Master Thesis Project

Optimization of fractal shape piezoelectric microenergy generator for Internet of Things application

Background:

The development of powering sensors and circuit systems using energy from ambient environment is very promising, as it enables power solutions that are eco-friendly, cost efficient and not subjected to limitations posed by traditional batteries. The vision is to have an entirely Internet of Things (IoT)-based sensing platform having a self-sustaining source of energy, for example incorporating an energy harvester and an energy storage unit on a single chip.

A vibration based piezoelectric energy harvester, for example, can be used to power small IoT components, for extension of batteries' lifetime and/or replacement of battery or power cables. One of the harvester challenges is to have a useful electric voltage output for a broader frequency range and/or multiple frequencies (that are not harmonics of eigenfrequency). An effective approach to bandwidth broadening is using multiple-degree-of-freedom structures and reducing the gap between the eigenfrequencies. This may be accomplished adopting optimized models for micro-energy harvesters that enable prediction of their energy and power outputs.

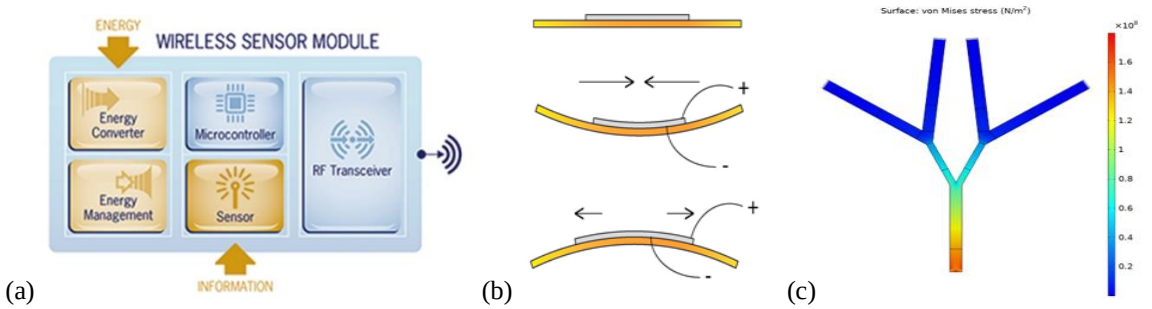

Figure 1: (a) Schematic of IoT sensor node based on energy harvesting; (b) Piezoelectric principle used for vibration-based energy harvester technology; (c) Finite Element simulation for stress distribution of a fractal-based harvester structure.

Purpose and Project Description:

In a previous master thesis, a fractal design structure with multiple resonances was studied [1] (see Fig.1c). The present thesis is to further study such a structure using FEM in combination to optimization techniques adopting a genetic algorithm.

The specific objectives of this thesis are:

- Analyse the FE code and the related optimization techniques used for the existing harvester design [1] as a base for further simulations.
- Optimise the fractal harvester design for electrical properties combined with the mechanical ones by taking in consideration the 'electrical influences' of the piezoelectric

elements on harvester operation via the 2D Finite Element (FE) model: energy and power outputs at different vibrational frequencies and accelerations. For this, it is necessary to analyse the structure using multi-objective optimization with respect to several objectives such as bandwidth and energy output.

- Conceptually describe the effects of electrical and mechanical parameters of the harvester have on final energy output (e.g. internal piezoelectric resistance/capacitance, piezoelectric material, piezoelectric volume, load).
- Depending on the simulation complexity and required time there is the possibility also for manufacturing of the fractal-based harvester and its experimental characterization at RISE (Sensors and Material group).

The FE code should be able to model the effects from the acceleration from the surroundings, influence of stress induced on the side-beams of the cantilever on the 3dB bandwidth, influence of material effects such as damping, etc. Recommended FE program is COMSOL Multiphysics, but others may also be used.

Student Background:
This project is suitable for students who are interested in computational mechanics and FEM. Students with strong interest and good experiences in programming are encouraged to apply. There will be interaction with the RISE institute through several joint meetings during the project.

The project is suitable for 1-2 students from MPAME, MPPDE, MPSYS, MPSEB and master programs linked to MC2 department or Engineering Physics.

Remark: *This project is connected to another master project (Fabrication of micro-energy harvester, MC2) and may serve as a collaboration between master and PhD students from different departments.*

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About:
RISE, Research Institutes of Sweden AB:
RISE is a Swedish research institute within electronics, optics and communication technologies. As one of Europe's top research institutes, we provide cutting edge resources and knowledge within electronics, optics and communication technologies. We have the facilities and lab resources to offer advanced R&D as well as small scale production and prototyping. Our mission is to find new ICT-solutions for existing and future demands, creating sustainable growth in industry and society.

References:
[1] B. Pamfil and R. Palm "Design and Optimization of Nature-inspired Piezoelectric Generators: Fractal design", Master thesis, Chalmers 2021
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