Validation of Measured Source Antenna Representation in the Numerical Simulation of a GNSS Antenna on Sentinel Satellite

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Abstract— **The measured source or Huygens box antenna representation has become an increasing popular solution to create accurate computational models of measured source antennas for the numerical analysis of antenna placement on complex platforms such as satellites. The equivalent representation of the measured antenna is obtained through the equivalent current (EQC) or inverse source technique, which is a measurement post-processing method that represents the measured antenna in terms of equivalent electric and magnetic currents on a surface conformal to the antenna. This technique enables computation of complex antenna scenarios in which the source antenna is physically available but the computational details are unknown. This is often the case for space antenna testing in which antennas from different suppliers are integrated on a platform representing the complex scenario.**

In this paper, the validation of this technique in space antenna testing application is presented. The test object is a GNSS antenna mounted on a Sentinel satellite mock-up (both designed, manufactured and measured by RUAG SPACE) working at 1227 and 1575 GHz. Preliminary results of this validation activity have been previously presented. This paper reports on the full validation activity.

I. INTRODUCTION

The measured source or Huygens box antenna representation has become an increasing popular solution to create accurate computational models of measured source antennas for the numerical analysis of antenna placement on large and complex platforms such as satellites [1-6]. For such scenarios, in fact, the accuracy of the representation of the radiating antennas is very relevant for the accuracy of the complete simulation in the Computational Electromagnetic (CEM) tool.

The use of a domain decomposition technique in which the radiating antennas are analyzed separately and then are included as radiating sources, in form of Huygens box, in the numerical simulation of the remaining part of the entire system allows to obtain a remarkable improvement of the results. Due to the conclusiveness and high reliability of actual measured data, antenna measurements can be used as accurate radiation sources in numerical simulations for a wide set of antenna scenarios instead of using numerical or simulated antenna sources.

The equivalent representation of the measured antenna in form of Huygens box is obtained through the equivalent current (EQC) or inverse source technique [7-10], 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.

The EQC representation can be derived from the MVG Software INSIGHT [6] which is able to process measured data of the isolated antennas. Several activities [1-6] 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.

The highly accurate representation of the measured antenna can be used for both suspended and flush mounted antenna and the format is compatible with most commonly used commercial CEM solvers. This technique enables computation of complex antenna scenarios in which the source antenna is physically available but the mechanical and/or electrical details are unknown. This is often the case for space antenna testing in which antennas from different suppliers are integrated on a platform representing the complex scenario.

Preliminary results of this validation activity have been previously presented [13]. This paper reports on the full validation activity for space antenna testing application.

Section II shows the test object: a GNSS antenna mounted on a Sentinel satellite [11] mock-up working at 1227 and 1575 MHz. The GNSS antenna and Sentinel satellite structure have been designed, manufactured and measured by RUAG SPACE.

Section III presents the validation workflow. The EQC representation, in form of Huygens box, of the GNSS antenna, measured in standalone configuration, has been accurately computed through the MVG software INSIGHT using the measured source technique. The Electromagnetic (EM) field of the GNSS antenna installed on the Satellite has been computed using CST[12], thanks to the link that enable the INSIGHT to export the electromagnetic model to a number of CEM solvers.

Section IV reports on the validation results: the simulations are compared to measurement of the GNSS antenna installed on the satellite mock-up model at the working frequencies of 1227 MHz and 1575 MHz.

In Section V conclusions are drawn.

II. TEST OBJECT AND COMPLEX SCENARIO

The GNSS antenna, visible in Figure 1, is characterized by a pencil beam type pattern, with +/-70° of coverage working at frequencies between 1227 to 1575 MHz. The antenna is a patch Excited Cup (PEC) with two stacked patches placed in a short cylindrical cup and four-points feed with capacitive coupling of the bottom patch and an isolated feed network (phase quadrature). The design work has been concentrated on the antenna radiation in the back direction and the possibility to, at the same time, keep a good coverage at low elevation angles.

Figure 1.   GNSS antenna drawing (RUAG courtesy).

The complex scenario is represented by the antenna installed on a Sentinel [11] satellite mock-up, shown in Figure 2.
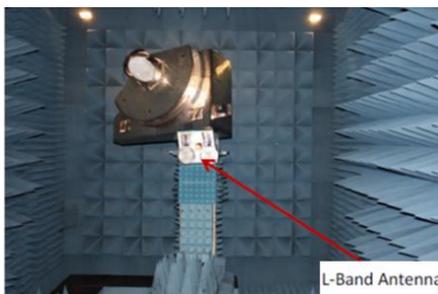

Figure 2.   Sentinel satellite mock-up (RUAG courtesy).

III. VALIDATION WORKFLOW

The validation workflow, shown in Figure 3, consists of four steps:

A. FF radiating standalone measurement;

B. Antenna characterization with EQC;

C. Simulation in CEM tool;

D. Comparison with complex scenario measurements.
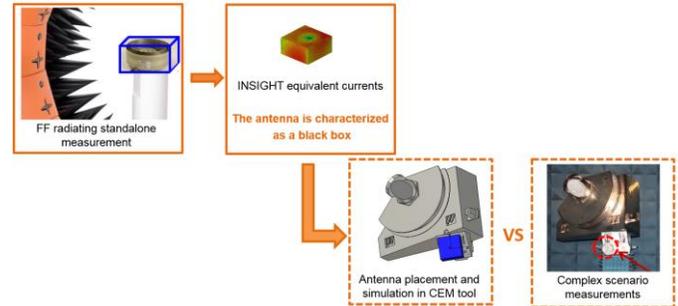

Figure 3.   Validation workflow.

A. FF radiating standalone measurements

The GNSS antenna has been measured in stand-alone configuration, at 1227 and 1575 MHz, as visible in Figure 4.
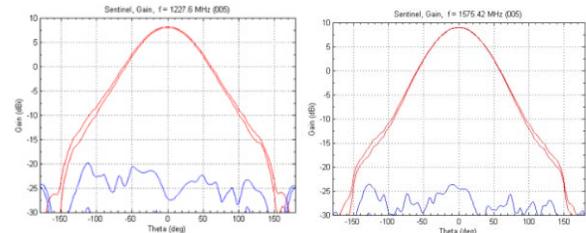

Figure 4.   Gain pattern of the GNSS antenna at 1227 MHz (left) and 1575 MHz (right).

B. Antenna characterization with EQC

EQC field representation, at 1227 and 1575 MHz, is calculated from the measured radiation pattern of the antenna under test by the inverse source method [1-10], implemented in INSIGHT, following the workflow depicted in Figure 5 and Figure 6.
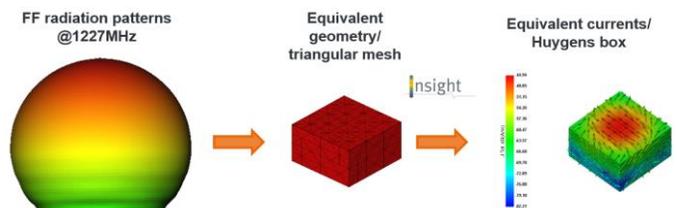

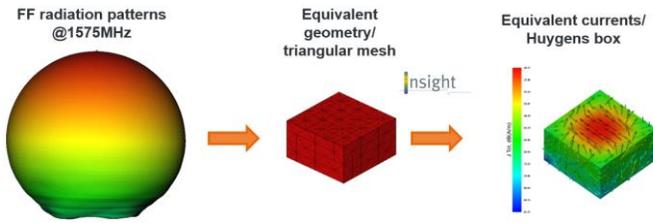Figure 5.   Antenna characterization in terms of EQC using INSIGHT @1227MHz.

Figure 6. Antenna characterization in terms of EQC using INSIGHT @1575MHz.

C. Simulation in CEM tool

The EQC are computed in form of Huygens box enclosing the radiator to exchange the antenna source data in the numerical software CST [12]. The computed Huygens box (measured data) representing the PEC antenna is positioned on the spacecraft model, as visible in Figure 7 and Figure 8.
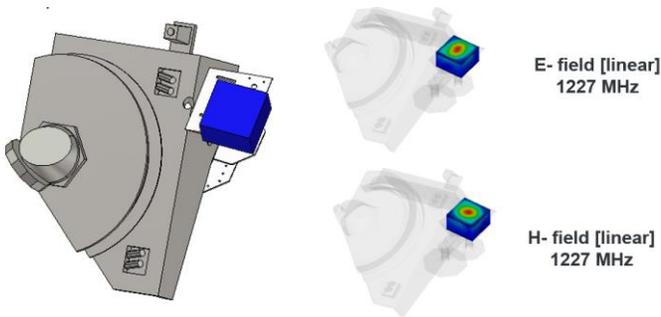

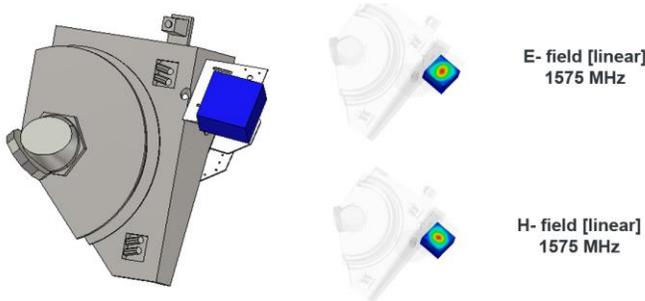Figure 7. Placement and simulation in CEM tool @1227MHz.

Figure 8. Placement and simulation in CEM tool @1575MHz.

IV. RESULTS

The comparisons between complex scenario measurements and the field computed with CST, after importing the INSIGHT Huygens box, are shown in the following plots.

The copolar (CO) and crosspolar (CX) components at 1227 MHz and 1575 MHz, phi=0° and phi=90°, of measurements and of CST simulation based on measured NF Source (INSIGHT Huygens box) are shown, together with the weighted difference on the copolar component (computed using the method outlined in [14]), from Figure 9 to Figure 12.

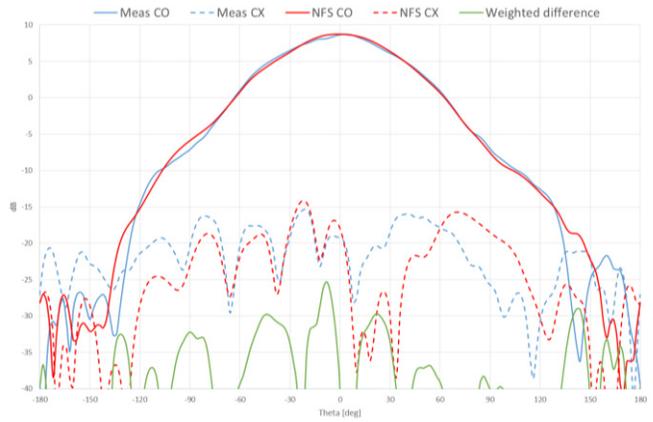The visual agreement is confirmed by the computation of the equivalent noise level reported in Table I.

Figure 9. Copolar and crosspolar components at phi=0° of measurements (MEAS) and of CST simulation based on INSIGHT NF measured Source (NFS) at 1227 MHz.
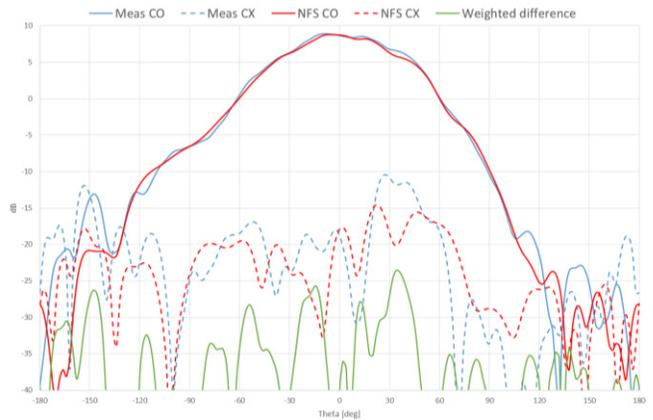

Figure 10. Copolar and Crosspolar components at phi=90° of measurements (MEAS) and of CST simulation based on INSIGHT NF measured Source (NFS) at 1227 MHz.

Figure 11. Copolar and Crosspolar components at phi=0° of measurements (MEAS) and of CST simulation based on INSIGHT NF measured Source (NFS) at 1575 MHz.
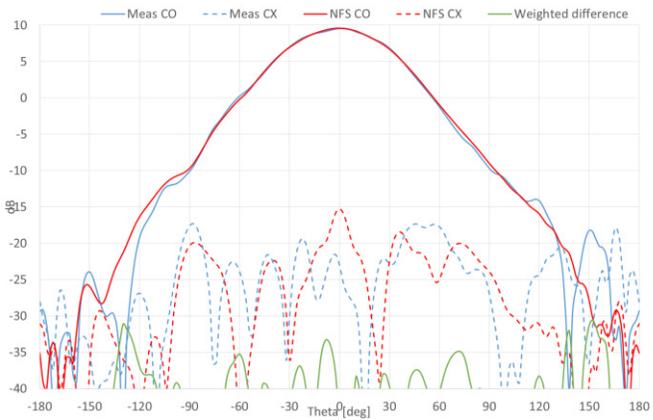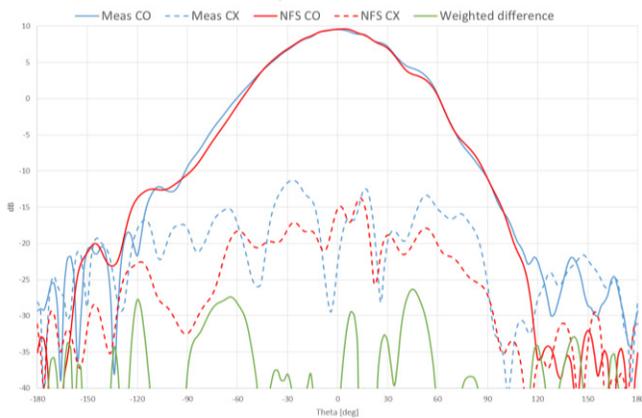
Figure 12. Copolar and Crosspolar components at phi=90° of measurements (MEAS) and of CST simulation based on INSIGHT NF measured Source (NFS) at 1575 MHz.

TABLE I. EQUIVALENT NOISE LEVEL

Freq [MHz]	Phi	Component	Equivalent Noise Level [dB]
1227	0°	CO	-35.33
		CX	-34.96
	90°	CO	-33.18
		CX	-33.95
1575	0°	CO	-39.10
		CX	-37.78
	90°	CO	-34.93
		CX	-33.96

V. CONCLUSIONS

The RUAG GNSS antenna representation as INSIGHT NF source imported in CEM tool has been computed in a complex scanario, represented by a Sentinel satellite mock-up. The validation has further demonstrated the reliability of the EQC approach in a test case characterized by a complex configuration where the measurements are characterized by interactions with the positioner.

The visual agreement between the patterns is confirmed by the equivalent noise level, which in some cases, is around -39 dB, confirming the accuracy achieved in recent validation activities [14].

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REFERENCES

[1] L. J. Foged, L. Scialacqua, F. Saccardi, F. Mioc, G. Vecchi. J. L. Araque Quijano, "Antenna Placement based on Accurate Measured Source Representation and Numerical Tools", IEEE Antennas and Propagation Society International Symposium, July 19-24, 2015.

[2] L. J. Foged, L. Scialacqua, F. Saccardi, F. Mioc "Measurements as Enhancement of Numerical Simulation For Challenging Antennas", EUCAP 2015 April 12-17, 2015.

[3] L. J. Foged, L. Scialacqua, F. Saccardi, F. Mioc, D. Tallini, E. Leroux, U. Becker, J. L. Araque Quijano, G. Vecchi, "Bringing Numerical Simulation and Antenna Measurements Together", IEEE Antennas and Propagation Society International Symposium, July 6-11, 2014.

[4] L. J. Foged, B. Bencivenga, F. Saccardi, L. Scialacqua, F. Mioc, G. Arcidiacono, M. Sabbadini, S. Filippone, E. di Giampaolo, "Characterisation of small Antennas on Electrically Large Structures using Measured Sources and Advanced Numerical Modelling", 35th Annual Symposium of the Antenna Measurement Techniques Association, AMTA, October 2013, Columbus, Ohio, USA

[5] L. J. Foged, F. Mioc, B. Bencivenga, E. Di Giampaolo, M. Sabbadini "High frequency numerical modeling using measured sources", IEEE Antennas and Propagation Society International Symp, July 9-14, 2006.

[6] http://www.satimo.com/software/insight

[7] J. L. Araque Quijano, G. Vecchi, "Improved accuracy source reconstruction on arbitrary 3-D surfaces. Antennas and Wireless Propagation Letters, IEEE, 8:1046–1049, 2009.

[8] J. L. A. Quijano, G. Vecchi, L. Li, M. Sabbadini, L. Scialacqua, B. Bencivenga, F. Mioc, L. J. Foged, "3D spatial filtering applications in spherical near field antenna measurements", AMTA 2010 Symposium, October, Atlanta, Georgia, USA.

[9] L. Scialacqua, F. Saccardi, L. J. Foged, J. L. Araque Quijano, G. Vecchi, M. Sabbadini, "Practical Application of the Equivalent Source Method as an Antenna Diagnostics Tool", AMTA Symposium, October 2011, Englewood, Colorado, USA

[10] J. L. Araque Quijano, L. Scialacqua, J. Zackrisson, L. J. Foged, M. Sabbadini, G. Vecchi "Suppression of undesired radiated fields based on equivalent currents reconstruction from measured data", IEEE Antenna and wireless propagation letters, vol. 10, 2011 p314-317.

[11] https://sentinel.esa.int/web/sentinel/home

[12] www.cst.com, CST STUDIO SUITE™, CST AG

[13] L. J. Foged, M. Saporetti, L.Scialacqua, F. Saccardi, J. Zackrisson, D. Trenta, L. Salghetti, "Measurement and Simulation Comparison using Measured Source Antenna Representation of GNSS Antenna on Sentinel Satellite", APS, July 2017, San Diego, California, USA.

[14] L.J.Foged, M.A. Saporetti, M. Sierra- Castañer, E. Jørgensen, T. Voigt , F. Calvano D. Tallini, "Measurement and Simulation of Reflector Antenna", EuCAP, Lisbon, April 2015.