Evaluation of uncertainty in electromagnetic disturbance measurement in the 1 - 18 GHz range

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Abstract

The dispersion of the measurement of electromagnetic disturbance above 1 GHz is mainly affected by site imperfections (expressed by SVSWR). To evaluate the uncertainty in electromagnetic disturbance measurements at 1 - 18 GHz, we measured SVSWR and the field strength at 9 measurement site. From our result, the measured field strength at each measurement site was observed in the range of 2σ that derived from measured SVSWR, and we confirmed the relationship between SVSWR and the measured field strength. Using the relationship, we can determine the measurement uncertainty of measured field strength at test site.

1 Introduction

The International Special Committee on Radio Interference (CISPR) has standardized the method used for electromagnetic disturbance measurement in the frequency range 1 - 18 GHz [1]. Further, CISPR has standardized the limit of the interference due to emission from the information technology equipment (ITE) in the frequency range 1 - 6 GHz [2]. However, measurement uncertainties above 1 GHz are still under investigation [3].

Measurement uncertainty is affected by site imperfections (expressed by the site voltage standing wave ratio (SVSWR)) [4] and the material used for constructing the setup table. To determine the uncertainty budget sheet at our test site, we measured SVSWR and an effect of a setup table. Then, we measured the field strength radiating from the equipment under test (EUT) at 9 measurement site by changing the area covered by the RF absorber on the metal ground plane. From the results, we confirm the relationship between SVSWR and the measured field strength. If we know the relationships, we can use the measured SVSWR of test site to estimate the dispersion of field strength, and we can determine the measurement uncertainty of measured field strength at test site.

2 SVSWR measurement

To evaluate the effect of the reflected wave from the defects at a test site or surrounding objects of the site, we measure the SVSWR according to the CISPR 16-1-4 specifications [4]. SVSWR is defined as the ratio of the maximum and minimum received levels and is expressed as

$$S_{VSWR}\ [\mathrm{dB}] = V_{max} - V_{min}. \tag{1}$$

Here, V_{max} and V_{min} indicate the measured maximum and minimum levels in dB, respectively, and are determined by correcting the levels at the reference position. The moved distances of a transmitting antenna from reference positions are 2, 10, 18, 30, and 40 cm. The transmitting and receiving antennas are connected to a network analyzer. Each antenna height is 1 m. An omnidirectional dipole antenna is used as the transmitting antenna. The distance from the transmitting antenna to the receiving antenna is 3 m. To determine the relationship between the SVSWR and the dispersion of field strength, we measure the S_{21} of the S-parameter for each polarization when RF absorber was placed between the transmitting and receiving antennas as shown in Figure 1. Here, the placed area of the RF absorber at the measurement site are

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shown in small gray squares indicate the absorber unit with dimensions as shown in Figure 1. The difference between the sites (a) and (i) is the thickness of the RF absorber.

Figure 2 shows the measured SVSWR values for vertical polarization at each measurement site. Although the SVSWR values are less than 6 dB without sites (f), (g), and (h), which is the level prescribed by the CISPR 16-1-4 specifications [4], site imperfections may cause dispersion of the measured field strength, which depends on the SVSWR value.

3 Effect of setup table

The material used for constructing the setup table may cause the dispersion of the measured field strength. Thus, we measure the effect of setup table. In his paper, we measured the difference between the S_{21} values obtained for horizontal polarization with and without the table. The transmitting antenna was located 10 cm above the measurement table. Figure 3 shows the level difference in the S_{21} values when foam polystyrene was used. From the results of the measurement, level difference was very small and was within ± 1 dB in the frequency range 1 to 18 GHz.

4 Measurement of field strength radiated from EUT

To measure the dispersion in field strength measurement, we use an artificial EUT that emits radiation in discrete 200 MHz steps. The output of the EUT is stable within 0.1 dB in the frequency range 1 - 18 GHz. The EUT has a discone antenna, which is omnidirectional in the H-plane. The EUT is placed on the setup table. The distance from the EUT to the receiving antenna is 3 m. The receiving antenna is connected to the spectrum analyzer through a preamp. The RBW and VBW of the spectrum analyzer are 1 MHz, and a peak detector is used. First, we measure the electric field strength at each measurement site. We also measure the environmental noise when the EUT is switched off. The measurement results are shown in Figure 4. The symbols show the measured field strength for vertical polarization at each measurement site. The maximum data dispersion was 9.9 dB at 1.0 GHz. One of the reason of the dispersion was due to the S/N ratio at the measurement sites.

5 Discussion on uncertainty budget

The measurement uncertainty is affected by site imperfections and the setup table material. At site (i), the maximum SVSWR values in the frequency ranges 1 - 6 GHz and 6 - 18 GHz are 2.94 dB and 2.17 dB, respectively. By using our model [5], we estimate the field dispersion to be -1.59/+1.34 dB and -1.15/+1.02 dB in the frequency ranges 1 - 6 GHz and 6 - 18 GHz, respectively. Further, by assuming a triangular distribution function with half-widths of 1.59 dB and 1.15 dB, we can estimate the standard uncertainties caused by the imperfections at this test site to be 0.65 dB and 0.47 dB, respectively. The effect of setup table is 1 dB. Using the aforementioned values, we determine the uncertainty budget sheet at site (i) for EMI measurements in the frequency range 1 - 18 GHz, as shown in Table 1. The expanded uncertainties are 5.0 dB and 4.9 dB (1 - 6 GHz and 6 - 18 GHz).

To determine the relationship between SVSWR and the dispersion of measured field strength, we determine the measurement uncertainty at each frequency using the measured SVSWR and the effect of setup table. The dashed lines in Figure 4 show the range of the expanded uncertainty (2σ), and it determined from the measured field strength of (i). Each symbol is observed in the range of 2σ, thus, we can conclude that the SVSWR relate to the dispersion of measured field strength. If SVSWR values are decreased, the dispersion in the measured field strength data might decrease. CISPR16-1-4 specifies the site characteristics for which the SVSWR is less than 6 dB (corresponds to an error of -3.5 dB/+2.2 dB when using our model

[5]). Therefore, the CISPR standard uncertainty [3] in the emission measurement is estimated to be 2.77 dB and 2.80 dB (1 - 6 GHz and 6 - 18 GHz).

6 Conclusion

The dispersion in the measurement was mainly affected by site imperfections (SVSWR) and the material used for constructing the setup table. In this paper, we measured SVSWR and electromagnetic disturbance radiated from EUT at 9 measurement site to evaluate the uncertainty in the electromagnetic disturbance measurements at 1 - 18 GHz. From our results, the measured field strength at each site was observed in the range of 2σ that derived from SVSWR, thus, we can conclude that the SVSWR relate to the dispersion of measured field strength. Moreover, using the derived SVSWR, we can determine the measurement uncertainty of the measured field strength at test site. The results of this study revealed that the dispersion in the field strength data could be reduced by improving the site characteristics, using a foam polystyrene table, and increasing the S/N ratio with the help of a low-NF preamp.

7 References

[1] "Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-3: Methods of measurement of disturbances and immunity - Radiated disturbance measurements", CISPR 16-2-3 Ed. 2.0, Jul., 2006.
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[3] "Uncertainty in EMC measurements,", CISPR / A / 848 / CD, 2009.
[4] "Amendment 1 - Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-4: Radio disturbance and immunity measuring apparatus - Ancillary equipment - Radiated disturbances", CISPR 16-1-4 Amd.1 Ed. 2.0, Oct., 2007.
[5] T. Tosaka and Y. Yamanaka, "Evaluation of Uncertainties in Electromagnetic Disturbance Measurement above 1 GHz due to Site Imperfections", IEICE Trans. on Comm., Vol. E93-B, No. 7, pp. 1690-1696, Jul. 2010.

8 Figures and Table

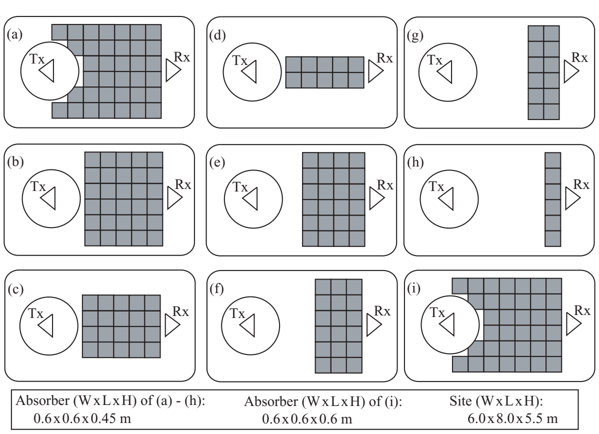

Figure 1: Area of RF absorber

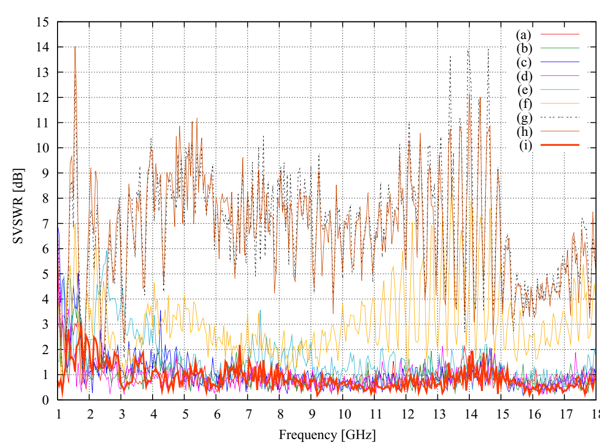

Figure 2: Measured SVSWR for vertical polarization

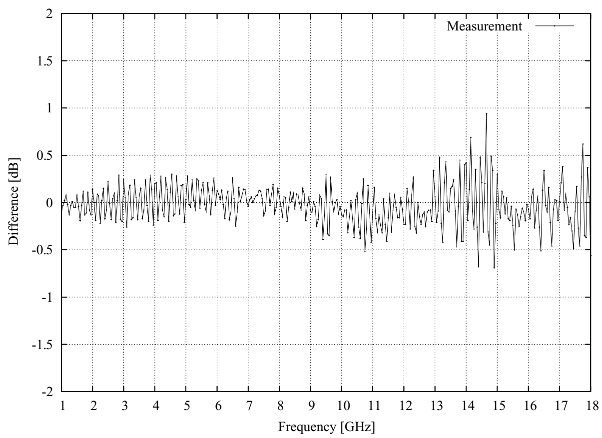

Figure 3: Level difference between S_{21} values with and without setup table

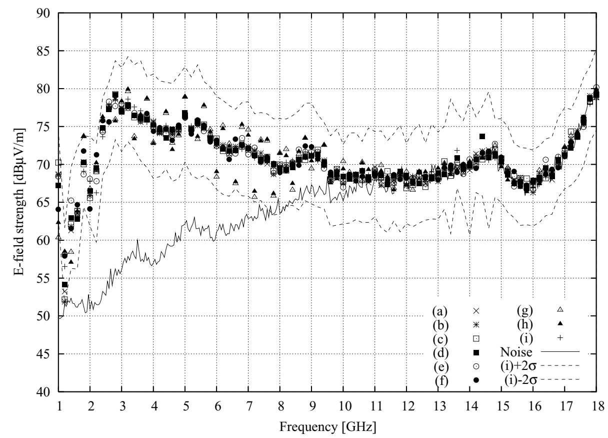

Figure 4: Measured field strength and range of expanded uncertainty (vertical polarization)

Table 1: Uncertainty Budget sheet for EMI measurement at site (i) in freq. range 1 - 18 GHz

Input quantity	X_i	Uncertainty of X_i		$c_i\ u(X_i)$
		dB	PDF	dB
Receiver reading	V_r	± 0.1	$k = 1$	0.10
Attenuation: antenna-receiver	L_c	± 0.6	$k = 2$	0.30
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}	± 2.0	Rectangular	1.15
Noise floor proximity (1 - 6 GHz)	δV_{nf}	+0.7/0.0	Rectangular	0.40
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-preamplifier	δM	+1.3/-1.5	U-shaped	1.00
Mismatch: preamplifier-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 (1 - 6 GHz)	δS_{VSWR}	+1.34/-1.59	Triangular	0.65
Site imperfections (6 - 18 GHz)	δS_{VSWR}	+1.02/-1.15	Triangular	0.47
Effect of setup table material	δA_{NT}	± 1.0	Rectangular	0.58
Separation distance at 3 m	δd	± 0.3	Rectangular	0.17
Table height	δh	± 0.0	$k = 2$	0.00
Combined standard uncertainty in measurement at 3 m (u_c(E)) 1 - 6 GHz : 6 - 18 GHz				2.46 : 2.45
Expanded uncertainty of measurement at 3 m (2 u_c(E)) 1 - 6 GHz : 6 - 18 GHz				5.0 : 4.9