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Author(s)	In, Visarath; Longhini, P.; Kho, A.; Leung, D.; Neff, J. D.; Palacios, A.; Meadows, B. K.
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Nonlinear Channelizer for RF Communication

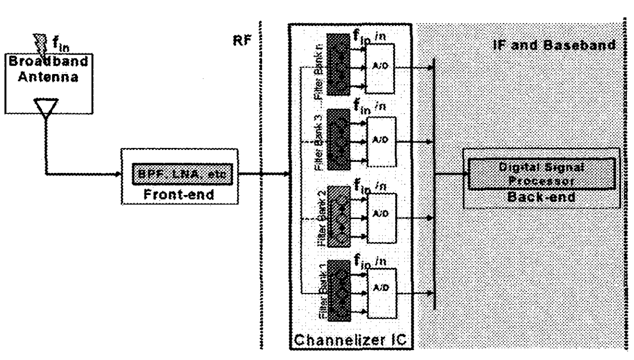
Visarath In[1], P. Longhini[1], A. Kho[1], D. Leung[1], J. D. Neff[1], A. Palacios[2], B. K. Meadows[1]

[1]*Space and Naval Warfare Systems Center Pacific, Code 71730, 53560 Hull Street, San Diego, CA 92152-5001, USA, visarath@spawar.navy.mil.*

[2]*Nonlinear Dynamics Group, Department of Mathematics & Statistics, San Diego State University, San Diego, CA 92182, USA, palacios@sciences.sdsu.edu.*

The overdamped bistable oscillators are prevalently found in many sensor systems. These dynamical elements would not display oscillatory behavior when isolated (i.e. uncoupled), unless they were appropriately driven. Our analysis showed that N (taken to be odd, although the oscillatory behavior can also be seen for N large and even) unidirectionally coupled elements with cyclic boundary conditions would, in fact, oscillate when a control parameter - in this case the coupling strength - exceeded a critical value [1, 2]. Typically, the oscillations emerge with an infinite period through a heteroclinic-cycle bifurcation, i.e., a global bifurcation to a collection of solution trajectories that connects sequences of equilibria and/or periodic solutions. In the particular case of overdamped bistable systems, the cycle includes mainly saddle node equilibria. As a control parameter (usually the coupling strength) approaches from above a critical value, the frequency of the oscillations decreases, approaching zero at the critical point. Past the critical value, the oscillations disappear and the system dynamics settles into an equilibrium. Furthermore, complex behaviors emerge from these coupled systems when an external signal (AC, DC) is applied uniformly to all the elements in the array [3, 4, 5]. The results have been successfully used to develop extremely sensitive (*room temperature*) magnetic sensors capable of resolving field changes as low as 150pT in an unshielded environment. Extending on this work, we now explore the underlying dynamics of a coupled bistable system realized in microelectronic circuits which belongs to the same class as the aforementioned system. The emergent behavior is being used to develop a radio frequency (RF) communication system called the Nonlinear Channelizer.

The Nonlinear Channelizer is an integrated circuit sized, large parallel array of analog nonlinear oscillators that serve collectively as a broad-spectrum analyzer which can take complex signals containing multiple frequencies and instantaneously lock-on or respond to a received signal in a few cycles, see Figure 1 and 2. The core technological approach takes advantage of phenomena that are almost universally unique to nonlinear systems: synchronization and coupling topology. These tools are being employed to develop a system capable of locking onto any arbitrary input (RF) signal. The system is efficient, by eliminating the need for high-speed, high-accuracy ADCs, and compact by making use of nonlinear coupled systems to act as a channelizer (frequency binning and channeling), a low noise amplifier, and a frequency down-converter in a single step which, in turn, will reduce the size, weight, power, and cost of the entire communication system. The presentation covers the theory and some engineering details that validate the concept.



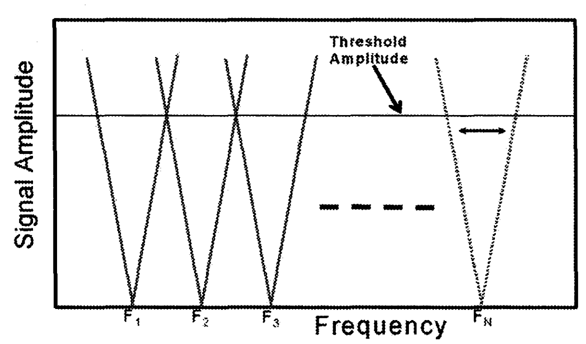


Figure 1: (left) Block diagram showing the Nonlinear Channelizer concept configure to cover a broad spectrum of frequencies. (right) Each channel can be configured to detect specific bands of frequencies. The V-shape regions represent lock-on for a specific channel, i.e. Channels 1,...,N. Each channel or the V-shape is reconfigurable via their accessible control parameters for the channel location and its bandwidth.

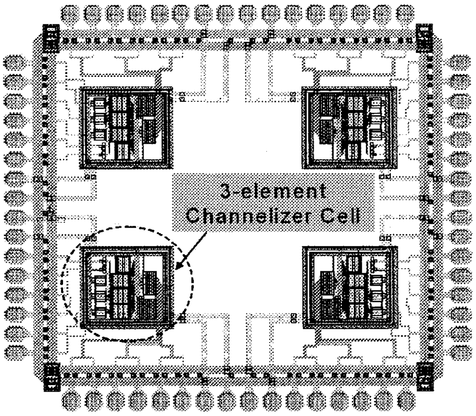


Figure 2: A four channel layout for the Nonlinear Channelizer where each channel is constructed from an array of three bistable nonlinear oscillators as illustrated in Figure 1.

Acknowledgments

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