High Speed Chaos Generated in an Opto-Electronic Oscillator

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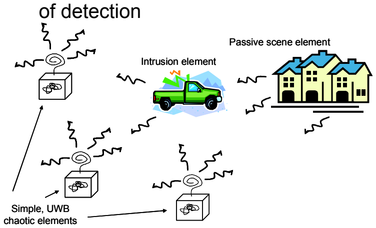
Introduction

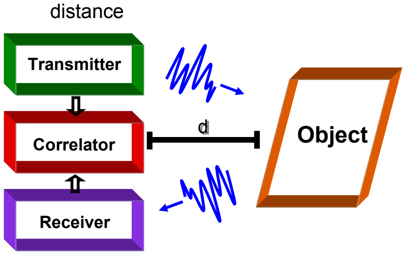
•Time-delayed feedback occurs in many systems
•Important at high speeds (time it takes signals to propagate through device ~ time scale of fluctuations)
•Simple nonlinear devices can show complex dynamics
•We report on a single time-delayed chaotic device

Possible Applications

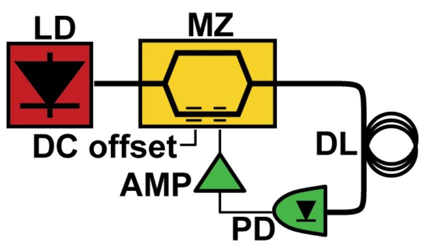
•Intrusion detection system
  •Envisioned system would use network of devices that transmit and receive chaotic signals
  •Dynamics of system incorporates received signals → high sensitivity
  •Complex signals → low probability of detection

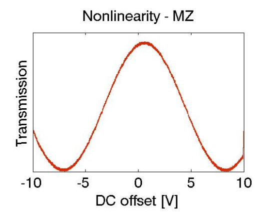


•Chaotic Radar
  •Amplified noise source radar systems require substantial post-processing
  •Proposed system would send chaotic signal, receive reflected signal and record only symbolic dynamics, then use lag in synchronization to gauge distance



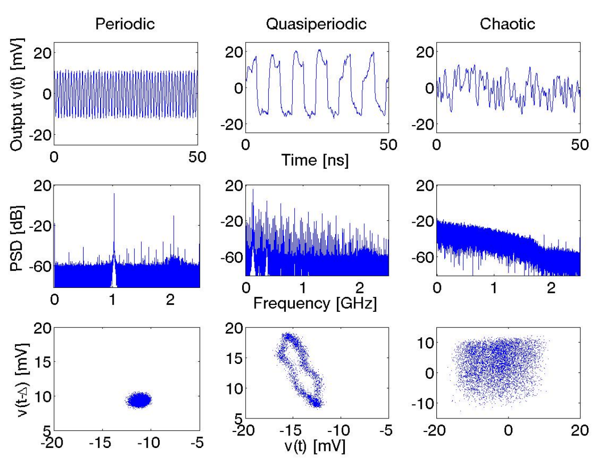
Single chaotic device





•Light passes through optical fiber to Mach-Zehnder modulator (MZ)
•Nonlinear transmission of MZ modulates light
•Photodiode (PD) converts light intensity to RF signal
•Electrical signal amplified and fed back to serve as input for MZ
•Antenna could be placed at output to transmit and receive signal

Observed dynamics



•Dynamics change with change in feedback strength, DC offset, and length of time delay
•Observed multistability and hysteresis effects
•Broadband chaos observed with featureless power spectrum

Mathematical Model

To model we consider:
•Nonlinear transmission function of MZ + Amplifier
•Electronic bandpass characteristics
•Time delay

Arrive at dimensionless system of equations:

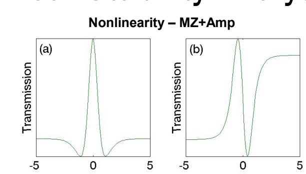
$$\dot{x} = -x(t) - \epsilon y(t) + F[x(t-\tau)]$$
$$\dot{y} = x(t)$$

where F is given by

$$F[x] = \gamma \cos^2[\frac{\pi}{2}a + \frac{\pi}{2}b\tanh(x)] - \gamma\cos^2[\frac{\pi}{2}a]$$

$x \propto$ voltage at PD, $a \propto$ DC offset, $b \propto$ saturation voltage, $\gamma \propto$ gain in feedback loop

Linear Stability Analysis



•At operating point (a):
  •Hopf bifurcation as γ is increased from zero
•At operating point (b)
  •Fixed point stable for all γ
  •This is point where broadband chaos is observed experimentally

Outlook

•Characterize single device dynamics
•Characterize dynamics of two coupled devices
•Model behavior of network of coupled devices

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