A Measurement on Electromagnetic Noises from ESD Generator just Before and After ESD Testing

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Abstract—

It is widely recognized that electrostatic discharge (ESD) generators cause electromagnetic (EM) noises even before and after ESD immunity testing specified in the International Electrotechnical Commission (IEC) standard. This may provide inconsistent test results, whereas its mechanism is not well understood. To explain the mechanism qualitatively, the authors investigated a generation modeling of EM noises from an ESD generator in conjunction with the functional sequences of built-in relay switches and a DC high voltage power supply. To validate this model, using a magnetic field probe, the authors measure the induced noise voltages from an ESD generator just before and after ESD testing for contact and air discharges to an IEC recommended current injection target. As a result, it is confirmed that the EM noises are generated when the relay switches operate before and after ESD tests. In addition, the authors find that the noises amplitude for low voltages (Types C,D and F) are relatively smaller than the ones (Types A&B,E) induced at the testing in both the contact and air discharge modes, while these peak noises increase with charging voltages and especially the noise peaks induced after the testing reach almost the same level as the case for 4 kV ESD test in the air discharge mode. A new sequence of the built-in relay switch is also proposed for reducing the noise voltages generated after ESD testing.

Keywords—ESD generator; contact and air discharge methods; induced electmagnetic noises; measurement

I. INTRODUCTION

The immunity test of electronic devices and systems against electrostatic discharge (ESD) events from a charged human body has been specified in the International Electrotechnical Commission (IEC) as IEC 61000-4-2 [1], which prescribes the specification of ESD generators, the test environment, the testing method and the evaluation of test results. According to the standard, the ESD generator is used to inject the discharge currents into equipment under test (EUT) by the contact discharge method specified for test repeatability, but it dose not always realize the ESD from the charged human body. The current waveform is also specified in the IEC standard, but it is not given for air discharges due to their poor reproducibility, although the air discharge normally accompanied by sparks is known to simulate a real ESD phenomenon. On the other hand, it has been reported that the EUT often suffers function errors just before or after the ESD test [2],[3]. For an example, the function error even after ESD testing sometimes occurs in spite of that the EUT has succeeded in passing the ESD testing. The situation has occasionally never been observed in realistic environments such as ESD events from charged humans, charged metal chairs, furniture and so on. This implies that the present ESD immunity standard sometimes provides unreliable and inconsistent test results, whereas its mechanism has not well been understood.

From the above viewpoint, the authors investigate a generation model of electromagnetic (EM) noises from an ESD generator just before and after ESD testing with respect to the functional sequences of built-in relay switches and a DC high voltage power supply. To validate this model, using a magnetic field probe placed near the ESD generator, the authors measure the induced noise voltages during the testing in contact and air discharge modes. The authors also show a revised sequence of the built-in relay switches for reducing the EM noise generated after ESD testing.

II. ESD GENERATOR AND GENERATED EM NOISES

A simplified structure and its equivalent circuit in the low frequency range of an ESD generator are shown in Fig.1.

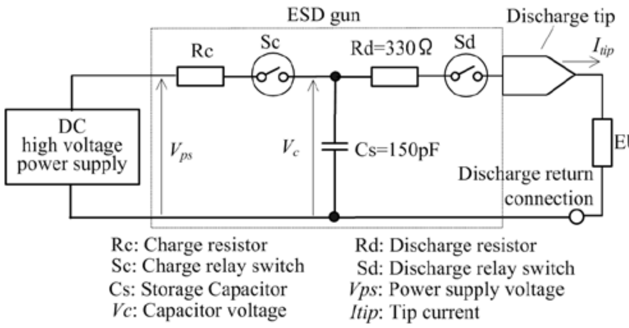

Fig. 1 Simplified structure of ESD generator and equivalent circuit in the low frequency range.

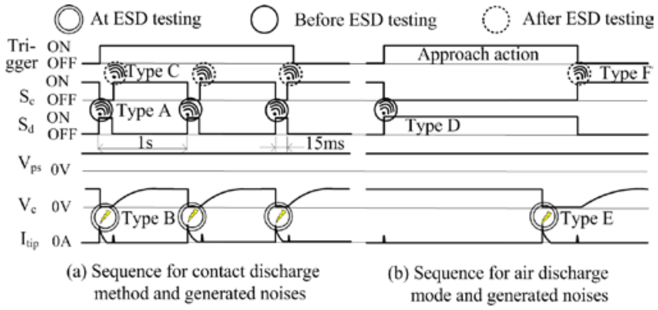

Fig. 2 Functional sequences for ESD testing and EM noises generated during ESD testing.

The ESD generator mainly consists of a capacitor C_s of 150 pF and a resistor R_d of 330 , which correspond to a human-body capacitance and a human body resistance with metal, respectively. In addition, two relay switches S_c and S_d which operate in synchronization filled in high-pressure inactive gas (SF6) are built into the ESD generator, and these do not turn on simultaneously.

A functional sequence of contact discharge and air discharge methods is shown in Fig.2 (a) and Fig.2 (b) respectively. The capacitor C_s is charged through resistor R_c by closing the charge relay switch S_c from a DC high voltage power supply. At the start of a contact discharge test, the relay switch S_c is turned OFF, and relay switch S_d is turned ON. After 15 ms, two switches return to the original positions. This sequence will be repeated every 1 second.

For an air discharge method, the high voltage is applied to a discharge tip in Fig.1, the relay switch S_c is turned OFF and the relay switch S_d is turned ON. By approaching the ESD gun to EUT, discharges occur. Then an operator turns off switch S_d and moves away from the EUT. The ESD gun changes to charging mode by relay switchs S_d OFF and S_c ON.

Each test method generates the EM noises when the relay switch S_c is being changed to the ON position and relay switch S_d is being changed to ON for both air and contact discharge to EUT [4],[5].

For a contact discharge method, EM noises named here Type A and Type B in Fig.2 (a) are generated at the discharge (current injection) to EUT for testing. The EM noises of Type A and Type B are almost observed simultaneously. Recharging the capacitor C_s, the EM noises named Type C in Fig.2 (a) are generated when each switch goes back to the original position.

For an air discharge method, Type D of EM noises in Fig.2 (b) occur when a discharge tip voltage potential goes up to the specific voltage. Type E noises generate by discharge to EUT. Type F noises generate after discharges due to the energy charging capacitor C_s.

III. Experimental Varidation

A. Measurement Method

For ESD discharge measurements, the authors used a measurement setup of ESD discharges consisting of a 2 Ω resistor in the current injection target placed on a Faraday cage

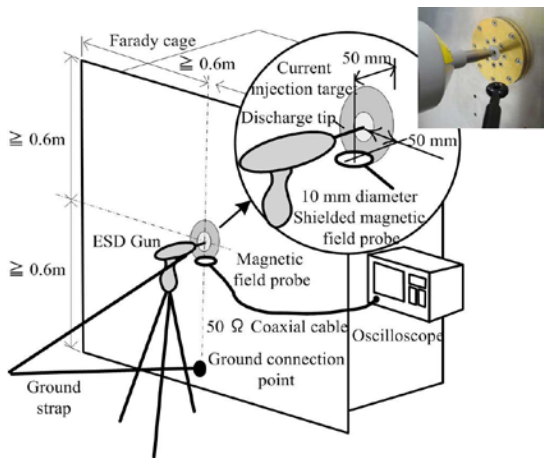

Fig. 3 Measurement setup for magnetic field noises caused by ESD generator

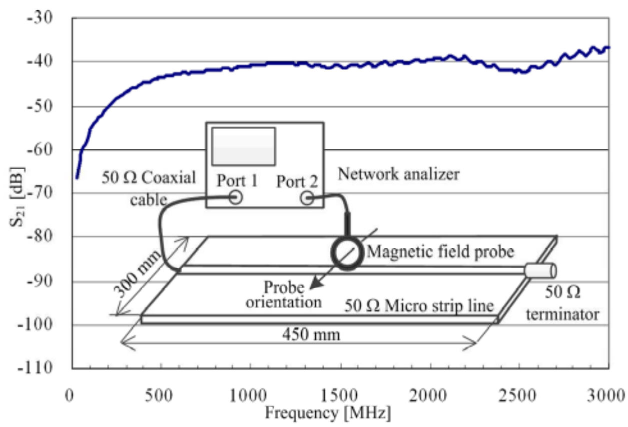

Fig. 4 Frequency characteristics for output response of magnetic field probe used for measurement.

according to IEC 61000-4-2, which is shown in Fig. 3. This Faraday cage and current injection target act as EUT. The radiated EM noises from an ESD gun are measured by using a 10 mm diameter shielded magnetic loop coil which is located 50 mm away from the ESD gun and Faraday cage surface. The probe face is placed in parallel to the direction of the current flowing on the discharge tip so as to obtain the maximum discharge current. S_{21} characteristics of a magnetic probe and its measurement method using 50 Ω micro strip line are shown in Fig.4. The magnetic probe has a flat frequency response from 1 GHz to 2.5 GHz.

For a contact discharge method, a discharge tip of the ESD generator is contacted to the current injection target. For air discharge method, a top of discharge tip is 10 mm away from the current injection target electrode, and the ESD gun is moved by hand with about 100 mm/s approach speed to the current injection target.

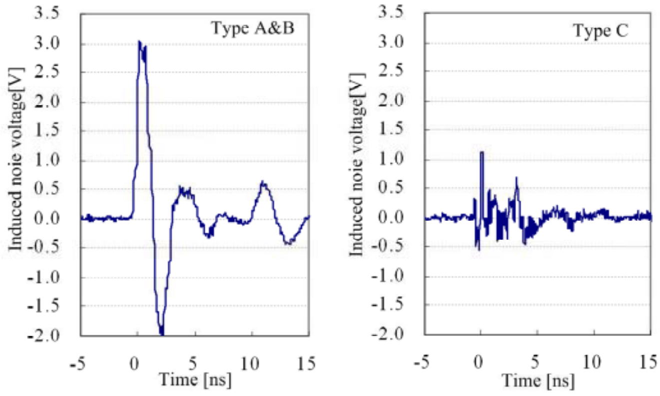

Fig. 5 Measured waveforms of induced noise voltages generated

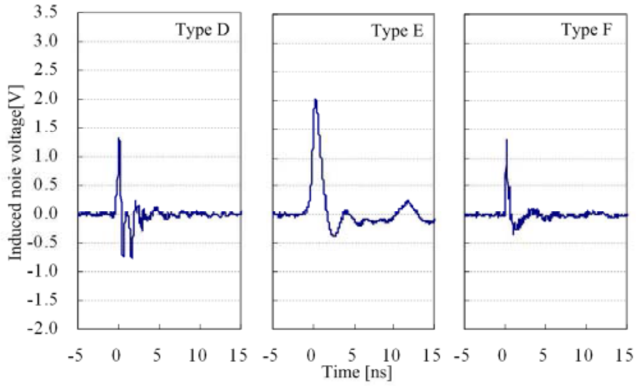

Fig. 6 Measured waveforms of induced noise voltages generated during 4-kV ESD testing in air discharge mode.

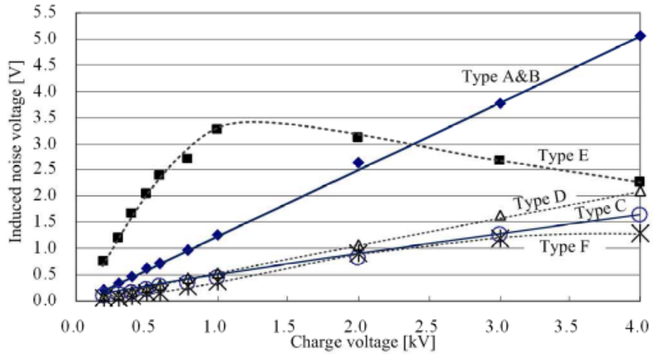

Fig. 7 Dependence on charge voltages of induced noise voltages during ESD testing in air and contact discharge modes.

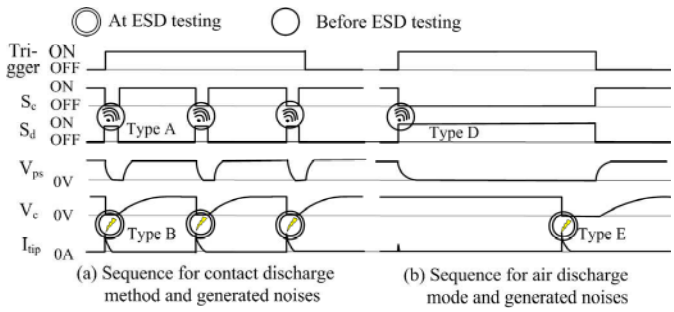

Fig. 8 New sequences for reducing EM noises generated after ESD testing in contact and air discharge modes.

B. *Results and Discussion*

Figs. 5 and 6 show measured waveforms of EM noises generated during 4 kV ESD tests in contact and air discharge modes, respectively. Each relay switch contact which is filled with inactive gas may generate EM noises at several hundreds of voltages in a narrow gap formed by relay switches while moving from OFF position to ON position.

The air discharge method makes insulation breakdown and impose the radiated EM noises to the EUT in the air. The insulation breakdown is affected by the humidity and the tip approach speed to the EUT. Otherwise, the measured waveform of the contact discharge method should be stable, however, in the case of a high voltage ESD test, some insulation breakdown brings about around the ON going relay switch. Contact discharge causes the EM noises of discharge rush currents by electrical charge injection to EUT when the relay switch S_d is switched to the ON position.

The amplitudes of EM noise waveforms were obtained by 20 times from 0.2 kV to 4 kV ESD tests. Peak to peak amplitudes voltage are shown in Fig.7. These amplitudes of EM noises have the following characteristics: The EM noise waveforms of Type A & Type B and Type C were observed before at and after the testing respectively in the contact discharge 4 kV ESD testing. It is found that the noise peak of Type C is one-third smaller than the results of Types A and B. It should be noted that Types A and B have a 400 MHz dumped oscillating waveform, while Type C has very high frequency oscillations. This means that the generation mechanism of Type C is entirely different from the case for Types A and B.

Type D, Type E and Type F shown in Fig.6 are observed during 4 kV ESD testing in the air discharge mode. The noises of Types D and F are generated before and after ESD testing, respectively, while the noise of Type E is generated at the testing. From Fig. 6, the noise peaks of Types E and F are found to be almost the same, while they are 0.65 times smaller than the one of Type E.

To examine the relationship between the above-mentioned noise peaks and charge voltages, the authors measure the dependence on charge voltages of the noise peaks during ESD testing in the contact and air discharge modes. The noise peaks except for Type E in Fig.7 increase in proportion to charge voltages, though the noise peak of Type E decreases with charge voltages because the spark occurs for larger gap over 1 kV charge voltage [6]. It is also found that the noise peaks of Types C and F after ESD testing are the smallest, while they increase with charge voltages and reach the same levels as the results of Type E in 4 kV air discharge mode. This suggests that the EM noises after ESD testing in the air discharge mode may cause malfunction of EUT.

An actual radiated EM noise of ESD phenomena is generated by only insulation breakdown in the air. The radiated EM noises that occur in discharges by the relay switch contact should be suppressed. However, all of EM noises could not always be controlled.

As a radiated EM noise by closing the relay switch S_c for charge to capacitor C_s can be controlled by the improving the contact and air discharge functional sequences are shown in Figs.8 (a) and 8(b), respectively. This sequence point is that a DC high voltage power supply output is not applied when the relay switch Sc changes to the ON, therefore the voltage difference between two relay switches is 0 V.

IV. CONCLUSION

The EM noises from an ESD generator just before and after ESD immunity testing were investigated in conjunction with functional sequences of built-in relay switches and a DC high voltage power supply in contact and air discharge methods. A generation model was given, and validated by measuring the EM noises from an ESD generator before and after ESD testing with a magnetic field probe. As a result, the authors found that these noise voltages are relatively smaller than those at the testing in both the contact and air discharge modes, however, these noise peaks increase in proportion to charging voltages and reach the same level as the case for 4 kV ESD test in the air discharge methods. To reduce the EM noises after the testing, a sequence of the built-in relay switch was given.

The next step is to propose a realistic and reliable ESD test method based on the results obtained in this study.

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