

Broadband Rotational Energy Harvesting Using Upward and Downward Piezoelectric Cantilevers under Aerospace-Induced Vibrations

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Summary:

A broadband piezoelectric rotational energy harvester with upward and downward cantilevers was developed. The system captures energy from both directions of rotation using PVDF materials. It was tested under two aerospace vibration profiles with distinct frequency content. The downward cantilever produced a peak average power of 57.8 μW . The upward cantilever reached 33.5 μW under different excitation. Results confirm broadband rotational energy harvesting capability for aerospace vibration environments.

Keywords: REH, bi-stability, nonlinear, Cantilever upward, cantilever downward.

Introduction

Energy harvesting from vibration in aerospace platforms presents an attractive solution for powering distributed sensor nodes in locations where battery replacement is impractical. Rotational energy harvesters (REHs) that use piezoelectric materials offer a compact and passive approach. However, one challenge is capturing energy across a broad frequency spectrum, especially under variable aerospace operating conditions. This study evaluates a broadband REH design that employs both upward and downward cantilever configurations to extract energy from rotation-induced vibrations in aerospace environments.

Background, Motivation an Objective

The harvester design is based on two flexible PVDF cantilevers mounted on a rotating structure—one directed upward and the other downward and one free moving magnet. These orientations leverage both gravitational and inertial (centrifugal) forces causes bi-stability to generate alternating strain during rotation [1]. This study focuses on representative aerospace vibration environments, specifically Aerospace in Flight which characterizes typical engine and aerodynamic vibrations during cruise and Aerospace in Elevation represents vibration during altitude change and maneuver [2].

The objective is to assess the broadband harvesting performance of each cantilever configuration under these two vibration sources and analyze their rms voltage and average power

output as well as input acceleration for both sources.

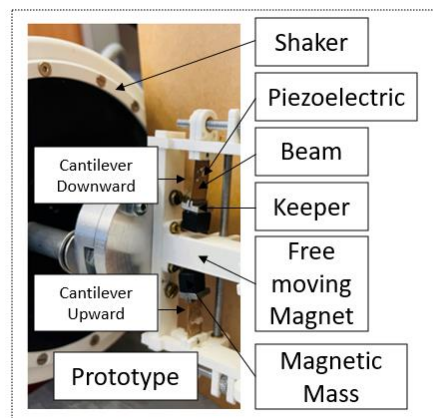


Fig. 1. Experimental Setup of proposed rotational energy harvester.

Methodology

The proposed system (Figure 1) employs two PVDF piezoelectric cantilevers mounted in upward and downward orientations on a rotating disc. This dual setup captures inertial strain during both upward and downward motion, enabling broadband energy harvesting without active tuning. A levitated magnet introduces nonlinear dynamics, enhancing sensitivity to a wider frequency range. The system is tested on a vibration shaker replicating aerospace noise. Output voltage is measured across resistive loads, and power is calculated from RMS voltage, demonstrating efficient passive harvesting under realistic flight conditions.

Results

Voltage and power outputs were measured from both cantilever configurations under two aerospace-specific vibration profiles: Aerospace in Flight and Aerospace in Elevation. The experiments used a vibration shaker system replicating real-world flight data setup with PVDF piezoelectric cantilevers.

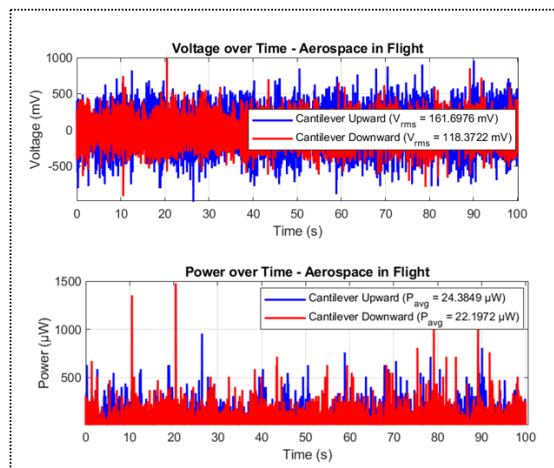


Fig. 2. Experimental results of voltage over time and Power over time for Aerospace in Flight.

Figures 2 and 3 present time-domain voltage and power plots over 100 seconds of vibration exposure. Under Aerospace in Flight, the upward cantilever produced slightly higher power than the downward. In contrast, under Aerospace in Elevation, the downward cantilever significantly outperformed the upward one, indicating stronger response to higher amplitude and more broadband frequency content.

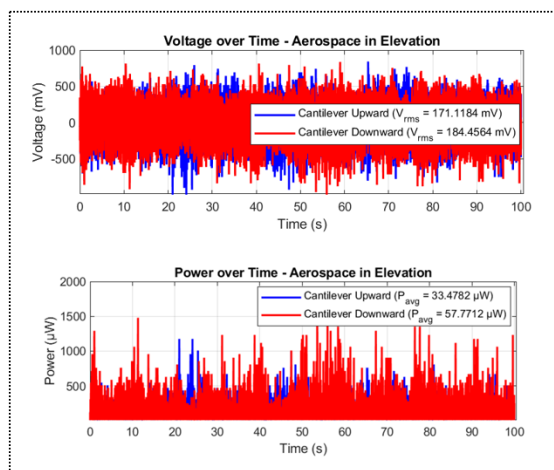


Fig. 3. Experimental results of voltage over time and Power over time for Aerospace in Elevation.

Conclusion

These results confirm that the dual-orientation configuration enables broadband energy harvesting by capturing complementary motion

patterns. The upward cantilever performs well under stable, low-amplitude vibrations, while the downward configuration excels in dynamic, high-energy environments, enhancing total power extraction across varying aerospace conditions.

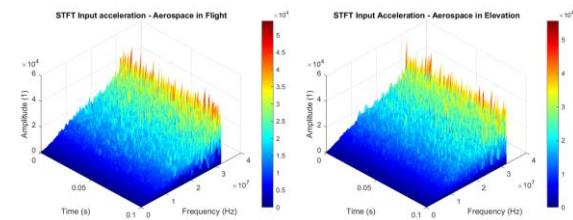


Fig. 4. STFT Input acceleration for Aerospace in Flight and Aerospace in Elevation.

Measured root mean square (RMS) voltage and average power output of upward and downward piezoelectric cantilevers under two distinct aerospace vibration environments: Aerospace in Flight and Aerospace in Elevation. Data were collected over 100 seconds using a resistive load of 50 k Ω . The upward cantilever showed higher performance in the flight condition due to better alignment with mid-frequency content, while the downward cantilever yielded higher power in elevation due to stronger broadband excitations.

Tab. 1: RMS voltage and average power output for upward and downward cantilevers under aerospace-induced vibration environments.

Cantilever Orientation	Noise Source	V_{rms} (mV)	P_{avg} (μ W)
Upward	In Flight	161.7	24.4
Downward	In Flight	118.4	22.2
Upward	In Elevation	171.1	33.5
Downward	In Elevation	184.5	57.8

References

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