Novel Fast SAR Methods for Compliance Testing of Wireless Devices

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Abstract—The current standardized SAR evaluation technique is optimized with respect to the requirements of maximal repeatability and minimal measurement uncertainty. The uncertainty satisfies the requirement of being independent of the source and source-phantom coupling mechanism. These requirements are best achieved by the current SAR evaluation technique that is adaptive and based on 3D scanning of the induced field inside a homogeneously-filled phantom with a single miniaturized isotropic probe. However, such an evaluation is time consuming, i.e., greater than 10 minutes per scan. Due to an increased demand for faster evaluation methods, novel techniques have recently been proposed and implemented for reconstructing the 3D SAR pattern based on sensor arrays, intelligent scanning protocols or combinations of both. The evaluation can be reduced to less than 1s for array systems and to less than two minutes for intelligent scanning. We compared the performance of 35 commercial phones for two array-system implementations. We will discuss the advantages and limitations/shortcomings of each of the novel fast SAR methods for the compliance testing of wireless devices.

I. INTRODUCTION

Well-established international standards and guidelines exist for assessing the peak spatial-average Specific Absorption Rate (psSAR) in the head or body of a user of a wireless device such as a mobile telephone (e.g., [1]-[3]). The developed test procedures have proven to meet all objectives, namely, high repeatability and reproducibility and conservativeness with respect to actual human exposure [4], [5]) without large overestimation. The standardized test procedure is based on scanning the electric field in a human phantom filled with homogeneous tissue simulating media using a miniaturized field probe. The electric field probe is optimized and characterized for isotropy, broad dynamic range (e.g., 0.01 – 100 W/kg) and broad frequency range (e.g., 30 – 6000 MHz) in tissue simulating media. The probe minimizes the disturbance of the electric field in the phantom and coupling to the device under test by employing an electrically very small dipole element and RF-transparent high-impedance transmission lines [6]. Some of the standardized system parameters resulting from coordinated research projects and user experience include measurement resolution, probe geometry and isotropy, and dielectric parameters of the lossy phantom.

II. FAST SAR MEASUREMENT METHODS

Since standard methods require physically moving the probe during the scanning of a relatively large number of points, the procedure is time consuming. Due to the increasing number of communication systems and operating configurations that must be tested for a wireless device, there is high demand for faster SAR measurement methods. Various fast SAR methods are described in the literature [8-17]. Recently published international standards permit fast SAR methods with standardized ‘full SAR’ methods [1], [3]. Fast SAR methods are used for relative comparisons of different configurations for the same wireless device, while full SAR methods are used for absolute compliance evaluation on the configurations having the highest psSAR as identified by the fast SAR method. This reduces the test requirements significantly, especially when a large number of configurations must be tested.

Fast SAR methods generally fall into two categories: those that use the same hardware as a full SAR system but employ intelligent scanning and post-processing techniques, and those that use different hardware, typically fixed probe arrays. The latter systems are easier to maintain and can reduce SAR evaluation times by orders of magnitude compared with full SAR measurement methods.
Fixed arrays are based either on diode-loaded sensors that measure the magnitude of the electric field or on vector sensors that measure both magnitude and phase of the field. Diode-loaded sensors made with RF transparent high-impedance lines can be placed very close to the surface. Although vector sensors offer more information, measurements are difficult to achieve with RF transparent lines. The low or medium impedance transmission line causes significant reflections inside the phantom. Reflections should be avoided near the phantom surface, as they can cause coupling with the device under test. Moving the probe array away from the phantom surface can reduce coupling; however, this may cause a significant underestimation, as evanescent fields near the surface may not be captured.

In any fixed array system, reflections within the probe array as well as a significant displacement of tissue equivalent material in the phantom may reduce the accuracy. Coupling between the probes must be avoided by making the sensor elements small and by maintaining a minimum distance between the probes. In practical systems, the probe resolution is larger than a few millimetres that may result in undersampling for some of the distributions.

Another disadvantage of probe array systems is the larger calibration uncertainty. For practical reasons, the probes are not calibrated independently, and only after they are inserted in the phantom. A transfer calibration to a single-probe system may be used.

Array systems are closed systems and the different uncertainty components cannot be characterized independently. In general, the sensors and the 3D reconstruction algorithms are not uncorrelated error sources. Therefore, different procedures other than those for uncorrelated sources in GUM [18] must be developed to assess the uncertainty budget.

Despite these limitations, probe array systems can provide accurate results in the majority of cases, making them suitable to reduce the overall test time when used together with full SAR systems. In the future, it is expected that fast SAR systems will replace robot-based systems.

III. FAST SAR MEASUREMENT PROCEDURE

The recently published IEEE 1528-2013 includes detailed procedures for fast SAR testing [1]. The draft version of IEC 62209-1 includes the same process and publication is expected in 2015. Specifications for system performance verification, system validation, measurement uncertainty, and measurement procedures are now clearly defined, thus providing testing laboratories and regulators with the necessary criteria to confidently assess the acceptability of a fast SAR method.

This section describes the basic measurement procedure. Details and examples are found in the draft standards. The following steps are applied:

a) Use the fast SAR method to perform measurements on a number of test configurations. Group the test configurations separately per the frequency bands and modulations evaluated;

b) For each of the frequency bands and modulations evaluated, find the test configuration having the highest SAR value, and measure it using the full SAR method. Select the maximum value among these full SAR measurements;

c) For the \(j^{th}\) frequency band and modulation, use the full SAR method to measure all other \(j^{th}\) test configurations if the following condition is met:

\[
\text{SAR}_{i,j,\text{fast}} \geq \text{SAR}_{i,\text{max,fast}} \times \left(1 - \left(1.64 U_{\text{fast}}\right)^2 \right)
\]

Where, \(B_{\text{fast}}\) is calculated according to:

\[
B_{\text{fast}} = \frac{1}{1 - (1.64 U_{\text{fast}})^2}
\]

\(U_{\text{fast}}\) is the measurement uncertainty of the relative fast SAR measurements.

d) From the full SAR measurements that have been measured so far, denoted \(\text{SAR}_{i,j,\text{full}}\), choose the highest value, \(\text{SAR}_{\text{highest,full}} = \max(\text{SAR}_{i,j,\text{full}})\);

e) for the other frequency bands and modulations that have not been evaluated according to step c), apply a threshold to determine if step c) is needed;

f) use the full SAR method to measure any other test configurations that have not been tested by the fast SAR method in step a) and are not excluded from testing by the standards or by applicable national regulations.

The fast SAR measurement procedure reduces testing times significantly (up to 80%) in comparison with standard methods.

IV. MATERIALS AND METHODS

The measurements of two fast SAR methods were compared with full SAR measurements for various mobile phones, configurations, and operating frequencies. All measurements were conducted for mobile phones located next to a flat phantom, in a manner specified for body-worn SAR measurements [3]. The results are presented for two configurations.

The full SAR method was applied with the DASY52 system (Schmid & Partner Engineering AG, Zurich, Switzerland) to existing standards. All of the system parameters were fully compliant with international standards during the measurements [1]-[3].
The two fast SAR measurements were performed on iSAR and cSAR3D (Schmid & Partner Engineering AG, Zurich, Switzerland). iSAR was developed for quality assurance applications, i.e., for identification of differences between the golden sample and production sample. It employs a coarse grid and a simple 2D algorithm [13], [14] to estimate the psSAR values, i.e., it was never intended to be for compliance testing. cSAR3D was explicitly developed for compliance testing. It employs novel sensors on a much denser grid combined with a sophisticated full 3D reconstruction algorithm. The dielectric parameters of the lossy material in both systems are within 10% of the values in [1]-[3] over a broad frequency range (500 - 6000 MHz). The dielectric material is stable over time and completely sealed so that it does not need to be replaced or adjusted over the life of the product.

V. RESULTS

Figures 1 and 2 show the measured psSAR for 35 wireless devices. The wireless devices represent 15 different mobile phone manufacturers and a broad range of sizes and form factors, including brick, clam, slider and smart phone designs. The devices were tested in GSM, UMTS and LTE modes, but GSM results at 900 MHz are shown here for brevity. Results are presented for the full SAR measurement system and for both fast SAR measurement systems and they are normalized to the DASY52 results.

In Figure 1, the psSAR10g values are shown for the configuration where the devices are placed with the front side facing the phantom. A 15 mm foam spacer is placed between the wireless device and the phantom, as typically applied for wireless device certification testing. The results show good overall agreement between the three systems. The average difference is negligible (0.05dB for cSAR3D and 0.2dB for iSAR), whereas the standard deviation of the difference is less than 0.5 dB. Good overall agreement is expected, as the wireless devices are at a large separation distance, resulting in a broad SAR distribution.

More complex and localized SAR distributions are expected when the devices are placed with the back side directly against the flat phantom. In Figure 2, the iSAR measurements underestimate the DASY52 measurements in many cases (average difference is -1.5 dB), while cSAR3D fully reconstructs the 3D pattern. The average difference between cSAR3D and DASY52 results is less than 0.1 dB, and the standard deviation is 0.4 dB. The maximum deviation is well below 2 dB. The next step is to characterize the maximum deviation for realistic worst-case sources.

VI. CONCLUSIONS

By providing quicker assessments of the psSAR values, i.e., less than 1s, fast SAR systems, such as iSAR and cSAR3D, can be used for a variety of R&D and QA applications. More importantly, as the latest standards permit the use of a combined fast SAR and full SAR systems approach, testing times and overall costs are reduced significantly while still providing exactly the same test results as the full SAR method. In the future, fast SAR systems will eventually replace full SAR systems for most evaluations as they gradually improve and mature.

REFERENCES


[2] IEC Std 62209-1, Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices - human models, instrumentation, and procedures - Part 1: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 6 GHz), 2005.
[3] IEC Std 62209-2, Human exposure to radio frequency fields from hand-held and body mounted wireless communication devices - human models, instrumentation, and procedures - Part 2: Procedure to determine the specific absorption rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz). 2010.


