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ANTI-SEU EFFECT METHODS OF SPACECRAFT AND ITS EVALUATION

Abstract

A spacecraft often operates in a rough natural radiation environment, which is composed of galactic cosmic rays, solar cosmic rays, and radiation belts of the Earth. The environment causes the Single Event Upset (SEU) effect of SRAM FPGA, which may cause spacecraft's electronic system failure. Space radiation environment is a big threat to spacecraft's normal operation in orbit. However, there has not a widely recognized method to evaluate the SEU probability of FPGA. Although we know much about the construction of FPGA, and the -LET curve can be achieved through ground radiation test, we have not seen the exact fitting values of Weibull distribution. Although there are some upset values of FPGA in some papers, they have not given calculation process in detail. The evaluation methods of system design are also scarcely seen in publications. In order to avoid in-orbit failure, the satellites that under development adopt many anti-SEU effect methods. The evaluation of the methods is a big challenge, which needs to quantify the SEU probability of system design.

In this paper, the mechanism of SEU effect was analyzed firstly. Existing methods of anti-SEU effect, including active and passive methods were concluded. Validity of every anti-SEU effect method was evaluated, especially the hot backup being expressed clearly. System's anti-SEU effect methods were evaluated on the basis of simulated calculation of electronic elements. The evaluation algorithms of active and passive protection methods were also given.

The TTC system of a spacecraft used 3 FPGAs with specifications of 6-million gates, 3-million gates and a 72-thousand gates, respectively. The SEU probability of the system is 2.16 Upsets/system day through simulation. And the discontinuous working probability of the system is no more than 2.05*10ˆ (-8) Upsets/system day. However, it can not cause permanent failure. The SEU probability of a single system was evaluated for the first time.

The evaluation method can be extended to wider applications and can be used to calculate SEU probability of a whole satellite or constellation.