Total Radiated Power Measurement above 1 GHz with Partially-Spherical Scanning of a Probe

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***Abstract*— The total radiated power (TRP) measurement has been used to small radio transmitters such as cell phones, but it may also be very useful for evaluating interference potential of electronic equipment. Therefore, the TRP measuring technique is investigate and improved to get accurate TRP of an EUT for the frequency range above 800 MHz. For example, to reduce unwanted reflection, an EUT turn table is made of a low reflective material, "Rohacell®" instead of glass-reinforced plastic. In addition, a cantilever arm is used to support the turn table. Furthermore, a metal-top turn table is employed to reduce the shadow region and measurement time, where a probe antenna is partially spherical scanned.**

I. INTRODUCTION

Usually radio regulations request the total radiated power (TRP) of a transmitter to be controlled by measuring the power supplied to the antenna terminals of a transmitter. However, it is very difficult to apply this terminal power measurement to small-sized radio equipment such as cell phones, because there is no space enough to accommodate additional measurement terminals in the equipment. Therefore, in such a case, the radiated field is directly measured using a probe antenna scanned spherically around the transmitter.

Similarly, in EMC field, TRP measurement of the disturbances radiated from electronic equipment has also been discussed, where a reverberation chamber is deemed to be one of the most practical measuring facilities [1].

Judging from the above situations, it is considered very convenient if the TRP of radiated disturbances from electronic equipment can be measured with a measuring facility that is widely used for radio transmitters. Thus, the present paper investigates improvement on the TRP measurement for the frequency range above 1 GHz where EM fields are surveyed with spherically scanning a probe antenna.

II. DEVELOPED TRP MEASUREMENT FACILITY

The TRP measurement requires measurements of the equivalent isotropically radiated power (EIRP) of an EUT on a spherical surface around it for both ϕ– and θ-polarizations. From these measurements, the TRP can be evaluated from

$$TRP = \frac{1}{4\pi}\int_{\theta=0}^{\theta_m}\int_{\phi=0}^{2\pi}\left[EIRP_\theta(\theta,\phi)+EIRP_\phi(\theta,\phi)\right]\sin(\theta)d\theta d\phi \cdot \quad (1)$$

For survey of the E-field around an EUT, some measuring systems employ rotation of the EUT in an azimuth plane (ϕ rotation), while a probe antenna being spherically scanned in a vertical plane (θ-rotation) as shown in Fig. 1. Other systems rotate an EUT about two orthogonal axes (ϕ and θ axes). The former scanning method is usually called "conical cut method" and the latter "great-circle cut method" [2].

(1) Improvement in the structure

Figure 2 shows the conical cut EIRP measuring facility that was developed in this study for the frequency range from 0.8 GHz to 26 GHz. A probe antenna was oriented for the ϕ– or θ-polarizations and rotated circularly around an EUT in a vertical plane. The EUT was mounted on a non-conducting turn table for rotation in the ϕ direction. Usually, the turn table is placed on a column support standing on the floor (refer to Fig. 9). However, in this study, it was supported by a cantilever arm, as shown in Fig. 2, in order to make radiated field measurements easily done under the turn table. The whole measuring facility was placed in a semi-anechoic chamber (SAC) where the metal ground plane and other reflecting objects were covered with RF absorbers.

(2) Material selection

Since the turn table and the supporting cantilever arm may

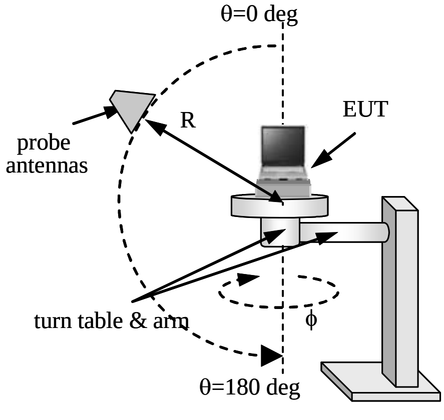

Fig. 1 Conical cut EIRP measuring system

affect radiated EM fields, it is very important to choose low reflective material for such structural objects for eliminating unwanted effects on the measurement results. Accordingly, three different turn table of the same dimensions were made of "formed styrene", "Rohacell®", and "polypropylene", respectively. Their reflection characteristics were measured using a pair of transmit and receive antennas in an arrangement similar to a radar configuration as shown in Fig. 3. Only the wave components reflected from the turn table were extracted from the measured data using the TDR technique. The results are expressed in terms of the received power as plotted in Fig. 4, where the reflected wave from a turn table was measured for each material at θ=0 deg for the ϕ-polarization. This figure clearly demonstrates that "formed styrene" has lowest reflectivity, but it is too fragile and deformable to make a rigid turn table and supporting arm. In contrast, "Rohacell®" may cause greater reflection in some degree, but it is considered much harder and easier to form the turn table and arm. Hence, we adopted "Rohacell®" for the material of a turn table and a cantilever arm as already illustrated in Fig. 2.

<u>(3) Validation measurement</u>

Validation method for an EIRP measurement facility is specified by the CTIA (Cellular Telecommunication & Internet Association) [2]. According to its specification, unwanted reflection from the surrounding objects (such as RF absorbers) and unknown effects of the turn table have to be evaluated by measuring radiated fields of an ideal dipole antenna placed in the EUT space. Hence, a sleeve dipole was positioned at several locations above the turn table as shown in Fig. 5 where the radiated field was measured with scanning a probe antenna in the θ-direction. Figure 6 illustrates variation in the received power as a function of the θ angle for each location of the sleeve antenna. This figure apparently indicates that the radiated field greatly changes in magnitude especially under the turn table (θ>150deg). In addition, measurement results become unstable when the sleeve antenna is placed close to the turn table. Thus, it may be concluded that the EIRP measurements under the turn table should be avoided as far as possible.

III. Total Radiated power measurement

Two simulated EUTs were developed for the total radiated power (TRP) measurements: EUT No.1 was a commercially available PC equipped with a wireless LAN card, while EUT No. 2 replaced a LAN card with a signal generator for the frequency range up to 26 GHz. Since numerical calculation for the TRP using Eq. (1) requires the entire spherical pattern (θ and ϕ) of the EIRP, radiated power measurement was performed on each simulated EUT with spherical scanning of the probe antenna (θ=0~180 deg) and rotation of the turn table. Before a series of EIRP measurements, the propagation loss was measured between the center of the EUT space and the probe antenna at frequencies of interest.

Examples of the EIRP pattern measured on EUT No. 1 are illustrated in Fig. 7. It is evident that radiation patterns of higher harmonics are more complicated than those of the

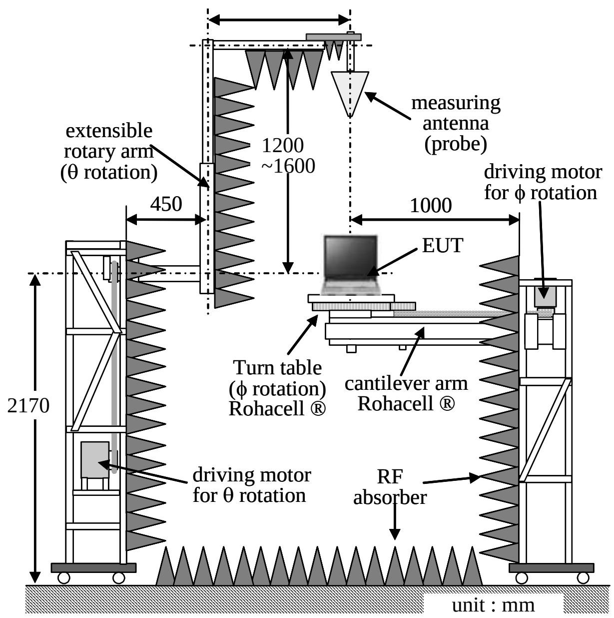

Fig. 2 EIRP measuring facility developed in this study

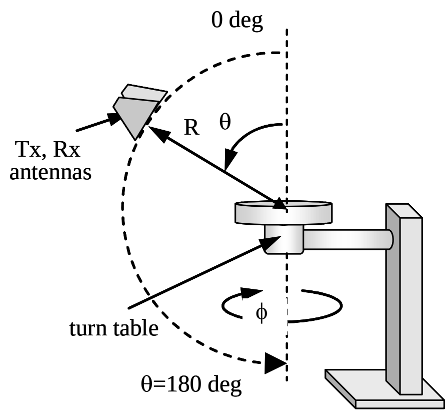

Fig. 3 Measurement of the reflected wave from a turn table

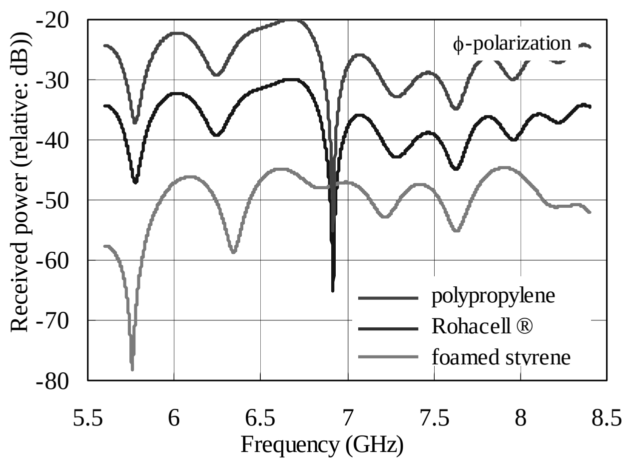

Fig. 4 Reflection characteristics of turn tables of different materials

fundamental frequency. Using these EIRP patterns, the TRPs were calculated from Eq. (1) for each EUT and frequency. In addition, power measurements were carried out at the antenna terminals of the same EUTs. Thus, the antenna terminal power was compared with the TRP as listed in Table 1. This table demonstrates that the measured TRP values differ from the antenna terminal power by about 3dB at lower frequencies, but more than 6 dB at higher frequencies. Such discrepancies may be caused by mismatching between the antenna and its power supply circuit.

IV. TRP MEASUREMENT USING PARTIALLY SPHERICAL SCAN

EIRP measurements with a probe antenna scanned spherically from θ=0 to 180 deg. is time-consuming and difficult especially at around 180 deg. as previously stated in section II. To cope with such difficulties, a partially-spherical scanning technique was proposed as an alternative by one of the authors [3]. It employs a metal-top turn table in order to reflect upward the power radiated from an EUT as shown in Fig. 8. In this case, partially spherical scan ($\theta=0\sim\theta_m$) of a probe antenna may be sufficient to obtain the TRP accurately. Examples of the EIRP pattern measured with a metal-top turn table are illustrated in Fig. 9. It is evident that radiation from the EUT is mostly concentrated in an upper hemi-sphere above the EUT. Using these EIRP patterns, the TRPs were calculated from Eq. (1) with changing the antenna scan range $\theta=0\sim\theta_m$. Figure 10 shows the variation of the yielded TRP with the maximum scan range θ_m. It is concluded from this figure that the antenna scan range θ=0~120 deg. is sufficient to obtain an accurate TRP value. Finally, we compared the TRP values measured with non-conducting turn table (probe scanning θ=0~180 deg) and with a metal-top turn table (probe scanning θ=0~120 deg) as listed in Table 2. This table evidently demonstrate that the partially scan technique is very effective to obtain the TRP.

V. CONCLUSIONS

The total radiated power (TRP) measurement has been used to small radio transmitters such as cell phones, but it may also be very useful for evaluating interference potential of electronic equipment. Therefore, the TRP measuring technique was investigate and improved to get accurate TRP of an EUT for the frequency range above 800 MHz. For

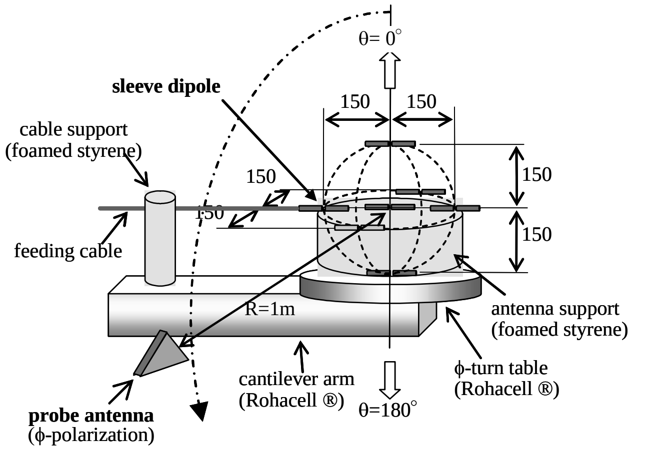

Fig. 5 Measurement arrangement for the RCS θ-axis ripple test

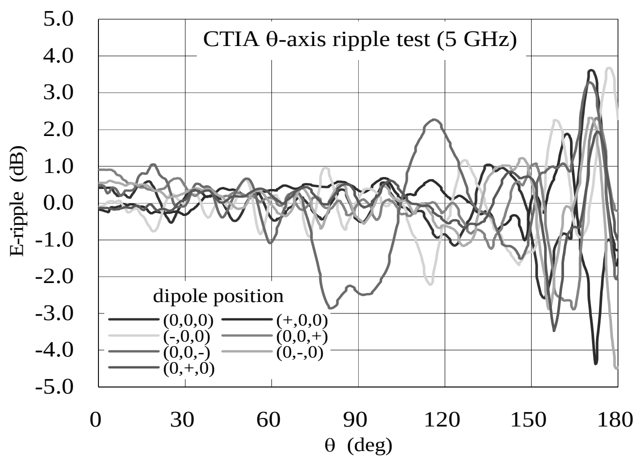

Fig. 6 Results of the RCS θ-axis ripple test

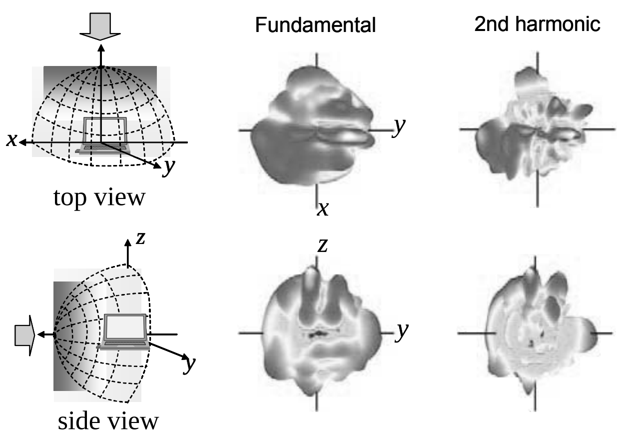

Fig. 7 EIRP pattern measured on a simulated EUT mounted on a non-conducting turn table (fundamental 2.45 GHz)

Table 1 Comparison between the TRP and the antenna terminal power

EUT	Frequency (GHz)		Output power at ant. port (dBm)	Total radiated power (dBm)
No. 1	2.45	Fundamental	9.79	6.79
		2nd harmonic	-33.86	-35.95
		3rd harmonic	-47.02	-45.82
	5	Fundamental	9.36	6.2
		2nd harmonic	-49.2	-46.68
		3rd harmonic	-56.0	-53.66
No. 2	2.45	Fundamental	-19.96	-21.54
		7th harmonic	-20.24	-26.67
		8th harmonic	-22.2	-31.37
		9th harmonic	-23.85	-33.82
		10th harmonic	-23.66	-34.22

example, to reduce unwanted reflection, an EUT turn table was made of a low reflective material, “Rohacell®” instead of glass-reinforced plastic. In addition, a cantilever arm was used to support the turn table. Furthermore, a metal-top turn table was employed to reduce the shadow region and measurement time, where a probe antenna is partially spherical scanned.

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[3] T. Yamada, N. Kuga, and H. Arai, “Radiation efficiency measurement with partial spherical scanning by using a reflector,” Proceedings of ISAP2007 (Niigata), 1B4-3, pp. 69-72, 2007.

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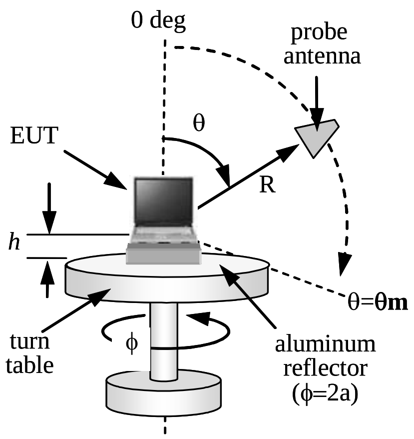

Fig. 8 TRP measurement method with partially-spherical scanning of a probe antenna

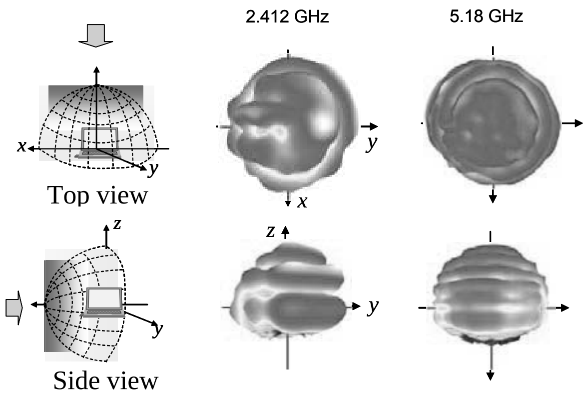

Fig. 9 EIRP pattern measured on a simulated EUT mounted on a metal-top turn table (fundamental 2.45 GHz)

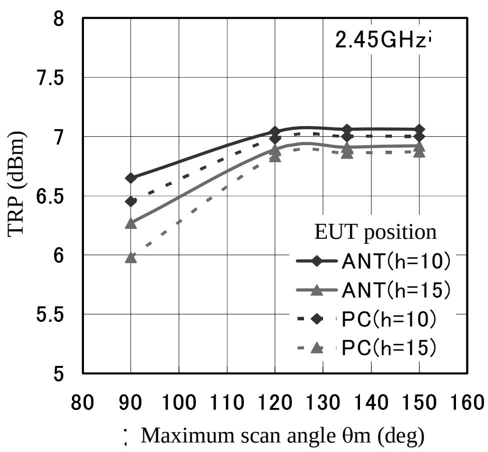

Fig. 10 Dependence of the yielded TRP on the antenna scan range $\theta=0\sim\theta_m$

Table 2 TRP values measured with the entirely scanning system and the partially scanning system

Frequency (GHz)	EUT rotation center	TRP (dBm)			Difference (dB) (b)-(a)
		(a) Spherical scanning	(b) Partially spherical scanning		
2.45	ANT	6.79	h=10 cm	7.06	0.27
			h=15 cm	6.92	0.13
	PC	6.67	h=10 cm	7.0	0.33
			h=15 cm	6.87	0.2
5	ANT	6.2	h=10 cm	5.13	-1.07
			h=15 cm	5.72	-0.48
	PC	6.15	h=10 cm	5.46	-0.69
			h=15 cm	5.36	-0.79