

Considerations of High Frequency (HF) Exposure Guideline

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Health Effects of Radio Frequency Electromagnetic Fields

- Subject of Investigation for 60 Years
- Safety Guidelines Promulgated for 40 Years
- *Deja Vu* ... Been There, Done That ...
- “What’s the Big Deal?”
- **Why Are We Still Discussing Exposure Guidelines and Standards?**

Some of the Reasons...

- There Are Concerns on Adequacy of Existing Guidelines and Standards
- ICNIRP RF (HF) Guidelines date back to 1998
- New Scientific Progress Since 1998
- Updated ICNIRP LF Guidelines, 2010

Interest in Human Health Protection Has Expanded

- Rise in Popularity of Cellular Mobile Telephones and Wireless Devices
- Proliferation of Devices and Systems Using RF Energy
- RF Sources Everywhere; On Body, In Car, Home, Office, etc
- Potential for Interaction with Brain Tissue at Low Level, From Repeated Exposure (IARC 2B Classification—RF as Possible Carcinogenic Agent)

Outline of Presentation

- 1. Introduction**
- 2. Process in Guideline Development**
- 3. Philosophical Approaches to Exposure Limits**
- 4. Science and Philosophy of 1998 ICNIRP Guidelines**
- 5. Current Scientific Issues**
- 6. Progress in SAR and Temperature Characterization**
- 7. Summary Observations**

Steps in Development of Human Exposure Standards For RF Fields

1. Review of Pertinent Scientific Literature
2. Evaluation of Biological Effects
3. Identification of Health Hazards
4. Assessment of Relative Risk & Uncertainties
5. Establishment of *Philosophy of Protection*
6. Review of *Current Guidelines* and Standards
7. Consideration of Implementation in Practice
8. Adoption of Basic Restrictions
9. Determination of Reference Levels or Permissible Exposure Limits

Philosophical Basis for Exposure Limits

Approaches to Basic Restrictions (BR)

- A. No Demonstrable Effect**
- B. Observable Effect with No Known
Physiological Consequence**
- C. Minimal Physiological Consequence**
- D. No Hazards or Adverse Effects on
Bodily Function and/or Tissue**

Scientific Considerations and Approaches for ICNIRP (1998) Guidelines

- Acute Cataract Induction in Rabbit Eye
- Local Threshold SAR at 100 W/kg (>15 min)
- Reduction Factor of 50 → 2.0 W/kg in Contiguous Local Tissue (Ocular Tissue)
- Behavioral Thermal Regulation or Interruption of Work Schedule at 4.0 W/kg Whole Body

Accounting for Uncertainty and Philosophical Approach to Protect Against Any . . .

D. Hazards or Adverse Effects on Bodily Function and/or Tissue

Precautionary Principle

“The Precautionary Principle provides a framework, procedures and policy tools for public policy actions in situations of scientific complexity, uncertainty and ignorance, where there may be a need to act before there is strong proof of harm in order to avoid, or reduce, potentially serious or irreversible threats to health or the environment, using an appropriate level of scientific evidence, and taking into account the likely pros and cons of action and inaction”

European Environment Agency, 2004

Risk Management for RF Radiation by Establishing Guidelines with Safety Margins or Reduction Factors

**One can argue the Precautionary Principle
has been applied – by another name**

Reduction Factor offers significant level of protection against acknowledged hazards of RF radiation – *Thermal Damage*

Major Scientific Issues Relevant to Updating HF Guidelines

- Repeated, long-term, low level exposures, possible delayed health effects such as cancer.
- Appropriate metric or quantity for induced field and current, **SAR**, power density, spatial averaging **mass**, averaging or exposure **duration** (and **frequency bands**).
- **Temperature** elevation related issues
- Exposure to pulse fields and non-sinusoidal signals.

Current Biological and Human Research Results From Mobile Phone Like RF Exposures – A Brief Summary

- Do not conclusively demonstrate evidence that proves or disproves a health risk
- Factual that more studies show no health effect than effect
- Majority of studies are short-term investigations, including epidemiology of head and neck tumors, except for animal studies

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Progress and Development in Computation and Measurement Are Exceptional and in Favor of Better Precision for SAR and Dosimetry

- 1. Computational Resources and Algorithms Easily Afford Better Than 1.0 mm Resolution**
- 2. Measurement Instrumentation are Capable of Providing ~ 1 mm Spatial Resolution**

1998 ICNIRP and 2005 IEEE Standards or Guidelines for General Public

Basic Restriction for 100 kHz to 3 GHz

- Whole Body Ave SAR: 0.08 W/kg
- Partial Body and Head SAR: 2 W/kg
- Extremity* and Pinnae SAR: 4 W/kg
- Averaging Mass: 10 g
- Averaging Period: 30 s to 30 min

*Extremities (arms and legs distal from elbows and knees, including fingers, toes, hands, and feet)

Averaging Mass in Guidelines and Standards: A Closer Look

- ICNIRP-1998: 2.0 W/kg in 10-g of Contiguous Tissue
- IEEE-2005: 2.0 to 4.0 W/kg in 10-g Cubic Volume
- US FCC-1996: 1.6 W/kg in 1-g Cubic Volume
- Volume (Mass) of Ear and Eyeball \sim 10 g
- SAR Based on 10 g Volume (Mass)
 - Do not Account for Anatomic Details & Tissue Types
 - **Nor** Wide SAR Variations with Tissues

SAR and Temperature in Regulatory Limits and Guidelines

Current RF regulatory limits and safety guidelines specify both SAR and related elevation in tissue temperature (1°C)

The allowable SAR limits expressed in any local 1 g or 10 g of tissue throughout the body

Limits and guidelines are exposure duration specific

Related Issues or Concerns

Convenient means of monitoring local SAR or local temperatures inside the body are not available.

Computational methods typically are used to predict local SAR and temperature.

What is the appropriate tissue mass for SAR and induced temperature characterization?

Is correlation of SAR and temperature distributions remain constant for all times?

Or would exposure duration influence correlation between mass and temperature elevation?

Electromagnetic and Thermal Computations in Anatomical Bodies

Numerical simulations of electromagnetic power deposition using conformal FDTD scheme and uniaxial-perfectly-matched-layer (UPML) boundary conditions for both near and far fields.

Alternate-direction-implicit, finite-difference (ADI-FD) formulation of bioheat equation (BHE) for temperature.

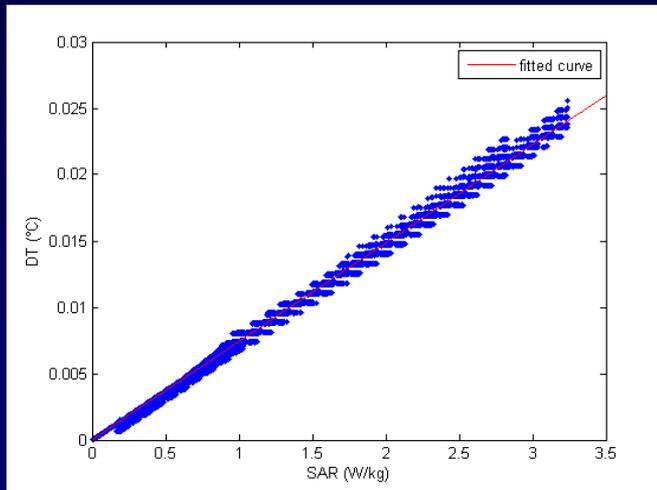
Correlation Analysis of Temperature Increase with Power Deposition

Regression analysis of temperature increase in each voxel as dependent variable, with power deposition as independent variable via least-squares linear fit.

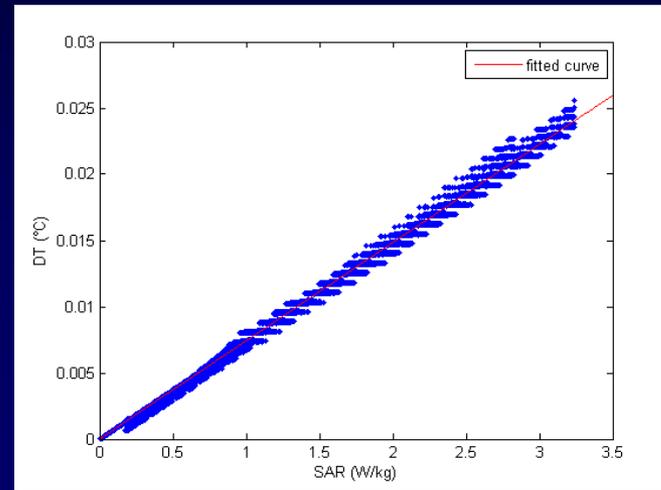
Linear fitting line forced to pass through origin for coefficient to predict zero heating in the absence of power absorption.,

Linear Regression of Temperature Increase vs. SAR for Different Averaging Mass after 30 s of RF Exposure

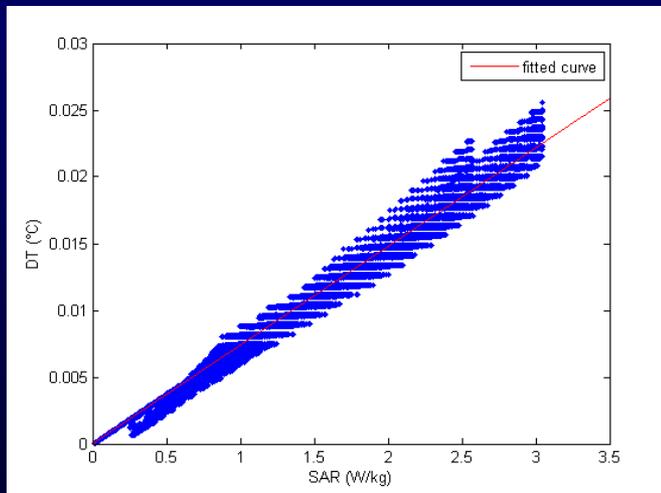
0.5 g



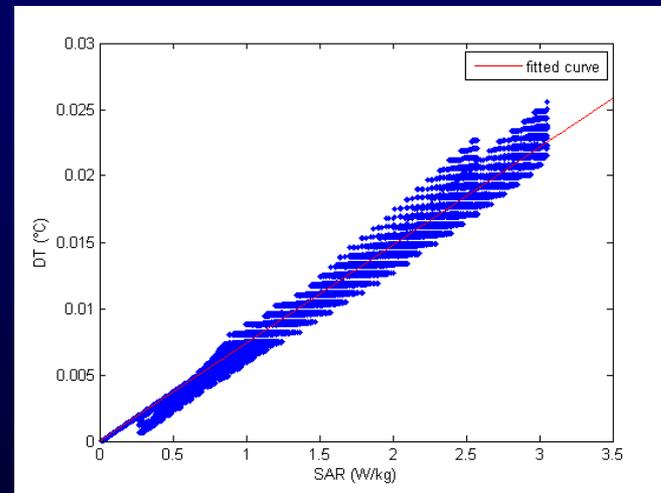
1.0 g



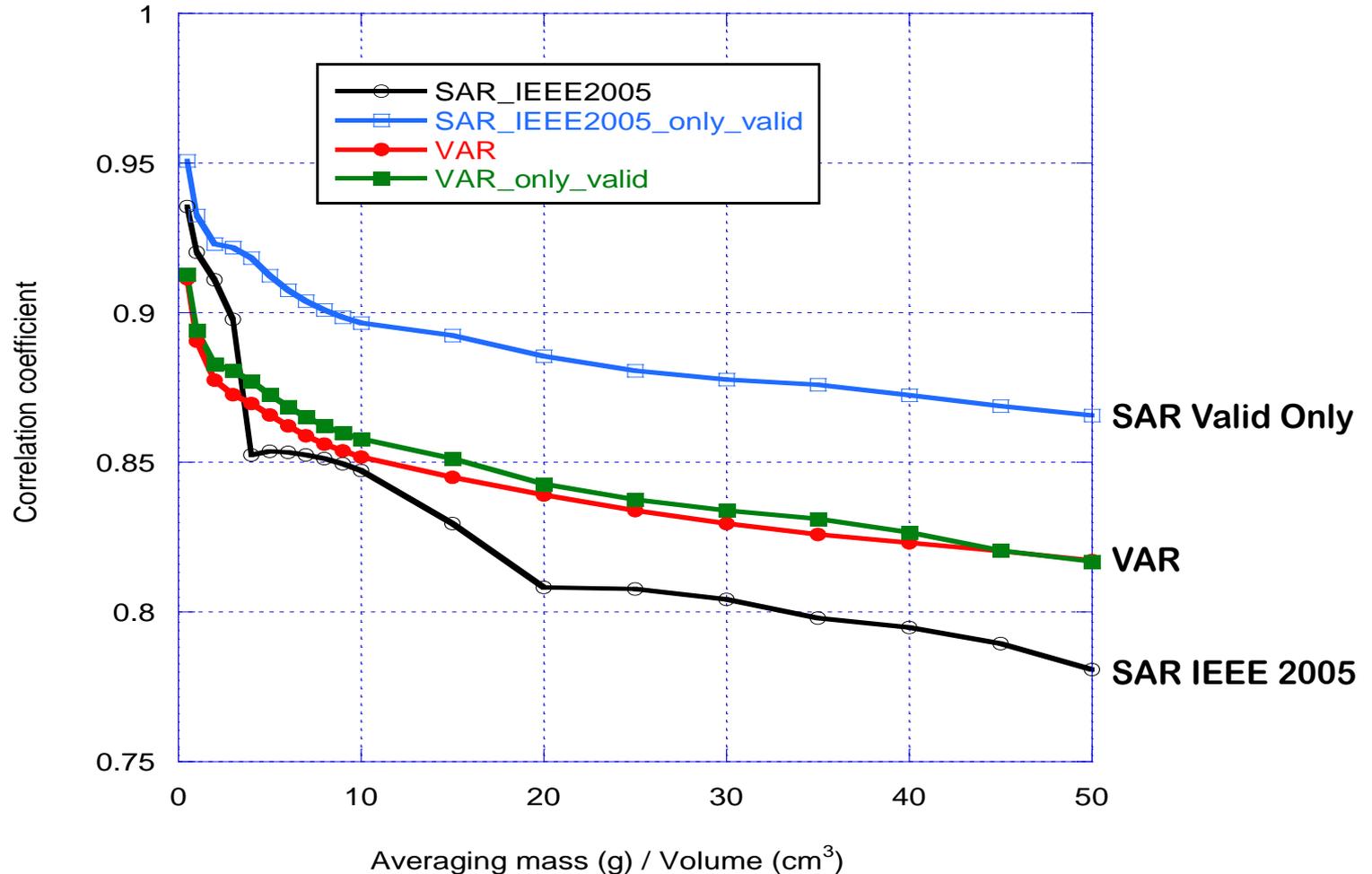
5.0 g



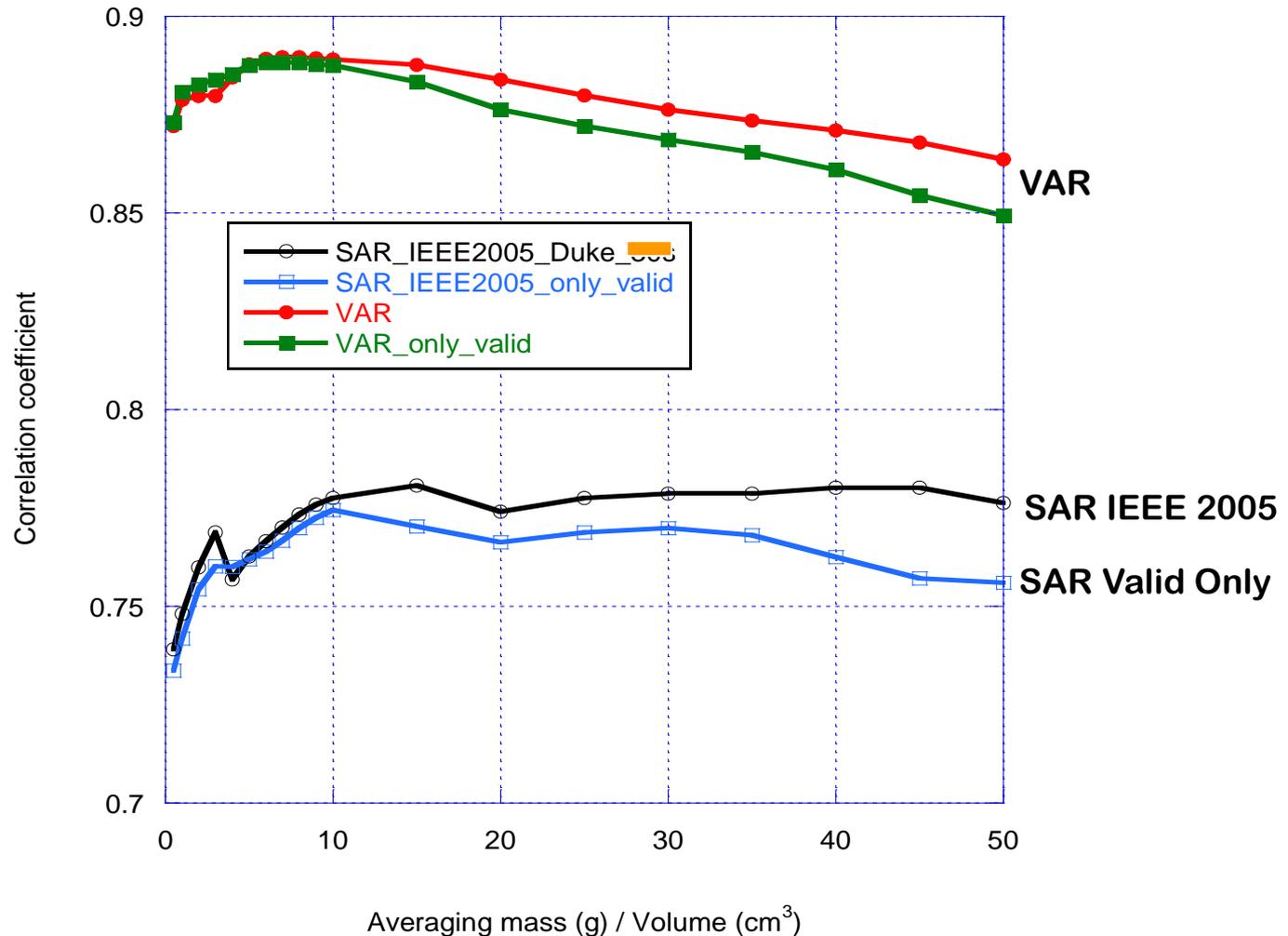
10 g



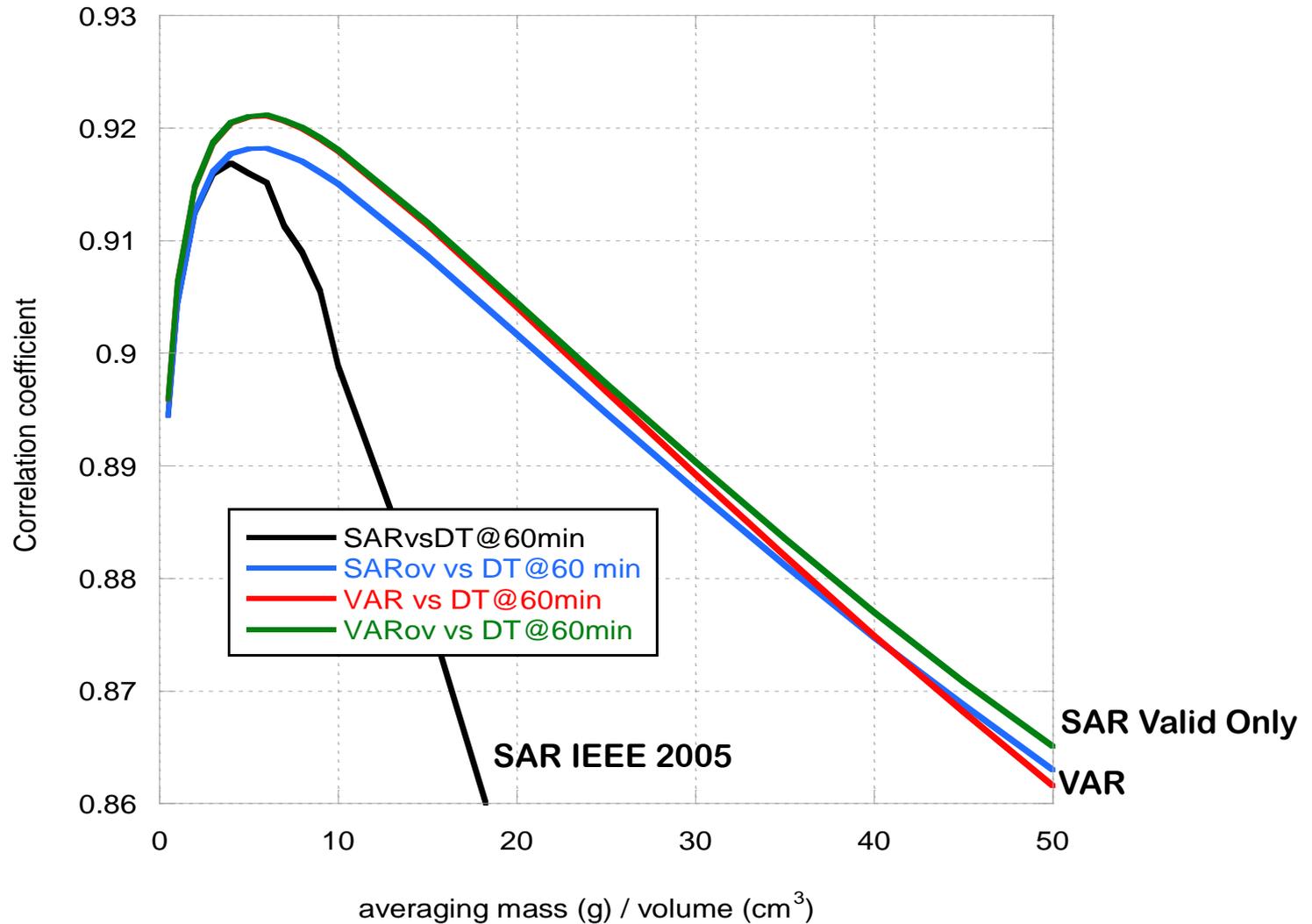
Correlation coefficients of linear fitting for different averaging schemes after 30 s RF exposure of the anatomical model



Correlation coefficients of linear fitting for different averaging schemes after **30 min** (**Steady State**) RF exposure of anatomical model



Correlation Coefficients Between SAR and Temperature for Different Averaging Mass and Scheme at 60 min (Steady State)



Correlation Coefficients Between SAR and Temperature for Different Averaging Mass and Scheme at 60 min

Averaging mass (g) / volume (cm ³)	SAR_IEEE_2005	SAR_IEEE_2005 _only_valid	VAR	VAR_only_valid
0.50000	0.89446	0.89444	0.89590	0.89591
1.0000	0.90443	0.90440	0.90624	0.90626
2.0000	0.91253	0.91254	0.91475	0.91479
3.0000	0.91592	0.91612	0.91864	0.91869
4.0000	0.91690	0.91771	0.92044	0.92049
5.0000	0.91593	0.91812	0.92096	0.92103
6.0000	0.91513	0.91821	0.92108	0.92116
7.0000	0.91128	0.91767	0.92062	0.92070
8.0000	0.90896	0.91701	0.91994	0.92003
9.0000	0.90553	0.91606	0.91901	0.91911
10.000	0.89883	0.91506	0.91796	0.91806
15.000	0.87713	0.90863	0.91141	0.91161
20.000	0.85115	0.90168	0.90410	0.90447
25.000	0.82697	0.89469	0.89660	0.89726
30.000	0.80927	0.88782	0.88923	0.89032
35.000	0.78929	0.88118	0.88197	0.88355
40.000	0.77008	0.87474	0.87490	0.87696
45.000	0.74976	0.86878	0.86812	0.87080
50.000	0.73884	0.86298	0.86159	0.86508

Summary of Correlation between SAR and Temperature Elevation

For Shorter Exposures (30 s)

Correlation Decreases Monotonically and is Better for Smaller Masses (< 0.5 g) due to Absence of Heat Diffusion Effects.

Under Steady State Conditions (30 – 60 min)

Correlation Rises and Falls and Reaches A Maximum Between 4 to 10 g.

Between 30 s and 60 min

Optimal Correlation Ranges from 0.5 g < to > 10 g.



Thank You !

