



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

Advanced Sensors and Instrumentation
Annual Webinar

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Project Overview

- **Goals and Objectives**

- Demonstrate ability to transmit information through physical boundaries at a nuclear facility

- **Participants (2020)**

- Alexander Heifetz, Dmitry Shribak, Sasan Bakhtiari, Richard B. Vilim – [Argonne](#), Xin Huang, Boyang Wang, Jafar Sanie – [Illinois Tech](#)

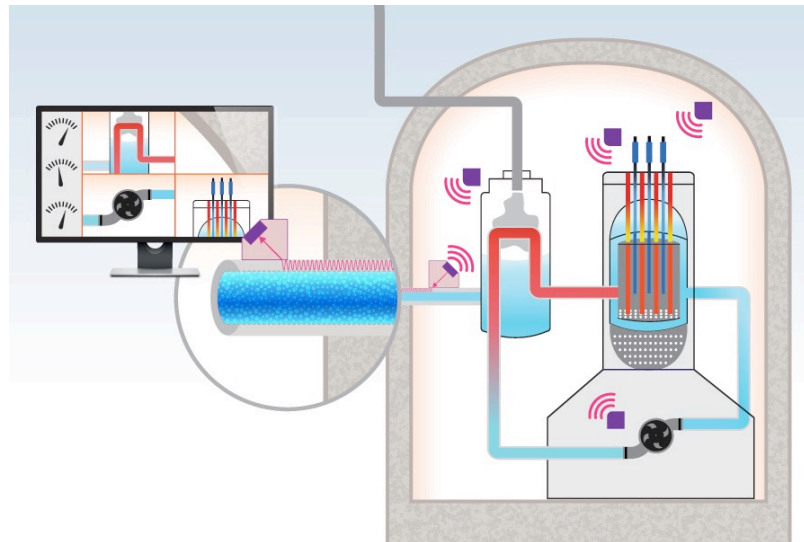
- **Schedule**

- Y1: developed system requirements and implemented ultrasonic communication setup on a pipe
- Y2: demonstrated ultrasonic data transmission on room temperature pipe
- Y3: demonstrated ultrasonic data transmission on elevated temperature pipe

Accomplishments

- **Communication System Specification**

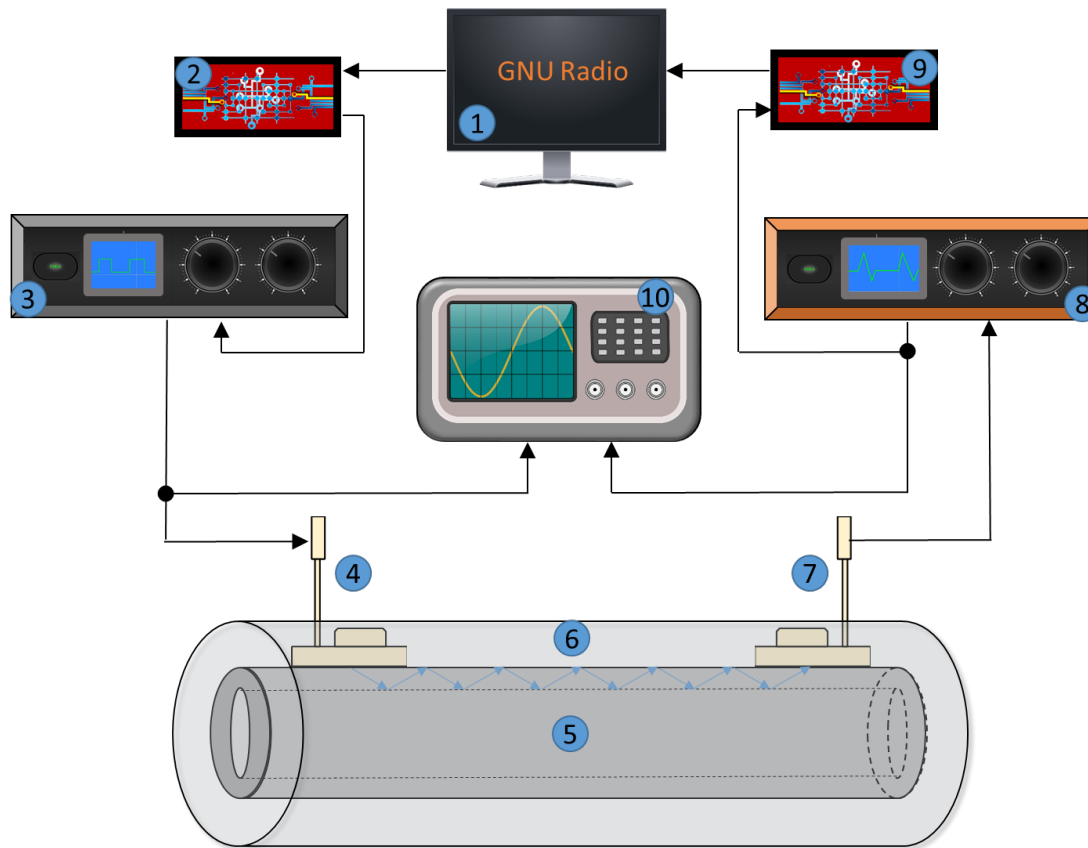
- Communication system at a nuclear facility would transmit information on steel pipes already in place for nuclear reactor operation
- Focused on information transmission of information in an out of the containment building
 - Identified charging line stainless steel pipe of chemical volume control system (CVCS) as viable conduit for information transmission
 - Pipe penetrates containment wall through a tunnel in concrete sealed on both ends by steel plates



A. Heifetz et al., "Transmission of Information Using Elastic Waves on Metal Pipes in Nuclear Facilities," Proc. Nuclear Plant Instrumentation, Control, and Human Machine Interface Technologies (NPIC&HMIT 2019), Orlando, Florida, February 9–14, 2019, pp. 49 (2019).

Accomplishments

- Developed Ultrasonic Communication System on Elevated Temperature Pipes



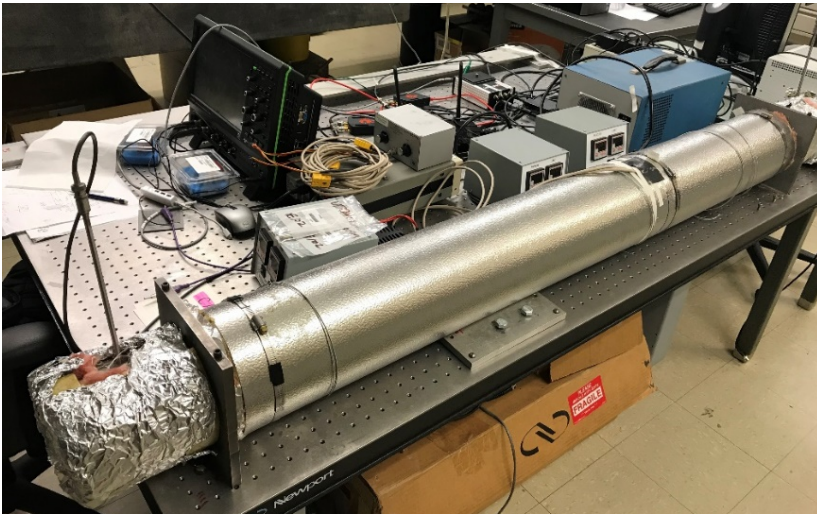
Typical environmental stresses on containment isolation function components

Parameter	Normal	Accident
Temperature	50-120 °F	300 °F
Pressure	atmospheric	70 psig, max
Relative Humidity	30-100 %	100 %
Radiation	50 rads/hr	150 Mrads/hr

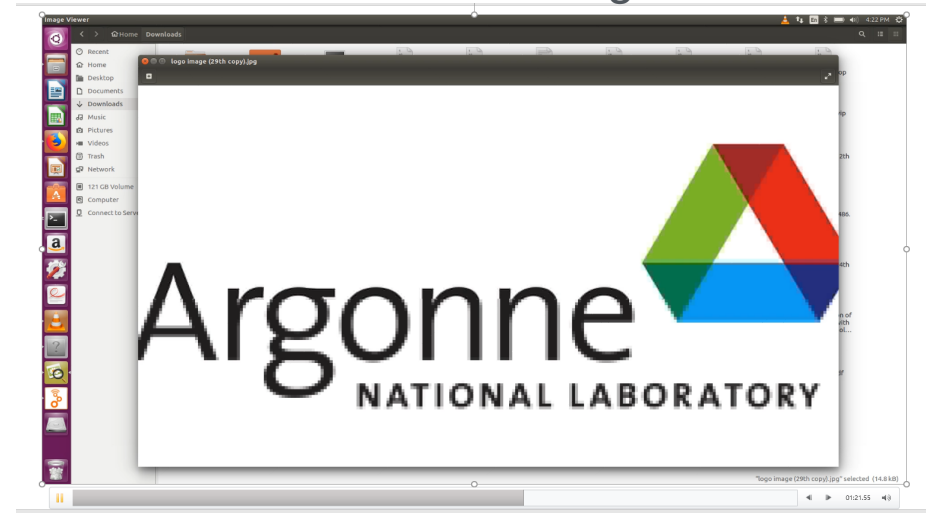
- (1) Digital computer with GNURadio software
- (2) RedPitaya transmitter board
- (3) Power amplifier
- (4) LiNbO₃ ultrasonic transmitter
- (5) Stainless steel pipe
- (6) Thermal insulation layer
- (7) LiNbO₃ ultrasonic receiver
- (8) Low noise amplifier
- (9) RedPitaya receiver board
- (10) Digital oscilloscope.

Accomplishments

- **Ultrasonic image transmission on a heated pipe**
 - Used the ASK transmission protocol implemented in GNURadio environment
 - SS304 2.375" OD schedule 160 pipe heated to 50°C and 150°C
 - LiNbO₃ transducers with carrier frequency is 728 kHz
 - 10KBps data rate (bit pulse duration is 100μs)
 - ISI suppressed with RRC filter, BER ~10⁻³



90KB Image



Accomplishments in 2020

- **Deliverables**

- Final Report for Transmission of Information by Acoustic Communication along Metal Pathways in Nuclear Facilities, ANL-19/42, September 30, 2019.

- **Publications/Presentations**

- A. Heifetz, D. Shribak, X. Huang, B. Wang, J. Saniie, R. Poncirolli, E.R. Koehl, S. Bakhtiari, R.B. Vilim, “Transmission of images on high-temperature nuclear-grade metallic pipe with ultrasonic elastic waves,” *Nuclear Technology* 10(1), 1-13 (2020).
- A. Heifetz, D. Shribak, X. Huang, B. Wang, J. Saniie, J. Young, S. Bakhtiari, R. Vilim, “Transmission of Images with Ultrasonic Elastic Shear Waves on a Metallic Pipe using Amplitude Shift Keying Protocol,” *IEEE Transactions in Ultrasonics, Ferroelectrics and Frequency Control* 67(6), 1192-1200 (2020).

Accomplishments in 2020

- **Publications/Presentations**

- X. Huang, J. Saniie, S. Bakhtiari, A. Heifetz, “Contoured PPM-EMAT Design for Ultrasonic Communication on Metallic Pipe Channels,” to appear in *Proceedings of IEEE International Conference on Electro-Information Conference (EIT) (2020)*.
- B. Wang, J. Saniie, S. Bakhtiari, A. Heifetz, “Ultrasonic Communication in Solid Channels using OFDM,” to appear in *Proceedings of 2020 IEEE International Ultrasonics Symposium (IUS) (2020)*.
- X. Huang, J. Saniie, S. Bakhtiari, A. Heifetz, “Performance Evaluation of High-Temperature Ultrasonic Communication System,” to appear in *Proceedings of 2020 IEEE International Ultrasonics Symposium (IUS) (2020)*.
- X. Huang, J. Saniie, S. Bakhtiari, A. Heifetz, “Software-Defined Ultrasonic Communication System Based on Time-reversal Signal Processing,” to appear in *Proceedings of 2020 IEEE International Ultrasonics Symposium (IUS) (2020)*.

- **Commercialization**

- Received request from information from Canadian Utility

Accomplishments Over Project Lifecycle

• Publications/Presentations

– Journal papers (2)

- *IEEE Transactions of Ultrasonics, Ferroelectrics and Frequency Control*
- *Nuclear Technology*

– Conference papers (14)

- **Seven** in Proceedings of *IEEE International Ultrasonics Symposium (IUS)*
- **Five** in Proceedings of *IEEE International Conference on Electro/ Information Technology (EIT)* (including **Best Paper Award**)
- **One** in Proceedings of *Nuclear Plant Instrumentation, Control, and Human-Machine Interface Technologies (NPIC&HMIT)*
- **One** in *Transactions of ANS Winter Meeting*

– Submitted **R&D100** application

– Project work profiled **twice** by ANL Media Office



• Patents

- *US Patent Application 15/947,303 has been filed in 2018.*

Technology Impact

- *Advances the state of the art for nuclear application*
 - *Provides capability to transmit information across physical barriers at a nuclear facility using in-place piping infrastructure*
- *Supports the DOE-NE research mission*
 - *Develops new means of secure and accident-resilient communication at a nuclear facility applicable to different reactor types*
- *Impacts the nuclear industry*
 - *Helps to increase safety of existing and future nuclear power plants*
- *Will be commercialized*
 - *US Patent Application 15/947,303 has been filed in 2018.*
 - *Received request from information from Canadian Utility*

Conclusion

- *Demonstrated information transmission on nuclear grade stainless steel pipe using ultrasonic transducers*
 - *Demonstrated high-bitrate ultrasonic transmission of images on a pipe at simulated normal and post-accident conditions*
- *Contact Information*
 - aheifetz@anl.gov
 - 630-252-4429



Clean. **Reliable. Nuclear.**