Optimization of Device Geometry of a Fully-Implantable Hearing Aid Microphone

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Abstract

Introduction: The hearing impairment is affecting more than 360 million people all over the world suffer [1]. In India alone, 63 million people suffer from significant auditory loss [2]. Considerable interest in middle ear implants has emerged over the years to facilitate patients who do not receive significant benefits with conventional hearing aids. Also, the social stigma of wearing external hearing aids discourages some users from even considering the conventional devices.The totally implantable devices provide the user freedom from the social and practical difficulties of using conventional hearing aids. In this paper, a MEMS capacitive accelerometer is demonstrated as a middle ear implantable microphone for the fully implantable cochlear prosthesis. The accelerometer is proposed to be attached to the middle ear bone structure, umbo to convert the bone vibration to an electrical signal representing the original acoustic information. This paper attempts to enhance the sensitivity of the fully implantable middle ear microphone by optimization of the device geometry using the Genetic algorithm. The optimized model satisfies the required design considerations with regards to the surgical implantation of the fully implantable microphone.
The comb drive accelerometer in this work consists of four folded beams, a proof mass, and movable fingers as shown in (Figure 1). The fixed parts include two anchors and left/right fixed fingers. The movable central mass is connected to both anchors through four folded beams. Here x1 is the distances of fixed finger from left movable finger and x2 from the right movable finger as shown in (Figure1).

Under external acceleration, the proof mass with the movable fingers moves in the direction of body force, which changes the capacitance between the movable and the fixed fingers.The capacitance is measured using electronic interface circuitry.
Use Of COMSOL Multiphysics® software: This model is simulated using COMSOL Multiphysics® in 2D as a plate structure. The physics used includes electrostatics, solid mechanics, and moving mesh. The geometry parameters of the model optimized using Genetic Algorithm are given in (Figure 2). Corresponding to the input voice signal, the acceleration values from 0 g to 1g are applied to the designed structures. The structures have been analyzed using silicon material and air as dielectric. The proof mass along with movable fingers is kept at 1 V and the fixed fingers with the ground.
Results: We have performed 500 iterations 50 times with a crossover probability of 0.8 and mutation probability of 0.01 to obtain the best result. The population size is taken as 500. The number of input variables is 7. The displacement vs. acceleration plot and change in capacitance vs. acceleration plot are presented in (Figure 3) and (Figure 4) respectively for

three different frequencies of 500 Hz, 2000Hz and 3500 Hz.
Conclusion: The optimized capacitance of 3.14 pF and sensitivity of 2.49 nm/g is obtained with total 128 number of sensing fingers. The optimized results will be used in designing high-performance MEMS accelerometer for fully implantable hearing aid applications.

Reference

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Figures used in the abstract

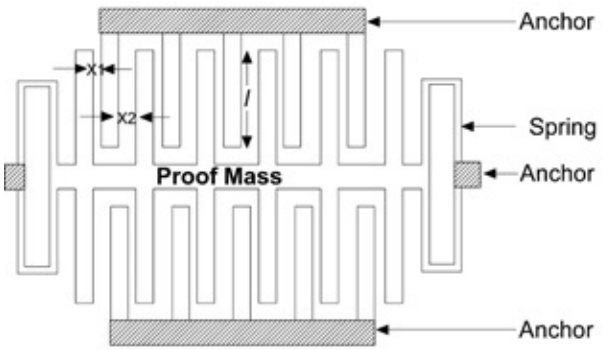

Figure 1: Prototype of Capacitive Accelerometer.

Parameter	Value
Gap Ratio (x_2/x_1)	6
Number of fingers	64
Length of finger	105 µm
Thickness of device	43 µm
Length of proof mass	747 µm
Width of proof mass	940 µm
Length of Spring Beam	119 µm

Figure 2: Optimized parameters.

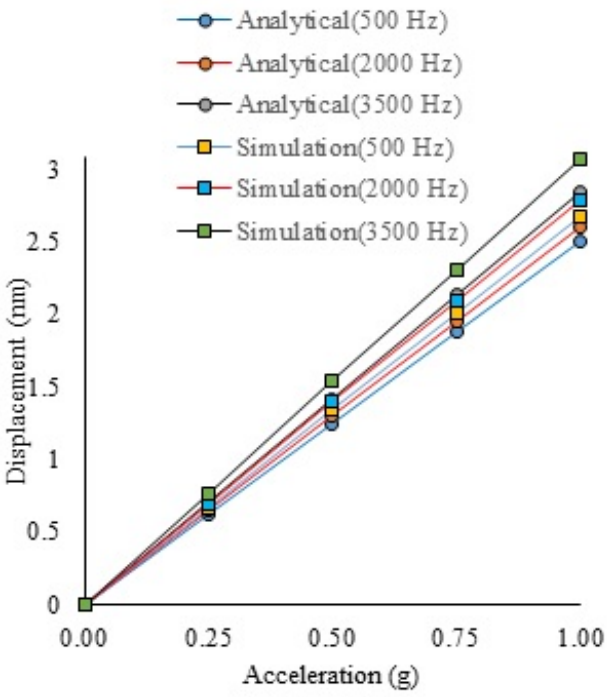

Figure 3: Displacement vs Acceleration.

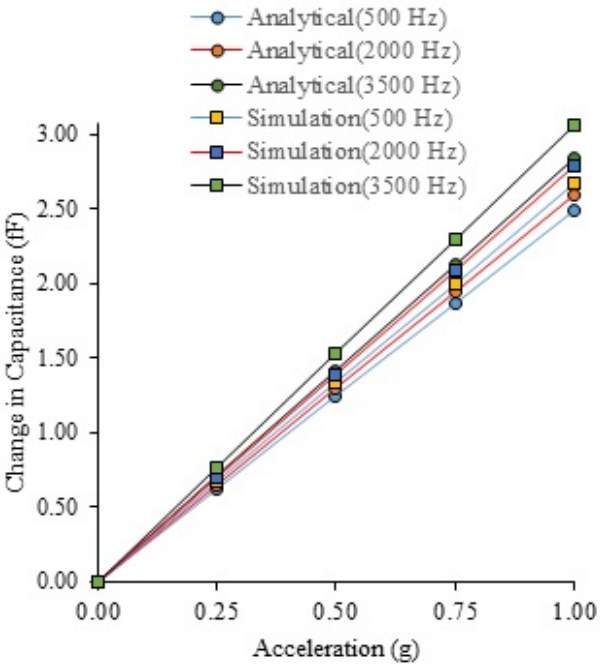

Figure 4: Change in Capacitance vs Acceleration.