Near Field Magnetic Probe Applied to Switching Power Supply

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***Abstract*—Near field measurements are a useful tool in the design process of a PCB board. It is a fast method to find which part of the circuit generates electromagnetic emissions and check if the solutions proposed actually works. This paper shows the construction of a Near Field Magnetic Probe, its characterization, and the explanation that how the correction factor can be obtained and measured as a function of the frequency. The Near field magnetic probe is basically a short loop antenna with a magnetic core to increase the sensibility, at the frequencies of switching power supply of a the Personal Computer. The construction of this probe is the first step for the construction of an automatized measurement system.**

I. Introduction

Near Field Measurements are widely used to infer properties of the electric and magnetic fields sorrounding integrated circuits (ICs) and printed circuit board (PCBs) [1]. Integrated Circuits (ICs) are often a significant source of radiated energy emissions from electronic systems, well designed ICs mantain good control of the currents that they generate. Poorly designed ICs can drive high frequency noise [2]. Some probes used for Near field measurements are double loaded loops that can simultaneously measure electric and magnetic field components [3], [4] and other probes are developed by two types of thick-film shielded loop coils as magnetic field probes [5]. The standard probes are electrically short dipoles, a resistive-loaded dipole, a half wave dipole, an electrically small loop, and a resistive-loaded loop [6]. Near Field Probes in EMC permit the localization of sources of electromagnetic interference, even in very confined arrangements. The Near Field Measurements on switch converters, can determine the frequencies of the greatest interference [7]. This paper discusses the application of low cost near-field magnetic scanning probe to determine areas of high noise emmited by a Power supply of a Personal Computer.

II. Probe construction

The construction of the magnetic probe can be observed in Figure1 was built using a cilinder of magnetic metal (steel) as a core, with diameter of the cilinder $d = 4\,mm$, and $N = 50$ turns of insulated copper wire, with the diameter of the wire: $0.3\,mm$. The length of the solenoide of the probe is $L_c = 19\,mm$.

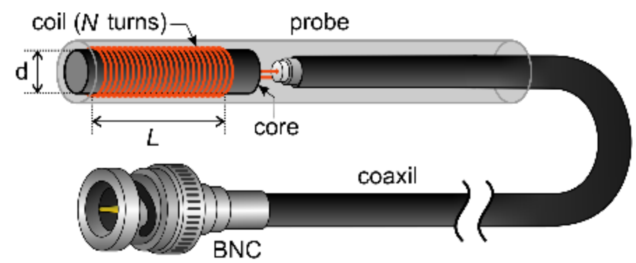

Fig. 1: Near Field Magnetic Probe picture

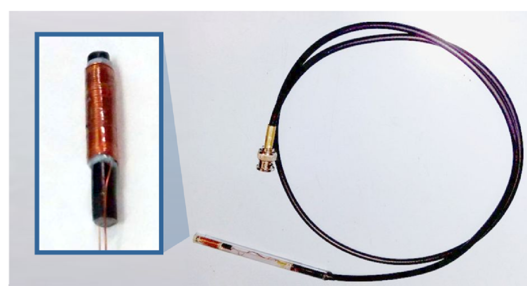

Fig. 2: Near Field Magnetic Probe construction

In the Figure 2 the magnetic field probe can be observed, that have been connected to a low loss RG58 coaxial cable of $Z_0 = 50\Omega$ and ended by a BNC male connector which allows the connection to the instrumentation.

III. Probe correction factor (antenna factor)

The Correction Factor is an important factor, because relates the Magnetic Field incident (H) to an antenna with the Voltage at the antenna terminals (V), this can be expressed thus:

$$H = VK \tag{1}$$

where K is the antenna factor $K[\frac{A}{Vm}]$.

The correction factor K, is the name in EMC papers [7], and Antenna Factor is named in Antennas.

The magnetic probe is bassically an inductor, and the voltage in the inductor is related with the variation of the magnetic flux (B), that can be calculated by mean of the Faraday Law [8], [9]:

$$\oint_c \overrightarrow{E} \cdot \overrightarrow{dl} = -N \oint_S \frac{\partial \overrightarrow{B}}{\partial t} \cdot \overrightarrow{dS} \tag{2}$$

where the first term of the eqn. (2) is the induced voltage in the probe.

For near field experiences, specially for low frequencies measurements like in a switching power suppy of a Personal Computer, the wavelength λ is much longer than the dimensions of the loop's probe [10], then:

$$V_{induced} = -N\frac{\partial B(t)}{\partial t}A \tag{3}$$

where A is the area of the core's section.

The $V_{induced}$ can be expressed thus:

$$V_{induced} = \omega\mu HAN \tag{4}$$

where μ is the magnetic permeability of the probe's core.

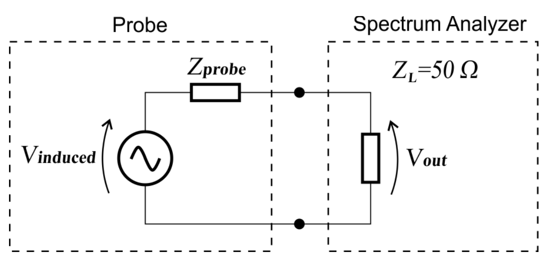

Fig. 3: Near Field Magnetic Probe equivalent circuit

Measurement of the induced voltage $V_{induced}$ of the probe are usually carried out in systems with input impedance of 50Ω. As it was stated the magnetic Probe is an inductor, that increase the reactance as a function of the frequency, and this probe's impedance can affect the measurements, (see Figure 3) introducing a probe's transfer function G_{Probe}:

$$V_{out} = G_{Probe}V_{induced} \tag{5}$$

Then:

$$V_{out} = G_{Probe}\omega\mu HAN \tag{6}$$

The correction factor is:

$$K[\frac{A}{mV}] = \frac{1}{G_{Probe}\omega\mu AN} \tag{7}$$

The impedance of the probe can be affected by the magnetic permeability of the magnetic core. The magnetic core permits a better sensibility of the probe.

To obtain the correction factor, a given magnetic field have been generated by the Air Coil, and the setup can be observed in the Figure 4. The voltage of the generator is placed sinusoidal, for different frequencies, and then the current of a coil can be obtained by the oscilloscope measuring the voltage over a 10Ω Resistance, and also the magnetic field can be determined in a point, as [9]:

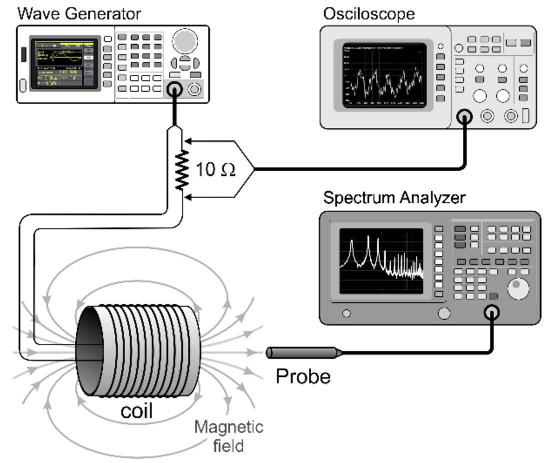

Fig. 4: The correction factor measurement setup for Near Field Magnetic Probe

$$H_{ext} = \frac{N_c\, I}{L_c}\frac{(\cos(\alpha_1) + \cos(\alpha_2))}{2} \tag{8}$$

where

N_c is the number of turns of the air coil

I is the current of the air coil

L_c Length of the air coil

α_1 and α_2 are the angles described in the Figure 5

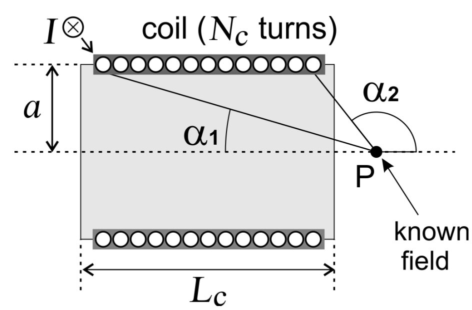

Fig. 5: Air Coil to generate a known magnetic field

The probe is placed on the Air coil as can be observed in Figure 6, and the Power received for a probe is measured by mean the spectrum analyzer of Figure 4. Then with the data of Magnetic Field on the probe and the power measured the Correction Factor can be determined by mean of eqn. (1). The response of the correction factor is showed in Figure 8.

IV. Measurements and results

The impedance of the probe with air core and magnetic core have been obtained by mean of an LCR and ploted in Figures 9 and 10. The Magnetic permeability is the ratio of the reactance of the probe with Magnetic core and with air core, plotted in Figure 11.

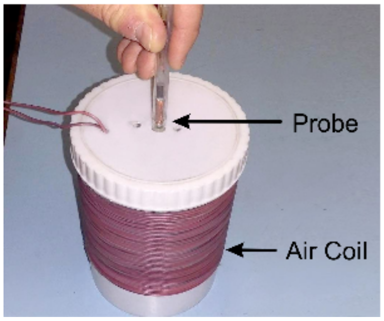

Fig. 6: The correction factor measurement for the Near Field Magnetic Probe

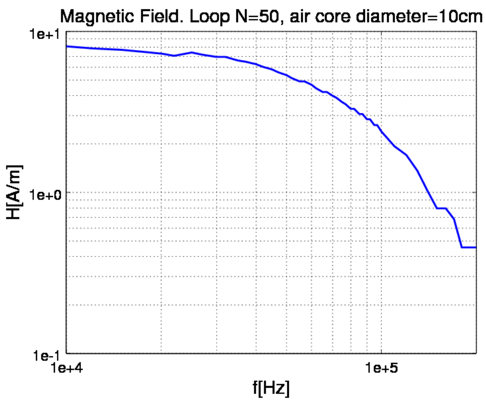

Fig. 7: Magnetic field generated by the coil

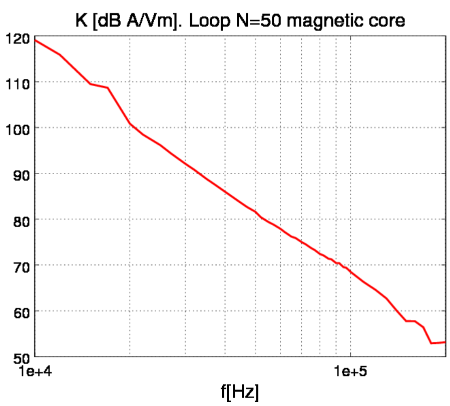

Fig. 8: Probe correction factor as a function of the frequency

The magnetic field of a computer's power supply has been measured using the probe developed in this paper. The probe was connected to an spectrum analyzer and passed over the power supply to find frequency of the highest received power peak. The highest peak frequency is at $f = 91kHz$.

In order to define the position of the probe on the X-Y plane, a millimeter grid paper was set over the surface of the power supply of personal computer, this is shown in Figure 12.

A coordinate system was defined on the paper. Then, samples of received power at the frequency of interest were

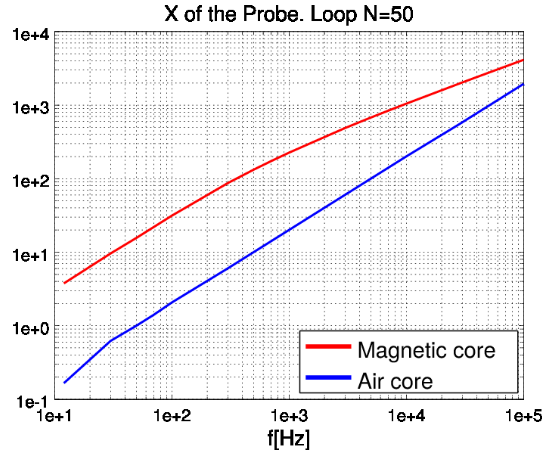

Fig. 9: Reactance's Measurement of the Near Field Magnetic Probe

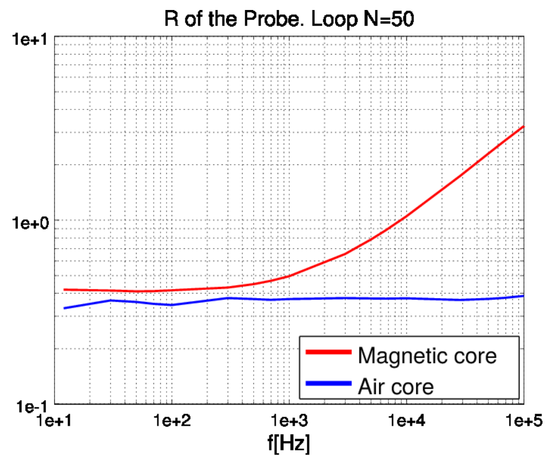

Fig. 10: Resistance's Measurement of the Near Field Magnetic Probe

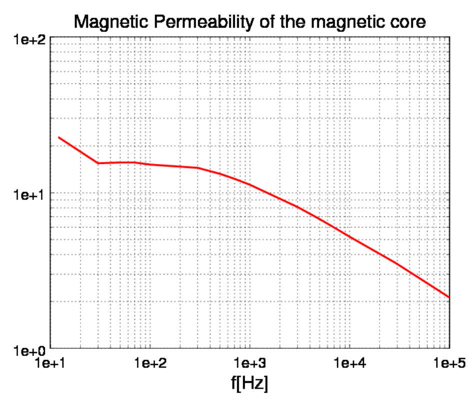

Fig. 11: Magnetic Permeability of the Near Field Magnetic Probe

registered, every 5mm on the X axis and every centimeter on the Y axis by moving de probe over the surface of the paper.

The results obtained shows the emissions of the magnetic field intensity at the frequency of 91kHz. The Figure 13 clearly shows which part of the circuit is generating most of the power emissions. The area of the choke and the diode heatsink in the switching power supply is where the more high emissions have been detected. This is a useful tool for solving problems of Pre-compliance of EMC, helping to find the source of the noise and interference.

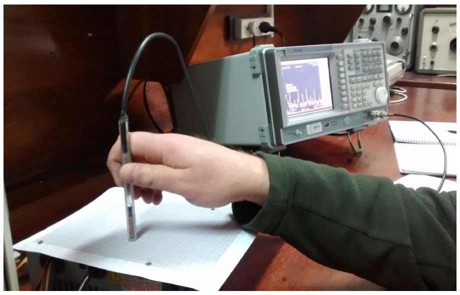

Fig. 12: Measurement of a power supply of a personal computer

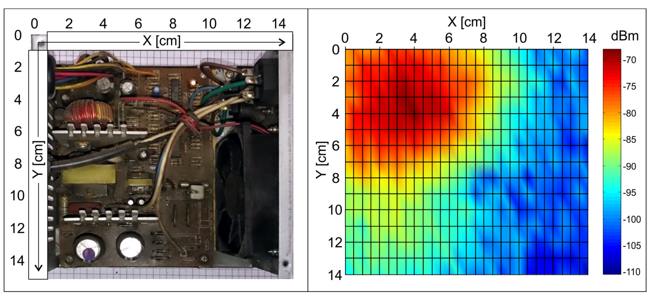

Fig. 13: Picture of the PC power supply and the Power received in spectrum analyzer by the Near Field Magnetic Probe developed

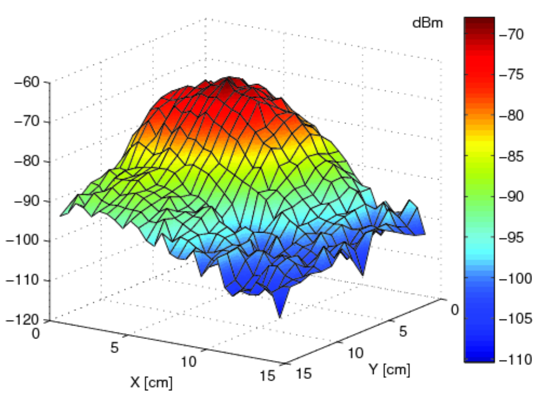

Fig. 14: Picture of the Power received in the spectrum analyzer by the Near Field Magnetic Probe

Figure 14 shows the power detected by the near Field Magnetic Probe and can be translated to magnetic field (dBA/m). From this Figure the red color is:

Power measured: $W_R = -70dBm\ (10^{-7}mW)$

The voltage over 50Ω spectrum analyzer:
$V = \sqrt{10^{-7}mW50\Omega} = 70\mu V(-83dBV)$.
The magnetic field:
$H = -83dBV + 70dBA/mV = -13dBA/m(0.22A/m)$

V. Conclusion

A low cost and simple near field magnetic probe has been builded and measured. It was used to determine the field emission by a power supply of the personal computer. Showing which part of the circuit causes most of the emissions. The information obtained is of great utility for precompatibility on EMC issues. In this paper the correction factor of the near field magnetic probe has been discussed theoretically and measured with a given magnetic field applied, an experimental set up is also showed and explained. The manual measuring process will be updated by an automatic device in the near future by the authors.

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