Robust vibration energy harvesting from nonlinear mechanisms

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Challenge
- Ambient vibrations are stochastic, multi-frequency, and time-varying
- Traditional linear oscillators can only absorb ambient energy at one frequency
- Example scenarios:
  - Ambient vibration energy harvesting
  - Cell phones carried by people
  - Ocean wave utility-scale generators
  - Small electronics in remote locations
  - MEMs sensors implanted in the body
- Shock absorption
  - Protect offshore platforms from water wave impacts
  - Protect buildings from earthquakes

Solution
- Nonlinear oscillators are more robust to vibration signal changes than linear systems
- Passive solution (versus using controls)

How to implement nonlinear springs?
- A design with essential nonlinearity, low-friction, and one moving part (which increases device lifetime)

Case Study: Power a cell phone from a person walking

Hip motion

Power for varied parameters

Comparison of 2DOF Nonlinear and 2DOF Linear Dynamics

Future Work
- Build and test full prototypes with electromagnetic system
- Modify contact-surface stiffening-spring effect to be more volume-compact
- Analytically study stochastic nonlinear dynamics to predict maximum power and robustness
- Apply concepts to utility-scale ocean-wave electricity generation

Conclusions
- Nonlinearity makes the system more robust to environmental vibration spectrum changes

System performance comparison

Nonlinear systems are also more robust to parasitic damping

Robustness to Parasitic Damping

Wave spectra of a developing sea for different fetches according to Haselmann et al., (1973).