Link Between Measurement and Simulation Applied to Antenna Scattering and Placement Problems

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***Abstract*—Recent use of measured data as near field sources in Computational Electro Magnetic (CEM) tools has opened the possibility to represent antennas in numerical simulations, even when the antenna characteristics and geometry are unknown and therefore cannot be included in a full wave model [1-4]. The near field source consists of an equivalent current representation of the antenna, which is prepared by the inverse source method from the measured radiation pattern [5-9]. This link bringing together numerical simulations and antenna measurements has been validated by a proper campaign, that involves MVG and different software (SW) vendors [10-15].**

In the first part of this paper, the latest results of the validation are presented completing the activities described in [1-3]. In the second part of the paper, the link between measurements and simulations has been applied to more complex and/or realistic problems, including scattering problems.

***Index Terms*— Antenna measurements, Antenna radiation patterns, Numerical simulation.**

I. Introduction

While measurements of radiation patterns are widely required for final validation of deployed antenna systems due to the conclusiveness and high reliability of measured data, numerical modeling is increasingly used in the initial stages of antenna placement investigation and optimization. Due to the increasing complexity of test scenarios, CEM simulation tools implement the Domain Decomposition Technique (DDT) and apply different numerical methods to solve the sub-domains/problems.

In some cases, when implementing an antenna supplied by a third party, the mechanical and electronic characteristics needed for a full-wave representation of the antenna may be unavailable, particularly in the format required by the CEM tool. To overcome this problem, the radiating antenna can be characterized by a true pattern measurement, as sub-problem of the complete domain under test [1-3]. Indeed, an Equivalent Current (EQC) representation of the source antenna is determined from the measured radiation pattern [5-9], as an equivalent Huygens box [10]. Afterwards, the source can be imported and used into the CEM tools [11-16].

The link bringing together numerical simulation and antenna has been validated by an extensive campaign promoted by MVG and with participation of different SW vendors [11-16]. The last results from the validation process are presented in the first session of this paper.

The second session is dedicated to the next phase of analysis, hence the application of the link to more complex scenarios, including scattering problems. The scenario under test is an antenna placement problem where the radiator is placed on a plate in proximity of two scattering objects. The radiator consists of cavity backed cross dipoles operating at the test frequency of 1940MHz.

II. Completion of the Validation Campaign

A. Open ended waveguide on a rectangular plate

An open ended waveguide antenna (OEW) mounted offset on a rectangular plate of 30 x 60 cm has been examined as final case of validation campaign of the link with the SW vendors. The source antenna is located in a corner of the plate, positioned at a distance of 1.5λ and 2λ from the nearest edges at the validation frequency. The validation structure during measurements in the MVG SL18GHz spherical near-field multi probe system [17] is shown in Fig. 1. The longest side of the rectangular plate and the E-plane of the antenna are oriented along the RF x-axis (i.e. phi=0° in spherical coordinates) in the measurement system.

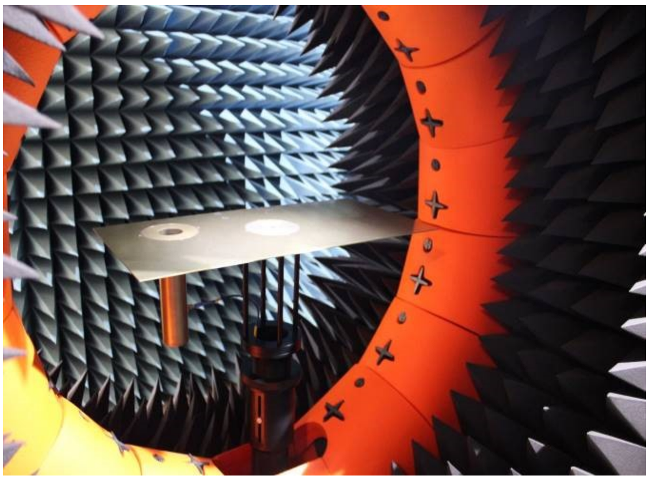


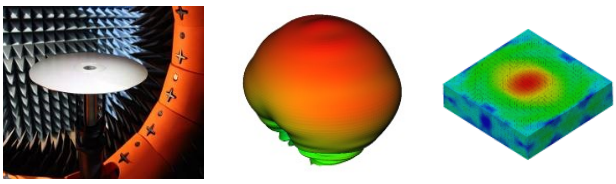
Fig. 1. Measurement of the OEW on the rectangular ground plane in the MVG Spherical Near Field antenna measurement system, SL18GHz.

The aim of the validation was to prove the accuracy of the link by comparing the simulation of the full scenario using the measured representation of the antenna in isolation and the reference measurement in Fig 1. During the validation, the same representation of the measured source in terms of equivalent currents has been provided to all the SW vendors. The preparation of the measured source and the results of the validation are shown in the following sections. No exchange of numerical results of simulations has been performed among SW vendors during all validation campaigns. This is the philosophy to preserve the spirit and validity of the validation campaign.

B. *Preparation of the Source Antenna/Huyegns Box*

The measured representation of the source antenna has been prepared starting from measuring the radiation pattern of the stand-alone antenna in free space. In flush-mounted antenna problems, the proximity of scattering structures modifies the current distribution on the antenna itself. To approximate this condition and obtain a source that can be installed efficiently on a generic final structure, an infinite ground plane boundary condition is adopted. In practice, such a boundary condition is obtained measuring initially the antenna on a circular ground plane with minimum λ radius. Then, in post-processing, diffractive contributions from the edges of the finite ground plane are removed [18], reproducing the radiation on an infinite ground plane.

In the validation example, the antenna has been measured on a circular ground plane of 6λ in diameter at the test frequency of 4.38 GHz. The measurement set-up and the radiation pattern are shown in Figure 2 (a) and (b). A near-field source model as Huygens box has been created by the SW INSIGHT [6], which implements the inverse source technique [7-9]. The equivalent currents are shown in Figure 2 (c).



(a) (b) (c)

Fig. 2. Measurement of the open ended waveguide on a limited ground plane in the MVG, SL18GHz spherical near field multi probe system (a); meaured radiation pattern @ 4.38GHz (b); EQC source/Huygens box (c).

C. *Results*

The resulting pattern of the test case in Figure 1 has been simulated using the measured open ended waveguide antenna as source representation. The measured and simulated peak directivities @ 4.38GHz of the rectangular plate with OEW antenna are reported in Table I. In this table, the label "MEAS" indicates the measured reference from MVG.

Very good agreement between measurements and simulation can be observed.

TABLE I. PEAK DIRECTIVITY @ 4.38GHZ – OEW ON PLATE

	MEAS	CST	Savant	FEKO	HFSS	WIPL-D
Peak Directivity [dBi]	8.09	8.15	8.22	8.09	8.34	8.26

The measured reference pattern is compared in Figure 3 to the simulated co-polar patterns obtained from simulations using the measured source. The achieved agreement between simulation and measurements is very good.

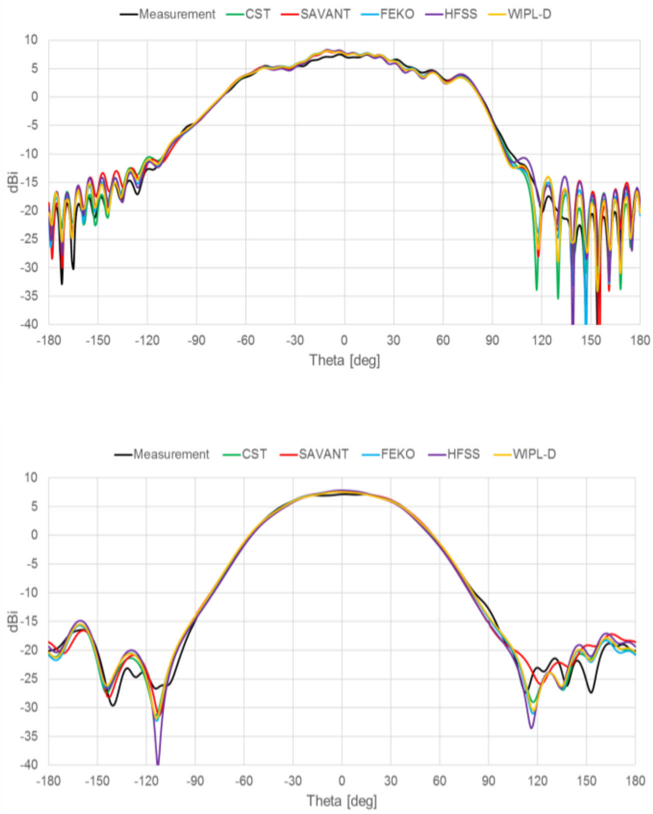


Fig. 3. Directivity pattern of OEW antenna on rectangular plate @ 4.38 GHz. phi=0° plane (top), phi=90° plane (bottom). Measurement and simulation using measured source: CST [11], Savant [12], FEKO [13], HFSS [14], WIPL-D [16].

The correlation between simulations and the reference measurement has also been evaluated in terms of weighted difference [1]. The results for the different CEM tools are shown in Fig 4. For improving the reading comprehension of the plot, the curve of the reference measurement has been added as dashed line.

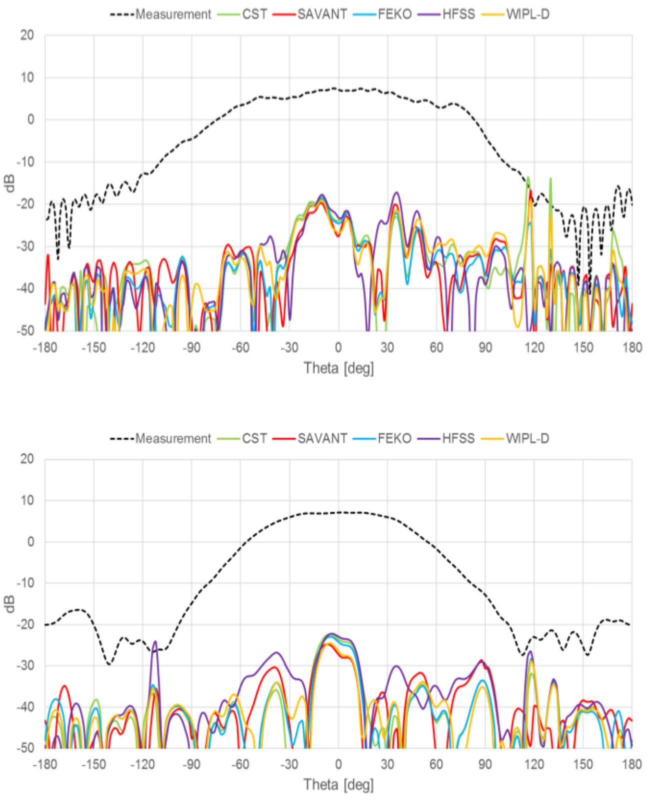


Fig. 4. Weighted difference of simulations and measurements overlaid to the antenna pattern, phi=0° and phi=90° plane. Simulations using measured source: CST [11], Savant [12], FEKO [13], HFSS [15], WIPL-D [16].

The mean values of the curves representing the weighted differences, have been calculated over the principal cuts and the results are shown in Table II. The average correlation between simulations and measurements is ~30dB, which is comparable to what is obtainable with full-wave simulation of the entire scenario. This positive result confirms the accuracy of the link between measurements and simulations and concludes the validation campaign.

TABLE II. MEAN WEIGHTED DIFFERENCE WITH MEASUREMENT OEW ANTENNA ON RECTANGULAR PLATE

	CST	Savant	FEKO	HFSS	WIPL-D
Phi=0° plane [dB]	-32.3	-33.0	-32.9	-32.3	-31.8
Phi=90° plane [dB]	-39.4	-38.9	-38.5	-35.2	-38.9

III. APPLICATION OF THE LINK

After validation, a new phase of the study was initiated focusing on the application of the link to new and more complex test cases, including scattering problems.

The first test case, shown in Figure 5, consists of an antenna placement problem where cavity backed cross dipoles are installed in the center of a rectangular plate in proximity of two scattering objects. The longest side of the rectangular plate is oriented along the RF x-axis (i.e. phi=0° in spherical coordinates) in the measurement system.

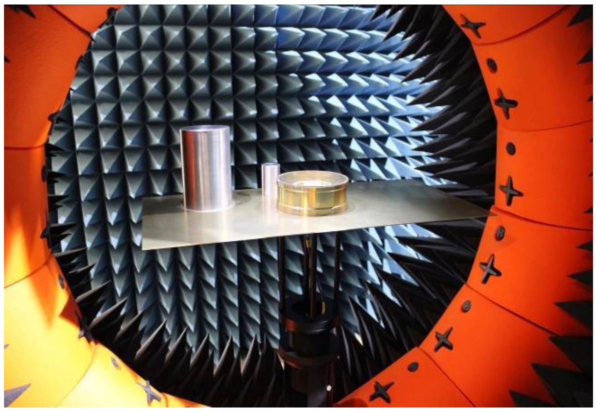


Fig. 5. Cavity back cross dipoles on the rectangular ground plane and scattering cylinders in the MVG Spherical Near Field antenna measurement system, SL18GHz.

The scattering objects are two cylinders. The small cylinder has a diameter of 0.25λ, a height of 0.33λ and the center at (x,y) = (-0.33λ, 0.64λ). The big cylinder has a diameter of 0.58λ, a height of 0.88λ and the center at (x,y) = (-1.17λ, 0.40λ). The tested frequency is 1940MHz. The cylinders are both in the near field region and their presence affects the shape of the radiation pattern, as is shown in Figure 6.

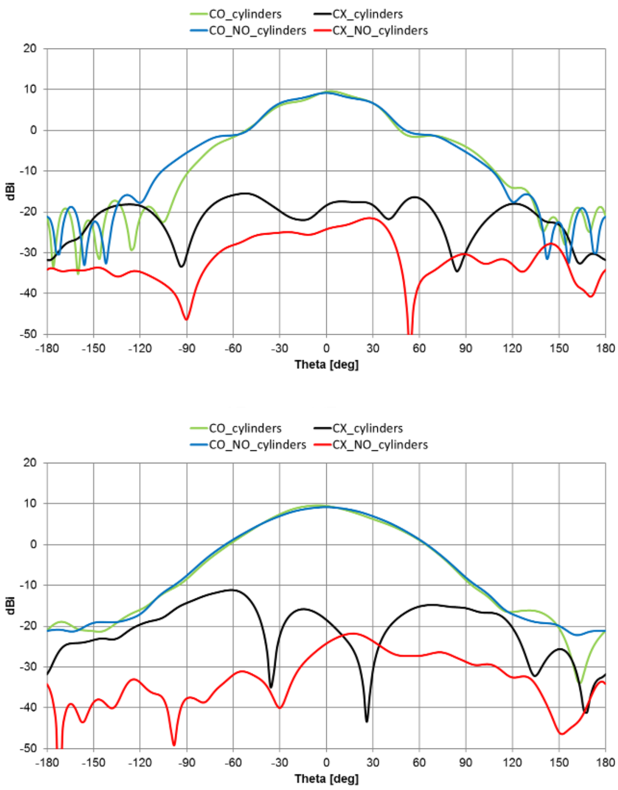
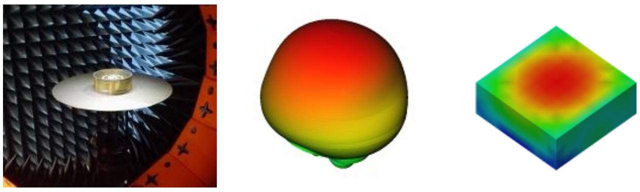


Fig. 6. Directivity radiation patterns at 1940MHz of the cavity back cross dipoles on the rectangular plane, with cylinders and without cylinders as scattering objects; phi=0° (top) and phi=90° (bottom) planes.

A. Preparation of the Source Antenna/Huygens Box

The measured representation of the source antenna has been prepared using the procedure for flush mounted antennas, described in section II.B. Therefore, the cavity backed cross dipoles have been measured on a circular ground plane of diameter 2.6λ at the test frequency of 1.94 GHz. The measurement set-up and the radiation pattern are shown in Figure 7 (a) and (b). After post-processing to eliminate edge diffraction, an equivalent Huygens box is created by the SW INSIGHT [6] as shown in Figure 7 (c).



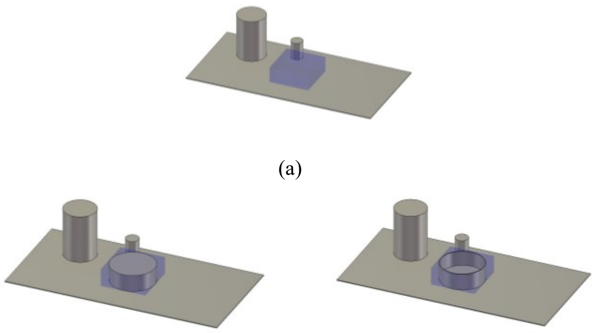
(a) (b) (c)

Fig. 7. Measurement of the cavity backed cross dipoles on a limited ground plane in the MVG, SL18GHz spherical near field multi probe system (a); meaured radiation pattern @1.94GHz (b); EQC source (c).

B. Including a Mock-Up of the Antenna Model Inside the Huygens Box

Preliminary analyses have been carried out on the measured source in simulations to evaluate the need of including a mock-up of the antenna model inside the Huygens box [11]. Indeed, in case of strong interaction between the radiator and the scattering objects, the mock-up approximates a blockage effect of the real antenna, improving the accuracy of the simulation [19-20].

At this scope, the case without the mock-up of antenna model (Figure 8-a) has been initially compared with the case of using a cylinder as mock-up (Figure 8-b). The comparison in terms of directivity is shown in Figure 9. The mean weighted difference between the curves is ~40dB. Then, at increasing complexity, the use of a cavity (Figure 8-c) with respect to the simple cylinder, has been studied. The comparison in terms of directivity is shown in Figure 10. The mean weighted difference between the curves is ~50dB.



(a)

(b) (c)

Fig. 8. Scenario under test: (a) No mock-up of the antenna model inside the Huygens box; (b) a cylinder as mock-up; (b) a cavity as mock-up.

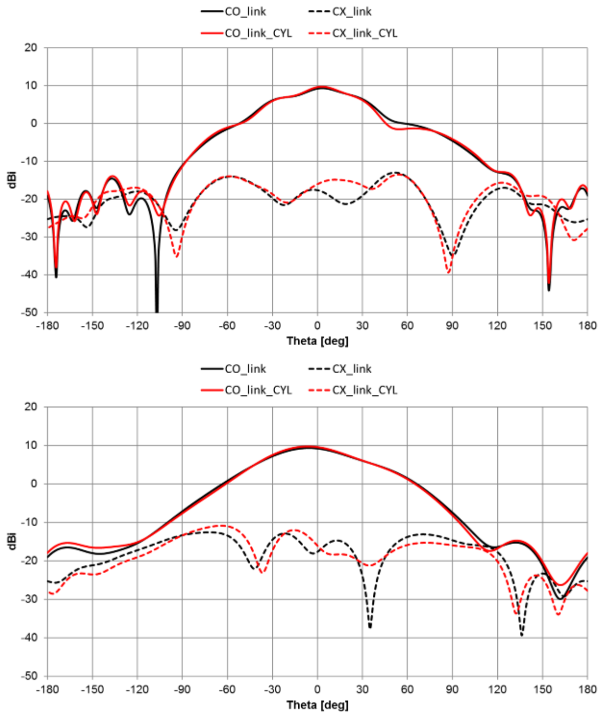


Fig. 9. Directivity radiation patterns of the cavity back cross dipoles on the rectangular plane, with (link_CYL) and without (link) the mock-up of the antenna model; phi=0° (top) and phi=90°(bottom) plane at 1940MHz.

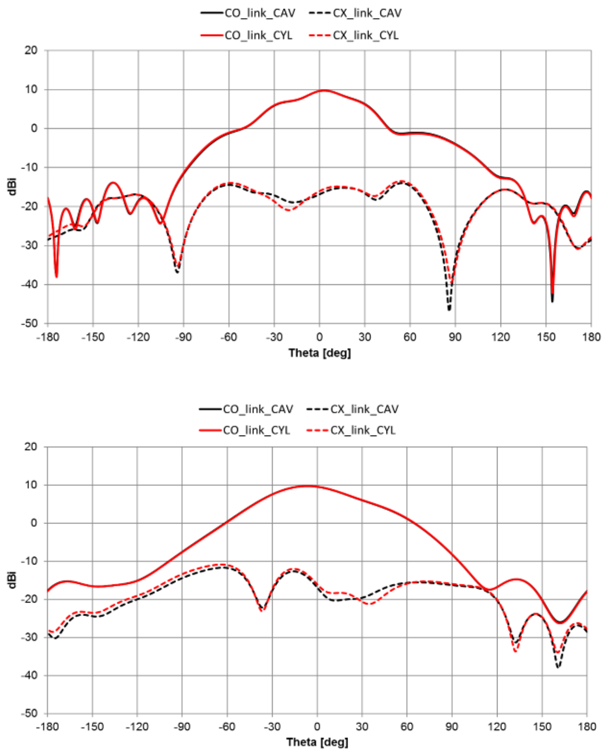


Fig. 10. Directivity radiation patterns of the cavity back cross dipoles on the rectangular plane, with the cavity (link_CAV) and the cylindrer (link_CYL) as reduced antenna model in the Huygens box; phi=0° and phi=90° plane at 1940MHz.

The achieved results confirm that including a mock-up of antenna model inside the Huygens box leads to a negligible improvement of the simulation accuracy, at least for the scope of the activity.

IV. Results

The Huygens box of the measured antenna in stand-alone condition has been provided to all the SW vendors [11-16] for simulation on the plate with the scattering cylinders. Since no mock-up of the antenna model is needed inside the Huygens box, no mechanical information of the antenna has been disclosed. The set-up under test is shown in Figure 11, where the source antenna is represented by the red box. Testing by the SW vendors is in progress and the complete results will be presented at the conference.

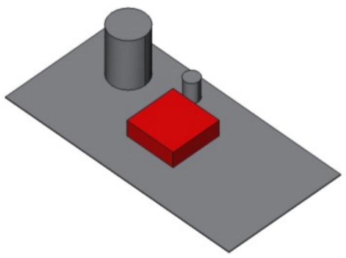


Fig. 11. Set-up under test provided to the SW vendors. The source antenna is represented by a red box.

V. Conclusion

Results of the latest test cases of the validation campaign have been reported in this paper. The scenario under test consists of an open ended waveguide offset mounted on a rectangular plate. The average correlation between simulations with the measured source and the reference measurement of the final scenario is ~30dB, which is comparable to what is achievable with a full-wave simulation of the scenario. This positive result confirms the accuracy of proposed approach, based on the link between measurement and simulation, concluding the validation campaign.

The second session has been dedicated to the next phase of analysis, hence the application of the link to more complex scenarios, including scattering problems. The scenario under test was an antenna placement problem where the radiator was placed in proximity of two scattering objects on a plate. The radiator consisted of cavity backed cross dipoles at the testing frequency of 1940MHz.

The antenna source has been prepared from the measured radiation pattern and the source has been provided to the SW vendors for modeling. Preliminary studies on the measured source show that including a mock-up of the antenna model inside the Huygens box leads to a negligible improvement of the accuracy of the simulation, therefore the antenna under test can be unknown.

Testing by the SW vendors is in progress and the complete results will be presented at the conference.

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