

# Literature review on topic «Chaos optical communication»

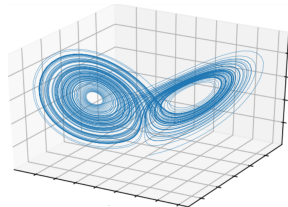
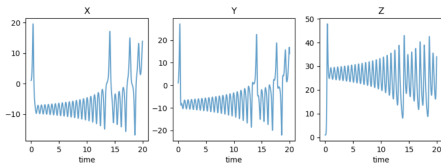
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05.03.2021

# Definition of dynamic chaos

Map<sup>1</sup>  $f$  is **chaotic**, if

- Periodic points are dense everywhere in  $\mathbf{E}$ .
- Orbits are mixed (almost):  
let  $U_1, U_2 \subset \mathbf{E}$ .  $\forall x_0 \in U_1 \exists N \in \mathbb{N} : f^N(x_0) \in U_2$ .
- $f$  Sensitive to the i. c.  
 $\forall x_0 \in \mathbf{E}, \forall U_\varepsilon(x_0) \exists y_0 \in U_\varepsilon, \exists N \in \mathbb{N} : |f^N(x_0) - f^N(y_0)| > \beta$ .



<sup>1</sup>W. Hirsch, S. Smale, Introduction to Chaos.

# Sensitivity to initial conditions

Example of sensitivity to initial conditions with map

$$x_{n+1} = rx_n(1 - x_n), \quad r \in (0, 4]$$

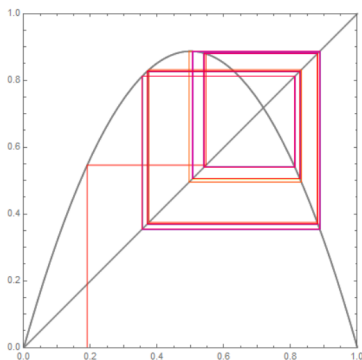


Figure 1:  $r = 3.55$

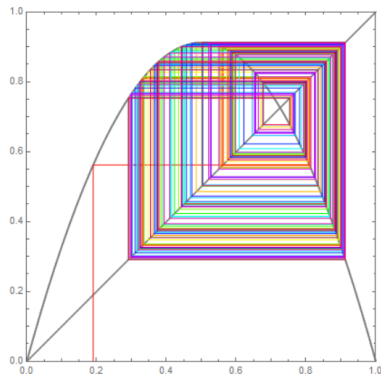


Figure 2:  $r = 3.65$

# Initial ideas

Consider<sup>2</sup> an autonomous  $n$ -dimensional dynamical system:

$$\dot{u} = f(u) \Leftrightarrow \begin{cases} \dot{v} = g(v, w), \\ \dot{w} = h(v, w) \end{cases} \quad \text{where} \quad \begin{aligned} v &= (u_1, \dots, u_m) \\ w &= (u_{m+1}, \dots, u_n) \end{aligned}$$

and  $g = (f_1(u), \dots, f_m(u))$ ,  $h = (f_{m+1}(u), \dots, f_n(u))$ .

Then, at system  $\dot{w}' = h(v, w')$  it's right that

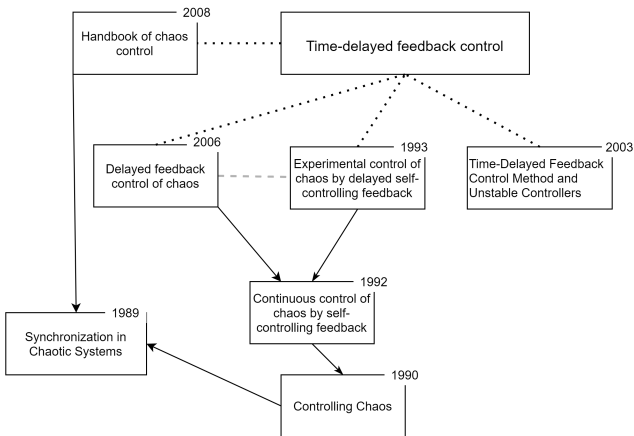
$$\lim_{t \rightarrow \infty} (\Delta w = w' - w) = 0, \quad \text{only if } \text{LyapunovExponent}(w) < 0.$$

Also, it could be shown, that with noise in system parametrs  $\Delta w(t) \rightarrow \text{const}$  at some additional conditions.

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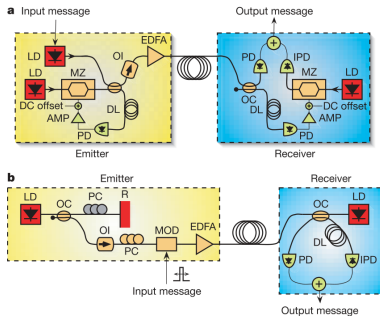
<sup>2</sup>M. Pecora, L. Carroll, Synchronization in Chaotic Systems, 1990.

# Some articles



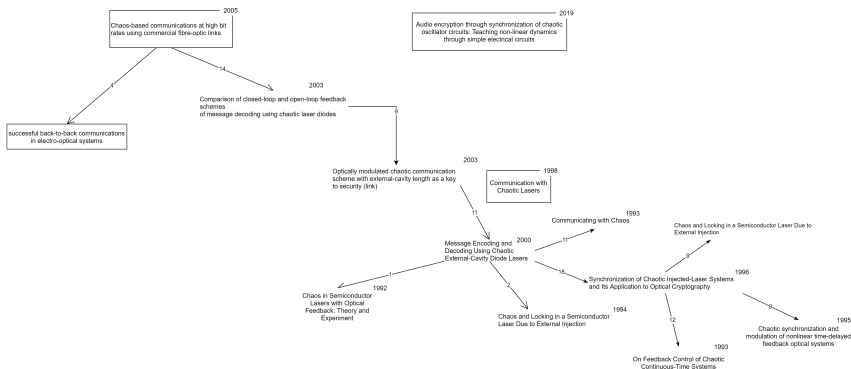
# Greece realization

The use of such encryption on a commercial scale is possible<sup>3</sup>



**Figure 3:** Two schematic set-ups for optical chaos communication

<sup>3</sup>A. Argyris, D. Syvridis, Chaos-based communications at high bit rates using commercial fibre-optic links.



# Chaotic Circuit

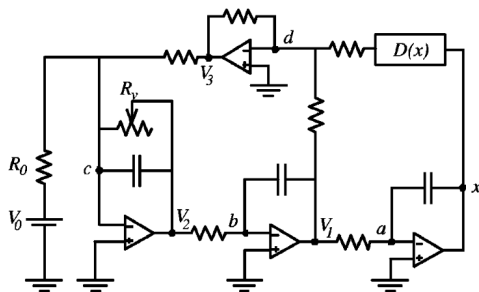


Figure 4: Schematic diagram of the circuit used.

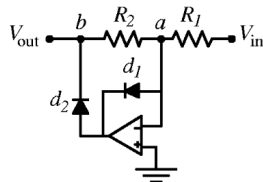
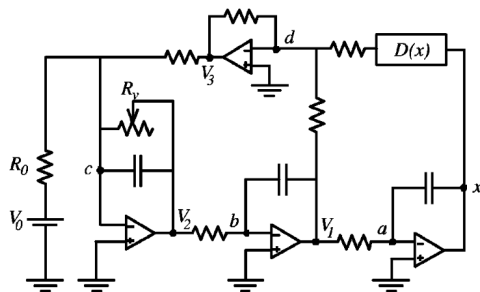


Figure 5: Nonlinear subcircuit  $D(x)$ .  
 $V_{\text{out}} = D(V_{\text{in}}) = -(R_2/R_1)\min(V_{\text{in}}, 0)$ .

$$RC \frac{dV_2}{dt} = - \left( \frac{R}{R_v} \right) V_2 - \left( \frac{R}{R_0} \right) V_0 - V_3. \quad (1)$$



# Chaotic equation



$$V_1 = -RC \frac{dx}{dt} = -\dot{x}$$

$$V_2 = -RC \frac{dV_1}{dt} = \ddot{x}$$

$$V_3 = -V_1 - D(x)$$

Figure 6: Schematic diagram of the circuit used.

$$\ddot{x} = -\left(\frac{R}{R_v}\right) \ddot{x} - \dot{x} + D(x) - \left(\frac{R}{R_0}\right) V_0. \quad (2)$$

# Chaotic Results

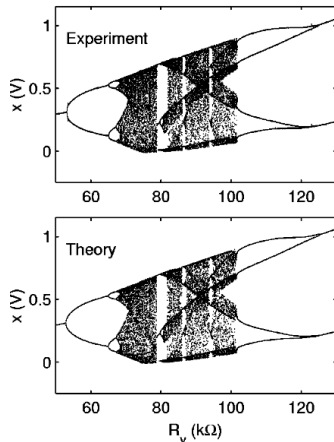


Figure 7: Bifurcation plots of the circuit.

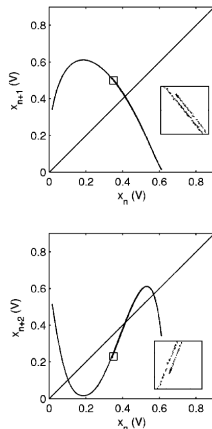


Figure 8: Exponential coupling for  $R_v = 72.1$  kΩ.

# To the Further Article



«Precision measurements of a simple chaotic circuit»

Ken Kiers and Dory Schmidt, J. C. Sprott

DOI: 10.1119/1.1621031 27 August 2003



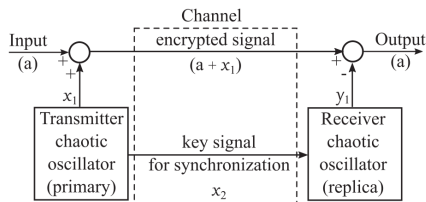
«Audio encryption through synchronization of chaotic oscillator circuits: Teaching non- linear dynamics through simple electrical circuits»

Keyur Mistry, Sudeshna Dash, and Siddharth Tallur

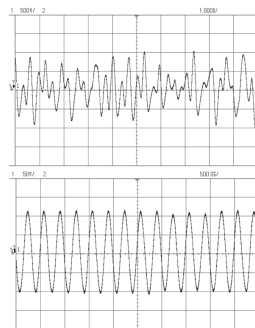
American Journal of Physics 87, 1004 (2019); doi:

10.1119/10.0000024

# Chaotic Synchronization

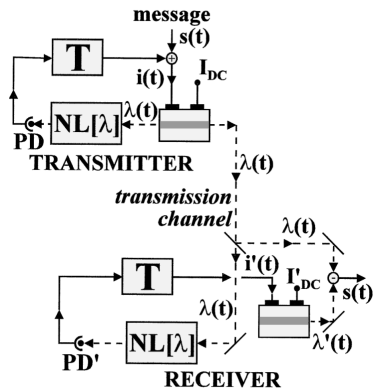


**Figure 9:** Block diagram of audio encryption scheme using chaotic oscillators.

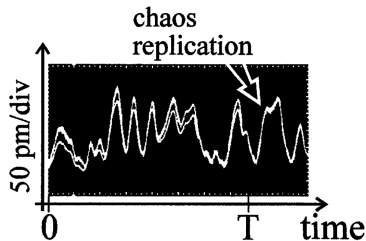


**Figure 10:** Modulated recorded audio signal unsynchronized and synchronized.

# Nonlinearity in Wavelength

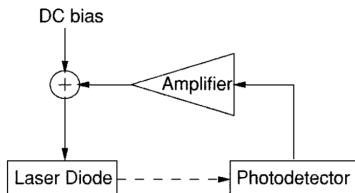


**Figure 11:** chematic diagram of the cryptosystem. NL stands for the nonlinear  $F(\Lambda)$ .



**Figure 12:** Evolution to the synchronization of the two chaos  $\lambda(t)$  and  $\lambda'(t)$ .

# Initial ideas



- DFB laser diod
- AR laser diod
- AlGaAs Single Mode Laser Diode