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A Broadband Tri-Cantilever Vibration Energy Harvester with Magnetic Oscillator

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Abstract : A novel tri-cantilever energy harvester with magnetic oscillator was presented, which could convert the ambient vibration into electrical energy to power the low-power devices such as wireless sensor networks. The most common way to harvest vibration energy is based on the use of linear resonant devices such as cantilever beam, since this structure creates the highest strain for a given force. The highest efficiency will be achieved when the resonance frequency of the harvester matches the vibration frequency. The limitation of the structure is the narrow effective bandwidth. To overcome this limitation, this article introduces a broadband tri-cantilever harvester with nonlinear stiffness. This energy harvester typically consists of three thin cantilever beams vertically arranged with Neodymium Magnets (NdFeB)magnetics at its free end and a fixed base at the other end. The three cantilevers have different resonant frequencies by designed in different thicknesses. It is obviously that a similar advantage of multiple resonant frequencies as piezoelectric cantilevers array structure is built. To achieve broadband energy harvesting, magnetic interaction is used to introduce the nonlinear system stiffness to tune the resonant frequency to match the excitation. Since the three cantilever tips are all free and the magnetic force is distance dependent, the resonant frequencies will be complexly changed with the vertical vibration of the free end. Both model and experiment are built. The electromechanically coupled lumped-parameter model is presented. An electromechanical formulation and analytical expressions for the coupled nonlinear vibration response and voltage response are given. The entire structure is fabricated and mechanically attached to a electromagnetic shaker as a vibrating body via the fixed base, in order to couple the vibrations to the cantilever. The cantilevers are bonded with piezoelectric macro-fiber composite (MFC) materials (Model: M8514P2). The size of the cantilevers is 120*20mm2 and the thicknesses are separately 1mm, 0.8mm, 0.6mm. The prototype generator has a measured performance of 160.98 mW effective electrical power and 7.93 DC output voltage via the excitation level of 10m/s2. The 130% increase in the operating bandwidth is achieved. This device is promising to support low-power devices, peer-to-peer wireless nodes, and small-scale wireless sensor networks in ambient vibration environment.

Keywords : tri-cantilever, ambient vibration, energy harvesting, magnetic oscillator
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