Influence of H-Plane Pattern Performance of the Omnidirectional Transmit Antenna to the Site VSWR Result

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Abstract—**This paper shows the first analysis of the influence of the H-plane performance to the Site VSWR result. An effective model to estimate the error is presented. Measurements with four different antennas in three different test sites prove the correctness of the model. The measurement error depends on the pattern performance as well as on the chamber performance itself. Guidance to improve the reliability of Site VSWR measurement result is given.**

Site VSWR; Site Validation; EMC above 1 GHz; omnidirectional antennas; Precision Omnidirectional Dipole

I. Introduction

In the past years EMC above 1 GHz had been a hot topic in the EMC world. Since a couple of years experts from all over the world are working toward an international standard. In May 2005 an addendum [1] to CISPR 16-2-3 [2] had been published which deals with the measurement of radiated emissions in the frequency range 1 GHz to 18 GHz. Also a validation procedure for test sites will be part of the CISPR 16 standards. This project is in a final stage and will be finished and published in CSPR 16-1-4 [3] in 2007. The latest document is 648/CDV [4], a revised version of the first Committee Draft for Voting 602/CDV [5].

The validation technique is called Site VSWR whose root is the Free Space VSWR [6] technique used for characterization of microwave chambers. On the contrary to the Normalized Site Attenuation (NSA) method below 1 GHz the knowledge of the antenna factors of the used antennas is not necessary. This procedure determines the ripple that originates from the superposition of direct and reflected waves.

A new approach has been taken for the illumination of the test site. Omnidirectional antennas are prescribed as transmit source and are implemented by dipole antennas. Minimum requirements of those antennas are described in the standard by the definition of E-plane and H-plane limits. At the moment there are two antenna manufacturers who supply broadband dipole antennas that comply with the requirements. These are the Small Biconical Antenna (SBA) [7][8] from Schwarzbeck GmbH and the Precision Omnidirectional Dipole (POD) [9] from ARC Seibersdorf research GmbH. Both products cover the frequency range with two broadband dipoles.

In the uncertainty calculation for Site VSWR measurements the influence of the imperfection of the omnidirectional transmit antenna is estimated by ± 1.5 dB. This number is a very quick estimation without a mature knowledge of the underlying effects. The goal of this paper is to present an extensive analysis of the problem and tries to give ideas for further improvements. Therefore we decreased the H-plane performance of an omnidirectional antenna intentionally by adding material near the radiating elements. We performed measurements with these antennas in the frequency range 1 GHz to 6 GHz. The reason for this frequency range is the behavior of typical anechoic chambers. Due to the decreased directivity of the receive antenna and the lower reflectivity of the absorbing material higher Site VSWR values are obtained.

II. Intentional Deformation of the H-Plane Pattern

We used a POD 16 antenna and mounted different materials near the radiating elements, see Fig. 1. This decreases the H-plane performance because of standing waves between them. Three different materials are used to get the “bad antennas”:

- Grade 1: A PVC (polyvinyl chloride) rod with a diameter of 41 mm and a length of 35 cm was mounted 70 mm behind the radiating elements.
- Grade 2: A PE (polyethylene) tube with an outer diameter of 25 mm a length of 32 cm and a wall thickness of 2.5 mm was mounted 50 mm behind the radiating elements.
- Grade 3: A copper tube with an outer diameter of 10 mm a length of 27 cm and a wall thickness of 1 mm was mounted 50 mm behind the radiating elements.

The measured H-plane pattern of these three antennas and a POD 16 antennas at the frequencies 1 GHz, 3 GHz and 6 GHz are shown in Table I.

The H-plane pattern of the POD 16 is nearly perfect – the deviation to the circle is less than ± 1 dB. Antenna Grade 1 has two nulls between ± 135° but a strong backlobe. Antenna Grade 2 is compliant with the limit of 648/CDV over the whole frequency range. Antenna Grade 3 has a weak backlobe in a wide frequency range.

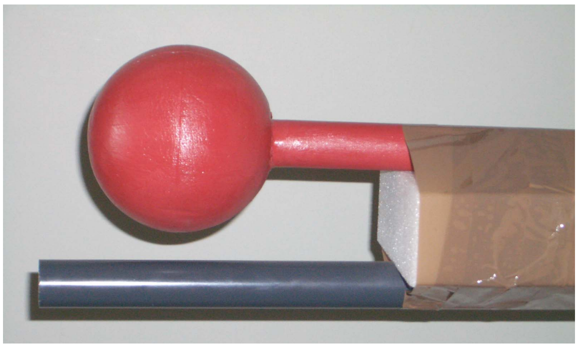


Figure 1. Picture of modified POD 16 antenna

III. Mathematical model of H-plane pattern influence

A simple model with only one scatterer is used to describe the behavior. In this case there a two rays, the direct ray D and the reflected ray R, see Fig 2a).

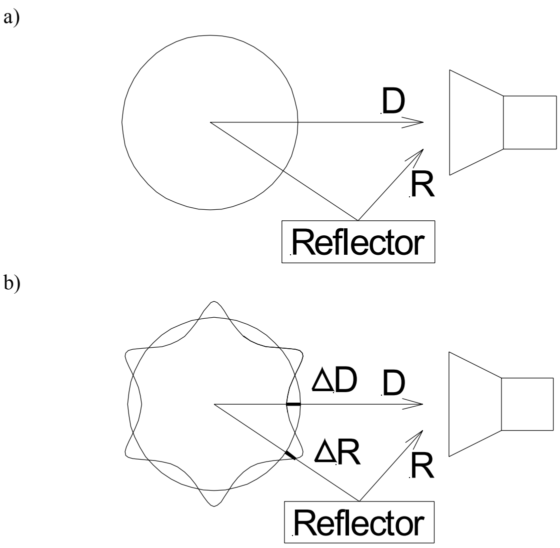


Figure 2. Site VSWR model for a transmit antenna with a a) perfect H-plane pattern b) deformed H-plane pattern

The Site VSWR can be calculated by

$$S_{VSWR} = 20\log\left(\frac{D+R}{D-R}\right) \tag{1}$$

when

$$D > R \tag{2}$$

If a real antenna is used the direct ray becomes D+ΔD and the reflected ray becomes R+ΔR, see Fig. 2b). So the Site VSWR measured with a real antenna is calculated by

$$S_{VSWR} = 20\log\left(\frac{(D+\Delta D)+(R+\Delta R)}{(D+\Delta D)-(R+\Delta R)}\right) \tag{3}$$

From this simple model it is easy to see the impact of ΔD and ΔR. Depending on the sign of ΔR and ΔD the error is positive or negative. If ΔR is positive and ΔD negative the error becomes positive. This results in overestimation where the result is worse than it is really is. The other possibility is underestimation where the result seems to be better. This can happen due to an negative error which means ΔR is negative and ΔD positive.

Fig. 3 shows the worst case estimation of the error in Site VSWR measurements. The error is drawn for four different values of ΔR and ΔD. From this plot it can be seen that the error is depending on the magnitude of ΔR and ΔD as well as from the Site VSWR itself.

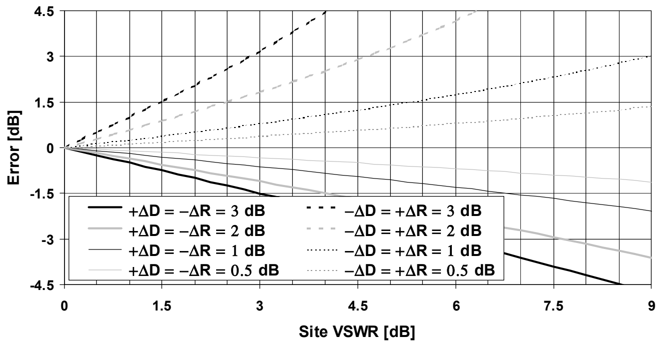


Figure 3. Error in Site VSWR result depending on pattern imperfection

IV. Measurement of Site VSWR

We performed several measurements in an anechoic chamber with a size of 6.98 m by 4.2 m by 4.05 m and full absorber lining with 24” microwave foam absorber. An EMCO 3115 acts as receive antenna and POD 16 antennas with and without modification was used as transmit antenna. The site attenuation was measured with a vector network analyzer HP 8722C. A two axis precision antenna positioner helped to place the transmit antenna. This positioner has a linear axis to move along the 40 cm Site VSWR scan line. A rotational axis turns the antenna.

We used a scatterer to decrease the performance of the chamber. A balloon made from metallized Nylon and filled with helium had been used, see Fig. 4. This balloon with a diameter of 24” is more suitable as scatterer than metallic plates. Due to the low conductivity and round shape the radar cross section is low.

Figure 4. Picture of the balloon

The balloon was placed at the back wall and at the side wall of the chamber, see Fig. 5. These two locations are within the 3 dB beamwidth of the receive antenna so the scatterer are "seen" by the receive antenna.

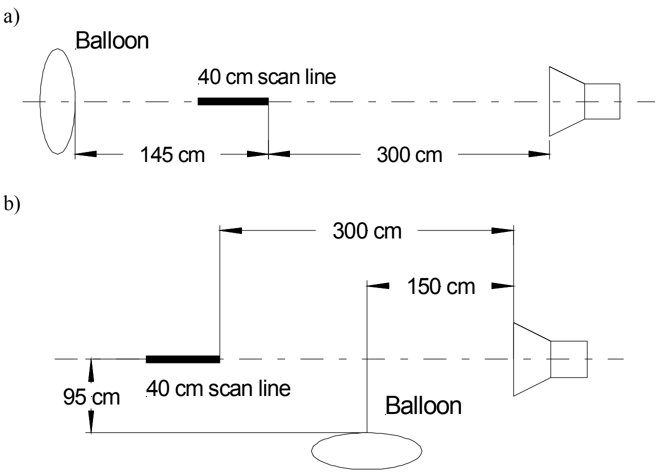


Figure 5. Modified chamber with a) balloon at back b) balloon at side wall

The Site VSWR is measured with the four antennas described in chapter II. After each single measurement the transmit antenna was turned by 10° and the Site VSWR was measured again until a full circle was finished. This was done to change the values of ΔD and ΔR. In Table II the results of the measurements are shown for all antenna and test site combinations. In each diagram the maximum, the minimum and the mean Site VSWR is plotted.

This extensive collection of measurement data is the basis for evaluations according to different criteria. Combinations of "good"/"bad" antenna with "good"/"bad" chambers are investigated.

The validity of the mathematical model presented in chapter III can be proved by following facts that are seen in the results in Table II:

- When measuring a very good test site the imperfection of the H-plane pattern is not relevant for the result. This can been seen from the very good results in the first row. There is one exception for antenna Grade 1. Due to the nulls at approximately + 150° and – 150° of the Grade 1 antenna a Site VSWR of 8 dB is measured. If a null points to the receive antenna ΔD becomes negative and extremely large.
- The error is between ± 0.2 dB and ± 1 dB if a POD 16 is used for Site VSWR measurements, seen at the first column. A larger error occurs when the Site VSWR value is larger. This fits well to Fig. 3 where the error is also dependent to the Site VSWR value itself. The POD 16 is still compliant with the H-plane limit if it is turned. So all of the obtained measurement values are valid and could occur.
- The mean Site VSWR is similar for all antennas. This means that there is a good statistical distribution of ΔD and ΔR in this experiment. The second impact of this is that the chamber performance can be estimated by averaging the results obtained with bad antennas which are placed in multiple angles.
- Fig. 3 shows that the error is not distributed symmetrically. This can be seen well at the measurements with antenna Grade 3 with the balloon at the back wall. Between 3.5 GHz and 5 GHz the positive error is around + 3 dB while the negative error is about – 2 dB. Also at the measurements with antenna Grade 1 this is seen. Some of the results are above + 10 dB and are not shown in the diagram. Some are below + 1 dB.

V. Practical Considerations

The most important question of the pattern issue: "Is underestimation or overestimation the more severe problem?". Of course underestimation is worse because bad test site will pass the Site VSWR criterion. Nobody will assume a problem if the results are within the limit. In case of overestimation there will be an extensive analysis of the problem by the test engineer if the chamber fails.

There is a simple method to identify a problem of the omnidirectional transmit antenna. Site VSWR measurements are performed several times with turning the transmit antenna around the dipole axis between the measurements. If the change in the Site VSWR result is small e.g. less than 1 dB the antenna performance is acceptable and any of the traces can be taken as result. If the result shows a larger spread e.g. 1.5 dB, the real chamber performance can be estimated by calculating the average.

VI. Residual Error after averaging

As mentioned in chapters IV and V it is possible to reduce the error by measuring the Site VSWR in several angles and calculating the average. This works well if there is a good statistical distribution of ΔD and ΔR and enough samples present.

TABLE I. H-PLANE PATTERN FOR OMNIDIRECTIONAL ANTENNAS

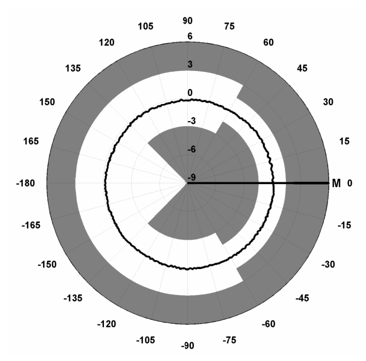
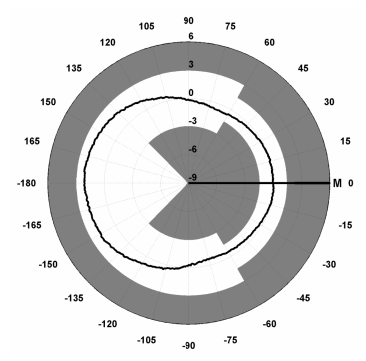
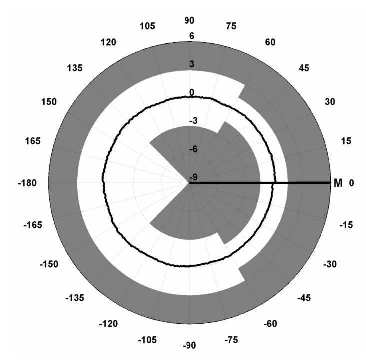
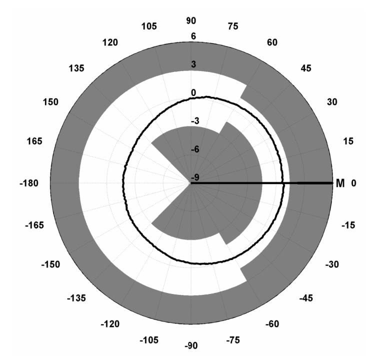
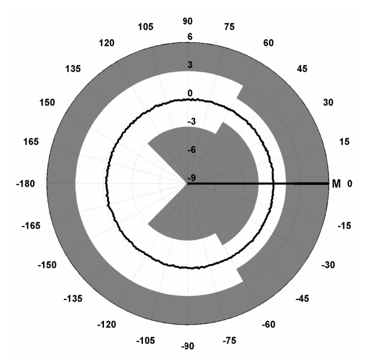
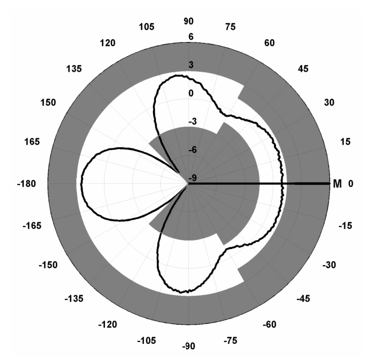
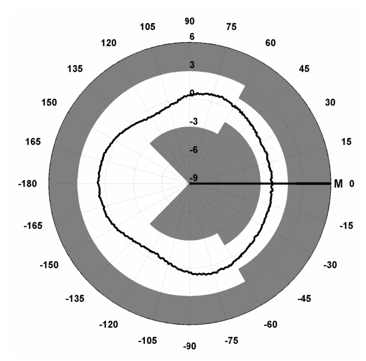
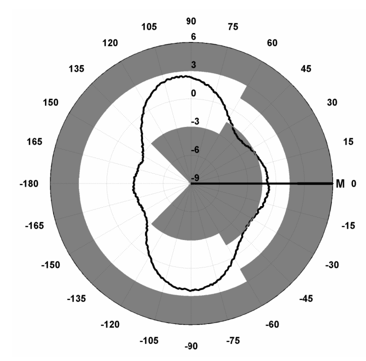
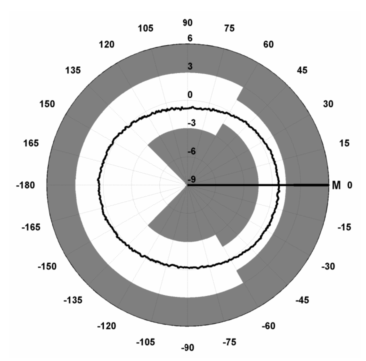
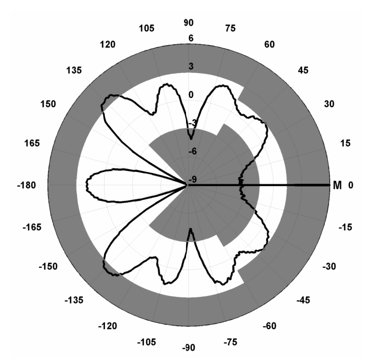
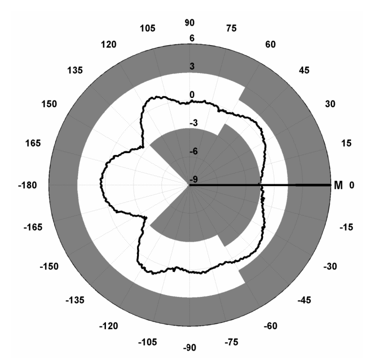
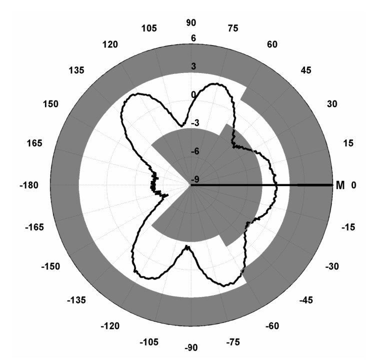
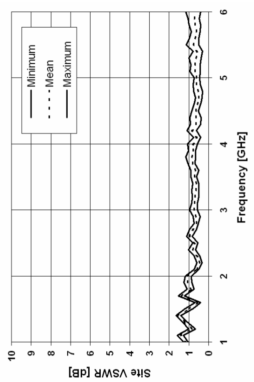
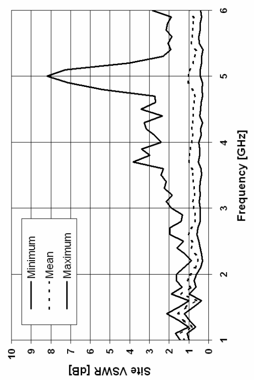
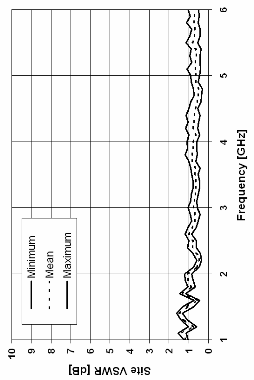
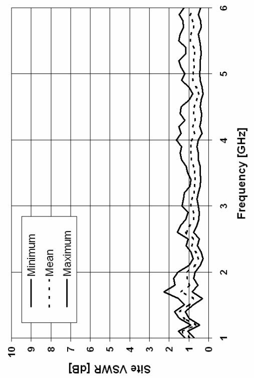
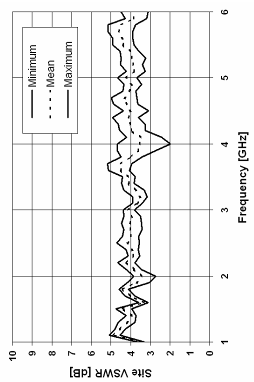
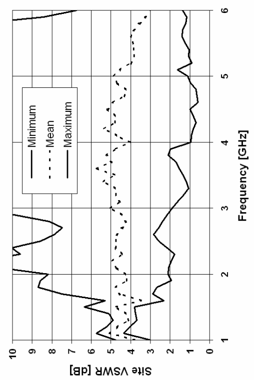
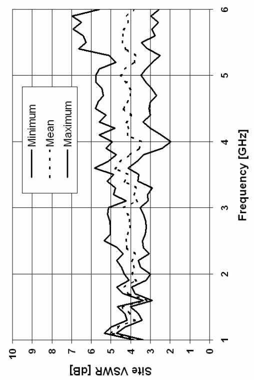
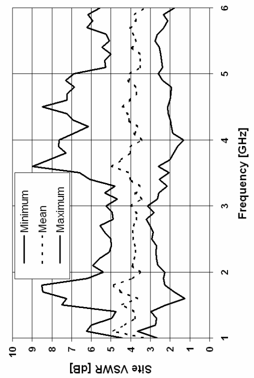
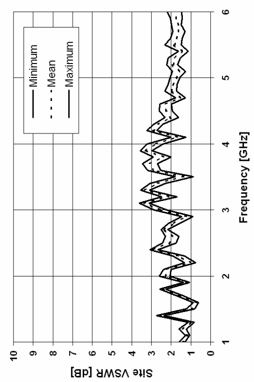
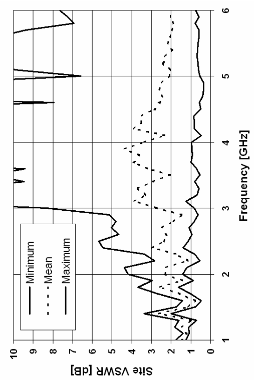
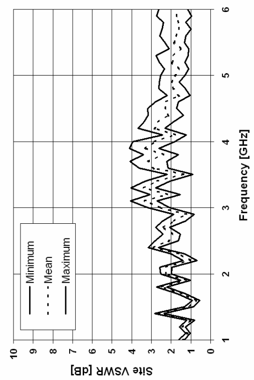
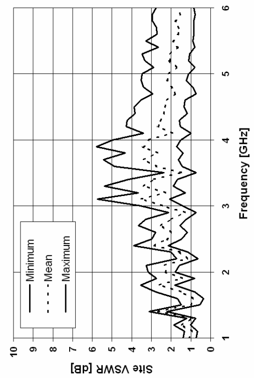
Frequency	**Test Antenna**			
	POD16	***Grade 1***	***Grade 2***	***Grade 3***
1 GHz				
3 GHz				
6 GHz				

TABLE II. SITE VSWR FOR DIFFERENT ANTENNA AND TEST SITE COMBINATIONS

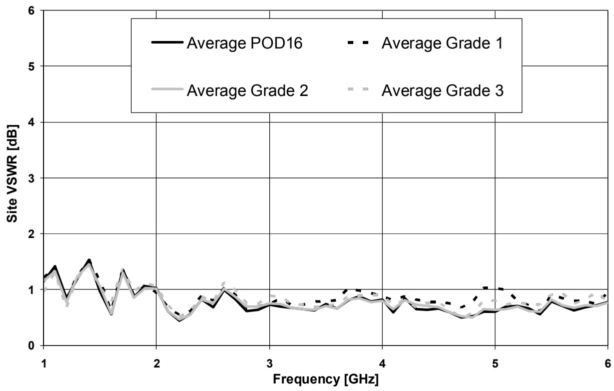
Test Site	Test Antenna: *POD16*	*Grade 1*	*Grade 2*	*Grade 3*
Not modified				
Balloon at back wall				
Balloon at side wall				

In Fig. 6 the average Site VSWR for the all three test sites are shown. The maximum difference between the traces are not more than 1 dB even for antenna Grade 1 in the chamber with the balloon at the back.

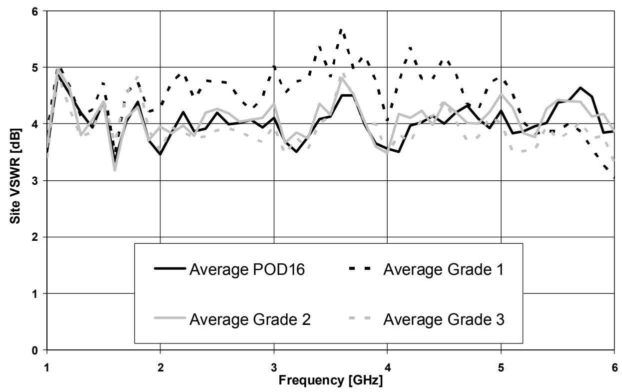
If the average of antenna Grade 1 is not take into account the result gets much better. The remaining maximum difference between the traces exceeds 0.3 dB only at the test site with the balloon at the back wall.

Unfortunately this technique is very laborious if an automatic antenna positioner is not available.

a)



b)



c)

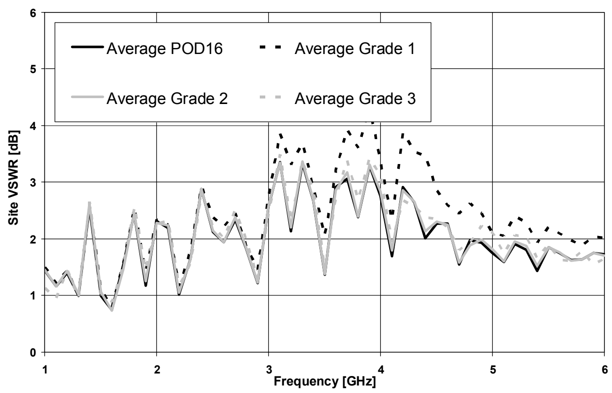


Figure 6. Average Site VSWR with different antennas
a) not modified b) balloon at back c) balloon at side wall

FURTHER WORK

The next step is a further investigation of Fig. 3 without assuming a worst case scenario. In a realistic point of view it is not probable that the maximum and minimum deviation of the pattern occur at the angles pointing toward the receive antenna and the scatterer. Generally the location of the scatterer in the anechoic chamber is not known. A statistically approach has to be taken to calculate a mean pattern deviation. Anyway the first suggestion to the standardization organization is to reconsider the behavior in the backlobe of the antenna. This blind spot allows antennas that are unable to see chamber imperfection at the back wall of the chamber.

The long term goal is a complete error analysis that also includes the influence of the E-plane performance. It is a sophisticated task to modify the E-plane pattern of an omnidirectional antenna. To do so the size and shape of the radiating elements must be changed. The placement of conducting or permittive materials is not sufficient to do this.

ACKNOWLEDGMENT

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