm
Leg – calf	0.79 – 1.31 mm	2.05 – 23.88 mm

Literature review by Dr. Eduard David

71 page report, containing skin and fat thickness tables

Example for fat data:

Back - suprailiac							
Age [y]		*5-12*	*13-24*	*25-34*	*35-44*	*45-54*	*plus 55*
Caucasian	m	**3.9** ± 1.0	**6.6** ± 1.5	**8.3** ± 2.0	**9.8** ± 1.8	-	**8.6** ± 0.3
	f	**3.8** ± 1.2	**5.1** ± 2.8	**8.0** ± 1.1	**8.2** ± 0.7	-	**9.6** ± 1.2
Asian	m	**3.6** ± 1.3	**5.4** ± 2.9	**8.3** ± 4.7	-	**10.9** ± 0.1	-
	f	**3.7** ± 0.1	**6.2** ± 3.5	**6.3** ± 1.1	**6.7** ± 1.7	**11.2** ± 4.0	-
African	m	**3.5** ± 3.9	-	-	-	-	-
	f	**3.6** ± 3.2	-	**5.5** ± 2.7	-	-	-
Hispanic	m	-	-	-	-	-	-
	f	-	-	-	-	-	-
N African	m	-	-	-	-	-	-
	f	-	-	-		-	-

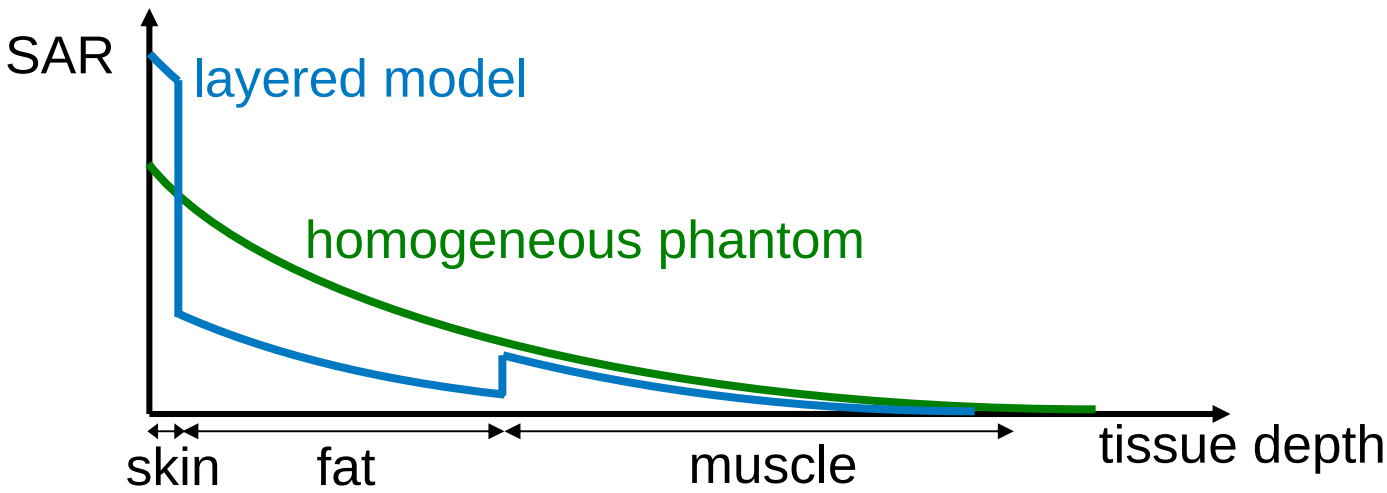
Table 8. Subcutaneous fat layers [mm] of different body parts of persons with normal weight in relation to age, ethnic groups and sex. Values are mean with standard deviation.

Derive SAR Enhancement Factor

- **SAR Enhancement Factor (EF):**
  - Ratio of SAR in anatomical (layered) model to SAR in homogeneous phantom

$$EF_{10g} = \frac{SAR_{10g,layered}}{SAR_{10g,phantom}}$$

- **EF is due to high SAR in skin**

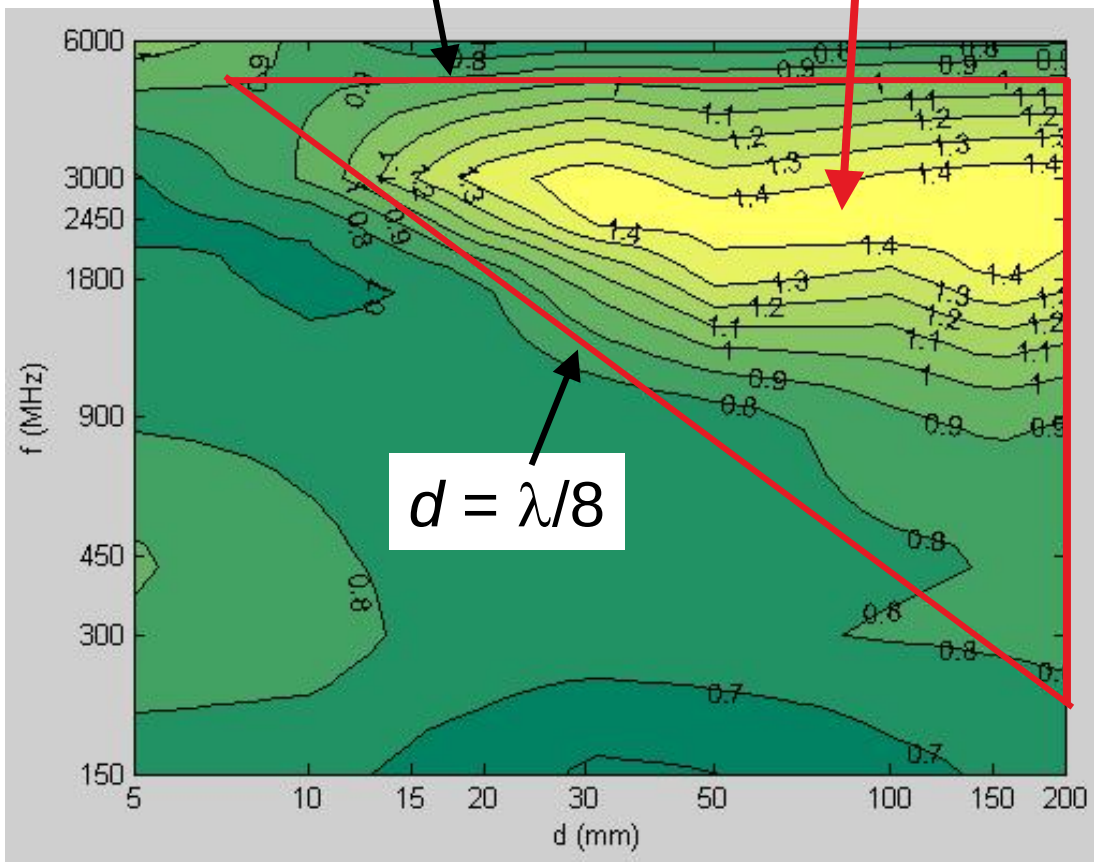


SAR enhancement factor

Using Anderson and David data

EF is plotted vs frequency (*f*) and distance of antenna to body (*d*)

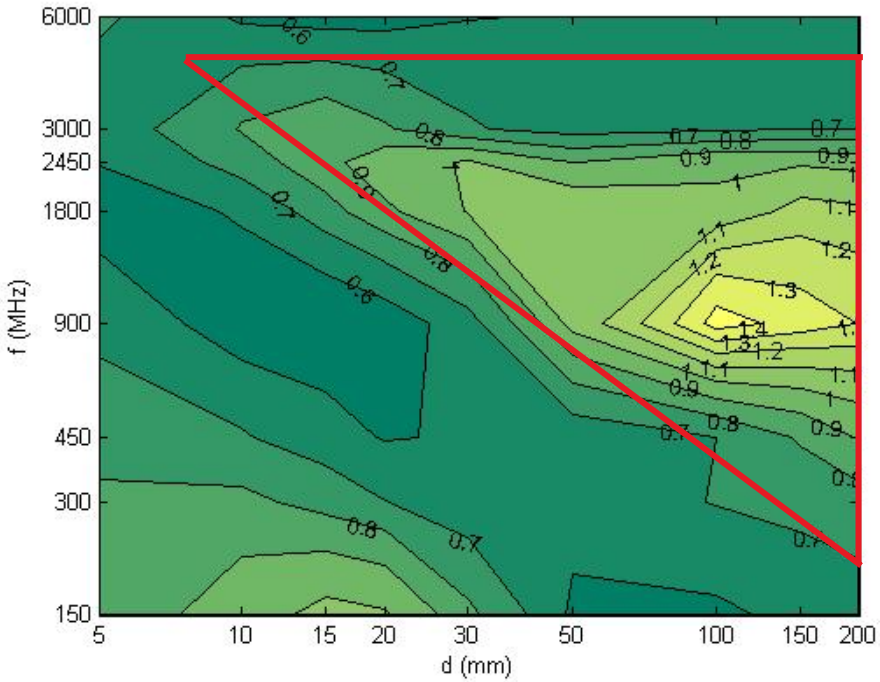
Typical example (from > 100 cases)



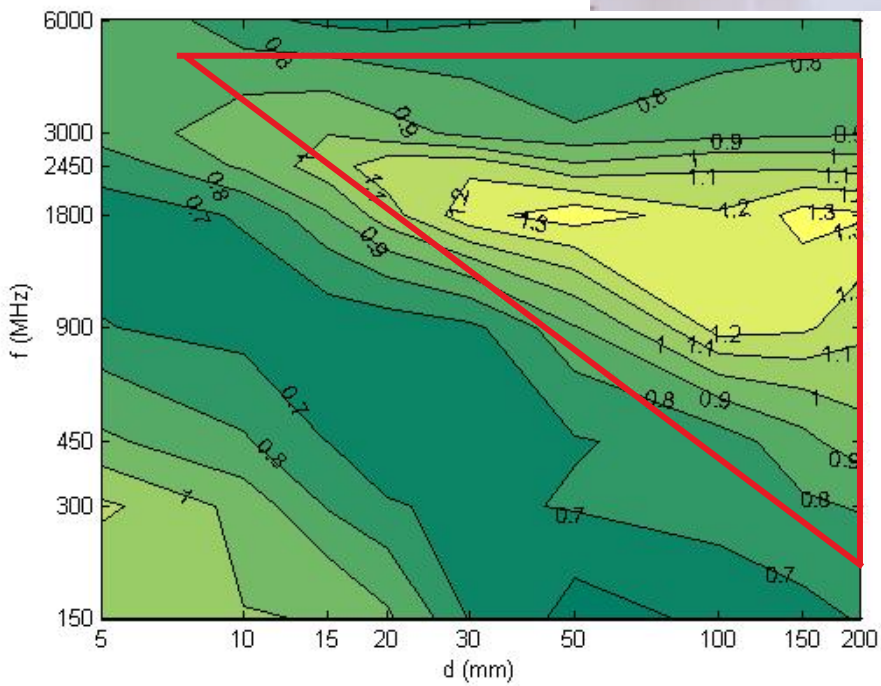
Results: Back – Subscapular

From Anderson data

Skin: 1.58 – 2.37 mm, Fat: 4.72 – 22.03 mm



EF_{1g}

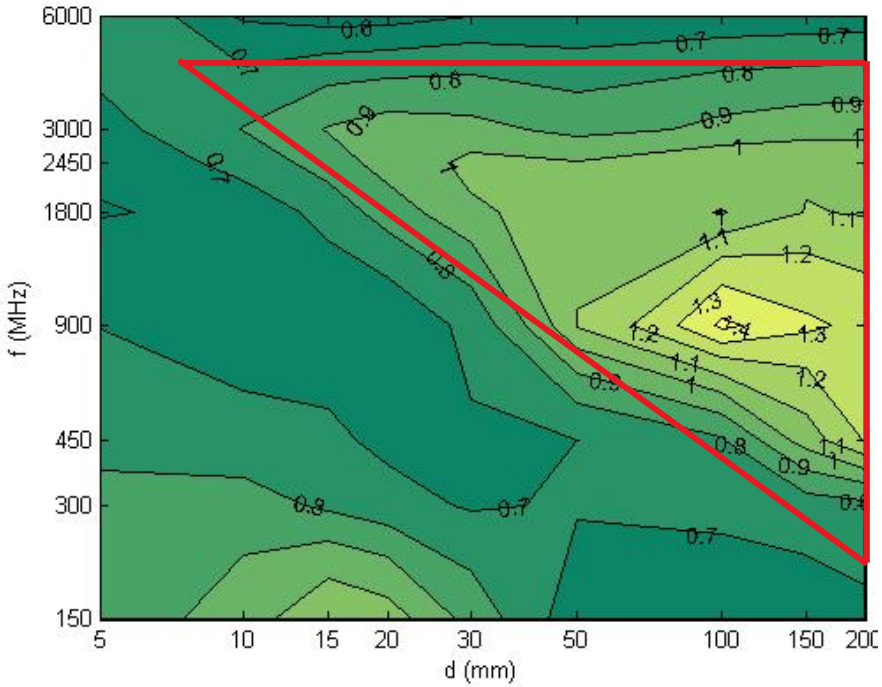


EF_{10g}

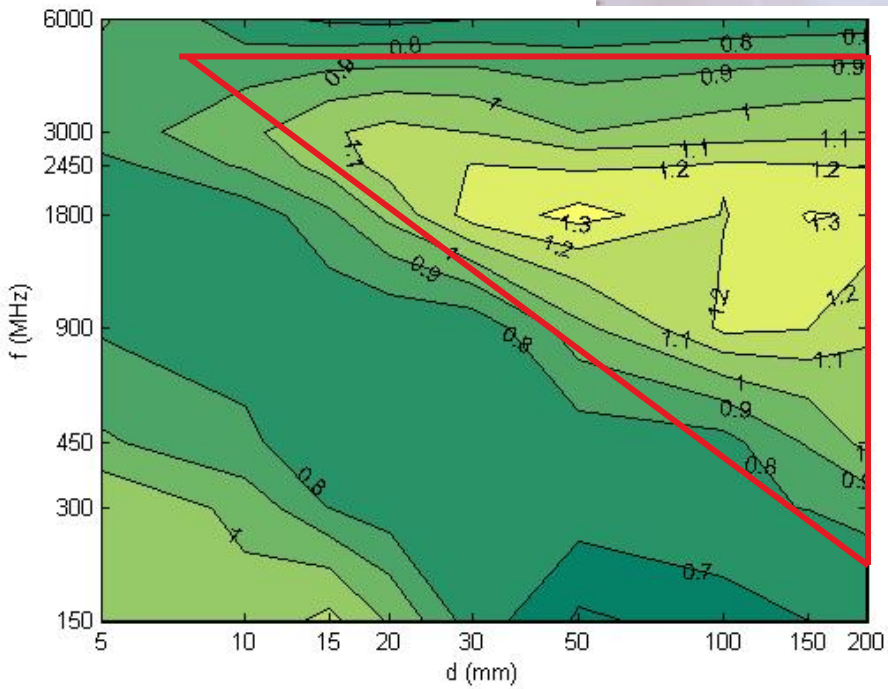
Results: Back – Suprailiac

From Anderson data

Skin: 1.58 – 2.37 mm, Fat: 0.72 – 30.58 mm



1g

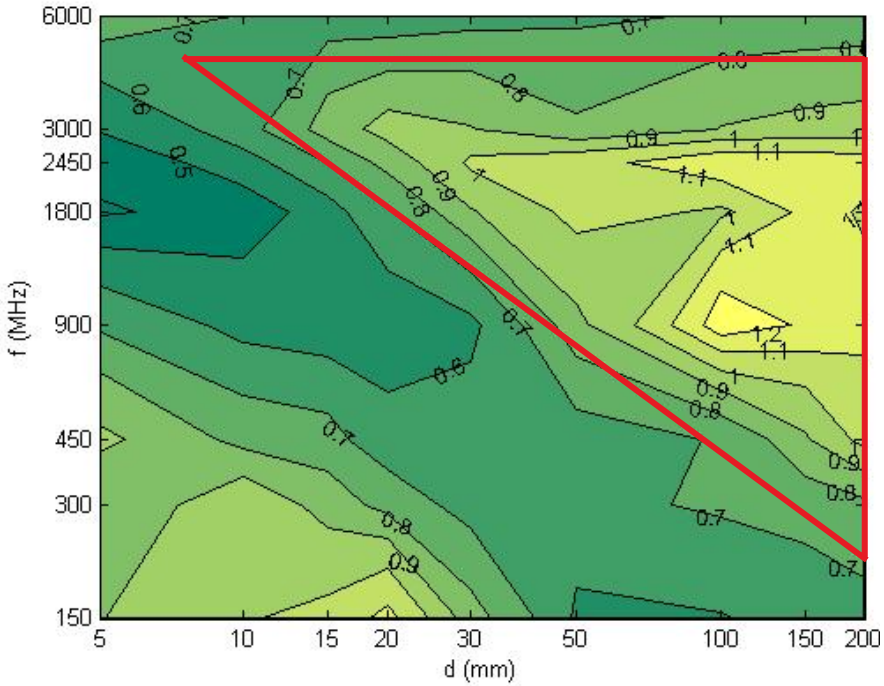


10g

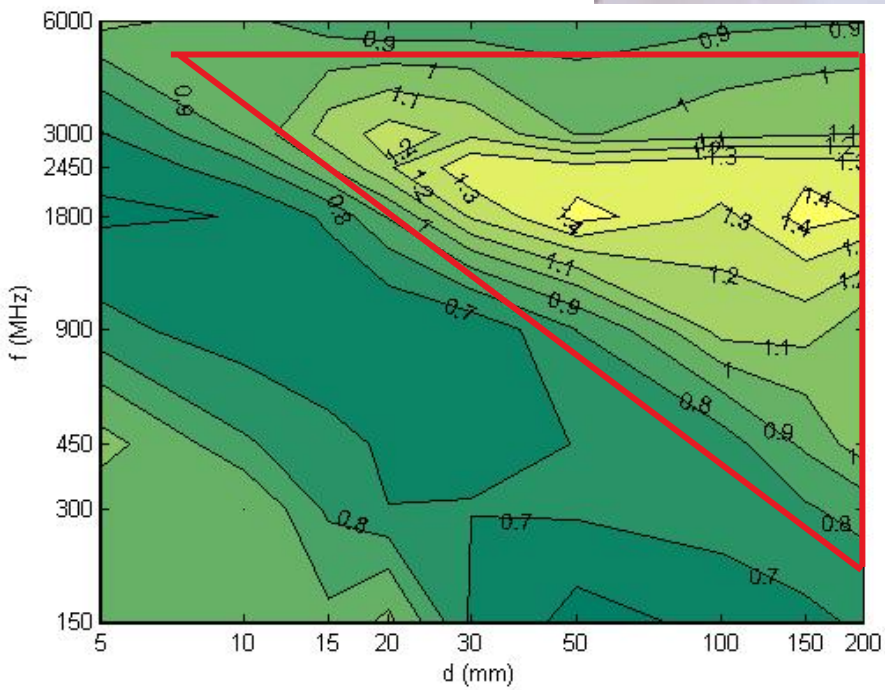
Results: Thigh – Front

From Anderson data

Skin: 0.99 – 1.30 mm, Fat: 3.96 – 33.72 mm



1g

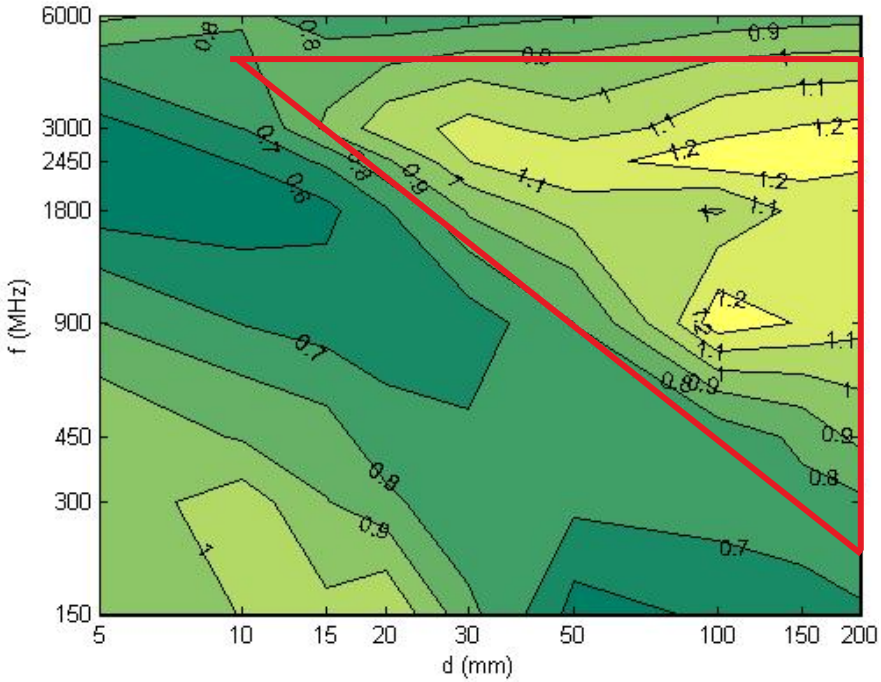


10g

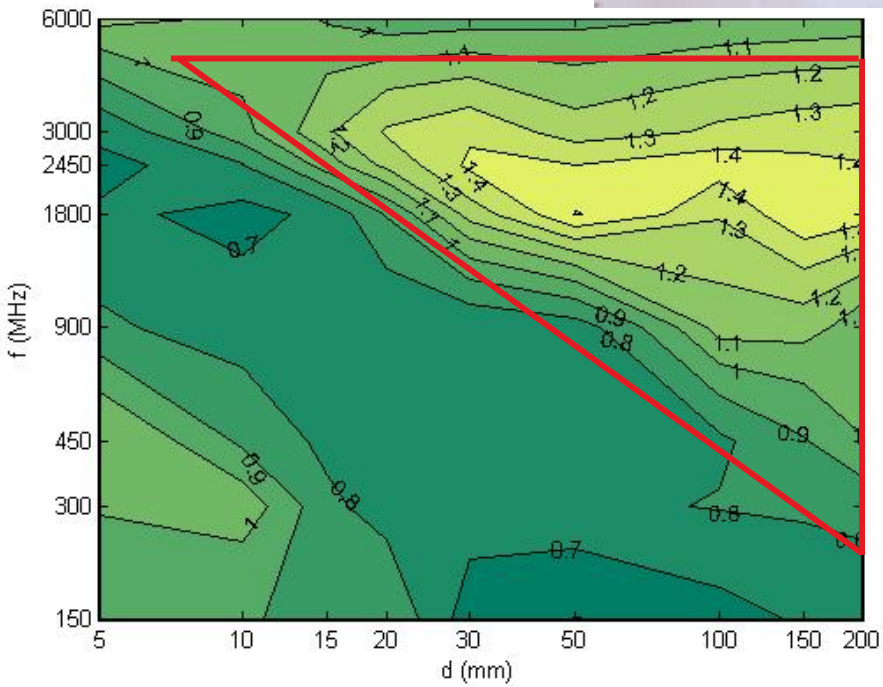
Results: Leg – calf

From Anderson data

Skin: 0.79 – 1.31 mm, Fat: 2.05 – 23.88 mm



1g



10g

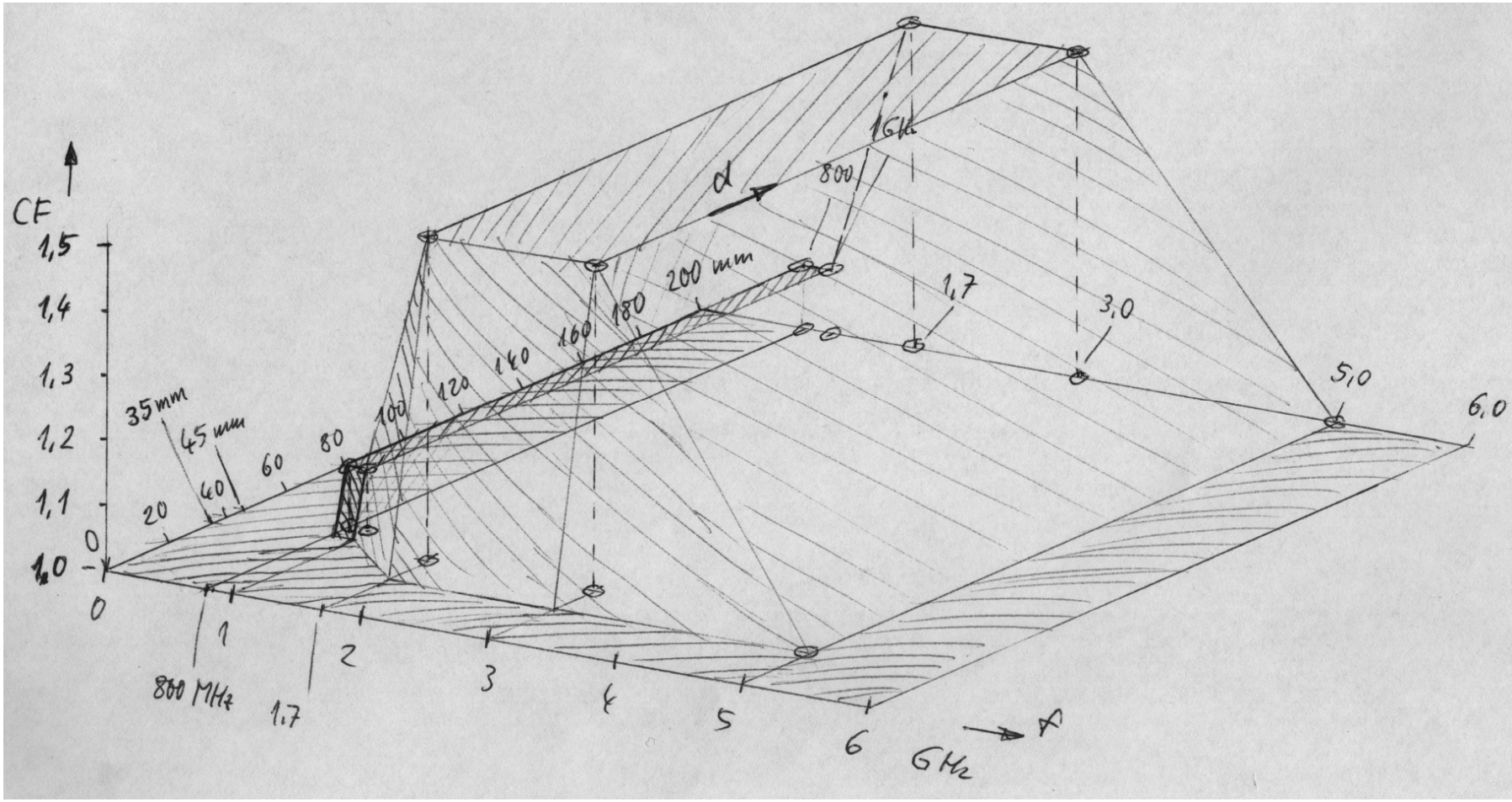
Proposed SAR Enhancement Factors

Approved at October 2006 meeting

f (MHz)	Device to phantom distance (mm)	Enhancement factor
300 – 800	0 – 200	1
800 – 1000	0 - 40	1
	45 – 200	1.1
1700 – 3000	0 - 20	1
	35 – 200	1.5
5000 – 6000	0 – 200	1

Linear interpolation is used between the frequency and distance ranges shown.

Proposed SAR Enhancement Factors



Physiological relevance

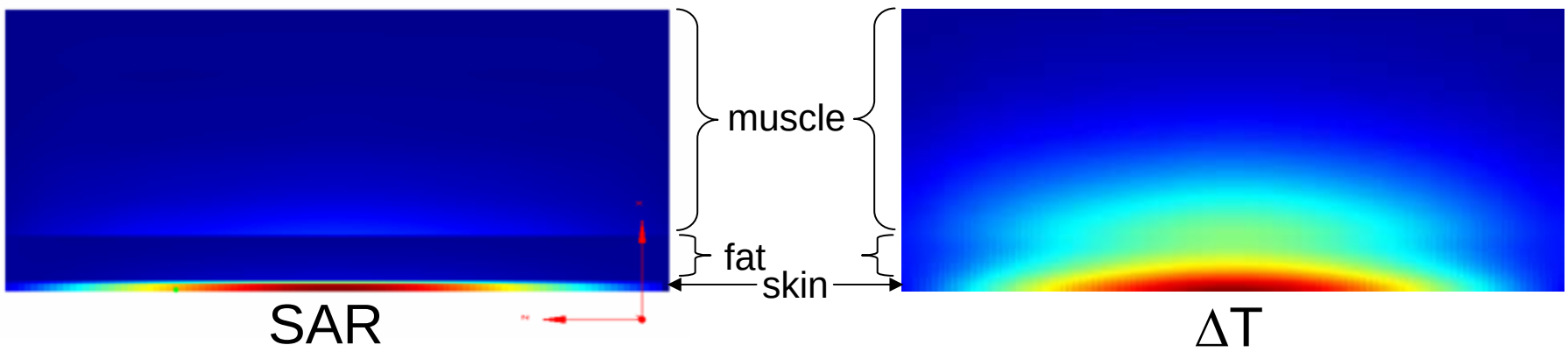
High SAR is confined to skin layer

- SAR in fat is low due to low electrical conductivity

Temperature more spread

Thermoregulatory mechanisms reduce ΔT

Is this physiologically relevant?



Excerpts from IEEE C95.1-2005

Basic Restrictions:

"The localized exposure BRs are established to protect against *excessive temperature rise* in any part of the body that might result from localized or non-uniform exposure."

Rationale for extending the definition of "extremities":

"(1) the relatively high surface-to-volume ratios of these parts of the body,

(2) the common experience of relatively large temperature excursions in these parts of the body that normally occur without apparent adverse effects, and

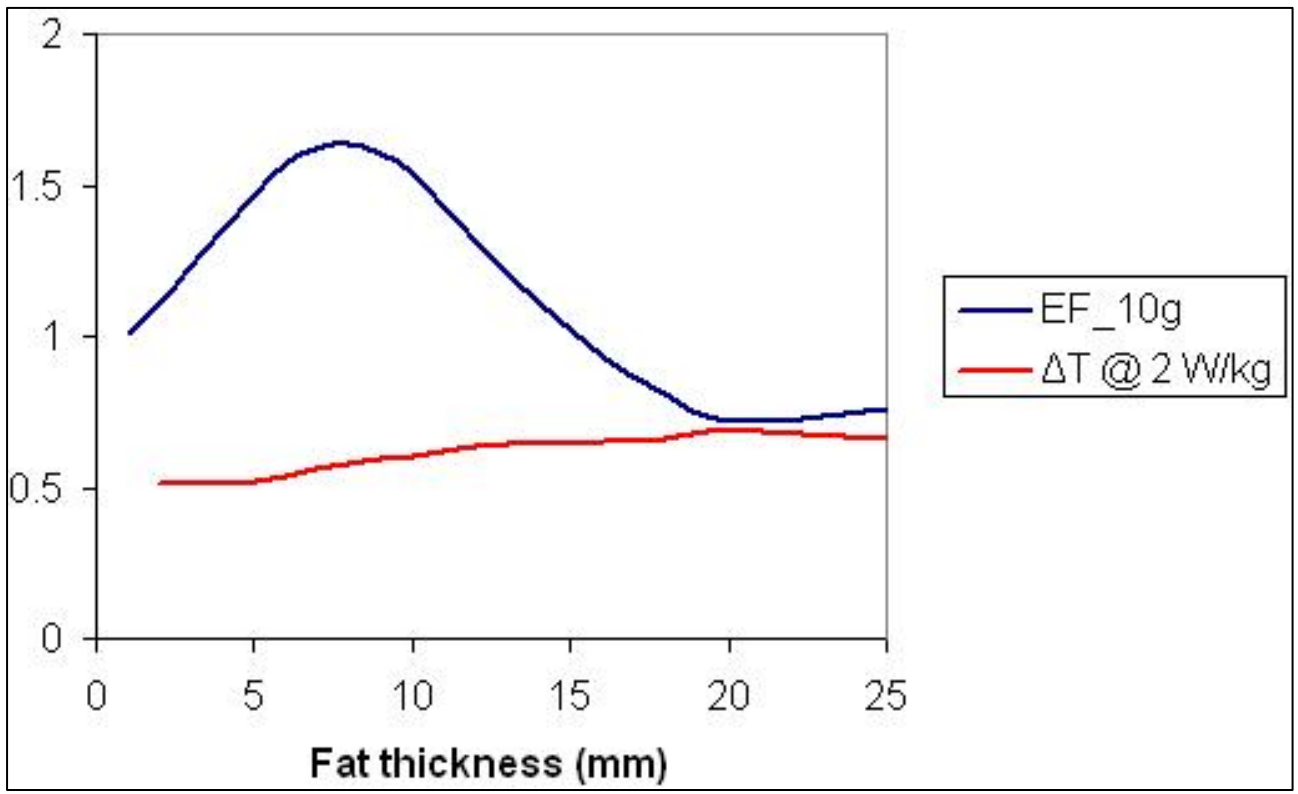
(3) the lack of critical physiological/biochemical function when compared with vital organs."

Case study at 1800 MHz

Vary fat thickness: 1 – 25 mm

- f = 1800 MHz, d = 60 mm, skin thickness = 1 mm,

ΔT not correlated with enhancement factor



Conclusions

Computational studies indicate that the SAR in an anatomical model can in some cases exceed the SAR in the homogeneous phantom.

The higher peak spatial-averaged SAR computed in the layered model is due to an enhanced SAR in the skin layer, due to field reflections at tissue boundaries.

SAR scaling factors up to 1.5 were found at some frequencies and distances.

SAR enhancement factors less than 1 have been found in many other conditions

Conclusions (cont.)

Thermal simulations suggest that SAR scaling factors might not be necessary for the protection of the skin

SAR limits in IEEE C95.1-2005 are established to protect against excessive temperature rise.

We expect that the limits for the head and torso are meant to protect the internal organs, as there are higher SAR limits for the extremities and limbs where skin also exists.

We seek the expert advice of IEEE ICES TC95 SC4 to answer:

1. Is it necessary to apply a scaling factor to limit the skin SAR?
2. Is experimental measurement in the homogenous phantom without a scaling factor adequate to protect the users?

Thank you.