The Test of Electromagnetic Field Radiated by Electrostatic Discharge (ESD) from the Real Charged Human Body in the Office

Huang Jiu-sheng
Research Institute of Special Electromechanical Technologies
No.1, Bei Yuan Da Yuan, An Ding Men Wai
Beijing, 100012, P. R. China
Tel: +86-10-66749395 Ext 05
jiushuang@263.net jshuang@hns.cjfh.ac.cn

Abstract **-** A customed ultra-wide band E-field probe and H-field probe with wide band oscilloscope were used to test the electromagnetic field radiated from electrostatic discharge (ESD). Many tests were carried out by real charged human body discharging to the ground. The results show that the electric field in 10 cm by human holding a metal pen with potential of 2kV discharging to ground is about 410V/m and the magnetic field is about 28A/m in the distance of 3cm from the discharge. The band of the field is extremely wide, ranging from several MHz to above 1GHz. The experiments also show that the amplitude of electric field radiated by ESD when human holding a metal screwdriver discharging to the ground metal 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 the office environment.

I. Introduction

The threat of electromagnetic field radiated by electrostatic discharge (ESD) to the electronic equipment is becoming more and more serious with the electromagnetic compatibility (EMC) becoming more and more important to the electronic equipment. Human body is one of the most common electrostatic sources. The electrostatic potential on the human body may be very high in dry atmosphere. When the electrostatic potential on the human body exceeds some degree, electrostatic discharges (ESD) may occur. Many works have been done on the electrical parameters of the human body model (HBM) such as the capacitance and the resistance of human body [1-4]. Many ESD models have been presented, but most of the researches are focused on the heat effects such as the explosion or the breakdown of the device due to the ESD. The test of the EM field from the ESD is difficult because the ESD is a transient process and it lasts very short time (The discharge current rise time is less than 1nS and the duration is less than several hundred nano seconds). The electromagnetic field will be very strong and very wide band in the near field of ESD [5-8]. This paper is to present a new test method and the results of the electromagnetic field radiated by electrostatic discharges from real charged human body simulated the operation in the office.

II. Test Methods And Apparatus

The test apparatus are shown in figure.1. One hand of the human body in the test is connected to the high voltage source via a high resistance (10^8Ohms) in order to maintain a stable and specified potential. The other hand may discharge to the ground directly or through a metal tool. The high voltage in all the experiments is about 2kV, so that the electric shock is insensitive when the discharge occurs [9]. A 10 mm-length short monopole antenna and a digitizing oscilloscope (TDS680B) with sample rate of 5GS/s and bandwidth of 1GHz were used so that the discharge transient EM field in the time domain could be recorded. The waveform is recorded in the *.csv format documents in a 3.5 inch floppy diskette. The waveform document contains two columns and 500 rows of data. The first column data is the time, and the second column data is

the voltage. A computer software is used to analyze the waveform of ESD field (Figure.2). The time domain E-field can be easily transformed into the frequency domain of amplitude and power spectrum via an FFF operation. The power spectrum can also be obtained (Figure.3).

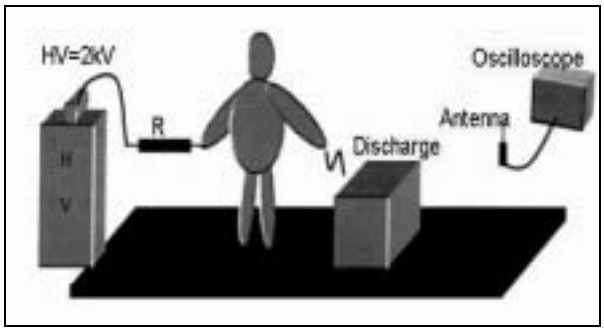

Figure 1. Test Rig

III. Test Results

3.1 E- Field radiated by human body holding a wooden handle screwdriver discharging to ground

Figure. 2 shows the electric field in the distance of 34cm radiated by human holding a metal screwdriver with a wooden handle discharging to a grounded metal ball with diameter of 8cm. The human body is charged with electrostatic potential of 2kV. The capacitance of the human body to the ground is about 80pF. It indicates that the field is a very short duration ringing waveform that takes a long time for dumping. It can be seen that the peak-to-peak field Epp is about 110V/m. Figure.3 shows the amplitude and power spectrum of the electric field in the frequency domain. The band of the spectrum is very wide, from several MHz to above 1GHz. The main content amplitude of the field is about 500MHz. The power spectrum of is above 3GHz.

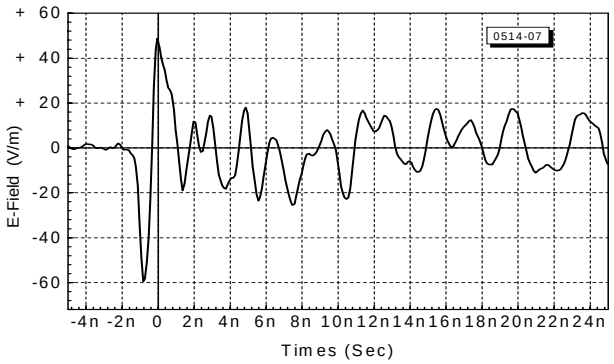

Figure 2. ESD Field Waveform (2kV, 34cm, Epp=110V/m)

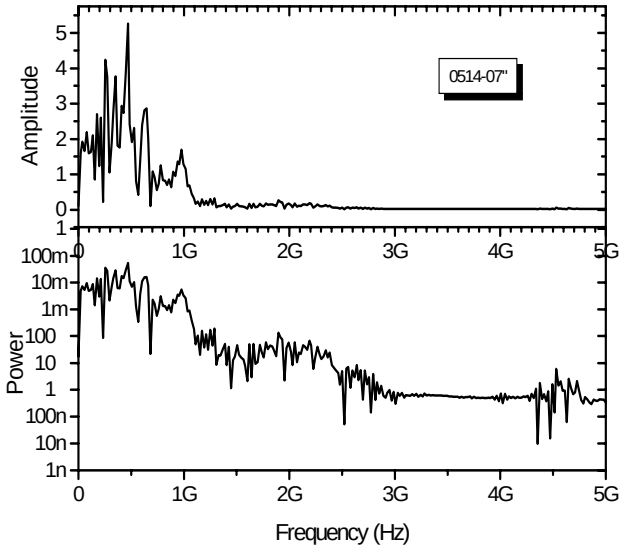

Figure 3. Amplitude and Power Spectrum of E-Field

3.2 E- Field radiated by human body holding a metal screwdriver discharging to ground

Figure. 4 shows the electric field in the distance of 10 cm radiated by human holding a metal screw driver discharging to a grounded metal. The human body is charged with electrostatic potential of 2kV. The capacitance of the human body to the ground is about 80pF. It indicates that the waveform is ringing waveform and the peak-to-peak field Epp is about 410V/m. Figure.5 shows the amplitude and power spectrum of the electric field. The band of the spectrum is very wide, from several MHz to above 1GHz. The main component of the amplitude is about 300MHz.

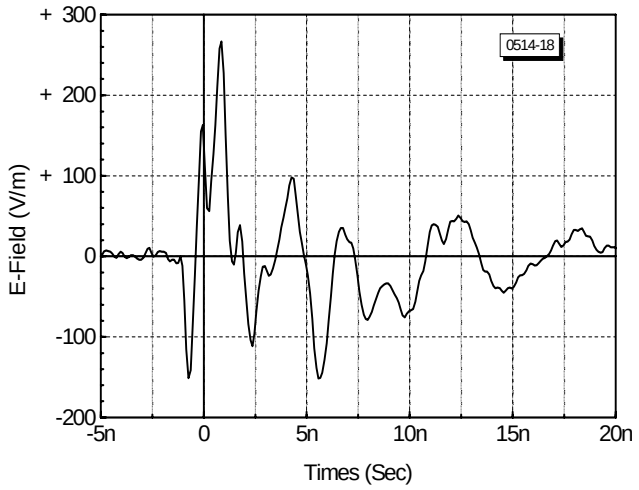

Figure 4. ESD Field Waveform (2kV, 10cm, Epp=410V/m)

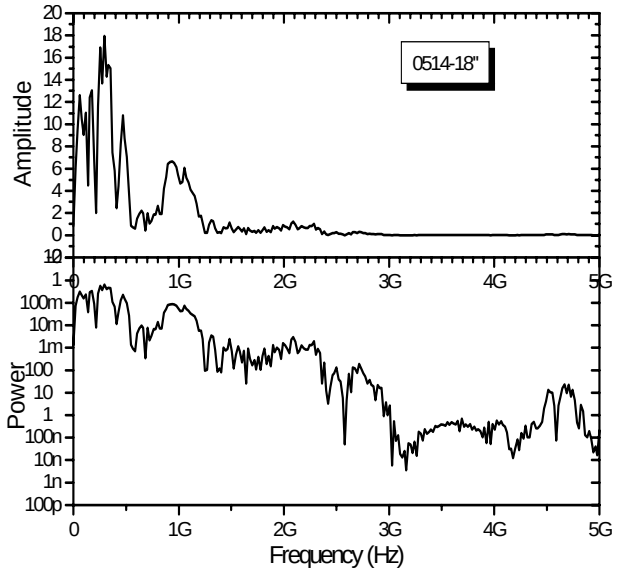

Figure 5. Amplitude and Power Spectrum of E-Field

3.3 E-Field radiated by human finger discharging directly to computer desktop metal

Figure. 6 shows the electric field in the distance of 126 cm radiated by human body discharging directly to a personal computer metal parts. The human body is charged with electrostatic potential of 2kV. The capacitance of the human body to the ground is about 80pF. It indicates that it is a very short duration ringing waveform. It can be seen that the peak-to-peak field Epp is 60V/m. By comparison with Figure.2 and Figure.4, it is much lower than that of the near (10cm) field radiated from metal to metal ESD. Figure.7 shows the amplitude and power spectrum of the electric field. The band of the spectrum is very wide ranging from several MHz to above 1GHz.

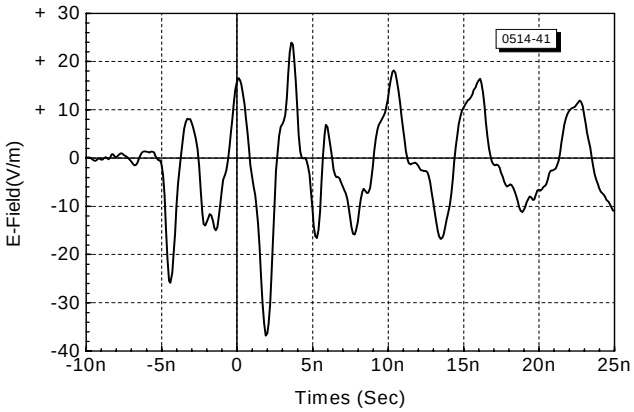

Figure 6. ESD Field Waveform
(2kV, 126cm, Epp=60V/m)

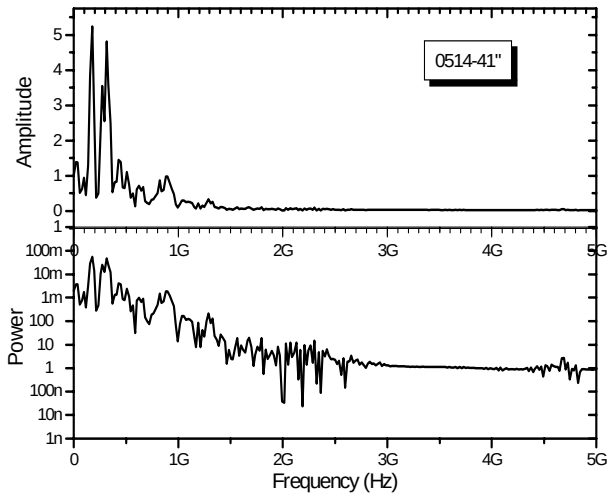

Figure 7. Amplitude and Power Spectrum of E-Field

3.4 E-Field radiated by human body holding a metal pen discharging to computer desktop metal

Figure. 8 shows the electric field in the distance of 10 cm radiated by *human* body holding a metal pen discharging to a grounded computer desktop metal. The human body is charged with electrostatic potential of 2kV. The capacitance of the human body to the ground is about 80pF. It can be seen that the peak-to-peak field Epp is 410 V/m.

It is similar to that in Figure.4. Figure.9 shows the amplitude and power spectrum of the electric field. The band of the spectrum is very wide ranging from several MHz to above 1GHz. The main component of the field is in the range of 500MHz and 1GHZ. Comparing with Figure.5, the main amplitude is shifted to the high frequency.

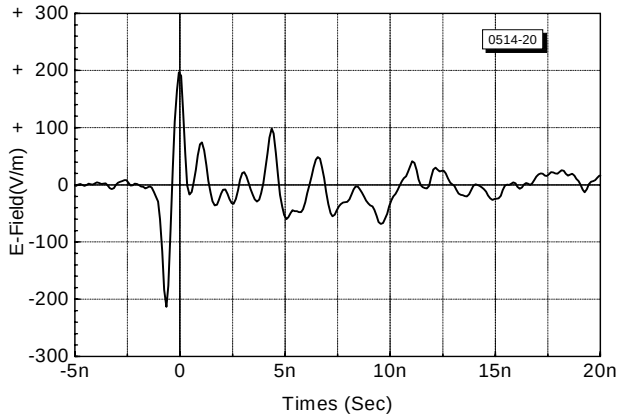

Figure 8. ESD Field Waveform
(2kV, 10cm, Epp=410V/m)

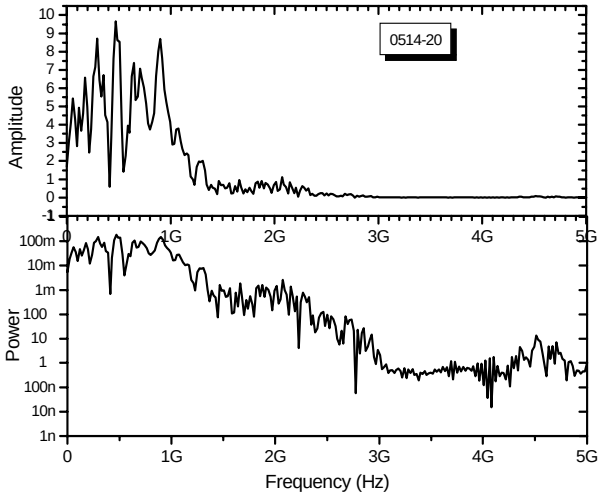

Figure 9. Amplitude and Power Spectrum of E-Field

3.5 H-Field Radiated by charged human body holding a metal pen discharging to computer desktop metal

Fig. 10 shows the magnetic flux density derivate dB/dt in the distance of 3cm from the discharge by human body holding a metal pen. The human body is charged with potential of 2kV and discharging to the computer desktop metal. It is measured by an H-field probe and a digital oscilloscope HP54845A (8GS/s, 1.5GHz bandwidth). The peak-to-peak amplitude of the magnetic flux density derivate is about 5.4×10^{4}T/s and the rise time is less than 1ns.

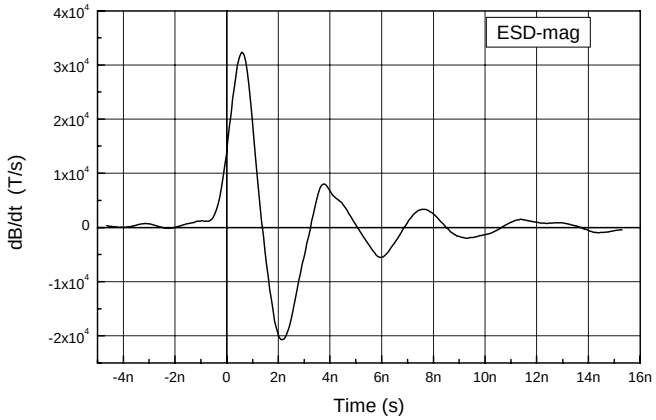

Figure 10. Magnetic flux density derivative, dB/dt
(2kV, 3cm)

Fig. 11 shows the spectrum of magnetic flux density derivative. It is convernted into frequency domain by using fast fourier transform (FFT) from figure10. It can be seen that the significant frequency content in 250MHz.

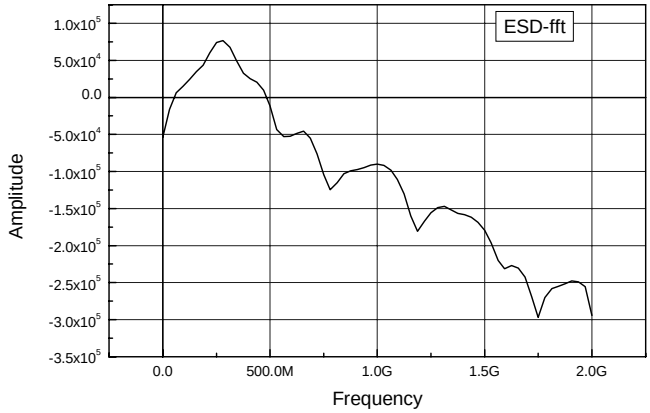

Figure 11.The spectrum of magnetic flux density derivative (2kV,3cm)

Fig. 12 shows the magnetic H field at the distance of 3cm from the discharge. It can be seen that the peak-to-peak amplitude of the H-field is about 28A/m and the rise time is about 1ns.

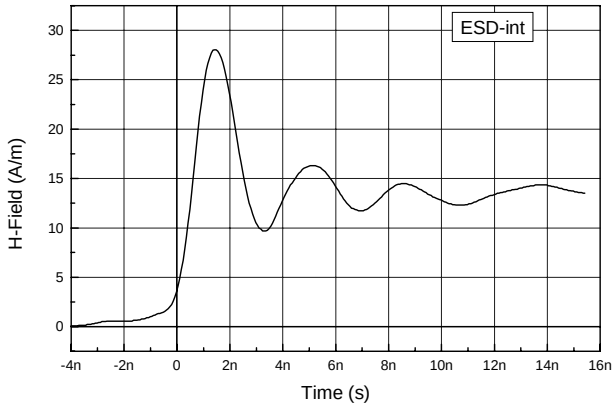

Figure 12.The waveform of the ESD H-field (2Kv, 3cm, Hp-p=28A/m)

IV. Conclusions

The electric field and magnetic radiated by electrostatic discharge from the charged human body is tested and the characteristics of the waveforms and spectrums of the electromagnetic field are analyzed. Some important results are:

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 cm is above several 100V/m and the magnetic field can be 28A/m.

The rise time of electric field and magnetic field is about 1ns. The bandwidth of the spectrum of the electrostatic discharge electric field is extremely wide, ranging from several MHz to above 1GHz.

The electric field radiated from the electrostatic discharge when a human body holds a metal tools discharging to the ground is many times larger than that of human discharging directly from the human finger.

Electromagnetic field radiated by the electrostatic discharge is one of the most common dangerous electromagnetic sources to the electronic equipment in our office environment due to the strong amplitude and wide band spectrum of near electromagnetic field.

References

[1] W. D. Greason. Analysis of the charge/Discharge Processes for the Basic ESD Models. IEEE IAS, vol.29,no,5, 1993, pp.887-895.

[2] Huang Jiu-sheng, Liu shang-he. On the Measurement of Human Body Capacitance. Proceedings of the Third International Conference on Applied Electrostatics (ICAES), Shanghai, China, 1997, pp.264-267.

[3] Huang Jiu-sheng, Liu shang-he. Why the Human Body Capacitance is so Large?. 19th International EOS/ESD Symposium, CA, USA, Sep.21-25,1997.

[4] Huang Jiu-sheng. The Measurement of Electrostatic Capacitance of Human Body. Fourth International Conference on Electronic Measurement & Instruments. Harbin, China, August 18~21, 1999, pp.123~127

[5]Tiffany Sterner, John E. Muholland. The Measurement of Solar Array Discharges in a Simulated Space Environment. IEEE-EMC, 1991, pp.242-247.

[6] Masamitsu Honda. Impulsive Fields Generated by Low-Voltage ESD. IEEE-IAS, 1991, pp.577-579.

[7] David Pommerenke, Martin Aidam. ESD: waveform calculation, field and current of human and simulator ESD, Journal of Electrostatics vol.38, 1996, pp. 33-51.

[8] Huang Jiu-sheng, Liu shang-he. Experiment Investigation of the Field Radiated by Human Electrostatic Discharge (ESD). Proceedings of the Third international Conference On Applied Electrostatics, Nov.14-16, Shanghai, China, 1997, pp.345-348.

[9] Wu Zhancheng, Liu Shenghe and Huang Jiusheng. *Effects of Electrostatic Discharge on Human Body*. Proceedings of the Third International Conference on Applied Electrostatics (ICAES), Shanghai, China, 1997, pp.330-333.