Overview of emission and susceptibility investigation and modeling with near-field measurements.

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Abstract

Over the last years, the techniques of measurement in near field have experienced a significant development in the area of electromagnetic compatibility. These techniques are used to locate emission sources, to extract equivalent models of radiation and to study the local susceptibility. After a brief overview of the methods that are used to measure the near electromagnetic field, several applications of this technique are presented. These applications cover the study of emission and susceptibility phenomena from the component (passive or active) to the system.

1. Introduction

Nowadays, electronic systems are integrating more and more functionalities in a confined volume; consequently some components can generate Electromagnetic Interference (EMI) problems. Knowledge of the electromagnetic environment of components and systems is therefore essential. The traditional measurement systems used for ElectroMagnetic Compatibility (EMC) validations only give global information of EMI problems. Another way is to use simulation tools but it is currently not possible to calculate the electromagnetic near field and far field which are created by complex and especially active devices. Thus the electromagnetic near-field mapping seems to be extremely useful to characterize EMI problems in EMC designing of industrial, active or passive circuits. These techniques are used at different stages of the product design and are presented in the next two parts of this paper.

Different techniques are used to measure the electromagnetic near-field for EMC applications. Most of them are based on a direct measurement method and use a sensor to convert electric or magnetic field to voltage, current or power. Measurements are performed in the zone of near electromagnetic field containing evanescent and propagating waves. In EMC, the limit of this zone is fixed at $\lambda/2\pi$ from the source, where λ is the wave length. Traditionally, the distance between the probe and the circuit ranges from hundreds of micrometers to some millimeters, depending of the size of the device under test and the needed spatial resolution. A first category of test benches uses sensors constituted of electro/magneto-optic crystals [1-2]. The electromagnetic field induces a modification of the crystal properties and this variation can be measured with an optical system and converted to an electrical signal. The main advantages of this method are the low invasiveness of the sensor, a high bandwidth and a high spatial resolution. The disadvantages are due to the sensor manufacturing complexity and to the cost of the optical chain. Another method uses resistive photothermic films and measures a power linked to electric or magnetic field [3]. This technique allows a fast measurement of the electromagnetic field related to the size of the film used. Major limitations are due to the lack of selectivity and sensitivity of the system. The last method, very much employed in EMC, is based on electronic probes [4-9]. An example of near-field setup based on electronic probes is presented in Fig.1 [8-9]. In a classical test bench using electronic probes, the sensor is connected to a spectrum analyzer or network analyzer and is mounted on a robot. A computer monitors the probe displacement over the device under test and acquires data provided by the measurement receiver. Several probes are used to measure the different components of the electric or magnetic field: monopole probe [10-12], dipole probe [7] and loop probe [13]. Phase measurement on active device needs a stable reference signal. This signal can be taken directly from the card or obtained from a second probe which is fixed. Phase measurements can be carried out, for example, with a network analyzer in external mode or with a spectrum analyzer [14]. In the cases of phase measurement with the spectrum analyzer, it will need three measurements.

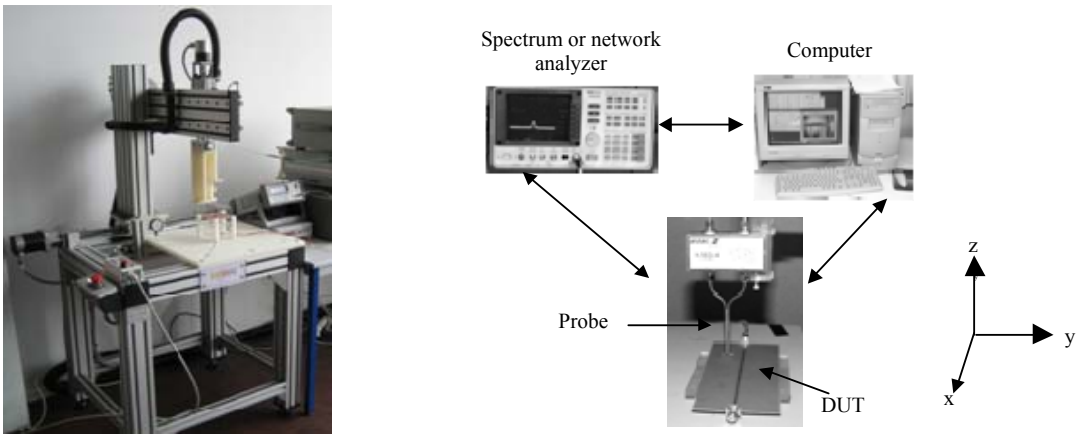


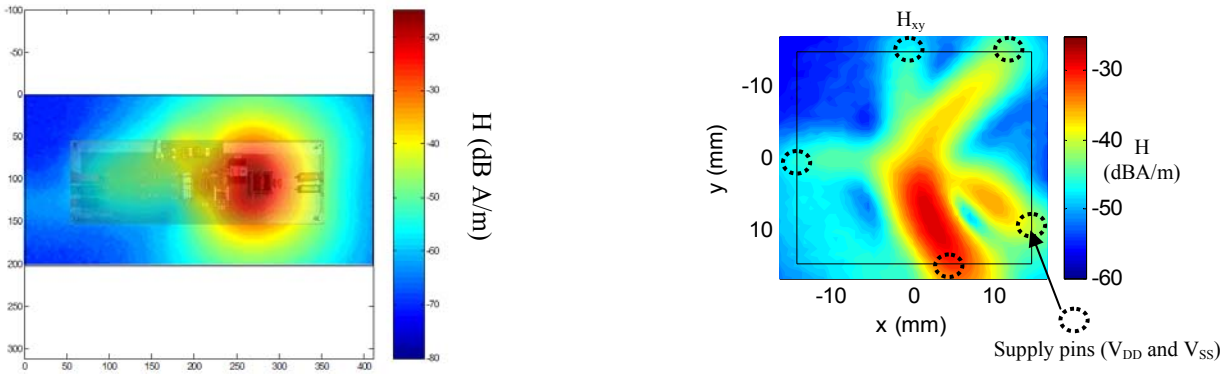
Figure 1 : Example of near field test bench and associated setup [8-9].

2. EMC diagnosis in emission

Traditional measurements tools of electromagnetic emissions (Transverse ElectroMagnetic (TEM) cell, Anechoic chamber, Steering mode chamber,…) give information on the whole radiation of the system under test according to its orientation and to the frequency. But they do not make it possible to determine the internal radiation sources of the device. Near-field techniques can overcome this limitation and enables a precise location of the radiation sources. The cartography of the electromagnetic field can be used during the design process to locate areas of high field levels and to prevent interferences' problems due to some components [5-9]. From the cartographies that are obtained, it is possible to visualize the couplings between different components allowing an optimization of the shielding or a repositioning of the components in order to reduce electromagnetic interferences. For these investigations, we measure only the amplitude. An example of measurement of the magnetic field emitted by a power card at a frequency of 1 MHz is given on Fig. 2a [15].

These measurements are also used to model the radiated emissions of electronic cards [15-17]. In simulation, the principle is to substitute a set of equivalent sources obtained from the near-field measurements for the electronic card. From these sources it is possible to calculate the electric or magnetic field at distances greater than the distance of measurement. Generally, the process used to extract the equivalent sources needs both amplitude and phase data. Near-field measurements can also be integrated directly in electromagnetic simulation software as sources of emission. Numerical study of the coupling between active and passive devices is therefore possible with these data. Post-processing of near-field measurement can also be applied to compute far-field emission.

Near-field scan is also used while designing or integrating integrated circuits (ICs) to locate the emission sources of the IC. To illustrate this part, an example of the tangential components of the magnetic field above an integrated circuit is presented on Fig. 2b [9].



(a) (b)

Figure 2 : Example of near-field measurement: (a) magnetic field above a power card [15], (b) tangential components of the magnetic field above an integrated circuit [9].

In this part, near field techniques have various applications. The first one is the measurement of the conducted emissions flowing through the supply pins or input/output pins of an integrated circuit. The current flowing on the pins of the component is obtained thanks to the measurements of the magnetic field in near field. This method is standardized (IEC 61967-6 [18]). The second application is the characterization of the electromagnetic radiation emitted by an integrated circuit (standard IEC 61967-3 [18]). The near-field scan method is used during the design stage of an integrated circuit to study the internal activity of the component [19-20]. The measurement of the tangential components of the magnetic field ($H_t = \sqrt{H_x^2 + H_y^2}$) makes it possible to highlight privileged current path in the integrated circuit. The measurement of the vertical electric field (Ez) makes it possible to locate areas having a strong density of electric charges. The spatial resolution and sensitivity of the measuring probe must be sufficient to highlight areas (hot spots) responsible for high emissions. By using these data, the design of the component can be modified in order to reduce the electromagnetic emissions [19-20]. Near-field maps also make it possible to characterize the total radiated emissions of the integrated circuits [9,21]. Various information is thus extracted from these measurements such as:

- comparative levels of emissions of various components having equivalent functionalities,
- the knowledge of electromagnetic topology,
- the influence of the packaging on radiated emissions, …

Currently, these data are not in the technical data of IC provided by the founders.

The last application is to use data provided by near-field measurements to build an electromagnetic model of the component making it possible to predict the emissions in radiated mode. Like models used for electronic cards, IC modeling is built by using equivalent sources (electric dipole or magnetic dipole) extracted from near-field measurements [22-26]. For example, elementary current sources can be obtained from the measured magnetic field and the radiated magnetic field is then calculated by expressing the potential vector according to these elementary current sources [25-26].

3. EMC diagnosis in immunity

Currently, research in this field knows a strong industrial and academic interest. One of the first applications of the near-field measurement techniques is the characterization of susceptibility of IC to electrostatic discharges [27-28]. This device makes it possible to test susceptibility at the pin level of the integrated circuits. The aggression in near-field is also used to characterize electronic cards and components stressed by harmonic electromagnetic wave [29-31]. On these setups, probes are used to create high levels of transient or harmonic electromagnetic fields. The main part of the energy created is located in a small volume allowing a local diagnosis of the susceptibility of electronic cards and IC. Some works are actually dedicated to model the disturbances injections in order to be able to predict the susceptibility of integrated circuits [31].

4. Conclusion

In this paper, we have presented an overview of the applications of near-field techniques for EMC investigations and modeling. These techniques are used to locate emission sources, to extract equivalent model of radiation and to study the local susceptibility. We have seen that near-field methods can be used during the design of an electronic card but also to study the emission of an integrated circuit. A lot of works is made to be able to create an emission model from this data and to insert it into simulation process. The main prospects are the development of near-field scan for immunity and also that of new probes with a better spatial resolution for system on chip (SOC) or system in package (SIP) characterization.

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