Measured Antenna Representation of Flush Mounted Antennas for Computational Electromagnetic Solvers

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***Abstract*—Accurate representative electromagnetic models of measured antennas based on the MVG software INSIGHT processing, implementing the inverse source technique, have been demonstrated [1-5]. The measurement processing is based on the expansion of the measured field using equivalent currents [7-10]. A recently created link enable the INSIGHT to export the electromagnetic model to a number of commercial Computational Electromagnetic (CEM) solvers [11-16]. In flush-mounted antenna applications, the antenna measurement and the data processing has to be carefully performed.**

This paper discuss the source antenna measurement, post processing and successive link to commercial CEM solvers for numerical simulations of the antenna characteristic within a large complex environment, with particular attention to the accuracy of the near field radiation when the measured source is flush-mounted in the simulation scenario.

***Index Terms*— antenna, simulation, measurement.**

I. INTRODUCTION

Domain decomposition techniques based on near field description of the local domain are available and commonly used in most CEM solvers in case of complex and/or large scenarios [11-16]. This approach of analysis it is usually adopted using only numerical simulations, but thanks to the direct link between INSIGHT processing of measured antenna data and CEM tools, when measurements of antennas are available, these can be imported and used efficiently in numerical simulations, as discussed in [1-3]. A validation campaign of the link between INSIGHT and CEM solvers is on-going [1-3].

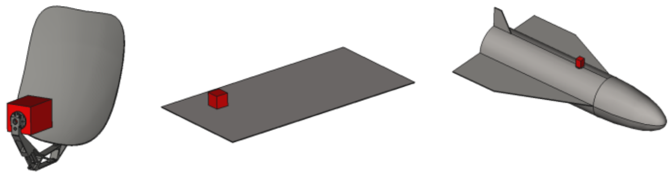
The purpose of this paper is to describe the philosophy of the validation campaign and to show the updated results by new CEM tools as participants, with particular attention to the flush-mounted measured antenna representations of SMC2200 monocone antenna on a rectangular plate (flat structure) and of SM6000 monopole on a mock-up of a space plane (curved structure). Finally a new test case is presented consisting of an open ended waveguide (OEW) flush mounted on a flat rectangular plate. This test case has been selected to investigate the accuracy of the method when the polarization of the source antenna is parallel to the flat structure, and then a different set-up with respect to the monocone having polarization orthogonal to the plate.

II. VALIDATION CAMPAIGN PHILOSOPHY

Validation campaign of the link between measurements and simulations is focused to verify the accuracy of the measured near field source representation and its application to different CEM tools and numerical methods.

For simplicity a box is selected for exchanging the antenna source data since it is the geometry type supported by all CEM tools see Fig 1. For guaranteeing the independence of the generation of the data in the different CEM tools we adopted the following procedure.

The prepared Huygens box sources have been provided to the SW vendors for simulation in the final scenarios, see Fig 1. Same data set has been provided to all of them. Additionally to the source data the following information has been transferred: CAD of the final scenario, position of the box in the final scenario and reference measurement of the source in the scenario for preliminary check of the accuracy of the simulation.



(a) (b) (c)

Fig. 1. Test cases for the validation campaing of the link between INSIGHT and CEM solvers. (a) Reflector antenna fed by an horn; (b) Flush mounted monocone antenna on a flat structure; (c) Flush mounted monopole antenna on a curved structure. Measured Near-Field sources are represented as red boxes.

During the first part of the campaign data from the SW vendors have been collected by MVG and only after all data being available these have been compared and published. The SW vendors, participating to the second run of the validation campaign, could only check the results by visual inspection of published plots. No exchange of numerical results of simulations has been performed with SW vendors during all validation campaigns.

This is the philosophy to preserve the spirit and validity of the campaign.

III. APPLICATION SCENARIO

Different applications of flush mounted antennas in complex environments have been examined, a rectangular ground plane and a space-plane mock up.

A simple ground plate of 30 x 60 cm has been chosen as initial validation scenario to minimize errors not directly related to the validation of the measurement/simulation link (see Fig.2). The test antennas are:

- monocone antenna (SMC2200);
- open ended waveguide (OEW).

Initially the SMC2200 antenna has been studied having polarization orthogonal to the ground plane [1-3]. Later the OEW has been investigated to verify the accuracy of the NF-model of ground plane aperture antenna.

The source antennas are mounted 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 is shown in Fig. 2 during measurements in the MVG of the SMC2200 monocone antenna, SL18GHz spherical near-field multi probe system [17].

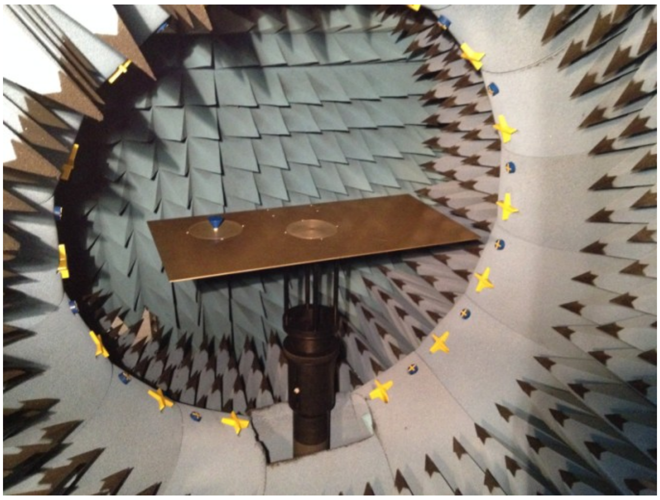


Fig. 2. Rectangular ground plane validation structure during measurement in the MVG Spherical Near Field antenna measurement system, SL18GHz.

The accuracy of the method is investigated by comparison with measurements and/or full-wave simulation of the full structure. Experiments have been designed to minimize errors, not directly related to the validation of the measurement/ simulation link.

As more complex validation scenario has been considered a flush mounted antenna on a curved structure (see Fig.3). The test antenna is monopole antenna. The source antenna is mounted directly on the back of the mock-up of a space plane.

The purpose of this investigation is to quantify the error deriving from the flat ground plane approximation employed in the measurement and processing of the measured source.

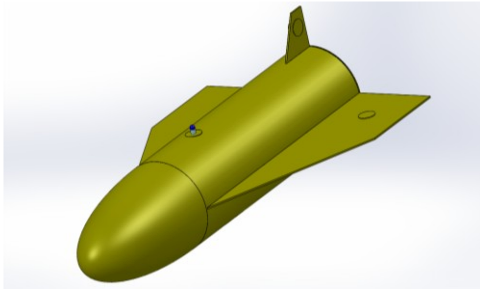


Fig. 3. Space plane CAD model with the monocone antenna.

IV. PREPARATION OF THE NEAR-FIELD SOURCE

The evaluation of the electromagnetic model of the source antenna for flush mounted applications is much more complex respect to the determination of the model of an antenna detached from the scattering structure. The proximity of scattering structure modifies the current distribution on the antenna itself.

An infinite ground plane boundary condition is a good approximation of the correct boundary conditions; however, it could be not directly obtained on a realistic measurement scenario. This condition can be emulated from measurements of the source antenna installed on a finite ground plane together with the application of measurement post processing, as discussed in [1-2].

The post processing of the measured data removes the diffractive contributions from the edges of the finite ground plane creating the wanted infinite ground plane boundary conditions. A circular ground plane with minimum 5λ diameter is considered adequate for most measurement source antennas.

In the validation examples all antennas have been measured on a circular ground plane of diameter 7λ (at the test frequency of 5.28 GHz) in the MVG, SL18GHz spherical near-field multi probe system as illustrated in Fig. 4. After post processing, to eliminate edge diffraction, the 3D electromagnetic model in the form of equivalent electric and magnetic currents associated to the source can be evaluated with INSIGHT. It should be noted that, since an infinite ground plane condition is considered, the image of the source antenna is initially included in the equivalent current computation and then removed when determining the Huygens Box representation of the measured source.

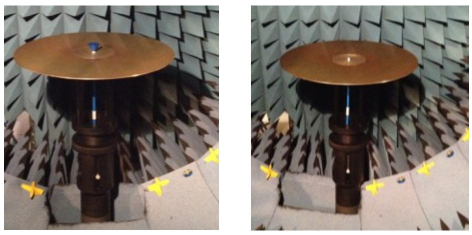


Fig. 4. Measurement of the monocone antenna, monopole antenna on a limited ground plane in the MVG, SL18GHz spherical near-field multi probe system [14].

For the Open Ended Waveguide (OEW) a preliminary analysis of the validity of the representation of the source in terms of equivalent currents has been carried out based on simulated results [11]. The OEW source antenna has been simulated on a circular ground plane of diameter 6λ (at the test frequency of 4.38 GHz). The simulation set-up is shown in Fig 5 (left). The simulated FF radiation pattern has been post-processed by INSIGHT to prepare the NF source correspondent to the OEW. The computed NF source has been imported and simulated on the same circular plane as is shown in Fig 5 (right). The representation of the source in terms of J electric and M magnetic currents is shown in Fig 6.

Comparison between the full wave simulation and the simulation of the NF source in the same environment is shown in Fig 7 for the cut phi=90° @4.38GHz. The good agreement demonstrates the accuracy of the method for representing a antenna source with polarization parallel to the placement structure.

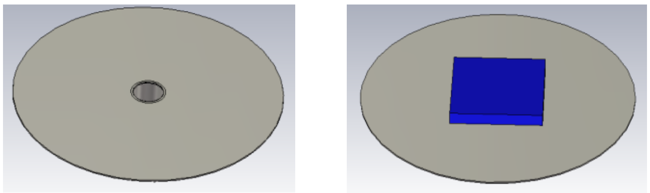


Fig. 5. Simulation of the OEW on the circular plate, simulation of the Nerar-Field source of the OEW (from INSIGHT) on the circular plate @4.38GHz.

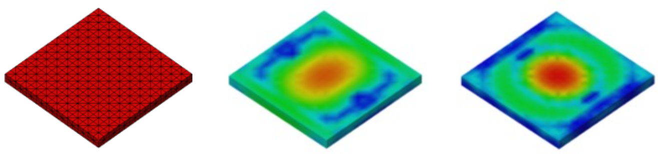


Fig. 6. Equivalent current represnetation of the OEW source computed by INSIGHT, @4.38GHz. Meshed eometry of recocctruction (left), J electric currents (center), M magnetic currents (right). Dynamic range 30dB.

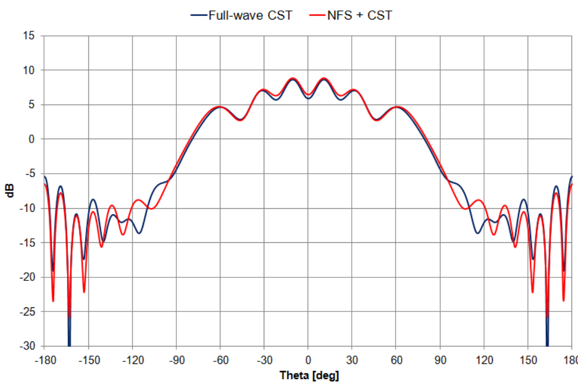


Fig. 7. Directivity pattern of OEW on the circular plate @4.38GHz. Compartison between full.wave simuation [11] and Near-Field source simualted in the same scenario.

V. RESULTS

The resulting pattern of the validation structures in Fig. 1 has been computed using the measured monocone antenna as source model. The measured and simulated peak directivities @ 5.28GHz of the rectangular plate with SMC2200 mono-cone antenna are reported in Table I. MEAS is the measured reference from MVG. The simulated results [11-15] are updated with data from new CEM tool [16] involved during the validation campaign.

Very good agreement between measurements and simulation can be observed.

TABLE I. PEAK DIRECTIVITY @5.28GHZ – SMC2200 ON PLATE

	CST	Savant	FEKO	ADF	HFSS	WIPL-D
Peak Directivity [dBi]	6.2	5.7	5.9	5.8	6.0	5.5

The measured reference is compared to the simulated co-polar patterns from simulation using the measured source. The agreement between simulation and measurements is very good even though an approximation due to the feed representation and uncertainties arising from measurement, manufacturing and simulation.

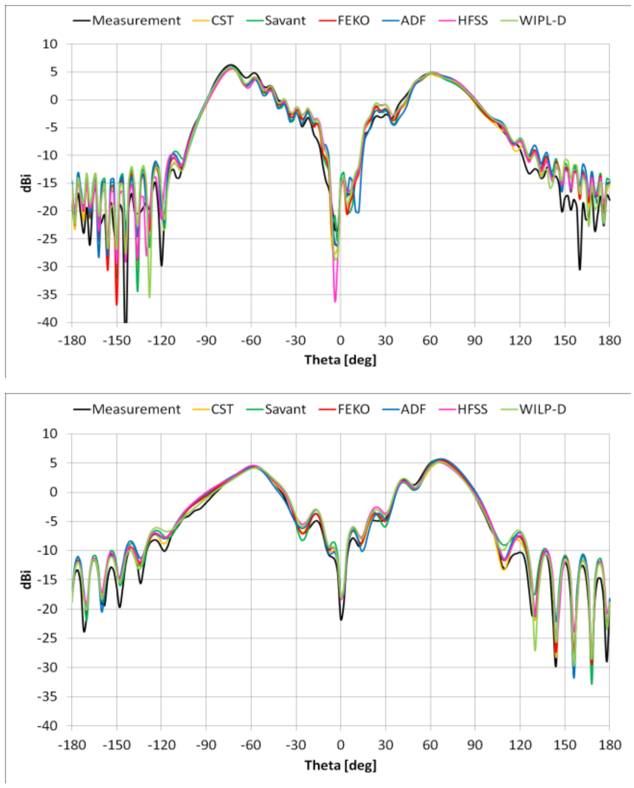


Fig. 8. Directivity pattern of SMC2200 monocone antenna on rectangular plate @ 5.28 GHz. phi=0° plane (top), phi=90° plane (bottom). Measurement and simulation using measured source: CST [11], Savant [12], FEKO [13], HFSS [14], ADF [15], WIPL-D [16].

The agreement or correlation between simulations and measurements has been evaluated in terms of weighted difference [2] between measured and simulated field. The measured far field has been evaluated as reference field. An overlay of the weighted difference for each simulation tool with the measured, patterns @ phi = 0° and @ phi = 90° in the forward hemisphere is shown in Fig. 9.

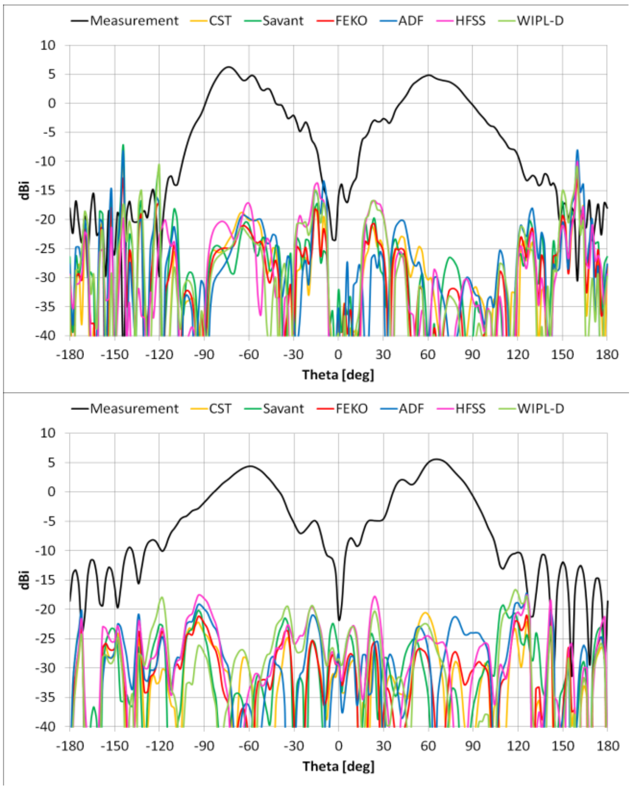


Fig. 9. Weighted difference of simulation and measurements, phi=90° plane. Simulation using measured source: CST [11], Savant [12], FEKO [13], HFSS [14], ADF [15], WIPL-D [16].

The medium value of the weighted difference have been calculated representing the correlation in a single value as shown in Table II. The average correlation between simulations and measurement is ~30dB, which is similar to what is obtainable with full-wave simulation of the antenna. This promising result confirms the accuracy of the measured source representation and the validity of the method implementing the link between measurements and CEM tools.

TABLE II. MEAN WEIGHTED DIFFERENCE WITH MEASUREMENT MONO-CONE ANTENNA SMC2200 ON RECTANGULAR PLATE

	CST	Savant	FEKO	ADF	HFSS	WIPL-D
Phi=0° plane [dB]	-30.2	-30.1	-30.5	-28.7	-30.17	-31.02
Phi=90° plane [dB]	-33.2	-32.4	-33.4	-30.5	-30.79	-31.63

Analyses using the open ended waveguide and the SM6000 monopole as measured sources for the CEM tools are under development.

VI. CONCLUSIONS

Use of flush-mounted measured antennas as NF sources in commercial numerical simulations tools has been presented in this paper. Validation campaign is focused to verify the accuracy of the Near-Field source representation and its application to different numerical methods. The status of the validation campaign has been updated with results computed by new CEM tool vendors as participants. The accuracy of the new results is of the same order of those previously obtained [1].

Finally an open ended waveguide as source has been analyzed to verify the validity of the approach even for antennas having polarization parallel to the placement structure. Preliminary results based on simulated data shown a good accuracy of the source representation and this is very encouraging for the further application of the source in the final scenario.

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