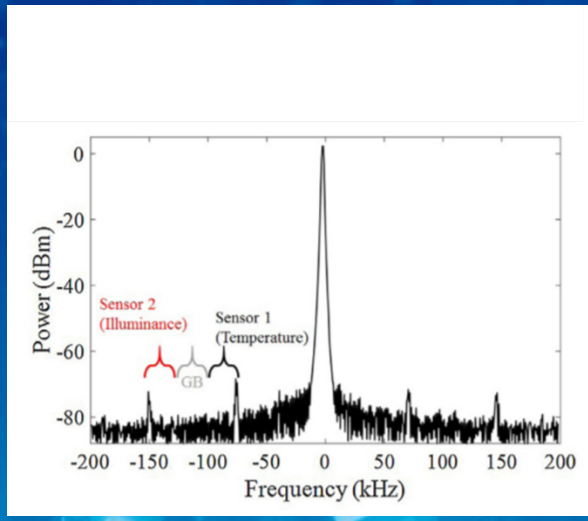
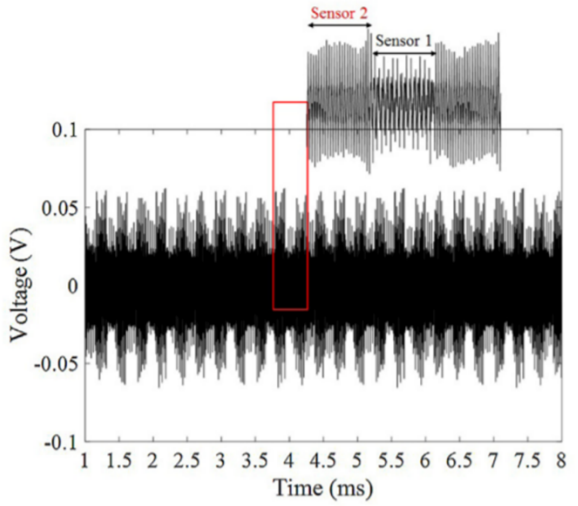
U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

Clean. Reliable. Nuclear.

Assessing of Wireless Communication Technologies





Advanced Sensors and Instrumentation Annual Webinar

October 29, November 5, November 12 , 2020

Vivek Agarwal, James A. Smith, Koushik A. Manjunatha

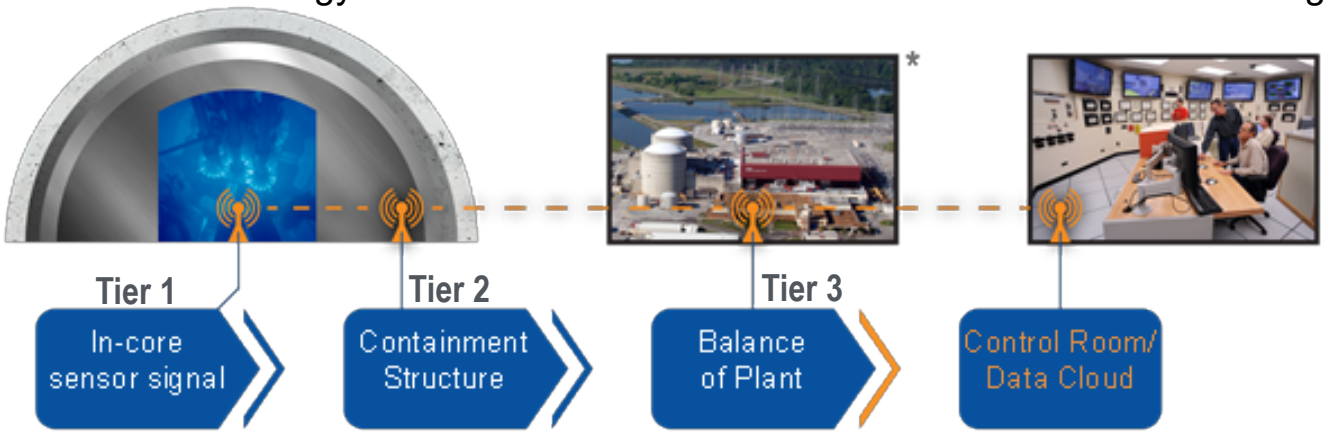
Idaho National Laboratory

Project Overview

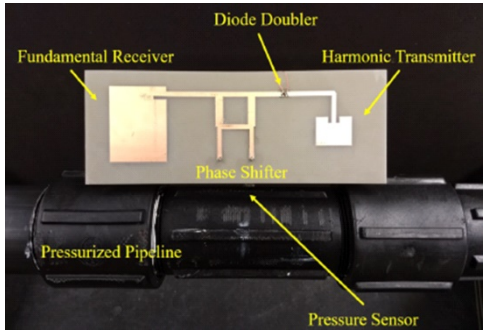
- Goals and Objectives
  - Assessment of wireless communication technologies and their applications in nuclear environment to support development of a technology demonstration test plan
  - Advance the implementation of “smart” processes and structures to enable the ability to cost effectively create a large network of sensors and better data analytics for operational decisions
  - Develop three-tier sensing and communication strategy
    1. **In-core**: data signal from in-core to outside the pressure vessel
    2. **Containment building**: data from containment building to balance of plant network
    3. **Balance of the plant network**: transmit to the data cloud and control room.
- Participants (2020)
  - INL: Vivek Agarwal, James A. Smith, and Koushik A. Manjunatha
  - North Carolina State University: Cheryl Xu
  - Michigan State University: Yiming Deng
- Schedule
  - Milestone report completed, August 2020, “Wireless Sensing and Communication Capabilities from In-Core to a Monitoring Center”

Accomplishments

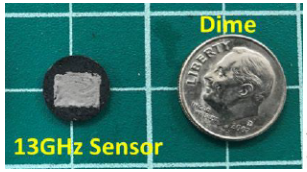
- **Sensing Communication Infrastructure**
  - Developed a three-tier strategy for wireless transmission of measurements to a monitoring center or the cloud



Tier 1: In-core and Containment Sensors

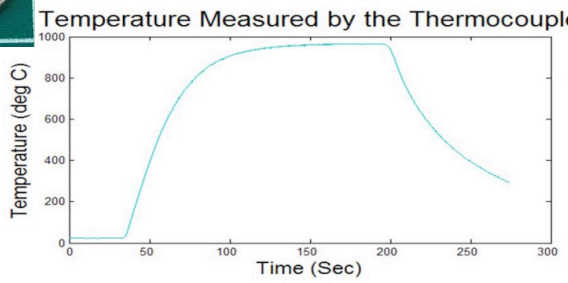


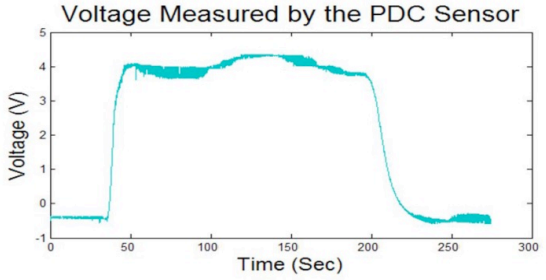
Pressurized pipeline setup with a harmonic RF sensor tag



In-Core: High Temperature PDC Sensor (>1000 °C)

Voltage of a Polymer Derived Ceramic (PDC) sensor as a function of temperature.

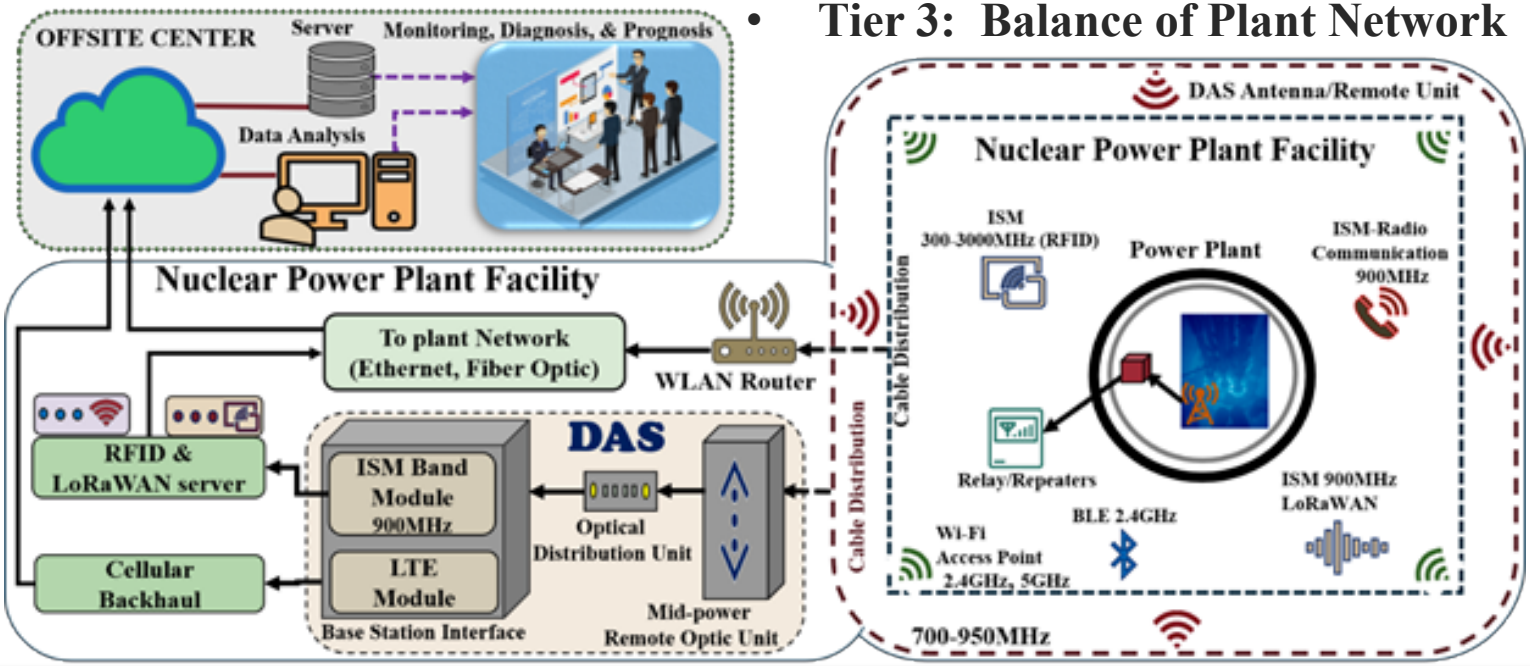




Accomplishments II

- **Tier 2: Containment Area Interrogator**
  - Sensors located in-core and containment area
  - Energize RF sensors and receive sensor signals
  - Process the signals and extract precise measurements
  - Transmit to balance of plant

- **Tier 3: Balance of Plant Network**



- **Documentation and Participation**
  - James A. Smith "Using a RFID Sensor as a Voltage Control Oscillator," provisional patent no. 62/926,820
  - Participated on the IEEE working committee for IEEE 21451-7-2011 --Smart transducer interface for sensors
  - Milestone report

Technology Impact

- *Advances the state of the art for nuclear application*
  - Developed a three-tier strategy to obtain in-core measurements and wirelessly transmit to a data center
  - Technology maturity (TRL) varies between tiers
- *Supports the DOE-NE research mission*
  - Wireless sensors and data transmission will enable nuclear plants to compete
- *Impacts on the nuclear industry*
  - Reduce costs
    - Laying new cabling in nuclear plants is ≈$2,000 per foot in 2009 [1]
    - Industrial wireless expenses expected to drop from $20/foot to $2/foot in 2010 [2]
  - Increase productivity and plant efficiency
    - Reduce manual measurements
    - Make measurements in critical new areas such as the core
    - Have the confidence to operate with lower margins
    - Provide more effective data analytics for operational decisions
- *Commercialization*
  - License technology to power plant vendors or instrumentation suppliers

[1] Hashemain, H.M., "State of the Art in Nuclear Power Plant I&C", IJNEST, 2009, 330-354.
[2] Tsvetkov, P. V., "Nuclear Power-Control, Reliability and Human Factors, Chapter 4.5", 2011.

Conclusion

- *Designed an in-core wireless sensing and communication system*
  - *Passively powered ceramic high-temperature sensors that are wireless*
  - *Provide real-time sensing in-core and within the containment structure*
  - *Capable of multi-sensing of temperature, pressure, strain, etc.*
  - *Integrated into a communication network for delivery to a processing center*
- *Identified two areas for additional wireless development*
  - *Transmission through the containment structure*
  - *Pressure vessel wall*
- *Provided intellectual property*
  - *James A. Smith "Using a RFID Sensor as a Voltage Control Oscillator," provisional patent no. 62/926,820 and full patent application*
  - *Milestone Report: "Wireless Sensing and Communication Capabilities from In-Core to a Monitoring Center"*
- *Advanced technology that enables*
  - *Reduced costs*
  - *Increase productivity, plant efficiency, wide-ranging* data analytics for operational decisions
- *Questions*
  - *James.Smith@INL.Gov*, vivek.agarwal@inl.gov