Piezoelectric Active Sensing for Damage Detection in Pipeline Structures

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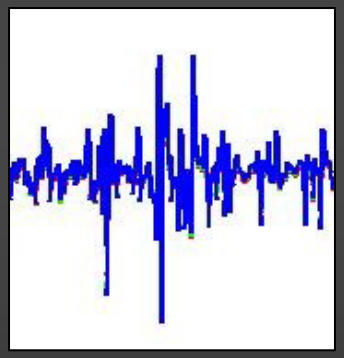
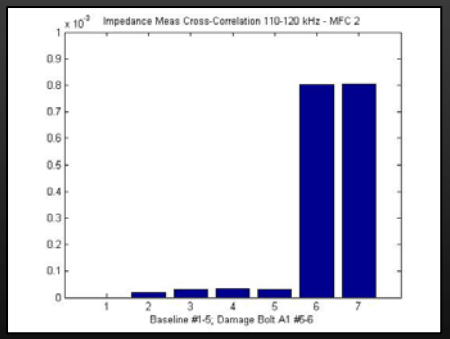
This presentation evaluates the performance of a piezoelectric pipeline health monitoring system

Introduction and motivation



Background of damage detection methods



Results and future work

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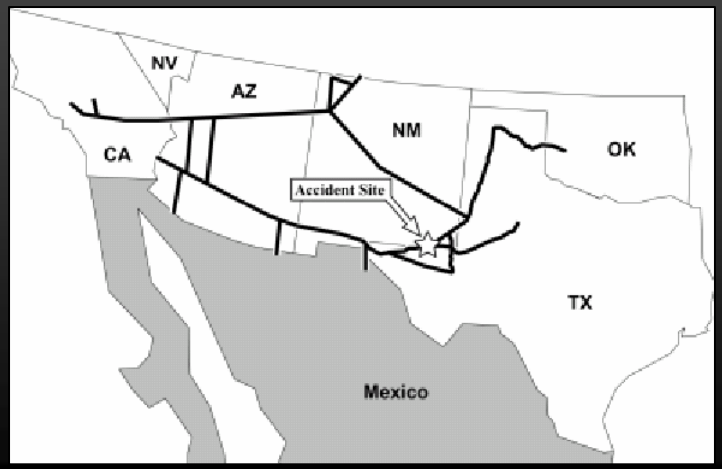
Introduction

- Millions of miles of pipelines exist in the US to transport natural resources.
- Pipelines are subjected to various failure modes during normal operating conditions and natural disasters.
- A low-cost, advanced piezoelectric-based pipeline monitoring technique is investigated in this study.



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A real-time health monitoring system is needed to detect and minimize pipeline related accidents

Resulting fire from gas pipeline rupture at El Paso

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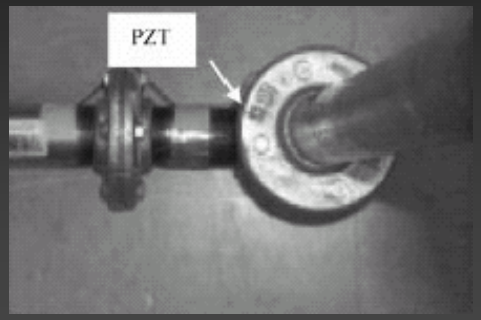
The advantages of a health monitoring system have fueled similar research



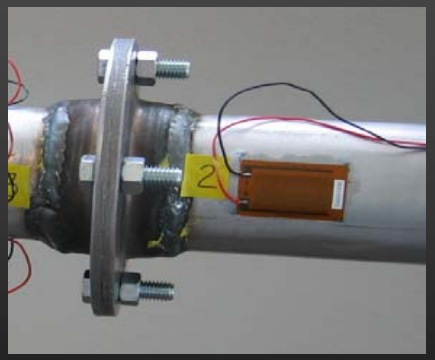
Park, Cudney, Inman (2001): Studied damage to joint connections in pipes

Cawley, Alleyne, Lowe, Pavlakovic (2002): Lamb wave propagation through pipelines

Southwest Research Institute (2001): Guided waves using magnetized ferromagnetic strip.

The goal of the project is to test the feasibility of a low cost, real-time pipeline SHM system

- Current research investigates the use of more advanced, flexible Macro-fiber Composite (MFC) for pipeline monitoring
- MFC patches offer advantages over traditional ceramic PZT materials



[MFC, (Wilkie et al, 2000), Courtesy of NASA Langley and Smart Materials Corp.]

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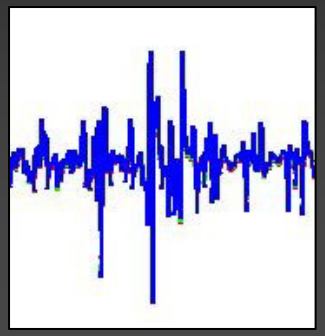
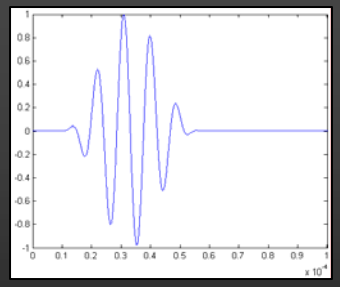
Two SHM techniques are integrated for pipeline Monitoring using MFC patches



Impedance-based Structural Health Monitoring: joint monitoring



Lamb Wave Propagations: surface monitoring

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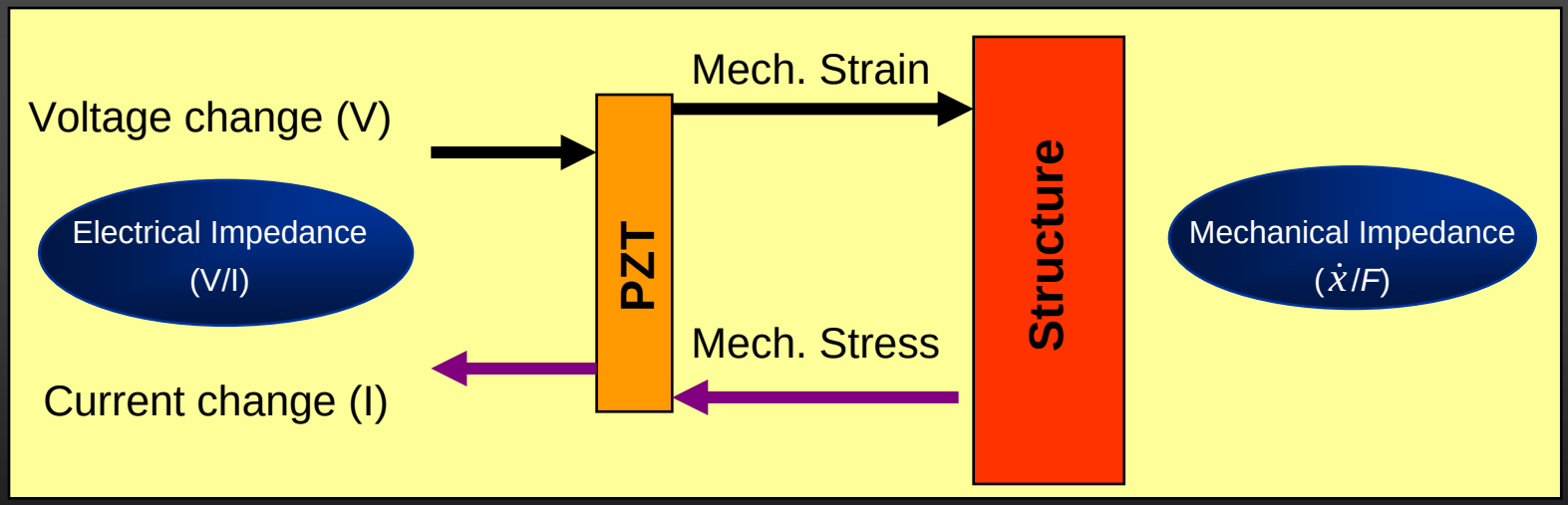
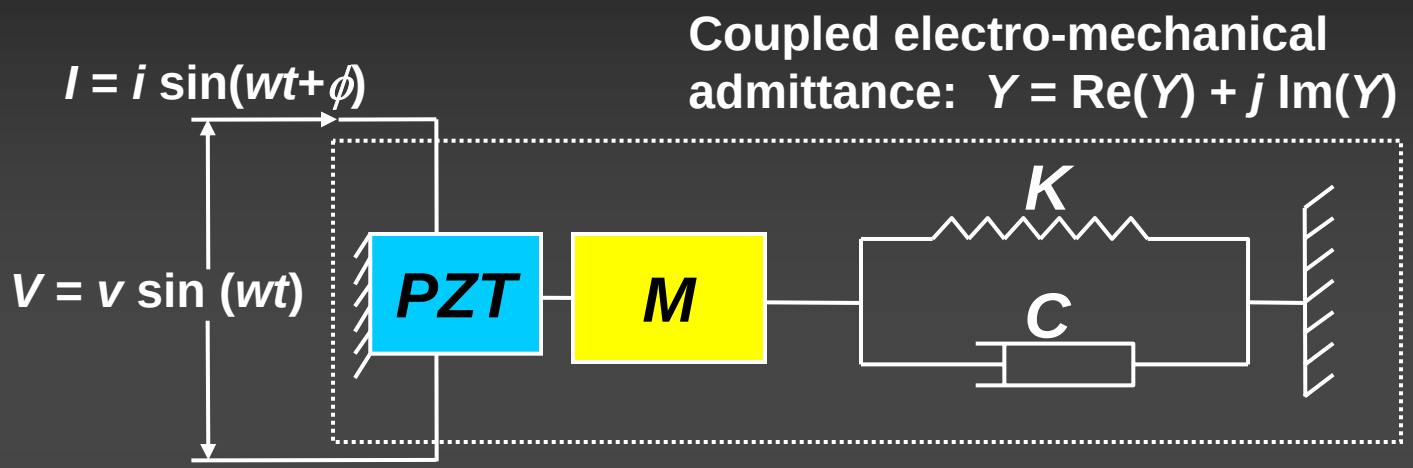
PZT patches used to measure the mechanical impedance of a structure

- mechanical impedance of a structure is coupled to the electrical impedance of PZT
- mechanical impedance used to monitor structural damage at high frequency ranges



The electrical impedance of the PZT patch can be used to monitor the damage of its host structure

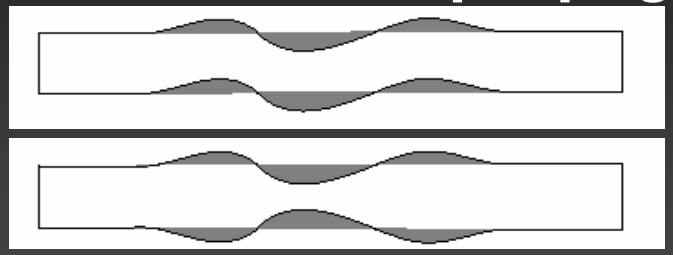


$$Y = i\omega a\left[\varepsilon_{33}^{T}\left(1 - i\delta\right) - \frac{Z_s(\omega)}{Z_s(\omega) + Z_a(\omega)}.d_{3x}^{2}\,Y_{xx}^{E}\right]$$

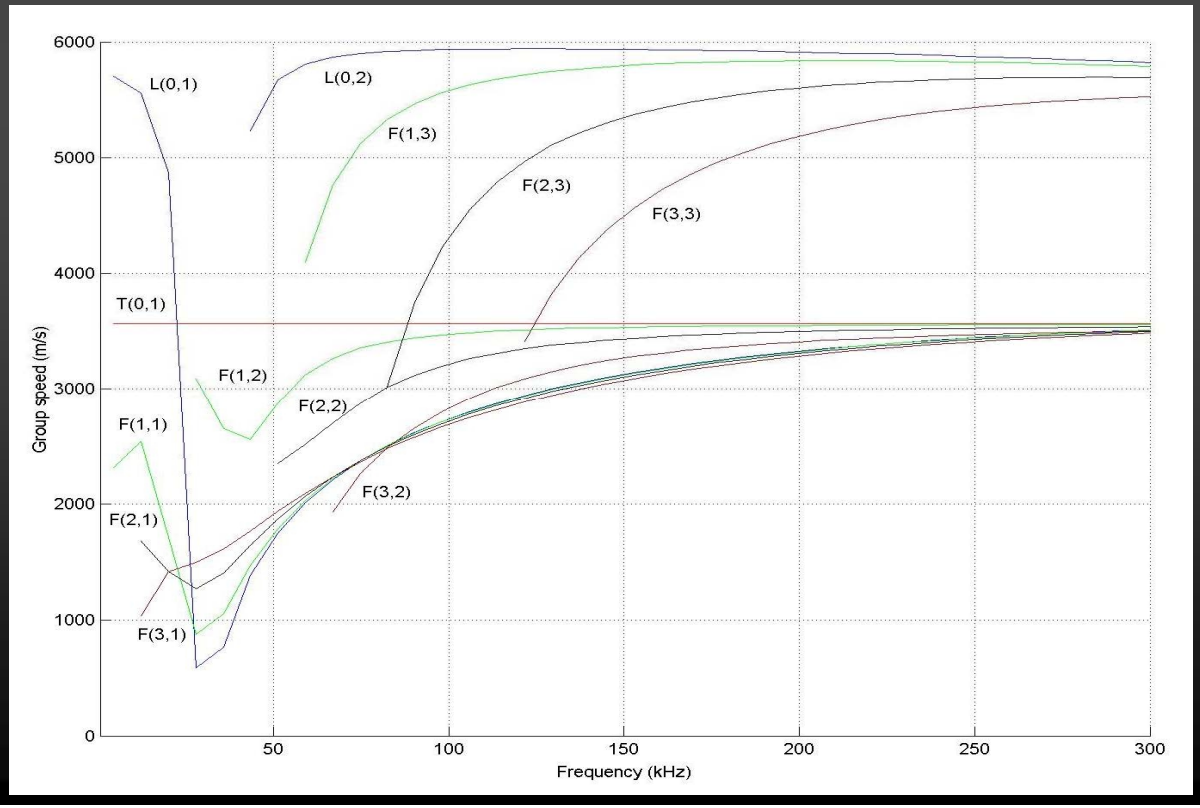
[Sun, 1995]

PZT patches are used to excite Lamb waves in a structure AND measure corresponding responses

- Two fundamental modes for propagating waves
  - Asymmetric:
  - Symmetric:



- Select least dispersive freq. band for desired mode



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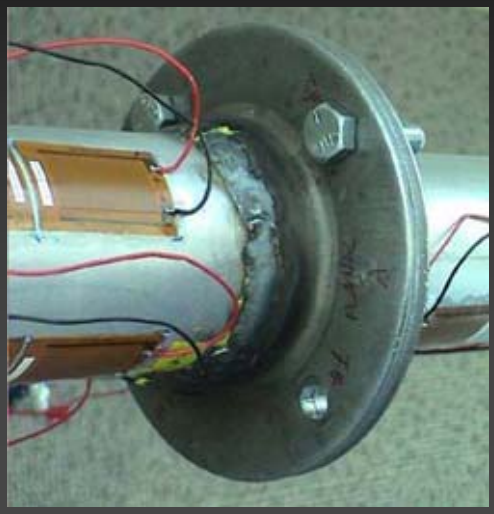
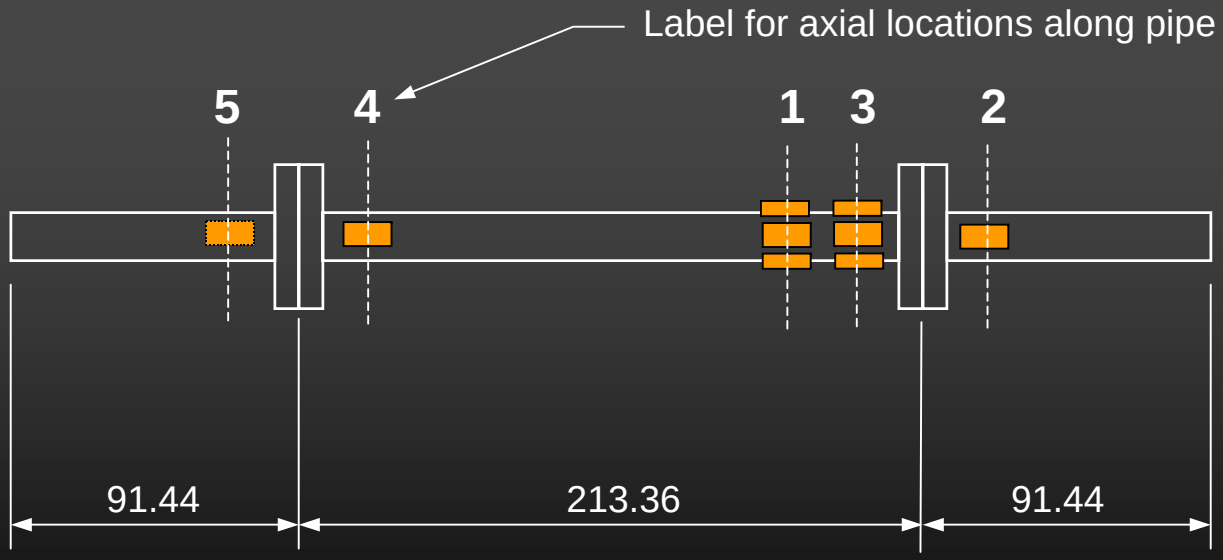
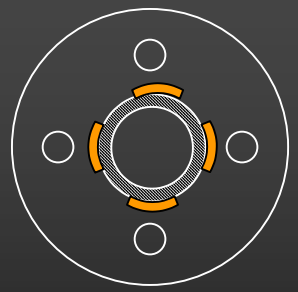
Test structure consists of three pipe sections bolted together with flanges







All dimensions in centimeters

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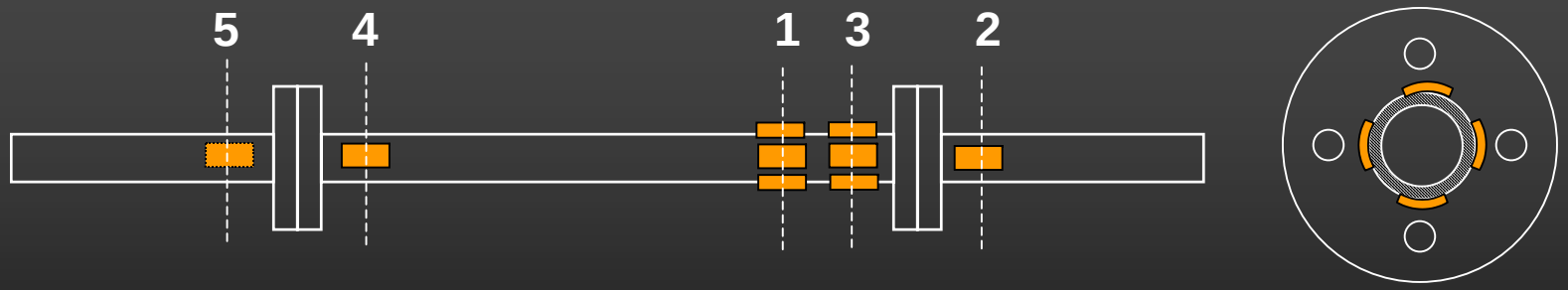
Several methods were used to simulate damage in the flanged joints and in the pipe's surface

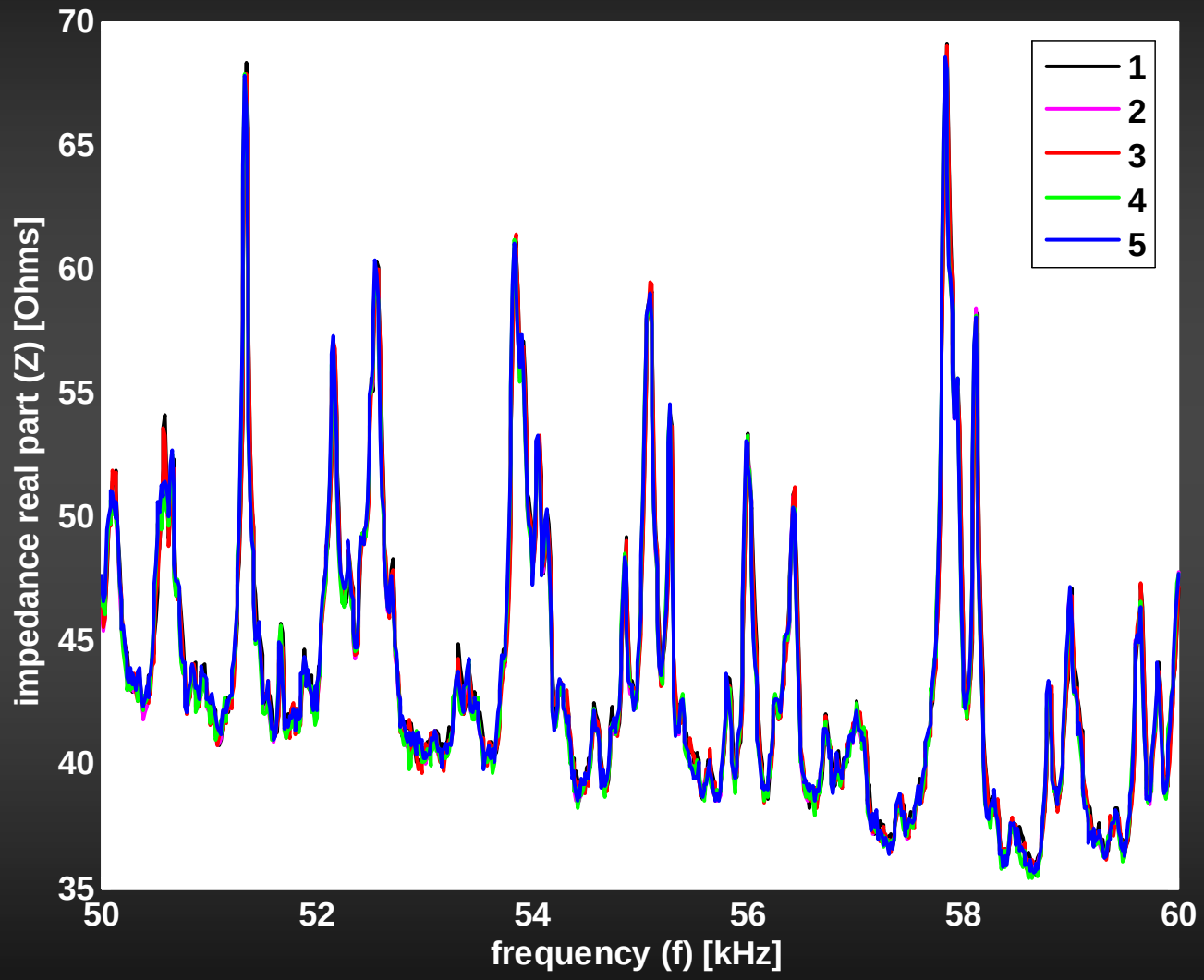
- **Impedance measurements**
  - **joint damage with bolts**

Damage case	Description
Case *1*	Bolt one removed from Flange *A*
Case *2*	Bolts one and two removed from Flange *A*
Case *3*	Same bolts as Case *2* , but pipe rotated 180



- **Lamb wave measurements**
  - **surface damage with muffler clamp**

Impedance: Several impedance measurements were made to monitor the condition of joints



Baseline measurements are repeatable

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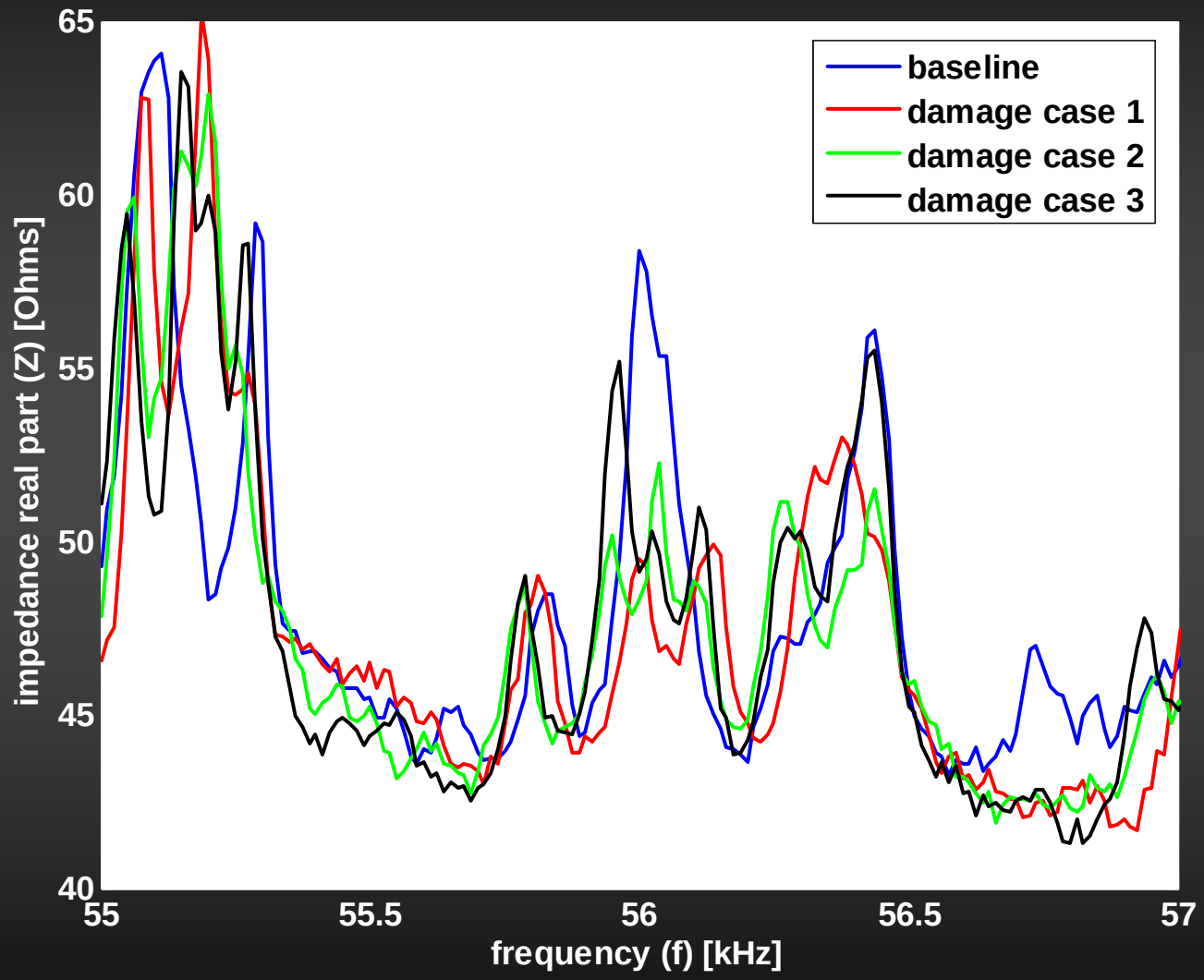
“Joint damage” was introduced by loosening connection bolts



Damage causes changes in impedance

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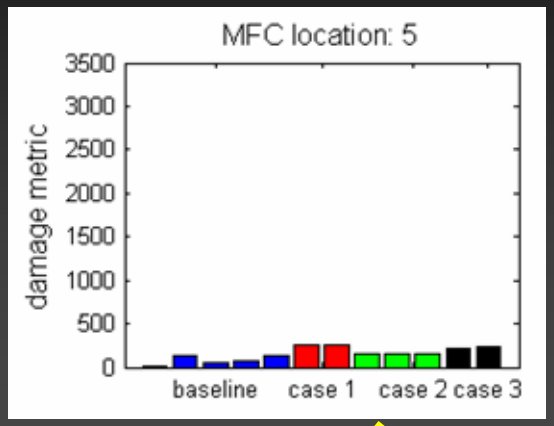
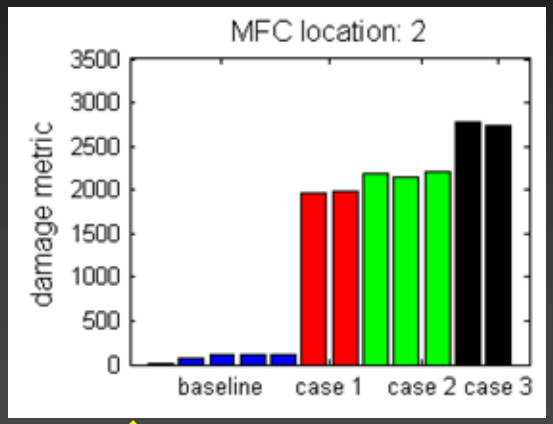
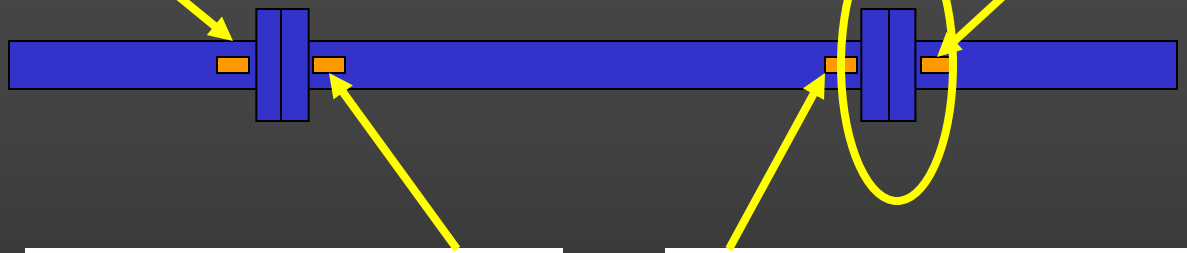
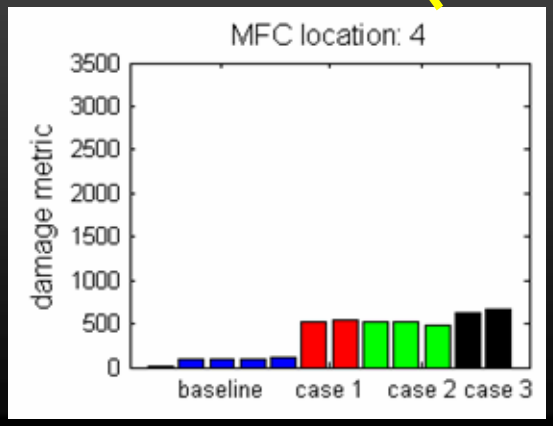
Damaged joint could be detected and located by looking at correlation-based damage metric

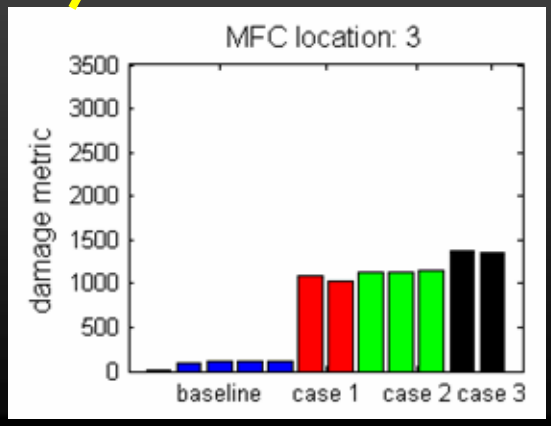




Damaged Joint







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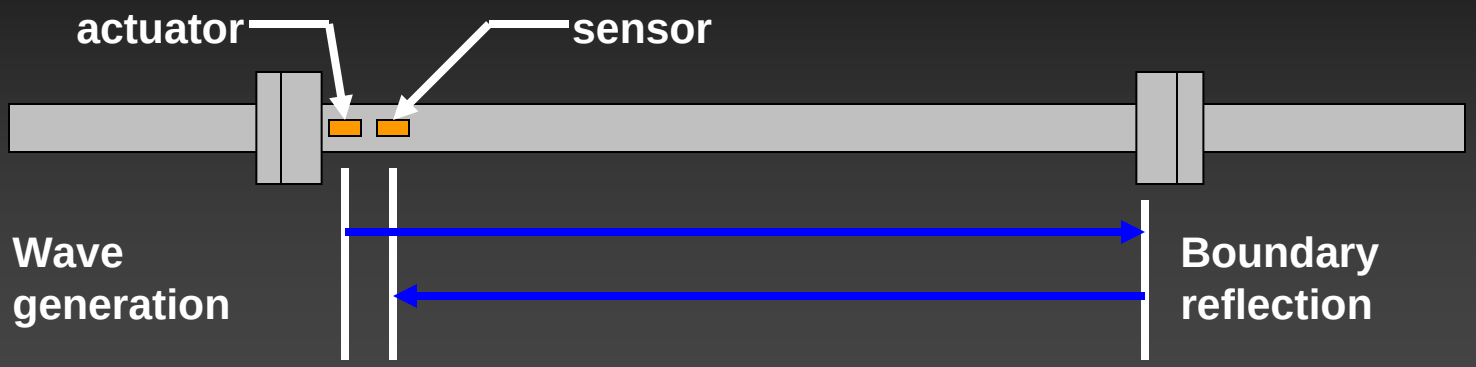
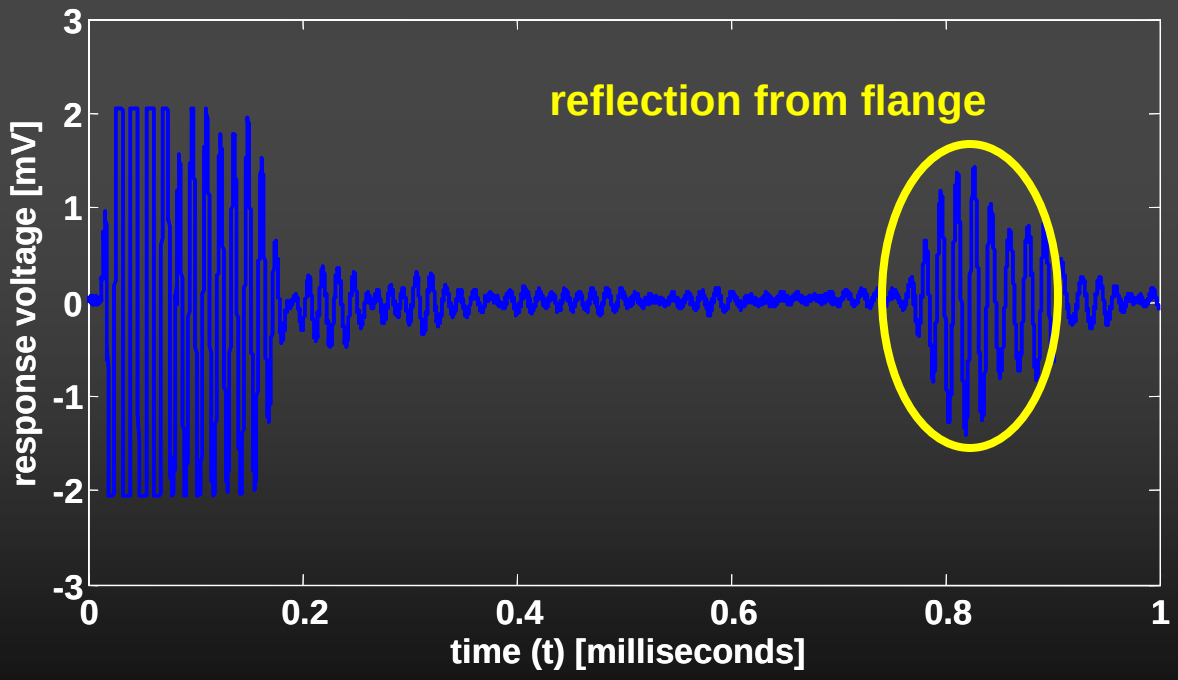
Lamb wave method tracks the attenuation and reflection of the waves to detect damage





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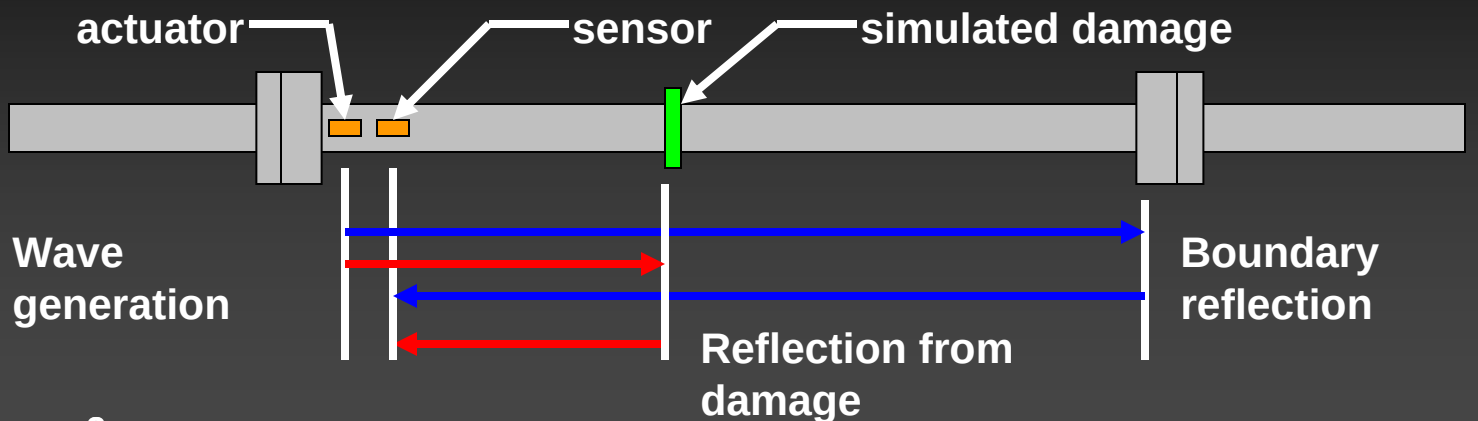
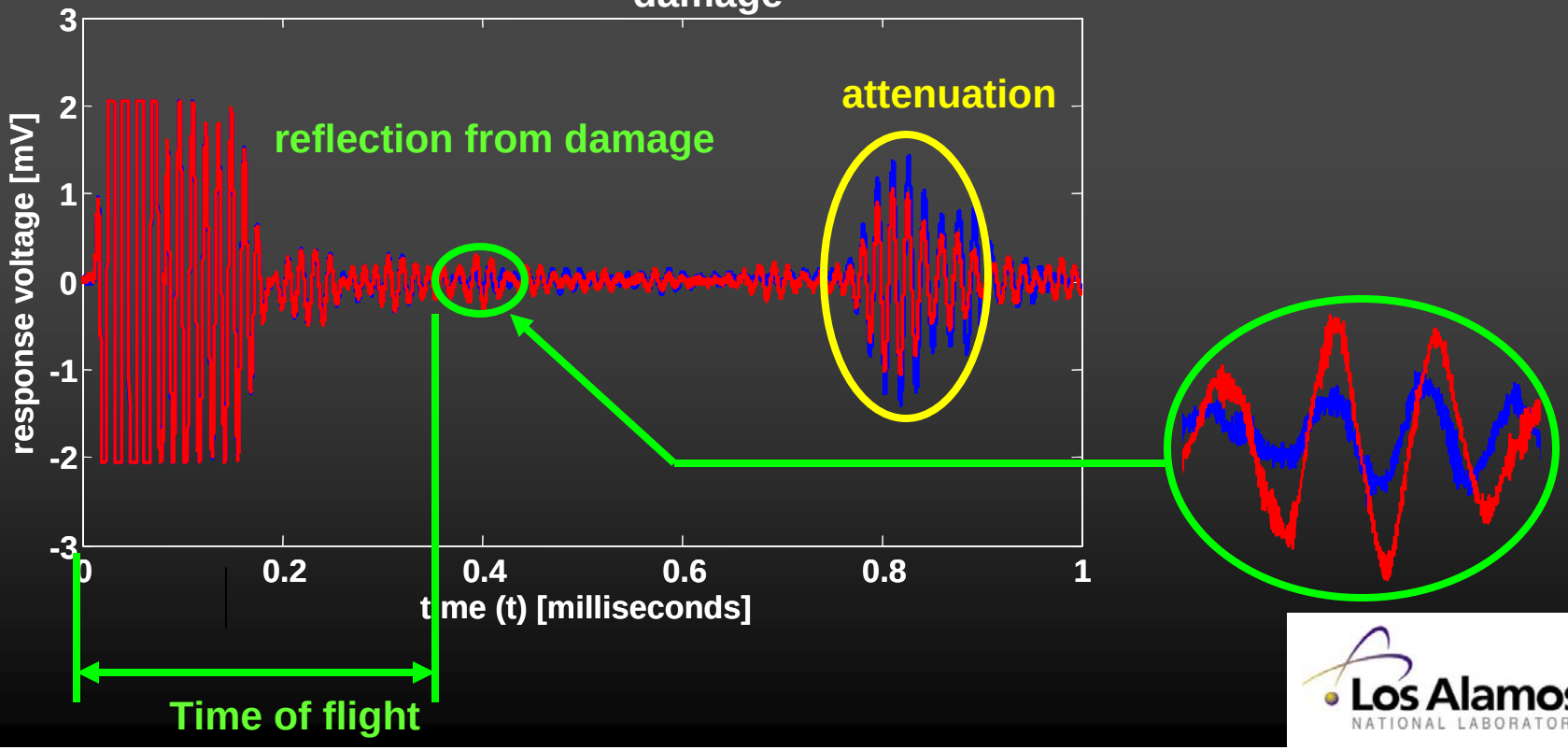
Lamb wave propagation results show that damage can be detected and possibly located





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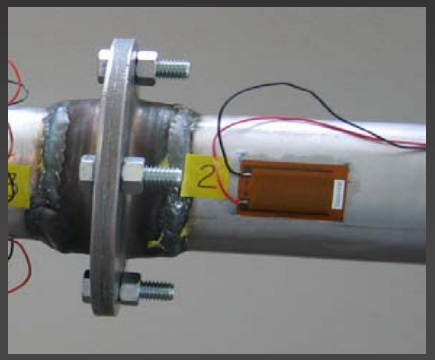
We have presented a method of pipeline damage detection using piezoelectric, active sensing.

Low cost integrated solution



Impedance method

Lamb wave propagation

Joint damage

Corrosion damage

Real time structural health monitoring system

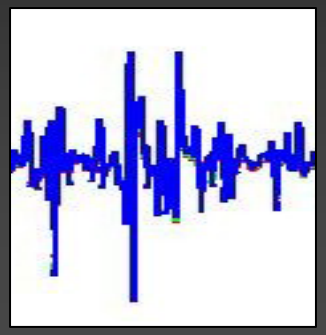
Conclusion

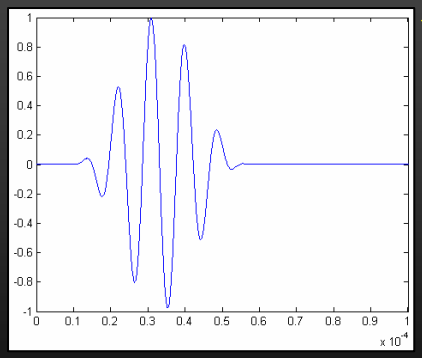
- Results show that the proposed integrated approach is successful.
- Joint damage can be detected and located using the impedance methods.
- Attenuation/Reflection features were efficiently used to identify simulated (crack/corrosion) damage in the main body of pipelines.
- MFC shows its potential for pipeline systems.

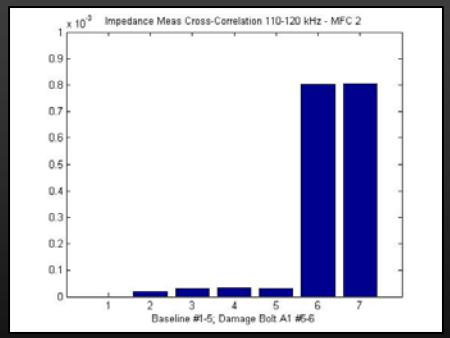
Future Work

- Optimal Number of Sensor/Actuators
- Portable system to simplify setup application
- Advanced data processing techniques
- Sensor self-diagnostics

Preliminary results clearly show the feasibility of our integrated active sensing for pipeline monitoring







Questions?

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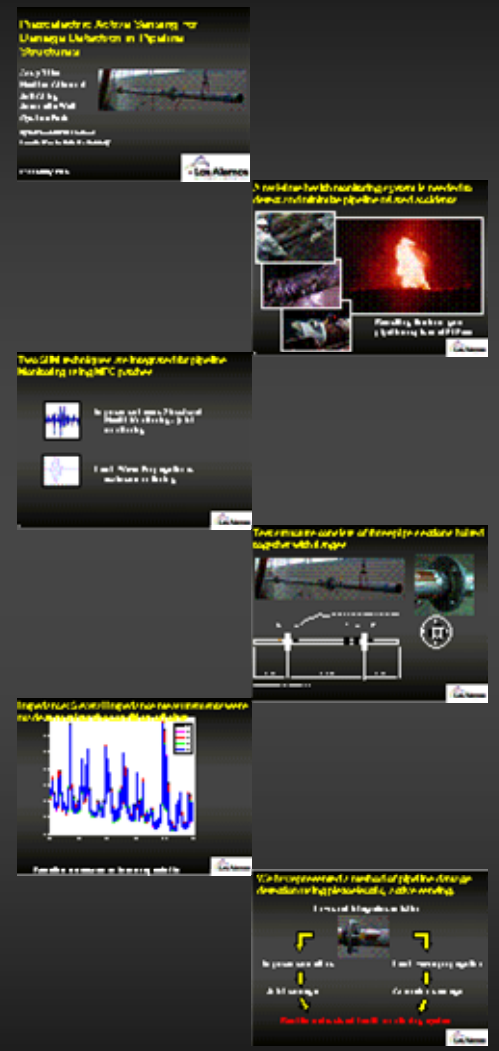
Presentation Map

Questions?

- Title slide and Introduction (1-3)
- Purpose and objectives (4-6)
- Background theory (7-10)
- Experimental procedure (11-12)
- Results (13-17)
- Conclusions (18-21)



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