Incidents and Accidents: The Way of the Single Event Tester

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***Abstract*— When performing a single event effect (SEE) test during a test campaign, flexibility and out of the box thinking is often required for unexpected and unplanned events.**

***Index Terms*— Radiation effects, single event effect (SEE) test planning**

I. Introduction

In 2011 RADECS, a tutorial was presented [1] on SEE test planning. In that presentation, the topic of planning backup test options and the ability to modify tests at a test site were discussed. In this submission, examples are discussed based on real-life testing that modified the planned tests. The bottom line up front: the more complex the device under test (DUT) or the less we know about the technology's radiation tolerance, the more we need to think beyond the framework of SEE test standards.

II. SEE Test Standards

In the full submission, a brief overview of the SEE Test Standards will be discussed.

III. Terminology:

In this presentation, two terms will be used: incidents and accidents. They are defined for our purpose as:

-- *Incidents* are events that occur during testing while performing according to the test plan or standard, but are not expected. A simple example might be a destructive condition on a technology where none was expected.

-- *Accidents* are events that occur during testing when an unplanned test condition is used and an unexpected result is observed. Simple test condition examples might include changing voltage levels or operating frequency.

IV. Story 1: An Incident

Back in the early days of field programmable gate arrays (FPGAs), Actel Corporation (now part of Microsemi Corporation) made the first commercial non-volatile FPGA that had both combinatorial and sequential logic cells [2]. This appealed to many NASA spaceflight projects looking for cost and schedule effective solutions for designs. The Radiation Effects and Analysis Group (REAG) at NASA GSFC was internally tasked to perform SEE tests on this (at that time) novel device.

Testing was performed at Brookhaven National Laboratories' Single Event Upset Test Facility (SEUTF) [3]. All was going as planned, errors occurring in the logic cells as we expected, when "Pop", a destructive event occurred. The symptoms didn't appear like SEL, but much more like a rupture.

The decision was made to change ions to reduce the LET and continue testing, however, when we returned to the test area when the beam was ready, the customer was taking his parts out of the chamber. Claims were made that we were "testing the DUT all wrong"! A single fail on a single device doesn't necessarily provide sufficient fuel to publish the result though it was noted on internal test reports of the destructive event looking "much like a rupture" [4] [private communication].

The customer then took the FPGA to another test group and they discovered single event dielectric rupture (SEDR) just a few months later [5].

Moral of Story: if it's an unexpected incident, it's worth verifying that it's real and not assuming it's not.

Other recent examples of incidents include rupture in Schottky diodes [6] and failures in SiC [7].

V. Story 2: An Accident

On November 13, 2012, the Solar Anomalous Magnetospheric Particle Explorer (SAMPEX) spacecraft reentered the earth's atmosphere [8]. SAMPEX, the first of NASA's Small Explorer (SMEX) spacecraft, was launched in 1992 with a three year design lifetime (5 year goal). It lasted operationally nearly twenty years due to a myriad of testing, electronic parts selection, and system architecture, thrilling the scientific investigators who were able to obtain tremendous new scientific data.

One should note that the entire spacecraft was designed, built, and validated in three years (1989-1992) by NASA.

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Of note was that this was the first use of a fiber optic data bus (MIL-STD-1773) in a mainline space application [9]. This included selection and testing of the optical and electrical components, protocol electronics, connectors, couplers, and optical fiber. Radiation testing was partnered with U.S. Department of Defense (DoD) (Naval Research Laboratories) which has led to continued collaboration between our organizations. This is where the accident occurred.

While testing with protons at Crocker Nuclear Laboratory (CNL), I posed the question: “what happens if we tilt the beam direction from normal incidence (into the side of photodiode)?” All of sudden, the measured error rates increased directly as angle increased (see Figure 1). Analysis showed that this effect was first evidence of direct ionization effects from protons as a concern for space usage. This was an accident (though you can argue this might have been expected since photodiodes are “detectors”). However, long term, this discovery brought new concepts to performing rate prediction eventually leading to physics-based Monte Carlo analysis tools.

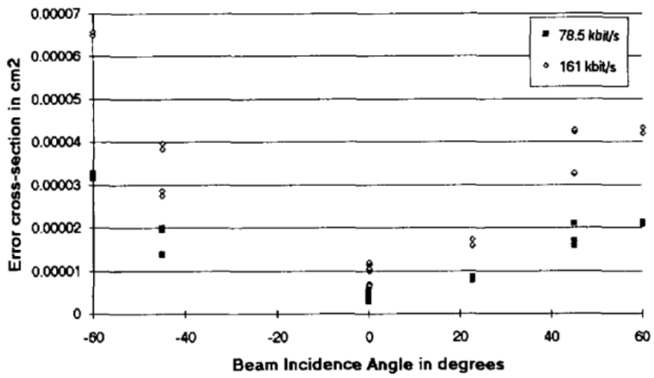

Fig. 1. Increase of measured error rates as incident beam angle changed from normal incidence. [9]

Moral of Story: Unplanned test conditions sometimes lead to new discoveries. It pays to think beyond the standard approaches at times.

VI. Recommendations to SEE Testers

There are numerous caveats when performing SEE testing following “standard” approaches. As such, we pose a few questions that the SEE tester needs to consider:

-- What do you do when you can’t test at grazing angles?

-- Is proton direct ionization a concern or the role of secondaries from heavy ion interactions with material nearby the sensitive areas? And so on…

Take the latter concern of proton direct ionization, is it possible that high precision mixed signal devices may be sensitive regardless of the technology? Consider the lowest significant bits (LSBs) of a 24-bit analog-to-digital converter (ADC): extremely low amounts of direct charge (such as from a low energy proton) would be required to cause flips in the LSBs – it is very likely that proton direct ionization would influence error rates for many missions. However, LSBs are often “don’t cares” in systems.

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