Numerical investigation of normal mode radiation properties of ducts with low Mach number inlet flow

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Summary

Totally implantable hearing devices

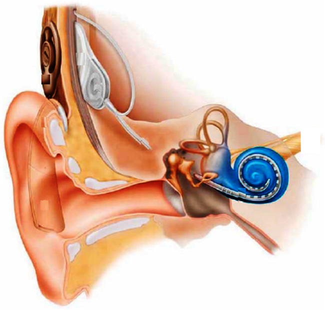

Figure 1: Traditional Cochlear implant. Source: [2]

- Presence of an external element in hearing aids and cochlear implants (CI)
- Totally implantable CI (TICI) and totally implantable hearing devices have been proposed [1]
- Hence, Implantable sensor

Summary

Implantable sensors

- Subcutaneous microphone [3, 4] - skin infections, body noise and variable sensitivity - sensitivity equals to 2 mV/Pa at 90 dB SPL at 1 kHz [5]
- Piezoresistive accelerometer [6] - bandwidth from 900 Hz to 7 kHz, but high power consumption (1 mW)
- Capacitive accelerometer [7, 8] - limited sensitivity between 2 and 4 kHz, 30 mV/Pa at 94 dB SPL at 1 kHz, power consumption about 4.5 mW
- Piezoelectric accelerometer [9, 10] - bandwidth from 300 Hz to 6 kHz and sensitivity equals to 10 mV/Pa for 90 dB SPL at 1 kHz

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Requirements of totally implantable sensors

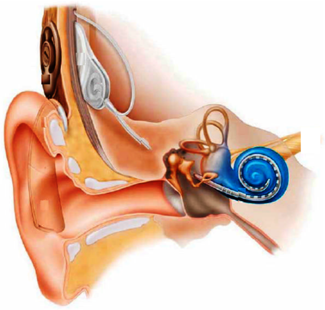

Figure 2: Traditional Cochlear implant. Source: [2]

- Appropriate dynamic range has been assumed to be from 40 to 100 dB SPL [7].
- Bandwidth has been defined as from 100 Hz to 5 kHz
- maximum dimension of 2 mm [11]
- sensor mass must also be less than 10% of the ossicle's mass to which it will be fixed

To achieve such limitations, fabrication via micro electromechanical systems (MEMS) technology is considered.

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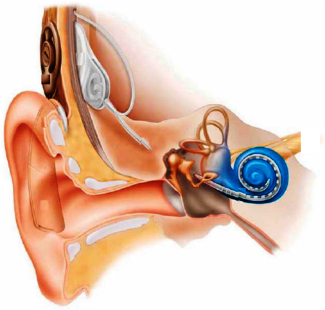

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Summary

Design of implantable MEMS piezoelectric

- Three designs are analysed via Finite element method (FEM)
- MEMS fabrication restrictions imposed by Piezoelectric Multi-User MEMS Processes (PiezoMUMPS^{TM}by MEMSCAP®) are considered

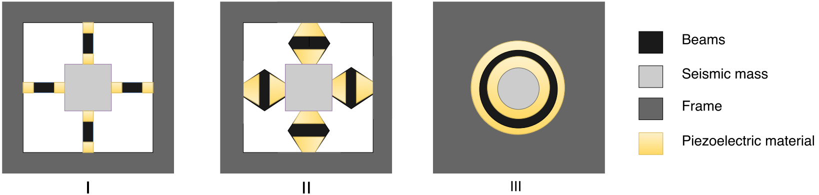

Figure 3: Top view of the different MEMS designs analysed. Design I: trampoline, design II: hexagonal beams with square seismic mass, design III: annular

Summary

Lumped parameter model of the middle ear

Lumped parameter model was used to represent the coupled system formed by the accelerometer and the ossicles of middle ear [12].

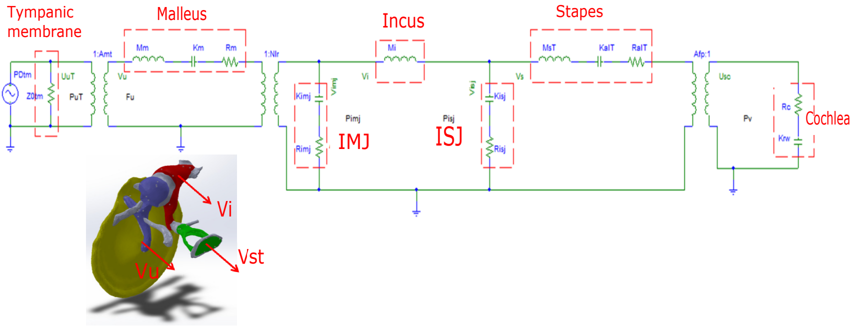

Figure 4: Equivalent circuit model of the middle ear and direction of velocities

Lumped parameter model of the

Lumped parameter model of the accelerometer and pre-amplifier is coupled to the lumped model of the middle ear.

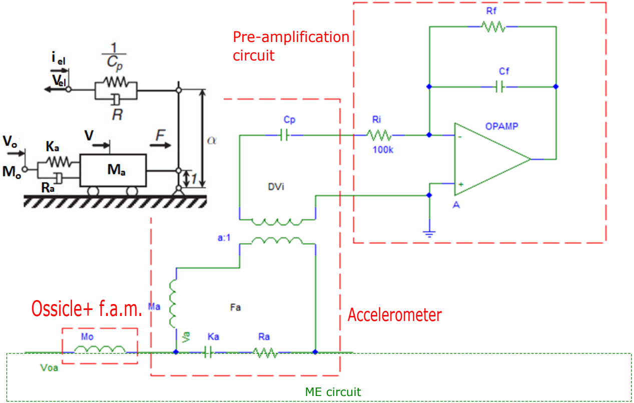

Figure 5: Equivalent circuit model of the accelerometer with its pre-amplification circuit coupled to the ossicular chain

Summary

Accelerometer response optimization

Table 1: Response of optimized MEMS accelerometers.

Design	Natural frequency [kHz]	Charge sensitivity [pC/g]
I	15.4	0.048
II	10.0	0.051
III	18.8	0.071

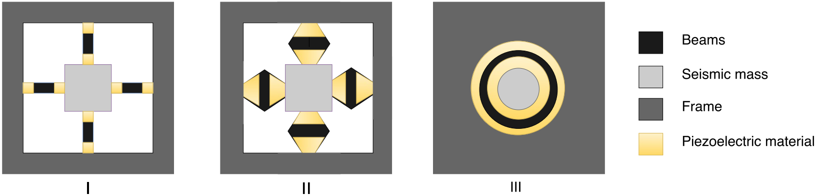

Figure 6: Design I: trampoline, design II: hexagonal beams with square seismic mass, design III: annular

Voltage sensitivity of accelerometers

Voltage responses reach a maximum of 30 mV/Pa at 300 Hz, decaying to 0.7 mV/Pa at 1 kHz.

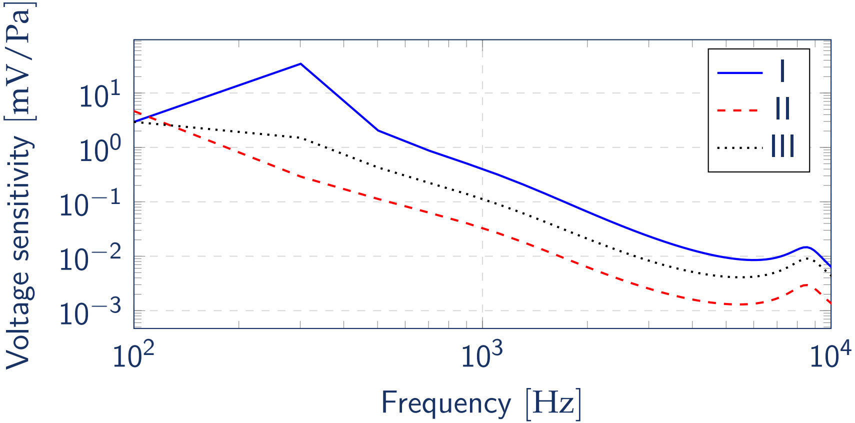

Figure 7: Voltage sensitivity of the different designs coupled to the malleus.

Voltage sensitivity coupled to different ossicles

According to this simplified model, malleus and stapes are the best candidates to fix an accelerometer.

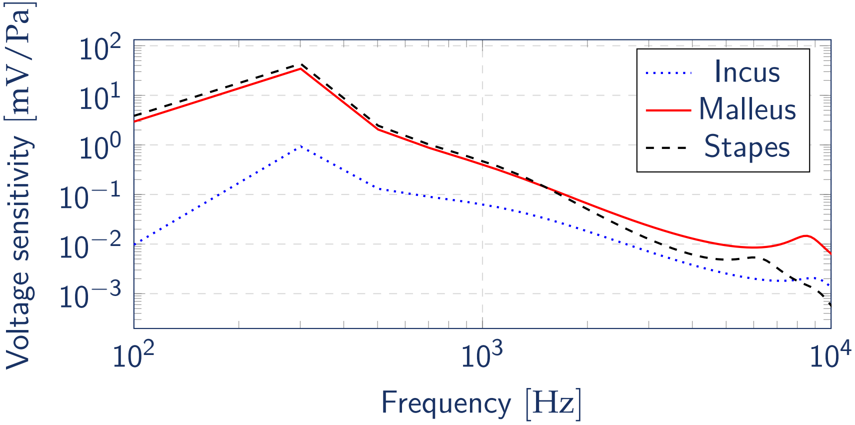

Figure 8: Voltage sensitivity of the design I (trampoline) accelerometer coupled to different ossicles of the middle ear.

Summary

Conclusions and ongoing work

Conclusions

- An approach based on FEM and EC can be applied to investigate the behaviour of an implantable sensor for hearing devices.
- Promising results for piezoelectric MEMS accelerometers. Voltage sensitivity equals to 0.7 mV/Pa at 1 kHz (2 mV/Pa in subcutaneous microphone).
- Mass of the designed accelerometers vary from 1.9 to 2.3 mg.

Conclusions and ongoing work

Ongoing work

- Validation of FEM accelerometer models (prototypes will arrive in September 30).
- Consideration of amplifier circuit on analysis.
- Development of a multibody dynamic system that represents the behaviour of the middle ear more realistically.

Thank you!

Questions?

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