Numerical simulation of sound propagation in pipes in application to robotic sensing and navigation

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Introduction

The UK's extensive buried water pipe network, spanning approximately 1 million kilometers, remains largely shrouded in uncertainty regarding its structural integrity. This research initiative resolves around the development of an autonomous robot platform equipped with state-of-the-art sensing technology, poised to revolutionize the assessment of buried pipe networks by offering pervasive and prolonged inspection, localization, and navigation capabilities.

Aim

► Deliver **better understanding of the influence of the robot's shape** on the quality of the collected **acoustic data** in a range of pipes

Objectives

► **Simulate acoustic wave propagation** in a pipe with a range of robot's shapes

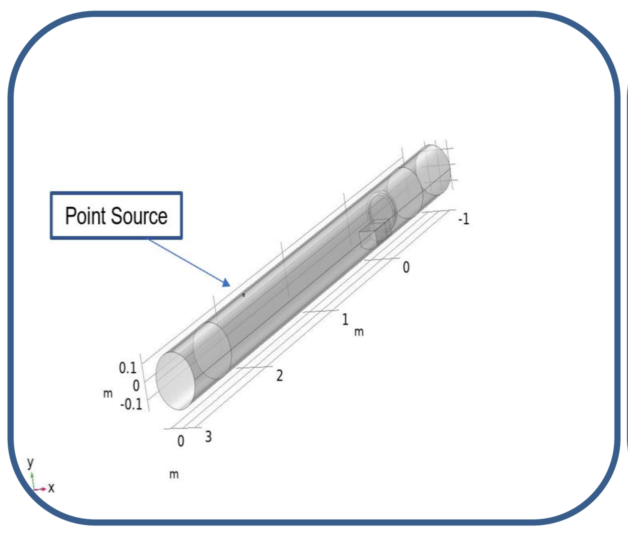
► **Study** the **influence of the presence of a robot** in the pipe **on the acoustic waveform** recorded on the microphone deployed on the robot

► **Make** sensible **modification to the robot's body** shape and materials to **minimize the influence** of the robot **on the acoustic waveform** reflected from the in-pipe artefacts

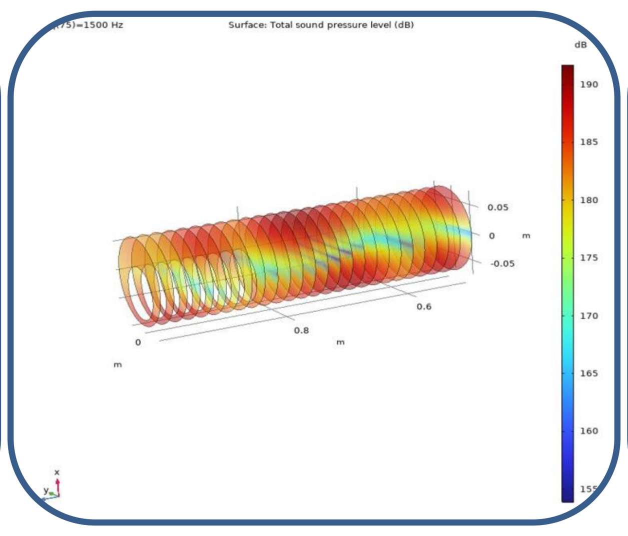
Methodology

Employing advanced numerical methodologies utilizing software like **COMSOL Multiphysics and MATLAB**, the study **simulated acoustic wave propagation** in pipes containing **a spectrum of artefacts**.

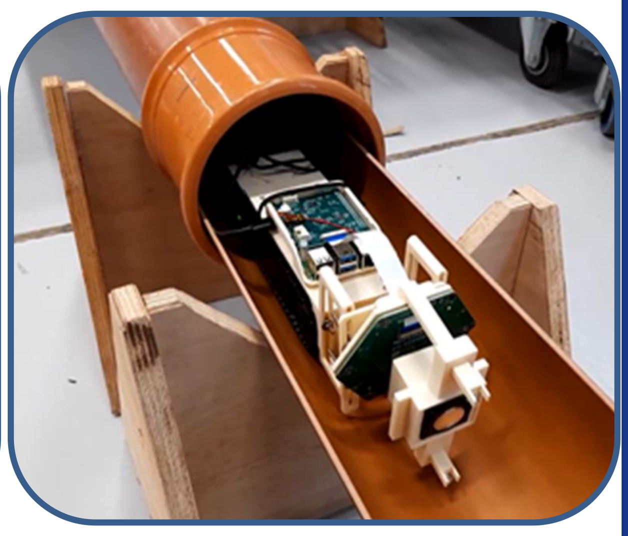
STEP 1	**Build 9 different size robots** in a 150 mm diameter pipe using **COMSOL Multiphysics**
STEP 2	**Simulate acoustic wave propagation** around 9 different size robots in a 150 mm diameter pipe using **COMSOL Multiphysics**
STEP 3	Do **experiments using an actual robot and use MATLAB to sort and validate the data** obtained from COMSOL Multiphysics and experiments



STEP 1



STEP 2



STEP 3

Findings

► **Total sound distribution around a robot**

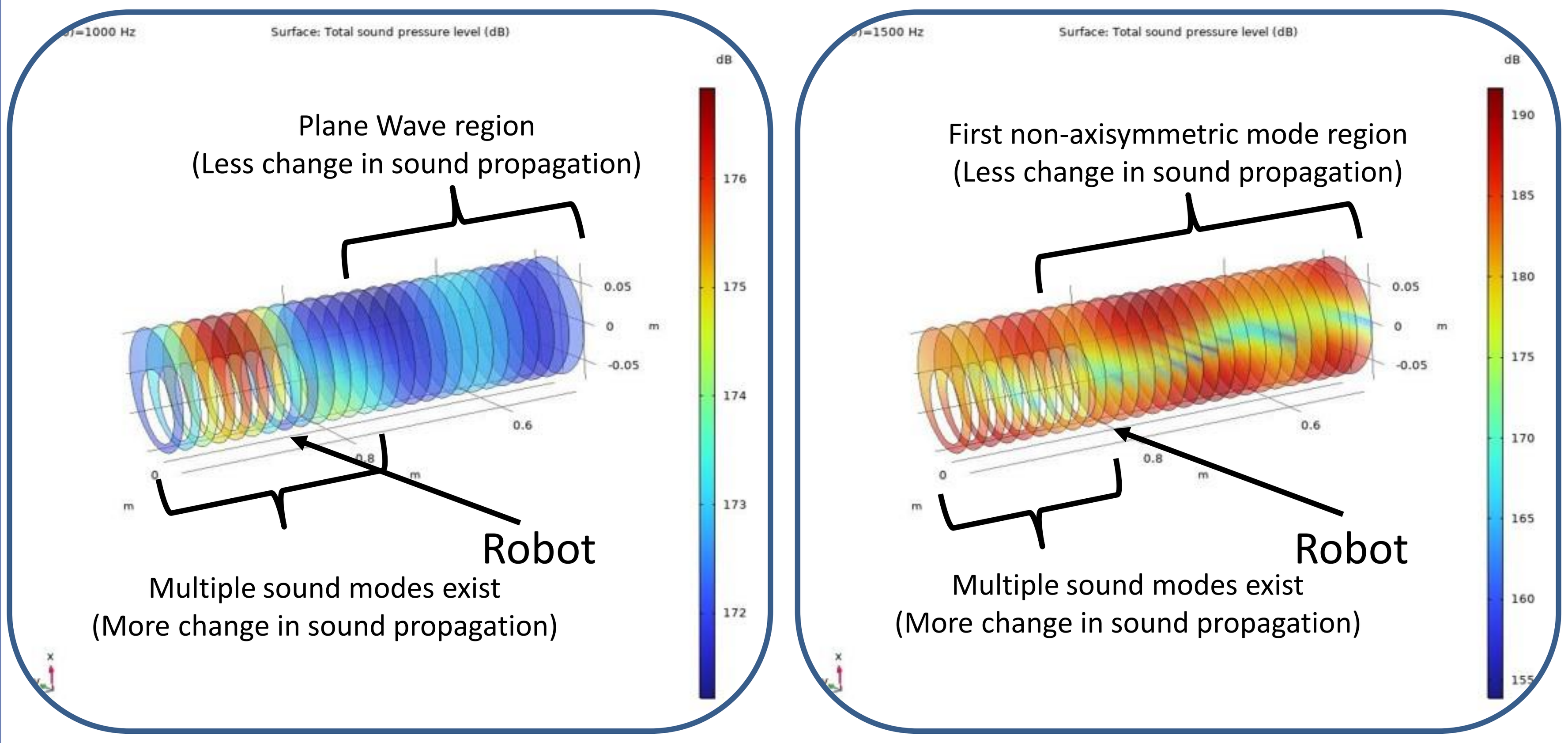


Fig 1. Total sound distribution at 1kHz (left), 1.5kHz(right)

► **Total acoustic x component velocity around a robot**

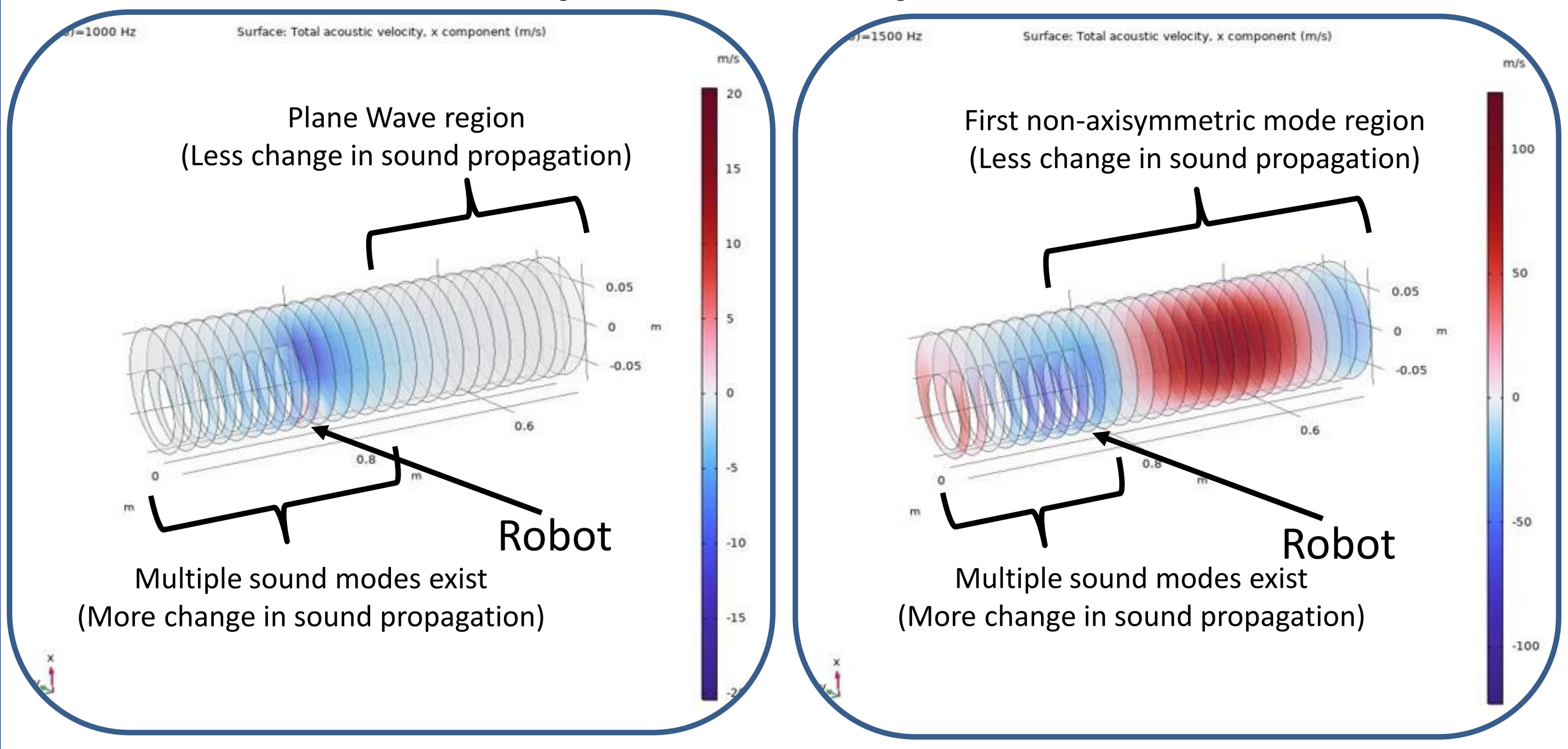


Fig 2. Total acoustic velocity at 1kHz (left), 1.5kHz(right)

(i) It is observed that there are more acoustic response changes in plane wave region close to the top or the side of the robot than that of the front of the robot.

(ii) Placing acoustic sensors on the top or side of the robot is not recommended since there are more distortions in the acoustic wave form than that of front of the robot. Therefore, it is recommended to mount sensors at the front or back of the robot.

(iii) There is a slight distortion of acoustic response close to the front side of robot. It is recommended that sensors should be placed at least 1 cm away from the front board.

Conclusion

By mitigating the distortion and preserving the fidelity of acoustic responses, this research strived to **enhance the accuracy and reliability of condition classification and navigation systems**, thus catalyzing the effective evaluation and management of the UK's vast buried water pipe network.

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