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ELECTROSTATIC DISCHARGE E-FIELD SPECTRUM ANALYSIS AND GRAPHICAL INTERPRETATION

BY

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Abstract. The aim of this paper is the experimental evaluation of electric field that is involved during an electrostatic discharge (ESD), simulated with a commercial ESD gun. Measurement of the electric field generated by electrostatic discharges is made at different distances from the point of discharge with a spherical field sensor. To assure realistic tests it is necessary to characterize the ESD environment. Results of measurements showed that the generator produces a transient electric field, depending on the charging voltage, that could affect test equipment differently.

Key words: electrostatic discharge; E-field; waveform; field probe; discharge current.

1. Introduction

Electrostatic discharges (ESD) are a common type of electromagnetic perturbation. This event may occur throughout the manufacturing, test, shipping, handling or operational processes and the electrostatic fields involved are associated with charged objects. When an ESD event occurs, electric and magnetic fields are generated. Electric field appears due to the sharp reduction

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of static voltage that caused the ESD event, while the magnetic field is generated by the current produced during the phenomenon. If the discharge occurs at some distance from the object of interest in the nearby area it is created an electromagnetic field. In order to determine the impact of ESD over the test device, there must be measured the field strength in the immediate vicinity of interest object.

Taking into account that ESD is a transient, very short event (few nanoseconds), the generated frequency spectrum has a very broad distribution. The electrostatic discharge being an electromagnetic phenomenon generates both types of fields: electric and magnetic. The electric field, the subject of interest in this paper, is produced due to the sharp reduction of static voltage that causes the ESD event and his strength is measured in V/m.

Electrostatic discharges can generate electronic equipment malfunction and even physical damage. While malfunction refers to data corruption and equipment's lock-ups, the physical damage may include irreversible destroys.

The IEEE Guide for Electrostatic Discharge (1992) describes the electromagnetic influence parameters, due to ESD that are believed to cause malfunction of electronic equipment and the ESD environment characterization.

The IEC 61000-4-2 Standard (2001) establishes the electrostatic discharge mode and is related to test system, usable equipment in a static electricity discharge. According to this standard, the most interesting parameter in an electrostatic discharge is the discharge current, for which must be specified four values: rise time, maximum discharge current and the current at 30 ns, respectively 60 ns.

2. E-Field Measurement System

The study of transient electric field radiated by commercial generator NSG 435 electrostatic discharges has been performed for various charging voltages of the simulation. Research of the transient **E**-field radiated by the commercial generator NSG 435 for electrostatic discharges was made for different charge voltages of the simulator.

Measurements of the electrical field generated by contact electrostatic discharges were made at different distances far from the discharge point. The measurement results have shown that the generator produces a transient electrical field which could affect differently the tested equipment.

Also the generator produces a different electrical field for various load voltages of the discharge generator. In our situation the discharge current visualized on the oscilloscope is numerical equal to the load voltage, due to the target's construction diagram.

In Fig. 1 is represented the network configuration for electric field measurement associated with electrostatic discharge. We used for these measurements an oscilloscope Tektronix DPO 7254 with four channels for visualization the waveform, and an ESD gun produced by Shaffner, NSG 435.

We also used the 3.2 cm diameter loop electric sensor of the EMCO 7405 set. All measurements were made 10 cm high above the table plane.

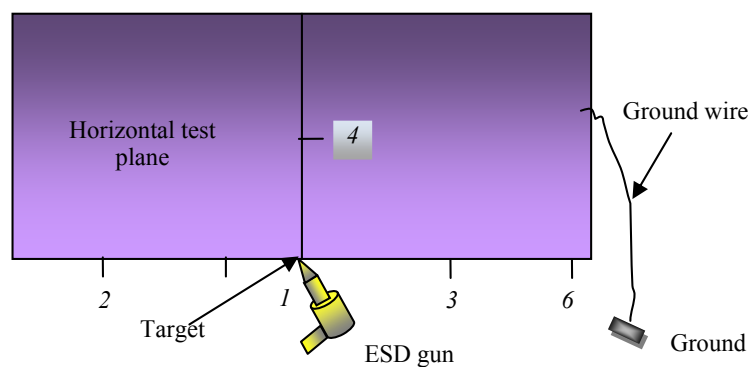


Fig. 1 – Control board scheme.

Tests were conducted only on the horizontal coupling plane. The sensors were placed at different distances (10, 25 and 40 cm) and at a height of 10 cm from the metal surface of the horizontal plane, as can be seen in Fig. 2.

Electrostatic gun is placed in point 1 situated in the middle plane. It is known that the earth cable position affects test waveform minimizing the uncertainty of obtained measurements of the electric field, the ground cable being arranged in broad loops, as required by the standard.

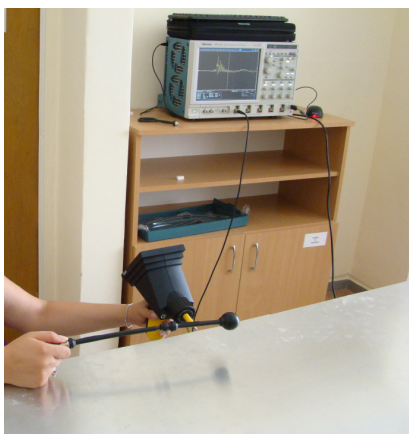


Fig. 2 – Measuring points on horizontal and vertical directions.

3. Measurement Results

3.1. Waveforms of Electric Field for Different Distances from Discharge Point

The electric field was measured following the procedure which was described previously, using an ESD gun. The discharge environment respects

the IEEE Guide; the temperature and the relative humidity were measured and found to be $24 \pm 2^\circ\text{C}$ and $50\% \pm 5\%$, respectively (Fotis *et al.*, 2006).

In Fig. 3 the electrical field waveforms in six points for +2 kV load voltage of the simulator can be observed. All measurements are made 10 cm high above the table plane. Fig. 3 *a* shows the form of the electrical field, horizontally in point 1 (discharge point). Fig. 3 *b* shows the electrical field in point 2 in left sides, 25 cm far from the discharge point.

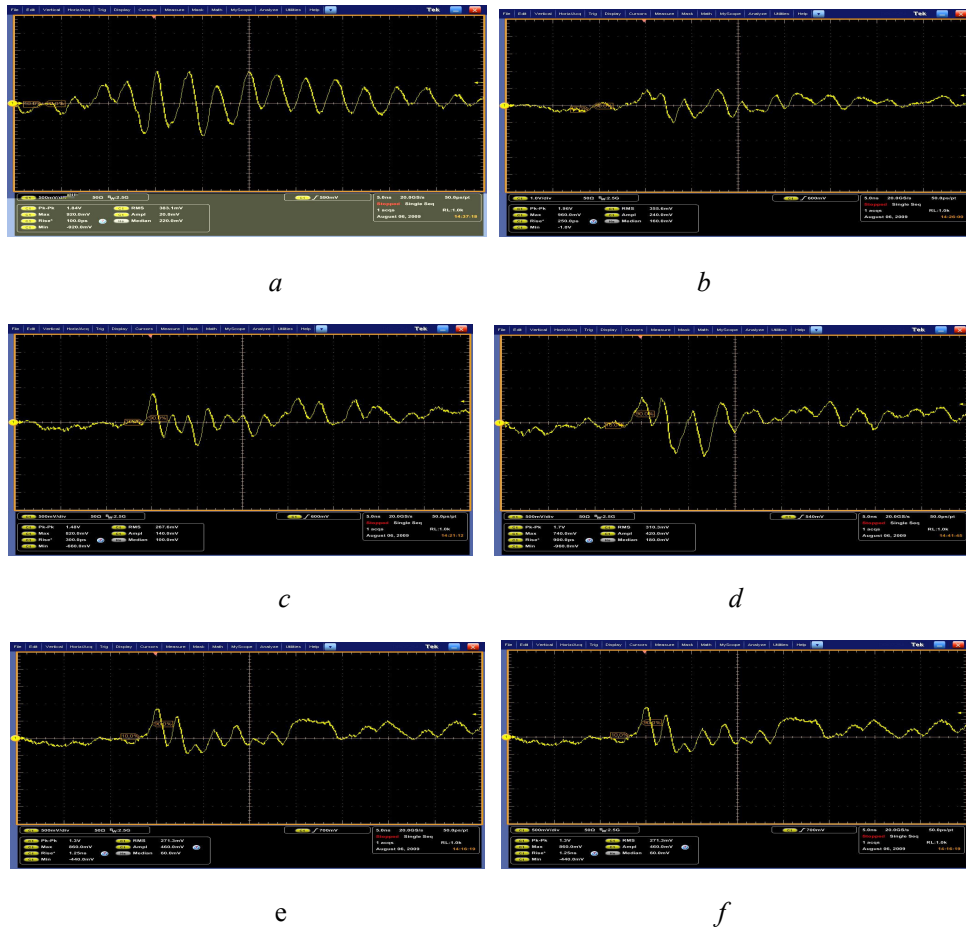


Fig. 3 – Electric fields waveforms for +2 kV charge voltage for different distances far from discharge point

Fig. 3 *c* shows the electrical field in right side 25 cm far from the discharge point. Fig. 3 *d* shows the electrical field 25 cm vertically far from the discharge point. Fig. 3 *e* shows the electrical field in point 5, horizontally 10 cm far from the discharge point. Fig. 3 *f* shows the electrical field in point 6, 40 cm far from the discharge point.

Overlapping the waveforms we can notice the electrical field for +2 kV

load voltage (Fig. 4) in six points side (X -axis of the table plane) and frontal (Y -axis of the table plane), on the horizontal coupling plane.

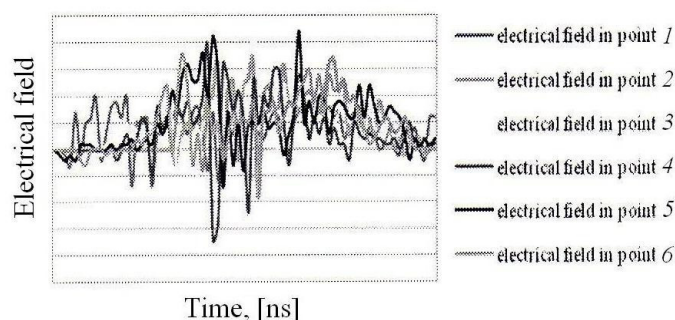


Fig. 4 – Electrical field at different distances from the discharge point.

Table 1 shows data obtained by measurements made for +2 kV load voltage (discharge in point 1). To protect the oscilloscope, a 20 dB attenuator was used for all measurements.

Table 1
The Measurement Points

| Measurement point | Peak-to-peak value U_{vv} mV | RMS value mV | Max. value mV | Min. value mV |
|-------------------|--------------------------------|--------------|---------------|---------------|
| Point 1 | 1.96 | 355.6 | 960.0 | -1,000.0 |
| Point 2 | 1.84 | 338.1 | 920.0 | -920.0 |
| Point 3 | 1.48 | 267.6 | 820.0 | -660.0 |
| Point 4 | 1.7 | 310.3 | 740.0 | -960.0 |
| Point 5 | 1.52 | 279.9 | 940.0 | -580.0 |
| Point 6 | 1.3 | 271.3 | 860.0 | -440.0 |

We could notice that the electrical field values are increasing once the discharge point is closer and they decrease when the electrical field sensor is moved to a greater distance.

In what follows we present the testing of the electrical field associated to contact electrostatic discharges in all points.

Using the above mentioned data we can observe that the electrical field's values on Y -axis are higher than those on X -axis of the coupling plane values. Values obtained by testing the electrical field at a distance of 25 cm on Y -axis are similar with data obtained by testing the electrical field in point 1, that is in discharge point, but on X -axis of the coupling plan.

3.2. Graphical Interpretation of Electric Field Distribution

Fig. 5 presents three graphs that illustrates the electrical field in point 1 (discharge point), point 4 (at a distance of 25 cm, on Y-axis of the coupling plane) and in point 6 (at a distance of 40 cm on X-axis of the coupling plane) for all four simulators load voltages.

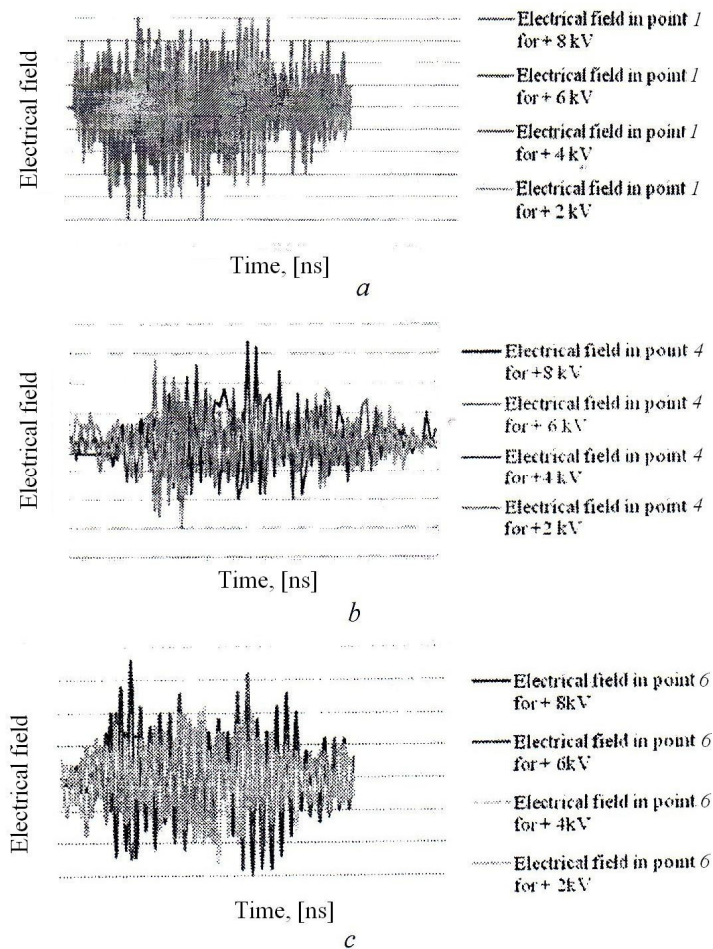


Fig. 6 – Electrical field in points 1 (a), 4 (b) and 6 (c) for different generator's charge voltages

Also we can observe that the electrostatic discharge simulator produces a different electrical field, depending on the direction of the measurements. That's why depending on the generators orientation induced voltages are different (Cerri *et al.*, 2001). For this reason tested equipments are passing for one direction and failing for another. Generally we can say that the level of the electrical field is decreasing once the distance from the discharge point increases (Neacșu *et al.*, 2010).

Tables 2,...,4 present the measurements results at +2 kV, +4 kV, +6 kV and +8 kV load voltage for points 1, 4 and 6, respectively. To protect the oscilloscope a 20 dB attenuator was used for all measurements. Obtained data shows that the peak-to-peak voltage provided by the electrical field sensor for +2 kV generators load voltage, in point 1 is of 1.96 V, in point 4 is of 1.7 V and in point 6 is of 1.3 V. For +8 kV load voltage of the generator, peak-to-peak voltage in point 1 is of 8.72 V, in point 4 is of 7.44 V and in point 6 is of 5.08 V.

Table 2*The Measurements Results in Point 1*

| Point 1 kV | Peak-to-peak value U_{vp} , [V] | RMS values mV | Max. value V | Min. value V |
|---------------|---|---------------------|--------------------|--------------------|
| +2 | 1.96 | 355.6 | 0.96 | -1.0 |
| +4 | 3.36 | 648.2 | 1.66 | -1.7 |
| +6 | 5.28 | 1,025 | 2.6 | -2.68 |
| +8 | 8.72 | 1,527 | 4.4 | -4.32 |

Table 3*The Measurements Results in Point 4*

| Point 4 kV | Peak-to-peak value U_{vp} , [V] | RMS values mV | Max. value V | Min. value V |
|---------------|---|---------------------|--------------------|--------------------|
| +2 | 1.7 | 310.3 | 0.740 | -0.960 |
| +4 | 3.64 | 625.5 | 1.54 | -2.1 |
| +6 | 5.52 | 976.8 | 2.4 | -3.12 |
| +8 | 7.44 | 1.3 | 3.44 | -4 |

Table 4*The Measurements Results in Point 6*

| Point 6 kV | Peak-to-peak value U_{vp} , [V] | RMS values mV | Max. value V | Min. value V |
|---------------|---|---------------------|--------------------|--------------------|
| +2 | 1.3 | 271.3 | 0.860 | -0.440 |
| +4 | 3.08 | 568 | 1.72 | -1.36 |
| +6 | 3.92 | 755.9 | 2.2 | -1.72 |
| +8 | 5.08 | 1,002 | 2.92 | -2.08 |

4. Conclusions

1. The electrostatic discharge simulator produces different electrical fields for different charging voltages. For this reason the tested device could pass for one direction and fail for another one. Generally we can say that the power of the electrical field is decreasing once the distance from the discharge point increases.

2. Due to rotational mismatch of the distributed electrical field around an electrostatic discharge generator tested equipment can be differently affected. Two possible reasons for this phenomenon could be, namely

a) there is no rotational symmetry for high voltage relays inside a generator;

b) return paths positioning and the high voltage cable of the NSG-435 generator have a direct influence on the equipment.

3. It is necessary to mention that the positioning of the cables during calibration settings is well defined and field's measurements are repeatable. When testing equipment positioning of the cables is not well defined, the repeatability is lower. Also ESD generators should be tested at different directions of field propagation. The **E**-field produced by ESD varies function of the charge voltage and other parameters. Theory showed that near **E**-field depends directly on the discharge current and the far **E**-field depends on the time derivative of the current.

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ANALIZA SPECTRALĂ ȘI INTERPRETAREA GRAFICĂ A CÂMPULUI ELECTRIC AFERENT DESCĂRCĂRII ELECTROSTATICE

(Rezumat)

Scopul acestei lucrări îl constituie evaluarea experimentală a câmpului electric implicat într-o descărcare electrostatică (DES) simulată cu un pistol DES comercial. Măsurarea câmpului electric generat de DES este realizată la diferite distanțe față de punctul de descărcare cu ajutorul unui senzor sferic de câmp. În vederea asigurării unor teste realiste este necesară caracterizarea mediului DES. Rezultatele măsurărilor au arătat faptul că generatorul produce câmp electric tranzitoriu care depinde de tensiunea de încărcare ce poate afecta în mod diferit echipamentul de testare.