Laboratory Simulation of Spacecraft Surface Charging and Discharging Caused Structural Potential Transients and its Interference Test Method on DC-DC Converter .

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ABSTRACT - This paper will introduce the first laboratory simulation of spacecraft surface charging and discharging effect on its structural potential, including test principle, experiments and result curves etc. Surface discharging on spacecraft will cause its structural potential transient . Since structural potential is grounding potential of spacecraft, the reference function of grounding potential will lose during the discharging process. Such structural potential transients are pulse group with high amplitude and high frequency which will easily interference the electronics especially for digital electronics. Based on this principle, an interference test method is developed. A test method of surface discharging caused structural potential transients on output of DC-DC converter are introduced also.
Keywords: Spacecraft Charging, Electrostatic Discharging, Structure Transients, Electromagnetic Interference, Space Environment, Test

1 INTRODUCTION

Geosynchronous satellites have experienced anomalous electronic switching in the midnight to dawn region of their orbits which is the time for . geomagnetic substorm environment. It is considered as a main environmental factor for anomalies of geosychronous satellites.

Three forms of discharging caused by surface charging are blow-off discharging, punch-through discharging and flash-over discharging. Blow-off discharging is considered as the most dangerous discharging mode because it forms a large structure current which will be coupled to digital electronics of satellite. We have found during our laboratory study that blow-off discharging will cause severe structure potential transients. The structure potential is the ground potential for a satellite, which is the reference potential for satellite's electronics. Transients in reference potential have disturbance function to electronics for it is impossible for every parts of the electronics to change the potential as fast as ground transients. The satellite ground transient is easily formed since the capacity of satellite structure is not so large that small charges will cause high potential. Earh ground is a very ideal ground since it has so large capacity that any amount charge will not cause its obvious increase of potential. That is why earth grounding is a very useful method to overcome interference in electronics.

Satellite surface insulating materials accumulate electrons when they encounter substorm environment. Accumulated electrons induce opposite charges on its back metal coating, which result in negative potential of satellite structure. During discharging, accumulated electrons vanished instantly and also the induced charges on back metal side will return to satellite structure instantly . The potential of structure at the same time will increase instantly. If the structure normal function of electronics. But the transient increase of ground potential is harmful to the electronics since it causes transient interference in electronics due to different capacities and different charging time in circuit.

This paper introduces firstly laboratory simulation of spacecraft surface charging and discharging caused by structural potential transients. Secondly, the structure potential transient's interference to DC-DC Converter is introduced.

2 LABORATORY SIMULATION OF STRUCTURE TRANSIENTS

Insulating films with metal coating on back side are used as a charging simulation target which is located inside a vacuum chamber in a opposite direction to a electron gun. Back metal coatings of the target are connected to a floating metal plate which acts as satellite structure outside the vacuum chamber. The whole experimental system is illustrated in Fig.1

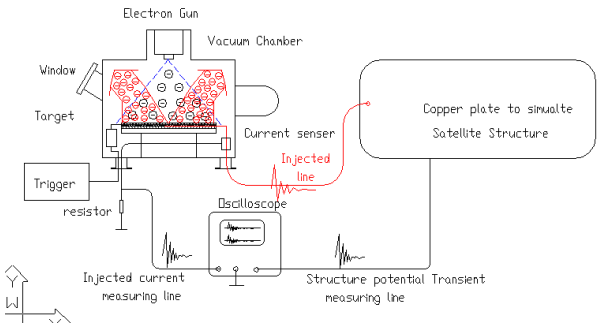

Fig 1 Structure Transient Simulation Experimental

This system consists of a substorm simulation facility, a copper plate simulating the structure of satellite, TDS350 two channel digital oscilloscope, discharging trigger, transient current induce ring etc..

The substorm simulation facility has following specifications:

1) Electron energy: 25keV;
2) Electron flux:0.1~100nA/cm^2;
3) Irradiation area: _300mm;
4) Vacuum Chamber:_500mm_700mm;
5) Vacuum: beter than 1_10^{-3}Pa.

Since natural triggering of discharging during electron irradiation has many random factors which are very difficult for application to evaluation test. A contacting trigger is used for automatic and manual triggering. Automatic triggering is once per second and the total time can be regulated from 5 to 180 seconds.

During discharging, a transient current is coming from simulation target inside the vacuum chamber to the large copper plate outside the vacuum chamber. This current is measured by mutual induction based on the principle of transformer. The transient current line acts as the first turn and the second turns are on magnet ring which is grounded through a 50_.The sensitivity for this device is 6.12V/1A.

The experimental parameters are as follows:

1) Electron energy:500V,1000V,5000V,10kV, 20kV,25kV.
2) Electron flux:0.1 to 1 nA/cm^2.
3) Vacuum:10^{-3}Pa;
4) Measuring floating plate potential;
5) Measuring injecting transient current.

The experiments of the floating plate potential variance with electron energy and flux have been performed. As we know from these experiments, surface charging will cause the potential of structure to change from zero to a negative volt. The more the current of electrons irradiated, the more the negative potential of the structure is. The higher the energy of electrons, the more the negative potential of the structure.

During discharging, accumulated electrons on the surface of target disappear instantly and induced charges on its back metal coating that injects into the copper plate. Potential of satellite structure will increase instantly. Injected current into the copper plate and potential of the copper plate are measured by TDS350 two channel digital oscilloscope as Fig.2.

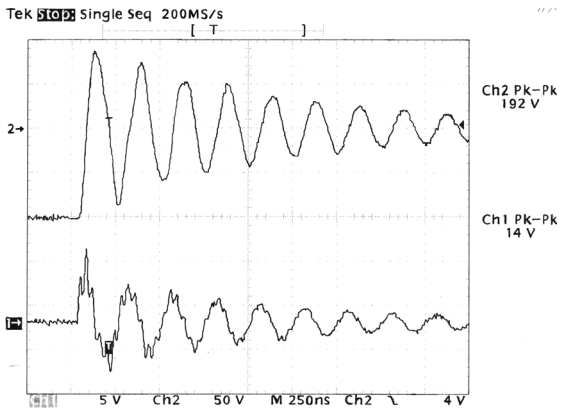

Fig.2 Structure potential transient caused by injected discharging current.

CH1 is the injected transient current curve.
CH2 is the potential transient of copper plate.
we could find following points from that curves:

1) Injected current transient curves are damped oscillating pulses. The current amplitude is 2.28A and the width of pulses are about 200ns.
2) The potential of the floating plate increases from -100V to 92V. The potential curves are damped oscillating pulses .The amplitude is about 23V~192V.
3) Injected transient current is a little time ahead of the potential transient. It shows that the potential transients are directly caused by injected current.

3.SIMULATION EXPERIMENT FOR SATELLITE STRUCTURE POTENTIAL TRANSIENT INTERFERNCE

The experimental system for simulating structure potential transient interference in DC-DC converter is almost the same with the former system. DC-DC converter is FDI 2680 S12. The first power is storage battery which supply 37V direct voltage to DC-DC converter that is the second power. The 12V output has a resistor. By using a current mutual inductor, the voltage changes on the resistor are measured. Experimental system is shown as in fig.3.

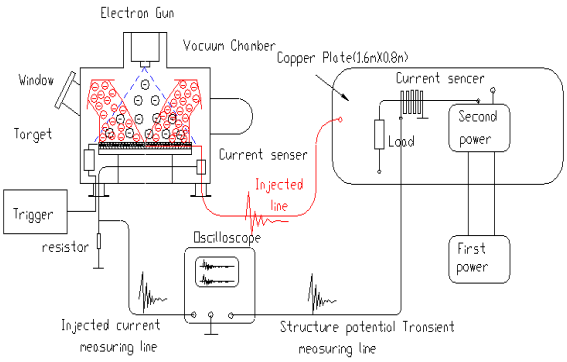

Fig3 Surface discharging caused structure transient Interference simulation system

The experiment parameters are:

1) electron energy: 5keV
2) electron flux:0.68~1.2 nA/cm^2
3) Triggering mode: automatic
4) Vacuum:1.5_10^{3}Pa

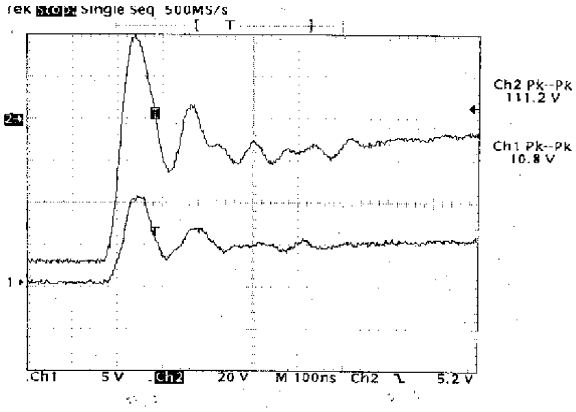

Fig.4 The effect of structure potential transient on output of DC-DC converter.

CH2is structure potential transient curve and CH1 is DC-DC converter output current curve. If there is no interference, the output is direct current. As we know that during electron irradiation of that flux, the floating potential will increase negtively.from 0V to -70V. During discharging, floating potential is increased to 40V instantly and then damped in oscillation. 10V~19V add on 12V output of DC-DC converter can be seen from the CH1 curves. The width of the first pulse is about 150 ns. Pulses are also damped.

4 CONCLUSION

Vacuum-electron ESD simulator can simulate blow off discharging without unnecessary other environment stress which has risk of damage of electronics. Real satellite materials are used for this charging and discharging target which acts as ESD source of this test. Structure of satellite is simulated by floating copper plate with a large capacity outside the vacuum chamber. Instrument of satellite for testing is mounted on the copper plate and grounded to the copper plate. This way of simulation retain the advantage of electron irradiation test and avoid the disadvantage of using air arc discharging source. During charging and discharging of target inside the vacuum chamber, the outside copper plate' potential is changed slowly for charging and instantly for discharging. The instrument of satellite is mounted on the copper plate for ESD injecting test. Instrument test outside the vacuum chamber is very convenient and flexible for finding problems and performing inspection.

Geosynchronous satellites in near midnight may experienced charging and upset. Geomagnetic substorm environment is considered as a main factor for anomalies for geosychronous satellites .

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