WAAP-10784, Rev. 1

Wireless in Nuclear – Nuclear Radiation-Tolerant Wireless Transmitters

Eva Gustavsson, Marketing Manager

Westinghouse Electric Company Sweden AB

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OUR VISION AND VALUES

Westinghouse will be the global nuclear energy industry's **first choice** for safe and efficient solutions as the world seeks clean, safe, environmentally sustainable energy programs now, and into the future.

We enhance our delivery of that vision by living our strong value system every day:

- Safety & Quality First
- Valuing Ethics, Integrity & Diversity
- Passion for Serving Our Customers Globally
- Dedication to Each Other Through Servant Leadership
- Fiscal Responsibility and Stability
- Consistently Delivering On Our Commitments

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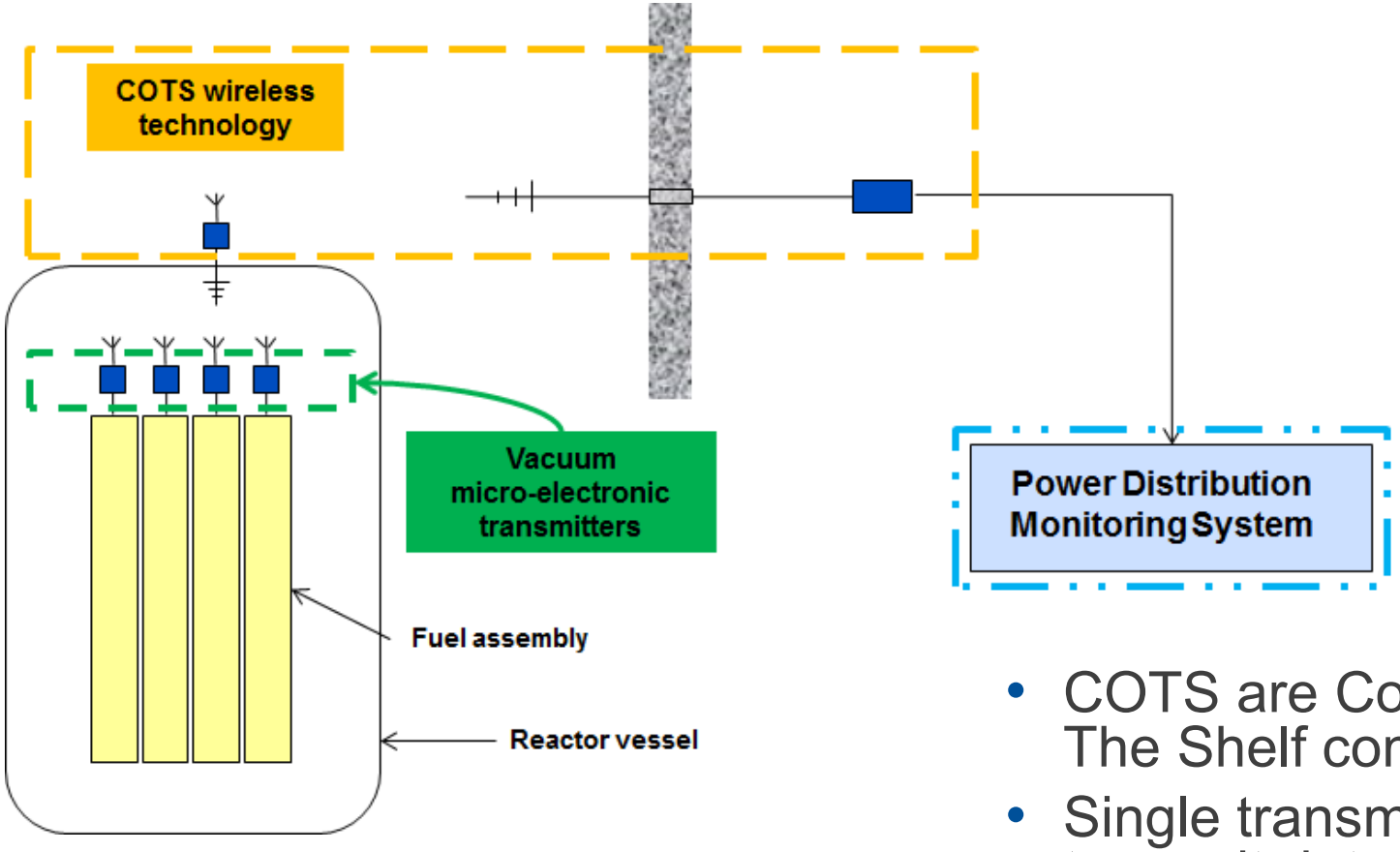
Agenda

- Introduction
- Benefits
- 2015 test recap
- 2016 DOE funded project status
- Other applications

Introduction

- Radiation and temperature tolerant wireless transmitter operating inside a fuel assembly top nozzle, capable of continuously transmitting neutron flux data during plant operation. Device itself would be powered by harvesting radiation from the core.
- Serves as an enabling technology for other applications such as In-pile sensors and in-containment applications.

System Configuration



- COTS are Commercial Off The Shelf components
- Single transmitter to transmit data from all fuel assemblies to single receiver antenna at the containment wall

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Benefits

- Technology applicable to PWR and BWR.
- Increase in reactor operating margin due to measurement density increase: 100% of fuel assemblies are instrumented vs. 33% (existing configuration).
- The increased knowledge of the reactor power distribution will allow an increase in reactor operating margin:
  - More electrical power from same fuel load
  - Same amount of electrical output from less fuel
- Reduction in outage and operating cost associated with in-core detector equipment manipulation and reactor vessel penetration inspection.

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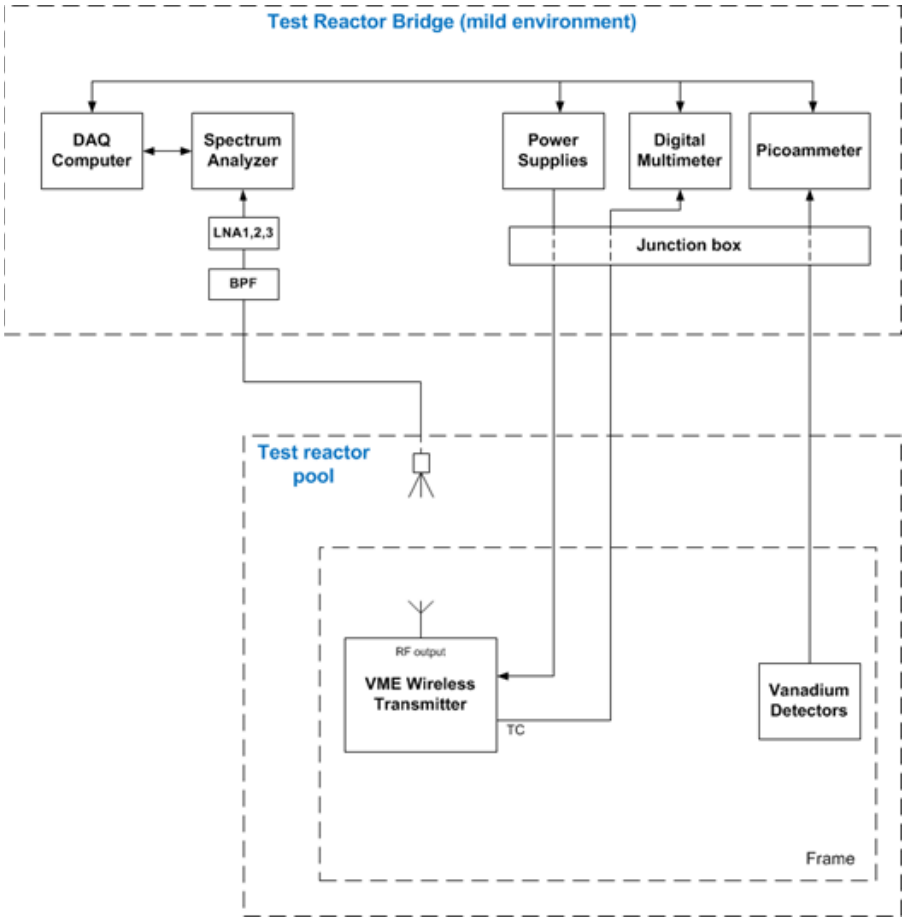
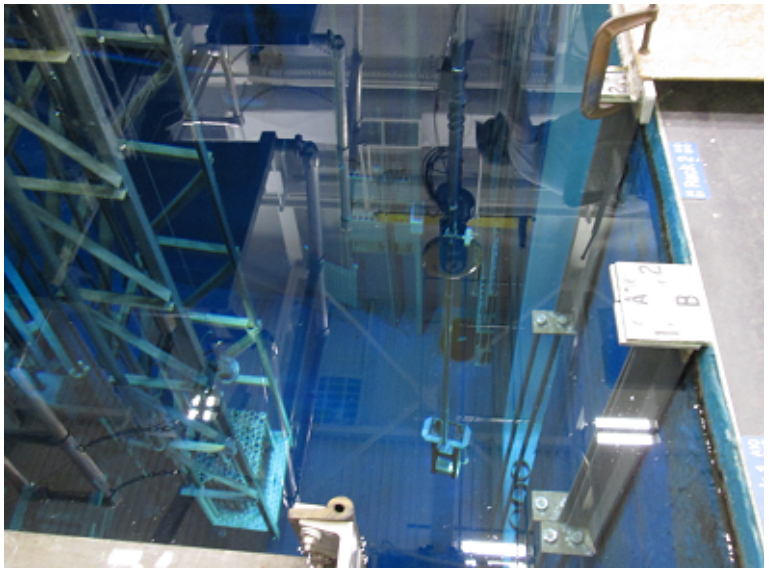
Proof-of-principle Test Configuration, Spring 2015

- A Vacuum Micro-Electronic (VME) was configured as a free running Colpitts voltage controlled oscillator wireless transmitter with a simulated input voltage.
- Objective was to assess radiation effects on oscillator. Oscillator was continuously transmitting.
- Results published in the American Nuclear Society February 2017 Nuclear Technology Journal, “Nuclear Radiation Tolerant Wireless Transmitter Irradiation Test Results.”

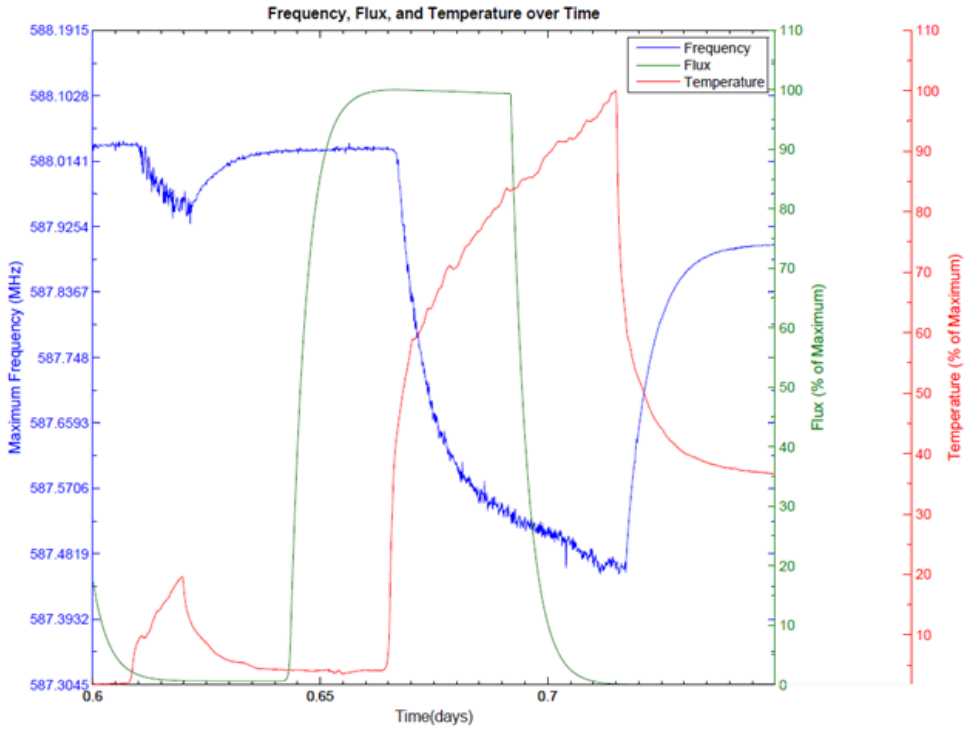


Proof-of-principle Test Results, Spring 2015

- Tested at the Penn State Breazeale Reactor
- Wireless transmitter system functioned as expected when exposed to a neutron fluence of 4x10^17 n/cm^2 and total gamma dose of 7.3x10^8Rads.
- Vacuum Micro-Electronic device operational after fluence of 1.8x10^18 n/cm2 and total gamma dose of 3.3x10^9 Rads.
- Order of magnitude higher radiation tolerance than other discrete components such as JFET (even SiC based), BJT or MOSFET.



Photograph courtesy of The Pennsylvania State University RSEC



DOE Funded Project

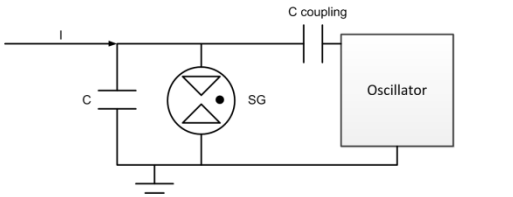
- Background
  - US Department of Energy (DOE) in 2016 awarded Westinghouse a research grant for a 3 year project.
  - The Penn State Breazeale Reactor (PSBR) is our collaborator and test reactor facility.
- Scope
  - Develop and irradiate amplitude modulated (AM) wireless transmitter (VME based from 2015 test) capable of processing a real self-powered Rhodium neutron detector signal.
  - Develop in-core neutron flux and gamma harvesting power supply.
  - Irradiate supporting passive components independently.

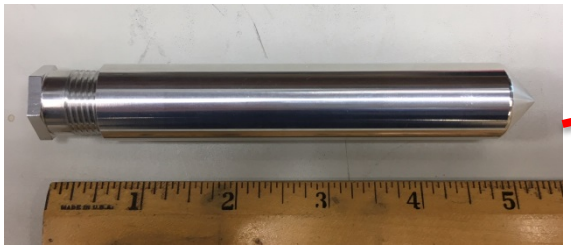
DOE Funded Project Test Configuration

- Hardware installed at PSBR.

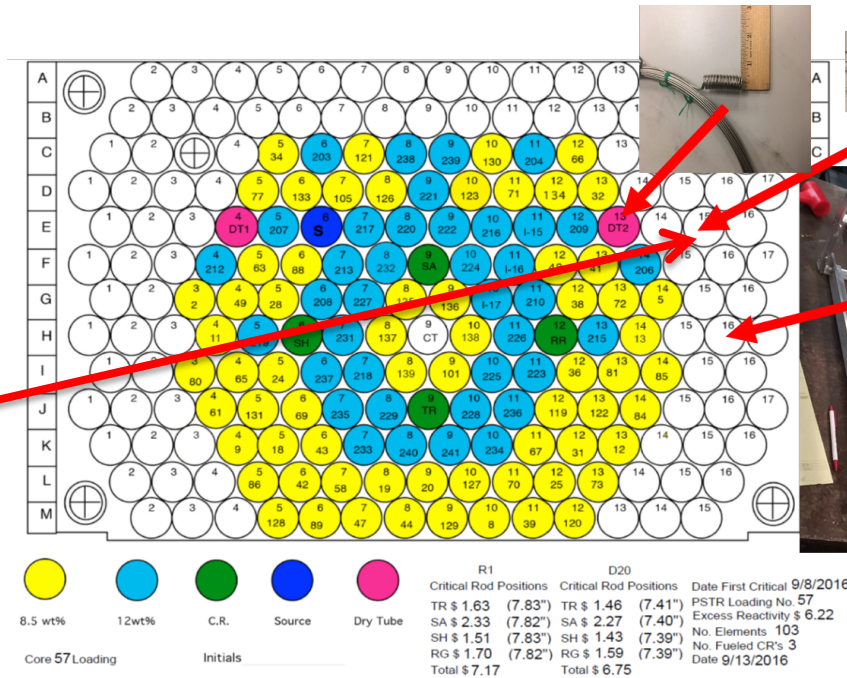
Rhodium SPD (*)
-Neutron flux detector

Capacitors





Transmitter enclosure



Wireless transmitters

(*) 1 detector connected to wireless device
1 detector as reference

DOE Funded Project Results to Date

Red top trace frequency pulses:

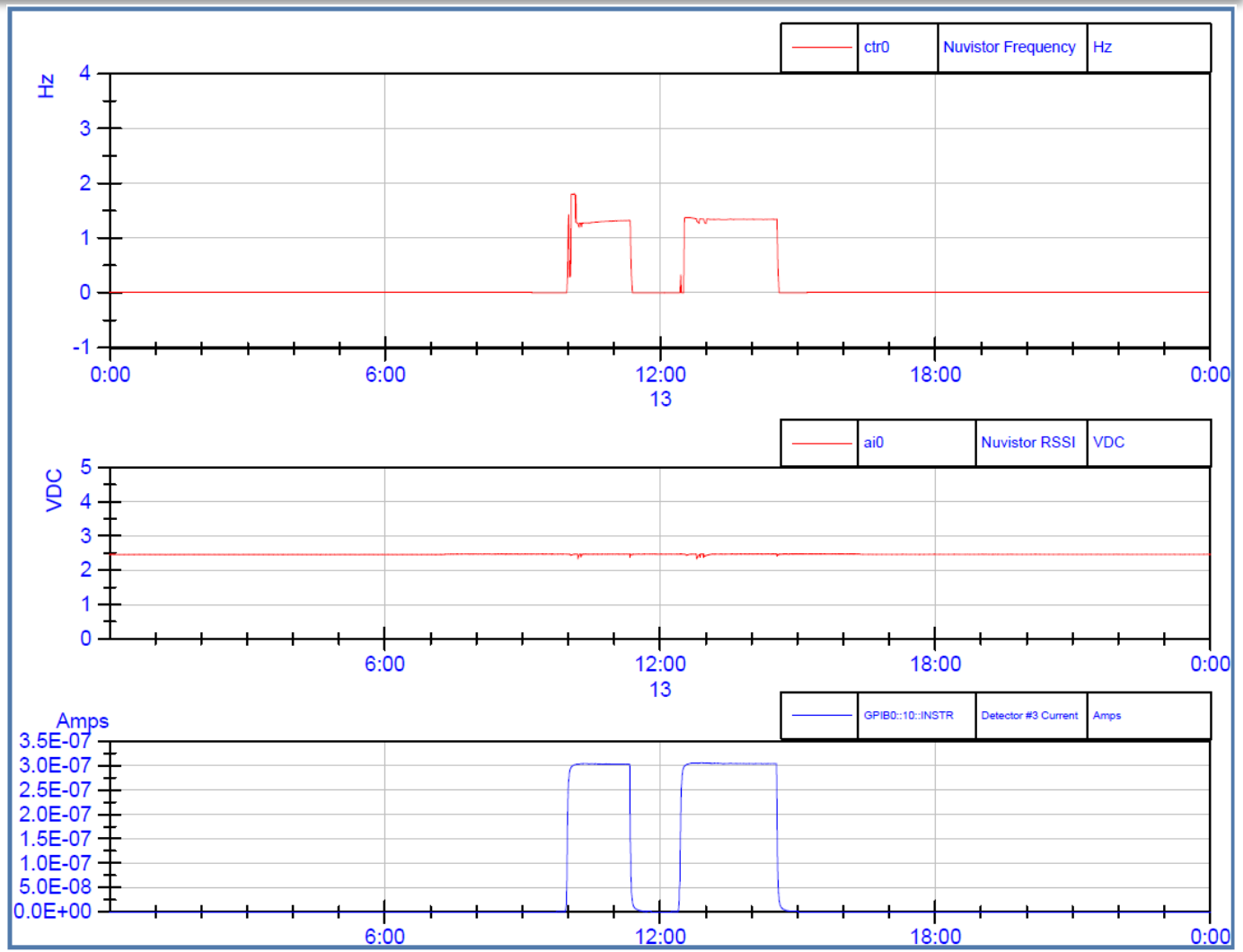
- Pulse repetition frequency varies as reactor power changes

Red middle trace is the RF amplitude:

- RF carrier amplitude remains stable during irradiation.

Blue bottom trace is the Rhodium (Rh) detector current:

- Reactor power monitored with Rh self-powered detector.



DOE Funded Project Summary

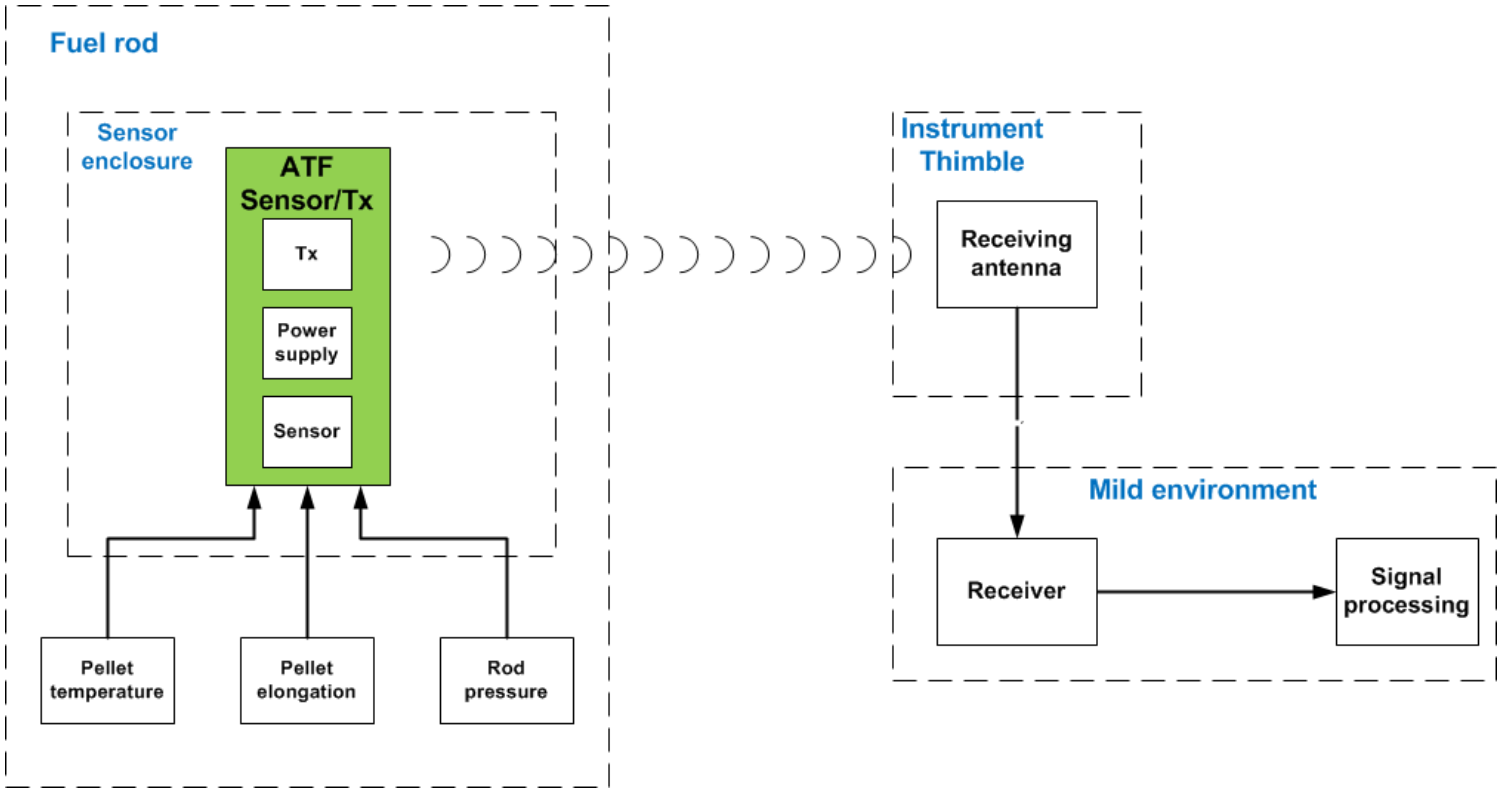
- Wireless transmitter capable of processing the small DC current from the Rh self-powered detector (SPD).
- Transmitter outputs a repeatable and accurate signal proportional to the Rh SPD current in the presence of neutron and gamma radiation.

Other Wireless Transmitter Applications

- Integral Fuel Rod Real-Time Wireless Sensor.
  - Wireless sensor located inside a fuel rod that provides real time data such as centerline fuel temperature, fuel pellet elongation and rod internal pressure to facilitate new fuel product licensing, and utilization of margins to enhance operations.

- GVMS.
  - Plants are required to monitor gas voids within their safety related systems and a permanent monitoring system is desirable to reduce personnel dose and labor costs. Adding wireless capability reduces plant cost.

Integral Fuel Rod Real-Time Wireless Sensor



- Wireless transmission from fuel rod to instrument thimble within the fuel assembly.
- Wireless sensor being tested at the Massachusetts Institute of Technology Test Reactor.

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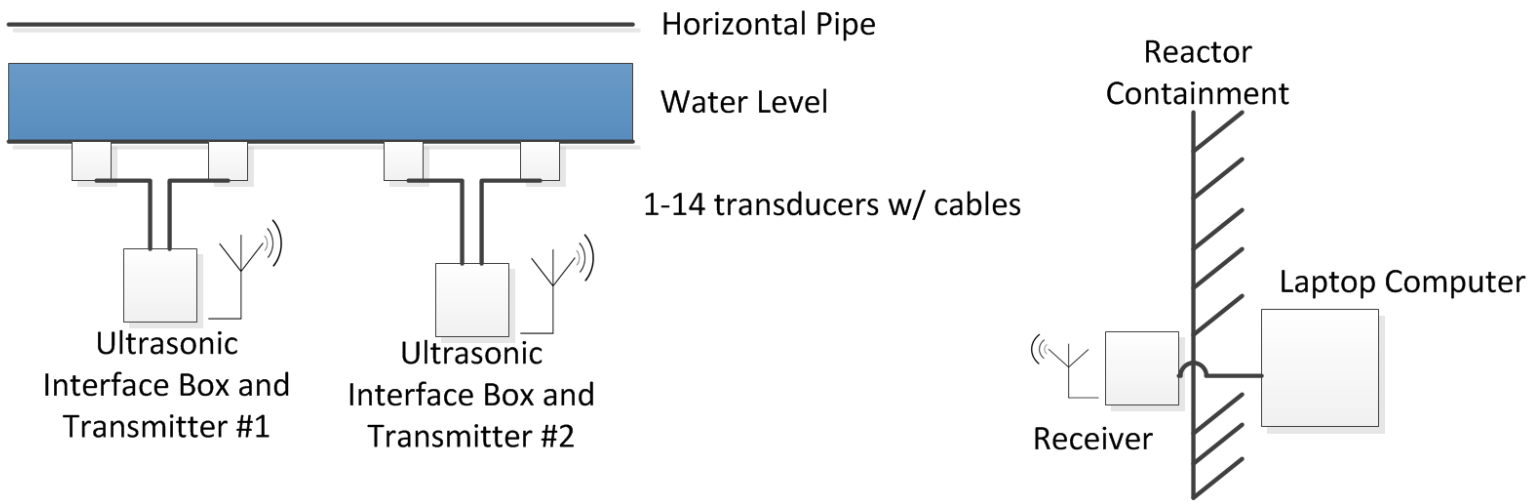
Gas Void Monitoring System



- This allows the ultrasonic interface box to be adjacent to the pipe being monitored significantly reducing cable length.
- This could save significant cabling and conduit costs.
- Proposed configuration improves the ALARA metrics.
- GVMS low power consumption allows for battery operation.

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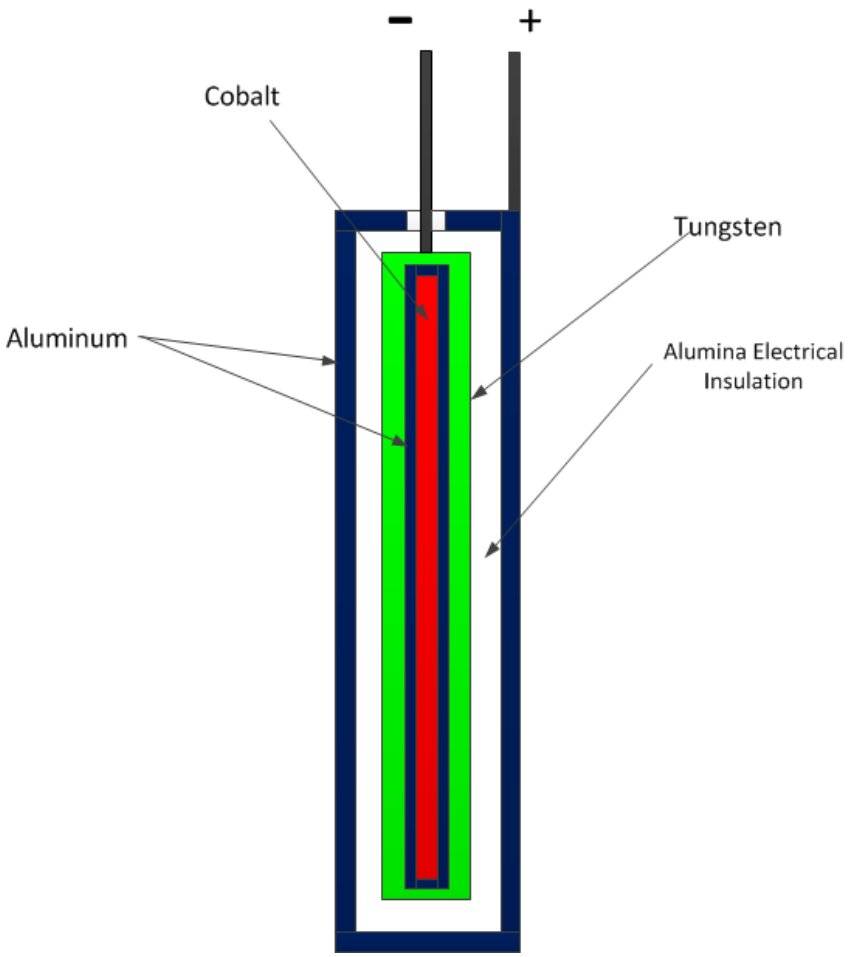
Thank you!

Back up slide: Gamma Harvesting Power Supply

- Schematic representation of the cylindrical radiation harvesting power supply (CRHPS) including Co-60 power generation mechanism
- Co-59 becomes Co-60 during reactor operation
- The high energy gamma radiation emitted by the Co-60 will interact with the surrounding Tungsten to produce high energy electrons that will preferentially travel from the emitter to the collector. This will result in a large electric current generation even when the reactor is shutdown



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