Determination of Radiation Models Based on Measured Electromagnetic Field Distribution

Zongyi Chen, Denis Rinas, Stephan Frei

On-board System Lab
TU Dortmund University
Dortmund, Germany
zongyi.chen @tu-dortmund.de

Abstract

In EMC far-field measurements are commonly used to detect emission problems of electronic systems. Numerous standards have defined far-field thresholds. Far field measurements require large and expensive test facilities. Using more simple to realize near field measurements and Huygens principle for the calculation of the far-field can be a problem solution. The method is quite robust for higher frequencies. For lower frequencies the model needs to be further improved. A method that combines measurement data with simulation data, gathered from a standardized measurement setup, can provide quite accurate field estimations and is presented here.

1 Introduction

In EMC far field measurements are commonly used to detect emission problems of electronic systems. Numerous standards have defined far-field thresholds. Far field measurements require large and expensive test facilities. Using more simple to realize near-field measurements and Huygens principle for the calculation of the far field can be a problem solution. Alternatively, the measured electric and magnetic near-fields can be used for the reconstruction of the sources by a set of equivalent electric and/or magnetic dipoles [1]. However, using dipole method for a complex radiating structure, like a several layers-PCB, the radiation model can work with acceptable accuracy only if geometry information is known and many near-field scan points are taken. Huygens' principle [2-3] is independent from knowledge on the internal structures and requires only the near field distribution.

A Huygens surface model can be constructed that does not consider the complexity of the radiating structure. For this reason, this research is based on Huygens principle.

2 Theory

According to Huygens principle description [4], normally a closed fictitious Huygens surface is chosen to enclose the radiating structure. As shown in **Figure 1**, using electric and magnetic fields on the Huygens surface, equivalent currents can be calculated and considered as a new radiating source that replaces the radiating structure and emulates fields in the exterior region of the Huygens surface. Inside of the surface the field is zero.

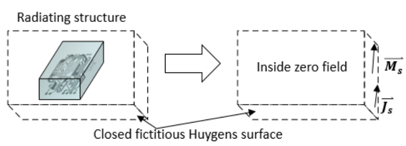

Figure 1 Representation of the Huygens principle

The new radiating sources are equivalent electric current $\overrightarrow{J_s}$ and magnetic current $\overrightarrow{M_s}$, which are given by:

$$\overrightarrow{J_s} = \vec{n} \times \overrightarrow{H_s} \quad (1)$$

$$\overrightarrow{M_s} = -\vec{n} \times \overrightarrow{E_s} \quad (2)$$

where $\vec{n}$: Normal vector of Huygens surface (pointing to outer side of Huygens surface **in Figure 1**),

$\overrightarrow{E_s}, \overrightarrow{H_s}$: Fields on Huygens surface.

As illustrated in **Figure 2**, if the proper Huygens surface S has been chosen, and both electric currents and magnetic currents on Huygens surface are known, the radiation model can be created.

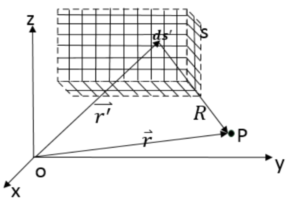

Figure 2 Field calculation in Cartesian coordinate system

By integrating all sources the field at an observation point P can be expressed as:

$$\vec{E}(\vec{r}) = \iint(-j\omega\mu\vec{J_s}G(\vec{r},\vec{r'}) + \overrightarrow{M_s} \times \nabla'\vec{G}(\vec{r},\vec{r'}) - \frac{1}{j\omega}(\nabla' \cdot \vec{J_s})\,\nabla'\vec{G}(\vec{r},\vec{r'})]ds' \quad (3)$$

Where $G(\vec{r},\vec{r'})$ is free space Green's function.

3 Simulations and Measurements

3.1 Comparison of Huygen's surface calculation with full wave simulation of the complete structure with Method of Moment (MoM)

A dipole antenna structure in free space, as represented in **Figure 3**, has the length of 15 cm and the radius of 1 mm. An excitation of 1 V in the middle of the antenna is assumed. Observation point is [0.25 m, 0.25 m, 0.25 m]. Size of Huygens surface is 4 cm (length) x 4 cm (width) x 19 cm (height). The electric field of from Huygens surface and calculation with MoM of the physical structure matches well for all three components. MoM based software Concept-II [5] is used in this research.

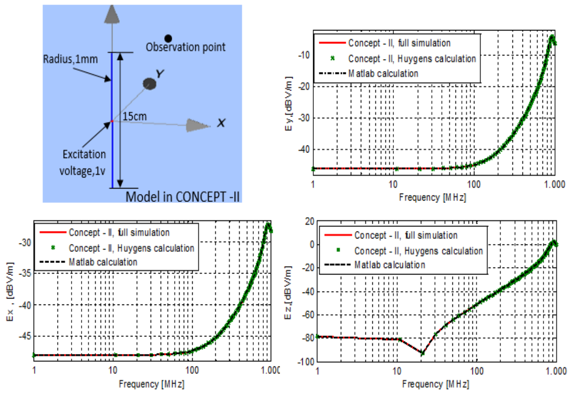

Figure 3 Comparison of electric field from theoretical calculation with MoM using a dipole antenna

3.2 Huygens surface size and discretization size

Error caused by different Huygens surface and discretization sizes has been investigated by observing the error of field magnitude at the observation point. As shown in **Figure 4**, a 1.5 m wire placed at 5 cm above a metal plate (2 m x 1 m) is taken as a wire loop structure, the structure is above infinite ground 0.9 m. The wire loop is excited with 1 V and terminated with 50 Ohm. Observation point is at [0.75 m, -1 m, 0.95 m], which is 1 m distant to center of wire, and with the same height as wire. As represented in **Figure 5**, upper figure shows that when discretization size is 2.5 cm (mesh size), error caused by different distances (Distance is the height between real radiating structure and each side of Huygens surface, different distance results in different size of closed Huygens surface). The magnitude of horizontal electric field has error of less than 1.5% for non-resonance frequencies.The lower figure shows when each side of Huygens surface is 5 cm distant to radiating structure, discretization sizes (mesh sizes) have been varied from 1 cm to 3 cm, the error of non-resonances are less than 0.5 %. Both subfigures show that the error is larger, maximal up to 5.5 % only for resonances.

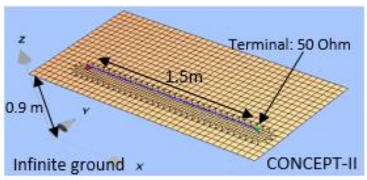

Figure 4 Structure used for investigation of Huygens surface size and discretization size

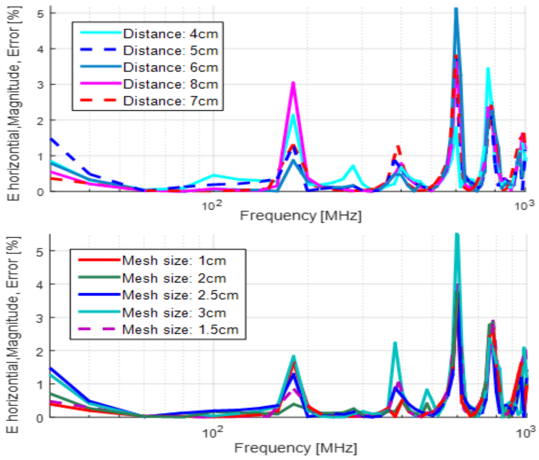

Figure 5 Field magnitudes resulting from Huygens surface sizes (upper) and discretization sizes (lower)

3.3 Near-field measurements

The structure shown in **Figure 6** has been used for near-field measurements, it's a wire (8 cm) above a metal plane (10 cm x 5 cm) with height 0.25 cm. The excitation is 2 V with 50 Ohm internal resistor. Each side of the Huygens surface has 1 cm distance to the structure. Firstly, using simulated fields from Concept-II, Gaussian white noise with different SNR have been added to complex field data (both electric and magnetic fields). The predicted electric field at 3 m (illustrated in **Figure 7**) shows that radiation model created based on Huygens principle can work quite robustly. For lower frequencies, the deviation becomes larger. As a verification, **Figure 8** shows comparison of the near-field measurement on top side of Huygens surface for magnetic field y-component at 31 MHz. It can be seen from the figure, both magnitude and phase are very noisy, which cause problem for radiation model creation, the near-field measurement result (in **Figure 8**) shows a good agreement with the simulation result (in **Figure 7**).

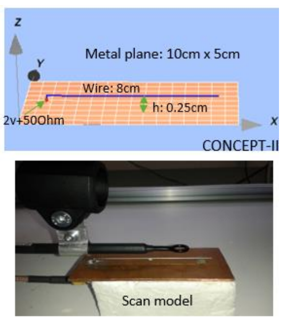

Figure 6 structure used for near-field measurements

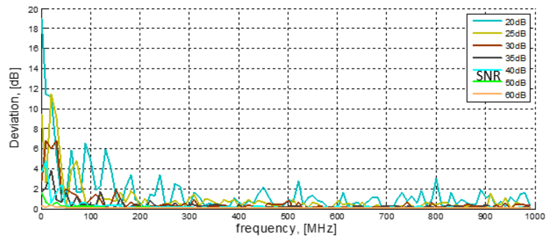

Figure 7 Electric field at 3 m with different SNR added to complex electric and magnetic field on Huygens surface

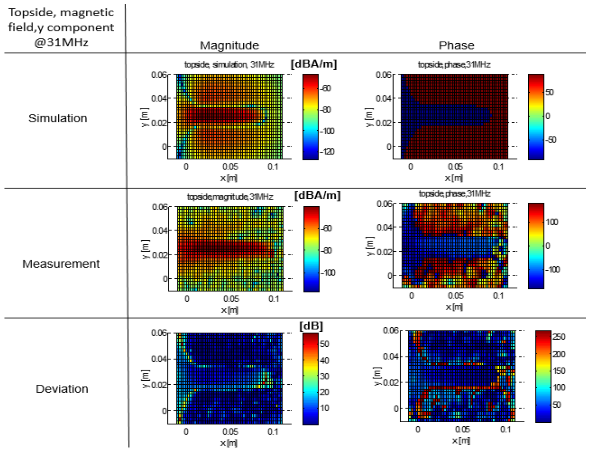

Figure 8 Comparison of simulated field with measured field

4 Conclusion and future work

In the research calculation of electric far-field using ideal electric and magnetic field distribution on Huygens surface has been compared with the simulated field from the physical structure model. Furthermore, investigations on discretization and size of Huygens surface were carried out such that an accurate radiation model could be determined for meaningful far-field prediction. Besides, this research has investigated how accuracy of radiation model is influenced by noisy field data using different SNR, and has shown deviations between field data that obtained from near-field measurement test bench and simulation. It can be concluded that noisy electric and magnetic field distributions on Huygens surface cause much more problems at lower frequencies than at higher frequencies for determining the far-field. Future work will focus on how to improve radiation model for lower frequencies.

5 References

[1] T.Xin, D. W. P. Thomas, A. Nothofer, P. Sewell, and C. Christopoulos. "Modeling Electromagnetic Emissions From Printed Circuit Boards in Closed

Environments Using Equivalent Dipoles," *IEEE Trans. Electromagn. Compat., vol. 52, no.2, pp.462–70, May.2010.*

[2] A.Taaghol, T. K. Sarkar, "Near-Field to Near/Far-Field Transformation for Arbitrary Near-Field Geometry, Utilizing an Equivalent Magnetic Current,'' *IEEE Trans. Electromagn. Compat., vol. 38, no.3, pp.536-542, Aug.1996.*

[3] P. Barri`ere, J. Laurin, Y.Goussard, "Mapping of Equivalent Currents on High-Speed Digital Printed Circuit Boards Based on Near-Field Measurements,'' *IEEE Trans. Electromagn. Compat., vol. 51, No. 3, pp. 649–658, Aug. 2009.*

[4] C. A. Balanis, Advanced Engineering Electromagnetics. New York: JohnWiley & Sons, 1989.

[5] CONCEPT-II-12.0, Technische Universitaet Hamburg-Harburg. (2015). [Online]. Available: http://www.tet.tuhh.de/en/concept/.