# 2-6 Site Validation of the Open-Area Test Site and the Semi-Anechoic Chamber

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The open-area test site (OATS) and the semi-anechoic chamber (SAC) owned by NICT are tested using the validation method to EMI antenna calibration test site (CALTS) that is standardized by the CISPR. In addition, they are also tested by the validation method to the reference test site (REFTS) for the reference site method that is used to validate the compliance test site (COMTS) for EMI measurements. As a result, the OATS and the SAC are revealed to satisfy the conditions as CALTS and REFTS.

## 1 Introduction

Measurement of Electromagnetic Interference radiated in areas from electronic devices, etc. (EMI measurement) is performed at 30 MHz to 1 GHz frequencies on a site floored with large flat electrically conducting metal called a metal ground plane. Various standards are established for this, such as international standards by the International Special Committee of Radio Interference (CISPR standards) [1][2]. An outdoor site floored with a metal ground plane is generally called an Open Area Test Site (OATS), abbreviated as an "open site". An indoor anechoic chamber site floored with a metal ground plane is generally called a 5-sided anechoic chamber or Semi-Anechoic Chamber (SAC).

As shown in Fig. 1, EMI measurement at 30 MHz to 1 GHz frequencies is performed by using a receiving antenna placed a standard distance away (e.g. 10 m) to measure interference generated from equipment under test (EUT) (e.g. a computer) placed on the metal ground plane. EMI measurements are performed constantly to certify that EMI is smaller than tolerance value, by specialized test houses, and by electric equipment manufacturers, electronics manufacturers, etc. There are many sites in Japan and overseas used for EMI measurements. Ideally, the same test results must be obtained regardless of the site, but to achieve that, it is essential to meet the following conditions: (1) the receiving system (antenna, cables, preamplifier, and receiver) is calibrated correctly and operated stably, (2) the site has a flat ground plane, a reflection ratio considered as electrically complete reflection, sufficient dimensions, with no reflecting objects in its surroundings, and sufficient lack of broadcast waves and noise from the surroundings.

In order to ensure reproducibility of EMI measurements, CISPR established standard site validation methods: the antenna Calibration Test Site (CALTS) validation method, the Compliance Test Site (COMTS) method to assess compliance for EMI measurements, and the Reference Test Site (REFTS) method to validate sites as reference for COMTS [3]. This paper uses two of the three methods established in these CISPR standards to actually validate NICT's OATS and SAC sites, and judge whether the sites satisfy the conditions of CALTS and REFTS. We also show results from measuring the OATS again in a 5-year period.

## 2 NICT's OATS and SAC

NICT has OATS and SAC sites equipped with metal ground planes. They are described briefly below.

### 2.1 Open Area Test Site (OATS)

NICT has its OATS on the south side of its headquarters. Figure 2 is a photo of its OATS, and Fig. 3 is its ground plan. Its metal ground plane is 45 m × 30 m with its outer edges connecting to the ground. Buried coaxial cables

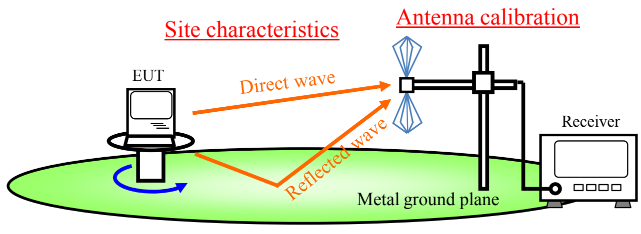


**Fig. 1** EMI measurement

connect an adjoining measurement room to the pits installed in the metal ground plane. Transmitter and receiver placed in the measurement room can be used to measure propagation characteristics between transmitting and receiving antennas placed on the metal ground plane.

### 2.2 Semi-Anechoic Chamber (SAC)

The SAC is in NICT Head Office Building 3. Figure 4 is a photo of the SAC. Figure 5 is its ground plan[4]. The shielded room size is 28.5 m (L) × 17.0 m (W) × 11.7 m (H). Hybrid electromagnetic wave absorbers made of ferrite tiles and 2.5 m long wave absorbers are attached to the walls and ceilings. Like in the open site, buried coaxial cables connect an adjoining measurement room to the pits installed in the metal ground plane, and transmitter and receiver placed in the measurement room can be used to measure propagation characteristics between transmitting and receiving antennas placed on the metal ground plane.

The SAC is equipped with a 5 m diameter turntable (4-ton load capacity), and inside that a small 1 m diameter turntable (100 kg load capacity). These enable efficient EMI measurements of different sized EUT. By installing EM wave absorbers on the metal ground plane, it can be used as a Fully Anechoic Room (FAR) [5].

## 3 CALTS and REFTS

### 3.1 Validation Method of an Antenna Calibration Test Site (CALTS)

A Calibration Test Site (CALTS) satisfies compliance judgement conditions for use in calibrating antennas for EMI measurements. That is, antennas for EMI measurements must be calibrated at a CALTS. CALTS conditions are specified in a CISPR standard [3]. Calibration of EMI antennas is performed with horizontal polarization.

To be approved as a CALTS, the condition is that two

**Fig. 2** Open Area Test Site (OATS)

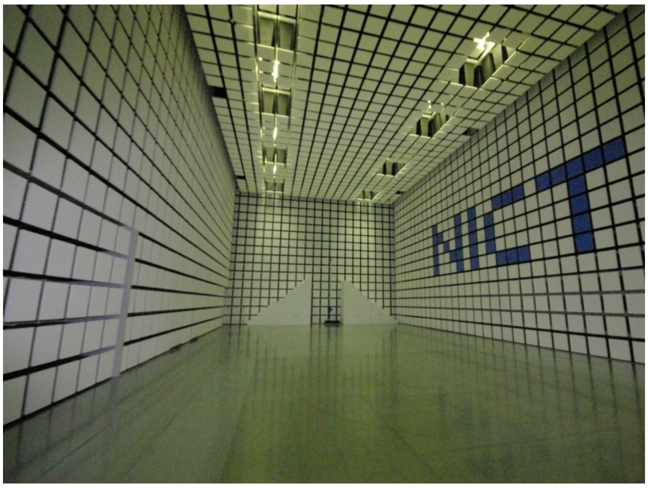


**Fig. 4** Semi-Anechoic Chamber (SAC)

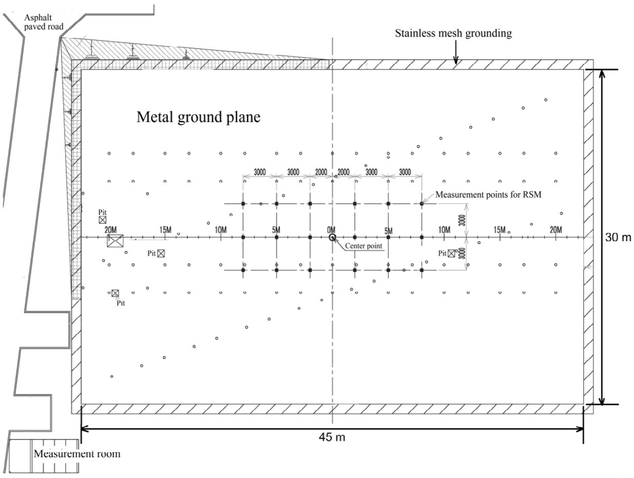


**Fig. 3** Ground plan of Open Area Test Site (OATS)

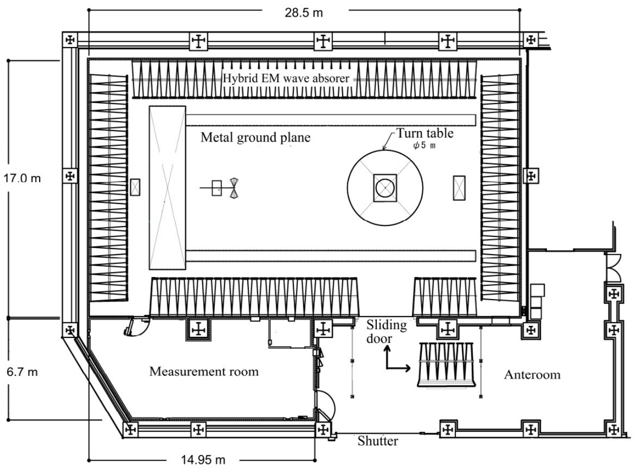


**Fig. 5** Ground plan of Semi-Anechoic Chamber (SAC)

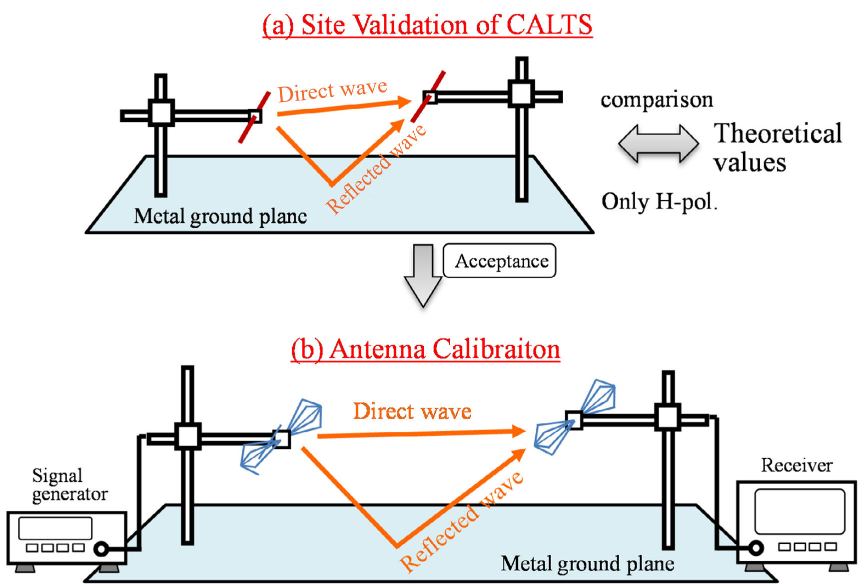


**Fig. 6** Calibration of antenna for EMI measurements

half-wave resonant dipole antennas suitable for CALTS measurements are used as a transmitting antenna and receiving antenna as shown in Fig. 6 (a), with the antenna positions (only horizontal polarization) shown in Table 1; they propagate radio waves, and the differences between $A_{im}$ (*f*) [dB] measurement values of Site Insertion Loss (SIL) obtained, vs. $A_{ic}$ (*f*) [dB] theoretical values by calculation, satisfy the following formula.

$$\left|A_{ic} - A_{im}\right| < T_{SIL} - \Delta A_{im} \quad \text{[dB]} \qquad (1)$$

Here, $T_{SIL}$ is 1.0 dB tolerance, and $\Delta A_{im}$ is the uncertainty of SIL measurement. In usual measurements, $\Delta A_{im}$ is approximately 0.3 dB. Therefore, the condition to approve as a CALTS is that differences between measured and calculated values are within ±0.7 dB. If approved as a CALTS, then one can calibrate not only dipole antennas, but also wideband antennas used in EMI measurements (biconical antennas and log-periodic dipole antennas), as shown in Fig. 6 (b).

### 3.2 Validation method of a reference test site for assessing EMI measurement sites

A method called Normalized Site Attenuation measurement [1][2] (NSA measurement) is used widely to validate an EMI measurements Compliance Test Site (COMTS). In NSA measurement, criteria have been set that the differences between theoretical values obtained by calculation, vs. values measured at an EMI measurement site, must be within 4 dB. This validation method is often affected by uncertainty of antenna factors of the transmitting and receiving antennas used, so in recent years, the Reference Site Method (RSM) was established as a CISPR standard.

Figure 7 is an outline of RSM. Like NSA measurements, RSM is (d) assessment with the EUT (interference wave source) replaced by a transmitting antenna, at a COMTS where EMI measurements shown in Fig. 1 are performed. This time, we use a pair of transmitting and receiving antennas to which SIL values (both horizontal and vertical polarization) measured at a reference test site called a REFTS, are assigned (b). Using this antenna pair, if the values obtained by measuring at the COMTS are within ±4 dB of the SIL values measured at the REFTS, then this COMTS is judged to be a site that satisfies the standard for EMI measurements. That is, RSM is a method to judge its compatibility as a COMTS, whether one can properly measure EMI there, by comparing to see whether measured results at a REFTS compare to those obtained using the same antenna pair at a COMTS. Therefore, differing from the conventional NSA measurement method, RSM is in principle not affected by the antenna factors of the transmitting and receiving antennas. However, it is important to maintain high quality of the REFTS. To deal with this issue, we will use a half-wave resonant dipole antenna suitable for REFTS measurements, as shown in Fig. 7 (a), and position the antennas as shown in Table 1 to measure SIL with horizontal polarization, or position them as shown in Table 2 to measure SIL with vertical polarization. Then, we will compare it with theoretical values obtained by calculations, to assess compatibility as a REFTS.

The condition to approve as a REFTS is that SIL mea-

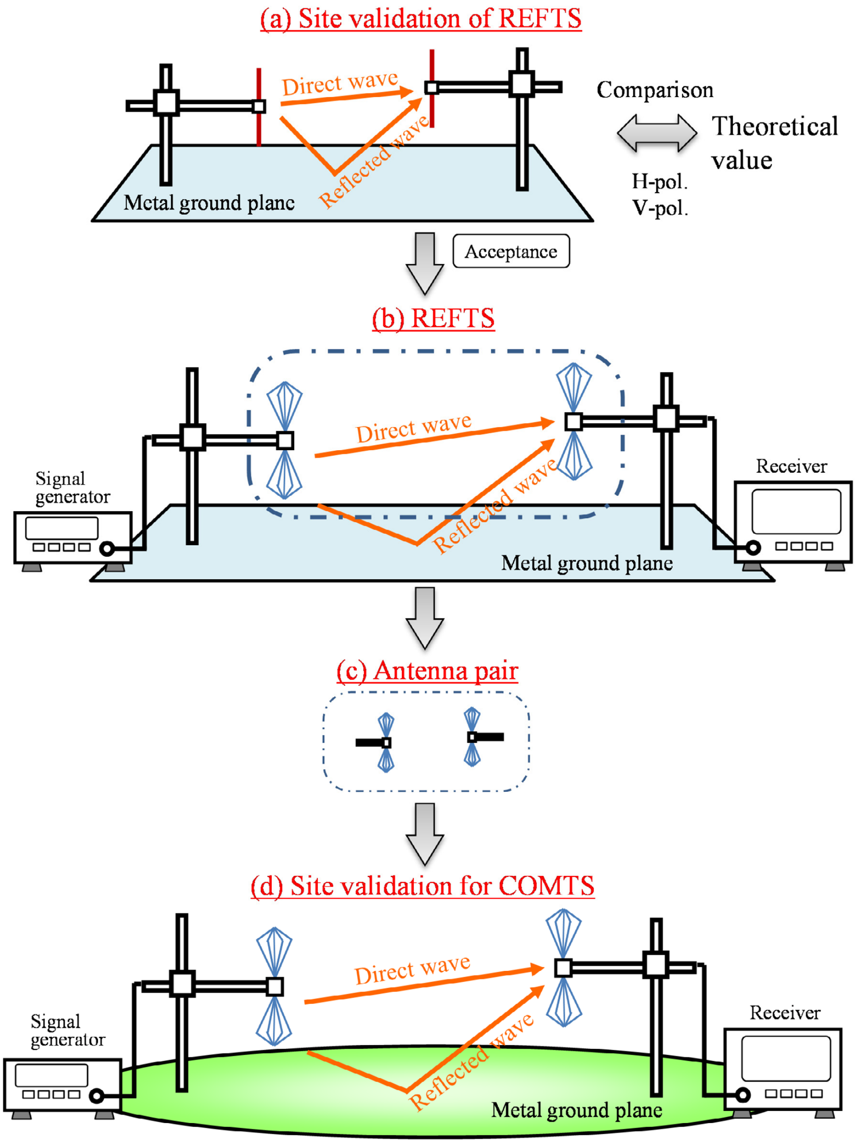


**Fig. 7** Reference Site Method (RSM)

**Table 1** Positions for SIL measurement (Horizontal polarization)

Distance $d$ = 10.00 m, Transmitting Antenna Height $h_t$ = 2.00 m

| Frequency MHz | $h_r$ m | Frequency MHz | $h_r$ m | Frequency MHz | $h_r$ m |
|---|---|---|---|---|---|
| 30 | 4.00 | 90 | 4.00 | 300 | 1.50 |
| 35 | 4.00 | 100 | 4.00 | 400 | 1.20 |
| 40 | 4.00 | 120 | 4.00 | 500 | 2.30 |
| 45 | 4.00 | 140 | 2.00 | 600 | 2.00 |
| 50 | 4.00 | 160 | 2.00 | 700 | 1.70 |
| 60 | 4.00 | 180 | 2.00 | 800 | 1.50 |
| 70 | 4.00 | 200 | 2.00 | 900 | 1.30 |
| 80 | 4.00 | 250 | 1.50 | 1,000 | 1.20 |

surement values $A_{im}$ obtained at the transmitting and receiving antennas provided in Tables 1 and 2, and theoretical values $A_{ic}$ by calculation, satisfy

$$\left|A_{\rm ic} - A_{\rm im}\right| < T_{\rm SIL} - \Delta A_{\rm im} \quad \text{[dB]} \qquad (2)$$

Here, the tolerance value $T_{SIL}$ = 1.0 dB for horizontal polarization which is the same as the CALTS compliance conditions, and $T_{SIL}$=1.5 dB for vertical polarization. In usual measurements, $\Delta A_{im}$ is approximately 0.3 dB, so the condition to be approved as a REFTS is that the difference

**Table 2** Positions for SIL measurement (Vertical polarization)

Distance $d$ = 10.00 m

| Frequency MHz | $h_t$ m | $h_r$ m | Frequency MHz | $h_t$ m | $h_r$ m | Frequency MHz | $h_t$ m | $h_r$ m |
|---|---|---|---|---|---|---|---|---|
| 30 | 2.75 | 2.75 | 90 | 2.00 | 1.15 | 300 | 2.00 | 2.60 |
| 35 | 2.75 | 2.40 | 100 | 2.00 | 1.00 | 400 | 2.00 | 1.80 |
| 40 | 2.75 | 2.40 | 120 | 2.00 | 1.00 | 500 | 2.00 | 1.40 |
| 45 | 2.00 | 1.90 | 140 | 2.00 | 1.00 | 600 | 2.00 | 1.40 |
| 50 | 2.00 | 1.90 | 160 | 2.00 | 1.00 | 700 | 2.00 | 1.00 |
| 60 | 2.00 | 1.50 | 180 | 2.00 | 1.00 | 800 | 2.00 | 1.00 |
| 70 | 2.00 | 1.50 | 200 | 2.00 | 1.00 | 900 | 2.00 | 1.60 |
| 80 | 2.00 | 1.15 | 250 | 2.00 | 3.10 | 1,000 | 2.00 | 1.60 |

between the measured value and calculated value is within 0.7 dB (horizontal polarization) or 1.2 dB (vertical polarization).

## 4 Measurement results

We measured SIL at the open site (OATS) in September 2010, and measured SIL in the Semi-Anechoic Chamber (SAC) in January 2011 [4]. We measured at the OATS again in October 2015. The half-wave resonant dipole antenna used to measure in fiscal 2010 was a dipole antenna (PRD) from the Austrian Research Center (currently Seibersdorf Laboratories), while we used a dipole antenna (6500 series) from Shaffner-Chase (currently Teseq) for the measurements in fiscal 2015.

When determining the theoretical values, the characteristics between dipole elements are calculated using NEC2 electromagnetic field simulation software based on the method of moments, and the balun part's characteristics are determined using S-parameters measured by using a vector network analyzer [3][6]–[8].

### 4.1 OATS

Figures 8 to 11 show measurement results at the OATS. Figure 8 is for horizontal polarization. Figure 10 is for vertical polarization. The ● symbols (red) are fiscal 2015 measurement results. The ▲ symbols (blue) are fiscal 2010 measurement results. The solid lines (black) and dashed lines (black) are both theoretical values. Differences in SIL measurement values between fiscal 2010 and 2015 are attributed to the fact that the 2010 measurements did not include insertion losses at the balun part of the dipole antenna, but the 2015 measurements did. We were able to obtain both theoretical values and measured values. Figures 9 and 11 show results for differences between theoretical values vs. measured values. The dot-dash lines (green) are the tolerances (±0.7 dB, ±1.2 dB) that must be satisfied for approval as a CALTS (only horizontal polarization), or REFTS (both horizontal and vertical polarizations).

Since all of the results satisfy the tolerance values, we concluded that "NICT's OATS satisfies both the CALTS and REFTS conditions." Differences vs. theoretical values are large in the high frequency range, with large differences especially for vertical polarized waves; this may be affected by reflections from cables and antenna masts, so there is still room for improvement.

Also, Figure 12 shows results for horizontal polarization at 300 MHz, 600 MHz and 900 MHz frequencies, with receiving antenna height scanned from 1 m to 4 m. When a receiving antenna is set at a specific height, direct waves and reflection waves interfere with each other, minimizing (null) receiving levels. By comparing the receiving antenna height for null found by calculations, vs. the height that minimizes measurement values, one can check the validity of measurement results. The CISPR standard [3] describes this as a method to validate measurements. Results from null measurements in fiscal 2010 revealed that differences in terms of receiving antenna height were up to 2 cm between theoretical calculations and measured values.

### 4.2 SAC

Figures 13 to 16 show measurement results at the SAC. Figure 13 is for horizontal polarization. Figure 15 is for vertical polarization. The ▲ symbols (blue) are measured results. The dashed lines (black) are theoretical values. Figures 14 and 16 show differences between theoretical values and measured values. The dot-dash lines (green) are satisfactory tolerance values (±0.7 dB, ±1.2 dB) for approval as a CALTS (only horizontal polarization) or REFTS (both horizontal and vertical polarization).

Figure 14 indicates that the measurements meet the ±0.7 dB tolerance levels for horizontal polarization. We

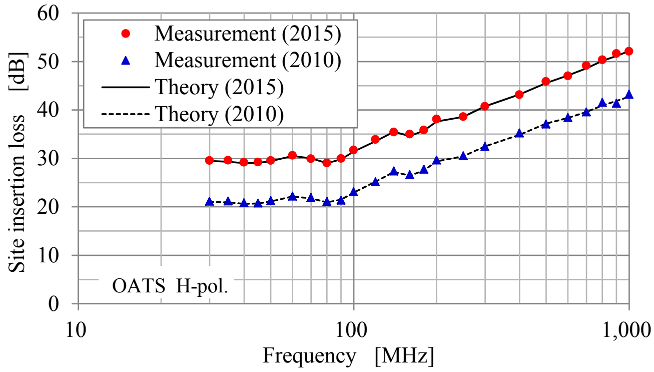


**Fig. 8** SIL measurement results at OATS (Horizontal polarization)

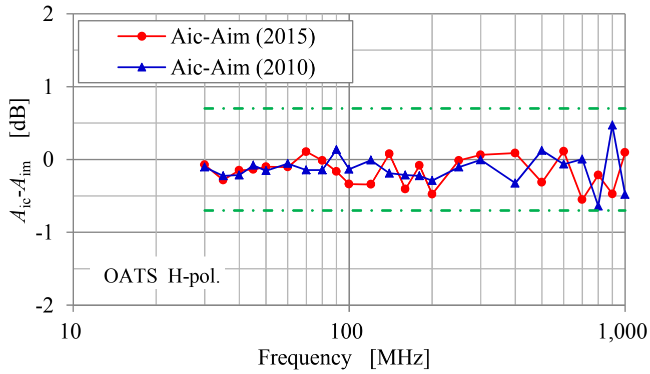


**Fig. 9** Differences between theoretical values and SIL measurement results at OATS (Horizontal polarization)

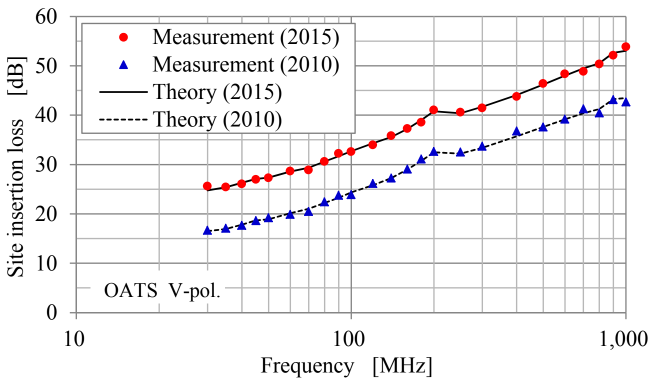


**Fig. 10** SIL measurement results at OATS (Vertical polarization)

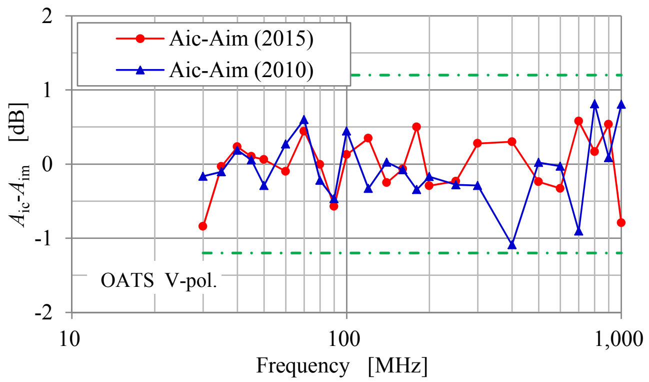


**Fig. 11** Differences between theoretical values and SIL measurement results at OATS (Vertical polarization)

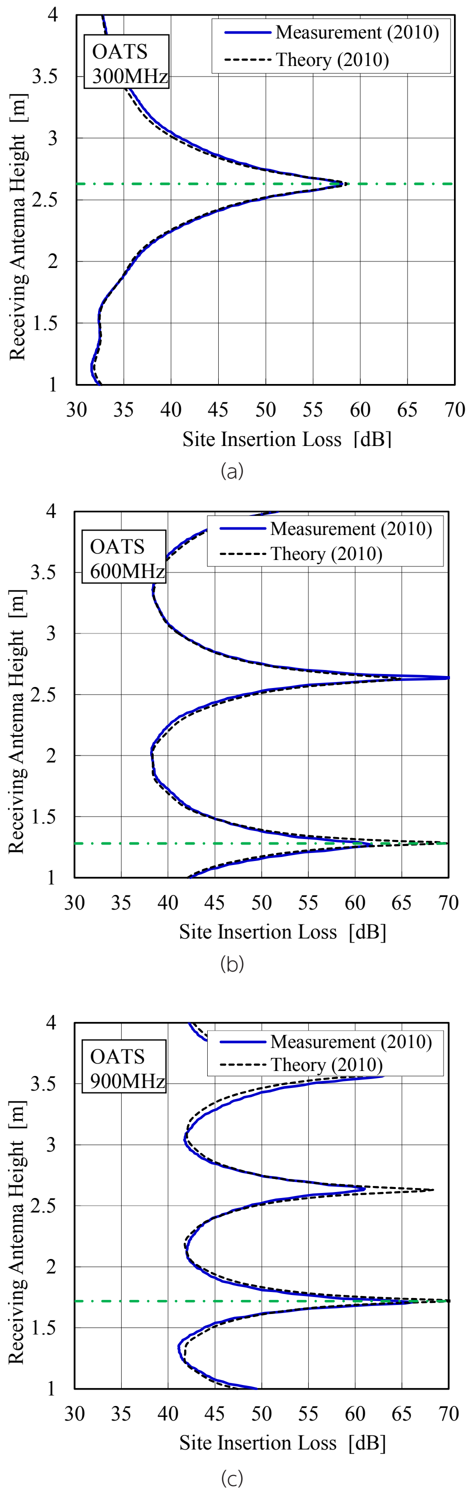


**Fig. 12** Height scan measurements of receiving antenna at OATS (Horizontal polarization)
(a) 300 MHz, (b) 600 MHz, (c) 900 MHz

presume that relatively large differences at 35 MHz, 40 MHz and 140 MHz are attributed to unique characteristics of the anechoic chamber, and large differences at 800 MHz are due to effects of reflection from cables and antenna masts.

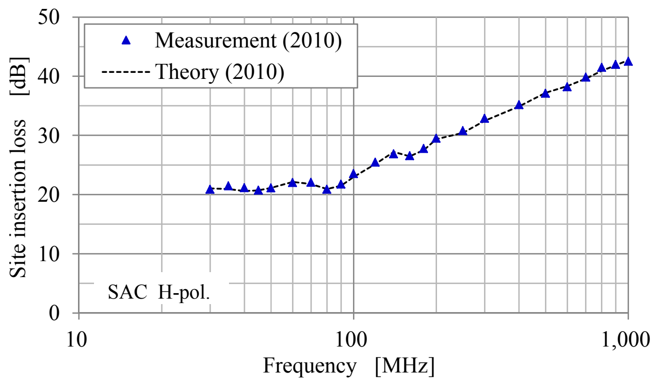


**Fig. 13** SIL measurement results at SAC (Horizontal polarization)

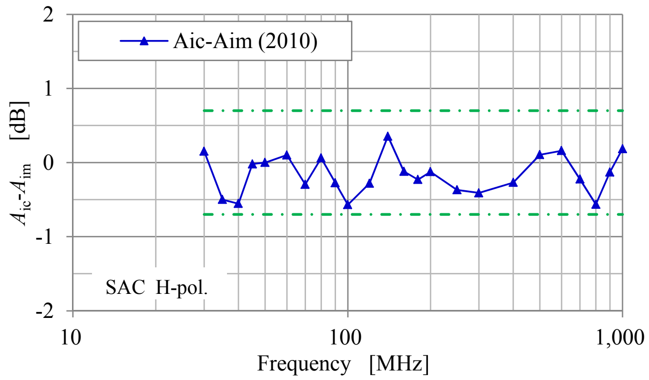


**Fig. 14** Differences of SIL between theoretical and measurement values at SAC (Horizontal polarization)

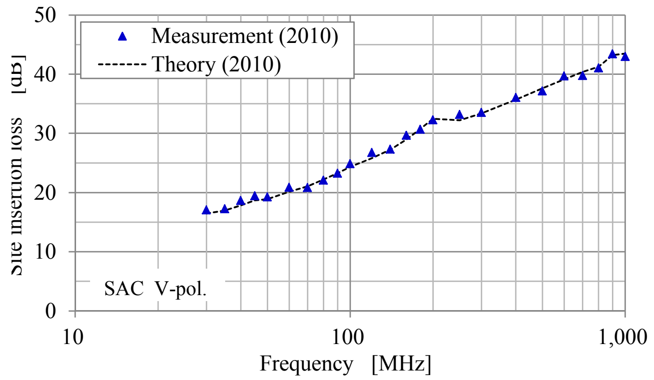


**Fig. 15** SIL measurement results at SAC (Vertical polarization)

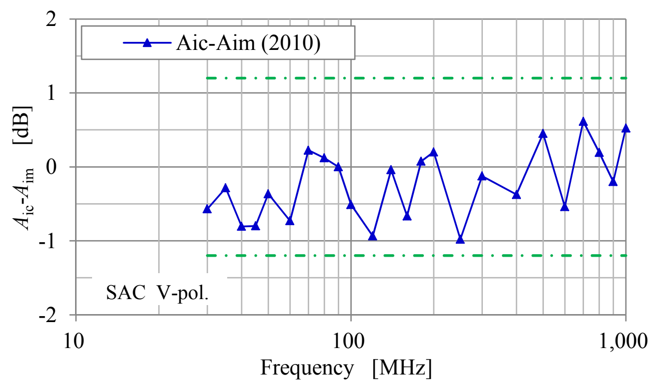


**Fig. 16** Differences of SIL between theoretical and measurement values at SAC (Vertical polarization)

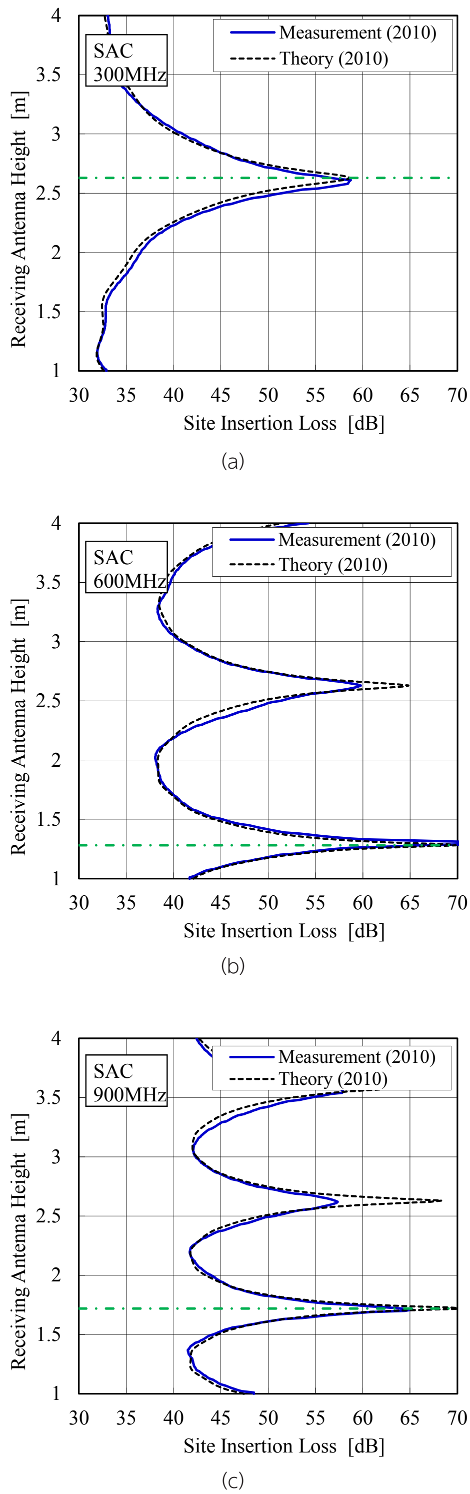


**Fig. 17** Height scan measurements of receiving antenna at SAC (Horizontal polarization)
(a) 300 MHz, (b) 600 MHz, (c) 900 MHz

Similarly, Figure 16 shows that SIL measurements of vertical polarized waves satisfy the ±1.2 dB tolerance values of REFTS. However, relatively large differences were obtained at 40 MHz, 45 MHz and 250 MHz, probably due to unique characteristics of the anechoic chamber, similar to for horizontal polarization. We must continue to measure, and clarify causes of differences from theoretical values.

Figure 17 shows results for horizontal polarization at 300 MHz, 600 MHz and 900 MHz frequencies, with receiving antenna height swept from 1 m to 4 m. The measured values shown in the figures are results in fiscal 2010. There is a maximum 2 cm of receiving antenna height differences from theoretical values, which confirmed that these measurements are valid.

## 5 Conclusion

CISPR standards established a method to assess compliance of an EMI antenna Calibration Test Site (CALTS), and a method to assess Reference Test Site (REFTS), which is used to assess compatibility of an EMI measurement site. These methods were used to measure characteristics of NICT's open area test site, and its Semi-Anechoic chamber set up in fiscal 2010. The open area test site is being used in actual calibration work, and it may be affected by the surrounding environment, etc. Thus, to check changes that may occur to NICT's open area test site over the years, we took measurements twice (fiscal 2010 and fiscal 2015). The results showed that the open area test site satisfied the conditions for CALTS and REFTS, both times it was measured. Similarly, we found that the Semi-Anechoic Chamber also satisfies the conditions of CALTS and REFTS. We will continue to measure it periodically, ensure its performance as a site for antenna calibrations, and maintain the quality of our antenna calibrations.

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