Ultrasonic sensors: From analytical modelling to design optimisation and validation

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Aim:

The primary aim of this project is to apply an analytical modelling technique, for design and optimisation of an application specific ultrasonic sensor.

Background/Motivation:

Ultrasonic sensors are used routinely in many application areas, including medical imaging and therapy, non-destructive testing, SONAR and industrial process monitoring. Successful and cost effective design of an ultrasonic sensor can be problematic, for a variety of well-established reasons, and is reliant traditionally on practical experience, supplemented by performance evaluation via computer modelling. Even while considering a simple ultrasonic sensor configuration, there is a wide variety of possible designs. Backing layers, matching layers, electrical load, and the active piezoelectric element used are among the many parameters that could be varied, and successful design of a sensor device is often very difficult, owing to its complex interaction with these influencing factors. As technological requirements have advanced, sensor complexity has increased dramatically, making intuitive design very difficult. Consequently, new improved models, capable of predicting the device characteristics, are vital for designing complex ultrasonic sensors/systems and keep pace with the increasingly stringent technological requirements of the future.

Method:

There are many ways to model piezoelectric sensors. However, within this project we will mainly adopt an analytical approach to model one specific type of ultrasonic sensor configuration. It consists of a thickness mode piezoelectric element and two passive layers, and the sensor is intended for operation in air. Specifically, this project would involve the following tasks:

1. Study and apply analytical model for a conventional ultrasonic sensor. Initial focus will be to build a 1D model, assuming simple material properties that could be easily implemented in a programming environment (such as Matlab). We will follow a stepped approach whereby the student will progressively introduce more realistic parameters such as viscoelasticity and material damping into their model.
2. Analyse using the analytical technique implemented, a multidimensional sensor design problem – varying the many key interdependent parameters in the model and study their effect on the overall sensor characteristics.
3. Validate simulation results by a finite element modelling method. There is also potential to experimentally test the findings in our ultrasound lab (in Physics).
4. Investigate and report on possible improvements to the analytical model studied – For example, to make it more robust/accurate and applicable to a more complex sensor configuration.

Please Note: Adequate training/support will be provided for all simulation and experimental work required in this project.

Further work:

This project will provide the student with a good introduction to analytical modelling for application specific ultrasonic sensor design. The student will also be trained in a suitable finite element modelling technique and essential experimental procedures, required for the project. These skills will form an excellent foundation to proceed into a PhD research topic, were one could look at developing novel and improved analytical models, that is capable of simulating more complex sensor configurations (such as piezoelectric stacks and arrays), and applicable to a wide range of application areas.