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RAVI-2017: A SOLAR PROTON FLUENCE MONITOR FOR LEO NANOSATELLITE MISSIONS BASED ON COTS ELECTRONICS

Abstract

Protons of a wide energy distribution between 100 keV - 250 MeV originated from Coronal Mass Ejection (CME) from sun are trapped within the inner region (1000-8000 km) of the Van Allen belt surrounding our earth. Consequently, all spacecrafts, in particular nanosatellites operating in the low earth orbit (LEO) environment are exposed to those trapped protons of solar origin. High-energy protons trigger irreparable displacement damage (IDD) in unbiased Gallium Arsenide (GaAs) Light-Emitting Diode (LED). The physical process is known as NIEL (non-ionising-energy-loss). The IDD results in reduction of light emission of the LED. Based on this phenomenon the authors had developed a lightweight, ultra-low power consuming proton fluence monitor for space applications. Commercial off the shelf (COTS) components: combination of a GaAs-LED optically coupled to a Light-to-Frequency converter (LFC) chip was the core of Ravi-2017 proton fluence monitor. The device was calibrated by irradiating the LED with 180 MeV proton beam form a medical cyclotron at various dose levels. The resulting LED light output was detected with the LFC as a function of proton dose (fluence). The results were parameterised for the realistic NASA radiation belt models AP8-Max and AP8-Min and proton NIEL distribution function in GaAs LED. The highest detectable integrated proton fluence ($protons/cm^2$) were evaluated to be $1.84 * 10^9$ and $1.58 * 10^9$ for AP8-Max and AP8-Min models respectively. The footprint, mass and average power consumption of Ravi-2017 proton fluence monitor (1st prototype) were 0.16 cm^2, 0.28 g and $\sim$5 mW respectively. This makes the GaAs-LED based solar proton fluence monitor ideally suited for LEO nanosatellite missions of short lifetime, usually 6-18 months.