Validating Anechoic Chambers Above 1 GHz Using a Reciprocal Site VSWR Technique

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Abstract—**In this paper, three validation methods for anechoic chambers above 1 GHz are presented. They are related to the Site VSWR concept developed by CISPR/A. The Reciprocal Site VSWR method as well as the Site VSWR method are proper methods to validate EMC chambers. The use of omnidirectional field probes and omnidirectional antenna does not have a significant impact on the test result. The required time for the Reciprocal Site VSWR method is significantly higher. For antenna and microwave chambers other methods using continuous scan techniques have to be applied.**

Anechoic chamber; chamber validation; VSWR technique; EMC above 1 GHz; Site VSWR

I. Introduction

The validation of anechoic rooms above 1 GHz has been an important topic in the EMC community for several years [1]. CISPR/A has been working towards an international standard in the past years. This development took longer than expected due to the development of new technology. Above 1 GHz, the world looks different compared to frequencies below:

- The available antennas are not omnidirectional anymore like biconical or "low frequency" LPDAs. Above 1 GHz LPDA antennas have a moderate gain and horn antennas have a high gain.
- The cable attenuation is higher which results in lower signal to noise ratio.
- The influence of antenna masts and mounting brackets becomes more significant due to reflections from dielectric material, if omnidirectional antennas/probes are used.
- The physical effect of coupling can be neglected in this frequency range.
- The small wave length has several impacts: positioning needs higher accuracy, measurement points are separated several wavelengths, etc.

One fact is the same for radiated emission measurements in all frequency ranges: The radiation characteristic of the EUT is unknown. Therefore, the worst case situation is assumed for validation: the omnidirectional EUT. It maximizes the chamber influence by well illuminating the walls. Below 1 GHz, the radiation of the EUT is simulated by signal generator driven omnidirectional antennas which are located in the test volume. It is a good idea to keep this principle but the realization is not easy. Some years ago, when the development of the standard started, omnidirectional antennas with an acceptable behavior were not available.

Another way to go is to use a reciprocal approach. The electromagnetic field is established by the former receive antenna. The field at the former transmit antenna location is measured with an omnidirectional field probe. An important advantage of field probes is the good omnidirectional behavior at high frequencies. Drawbacks are the low sensitivity and the larger noise of wide band probes.

II. Current CISPR/A Requirements

In the latest draft documents of CISPR/A to validate EMC chambers for emission measurements, a new technique called Site VSWR is used. This technique can also be used in a reciprocal way which is an alternative method. Both methods shall lead to the same result of the chamber validation.

A. *Site VSWR Technique*

The Site VSWR technique was derived from the Free Space VSWR technique [2][3], which is also called quiet zone field probe test. The Site VSWR can be seen as the wide band version of the Free Space VSWR technique.

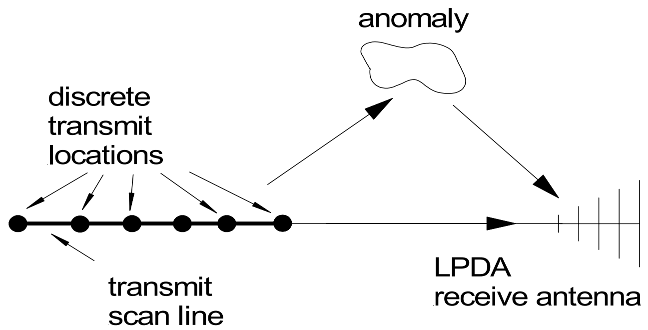

Figure 1. VSWR measurement: fixed locations and continuous movement along the scan line

Both methods are based on the same principle, the vector addition of direct and reflected wave fronts. Vectors are recorded, while the phases of the signals change. For Free Space VSWR measurements, the phase variation is realized by continuous scanning on a line at a discrete frequency. For Site VSWR measurements, the phase variation is achieved in the frequency domain, and not by spatial scanning, see Fig. 1. The transmit antenna is located at discrete locations, while the frequency sweeps in very fine steps of less than 50 MHz. This approach ensures "valid" results per octave – absolute maxima and minima of the standing wave pattern are found.

The result of the Site VSWR test is the ratio between minimum and maximum field strength. This ratio must not exceed 1.78 – or 5 dB if expressed in a logarithmic scale – to pass the limit for a radiated emission test site according to CISPR/A.

$$\begin{aligned} \text{SiteVSWR}[1] &= \frac{E_{Max}[V/m]}{E_{Min}[V/m]} \le 1.78 \\ \text{SiteVSWR}[dB] &= E_{Max}[dB\mu V/m] - E_{Min}[dB\mu V/m] \le 5dB \end{aligned} \tag{1}$$

To correct the field strength variation for different distances to the transmit antenna, a 1/R decrease of the electric field strength is applied.

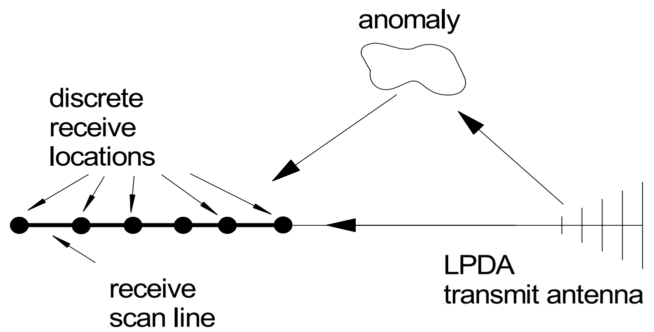

Figure 2. Reciprocal Site VSWR: fixed locations and continuous movement along the scan line

B. Reciprocal technique

The electromagnetic field is established by the "receive" antenna and an electric field probe is placed in the test volume, see Fig. 2.

The test setup is similar to IEC 61000-4-3 [4], see Fig. 3. The transmit antenna is fed by a RF power amplifier which is driven by a signal generator. The transmitted power is recorded via a directional coupler and a test receiver. A computer controls the devices via GPIB bus and the field probe via an optical link.

This procedure can be performed, because all requirements of the reciprocal theorem [5] are fulfilled. All materials present in the setup must be:

- linear
- passive
- isotropic

The non-linearity of ferrite absorbers and pyramidal absorbers can be neglected because of the low field strength used for these measurements.

C. Selection of Measurement Points

Like in CISPR 16-1-4 [6] or ANSI C63.4 [7], a volumetric method is used to validate an anechoic room. Instead of a single measurement point, arrays are distributed in a volume, see Fig. 4. There are four in one height (right, left, front and center) and one in a second height at location front.

Each array consists of six measurements in one line of 40 cm length. The locations are unequally spaced with distances of 2 cm, 10 cm, 18 cm, 30 cm and 40 cm, measured from the first point. More than six points or continuous scans are not required by CISPR/A, but could take precedence in case of dispute.

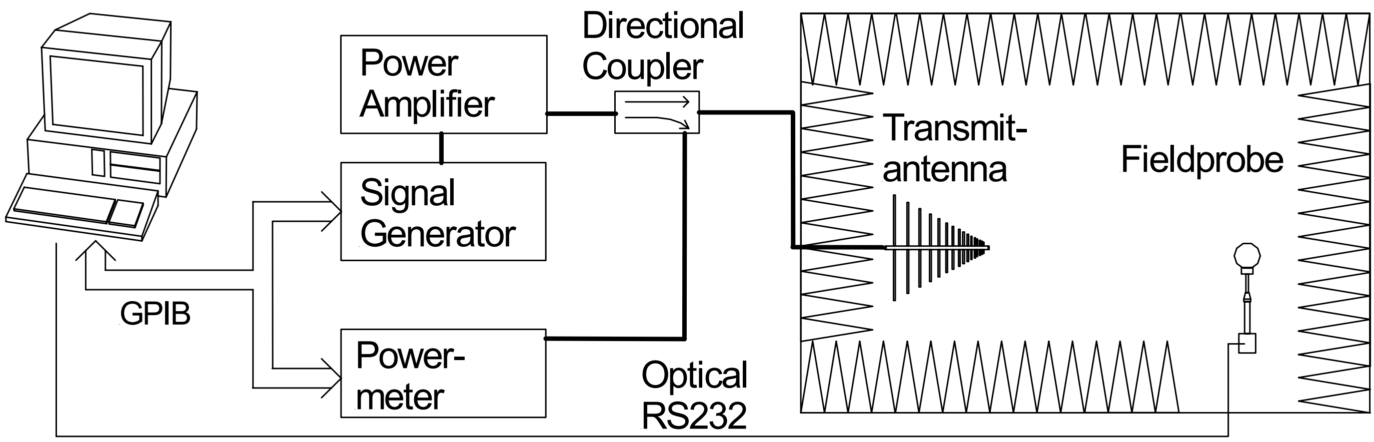

Figure 3. Reciprocal Site VSWR test setup

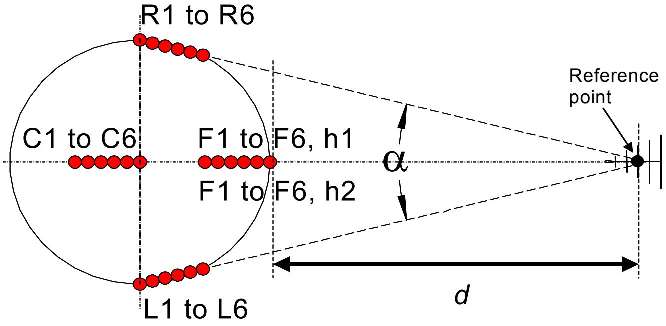

Figure 4. Location of the arrays – top view

III. RESULT OF MEASUREMENTS

We performed measurements in a fully anechoic chamber of 6.98 m x 4.2 m x 4.05 m filled with 18” pyramidal microwave absorbers. The test distance was 3 m and the volume diameter was 1 m. The first height was 1 m and the second height was 1.8 m, both measured from the absorbers tips.

A. Site VSWR

The Site VSWR was measured according to the draft standard at one of the arrays. An omnidirectional antenna and a network analyzer were used. For this reason, we designed a suitable antenna for the frequency range of 4 GHz to 18 GHz. This dipole-like antenna has an anisotropy in the H-plane of less than 2 dB. The E-plane beam width is larger than 60°.

The result, shown in Fig. 5, is a Site VSWR of less than 2.1 dB.

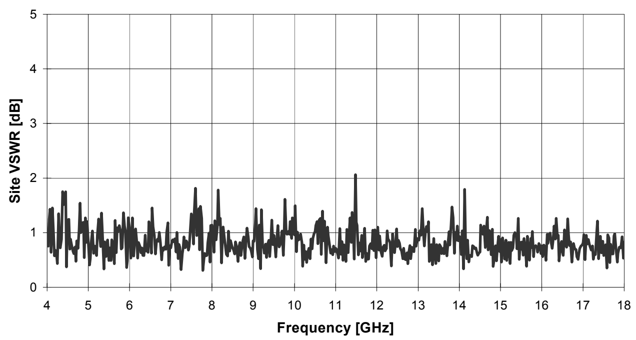

Figure 5. Standard Site VSWR, front, first height, vertical polarization

B. Reciprocal Site VSWR, continuous scan

With an automatic antenna positioner we performed one continuous scan at 4 GHz. We measured more than 350 points in the 40 cm line. To show the result we introduce the position dependent Site VSWR:

$$\mathrm{SiteVSWR(x)[dB]} = 20\log\left(\frac{\mathrm{E(x)[V/m]}}{\mathrm{min(E(x)[V/m])}}\right) \qquad (2)$$

The Site VSWR can be easily calculated from the position dependent Site VSWR:

$$\mathrm{SiteVSWR[dB]} = \mathrm{max(SiteVSWR(x)[dB])} \qquad (3)$$

The result, see Fig. 6, shows a Site VSWR below 1.2 dB in horizontal and 1.4 dB in vertical polarization.

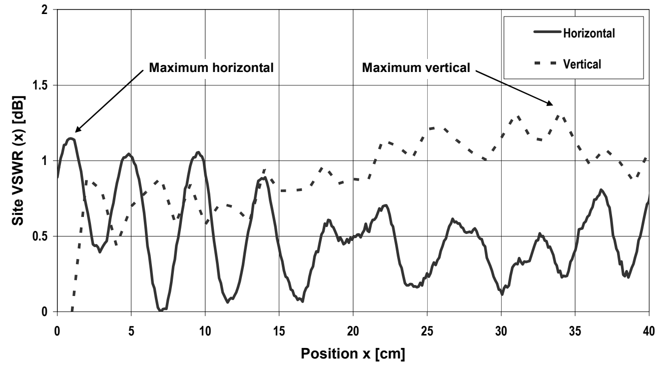

Figure 6. Continuous scan Site VSWR, front, first height, both polarizations, 4 GHz

C. Reciprocal Site VSWR, discrete scan

The reciprocal Site VSWR is measured according to the draft standard at all arrays.

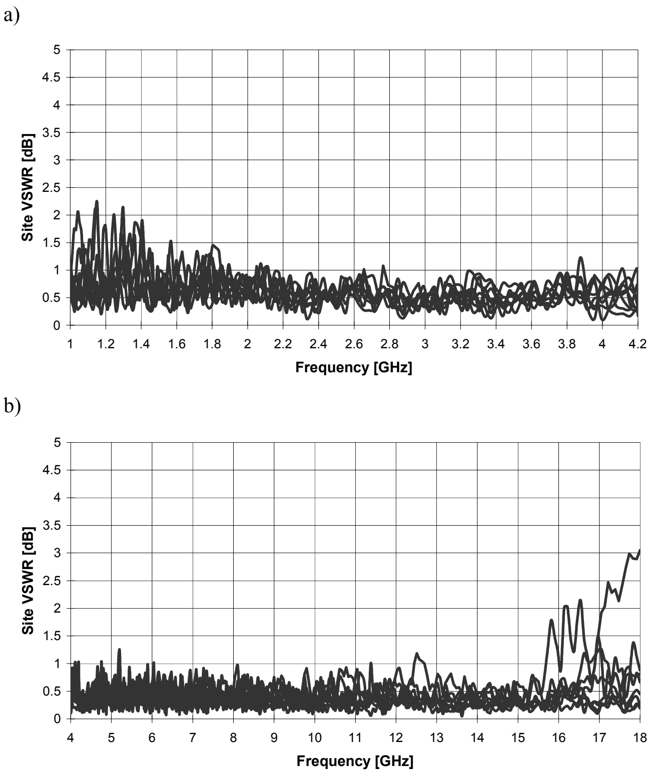

Figure 7. Reciprocal Site VSWR, all arrays, both polarizations a) 1 GHz to 4.2 GHz, b) 4.2 GHz to 18 GHz

The result, see Fig. 7, shows that the limit of 5 dB is not exceeded in the whole frequency range. Apart from the start and stop frequency, the Site VSWR is around 1 dB. From 1 GHz to 1.5 GHz the result is approximately 2 dB. This can be explained by the characteristics of the transmit antenna (EMCO 3115). The wide beam width of the antenna illuminates the absorbing material more and this leads to worse results. Above 15 GHz there is a similar situation. The Site VSWR at the side points reaches 3 dB. In this frequency range, the half power beam width of the antenna drops down. So the field strength of the direct wave front decreases, which increases the ratio between reflected waves and the direct wave.

We also checked the repeatability of the Site VSWR measurements, see Fig. 8. It has been determined by measuring at the same point twice, without moving the field probe and the antenna. In the whole frequency range the repeatability is better than 0.2 dB. This excellent value is obtained by reading out the probe 40 times and calculating the median value. Using this technique, the impact of the noise of the probe can be reduced. Also, other imperfections of the test setup, like harmonics, must be kept at a low level. Unfortunately, all these arrangements to reduce the measurement uncertainty increase the measurement time.

a)

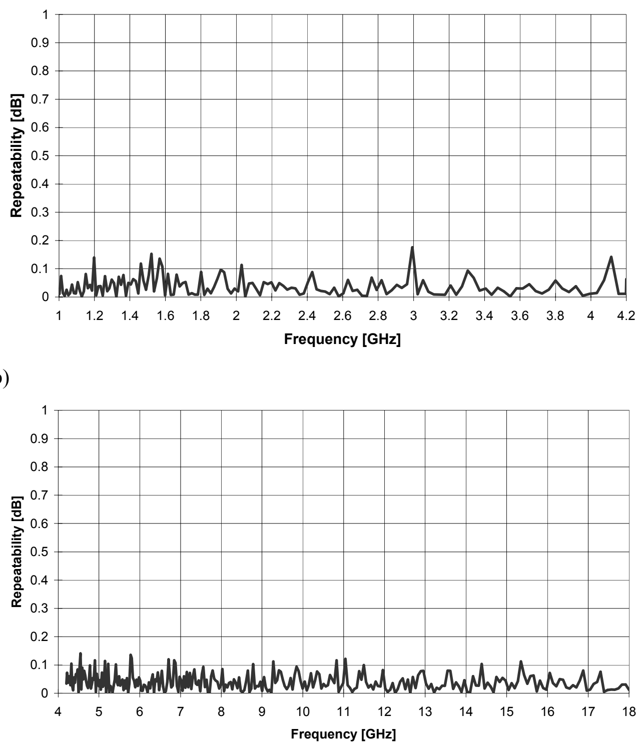

Figure 8. Repeatability Site VSWR a) 1 GHz to 4.2 GHz, b) 4.2 GHz to 18 GHz

CONCLUSION

If we estimate the Site VSWR from absorber return loss – better than 20 dB – the result should be better than 2 dB. This estimation fits well to the results we get from the three tested methods: Site VSWR, discrete scan method, Reciprocal Site VSWR, continuos scan method and Reciprocal Site VSWR, discrete scan method. All three methods have their advantages and disadvantages and can coexist.

The Site VSWR, discrete scan method, is the fastest one. It takes less than two days to perform a full chamber validation. An omnidirectional antenna above 1 GHz with a well defined radiation characteristic is required. Only few antennas are available now, but such an antenna will be standard equipment of an EMC lab in a few years.

The Reciprocal Site VSWR, continuos scan method, is the most sensitive method. A high precision antenna positioner is necessary, which is normally owned by specialized third party chamber validation companies [8][9]. This method is very similar to the well-known method Free Space VSWR used for antenna chamber characterization. Unfortunately, it is a narrow band method, so its practical value for EMC applications is questionable.

The Reciprocal Site VSWR, continuos scan method, is the easiest method for EMC labs. All necessary measurement devices are available at a well equipped laboratory. Special care has to be taken when using the method. The test engineer must look at the proper mounting of the field probe to avoid unwanted reflections. The influence of the probe stand and the mounting brackets must be minimized. Unfortunately, the required amount of time is large. It takes nearly one week to perform the complete chamber validation.

Further work will include a comparison of the radiation characteristics of field probes and omnidirectional antennas.

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