Comparison of SARs in SAM and Child Head Models at 835 MHz

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***Abstract*— A Korean child and an European child head voxel models were considered to inspect if the SAM phantom offers conservative SAR estimation for children’s head exposure to a mobile phone. The sizes of the head models and the ear protrusion were compared. The cheek and tilt positions in the standards for SAR evaluation were used and the ear-compressed condition for more real situation was also simulated. As a result, the SAR level in the European child head model when the ear was compressed under the tilt position was very high and exceeded that in the SAM phantom. The factors to affect the SAR result are discussed.**

I. Introduction

In most of countries, mobile phones are presently tested in the SAM phantom prescribed in IEEE or IEC standards [1],[2]. Therefore, the SAM phantom should provide a conservative estimation in a local SAR result to cover most of population who use a mobile phone.

The SAM phantom had been designed in order to produce the peak spatial-average SAR conservative for the actual value in the heads of a significant majority of persons during normal use of mobile phones. Therefore the ear protrusion of the SAM phantom had been selected to be very thin compared with a normal adult’s although most of the dimensions have been derived from the 90th-percentile male head data of U.S. Army[1]-[4].

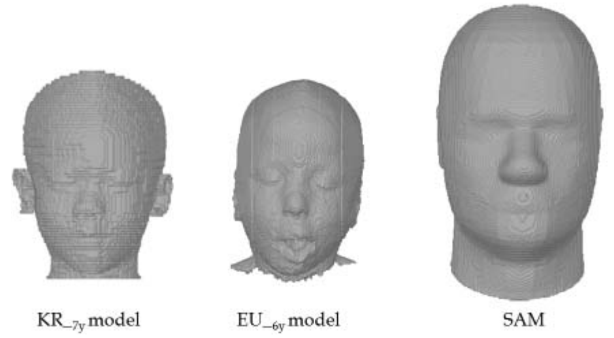
Meanwhile a Korean child voxel model was developed based on MR images of a 7-year-old volunteer and the body sizes were adjusted to the 50th-percentile values of 7-year-old Korean males [5]. In this paper, the head part was used to investigate if the SAM phantom offers a conservative SAR result for children’s head exposure to a mobile phone operating at 835 MHz. An European child head model [6] which has very thin auricles was also used to achieve this end.

The FDTD technique is used for numerical analysis and the grid size of 1x1x1 mm^3 is constantly employed in all cases.

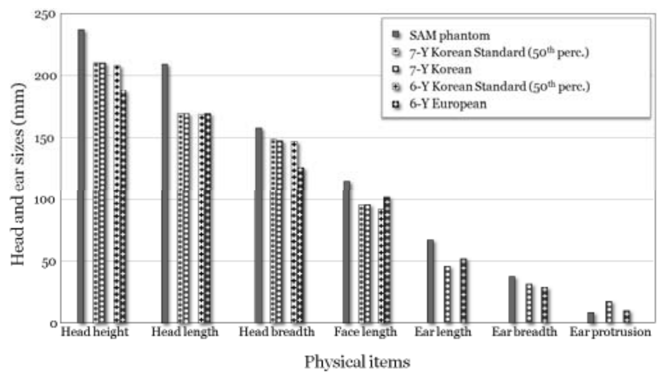
II. Models and Test Positions

A. Head Models

The used head models and their dimensions are in Fig. 1. The left one of Fig. 1 (a) is the developed 7-year-old Korean child head model (KR$_{_7y}$ model) which has been adjusted to the standard size (the 50th-percentile dimensions). The 6-year-



(a) Head models



(b) Comparison of head and auricle sizes.
Fig. 1. Head models.

old European child model (EU$_{_6y}$ model) and the SAM phantom are compared with the Korean child model in head and auricle sizes in Fig. 1 (b). The voxel size of all the head models was modified to be 1x1x1 mm^3.

The types of classified tissues are different between the two child models; the number of tissues whose dielectric properties are known is 16 and 11, respectively. The fat tissue is thicker in KR$_{_7y}$ model.

As shown in Fig. 1 (b), the ear protrusion of the SAM phantom is very small and a little thinner compared with that of EU$_{_6y}$ model. We can see roughly the differences in the ear protrusion in Fig. 1 (a). The ear protrusions of the head models were estimated at the halfway height of each right auricle. This is one of major factors to affect a local SAR result in head models exposed to a mobile phone.

(a) Cheek

(b) Tilt

Fig. 2. Test positions.

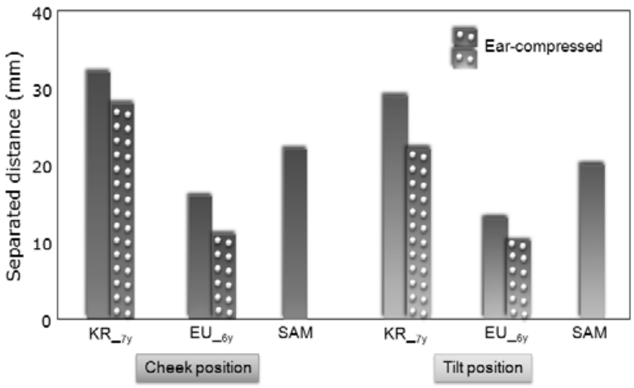


Fig. 3. Separated distance between the phone and head tissue.

B. Test Positions

A simple phone model operating with a monopole antenna at 835 MHz was positioned against the head models. It is the generic phone model of [7], having a monopole antenna and the power was applied at the gap between the antenna and a conducting plane inserted into a dielectric box. The cheek and tilt positions were used and the rotating angles were a little different with the head models due to the dissimilarities in the head and auricle shapes. Fig. 2 shows the phone-positioned head models for the two test positions.

The compressed ear for each head model was also considered for the test positions. The process for implementing was a little different from each other for head models and positions. Consequently from the position in Fig. 2, the phone model has been pressed additionally by about a few millimeters against the ear or/and the cheek.

Fig. 3 compares the distance between the feed point of the phone and head tissue. We can see that the space order between head tissue and phone antenna in Fig. 3 is not exactly in accord with the ear protrusion order: it is the largest for the Korean child model and the smallest for the SAM phantom. Since the SAM phantom includes the dielectric shell all over the surface of the phantom, the separation between the phone and liquid is bigger than the outside appearance. It is noteworthy that all the separated distances for the European child model are smaller than those for the SAM phantom.

After positioning phone model and generating the combined mesh, the auricles of the heterogeneous models were distinguished from the head tissues because the maximum local SAR should be estimated in only the head tissue, not the auricle.

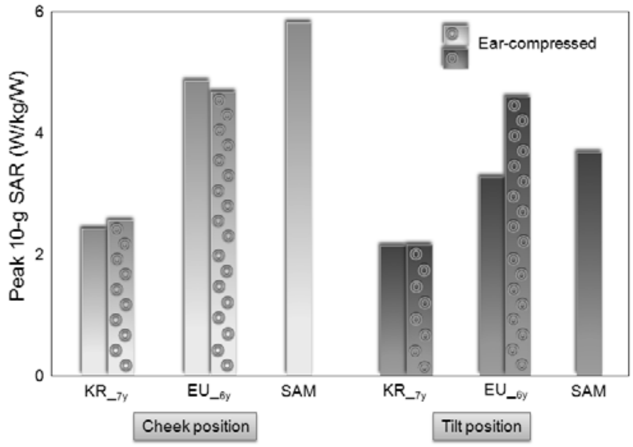


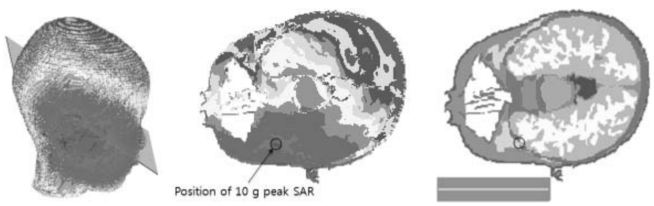
Fig. 4. SAR comparison in child and SAM models.

III. RESULTS

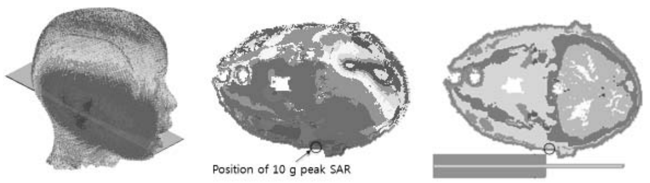
Fig. 4 represents the 10 g averaged peak SARs in the head models. SAR levels for the cheek position are higher than those for the tilt position. The SAR value for the ear-compressed condition of each child model is also compared with the result that the ear is not compressed as shown in Fig. 2. The difference in the SAR values is not significant except the case of the 6-year-old European child head under the tilt position.

In order to implement a compressed ear, in some case, the phone model was not moved straightly to be closer to the head model: for the ear-compressed condition under the cheek position of the 6-year-old model, the phone was shifted towards the head after it was rotated by 4 degrees to be farther from the cheek. If the phone is pressed to the head directly from the cheek position, the cheek is excessively getting flat. We press the mobile phone usually on our ear, not on the cheek in order to listen carefully to the sound from the earpiece of the phone.

Consequently the 6-year-old European head model produced a very high 10 g peak SAR value when its ear was compressed under the tilt position. It exceeds that in the SAM phantom while SARs in the 7-year-old Korean head model are much lower. As was stated above, the ear protrusion is a critical factor to affect the SAR result for mobile phone exposure. The ear protrusion of the European model is very small compared with that of the Korean model. These results show that the SAM phantom does not necessarily offer conservative estimation for children's exposure to a mobile phone. Even in the case that the ear was not compressed, the SAR gaps between in the 6-year-old model and in the SAM



(a) 7-year-old Korean child model.



(b) 6-year-old European child model.

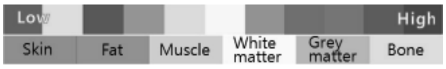


Fig. 5. Point-SAR distributions and the internal morphology of the head models (Tilt position).

phantom are only 17 and 11 %, for the cheek and tilt positions, respectively.

Another factor to have an effect on the peak SAR result seems to be the internal morphology of a head model. Fig. 5 shows the internal view of the head model and the corresponding point SAR distribution on the plane parallel to the vertical axis of the phone model, where produces the 10 g peak SAR.

The corresponding colors of some major tissues are shown below the figures. It is certain that the portion of the fat tissue is getting relatively different according to the height of the plane in Fig. 5. Nevertheless, the fat tissue takes much broader area in the Korean child head model than in the European model. The locations of the 10 g peak SARs of the two models are noticeably different and this phenomenon similarly appeared in case of the cheek position as well.

The conductivity as well as permeability of the fat tissue is much lower compared with other tissues, especially the muscle. It might cause lower SAR in the fat tissue and higher SAR in the muscle although the muscle tissue is positioned farther from the phone. Meantime, the Korean child model has little muscle just below the skin layer. Therefore the 10 g peak SAR in the Korean model occurred in the muscle deeply from the surface.

In conclusion the 6-year-old European model considered in this paper has two conditions to produce relatively higher SAR: one is a small distance between the phone and head models and the other is to have a smaller quantity of fat tissue in the head.

Since the material of the SAM phantom is homogeneous, the peak SAR obviously appears on the surface of the phantom.

IV. Conclusion

The extensive use of mobile phones is accompanied by public concerns about possible effects on human health as a result of exposure to radio-frequency radiation from the phones. Especially the issue of whether children are more sensitive to electromagnetic fields emitting from mobile phones has been a hot topic among many researchers. It has led many studies on comparison of SARs between adult and child head models [6]-[12].

Meantime the SAM phantom should provide a conservative local SAR result for most of population who can use a mobile phone since currently mobile phones for the public are tested in the SAM phantom as prescribed in IEEE or IEC standards.

In this paper, a Korean and an European child head models developed based on real magnetic resonance images were considered to investigate whether the SAM phantom, the standard phantom for compliance test of mobile phones provides a conservative estimation for children’s exposure to a mobile phone.

As a result, a very high 10 g peak SAR was produced in the 6-year-old European model under the tilt position which the ear was compressed and it exceeded the value in the SAM phantom. The two child models are different in the ear protrusion and the internal morphology. All of which seem to draw a high SAR in the European child head model.

The results in this paper suggest that the SAM phantom is not necessarily conservative for children’s exposure. However, variability in internal and external morphology for children should be surveyed and simulations for more various child models are needed in order to validate this result.

Acknowledgments

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