The interplay of nonlinearity and noise in tiny resonators

Abstract:
Small vibrating structures, with dimensions on the scales of micro- and nano-meters, are playing increasingly important roles in sensing and time-keeping technologies. The success of these micro/nano-electro-mechanical-systems (M/NEMS) in inertial and other sensors has been transformational, for example, in sensors for automotive air bags and stability control. A similar shift is occurring in the development of the frequency generating elements that are used in virtually all electronic devices. Some basic differences exist between these tiny mechanical structures and their macro-scale counterparts, perhaps the most important of which is that they rely on resonant vibration with extremely low damping, having quality factors in the range 10^2-10^6. At these sizes, one can achieve resonances in the radio frequency range and also take advantage of electrostatics for actuation and readout. However, the susceptibility of these structures to noise and nonlinearity can lead to complications, and one of the basic challenges in designing resonant M/NEMS is maintaining a good signal to noise ratio without driving them into nonlinear operating regimes. This presentation will provide an overview of nonlinearity and noise in M/NEMS and describe how a fundamental understanding of these effects plays an important role in improving their performance. Specific examples will be taken from time-keeping applications, for which recent analysis and experimental results demonstrate attractive possibilities for using nonlinearity to reduce phase noise in MEMS-based clocks, and from resonant sensors, where nonlinear mode coupling can be used to increase the input-output gain in vibratory rate gyros.
Acknowledgments: This work is currently supported by the US NSF. The work is done in close collaboration with groups led by Mark Dykman at Michigan State, Daniel López at Argonne, Kimberly Foster at UCSB, Oriel Shoshoni at Ben Gurion, and Tom Kenny at Stanford.

Bio:
Steve Shaw is Harris Professor in the Department of Mechanical and Civil Engineering at Florida Institute of Technology, Melbourne, Florida, USA. He is also University Distinguished Professor Emeritus in the Department of Mechanical Engineering and Adjunct Professor of Physics and Astronomy at Michigan State University. He received an A.B. in Physics (1978) and an M.S.E. in Applied Mechanics (1979) from the University of Michigan and a Ph.D. in Theoretical and Applied Mechanics from Cornell University (1983). His research interests focus on the understanding and utilization of nonlinear dynamic behavior in engineering systems. Current applications include the interplay of nonlinearity and noise in micro/nano-scale resonators used in sensing and signal processing, and the development of torsional vibration absorbers for automotive power/drive-train components. Steve's expertise is primarily in modeling and theory and he collaborates closely with experimental groups at universities, industries, and national labs, as well as with other theorists. He has held visiting appointments at Cornell University, the University of Michigan, Caltech, the University of Minnesota, the University of California-Santa Barbara, and McGill University. He serves on the Editorial Board for *Nonlinear Dynamics* and as an Associate Editor for the *SIAM Journal on Applied Dynamical Systems*. Steve is an ASME Fellow, recipient of the Henry Ford Customer Satisfaction Award, the ASME Henry Hess Award, the SAE Arch T. Colwell Merit Award, and the ASME N. O. Myklestad Award, the latter "in recognition of a major innovative contribution to vibration engineering."