Hybrid Wireless Ultrasonic Sensor Networks with Temperature Compensated Thickness Measurement

inductosense

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Outline

Digital transformation in the NDT (non-destructive testing) market

Manual NDT

- Skilled UT inspectors
- Subject to human error
- Less frequent measurements
- Expensive

Deskilled inspectors

Semi-automated data collection, e.g., by robots

Goals:

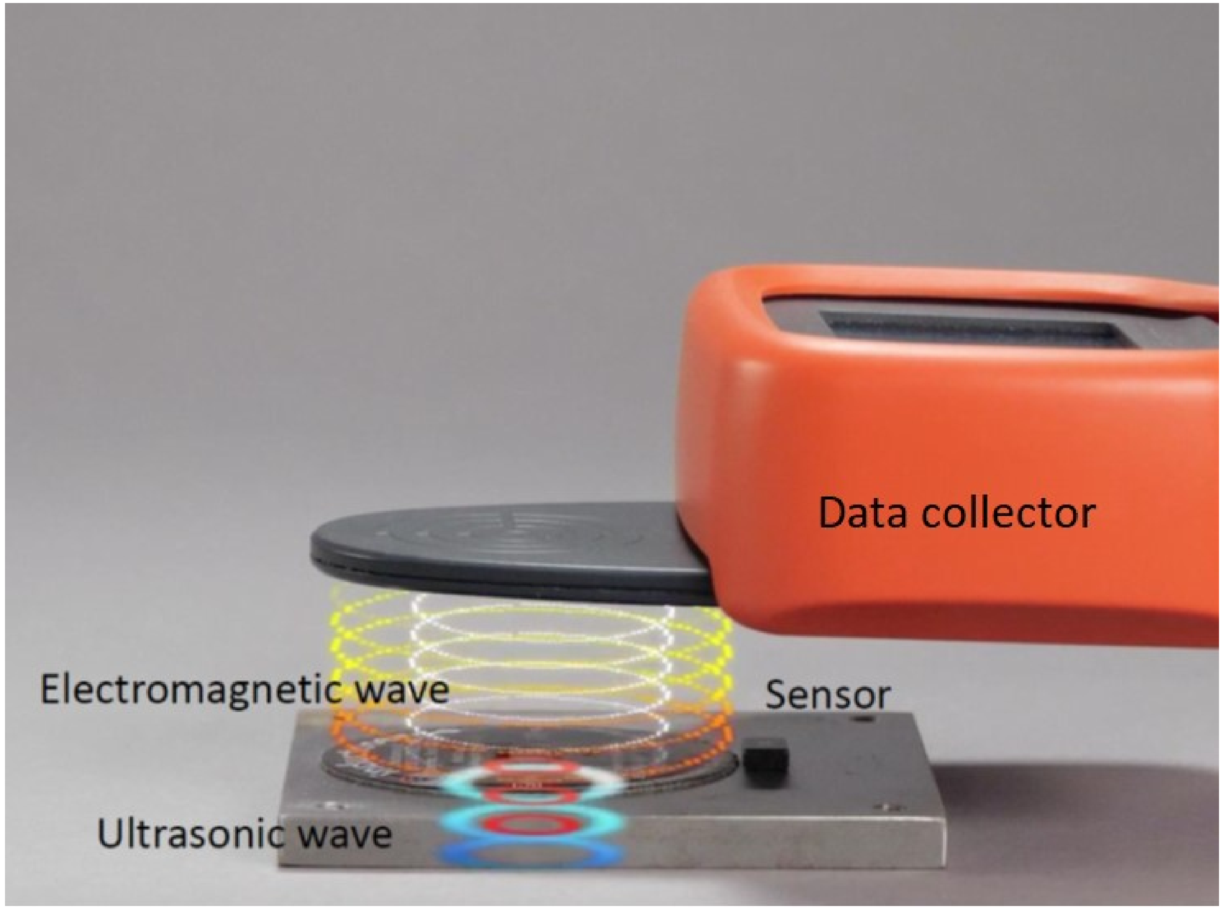
- Make measurement results consistent during the transition
- Minimise discrepancy between different inspection methods

Digitised NDT

- Fully automated data collection
- More frequent measurements
- Enables predictive maintenance
- Reduces costly system downtime

Technology

WAND (Wireless And Non-Destructive) for corrosion monitoring



- Batteryless, compact sensor
- Active data collector
- Fast, repeatable measurement

Current system

Sensor

IDM software

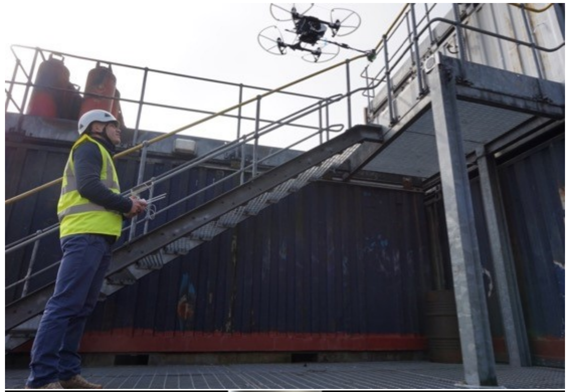
WAND probe

The data is acquired from the sensors using the handheld WAND probe. The WAND probe is then plugged into a tablet or PC via a USB connection to upload the data. The IDM software analyse the data and provide wall thickness loss trend.

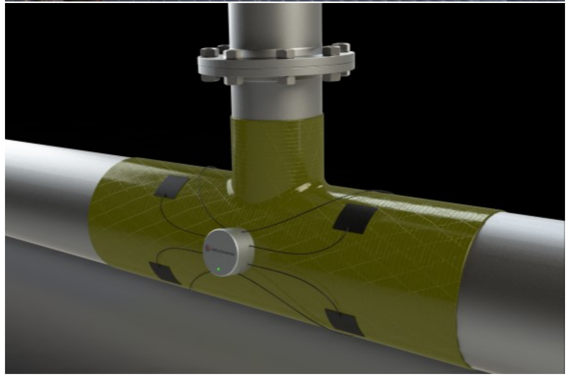
Data collection methods to integrate with digitisation

WAND sensors are installed under coating/insulation/repairs

Fast, deskilled, human error-free manual data collection for lower risk, infrequent measurements

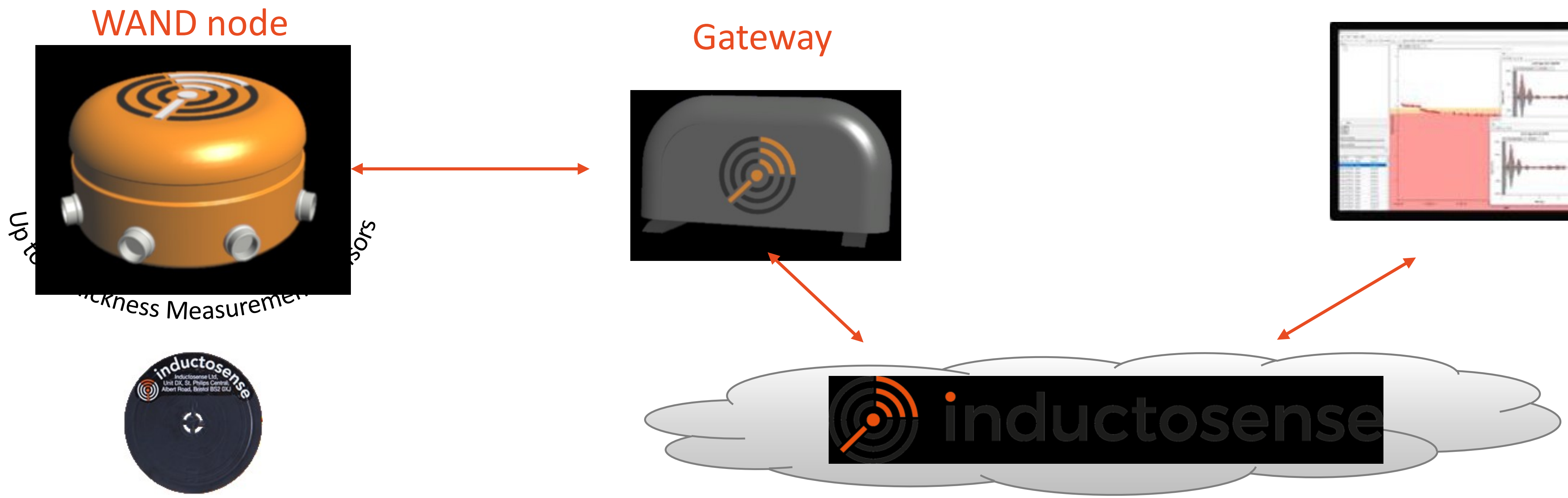


Robotic inspection for difficult to access areas



Remote inspection for frequent measurements, hard to reach areas

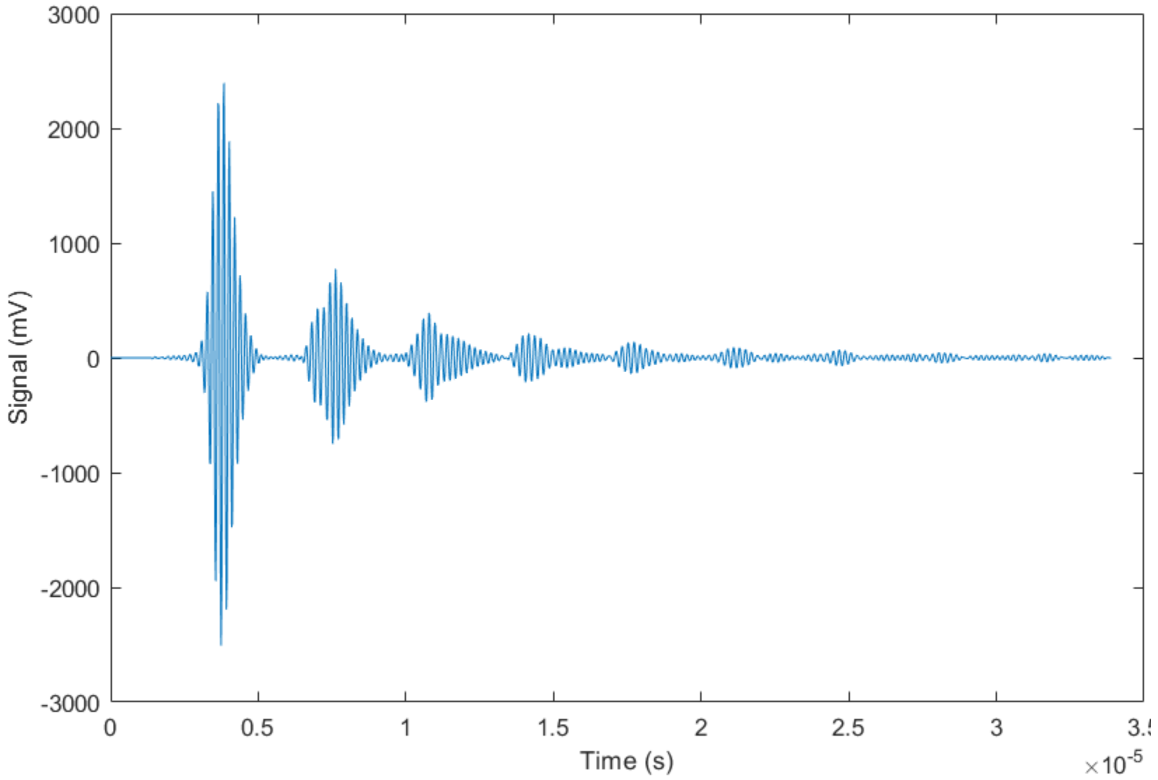
Hybrid wireless ultrasonic sensor network

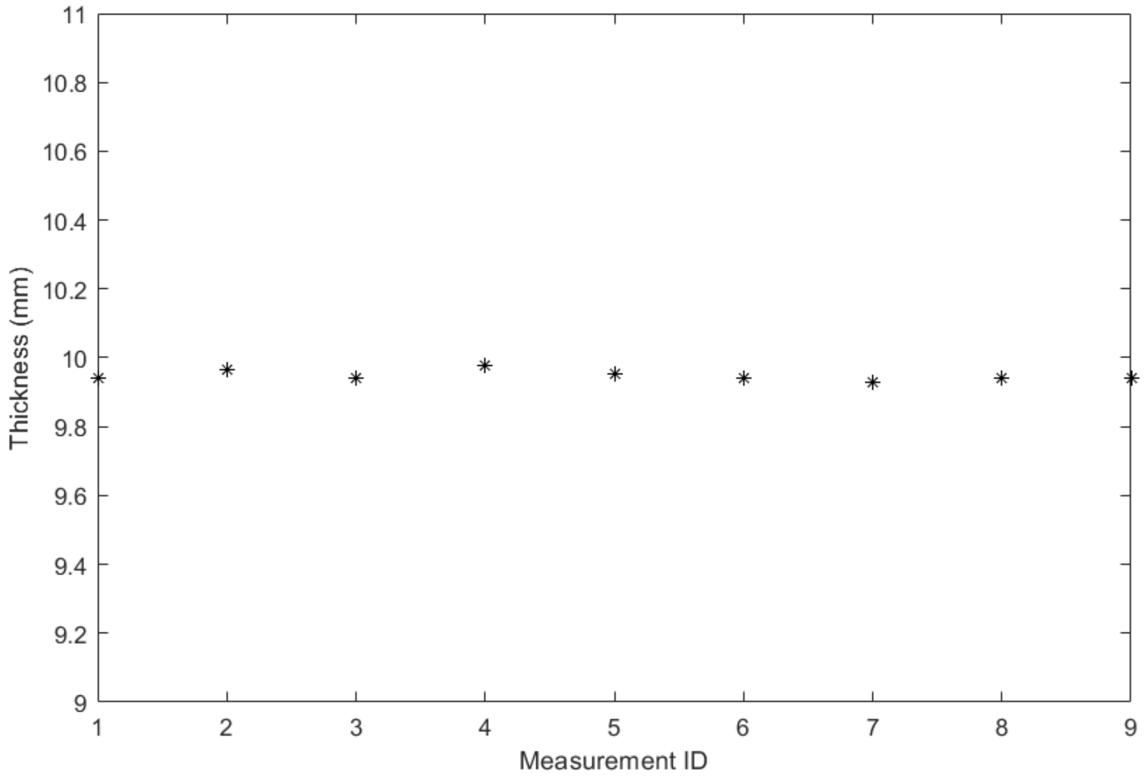


The WAND node automatically takes measurements from ultrasonic sensors and transmits the data to the gateway. The data is then uploaded to the cloud and analysed by the software.

Get the data → Analyse and visualise → Solve and execute

Analyse and visualise: A-scan and thickness





Data collection options

The WAND data collector and gateway can be stationary or mobile.

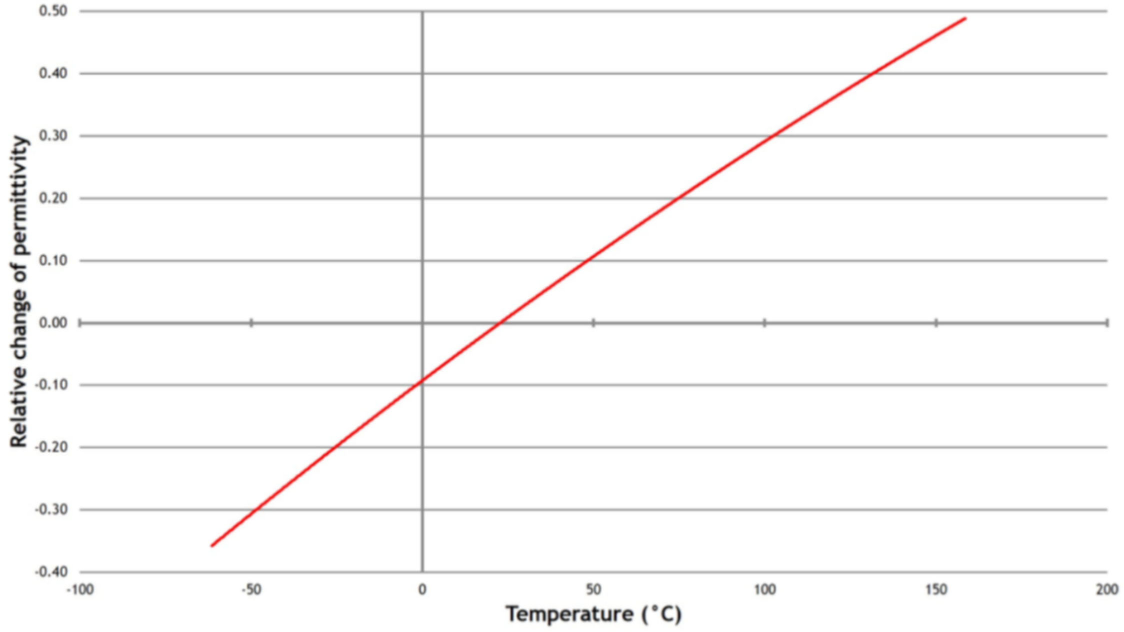
- Stationary data collector: WAND node
- Mobile data collector: WAND crawler, WAND drone, etc.
- Mobile gateway can be carried by humans or robots, e.g., crawler, drone, etc.

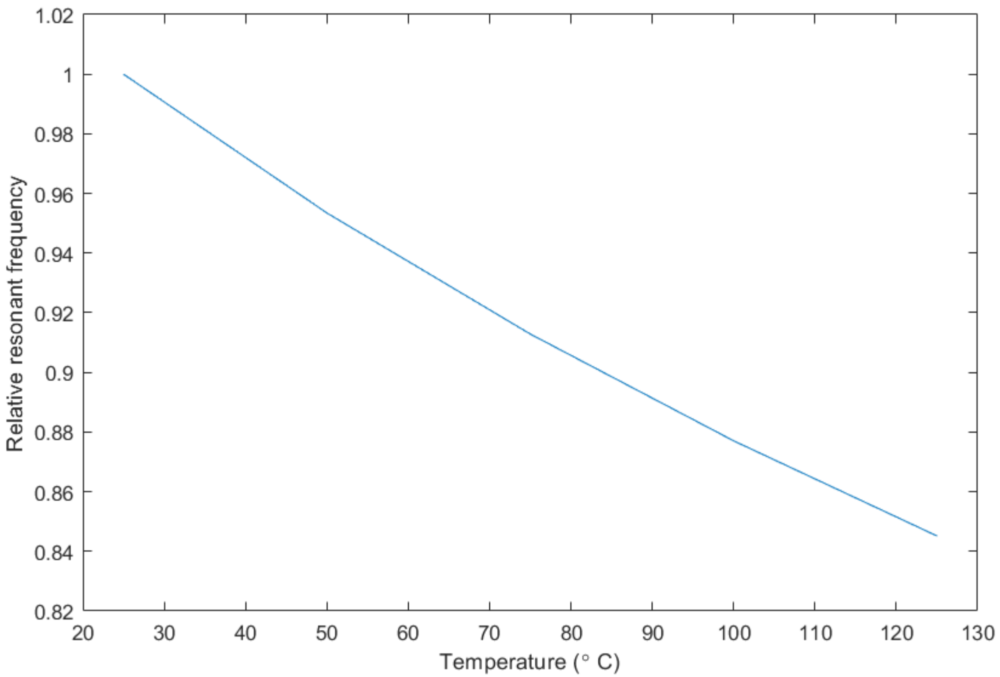
Accurate thickness measurement of hot materials


Sensor installed under composite

- Sound velocity in all materials changes with temperature, e.g., in steel, this change is approximately 1% per 55 °C change in temperature.
- Accurate thickness measurement of hot materials requires velocity calibration.
- For sensors installed under coating/insulation/repairs, wired thermocouple, infrared thermometer etc. are not feasible to get the exact temperature of the structure.
- Using the existing measurement data to estimate the structure temperature provides a solution.

Temperature estimation basis





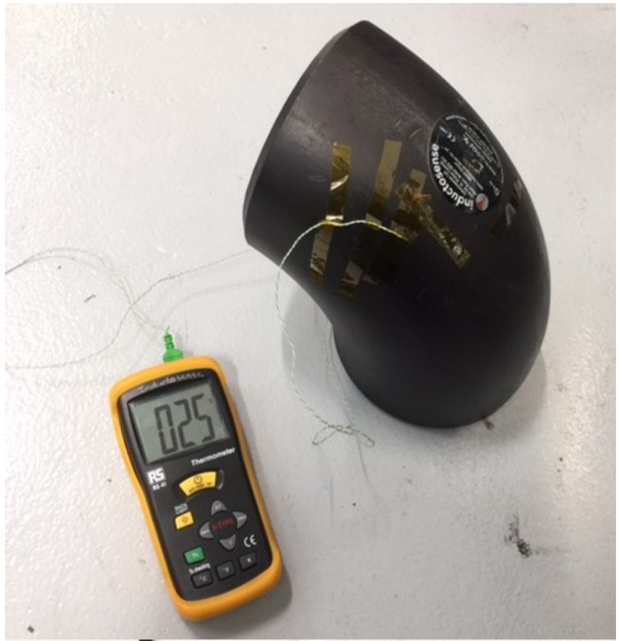
Capacitance = Permittivity × $\frac{A}{d}$

$$\frac{C_T}{C_{25}} = 1 + \frac{0.38}{100}(T - 25)$$

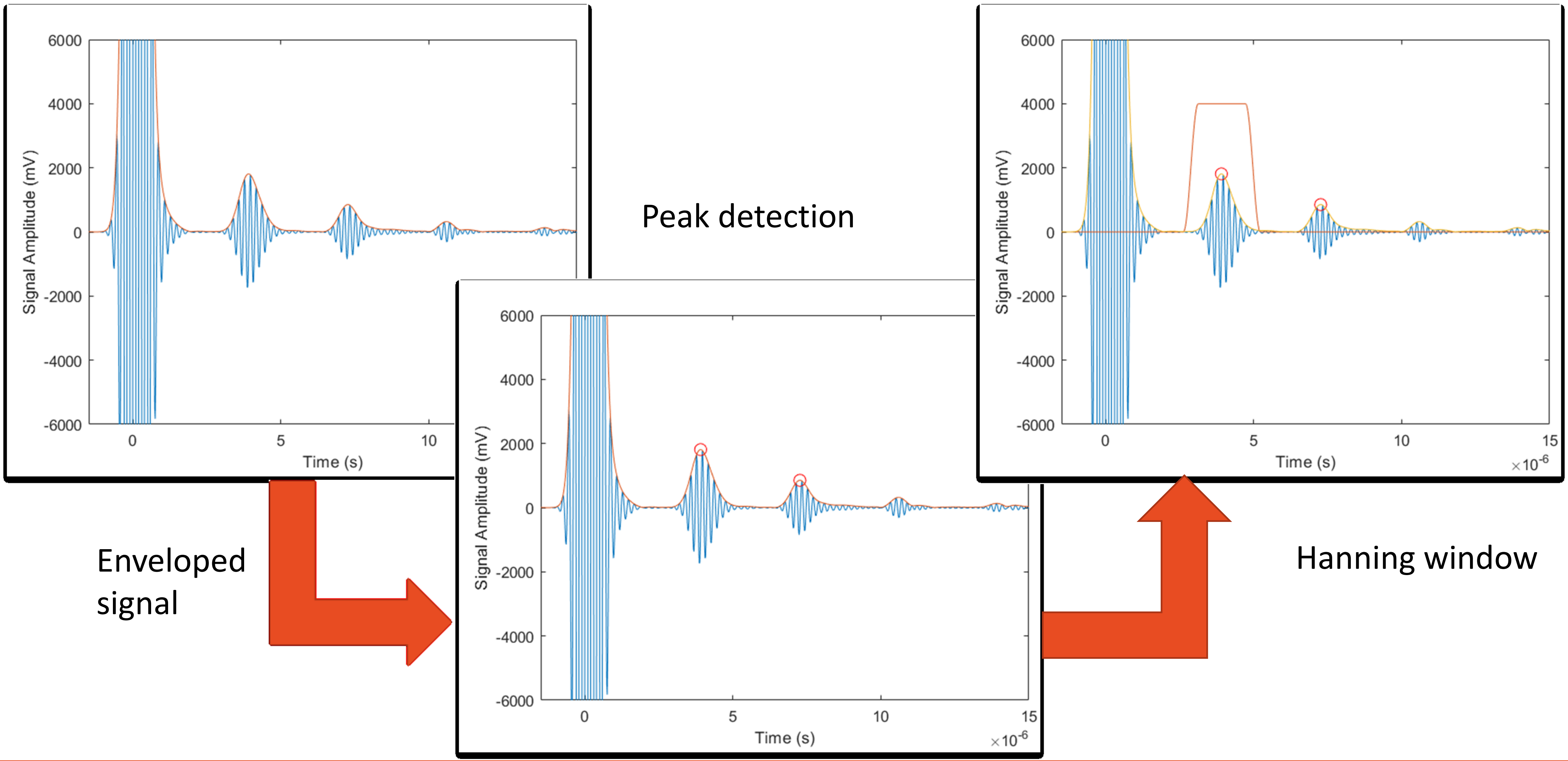
$$Relative\ resonant\ frequency = \frac{f_T}{f_{25}} = \frac{\frac{1}{2\pi\sqrt{LC_T}}}{\frac{1}{2\pi\sqrt{LC_{25}}}} = \sqrt{\frac{C_{25}}{C_T}}$$

$$For\ example, f_{125} = 0.85 f_{25}$$

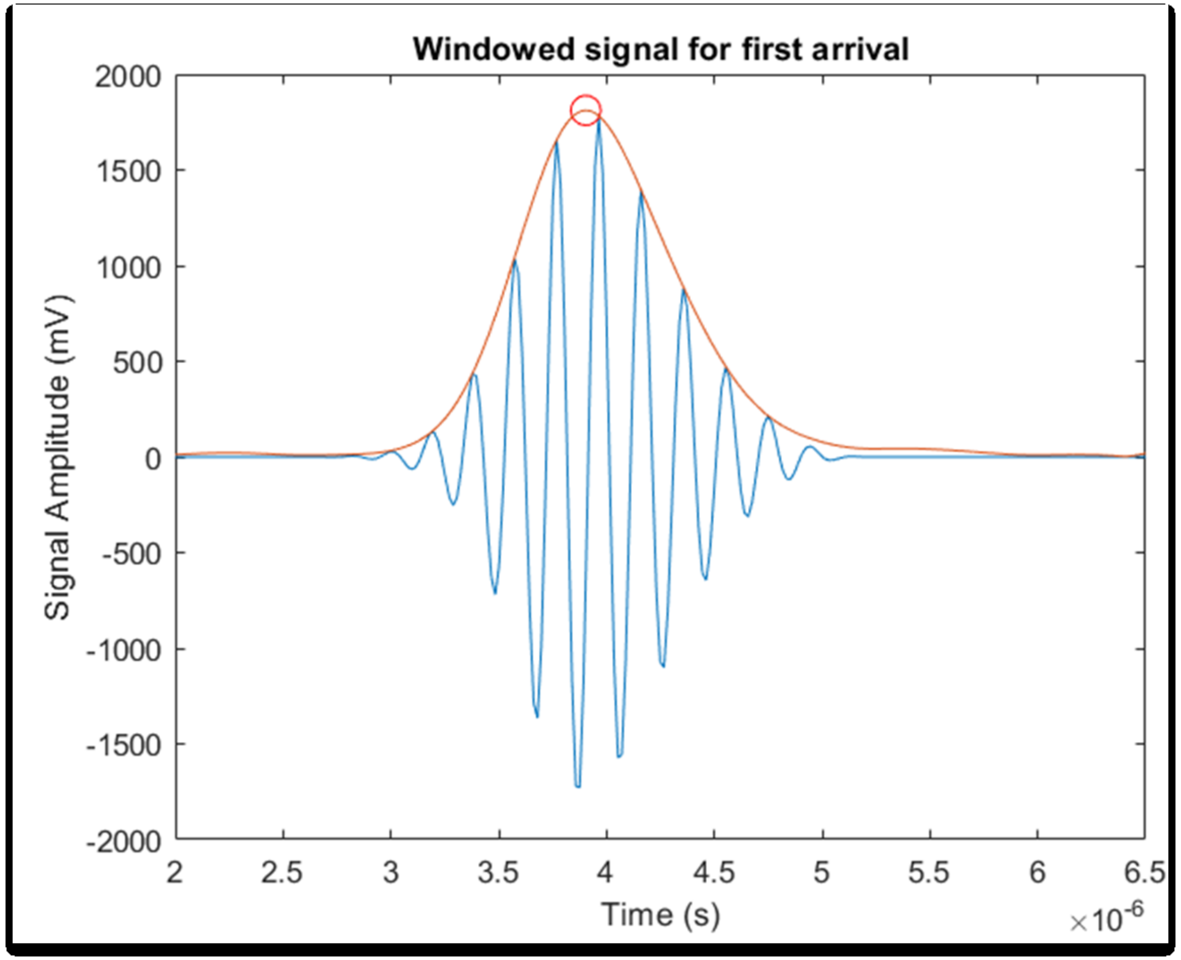
Experiment set up



Signal processing

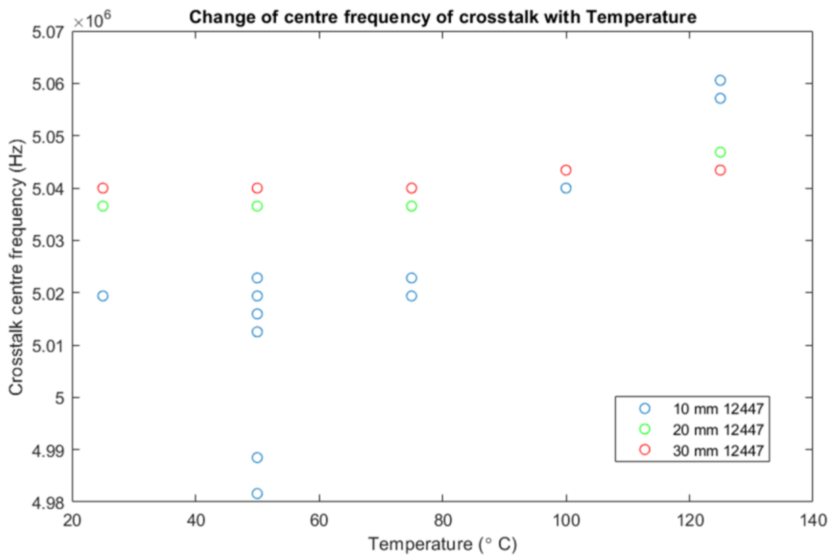


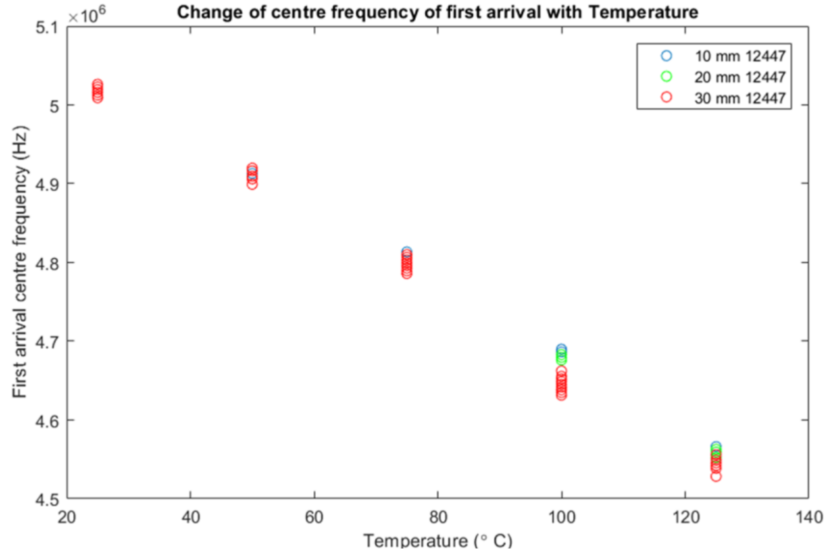
Signal processing (continue)

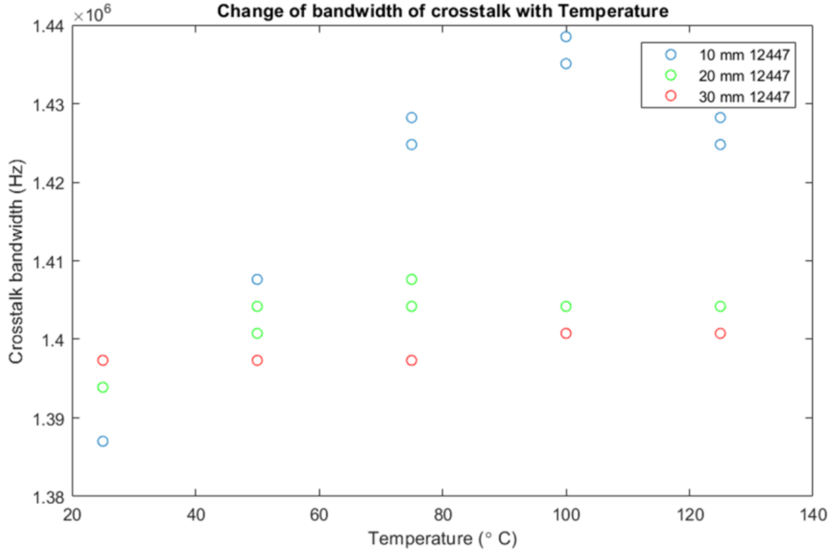


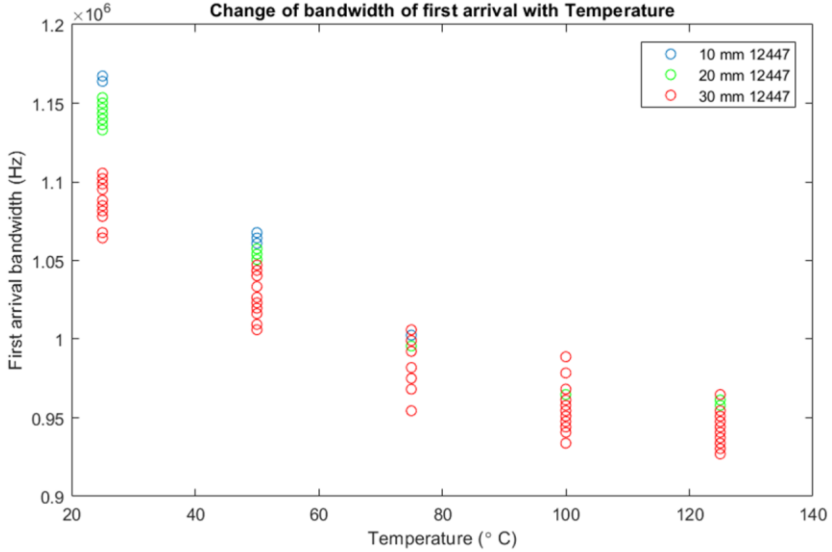
- Calculate centre frequency and bandwidth of time signals
- Signals of interest: crosstalk, first arrival, etc.

Results: identify temperature dependent parameters



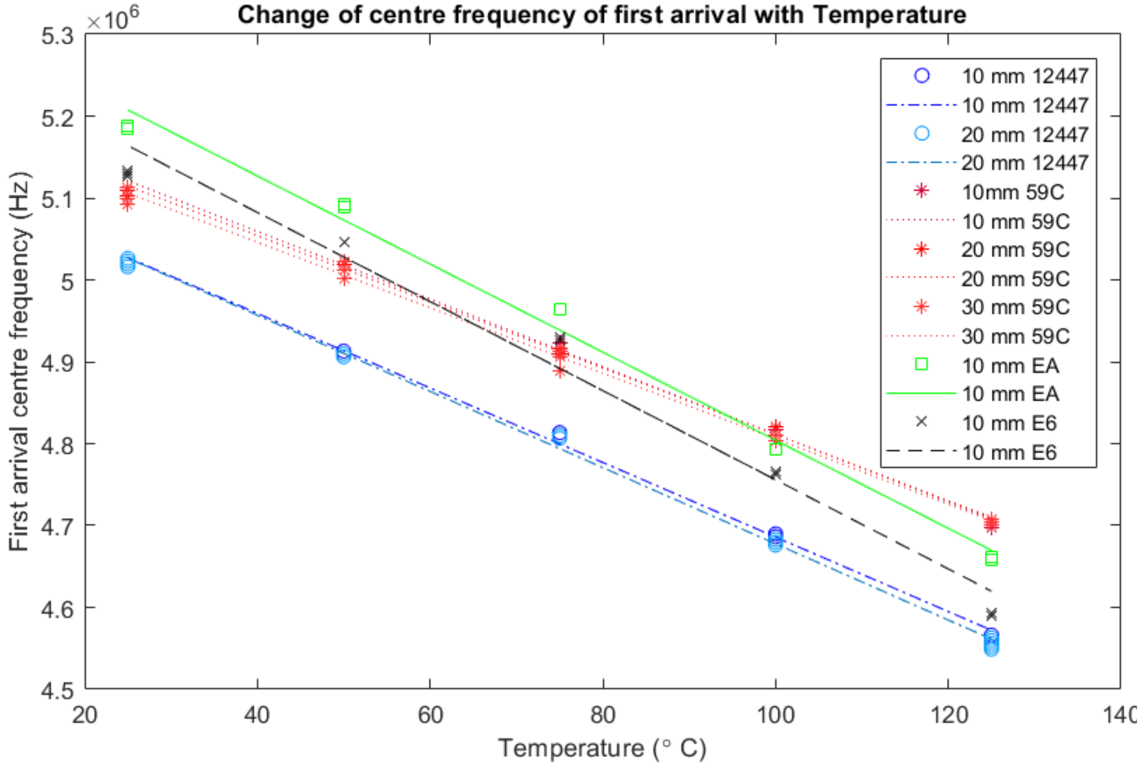


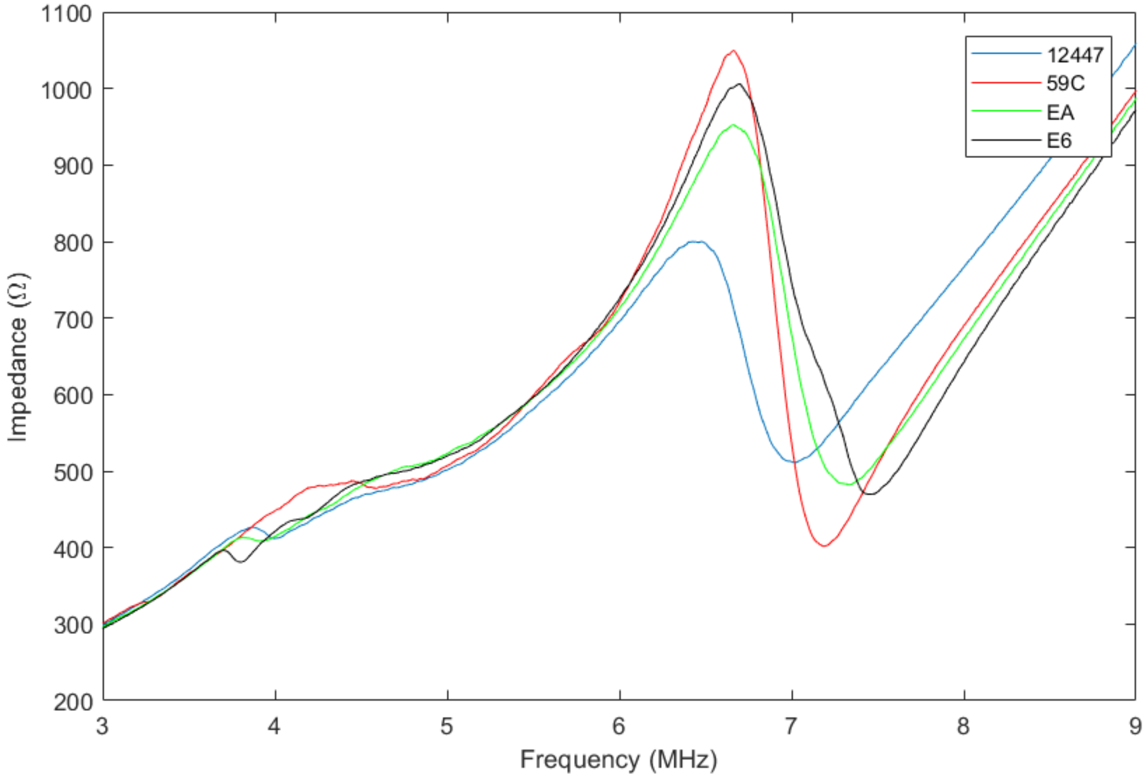




Centre frequency of first arrival is sensitive to temperature changes and less sensitive to different stand-offs.

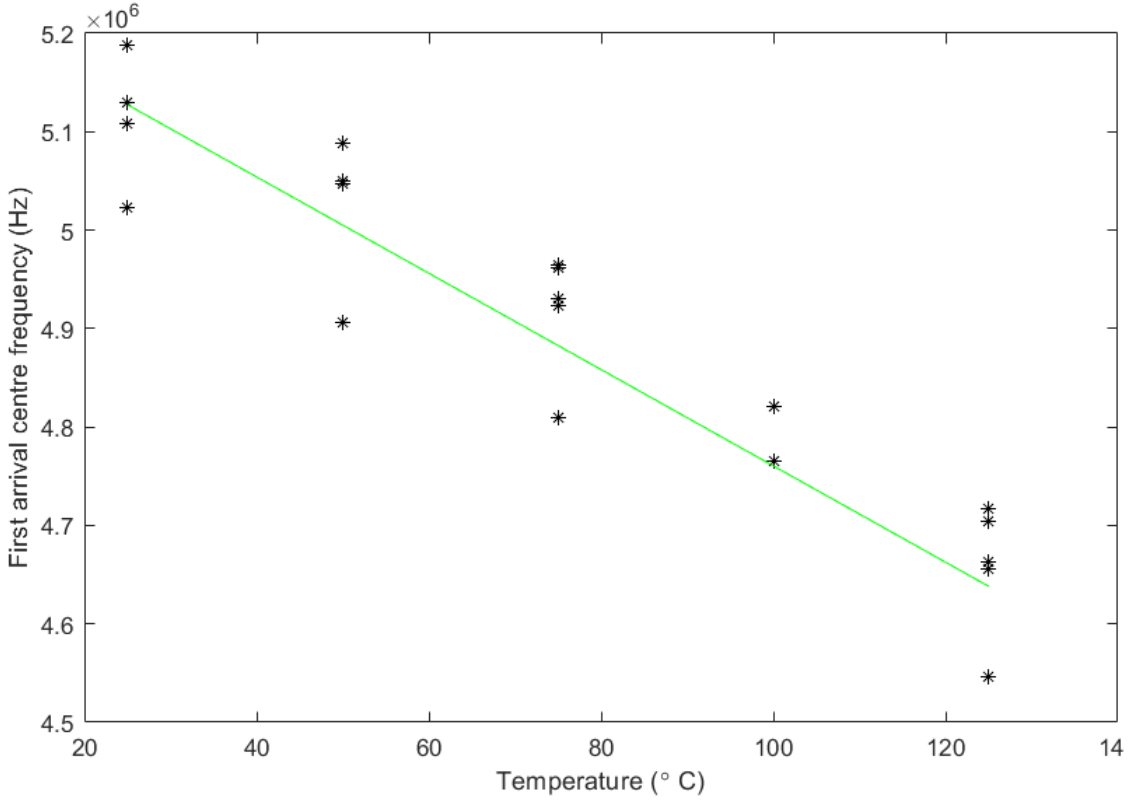
Results: effect of sensor resonant frequency

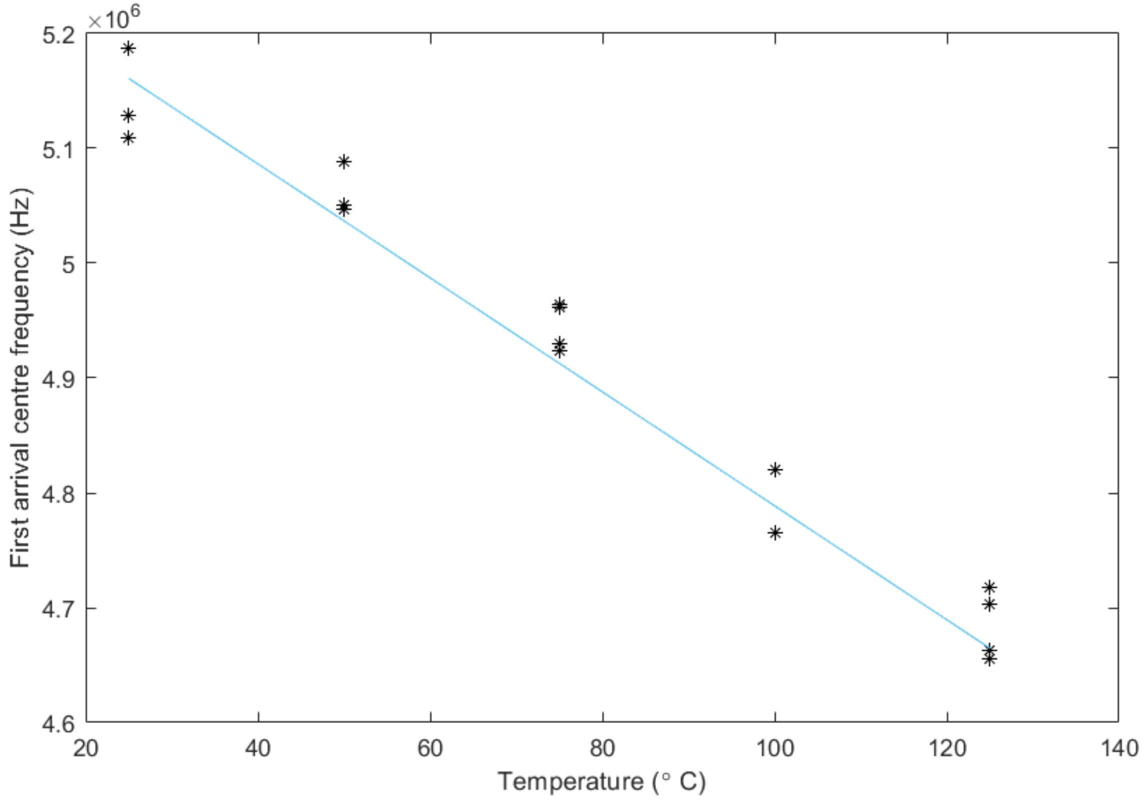




Correlation between the resonant frequency of sensor and the centre frequency of first arrival

Results: performance evaluation





- Left: the temperature estimation line is the average of all the sensors
- Right: improved temperature estimation by controlling the sensor resonant frequency

Conclusions

- Hybrid wireless ultrasonic sensor networks enable repeatable and automatic thickness measurements in remote or hard to access areas.
- The temperature of structure can be estimated from the centre frequency of first arrival.
- Limitations:
    - Only one type of material, i.e. steel
    - Limited number of sensors

  have been analysed in this study.
- Future work:
    - Analyse other materials, e.g., aluminium
    - Collect data from more sensors

Future application: High Performance Composites

Inductosense are progressing with an exciting project to further develop our WAND sensing technology for composite applications. Titled *'Wireless, battery-free sensing of composite structures'* our vision is to provide a commercial solution to meet the current manufacturing and non-destructive evaluation (NDE) in-service challenges met by end-users and OEM suppliers, across all composite sectors.

Supported by Innovate UK, we are primed to engage with the entire composites supply chain to best optimise our technology for end-user uptake. We would like to hear from you to help us scale-up our technology appropriately for commercial deployment. It is anticipated that the following functionality, applications and detection capabilities will be achievable at the project endpoint:

Functionality

- Cure monitoring
- In-situ structural monitoring

Detection

- Degree of cure
- Barely visible impact damage (BVID)
- Delamination and crack propagation
- Through-sandwich panel measurement

Applications

- Hybrid and composite structural assemblies (i.e. bond line monitoring)
- Retrofit (surface mounted) and new build (embedded) components
- Integrated within tooling
- Composite repair (metallic pipes)

Contact us

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