U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Office Of Nuclear Energy
Sensors and Instrumentation
Annual Review Meeting

Transmission of Information by Acoustic Communication along Metal Pathways in Nuclear Facilities

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Project Overview

- **Goal - Develop and demonstrate methods for transmission of information in nuclear facilities by acoustic means along existing in-place metal piping infrastructure**
  - Develop and demonstrate the ability to transmit greater amounts of data and other signals through physical boundaries in nuclear facilities
  - Address new communication demands needed for advanced measurement and control technologies including protection of data.
  - Take into consideration the environment and the conditions under regular operation and/or accident scenario.
  - Test and validate prototype through demonstration in appropriate representative environment.
- **Participants**
  - Argonne National Laboratory
  - University of Illinois Urbana-Champaign
- **Schedule**
  - Three-year project, Year 1 just completed

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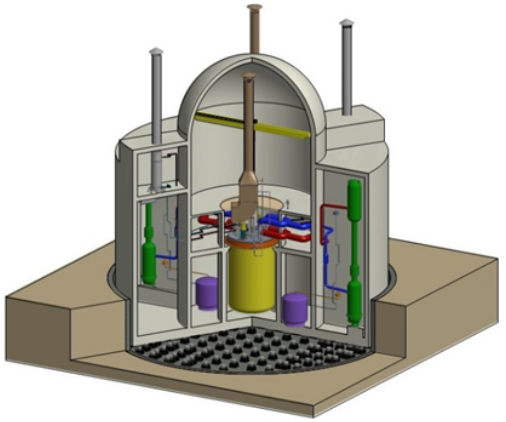
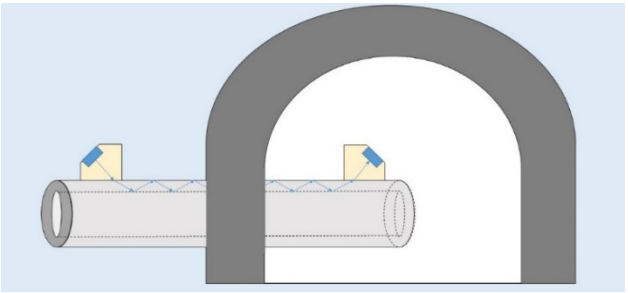
Background

- **Seek innovative means to transmit information that overcomes physical hurdles that beset conventional communication methods, i.e. both wired and radio frequency wireless.**
  - Establishing a wireless RF system at a nuclear facility requires careful positioning of transmitters and receivers that take into account the plant topology.
  - In case of a disruptive event, such as a major natural disaster or accident, wireless sensors are likely to be perturbed
  - Post-accident water sprays can strongly scatter free-space RF waves
  - Pipes are omnipresent in a nuclear facility
  - Adopt pipes and other metal structures as conduits for signals launched as guided acoustic surface waves





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Background

Challenge

- Because of harsh environment (mostly high temperature of up to 350C of the process fluid pipes), ultrasonic transducers developed and demonstrated in prior studies on acoustic wave communications might not be suitable for deployment in communication system developed for nuclear reactor.

Mitigation

- Prior experience of developing temperature-resilient contactless electromagnetic acoustic transducers (EMAT)
- Explore the use of EMAT in developing acoustic communication system for nuclear reactor applications.
- Survey low-temperature process piping inside containment

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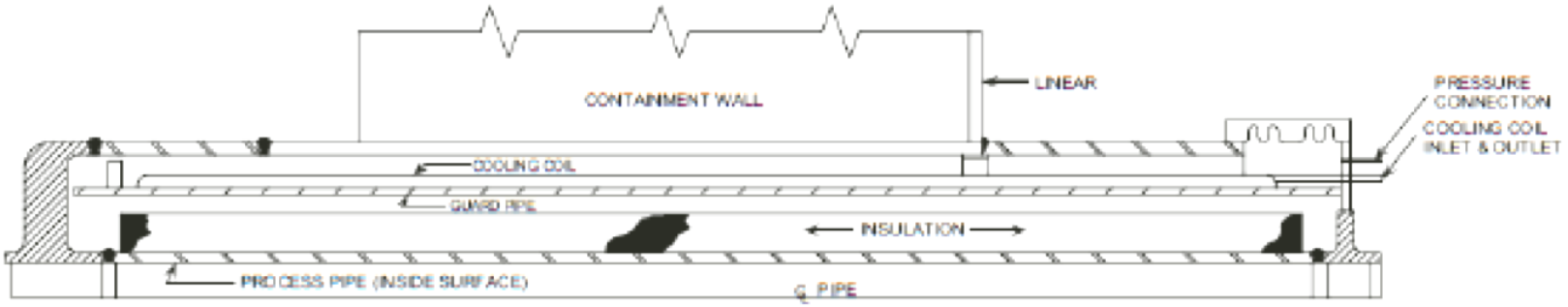
Accomplishments

- **Surveyed NPP process piping for good acoustic candidate**
  - Selected through-containment as a challenge problem
  - Identified CVCS piping as good candidate – Relatively low temperature
  - Setup experiment benchtop to replicate material and geometry



Representative through-containment piping

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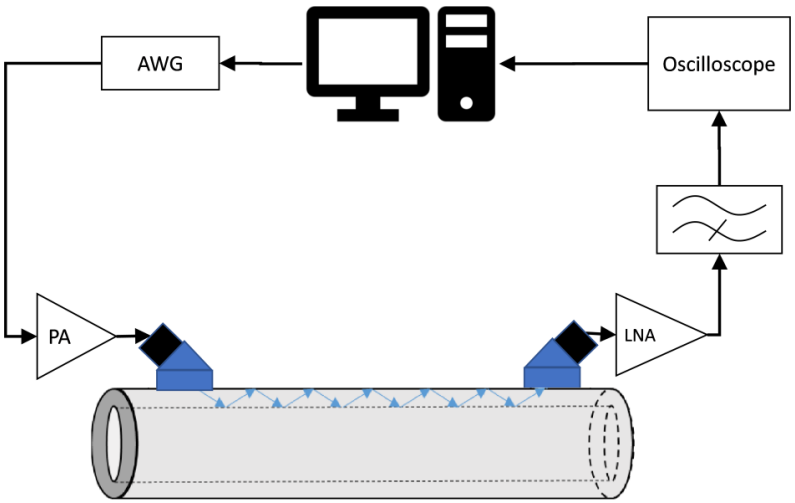
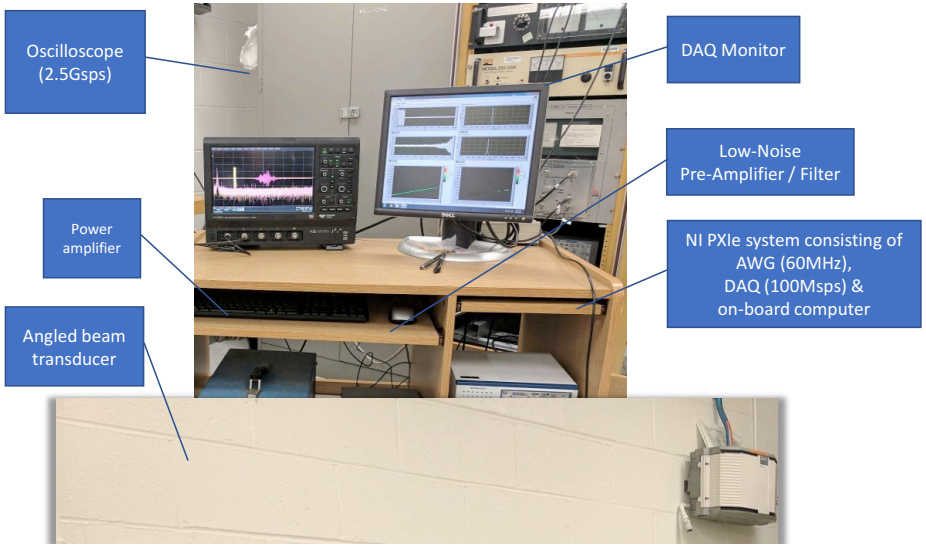
Accomplishments

- **Task 1.1 - Identify and test ultrasonic transducers and amplifiers for coupling into, transmission along, and reception out of pipe infrastructure.**
  - Setup benchtop scale experiment facility – Replicates through-containment CVCS piping





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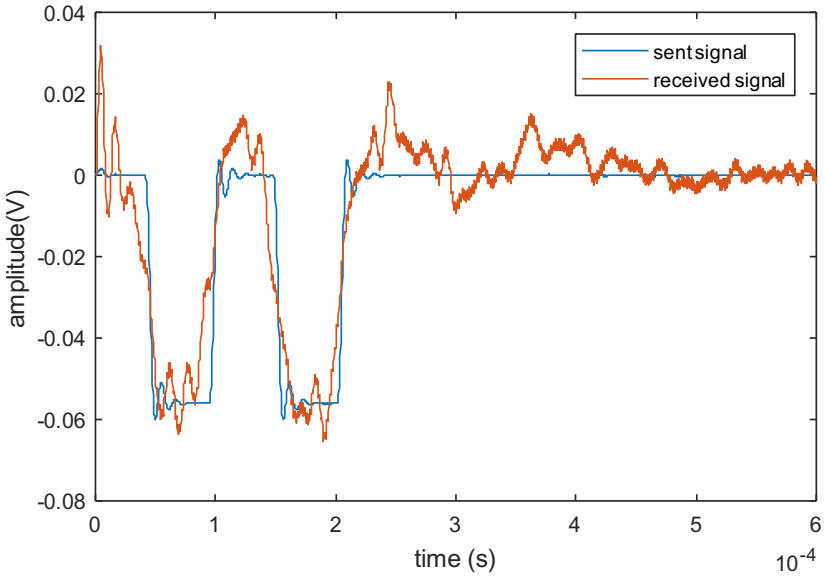
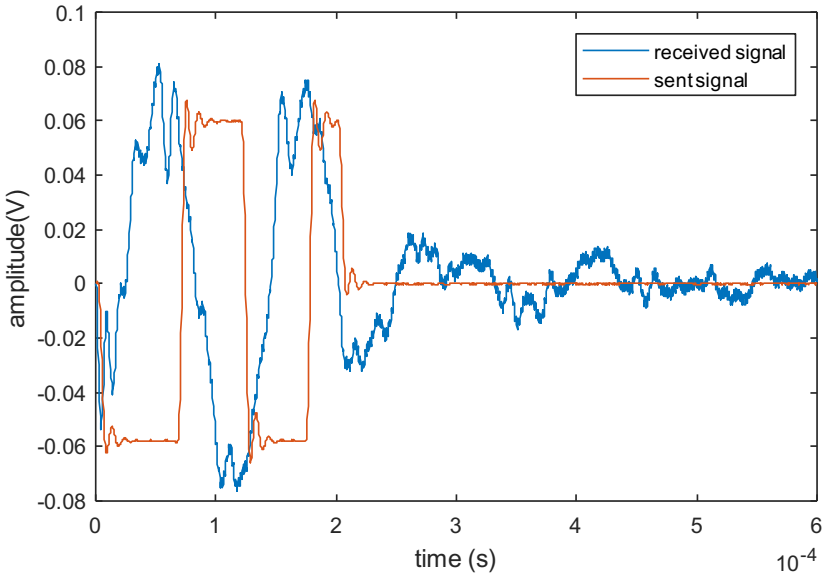
Accomplishments

- **Task 1.1 - Identify and test ultrasonic transducers and amplifiers for coupling into, transmission along, and reception out of pipe infrastructure.**
  - Experimentally investigated different communication modulation schemes



ASK modulation with 50 ms bit pulse duration



PSK modulation with 50 ms bit pulse duration

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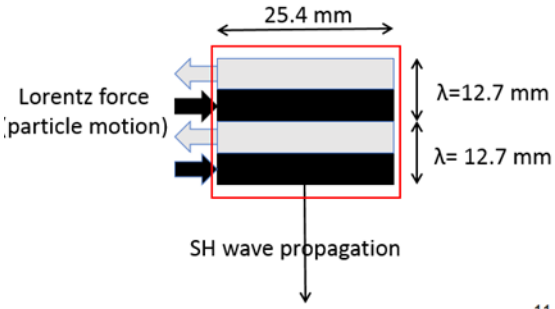
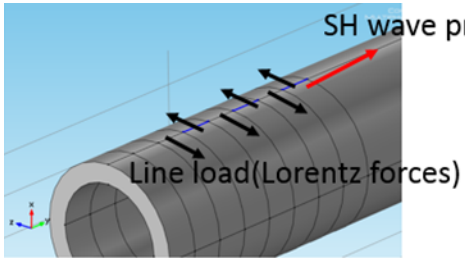
Accomplishments

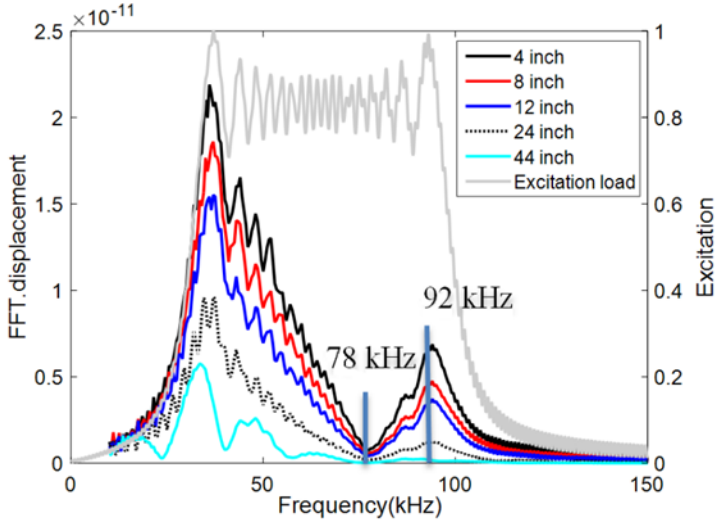
- **Task 1.2 - Derive performance specifications for individual transducers, amplifiers, and couplers**
  - Performed COMSOL multi-physics simulations



EMAT Design



EMAT simplified model



Response signals due to axial SH wave mode

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Technology Impact

- **Developing information channel for through-barrier communication**
  - Solves weak link in wireless communications – RF attenuates significantly in concrete
- **Developing a diverse means of communication for use during accidents**
  - Solves weak link in wireless communications – Disrupted geometric orientations, high humidity, high temperature

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Conclusion

- In-containment CVCS piping was identified as a good candidate for acoustic communications medium
- Identified through experimental activities to date a number of parameters that could affect the transmission of signals over long distances
- Based on preliminary results of signal transmission, OOK looks like the preferred modulation scheme for information transmission
- Partnered with a commercial partner for Year 3 tests in a nuclear facility