Research of Electrostatic Discharge (ESD) Pulse Injection System

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Abstract Satellites on orbit have been observed to exhibit anomalous behavior attributable to electrostatic discharge resulting from surface charging or internal charging. An electrostatic discharge (ESD) pulse injection system is described in this paper, which is a special equipment used to verify the capability of electronic unit withstanding to ESD and to provide several categories of test requirements. The system consists of ESD simulator, ESD pulse injection coupling board, ESD test platform, scaling model of satellite structure, electrostatic interference shielding room, and test diagnostic instruments. The electronic unit under test is isolated from measurement. This equipment has been applied to ESD evaluating test for several topical electronic circuits; the test methods are radiated field test single-point injection test and capacitor coupling injection test. Two ESD sources used in the test are MIL-STD-1541 arc source and spherical-flat plate capacitor discharg source.

Keywords: Spacecraft charging, Electrostatic discharge, Electromagnetic interference coupling, Injecting test

1. Introduction

The analysis for failures of spacecraft on orbit indicate that the anomalies induced by electrostatic discharges of spacecraft are approximately up to 1/3 of all anomalies caused by space environment. Most of these anomalies are due to effects of the ESD electromagnetic interference coupled on electronic circuits or sensitive electronic devices on spacecraft. The electromagnetic interference coupling is mainly through conducted coupling and radiated coupling. At present, most spacecraft should be tested severely for their electromagnetic compatibility and alternatively for their discharging immunity. But types of these tests usually focused on the system level test and can't determine all electronic units which sensitive to ESD on the satellite. Additionally these tests usually cost too much.

A special electrostatic discharge pulse injection system is described in this paper. As a evaluating test for ground test, it provides varieties of discharge pulses and coupling channels which currents inject, and can easily verify withstanding to electrostatic discharge of electronic devices or electronic circuits under various pulse injection modules. It also gives the response characteristics to the interference signals. By using the set of the system, we have attained the response characteristics to electrostatic discharge interference signals of a typical digital circuit and an analog circuit under capacitor injection testing respectively.

2. ESD pulse injection system

ESD pulse injection system consists of ESD simulator, ESD pulse injection coupling board, ESD test platform, the scaling model of satellite shell, electric magnetic interference shielding room and test diagnostic instruments. The outputs of the electronic units in this test are coupled to the measurement instruments in the shielding room by optical-electric isolator. The schematic block diagram shown in Figure 1:

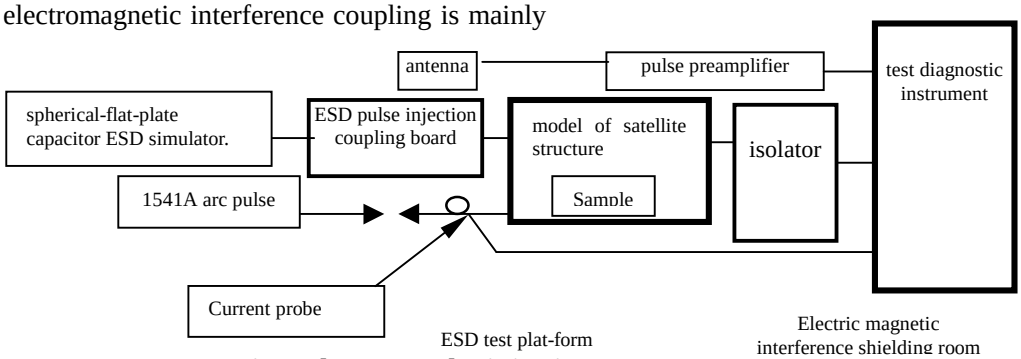

Fig1, The ESD pulse injection system structural drawing

The compositions of this system will be described in the following:

(1) ESD simulators

The electrostatic discharge simulator described by military standard MIL-STD-1541 is a important arc source being used to test for ESD immunity. The ESD pulse injection system described in this paper provides not only the arc source but also a spherical-flat-plate capacitor ESD source.

The basic principal of the spherical-flat-plate capacitor ESD source is using a adjustable spherical gap discharges to control discharge voltage and discharge frequency, while ESD pulse parameters is adjusted by electrode of flat-plate dielectric capacitor. It can be used to simulate a widespread discharge from thermal control surface or dielectric surface on spacecraft. Its main technical specifications are show as follow:

Capacitance: 10nF~ 60nF
Breakdown voltage: 4~10kv
Energy: 20~180mJ
Peak current: 20~80A
Discharge current rise time: <50ns
Discharge current pulse width: 100~1000ns

A comparison between serial typical types of ESD pulse waves forms is shown in figure 2.

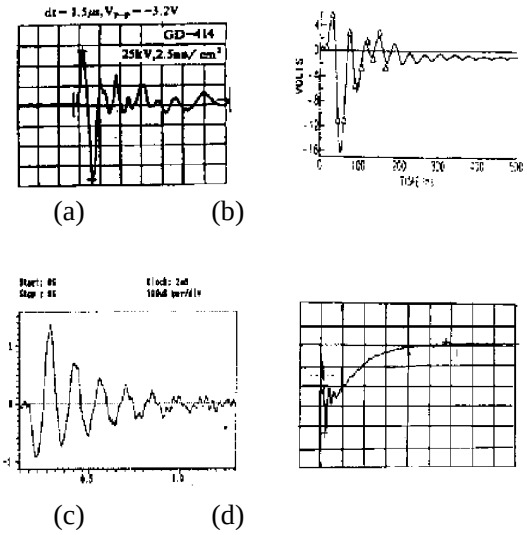

Fig 2, Four types of ESD pulse waveforms

a, the typical material surface discharge pulse form laboratory

b, a typical ESD pulse observed by SCATHA Satellite

c, a typical discharge pulse form 1514A arc source (measured by antenna)

d, a typical discharge pulse form spherical-plat capacitor discharge source

The two ESD simulators can nearly meet the needs of performing ESD radiated coupling test and conducted coupling test.

(2) ESD signals injection coupling board

ESD signals injection coupling board can inject ESD signals to any wires, such as signals wires, power wires or ground wires. There are two parallel conducted channels with adjustable distance on the board. One is used to fix wires seriated with ESD pulse outputs of the spherical-flat-plate capacitor discharge source, the other is used to fix wires with coupled interference signals.

(3) ESD test platform

The platform dimension is 2m length, 1.2m width and 1m height. Its structure are all dielectric, with 1mm thick copper layer on its surface for providing ground-wire network with low impedance for tests. It also provides power supply equipped with punched capacitor or power filter.

(4) The scaling model of satellite shell

The model is a cylinder with 600mm diameter. It's made up of aluminum honeycomb materials with holes on its top layer shield by double layer copper grid. All the electronic units in tests are placed into the model. The structure ground is linked with or isolated form the platform ground according to the test requirements.

(5) Measurement system

The system involves varieties of electromagnetic field sensor, voltage, current probes and other measurement instruments. The measurement units mainly consist of digital memory oscilloscopes preamplifier, logical analyzer and computer which equipped with a special discharge signals analytical software. All the measurement unite and support equipment of testing unit are in an adjacent electromagnetic shielding room.. Date are transmitted into shielding room through optical-electric isolator.

3. ESD pulse injection method

The electrostatic discharge pulse is a transient signal with wide frequency range. The principle of coupling with the electronic circuits is complicated. To simulate the interaction proceeding between electrostatic discharge pulses from spacecraft and electronic devices on board completely is fairly difficulty in the laboratory. The test methods are being developed.

Three ESD pulse injection methods are used in this system. Two of them are radiat field coupling test method and single-point injection test method recommended in NASA-TP-2361 documents, and can be performed by using 1541A arc source. Another injection method is capacitance coupling injection test method. Using spherical-plat capacitor discharge source through ESD pulse injection coupling board can perform it. These three types of pulses injection method mentioned above can

basically simulate the interference situations from faint electromagnetic interference to heavy conducted interference through cables which electronic units on spacecraft may be subjected In the testing, the electronic unit and cabling inside the shielding room should be flight condition.

4. ESD experiments for two typical electronic circuits

ESD experiments have been performed for a digital circuit (square signal generator) and an analog circuit (DC amplifier) respectively by use of ESD pulse injection system.

(1) Test circuits

Selected test circuits as follows:

a, square sign generator circuit (figure 3)

b, DC amplifier circuit (figure 4)

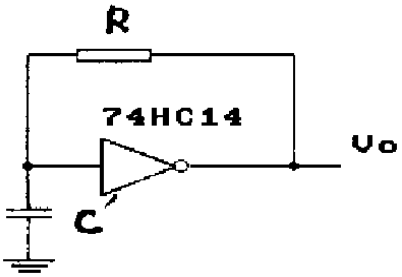

Figure 3. Schematic diagram of a Square signal generator circuit

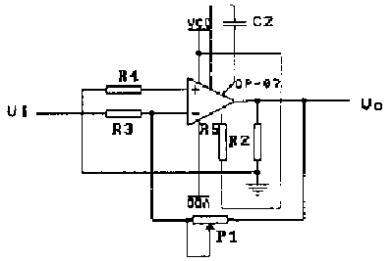

Figure 4. Schematic diagram of a DC amplifier circuit

(2) Phenomena in ESD experiments

Two test circuits were placed into the scaling model of satellite respectively.. There were no anomaly occurs during radiate field test. The capacitor coupling injection experiment was done subsequently. The input wire of 74HC14 square sign generator and the power wire were used as inject points of interference signals, then we observed some phenomena as follow. When ESD pulse were injected from input wire, the ESD pulse coupling produced by 4kV discharge voltage was strong enough to cause upsets in circuits, when ESD signals were injected from power wire, the ESD pulse produced by discharge voltage under 5kv only caused interference to its outputs rather than upsets(figure 6a).But when the discharge voltage was above 5kV, upsets were occurred (figure 6b). For the DC amplifier made up of 0P07, circuit outputs included interference signals and had a 0.1ms delay time when ESD pulse produced by discharge voltage over 4kv is injected from input line (figure 7).

The experiments illustrated that ESD conducted interference can easily cause upsets of digital circuits and will interfere the operation of analog circuits, which should be noticed in electrostatic protecting and ground test.

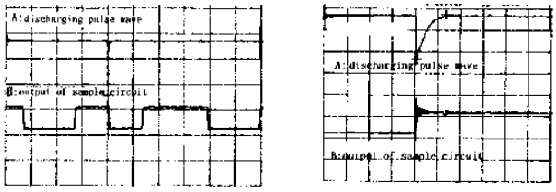

Figure 5. Circuit upsets induced by ESD pulse injected from input wire of 74HC14

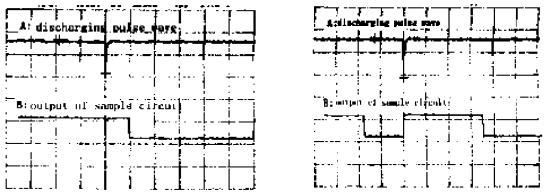

Figure 6. Circuit upsets induced by ESD pulse injected from power wire of 74HC14

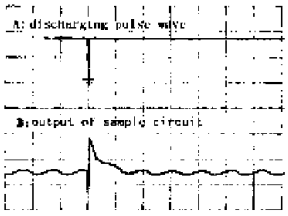

Figure 7. Circuit interference induced by ESD pulse injected from input line of OP07

5. Conclusion

ESD pulse injection system is an efficient tool to assess the capability of electronic circuits withstanding against ESD. Parameters of ESD pulses provided by two types of ESD sources basically fit with most actual parameters of ESD on spacecraft. Radiate field test, single-point injection test and capacitance coupling injection test can completely evaluate the capabilities of electronic devices and electronic circuits withstanding to ESD, and it is also a useful tool to test the validity of

electronic devices against ESD interference.

6. Reference

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