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Design and Development of Low Frequency Vibration Energy Harvester for Wireless Sensor Networks

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Abstract

Motivated by wireless sensor networks technology for surveillance and tracking of animals, the energy harvesters are designed and fabricated. Since energy harvester is designed to harvest low frequency seismic noise, electromagnetic principle will be used in the harvester. It can be noted that structure undergoes small strains and thus piezoelectric based harvester is not suitable for low strains. Folded beam structure, circular spiral and square spiral geometries have been considered for the design of vibration energy harvester. Folded beam structure has been tested against experiments and it agrees well with the simulated results. Simulations performed on circular and square spiral geometries show that the first natural frequency is about 0.2 Hz. Square coil was manufactured and tested which gave natural frequency of 0.29 Hz.

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Keywords: Energy harvester; seismic noise; low frequency structures; electromagnetism

1. Introduction

With development of microelectronics and wireless communication technology, wireless sensor networks became popular as they can handle very complicated remote sensing and measurement. Applications of wireless sensor networks range from in health monitoring in aircrafts to surveillance [1]. Wireless sensor networks have numerous advantages over conventional sensors as they do not require wired connections. Although wireless sensors have an advantage, energy source for the sensors possess a problem when they are intended to have a long term operations about years to decades. Also there are limitations on the applications and deployments of conventional electrochemical power sources arising from their short lifespan.

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Energy can be harvested from different sources like solar, wind, thermal gradients and seismic vibrations. Although solar, wind and thermal gradients have been proven to be massive energy sources, they can have interruptions when there is no sunlight, wind movement or temperature difference, respectively. Harvesting the seismic vibrations can't be massive energy source like others mentioned above but it can provide uninterrupted energy. Since the wireless sensor networks demand low power, vibration based energy harvester is suitable for the application.

There have been attempts in the literature to develop energy harvester using based on electromagnetic principle for various applications such as health monitoring of aerospace and civil engineering structures, traffic control and healthcare systems [1]. Devices which are available in literature and commercially operate between frequency ranges 15 Hz to 4400 Hz [2].Seismic noise of frequency 0.17 Hz to 0.5 Hz is omnipresent [3] which can be harvested for surveillance and tracking of animal movements. Since the frequency range is very low, the design of energy harvester becomes a challenging task.

Another challenging task in the designing of vibration energy harvester is to reduce energy dissipation. Literature states that damping involved in these system can be one or more of the following - thermoelastic damping, loss due to air, squeeze film damping and anchor losses [7]. Out of the four losses mentioned above, squeeze film damping and energy loss in air can be eliminated using vacuum in the device. Anchor losses can be minimized using symmetric design and employing manufacturing accuracy. But thermo-elastic damping can't be avoided. Various experimental work suggests that thermo-elastic damping is function of various factors namely temperature, frequency, specific heat, stress levels and the least value of thermoelastic damping achievable is 10^{-6} [8].

2. Design of structures for low frequency

There has been an attempt to come up with a design of vibration energy harvester for low frequency using topology optimization [4]. Solutions obtained from topology optimization leaves the grey areas between the support of structure and proof mass which can't be manufacturable. Although topology optimizations could not provide manufacturable structures for low frequency, they give insights of a design. Insight obtained from topology optimization is that the connecting structure between proof mass and the support should have low stiffness to meet low frequency requirements. In this work, the designs have been developed based on folded beam structures (Fig 1a), circular spiral (Fig 1b) and square spiral (Fig 1c) that can provide required frequency.

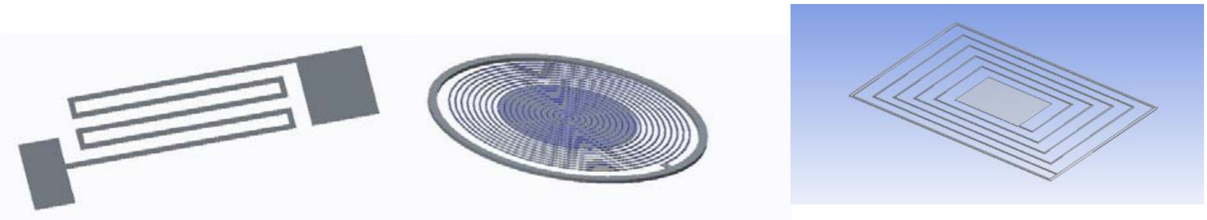

Fig. 1. (a) Folded beam; (b) Circular spiral; (c) Square spiral

3. Results and discussion

Natural frequency of designs (Fig 1) have been evaluated nu merically and the folded beam (Fig 1a) structure was tested using LASER vibrometer. Experimentally observed first natural frequency of folded beam structure is 1.75 Hz which agrees with simulations.