

# Combining Near-Field Measurement and Simulation for EMC Radiation Analysis

Electronic components are required to comply with the global EMC regulations to ensure failure free operation. Currently, EMC measurements in certified institutes are mandatory to certify performance complies with regulations. Since these measurements are performed at the end of the product design process, failing an EMC test can imply a costly redesign. However, the process that is outlined in this paper enables EMC testing to be performed earlier in the design cycle.

This paper describes a practical method of combining near-field measurements and simulations to explore the radiation behavior of electronic components. This approach enables not only near-field characterizations and far-field predictions, but also detailed system level analysis of how the component radiates in its installed environments. For example, how an electronic control unit (ECU) performs when installed in a vehicle.

## Introduction

Even though simulation can be used to predict component behavior, it may not always be feasible or possible for several reasons. These include complexity of the component, but also information that may not be provided by the supplier, including data about parts used, layout schematics, etc. In this case, a combination of near-field measurement and simulation using FEKO [1] can be applied to calculate the radiated EMC emissions at both a component and a system level.

The presented approach is based on the Huygens-Box principle [2], whereby the tangential components of the near-field on each side of a box surrounding the device-under-test (DUT) are measured and then imported into FEKO. Using the imported data as an aperture excitation, the radiated emission can be calculated for the component, or, by including a platform (e.g. the vehicle model where the component will be used) the system level emissions can be calculated. These steps will be described in the following sections.

A significant advantage of this combined approach is that the frequency ranges that fail the EMC test are determined, as well as which areas of the component might be responsible for these failures. Furthermore, it provides a complete workflow to perform EMC investigations even when information regarding DUT might be unavailable (e.g. to protect IP). Finally, by applying a model decomposition approach and replacing complex geometry by measured fields, the computational resource required to simulate the system level response can be reduced significantly.

## Near-Field Measurement on the Huygens-Box (Radiation Model)

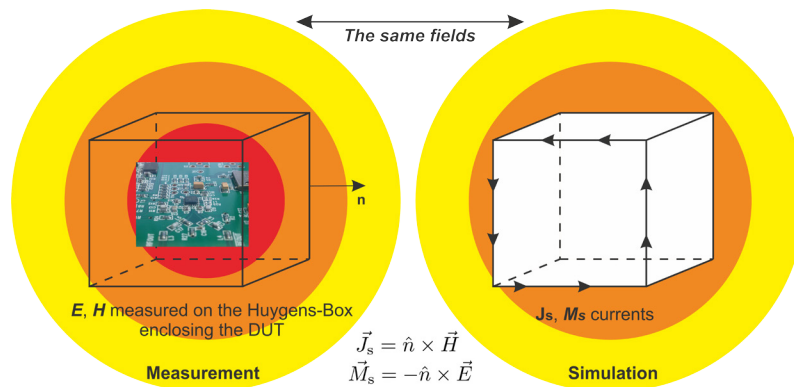


Figure 1: Huygens-Box principle

(reference: Ondrej Franek, Aalborg University, Denmark How to Use the Near-Field Scan as a Source for Electromagnetic Simulations)

The combination of near-field measurements and simulations using FEKO is based on the Huygens-Box principle. This principle and the optimized near-field measurement equipment are presented here. When considering linear materials and environments, based on the

surface equivalence theorem, a radiating system can be represented by a set of electric and magnetic surface current densities on a cuboid entirely enclosing the structure. This cuboid is called a Huygens-Box. The surface current densities can be defined by the electric and magnetic field, where  $\mathbf{n}$  is the normal vector on each surface of the Huygens-Box oriented as depicted in Figure 1 [2-4].

To determine the electrical and magnetic field components, a near-field measurement in the very close vicinity of the DUT can be performed [5]. Since the Huygens-Box principle requires both magnitude and phase information of the E- and H-fields, the near-field scanner NFS3000 [6] in Figure 2 is used. To increase the sensitivity of the measurement, a non-planar surface is measured as depicted in Figure 3. Plane wave theory is then applied to calculate the fields on a corresponding planar surface [7] needed for the Huygens-Box. Since the six field components (electrical and magnetic field components in x-, y- and z- direction) are linearly dependent, the tangential field components on the surfaces of the cuboid are sufficient to fully characterize the surface current densities.

The field distribution on this Huygens-Box can be used within FEKO as an equivalent source (or receiver) to calculate the component emissions or to perform further system level analysis where the component is installed. Furthermore, inspection of the near-field data can determine possible causes of EMC issues on the component. It is noted that the Huygens-Box does not include the original DUT, so that backscattered fields will not be influenced by the geometry of the DUT. However, recent research results suggest that a simplified ground plane of the DUT can be sufficient to model these backscattering effects. When assessing the EMC compliance of a system, the Huygens-Box seems to be sufficient to predict a fail or a pass of the EMC measurement, as will be shown later.

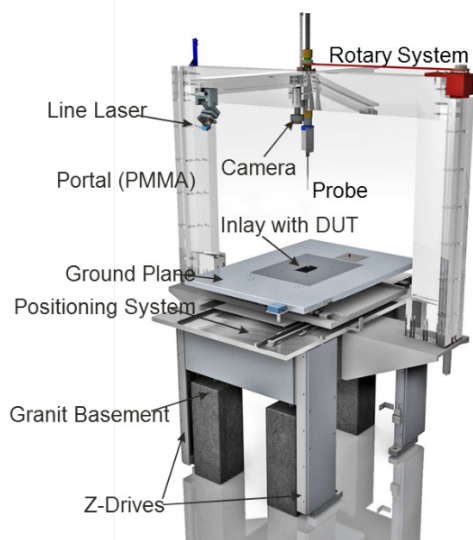


Figure 2: Near-Field measurement system NFS3000 [6]

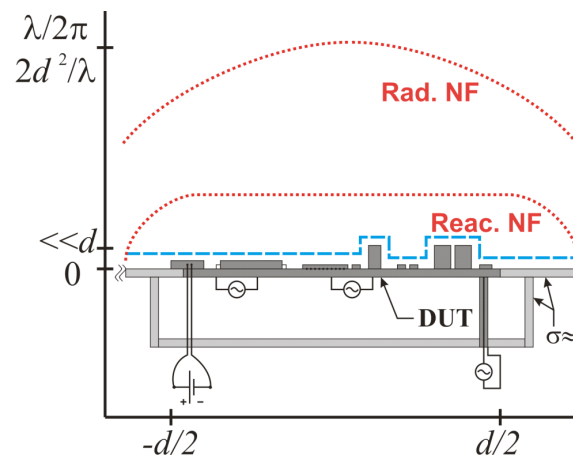


Figure 3: Definition of the Near and Far-Field regions [9]

## Combining Near-Field Measurement and Full-Wave Simulation

As mentioned, the NFS3000 is used to measure the magnitude and phase of the tangential electromagnetic fields on the Huygens-Box. The measurement files are then converted to .efe and .hfe files that can be read directly into FEKO and used as equivalent aperture sources for further simulations.

There are two main simulation scenarios to consider. In the first scenario, the aperture source is used to calculate the component level radiated emissions (see Figure 3). In the second case, the system level radiated emissions are calculated. In this case, the aperture source is used in a system level simulation, which includes the platform where the component will be installed.

Once the component has been characterized by measurement, it is straightforward to investigate how different conditions in the installed environment will affect the EMC performance. For example, comparing how installing a component at different locations in a vehicle will affect the system level radiated emissions.

## Validation Example

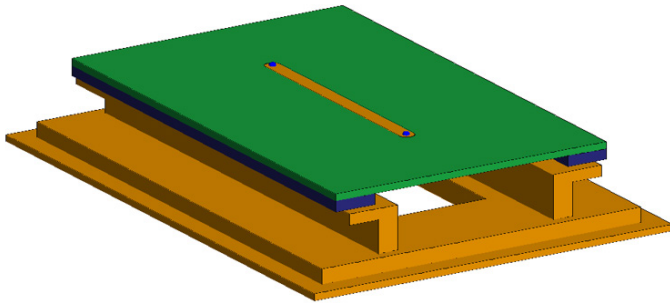


Figure 4: Device-Under-Test (DUT) modeled in FEKO

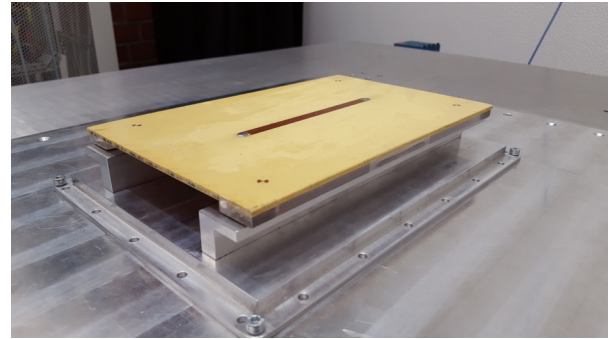


Figure 5: Device-Under-Test (DUT) and fixture used for the near-field measurement utilizing the NFS3000

To validate the above mentioned approach, a test case is modeled in FEKO (Figure 4) and fabricated (Figure 5). The DUT is a 50  $\Omega$  microstrip line, which is fed by a signal generator and terminated with 50  $\Omega$ . In this case, because the exact geometric information of the DUT is known, it can be modeled accurately in FEKO to validate the measured results.

The fabricated microstrip line is placed on the NFS3000 scanner with a special fixture so that five surfaces of the box surrounding the DUT can be measured easily. The fields on the bottom surface under the DUT ground plane are negligible and therefore not measured. Validation of the DUT was performed at 3 frequencies: 500 MHz, 1 GHz and 1.5 GHz. Figure 6 - 8 show the validation of the simulated and measured H-field at 1 GHz.

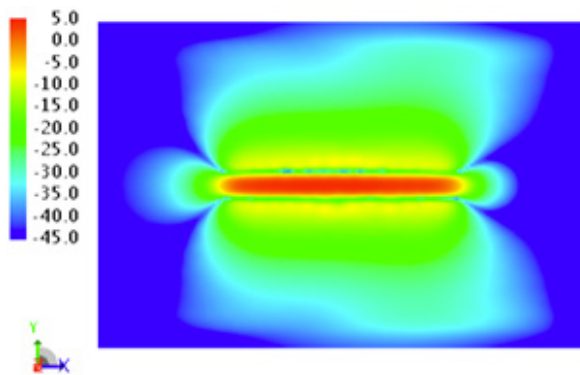


Figure 6: Simulated magnitude of  $H_y$  in dB(A/m) at 1 GHz, 3mm above the DUT

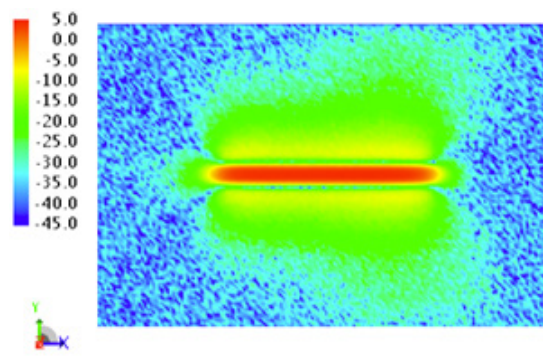


Figure 7: Measured magnitude of  $H_y$  in dB(A/m) at 1 GHz, 3mm above the DUT

It can be observed that the measured and simulated field distributions are very similar, exhibiting only slight differences. The reason for this difference is probably the usage of several adapters across the measurement chain which were not compensated. Furthermore, the distortion at the borders of the plotting plane are due to the limited dynamic range and noise performance of the measurement equipment.

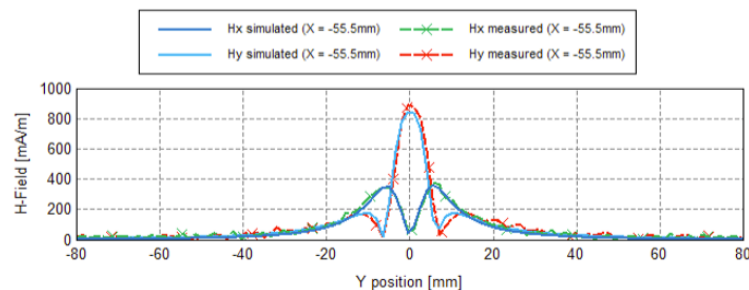


Figure 8: Comparison of simulated and measured near-field results regarding the magnitude of the magnetic field in x- and y-direction

Figures 9 and 10 show the simulated and measured phase distribution of the  $H_y$  field component at 1 GHz, which agree well near the microstrip line. When considering the borders of the plotting plane the measured phase is noisy. In these areas, the measured magnitude is very small and nearly vanishes into the noise floor, which limits the capability to determine the phase information accurately. Because the measured phase is less significant for small magnitudes it will not influence the far-field much.

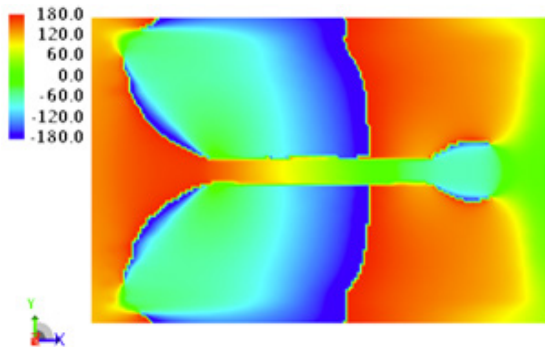


Figure 9: Simulated phase of  $H_y$  in degrees at 1GHz, 3mm above the DUT

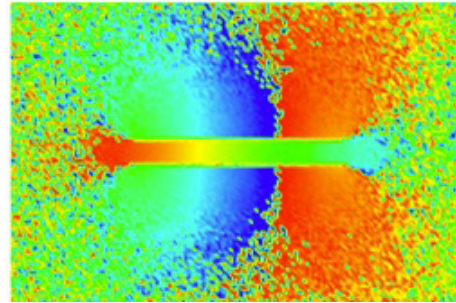


Figure 10: Measured phase of  $H_y$  in degrees at 1GHz, 3mm above the DUT

In addition to the validation of the near-field, we can also validate the far-field behavior of the DUT. For this purpose, we must first import the measured Huygens-Box source data into a second FEKO model where it is used as an aperture source. An investigation was also performed to determine what spatial resolution was needed for the near-field data, 3mm resolution was sufficient for this example. The comparison of the radiation patterns is shown in Figure 11 and 12 for 1 GHz. The results agree well, the small deviation can be explained by the differences already occurring in the near-field data.

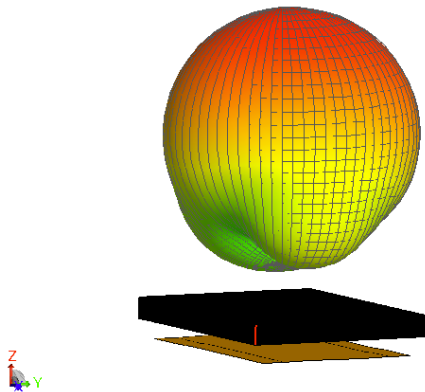


Figure 11: Far-field plot of the simulation with aperture source at 1 GHz

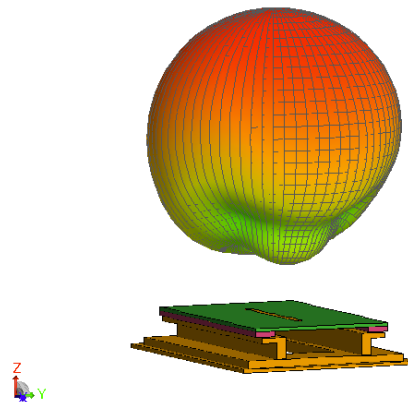


Figure 12: Far-field plot of the simulation with DUT geometry at 1 GHz

Finally, the radiated EMC emissions can be calculated, e.g. at a 3m distance. Figure 13 shows the frequency response calculated with the geometric model as well as 3 points calculated using the measurement data as an aperture source. The predicted emissions based on the measured near-field agree very well with the simulation using the geometry, even correctly predicting the notch responses at 500MHz and 1.5 GHz. This clearly demonstrates the accuracy and the strength of this approach.

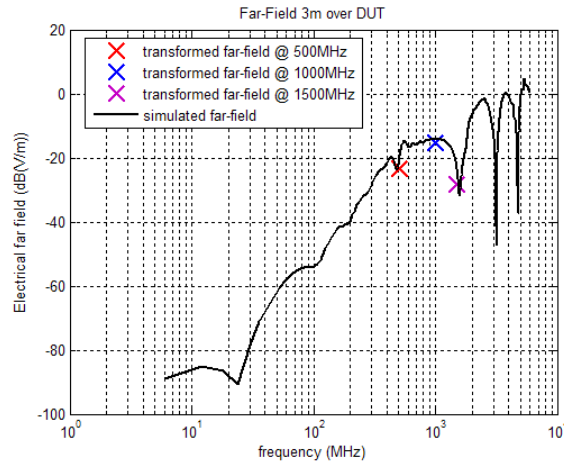


Figure 13: Radiated emissions at 3 meters comparing the simulation using the DUT geometry with that based on the measurement near-field data.

## Conclusion

In this paper, a practical method to combine near-field measurements and FEKO simulations of arbitrary DUTs is introduced. It can be used to predict the DUTs' far-field behaviors efficiently and its interaction with the environment, which enables EMC emission analysis during the whole design. This approach is possible because of the accurate near-field measurement capabilities of the NFS3000, especially the ability to measure both the magnitude and phase of the field components, which is required for the Huygens-Box principle. The validation example demonstrates the accuracy of the method in both the near-field and far-field predictions.

Thus, the presented method is applicable to electronic system design by significantly reducing the chances of EMC failure at the end of the design flow. The presented combination of the measurement and simulation domain therefore enriches the design of electronic systems.

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