Using Measured Sources in Installed Performance Analysis

Electromagnetic simulation allows engineers to investigate the performance of antennas in a wide range of different environments which may be inaccessible or infeasible to measure. However, it is often the case that a suitable model of the antenna is not available for the simulation, especially for off-the-shelf antennas with geometries that are protected by intellectual property. This article demonstrates how domain decomposition, combining measured data and simulation using MVG INSIGHT and CST STUDIO SUITE®, can overcome these difficulties and allow the installed performance of an antenna to be characterized.

The performance of an antenna can be affected greatly by the platform that the antenna is installed on. For this reason, engineers typically want to know not just how an antenna behaves in the free-space environment of the anechoic chamber, but also how it will perform in its environment.

Performing an installed performance analysis using prototypes alone can be expensive, time-consuming, or even impossible. Simulation can make the process of deciding where to place an antenna and analyzing its performance much more straightforward, by making it possible to use a virtual prototype of the system.

However, an accurate simulation requires accurate models. For many off-the-shelf antennas, these are not available for intellectual property reasons. Even if the antenna is sitting on the engineer's desk, getting it into the simulation can be a challenge. In these cases, the most efficient way to proceed is to combine the two techniques using a "best of both worlds" approach: measurement to characterize the performance of the antenna in free space, and simulation to calculate its performance when installed.

This is made possible by the use of field sources. Both nearfield and farfield sources exist: a nearfield source is a representation of the electric and magnetic fields on the surface of a given volume, while a farfield source is a point source representing the radiation of the antenna as seen from a distance. Both can be used as the excitation for a simulation, but for situations where the antenna is located close to the structure, the nearfield source is the more accurate option.

Workflow

The first stage of the process is to generate the nearfield source. When a CAD model of the antenna geometry is available, this can be done with simulation, but otherwise, the antenna needs to be measured.

An antenna measurement, as shown in the Figure 2, will give the radiation pattern of the antenna, but the pattern then needs to be converted into a nearfield source for using it in a numerical simulation. The desired Nearfield representation demands a very accurate description of the radiation properties of the antenna.

This description can be obtained by INSIGHT, a software from Microwave Vision Group, which allows to calculate from the measured radiation pattern, the equivalent electric and magnetic current representation of the antenna. The equivalent currents approach can be defined on geometry tight-fitting the antenna under test (AUT), and therefore it is more accurate for representing antennas in close proximity, or mounted directly on complex structure, than the spherical wave expansion. The equivalent currents are the accurate nearfield source that can be used as basic input for numerical simulations (Figure 3).

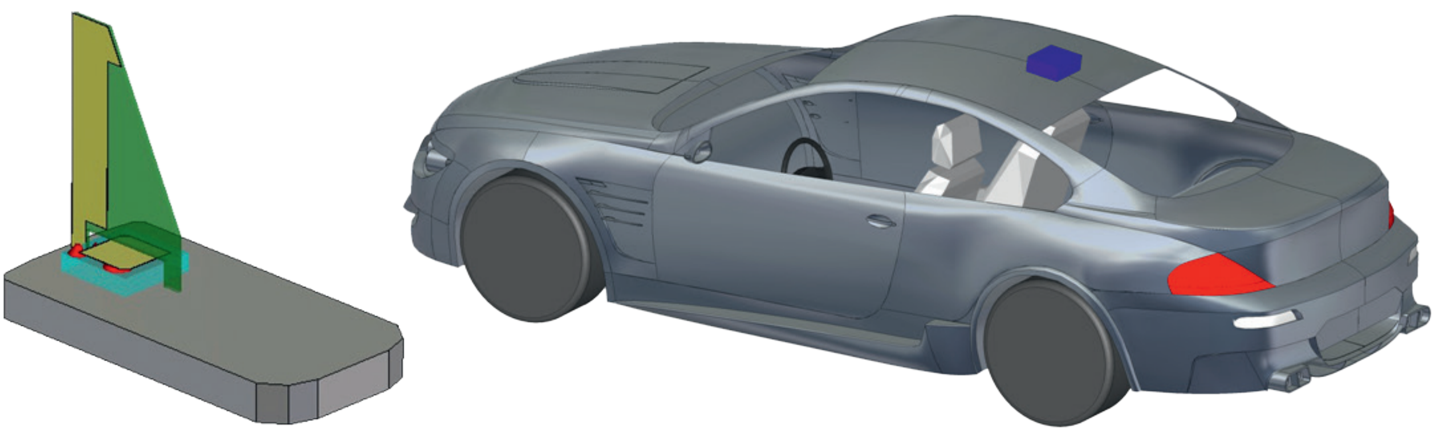


Figure 1: *(left)* A GPS antenna with a fin *(right)* The nearfield source equivalent, represented by a blue box, on a car.

Figure 2: Measurement of a horn antenna, using MVG StarLab measurement system.

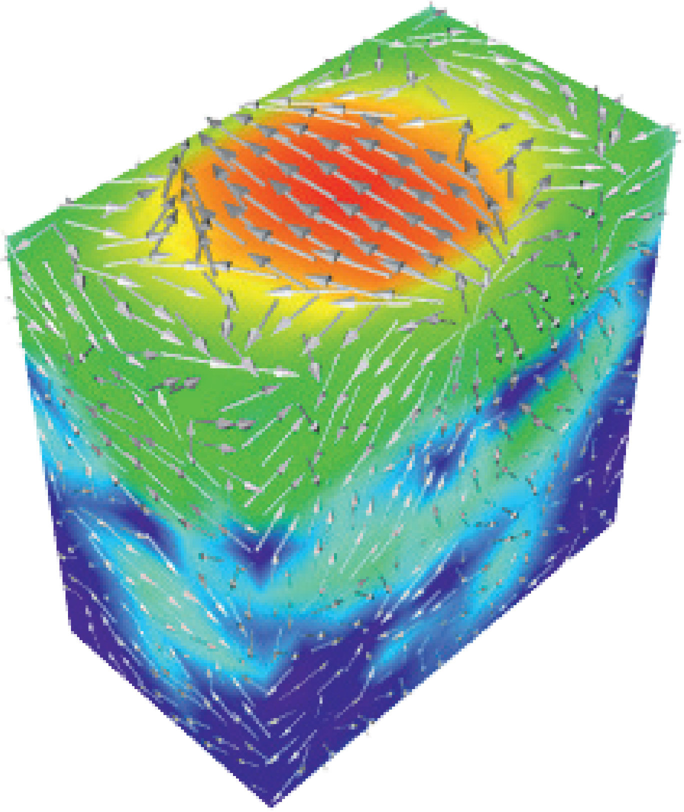


Figure 3: The equivalent current representation of the horn from Figure 3, produced using INSIGHT.

The nearfield source is then imported into CST STUDIO SUITE, a suite of electromagnetic design and simulation tools, and placed on a 3D model representing the antenna platform. Since the release of CST STUDIO SUITE 2014, the nearfield source can be used as the basis of simulations using the frequency domain solver and the integral equation solver as well as the transient solver.

The different solvers each have their own strengths for certain types of problem – for example, the transient solver is efficient for broadband simulation, while the integral equation solver offers good performance for electrically large antennas. Simulations with different solvers can also be compared, in order to validate the accuracy of the calculations – having two different solvers converge to the same answer increases the confidence that there were no errors in the simulation set-up.

Relevant results for antenna placement simulations include the farfield pattern, which also gives the gain and directivity of the antenna, and the fields and surface currents, which allow the interaction between the structure and the radiation to be visualized. These can be calculated within CST STUDIO SUITE by defining monitors or probes in the regions of interest.

Examples

Horn antenna installed on a reflector dish

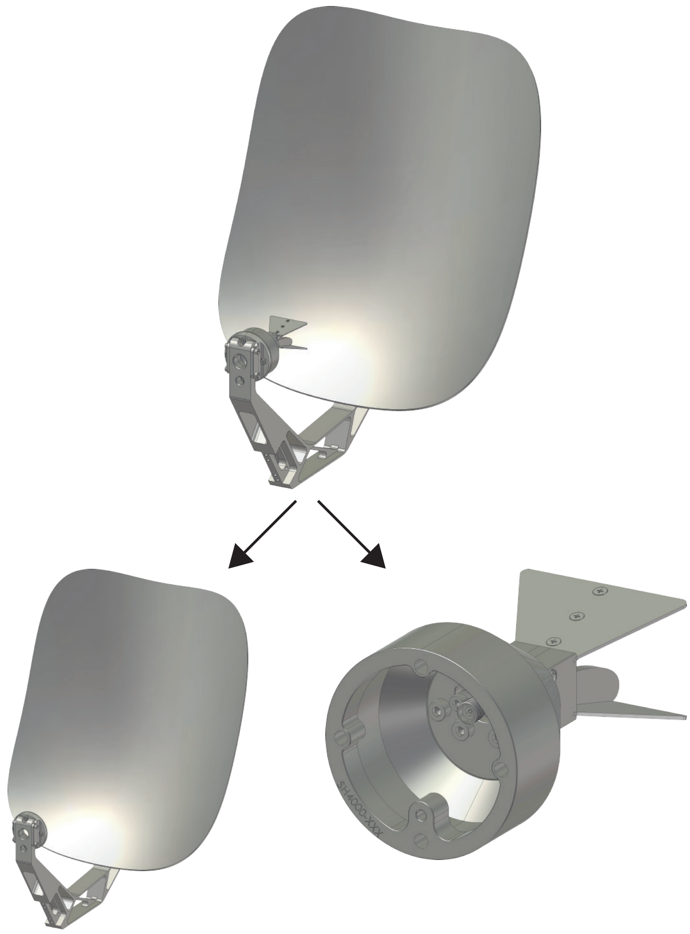
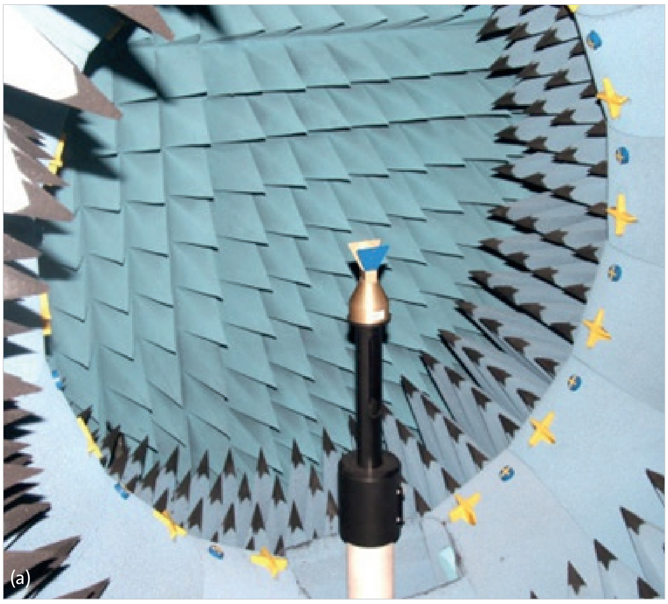
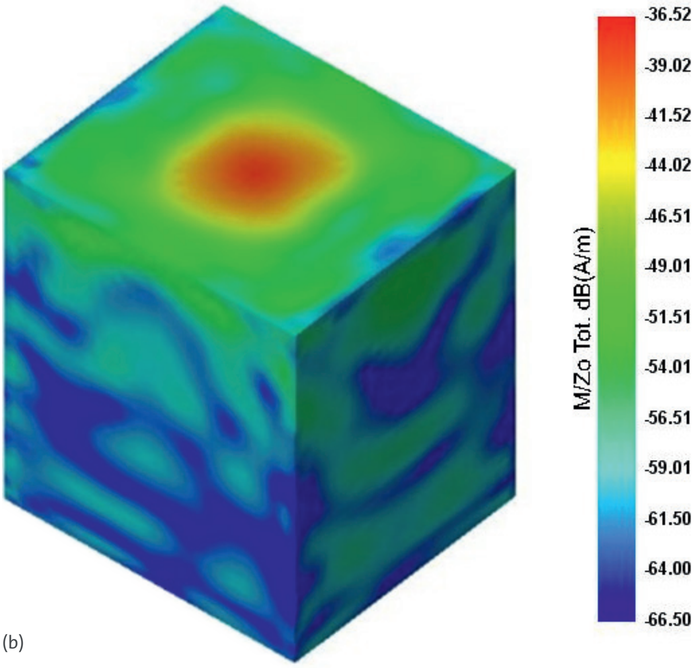


Figure 4: A CAD model of the antenna, consisting of an MVG SR40-A reflector (left) and an MVG SH4000 horn (right). The simulation domain can be decomposed as shown in the current picture.

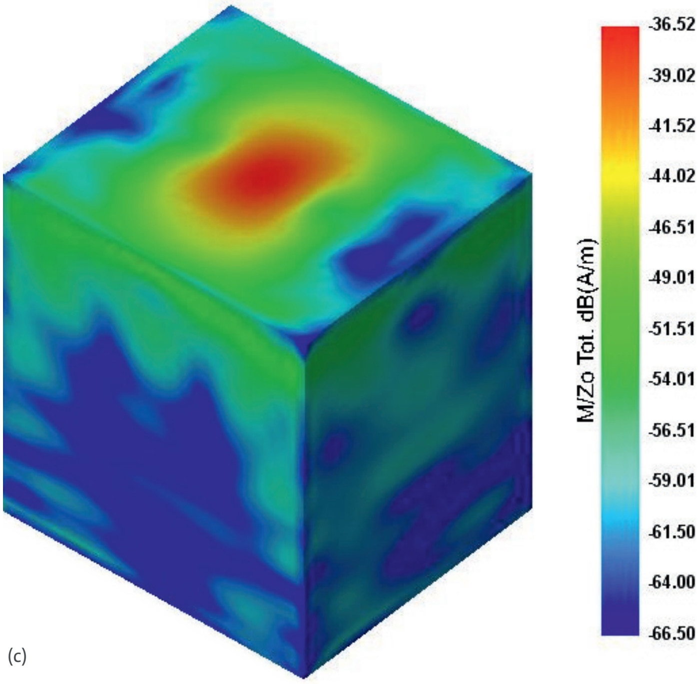
The first example consists of an MVG single offset reflector SR40-A fed by the dual ridge horn SH4000, operating in the frequency range [4–40] GHz. From the perspective of antenna design, the two main elements of a reflector antenna – the feed horn and the reflector dish – are almost totally mechanical independent. This means that simulation domain can be divided easily in two parts, where the feed horn is represented by the nearfield source (Figure 4). Investigations have been performed at 4 GHz and 8 GHz.

The horn SH4000 was initially measured in the StarLab 18 GHz nearfield measurement system, as isolated source, as is shown in Figure 5 (a). The computation of the equivalent currents (EQC), representing the nearfield source from the SH4000 measured data, has been performed by INSIGHT. Results are shown in Figure 5 (b) and Figure 5 (c) at 8 GHz.


(a)



(b)



(c)

Figure 5: (a) Measurement of the isolated SH4000 dual ridge fed in the MVG StarLab 18 GHz facility in Pomezia, Italy; SH4000 dual ridge horn (isolated feeder) equivalent current representation from the measurement @ 8 GHz, (b) J electrical equivalent currents, (c) M magnetic equivalent currents. Dynamic range 30dB.

Afterwards, equivalent currents representing the Nearfield source have been imported in the simulation replacing the original horn in the reflector system.

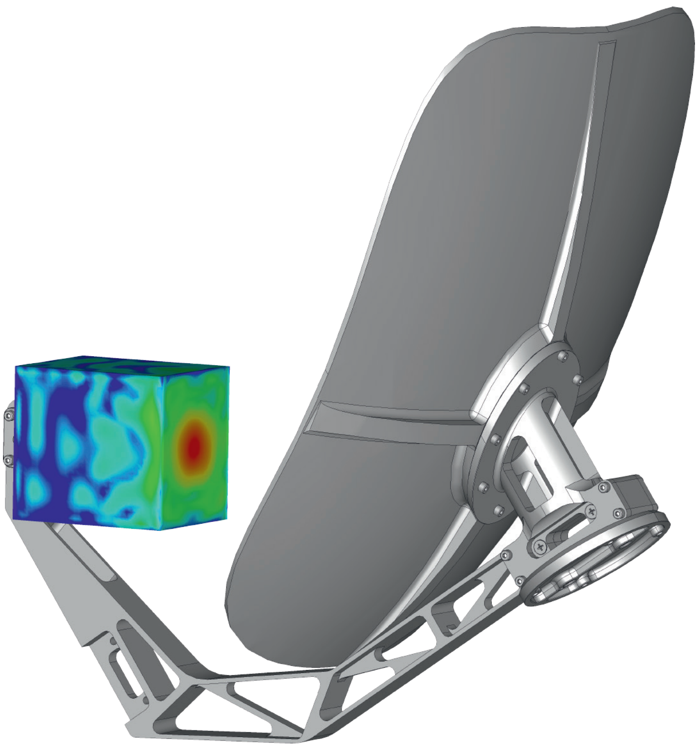


Figure 6: Nearfield source imported in CST STUDIO SUITE and mounted on the reflector dish CAD model.

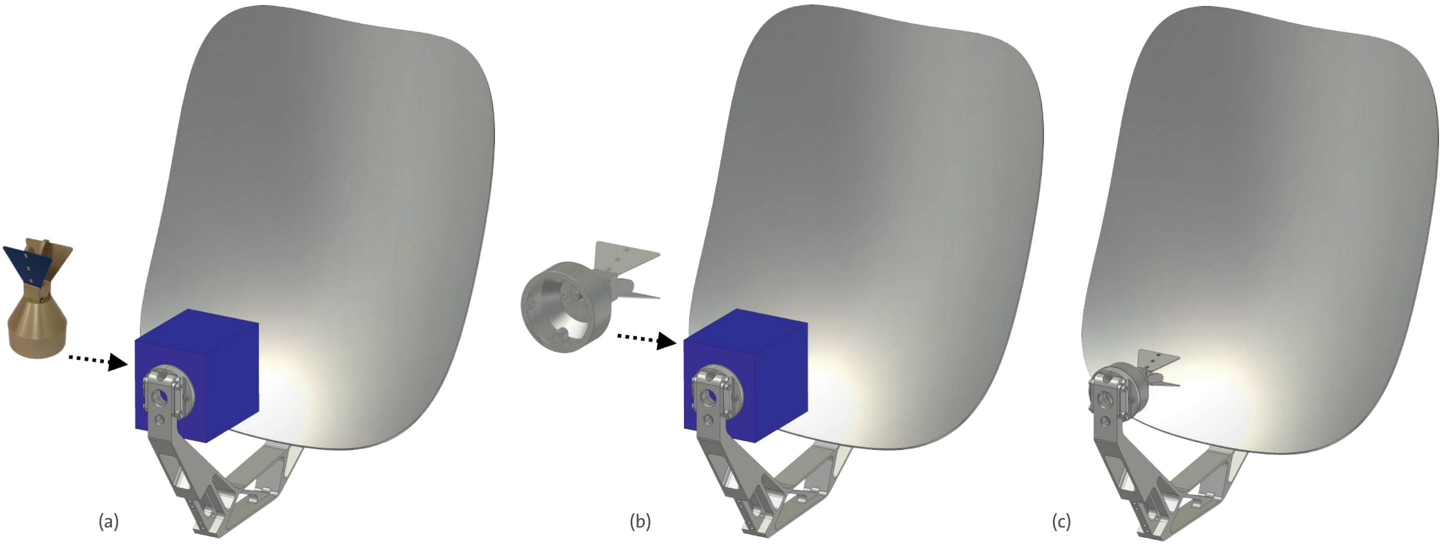


Figure 7: In the measured source with the reflector the equivalent currents are used as a source model in the simulation of the AUT, as is shown in Figure 5 (a). In the simulated source with the reflector, the feed is simulated and represented with equivalent currents computed directly in CST STUDIO SUITE, as is shown in Figure 5 (b). In the simulated reflector system, the AUT is full simulated, as is shown in Figure 5 (c).

In order to validate the accuracy of the procedure the following results have been compared:

- measured source with the reflector (M Sou + Ref)
- simulated source with the reflector (S Sou + Ref)
- simulated reflector system (S Ref)
- measured reflector system (M Ref)

To demonstrate how different solver types can be used to verify a simulation result, the reflector system was then simulated using the finite integration technique (FIT) transient solver (T-solver) and the multilevel fast multipole method (MLFMM) integral equation solver (I-solver).

Reference measurement of the reflector antenna and feed was performed in the MVG SG-64 spherical nearfield facility in Paris, as is shown in Figure 8.

3D plot comparison in terms of nearfield and far field, between the full wave simulation of the reflector system and measured source with the reflector are shown in Figure 9.

The farfield results are shown in Figure 9. There is an extremely close agreement between the measured data, simulated data and data from the combined measurement-simulation approach. The measured directivity tends to be lower than the simulated directivity at around ±180°. This is due to the shielding effect of the additional support required to hold the antenna in place for measurement (Figure 9). There is also a small discrepancy in the measured nearfield results at around -60° in the E-plane at 4 GHz – this due to a difference in the back radiation level of the isolated feed.

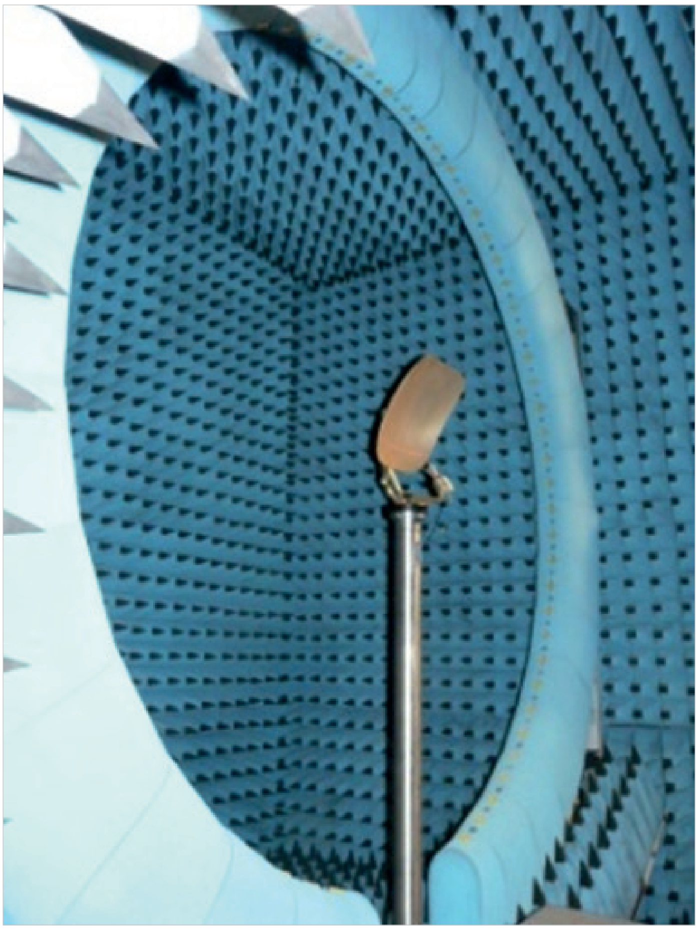


Figure 8: Reference measurements of the reflector antenna and feed in the MVG SG-64 spherical nearfield facility in Paris.

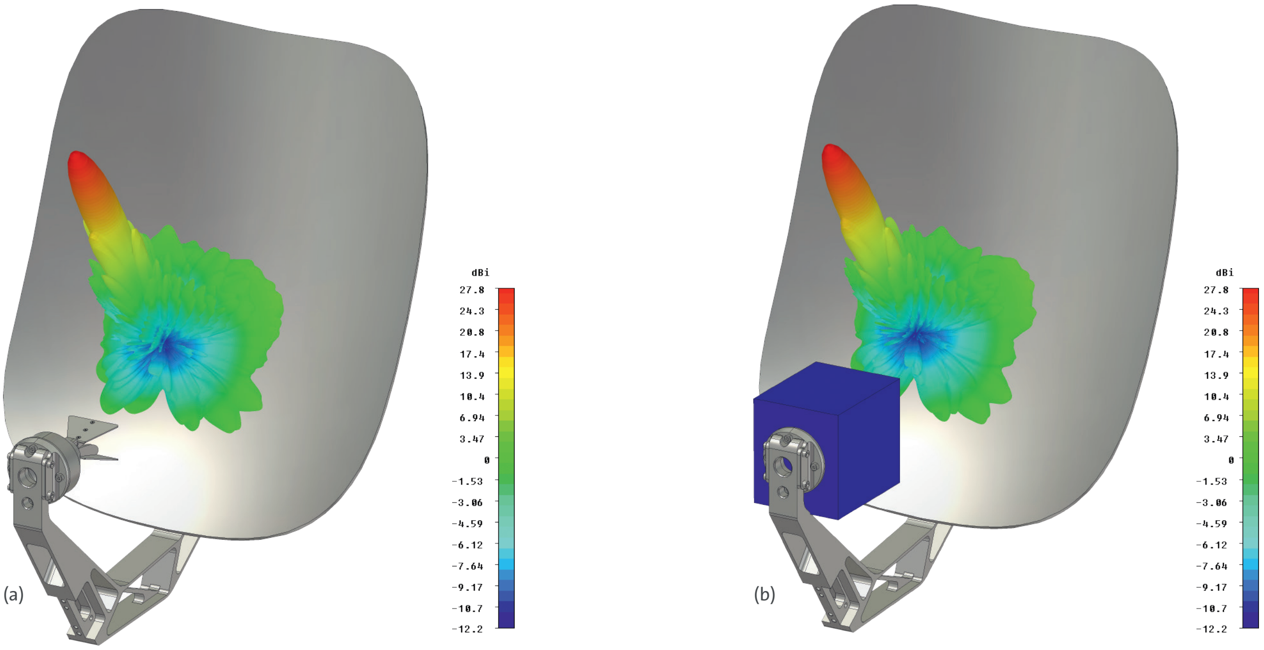


Figure 9: 3D Far Field comparison @8GHz between the simulation of the reflector system (a) and the measured source with the reflector (b).

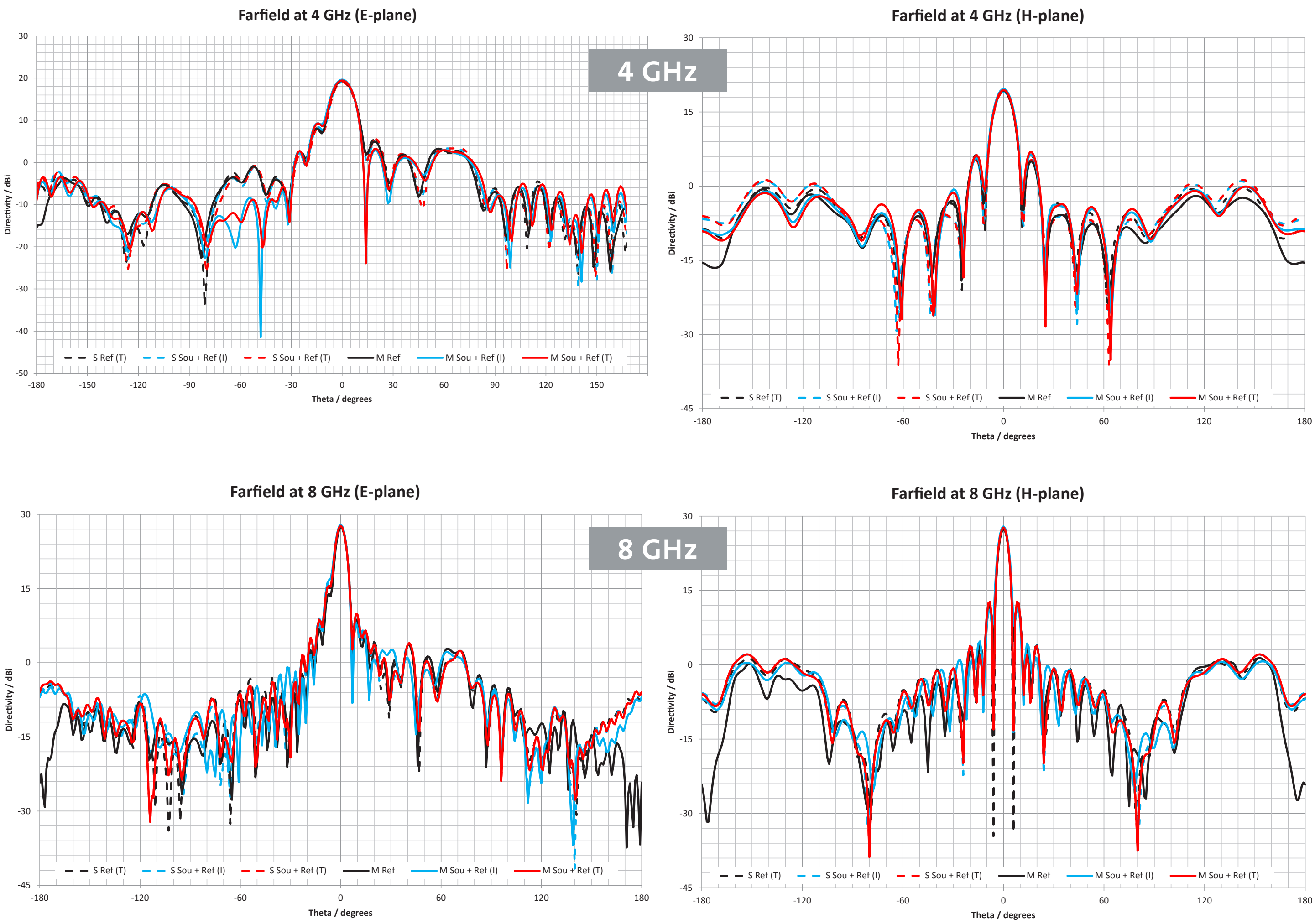


Figure 10: Directivity elevation plane pattern of the offset reflector antenna fed by the dual ridge horn. E plane (left), H plane (right). Comparison between measured source with the reflector (M Sou + Ref), simulated source with the reflector (S Sou + Ref), simulated reflector system (S Ref), measured reflector system (M Ref). (T) indicates the FIT T-solver and (I) represents the MLFMM I-solver.

Very good correlation between the results obtained using the measured sources and the other references (simulations and measurements) on the entire antenna system, confirms the validity of the approach at both investigated frequencies.

Monocone antenna installed on a plate

The second example consists of an MVG monocone antenna SMC2200, flush mounted on a rectangular plate, operating in the frequency range [2.2–6] GHz. This example is used to demonstrate the effect of the platform on the performance of an antenna.
The platform that an antenna is installed on can have a significant effect on its performance by shadowing and reflecting the radiation from the antenna, and by absorbing, conducting and re-radiating the fields elsewhere in the structure. For this reason, the installed performance of the antenna needs to be taken in account when designing RF systems.

Alongside the difficulty of obtaining models of off-the-shelf antennas, there are several additional issues in installed performance analysis that can be efficiently solved with nearfield sources. The antenna is often very small and complex compared to a platform such as a plane or a ship, which can make a direct simulation of the full system very inefficient. Moreover, the size of the platform and the cost of constructing full scale prototypes mean that measuring the performance of the antenna in situ is often very difficult.

If the antenna is isolated the determination of the equivalent currents is straightforward. If the antenna is "flush mounted" on the structure, the antenna needs to be measured on a minimal representative ground plane. The edge scattering from the ground plane is then eliminated in an additional post processing step, in the INSIGHT software, as is shown in Figure 11.

The platform in this example is a simple metallic plate (Figure 12), in order to make the fabrication and measurement of the reference model easy. However, the same approach can be applied just as readily to more complex structures such as cars, aircraft, trains, masts and buildings.

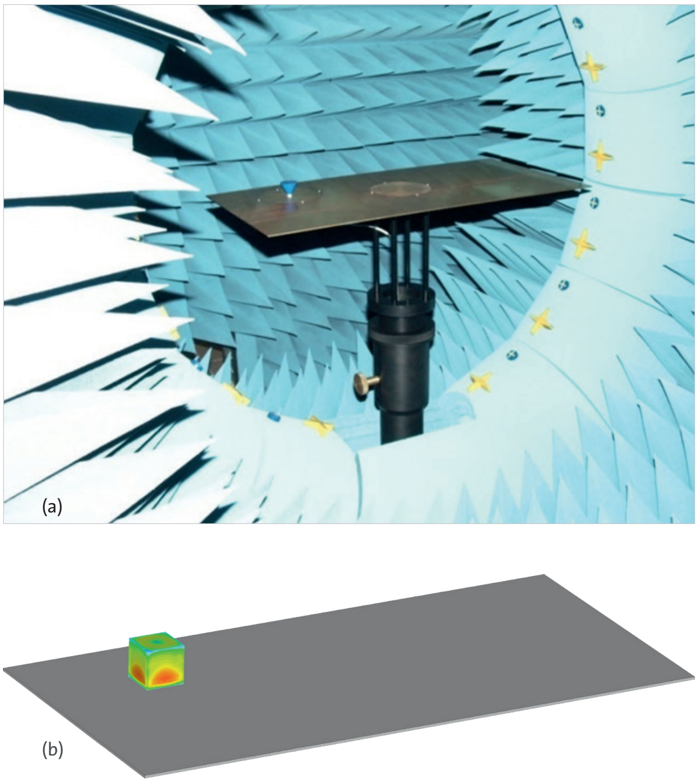


Figure 12: SMC2200 monocone antenna flushed mounted on the plate (a) and the equivalent model in CST STUDIO SUITE with the measured Nearfield source (b).

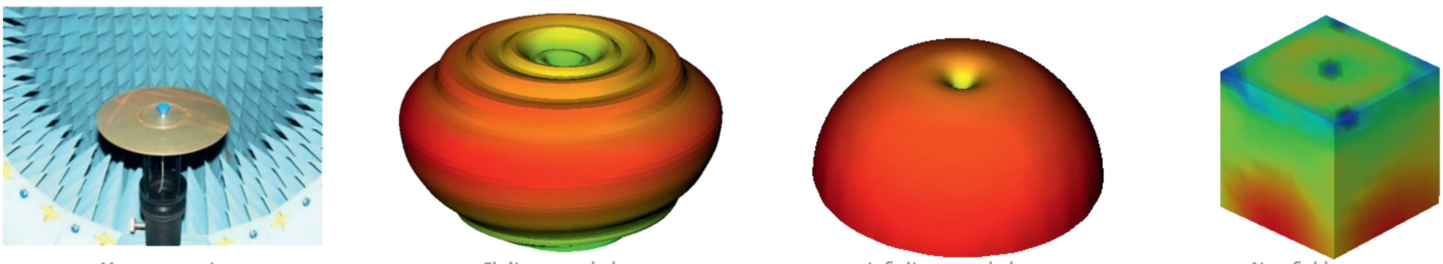


Figure 11: Workflow for creating the nearfield source for a Satimo SMC2200 monocone antenna.

As shown in Figure 13, a good correlation between the results obtained using the measured sources and the other references (simulations and measurements) can be observing, confirming the validity of the approach for the analysis of flush mounted antenna scenarios.

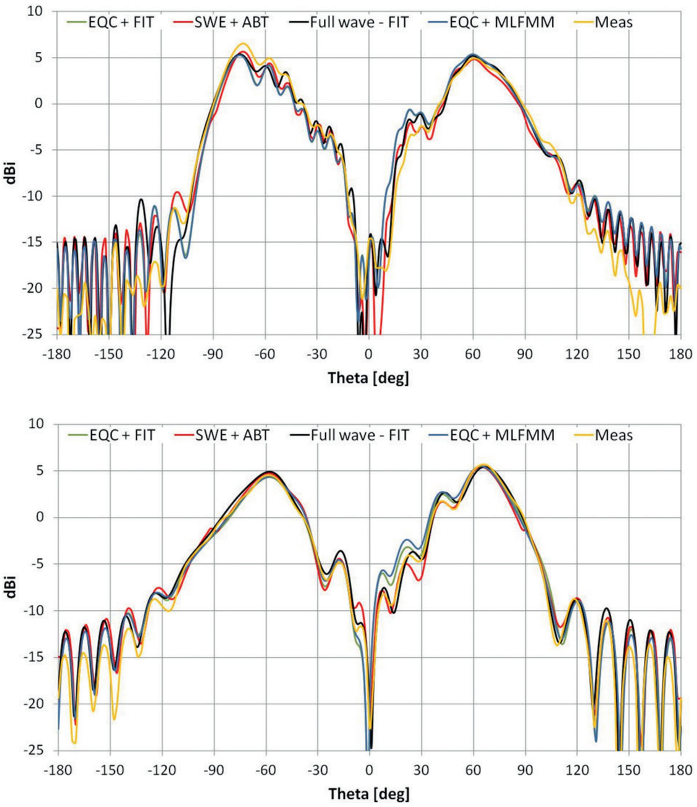


Figure 13: Elevation plane pattern SMC2200 @5.28 GHz on the rectangular plate: phi=0° (lef) and phi=90° (bottom). Proposed method combining EQC and numerical modelling (EQC + FIT); full numerical modelling (Full-wave – FIT); spherical waves and numerical modelling (SWE +ABT); a combination of EQC and numerical modelling (EQC + MLFMM); reference measurement (Meas).

Conclusions

Based on INSIGHT processing of measured data, MVG and CST have established a new direct link between MVG's multi-probe measurement systems such as StarLab and the simulation tool CST STUDIO SUITE.

No additional modification to the source files are necessary in the implemented working procedure, and the EQC model can be used as nearfield source for different simulation methods. The results of this hybrid analysis agree very well with both pure simulation and pure measurement. Combining simulation and measurement helps to overcome the difficulties inherent in both methods.

About MICROWAVE VISION - MVG

Since its creation in 1987, The Microwave Vision Group (MVG) has developed a unique expertise in the visualization of electromagnetic waves. These waves are at the heart of our daily lives: Smartphones, computers, tablets, cars, trains, planes – all these devices and vehicles would not work without them. Year after year, the Group develops and markets systems that allow for the visualization of these waves, while evaluating the characteristics of antennas, and helping speed up the development of products using microwave frequencies.

The Group's mission is to extend this unique technology to all sectors where it will bring strong added value. Since 2012, MVG is structured around 4 departments: AMS (Antenna Measurement Systems), EMC (Electro-Magnetic Compatibility), EIC (Environmental & Industrial Control), and NSH (National Security & Healthcare).

MVG is present in 9 countries, and generates 90% of sales from exports. The Group has over 300 employees and a loyal customer base of international companies. The Group generated revenues of € 51.5 million in 2013. MVG has received the BPI "Innovative Enterprise" certification, and is illegible for PEA-PME.

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About CST

Founded in 1992, CST offers the market's widest range of 3D electromagnetic field simulation tools through a global network of sales and support staff and representatives. CST develops CST STUDIO SUITE, a package of high-performance software for the simulation of electromagnetic fields in all frequency bands, and also sells and supports complementary third-party products. Its success is based on a combination of leading edge technology, a user-friendly interface and knowledgeable support staff. CST's customers are market leaders in industries as diverse as telecommunications, defense, automotive, electronics and healthcare. Today, the company enjoys a leading position in the high-frequency 3D EM simulation market and employs 250 sales, development, and support personnel around the world.

CST STUDIO SUITE is the culmination of many years of research and development into the most accurate and efficient computational solutions for electromagnetic designs. From static to optical, and from the nanoscale to the electrically large, CST STUDIO SUITE includes tools for the design, simulation and optimization of a wide range of devices. Analysis is not limited to pure EM, but can also include thermal and mechanical effects and circuit simulation. CST STUDIO SUITE can offer considerable product to market advantages such as shorter development cycles, virtual prototyping before physical trials, and optimization instead of experimentation.

Further information about CST is available on the web at https://www.cst.com.

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