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Modeling of Discharge-Triggered Electric Field Redistribution on the Interior Components of a Satellite

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Abstract

This work examines an electrostatic charging/discharging cycle of a populated circuit board inside an equipment housing of a satellite at GEO. Component potentials and electric field strengths are examined before and after a common ground discharge event. Field reversal after the discharge suggests that favourable conditions exist for charge dissipation from dielectrics.

I. Introduction

Many of the in-orbit anomalies and spurious events observed in satellites have been attributed to the accumulation of high-energy electrons in the metal and dielectric components of the satellite. Much of the scientific work carried out over the last couple of decades was aimed at understanding the factors involved in spurious discharging phenomena. In this work we focus our attention on some of the stress factors that can occur on the internal components of a satellite. Specifically, we investigate the potential and electric field redistribution that occurs inside a typical equipment housing in a satellite during and immediately after a surface/common ground discharge event.

II. Modeling Approach

The satellite system modeled is a 1mm thick 20cm x 20cm x 10cm Al equipment housing containing a 13cm x 11cm printed circuit board (PCB) that is populated with active and passive components. The housing and all the metal components on the PCB are connected to a common electrical ground (i.e. no floating metal components). In more practical terms, this means that if there is common ground discharge, the charge will be drained from the metal objects virtually at the same time. We also assume that the charge drainage from metal components is instantaneous in comparison to charge drainage from any of the dielectric components of the satellite. This is a very reasonable assumption given the fact that the conductivity of a dielectric material is on average several orders of magnitude smaller than the conductivity of a metal even after a significant deposition of electron dose [1].

To enable potential (or electric field) distribution calculations, the space occupied within the housing (including PCB components and housing) was subdivided into 2.4×10^6 voxels (volume pixels). The 3D ITS Monte Carlo code "ACCEPT" was used to calculate the charge deposition into the individual voxels. With this information, the 3D POISSON equation solver was used to determine the potential and electric field throughout the volume of the housing. The electron source used in the model represents a substorm condition at GEO. For this we have used NOAA electron flux data of GOES 8 satellite for E>0.6 MeV modulated by the AE8 spectrum envelope (flux on satellite of 8.85×10^5 electrons cm^{-2} s^{-1} sr^{-1}). We have selected a twelve-hour charging period for our modeling based on a time period that a satellite at GEO spends between the evening and morning sectors.

III. Results

Electric fields that have developed inside the equipment housing volume after a twelve-hour charging period at GEO is shown in Figure 1a. Figure 1a is a cross-sectional view with the cut made horizontally through the solid state devices, pins, vacuum, and the housing enclosure when viewed from above. The electric field strength is observed to be the highest along the edges of device dielectrics and device pins with strengths reaching 5×10^3 V cm^{-1}. The electric field is directed toward the metal components of the board so that any electrons embedded inside the dielectric would tend to drift away from the common ground and into the dielectric. Figure 2a shows an enlarged view of one section with more detailed information about the direction of the field.

If there is a common ground discharge, the electric field gets reconfigured, in some locations this can be quite dramatic. Figure 1b shows that an overall drop in the field intensity occurs throughout the volume of the equipment housing due to withdrawal of the charge from the metal components. There is also a field reversal, which can be observed by comparing Figures 2a and 2b. Charge bleeding into the common ground of the satellite would be accelerated during this period. Spontaneous discharge into the common ground may also occur at this time if the electric field is in the vicinity of the dielectric breakdown value of $\sim 10^5$ V cm^{-1}.

IV. Conclusions

Based on the previous charging of a model satellite [2], we have examined in detail a scenario that may occur in the interior of a satellite at GEO during charging/discharging events. The simulation revealed that dynamic electric field reconfigurations are possible when surface/common ground discharge occurs. Situations for spontaneous dielectric discharge occurrence have been suggested.

References

[1] Frank. M. Rose, "Electrical Insulation and Dielectrics in Space Environment", IEEE Transactions on Electrical Insulation, Vol. E1-22, No 5, October 1987, pp. 555-571.

[2] L. Varga and E. Horvath, "Spacecraft 3-Dimensional Charge Deposition Modeling", RADECS 97 Conference Proceedings, Cannes, France, 1998.