

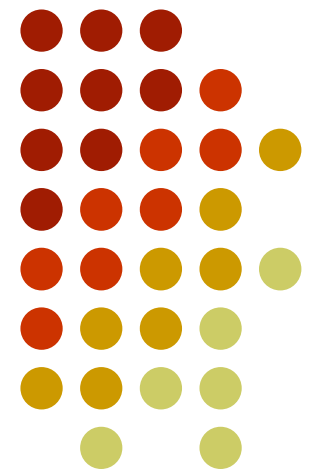


CensCIR

Center for Sensed Critical Infrastructure Research

***Interdisciplinary research:
Flaw detection and structural
health monitoring in steel pipes***

***Irving J. Oppenheim
ijo@cmu.edu***



Carnegie Mellon

Interdisciplinary project

- CMU is subcontractor to CTC, funded by DOE National Energy Technology Laboratory
- Project started October 2008
- CenSCIR is an interdisciplinary center at CMU
- Project breakthrough from using radar results (**time reversal**) in ultrasonic flaw detection
- Two electrical engineering faculty, including J.F.M. Moura, three civil engineering faculty
- Three graduate and two undergraduate students

CMU laboratory pipe specimen



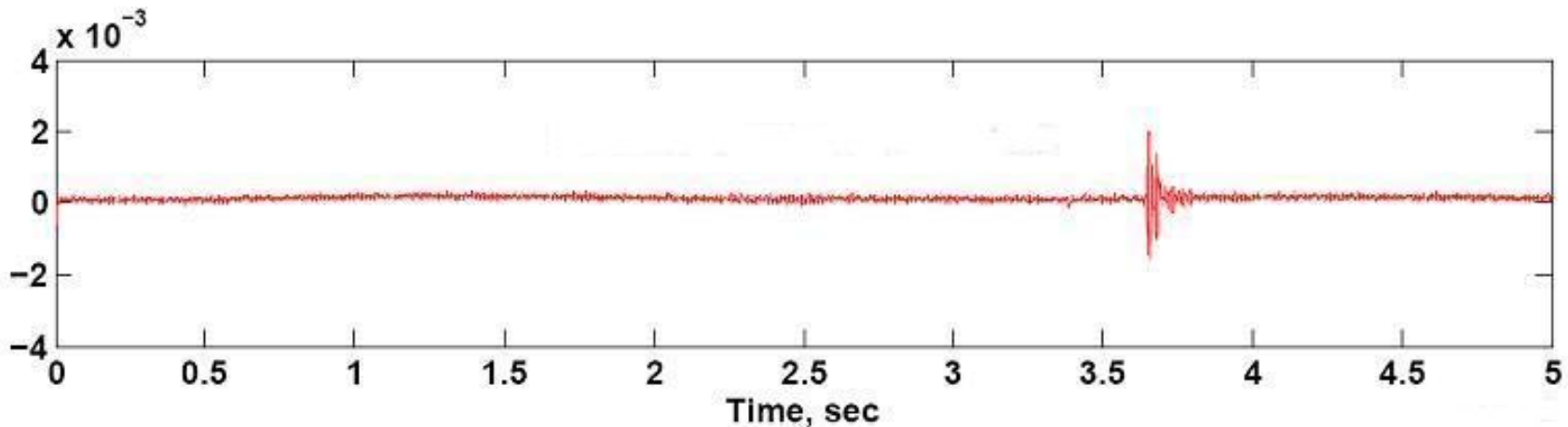
- Length: 3.05m
- Diameter: 60.3 mm
- Thickness: 3.6 mm
- Transducers: PZT wafers, 6 x 12 x 1 mm
- Excitation at only 10 V
- Transducers spaced 1.2m
- Signal propagates ~30m

Conventional ultrasonics



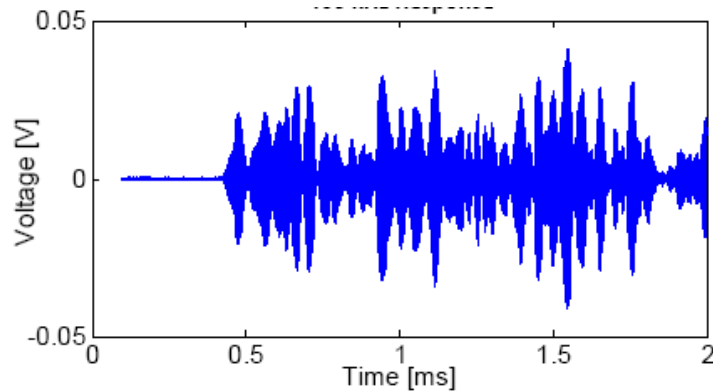
Guided Ultrasonics, Ltd.

- Excite only a single mode
- Constant wave speed
- Produces an undistorted flaw echo, and only one
- However, use on pipes requires a probe array



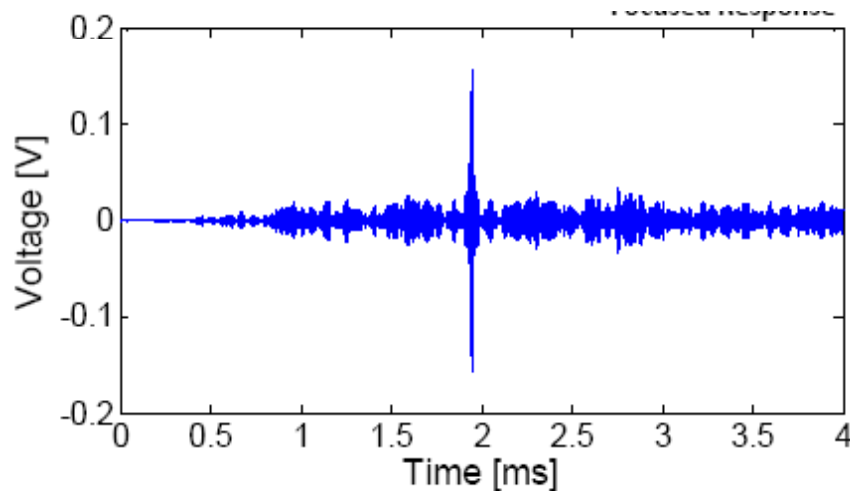
Fluid-coupled ultrasonics, laboratory data, CMU

The specific problem in pipes: multi-mode and multi-path



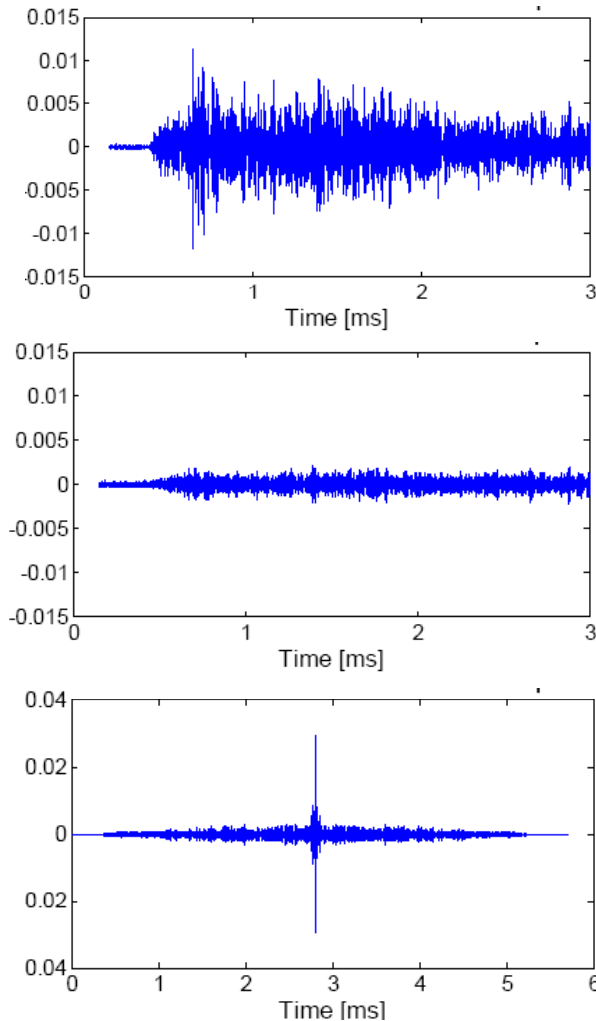
- Excitation is only 40 μ sec
- Response exceeds 2 ms
- Caused by multi-modes and multi-paths
- Pipes **invite** multiple paths
- This makes conventional pipe ultrasonics so difficult; multiple modes and paths are the **enormous problem**

Time reversal as a solution to multi-mode and multi-path



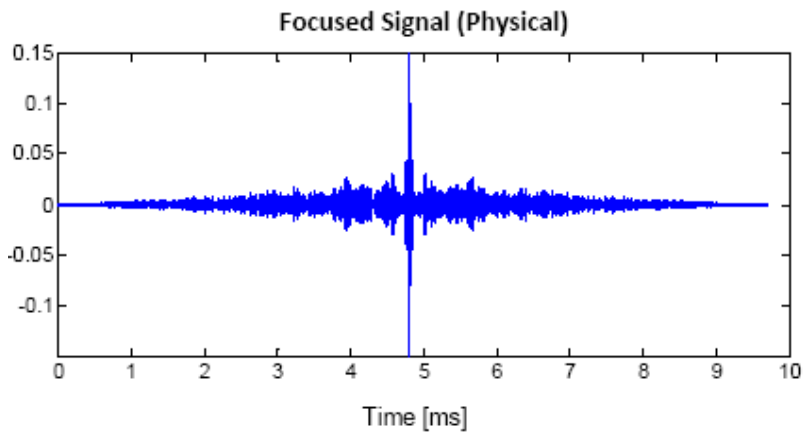
- Reverse the previous signal and transmit it back to its source
- Focuses all modes and paths to one time point
- **The more multiple paths and modes, the more powerful the focus**

Time reversal applied to flaw (change) detection

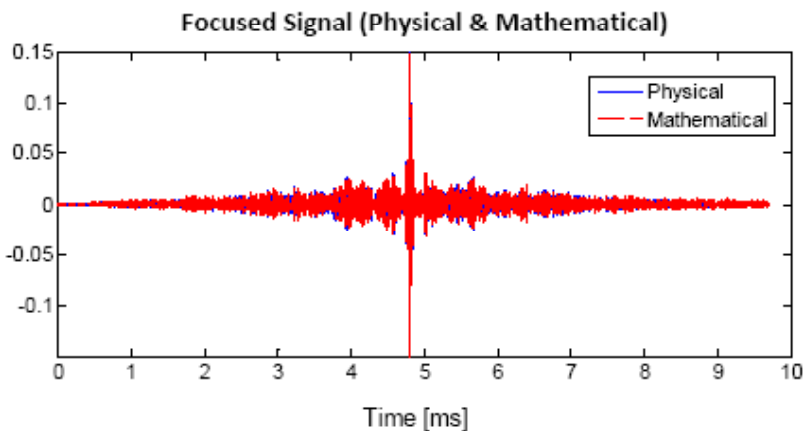


- Top: typical record
- Middle: change from flaw, or noise? Who knows?
- Bottom: time reversal shows an unmistakable central peak from flaw
- Again, the more multiple modes and paths, the more sensitive the detector

Time reversal can be performed mathematically



- By theory, only one data record is needed
- By theory, time reversal can be calculated
- In practice, the methods give identical results



Summary

- Research expertise in signal processing and radar is applied to guided wave ultrasonics
- The **problem** of multiple paths and modes becomes the **benefit** of multiple paths and modes when time reversal is employed
- Potential for structural health monitoring with resident transducers
- Initial results obtained in first year
- Interdisciplinary research, typical of CenSCIR and other units at Carnegie Mellon University