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Electromagnetic Field Generated by Transient Electrostatic Discharges (ESD) from Person Charged with Low Electrostatic Voltage*

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Abstract - Tests were carried out by real charged human body discharging to the ground. The results show that the peak-to-peak electric field radiated in the distance of several centimeters is in the range of 10^2-10^3V/m and the magnetic field strength can be in the range of 10-10^2A/m in the distance of 10cm from the discharge. The spectrum of the field is extremely wide. The experiments also show that the amplitude of electric field radiated by ESD when human holding a metal tool discharging to the ground is about many times larger than that of the human finger discharging directly to the ground. Electrostatic discharge is one of the most common harmful electromagnetic sources to the electronic equipment in many environments. Tests also show that the captured waveform may be ringing which is stimulated by the fast rise ESD due to capacitance and inductance including any parasitic LC parameter of the probe and cable.

I. Introduction

Many industries have realized the importance of the control of electrostatic discharge (ESD). More attentions are put to the effects of heat and breakdown due to the ESD than to the indirect effects of transient electromagnetic field generated by ESD especially when the discharge often take place at the low electrostatic voltage (about 2-3kv) below which the human could not be feel the pain of electric shock. Human body is one of the most common electrostatic sources. Many works have been done on the electrical parameters of the human body model (HBM) such as the measurement of capacitance and the resistance of human body [1-4]. With the rapid development of the electronic industry, the electromagnetic compatibility (EMC) is becoming more and more important to some of the new electronic equipment. The fast transient close ESD field not only interfere the circuit but also may produce latent effects in the microelectronics. People now pay more attentions to the transient electromagnetic field radiated from ESD [5,6]. Wilson and Ma [7] measured the far electric field generated by ESD at 1.5m. Pommeremke [6] measured the electric and magnetic fields of ESD at different distance from 0.1 to1m. Bendjamin etc[9] measured the electric and magnetic field at different distance from 10 to 60 cm for 10kV voltage electrostatic discharge. Few papers present the electromagnetic field radiated from the real person. Pommeremke [8] shows that fields produced by human ESD are not exactly the same as that produced by ESD simulators. Many tests were carried for ESD from the human body discharge [10] charged with low electrostatic voltage such as 2-3kV. This paper is to present new test results of the electromagnetic field radiated by electrostatic discharges from real charged human body.

II. Experimental System

Human body in the test is isolated from the ground and connected to the high voltage source via a high current limiting resistance (10^8 Ohms) in order to maintain a stable and specified electrostatic potential. The tester is discharged to the ground metal ball directly or through a plastic ball pen or a metal tool such as the pinchers. The electrostatic voltage in all the experiments is 3kV, so that the electric shock is less pain to the tester when the discharge occurs [11]. A 10 mm-length short monopole antenna is connected to one of the two channels of the digitizing oscilloscope (HP54845A) with sample rate of 8GS/s and bandwidth of 1.5GHz and an electrically shielded

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magnetic field probe with a loop of 12mm in diameter is connected to another input channel of the oscilloscope. So, the electric field and magnetic field in the time domain will be recorded in the same discharge. A computer software is used to analyze the waveform of ESD field. The time domain electric field (E-field) can be easily transformed into the frequency domain of amplitude and power spectrum via an FFT operation. The magnetic field will be obtained by numerical integration of the measured waveform from the magnetic probe. The relative humidity in all the experiments was less than 40% and the temperature was about 25 celsius degrees. Figure 1 shows the experimental system.

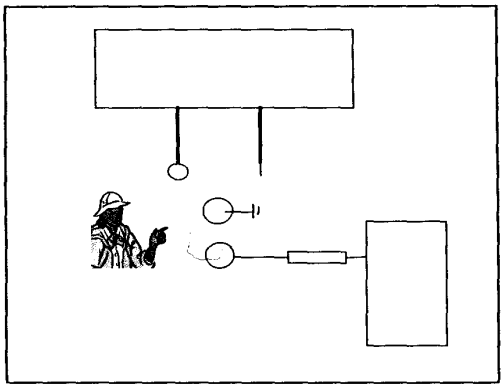

Figure 1: The Experimental System (not to scale)

II.a. Ringing Problems

Figure 2 shows the captured waveforms of the same ESD event from two channels of the scope which is connected to two different length of cables. The length of cable for the top waveform is zero, that is the short monopole antenna is soldered to the plugs. The length of the cable for the bottom waveform in figure 2 is1.3m. It can be seen from figure 2 that the top waveform last less than 50ns, that is to say the durations of the discharge is less than 50ns, but the bottom waveform is ringing. It last very long time and the peak-to-peak voltage is several times larger than of the top waveform. So, the captured waveform is not the real ESD signal due to capacitance and inductance including any parasitic LC parameter of the probe and cable.

II.b. Analysis of Ringing

The capacitance of the probe and the cable forms an LC circuit. The ringing frequency of this circuit is:

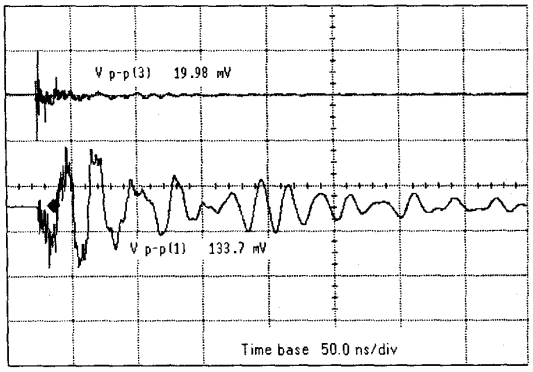

Figure 2: The Comparison of Ringing Waveforms

$$F = \frac{1}{2 \times 3.14\sqrt{LC}}$$

If the rise time of the waveform is sufficient to stimulate this ringing, then it can appear as part of the captured waveform. To calculate the ringing frequency, assume the cable has an inductance of approximately 10nH per centimeter. So, a test system with a input capacitance of 8 pF(including the capacitance of the input of the oscilloscope) and a 5 cm probe cable has a ringing frequency of approximately:

$$F = \frac{1}{2 \times 3.14\sqrt{LC}} = \frac{1}{2 \times 3.14\sqrt{(10nH)(5)(8pF)}} = 252MHz$$

$$t_{rise} = \frac{0.35}{252MHz} = 1.4ns$$

Therefore, a waveform with a rise time of less than 1.4 ns can stimulate ringing. The rise time of many ESD is about 1ns. So, it is important to reduce the inductance and capacitance of the test system in order to record the field of ESD accurately. The length of cable connected the antenna to the oscilloscope in all tests of this paper is 5 cm.

III. Results

III.a. E-Field Radiated from ESD

III.a.1. Discharge from Finger

Figure 3 shows the electric field generated from tester's finger. The tester is charged to 3kV and then directly discharged to the grounded ball with diameter of 100mm. The distance from the field test point to discharge is 10cm. It shows that the peak-to-peak electric field Ep-p is up to 383.2V/m.

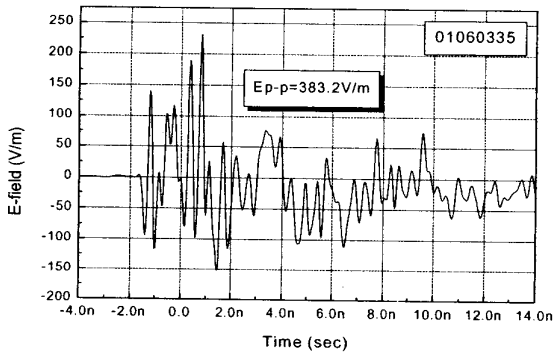

Figure 3: Electric Field generated by ESD from the finger

III.a.2. Discharge from Plastic Ball Pen

The charged tester holds a plastic ball pen in the hand and then discharges the ballpoint to the grounded metal ball. The distance between the discharge and the probe is 10cm. Figure 4 shows the waveform of electric field. It is show that the peak-to-peak electric field Ep-p is 544.4V/m, although the tester holds the plastic part of the ball pen, the electric field is larger than that of the direct finger discharge.

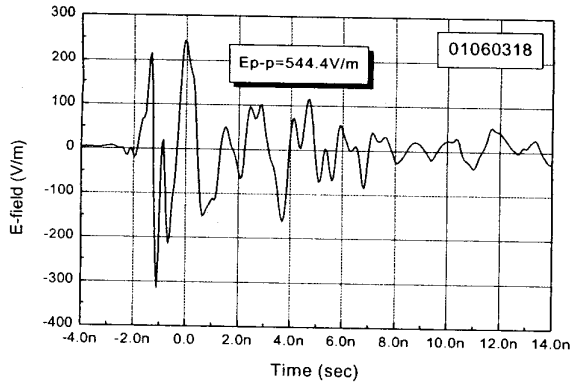

Figure 4: Electric Field generated by ESD from the charged person holding a ball pen discharging to the ground

III.a.3. Discharge from Metal Pinchers

Tester holds a metal pinchers and charged to 3kV, then quickly discharge the metal pincher to the grounded ball with diameter of 100mm. The distance from the discharge to the test point is 10cm. Figure 5 shows the electric field waveform radiated from the discharge. It can be seen from the figure that the peak-to-peak field Ep-p is 1774.4V/m, which is very larger than that of the discharge directly from the finger.

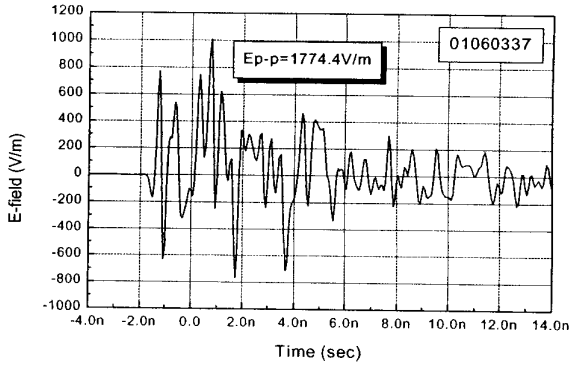

Figure 5: E-Field generated by ESD from the charged person (3kV) holding a metal pinchers discharging to the ground

III.a.4. Spectrums of ESD

The spectrums of electrostatic discharge can be obtained from the time domain waveform by the FFT operation. Figure 6 shows the spectrum of the ESD corresponding to the time domain ESD waveform of the figure 5. It can be seen that the spectrum of the ESD is very wide. The range of the frequency may be above 4GHz, half of the oscilloscope sample frequency.

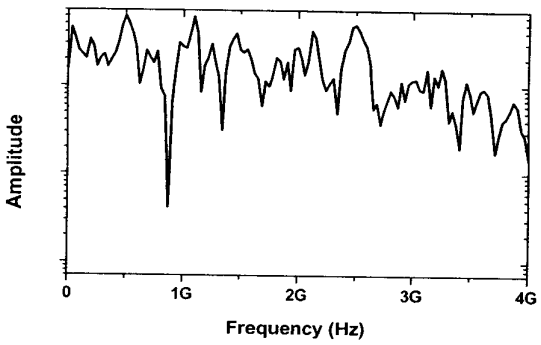

Figure 6: Spectrum of the ESD

III.c. H-Field Radiated from ESD

The magnetic field may be obtained by the H-probe which is connected to another input of the oscilloscope. Figure 7 shows the time derivative of the B-field. The peak-to-peak of the dB/dt is about 70kT/s. The magnetic field strength H can be obtained by numerical integral calculus of the measured derivative waveform of the magnetic field.

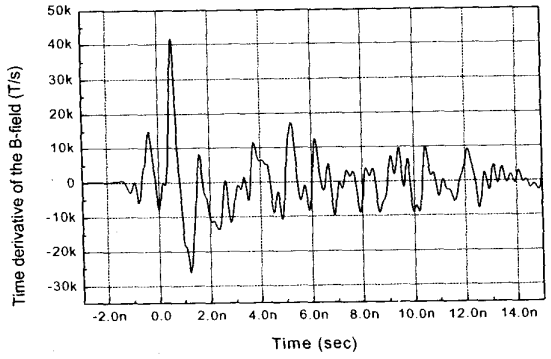

Figure 7: Magnetic flux density derivative,dB/dt

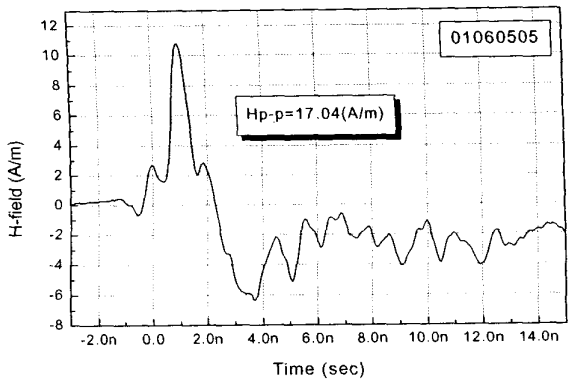

Figure 8: Magnetic H-Field generated by 3kV ESD

IV. Conclusions

The rise time of the electrostatic discharge is very short and it can easily stimulate the oscillation of the test systems due to capacitance and inductance including any parasitic LC parameter of the probe and cable. The peak-to peak field and the durations of the measured waveform may be several times larger than that of the real ESD waveform. It is very important to reduce the capacitance and inductance of the test system.

Even if the electric shock of the low potential (2~3kV) electrostatic discharge is insensitive to the charged human body, the peak-to-peak electric field radiated in the distance of several centimeter is in the range of 10^2-10^3V/m and the magnetic field is in the range of 10-10^2A/m. The bandwidth of the spectrum of the electrostatic discharge electric field is extremely wide, it may be above 4GHz.

The peak-to-peak electric field radiated from the electrostatic discharge when tester holds a metal tools discharging to the ground is many times than that of human discharging directly from the fingers.

The test of ESD fields is very complicated because it may be influenced by many factors. Many works must be done before the precision measurement can be made. But recent works show the electromagnetic field radiated by the electrostatic discharge is one of the most common dangerous electromagnetic sources to the electronic equipment due to the strong amplitude and wide band spectrum of the ESD field.

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