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VALIDATION OF SEMI-ANECHOIC CHAMBERS WITH TUNED HALFWAVE-DIPOLES WORKING OVER A WIDE FREQUENCY BAND

Alexander Kriz, ARC Seibersdorf research
Wolfgang Müllner, ARC Seibersdorf research
Jochen Riedelsheimer, Albatross Projects
Friedrich-Wilhelm Trautnitz, Albatross Projects

Abstract: In this paper the latest techniques for validation of anechoic chambers are described. The Short Dipole Site Validation Method (SDSV) is based on the use of the CISPR 16 dipole in an expanded, non-resonant frequency range. The SDSV idea is great as it combines advantages of the Site Reference method (direct comparison of two site attenuations, no antenna factors involved, quasi-swept frequency scan, fast, volumetric) with advantages of the tuned half-wave dipole method (numerically calculable, very accurate). We have compared site validations done according to the Site Reference Method to SDSV results. Thereby we encountered several disadvantages of this new SDSV procedure. Due to the high antenna factors below the resonance frequency a good dynamic range of the test receiver is required. Another problem is the amount of time needed for the measurements. A set of at least three dipole pairs is required to cover the frequency range from 30 MHz to 1 GHz instead of two broadband antennas. The antenna pattern of dipole and broadband antenna are different this leads to different results in the site validation. For chamber validation the performance of the chamber itself should be checked. Therefore the antenna system for the validation procedure must be calibrated under exactly the same setup conditions (including antenna mast, tripod and antenna cables) as used for site validation. In the numerical simulation of the SDSV reference these influences can not be considered. Finally there is no reason to prefer the SDSV method to the site reference method.

Keywords: Semi Anechoic Chamber, Precision Reference Dipole, NSA, Site Attenuation, Site Validation.

1. INTRODUCTION

In several standards the use of broadband antennas is prescribed for chamber validation of semi-anechoic chambers (SAC) [1][2][3][4]. High precision antenna calibration is essential to achieve an acceptable low measurement uncertainty. Unfortunately the standardized site validation procedures do not contain these calibration procedures. At the moment there are two kind of measurement procedures which can guarantee the necessary high measurement accuracy.

- Site Reference Method
- Measurement with tuned halfwave-dipols

For the Site Reference Method the antennas used for site validation are calibrated as a pair on a reference site [1]. This method accounts for mutual coupling of the antennas, near field effects and also coupling influences to antenna masts and cable layout which can have a significant influence on the measurement results.

The advantage of the tuned dipole according to CISPR 16-1 [1] is that the antenna factor is calculated via simulation. The measurement uncertainty of this procedure is low enough to validate calibration test sites (CALTS, [1]).

Also the measurements with tuned half-wave dipoles are in principal possible in SAC's, but especially in the frequency range from 30 MHz to 100 MHz a handling of the dipole is complicated caused by the length of the antenna elements. Resonances of the chamber can be missed, since only discrete frequencies are measured. Normally no volumetric measurement is carried out with respect to expenditure of measurement, against the common requirement for alternate test sites. Except for VCCI Standard [4] which offers a method using shortened dipole antennas for volumetric measurements in the frequency range of 30 MHz to 80 MHz.

This paper describes the Short Dipole Site Validation Method (SDSV). It is based on the use of the CISPR 16 dipole in an expanded, non-resonant frequency range. The SDSV combines advantages of both procedures (calculable antenna factor, quasi-swept frequency scan, fast, volumetric). We compare site validation results obtained by Site Reference Method and SDSV.

2. MEASUREMENT PROCEDURE

2.1 Definitions

The site attenuation (SA) measurement procedure requires two different measurements of the voltage received. The first reading V_{DIRECT} is with the two coaxial cables disconnected from the two antennas and connected to each other. The second reading V_{SITE} is taken with the coaxial cables reconnected to the antennas and the maximum signal measured with the receive antenna scanned in height. See Figure 3a, b.

$$SA = V_{DIRECT} - V_{SITE}$$

The classical approach to measure the performance of a chamber is the Normalized Site Attenuation (NSA), where special care has to be taken on the appropriate calibration of the antenna factors AF_{TX} and AF_{RX},

$$NSA = SA - AF_{TX} - AF_{RX}$$

The result is the difference to the theoretical NSA,

$$\text{Result} = \text{NSA} - \text{NSA}_{Theory}$$

To avoid the use of the critical antenna factors in the NSA, we define the Deviation of Site Attenuation (DSA) [5]. It is a comparison of two site attenuations measured with the same antennas. One is measured in the chamber to be validated, the other represents the ideal case on an infinite Open Area Test Site. The DSA is mathematically the same as the NSA result.
When using the Site Reference Method, the site attenuation SA_{REF} is measured on the Reference Open Area Test Site. The next step is to perform a SA measurement SA_{VAL} in the chamber to be validated. The DSA for the Site Reference Method is defined as

$$DSA = SA_{VAL} - SA_{REF}$$

If calculable dipoles are used the procedures are very similar. The reference site attenuation SA_{SIM} is determined via simulation.

$$DSA = SA_{VAL} - SA_{SIM}$$

The simulation of the site attenuation is carried out with the NEC based software ANTENNA [6]. The site attenuation can be calculated over a wide frequency range, not only at the dipole resonance frequency. ANTENNA is written according to the calculable dipole technology from Garn [7] and Alexander [8]. The job of ANTENNA is to deliver the input files for NEC and to calculate the SA from the transmit antenna impedance and the receive antenna load current.

For the SDSV method dipole antennas are used over a wide frequency range. To distinguish the different dipoles we label them with their half-wave resonance frequency. Therefore PRD80 designates the dipole with 80 MHz resonance frequency.

2.2 Choosing the Dipoles

There are two factors, which determines the practically useable frequency range of the dipoles. The upper boundary is the radiation pattern of the dipole. Starting from the sinusoidal pattern of the hertzian dipole the main lobe gets narrower when increasing the frequency. Above the full-wave resonance side lobes would occur. The lower boundary is the dynamic range of the test setup. The impedance of a short dipole has a very strong capacitive part. Due to the mismatch a high antenna factor results.

2.2.1 Pattern of Site Validation Antennas

The result of a chamber validation is depending on the pattern of the two measurement antennas. Various pattern are shown in Figure 1.
The change in the pattern from the short dipole up to the half-wave resonance can be neglected. Above $\lambda / 2$ an increasing directivity can be observed in E-plane, while the pattern in the H-plane is circular and keeps unchanged. For the SDSV method the use of the tuned half-wave dipoles up to the full-wave resonance is not

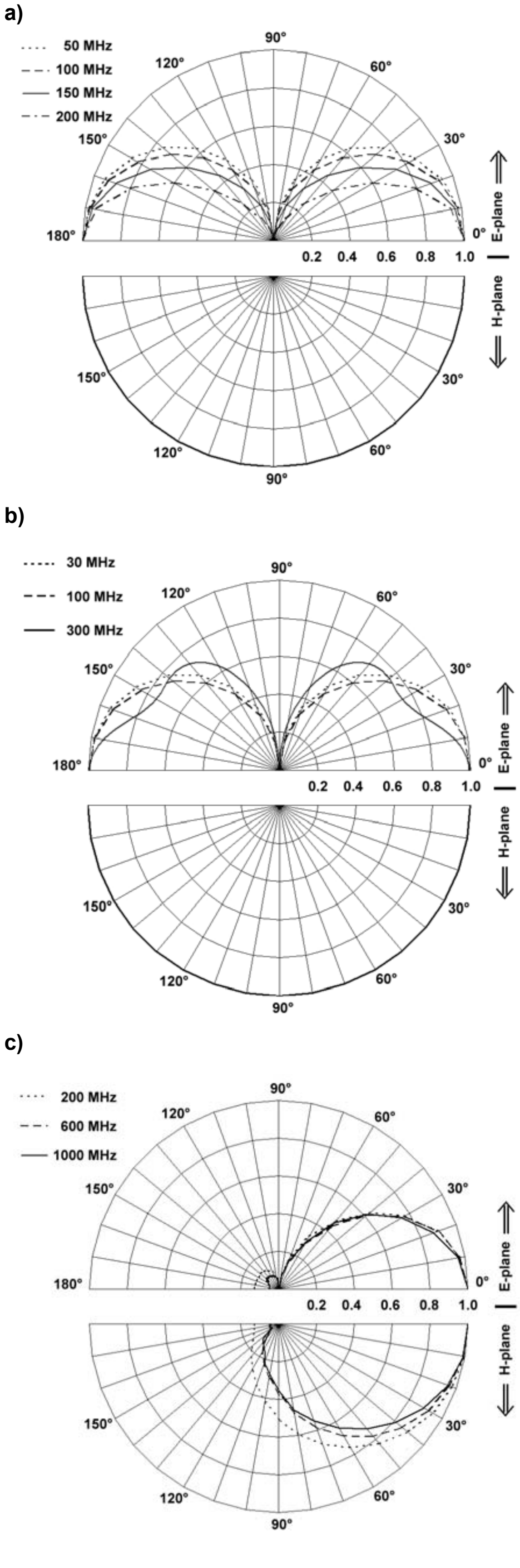


Figure 1: E-Plane and H-Plane Pattern a) PRD100, b) biconical antenna, c) log. per. antenna

recommended. Also in the work of Maeda [9] the dipoles are used up to the half-wave resonance.

The pattern of a biconical antenna below 200 MHz is similar to the dipole. Below 300 MHz the characteristic changes dramatically (Figure 1b). It is not recommended to use biconical antennas above 250 MHz. The main characteristic of the log periodic antenna is that the energy is transmitted mainly in one direction. The antenna has a good front/back ratio (Figure 1c) in E-plane and H-plane.

2.2.2 Sensitivity of the Dipoles

Using one dipole for the whole frequency range tuned to a frequency of 1 GHz seems to be the most pleasant way for measurement. Since this would call for a dynamic range of nearly 200 dB at 30 MHz this procedure is not practical regarding available measurement instrumentation. Therefore a suitable selection of dipoles is necessary in view of the available dynamic range. Figure 2 shows the SA for several tuned half-wave dipoles simulated for a measurement distance of 10 m.

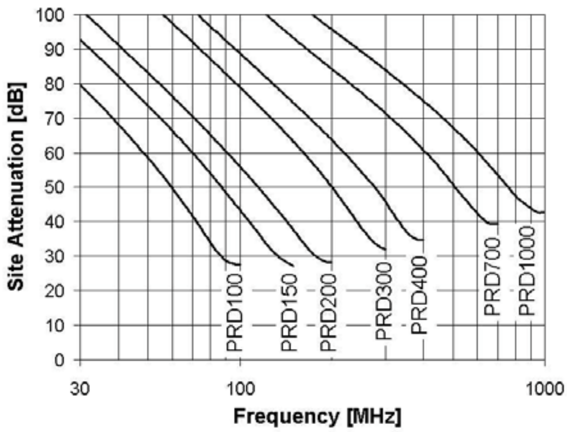


Figure 2: PRD site attenuation in horizontal polarization, 10 m distance

Special attention has to be paid to the cabling, which could reduce the dynamic via side to side coupling. This could occur when cables with at low shielding attenuation are used or if there is a bad mounting of the connectors in the panel.

Additional to V_{DIRECT}, the voltage $V_{DYNAMIC}$ should be measured, see Figure 3. To keep the uncertainty for voltage measurement low, a Signal to Noise Ratio (SNR) of minimum 10 dB should be considered. In this case the uncertainty in the voltage measurement is about 0.4 dB if an average detector is used [10]. The maximum value of the SA which can be measured practically is calculated via

$$SA_{MAX} = V_{DIRECT} - V_{DYNAMIC} - SNR$$

The number of dipoles which are required to cover the frequency range from 30 MHz to 1 GHz is depending on SA_{MAX}.

3. RESULTS OF MEASUREMENTS

Measurements were carried out in a semi-anechoic chamber at 10 m test distance. After the validation according to the Site Reference Method (biconical and log.-periodic antenna) the Short Dipole Site Validation was

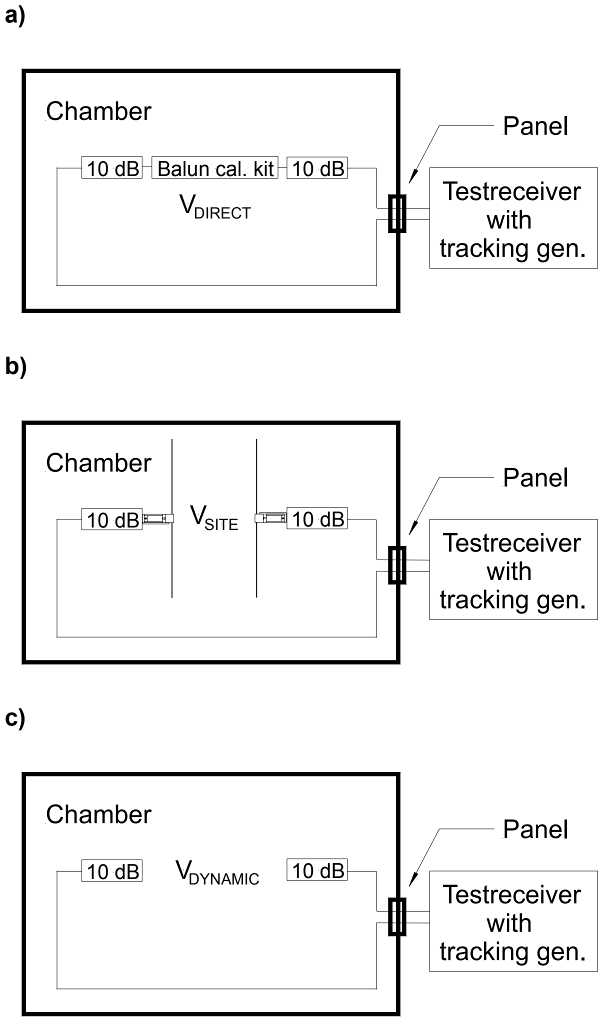


Figure 3: Voltage measurements
a) V_{DIRECT} b) V_{SITE} c) $V_{DYNAMIC}$

performed with four Seibersdorf Precision Reference Dipoles (PRD80, PRD160, PRD300 and PRD1000).

3.1 Comparison between broadband and tuned dipoles

Figure 4 shows the DSA for the dipoles and the broadband antennas in the corresponding frequency range. The results are presented for the center point at a transmitting height of 1 m for horizontal and vertical polarization.

In the frequency range from 30 MHz to 80 MHz, Figure 4a and 4b, where the dimensions of dipole and biconical antenna are nearly the same and also the directional pattern of the antennas are nearly identical, a

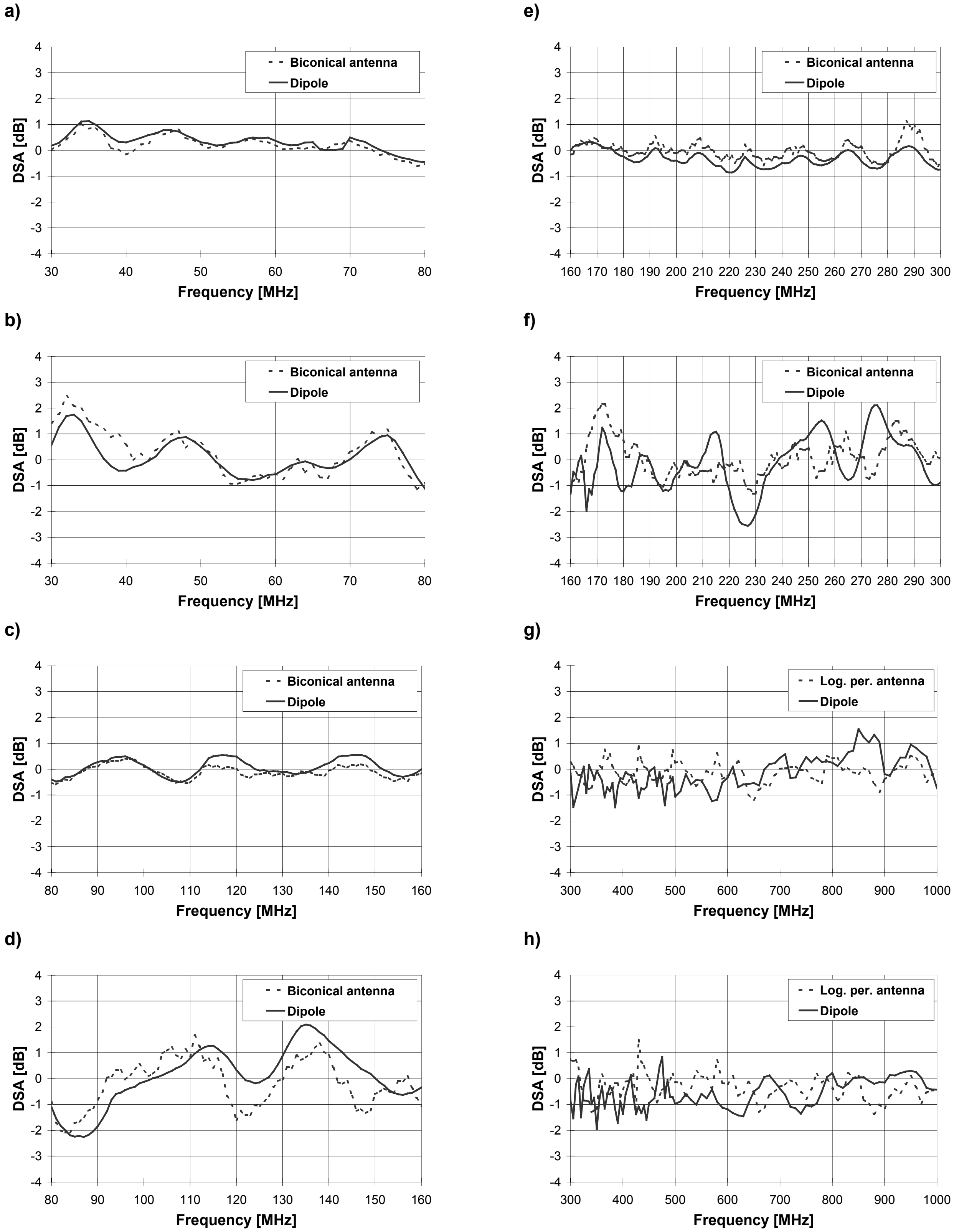


Figure 4: DSA with Broadband antennas and dipoles

a) Biconical antenna and PRD80, horizontal
b) Biconical antenna and PRD80, vertical
c) Biconical antenna and PRD160, horizontal
d) Biconical antenna and PRD160, vertical
e) Biconical antenna and PRD300, horizontal
f) Biconical antenna and PRD300, vertical
g) Log. per. antenna and PRD1000, horizontal
h) Log. per. antenna and PRD1000, vertical

good correspondence in the measurement results. In the following frequency ranges from 80 MHz to 300 MHz the deviation between dipole and broadband measurement is increasing especially in vertical polarization.

Larger deviations can also be detected in the dipole measurements above 300 MHz, which were caused by increasing disturbances caused by the dielectric material of the antenna mast. This is shown in more detail in 3.2. Beside the problems caused by non smooth antenna factor of broadband antennas and disturbances of the mast the differences in antenna pattern and antenna dimensions are also a source of increasing deviations.

3.2 Influence of the antenna mast

During measurement according to the Site Reference Method the influence of antenna mast and tripod is included in the calibration results. For the dipoles this influence is not included, because the mast is not modeled in the simulation.

In the frequency range from 30 MHz to 300 MHz an influence of the antenna mast can be detected especially in vertical polarization produced by coupling effects between antenna elements and the metallic parts of the antenna mast.

In the frequency range above 300 MHz, when the dimensions of the dipole is getting rather small, the influence of dielectric materials is strongly increasing and can be detected in both horizontal and vertical polarization. This effect can be easily proofed by varying the distance between antenna and mast / tripod. Figure 5 shows the difference of two SA measurements in vertical polarization with a distance variation of 75 mm between antenna and mast. The position of the antenna in the chamber is kept constant.

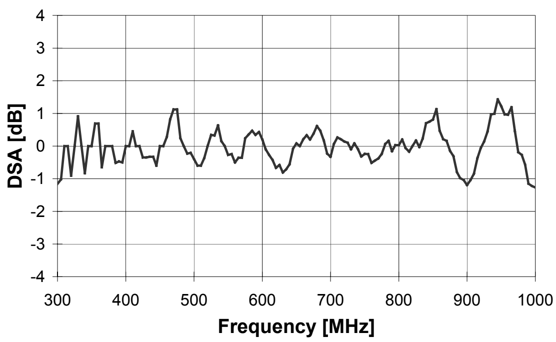


Figure 5: Influence of an antenna mast

When using a log. per. Antenna in that frequency range such a problem does not occur. The front to back ratio is larger than 10 dB and therefore reflections from the mast don't disturb the DSA result.

3.3 Equivalence of Chosen Dipoles

To proof the equivalence of the chosen dipoles the frequency range from 30 MHz to 160 MHz was measured with the PRD80 and the PRD160.

In horizontal polarization a deviation from the DSA traces can be found, see Figure 6 a. Reflections from the side walls are modified by the directional pattern. The measurement data for the PRD160 below 70 MHz are influenced by the reduced SNR.

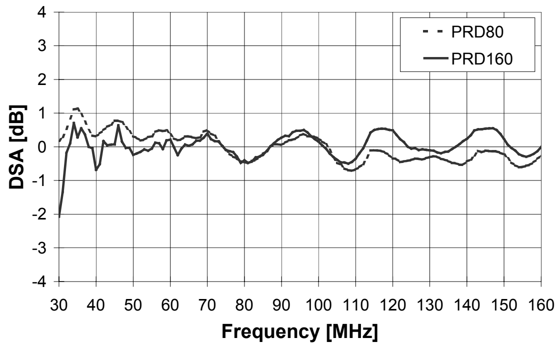
For vertical polarization, see Figure 6 b, there is a good correlation over the whole frequency range.

4. CONCLUSION

The paper presents a comparison between a volumetric NSA measurement proceeded with typical broadband antennas (biconical and log. - per. antennas) and short dipole antennas operating over a certain frequency range.

Where antenna pattern and dimensions of the antennas are of the same order and the influences of the additional installations (mast and tripod,...) can be neglected, the measurement results between broadband and dipole measurement are within small measurement uncertainty as shown in the frequency range up to 100 MHz.

a)



b)

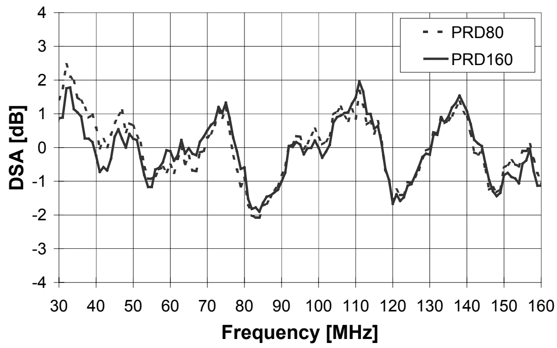


Figure 6: Equivalence of chosen dipole
a) horizontal polarization, b) vertical polarization

Above 100 MHz the deviation between measurements with biconical antenna and dipole can be reduced to the influence of the setup (mast, tripod, cables) which is included in the calibration data of the broadband measurement.

An evaluation of the different measurement results of log. – per. antenna and small dipole seems to be rather difficult regarding the completely different radiation pattern of the two antennas, the antenna dimensions and the non fixed phase center of the log. – per. antenna which results in an completely different illumination of walls and ceiling of the chamber.

For chamber validation the performance of the chamber itself should be checked. This means the absorber layout and the correct installation of the absorber material has to be inspected and not any non fixed, movable objects which were not part of the installation and sometimes changed later on. Therefore the antenna system used for validation procedure must be calibrated under exactly the same setup conditions (including antenna mast, tripod and antenna cables) than it is used for qualifying EMC chambers.

Regarding the differences and the determined deviation of the two measurement procedures it does not seem to be practical to demand a chamber validation by dipole antennas, rather it seems to be much more wise to check the chamber performance in quite similar way as the radiated emission measurement is proceeded later on. Therefore the measurement should pay special attention to the radiation characteristic of receiving antenna and EUT source. A measurement procedure, only based on simulation data without regarding the influences of measurement set up is therefore no practical validation procedure.

For radiated emission testing a typical EUT has no omnidirectional radiation pattern at higher frequencies. Therefore a site validation with omnidirectional antennas like SDSV does not characterize the site for its intended application. The Site Reference Method with the use of biconical and log.-per. antennas is most suitable, as it illuminates the walls and ceiling under more realistic circumstances.

Measurement with dipole antennas is much more time consuming than the measurement with broadband antennas which results not only in a longer test period it will also result in more expensive testing.

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BIOGRAPHICAL NOTES

Alexander Kriz
Study of electrical engineering at the Vienna University of Technology. He performed his diploma thesis at the Austrian Research Centers Seibersdorf (ARCS), where simulations of antennas and open area test sites were carried out. Since 2001 he is an employee of the ARCS, where he improves measurement techniques and calculates measurement uncertainties.

Wolfgang Müllner
Study of electrical engineering at the Vienna University of Technology. Since 1990 he is an employee of the ARCS and is the head of the business unit Electromagnetic Compatibility and RF Engineering since 1997. His major work is the coordination of site validation measurements and responsibility for research and development projects.

Jochen Riedelsheimer
Study of electrical engineering at university of Kaiserslautern until 1996. Afterwards competent for the department of calibration at Conformitas GmbH in Kaiserslautern. Since 2000 responsible for research and development at Albatross Projects GmbH in Nattheim.

Friedrich-Wilhelm Trautnitz
Study of microwave and information technology at university of Erlangen Nürnberg from 1977-1982. Project engineer of big earth satellite station antennas and microwave links at ANT Nachrichtentechnik Backnang from 1983-1989. Development engineer and manager of the project department of EMC systems at Siemens Matsushita Heidenheim 1989-1999. Technical director of Albatross Projects since 1999