A STUDY ON FREQUENCY CHARACTERISTICS OF SAR-PROBE CALIBRATION FOR RF SAFETY COMPLIANCE TESTS

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1. Introduction

International standards of compliance tests of cellular telephones to radio-frequency (RF) safety guidelines have recently been issued [1,2]. The standards require that a SAR probe should be accurately calibrated and that the uncertainty of the measurement should be evaluated. The standards also require SAR measurements at several frequencies, i.e., the lowest, center, and highest frequencies at which the device under test is operated. However, the SAR probe is usually calibrated only at the center frequency of each operation band.

In order to evaluate the uncertainty of the SAR measurement at frequencies shifted from the center frequency, therefore, we have investigated the frequency characteristics of the SAR-probe calibration and its impact on the SAR measurements. In this study we present the investigation of the frequency characteristics around 1.95 GHz , the center frequency of the up-link of Japanese IMT-2000 (W-CDMA) system.

2. Method and Material

2.1 Head-tissue-equivalent liquid

Before the SAR-probe calibration and the SAR measurements which are described later, we prepared head-tissue-equivalent liquid. The liquid has been developed by ourselves and has non-toxic properties [3]. This electrical properties of the liquid were tuned to those described in the standard at 1.95 GHz. We also measured the frequency characteristics of the liquid.

2.2 SAR probe calibration

While various methods of SAR-probe calibration are described in the standards, we have been using the waveguide (WG) method which is the most popular method [1,2]. The rational and procedures of this method are described below: The calibration system consists of a coaxial-line-WG transducer, a WG filled with an air, a WG filled with a λ/4-matching dielectric slab, and a WG filled with phantom liquid which is used for SAR measurement (Fig. 1). The calibration factor of a SAR probe is defined as the sensitivities of the probe, γ_x, γ_y, and γ_z, as described below.

$$|E|^2 = V_x/\gamma_x + V_y/\gamma_y + V_z/\gamma_z ,$$

where V_x, V_y, and V_z are output voltage of three sensors in the SAR probe. These voltages are in proportional to power of the E-field strength ($|E_x|^2$, $|E_y|^2$, and $|E_z|^2$). We performed SAR-probe calibration from 1.85 GHz to 2.05 GHz with 25-MHz interval.

2.3 SAR measurement

In order to examine the effect of frequency characteristics of SAR-probe-calibration factors on SAR values, SAR measurements for the system validation test have been performed (Fig. 2). The system validation test is to be performed periodically, which is required by the standards, and uses a standard dipole antenna and a flat phantom [1,2]. The SAR measurements were performed with a standard-compatible measurement system (SPEAG Inc., DASY3). The same liquid and dipole antenna ,which were tuned at 1.95GHz, were used at the different frequencies.

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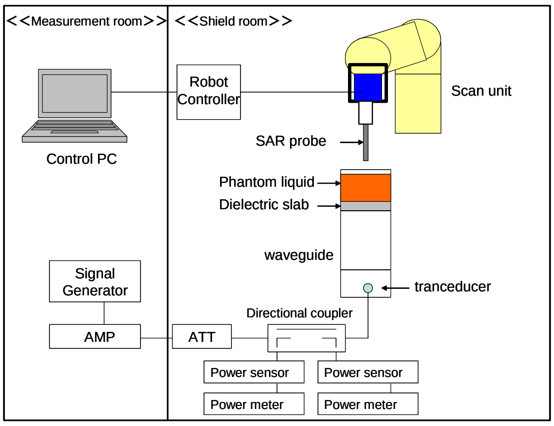


Figure1: SAR-probe calibration setup

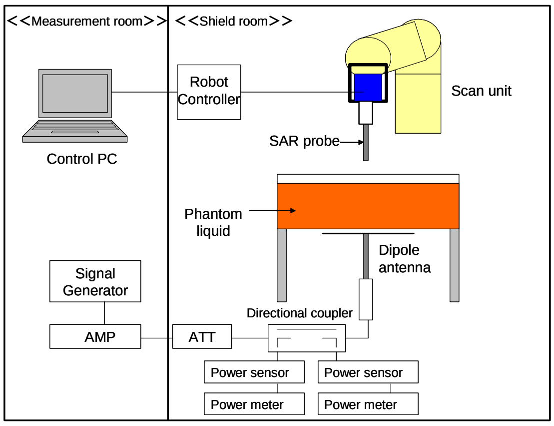


Figure2: Setup of the system validation

2.4 Numerical simulation

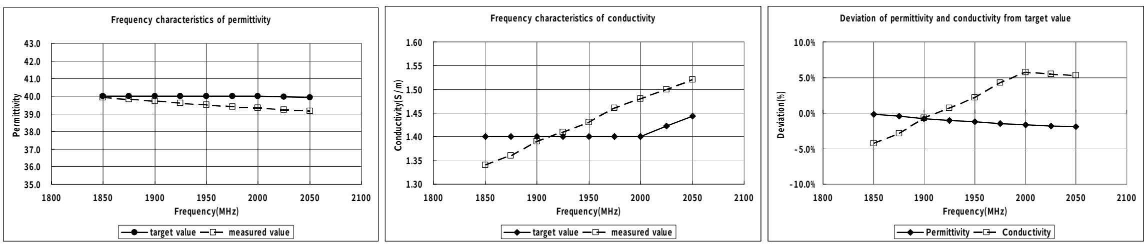
Finite-Difference Time-Domain (FDTD) simulations were also performed at each frequency. We performed the simulation assuming the target electrical properties of the head-tissue-equivalent liquid. This simulation was used for investigation of the adequacy of the SAR measurements at the frequencies shifted from the center frequency.

3. Results and discussion

The frequency characteristics of the head-tissue-equivalent liquid are shown in Fig. 3. The deviation of the measured constants from the target values are within 6% from 1.85 GHz to 2.05 GHz. This means the liquid can fairly be used in the frequency region because the standards require the electrical properties of the head-tissue-equivalent liquid to be within 5% from the target values.

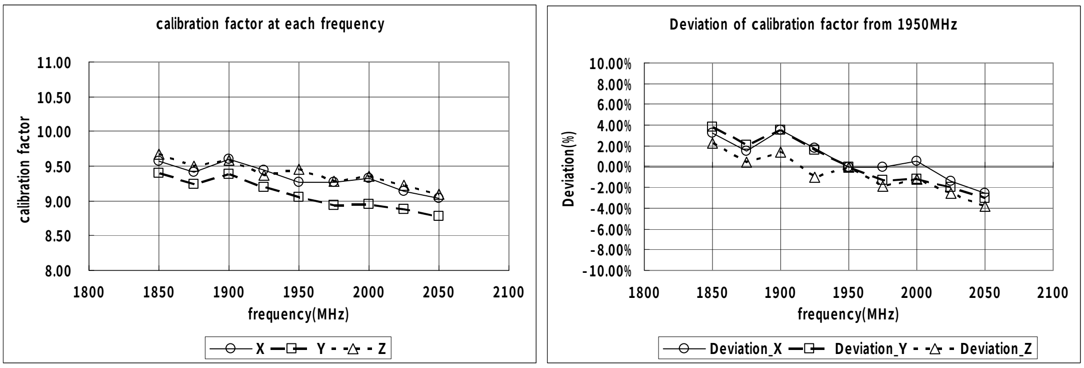
The frequency characteristics of the calibration factors of the SAR probe are shown in Fig. 4. It shows that the calibration factors tend to decrease slightly with increasing frequency. Similar characteristics are shown among X, Y, and Z sensors. The maximum deviation form the center frequency (1.95 GHz) is within 5%.

Figure 5 shows the comparison of the SAR value of the system validation between the measurement and the numerical simulation. The deviations of the measured value from the calculation values in which the target electrical properties of the head-tissue-equivalent liquid are assumed, are within 15% and16% for 1-g SAR and for 10-g SAR, respectively.



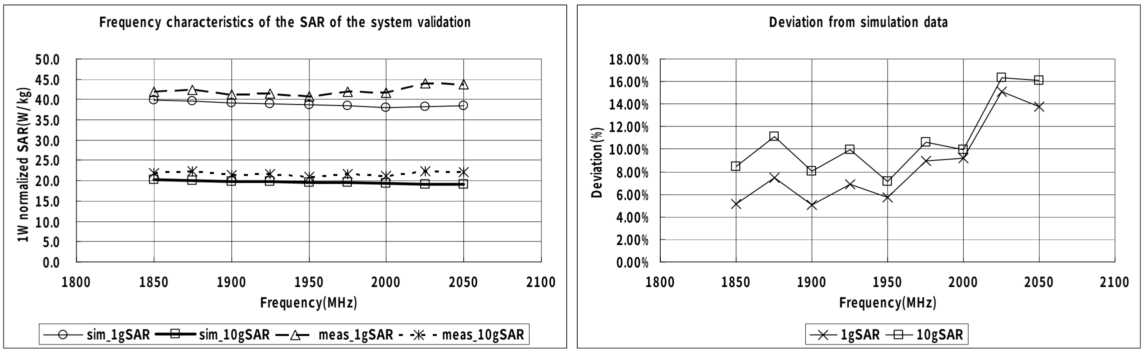
(a) (b) (c)

Figure 3: Frequency characteristics of the electrical properties head-tissue-equivalent liquid and of the target values.((a):permittivity, (b):conductivity) and deviation from electrical properties head tissue-equivalent liquid from target value(c).



(a) (b)

Figure 4: Frequency characteristics of the calibration factor for the SAR probe (a) and their deviation from the data at 1950 MHz (b).



(a) (b)

Figure5: Frequency characteristics of the SAR of the system validation (a) and the deviation of the measured values from the calculation values assuming the target electrical properties of the head-tissue-equivalent liquid (b).

4. Discussion

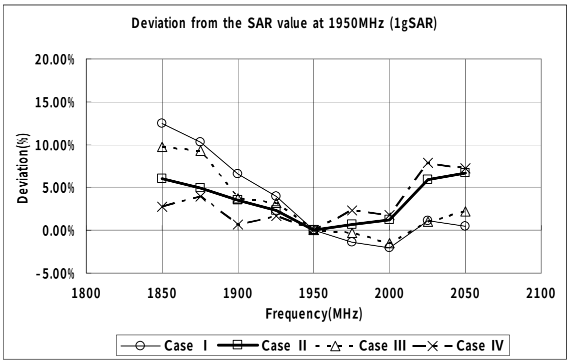
In order to clarify the effects of the electrical properties of the head-tissue-equivalent liquid and of the SAR-probe calibration factors, we have evaluated again the SAR of the system validation under the conditions listed in Table 1.

Deviations of the re-evaluated SAR values at the shifted frequencies from that at 1950MHz are shown in Fig. 6. From the comparison between Case I and Case III or between Case II and Case IV, it is shown that the impact of the used calibration factor on the frequency characteristics of the measured SAR is not significant. On the other hand the electrical properties of the head-tissue-equivalent liquid significantly affect on the frequency characteristics of the SAR measurement.

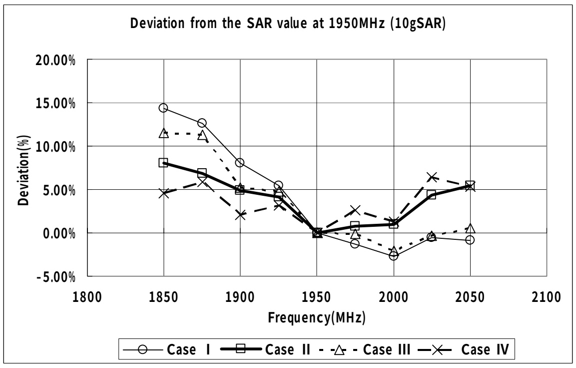
The deviation of the SAR values for the conditions listed in Table 1 from the calculation assuming the target head-tissue-equivalent liquid is shown in Fig. 7. The maximum deviation of the measured SARs for Case II, which are corresponding to usual cases, is 11% and 16% between 1.9 GHz and 2.0 GHz and between 1.85 GHz and 2.05 GHz, respectively. The result of Case II is also similar to those of Case IV, which is corresponding to the most accurate measurement condition.

Table1. Conditions for the SAR measurement of the system validation.

	Used calibration factor (CF)	Used conductivity (σ) for SAR evaluation
Case_ **I**	CF at 1950MHz	Measured σ at 1950MHz
Case_ **II**	CF at 1950MHz	Measured σ at each frequency
Case_**III**	CF at Each frequency	Measured σ at 1950MHz
Case_**IV**	CF at Each frequency	Measured σ at each frequency

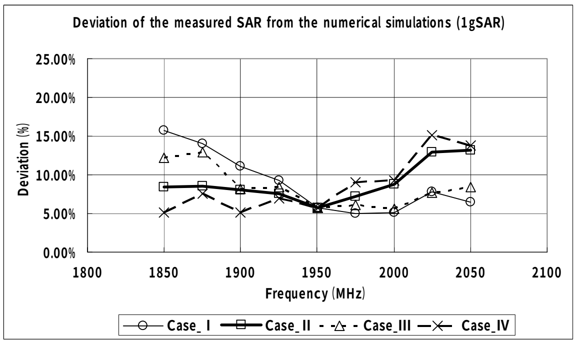


(a)

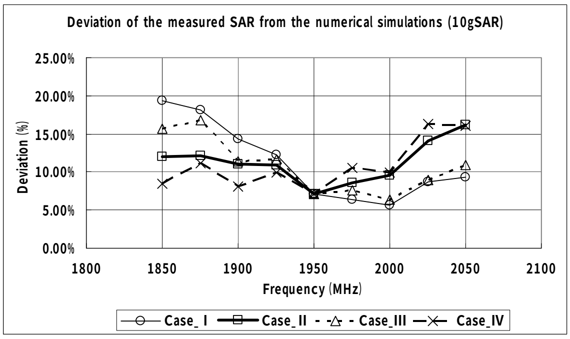


(b)

Figure 6. Frequency characteristics of the measured SAR (a: 1-g SAR, b: 10-g SAR) value of the system validation under the conditions listed in Table 1.



(a)



(b)

Figure 7: Deviation of the measured SAR for the conditions listed in Table 1 from the numerical simulation assuming the target electrical properties of the head-tissue-equivalent liquid.(a:1-g SAR, b:10-g SAR)

It should however be noted that the results described in this paper have limited generality because the frequency characteristics of the SAR measurement are strongly dependent on the frequency characteristics of tissue-equivalent liquid. Further studies using other-composition liquid of which the electrical properties has different frequency characteristics are therefore required.

References

[1] IEC PT62209-1 "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)", 2005.

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[3]S.Wanabae, H.Asou, K.Fukunaga, Y.Yamanaka, K.Sato, "Development of new non-tonic tissue-equivalent liquid for SAR evaluation " IEICE Society Conference, B-4-37, Sep 2004.