Measurement Field Source for Antenna Placement in Space Applications

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***Abstract*—Measured antennas as field sources in numerical simulation is by now a consolidated method to investigate deployed antenna performance. Typical applications are situations where a measurement of the entire scenario or a full-wave representation is unfeasible or unavailable [1-5]. Antenna placement on complex platforms such as satellites are good examples of such application. In these scenarios, the antennas are often supplied by a third party. Thus the mechanical and electronic characteristics needed for a full-wave representation of the antenna are likely unavailable or not in the right format for use by the Computational Electromagnetic (CEM) tool. To overcome this problem, the antenna can be fully characterized by measurement. The equivalent field source, compatible with the CEM tool, can then be derived, as a Huygens box, using an Equivalent Current (EQC) expansion [6-7].**

The measured field source was applied in the investigation of a GNSS antenna on a mock-up of the Sentinel satellite designed, manufactured and measured by RUAG SPACE [8]. This scenario was investigated in [9-10]. In this paper, the accuracy investigation is extended to include different CEM tools [11-12] and comparison with measurements of the full mock-up.

***Index Terms*— GNSS antenna; simulation; measurement; satellite.**

I. INTRODUCTION

The analysis of deployed antenna performance in complex scenarios can prove to be problematic due to the realistic details to be taken into account in the investigation. In these cases, both numerical modeling and measurements are fundamental tools to evaluate the antenna performance. The numerical modelling created with Computational Electromagnetic (CEM) tools requires a particular representation of the source antenna. This can be achieved by knowing the exact characteristics of the antenna. However, in many practical cases, a full-wave representation is unfeasible or unavailable.

In such situations, the radiating antenna can be characterized by a true radiating measurement. From the measured radiation pattern, an Equivalent Current (EQC) representation of the measured source antenna in near field can be determined and this can be imported into the CEM tool for simulations. The obtained EQC model is an electromagnetic complete representation of the radiation pattern of the antenna and can be used as an equivalent black box, defined by Huygens' formulation, in simulations on the basis of the Domain Decomposition Technique (DDT) [1-5].

The equivalent representation of the measured antenna in form of Huygens box is obtained through or inverse source technique [6], which is a measurement post-processing method that represents the measured antenna in equivalent electric and magnetic currents on a surface conformal to the antenna. This method is implemented in the MVG INSIGHT software [7] which is able to process measured data of the isolated antennas. Several activities have demonstrated the use of EQC as highly efficient source representation of the measured antenna in complex environment analysis, using a wide range of commercial CEM solvers.

In this paper the link between measurement and simulation is applied in the study of a GNSS antenna on a mock-up of the Sentinel satellite designed, manufactured and measured by RUAG SPACE [8]. This scenario was investigated in the past [9-10], while in this new study the accuracy has been proven including different CEM tools [11-12] and comparing simulations with measurements of the full mock-up. Section II of this paper shows the scenario under test, that consists of a GNSS antenna mounted on a Sentinel satellite [11] mock-up at the working frequencies 1227 and 1575MHz. Section III reports the validation procedure. The EQC representation (Huygens box) of the source antenna, measured in standalone configuration, has been accurately prepared by [7] based on the measured source technique. The Electromagnetic (EM) field of the source antenna (GNSS) installed on the Satellite has been numerical simulated by [11-12]. Thanks to the link that enables [7] to export the electromagnetic NF source to different CEM solvers, the data are easily exchanged between the tools to finalize the study. Section IV reports and comments the results of the validation, such as the comparison between measurements and simulations of the GNSS antenna, mounted on the satellite mock-up model at both the tested frequencies 1227 MHz and 1575MHz. In Section V conclusions are reported.

II. GNSS ANTENNA AND SENTINEL SATELLITE MOCK-UP

The source antenna consists of the GNSS antenna shown in Fig.1. The radiator implements a pencil beam type pattern, with +/-70°. Working frequency range is from 1227 to 1575 MHz. The antenna is designed as a patch Excited Cup (PEC) with two stacked patches placed in a short cylindrical cup

(200mm diameter, 87mm height) and four-points feed with capacitive coupling of the bottom patch and an isolated feed network (phase quadrature).

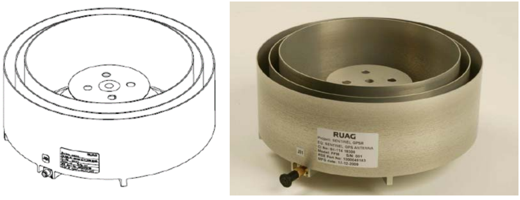


Fig. 1. GNSS antenna drawing (RUAG courtesy).

The system composed of the antenna and the Sentinel satellite mock-up is shown in Fig. 2 during radiated measurement. The position of the mounted antenna (L-Band antenna) is under lighted by a red arrow on the picture. Z-axis is orthogonal with respect to the cup basement.

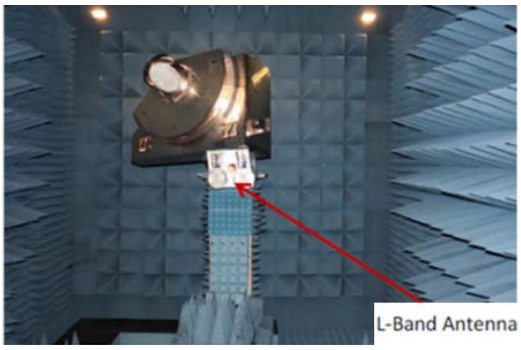


Fig. 2. Sentinel satellite mock-up (RUAG courtesy).

III. MEASURED FIELD SOURCES IN SIMULATION

The use of measured field sources is based on the link between antenna measurement equipment, CEM numerical modelling and an EQC model of an NF measurement of the source antenna suitable for the CEM solver. The complete validation procedure of the link is shown in Fig. 3, and includes the measurement of the source radiator (GNSS antenna), the preparation of the measured field source (Huygens' box), the simulation in [11-12] and finally the comparison with the measured full scenario for accuracy testing.

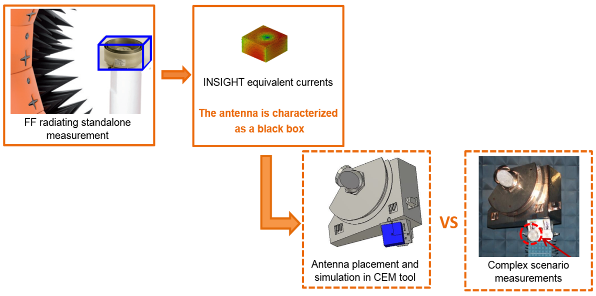


Fig. 3. Link between measureemnt and simualtion: validation procedure.

A. FF radiating standalone measurements

The radiation pattern (near field and/or far field) of the horn in isolation is to be initially measured. For this antenna the far field radiation pattern has been measured in stand-alone configuration, at the working frequencies 1227 and 1575 MHz, as reported in Fig. 4. The radiation pattern is stable over frequency and it has an azimuthally symmetric shape, guaranteeing a good antenna coverage, required for GNSS antennas.

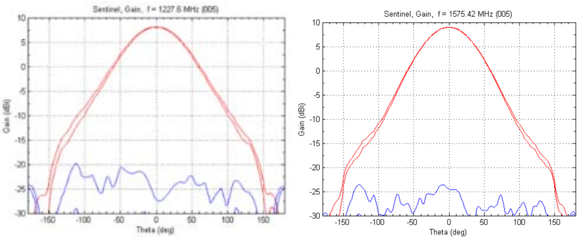


Fig. 4. Gain pattern of the GNSS antenna at 1227 MHz (left) and 1575 MHz (right).

B. Measured field source preparation

The measured data is then post-processed to obtain an equivalent black box, based on a Huygens' formulation., The NF sources are calculated from the measured radiation pattern of the antenna under test by the inverse source method [6-7]. The procedures for calculating the EQC are shown in Fig. 5 and Fig. 6. at 1227 and 1575 MHz respectively. The geometry of reconstruction is a box enclosing the antenna and discretized by a mesh of step 0.1 λ at the higher limit of the frequency band (1575MHz).

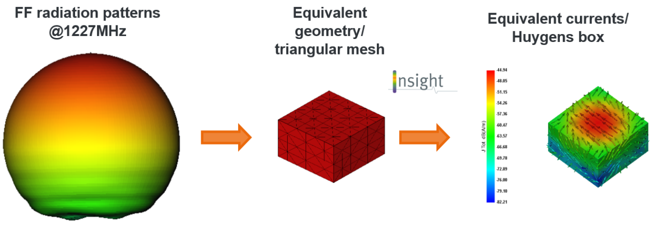


Fig. 5. Antenna characterization in terms of EQC using INSIGHT [7] @1227MHz.

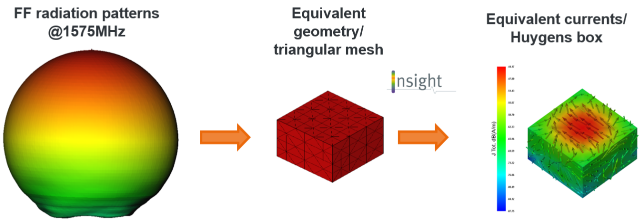
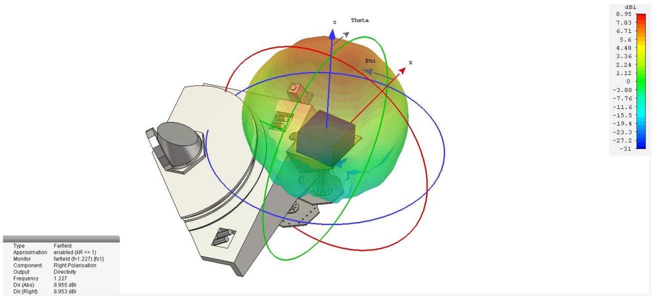


Fig. 6. Antenna characterization in terms of EQC using INSIGHT [7] @1575MHz.

C. *Simulation of the measured field source in CEM tool*

Once the measured field source has been created by the EQC method, it can be implemented into a number of CEM tools. The CEM solvers will consider it as a full representation of the antenna in any scenario required for simulation. Applying the Huygens' box approach, the simulation is carried out with no more additional information. The advantages are that no modifications to the source files are necessary and the EQC representation can be used in any scenario to be tested, even the most complex. The computed Huygens box (measured data) representing the PEC antenna is positioned on the spacecraft model in [11-12] and far-field radiation pattern is simulated in [11] and [12], as is shown in Fig. 7 and in Fig. 8 respectively.



Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=1.227) [fs1]
Component	Right Polarisation
Output	Directivity
Frequency	1.227
Dir.(Abs)	8.955 dBi
Dir.(Right)	8.953 dBi

Fig. 7. Placement and far field simulation in CEM tool @1227MHz in [11].

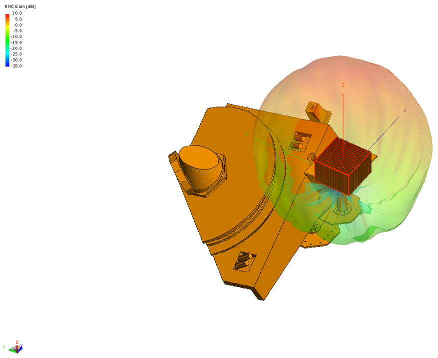


Fig. 8. Placement and far field simulation in CEM tool @1227MHz in [12].

IV. RESULTS

The comparisons between the satellite mock-up measurements and the radiated field simulated by [11] and [12], after importing themeasured fioeld source, are shown from Fig. 9 to Fig. 12.

The copolar (CO) and crosspolar (CX) components at 1227 MHz and 1575 MHz, phi=0° and phi=90°, of measurements and of simulation [11-12] based on measured NF Source (Huygens' box) are shown, together with the weighted difference on the copolar component (evaluated by the method outlined in [2]).

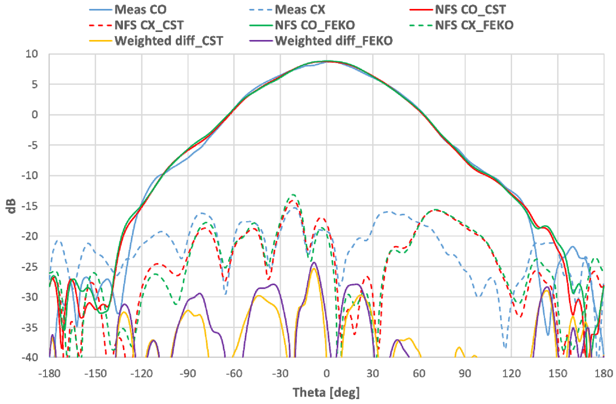


Fig. 9. Copolar and crosspolar components at phi=0° at 1227 MHz of measurements (MEAS), simulation based on INSIGHT NF measured source (NFS) by CST Studio Suite [11] , FEKO [12] and weighted difference.

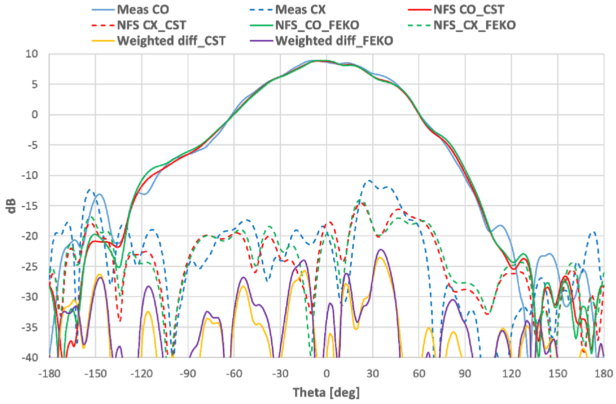


Fig. 10. Copolar and crosspolar components at phi=90° at 1227 MHz of measurements (MEAS), simulation based on INSIGHT NF measured source (NFS) by CST Studio Suite [11] , FEKO [12] and weighted difference.

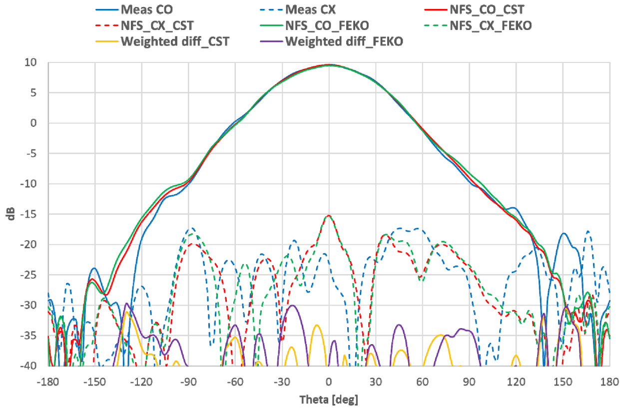


Fig. 11. Copolar and crosspolar components at phi=0° at 1575 MHz of measurements (MEAS), simulation based on INSIGHT NF measured source (NFS) by CST Studio Suite [11] , FEKO [12] and weighted difference.

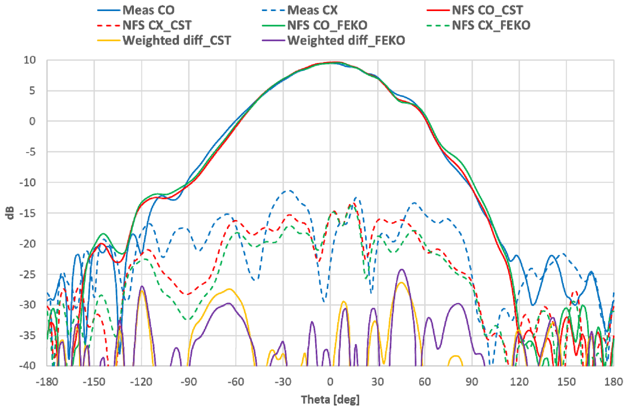


Fig. 12. Copolar and crosspolar components at phi=90° at 1575 MHz of measurements (MEAS), simulation based on INSIGHT NF measured source (NFS) by CST Studio Suite [11] , FEKO [12] and weighted difference.

The measured (MEAS) and simulated peak directivities at 1227 MHz and 1575 MHz, by [11] and [12] of the satellite are reported in Table I. Very good agreement between measurements and simulation can be observed.

The medium value of the weighted differences (equivalent noise level) for the copular component has been calculated representing the correlation in a single value for [11] and [12] as shown in Table II.

TABLE I. PEAK DIRECTIVITY

	Peak Directivity [dBi]		
Freq [MHz]	**MEAS**	**CST Studio Suite**	**FEKO**
1227 MHz	8.91	8.80	8.86
1575 MHz	9.58	9.63	9.49

TABLE II. EQUIVALENT NOISE LEVEL

		Equivalent Noise Level [dB]	
Freq [MHz]	**Phi**	**CST Studio Suite**	**FEKO**
1227 MHz	0°	-35.33	-34.05
	90°	-33.18	-31.93
1575 MHz	0°	-39.10	-37.18
	90°	-34.93	-34.56

V. CONCLUSIONS

The measured field source method based on the link between measurement and simulation has been applied in the study of a GNSS antenna on a mock-up of the Sentinel satellite designed, manufactured and measured by RUAG SPACE.

The comparison between reference measurement and the simulations by different CEM tools confirms the reliability of the EQC method to represent the radiating antenna in placement problems.

A good agreement between the patterns is detected and this is confirmed by the equivalent noise level, which in some cases, is around -39 dB. These results are perfectly aligned in terms of accuracy with the precedent validation campaigns on this scenario.

ACKNOWLEDGMENT

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