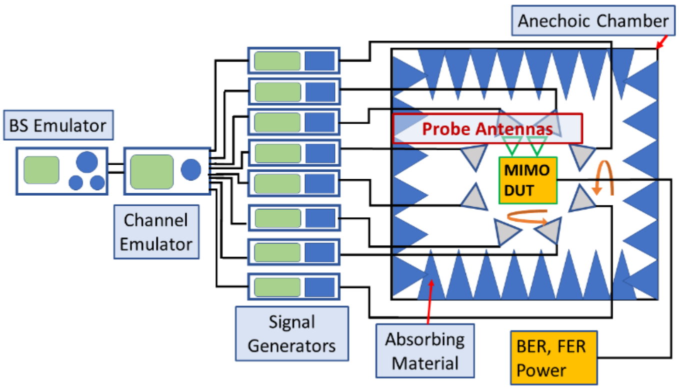
# MIMO OTA in Anechoic Chamber

## Introduction

Common systems in the modern engineering to be investigated are **multiple-input and multiple-output** (MIMO) systems. Quite often, the performances of such systems are verified solely through measurement since the electromagnetic (EM) simulations are rather complex. One of the investigation methods is to place two or more antennas inside of anechoic chamber and to investigate MIMO device under test (DUT). In this particular case, over-the-air (OTA) analysis will be used to determine system performance.




The **WIPL-D software suite** is the best candidate among the commercially available full-wave solvers for verifying such measurements via EM simulation. The reasons are numerous.

Since anechoic chambers are inherently electrically large in volume and surface, **Method of Moments (MoM)** codes (such as WIPL-D Pro) are very suitable for this type of simulations. In addition, WIPL-D state-of-the-art MoM implementation offers some unique **advantages for simulation of electrically large structures**. Namely, WIPL-D kernel uses quadrilateral mesh of structures, compared to more commonly used triangles. This significantly reduces the simulation requirements, but more important, the advantage is the use of Higher Order Basis Functions (HOBFs). They enable the **usage of larger mesh elements**, up to 2 wavelengths. In case of anechoic chamber simulations, the chamber surface is usually geometrically canonical which is ideal for very large mesh elements supported in WIPL-D Pro. Hence, there are 3-10 times less unknown coefficients in MoM matrix compared to the low order triangular mesh based MoM matrix.

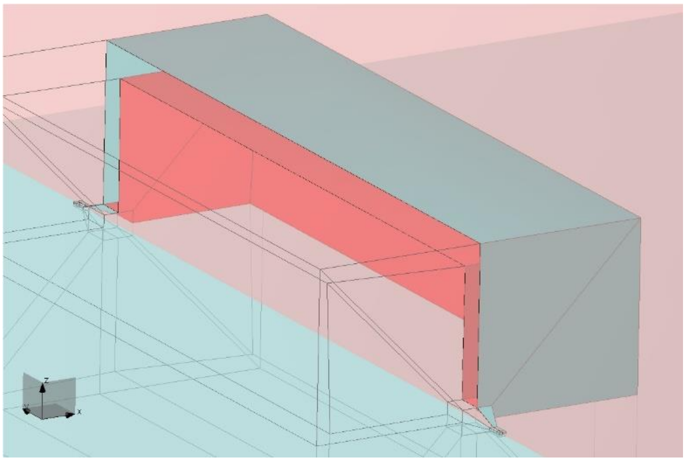
However, all of the aforementioned would not be enough for chambers extending dozens or hundreds of wavelengths since these scenarios are very demanding when it comes to the required number of unknowns. Since the chamber surface usually does not have rapid changes of the current distribution, required number of unknowns can be significantly reduced, thus reducing the simulation requirements. WIPL-D software suite offers **several techniques to reduce number of unknowns** on parts of the model. Combining these techniques along with extensive experience in chamber simulations which WIPL-D support team has gathered through years, we can greatly reduce the number of unknowns. The aim is to **reduce requirements and preserve the accuracy**. Also, when the simulation is performed in wide band, WIPL-D suite offers features to **adjust the requirements according to the current frequency**. For example, the simulation at 26 GHz, can be far less demanding than the same scenario at 40 GHz.

For simulation of electrically large structures, WIPL-D recommends usage of **inexpensive GPU platforms**. A regular desktop PC can be turned into GPU platform by adding 1-3 GPU cards. The largest problems can be solved by adding 4+ GPU cards, or by using the WIPL-D GPU Cluster solution.

WIPL-D support team has significant experience in simulation of devices inside cavities and chambers. In this application note, the chamber is 12x12x24 inches large. The frequency band of interest is 26-40 GHz. At the highest frequency, the chamber is 80 wavelengths long.

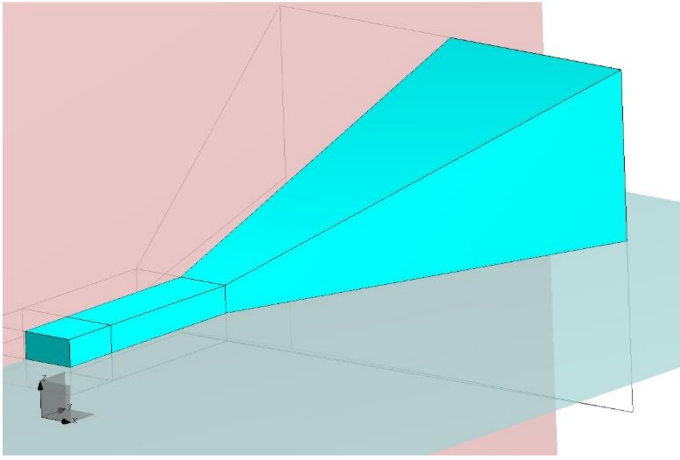
## Simulation Scenario

For the purpose of demonstrating the **advantages of WIPL-D suite** in the MIMO inside of anechoic chamber, we focus to a rather simple scenario. The chamber is a simple box (12x12x24 inches). Two horn antennas are placed in such a way that their aperture directly lays on the side of the chamber. The interior walls of the chamber are coated with 25 mm thick absorbing material.

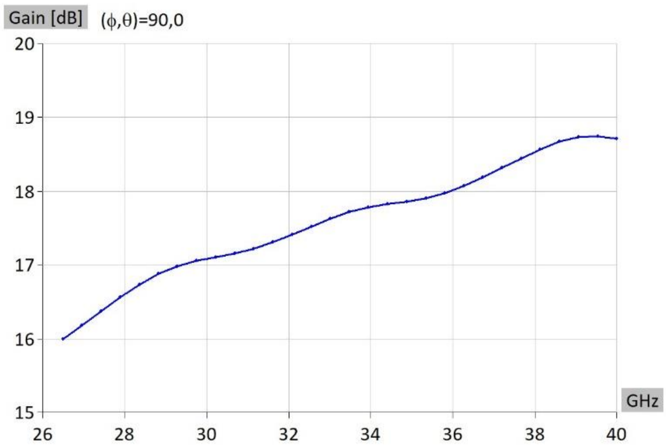


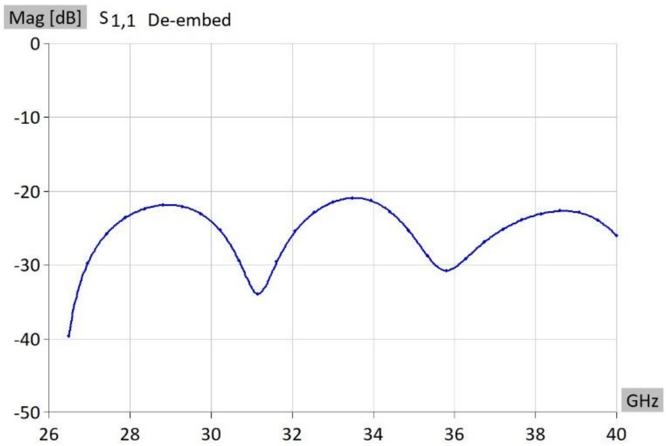
The two antennas are SAGE Horn antennas (SAR-1725-28KM-E2). Since the exact configuration is not known (the connector, flange etc.), we have used a simple approximative model with the known dimensions. The horn is feed via WR-28 waveguide (cross section size is 7.112x3.556 mm large). The horn aperture is 27.4x21.9 mm large, while the length from the end of the waveguide to the aperture is estimated to 26.5 mm (since the manufacturer datasheet does not offer all the details).

The waveguide length is estimated to 1.5 wavelength at 30 GHz. This is less relevant for the EM simulations. The waveguide is feed with a simple wire probe, which implies that for the accurate S-parameters the results have to be de-embedded by using the WIPL-D built-in procedure.



The return loss of the antenna and its gain quite resemble the antenna datasheet having in mind that the exact geometry is not known.

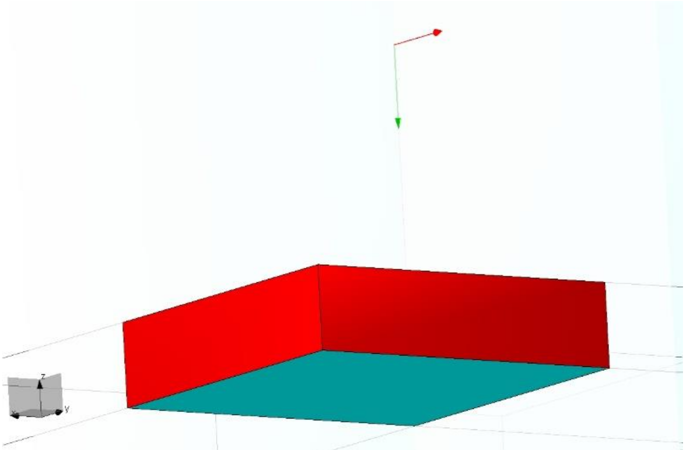


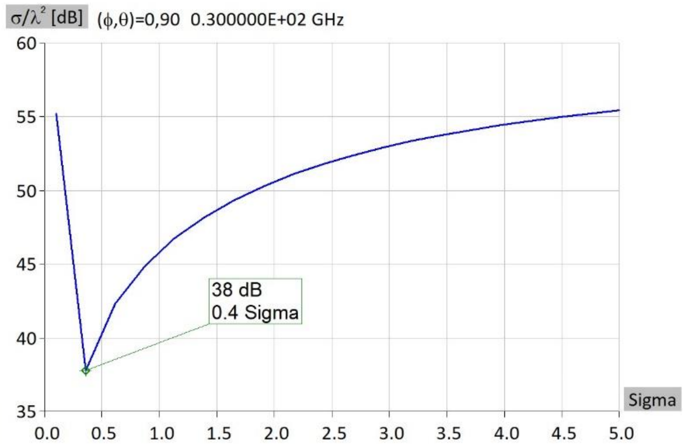

## Material Characterization

The walls of the chamber are coated with Eccosorb HR-25. As announced at the manufacturer website, this is gradient loaded absorber. The short investigation at the available Internet materials suggests that $\varepsilon_r$ of such material varies between layers from 1 to 2 and is less important for the EM purpose. The *Sigma* is not exactly known.

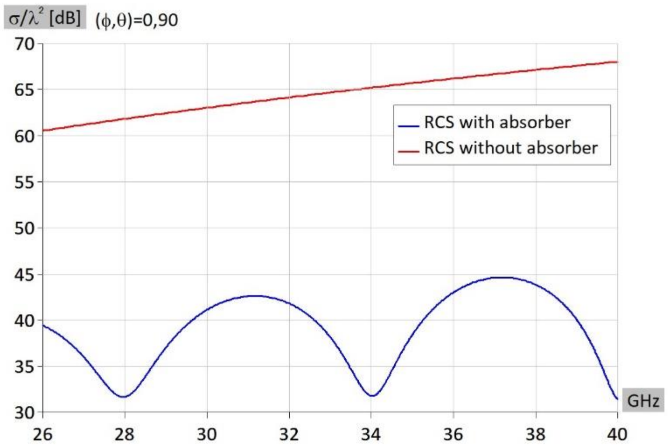
In that sense, we suggest a simple procedure to make an equivalent material in WIPL-D. Since the manufacturer requires a metallic plane behind the material, we simulate 10x10 lambda metallic plate, with and without the absorber covering it. The simulation is run as RCS. The scattering from metallic plate without the absorber is the referent result. After adding the absorber, the RCS is decreased for 5-40 dB, based on *Sigma*. The material characteristic indicates that the field suppression should be between 20 and 25 dB.



Thus, we replace the multilayer material with single layer material with $\varepsilon_r = 1$ and varying *Sigma*. At 30 GHz, we sweep *Sigma* and acquire the value where suppression is around 25 dB. The estimated *Sigma* is 0.4 S/m.




A simple test is to run the RCS problem in the frequency band (26 to 40 GHz) and verify that the chosen *Sigma* satisfies the characteristic (another solution would be to use frequency dependent *Sigma*). However, the simulations show that the suppression is around 25 dB (or more) in the entire frequency band. The difference (in dB) between the red and blue curve is the actual suppression level.




## Simulation Details

The last step is to run a complete simulation scenario. It included two horn antennas as described above, the metallic chamber covered with single dielectric layer and two apertures where the horns radiate the field inside the chamber. The frequency band is 26-40 GHz. We have used a feature where the number of unknowns is adjusted to the currently simulated frequency (so called "freq" feature). Thus, for 15 frequency points the code runs 15 independent simulations and combines them into a single final result.

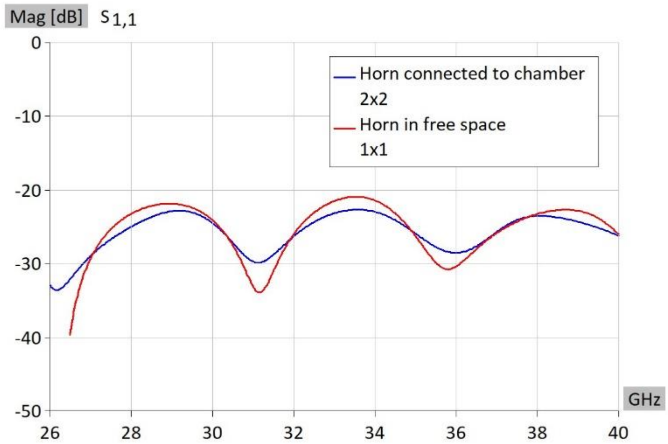
In addition, at each frequency the referent frequency is reduced for 10%, not affecting the results. For example, at 40 GHz, the walls of the chamber are simulated with number of unknowns adjusted to 36 GHz. For all simulations, the horn antennas and the connection of the horn to the chamber are simulated with the increased accuracy (referent frequency fixed to 48 GHz) for the entire band. These EM parts are vital for the EM simulation and the number of unknowns is not decreased here.

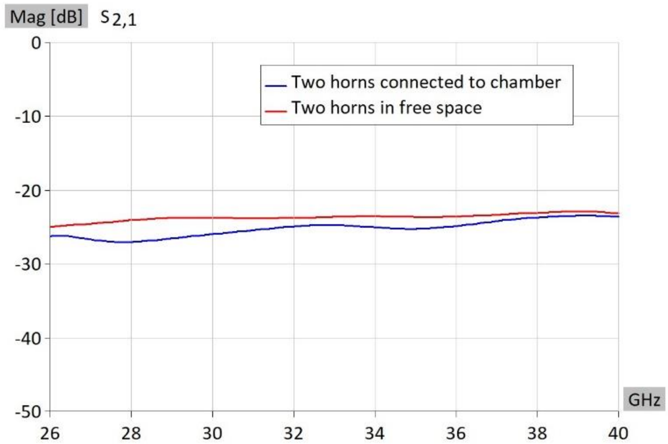
The result for two horns pointing into the chamber is verified by comparing the results $S_{21}$ to the project where two horns point in free space (their respective positions are kept constant). Such simulation runs in seconds. **WIPL-D MoM does not require bounding box**. The two horns can be separated arbitrarily without increasing the simulation settings. The result for $S_{11}$ was verified by comparing it to the simulation of single horn in free space.

The simulation is carried out at the **following workstation**:

Intel® Xeon® CPU E5-2650 v4 @ 2.20 GHz (2 processors) with 256 GB RAM and four GPU cards NVIDIA GeForce GTX 1080 Ti, 6 SATA HDDs configured in RAID-0.

**The most demanding scenario** with two horns pointing into the chamber lasts **17,000 seconds for 15 frequency points**. Time per frequency point varies, as well as number of unknowns. At 24 GHz, the number of unknowns is around 52,000, while it is 118,000 at 40 GHz.




## Conclusion

This application notes describes a simplified MIMO scenario showing how multiple horn antennas can be placed inside a large material coated anechoic chamber to test their OTA compatibility. The material characteristic is often unknown, but we show a simple procedure to emulate the characteristic satisfying the simulation demands.

The simulations are carried out on multicore CPU and multi-GPU workstation so that **simulation times are very short for a very wide frequency band**. Built-in **interpolation allows quite smooth results**, even with 15 points in a very wide band. If a single point is needed, the simulation can be carried out on a regular desktop PC equipped with a single GPU card, owing to GPU solver. The simulation time dramatically depends whether the frequency point is closer to start or end of the band.

Although the realistic problem where 80 lambda long anechoic chamber is covered with absorbers seems unreachable to full-wave EM solvers, WIPL-D suite proves otherwise. Efficient kernel, usage of GPU cards and **WIPL-D GPU solver**, efficient characterization of the coating material lead to **straightforward simulation carried out in reasonable time**.