Dáibhid Ó Maoiléidigh, A.J. Hudspeth

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Sinusoidal-signal detection by active, noisy oscillators on the brink of self-oscillation

Dáibhid Ó Maoiléidigh[a,b,*], A. J. Hudspeth[a,c]

[a] *Laboratory of Sensory Neuroscience*
The Rockefeller University
New York, NY 10065, USA
[b] *Present Address: Department of Otolaryngology–Head and Neck Surgery*
Stanford University School of Medicine
Stanford, CA 94305, USA
[c] *Howard Hughes Medical Institute*
The Rockefeller University
New York, NY 10065, USA

Abstract

Determining the conditions under which an active system best detects sinusoidal signals is important for numerous fields. It is known that a quiescent, deterministic system possessing a supercritical Hopf bifurcation is more sensitive to sinusoidal stimuli the closer it operates to the bifurcation. To understand signal detection in many natural settings, however, noise must be taken into account. We study the Fokker-Planck equation describing the *sinusoidally forced* dynamics of a noisy supercritical or subcritical Hopf oscillator. To distinguish an oscillator's motion owing to sinusoidal forcing from that provoked by noise, we employ the phase-locked amplitude and vector strength, which are zero in the absence of an external signal. The phase-locked amplitude and entrainment to frequency-detuned forcing—but not resonant forcing—peak as functions of the control parameter. These peaks occur near but not at the bifurcations. Moreover, an oscillator can detect stimuli over the broadest frequency range when it spontaneously oscillates near a Hopf bifurcation. Although noise exerts the greatest effect on the phase-locked amplitude when a Hopf oscillator is near a Hopf bifurcation, the oscillator nevertheless performs best as a sinusoidal-signal detector when it operates close to the bifurcation. The oscillator's ability to differentiate detuned signals from noise is greatest with it autonomously oscillates near to but not at the bifurcation.

Keywords: Driven Oscillator, Noise, Hopf bifurcation, Fokker-Planck, Signal Detection

*Corresponding author
Email address: dmelody@stanford.edu (Dáibhid Ó Maoiléidigh)