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Synchronization Phenomena and Chaos Propagation in Coupled Chaotic Circuits of Ladder System

Shogo TAMADA Kenta AGO Yoko UWATE Yoshifumi NISHIO
(Tokushima University)

1. Introduction

In this study, we investigate synchronization phenomena and chaos propagation in coupled chaotic circuits, each circuit is coupled by the resistor in the ladder system. The central circuit is set to generate chaotic attractor and the other circuits are set to generate three-periodic attractors. Moreover, we measure the phase difference by computer simulations. We investigate the relationships between the coupling strength and the number of coupling circuits.

2. System model

Figure 1 shows the chaotic circuit. We propose a system model in Fig. 2. In this system, each circuit is coupled by the resistor in the ladder system. The central circuit is generated chaotic attractor and the other circuits are generated three-periodic attractors. We observe the chaos propagation by changing the coupling strength.

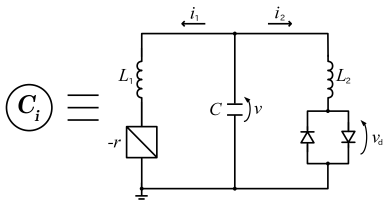

Figure 1: Chaotic circuit.

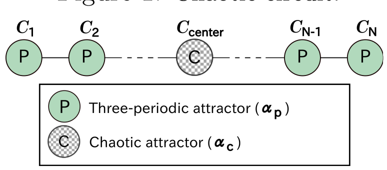

Figure 2: System model.

The normalized circuit equations of the system are given as follows:

$$\begin{cases} \dfrac{dx_i}{d\tau} = \alpha x_i + z_i \\ \dfrac{dy_i}{d\tau} = z_i - f(y_i) \\ \dfrac{dz_i}{d\tau} = -x_i - \beta y_i - g(2z_i - z_{i-1} - z_{i+1}), \end{cases} \quad (1)$$

where $i = 1, 2, \cdots, N$, g represents the coupling strength, α represents the chaos degree and N represents the number of the coupling circuits. $f(y_i)$ in the formula can be expressed as follows:

$$f(y_i) = \frac{\delta}{2}\left(\left|y_i + \frac{1}{\delta}\right| - \left|y_i - \frac{1}{\delta}\right|\right). \quad (2)$$

The number of circuit is used an odd number as $N = 5, 7, 9, \cdots, 21$. For the computer simulations, we calculate Eq. (1) using the fourth-order Runge-Kutta method with step size $h = 0.01$.

3. Simulation results

In this study, we set the parameters of the system as $\alpha_c = 0.46$, $\alpha_p = 0.412$, $\beta = 3.0$ and $\delta = 470.0$. Figure 3 shows the observed attractors and the phase differences in the case of $N = 5$. By increasing g, three-periodic attractors are affected from chaotic attractor and all circuits close to the synchronous state.

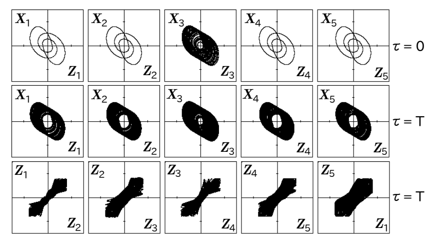

Figure 3: Attractors and phase differences ($N = 5$), $\alpha_c = 0.46$, $\alpha_p = 0.412$, $g = 0.01$, $\beta = 3.0$ and $\delta = 470.0$.

Moreover, the synchronous state can be defined if the average of the phase difference between C_1 and C_N below $10°$. Figure 4 shows the relation between the coupling strength and the number of coupling circuits when all circuits are synchronized in chaotic state. As a result, the coupling strength increases by increasing the number of coupling circuits when all circuits are synchronized in chaotic state.

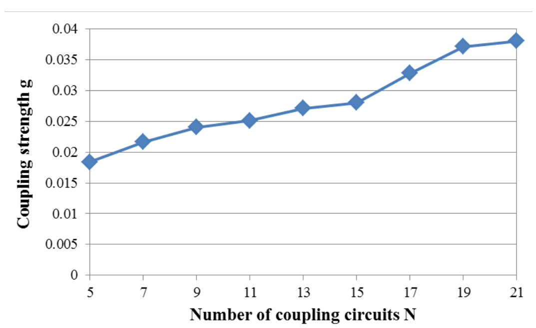

Figure 4: Relation between the coupling strength and the number of coupling circuits.

4. Conclusions

In this study, we have researched about synchronization phenomena and chaos propagation in coupled chaotic circuits of the ladder system. By computer simulations, we have observed that chaotic attractor of the central circuit propagates to all circuits. Moreover, we define the synchronous state from a certain phase differences, we measure the coupling strength in the synchronous state. By increasing the number of coupling circuits, the coupling strength almost proportionally increases.