Measurement of Induced Voltages on Simple Printed Circuit Board due to Indirect Discharges of ESD Generators

Norio Yamamoto[#1], Yoshinori Taka[*2], Osamu Fujiwara[*3]

[#]*Industrial Research Center of Shiga Prefecture*
232 Kamitoyama, Ritto, Shiga, Japan
[1]yamamoto.norio@shiga-irc.go.jp

[*] *Graduate School of Engineering, Nagoya Institute of Technology*
Gokiso-cho, Showa-ku, Nagoya, Aichi, Japan
[2]taka@nitech.ac.jp
[3]fujiwara@odin.nitech.ac.jp

***Abstract*— The International Electro-technical Commission (IEC) prescribes immunity tests (IEC610000-4-2) of electronic equipment against electrostatic discharges (ESDs), and specifies indirect discharges of an ESD-gun to a vertical coupling plane (VCP) in the vicinity of equipment under test (EUT) that simulate personnel discharges to conductive materials adjacent to the EUT. According to IEC 61000-4-2 2001-04, the VCP shall be placed parallel to the EUT at a distance of 0.1m from the EUT, while the discharge shall be applied to the centre of one vertical edge of the VCP without specifying any angles of inclination and rotation of the ESD-gun to the VCP, and a reference position of an EUT to the VCP as well. In order to examine to what extent the above discharges affect the results, using a simple printed circuit board (PCB) with a trace in lieu of EUT, we measured the voltages induced on the trace due to indirect discharges with different angles of inclination and rotation of an ESD gun to the VCP. As a result, we found that the induced peak voltages greatly vary by a factor of 1.96 with respect to angles of inclination and rotation of an ESD gun onto the VCP.**

Key words: ESD, IEC standard, vertical coupling plane, indirect discharge, test method.

I. INTRODUCTION

As a result of the high speed and the high integration of ICs according to the rapid advancement of semiconductor technology in recent years, various kinds of high-performance electronic equipment are being supplied to the market. On the other hand, deterioration in the immunity of electronic equipment against an electromagnetic noise becomes a problem. Especially, electrostatic discharges (ESDs), which include wideband electromagnetic noises, can cause more serious malfunctions in high-tech equipment [1], [2].

From this background, ESD immunity test methods for electronic equipment have already been standardized in International Electro-technical Commission (IEC). For instance, the test method that simulates an ESD from a charged human is prescribed, and a typical current discharge injected by an ESD generator (ESD-gun) is also specified specifically in IEC61000-4-2 2001-04 [3]. Moreover, this standard concretely defines application of discharges to equipment under test (EUT) (direct application), a horizontal coupling plane (HCP) and vertical coupling plane (VCP) in the vicinity of the EUT (indirect application) in order to simulate personnel discharges to objects which are adjacent to the EUT.

According to IEC 61000-4-2 2001-04, the VCP shall be placed parallel to the EUT at a distance of 0.1m from the EUT, while the discharge shall be applied to the centre of one vertical edge of the VCP without specifying any angles of inclination and rotation of an ESD gun to the VCP, and a reference position of the EUT to the VCP. It has empirically been accepted, therefore, that there are not good correlations between the results obtained by one and other test sites even for the same products.

In this paper, using a simple printed circuit board (PCB) with a trace in lieu of EUT, we show the uncertainty of voltage waveform induced on the trace due to indirect discharges for different angles of inclination and rotation of an ESD gun to the VCP in order to reveal to what extent the difference of the above locations of an ESD-gun affects the test results.

II. MEASUREMENT METHOD

Figure 1 shows a typical measurement system for testing the immunity of EUT due to indirect discharges of an ESD-gun onto a VCP, which is being specified in IEC 61000-4-2 2001-04 [3].

Figures 2(a) and 2(b) show the top view and side view of a simple printed circuit board (PCB) with a trace, which was used in lieu of EUT. Based on IEC62333-2-2 Ed. 1.0 en: 2006 [4] specified in evaluating effects of noise suppression sheet for digital devices and equipment, we constructed the PCB, which consists of a dielectric substrate with a microstrip line (characteristic impedance: 50Ω) on the front side and two SMA connectors attached on the backside as a ground plane of this substrate. Both ends of this microstrip line are fixed

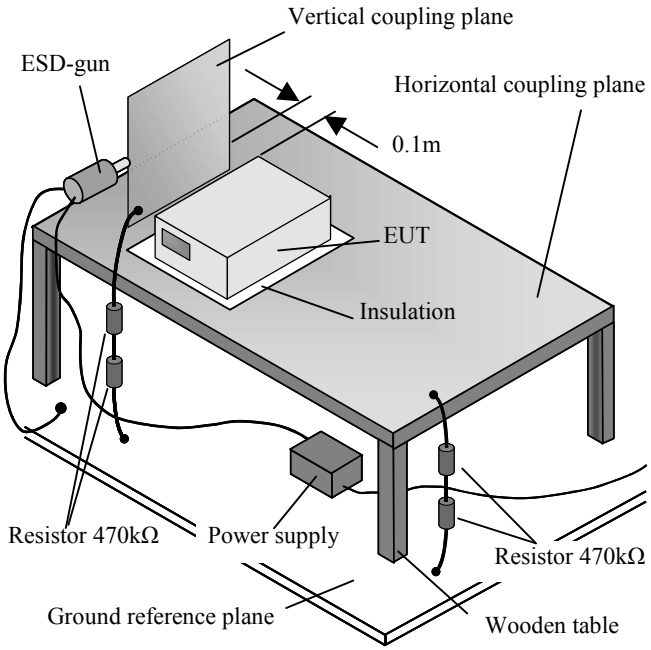


Fig. 1 Measurement system for immunity testing due to indirect discharges of an ESD-gun.

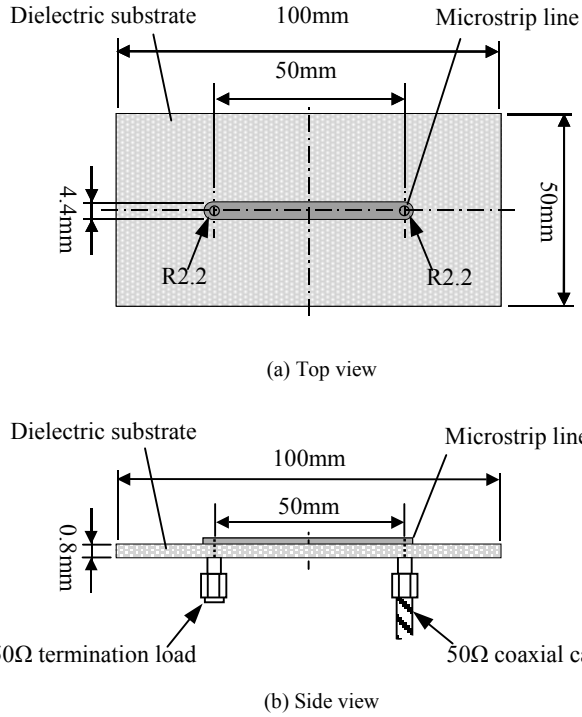


Fig. 2 A simple PCB used in lieu of EUT. (a) Top view and (b) side view.

through holes to the center conductors of SMA connectors, which are also connected to a 50Ω termination load and a 50Ω coaxial cable, respectively.

Figure 3 shows a setup for measuring induced voltages on the trace of the PCB due to indirect discharges of an ESD-gun. The PCB on the styrene foam was placed on the insulation in

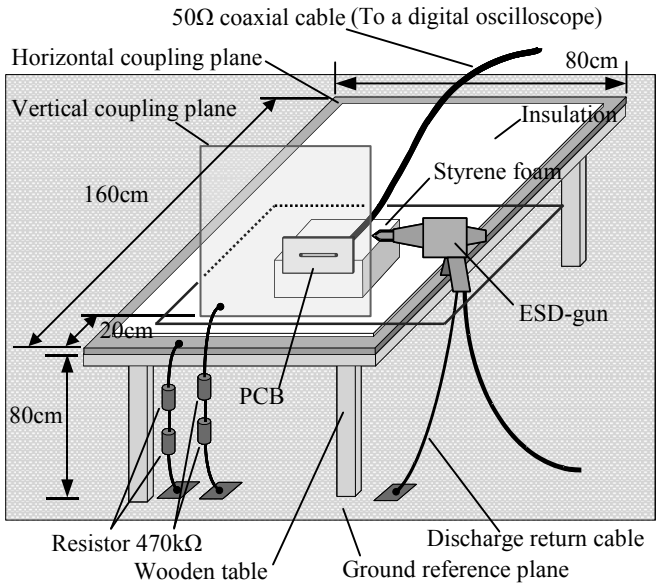
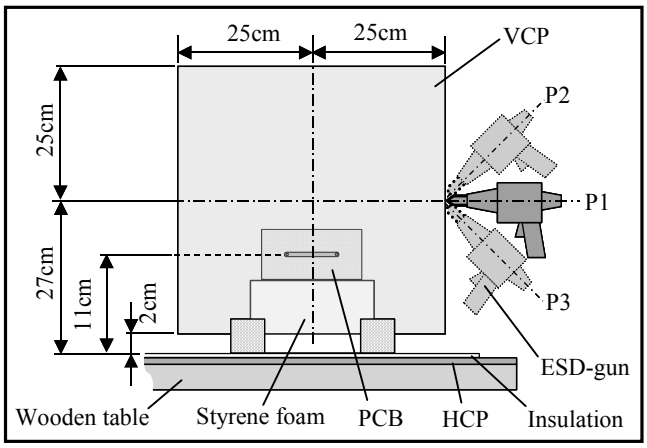


Fig. 3 Setup for measuring induced voltages on the trace of a simple PCB due to indirect discharges of an ESD-gun.



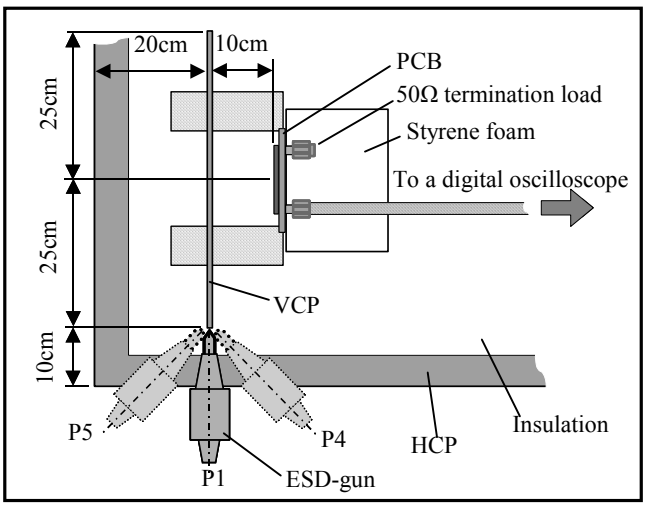


Fig. 4 Inclined arrangements of an ESD-gun to a VCP. (a) Front view and (b) top view.

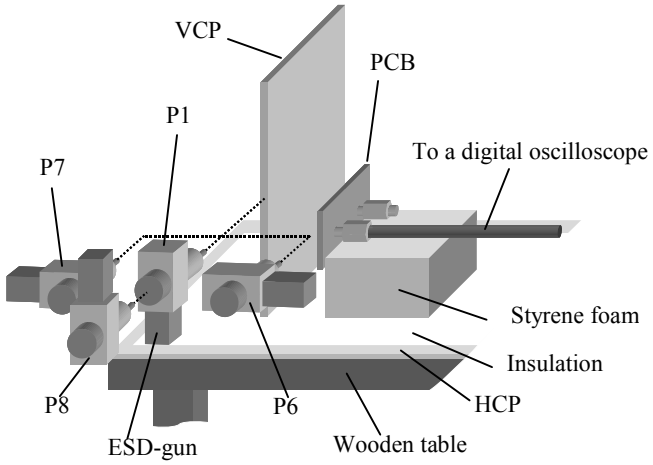


Fig. 5 Rotated arrangements of an ESD-gun to a VCP.

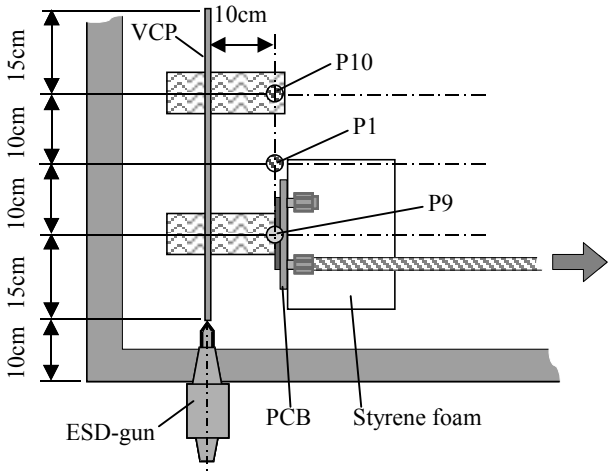


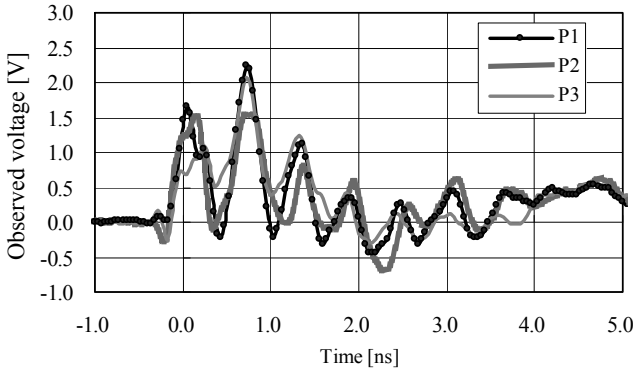
Fig. 6 Configurations of a PCB to be tested.

lieu of EUT as shown in Figure 1.

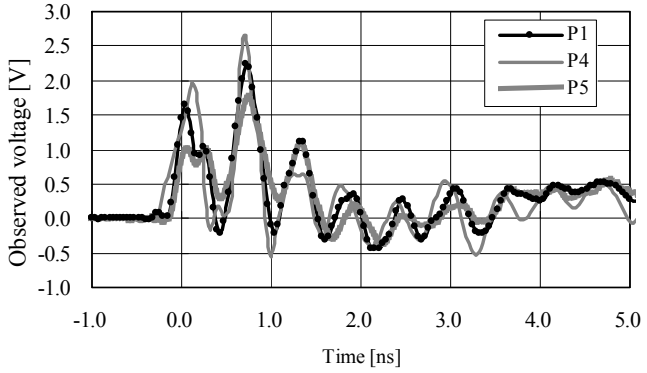
According to IEC 61000-4-2 2001-04, on the other hand, the VCP shall be placed parallel to EUT at a distance of 0.1m from the EUT, while discharges shall be applied to the centre of one vertical edge of the VCP without specifying any angles of inclination and rotation of an ESD gun to the VCP, and a reference position of the EUT to the VCP as well.

For this reason, we measured voltages induced on the trace with respect to various angles of inclination and rotation of an ESD-gun to the VCP through a 50Ω coaxial cable with a digital oscilloscope (bandwidth: 4GHz and sampling frequency: 25GHz) .

Figures 4(a) and 4(b) show the front view and side view of inclined arrangements (P1, P2, P3, P4 and P5) of an ESD-gun to a VCP, respectively. Also shown in Figures 5 and 6 are the rotated arrangements (P1, P6, P7 and P8) and PCB configurations (P1, P9 and P10), respectively.



(a)



(b)

Fig. 7 Measured waveforms of induced voltages due to indirect discharges to the VCP for different angles of inclination of an ESD-gun.

III. Results and Discussion

Figure 7 shows the measured waveforms of voltages induced on the trace due to indirect discharges to the VCP for different angles of inclination (P1, P2, P3, P4 and P5) of an ESD-gun with a charge voltage of 10 kV. We found that the indirect discharge at P4 produces the highest amplitude of a voltage peak of 2.67 V, while the discharge at P2 gives the smallest amplitude of a voltage peak of 1.55V.

Figure 8 shows the measured waveforms of voltages induced on the trace due to indirect discharges with different angles of rotation (P1, P6, P7 and P8) of an ESD-gun to the VCP. It was found that the discharges of P1 and P8 give the highest and smallest voltage peaks of 2.30 V and 1.36 V, respectively.

Figure 9 shows the measured waveforms of voltages induced on the trace due to indirect discharges at three different positions of P1, P9 and P10 of the PCB to the VCP, which demonstrates that the discharges of P9 and P10 give the highest and smallest voltage peaks of 2.63 V and 1.93 V, respectively.

The above results show that the peak of induced voltages due to indirect discharges of an ESD-gun greatly varies by a

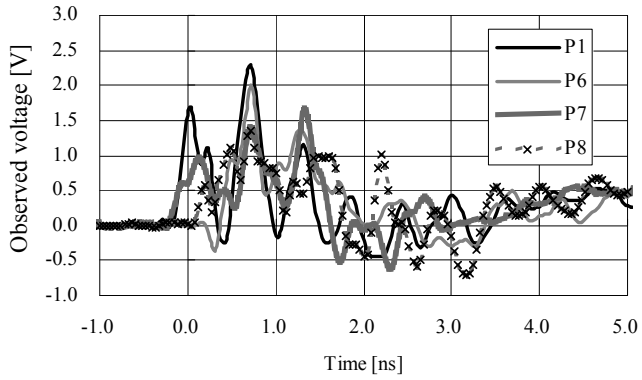


Fig. 8 Measured waveforms of induced voltages due to indirect discharges to the VCP for different angles of rotation of an ESD-gun.

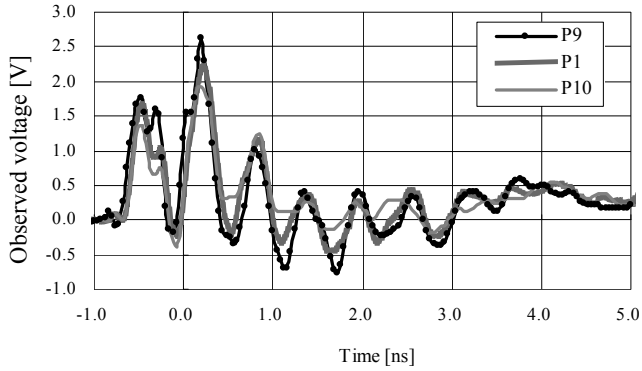


Fig. 9 Measured waveforms of induced voltages due to indirect discharges to the VCP for different positions of the PCB.

factor of 1.96 with respect to the angles of inclination and rotation of the ESD-gun and the PCB positions as well. This finding suggests that immunity test results due to indirect discharges may be affected by the angle of inclination and rotation of an ESD-gun and EUT position to a VCP.

IV. CONCLUSION

With a simple PCB with a trace in lieu of EUT, we measured the voltages induced on the trace, when making indirect discharges for different angles of inclination and rotation of an ESD gun, and different positions of the PCB to a VCP. As a result, we found that each location of an ESD-gun and the PCB causes a different induced voltage, which may produce different test results even for the same EUT.

In enterprises that have done quality control based on the standard for ESD immunity tests, therefore, it is necessary to consider beforehand not only test conditions being specified in the IEC standard but also configurations of ESD-guns and EUT to a VCP in order to improve the reproducibility of ESD immunity test results.

Future work includes measurements of electromagnetic fields radiated from indirect discharges to the VCP for the same experimental set-up. Furthermore, a new test method to reduce the uncertainty of ESD immunity test results for indirect discharges should be investigated.

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