The Specific Absorption Rate of Mobile Phones Measured in a Flat Phantom and in the Standardized Human Head Phantom

Lira Hamada[#1], Takahiro Iyama[#2], Teruo Onishi[#2], and Soichi Watanabe[#1]

[#1] *National Institute of Information and Communications Technology*
4-2-1, Nukuikitamachi, Koganei, Tokyo 184-8795, Japan
[1]hamada@nict.go.jp
[#2] *NTT DOCOMO, INC.*
3-6, Hikarino-oka, Yokosuka, Kanagawa 239-8536, Japan

***Abstract*— We have investigated a simplification procedure of the Specific Absorption Rate (SAR) compliance test for mobile phones. In this paper, it is shown that maximum averaged SARs of a flat phantom and the SAM phantom are measured and compared for 38 mobile phones in the market in order to investigate on the applicability of using the flat phantom instead of the SAM phantom for the SAR measurement. A simplified test procedure is also proposed. The result shows that the flat phantom may be utilised to test Slide and Straight shape phones.**

Key words: Specific Absorption Rate (SAR), flat phantom, compliance test, mobile phone.

I. Introduction

In compliance test of mobile phones, measurement and report of the Specific Absorption Rate (SAR) is mandatory in many countries, in view of non-ionizing radiation protection.

The SAR is employed as an evaluation index for the electromagnetic fields in the human body, which is shown in

$$\mathrm{SAR} = \sigma \mathrm{E}^2 / \rho \qquad [\mathrm{W/kg}], \qquad (1)$$

where E (V/m) is the electric field strength(RMS), σ (S/m) is the conductivity and ρ (kg/m^3) is the density of the media. Peak spatial-average SAR is defined as the maximum value of SAR averaged over a specific mass [1]. A 10-g or 1-g average SAR is commonly used.

First of all, the outline of the SAR measurement is shown in Figs. 1 and 2. For the compliance test, the Specific Anthropomorphic Mannequin (SAM) phantom is used as the standardized human head. The test procedure is described in international standards in detail [1] [2]. This standard phantom shape is derived from the size and dimensions of the 90th-percentile large adult male head reported in an anthropometric study, with the ears adapted to represent the flattened ears of a handset user [1].

The phantom liquid which simulates the electrical properties of the human head is filled in the SAM. Then, electric field in the SAM irradiated from the mobile phone under test is scanned with a miniature probe, and the maximum SAR is obtained.

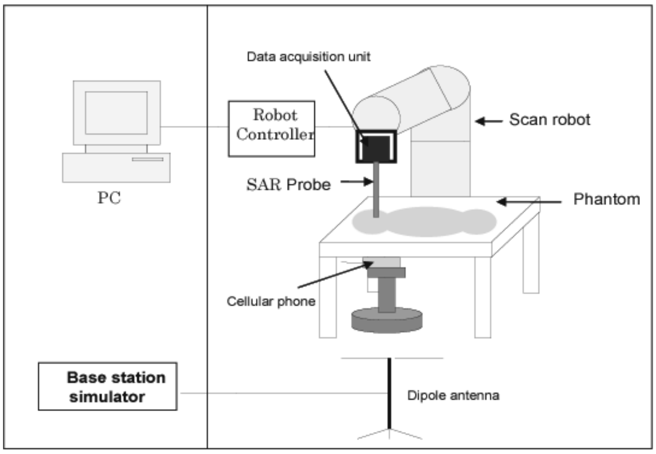

Fig. 1. Outline of the SAR measurement system.

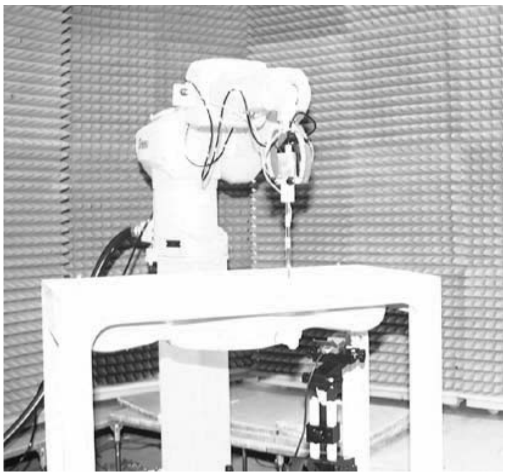

Fig. 2. A conventional SAR measurement system..

In the test procedure one must measure at least in four phone positions, i.e., in the right and the left sides of the SAM head at tilt and cheek positions [1, 2], to find the maximum

SAR for all operating frequency bands of the phone. Recently, various shapes of mobile phones have been in market along with the evolution of the functionality of the mobile phone. This causes the increase of the number of the measurement per one mobile phone in the compliance test, because some mobile phones have movable parts. For instance, a phone whose display swings to the right and the left should be tested for all of the following positions: right/left at SAM head, cheek/ tilt positions, and display swinging to right/left. That is, the required number of the measurement is 2 x 2 x 2 = 8. If this terminal works in multiband, above measurements must be repeated at each frequency. This measurement procedure of the SAR is highly reliable, however, it is very complicated and time consuming above reasons.

Moreover, the standards set a limitation about the insertion angle of the SAR probe toward the normal line to the inner surface of the SAM phantom shell to minimize the measurement uncertainty [1] [2]. For SAR measurement systems shown in Fig. 1, the position of the scanning robot arm (probe jig) and the SAM phantom is fixed. Therefore, there is a limitation of the probe insertion angle. Conventional phones often yields the peak SAR at the bottom of the SAM phantom (i.e. vicinity of the pinna), and the requirement for the probe insertion angle is easily achieved (See Fig. 3, Case (a)). However, for the phones having built-in antennas, the peak SAR often appears other parts as shown in Fig. 3 Case (b). For such cases, it is difficult to put the SAR probe within this angle limitation.

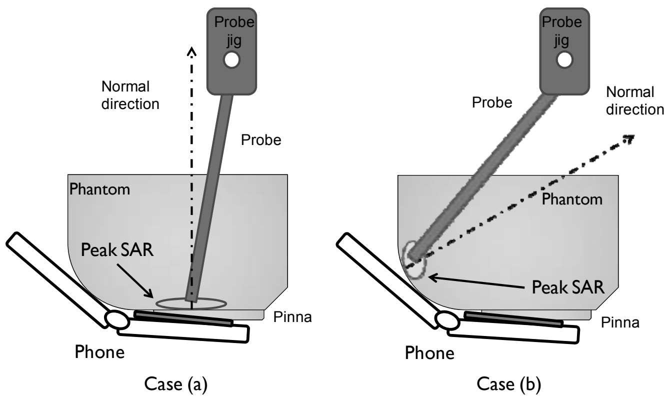

Fig. 3. Position of the peak SAR and probe insertion angle

In the draft of the IEC 62209-2 [3], a flat phantom will be utilized for compliance tests for mobile wireless communication devices used in close proximity to the human body except the devices used close to the ear, i.e. wireless devices mounted on the body, push-to-talk handy terminal and so on. If this flat phantom can be used for the compliance test of the mobile phones used close to the ear, the tests at right/left and cheek/tilt positions can be consolidated into one measurement and the total number of the measurement will be much reduced. In addition, it is also easier to overcome the limitation with respect to the probe insertion angle than the SAM phantom if the flat phantom is used.

Therefore, we investigated on the applicability of the flat phantom in compliance test of mobile phones used close to the ear.

II. METHOD AND PROCEDURE

Figure 4 shows the typical shapes of mobile phones. In this study, 38 mobile phones used in Japan are investigated. The phones are categorized into three types from their shapes as shown in Fig. 4: Clam-shell (23 phones), Straight (6 phones) and Slide (9 phones). Figure 5 shows the setting of the mobile phone positioned below the flat phantom. We measured the SAR in the phantom liquid according to the method described in the standards [1] [2] using the SAM and the flat phantoms.

Four frequency bands are considered: 800 MHz, 900 MHz, 1700 MHz and 2000 MHz. Some mobile phones are measured in multiple frequency bands, when the phone is a multiband terminal.

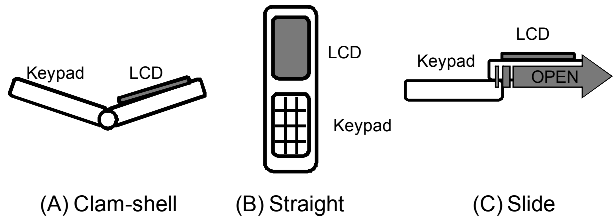

Fig. 4. Categories of the mobile phones.

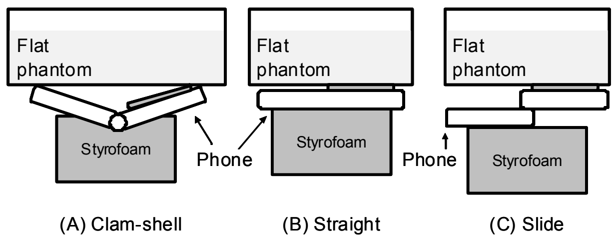

Fig. 5. Measurement setup for the flat phantom.

III. RESULTS AND DISCUSSIONS

Figure 6 shows the relationship between the maximum SAR values and the deviation for all of the mobile phones and frequencies. The deviation of the SAR value is evaluated by the following equation:

$$Deviation = \left(\frac{SAR\_flat}{SAR\_SAM} - 1 \right) \times 100 \quad [\%] \quad (2)$$

where *SAR_flat* is the maximum SAR value using the flat phantom, and *SAR_SAM* is that measured using the SAM in all right/left and cheek/tilt positions, respectively.

From the result, we can see that in most cases the *SAR_flat* is larger than the *SAR_SAM*, for Straight and Slide phones. Particularly, this is obvious for the data when the *SAR_SAM* is larger than 1 W/kg. This means that if the flat phantom is used for the measurement of these types of mobile phones, the measured maximum SAR can be overestimated, i.e. the evaluation is conservative. On the other hand, for the Clam-shell type phones, there are no clear tendency between the magnitude of the *SAR_flat* and that of the *SAR_SAM*. Therefore, a simple compliance evaluation using the flat phantom may be difficult for this type of mobile phones.

The reason of the results can be explained by the location of the radiating components of the mobile phone to the flat phantom. For Slide and Strait phones, almost the entire front surface of the phone touches to the flat phantom, and this will make the maximum absorption of the radiated field to the phantom. On the other hand, as shown in Fig. 4 (A), Clam-shell phone is touching to the phantom only at two edges of the top and the bottom of the body. This position will make longer distance between the radiating components in the phone to the phantom than that using the SAM phantom, particularly if the antenna is mounted at the hinge of the phone. This will cause lower SAR.

Considering above results, we propose a modification of the current test procedure for reducing the number of the measurement for Straight and Slide phones:

Step 1: Firstly measure the SAR using the flat phantom as shown in Fig. 5.

Step 2: If the maximum SAR does not exceed the SAR limitation which is determined considering overestimation margin not to underestimate the SAR by SAM, additional measurement using SAM might not be necessary.

Step 3: In case the maximum SAR exceeds the limitation, then use the SAM.

Here the data in Fig. 6 was evaluated according to the proposed test procedure. Considering the underestimation in the flat phantom is approximately 50 % in maximum, the SAR limitation for the flat phantom is set at the 50% reduced value from the compliance limit of 2 W/kg for 10g-averaged SAR: 1 W/kg [1]. This is to avoid misjudge in case the SAR by SAM is higher than that by the flat phantom. For Slide phones, the number of the phones which requires step 3 measurement was 2, 22% of the tested terminals. For Straight phones, it was 2 and 33% of the tested terminals. Therefore, more than 60 % of these phones can be tested by only one measurement using the flat phantom, and it is useful for test reduction.

IV. Conclusion

We compared the maximum average SAR of the actual mobile phones between the flat phantom and the SAM phantom in order to investigate on the applicability of the flat phantom instead of the SAM phantom for the compliance test.

We found that the maximum average SAR is generally higher for the flat phantom than for the SAM phantom, except some Clam-shell type phones. Therefore, we proposed the simplified test procedure for Slide and Straight phones, based on the criteria that if the measured SAR by the flat phantom does not exceed compliance limit, the measurement using SAM is not necessary. These results suggest that we can reduce the measurement time for the compliance test of a cellular phone, although more mobile phones should be investigated.

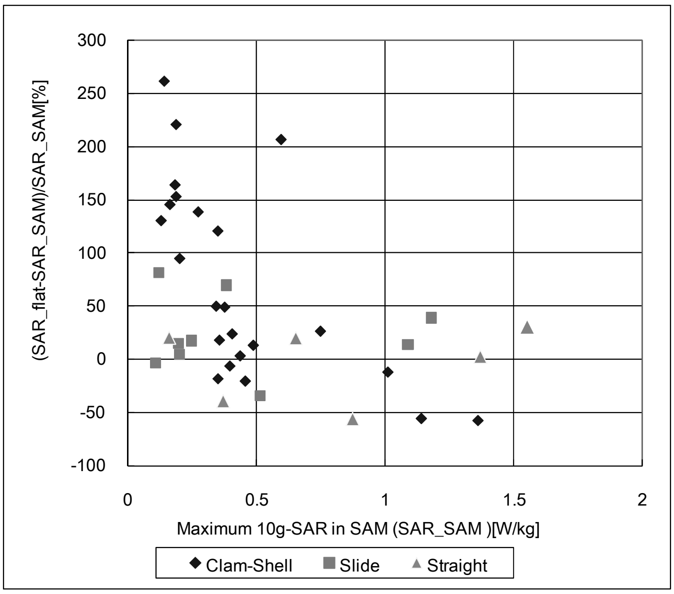

Fig. 6. Deviation of the maximum SAR in flat phantom from that by the SAM for various frequencies and shapes of mobile phones.

References

[1] IEC 62209-1 (2005): 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)

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