Past, Present and Future of SAR Evaluations

Mark Douglas, IT'IS Foundation, Zurich, Switzerland

Katja Pokovic, Schmid & Partner Engineering AG, Zurich, Switzerland

Niels Kuster, Swiss Federal Institute of Technology, Zurich, Switzerland

Introduction

Novel and innovative systems for fast measurement of Specific Absorption Rate (SAR) have recently entered the market. SAR measurement systems are used to determine the exposure of users to radiofrequency (RF) electromagnetic energy from wireless devices, such as mobile phones. The measured SAR is compared to the basic restrictions defined by international standards and enforced by national regulatory agencies so that the wireless device can be approved for use by the general public.

New techniques in Specific Absorption Rate (SAR) measurement are dramatically reducing the time needed to fully test wireless devices for regulatory approval. These techniques are driving the IEC and other organizations to update their SAR measurement standards. Improvements in these standards are underway to allow faster measurement systems while ensuring consistency in the results, low measurement uncertainty, and confidence that the measured SAR is a conservative estimate of exposure in the majority of the users. This work is greatly benefitting the wireless device manufacturers, testing laboratories, regulators and the general public.

This article describes the features and advantages of fast SAR measurement systems, with specific descriptions of two leading systems on the market. It also describes the state of standards and regulatory adoption of these devices, and the new validation methods that bolster the confidence in fast SAR measurement systems.

Rapid Advances in Wireless Technology

The number of required SAR tests for SAR regulatory approval has grown substantially in recent years, due to advances in wireless device technology. Today's wireless devices are likely to have a combination of 2G, 3G and 4G communication systems operating over several frequency bands, even simultaneously. They can include multiple antennas with MIMO or switched diversity. They may also include proximity sensors to lower the RF exposure under some usage conditions. Regulatory needs and rules have expanded to incorporate the growing device complexity into test requirements. The result is that full SAR testing for regulatory approval can take several weeks.

New SAR measurement systems make use of different techniques to dramatically reduce the time needed for SAR assessment. The goal is not only to reduce the scan time, but also to reduce manual handling by the test engineers. To minimize the scan time, systems implement intelligent scanning protocols or probe arrays. To reduce handling, systems have integrated expert systems, broadband tissue-equivalent media and test reduction protocols.

Fast SAR Measurement Systems

Two SAR measurement systems are described here: DASY6 and cSAR3D. Both are manufactured by Schmid & Partner Engineering AG (SPEAG) in Zurich, Switzerland. SPEAG has partnered with the IT'IS

Foundation and other leading research institutions to develop the scientific foundation for its instrumentation and algorithms.

DASY6

DASY6 (Figure 1) is a new system for SAR measurement that builds on the industry-leading DASY product line with several improvements to significantly reduce SAR assessment time compared to DASY5. DASY6 is fully compliant with the IEC 62209-1, IEC 62209-2, IEEE 1528 standards and all national regulations (including China, Australia, India, Europe and USA). It uses a miniaturized 3D electric field probe to scan the induced field inside a phantom, making it very versatile and applicable to a variety of phantom geometries. The system is accurate anywhere in the phantom with known measurement uncertainty, and can be validated independently by the user. A variety of phantoms are available, including the standardized phantoms TwinSAM (for testing at the ear), ELI (for testing body worn usage), BaseStation (for evaluating large base station antennas). Recently, other phantoms have been introduced to accurately evaluate new technologies. These are based on either the SAM head or CTIA hand phantoms and include FaceDown, Head Stand, Wrist and Torso phantoms. Custom phantoms can also be developed rapidly to meet changing needs. Probe isotropy errors are minimized by keeping the probe normal to the phantom surface during scanning.

Figure 1: DASY6 hardware.

DASY6 incorporates new features for fast SAR measurements, including intelligent scanning protocols with speed-maximized probe movements applicable in the band from 30 MHz to 6 GHz. A frequency extension from 5 MHz to over 80 GHz is currently in development. The intelligent scanning protocols minimize the number of measurement points to determine the peak spatial-average SAR within certain confidence bounds. Traditional volumetric scanning can also be applied. DASY6 eliminates the swapping of liquids, as it utilizes a novel broadband tissue-simulating liquid covering the frequency range from 600 MHz to 6000 GHz. An integrated expert system defines the optimal set of tests for compliance evaluation based on the available communication systems and usage conditions of the wireless device. It also applies test reduction protocols according to international standards. Software control of base station simulators enables the call handling to be automated during the tests. The time required to certify complex wireless products for the worldwide market is reduced by more than a factor of five compared to the previous versions of robot scanning systems. The DASY systems are recognized as the golden standard in SAR evaluations and are used by regulators and government agencies worldwide.

cSAR3D

cSAR3D (Figure 2) is an advanced implementation of the new array systems for which the new standard IEC 62209-3 is currently being developed. It uses a vector array to acquire the full SAR distribution within 1 second. The electric field sensors are located at fixed locations inside a body or head phantom to allow for extremely fast measurements. The sensor array is designed to minimize the disturbance of the field from the wireless device. This allows the sensors to be placed as close as possible to the phantom surface for high accuracy under both inductive and capacitive coupling conditions. The high sensor resolution reduces under-sampling errors. A novel 3D field reconstruction algorithm is used to determine the SAR distribution throughout the phantom.

Figure 2: cSAR3D hardware.

cSAR3D includes four phantom geometries. Flat phantoms are used for testing of devices in body-worn configurations and consist of over 1000 sensors. Head phantoms (left and right sides) use the Specific Anthropomorphic Mannequin (SAM) geometry defined by international standards and are used for testing of devices used at the side of the head. A Quad geometry is also defined for high-resolution measurement of larger devices such as laptops and tablets. A broad-band tissue-equivalent medium is sealed inside each phantom enabling SAR measurement over the wide frequency range of 300 MHz to 6 GHz.

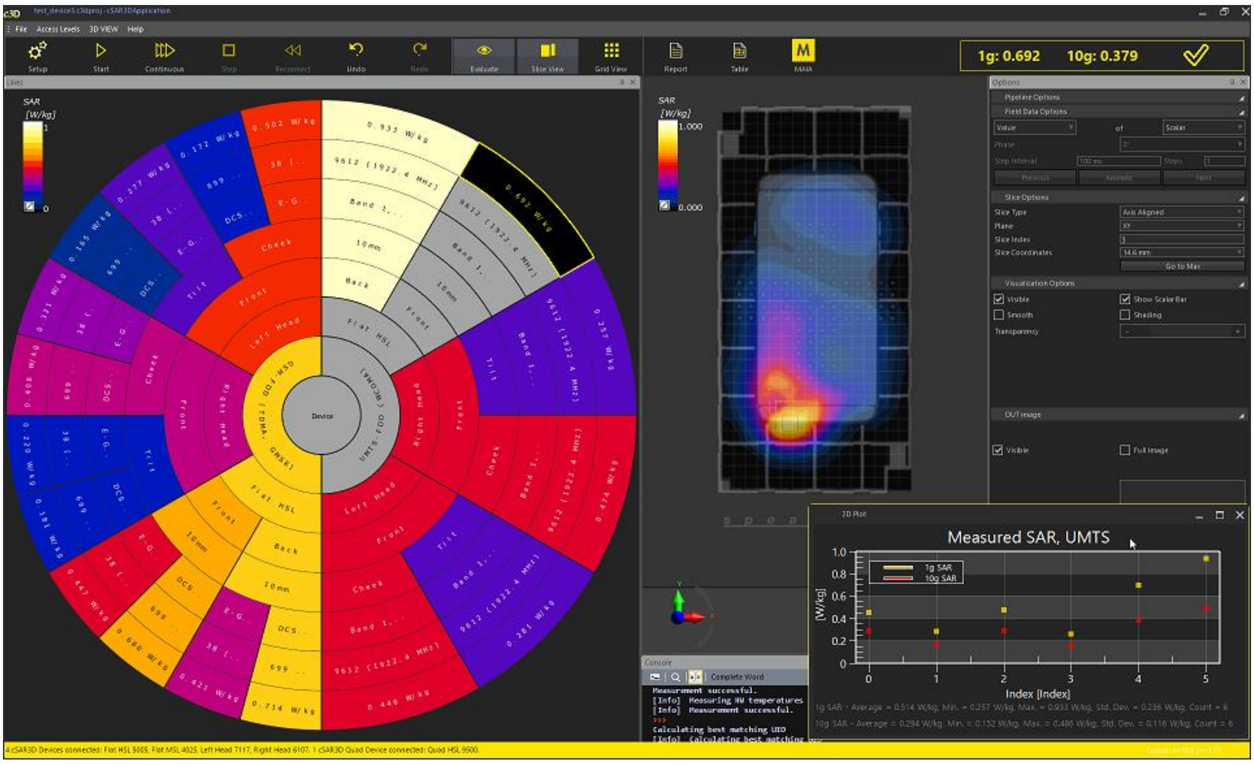


Figure 3: cSAR3D software interface.

The software interface used by cSAR3D (Figure 3) is uniquely designed for compliance testing of wireless devices. It allows the user to create sequences of several combinations of multiple test conditions, including all modulations, frequency bands, channels, phantoms and device positions. The user interface allows all test conditions to be viewed on the screen. The user can dynamically control the project by adding or removing tests (e.g., modulations) or test categories (e.g., device positions) to the sequence. A photograph of the device taken with the overhead camera records the device and its location during the measurements so that the peak SAR can be located precisely with respect to the device.

International Standards

International standards bodies and national regulatory agencies have adapted to the use of fast SAR technologies. Detailed procedures for acceptance of fast SAR methods were first introduced into IEEE 1528 in 2013, and IEC 62209-1 is expected to release harmonized procedures in 2016. IEC has also started development of standard 62209-3 for vector-based measurement systems, the publication of which is not expected before 2017. SAR measurement standards have been built on a foundation with four principles:

1) provision of a conservative estimate of the exposure of the majority of users;
2) excellent inter-laboratory reproducibility;
3) validation of the absolute accuracy of the measurement system using independent sources;
4) robust and extensive quantification of the measurement uncertainty.

Regulatory agencies have been moving forward while taking steps to require demonstration that new fast SAR technologies still deliver the same accuracy, reliability, and conservativeness as present methods. A fast SAR interlaboratory comparison study has been organized under the guidance of the IEC and with the participation of different regulatory agencies, test laboratories, wireless device manufacturers and SAR measurement system manufacturers.

Validation of Fast SAR Measurement Systems

Single-probe SAR measurement systems such as DASY6 are validated with simple sources (dipole antennas or waveguides) according to the requirements of IEEE 1528-2013, IEC 62209-1 and IEC 62209-2. The probes of these systems are well described in the standards and are calibrated using primary standards with known field distributions. Also, the movement of the probe allows measurement at any location and self-checking of the accuracy.

Array systems such as cSAR3D require more validation efforts. Array systems are generally sealed devices with a fixed probe arrangement within the phantom. A transfer calibration may be applied instead of a primary calibration, due to the need to calibrate the final assembly in situ. Mutual coupling of the sensors, spatial under-sampling, back-scattering, and scattering within the array create additional uncertainties. Some uncertainty components are correlated and therefore cannot be treated independently. Moreover, IEC 62209-3 is designed to allow different implementations. More stringent validation is therefore imperative to ensure consistent, accurate, and conservative results.

The authors recommend that validation sources of IEC 62209-3 meet minimum requirements for peak spatial-average SAR, including:

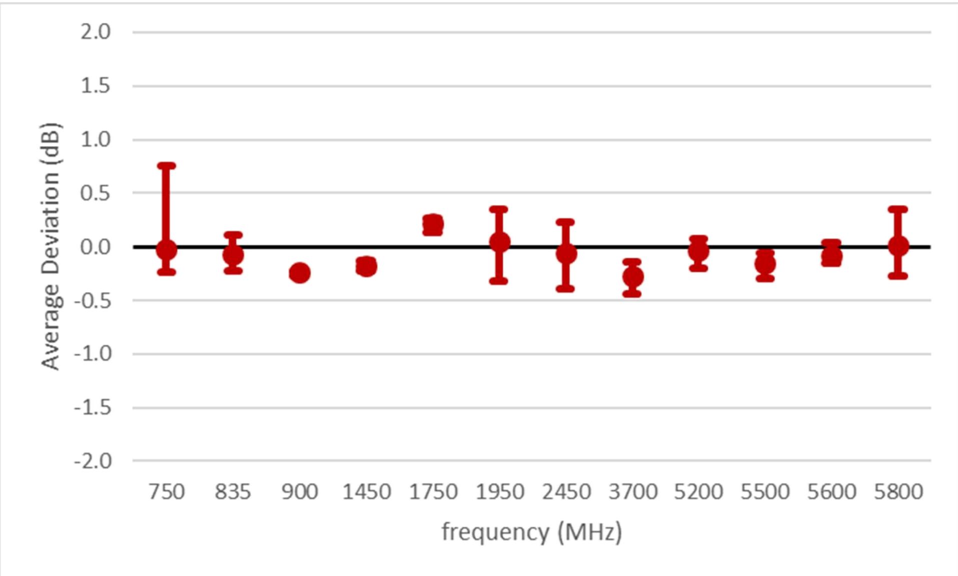
1) peak locations over the measurement area of the phantom;

2) distributions having single and multiple peaks;
3) distributions having sharp and broad spatial gradients;
4) power levels covering the dynamic range of the system;
5) frequency bands covering the frequency range of the system.

We also propose validation criteria in which 95% of the results are within the combined expanded uncertainty of the measurement system and validation sources (two standard deviations), and none of the test outcomes are larger than the 99.7% confidence interval (three standard deviations). To ensure consistency with existing SAR measurement procedures the overall uncertainty criteria must be same: array and vector-based SAR measurement systems are suited for full SAR testing if the expanded uncertainty of the system is less than ±30%.

Validation results comparing cSAR3D and DASY6 are shown in Figure 4 for the flat phantom. Dipole antennas were measured at over 490 combinations of frequency (750 to 2450 MHz), power level (two orders of magnitude), modulation (CW, WiFi, Bluetooth, LTE-FDD, LTE-TDD), dipole position, dipole orientation (0°, 22.5°, 45°, 67.5° and 90°) and distance to the phantom. The average and standard deviation of the results are presented at each frequency.

The results in Figure 4 show excellent accuracy, even for signals having sharp field gradients. This type of supporting data will help to give confidence in the accuracy of this fast SAR system to testing laboratories, wireless device manufacturers and government agencies.



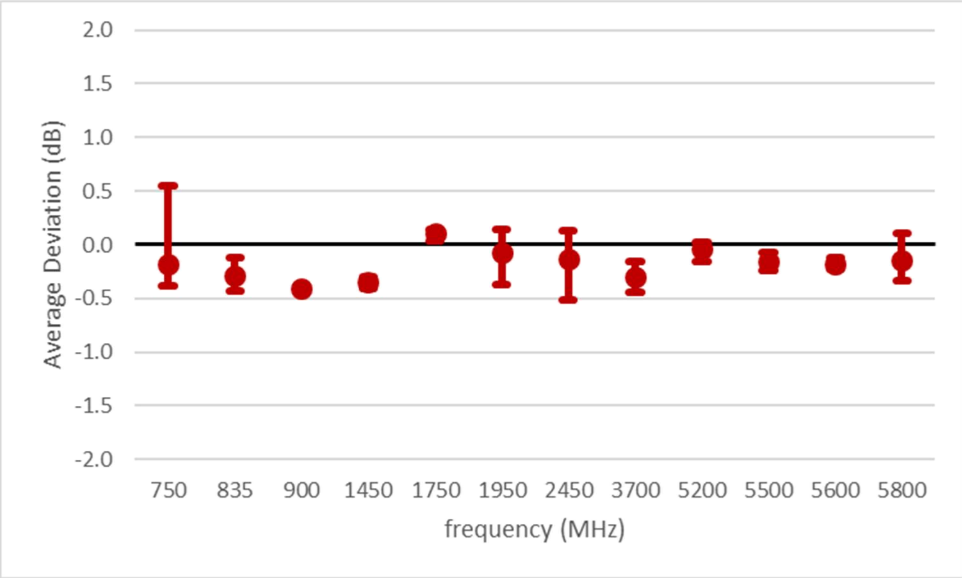


Figure 4: Difference between cSAR3D Flat and DASY6 (above: 1g and below: 10g) for more than 490 tests for different antennas at different frequencies, power levels, modulations, locations and orientations. Shown are the mean and the 95th percentile., i.e., all values are within +/-12% except at 750 MHz.

Conclusion

Fast SAR measurement systems have been developed to meet the need for rapid RF exposure evaluation of today's wireless devices. The features of DASY6 and cSAR3D have been described. Both systems are designed for SAR compliance evaluation and significantly reduce SAR assessment time using fast scanning, optimized hardware and test automation. A validation protocol and sources are proposed for array systems, with the aim of rigorously evaluating their accuracy. This will generate confidence in the performance of these systems which in turn may accelerate their adoption by regulatory agencies, supported by the insurance that the results are conservative and comparable in relation to those of existing measurement systems.