Conversion of Semi to Fully Anechoic Rooms per CENELEC prEN50147-3

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1. Abstract

Many small to medium sized EMC anechoic chambers today are built as Fully-Anechoic Rooms (FAR). The current draft prEN50147-3 standard by CENELEC TC210A/WG4 defines FAR validation and product measurement methods. The feasibility of converting a standard full-sized 3m Semi-Anechoic Room (SAR) to a compliant FAR is examined in this paper.

2. Introduction

The use of Fully Anechoic Rooms (FAR) as an alternative site to Semi-Anechoic Rooms (SAR) for Radiated Emission measurements has been a topic of discussion amongst EMC engineers for some time [1][2][3][4]. In Europe the CENELEC TC210A Working Group 4 has been developing a standard prEN 50147-3[5] since 1995 as an alternative to the EN 50147-2[6] standard written for SARs. The latest version of prEN50147-3, Jan.2000 was submitted to CENELEC national committees for comment and a modified draft is expected at the time of writing. The document defines a chamber validation method, an antenna calibration method for site validation and product measurement methods.

At the same time a European Union funded project [7] was conducted from January 1997 to January 1999 by a group of European laboratories. This work included a number of round robin tests. The aim was to develop an alternative to the standard CISPR site. Similar agreement was found between 10m OATS and a FAR for 5 test houses. Although one of the initial ideas was also that FARs be “smaller and relatively inexpensive” this concept has been better identified as a comparison between 3m FAR and 10 OATS/SARs. 3m FARs clearly do now have better reproducibility than 3m SARs/OATS and compare to 10m SARs/OATS. However, as this paper shows a compliant FAR must be almost the same size as a compliant SAC and with the added cost of extra anechoic material coverage on the floor. In addition, EUTs larger than 1.5m will probably need a larger test distance and FAR.

At IEC/CISPR level CISPR/A/WG2 has begun work on introducing Fully Anechoic emission measurements to CISPR 16-1 [8], with the current document based on the current draft of the prEN50147-3.

The need for experience in performing measurements in such a configuration is high as well as a clear indication as to what size chamber will pass the prEN50147-3 validation criteria. Some results have already been presented in other papers [9]. Here we present measurements according to prEN50147-3 taken in a fully compliant SAR, Fig.1, with FCC site classification converted to a FAR by covering the whole floor with ferrite panels.

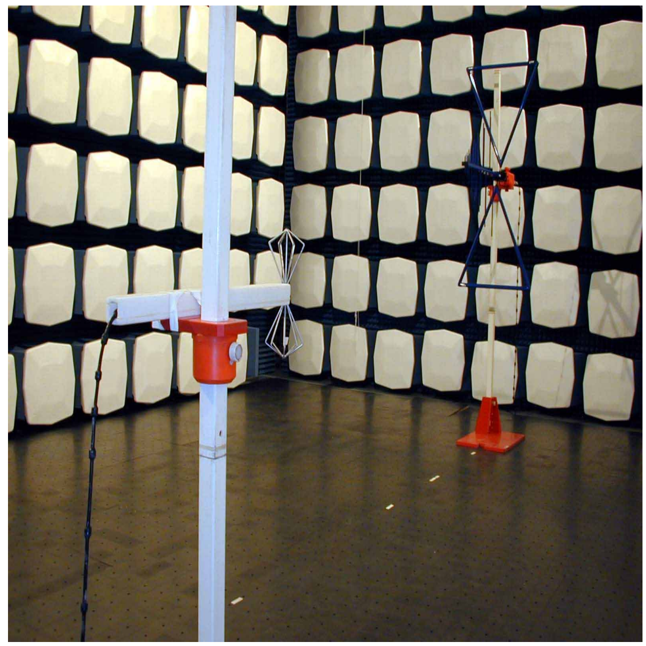

Fig.1 prEN50147-3 chamber validation in converted SAR

3. Background

There are two main factors driving the development of FARs as an alternative test site.

Firstly, from a practical point of view, SARs require the movement of absorber in and out when converting from Radiated Immunity to Radiated Emission measurements, this is obviously time consuming and reduces the efficiency of a test laboratory.

Secondly, from a theoretical point of view, it has long been recognized that the use of a ground plane in OATS/SARs introduces an error for horizontal measurements below 70MHz.This is due to the fact that it is impossible to achieve in-phase direct and ground reflected signals in order to achieve a maximum signal when scanning from 1 to 4m . (Any additional increase in scan height increases the test distance further so the test is no longer a 3 or 10m test). This is caused by the 180º phase change on the ground reflected signal for horizontal polarization which is not present for vertical polarization. For 10m measurements this means the signal is 13dB lower and for 3m measurements it is 9dB lower. However, the emission limits are the same for both horizontal and vertical polarizations. This problem is corrected in the FAR by the elimination of the ground reflected signal.

4. prEN 50147-3

The chamber validation method prescribes a volumetric test method with 15 positions measured within a cylinder comprising 3 planes: Lower, Middle and Upper ; 5 positions in each plane Front, Left, Centre, Right and Rear and for each polarization Horizontal and Vertical ,Fig 2.The receive antenna (RX) 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 (TX) 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.

Prior to the chamber validation the two antennas to be used must be calibrated according to Annexe A of prEN50147-3 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.

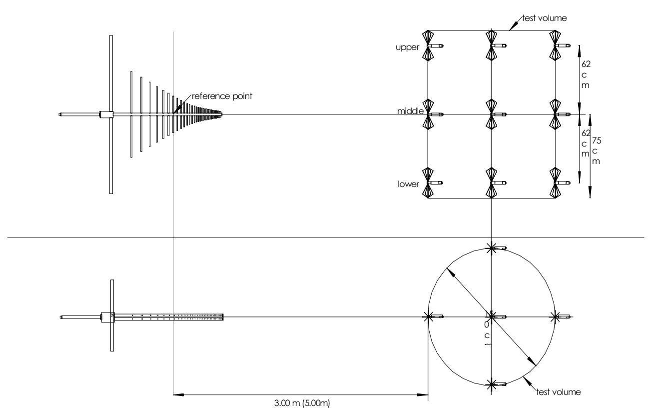

Fig.2 prEN50147-3 Volumetric test

5. Discussion on test distance

The method described in the previous section has been designed to overcome some of the deficiencies of EN50147-2 where the receive antenna is artificially moved horizontally during the site evaluation but not during the emission measurement. Also the receive antenna is pointed at the transmit antenna during site evaluation which does not happen during the emission test. In addition, this method is faster to carry out than the standard volumetric NSA test as a result of not having to move RX and can be done in as little time as 90 minutes if both antennas can cover 30-1000MHz .

However, prEN50147-3 antenna calibration is too complex. A multitude of geometries must be measured in order to obtain antenna factors for each position (due to variable distance) in the test volume. In addition antenna calibration almost becomes chamber specific if test volume dimensions vary from chamber to chamber. Also as a result of the fixed RX position , Fig 3, the Rear position for a 3m distance becomes a 4.2m test for a 1.2m diameter test volume and this Rear position has been observed to be the worst case measurement in all measurements .The use of a combination antenna (Biconical and Log periodic sections combined) can further increase this test distance by half the antenna length which is typically 60 to 90cm and therefore not insignificant at 3m test distances .As a consequence a number of distance related compromises have come under discussion .

Firstly , and in line with NSA volumetric described in EN 50147-2 the Rear position may be omitted as this has little meaning to EUT emission tests . A condition could be that the Rear position be at least 1 m from the surface of the absorber and that it may be measured but not included in the final acceptance conformance criteria of the chamber.

Notwithstanding the proposed adaptations to the current method an alternative involving a fixed test distance, Fig 4, is also under discussion. This alternative requires that the TX and RX separation remains constant during chamber validation. Although the front position remains the reference position the geometry of the test is therefore similar to the volumetric NSA of EN 50147-2. The consequences of adopting the fixed distance method would be that one antenna factor would be required thus reducing calibration time. Also, since the antenna factor is derived with a unique configuration it will be necessary to reproduce this during chamber validation and therefore TX and RX will be allowed to point at each other.

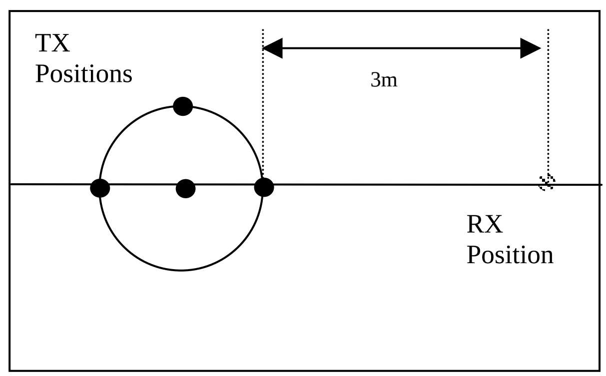

Fig.3 prEN50147-3 Geometry

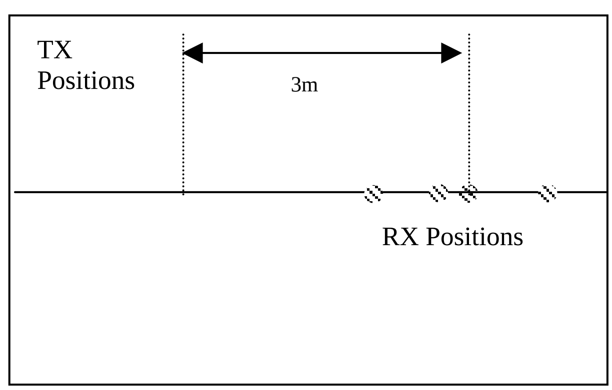

Fig.4 Fixed Distance Geometry

6. Investigations

Under the assumption that a compliant 3m SAR should be able to fulfill the requirements of the current criteria a suitable chamber was identified. The chamber in question was a full sized (1-4m height scan) SAR of dimensions 8.5 x 6.1 x 6.1 meters (L x W x H) and had been validated according to EN 50147-2/ANSI C63.4 NSA to better than ±2.3dB and is also a registered FCC 3m site .It is currently being used as a type approval facility. The walls and ceiling are lined with Hybrid (Ferrite tile/Foam) material and the floor has removable hybrid absorbers on carts for performing Radiated Immunity tests. The chamber was initially tested according to prEN50147-3 using the partial floor configuration as shown in Fig 5. The results in Figs 9,10 show that this basic set up is non-compliant.

For the conversion to FAR mode it was decided to completely cover the ground plane with ferrite tiles. Arrangements were made for the installation of some 120 600 x 600mm ferrite panels, each weighing about 12Kg, on top of the existing ground plane. This operation took about 2 hours with 3 people and was very tiring. It is difficult to imagine carrying out such an operation on a regular basis and we would recommend that any future conversions of SARs remain permanent.

Once the chamber floor was ready , Fig.1 , the aim was to simply carry out measurements in different positions of the chamber either by modifying the position of the test volume with respect to the walls or by modifying the height of the test volume . If compliant data was not achieved with these measurements it was envisaged that additional tuning devices may be used to improve initial performance. In SARs this generally involves the use of extra materials along the side walls at floor level but FARs are generally more sensitive to different materials in different areas but as we shall see this was not actually required.

Previous experience had shown that size of chamber and proximity of the antenna to the walls were the key parameters, and possibly the only ones, in determining final performance. Therefore with the chamber already fixed the only means of getting optimum performance is by looking for the best position. For SARs this philosophy is very common and often results in the measurements axis being slightly diagonal across or OFF-AXIS in the chamber, the center axis often being the worst possible position due to symmetry. To some extent this effect can be attributed to antenna absorber coupling in smaller chambers but in most cases the asymmetry clearly improves the performance from the center axis .The use of the smaller biconical will reduce this effect. However, it has also introduced other issues such as very high antenna factor which use the total dynamic range of the receivers available. Also the lack of directivity above 200MHz as compared to the more typically used Log Periodic (LPDA) antennas has unmasked chamber effects previously hidden by the LPDA's directivity.

Optimization techniques used in SARs only use two dimensions by repositioning the antennas around the floor, in FARs we have 3 dimensions to use and this was the basis of the measurements we will now report.

Initial measurements according to prEN-50147-3 were carried out along the center line of the chamber, Fig.6 , with the middle of the test volume set at 1.65m and a test volume of 1.5m wide and 1.5m high . The results for horizontal and vertical polarization at 3m are given in Fig.11 and 12 respectively. The whole set-up was then moved off axis, Fig.7, and the measurements repeated . The results for horizontal and vertical polarization at 3m are given in Figs. 13 and 14 respectively.

We then elevated the middle of the test volume to a height of 2.4m. The results for horizontal and vertical polarization at 3m are given in Figs. 17 and 18 respectively.

Finally, additional measurements with fixed distance between antennas, Fig.8, were carried out at 1.65m and 2.4m and the results for horizontal and vertical polarization at 3m are given in Figs.15 and 16 (1.65m) and 19 and 20 (2.4m) respectively.

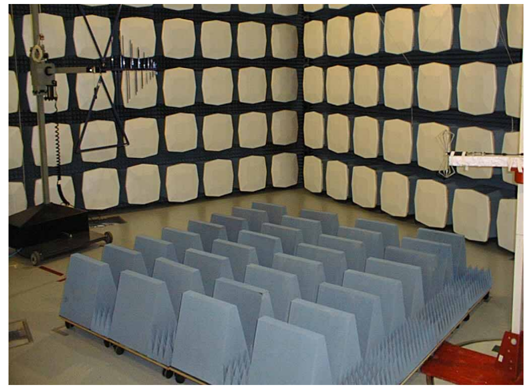

Fig.5 prEN 50147-3 in SAC - partial floor absorbers

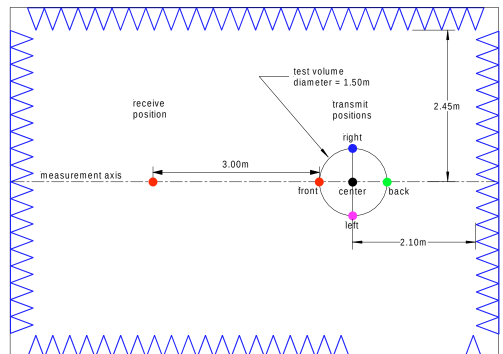

Fig.6 prEN 50147-3 in SAC On Axis - full ferrite floor

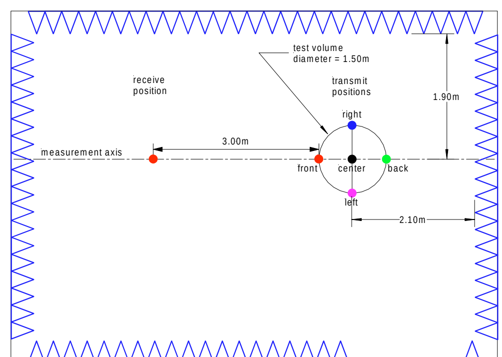

Fig.7 prEN 50147-3 in SAC Off Axis - full ferrite floor

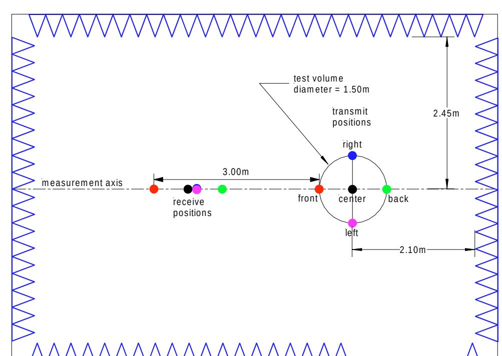

Fig.8 Fixed Distance 3 in SAC On Axis - full ferrite floor

7. Results

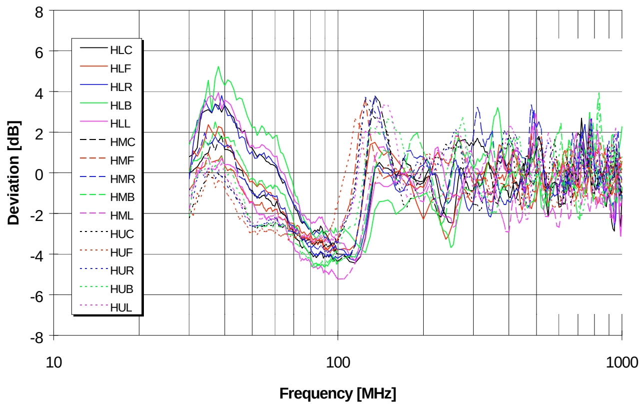

Fig. 9 SAC h=1.65m Horizontal 3m prEN50147-3

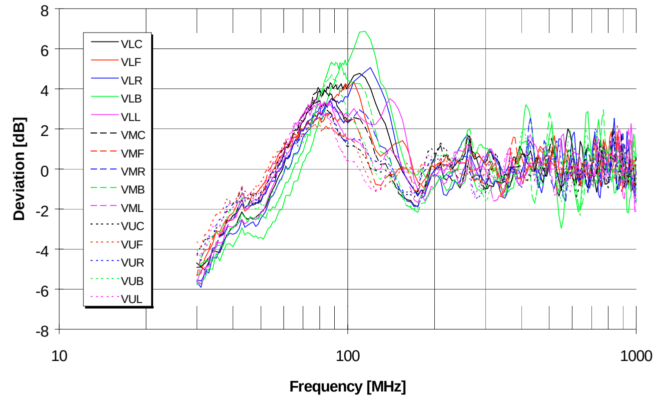

Fig.10 SAC h=1.65m Vertical 3m prEN50147-3

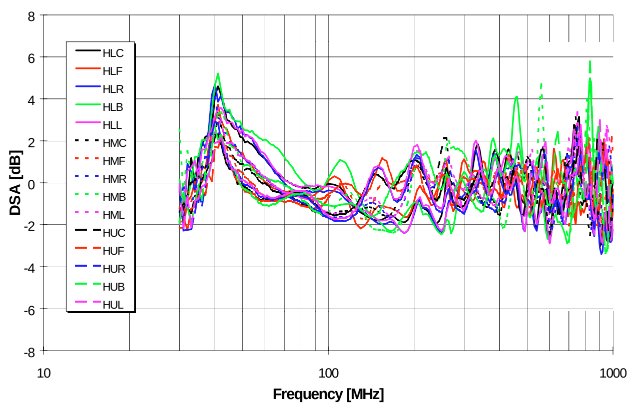

Fig.11 IN AXIS h=1.65m Horizontal 3m prEN50147-3

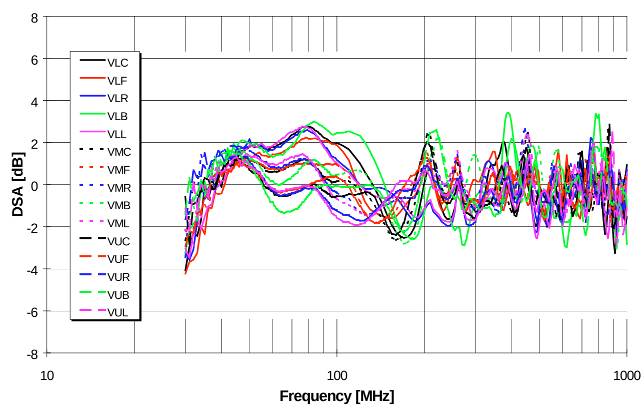

Fig.12 IN AXIS h=1.65m Vertical 3m prEN50147-3

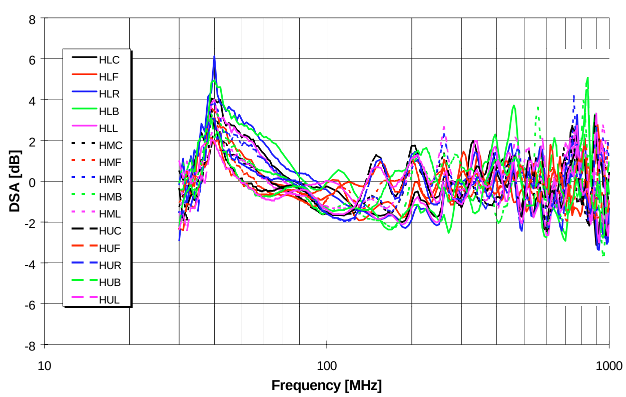

Fig.13 OFF AXIS h=1.65m Horizontal 3m prEN50147-3

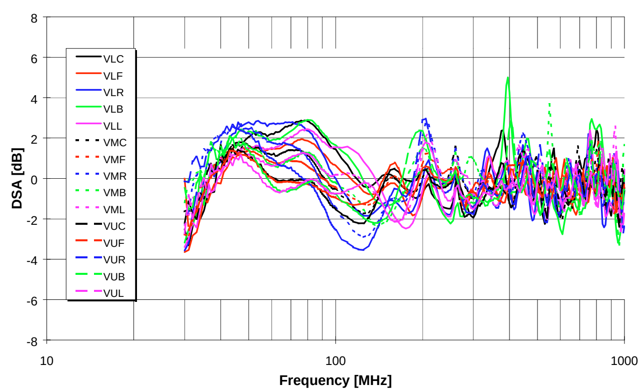

Fig.14 OFF AXIS h=1.65m Vertical 3m prEN50147-3

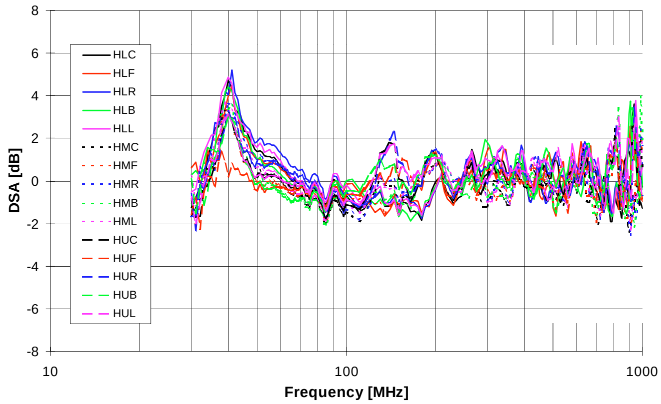

Fig.15 ON AXIS h=1.65m Horizontal 3m FIXED DISTANCE

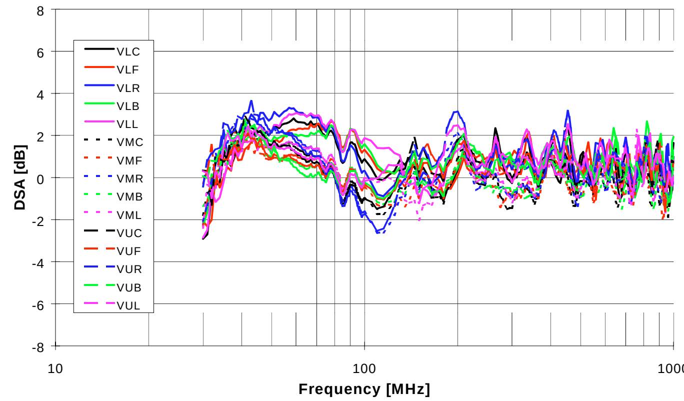

Fig.16 ON AXIS h=1.65m Vertical 3m FIXED DISTANCE

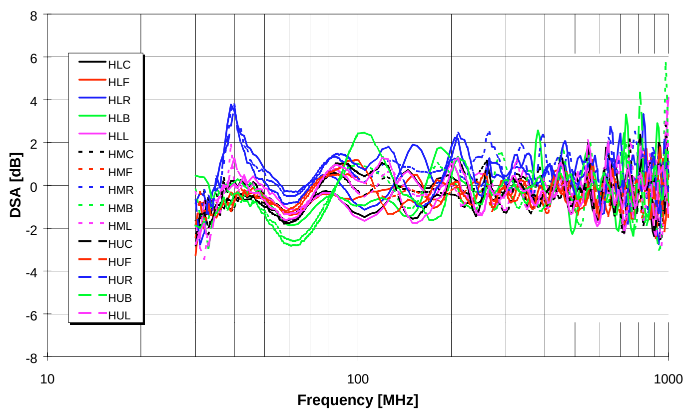

Fig.17 ON AXIS h=2.4m Horizontal 3m prEN50147-3

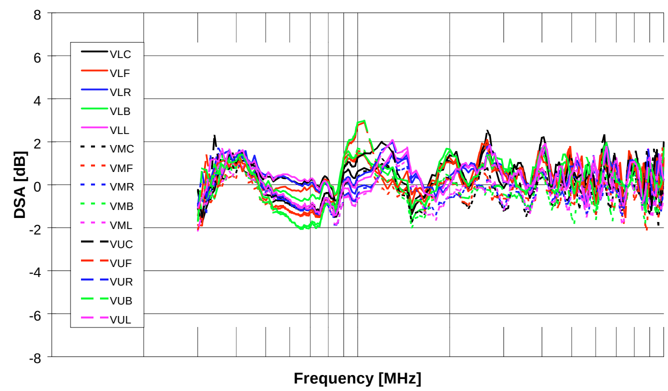

Fig.18 ON AXIS h=2.4m Vertical 3m prEN50147-3

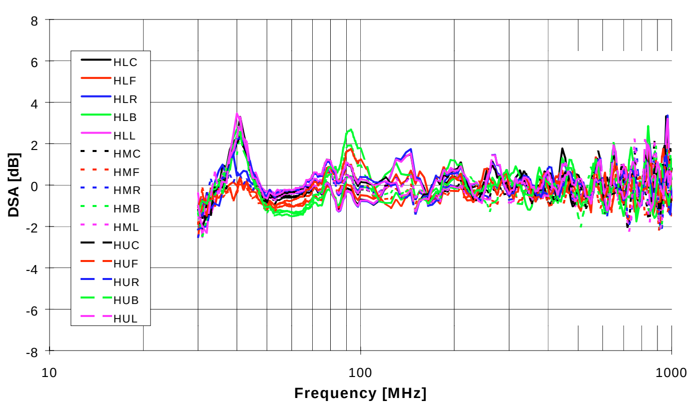

Fig.19 ON AXIS h=2.4m Horizontal 3m FIXED DISTANCE

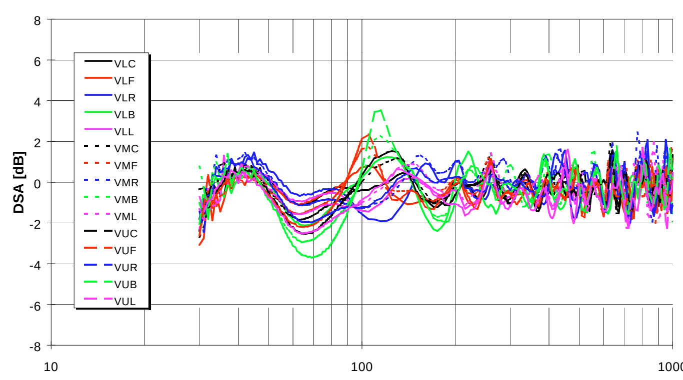

Fig.20 ON AXIS h=2.4m Vertical 3m FIXED DISTANCE

8. Analysis of results

The results given in section 7 show a sequence of measurements where the aim was to find compliant results in the chamber. The assumption being that chambers with such dimensions should be able to pass the ±4dB criteria of prEN50147-3:2000.

At 1.65m height, a typical floor level set-up, the lower plane performed worse than the middle plane and the top plane was better than the middle plane. Also the results off axis were worse than on axis. By moving to a position almost centered both in width and height the optimum position was found. It would thus seem that unlike SARs no advantage is to be gained by moving off axis. It could also be concluded that the weakest point of a FAR is the smallest cross-section dimension, or in other words it is important to make the width and height equal otherwise the smaller of the two will dictate final performance.

According to the prEN50147-3 measurements the Rear position remained non-compliant in this chamber and this is probably due to the proximity of the rear wall absorbers to the antenna. The equivalent measurement using fixed distance showed compliant performance. Depending on which test distance rule is adopted both sets of measurements show compliance and this confirms the assumption that at least such sized chambers are able to fulfill the requirements of prEN50147-3:2000. The practicalities of carrying out such conversions are clear, and here we have only installed ferrite panels without the hybrid foam for higher frequency performance. Future work will investigate measurements above 1GHz and the practical issues of having Hybrid absorber of between 400 and 1000mm on the floor.

Until now we have only concerned ourselves with the chamber validation. The consequences of our findings above however must now take into account the practicalities of carrying out product testing under such conditions.

Clearly having to setup EUTs at a height of 2m to 3m is not as easy as setting them up on top of a turntable at floor level. For some laboratories testing small devices such as mobile phones this is not going to be too difficult. However for larger objects and in particular floor standing equipment this will be an issue that requires more thought. In addition, floor standing equipment typically requires a test volume diameter of 2 to 3m which is not suitable for 3m testing. Such EUTs will therefore still require a larger facility and will face the additional problem of positioning at half chamber height.The most simple solution will be to use a raised floor at say 1.5m height either over the whole floor area or a limited area between the main door and turntable. Some chambers in Europe already have such floors in anticipation of the new requirements. They have also set the general floor level inside and outside and access at this height. Inside the chamber, the compromise between RF and mechanical needs will be an issue in many designs. In chambers where a raised floor has been installed wood appears to be a common material but this has been found to pose problems above 600MHz. Better solutions using walkway type absorbers that contain materials such as polystyrene with a dielectric constant close to unity may be a possibility. Since such materials have limited load capacities it may be necessary to distribute the load through the use of a removable wooden area.

Finally, we also acknowledge that the important issue of cabling has not been discussed here but although such issues are not part of the scope of this paper they should clearly be addressed in any future work aiming to make the use of FARs for compliance testing a serious option.

9. Conclusion

We have presented measurements that discuss the requirement that the correct limit for accepting a FAR should be taken from a practical aspect: a fully compliant / full sized SAR (± 4 dB) should be able to be modified by using good quality floor absorber into a fully compliant FAR. The measurements demonstrate that such a conversion is compliant, with slightly better results using the alternative fixed antenna separation as compared to the current prEN50147-3 method using variable separation. Whilst at the time of writing the fixed or variable separation debate has not been decided it is now possible to show that a standard full-sized full 3m SAR can comply with the current draft if converted. Existing or new facilities should find this information of benefit when evaluating any future upgrades to FAR compliance. Practical issues have been discussed as a consequence of the findings and many of these remain unresolved, in particular the testing of large floor standing EUTs.

Progress is anticipated between the time of writing and the presentation of the paper and this will be reported during the presentation.

10. Acknowledgements

Mr. Gerhard Kolb of the Austrian Research Center , Seibersdorf , Austria is thanked for carrying out the measurements. The engineers responsible for this chamber are thanked for their cooperation during the testing.

11. References

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