Ultrasonic guided wave approach for ice detection on wind turbines

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About us

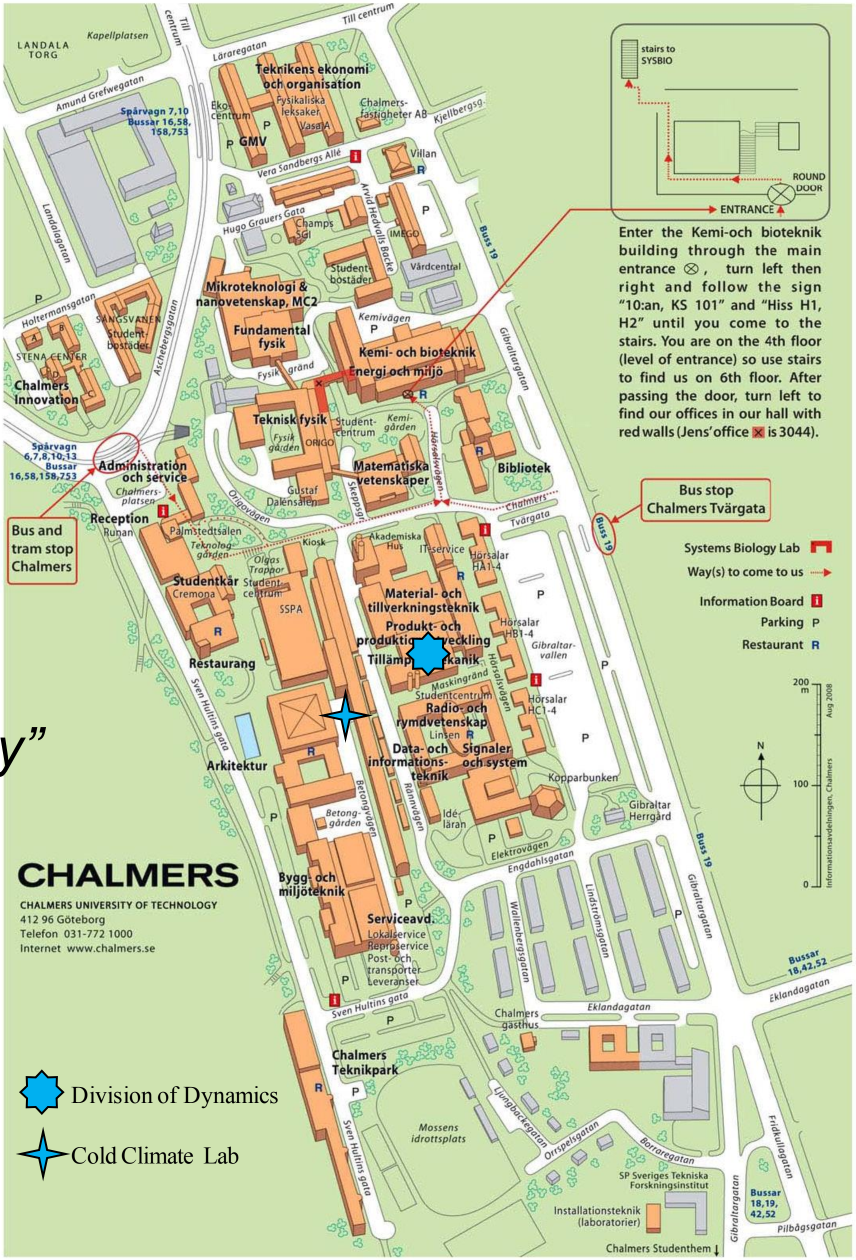
Location:

Division of Dynamics

Department of Applied Mechanics

Project:

- Ice detection for smart de-icing of wind turbines
- Funded by *"Swedish Energy Agency"*
- One year pilot research project was carried out (2012-09 to 2013-09) to develop the basic principles
- The project continued in a PhD program

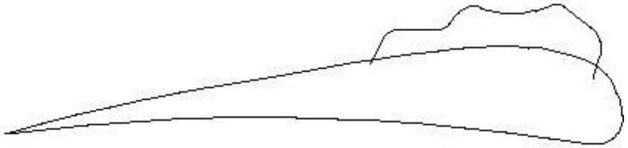


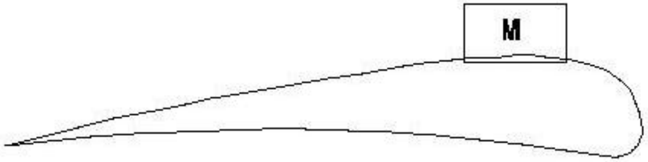
Background

- Wind turbines operating in cold regions or high attitudes face ice accumulation on the blades.

- Icing conditions on wind turbine causes:
  - Increases loads on the blades
  - Reduced aerodynamic efficiency
  - Undesired Vibrations and Turbulence
  - Safety issues

windpowerengineeringdevelopment.com





Methods of detection

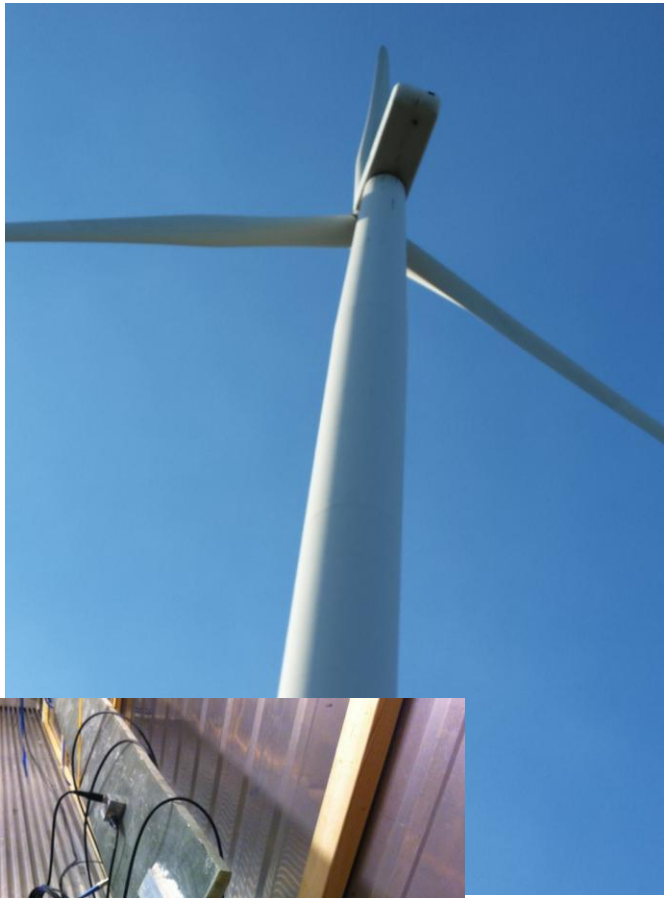
Currently there are many methods of detection available.

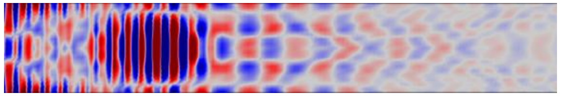
The available methods are divided into two groups of In-direct (Condition monitoring) and Direct (e.g., Radio wave, Ultrasonic wave, laser and …).

Although there are many methods available, there is still lack of accurate and efficient method of detection (Homola et al. 2006).

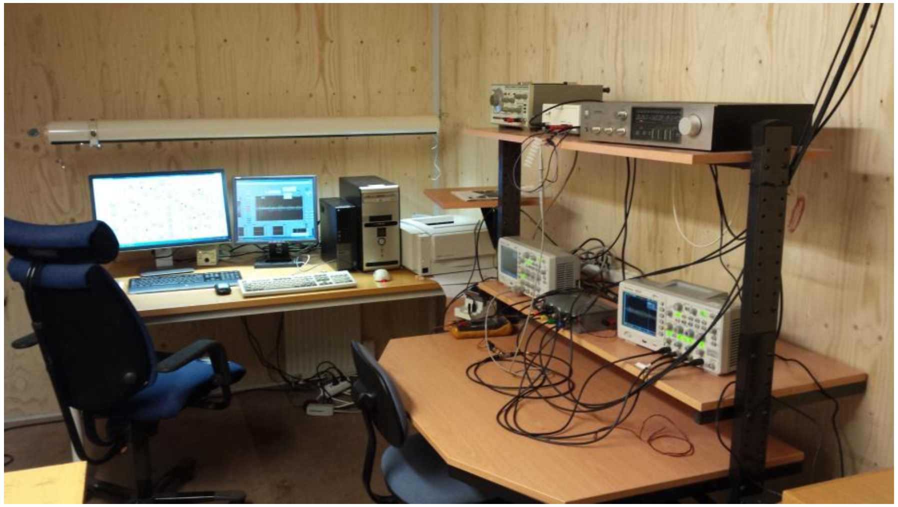
Method

- The aim of the project is to develop a method for early detection of ice using ultrasonic guided wave in turbine blades.
- The project includes mathematical and computational modeling of ultrasonic wave propagation in composite materials in order to be able to find the application for ice detection.
- It also includes experimental work in Cold climate lab on composites objects and layers of ice.



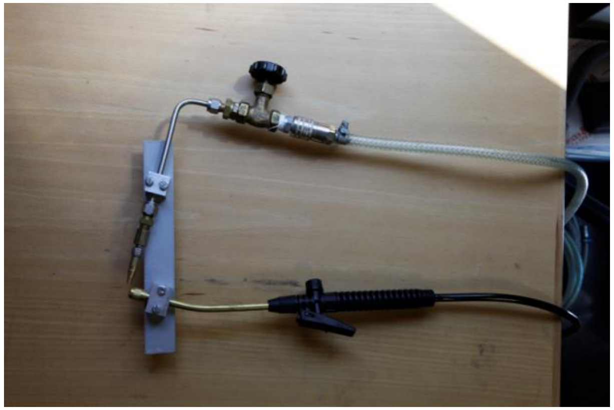


Cold Climate Lab at Chalmers

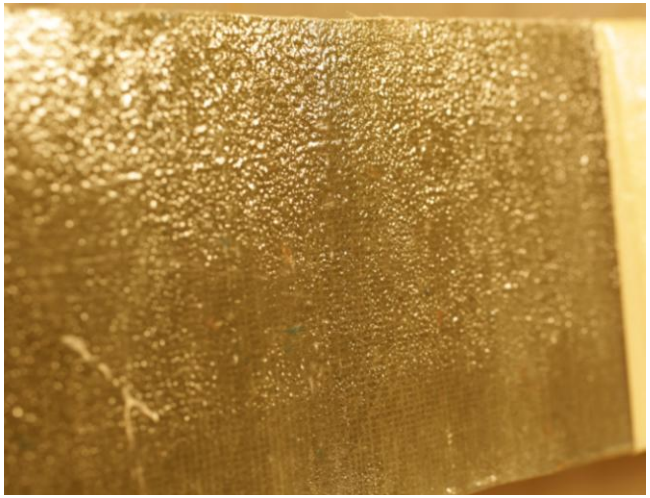


Ice Manufacturing

- Two devices were developed to manufacture glaze and rime ice.
- In both devices, compressed air splits up the water in small droplets to freeze under subzero condition in the lab.
- To make glaze ice, compressed air makes smaller droplets and spreads them on the work object to freeze.



Ice manufacturing device for Glaze ice



Sample of manufactured Glaze ice

Ice Manufacturing

- To make rime ice, the droplets should freeze before they reach the object.
- The souronding temperature should be around -10 ºC or lower.
- Mixture of water and air spreads out of the nozzle and freezes in the cold air.

Ice manufacturing device for Rime ice

Sample of manufactured Rime ice

Test Object

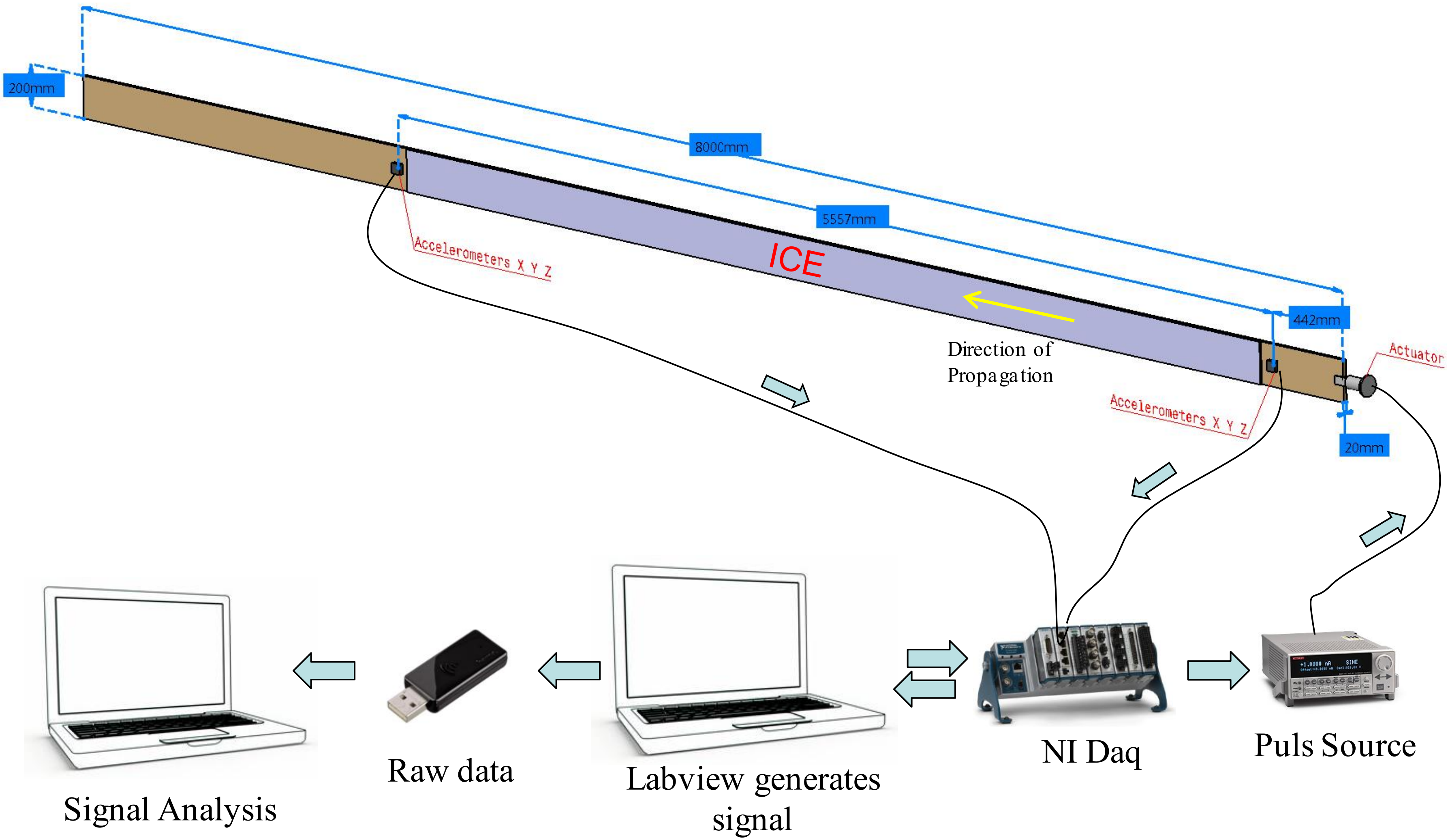
- The test object is a composite plate with dimensions $20 \times 200 \times 8000\ mm^3$

- The material consists of:
  - Outside face: 3 × (0º/-45º/90º/45º)
  - Inside face: 6 × (0º/-45º/90º/45º)
  - Core: 26 × UD

- Weight Fibre Fraction: 71%

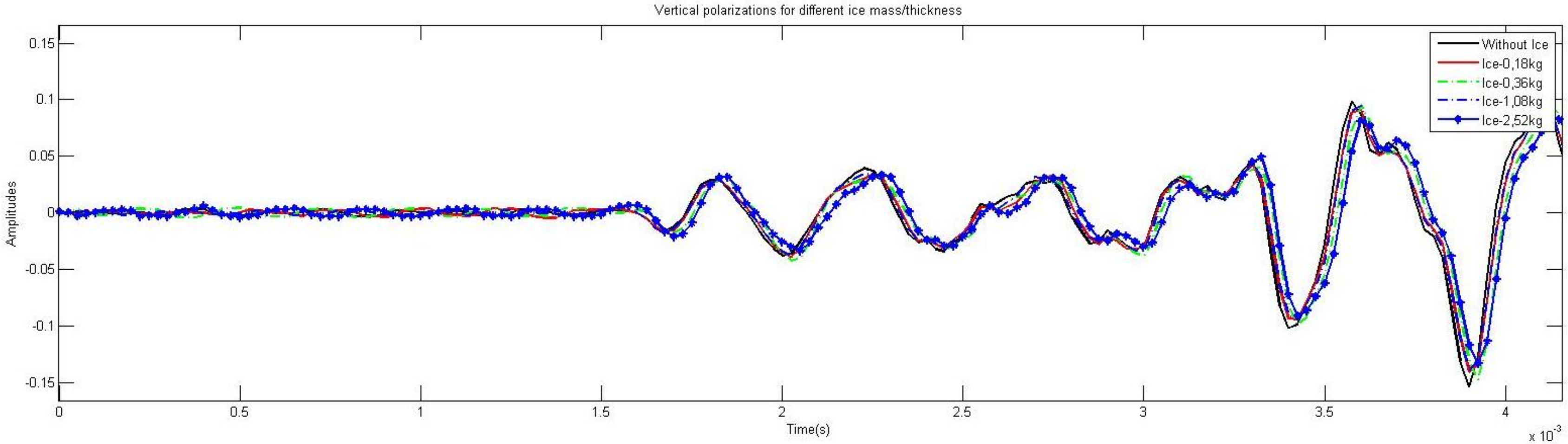
- The plate is excited in one side using a magnetostrictive actuator with a step function (170 volts, 0.3 ms)

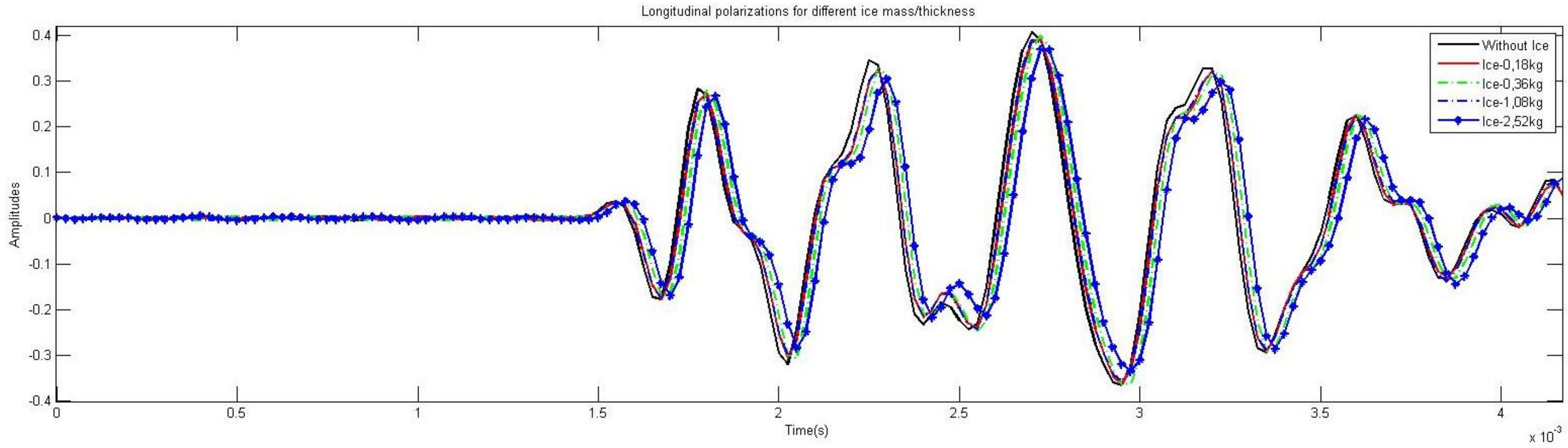
Test set-up


200mm
8000mm
5557mm
ICE
442mm
Actuator
20mm
Accelerometers X Y Z
Accelerometers X Y Z
Direction of Propagation
Signal Analysis
Raw data
Labview generates signal
NI Daq
Puls Source

Experimetal results

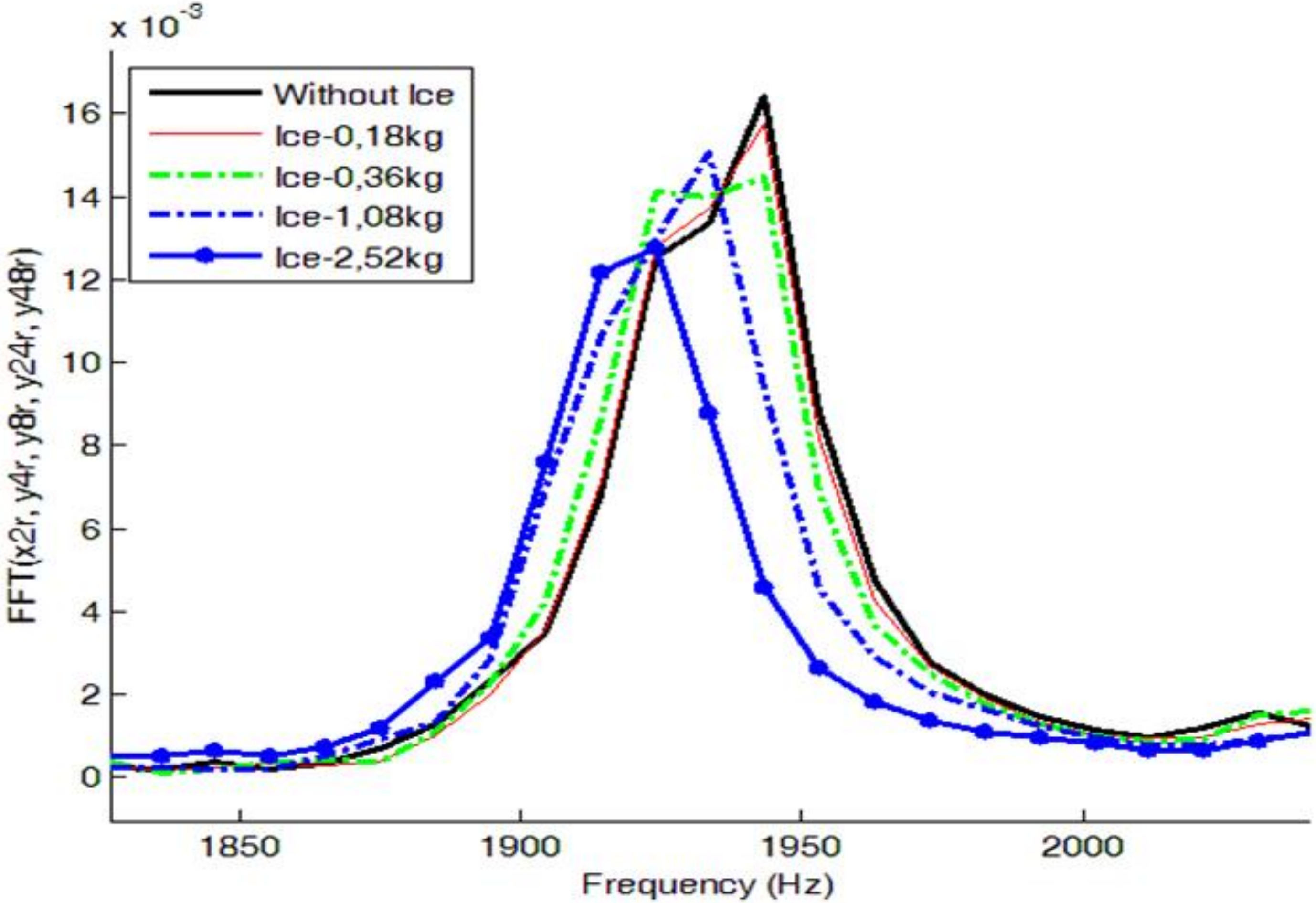
Amplitude of the signal in vertical and longitudinal directions with different amount of ice on the plate.





Experimetal results

FFT of the signal in vertical direction with different amount of ice on the plate.

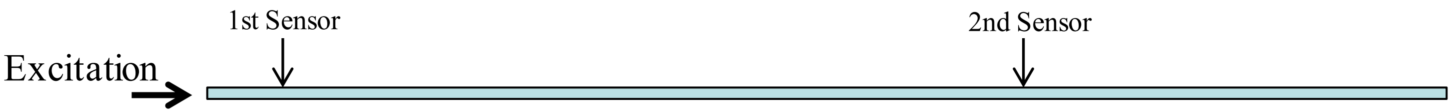


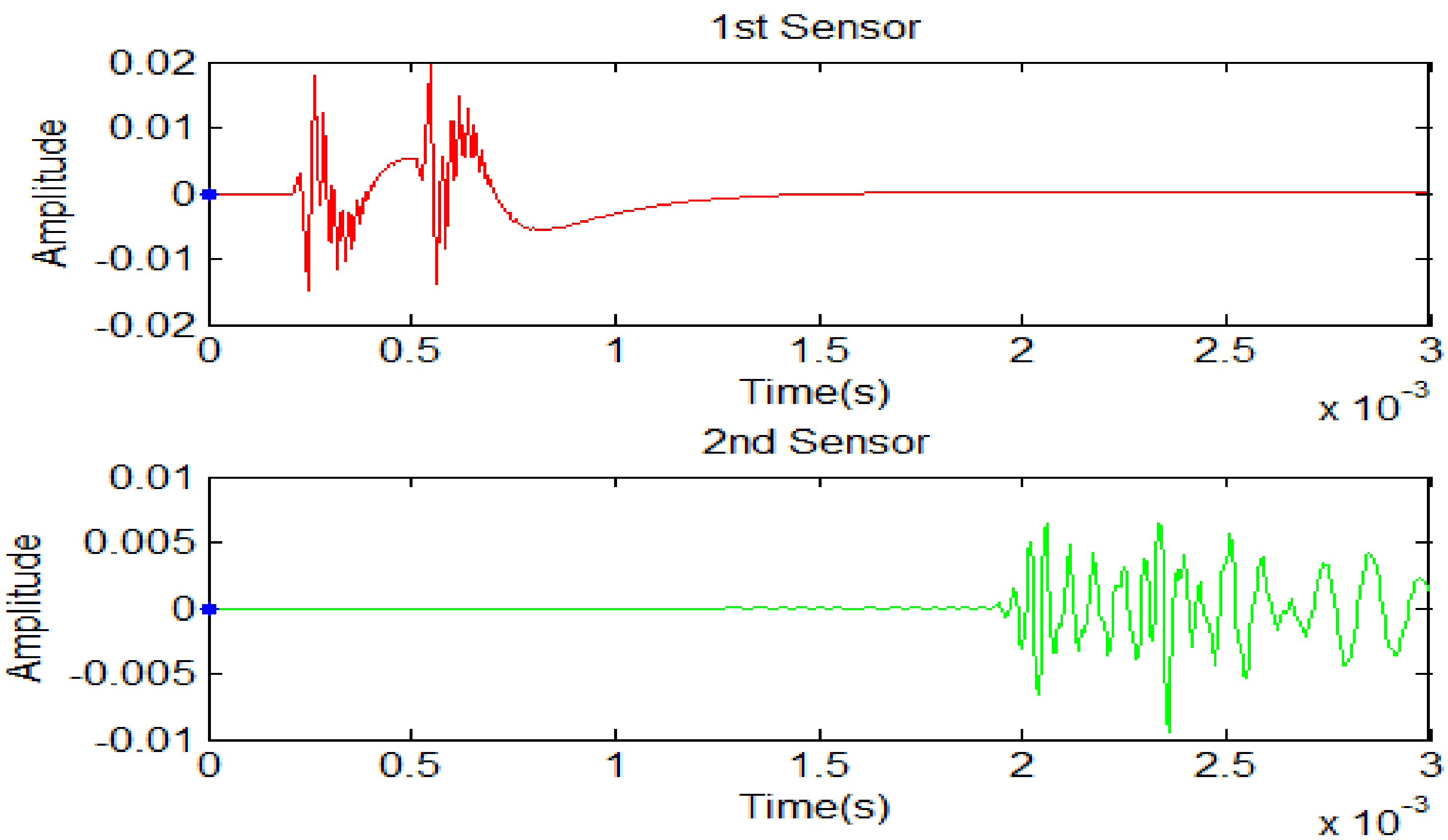
FE Simulation

- 2D finite element model is made to simulate the ultrasonic wave propagation.
- The plate is modeled as an anisotropic material.
- Ice is modeled with a second layer on the top as an isotropic material.
- Same excitation is applied to the model as displacement.
- Amplitude of displacement is collected in 2 points located at the place of the sensors.

FE Results

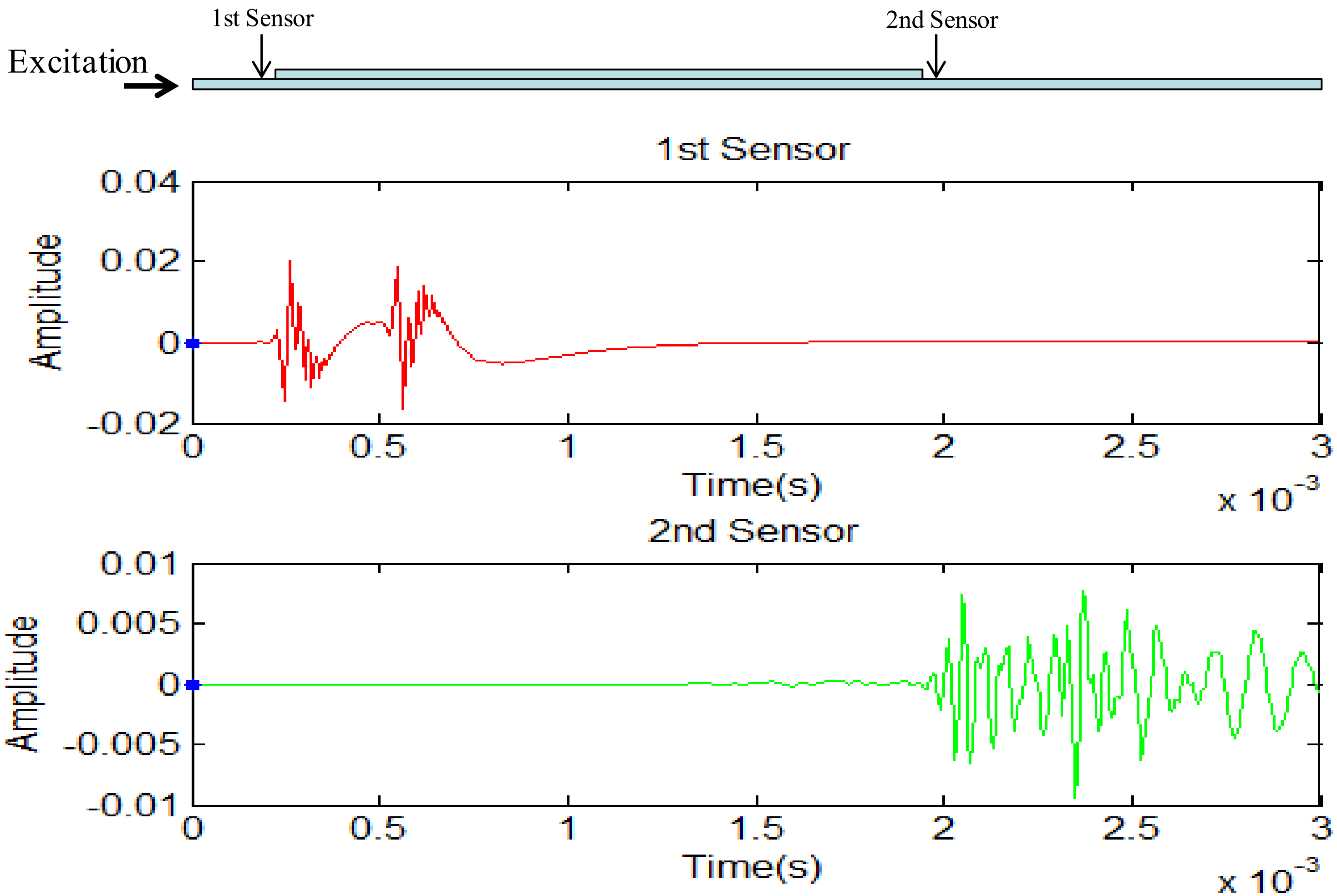
Amplitude of the signal in vertical direction (no ice).





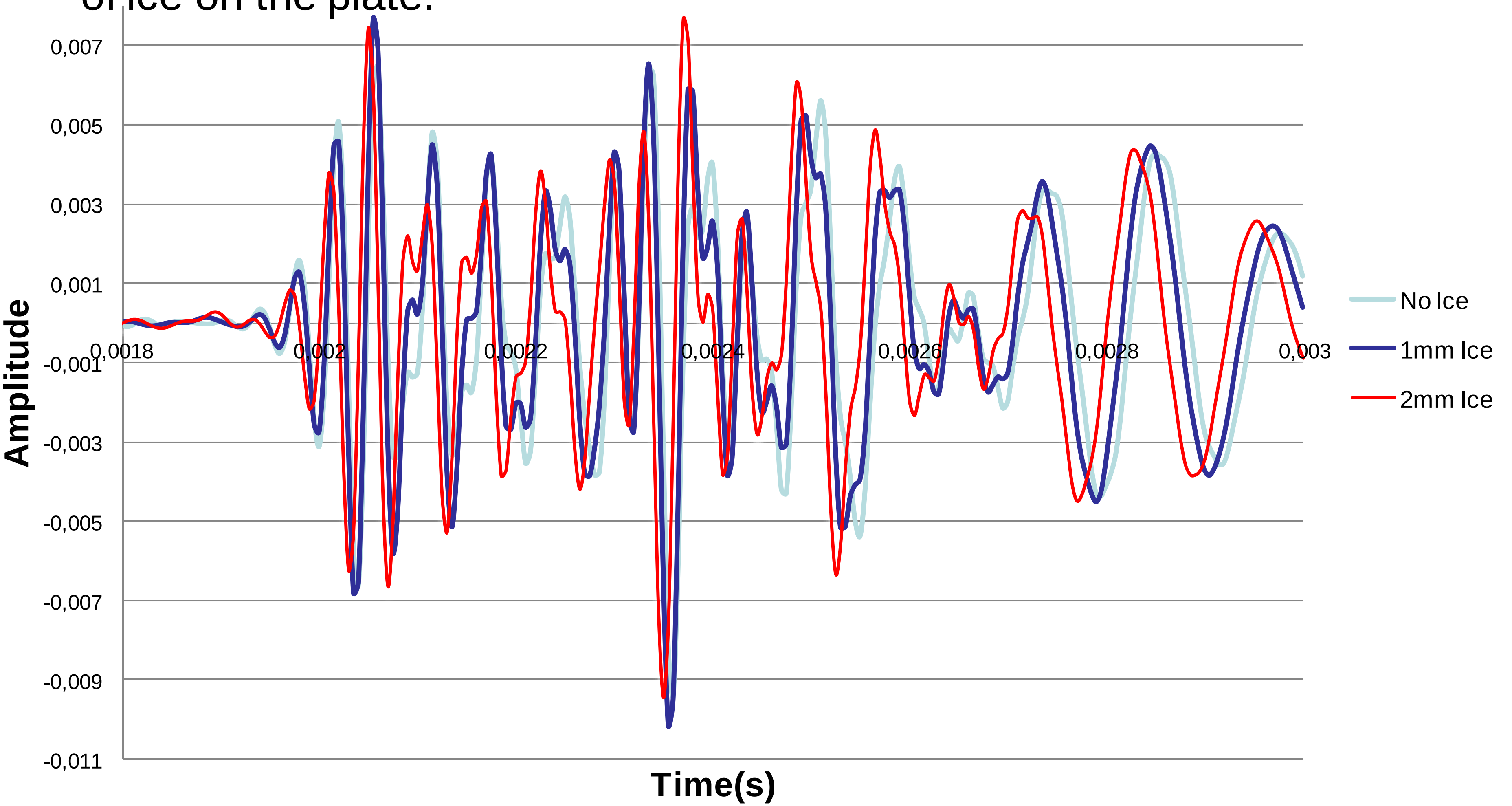
FE Results

Amplitude of the signal in vertical direction (2mm ice).



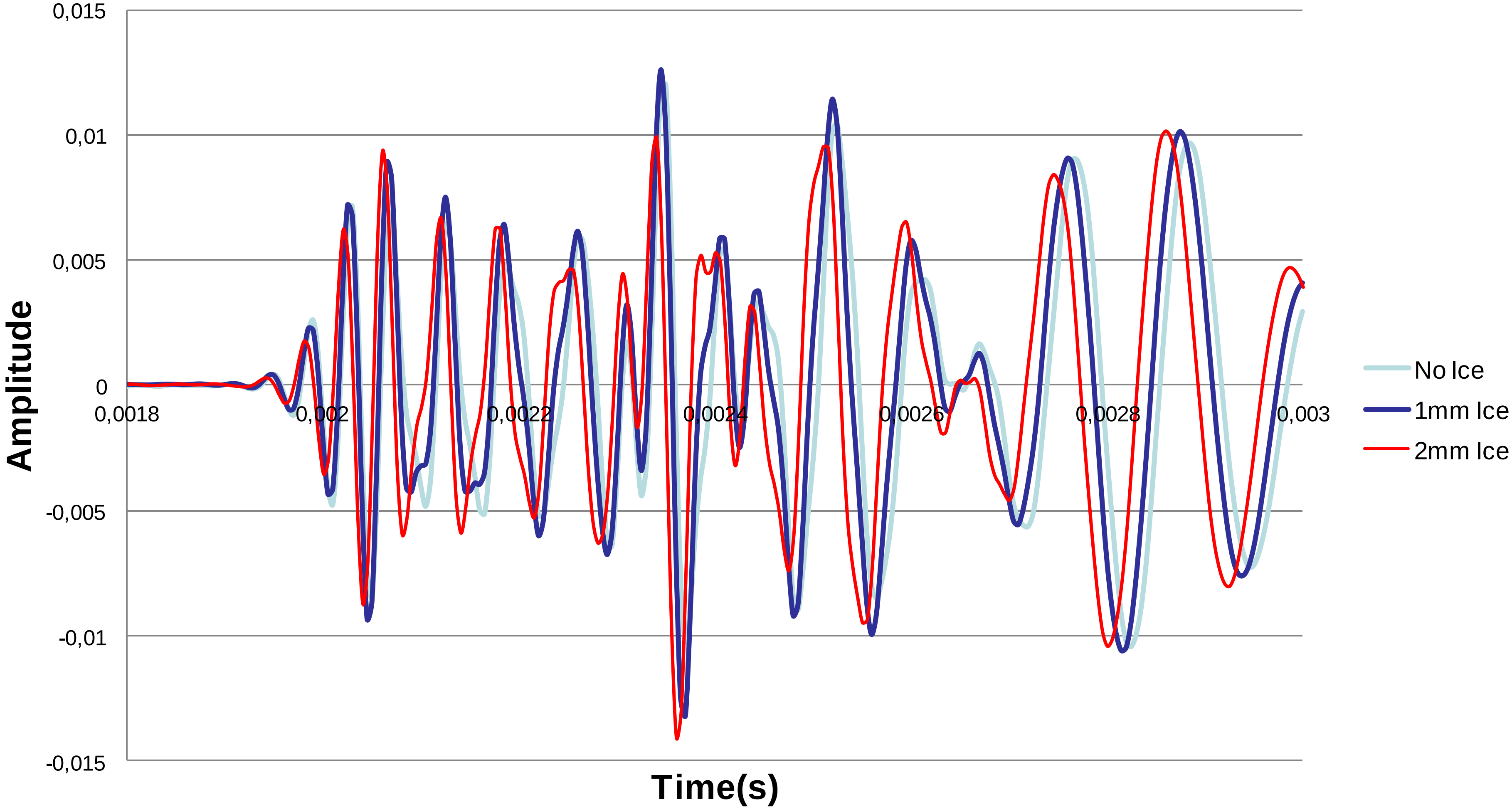
FE Results

Amplitude of the signal in longitudinal direction with different amount of ice on the plate.



FE Results

Amplitude of the signal in vertical direction with different amount of ice on the plate.



Comparison and Conclusion

- In both cases of experimental set-up and FE simulation, changing the amount of ice makes significant effect on the amplitude of the wave propagating toward the plate.

- In both cases, reduction of the amplitude and phase shift can be observed.

- By calibrating the FE model it is possible to obtain reasonable results for different scenarios.

- Changes of the amplitude can be observed by adding 1mm layer of ice, which is promising to use the method for early ice detection.

Aknowledgements

This project is part of a PhD program titled *“Ice detection for smart de-icing of wind turbines”* and funded by *Swedish Wind Power Technology Centre (SWPTC)* and *Swedish Energy Agency*.

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