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Use of a Block Hand Phantom for Mobile Phone Specific Absorption Rate Measurements

Chinthana J Panagamuwa, Ian Howells and Amir Kotb
School of Electronic, Electrical and Systems Engineering
Loughborough University
Loughborough, LE11 3TU, UK
c.j.panagamuwa@lboro.ac.uk

Abstract—Recent studies have shown when using a mobile phone in the talk position, the spatially averaged Specific Absorption Rate (psSAR) inside the head may increase due to the hand. As a result, the use of an anatomically correct hand phantom has already been proposed for psSAR compliance testing. This paper investigates an alternate solution which is more flexible and easier to implement. We test the hypothesis that a dielectric slab placed at the back of the phone during psSAR measurements may provide an acceptable conservative estimate. Measurements conducted on thirteen phones show that different size dielectric slabs can increase the psSAR but may not be representative of the large variations caused by a real hand.

Index Terms—user hand, CTIA hand phantom, SAR compliance testing, mobile phone

I. INTRODUCTION

Mobile phone antenna detuning and reduction in transmit power due to the hand (especially the index finger) is a known issue and consequently phone manufacturers would typically allow for a drop in the power budget. The hand holding the phone has also been shown to reduce the spatially averaged Specific Absorption Rate (psSAR) inside the user’s head [1]-[3]. Based on these studies, in order to obtain a conservative psSAR estimate, current standards do not require the hand to be included in mobile phone compliance testing [4]. However, more recently studies have indicated the hand may actually increase the psSAR in the head [5][6]. A parameter identified as having a major influence on the head psSAR is the separation gap between the back of the phone and the palm of the hand. In the past, simulation studies have investigated, mock phones held by block hands. These studies have particular advantages. Block hands are easily modeled in EM simulation software and they lend themselves well to parametric studies. However, their obvious differences to real hands bring into question their accuracy. In an attempt to incorporate the hand into head psSAR compliance testing, multiple lab studies have been conducted [7] looking at the feasibility of using the CTIA hand phantom [8].

This work tests the hypothesis that a simple lossy dielectric slab to represent the palm of a hand can be used instead of the CTIA hand phantom to provide a conservative estimate of the psSAR inside the head when using a mobile phone. The use of such a slab has an obvious advantage in that the positioning accuracy of the phone and the slab will be improved compared to the phone and CTIA hand phantom when carrying out compliance testing. With current hand phantoms, it is not possible to change the phone-palm separation distance without decreasing the grip stability. This is a major drawback because this separation distance has been identified as an important parameter. Furthermore, the index finger placed on the back of the phone is known to cause severe detuning, especially when the antenna is located at the top of the phone, thus reducing the transmitted power and the psSAR. The ‘Monoblock’ and ‘PDA’ CTIA hand phantoms [8] are designed with the index finger at the back of the phone. With a different grip style the detuning might decrease and the psSAR would increase. If the increase in psSAR inside the head can be attributed to the cavity formed by the palm and the back of the phone, then a conservative estimate is not provided by placing the index finger at the back of the phone. In order to identify the worst case scenario for psSAR, we must create a measurement setup that minimizes the antenna detuning and tries to recreate the phone-palm cavity in the measurements.

II. METHODOLOGY

The methodology for this study was as follows. The iSAR Head was used for measuring the 10g psSAR caused by mobile phones in the talk position. Thirteen different phones were used in this study. This device, manufactured by Schmid & Partner Engineering AG, allows for rapid head psSAR measurements and allows for a large number of phones to be tested quickly.

An Anritsu MT8810 base station simulator was used to communicate with the mobile phones. The phones were set to transmit in GSM 1800, band 512, power level 0 (30dBm).

Figure 1. Experimental setup of the liquid box and a phone under test

The experiment used three different rectangular plastic containers filled with tissue simulating liquid to represent the
hand. The containers were filled to a height of 20mm and had the dimensions (length x width):

1. Small: 100mm x 65mm
2. Medium: 180mm x 110mm
3. Large: 245mm x 135mm

The lossy dielectric liquid used for building the CTIA hand phantom could easily be produced as a dielectric slab to replace this liquid. With a mobile phone placed on the iSAR, the small liquid container was lowered on top of the phone to represent the scenario where the palm is touching the phone. A clamp was used to position the container and it was always centered above the phone. The experimental setup for the small container is shown in Figure 1. The separation distance between the phone and the underside of the container was then increased in steps of 10mm from 0 to 80mm. For each container height, the 10g psSAR value provided by the iSAR was recorded. An extra reading was taken at 5mm separation distance. The 10g psSAR was then recorded without the container positioned above the phone. This measurement provided the baseline for normalizing all the 10g psSAR values taken with the liquid containers and will be referred to as the normal measurement.

With the phone located in the same position on the iSAR, an author (Author 1) then gripped the phone with his right hand. While observing the 10g psSAR readout, the grip style and position were varied until a maximum 10g psSAR value was observed. Care was taken to ensure the final grip style was a realistic hold. The separation distance between the back of the phone and the furthest part of the palm was then measured. Due to the curvature of the palm, this can only be considered as a rough estimate. A second author then completed the same real hand psSAR measurement procedure with his own right hand (Author 2a). The second author’s 10g psSAR measurements were repeated again on a separate occasion in order to test the repeatability of the experiment (Author 2b).

This entire process was repeated for each of the thirteen phones. Once all the measurements with the small container were completed, the procedure was repeated with the medium container and then again with the large container.

The final set of 10g psSAR measurements were taken with the CTIA hand phantoms [8] gripping each of the thirteen phones in turn. The two hand phantoms used were the ‘Monoblock’ and the ‘PDA’ hand phantoms [8]. As shown in Figure 2, the PDA hand phantom is suitable for phones that are 56 – 72mm wide and the monoblock hand is able to grip narrower phones. Three of the phones used in this study comfortably fit into the PDA hand phantom and the rest into the monoblock hand phantom.

III. RESULTS

Figure 3, Figure 4, and Figure 5, show how normalized 10g psSAR varies as the small, medium and large liquid containers are raised above the mobile phones. In order to improve clarity, only six of the thirteen measured phone results are presented here. All the presented 10g psSAR values are normalized to their respective normal measurements and converted to dB. This then shows the increase or decrease in the 10g psSAR due to the liquid container.

![Figure 2. The CTIA monoblock (left) and PDA (right) hand phantoms holding two of the test phones. Note the index finger of both hands tend to sit on the back of the phone.](image)

![Figure 3. Change in the normalized 10g psSAR for different mobile phones as the separation distance between the back of the phone and the small liquid container is increased.](image)

![Figure 4. Change in the normalized 10g psSAR for different mobile phones as the separation distance between the back of the phone and the medium liquid container is increased.](image)
For all the tested phones, the liquid containers are able to cause an increase in the 10g psSAR compared to the normal measurements. The average maximum 10g psSAR increase across all phones, container sizes and heights is 0.5dB. The maximum increase observed was 0.76dB which was for phone 3 using the large container at a 20mm separation distance.

In all the measurements, when the container touches the back of the phone, the 10g psSAR is reduced, some more so than others. The largest reduction was 7dB for phone 11. These reductions are most likely due to the severe detuning of the phone antennas.

The three graphs show the biggest increase in the 10g psSAR is when the phone-container separation distance is between 20 and 50mm. The same is also true for the other phones not shown in the graphs. As the separation distance is increased beyond 50mm, in the case of the small container, the 10g psSAR increase tends towards 0dB whereas for the other two containers, a decrease in the 10g psSAR is observed compared to the normal measurements. This rise and fall could be an indication of a standing wave being created between the phone and the containers, and is particularly noticeable for phone 12. The standing wave pattern implies that the increase in the 10g psSAR with increasing phone-container separation distance cannot be solely attributed to the reduced detuning of the antennas.

Of the 39 sets of measurements taken with the thirteen phones and three containers, 23 of the measurements had a maximum increase in the 10g psSAR when the phone-container separation distance was about 40mm.

1. The first three bars for each phone (Small, Medium and Large) show the maximum Δ10g psSAR obtained with the small, medium and large containers. As mentioned before, these values are generally obtained when the phone-container separation distance was about 40mm.

2. The next three bars for each phone (Author 1, Author 2a and Author 2b) show the maximum Δ10g psSAR when the authors were holding the phones with their right hands. Recall, author 2 conducted each phone measurement twice (indicated by Author 2a and 2b) in order to test the repeatability of the experiment.

3. The last two bars for each phone (Small Phantom and Large Phantom) show the Δ10g psSAR observed when the monoblock (Small) hand phantom and the PDA (Large) hand phantom were used to grip the phones. Note that phones 2, 5 and 11 could be classed as PDA sized phones due to their larger widths and are thus better suited to fit the PDA hand phantom. The other phones, except for phone 1, were narrower but could still sit in the PDA hand phantom; phone 1 was too narrow for the PDA hand phantom. Where possible, 10g psSAR measurements were taken with both hand phantoms because the index finger position is different on each hand.
The thirteen phones are allocated to a graph (Figure 6, Figure 7, or Figure 8), depending on the effect seen when increasing the size of the container. For the phones in Figure 6, the Δ10g psSAR increased when the size of the container was increased. The single phone in Figure 7 saw the opposite effect. For the phones in Figure 8, there is no obvious pattern to the Δ10g psSAR when the container size is increased.

The following observations can be made from the above three graphs:

- The general trend when increasing the size of the liquid container is to see the maximum Δ10g psSAR increase slightly or remain constant. The average maximum increase in the 10g psSAR compared to the normal measurement was about 0.5dB.
- For a majority of the phones, all three liquid containers under estimated the Δ10g psSAR caused by the real hands.
- The Δ10g psSAR values for Author 1 and Author 2 are comparable for many of the phones, but can also show significant differences. For phone 4, Author 1 increased the 10g psSAR whereas Author 2 and both hand phantoms decreased the 10g psSAR. This example shows how the 10g psSAR can change significantly by simply moving the index finder from the back of the phone, as is the case with the two hand phantoms, to the side of the phone. If the CTIA hand phantom was to be used for SAR compliance testing, a design that did not have the index finder at the back of the phone would most likely produce a higher psSAR value.
- The hand phantoms were only able to provide a conservative estimate (compared to Author 1 and/or Author 2 real hand Δ10g psSAR values) for 3 of the 13 phones; these are phones 1, 2 and 9.
- With the exception of phone 12, the two sets of real hand measurements taken by Author 2 (results 2a and 2b) show good similarity suggesting the process is repeatable for a single user.
- With phone 12, the real hands reduced the 10g psSAR compared to the normal measurement which was correctly reflected by the hand phantoms but not by any of the liquid boxes.

IV. CONCLUSION

It is evident from this study that a mobile phone sandwiched between the user’s head and a dielectric block can increase the SAR inside the head. Phone-dielectric block separation distances of 20 to 50mm have the largest effect with 40mm being the most significant. The SAR increase has been attributed to the cavity formed by the head and the dielectric. This phenomenon and critical separation distances have been seen in previous studies. Although three different liquid container sizes were tested, none of them were able to recreate the large increases in 10g psSAR seen with the real hands. We surmise that the fingers are a crucial part of creating the cavity which results in much larger increases in psSAR.

The study shows that the hand phantoms are more suitable than the liquid containers for the psSAR measurements but by no means provide consistent conservative psSAR estimates. As the study has highlighted the importance of the 40mm phone-palm gap, further investigations should be carried out by creating a new C-shaped block hand phantom that creates a suitable cavity with a phone-palm gap of 40mm. This may provide a more suitable estimate of the maximum psSAR inside the user’s head when holding a mobile phone to the ear.

Although not addressed in this study, the asymmetric position of the index finger when using the left or right hand is likely to cause different psSAR values inside the head and so must be taken into account if hand phantoms are to be used in SAR testing.

REFERENCES