# Acoustic-Structure Interaction Simulation of a Differential Phase Sensor

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## Abstract

The idea of application as a hearing device based on a parasitoid fly, Ormia ochracea has been studied extensively recently. This paper addresses another possible application as an underwater directional sensor.

In order to study the feasibility of the application, it is necessary to investigate the feasibility of the underwater application of the directional sensor based on the hearing system of the parasitoid fly. Placing a sensor in water causes fluid loading to the sensor. Fluid loading has two main effects on vibrating structures. First, the fluid mass loads the structure, meaning that the structural natural frequencies are altered due to added mass. Secondly, the acoustic radiation is provided by the fluid medium additional damping. Vibrating structure in fluid, even in air, radiate sound, especially as frequency increases. In this paper, the half-power bandwidth method is used to estimate the radiation damping ratio based on the corresponding Q value from the frequency response function of a sensor which is excited by far field sound wave impinged on the sensor.

The harmonic responses of the sensor in air and water are compared to each other and it shows that there is more damping effect in the second natural frequency than the first and there is prominent damping effect in water than in air as expected. In order to analyze the characteristics of the sensor, harmonic analysis in water is performed and compared with the in vacuo case.

In COMSOL Multiphysics®, the Pressure Acoustics and Solid Mechanics physics interfaces have been used for a frequency domain analysis and for analysis of additional damping effect due to sound radiation. Background acoustic pressure is used to simulate an incident plane wave which acoustically excites the sensor in water.

The nature of the geometry of the sensor induces a high aspect ratio which is the ratio of the longest dimension to the shortest dimension of a quadrilateral element. For this reason, two-dimensional model was used instead of three-dimensional one by taking advantage of symmetry.

Perfectly Matched Layer is used to simulate the open boundary to purely capture the fluid effect of the sensor in the water without standing waves, hence the mode shapes are expected to remain unchanged in water from ones attained from in vacuo or in air.

## Reference

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2. J. H. Lee et al., "Modeling and Characterization of the Bio-Inspired Hydro-Acoustic Sensor," ASME Journal of Vibration and Acoustics in submission

3. J. H. Lee et al., "Parametric Analysis of Bio-Inspired Hydro-Acoustic Sensor for Directivity," IEEE Sensors Journal in preparation

4. J. H. Lee. "Bio-Inspired Acoustic Sensor for Sensing Directivity of Sound," Ph.D. Dissertation, University of Washington, Seattle, WA.

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## Figures used in the abstract

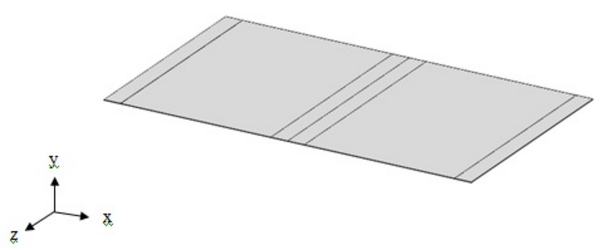



**Figure 1**: Three dimensional Finite Element model with axes.

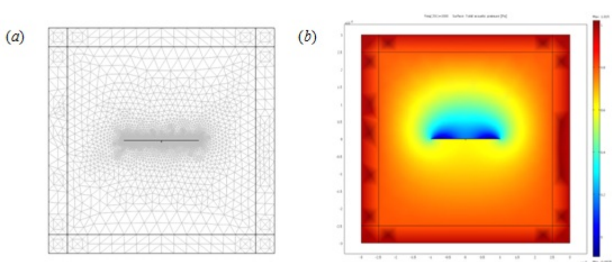
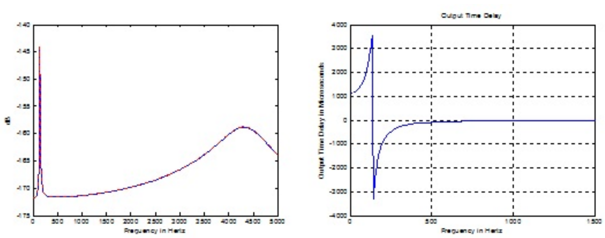



**Figure 2**: Underwater sensor (a) in Mesh, and (b) Simulated Modes.

(a) First mode (b) Second mode

**Figure 3**: (a) First, and (b) second mode shapes of the sensor model.



(a) (b)

**Figure 4**: Frequency response based FEA harmonic analysis in terms of (a) dB, and (b) Time delay.