Impact of the International Standardization of SAR Compliance Testing

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Abstract – Worldwide harmonization of SAR compliance testing methodologies have led to changes from previously used procedure and equipment. This study focuses on the impact of the introduction of the Specific Anthropomorphic Mannequin (SAM) phantom, different dielectric properties of the tissue simulating liquid, and the 15 degree tilt device position on SAR measurement. The assessment was performed using 4 actual phones and two generic phone models with monopole antennas powered by an external RF source. The results of this study show that the new requirements impact SAR and generate even more conservative results than previous tests.

I. INTRODUCTION

The *specific absorption rate* (SAR) is the dosimetric quantity defined by the most widely adopted scientifically-based safety standards for the human exposure to RF energy [1]-[2]. Motorola has led the development of SAR measurement techniques and the related equipment for the last twenty years [3]-[6]. Likewise, Motorola has played a crucial role in harmonizing the SAR compliance testing standards development worldwide, involving the IEEE, the International Electrotechnical Commission (IEC), and the European CENELEC [7]-[9].

The most significant changes in SAR compliance testing methodologies involve the associated equipment. A new dosimetric phantom, the so-called *Specific Anthropomorphic Mannequin* (SAM), has been developed. Up to now there was no standard for the plastic or fiberglass shells used to simulate the human head for SAR assessments and at least three different models were widely diffused. The SAM was designed to be conservative by representing a large adult head. It is stated in [10] that "a larger head with a larger curvature radius is more like a flat structure with the tissue boundary closer to the antenna thereby capturing more energy than a smaller head." The SAM also incorporates a lossless compressed simulated ear representing a conservative case for men, women, and children, as explained in [11].

New dielectric characteristics have been established for the tissue simulating liquids that are employed in the phantom shells to simulate the relevant human tissues. While previous tissue simulating liquids focused on specific tissues, e.g., brain, the new dielectric properties defined in [12] incorporate the characteristics of all the relevant tissues (skin, skull, CFS, gray and white matter) considered in order to achieve the highest expected 1g and 10g averaged SAR values [12].

A new testing position for hand-held phones has been introduced, the so-called *tilted* position, defined as 15-degree rotation of the handset away from the *touch* position.

The Federal Communication Commission (FCC) has drafted a set of guidelines for the assessment of SAR compliance of wireless devices [13], incorporating most of the recommendations of the IEEE draft standard, whereas the CENELEC standard [9] has been ratified in July 2001 and must be adopted by all the European Community nations by July of 2002.

II. PURPOSE

The purpose of this paper is twofold:

1. Provide an update on the recent worldwide harmonization of SAR compliance testing methods
2. Show that the new standards provide an even more conservative means to measure SAR than in the past

This will be achieved by comparing the SAR levels measured on the DASY Generic Twin phantom with those measured using SAM, as well as compare SAR at the *touch* and *tilted* positions on phantoms, for a variety of phones and form factors. The impact of the use of the tissue simulating liquid with the new dielectric parameters will also be determined.

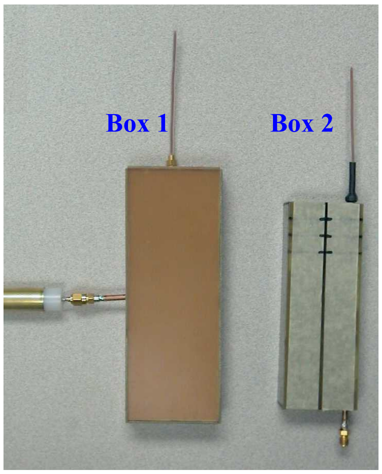
III. MATERIALS AND METHODS

Comparative SAR measurements of 4 production phones operating between 800 and 900 MHz and 2 generic phone models were made in different configurations to determine the impact on SAR depending on the phantom, position, and mixture. The following test configuration comparisons were made for the study.

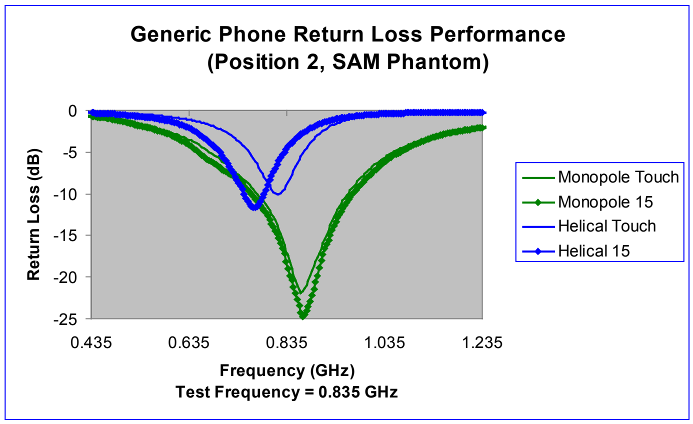
- DASY Generic Twin and SAM Head Phantoms
- Touch and 15 Degree Tilt Device Positions
- The Previous and New Tissue Simulating Liquids

Generic Phone Models

Two generic phone models consisting of a conductive box made of FR-4 and a monopole antenna were chosen for this study. The models were used so both incident and reflected power could be monitored and all SAR values were normalized to 1 W. A RF choke was used in both models to isolate the device from the RF feed. The box shape of the generic phone allows for easy repeatable positioning. The audio output location was chosen to be representative of this type of phone. The audio output location is important because acts as the reference for positioning the phone with the phantom. The phone reference point is aligned with the ear reference point (ERP) of the phantom (shown on the phantom pictures below).



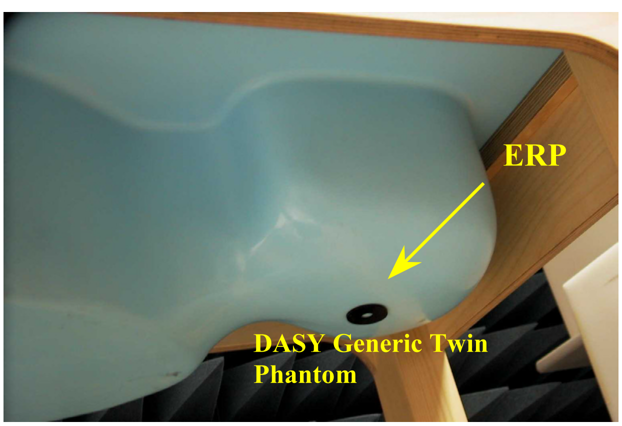
Box 2

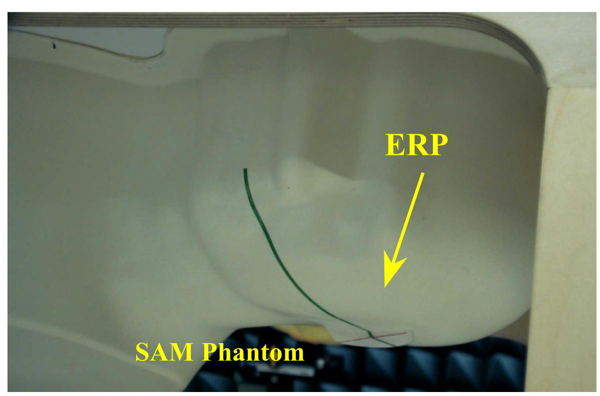


Significant detuning of the box 2 model can be seen at 835 MHz for the helical antenna when placed at the 15 degree position. The helical antenna results of box 2 were not available currently but will be shown at the conference. The antenna detuning caused several situations where the measured field strengths were low but normalized gram-averaged SAR values were significantly higher. To isolate the impact of each configuration from power variance, all SAR values in this study were normalized to 1W output power. This is not necessarily representative of the real world where the output power for these varying conditions would be dependent on the RF characteristics of the device.

Phantom Models

SAR is evaluated in a realistic human shaped phantom shell filled with simulated tissue liquid. Until recently, there was no standard phantom model. The DASY Generic Twin phantom is one of the original head models used in SAR testing. The IEEE SCC-34 / SC-2 has established criteria for a standard head model for SAR testing. A new dosimetric phantom, the so-called Specific Anthropomorphic Mannequin (SAM), has been developed.



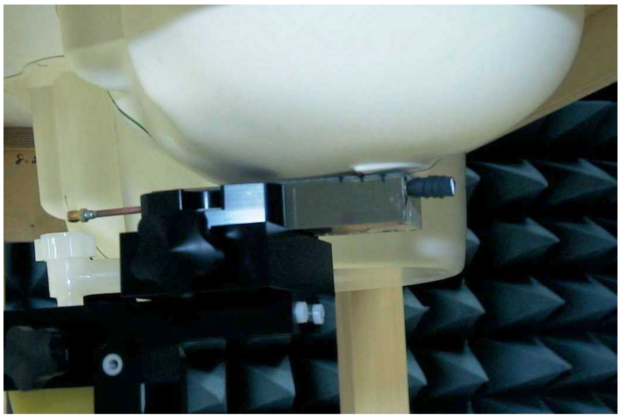


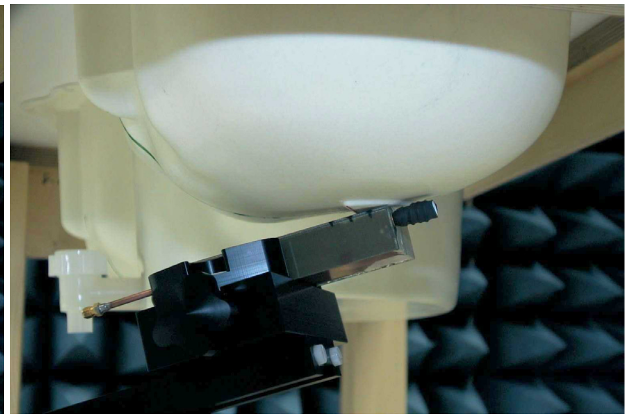
The characteristics of the SAM phantom include a flattened cheek area, less complex curvature, a tapered ear, and a larger size. In addition to more conservative measurements, these characteristics lead to more repeatable device positioning.

Tissue Simulating Solution

New dielectric characteristics have been established for the tissue simulating liquids that are employed in the phantom shells to simulate the relevant human tissues. The older tissue simulating liquid had dielectric targets of $\varepsilon_r = 42.5$, $\sigma = 0.85$ S/m, whereas the IEEE Head features $\varepsilon_r = 41.5$ and $\sigma = 0.97$ S/m. Though the permittivity stayed relatively constant, it is noted that the conductivity increased significantly, yielding significantly higher SAR values. For this study, brain-equivalent liquid suggested by SPEAG with measured characteristics $\varepsilon_r = 43.0$, $\sigma = 0.82$ S/m, and IEEE Head ($\varepsilon_r = 41.4$ $\sigma = 0.95$ S/m) tissue at 900 MHz were used.

Test Device Positions
A new testing position for hand-held phones has been introduced, the so-called tilted position, defined as 15-degree rotation of the handset away from the touch position. All standards require testing with two device positions, touch and 15 degree tilt.

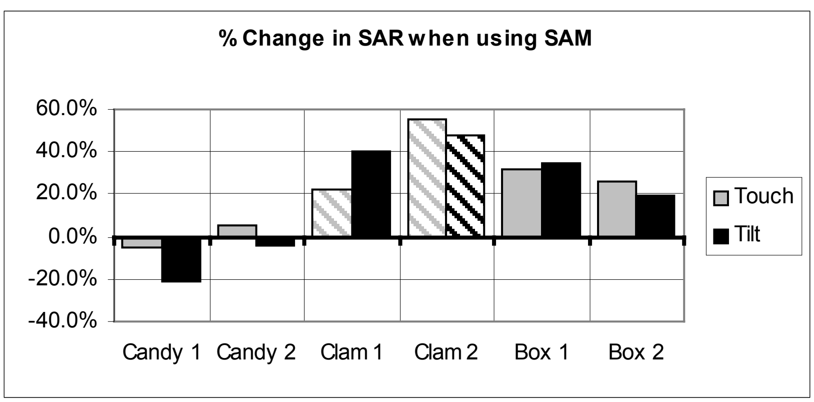




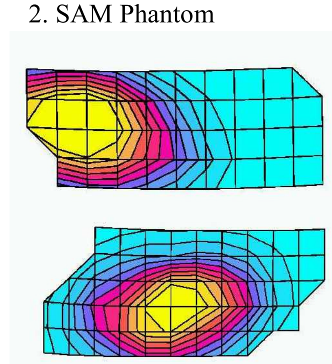
IV. EXPERIMENTAL RESULTS
The following test configurations comparisons were made for the study.

- DASY Generic Twin and SAM Head Phantoms
- Touch and 15 Degree Tilt Device Positions
- The Previous and New Tissue Simulating Liquids

DASY Generic Twin and SAM Head Phantoms
Comparison of the DASY Generic Twin and SAM Phantoms shows mixed results of SAR. The generic phone models, Box 1 and Box 2, show an increase in SAR when measured in the SAM. The candy bar type phone shows either little change or slight decrease when measured in the SAM.



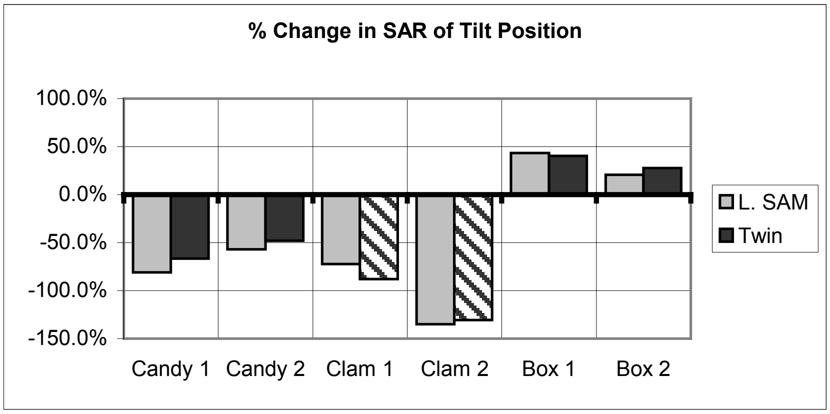
1. SPEAG Phantom
2. SAM Phantom



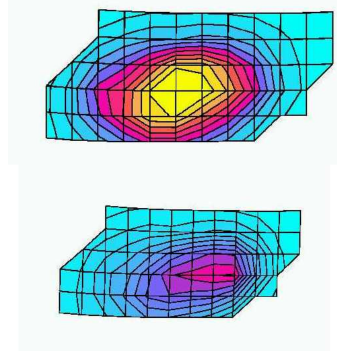
The clam shell phones are inconclusive. The striped bars on the graph indicate that the peak SAR was not captured in the scan. In other words, the location of the peak SAR was in a location near the mouth that was not reachable by the probe when performing the area scan. The probe was tilted to try to increase the reach, but peak SAR capture was still not attainable. The effect of the missed peak SAR is that the Generic Twin measurements are erroneously low, so the % change in SAR is erroneously high.

The advantage of the increased size of the SAM and the flattened cheek area can be seen as reliable capture of the peak SAR. This is evident in the area scans present to the left of the bar graph. In the scan performed in the SAM, the peak SAR is further away from the boundary than the original DASY Generic Twin.

Touch and Tilt Positions on Both SAM and Motorola Phantoms.
The 15 degree tilt consistantly had lower SAR for the production phones. This is evident in the area scans to the left of the bar in the following graph.

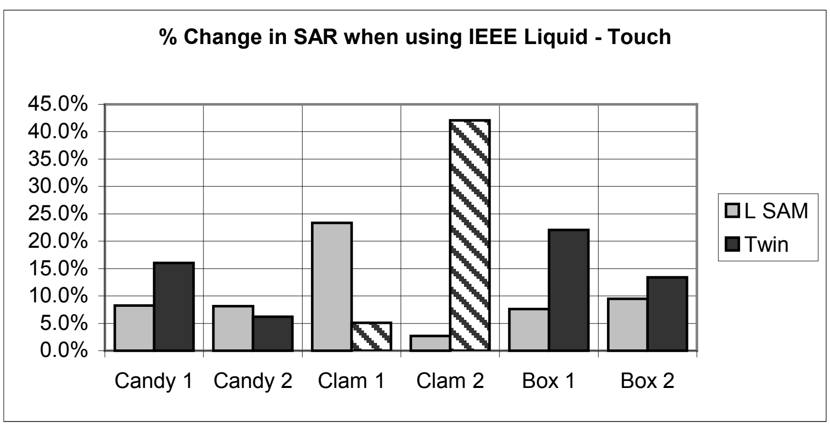


1. Touch Position
2. Tilt Position

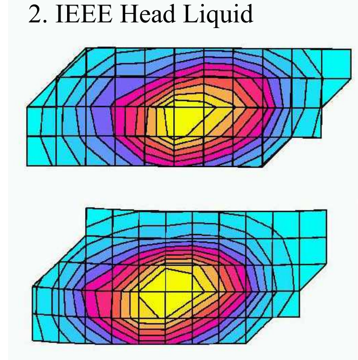


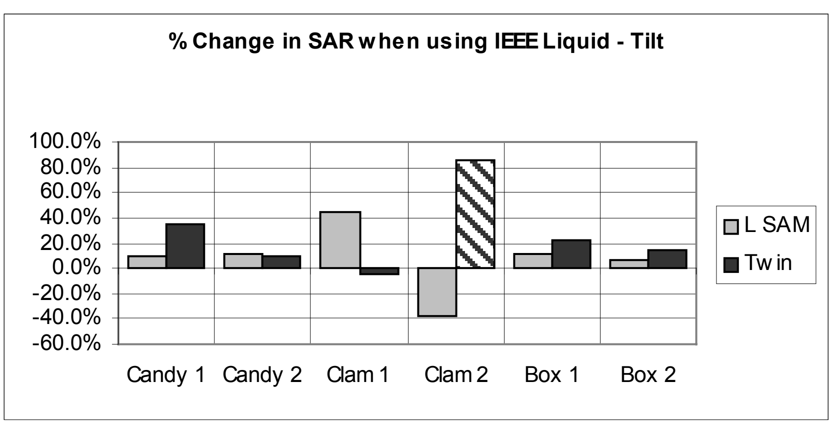
The peak SAR of the this particular phone is located on the body of the phone, so as the phone is tilted away from the face, there is a reduction in fields located in the phantom. Once again, unreliable data was obtained for the clamshell type phones in the DASY Generic Twin phantom, but the trends appear to be fairly representative of what is seen with the other phones. For the generic phone models, this was not necessarily the case. In touch position, the peak SAR was similarly located on the body, but for tilt position, the peak SAR moved closer to the antenna, which moves closer to the phantom during tilt. This, along with the normalization of power causes higher SAR.

The Previous and New Tissue Simulating Liquids
For most every phone and configuration, the new IEEE Head mixture showed higher SAR as expected when compared to the original brain mixture. The results for the comparison between the left and right sides of the SAM phantom follow.



1. Brain Liquid
2. IEEE Head Liquid





V. CONCLUSION

This study showed that changes in SAR can be expected when applying the new phantom, tissue simulating liquid, and device position requirements to the measurement of different phone models. The new requirements are even more conservative than the previous method. The magnitude of the impact of the changes appear to vary significantly depending on the phone. It is also noted that the generic phone was not an appropriate model of an actual production phone. The reason of this is may be attributed to the fact that the power was monitored and all SAR values normalized for the generic phone models, to account for any detuning of the model caused by the different positions or dielectric load.

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