Beam Steering by Lag Synchronization in Wideband Chaotic Arrays

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Chaotic oscillators are an intriguing source of waveforms for ultra wideband-radar applications. The broadband and nonrepeating nature of chaos provides an ideal combination of high range resolution and zero range ambiguity. Furthermore, it is known that coupled chaotic oscillators can be synchronized, i.e., oscillators that generate the same waveform at the same time. In the context of ultra-wideband radar, it is natural to consider the power combining and beam forming properties for synchronized arrays of chaotic microwave oscillators. Local coupling of neighboring array elements can be used to synchronize an extended array, thereby providing a coherent state suitable for beam forming in a wide-bandwidth radar system.

Such an architecture offers an efficient alternative to the use of a master oscillator in a phased array. However, a difficulty in any wideband array is achieving a practical and cost-effective mechanism for beam steering. Conventional approaches using phase shifters are impractical for bandwidths exceeding just a few percent of the carrier frequency, and for larger bandwidths true time-delay steering is required. Here, we explore the recently discovered phenomena of lag and anticipating synchronization in coupled chaotic oscillators to achieve steering. The natural frequency of each oscillator in a coupled array is tuned to create a uniform lag across the synchronized array. To first order this tuning is equivalent to the usual method of inducing lag or anticipating synchronization using delay coupling, yet here it is implemented instead using just a voltage controlled capacitor. We show that the direction and extent of the resultant steering is directly controlled by the orientation and magnitude of the induced lag or anticipation. We experimentally demonstrate this approach in a one-dimensional array of low-frequency chaotic oscillator circuits, where a consistent, controllable delay is induced between elements across the entire array. Using chaotic circuits operating at ~20 MHz, we show that lag synchronization can be practically controlled in arrays of rf devices. We conclude by describing ongoing efforts to produce a steerable VHF array suitable for practical range testing. Open questions include determining stability and dynamical limitations for steering the larger arrays that practical application will require.