Using Measured Fields as Field Sources in Computational EMC

L.J. Foged, L. Scialacqua, F. Saccardi, F. Mioc
Microwave Vision Italy
Pomezia (RM), Italy
lfoged@satimo.com, lscialacqua@satimo.com,
fsaccardi@satimo.com, francesca@mioc.info

Morten Sørensen
Bang & Olufsen A/S
Peter Bangs Vej 15 DK-7600 Struer
Denmark
mse@bang-olufsen.dk

G. Vecchi
Antenna and EMC Lab, Politecnico di Torino
Torino, Italy
giuseppe.vecchi@polito.it

J. L. Araque Quijano
Universidad Nacional de Colombia
Bogotá, Colombia
jlaraqueq@unal.edu.co

Abstract— The source reconstruction or equivalent source method allows to represent each type of radiating device as near-field equivalent source in form of equivalent electric and magnetic currents (EQC) [1-5]. The equivalent currents can be evaluated from measured data (near-field and far-field) through a post-processing step involving the solution of an integral equation. The currents constitute an accurate 3D electromagnetic model, ensuring that the near-field and far-field properties of the measured device are maintained. A newly created link enables export of the equivalent near-field model (Huygens' box) to a number of commercial computational electromagnetic (CEM) solvers.

Of special interest to the EMC community, equivalent current representation of measured devices is directly applicable in diagnostics/hot-spot finding and in the determination of radiated emission at any distance. The near-field equivalent source, derived from measurements, can be used in the numerical simulation tools for analyzing the emission in different scenarios, when the device is located in the vicinity of different objects such as shielding, cables etc.

This paper shows examples of diagnostics and emission analysis of a printed circuit board (PCB) using commercially available near-field measurement systems, EQC post-processing and a commercial CEM tool.

I. INTRODUCTION

All electronic devices present in commercial products and integrated in their intended enclosure, need to be tested using EMC methods. Tests include verifying the radiation emission from the devices to be compliant with regulatory EMC requirements. Given the very many varieties of electronic devices produced and commercialised these testing processes represent a specially interesting activity. Hence, electronic manufacturers continuously research for new and more efficient methods to do pro-active EMC work and precompliance test [6-9].

In this paper we examine an innovative method for the analysis of the radiating emission from a printed circuit board (PCB) in different scenarios. The measured radiation pattern of the stand-alone PCB is used for obtaining an accurate representation of the device (near-field equivalent source). The near-field source is imported in the CEM tool [12] and applied in the calculation of the radiating emission with a particular attention to the representation of the equivalent model of the device.

II. DEVICE UNDER TEST

The Device Under Test (DUT) (see Fig. 1) consists of a 150 x 225 mm PCB working in the frequency range [30-1000] MHz. The PCB has a substrate of 1.54 mm thick lossy FR4 layer, three traces on the top layer and a full unbroken ground plane on the bottom layer. Only one trace is excited and terminated. The traces are 3 mm wide and both source and load impedances were 50 Ω. The emission from the PCB is very low, indeed the power absorbed by the load is >99%.

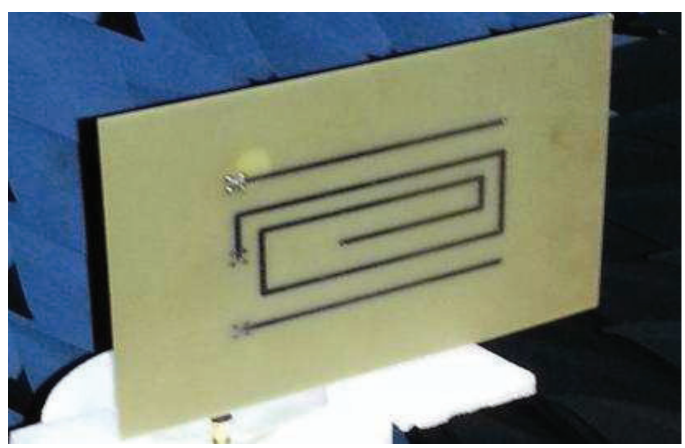


Figure 1. Tested Printed circuit board.

III. NF EQUIVAMENT MODEL FROM MEASUREMENT

Spherical Near-Field (SNF) measurement of the PCB has been performed in the MVG Multiprobe StarLab18GHz system [10]. The measurement set-up is shown in Figure 2.

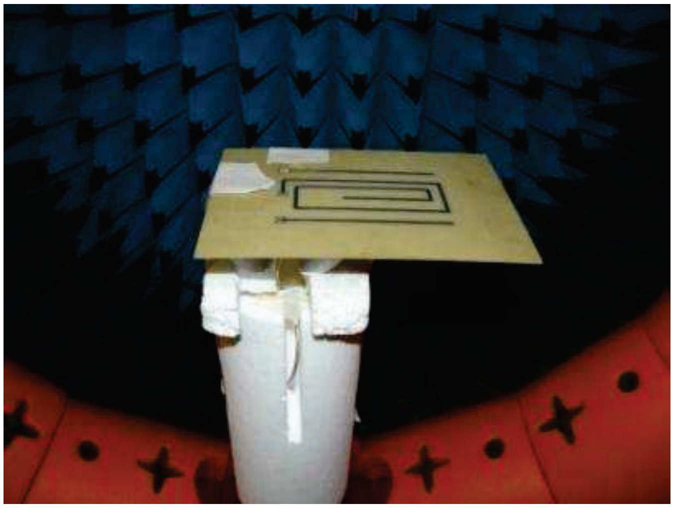
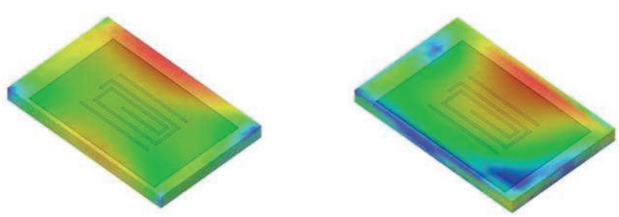


Figure 2. Tested PCB in the MVG Multiprobe StarLab18GHz system.

The measured near-field radiation pattern @640MHz has been processed by the MVG software INSIGHT [11] in order to create the measured equivalent model of the device. Electric J and magnetic M reconstructed currents are shown in Fig. 3. The dimensions of the reconstruction box are 26 cm x 17 cm x 2 cm, while the mesh step is $\lambda/40$ at the analysed frequency. Since Love’s boundary conditions are imposed in the INSIGHT formulation, the EM field generated by these sources inside the equivalent box model is negligible (ideally (E, H)=(0,0)).



(a) (b)

Figure 3. Reconstructed equivalent currents on a box enclosing the PCB @640 MHz ; (a) J currents (b) M currents.

The equivalent model can be imported in different CEM tools and applied as source for simulations based on different numerical methods.

Moreover the equivalents currents can be also used for diagnostics. Indeed if J and M currents distributions are overlaid with the PCB mechanical drawing, it is possible to detect the physical origin of critical radiation spots in the device.

IV. RESULTS

The 3D equivalent model in terms of equivalent currents has been imported in CST STUDIO SUITE® [12] as near-field Huygens’ box to be applied in computational EMC studies. Radiating emission in the following scenarios has been investigated:

1) PCB stand-alone;
2) PCB located in vicinity of a wire;
3) PCB inside an example of enclosure.

In the second and third cases the accuracy of the representation of the Huygens’ box of the PCB has been investigated. Results have been compared with the full wave simulation of the PCB in the different scenarios [12]. The simulation model of the PCB in isolation (i.e. stand-alone configuration) is shown in Figure 4.

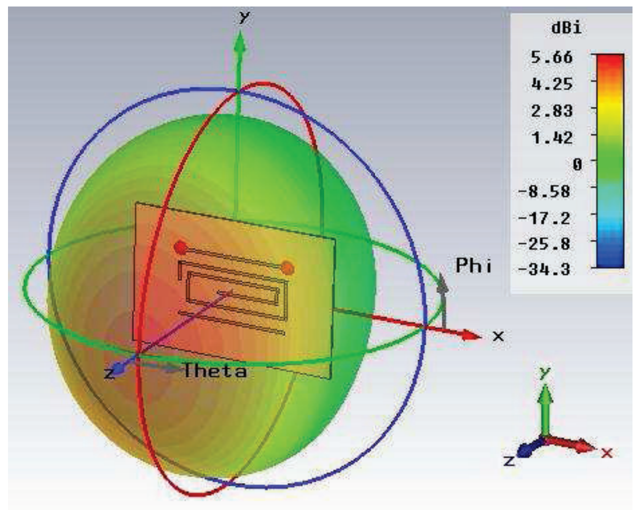
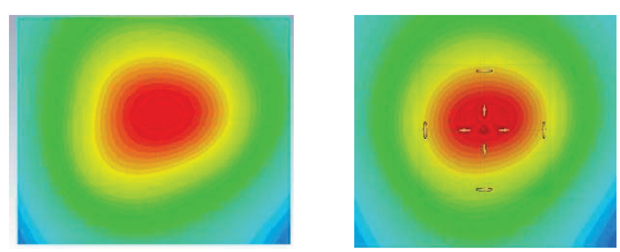


Figure 4. PCB simulation model, overlaied with the directivity radiation pattern @640 MHz.

A. Stand–alone PCB

For the PCB in stand–alone configuration, a preliminary comparison has been performed starting from the near-field source of the PCB between radiation pattern evaluated with measured EQC representation and full wave simulation of the device at distance $\lambda/4$ @640 MHz, see Figure 5.



(a) (b)

Figure 5. E near-field comparison at $\lambda/4$ @640MHz from the PBC. (a) Measured source (b) full wave simulation.

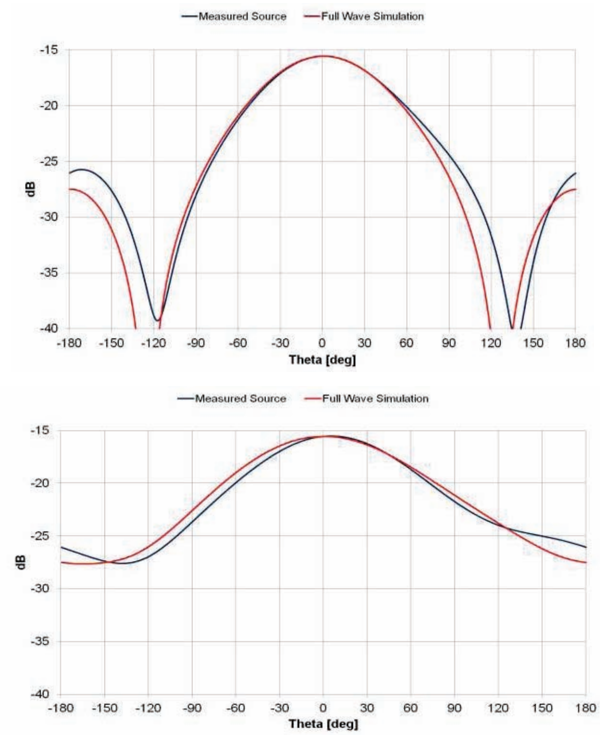


Figure 6. PCB E-field emission at 3 m distance @640 MHz (a) phi=0° elevation plane, (b) phi=90° elevation plane; Comparison between measured PBC source and full wave simulation of the PCB.

E-field emission at 3 m from the measured model of the PCB is evaluated with measured EQC representation and compared with the full wave simulated model. Results are shown in Figure 6. The agreement between the two curves is considered acceptable for both elevation cut planes. Differences between the two curves are due to the presence of the mounting support and the cable in the measurement set-up, which are not modelled in the full wave simulation.

B. PCB located in vicinity of a wire

The second scenario under test is the PCB located in vicinity of a wire, see the full wave model in Figure 7. (a). Such a test case is more challenging with respect to the previous one because the presence of scattering object in the vicinity of the device creates multiple interactions that have to be accounted.

In order to account for the multiple interaction between the PCB and the wire, a structure representing the device, even simplified, has to be added inside the Huygens box. It should be noted that due the Love's condition (zero field inside the box) adding an object inside the equivalent surface is allowed.

The measured NF model, previously calculated is imported in the CEM tool [12], see the blue box in Figure 7. (b). The wire is located in the same position of case (a).

The absence of this structure inside the box, would create the field flowing inside the box resulting in an inaccurate representation of the radiated field, see Figure 7 (f).

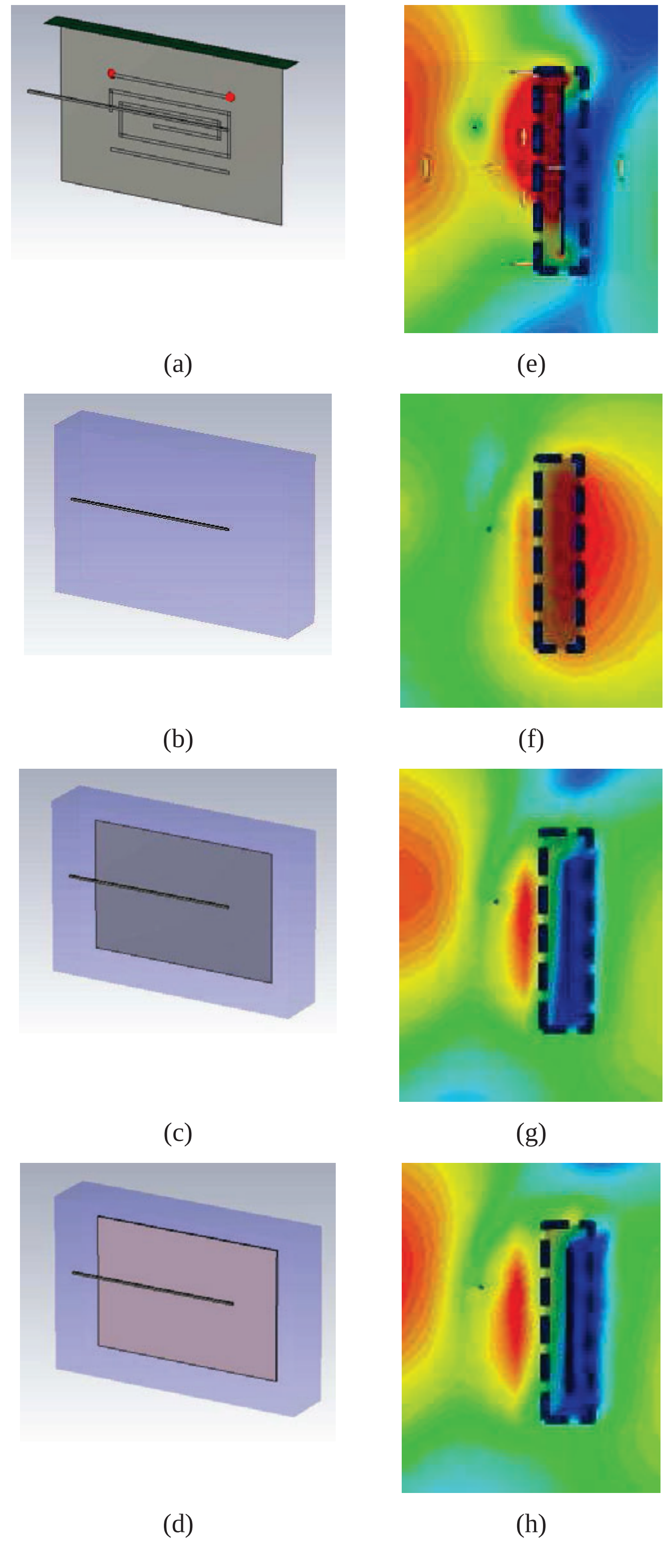
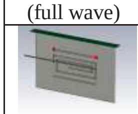
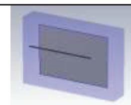
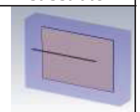


Figure 7. PCB E near-field emission at @640MHz. Lateral view of the box; box profile is represented in dashed line; the section of the wire is the black small circle. (a) PCB full wave model; (b) NF source and wire; (c) NF source, wire and PCB ground plane (GP); (d) NF source, wire, PCB ground plane (GP) and dieletric substrate.

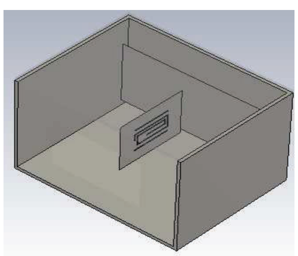
Based on the above considerations, other two simulations have been performed including different structures representing the PCB inside the box. In the first case, only the ground plane, has been considered, see Figure 7 (c) and (g). In the second case, both the ground plane and the dielectric substrate are added, see Figure 7 (d) and (h). In this latter case the radiated field pattern is more accurate because the model of the substrate is close to the real one. In fact the results are in better agreement with the reference. Comparison in terms of max radiation on the directivity pattern is reported in Table I.

TABLE I. NF MODEL OF A PCB WITH A WIRE: MAX RADIATION

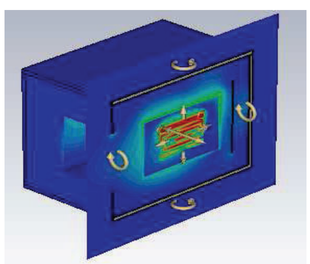
	(a) Reference (full wave)	(b) Free space	(c) wire, GP	(d) wire, GP, substrate
				
Max Radiation [dBi]	7.26	1.45	6.53	6.89

C. PCB inside an example of enclosure

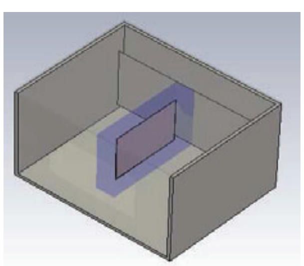
The third scenario under test is the PCB inside an example of enclosure, as shown in Figure 8. The aim of this study is to verify the accuracy of the near-field representation where the Huygens box is positioned inside an enclosure.



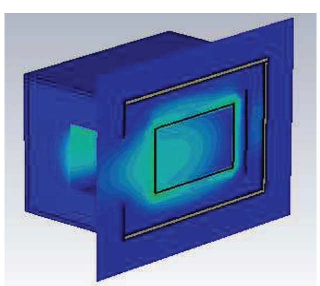
(a)



(c)



(b)



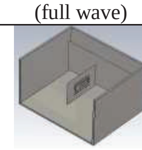
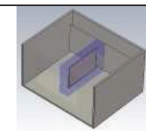
(d)

Figure 8. PCB model inside an example of enclosure @640MHz. (a) PCB full wave model; (b) NF source (c) NF source with the modelization of PCB ground plane and dieletric substate.

In Figure 8, the top and the lateral walls of the enclosure are visualised in transparency to show the content. The PCB and a metallic plate (the latter working as scattering object), are thus enclosed in a cavity with a rectangular aperture at the left face.

In case (a) the full wave simulation has been performed (reference), while in the case (b) the Huygens box, from measurement, has internally the model of the ground plane and the substrate of the PCB, as done in the previous example. The agreement of case (a) and (b) in terms of E-field pattern inside the enclosure is visually good (see Figure 8. (c) and (d)). A good agreement is also found for the radiated field external to the enclosure in terms of directivity, see Table II.

TABLE II. NF MODEL OF A PCB INSIDE AN ENCLOSURE: MAX RADIATION

	(a) Reference (full wave)	(b) NF source with GP, substrate
		
Max Radiation [dBi]	7.66	7.86

V. CONCLUSIONS

Results confirm that EQC method can be efficiently used for evaluation of accurate measured near-field representation of the PCB to be used on computational EMC studies. Therefore, the measurement of the PCB in a spherical near-field system can be used to determine the measured Huygens box model; the derived model is applicable to the simulation of emission in different scenarios.

When the PCB is considered in vicinity of objects, the Huygens box should be handled including internally also a suitable representing model of the device. This ensures a good accuracy of the solution during the calculation of the emitted radiation. Two test cases have been investigated. The PCB is in proximity of a wire that could emulate a simplified representation of a cable internal to an electronic product. In this case the deviation between using the PCB as measured model in the numerical simulation and the full simulation is 0.37dB. Then the PCB has been studied inside an example of an enclosure. In this latter case the deviation between the PCB as considered in the numerical simulation and the full simulation is 0.20dB. That it looks very promising although it is only tested for one frequency and the agreement could decrease if there is an resonance, e.g. at the resonance frequency of the cavity.

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References

[1] 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.

[2] 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.

[3] 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

[4] 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.

[5] 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.

[6] M. Sorensen, O. Franek, G. Pedersen, " Recent Developments in Using Measured Sources in Computational EMC", Antennas and Propagation (EuCAP), 2015 9th European Conference on, April 2015

[7] M. Sorensen, I. Bonev, O. Franek, G. Petersen, and H. Ebert, "How to handle a Huygens' Box Inside an Enclosure," in Electromagnetic Compatibility (EMC), 2013 IEEE International Symposium on, Aug 2013, pp. 802-807.

[8] O. Franek, M. Sorensen, H. Ebert, and G. Pedersen, "Influence of nearby obstacles on the feasibility of a huygens box as a field source," in Electromagnetic Compatibility (EMC), 2012 IEEE International Symposium on, Aug 2012, pp. 600-604.

[9] M. Sorensen, O. Franek, G. Pedersen, A. Radchenko, K. Kam, and D. Pommerenke, "Estimate on the Uncertainty of Predicting Radiated Emission from Near-field Scan Caused by Insufficient or Inaccurate Nearfield Data: Evaluation of the Needed Step Size, Phase Accuracy and the Need for all Surfaces in the Huygens' Box," in Electromagnetic Compatibility (EMC EUROPE), 2012 International Symposium on, Sept 2012, pp. 1-6.

[10] L.J. Foged, A. Scannavini, "Efficient testing of wireless devices from 800MHz to 18GHz, Radio Engineering Magazine, Vol 18, No 4, December 2009.

[11] http://www.mvg-world.com/products/field_product_family/antenna-measurement-2/insight

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