Radiation-Hardened Instrumentation, Sensors, and Electronics

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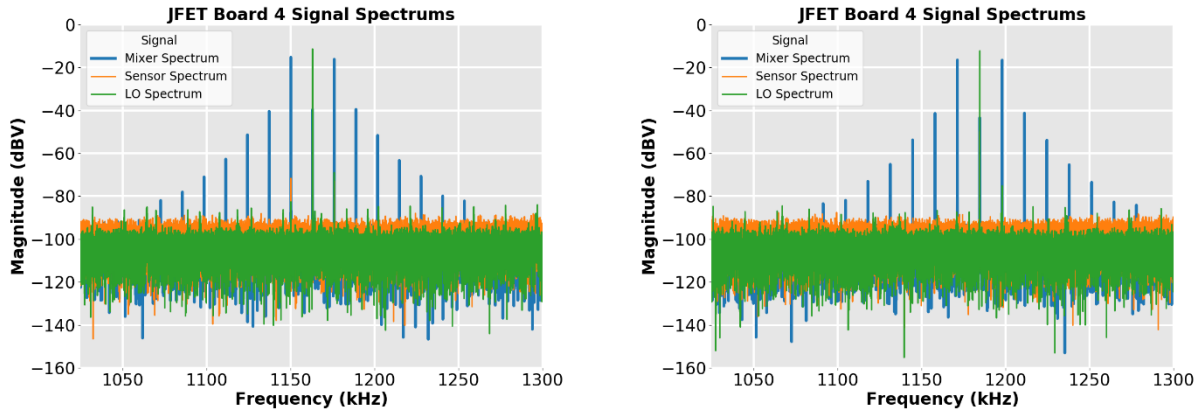
Project Description: To assist the US Department of Energy in defining a course for Office of Nuclear Energy–funded radiation-hardened (rad-hard) electronics research, Oak Ridge National Laboratory (ORNL) will focus on three main tasks in FY21. The first task will investigate the survivability of silicon junction-gate field-effect transistors (Si-JFETs) through a 100 Mrad total ionizing dose (TID) experiment and report the test results. The second task will investigate wide bandgap (WBG)-based JFET devices and sources. The third task is an investigation into commercially available systems and components and will be performed to determine whether a standardized list of devices can be identified for reactor instrumentation application. If the devices are feasible, then this list will provide direction to designers and equipment suppliers for selection of components to meet specific reactor requirements.

Impact and Value to Nuclear Applications: Historically, rad-hard electronics have been the proverbial Achilles' heel in nuclear sensing and instrumentation. Advanced sensors placed closer to the reactor core will improve reactor control and operation, resulting in safer and more efficient energy production. Because of the extremely harsh neutron and gamma radiation doses, coupled with the elevated temperature environment, research and development for new electronics and electronic materials technologies is essential for enabling improved monitoring and control of the existing nuclear reactor fleet and next-generation reactors, including microreactors.

Recent Results and Highlights: To achieve task three, ORNL is collaborating with Pacific Northwest National Laboratory to incorporate rad-hard electronics into the Nuclear Energy Sensors website, which was created under the Nuclear Energy Enabling Technologies program. The database provides filters that allow users to identify rad-hard electronics to be paired with sensors based on the temperature survivability, radiation tolerance, functionality, and several other criteria.

Focusing on task one, ORNL irradiated several sensing and transmission circuits using the Westinghouse Gamma Irradiation Facility. At this writing, two of the four boards have been irradiated to 170 Mrad (Si) TID in the center of the circuit, resulting in only a 5% shift in the transmission frequency, implying that the electronics can be used in this environment with minimal impact on performance (see Figure 1). The outcome of these irradiations will be presented in a milestone report in the fourth quarter of FY21.



(a) (b)

Figure 1: Spectrum of JFET sensing and transmission circuits after 1 Mrad (Si)[a] and 100 Mrad (Si)[b].