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Synchronization Phenomena of Complex Networks Arranged in One-dimensional Coordinate

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1. Introduction

In this study, we investigate synchronization phenomena observed from coupled chaotic circuits. First, we combine chaotic circuits by resister which are arranged in one-dimensional coordinate system. We investigated synchronization phenomena by changing the distance between the circuit and the number of coupling circuits. Also, we measured the phase difference between the central circuits using computer simulations.

2. Circuit model

Figure 1 shows the circuit model. This is a circuit model called nishio circuit.

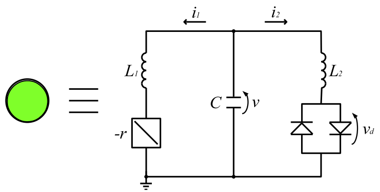

Figure 1: Circuit model.

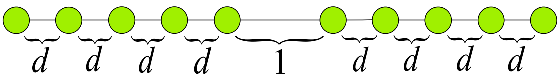

Figure 2: System model.

We can consider the following equations, when all circuits are coupled globally each other.

$$\frac{dx_i}{d\tau} = \alpha x_i + z_i$$
$$\frac{dy_i}{d\tau} = z_i - f(y_i) \quad (1)$$
$$\frac{dz_i}{d\tau} = -x_i - \beta y_i - \sum_{j=1}^{N} \gamma_{ij}(z_i - z_j)$$
$$(i, j = 1, 2, \cdots, N)$$

$f(y)$ in the formula can be expressed as follows:

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

where the parameter γ_{ij} represents the coupling strength between the circuits. The value of γ_{ij} reflects the distance between the circuits in an inverse way, described by the following equation:

$$\gamma_{ij} = \frac{g}{(d_{ij})^2}. \quad (3)$$

d_{ij} denotes the Euclidean distance between the i-th circuit and the j-th circuit. The parameter g is coupling coefficient that determines the coupling strengths. In this study, we set the parameter as $g = 1.0 \times 10^{-2}$.

In addition, we use the model shown in Fig. 2 in this study. The number of coupling circuits is N, and we do research in $N = 4,\ 6,\ 8,\ 10$. And we measured the phase difference between the circuits of the central circuits.The number of circuit always used an even number, we investigate system which is symmetrical system. We change the vary of distance between circuits and adjust the coupling strength. The distance between the circuit in the center of the system fixed, and after they are group of two symmetrically, we do research.

3. Simulation results

In this study, we carried out the simulation in $d = 0.08 \sim 0.5$. We show the simulation results in Table 1 and Fig. 3. We obtained the results that the phase difference becomes the minimum in $d = 0.1 \sim 0.2$. In $N = 6,\ 8,\ 10$, the phase difference becomes the minimum in $d = 0.1$, and the phase difference also increases as the distance increases. However, in $N = 4$, the phase difference become the minimum in $d = 0.2$, and the phase difference is smaller again in $d = 0.4$ as the distance increases.

Table 1: Simulation result [degree]

d	0.08	0.1	0.2	0.3	0.4	0.5
N=4	44.7	35.7	26.9	36.2	29.4	30.3
N=6	28.2	21.2	22.1	24.4	29.3	32.9
N=8	19.3	14.3	20.3	23.5	26.2	33.2
N=10	15.9	13.1	17.8	20.8	22.3	26.1

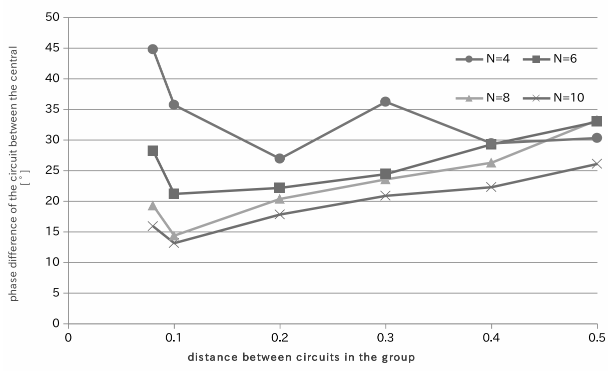

Figure 3: Simulation result.

4. Conclusions

In this study, we have researched the synchronization phenomena in coupled chaos circuits networks. We confirmed that the various results are obtained by changing the distance between the circuit and the number of coupling circuits.