

# Method and Tool for Improved, Rapid N-gram Average SAR Determination

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**Introduction:** When implemented according to prescription, the most widely-accepted method for calculating N-gram SAR [1] (such as 10-gram SAR for comparison to IEC limits) deals with regions near air/tissue interfaces by selecting the highest 10-gram average value in a nearby 10-gram contiguous cube rather than calculating an actual value, resulting in an artificially high N-gram SAR region near air interfaces (Fig. 1, lower right). Although this is designed to give a conservative result in regions where the calculation of N-gram SAR is not straightforward, the result includes rather arbitrary discontinuities in N-gram SAR distribution and further distance from intuitive relation to risk. Here, we implement a simple method for meaningful N-gram SAR calculation and provide a GUI for performing such calculations given an unaveraged SAR distribution. The tool was developed as a companion to a versatile MRI simulator (PSUdo MRI) recently released for public use [2], but also can be used with any unaveraged SAR dataset given in the right format.

**Methods:** A method for direct N-gram SAR calculation was developed that ensures a continuous N-gram region of tissue is identified and averaged, even near air-tissue interfaces. The method uses a region-growing approach adding only regions continuous with the origin. A GUI implementing the method was developed in MATLAB (The Mathworks, MA, USA). Currently, the GUI can read either (1) SAR data from the PSUdo MRI simulator, (2) XFDTD (Remcom, PA, USA) unaveraged SAR files, or (3) XFDTD electric field files along with the XFDTD geometry file. The GUI can display the averaged SAR, maximum SAR value, and its position in the unaveraged SAR data set, as well as calculate and display the same for 1, 10, and any N-gram averaged SAR (Figure 1). It also calculates the net dissipated power in tissues, and results can be scaled to any desired total dissipated power. The tool has the capability of parallel computation, if a user has a multi-core CPU, it certainly speeds up the larger weight calculations. To utilize the parallel computation capability, the MATLAB version should be at least 2008a and a Parallel Computing toolbox is required.

**Results and Discussion:** The upper portion of Figure 1 shows the GUI on the left and a zoomed-in (for better visualization) SAR statistics of 1, 10, and N (=4.5)-gram averaged SAR. The unaveraged SAR data is currently shown in the GUI display. The matrix size of the input SAR data was 167×123×127 in x, y, and z-direction. The computation time of 1-gram and 10-gram averaged SAR was about 30 and 60 seconds, respectively, on a dual 4-core 3.0 GHz Xeon CPU system with 8 GB memory. The lower portion of Figure 1 shows 1-gram, 4.5-gram, and 10-gram averaged SAR, respectively. A user can easily navigate or jump to a specific axial slice by using the slide bar. Sagittal and coronal slice views will be added shortly. The maximum SAR value, its position, and dissipated power at a specific slice position will immediately update at the 'In-Plane SAR' section. If a user sets a specific dissipated power to scale the results, then each of the SAR statistics are immediately updated. If the 'Use maximum scale' checkbox is selected, the SAR images were scaled to the global maximum SAR value, and then plotted. The air-tissue boundaries are well preserved at every averaged SAR, not likely when using conventional spatial averaged SAR. Additionally, development of a temperature calculation feature is almost complete. This feature will calculate temperature changes by utilizing a calculated SAR result of this tool and the Pennes bioheat equation for considering the effects of perfusion by blood and thermal conduction. We will also provide the user-specific SAR format feature as an input in the near future. In addition, the weight calculation processing will be done using C/C++ coding for better weight computation speed. The tool, including the current developing features, will be available online ([www.pennstatehershey.org/web/nmrlab/resources/software](http://www.pennstatehershey.org/web/nmrlab/resources/software)) soon.

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**References:**

- [1] IEEE Standard C95.3-2002(R2008), Annex E
- [2] Cao *et al.*, 18<sup>th</sup> ISMRM 2010, Stockholm, Sweden, p.1456

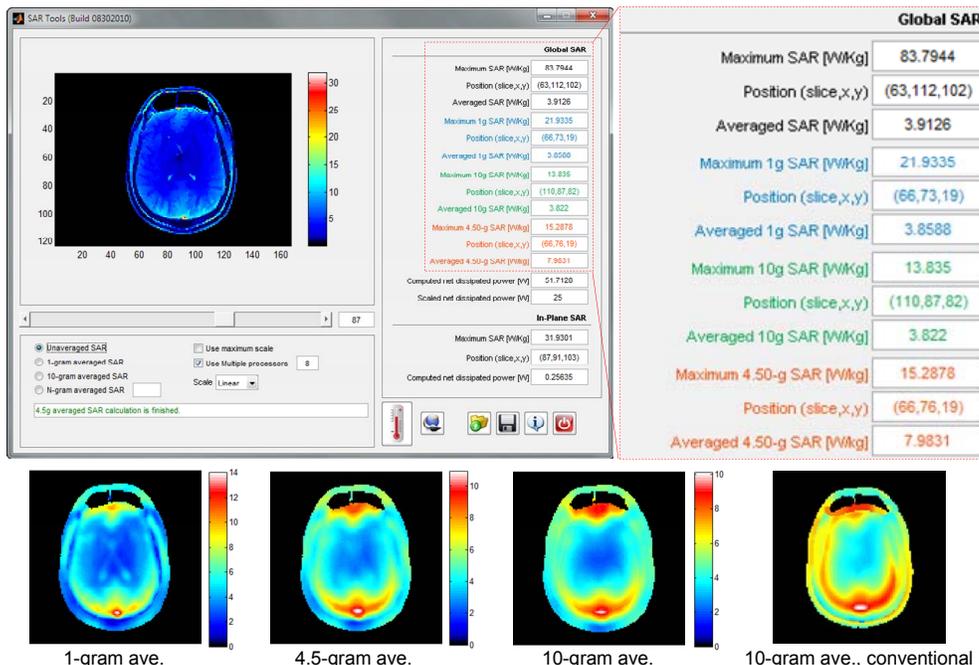


Figure 1. Top: GUI of the SAR calculation tool with unaveraged SAR displayed and (right) detail of the displayed SAR data. Bottom: SAR distributions from the proposed method (and tool) for 1g, 4.5g, and 10g averaged SAR as well as 10g average SAR calculated with the conventional method [1] showing an artificially high SAR near the boundary and associated discontinuity in the SAR distribution.