ATTACHMENT 15

Draft Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Body from Wireless Communications Devices, 30 MHz - 6 GHz: General Requirements for using the Finite Difference Time Domain (FDTD) Method for SAR Calculations

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Objectives of the Standard

- The overall goal of IEEE P1528.1 is to provide standardized methods and guidelines for the calculation of the specific absorption rate in the human body using the FDTD method.
- These methods include:
  - algorithm for SAR averaging
  - guidelines for the numerical uncertainty assessment
  - tests and benchmarks for the validation of the FDTD software
- The methodology described in P1528.1 is generic. Application specific guidelines are given in the follow up standards P1528.2 and P1528.3. The extension to further dosimetric applications is possible and envisaged.

Outline of the Document

- background, scope and definitions
- SAR averaging
- assessment of the numerical uncertainty
- code validation
- informative annexes
  - FDTD and special techniques
  - anatomical models

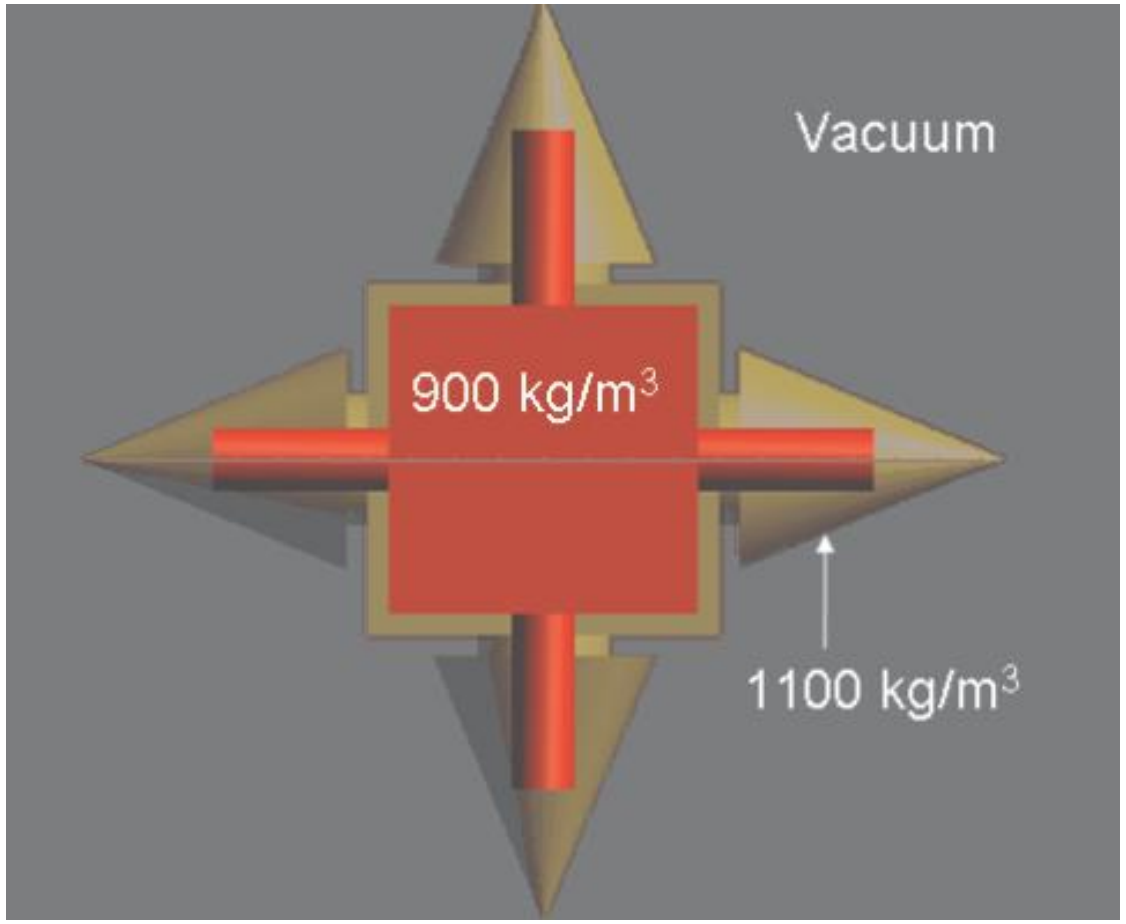
Revision of the SAR Averaging Algorithm

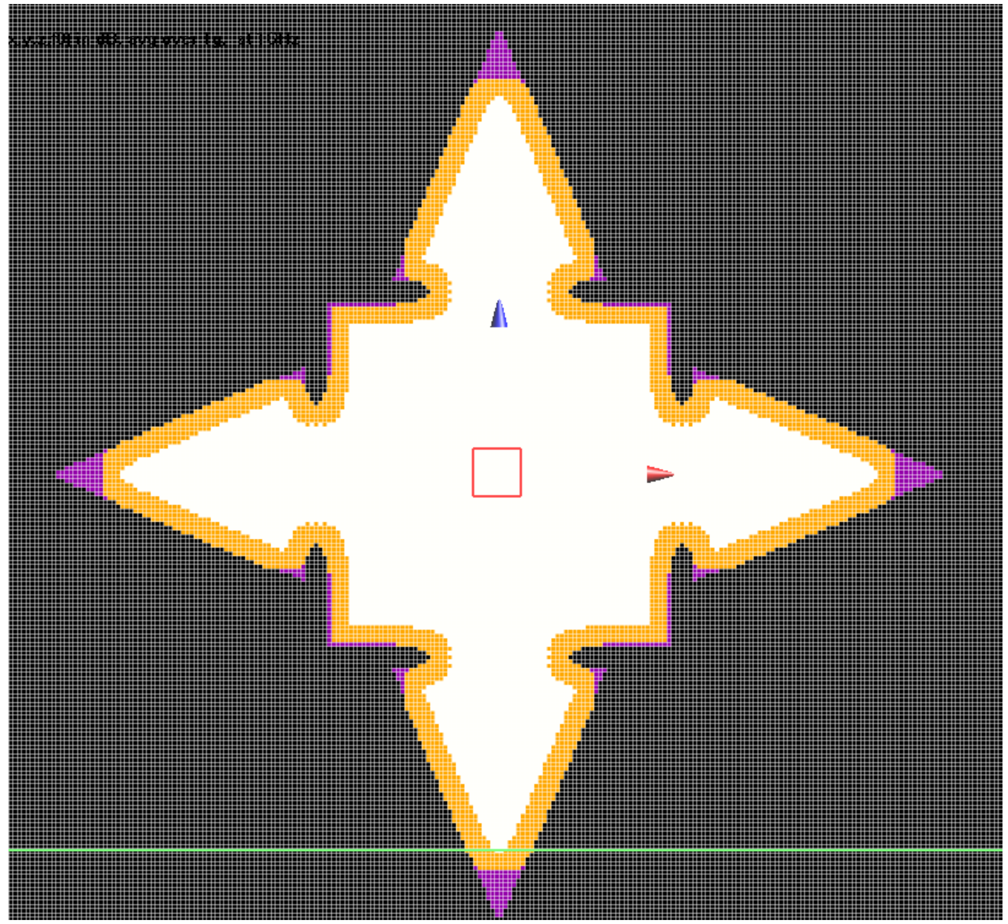
- Benchmarks using codes from different manufacturers revealed differences in the implementation of the algorithm as defined in Annex E of C95.3.
- The text of Annex E was revised and a few minor additions were made in order to avoid ambiguities when implementing the algorithm:
  - If a voxel is not completely integrated in an averaging volume, it will not be flagged as used.
  - If surface averaging results in multiple cubes of equal dimensions (e. g., in corners of homogeneous phantoms), the cube with the maximum SAR shall be selected.
  - The cubical volume averaged about a valid voxel must not contain more than 10% of background material, and all faces of the cube must intersect the tissue or be enclosed by it entirely.
  - The specification of the averaging mass was removed from the text.

Implementation of the Revised Algorithm

- The revisions were developed within the P1528.1 Working Group of the IEEE/ICES/TC34/SC2 Committee under participation of the most relevant code manufacturers.
- They are currently being implemented in the latest revisions of the simulation software.

SAR Star





- left: benchmark geometry “SAR Star”
- right: flagging of the voxels of the “SAR Star”: valid (white), used (orange), unused (violet), invalid (black)

Assessment of the Numerical Uncertainty

Uncertainty Budget	Experimental Compliance Testing	Numerical Compliance Testing
DUT	No uncertainty since the phone is tested under actual usage conditions.	The DUT must be modeled and the uncertainty cannot be determined without measurements.
Test facility (phantom, probes, etc.)	The uncertainty budget can be determined independent of the DUT for optimized phantom configuration that is a function of calibration, tissue material, phantom shape, positioning tolerance, etc.	The uncertainties due to the test configuration can be kept small, even for more complex configurations, provided that the numerical tool has been carefully validated.
Extra validation	A system performance check and validation is required to ensure consistency of the test facility	The model of the DUT need to be validated in a simplified test setup that can be easily translated to usage conditions.

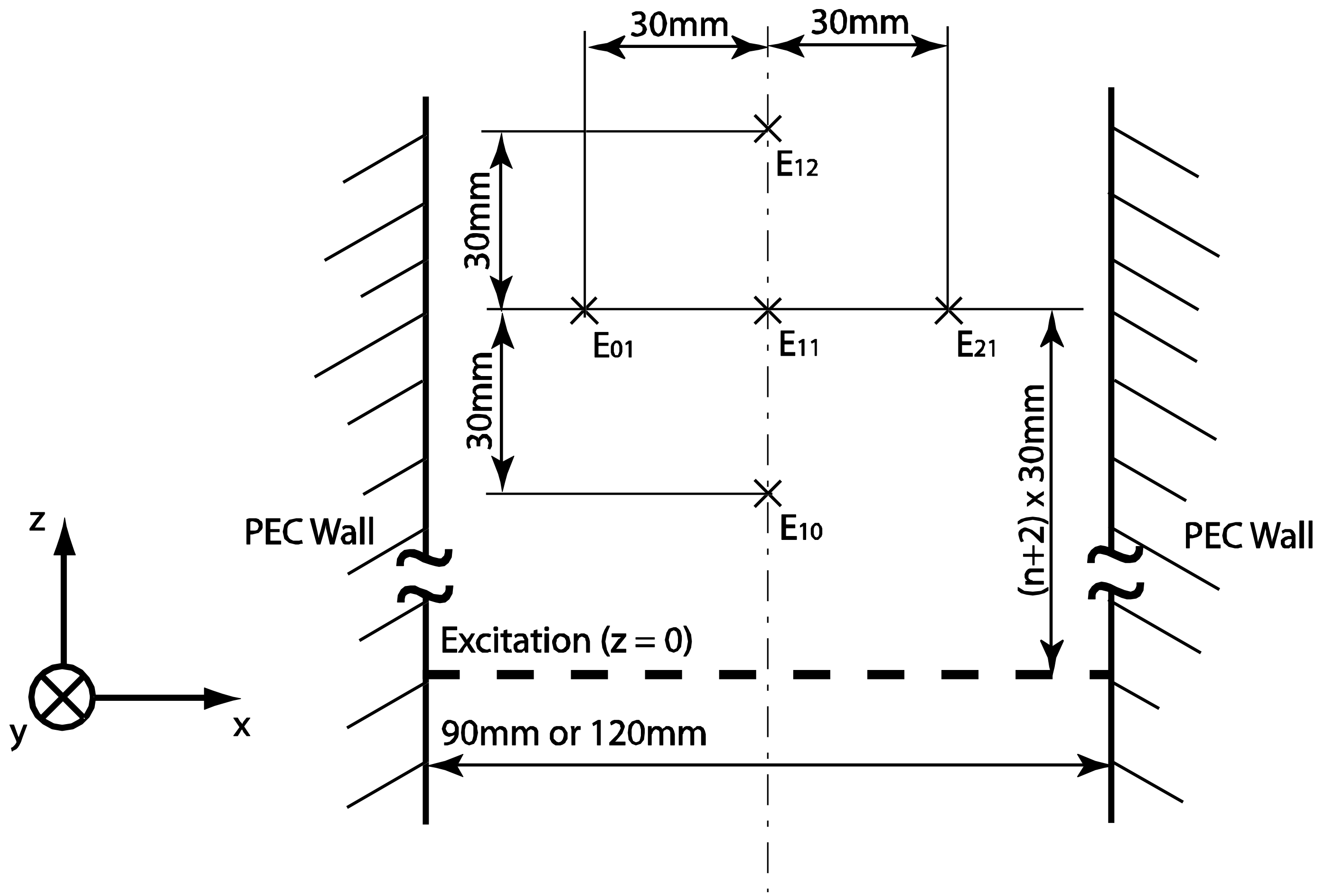
Numerical Uncertainty Budget

- uncertainty of the numerical algorithm
  - contribution of the code validation
- uncertainty of rendering the DUT model in the simulation grid
  - grid resolution, power budget, absorbing boundaries, etc.
- uncertainty of the numerical representation of the real DUT
  - experimental validation using simplified configurations (free space, appropriate body phantom, etc.)
  - three tier approach requiring increasing level of modeling detail dependent on the distance, coupling or backscattering between transmitter and body/phantom

Code Validation

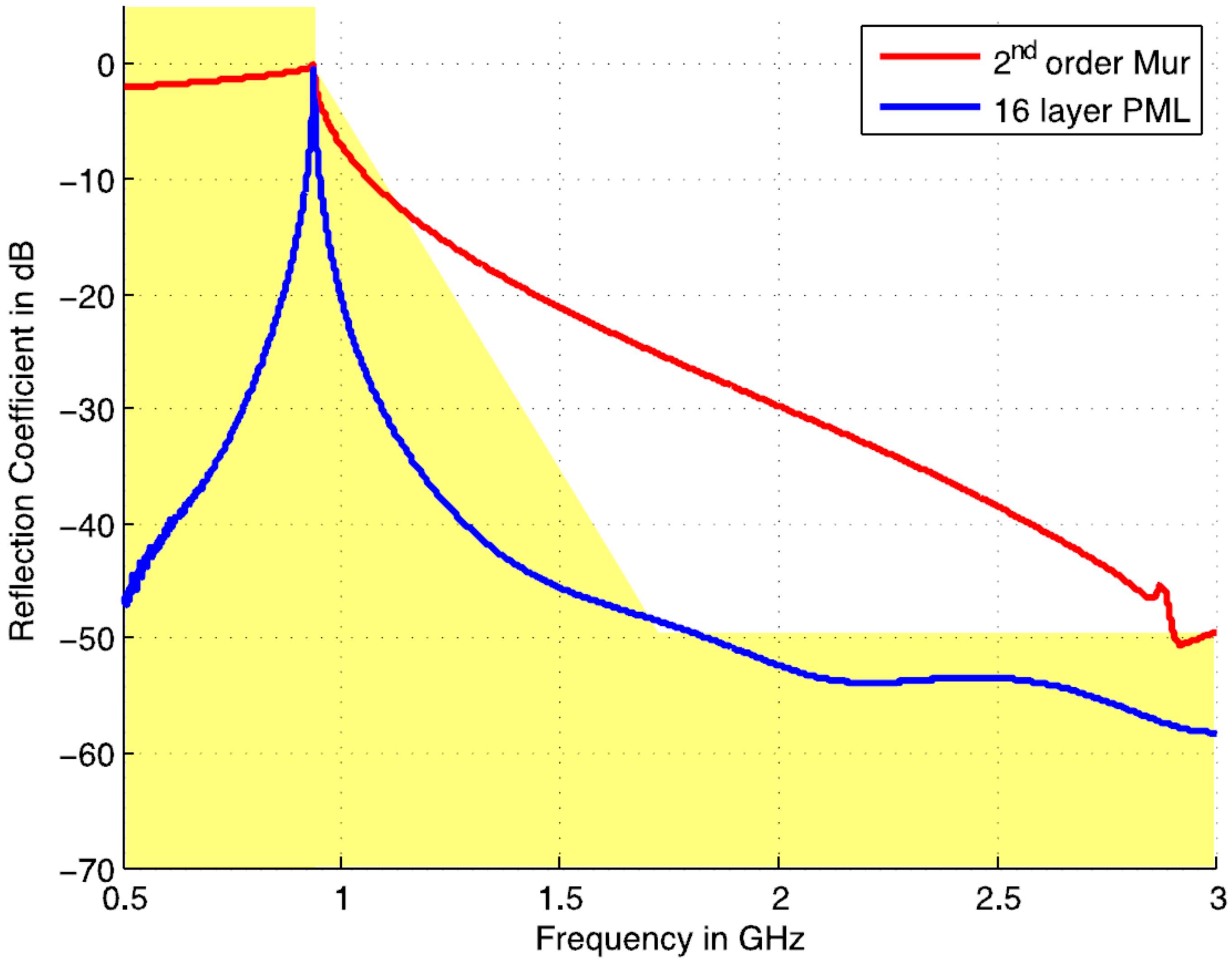
- validation of correct implementation and sufficient accuracy of the FDTD kernel
- canonical benchmarks for general assessment of the correctness and performance, tuning of the code for good benchmark performance not possible
- straightforward application of the proposed methods on extension of the standard Yee-scheme
- complemented by simple application benchmarks (dipole, Mie-scattering, generic phone, etc.)
- labeling of the software:“Compliant with IEEE 1528.1”

Waveguide Configuration



- numerical properties depend on grid resolution, direction of propagation and polarization
- extraction of numerical wave number and numerical reflection
- straightforward application on TE and TM modes, reflections in corners, etc.

Example: Reflection at an Absorbing Boundary



numerical propagation constant

$$k_z = -\frac{j}{\Delta}\ln\frac{E_{10}+E_{12}-\sqrt{-4E_{11}^{2}+\left(E_{10}+E_{12}\right)^{2}}}{2E_{11}}$$

amplitudes of propagating and reflected wave

$$E_p = \left[E_{10}e^{-jk_z\left(z_r-z_0-z_{11}\right)} - E_{11}e^{-jk_z\left(z_r-z_0-z_{10}\right)}\right]/\Psi$$

$$E_r = \left[E_{11}e^{-jk_z\left(z_{10}-z_0\right)} - E_{10}e^{-jk_z\left(z_{11}-z_0\right)}\right]/\Psi$$

$$\Psi = e^{-jk_z\left[2\left(z_r-z_0\right)+z_{10}-z_{11}\right]} - e^{-jk_z\left[2\left(z_r-z_0\right)+z_{11}-z_{10}\right]}$$

power reflection coefficient

$$r = \frac{E_r E_r^*}{E_p E_p^*}$$

Summary and Conclusions

- New methods have been developed to provide guidelines for the use of FDTD software for dosimetric applications with known precision.
- These include a revision of the SAR averaging algorithm and new techniques for the assessment of the numerical uncertainty and the validation of the correct implementation and performance of FDTD software.
- This work will serve as a basis for application related standards on dosimetric applications (IEEE 1528.2 and IEEE 1528.3 or other future standards or technical specifications).
- The editorial work on 1528.1 will be completed in September 2009.