Hand Effect on Head Specific Absorption Rate (SAR) Exposed By Two Realistic Phone Models

J Keshvari1 & M Kivento2

1 Nokia Corporation, Corporate Development Office, Keilahdentie 2-4, 00240 Espoo-Finland
2 Tampere University of Technology, Department of Biomedical engineering Tampere-Finland
E-mail: Jafar.keshvari@nokia.com

Abstract. There have been some reports about possible effect of the hand presence on the head SAR if hand phantom is included in the measurements of the head SAR compliance assessment procedure. The objective of this computational study was to examine the reported effect by using realistic head models and realistic CAD based phone models. A commercially available FDTD based EM solver was used to carry out the computational work. Based on the results of this study considering the SAR values without hand phantom as reference, following conclusions can be made: 1. In general presence of the hand lead to significantly less conservative SAR values in the head for large majority of cases 2. For lower band GSM frequencies the presence of the hand decreases the head SAR up to ~70%. 3. For the upper band GSM frequencies the presence of the hand decreases the head SAR up to ~55%. Based on the results of this study the present SAR compliance protocol where hand phantom is not included leads to more conservative head SAR results compared to the cases where hand is included.

1. Introduction
Compliance of the wireless devices is routinely assessed in laboratories by measuring head SAR in a Standard Anthropomorphic Model (SAM) using a computer-controlled robot system inside a human head phantom filled with tissue-equivalent liquid without including the hand phantom in the measurement. It was assumed that exclusion of the hand will lead to a more conservative assessment of SAR in the head. There have been some reports [1, 2, and 4] about possible effect on the head SAR if hand is included in the compliance measurement procedure in the IEC 62209 or IEEE 1528 standard [3, 6]. The IEC MT1-62209-1 committee executed two large projects in order to study the reported effect both experimentally and computationally. The objective of those projects by IEC MT62209-1 was to verify conservative nature of SAM phantom. The measurement study was lacking the use of real heads and the computational study did not use real mobile phones in their simulations. Because simulations with CAD based realistic phone models and MRI based head models are the closest exposure scenario representing real human head exposures we carried out this study to see how the inclusion of the hand will affect the head SAR in realistic exposure scenarios.
2. Materials and methods
In this section we will describe the head models, the hand models, the standardized head phantom (SAM) and the mobile phone CAD models.

2.1. Head models
Besides SAM phantom 9 anatomical head models were used. Most of the models are based on Virtual Family set which are developed by ITIS foundation and founded by Mobile manufacturer’s forum (MMF). Children models include male Child 3yo, male Child 7yo, male child 6yo, and female child 8yo, female 11yo. Furthermore two adult male and two adult female models were included in the simulations. The CAD model of the SAM phantom is taken from ICES SCC34 website. The electric properties of the homogeneous tissue simulant material were set to the target values from IEEE 1528b (Draft version, May, 2010) as shown in Table 1:

| Frequency (MHz) | $\varepsilon_r$ | $\sigma$ (S/m) |
|-----------------|-----------------|-----------------|
| 900 MHz         | 41.5            | 0.97            |
| 1800 MHz        | 40.0            | 1.4             |
| 2450 MHz        | 39.2            | 1.8             |
| 3500 MHz        | 38.0            | 2.91            |
| 5800 MHz        | 35.3            | 5.27            |

2.2. Hand models
The following hand models were used in this study: Two CTIA hand models for adult head models (Figure 1) and MRI based child hand model for child head models. The hand models grip provided representative practical way of holding each of the simulated transmitter models. For simulations with hand and head models the mobile phone was be positioned against the head the way as described in [5].

2.3. Mobile phone CAD models
Two Nokia mobile phone models (Figure 1) 6630 (GSM 900 / 1800, WCDMA 1950) and 8310 (GSM 900 / 1800) were used. The models are detailed CAD which are comprised of hundreds parts. The modelling phase of the mobile phones has been the most crucial phase of the computational work.

3. Simulations, frequency bands and normalization of the results
Simulations were carried out using commercially available FDTD based software. The study is based on comparison of the SAR values computed in a standard SAR compliance test configurations with SAR values computed in the conditions when the same mobile phone models are held in the hand against the anatomically correct head models. The frequencies covered by this study are GSM frequencies 900 MHz, 1800 MHz, and
UMTS 1950 MHz. Spatial peak average of 1g and 10g SAR values were calculated for each configuration with SAM phantom and the results were normalized to 1 W antenna input power. Also spatial peak average 1g and 10g SAR values were calculated for head only tissues and head tissue with pinna for each configuration with anatomical head models which were normalized to 1W input power.

4. Results and conclusions
Because the amount of results data is large, only some examples will be provided in this paper. For the lower frequency, 900 MHz, the results for both phone models for two adult and two child head models in touch position are given in Figure 2. The values are expressed in percentile compared to reference value (SAM phantom without hand). The result for 1800 MHz is given in Figure 3. Head only tissue means that pinna tissues are not included in the SAR calculations.

Figure 2. Relative SAR values for Nokia 6630 model (left) and Nokia 8310 model (right) at 900 MHz

Figure 3. Relative SAR values for Nokia 6630 model in touch position for GSM upper band (left) and tilt position UMTS (right).
Analyzing the results following conclusions can be made:

1. In general the presence of the hand leads to significantly less conservative SAR values in the head for large majority of cases.
2. For lower band GSM frequencies the presence of the hand decreases the head SAR up to ~70%.
3. For the upper band GSM frequencies the presence of the hand decreases the head SAR up to ~55%.
4. The simulation results for Nokia 8310 for touch position at upper band GSM frequency for child head models which show significantly higher values are possibly due to the fact that in simulations the fingers intersect with the head tissues. This has to be further studied to identify the overlapping of fingers touching the face and its effect on head SAR values.
5. Based on the results of this study, the present SAR compliance protocol where hand phantom is not included leads to more conservative head SAR results compared to the cases where hand is included in the measurements.
6. The conclusions are based on this limited number of phone models, so more studies may be needed to make a firm conclusion.

5. References
[1] Li C H, Douglas M, Ofli E, Derat D, Gabriel S, Chavannes N, and Kuster N 2012 Influence of the hand on the specific absorption rate in the head IEEE Trans. Antennas Propagation vol 60 no 2 pp 1066–1074.
[2] Li C H, Ofli E, Chavannes N, and Kuster N 2009 Effects of hand phantom on mobile phone antenna performance IEEE Trans. Antennas Propagation vol 57 no 9 pp 2763–2770.
[3] Human Exposure to Radio Frequency Fields from Handheld and Body- Mounted Wireless Communication Devices—Human Model 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 3 GHz) 2005 IEC Standard IEC62209-1.
[4] Pelosi M, Franek O, Knudsen M B, Pedersen G F and Andersen J B 2010 Antenna Proximity Effects for Talk and Data Modes in Mobile Phones IEEE Antennas and Propagation Magazine vol 52 no 3.
[5] Protocol for the Computational Comparison of the SAM Phantom to Anatomically Correct Model of the Human Head at Extended Frequencies: 300 MHz – 5.8 GHz 2008 IEEE SCC 34WG2.
[6] IEEE recommended practice for determining the peak spatial-average specific absorption rate (SAR) in the human head from wireless communications devices: Measurement techniques IEEE Standard 2003 IEEE SCC 34.