ABSTRACT

The external surfaces of a spacecraft exposed to the Earth's magnetospheric plasma can build up differential voltages which can result in an electrostatic discharge (ESD). The discharge results in transient structural current and radiated electromagnetic energy which can degrade the operation of the electronic units. The thesis deals with the development of an equivalent circuit model of a spacecraft for surface charging studies.

The ambient plasma is modeled in terms of Maxwellian distribution function , which gives a measure of the number of particles in an infinitesimal volume of space with a given velocity. The particle (electron / ion) density and its temperature are adequate to represent the plasma mathematically. These parameters are useful to determine the charging current sources of the plasma environment. The plasma environment modelling is discussed in Chapter 2. Also, parameters such as secondary electron yields, backscatter electron yield, photo-emission constant of different materials used on the surface of the spacecraft are required to determine the charging and discharging current densities. Analytical expressions have been derived for the current sources driving the equivalent circuit model in Chapter 3. Multiplication of these current densities by the surface area under consideration, yields the charging and discharging currents to the various nodes on the exposed surfaces. These currents constitute the source driving the equivalent electrical circuit model of the spacecraft.

Capacitance computation is an important step in the development of spacecraft equivalent circuit model to predict the surface charge build up. Chapter 4 presents a numerical procedure developed for computing the capacitance of conducting objects located in free space. The analysis assumes an equipotential surface having an unknown charge distribution. The charge distribution and the total charge are evaluated using the moment method by triangular patch modelling of the surface. The capacitance in free space of typical planar (Chapter 4) and non-planar (Chapter 5) conducting geometries have been numerically computed using the above technique. The results obtained for some of these geometries have been compared with the results available in the literature.

In Chapter 6, the steps involved in the development of equivalent circuit model of a spacecraft are discussed. In Chapter 7, the equivalent electrical circuit model of INSAT-2E spacecraft has been developed. The charging behaviour of the exposed surfaces and the structure has been studied and the potentials build up on the surfaces and the structure have been predicted. Further, the effect of partially conductive coating on the surface potential build up has been studied.

In Chapter 8, the ESD induced transient currents in a conducting plate located in free space have been modeled. The conducting plate is assumed to represent the structure which is charged to a high negative potential initially. Due to a blow off discharge transient currents flow and the surface potential becomes less negative. With the help of equivalent circuit of the conducting plate, the transient currents are computed using circuit simulation software.

Appendix-A gives an insight of the magnetospheric environment. Appendix -B describes secondary electron emission due to electron impact.

Keywords : Spacecraft charging, moment method, free space capacitance