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

Mathematical Model

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

Arrive at dimensionless system of equations:

\[
\begin{align*}
\dot{x} &= -x(t) - a y(t) + F(x(t - \tau)) \\
\dot{y} &= x(t)
\end{align*}
\]

where \( F \) is given by

\[
F(x) = \gamma \cos\left[\frac{\pi}{2} x + \frac{\pi}{2} \text{tanh}(x)\right] - \gamma \cos\left[\frac{\pi}{2} x\right]
\]

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

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Linear Stability Analysis

Nonlinearity – MZ+Amp

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