Autonomous Ultrasonic Thickness Measurement of Steel Bridge Members Using Mobile Sensors

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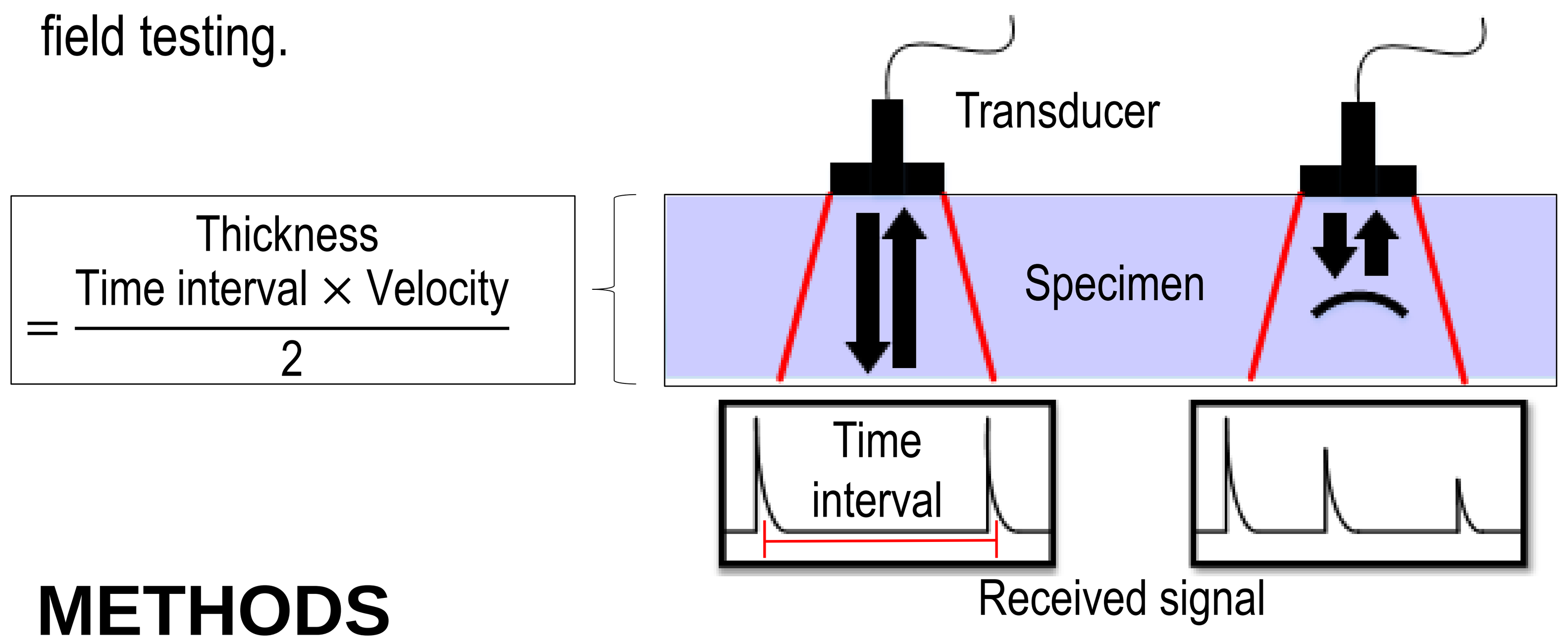
INTRODUCTION

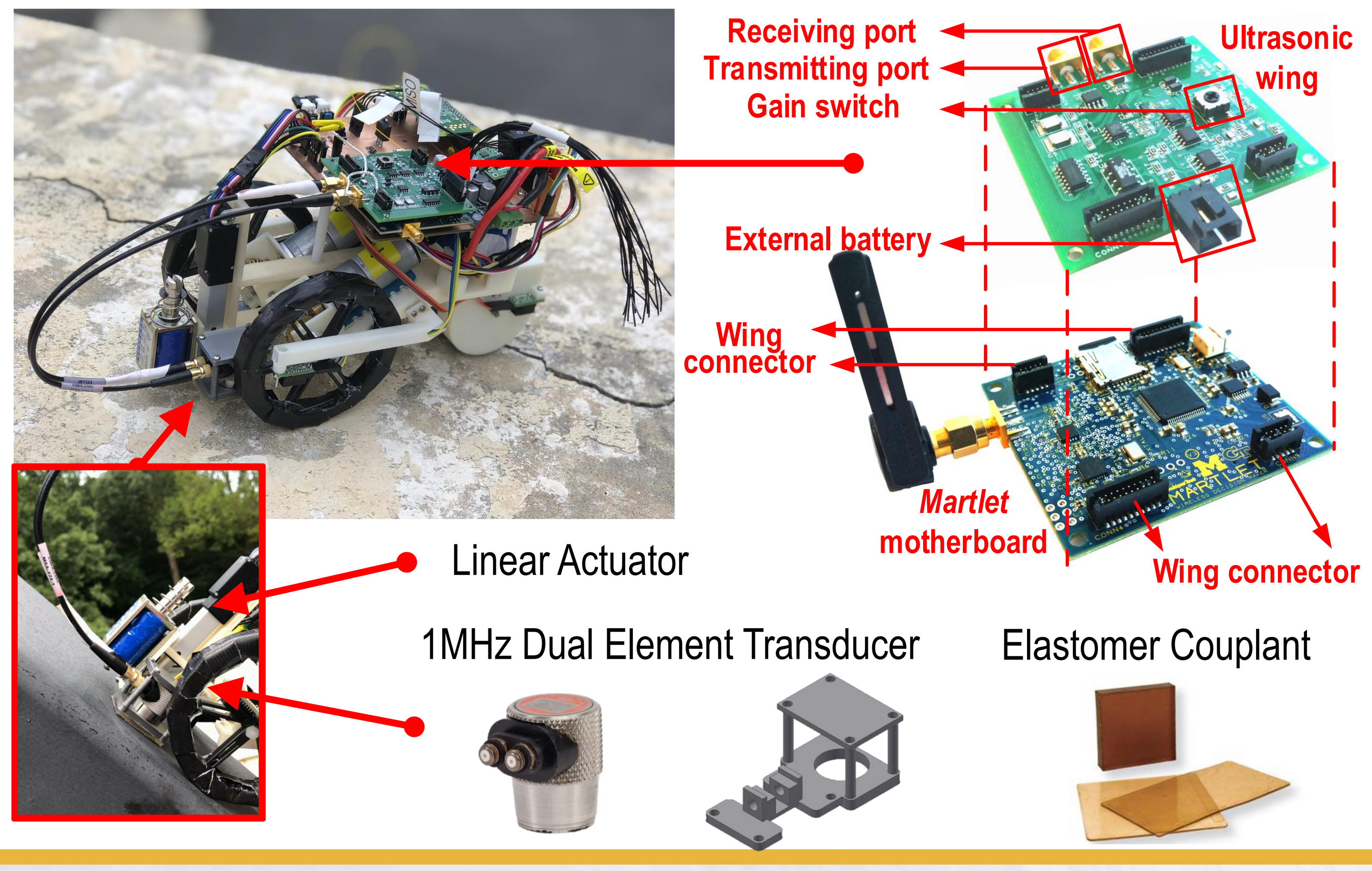
This research investigates autonomous ultrasonic thickness measurement of steel bridge members through the integration of wireless sensing and robotics. Intended for corrosion and defect detection, the ultrasonic thickness measurement only requires access to one side of a steel bridge member. Building upon the *Martlet* wireless sensing platform, this project develops an ultrasonic daughter board to generate pulse excitation and to filter and amplify the received ultrasonic signal. The entire *Martlet* wireless ultrasonic device is to be mounted on a magnet-wheeled mobile robot. The performance of the developed system is evaluated by laboratory and field testing.



METHODS

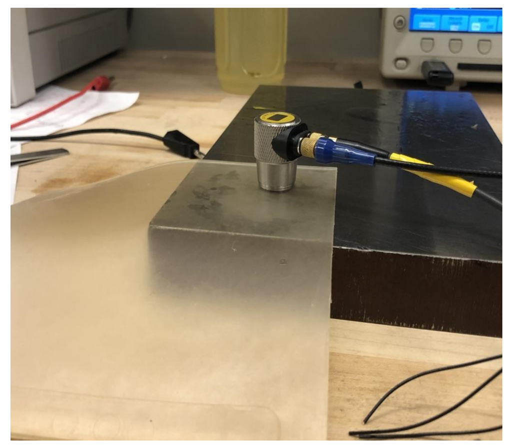
- *Martlet* ultrasonic board amplifies the excitation signal up to 20V. The received signal is filtered and amplified to improve the signal-to-noise ratio. The maximum sampling frequency of *Martlet* is 3MHz, which is sufficient for the 1MHz dual element transducer.
- *Martlet* and the transducer are integrated to a magnet-wheeled climbing mobile robot. The functionality of mounting/retrieving the transducer is achieved by a liner actuator.

Magnet-Wheeled Climbing Mobile Robot | *Martlet* and Ultrasonic Board

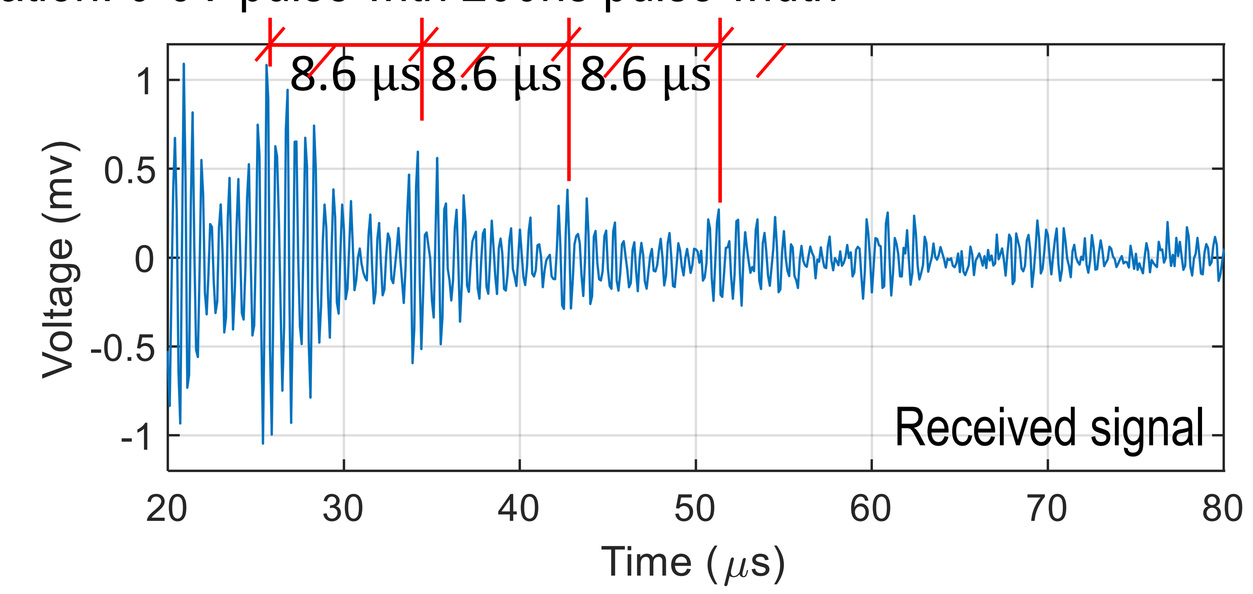


EXPERIMENTAL RESULTS

- Laboratory Test

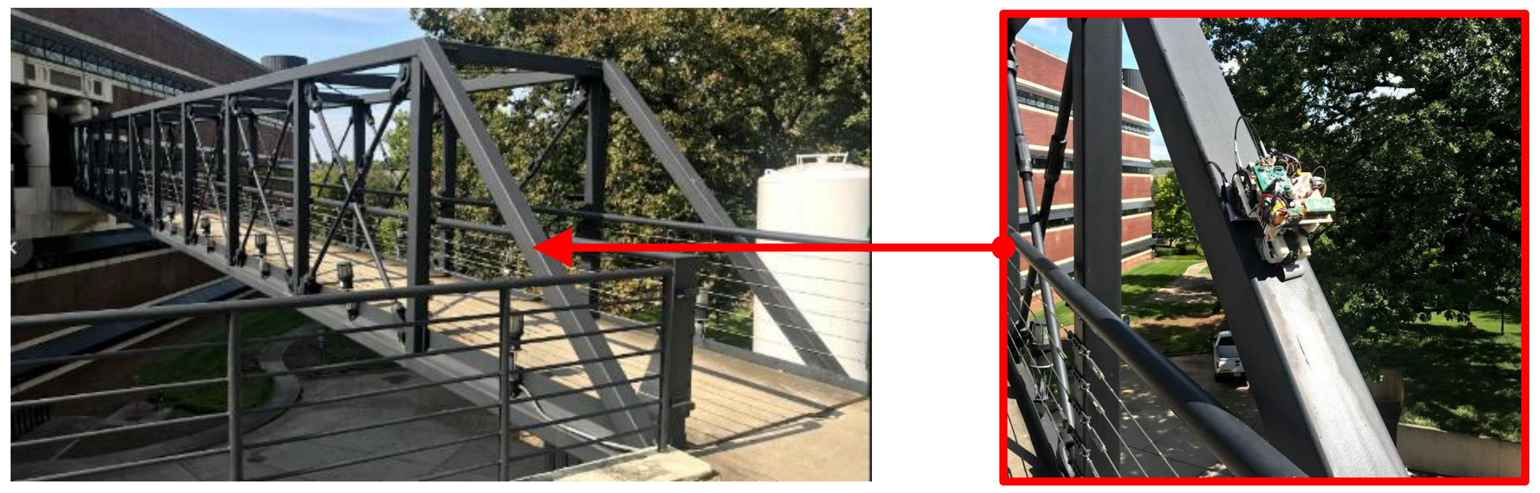


- 1 inch steel plate
- Validation of the 1MHz dual element transducer and elastomer couplant, measured by an oscilloscope
- Excitation: 0-9V pulse with 200ns pulse width

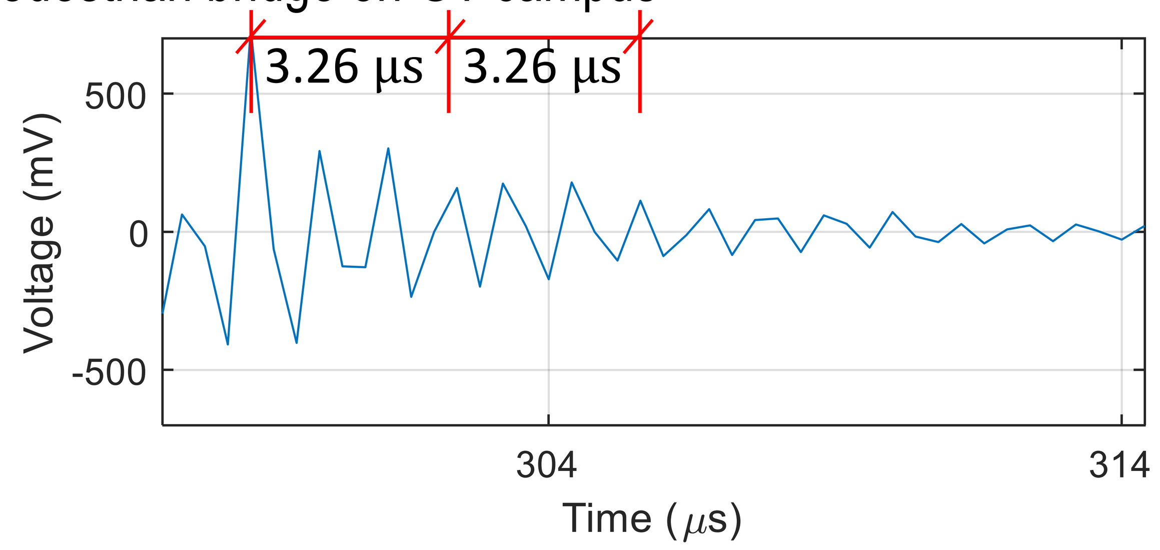


$$\text{Thickness}=\frac{\text{Tme interval}\times\text{Velocity}}{2}=\frac{8.6\ \mu s\times 0.230\ \text{in}/\mu s}{2}=0.99\ \text{in}$$

- Field Test



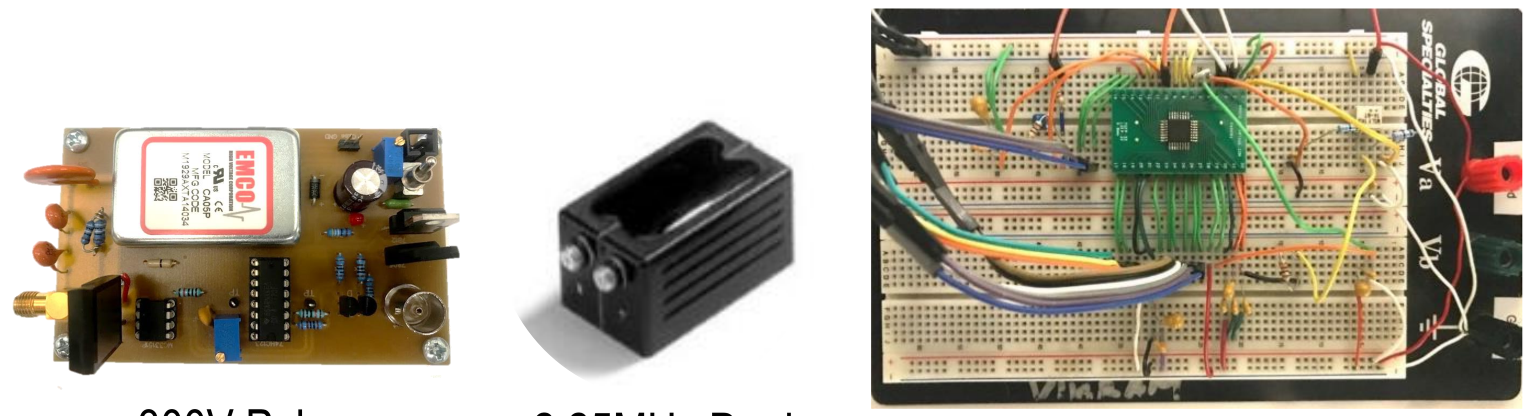
Steel pedestrian bridge on GT campus



- The wireless ultrasonic thickness measurement setup is successfully operated by the mobile robot and the received signal is wirelessly collected by *Martlet*.
- However the ultrasonic signal is not able to provide accurate thickness of 0.375 in (round-trip 3.26µs); future development is expected to improve the accuracy.

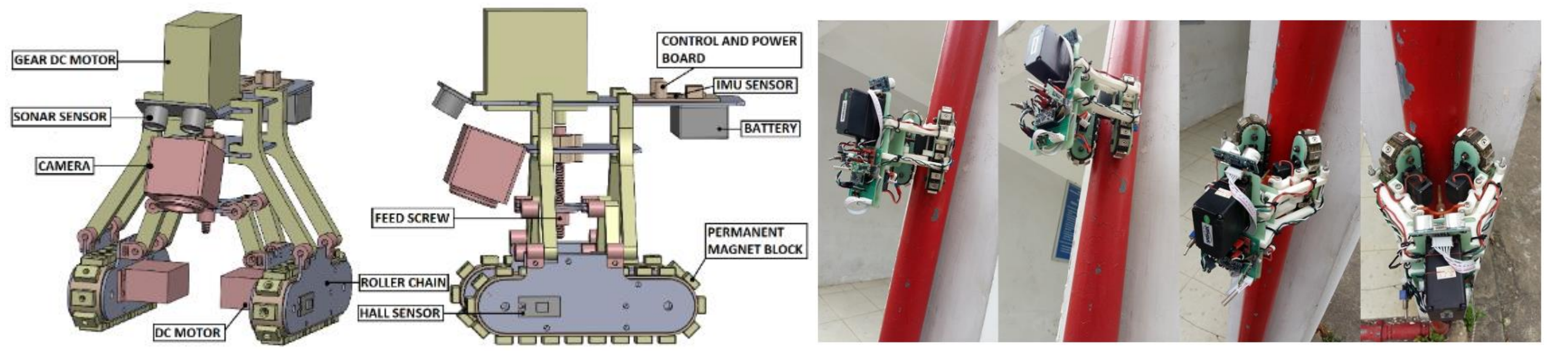
HARDWARE IMPROVEMENT

- A 300V pulser board has been developed. The excitation signal is amplified from the previous 20V to 300V, which significantly improves the signal-to-noise ratio.
- A 2.25MHz dual element transducer is selected considering the natural frequency, damping ratio, and internal electric circuit.
- A High-speed ADC board is under development. It consists of the high-rate ADC chip, a memory buffer, and a parallel-to-serial converter.



300V Pulser Board | 2.25MHz Dual Element Transducer | Evaluation board for the high-rate ADC chip

- *Martlet* will be integrated into the magnet-wheeled climbing robot developed at University of Nevada, Reno [1]. The robot can climb on different structural surfaces.



CONCLUSIONS

The wireless sensing device *Martlet* and the ultrasonic board are integrated into a magnet-wheeled mobile robot. The ultrasonic thickness measurement showed reliable performance in laboratory testing. The accuracy of the field test results is expected to improve with the new hardware development, including the 300V pulser board, the 2.25MHz dual element transducer, and the high-speed ADC board.

REFERENCE

[1] Nguyen ST and La H (2019). "Development of a Steel Bridge Climbing Robot." Proc. of IEEE/RSJ International Conference on IROS, Macau, China, Nov. 3-8, 2019.

ACKNOWLEDGEMENTS

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