Round Robin Test of EMI Measurement in the 1 - 18 GHz Range

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***Abstract*—To evaluate uncertainty in electromagnetic interference (EMI) measurement in the 1 - 18 GHz range, a round robin test was conducted at 13 measurement sites. The maximum data spread of the measured field strength of equipment under test (EUT) that mainly radiates vertical components was 5.0 dB for both the peak and average detector in the case of vertical polarization. The maximum data spread increased to as much as 14.5 dB in the case of horizontal polarization. It was found that the spread of the measurement was mainly affected by site imperfections (SVSWR), the material of the setup table, and receiver characteristics. Finally, the validity of the uncertainty budget sheet being developed by CISPR is discussed.**

Key words—Electromagnetic disturbance, uncertainty, round robin test

I. Introduction

The CISPR (International special committee on radio interference) has standardized the measurement method for electromagnetic interference (EMI) at 1 - 18 GHz [1], and the CISPR has standardized the limit of interference that radiates from information and communication technology (ICT) equipment at 1 - 6 GHz [2]. However, measurement uncertainty above 1 GHz is under developing [3]. We investigated the current state of data spread in the measurement of the electromagnetic disturbance.

Measurement uncertainty is affected by the SVSWR (site voltage standing wave ratio), the material of the setup table, and receiver characteristics. To confirm the relevance of the CISPR uncertainty budget sheet, we measured these items in a RRT (round robin test). Then, we measured the field strength radiating from a EUT (equipment under test) at 12 laboratories (13 measurement sites: A - L).

II. Round Robin Test

A. SVSWR Measurement

To evaluate the effect of the reflected wave that came from outside the test volume, each participant of the RRT measured SVSWR as shown in CISPR 16-1-4 [4]. The measurement setup is shown in Fig. 1. The transmitting antenna was connected to Port 1 of a network analyzer, and the receiving antenna was connected to Port 2 of a network analyzer through a preamp. To measure the SVSWR, the omnidirectional dipole antenna (ARC: POD16 and POD618) was used as the transmitting antenna. We measured the S_{21} of S parameter when an RF absorber was placed between the transmitting and receiving antennas. H_1 and H_2 are 1.0 m, D is 3.0 m, and the diameters of the test volume depend on each measurement site.

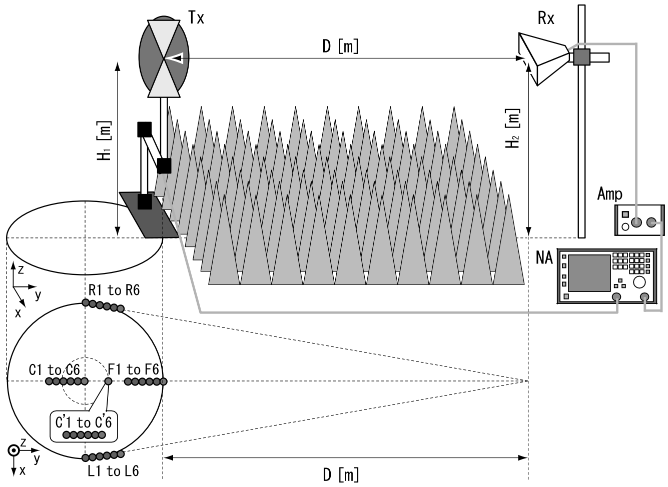

Fig. 1. Measurement setup of SVSWR

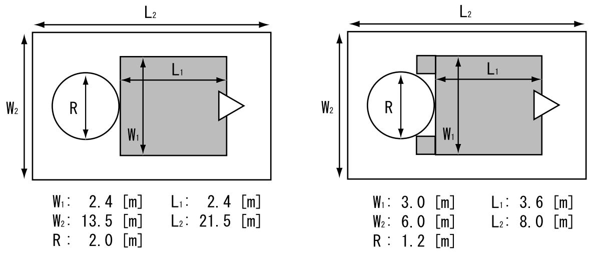

Fig. 2. Examples of size of measurement sites and area of RF absorber (left: site E, right: site G)

The SVSWRs were measured at the 5 positions (F, C, R, L, and C') indicated by the blue symbols in Fig. 1. The distance between $C6$ and $C'6$ was 10 cm. Then, S_{21} was measured when the Tx antenna was moved to 2, 10, 18, 30, and 40 cm from the original position (blue position), and SVSWR was calculated by the correcting the levels at the original position assuming free space propagation. The measured polarizations were vertical and horizontal. Fig. 2 shows examples of the size of the measurement site and the area of the RF absorber at measurement sites E and G. Fig. 3 shows the measured SVSWR at F, C, R, and L of each polarization when it was

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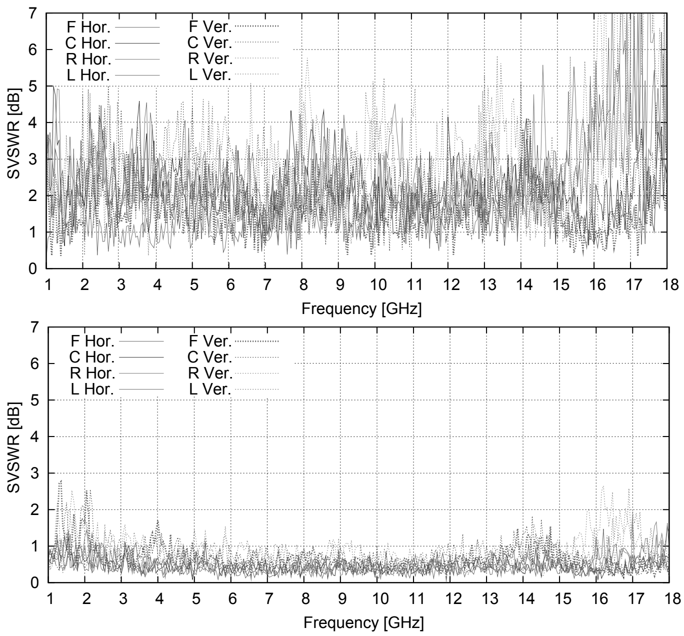

Fig. 3. Measured SVSWR at each position in horizontal and vertical polarizations (upper: site E, bottom: site G)

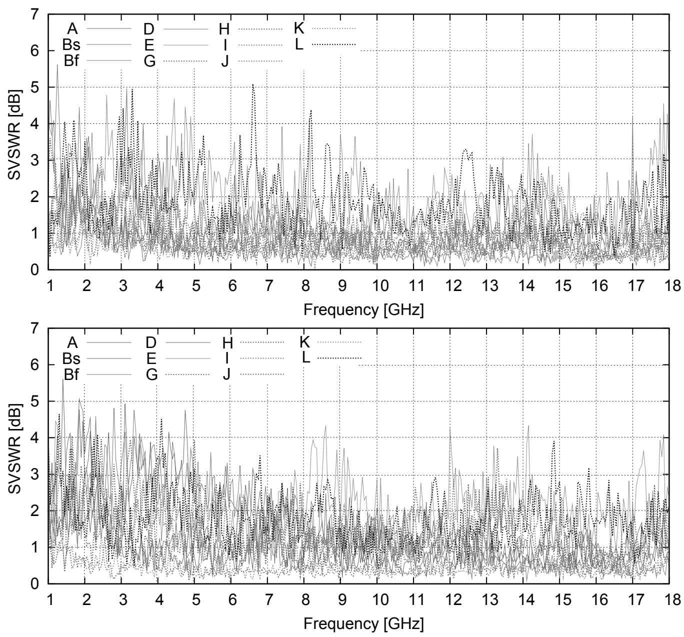

Fig. 4. Measured SVSWR at position C' (Upper: Ver. pol., Bottom: Hor. pol.)

measured at measurement sites E and G. The diameters of the test volumes were 2.0 m and 1.2 m. The SVSWR of the measurement site G was less than 3 dB at all frequencies; however, the SVSWR of the measurement site E was more than 6 dB at 16 - 18 GHz when the Tx was located at positions R and L. The reasons might be that the placed area of RF absorber was not enough, and the test volume was too large. These problems can be solved by reducing the size of the test volume. Fig. 4 shows the measured SVSWRs for each polarization at C' position at 11 measurement sites, and these values were less than 6 dB, and complied with the requirement in CISPR 16-1-4 [4].

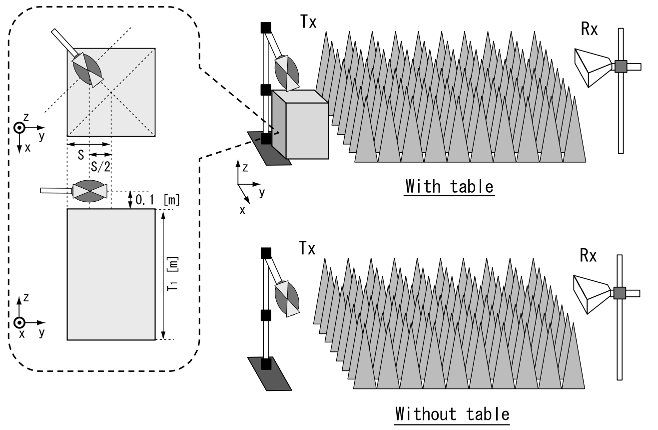

Fig. 5. Measurement of table effect

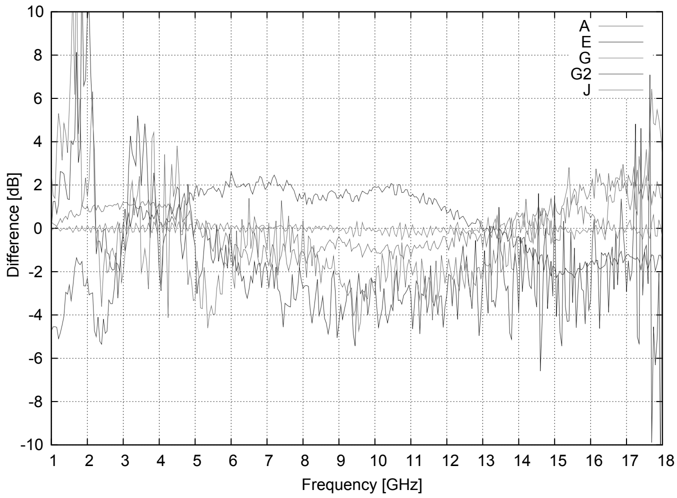

Fig. 6. Measured table effect

B. Effect of Setup Table Material

The data spread of the measured field is affected by the material of the setup table; therefore, we measured the effect of the table. The measurement setup was the same as for the SVSWR measurement. First, we measured the level difference from the measured S_{21} for horizontal polarization with the measurement table and without it. The transmitting antenna was located above the measurement table as shown in Fig. 5. Fig. 6 shows the level difference at measurement sites A, E, G, and J. Tables A, E, G, G2, and J were prepared from a thin Teflon on foam polystyrene, FRP (fiberglass reinforced plastic), foam polystyrene, a wooden table, and vinyl chloride with plasticized cardboard, respectively. From Fig. 6, the measured result showed no difference when a desk made of foam polystyrene was used. When the desks contain Teflon, FRP, and wood, the level difference becomes larger than for

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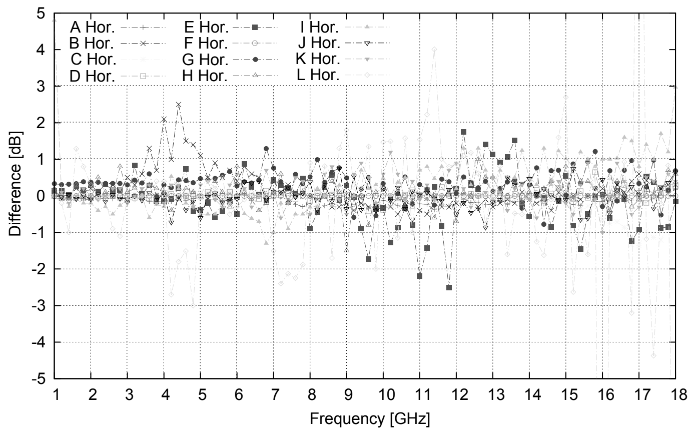

Fig. 7. Data spread of receiver reading when EUT directly connected by cable

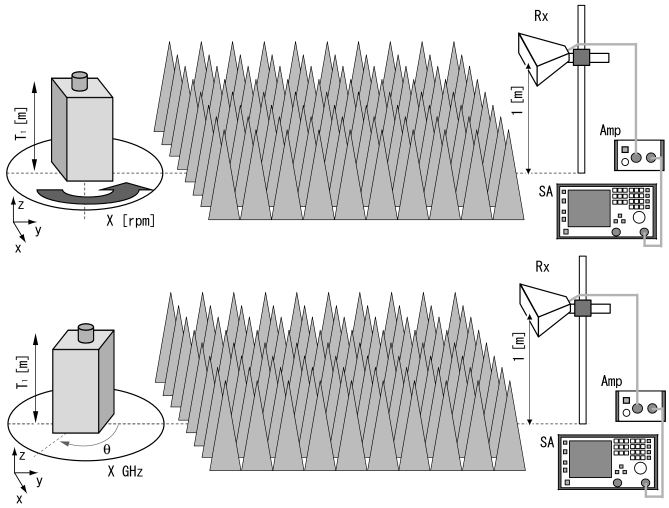

Fig. 8. EUT measurement (upper: pre. meas., bottom: final meas.)

polystyrene, and tables made of these materials may increase the measurement uncertainty.

C. EUT Measurement

To measure the data spread of EMI measurement, we used a common EUT that radiates EMI discretely in 200 MHz steps in the 1 - 18 GHz range. The EUT has a battery and columnar shape, the diameter and height of which are 155 and 82 mm, respectively. The EUT has a discone antenna, which is omnidirectional in the H-plane. The radiation level for vertical polarization is larger than that for horizontal polarization.

1) Stability of EUT: To evaluate the stability of the EUT, we measured the received voltage by using a spectrum analyzer before and after the measurements. A spectrum analyzer was directly connected to the EUT. Fig. 7 shows the level difference at each 200 MHz step before and after the measurement. The most of differences were less than ±2 dB in the 1 - 18 GHz range. Since the output voltage of the EUT was stable within ±0.25 dB at the given frequency range, instability of the connection of the RF connector at some sites may cause the difference.

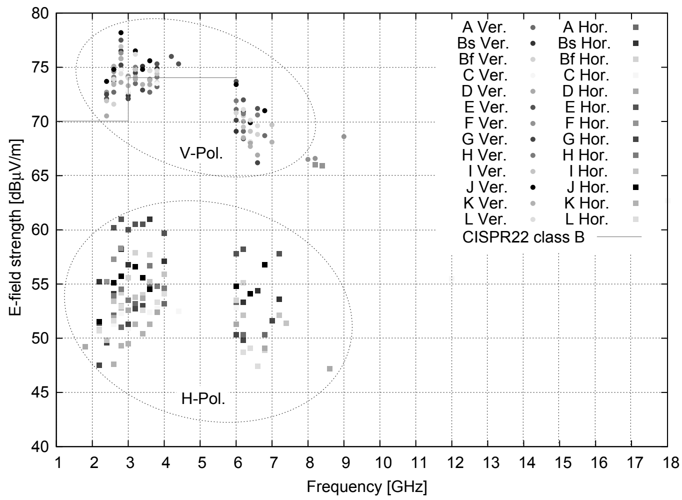

Fig. 9. Final measurement (peak detector)

2) Preliminary Measurement: The upper part of Fig. 8 shows the measurement setup for the preliminary measurement. By using this measurement setup, we measured the electromagnetic disturbance that radiated from the EUT. A receiving antenna was connected to the spectrum analyzer through a preamp. The RBW and VBW of the spectrum analyzer were 1 MHz, the detector was a peak detector, and the height of the receiving antenna was 1 m. Parameters such as size of the setup table, the sweep time of the spectrum analyzer, and the rotation speed of the turn table depended on each measurement site.

First, we measured the electric field strength for vertical and horizontal polarizations that radiated from the EUT when turn table was rotating. We then selected frequencies at three large levels in three bands (Band 1: 1 - 3 GHz, Band 2: 3 - 6 GHz, Band 3: 6 - 18 GHz). We also measured the environment noise when the EUT was switched off.

3) Final Measurement: From the preliminary measurement, we selected three frequencies in three bands (nine frequencies). The bottom part of Fig. 8 shows the measurement setup for the final measurement. In the final measurement, the maximum field strength was measured at the selected frequencies using the peak and average detectors.

Fig. 9 shows the measured electric field strength for the vertical and horizontal polarizations at 13 measurement sites using a peak detector. The largest data spreads for vertical and horizontal polarizations using a peak detector were 5.0 dB at 6.6 GHz (S/N: 11.3 - 29.0 dB) and 12.6 dB at 2.6 GHz (S/N: 0.3 - 21.8 dB), respectively. Similar results were obtained for average detector. The number in parentheses shows the range of the data spread of S/N of measurement sites. The data spread of the measured electric field strength for the vertical polarization was smaller than that for the horizontal polarization. The reason is that the low S/N measurement was included in the case of horizontal polarization.

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TABLE I
UNCERTAINTY BUDGET SHEET OF EMI MEASUREMENT AT 1 - 18 GHZ.

Input quantity	X_i	Uncertainty of X_i		$c_i\ u(X_i)$ [a]
		dB	Probability distribution function	dB
Receiver reading	V_r	± 0.1	k = 1	0.10
Attenuation: antenna-receiver	L_c	± 0.2	k = 2	0.10
Preamplifier gain	G_p	± 0.2	k = 2	0.10
Antenna factor	F_A	± 1.0	k = 2	0.50
Receiver corrections:				
Sine wave voltage	δV_{sw}	± 1.5	k = 2	0.75
Pulse response (Our proposal)	δV_{pr}	+0.82/-0.91	Rectangular	0.53
Noise floor proximity (1 - 6 GHz)	δV_{nf}	+0.5/0.0	Rectangular	0.29
Noise floor proximity (6 - 18 GHz)	δV_{nf}	+1.0/0.0	Rectangular	0.58
Instability of preamp gain	δG_p	± 1.2	Rectangular	0.70
Mismatch: antenna-receiver	δM	+1.2/-1.4	U-shaped	0.92
Antenna corrections:				
AF frequency interpolation	δF_{Af}	± 0.3	Rectangular	0.17
Directivity difference	δA_{dir}	+3.0/-0.0	Rectangular	0.87
Phase centre location at 3 m	δA_{ph}	± 0.3	Rectangular	0.17
Cross-polarization	δA_{cp}	± 0.9	Rectangular	0.52
Site corrections:				
Site imperfections [3] : Our proposal	δS_{VSWR}	+6.0 : +2.2/-3.5	Special [b] : Rectangular	1.33 : 2.02
Effect of setup table material [3] : Our proposal	δA_{NT}	± 1.0 : ± 2.0	Rectangular	0.58 : 1.15
Separation distance at 3 m	δd	± 0.3	Rectangular	0.17
Table height	δh	± 0.0	k = 2	0.00
[a] All ci = 1, [b] ±4.0 dB Gaussian distribution (k = 3)				
Expanded uncertainty of measurement at 3 m (2 u_c(E)) [3]: 4.68 dB (1 - 6 GHz), 4.79 dB (6 - 18 GHz) Our proposal: 6.54 dB (1 - 6 GHz), 6.61 dB (6 - 18 GHz)				

III. DISCUSSION ON UNCERTAINTY BUDGET

Table I shows the uncertainty budget sheet for EMI measurement at 1 - 18 GHz being developed by CISPR [3]. In the RRT, we measured the effect of setup tables using various materials such as wood, FRP, formed polystyrene and formed polystyrene covered with Teflon. Assuming formed polystyrene covered with Teflon as a standard table for EMI measurement above 1 GHz, ±2 dB should be used as a typical value in Table I. CISPR16-1-4 specifies the site characteristics where SVSWR will be less than 6 dB. From the definition of SVSWR, SVSWR = 6.0 dB corresponds to a -3.5 dB/+2.2 dB error in the received electric field strength. Assuming a rectangular probability having a half width of 3.5 dB, we can obtain a typical standard uncertainty of 2.02 dB caused by the imperfections of the test site.

The pulse response also affects an expanded measurement uncertainty for general EMI measurements. In CISPR 16-1-1 [5], an impulse bandwidth of 1 MHz is specified with ±10 % difference. Therefore, CISPR document [3] needs to consider these factors in typical uncertainty values.

With the above considerations, the typical expanded uncertainties of EMI measurement should be estimated as 6.54 dB (1 - 6 GHz) and 6.61 dB (6 - 18 GHz).

IV. CONCLUSION

To evaluate EMI measurement uncertainty in the 1 - 18 GHz range, an RRT was performed at 13 measurement sites. In the RRT, we measured the SVSWR, the effect of the setup table, and the field strength measurement that radiated from a EUT. In our RRT, the data spread of the measured electric field strength was 5.0 dB and 12 - 14 dB for vertical and horizontal polarization, respectively. It was found that the spread of the measurement was mainly affected by the site imperfections (SVSWR), the material of the setup table, and receiver characteristics. Thus, we can reduce the data spread of the final measurement by improving the site characteristics, by using a formed polystyrene table, by increasing the S/N ratio using a low NF preamp, or by using a receiver compliant with CISPR16-1-1.

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