Analysis on SAR Values of Commercial Mobile Phones

Ae-Kyoung Lee, Seon-Eui Hong, and Jong-Hwa Kwon
Radio Technology Research Department
Electronics and Telecommunications Research Institute, Daejeon, Korea

Abstract— For epidemiological studies on the possible association between mobile phone use and brain diseases, representative phone models had been numerically implemented based on the specific absorption rate (SAR) distributions and spatial peak 1-g SAR values from the SAR test reports of mobile phones released in Korea. The numerical phone models were intended to produce the mean SAR distribution for each corresponding phone type. However, measured SAR levels of commercial phones at the maximum power are in wide range even though they are the same type of model. This paper proposes a method to utilize SAR information of a specific commercial phone which is described in the corresponding SAR test report for SAR estimation in the human head exposed the numerical phone models.

1. INTRODUCTION

The specific absorption rate (SAR) of mobile phones has been regulated since 2002 and more than 1200 models have been tested for SAR compliance in Korea. The limits of spatial peak SAR in the head referred to IEEE Std 95.1-1999 [1]. A mobile phone model should be compatible with the spatial peak SAR, i.e., 1.6 W/kg for 1 g of mass based on the measurement procedure of IEC 62209-1 [2].

For epidemiological studies investigating the potential association between mobile phone use and the risk of brain diseases, more than 1400 SAR test reports from 2002 to June 2013 have been collected. We organized a large amount of data including a manufacturer, a frequency band, outer shape, antenna type (internal/external), a maximum output power, body dimensions, and spatial peak 1-g SAR values in the four test positions of left cheek, right cheek, left tilt and right tilt at the center frequency for all the models. SAR distributions of about 70 mobile phones were measured in the flat phantom. Eleven representative phone models different in phone shape, operating frequency and antenna type and location were numerically implemented based on the measured SAR distributions and spatial peak 1-g SAR values from the SAR test reports [3]. The numerical phone models were intended to produce the mean SAR pattern and level for each corresponding phone type. SAR distribution was calculated in the human head exposed to the numerical phone models.

However, SAR levels of commercial phones are in wide range even though they are in the same type of models. This paper analyzes SAR difference between the test positions for each type of commercial phone models and proposes a method to reflect the peak 1-g SAR data provided in the SAR test report of a specific phone to calculated SAR in the human brain.

2. SPATIAL PEAK 1-G SAR OF COMMERCIAL PHONES

Each SAR compliance test report provides the spatial peak 1-g SAR data measured in the four positions (left cheek, right cheek, left tilt, and right tilt) at center frequency of the corresponding phone. In this paper, spatial peak 1-g SAR values in the four test positions are statistically analyzed. The scatter plots of Fig. 1 represent SAR levels of commercial bar-type phone models on the right and left sides of the specific anthropomorphic mannequin (SAM) phantom along the Y- and X-axes, respectively. The scatter plots of Fig. 2 show SAR levels of commercial slider-type phone models in the tilt and cheek positions against the SAM phantom along the Y- and X-axes, respectively.

The plots indicate positive SAR correlations between the right and left sides as well as the tilt and tilt positions. Table 1 shows statistical SAR results for some types of commercial phones. Since the release of smart phones, most recent models have been bar type and the antenna of most bar-type models is located at the inside bottom of the body. The data in the table were also obtained from SAR values in SAR compliance test reports. In each type, the averaged SAR values for the left and right sides of the phantom are very similar, whose correlation was good (0.6–0.9). However, it was found that the SAR information of the test reports should be reflected for SAR estimation in the human head since SAR values are so widespread.

It is impossible to numerically implement all commercial phone models which have used by subjects participating in an epidemiological study. A previous epidemiological study had used the

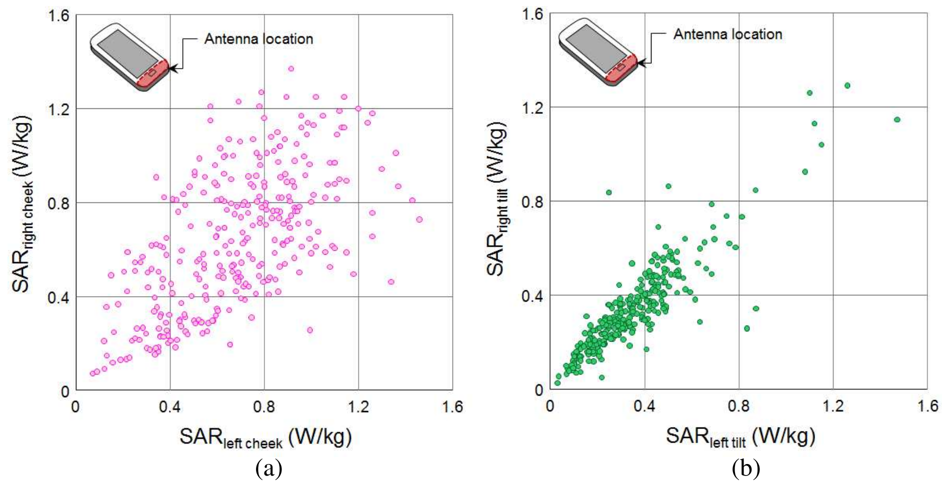

Figure 1: Scatter plot between SAR values measured on the left and right sides of the SAM phantom for the bar type of commercial phone models. (a) Cheek position. (b) Tilt position.

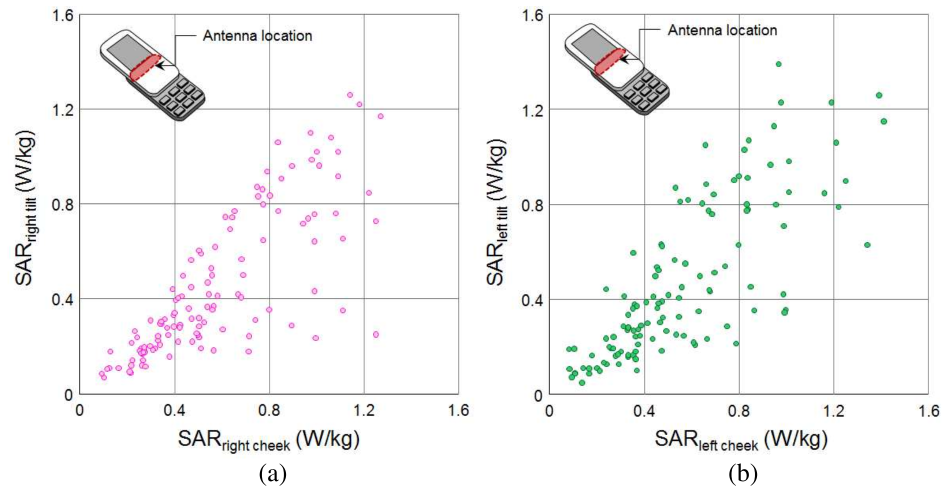

Figure 2: Scatter plot between SAR values measured in the SAM phantom under the cheek and tilt positions for the opened slider-type of commercial phone models. (a) Right side. (b) Left side.

median value of the maximum SAR (1- or 10 g-averaged spatial peak SAR) for the same type of phones [4]. The SAR factor of a specific phone using the SAR test data is proposed in the following section.

3. SAR FACTOR OF A SPECIFIC PHONE MODEL

The SAR test report of a specific phone model reported by a study subject is used to reduce the gap between the commercial model and its representative model. The spatial peak 1-g SAR in the SAM phantom had been already calculated under the four test positions for the numerical phone design. A numerical phone model had been so designed that the spatial peak 1-g SAR at each position becomes the average value of the same type of commercial phone models. Then an SAR ratio, averaged for the four positions of a representative phone model to a given commercial phone model, which is hereafter referred to as SAR factor. Fig. 3 represents the procedure to extract the SAR factor of a specific commercial phone model and apply it to the SAR data in an anatomical head model.

Subjects participating in an epidemiological study report commercial phone models which they have/had used. Assume that one of their phones is given as A-xxxx, a flip-type model with the antenna at the bottom, the SAR factor is obtained as follows.

The SAR test report of A-xxxx provides the spatial peak 1-g SAR values under the four positions, respectively; $[\mathrm{SAR}_{\mathrm{A-xxxx\_LC}}]$, $[\mathrm{SAR}_{\mathrm{A-xxxx\_RC}}]$, $[\mathrm{SAR}_{\mathrm{A-xxxx\_LT}}]$, and $[\mathrm{SAR}_{\mathrm{A-xxxx\_RT}}]$. The

Table 1: Statistical SAR data of commercial phone models.

Unit [W/kg]

Phone type		Frequency	Cheek position				Tilt position			
			Left		Right		Left		Right	
Shape	Antenna		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Bar	Bottom	CDMA PCS, WCDMA	0.683	0.281	0.642	0.291	0.348	0.200	0.341	0.189
Slider_c*	Top	CDMA Cellular	0.549	0.282	0.548	0.282	0.409	0.220	0.389	0.192
Slider_o*	Top	CDMA Cellular	0.570	0.295	0.572	0.298	0.300	0.204	0.289	0.183
Flip	External	CDMA PCS	0.788	0.253	0.811	0.259	0.206	0.182	0.186	0.150

*'c' and 'o' indicate closed and open states of a slider-type of phone, respectively.

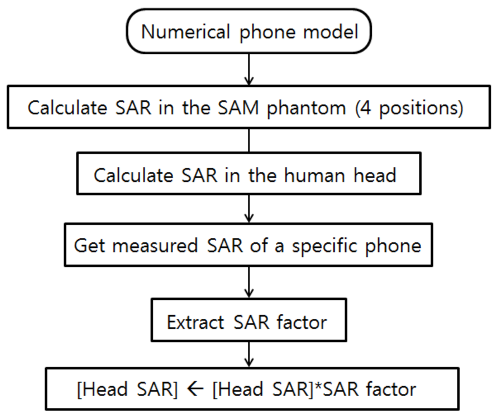

Figure 3: SAR factor.

subscripts, 'LC', 'RC', 'LT', and 'RT' indicate left cheek, right cheek, left tilt, and right tilt positions against the SAM phantom, respectively. Meanwhile, M6H is a numerical phone model, representative of flip-type phones with the antenna at the bottom. Its calculated spatial-peak 1-g SAR values in the SAM phantom are $[\mathrm{SAR}_{\mathrm{M6H\_LC}}]$, $[\mathrm{SAR}_{\mathrm{M6H\_RC}}]$, $[\mathrm{SAR}_{\mathrm{M6H\_LT}}]$, and $[\mathrm{SAR}_{\mathrm{M6H\_RT}}]$.

Since positive SAR correlations were identified between the right and left sides as well as the tilt and cheek positions, the SAR factor relating the SAR of a specific commercial phone model with that of the corresponding numerical model is written as (1).

$$\text{SAR factor } = \left\{ \begin{array}{c} \frac{[\mathrm{SAR}_{\mathrm{A-xxxx\_LC}}]}{[\mathrm{SAR}_{\mathrm{M6H\_LC}}]} + \frac{[\mathrm{SAR}_{\mathrm{A-xxxx\_RC}}]}{[\mathrm{SAR}_{\mathrm{M6H\_RC}}]} \\ + \frac{[\mathrm{SAR}_{\mathrm{A-xxxx\_LT}}]}{[\mathrm{SAR}_{\mathrm{M6H\_LT}}]} + \frac{[\mathrm{SAR}_{\mathrm{A-xxxx\_RT}}]}{[\mathrm{SAR}_{\mathrm{M6H\_RT}}]} \end{array} \right\} /4 \tag{1}$$

The Equation (1) can be applied to other types of phones but there is one exception to it. Some slider type of phone models can answer a phone call at its closed state. SAR compliance test had to be performed at both open and closed states of the slider and the SAR test results are given in the corresponding test report. This type of models cover about 60–80% of total slider models and the percentage was a little different according to frequency band and antenna location. These phone models mostly allow two methods to answer a call: ① tap the call button at the closed state and ② push up the slider. Because a user has to push up the slider to make a call, about 25% chance to use the phone at the closed state can be assumed if incoming and outgoing call times are equal. Therefore, the average SAR distribution in the user's head for this type of slider phone model is obtained using the following SAR factor.

$$\begin{aligned}\text{SAR factor} &= \left\{\begin{array}{c}\frac{[\text{SAR}_{\text{B}-\text{xxxx\_LC\_closed}}]}{[\text{SAR}_{\text{M3L\_LC}}]}+\frac{[\text{SAR}_{\text{B}-\text{xxxx\_RC\_closed}}]}{[\text{SAR}_{\text{M3L\_RC}}]}\\ +\frac{[\text{SAR}_{\text{B}-\text{xxxx\_LT\_closed}}]}{[\text{SAR}_{\text{M3L\_LT}}]}+\frac{[\text{SAR}_{\text{B}-\text{xxxx\_RT\_closed}}]}{[\text{SAR}_{\text{M3L\_RT}}]}\end{array}\right\}/4\times 0.25\\ &\quad+\left\{\begin{array}{c}\frac{[\text{SAR}_{\text{B}-\text{xxxx\_LC\_open}}]}{[\text{SAR}_{\text{M5L\_LC}}]}+\frac{[\text{SAR}_{\text{B}-\text{xxxx\_RC\_open}}]}{[\text{SAR}_{\text{M5L\_RC}}]}\\ +\frac{[\text{SAR}_{\text{B}-\text{xxxx\_LT\_open}}]}{[\text{SAR}_{\text{M5L\_LT}}]}+\frac{[\text{SAR}_{\text{B}-\text{xxxx\_RT\_open}}]}{[\text{SAR}_{\text{M5L\_RT}}]}\end{array}\right\}/4\times 0.75 \qquad (2)\end{aligned}$$

where, $[\text{SAR}_{\text{B}-\text{xxxx\_LC\_closed}}]$ represents the spatial peak 1-g SAR value in the SAM phantom at the closed state of a slider-type of phone model, B-xxxx under the left cheek position. The specific phone model can answer a phone call at the closed state has an internal antenna at top. The corresponding numerical phone model is M3L, a closed shape of slider phone. Similarly $[\text{SAR}_{\text{B}-\text{xxxx\_LC\_open}}]$ is for the open state of the same phone model, under the left cheek position and the subscript M5L indicates the numerical phone model of an open shape of slider phone.

4. CONCLUSIONS

Accurate and reliable dosimetry and exposure assessment are key requirements of scientific studies on health effects of electromagnetic fields. However, there are many limitations on the estimation of cumulative exposure for radiated electromagnetic field from a series of mobile phones that a study subject had/has used from the past. One of them is that we cannot numerically implement every specific phone model for SAR calculation in the human head.

Therefore, commercial phone models were classified into 11 groups according to frequency band, outer shape, antenna type and location and a numerical phone model representative of each group was developed in the previous study. In this paper, we proposed the SAR factor of a specific commercial phone which is obtained from the spatial-peak 1-g SAR data in the SAR test report. The SAR factor relates numerically calculated SAR in the anatomical head model with the measured result in the SAM phantom for a specific commercial phone. It would work to reduce the SAR gap between a real specific phone and the corresponding numerical model.

ACKNOWLEDGMENT

This work was supported by the IT R&D program of MSIP/IITP. [B0138-15-1002, Study on the EMF exposure control in smart society]. The authors thank the officials of Samsung Electronics Co., Ltd. and LG Electronics Inc. for allowing the data use of the SAR compliance test reports in this analysis.

REFERENCES

1. *IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz*, IEEE Standard C95.1, 1999.
2. *Human Exposure to Radio Frequency Fields From Hand-Held and Body-Mounted Wireless Communication Devices-Human Models, 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)*, International Electrotechnical Committee, Geneva, Switzerland, IEC 62209-1, Feb. 2005.
3. Lee, A.-K., et al., "Design of representative mobile phone models for epidemiological studies," *ETRI Journal*, submitted.
4. Cardis, E., et al., "Estimation of RF energy absorbed in the brain from mobile phones in the Interphone study," *Occup. Environ. Med.*, Vol. 68, No. 9, 686–693, Sep. 2011.