

Mechanical Realization of Stochastic Resonance and Noise-Enhanced Propagation

BACKGROUND: Stochastic resonance is a nonlinear phenomenon in which noise can paradoxically enhance a weak periodic signal. It has been implicated in a diverse range of phenomena, from the ice ages of Earth to the transduction of hair cells [1].

During our summer 1998 REU program, Sridhar Chandramouli '00 and I generalized this phenomenon in a novel way. We discovered that noise can extend signal propagation in one and two-dimensional arrays of two-way coupled bistable oscillators. In a numerical model, we sinusoidally forced one end of a chain of noisy oscillators. We recorded a signal-to-noise ratio at each oscillator. We demonstrated that moderate noise significantly extends the propagation of the sinusoidal input. The simplicity of the model suggested the generality of the phenomenon [2].

For his senior I.S., Dan Brubaker '03 attempted to construct a mechanical model of noise-enhanced propagation, but it failed partly due to the design of the bistable system and partly due to problems with generating the noise. However, just before he completed his I.S. manuscript, we discovered a much improved inverted pendulum bistable design, which he described in his final chapter, and which we have subsequently successfully used in our mechanical one-way arrays, including the successful senior I.S. of Kelly Patton '08 [3].

During the summer 2011 HHMI program, Ian Wilson '14 coupled one of these inverted pendulums to the irregular flapping of a flag being blown by a jet fan. This provided a broad-band noise source, with which Ian was able to demonstrate mechanical stochastic resonance. During the summer 2012 HHMI program, Elliot Wainwright '15 significantly improved Ian's design and obtained good stochastic resonance data, which he will present at the March 2013 meeting of the American Physical Society in Baltimore.

EXTENSION: This year, for his senior I.S., Sam Mermall '13 has devised a simple way to continuously vary the jet fan speed on a related project. This should enable a summer student to obtain sufficient stochastic resonance data for a publication. We would then be able to leverage our recent successful experience in creating one-way mechanical arrays, including CAD design and 3D printing of the array elements [4], to extend the apparatus to study noise-enhanced propagation.

- [1] [Stochastic Resonance in the Mechanoelectrical Transduction of Hair Cells](#), J. Lindner, M. Bennett, K. Wiesenfeld, *Physical Review E*, **72**, 051911(1-4) (2005)
- [2] [Noise Enhanced Propagation](#), J. Lindner, S. Chandramouli, A. Bulsara, M. Löcher, W. Ditto, *Physical Review Letters*, **81**, 5048-5051 (7 December 1998)
- [3] [Experimental observation of soliton propagation and annihilation in a hydromechanical array of one-way coupled oscillators](#), J. Lindner, K. Patton, P. Odenthal, J. Gallagher, B. Breen, *Physical Review E*, **78**, 066604(1-5) (2008)
- [4] [Electronic and mechanical realizations of one-way coupling in one and two dimensions](#), B. Breen, A. Doud, J. Grimm, A. Tanasse, S. Tanasse, J. Lindner, K. Maxted, *Physical Review E*, **83**, 037601(1-4) (2011)