Long term stability analysis of a guided wave SHM system for platelike structures

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Outline

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  - Motivation
  - Background
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- Ruggedized SHM system development
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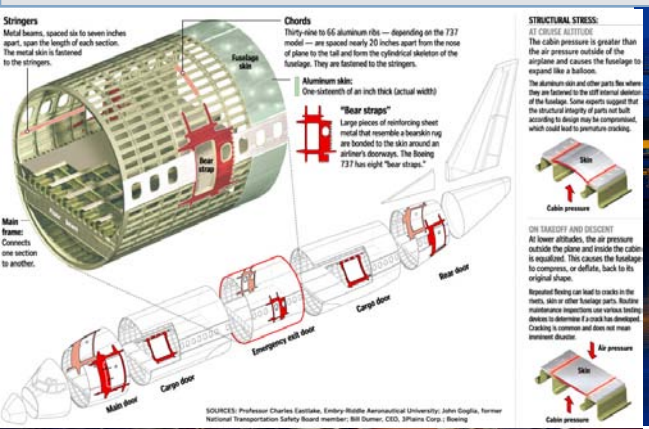
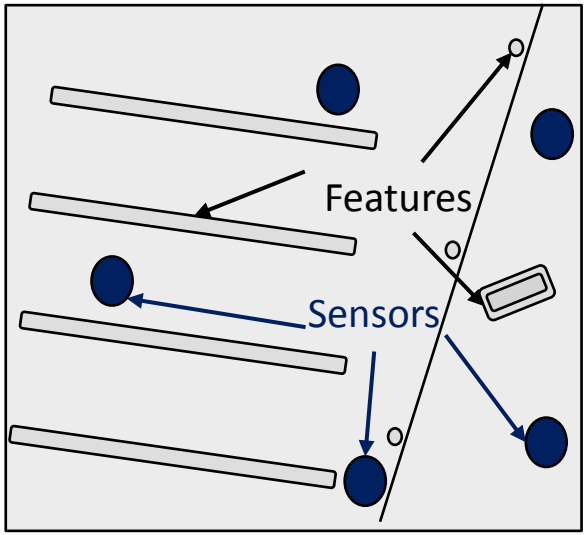
Introduction



Motivation

Guided wave transducers in sparse arrays



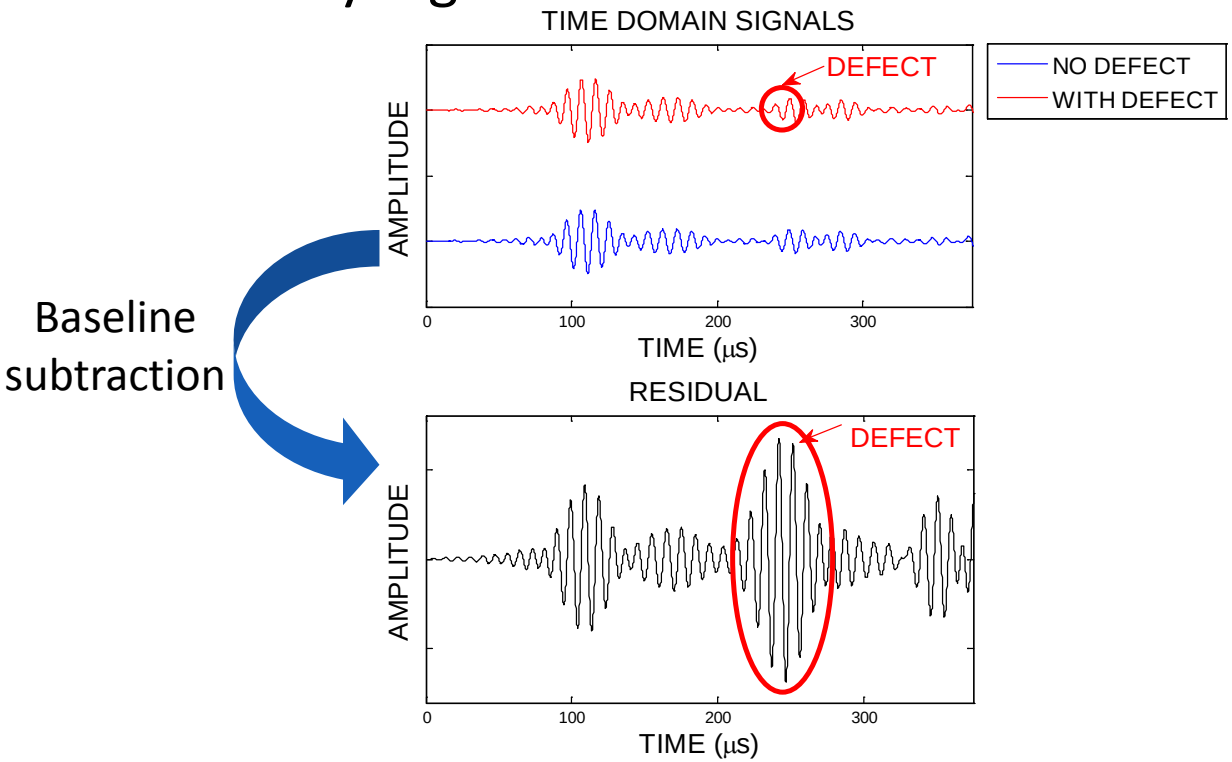
(1) Suitability for large area inspection

(2) Defect sensitivity

(3) Complex feature effects

Issues for monitoring platelike structures

- Feature density high in 2D

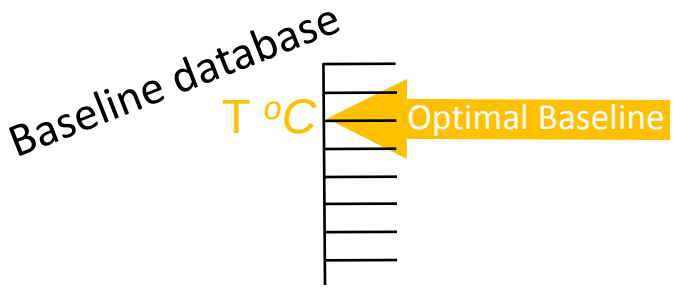


- Environmental variability effects
  - E.g. Temperature induced delays $\delta t \propto \Delta T$

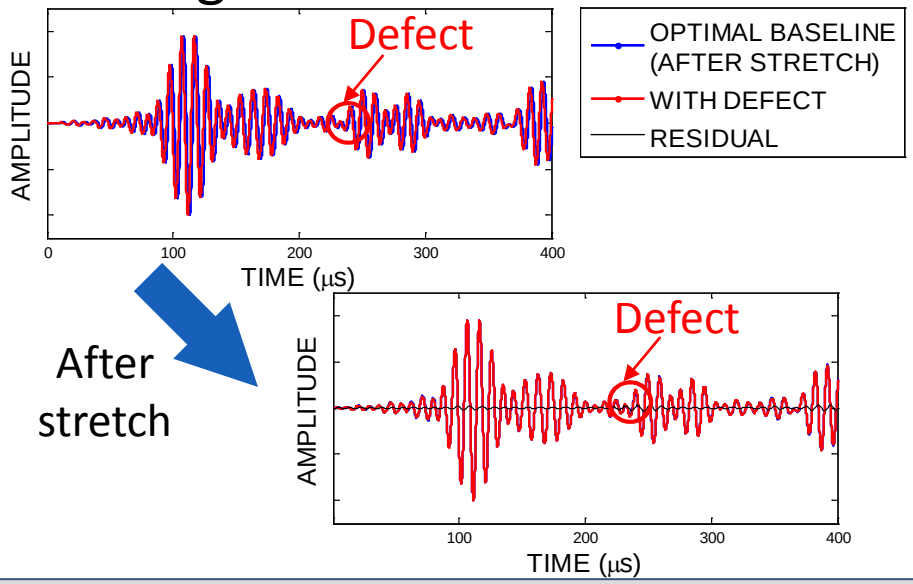
Compensation strategies

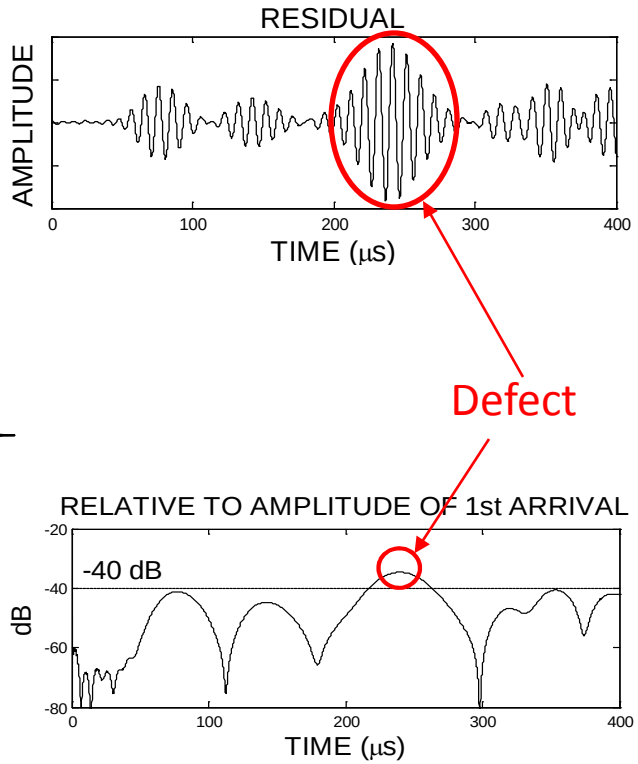
Temperature compensation strategies

- Optimal baseline subtraction

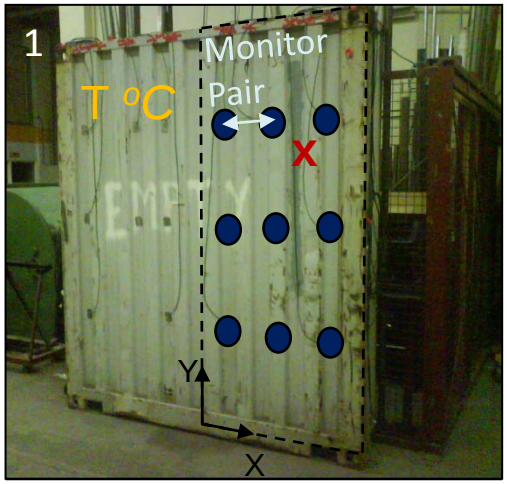


- Baseline signal stretch





Defect detection in container panel



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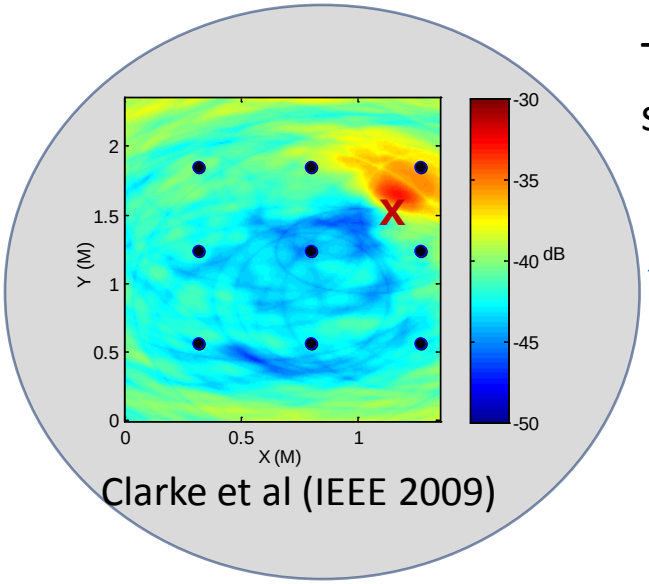
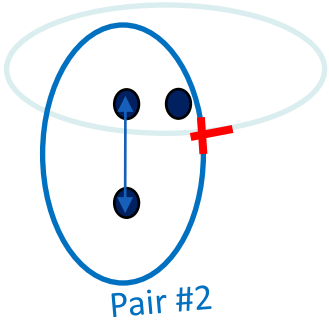


Clarke et al (IEEE 2009)

Triangulating with all sensor pairs

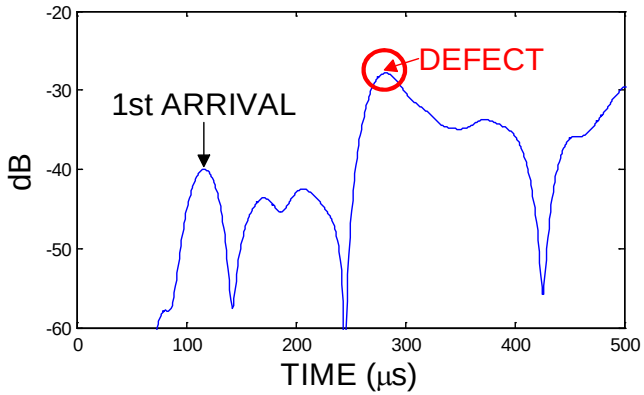
4



Ellipse imaging

2

Compensated baseline subtraction



3

Performance in real life scenario?

- Long term testing of structure in exposed weather
  - Need to ruggedize transducer
- Assess feasibility and variability of reliable monitoring
  - Robustness
  - Baseline stability
- Study on simple plate and complex structure

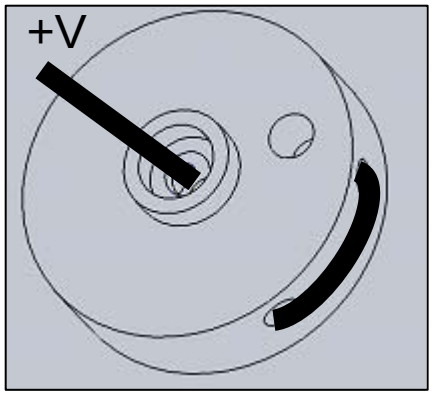
Transducer design

- Phase stability
- Pure mode excitation

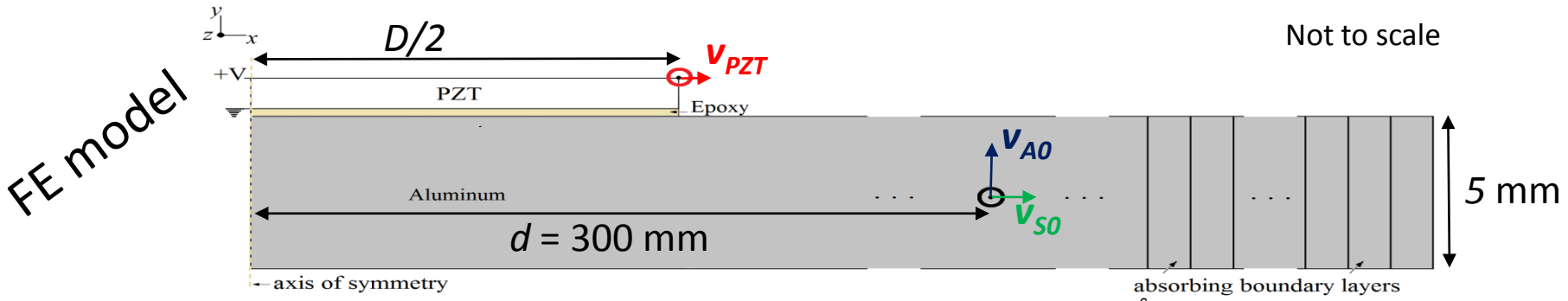
} Finite element analysis

- Strain relief
- Waterproof
- Electrical connectivity/ grounding

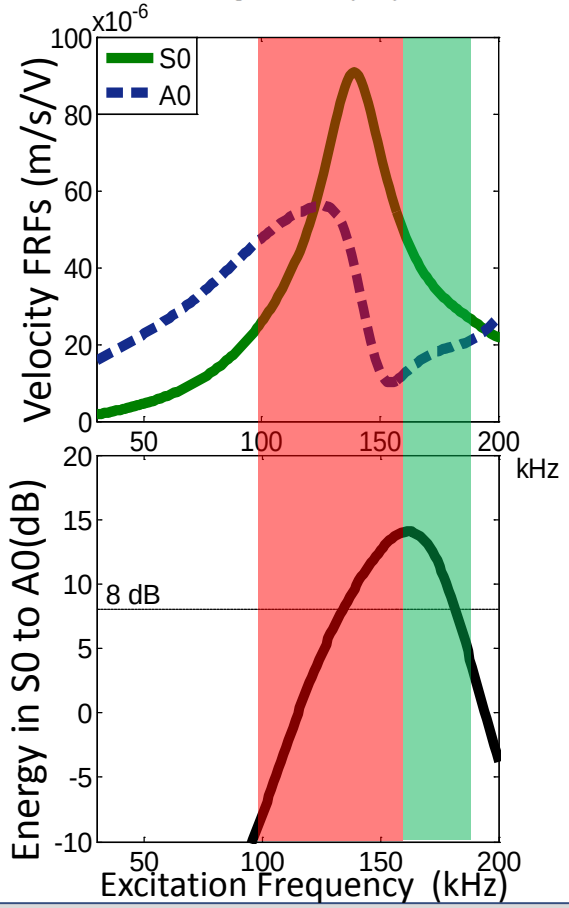
} Cap



Ruggedized SHM system development

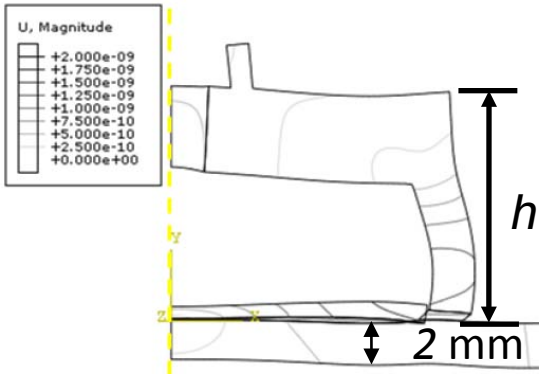


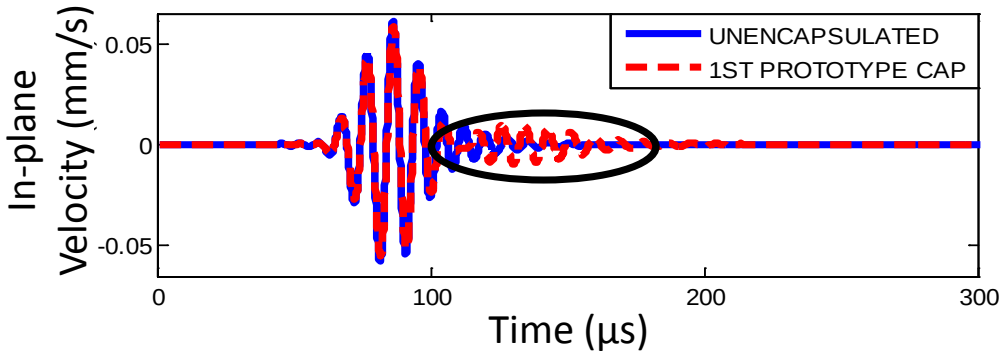
- Want to excite PZT
  - Strong S0
  - Off PZT resonance (outside red region)
  - High S0/A0 ratio (green)



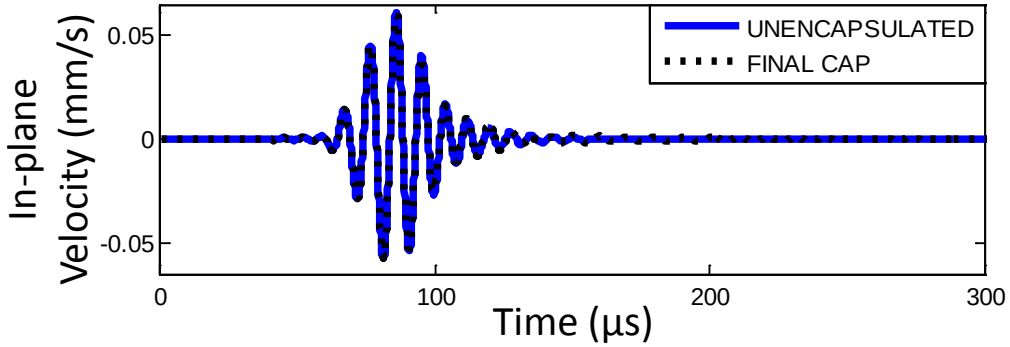
Minimize cap reverberations

- Undesirable coupling of portal frame dynamics in excited S0





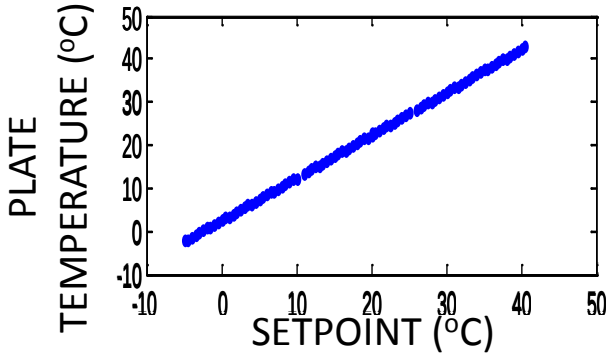
- Parametric + material changes allow shift to ω_n and damping



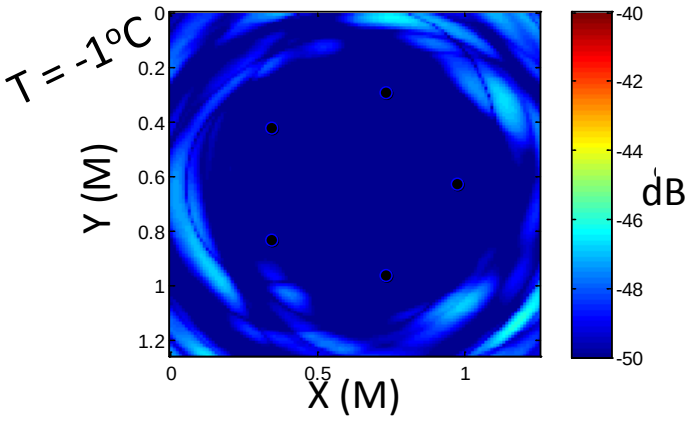
Final transducer

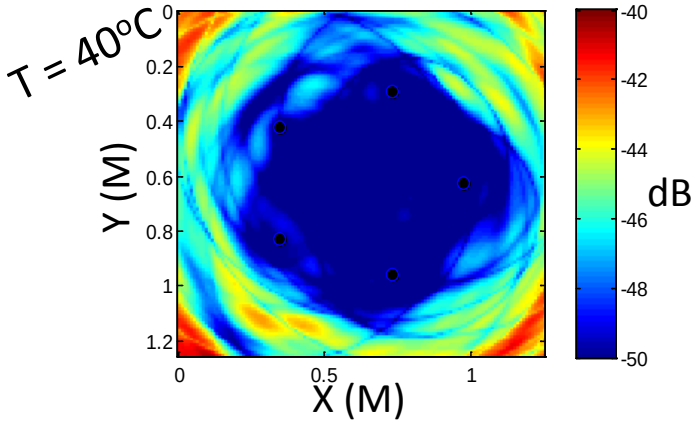
Baseline database collection

- Baselines collected after 3 months of outdoor robustness testing
- Signals acquired at 0.5°C increments in [-5, 40]°C



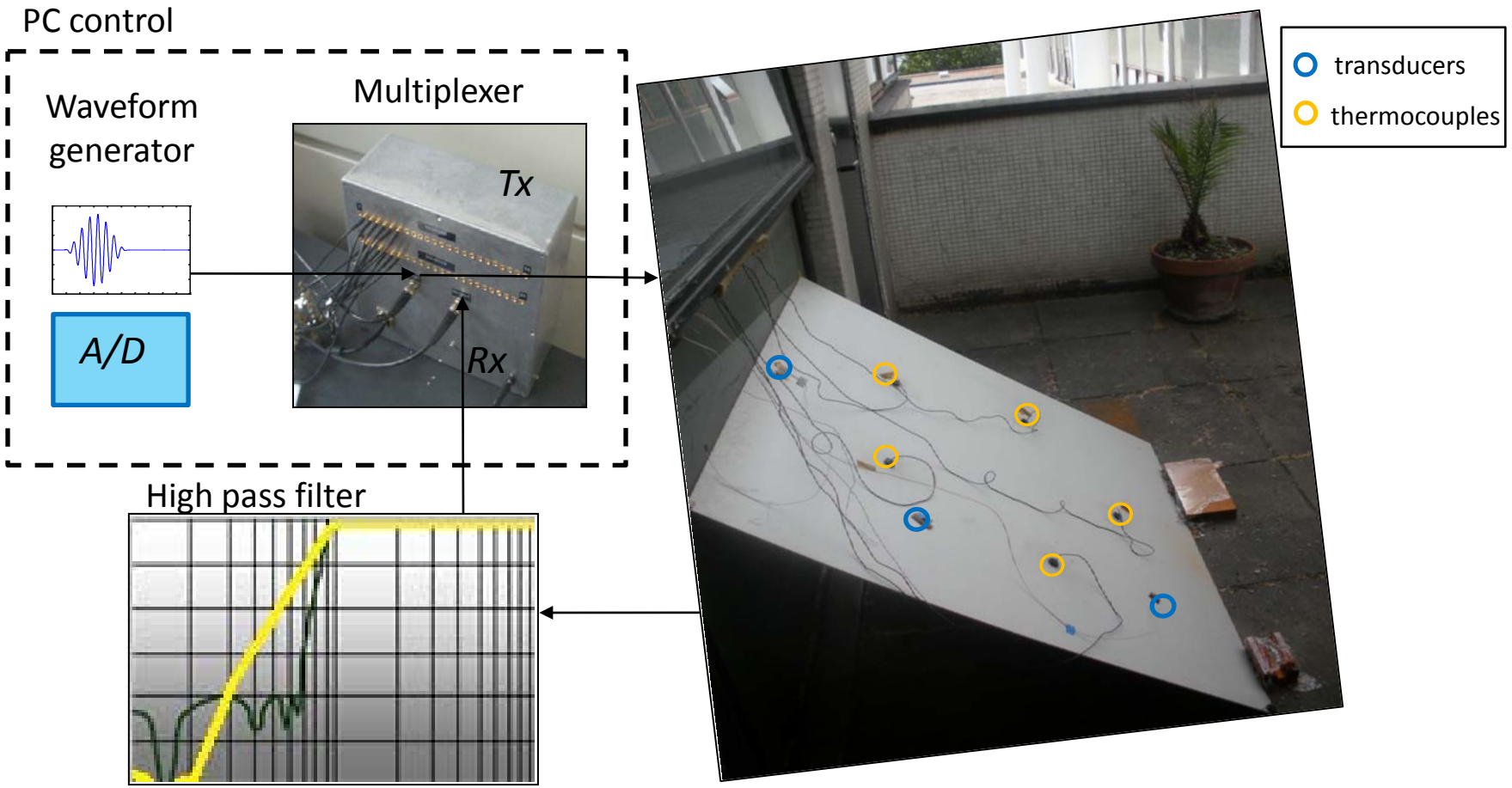
- *Noise floor* imaged with 0.5°C gap to nearest baseline throughout range





<-40 dB ➔ Sufficiently low noise for SHM

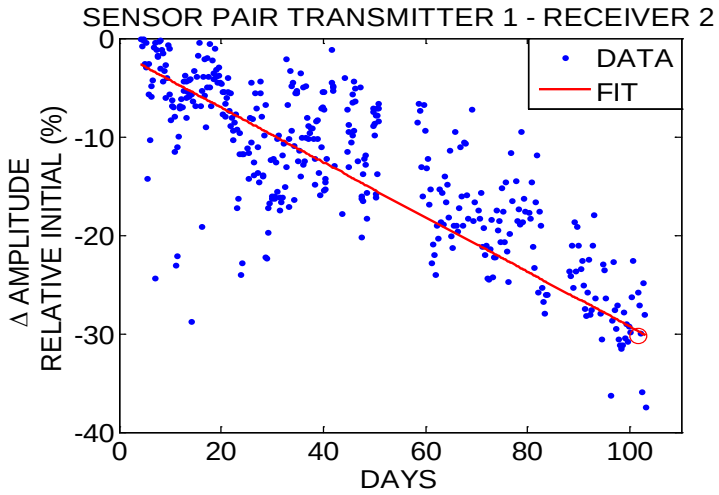
Instrumented plate outdoors



- Monitoring since beginning of March for +4 months

Robustness

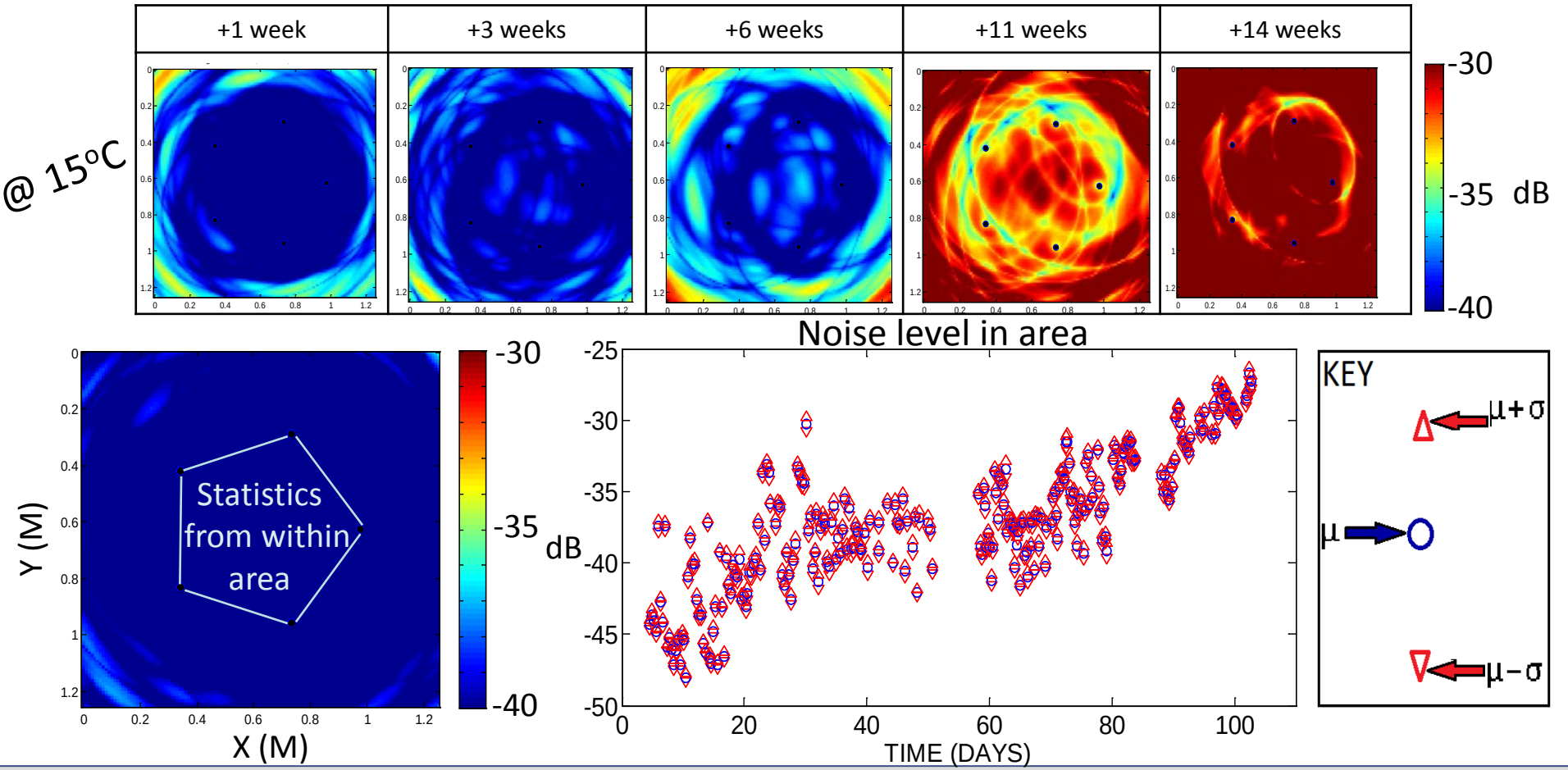
- Tx-Rx ok for $\frac{1}{2}$ yr through temperature swings (-10 to 30°C), rain, light snow
- Signal amplitudes



  - >80% pairs show Δamplitude
    - To -37% initial value, on average
    - Unrelated to temperature
  - Regressions on noise levels/pair indicate correlation with Δamplitude

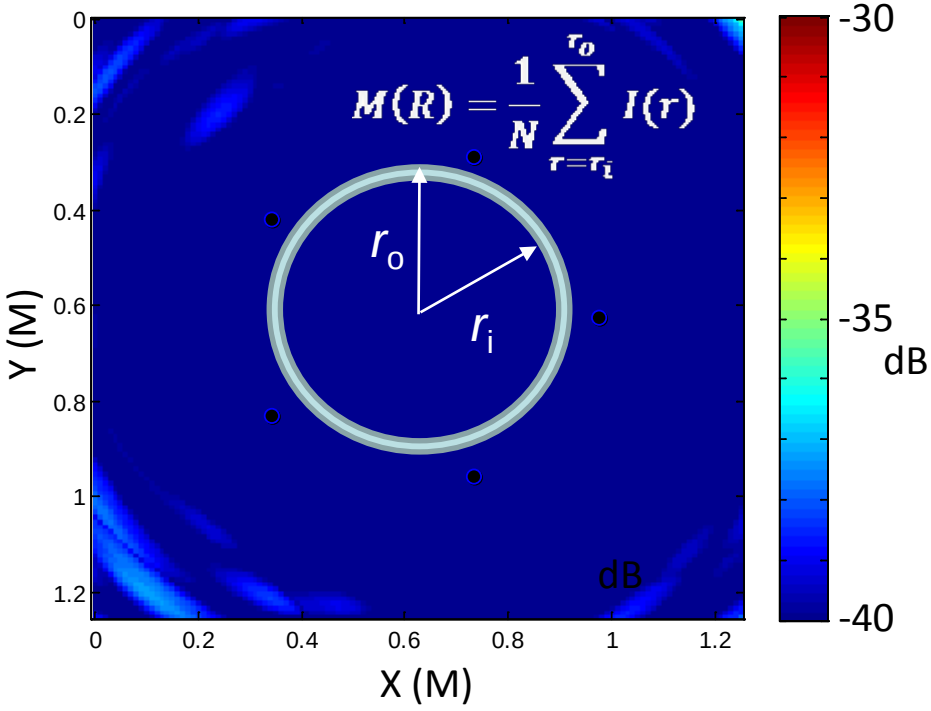
Baseline stability assessments

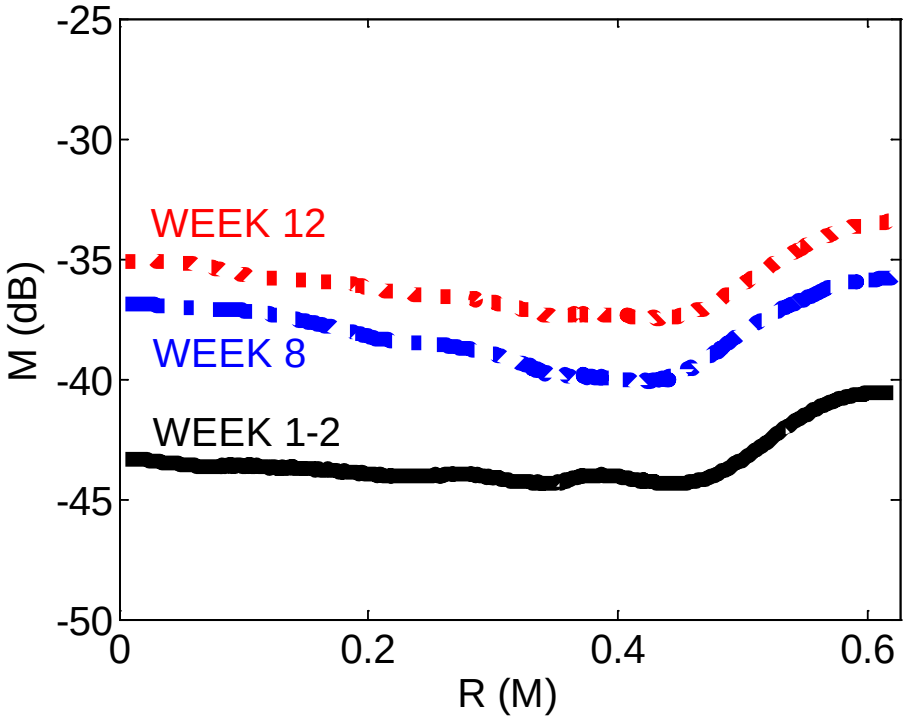
- Imaging suggests issues for monitoring small reflectors



Spatial distribution of noise

- Statistical metric suggests noise exhibits lack of sensitivity to location in coverage area





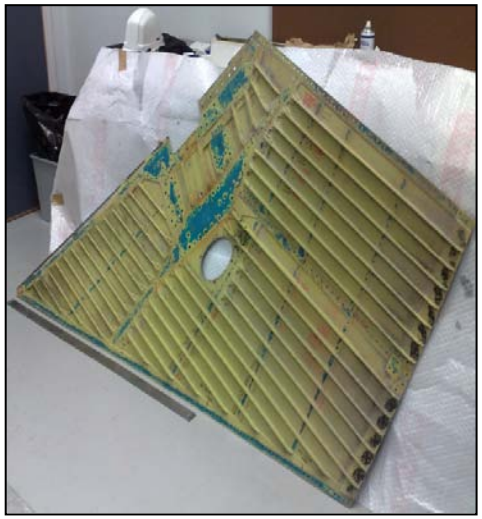
Conclusions

- Key findings
  - Rugged transduction of GW
    - feasible for >6 months
    - amplitudes decline over time identified
  - Noise floor changes quantified
    - drifts to -25 dB in +4 months observed + analyzed
    - trends don't exhibit spatial dependency

Possibility of frequent data collection and detrending

A. Galvagni talk @ 11:30 AM

- Future work
  - Continued monitoring outdoors/analysis
  - Fix amplitude decline issue
  - Quantifying defect detection sensitivity over time
  - Further prototyping of array on complex structure



Transducer @ ½ yr