Fully Anechoic Room Validation Measurements to CENELEC prEN50147-3

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Abstract
Many small to medium sized EMC anechoic chambers today are built as Fully-Anechoic Rooms or FARs. The draft prEN50147-3 document by CENELEC defines FAR measurement methods and this paper discusses them and makes recommendations for improvements.

1. Introduction

The potential benefits of Fully-Anechoic Rooms (FAR) as compared to Semi-Anechoic Chambers (SAC) have been well documented [1][2][3][4][5][6][7][8]. Activity in various standards organizations including CENELEC and IEC/CISPR is ongoing with already 5 years work completed.

At CENELEC level the draft standard prEN50147-3 [9] has produced probably the most detailed document so far. The January 2000 version had been submitted by CENELEC TC210A WG4 to national committees for comment at the time of writing, and these comments were due to be discussed at the next meeting of the group in January 2001. The document details a chamber calibration method as well as an antenna calibration method for site validation. Measurement limits are given as well as methods of dealing with cable issues. In support of this activity an EU funded project [3] was conducted from Jan 97 to Jan 99. A group of well-known European laboratories carried out a number of round robin tests. At IEC/CISPR level the CISPR/A/WG2 group has begun work on introducing FAR emission measurements to CISPR 16. Work is ongoing but has much in common with the CENELEC activities.

With the methods still embedded in draft standards little evidence has emerged to date that anechoic chambers can be built to meet the new document. Few companies so far have been willing to invest in such a chamber to meet prEN50147-3 with little known about it.

This paper presents results and recommendations from actual measurements in a 3/5m FAR. Such measurements and subsequent investigations have highlighted the need to further explore the current described methods. In addition a high performance 3m SAC (+/-2.3dB 30-1000MHz) has been calibrated to prEN50147-3 in order to see if such chambers would fulfill the draft.

2. The prEN50147-3 document

There are two methods proposed for validation of the chamber: The Site Reference Method and the NSA method. The former is preferred at distances of 5m or less since it takes into account antenna coupling and near field effects and we will concentrate on this method in this paper.

15 positions are measured within the test volume which is a cylinder comprising 3 planes: Bottom, Middle and Top ; 5 positions in each plane Front, Left, Centre, Right and Back and for each polarisation Horizontal and Vertical .(Fig 2).

Fig 1. Chamber validation according to prEN50147-3

The receive antenna is fixed in one position in the room with its reference position at either 3 or 5m from the front edge of the test volume. Its height is fixed at the middle plane of the test volume. There is no tilting towards the bottom or top plane and there is no pointing towards the Left or Right positions. The transmit antenna is placed at each one of the 15 positions and is an omni-directional antenna with maximum dimension of 40cm. The receive antenna is also a broadband antenna and should be the same for validation of the room and the product testing normally carried out in the chamber. The Site Reference is measured as follows:

1. Insertion Loss (M0) is measured in dB with the cables connected together.
2. The transmission Loss (M1) is measured in dB with the cables connected to the antennas.
3. The deviation of the measured site attenuation from the site reference SR is calculated.

$$DSA = (M0 - M1) - SR \ [dB]$$

Prior to the chamber validation the two antennas to be used must be calibrated according to Annexe A of prEN50147-3 (See Fig 3) in order to determine a site reference . This antenna calibration involves raising both antennas to a height of 1.67 times the test distance and performing an identical measurement to the Site reference described above. All measurements are performed in vertical polarization over a quasi-free space site in order to avoid any antenna to ground coupling. The total number of measurements can be as many as 13 if the diameter and height of the test volume are not the same.

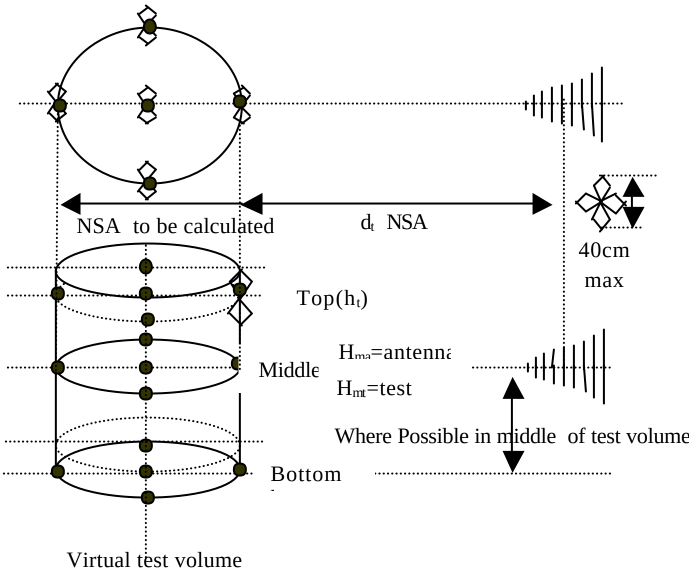

Fig.2 Measurement points in chamber validation procedure

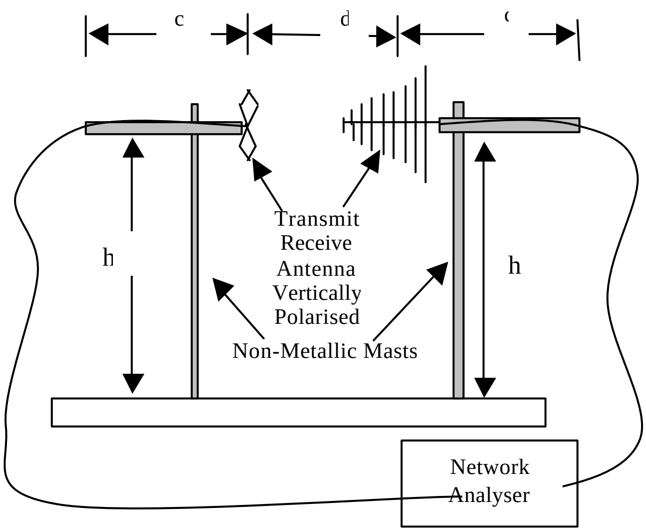

Fig.4 Site Reference Method

3. Investigations

For the purposes of this paper a FAR was available for carrying out a number of different validations. The aim was to investigate both the influence of the site reference method and also the influence of slightly different validation methods when measuring the chamber itself.

A first investigation would therefore involve looking at how the site reference calibration influences the final chamber results. To this end it was decided to calibrate the antennas under several different conditions:

Set (a) As per the Site Reference method given in the draft standard over a quasi free space site at 6m height. (Fig.5)

Set (b) Same geometry as (a) but over a ground plane at 6m .

Set (c) Use ferrite tiles over the ground plane at 6m. (Fig.6)

Set (d) Reduce the height of the antennas of Set (c) to the same height (1.65m) as that used in the chamber validations.(Fig.7)

One set of chamber measurements would be taken according to the prEN50147-3 method with the 4 different calibrations being substituted into the one set of measurements to yield 4 different chamber results each a function of the calibration used.

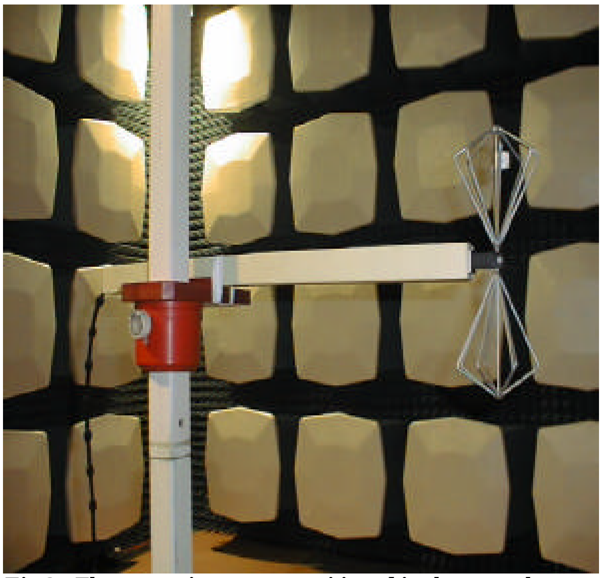

Fig.3 The transmit antenna positioned in the test volume.

Fig.5 Site Reference measurement on a "Quasi Free Space" site.

Fig 6 Site Reference measurement with ferrites on ground plane

Fig.7 Site reference at 1.65m over ferrites on ground plane

A second investigation would involve using slightly different validation methods as follows:

Set (e) Use a fixed 3m distance between antennas as per the volumetric method of EN 50147-2[10], including orientation of antennas towards each other at all positions.

Set (f) Use a fixed distance as per set (e) but take measurements at 3 different heights: 1.45,1.65 & 1.85m and taking the maximum reading .

Set (g) Again using a fixed distance carry out measurements according to the FSTL (Free Space Transmission Loss) method with a large biconical (Fig.8) and log periodic antennas calibrated with free space antenna factors. Many chambers are today calibrated using this Free Space Transmission Loss method. The test is identical to the volumetric NSA described in EN 50147-2. The difference lies only in the

(1) A free space antenna factor is measured instead of Antenna Factors on an OATS.
(2) The measured values are normalised to theoretical free space and not OATS.

In addition the difference with the prEN50147-3 method is that large biconicals (Max dim 1.2m) and log periodic antennas are used and the distance between antennas for the volumetric is maintained at a constant 3m or 5m with adjustment of the antennas to point at each other in the left and right positions on the turntable and to have identical heights of Transmit and Receive antennas. In comparison to the prEN50147-3 method the Free Space Transmission Loss method has several advantages in that it is use already and it is very similar to the existing NSA method.

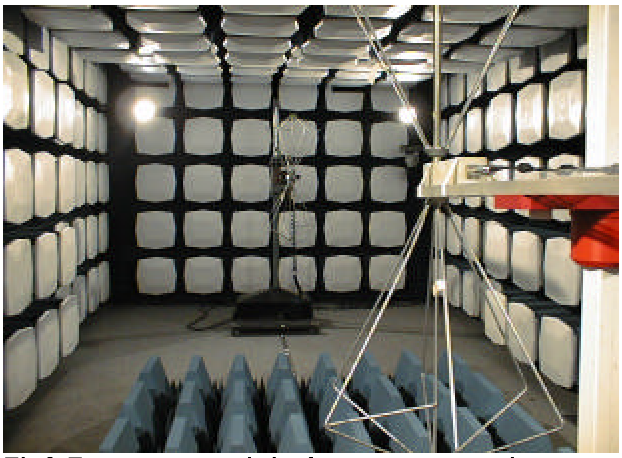

Fig 8. Free space transmission loss measurement using large biconicals

Fig.9 prEN50147-3 validation in a semi- anechoic chamber with partial floor treatment.

And finally, for information only, a Semi Anechoic 3m chamber holding FCC certification and NSA according to EN 50147-2 of better than +/-2.5dB was measured (Fig.9) according to prEN50147-3 using the partial floor treatment required for the IEC 61000.4.3 measurements. Further measurements will be reported at a later stage on this chamber with a full absorber cover on the floor.

4.Analysis of results

On the following pages the results of each of the abovementioned investigations are given at 3m distance for horizontal and vertical polarizations .

Measurements using different calibrations Set (a) to (d)

The results of set (a) Fig 10,11 are according to the current document and are taken as the reference measurement. This data shows a behaviour which can be classified into 3 frequency bands:

(1) Below 100MHz the results are relatively close to each but exhibit a deviation which is different between polarizations, as the chamber is wider than it is high this is predictable. Attempts to modify the results by modifying the absorber layout demonstrated a peculiar paradox in that the performance improved with less absorber material on the floor. At higher frequencies however this had the opposite effect.
(2) Between 100MHz and 600MHz the chamber is at its best.
(3) Between 600 and 1000MHz performance appears to degrade and this can be attributed mostly to the use of the small biconical, or put in another way a typical log periodic would mask any such effect due to its higher directivity .

With the same set of chamber results calibration data taken from a setup over an OATS was substituted into the previous data to produce set (b) in Fig 12,13 and as expected there is little change. The principle of calibrating both horizontal and vertical polarizations over a ground plane by using the vertical orientation at a relatively great height is supported. Taking this one step further the a similar substitution was done for set (c) in Fig 14,15 using a calibration performed at 6m over a ground plane but this time covered with the same 9x5m of Ferrite panels as found in the chamber. Little change again until we go to set (d) in Fig 16,17 with the calibration carried out in an identical geometrical and physical configuration to the chamber validation and in this case the chamber appears to perform better. The floor's influence has clearly been significantly subtracted out by doing this and we are now seeing the effect of the other surfaces, and probably mostly the ceiling. As the antenna calibration for EN 50147-2 is carried out in an identical configuration to the chamber validation it would seem that adopting the same approach prEN50147-3 would become easier.

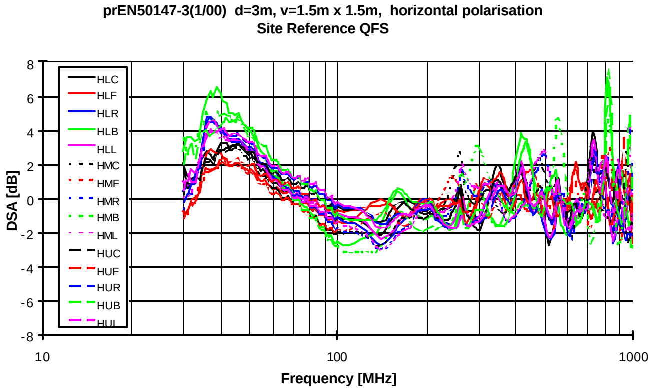

Fig.10 Set (a) Quasi Free Space
Height 6.0m Horizontal 3m

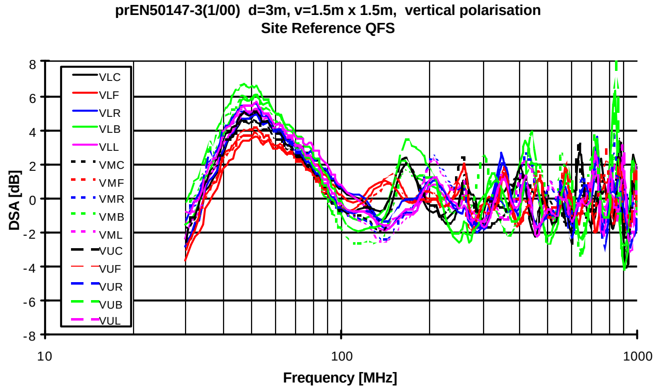

Fig.11 Set (a) Quasi Free Space
Height 6.0m Vertical 3m

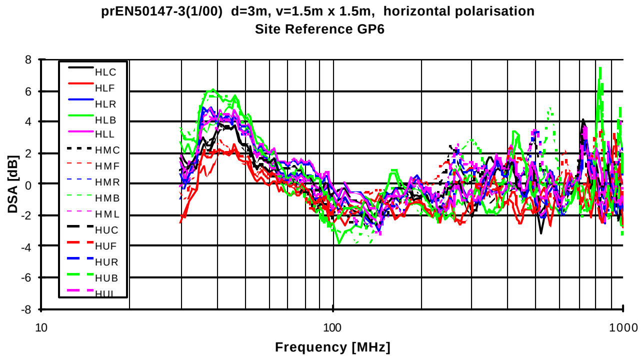

Fig.12 Set (a) Ground Plane
Height 6.0m Horizontal 3m

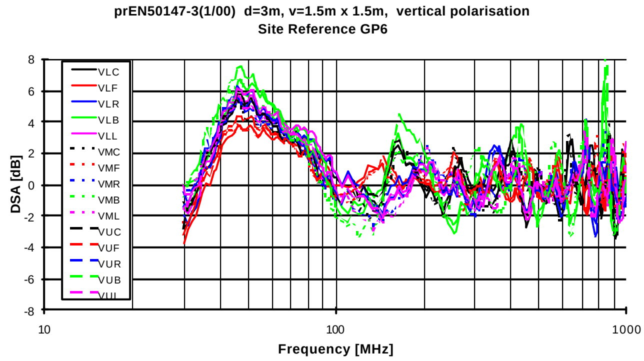

Fig.13 Set (a) Ground Plane
Height 6.0m Vertical 3m

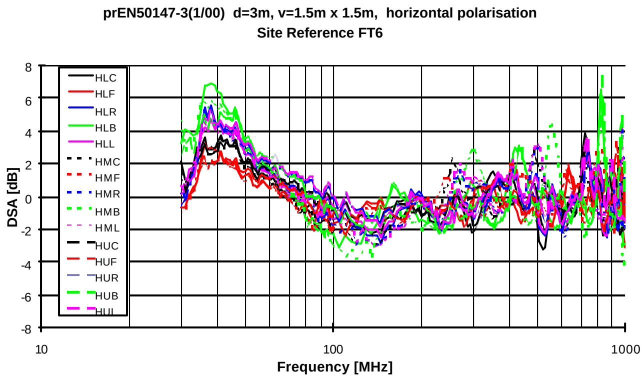

Fig.14 Set (c) Ferrite Tiles On Ground Plane
Height 6.0 m Horizontal 3m

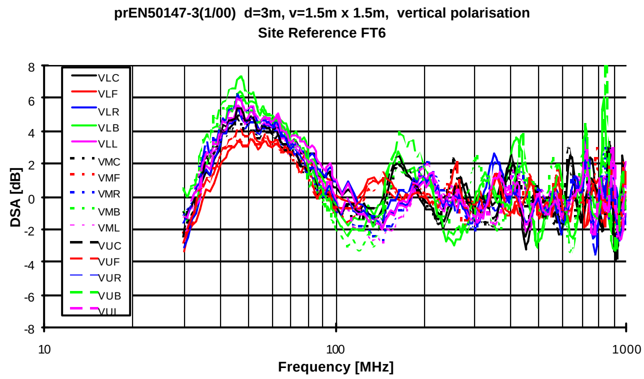

Fig.15 Set (c) Ferrite Tiles On Ground Plane
Height 6.0 m Vertical 3m

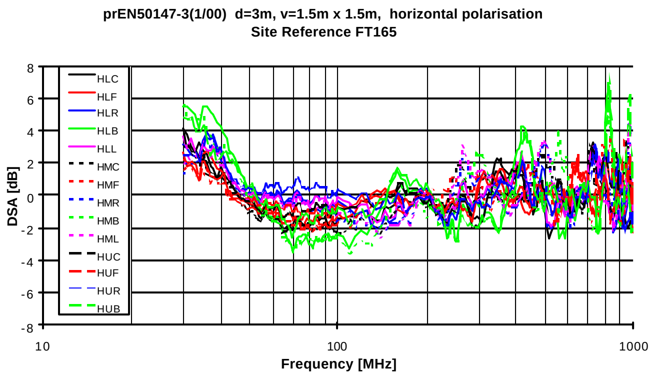

Fig.16 Set (d) Ferrite Tiles On Ground Plane
Height 1.65 m Horizontal 3m

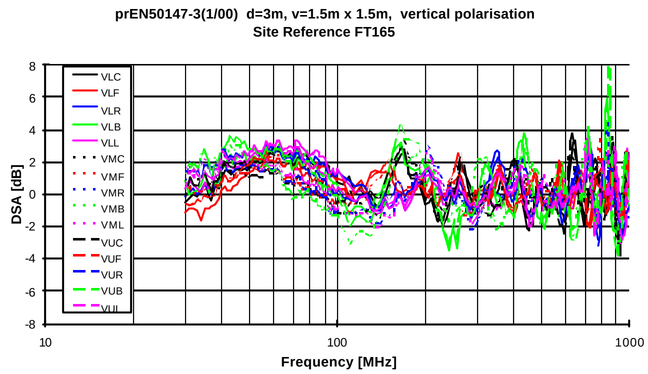

Fig.17 Set (d) Ferrite Tiles On Ground Plane
Height 1.65 m Vertical 3m

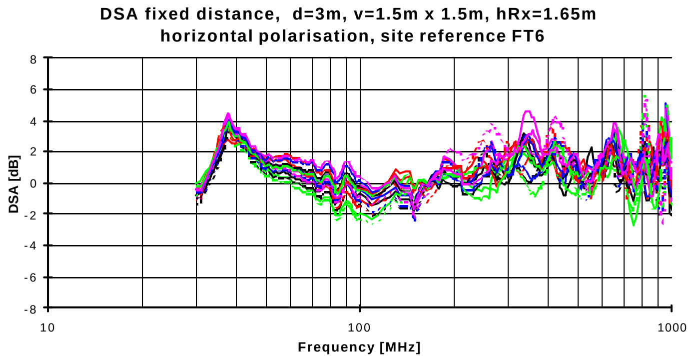

Fig.18 Set (e) Fixed Distance Horizontal 3m

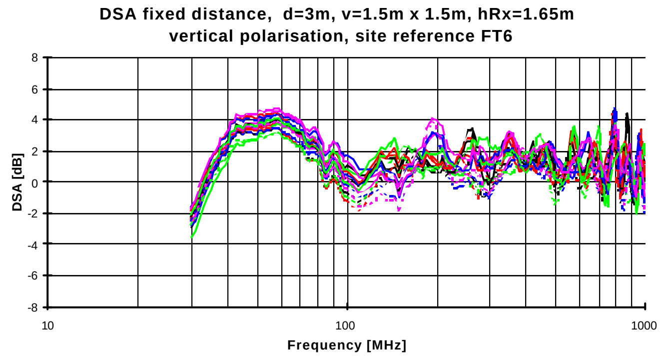

Fig.19 Set (e) Fixed Distance Vertical 3m

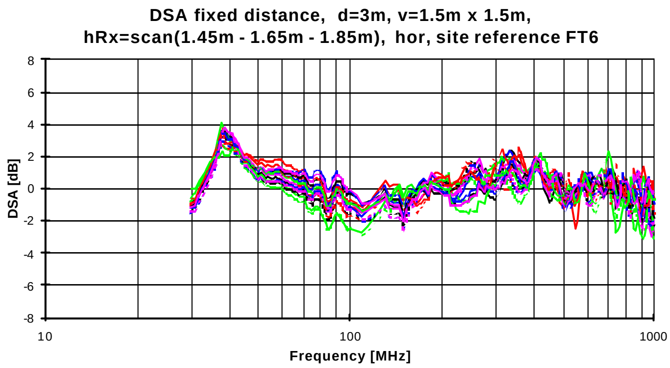

Fig 20 Set (f) Fixed Distance & Height Scan Horizontal 3m

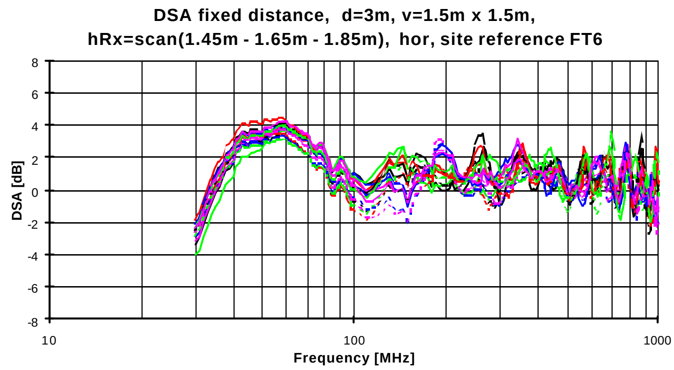

Fig.21 Set (f) Fixed Distance & Height Scan Vertical 3m

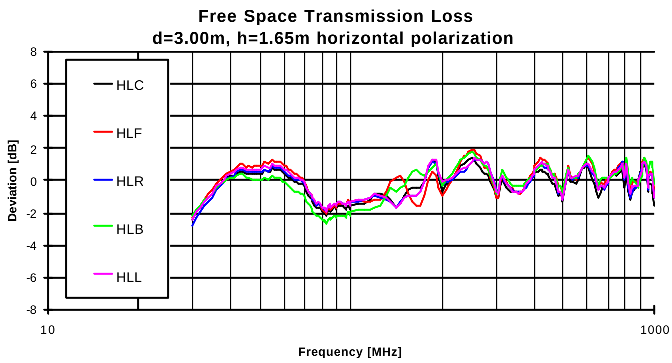

Fig.22 Set (g) Free Space Transmission Loss Horizontal 3m

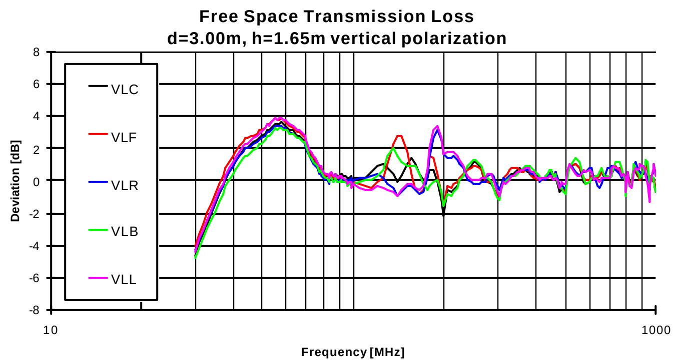

Fig. 23 Set (g) Free Space Transmission Loss Vertical 3m

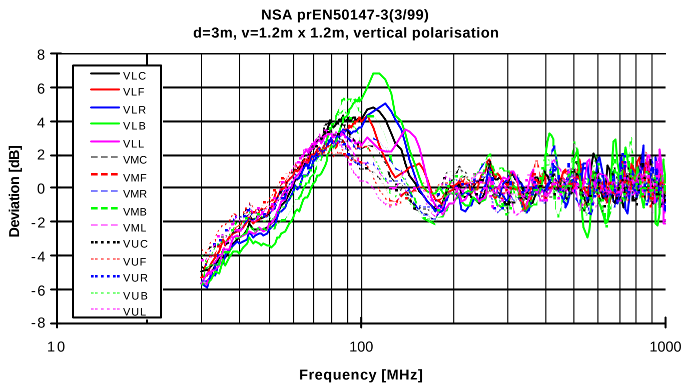

Fig.24 Set (h) prEN50147-3 in SAC   Horizontal 3m

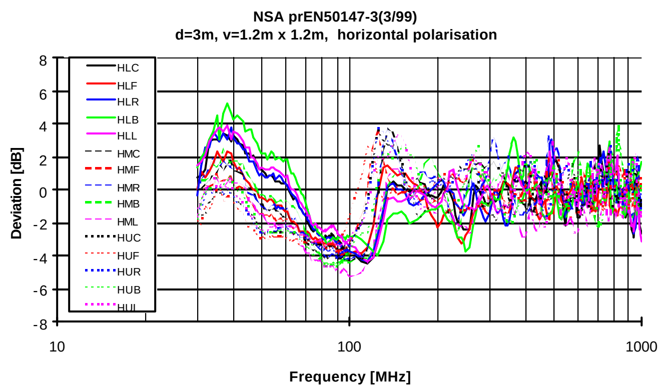

Fig.25 Set (h) prEN50147-3 in SAC   Vertical 3m

Fixed Antenna separation: Comparison of the measurement results from set (d) Fig 16,17 and set (e) Fig 18,19 shows an improvement by using a fixed antenna separation since the prEN50147-3 chamber validation uses the front position as the reference distance of either 3 or 5m. All other distances are greater than this reference, and in particular the rear position. (Fig.26 & 27). The test volume tested in the FAR was 1.5m diameter which makes the rear position a 4.5m measurement at 3m. In contrast, the geometry of the EN 50147-2 test (SAC) requires that the antenna must always be separated by 3m.. Even allowing for the fact that the distance is compensated for in the normalization calculations there is no compensation for the fact that the chamber must in fact be wider and higher than a compliant SAC. This problem is compounded by the fact that the RF absorber material has reduced efficiency at higher angles of incidence. Solid foam based pyramids typically perform well up to 70°, whereas ferrite tiles and ferrite based hybrids will perform well only to 45°. Assuming a chamber size of 7x3x3m, test distance 3m and quiet zone diameter of 1.2m then for a measurement with constant separation as per EN 50147-2 the maximum subtended angle is : 23° and with variable separation as per prEN50147-3 the maximum subtended angle is : 27°.

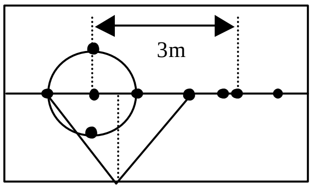

Fig.26 Constant separation

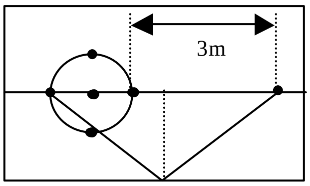

Fig.27 Variable separation

Or in other words the chamber would have to be increased from 3m wide to 4.2m wide in order to achieve the same angle of incidence at the walls. Although we have not taken into account the additional transmission loss of the reflected wave, prEN50147-3 is clearly at a disadvantage to its Semi-Anechoic equivalent EN 50147-2.

Height Scan: Comparison of the measurement results from sets (e) Fig 14,15 without and (f) Fig 20,21 with height scan shows a fair improvement in particular at higher frequencies by using 3 different receive heights. Carrying out the measurement in this way would still allow the use of the small biconical to achieve reasonable results whilst not having to revert to a log periodic transmit antenna above 200MHz , although the downside would be the increased validation time .

Free Space Transmission Loss: Set (g) Fig 22,23 performed with large biconicals and log periodics demonstrates probably the best performance of all. Given that this set differs from set (e) only by the antenna type this indicates that the choice of a smaller antenna impacts the performance below 100MHz and above 600MHz. **Semi Anechoic Chamber:** Set (h) Fig 24,25 cannot be easily compared to the previous measurements as it was carried out in a different chamber. Clearly 2.4x2.4m area floor absorber covering in this chamber is not enough and additional materials would be needed. Such tests will form part of another report. Note the reduction in the amplitude swings towards 1GHz due to the increased chamber dimension. This effect using with small biconicals is not seen when using the more typical log periodic antennas at the same frequencies. The **transmit antenna type** is a small biconical antenna PBA 3100. The total antenna length is 26 cm. The balun symmetry is better than 0.2° in phase and 0.2 dB in amplitude. It allows for higher precision by being electrically smaller than the more typical biconicals that are >1m in dimension. **Uncertainties:** The calibration procedure for site reference measurements has an uncertainty of ± 1.5 dB on the free space test site. The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor $k = 2$, which for a normal distribution corresponds to a coverage probability of approximately 95%. These uncertainties include also the contribution of the calibration site. For calibrations on the OATS and with the ferrite tiles the uncertainty was not evaluated. Finally the **antenna cables** have a significant influence on the test results. To reduce it the following measures have to be taken: Use well balanced antennas, use cables with ferrite beads, and route the cables horizontally behind the antenna as long as possible.

5. Conclusion

This paper has presented results that highlight several aspects of the draft standard that suggest modification will be required.

Firstly, the requirement for the receive antenna to remain in a fixed position increases the difficulty of the test since the test distance at the back of the turntable is greater than that at the front making a 3m measurement into a 4 to 5m measurement.

Secondly the antenna calibration according to the site reference method has a significant impact on the chamber NSA and must be simplified.

Finally measurements performed in a 3m SAC, that performed to better than +/-3dB according to EN 50147-2, have shown that 3m SACs cannot pass the current requirements.

All this indicates that the compliance criteria for FAR measurements as defined by pr EN 50147-3 will probably not lead to the less expensive test facilities predicted as long as the standard stays in its present form.

Our recommendations in the light of the tests, and in order to help these methods evolve, are as follows:

1. Use a constant separation between antennas during chamber validation.
2. Allow adjustment of the antennas to point at each other
3. 1 and 2 will make the calibration of the antennas (site reference) much easier and cheaper.
4. The correct limit for accepting a FAR should be taken from a practical aspect: A fully compliant SAC (± 4 dB) should be able to be modified by using good quality floor absorber to a fully compliant FAR.

At the time of writing prEN50147-3 is under review at national committee and its future development is unknown. Any such developments will be reported.

6. References

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