Self-powered Wireless Through-wall Data Communication for Nuclear Environments

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ABSTRACT:

In the nuclear industry many important components, such as nuclear reactor pressure vessels (RPV) and spent fuel storage canisters, are completely enclosed by metal barriers and surrounded by thick concrete walls. Monitoring the temperature, pressure, radiation, humidity, and other parameters inside these enclosed vessels is crucial to ensuring safe reactor operation and fuel security. However, the physical boundaries like metal enclosures and thick concrete present huge challenges to sensing and data communications because these enclosures shield radio-frequency (RF) signals and obstruct the wiring of power supplies and communications.

The objective of this proposal is to develop novel energy harvesting and wireless data communications technology for in-situ monitoring of interior conditions in enclosed metal vessels or thick concrete walls as found in dry storage canisters and nuclear reactor vessels. This objective is achieved with the collaborative effort of two universities a national laboratory and a company through three innovations: (1) directly harvest electrical energy from the gamma rays using the gamma heating and thermoelectrics, and from the beta radiation using betavoltaics; (2) transmit sensory data through the metal wall and thick concrete via "mode conversion" based ultrasound technology; and (3) creatively design and pack high-temperature electronics circuits with radiation-hardening and/or shielding inside the enclosed nuclear vessels.

This project will be completed through the collaboration of the Virginia Tech (VT), University of North Texas (UNT), Oak Ridge National Laboratory (ORNL) and Westinghouse Electric Company. Prof. Lei Zuo of VT, who won multiple national awards on energy harvesting, will direct this project as PI and also lead the design and fabrication of radiation energy harvester. Prof. Haifeng Zhang of UNT, who has over 10 years of experience on experimental ultrasonics and piezoelectrics for harsh environment applications will be a co-PI, leading the research of ultrasound data transmission. ORNL Distinguished R&D Members Roger Kisner and M. Nance Ericson will be co-PIs to lead the high-temperature electronics for the energy storage, sensing, and data transmission, with the support of Prof. Dong Ha at VT. Dr. Michael Heibel of Westinghouse, who has over 30 years of commercial nuclear power experience, will provide important guideline from nuclear industry perspective and lead the radiation tests as well as the overall system validation.