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Interlaboratory comparison of near field test benches

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An interlaboratory comparison has been achieved between three near field test benches. It consists on measuring the magnetic near field of a Buck chopper and on comparing the measurement results obtained by the three laboratories. The aim is to get a balance on the different results in order to understand the measurement differences in order to improve the final accuracy and measurement process of our test benches.

INTRODUCTION

The near field techniques in EMC are increasingly used to characterize EMI problems. Different test benches have been carried out in our laboratories. We have started an interlaboratory comparison between our three test benches. The device under test is a Buck chopper. The aims of this interlaboratory comparison are : to compare the measurement process with a same device under test, to study the test reproductibility and to improve the test quality. First, we will describe the three test benches and highlight their particularities. Then, we will describe the device under test and present the measurement results.

DESCRIPTION OF THE THREE TEST BENCHES

The three systems are based on direct measurement method [1][2][3]. The near-field probe is connected to a spectrum analyzer. A computer monitors the probe displacement over the device under test and acquires data provided by the spectrum analyzer.

The Lab. 1 test bench (figure 1) is essentially destined to measure the magnetic field radiated by electronic power devices. This is the reason why it has chosen to insert a copper ground plane on the displacement table in order to take into account this characteristic of power electronics. All the displacement devices (motors, electronic drivers), which are likely to induce electromagnetic perturbations, are located under the ground plane. All the structural parts, which stand above this area, are made of unreflecting materials (plexiglas, nylon).

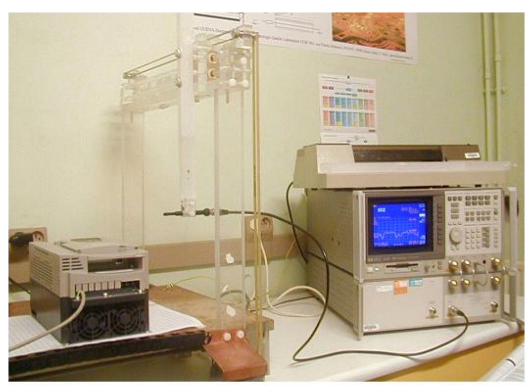


Figure 1 : Lab. 1 test bench .

The used magnetic probe is a AFJ LF-R50 (figure 2) with a negligible radius (5 mm) compared to the wavelength of the interfering signal. This probe averages the magnetic field strength in the loop area of the probe head. Its frequency range is 10 kHz to 50 MHz. It has been calibrated with a TEM cell in order to determine its antenna factor.

The calibration consists on comparing the field generated by a wide band RF amplifier in a TEM cell with the field measured by the magnetic field probe in the TEM cell. The Antenna Factor (AF) is given by

$$AF_{dB}(f) = 20 * \log_{10}(|H(f)| / V(f)) \qquad (1)$$

with: H(f) is the magnetic field generated by the TEM cell,
and V(f) is the voltage measured by the spectrum analyser through the probe.

Figure 2 : Probes used by Lab.1.

In Lab. 2, the probe is tied to the vertical support of the CNC machine (figure 3). Its orientation may vary to capture the X, Y or Z components of the field.

Figure 3 : Lab.2 test bench .

The machine can scan the whole surface of the board with a minimal step of 0.1 mm. The area of interest is divided into a grid with the appropriate resolution and a measurement is made on each cross point of the grid with the probe connected on the spectrum analyser.

The spectrum analyser and the CNC machine are controlled by a P.C. running a Matlab program. Communication is made through RS-232 lines.
The Matlab program allows the operator to choose amongst various parameters as frequency, step, speed… It carries the graphical representation of the data.

Probe used by Lab. 2 consists of a magnetic field probe Hameg HZ530 (figure 4). No information about the characteristics are given by the manufacturer, so the probe is calibrated thanks to the TEM Cell method to obtain the antenna factor, defined by equation (1).

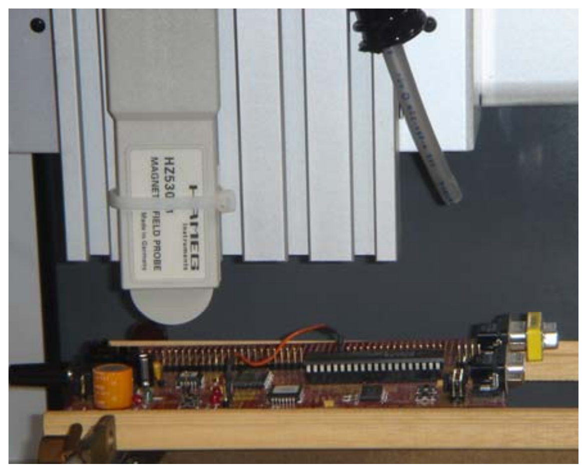


Figure 4 : Probe used by Lab .2.

Test bench used by Lab. 3 is presented on figure 5. The probe, connected to a measurement receiver, is mounted on a five-axis robot. A computer monitors the probe positioning over the device under test and acquires data provided either by a spectrum analyzer for amplitude measurements or by a network analyzer for amplitude and phase measurements. The maximum scanning area is 200 cm (x) * 100 cm (y) * 60 cm (z) with a mechanical resolution of 10 µm in the three directions (x, y and z) and 0.009 ° for the two rotations.

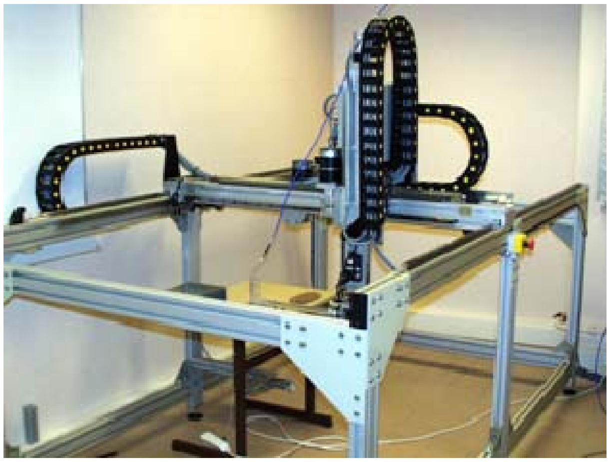


Figure 5 : Lab.3 test bench .

Probe used by Lab. 3 consists of a small loop made of the centre conductor of the coaxial cables (Figure 6). The loop has a diameter of 5 mm. A low noise amplifier (LNA) of 38dB is used to improve the sensitivity of measurement. This probe is calibrated in order to obtain the antenna factor (AF), introduced in (1).

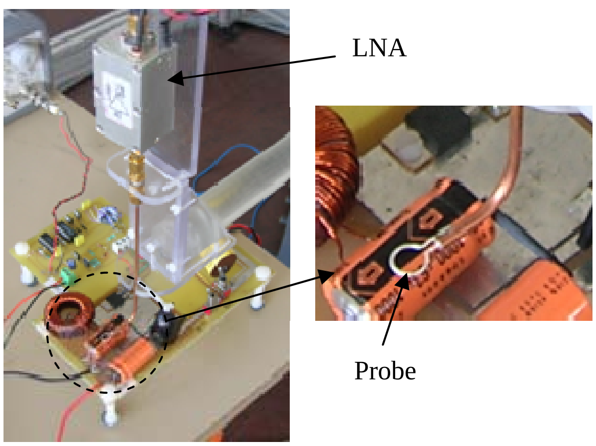


Figure 6 : Probe used by Lab. 3.

Contrary to the two other labs, the Lab. 3 doesn't use a TEM cell. The calibration process used a wire over ground plane in order to calculate an analytical expression of the magnetic field. The analytical expressions of the transverse magnetic field components are obtained by electrostatic calculation with the use of image theory [2], [4]. Table 1 draws out the different main characteristics of the three test benches.

DESCRIPTION OF THE DEVICE UNDER TEST

The Buck Chopper (figure 7) is fed by a 50 V voltage source E; its switching frequency is F_s=20 kHz. It provides a 2A current I_o in the output resistive load when the duty cycle is 0.5. The control signal is transmitted to the MOSFET thanks to a highly insulated driver, avoiding to propagate disturbances through this circuit and to influence the power part.

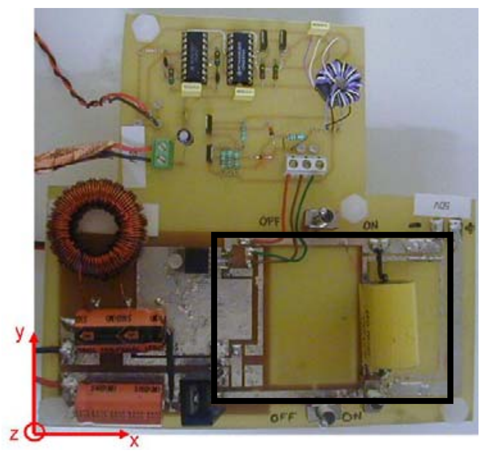


Figure 7: Picture of the Buck chopper

	Mines de Douai - SATIE	HEPL	IRSEEM
Laboratory	1	2	3
Automatic system	2D displacement	3 axis CNC machine	5-axis robot
Maximal scanning area	50 cm x 40 cm x 50 cm	40 cm x 30 x 13 cm	200 cm x 100 cm x 60 cm
Mechanical resolution	0.1 mm	0.1 mm	10 µm
Frequency range	9 kHz-1 GHz	150 kHz – 1,05 GHz	20 kHz – 2 GHz

Table 1: Characteristics of the test benches

MEASUREMENT RESULTS

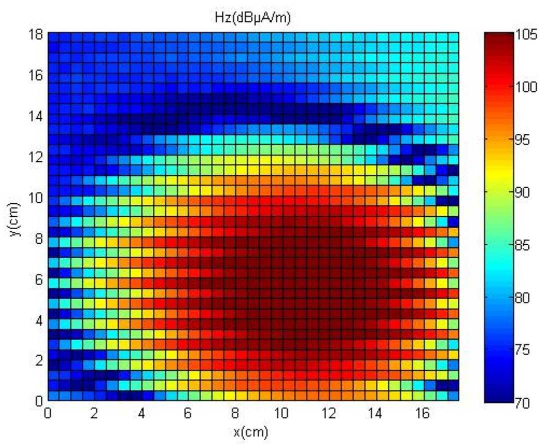
Hereunder, we present the magnetic field measurements of three labs (Figure 8). The magnetic field has been measured at 180 kHz, at the ninth harmonic of the switching frequency, at a height of 8 cm above the converter. The scan area is 18 cm x 18 cm. The reference point of near-field maps is indicated on figure 4 by x, y and z axis.

In the three cases, we can observe that the power circuit creates a significant magnetic field centred on the switching cell constituted by the MOS transistor, the diode and the decoupling capacitor C_e (solid line rectangle in Figure. 7). The maximum field value H_c is located at the centre of the switching cell ; it is given for the three laboratories (table 2).

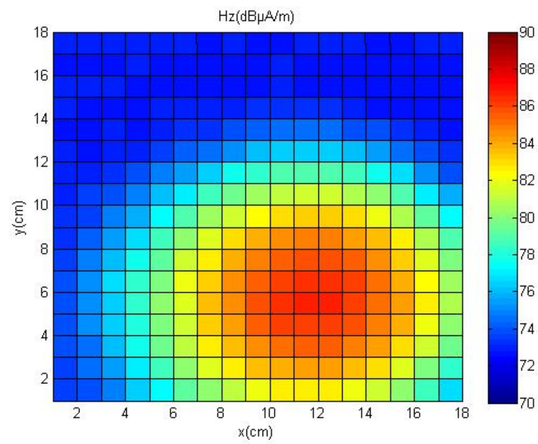
Laboratory	H_c(dBµA/m)
1	105.5
2	86
3	93.4

Table 2 : Maximum value of the magnetic field

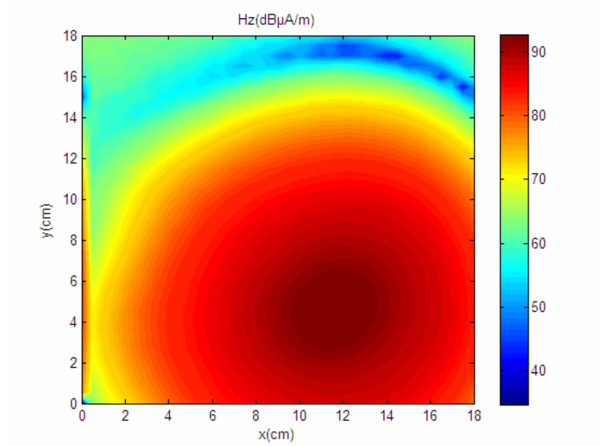
The obtained cartographies are similar but we note a difference of 10 dBµA/m for the maximum level between Lab. 1 and Lab. 3 and of 7 dBµA/m between Lab. 2 and Lab. 3.



(a) Lab. 1



(b) Lab. 2



(c) Lab. 3

Figure 8 : Z-component of the magnetic field measured on the three test benches.

The difference between the Lab 2. and Lab 3. is explained by the calibration process. Probe used by Lab. 3 has been calibrated on a transmission line, where as probe used by Lab 2. has been calibrated in a TEM cell, where the generated field is not quite uniform.

Contrary, we can explain the difference between the Lab 1. and Lab 3. by the ground plane.

Indeed, from the mappings of the figure 8, we can notice that they are very similar to the ones of an ordinary circular loop [5]. From the measurements of the Lab. 1, we have searched the characteristics of an equivalent loop (centre position, diameter and current) parallel to the ground plane in order to model the switching cell in this way. We have found a equivalent loop, which radius a is equal to 4 cm and run by a sine wave current I_{eq} which rms value is equal to 0,17 A. With these parameters, we have drawn the mapping of the z-component of the magnetic field radiated by this loop (figure 9).

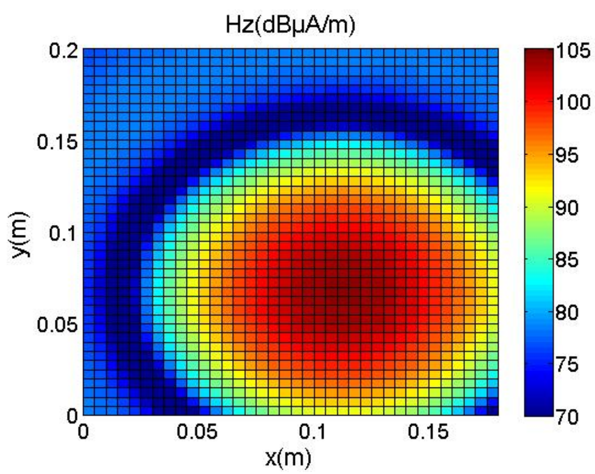


Figure 9 : Z-component of the magnetic field radiated by an equivalent loop above the ground plane.

This mapping can be compared to the mapping of the figure (8-a). The maximum value of the field is equal to 105 dBµA/m.

We can also take into account the effect of the ground plane by drawing the z-component of the magnetic field radiated by the equivalent, but this time, without ground plane (Figure 10).

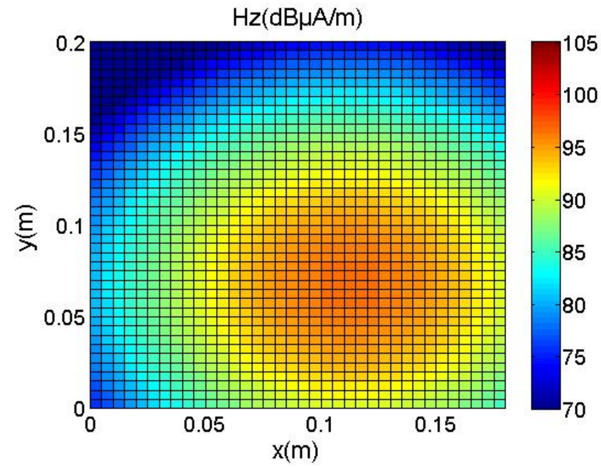


Figure 10 : Z-component of the magnetic field radiated by an equivalent loop.

The maximum value of the field is equal to 96 dBµA/m, which is in good accordance with the measurements of the Lab. 3.

Compared to the other ones, measurements made by Lab. 1, show a misalignment between even and odd rows. An evaluation has been made in the acquisition system (hardware and software) who has revealed a software mistake and a mechanical default in the X axis displacement system. Currently, solution is searched to solve this problem.

CONCLUSION

An interlaboratory comparison has been initiated by three laboratories, which have developed a test bench for measuring the magnetic field radiated by electronics devices. The first results are encouraging and have revealed differences whose analysis has helped to improve each system. This interlaboratory comparison could be continued by evaluation of the measurement uncertainties for each test bench in order to explain the remaining differences in absolute level.

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