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MEASURING THE ELECTRIC AND MAGNETIC FIELDS ASSOCIATED WITH THE ELECTROSTATIC DISCHARGES

BY

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Abstract. The aim of this paper is to achieve an evaluation of the electric and magnetic fields associated with the electrostatic discharge, influencing the ESD immunity tests. We have here withdrawn conclusions regarding the influence of the electrostatic discharges on the immunity level of the electric and electronic systems, even if these phenomena might only sporadically appear in operating conditions. Basing on the measurements of the induced voltage performed with near field probes, we have achieved the electric and magnetic fields by using numerical integration. Finally, experimentally acquired results were processed using the statistical analysis.

Key words: electrostatic discharge, electric and magnetic fields, numerical integration.

1. Introduction

The electrostatic discharge phenomenon is everywhere encountered and consists of the electric charge transfer between two bodies that are at different electrostatic potentials. The IEC 61000-4-2 standard, describing how electronic equipment should be tested, defines the quasi-ideal waveform of the current associated with the electrostatic discharge (IEC 61000-4-2, 2009).

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One of the most sensitive issues associated with the ESD immunity tests is their poor repeatability, even if the conditions imposed by IEC 61000-4-2 are rigorously respected. An acceptable explanation is provided by the different spatial distributions of the magnetic, respective electric fields produced by the very fast electrostatic discharge, (Kováč *et. al.*, 2012).

In this paper we mainly deal with the measurement of the electric and magnetic fields associated with the electrostatic discharge.

2. Experimental Set-Up

The electric and magnetic fields generated by the electrostatic discharges should be assessed depending on the distance to the discharge point.

The experimental setup for the determination of the previously mentioned electric and magnetic fields is composed of a calibration target, a 20 dB attenuator, a coaxial cable and a digital oscilloscope with 2.5 GHz bandwidth, as shown in Fig. 1 (Ursache *et. al.*, 2014; Lunca *et. al.*, 2012; Lunca *et. al.*, 2009).

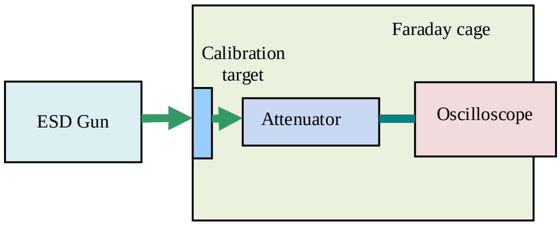

Fig. 1 – System for evaluation of the electric and magnetic fields.

Using the ESD gun, the electrostatic discharge is applied on the calibration target inserted in the wall of the Faraday cage. Around the discharge point, the electric and magnetic fields associated with the electrostatic discharge could be evaluated.

Considering this objective, a study has been performed, based on the measurements of the induced voltage due to the discharge, in positions horizontally placed at 10, 20 and respective 30 cm distance from the discharge point, the charge voltage being +2 kV, + 4 kV and +6 kV.

3. Results and Discussions

3.1. Determining the Magnetic Field Associated with the Electrostatic Discharge

For measuring the voltage induced by the magnetic field associated with the electrostatic discharges, the near field probe ETS-Lindgren 7405-901 (loop, 6 cm diameter) has been used.

The magnetic loop probe consists of a single-turn short-circuited wire, which is electrically screened by a metallic shield, Fig. 2 (ETS Lindgren, 2015).

Fig. 2 – The 9405-901 magnetic field probe.

The magnetic field probe measures the derivative of the magnetic field, as it is shown in eq. (1) (Fotis *et al.*, 2006):

$$V_0 = A_{eq}\frac{dB}{dt},, \tag{1}$$

where: V_0 is the output voltage of the magnetic field probe and A_{eq} is its equivalent area.

Based on (2) and the numerical integration available in the Matlab programming environment, we obtained the magnetic field associated with the electrostatic discharge, in terms of magnetic flux density, as shown in Figs. 3,…,5.

$$B = \frac{1}{A_{eq}}\int V_0 dt. \tag{2}$$

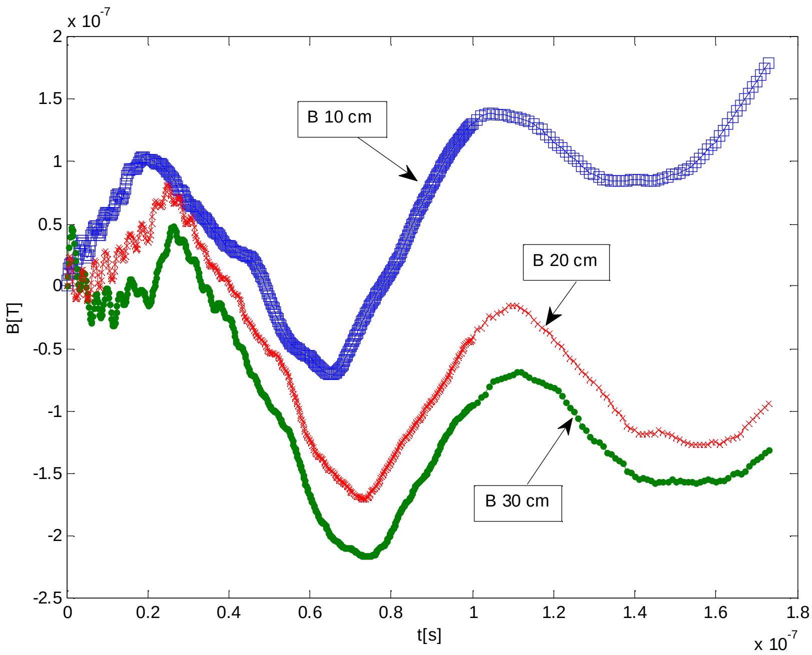

Fig. 3 – The magnetic field at +2 kV charge voltage.

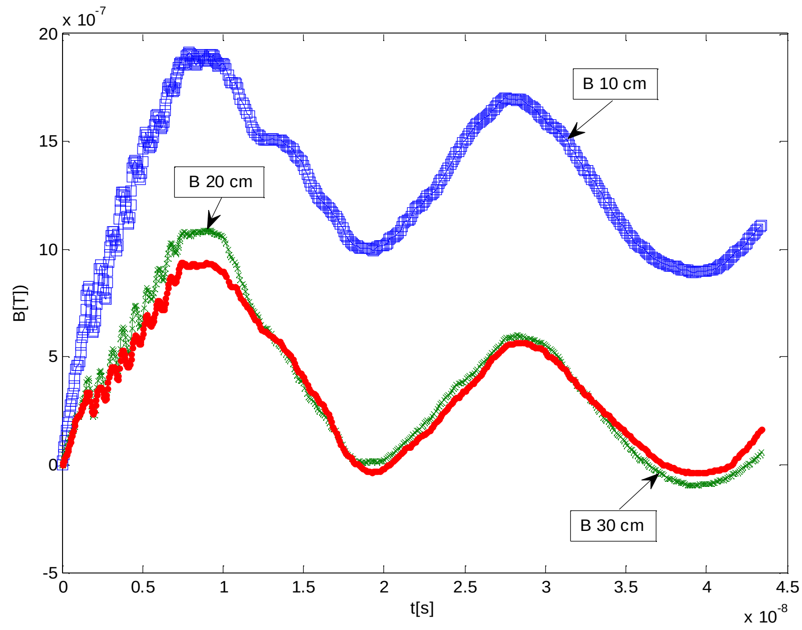

Fig. 4 – The magnetic field at +4 kV charge voltage.

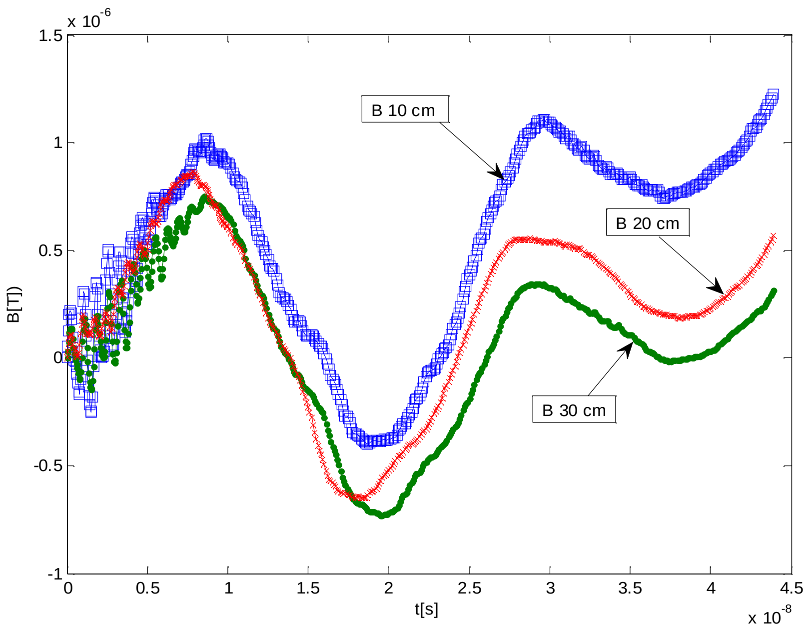

Fig. 5 – The magnetic field at +6 kV charge voltage.

The magnetic flux density decreases with increasing distance from the point where the discharge is applied.

2.2. Determining the Electric Field Associated with the Electrostatic Discharge

For measuring the voltage induced by the electric field associated with the electrostatic discharges, the near field probe ETS-Lindgren 7405-904 (ball probe, 3.6 cm diameter) has been used, Fig. 6 (Lunca *et. al.*, 2005).

Fig. 6 – The 9405-904 electric field probe.

The ball probe consists of a length of 50 ohm coax, whose center is extended beyond the 50 Ω termination and attached to a 3.6 cm diameter metal ball, which serves as an E-field pick up. The absence of a closed loop prevents current flow, allowing the ball probe to reject the H-field, (ETS Lindgren, 2015).

The ball probe measures the derivative of the electric field, as shown in (3), (Fotis *et al.*, 2007):

$$V_0 = RA_{\mathrm{eq}} \frac{\mathrm{d}D}{\mathrm{d}t} = RA_{\mathrm{eq}} \frac{\mathrm{d}\left(\varepsilon E\right)}{\mathrm{d}t}, \tag{3}$$

where: V_0 is the output voltage of the ball probe, A_{eq} is its equivalent area, R is the impedance of the transmission line, D is electric flux density (also so called displacement), E is the magnitude of the electric field and the electric permittivity constant is $\varepsilon_0 = 8.854 \times 10^{-12}$ F/m.

Applying the integration in (3), we obtain:

$$\int V_0 \mathrm{d}t = RA_{\mathrm{eq}} \varepsilon E\ . \tag{4}$$

Using (4) and based on the numerical integration available in the Matlab programming environment, we have obtained the electric field associated with the electrostatic discharge, in terms of electric field strength, as it is shown in (5):

$$E = \frac{1}{RA_{\mathrm{eq}}\varepsilon} \int V_0 \mathrm{d}t\,. \tag{5}$$

In Figs. 7,…,9 are plotted the electric field strengths associated with the electrostatic discharge for +2 kV, +4 kV and +6 kV charge voltage at 10 cm, 20 cm and respective 30 cm distance from the discharge point. The registered values are around hundreds of V/m, being significantly influenced by the distance from the discharge point.

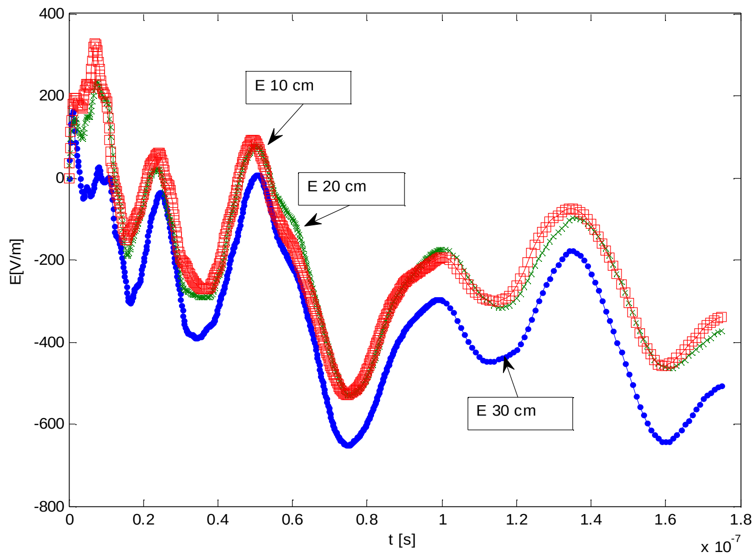

Fig. 7 – The electric field at +2 kV charge voltage.

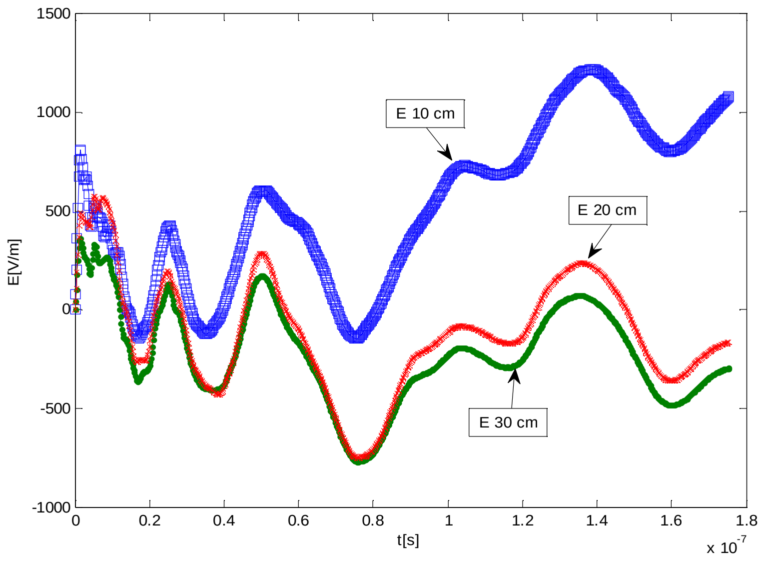

Fig. 8 – The electric field +4 kV charge voltage.

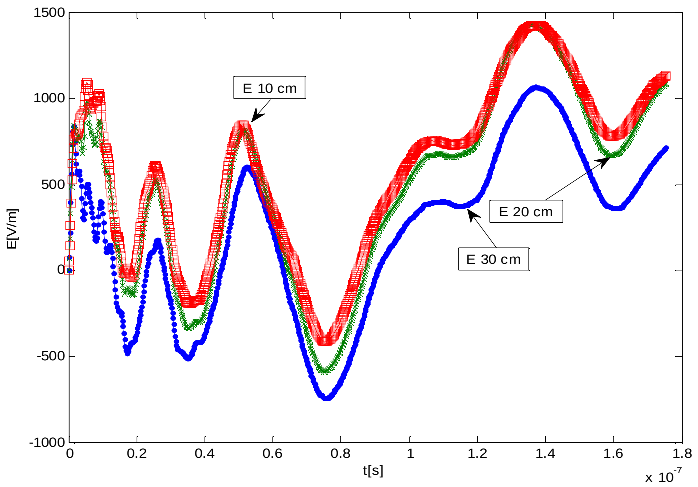

Fig. 9 – The electric field at +6 kV charge voltage.

4. Conclusions

The integrals encountered in a mathematical analysis course are chosen for their simplicity. In the real applications, the functions that must be integrated are more complicated. The solution for solving this inconvenience might be the usage of the numerical integration.

The advantages of the numerical integration consist in accuracy, reliability, efficiency and high level of confidence.

The relative position (the angle of attack) between the ESD gun and device under test also influences the values of the electric and magnetic fields associated with the electrostatic discharge.

The issue of the approximation of functions is encountered in many problems in numerical analysis, including the numerical integration.

In practical terms, the interpolation is used to approximate the numerical values of a function in a point that is not considered node. Consequently, more values of the function mean more accurate approximation.

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MĂSURAREA CÂMPURILOR ELECTRICE ŞI MAGNETICE ASOCIATE DESCĂRCĂRILOR ELECTROSTATICE

(Rezumat)

Scopul acestei lucrări este de a dezvolta o metodologie de măsurare a câmpurilor electrice şi magnetice asociate fenomenului de descărcare electrostatică, bazată pe integrarea numerică a tensiunii induse în sonde de câmp apropiat. Deşi se produc în mod aleator, sporadic, descărcările electrostatice produc câmpuri electrice şi magnetice care pot afecta atât repetabilitatea testelor de imunitate cît şi comportarea generală a echipamentelor testate din punctul de vedere al compatibilității electromagnetice. Pe baza determinărilor experimentale, care au constat în măsurarea tensiunilor induse la ieşirea sondelor pasive, la tensiuni de încărcare de +2 kV, +4 kV, respectiv + 6 kV, am obținut valorile câmpului electric şi respectiv magnetic asociate fenomenului de descărcare electrostatică. Variațiile în timp ale câmpurilor electrice şi magnetice au fost reprezentate grafic cu ajutorul integrării numerice a tensiunilor induse în probele de câmp electric şi magnetic apropiat, efectuată în programul de calcul MATLAB.