Multi-Purpose Anechoic Chambers - EMC (SAR/FAR) to Antenna Measurements

Martin A.K. Wiles B.Sc.(Hons), M.Sc.[1], Dipl. Ing. Alexander Kriz[2]

[1]ETS-Lindgren, Stevenage, SG1 4TH, Hertfordshire, United Kingdom, Martin.Wiles2@ets-lindgren.com
[2]ARC Seibersdorf research GmbH, A-2444 Seibersdorf, Austria, Alexander.Kriz@arcs.ac.at

Abstract — **In recent years there has been considerable progress in standardization within the Consumer Electronics, Automotive, Aero-space, Military, Medical and Telecom industries. As a result anechoic chambers today can be required to conform today to a variety of different published EMC standards. In many cases the standards are so similar that the chamber does not require a set up change, in others this may require a substantial set up change. This paper looks at how a typical 3 m semi-anechoic chamber (SAR 3) manages to respond to this demand and remain versatile. The direction of some of the current standards that might influence further this chamber in the future will also be discussed.**

I. Introduction

Many EMC test laboratories require their facilities to be fully compliant with as many possible EMC standards in order to offer as many tests as possible.

The most common test facilities can be a compact chamber (Inner dimension 7 m by 3 m by 3 m) which can be fully compliant to Radiated Immunity tests, or the 3 m semi-anechoic chamber (Inner dimension 9 m by 6 m by 6 m) which is fully compliant to Radiated Immunity and Emissions. Standard validation methods can be separated into two frequency ranges:

Below 1 GHz:

- EN 50147-2 1996 [1]
  Normalized Site attenuation 30 MHz - 1000 MHz
- IEC 61000.4.3-2002 [2]
  Field Uniformity 80 MHz -1000 MHz

Above 1 GHz:

- Free Space Tranmission Loss 1 GHz – 18 GHz at 3 m, Loosely based on EN 50147-2 1996
- IEC 61000.4.3-2002 Field Uniformity

In recent years CISPR/A has been working on developing alternative techniques for measurements below 1 GHz as well as above 1 GHz. Firstly the concept of FARs (Fully Anechoic Rooms) as an alternative to Semi-anechoic chambers (SARs) has been discussed over many years [3]-[8]. The method was approved within CISPR in March 2004 and will be published as an amendment to CISPR 16-1-4 by the time this paper is presented. Above 1 GHz CISPR/A is discussing a number of different measurement techniques [9]-[10].

The automotive industry [11]-[13] requirements today can be divided into large or medium size facilities but there is an increasing trend to allow them to comply also with Telecom requirements due to the commonality of accessory equipment pushing the R&TTE directive [14] by E.T.S.I. (European Telecom Standards Institute) to develop automotive/telecom standards approach. Automotive EMC tests are mainly in SARs whereas many Telecom requirements are FAR. Finding a solution to suit both can be difficult especially if the load requirement on the chamber floor is at the vehicle level.

Fig. 1. The SAR3 during FU measurements <1GHz

Whilst some of the standards currently under the R&TTE directive will refer to common standards such as CISPR 22 [15] and the IEC 61000.4 series there are also other standards that require additional measurements such as spurious emissions [16]-[18]. Many of the Telecom groups with facilities are required to perform many of their tests in the same chamber where possible due to space and budget problems. In this case it can be required to also have the capability of performing antenna pattern type tests. Again this will require a minimum transformation of the chamber, this will be discussed later.

II. Discussion

In the following sections we describe how the chamber can be used for EMC measurements above and below 1 GHz and then converted into an antenna measurement chamber.

A. Radiated Measurements < 1 GHz SAR

The baseline SAR 3 chamber has fixed ferrite hybrid absorbers on all walls and ceiling and a ground plane floor. For practical reasons we are also keeping the 16 pieces of floor absorbers used for the radiated immunity

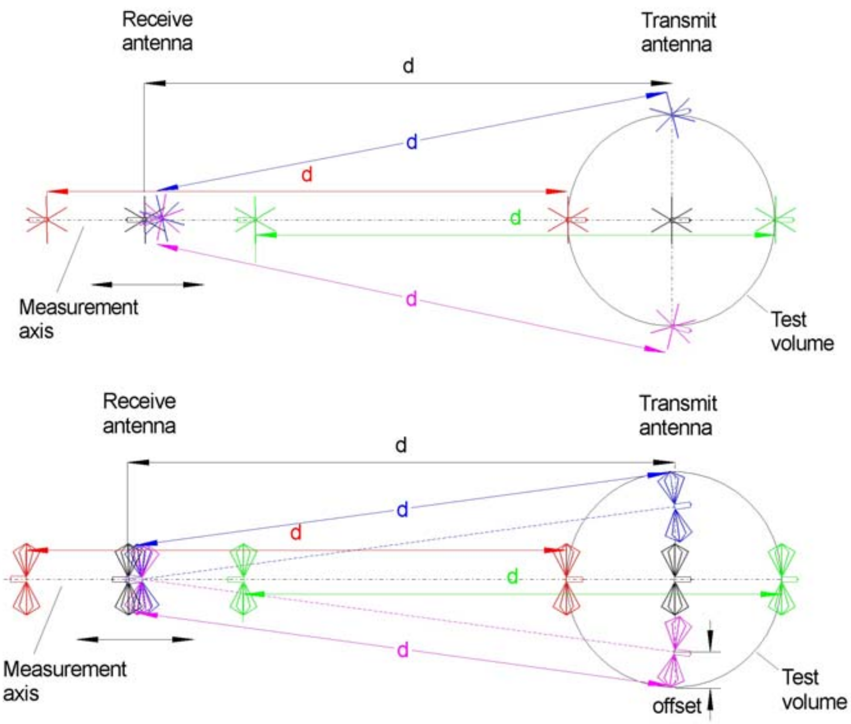

Fig. 2. The NSA measurements set-up < 1 GHz

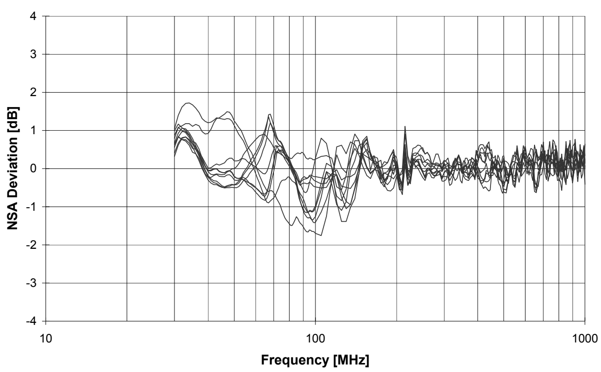

Fig. 3. NSA measurements < 1 GHz, horizontal polarization

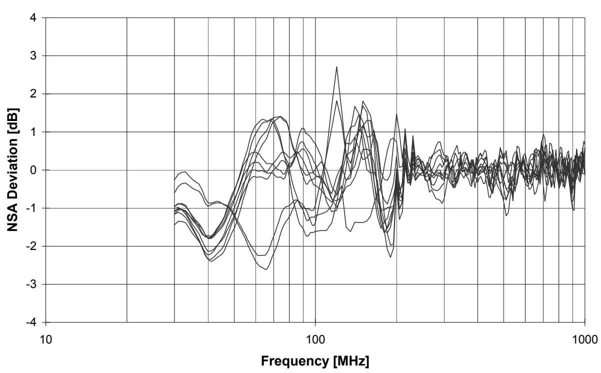

Fig. 4. NSA measurements < 1 GHz, vertical polarization

tests along the sides. The SAR design is based on meeting the Normalized Site Attenuation requirements according to EN 50147-2 at 3 m and for a quiet zone of 2 m diameter, Fig. 2. Sufficient floor space must be left to perform this measurement with an antenna mast on the RX side and cable lengths of at least 1 m behind the antennas. Sufficient height must be used to allow a full 4 m scan especially if FCC filing is required as this is mandatory. The results of this measurement shown in Fig. 3 and Fig. 4 demonstrate the chambers compliance with the 30 MHz – 200 MHz frequency range being the more stringent. This test is a well established method and 3-meter chambers (SAR 3) or becoming common place these days.

B. Radiated Measurements < 1 GHz FAR

As of March 2004 the FAR measurement method within the CISPR/A group has been approved. This means that there is a normative document describing how to validate fully lined chambers FARs. This has been the subject of much debate in recent years. None the least because it poses a problem for existing chambers and whether or not they can be used in the future. CISPR/A/499/FDIS discusses a site validation method as described in Fig. 7. Essentially the basic idea of the validation tests does not vary a great deal from the NSA measurement described in EN 50147-2, or similar documents such as CISPR 16, CISPR 22, ANSI C63.4-2002. A volumetric test is performed with the TX antenna positioned at various points within the quiet zone and the RX antenna positioned at a 3 m distance away from it. The result is shown in Fig. 5 and Fig. 6.

A single pair of antennas is calibrated as a pair on a free field site over the whole frequency range of 30 MHz – 1000 MHz. The particularity of this test is that the TX antenna is a mini-biconical of maximum dimension 40 cm. The RX antenna is typically a larger combination antenna which should be subsequently used for the product testing. Over the course of the discussions either previously at CENELEC or now at CISPR/A the method has changed very little apart from the latest requirement to tilt the antennas towards each other. This is relatively impractical to do during testing. The transition from SAR 3 to a FAR 3 has been carried out by lining the floor with removeable ferrite panels, an operation that can be carried out within 30 minutes. These ferrite panels also have a special cut over the turntable to allow it to be used.

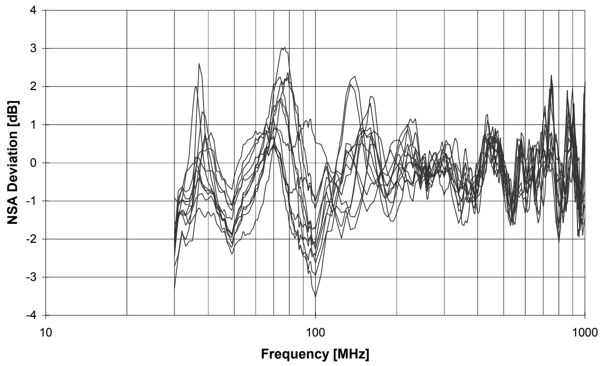

Fig. 5. FSNSA measurements < 1 GHz, horizontal polarization

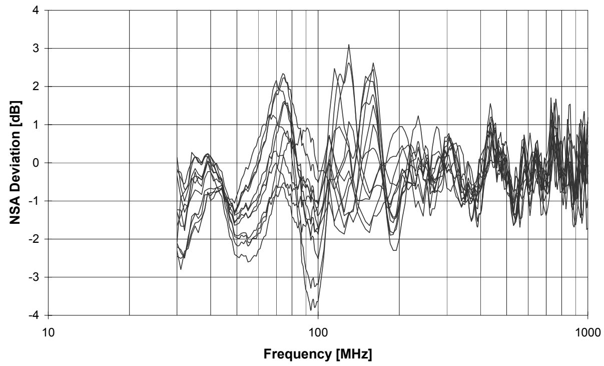

Fig. 6. FSNSA measurements < 1 GHz, vertical polarization

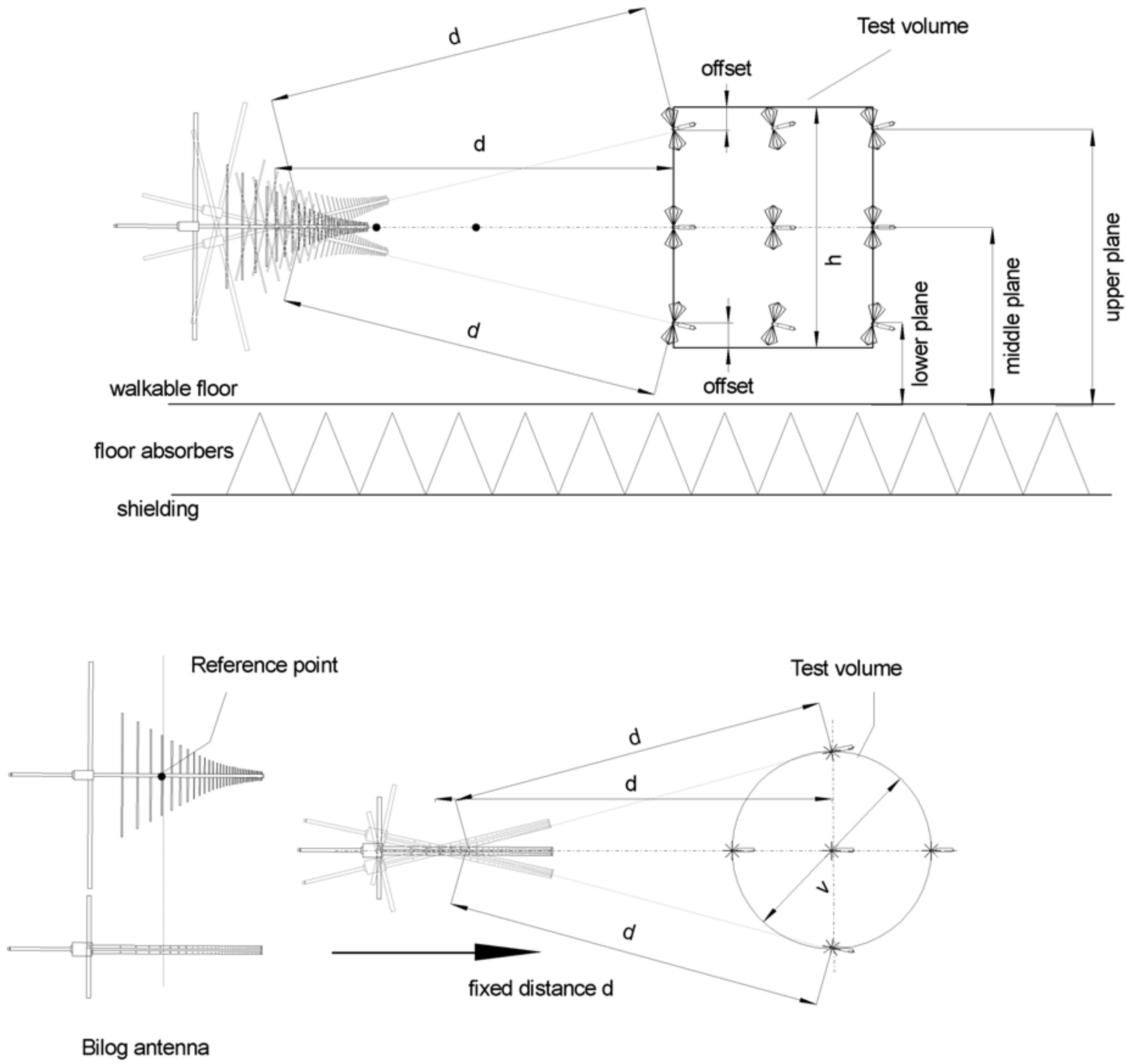

Fig. 7. The FSNSA measurements set-up < 1 GHz

Since the NSA test was performed using an offset position the so called FSNSA (Free Space NSA) measurements were also carried out in this position and were compliant with the ± 4 dB criteria using a mid-plane height of 2 m. Whilst the need to position the EUT at a height may be impractical, and for floor standing equipment this will obviously remain an issue, for most EUTs this can be overcome using transparent blocks of Styrofoam/Polystyrene.

C. Radiated Immunity 80 MHz – 1 GHz

According to IEC 61000.4.3-2002 the SAR 3 is converted for Radiated Immunity measurement below 1 GHz by positioning a set of 16 floor absorbers between the antenna and the probe positions defining the measurement test plane d = 3 meters away, Fig. 8. Since the floor absorbers are already in the chamber this set up change can take only 5 minutes. A SAR 3 can typically achieve 100 % within 0 dB to + 6 dB due to its size with only the 16 absorbers on the floor, Fig. 9.

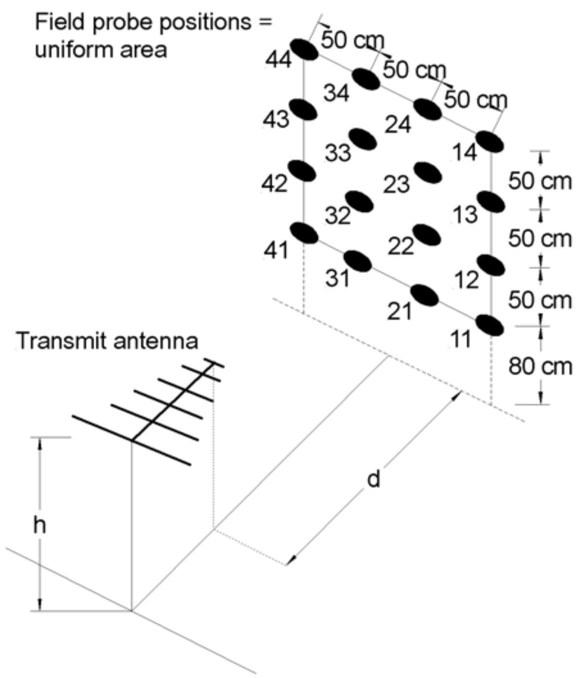

Fig. 8. Field uniformity measurement set up

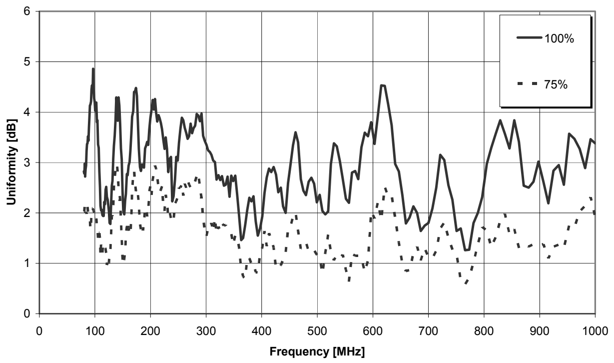

Fig. 9. Field Uniformity measurements < 1 GHz, horizontal polarization

D. Radiated Immunity > 1 GHz

With the 16 hybrid absorber on floor carts already in place for measurements < 1 GHz no change is required above 1 GHz. Results from the SAR 3 are shown in Fig. 10.

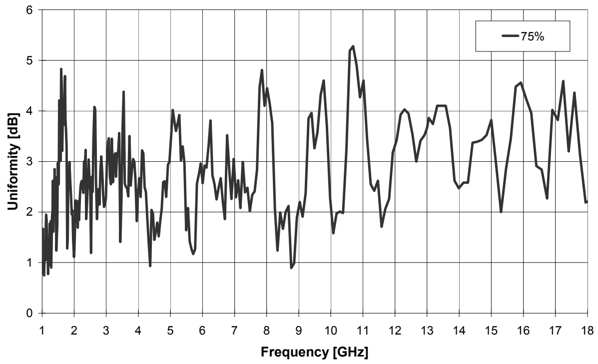

Fig. 10. Field Uniformity measurements > 1 GHz, horizontal polarization

The annex A of the IEC 61000.4.3-2002 document allows for the use of windows – multiple transmit antenna positions but the SAR 3 is large enough to not require this provided that broad beam-width antennas are used. More than one antenna may be required to cover this frequency band as well as several amplifiers. Work on methods > 1 GHz is continuing but not considered to require changes to chambers such as SAR 3s.

E. Radiated Emission > 1 GHz

Above 1 GHz the world looks completely different with nearly all components used in the evaluation process showing a divergent behavior in the frequency range from 1 GHz to 18 GHz.

The most widely used antennas in this range are double ridged horn antennas and log-periodic antennas. Usually the log-periodic antennas above 1 GHz are more directive than their counterparts for lower frequencies. Also remarkable is the unpleasant frequency response of the gain, which leads to an increased measurement uncertainty. Horn antennas have a better frequency response in many cases, but there are other difficulties with them like the pattern degeneration at the end of the frequency band. Finally each antenna type working in this frequency range have some disadvantages, but one has to keep in mind that they are working in a band of more than five octaves.

Flexible coaxial RF-cables above 1 GHz cause troubles many times. Cables with a dielectric made from foamed PE or PTFE are very sensitive to mechanical stress and are worn very quickly in a “rough” environment like an anechoic chamber. But the use of foamed dielectrics is absolutely necessary to keep the insertion loss low. Another characteristic is the change of insertion loss with flexure, which can amount some tenth of a dB.

There are very few standards available which deal with the validation of anechoic chambers above 1 GHz. The most common and widely known test technique is called

Transmission Loss. This technique is based on the NSA measurements from EN 50147-2. It is used to validate fully anechoic chambers by all well-known providers of EMC chamber.

In the Transmission Loss technique bore sighted antennas are used having been calibrated as a pair for their free space antenna factor. They are placed at certain points in the test volume as per EN 50147-2. The Transmission Loss is measured and the Normalized Site Transmission Loss is calculated with the help of antenna factors. Physically the chamber set up is the same as the Radiated Immunity > 1 GHz. The results from the SAR 3 are shown in Fig. 11.

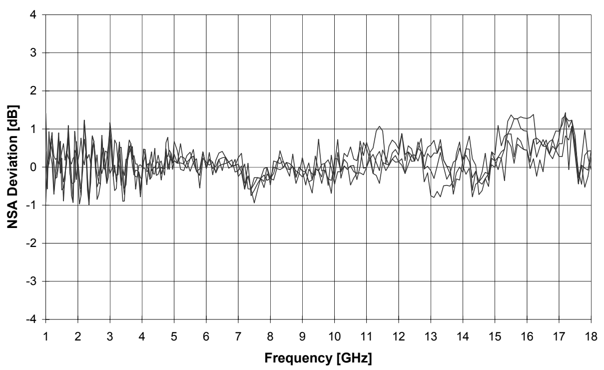

Fig. 11. Transmission Loss measurements > 1 GHz, horizontal polarization

Although this test is commonly practiced in chambers worldwide today (with the exception of the US which has its own version of the NSA measurement above 1 GHz) it is widely accepted that the test tells little about the chamber and more about the system uncertainty, as the results above indicate. It has also been argued that the use of directive antennas will not provide a true idea of what the chamber is really doing when a real high frequency emission source is tested. As a result, the experts in CISPR/A are currently working toward a new standard for measurements above 1 GHz [9]. Many different ideas are being discussed at the moment and at the time of writing a 6th draft had been tabled. Lack of data to corroborate the methods is hindering the finalization of this document. It is also widely believed that the new method would require many existing chambers to be upgraded to full hybrid coverage where they only had an existing partial treatment before. Furthermore, there is a conflict of goals in the evolution process, where many objectives have to be taken into consideration. At this point an estimation of the final result can not be given. Also relying on one of the committee drafts is not a good advice. And summarizing it is common practice at the moment to continue with the Transmission Loss measurement as described above.

F. Antenna measurements

There is a demand to perform free space measurements either for spurious emission [18] or antenna measurement and it is highest within the Telecoms market. Whilst the ideal choice would be to use a dedicated chamber separate to the main EMC facility we will demonstrate here that it is possible to modify the original SAR 3 to accommodate such tests.

To perform free space tests a major change in the floor set up is required, but how much will depend on the frequency range of interest. We will describe the setup for spurious emission (30 MHz - 12.75 GHz) at a later date and concentrate here on the conversion of the SAR 3 to an antenna measurement chamber from 400 MHz – 18 GHz. This conversion was carried out by installing a removable microwave absorber inside the bounds of the fixed EMC absorbers on both the floor and partially on the walls.

For antenna pattern measurements the chamber validation technique is described in the "Free Space VSWR Method" [19]. Bistatic reflectivity is determined by measuring the magnitude of interfering signals entering the quiet zone which is centered on the chamber longitudinal axis. The illuminating antenna will be positioned from the center of the quiet zone at a specified distance (path length). The Free Space VSWR measurement technique of chamber evaluation is widely used by the RF anechoic industry because of its sensitivity and reliability. This method of reflectivity testing is capable of revealing reflections that are well below - 60 dB with respect to the direct energy beam. The Free Space VSWR measurement technique is a CW measurement typically performed at the bottom middle and upper frequencies of use and requires a probe antenna to scan laterally and longitudinally in the quiet zone, Fig. 12 and Fig. 13.

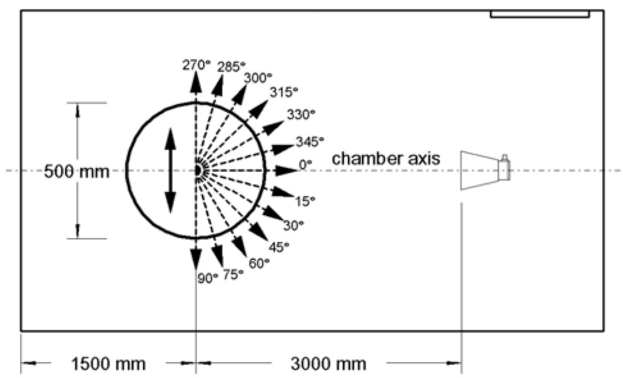

Fig. 12. Transverse measurement

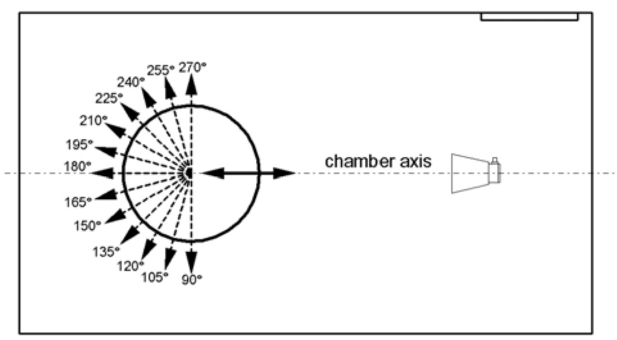

Fig. 13. Longitudinal measurement

From a practical point of view the absorber changeover typically takes about 1 hour for 2 people. In addition since the positioner requirements between EMC and antenna measurement are different it is necessary to install an antenna positioner on the chamber axis. For this it would be necessary to install a turntable (for azimuth axis) on the centre of the chamber in addition to the off center version and allow a capability for installing a removable elevation axis.

Once both the transverse and longitudinal measurements are completed it is possible to merge the measured data to form a complete polar pattern of the chamber reflectivity as shown in Fig. 14 for the lower and upper frequencies and for both polarizations. The data illustrates the chamber symmetry or asymmetry over a full rotation of the antenna and would allow offending reflecting objects to be identified at specific angles and removed if required. Antenna pattern measurement facilities typically require chamber reflectivity (ratio of reflected vs. direct power) levels 20 dB down from the main lobe of the antenna in order to provide enough discrimination between the main peaks and nulls of the antenna pattern. In reality a 40 dB requirement can be more typical as a 20 dB gain antenna would still need to be measured above noise floor and so an extra 10 dB - 15 dB is added to the required level. Given the rudimentary nature of this removable design the data presented in Fig. 14 demonstrates that the basic SAR can be used to provide sufficient accuracy for many typical antenna measurements albeit as a secondary function to the main use of the chamber.

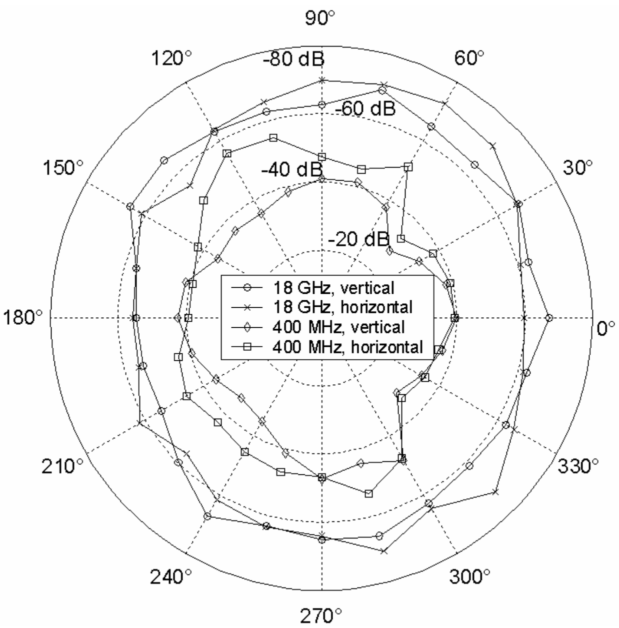

Fig. 14. Chamber reflectivity [dB] vs. Probe antenna angle [°]

III. Conclusion

The continued work on different measurement methods within existing EMC and other standards organizations requires greater versatility from existing or future anechoic chambers. The demand for such versatility is growing, this is a concern for many EMC test centers today, and this paper presents a number of ways of accommodating this growing demand. We have tested the ability of a SAR 3 (fully compliant FCC 3 - meter semi-anechoic chamber) to respond to the demands of a range of different measurements specified under current EMC standards. Two different EMC radiated emission measurement methods below 1 GHz are described together with the changes and different floor setup required. Radiated immunity tests are discussed below and above 1 GHz together with a more detailed discussion about up and coming radiated emission measurement methods above 1 GHz. Finally, antenna measurement methods have been described and a description given of how the chamber can be adapted to carry them out including the construction of a removable microwave chamber within the existing EMC chamber. The chamber has performed over and above the reuqirements of the methods. Other developments are anticipated by early 2005 [20]-[21] and these will also be presented.

Acknowledgements

Stefan Jagenbrein of ARC Seibersdorf research is thanked for his hard work during the course of this long series of tests.

References

[1] EN 50147-2, Anechoic Chambers Part 2, “Alternative test site suitability with respect to site attenuation”, CENELEC 1996
[2] IEC 61000.4.3 (2002-03), Consolidated Edition, “Electromagnetic Compatibility Part 4.3 Testing and measurement techniques radiated radio frequency electromagnetic field immunity test”.
[3] H. Garn, “Proposal for a new radiated emission test method using a completely absorber lined chamber without ground plane”, *9th Int. Symp. EMC*, Zurich, 1991, pp. 299-304.
[4] CENELEC report R110-003 “Guidelines on how to use anechoic enclosures that do not fulfill the requirements regarding normalised site attenuation for pre-compliance tests of products“, 1996.
[5] TR EN50147-3 / PD CR 210-010, CENELEC 2001
[6] CISPR/A/499/FDIS, Amendment CISPR16-1, “Alternative test site suitability without ground plane”, IEC/CISPR (2004)
[7] M. A. K. Wiles, W. Müllner, “Chamber Validation Measurements according to CENELEC prEN50147-3”. *Proc 14th Int. Symp. EMC Zurich 2001,* pp.475-480.
[8] M. A. K. Wiles, W. Müllner. “Conversion of Semi-to Fully anechoic rooms per pr EN 50147-3”.*Proc 14th Int. Symp. EMC Montreal 2001*
[9] CISPR/A/531/CD, “Site evaluation > 1GHz”, IEC/CISPR (2004)
[10] CISPR/A/504/CDV, “Measurement methods above 1GHz”, IEC/CISPR (2004)
[11] Automotive EMC Directive 95/54/ EC
[12] Automotive Directive 2002/2/EC
[13] M. A. K. Wiles, “An Overview of Automotive EMC Testing Facilities”, *AutoEMC Conference, Milton Keynes*, UK, Oct 2003.
[14] R&TTE Directive 1999/5/EC, OJEU (1999)
[15] CISPR 22, “Information technology equipment – Radio disturbance characteristics- limits and methods of measurement”, 1997-11
[16] DRAFT ETSI EN 301 489-1, V.1.5.1, ETSI (2003-12)
[17] TR 102 273 , “ERM Part 2: Anechoic Chambers”, ETSI (2001)
[18] 3GPP TS 34.124, V.5.4.0, ETSI/3GPP, (2004-03)
[19] IEEE Standard, “Test Procedures for Antennas”, IEEE.(1979)
[20] CISPR/A/482/CD, “Uniform measurement arrangement for emission and immunity testing”, IEC/CISPR (2004)
[21] CISPR/A/505/NP, “Emission and Immunity in FARs 30 MHz-18 GHz”, IEC/CISPR (2004)