Experimental Validation of UAV-Deployed Edge Sensors for Frequency-Based Bridge Damage Detection

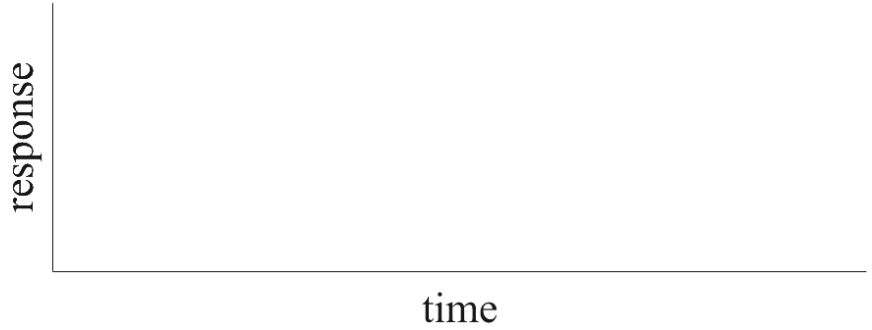
Joud N. Satme; Ryan Yount; Samuel Roberts; David Wamai;
Austin R.J. Downey; Jason Bakos; Jasim Imran

UNIVERSITY OF
SOUTH CAROLINA

Methodology | Experimentation | Results and Discussion | Future work

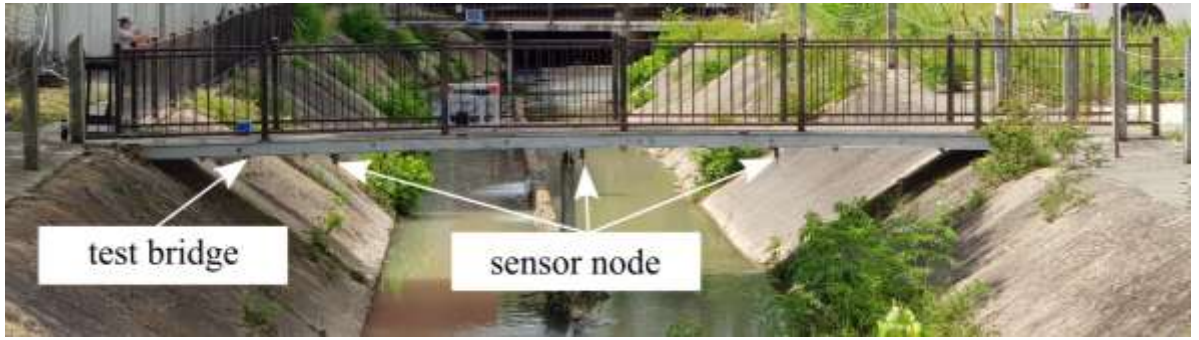
Outline

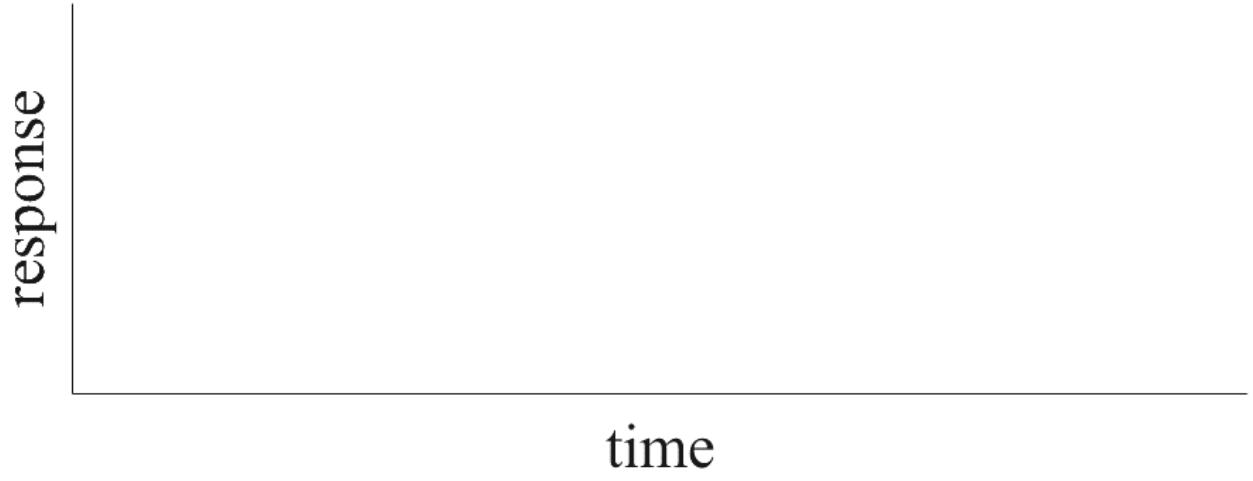
- Introduction:
  - Rapid structural health monitoring
  - Remote SHM sensing systems
  - Limitations in bandwidth and power
- Methodology:
  - UAV-deployable sensing system
  - Wireless sensing networks
  - SHM edge-processing algorithm
- Experimentation:
  - Modal frequency detection using UAV-deployable edge-computing sensing node
- Results and Discussion:
  - Frequency responses analysis
  - Sensing system strengths and experimental challenges
- Future work:
  - Sensor network algorithm enhancements
  - Rapid modal reconstruction on-edge



Introduction

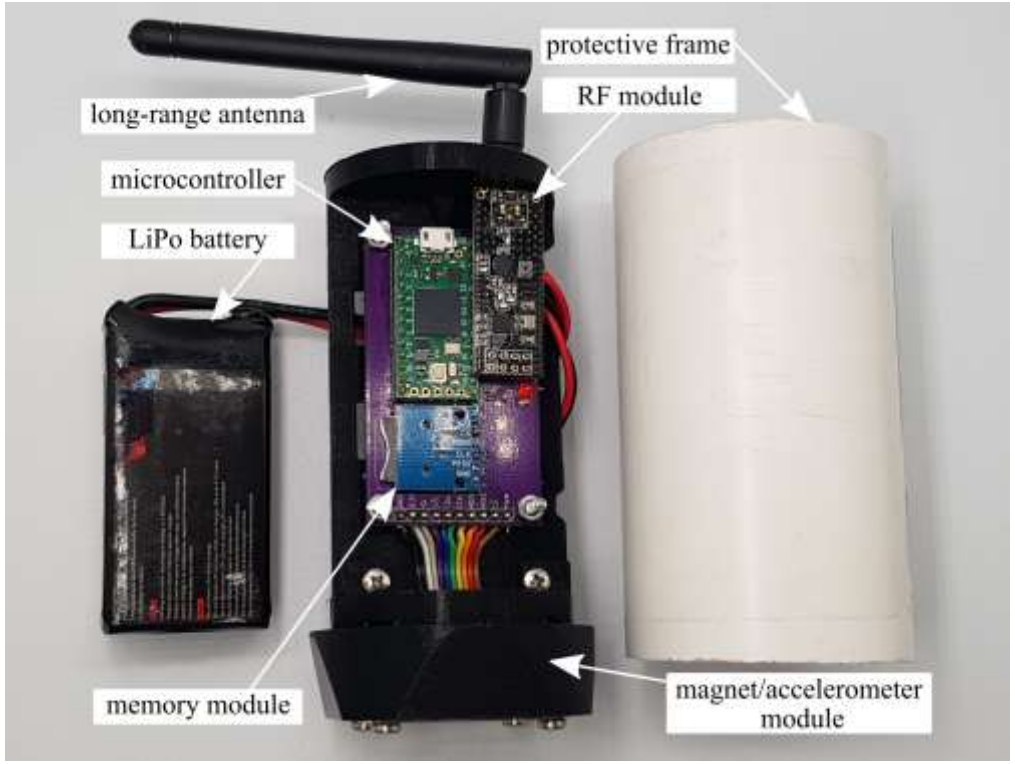
- Rapid structural health monitoring
  - The process from data collection to state inference.
  - Involves tools to facilitate rapid inspection
  - Aids in structural assessment of structures following sever weather and environmental disasters.

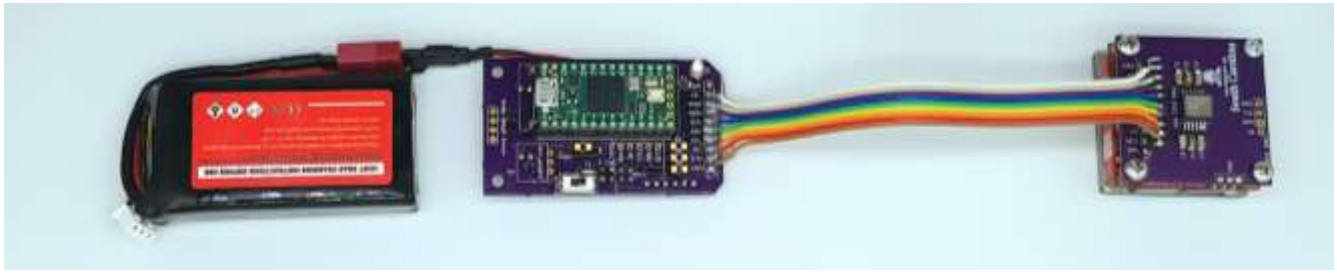


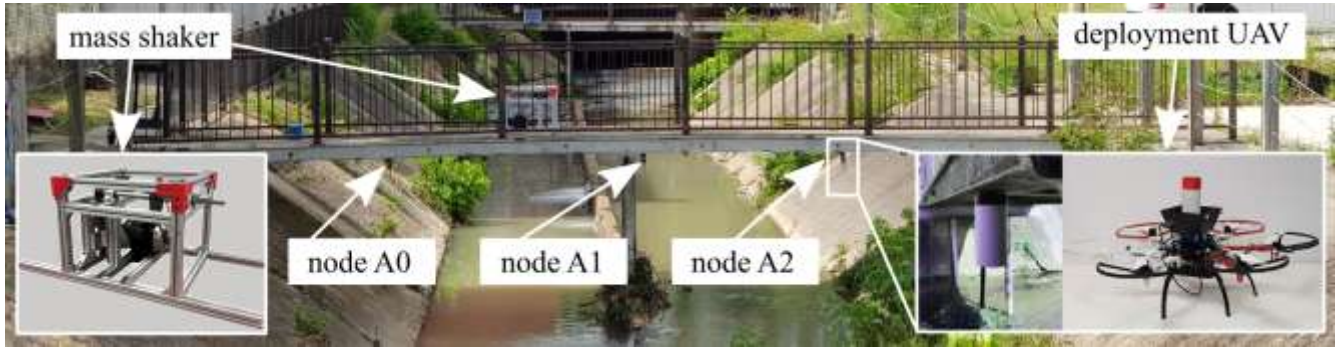


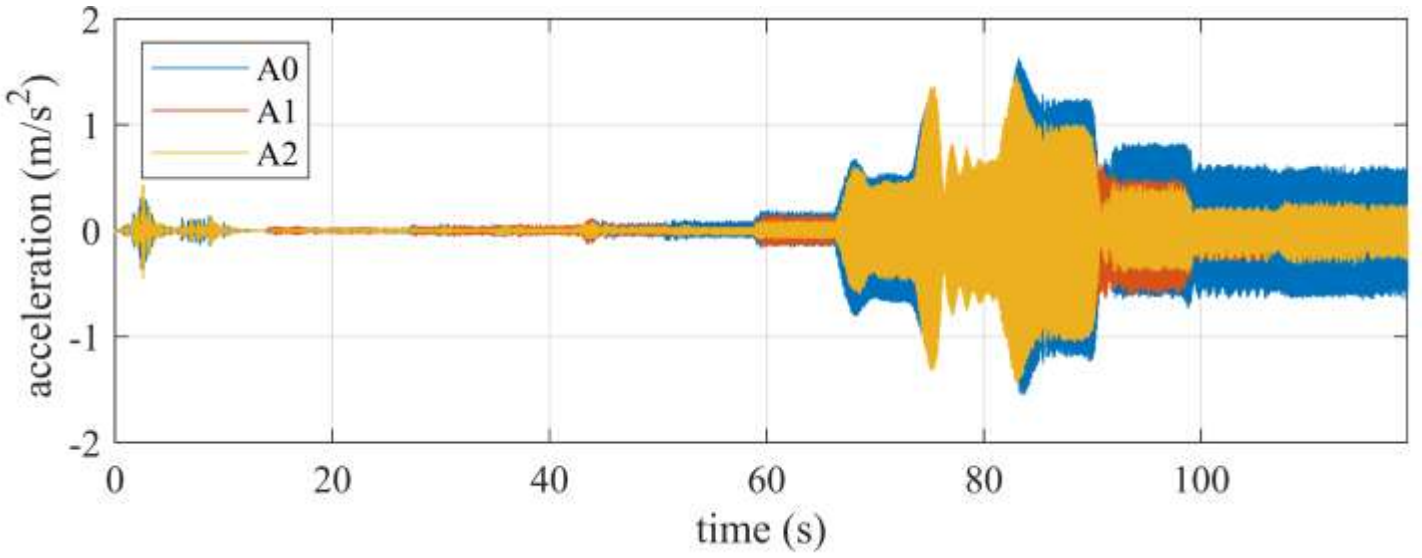
Introduction

- Remote SHM sensing systems
  - Standalone sensing units
  - Independent power
  - Wireless transmission
  - Memory storage capability



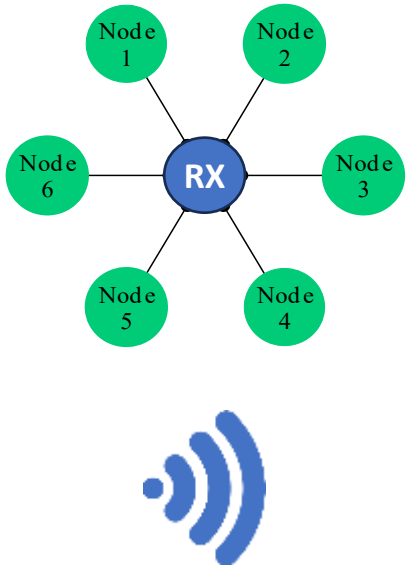


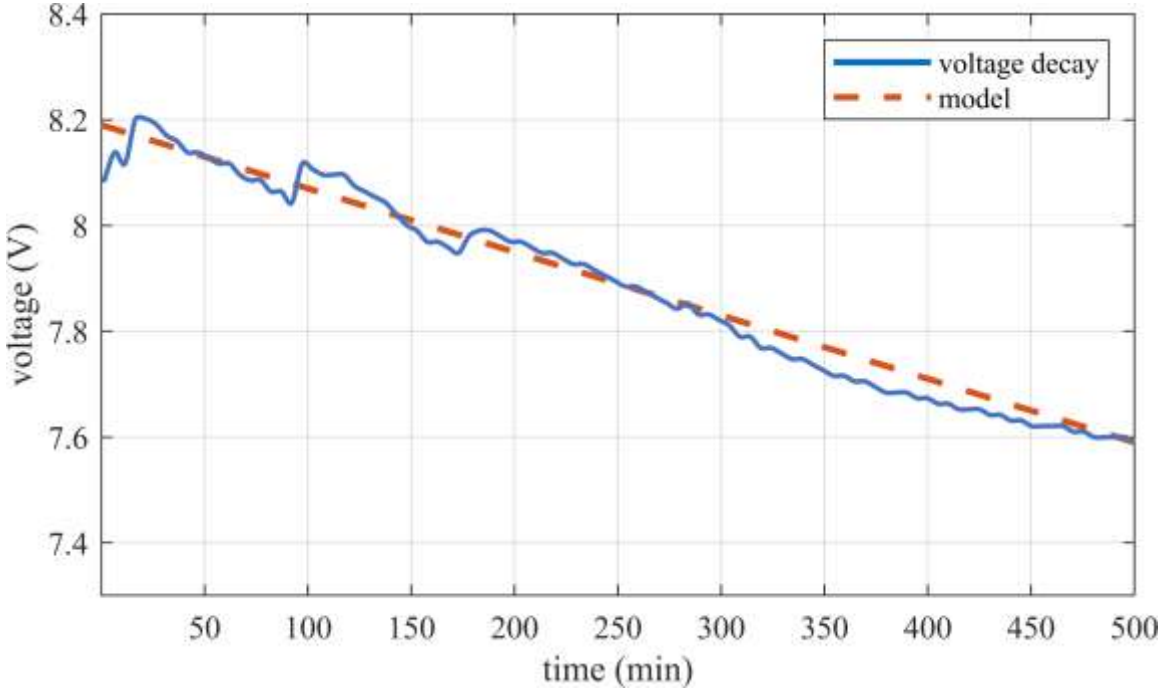


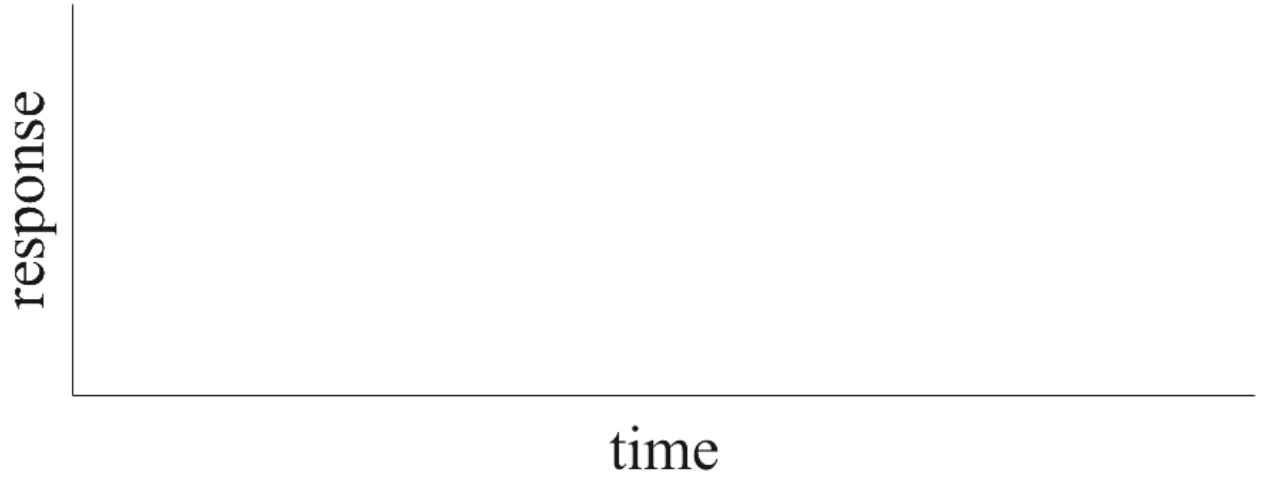


Introduction

- Transmission bandwidth and power limitations
  - Large amounts of transmitted data
  - Cause bottle necks and power shortages



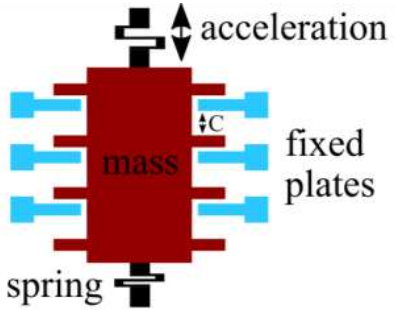


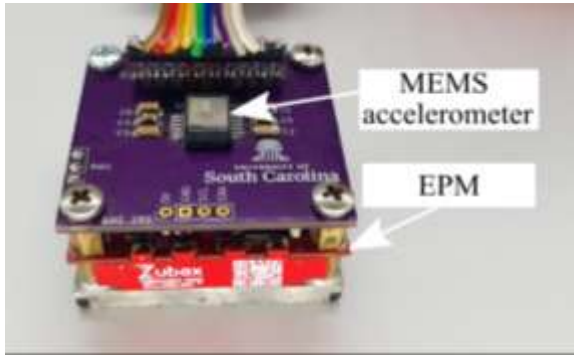


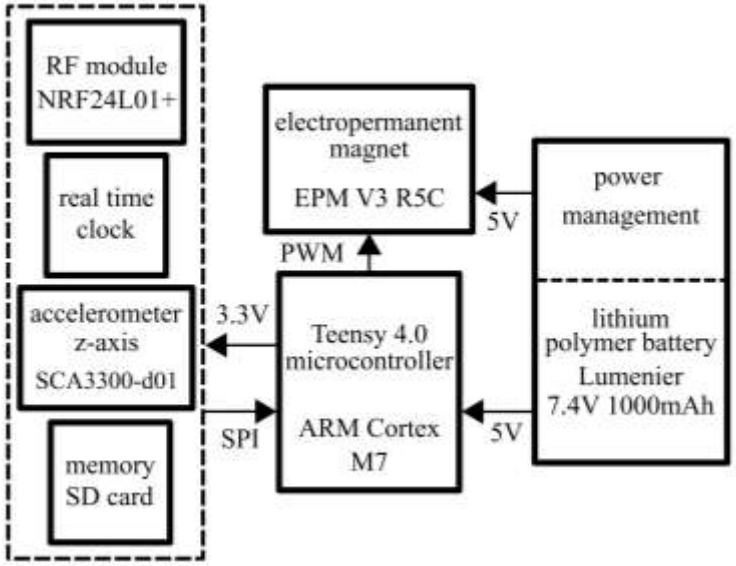
UAV-deployable sensing system

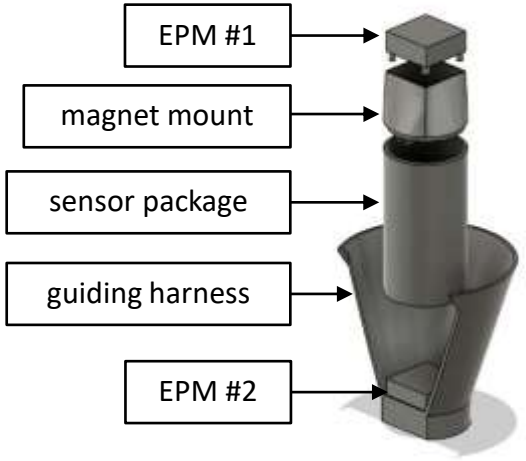
Features:

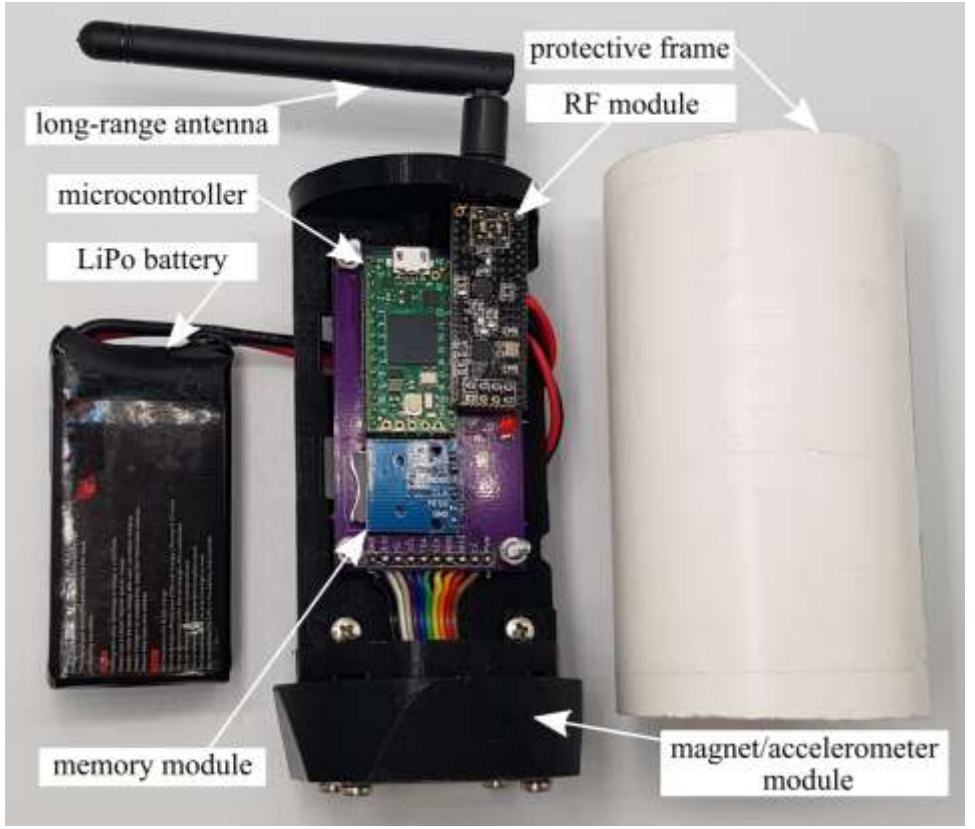
- MEMS accelerometer-based sensor
- Electropermanent magnet docking
- UAV-deployable capabilities
- Standalone power system
- Multi-link wireless communication
- Independent nonvolatile memory
- Real-time reference for data logging





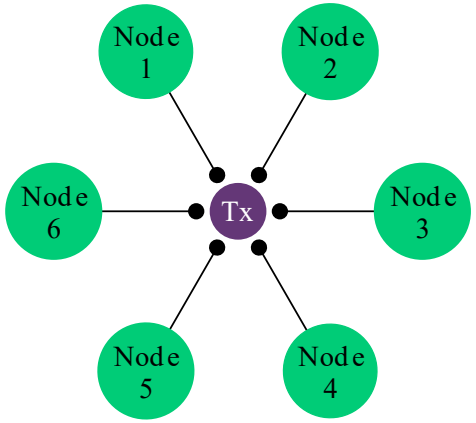


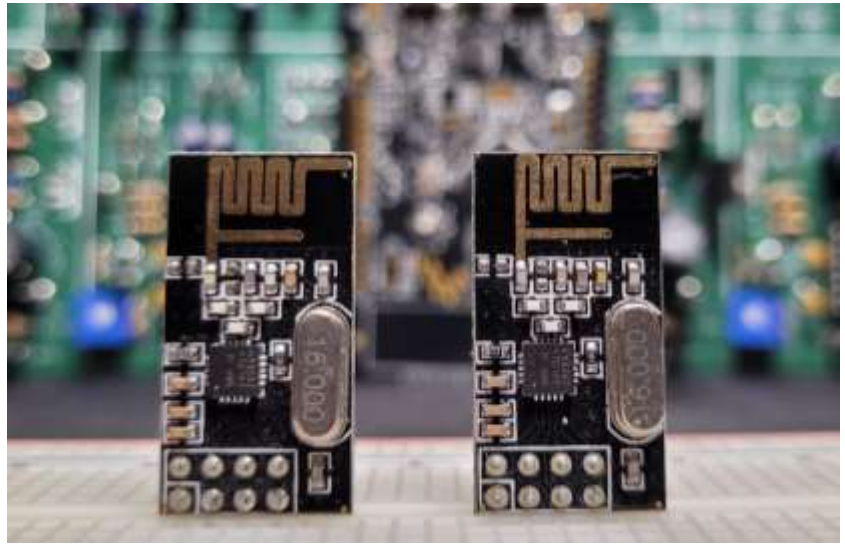


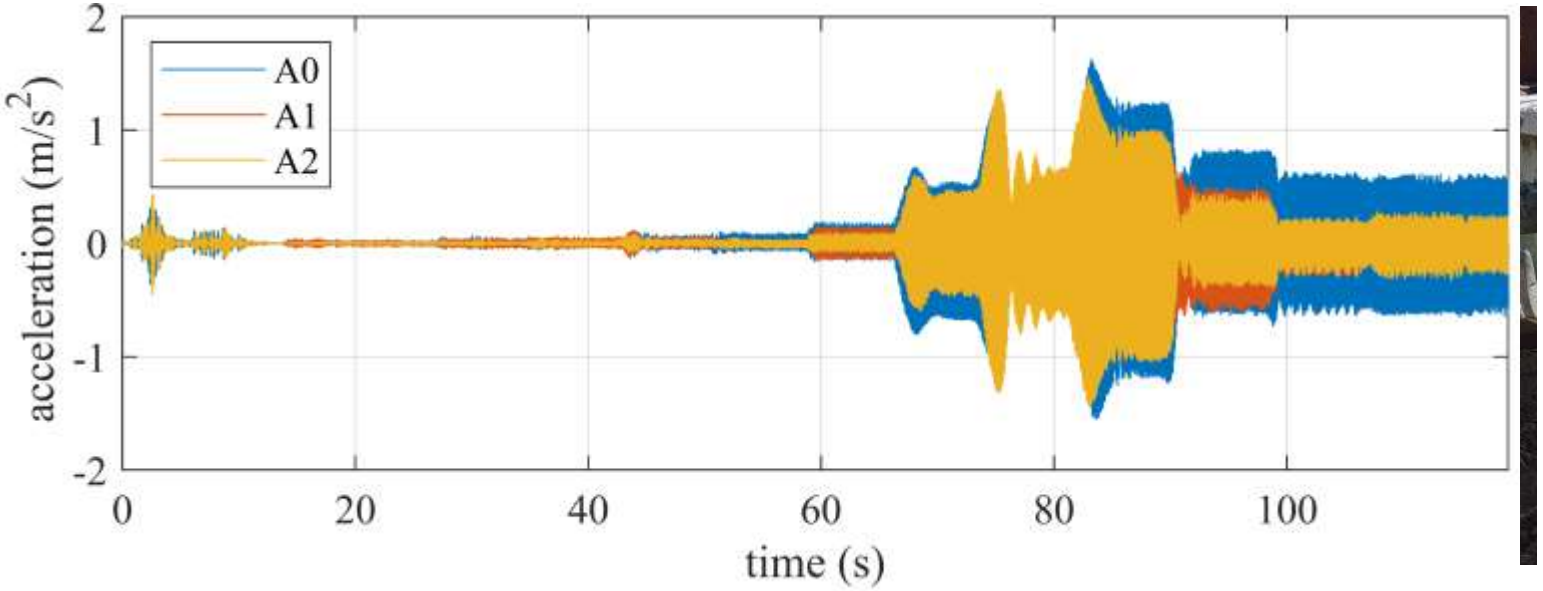


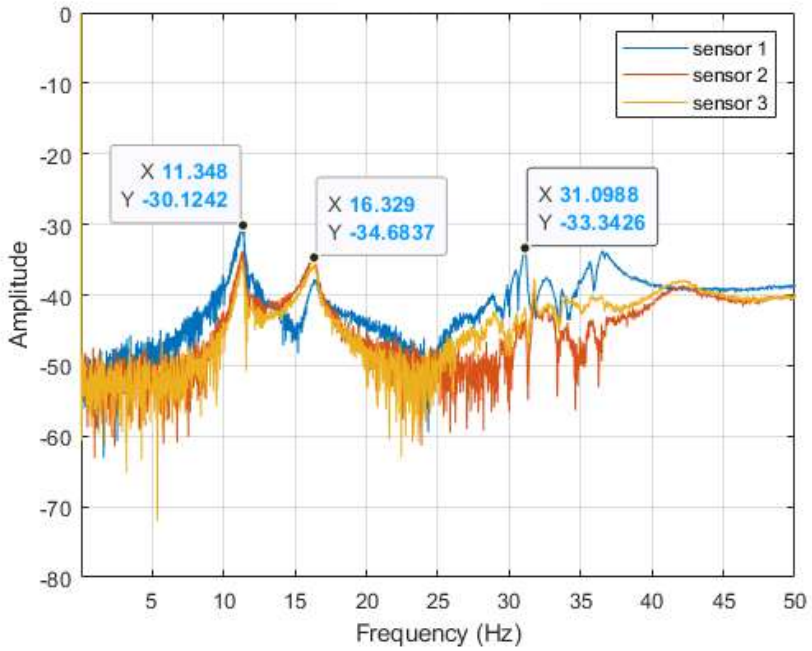
Wireless sensing networks

- Wireless 2.4 GHz ISM Bandwidth
- Enhanced ShockBurst protocol
- Wireless range of 100 meters
- Transmission rate of 2Mbps
- Up to six radio links per hub
- Optimal for low-power sensing networks



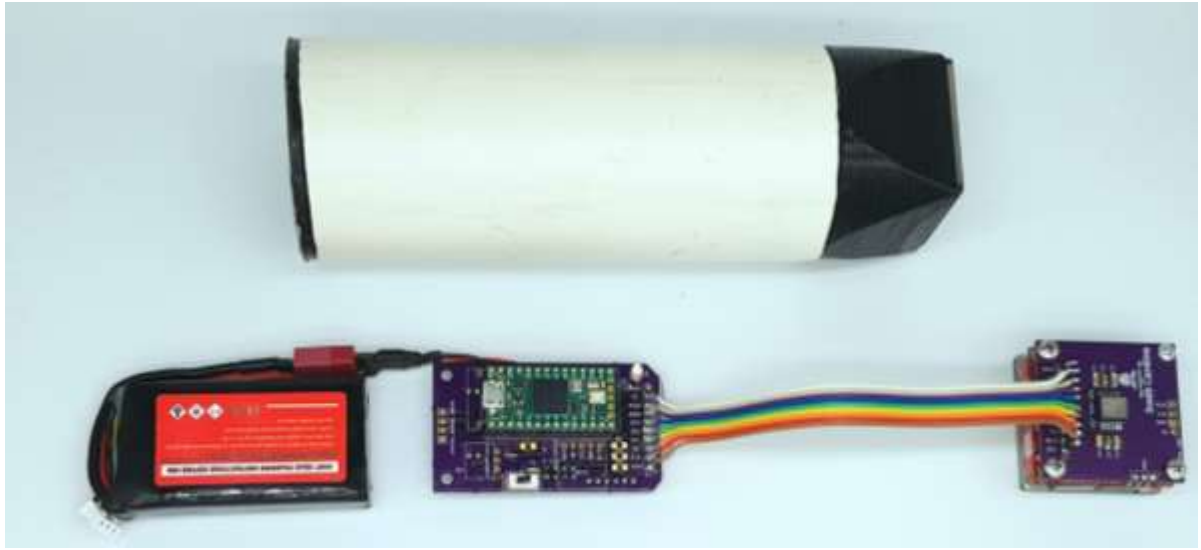


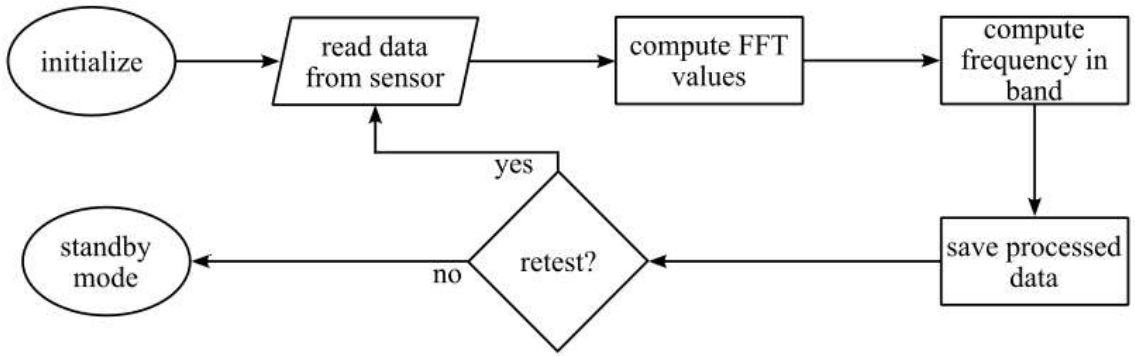


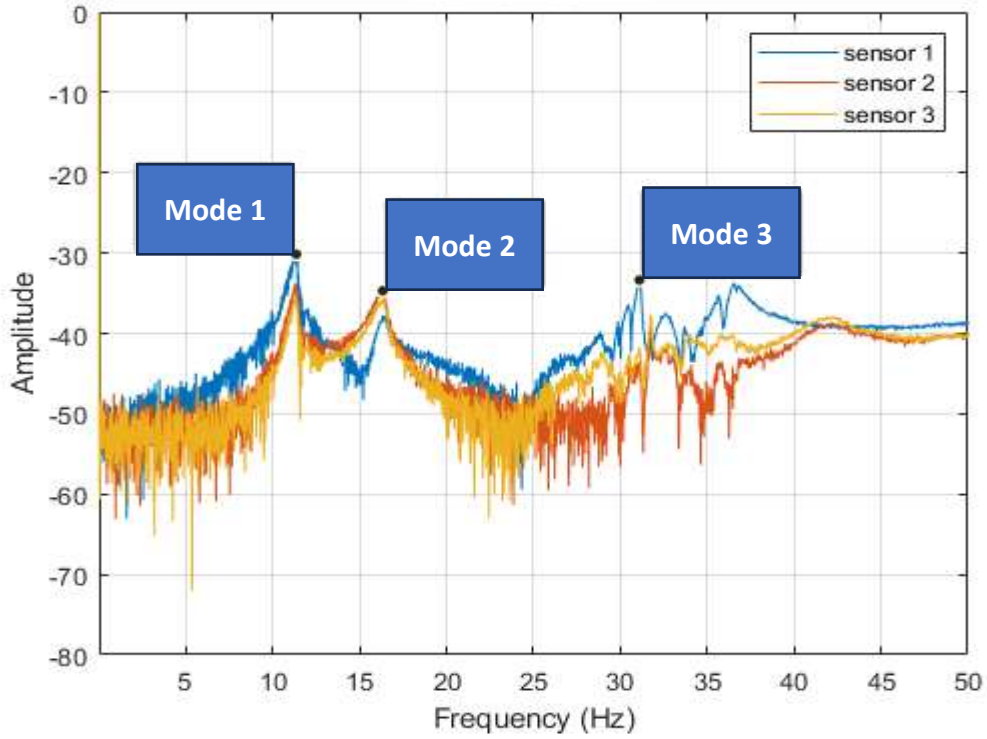


SHM edge-processing algorithm

- Power and transmission bandwidth restrictions
- Conduct computation on the edge
  - Import time domain data directly from accelerometer
  - Compute the frequency-domain representation
  - Conditions the spectrum and detects frequency peaks
  - Extends deployment time by saving transmission power
  - Speeds up data processing and allows rapid assessment

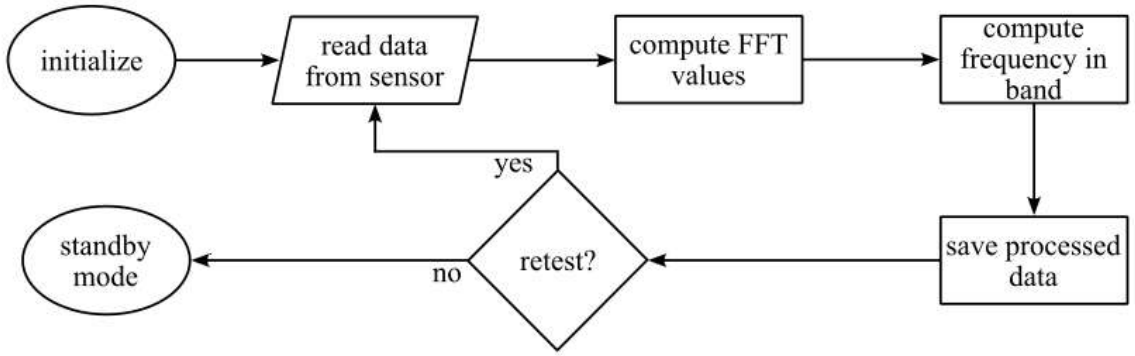


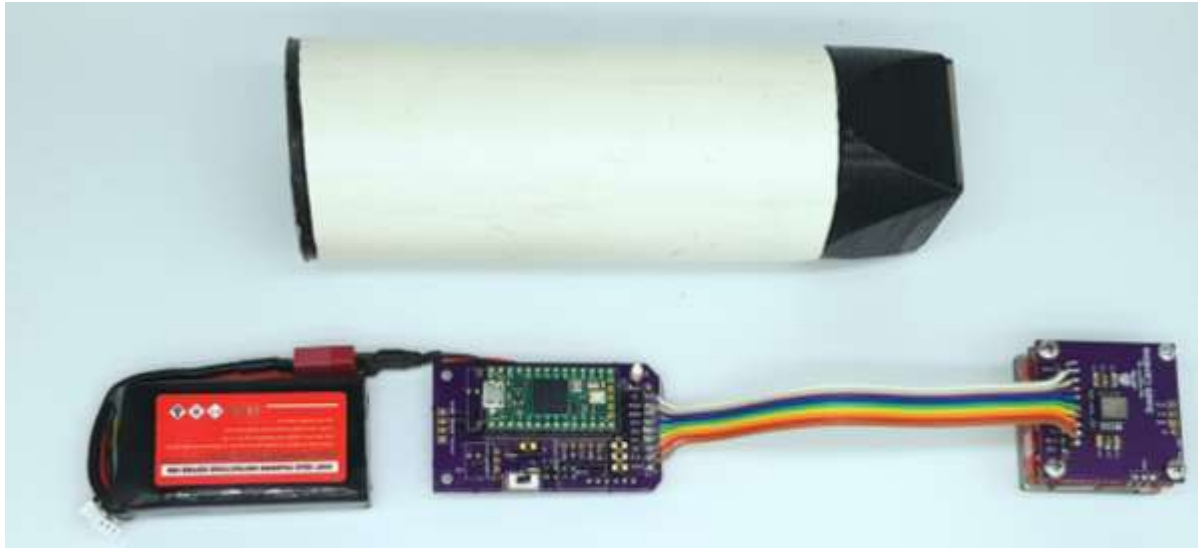


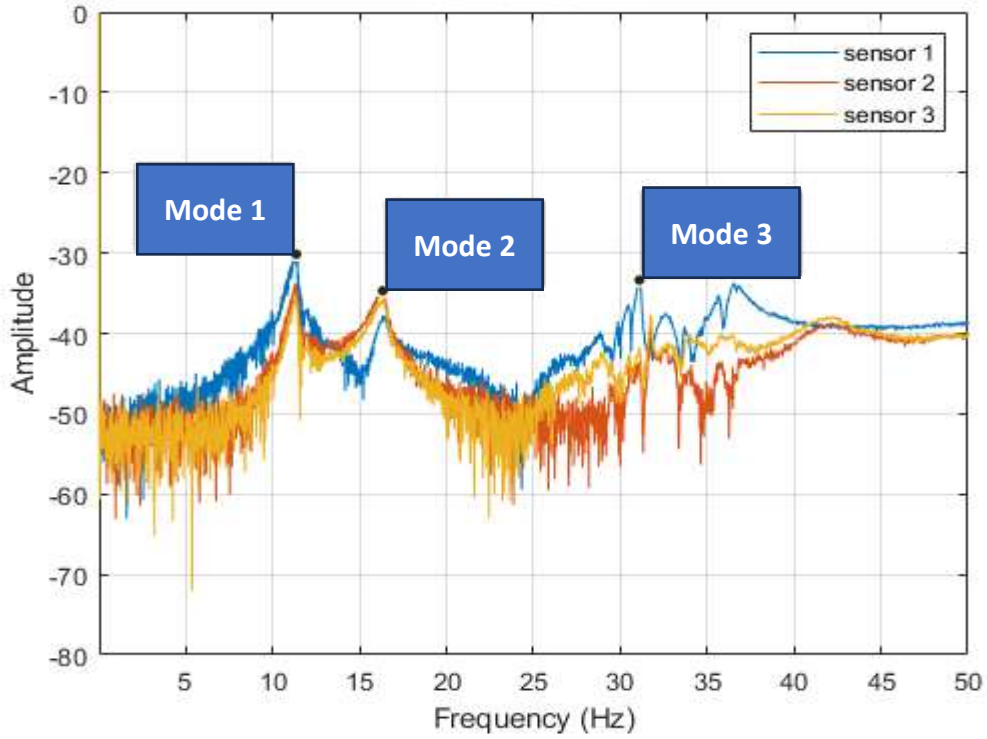


SHM edge-processing algorithm

- Algorithm specifications:
  - Sampling rate of 1600 S/s
  - Buffer size of 16,000 Samples
  - FFT width: 8192 bins
  - FFT resolution: 0.098 Hz

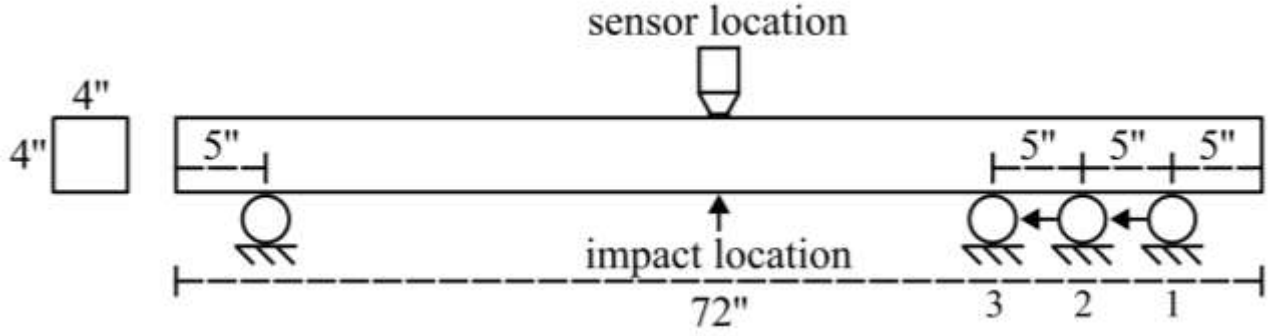


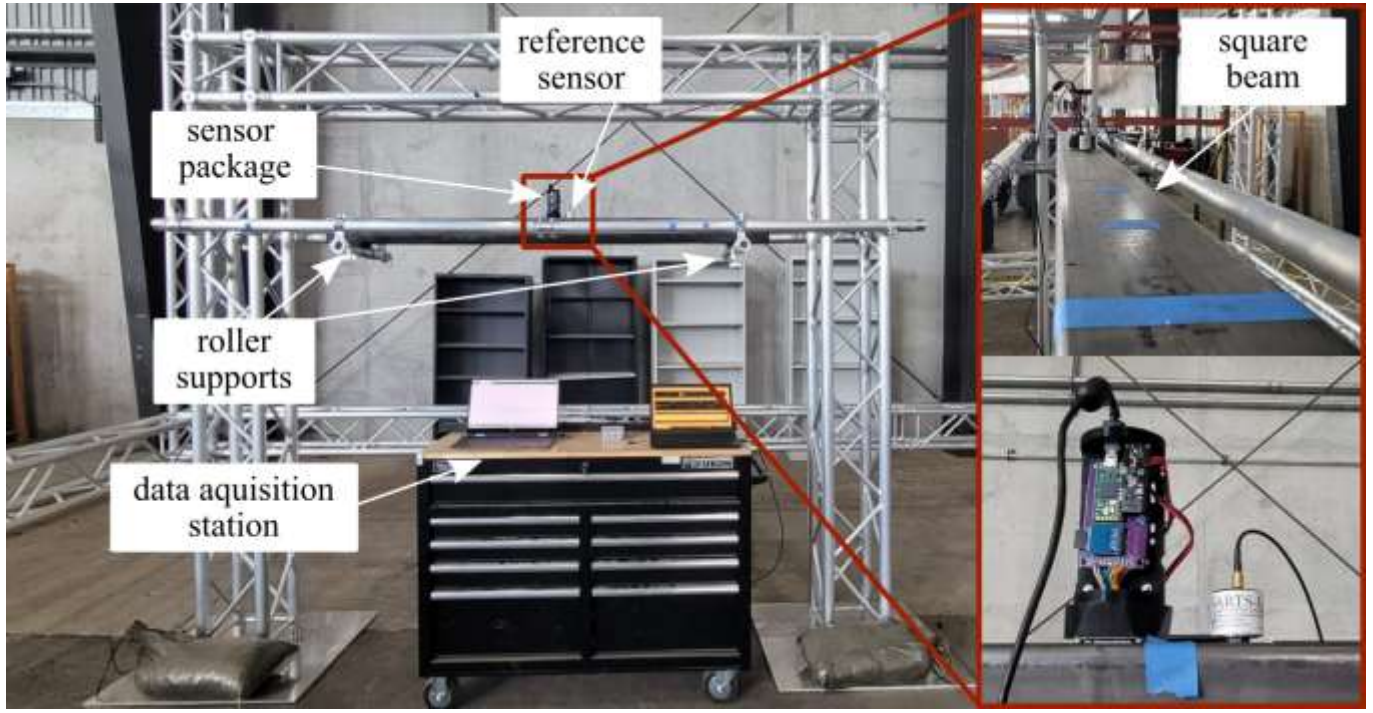




Modal frequency detection using UAV-deployable edge-computing sensing node

- Experiment consists of a structure suspended over to rollers.
- One roller is shifted to three different states
- The three states alter the frequency response
- The goal is to validate the algorithm's ability to detect a change in modal frequencies on edge
- A superior reference accelerometer is used for ground truth measurement

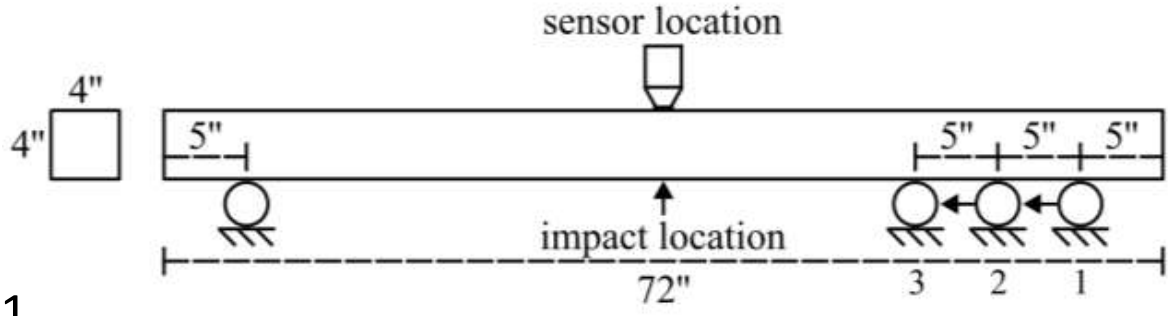


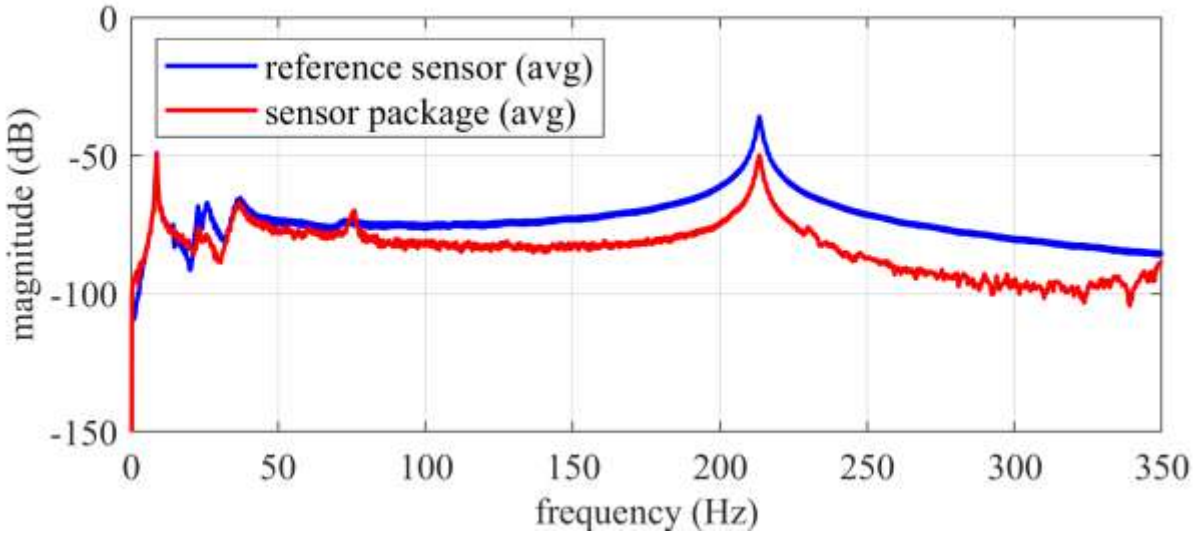


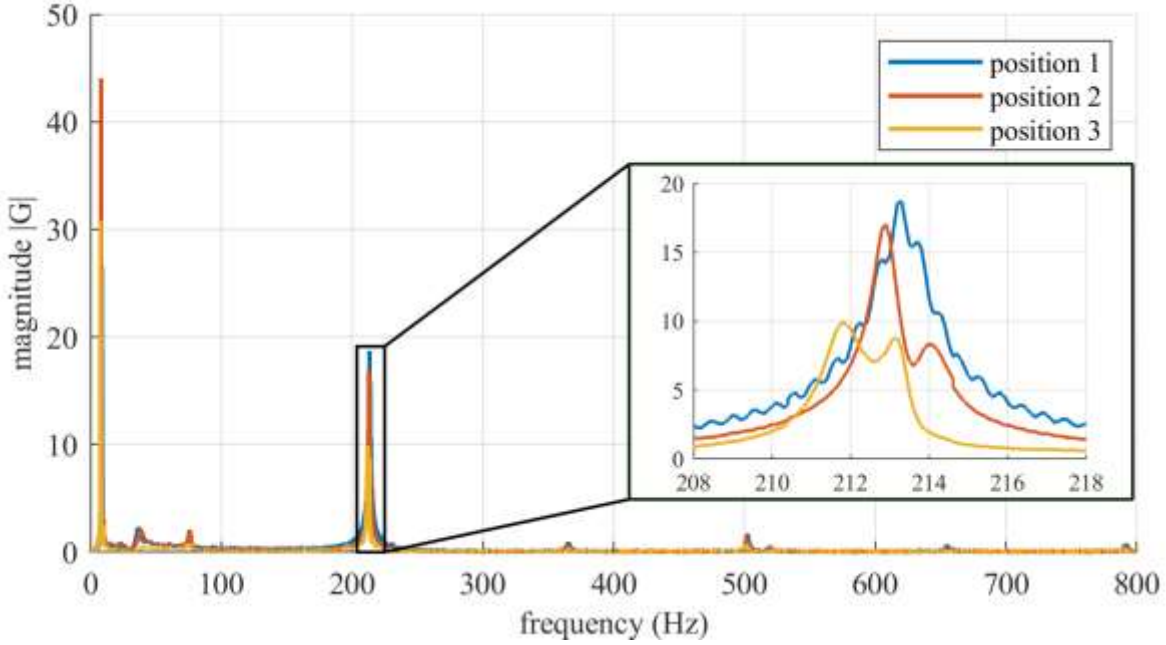
Frequency response analysis

- Experiment consists of a structure suspended over to rollers.
- One roller is shifted to three different states
- The three states alter the frequency response
- The goal is to validate the algorithm's ability to detect a change in modal frequencies on edge
- A superior reference accelerometer is used for ground truth measurement

Position	Frequency (Hz)	Magnitude (G)
1	213.02	18.68
2	212.63	17.05
3	212.11	9.91





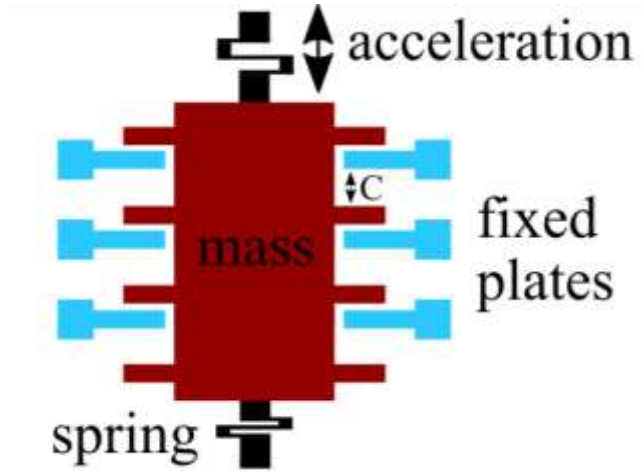


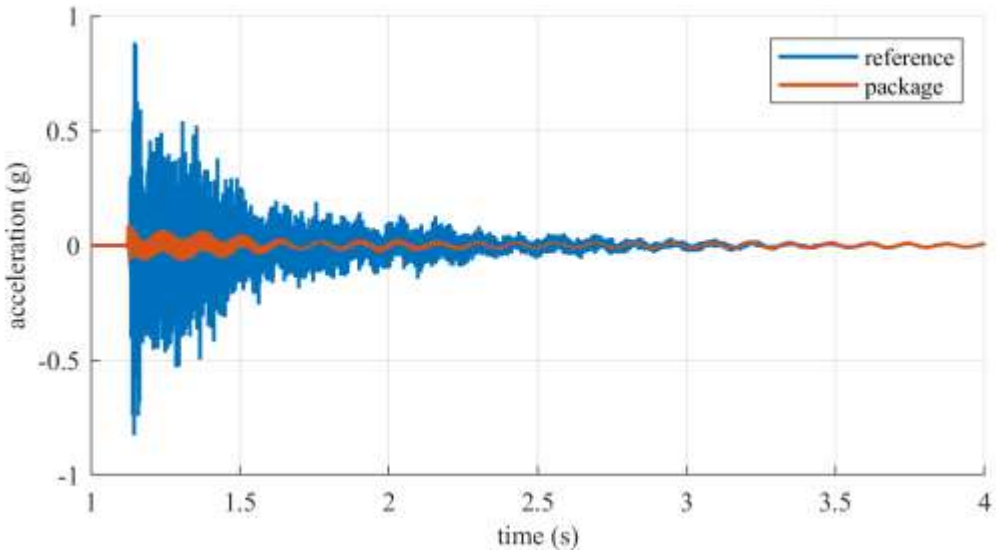
Sensing system strengths and experimental challenges

- Sensor package fails to capture time domain vibration magnitude accurately
- Suspected error due to mechanical transmissibility loss through the electro permanent magnet assembly
- A signal conditioning and error compensation algorithm is currently under development to combat this challenge

reference

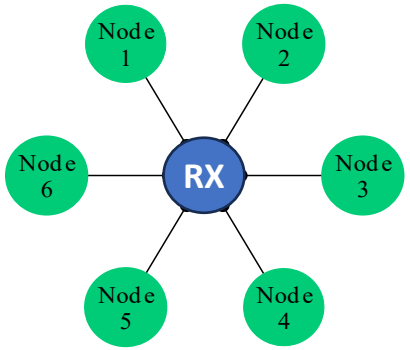
sensor package

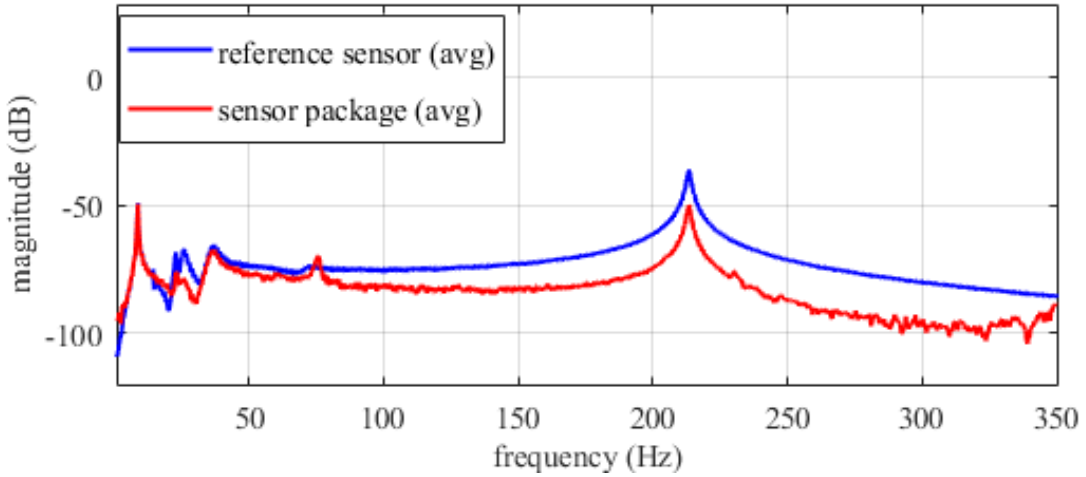


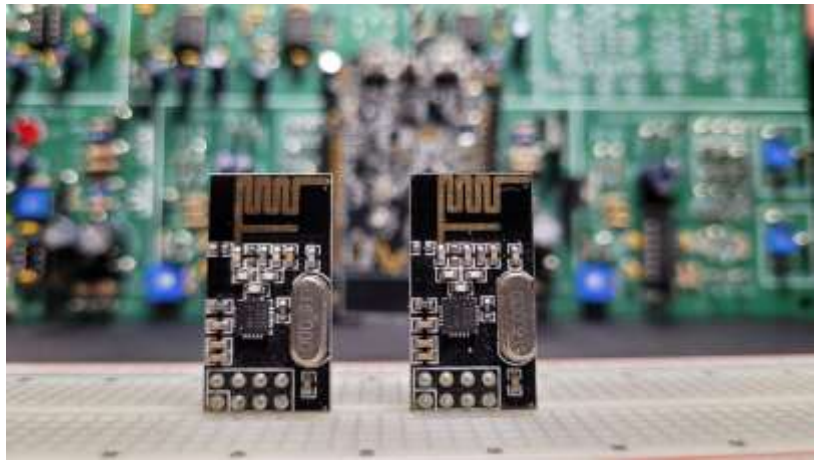


Sensing system improvements

- Sensor network algorithm enhancements to allow for rapid modal reconstruction on-edge using multiple sensing nodes







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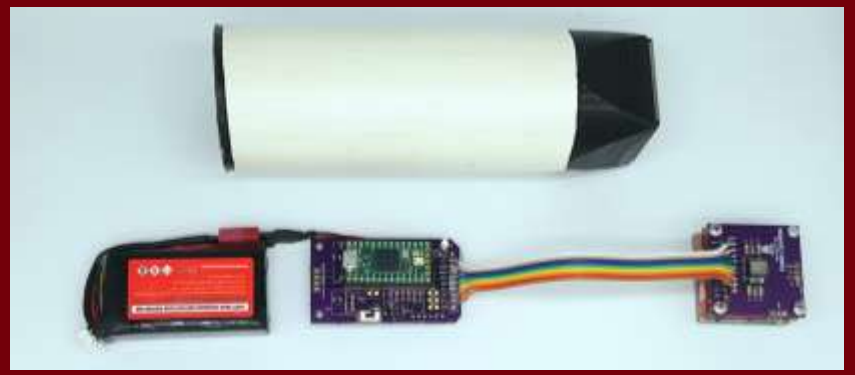
Open-Source hardware Designs

https://github.com/ARTS-Laboratory/Drone-Delivered-Vibration-Sensor

Open-source UAV-deployable vibration sensor package

Thanks for listening



Author Information
Name: Joud N. Satme
Email: Jsatme@email.sc.edu