Effect of Lateral Connection on Synchronization Phenomena in Chaotic Circuits Coupled with Non-Uniform Coupling Strength

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Abstract— **Synchronization phenomena in coupled oscillators have change in synchronization rate when lateral connection is added to chaotic circuits coupled with non-uniform coupling strength. As a result, it is confirmed that the change in synchronization rate differs depending on the location where the lateral connection is added.**

Keywords; Synchronization, Chaotic Circuits

I. INTRODUCTION

Synchronization is a phenomenon in which oscillators interact with each other and their oscillations are aligned. This phenomenon has been investigated in a wide range of research fields, including human brain networks [1] and communication networks [2]. Synchronization phenomenon is also observed in coupled oscillators. In particular, an interesting phenomenon called chaos synchronization, in which the behavior is aligned by coupling, can be observed even in systems with complex behavior such as chaotic circuits. Therefore, research on coupled chaotic circuits has been active. Previous studies have often focused on the topology and coupling strength of bi-directionally connected networks with uniform coupling strength [3],[4]. However, there is little study of the coupling strength in chaotic circuits with non-uniform coupling strength. Therefore, in this study, we confirmed the change in the synchronization phenomena when lateral connections are added to a chaotic circuit coupled with non-uniform coupling strength. We also confirmed the comparison of the synchronization phenomena when the location where the lateral connection added is changed.

II. NETWORK MODEL

Figure 1 shows the chaotic circuit used in this study. The chaotic circuit consisted of a negative resistor, an inductor, two capacitors, and a bidirectional diode. The chaotic circuit is called the Mori-Shinriki circuit. Figure 2 shows the network model proposed in this study. This mode is a network model with non-uniform coupling strength, as the coupling strength differs between the black and red arrows.

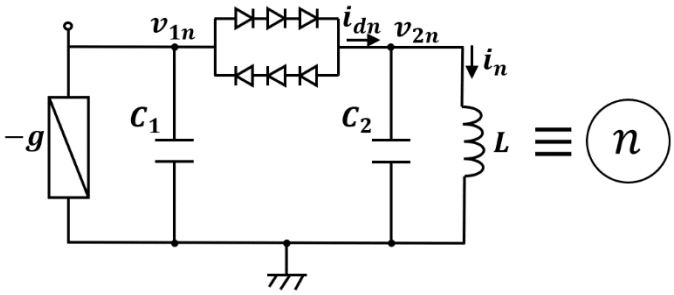


Figure 1. Circuit model.

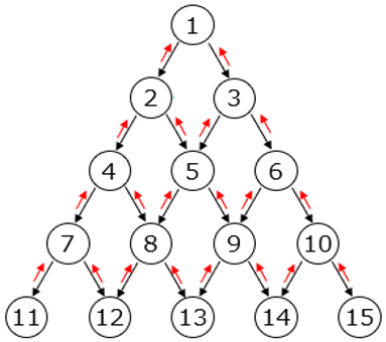


Figure 2. Network model.

The normalized circuit equations for the circuit in Fig.1 are shown as follows.

$$\begin{cases} \dot{x} = z_n \\ \dot{y} = \alpha\gamma y_n - \alpha\beta f(y_n - z_n) - \alpha\delta f(y_n - y_k) \\ \dot{z} = \beta f(y_n - z_n) - x_n \end{cases} \quad (1)$$

The normalized characteristic equations of the bidirectional diode are shown as follows.

$$f(y_n - z_n) = \begin{cases} y_n - z_n - 1 & (y_n - z_n > 1) \\ 0 & (|y_n - z_n| \le 1) \\ y_n - z_n + 1 & (y_n - z_n < 1) \end{cases} \quad (2)$$

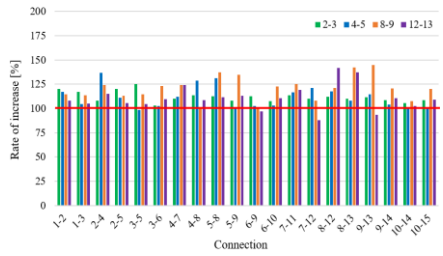
δ shows the coupling strength between the circuits.

III. RESULT

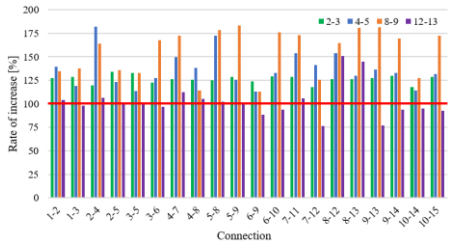
In this study, the synchronization phenomenon is observed by computer simulation. The parameters are $\alpha = 0.5$, $\beta = 20$, and $\gamma = 0.5$. We set $\delta = 0.70$ for the black arrows and $\delta = 0.35$ for the red arrows in Fig. 2

A. Case of adding lateral connections to the different layers

It is confirmed the change in synchronization rate for each connection when lateral connections are added to different layers: circuit 2 and circuit 3, circuit 4 and circuit 5, circuit 8 and circuit 9, and circuit 12 and circuit 13. Figure 3(a) shows the change in synchronization rate when a lateral connection (δ =0.35) is added. Figure 3(b) shows the change in synchronization rate when a lateral connection (δ=0.70) is added.



(a) lateral connection (δ=0.35).



(b) lateral connection (δ=0.70).

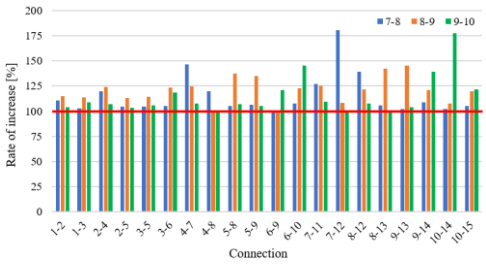
Figure 3. The change in synchronization rate when a lateral connection is added.

From Fig. 3, it is confirmed that the synchronization rate increases by adding lateral connections in circuits 2 and 3, circuit 4 and 5, and circuit 8 and 9. In contrast, it is confirmed that the synchronization rate decreases by adding lateral connections in circuit 12 and circuit 13.

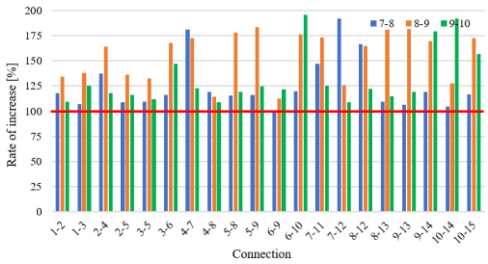
B. Case of adding lateral connections to the same layer

It is confirmed the change in synchronization rate for each connection when lateral connections are added to same layers: circuit 7 and circuit 8, circuit 8 and circuit 9, and circuit 9 and circuit 10. Figure 4(a) shows the change in synchronization rate when a lateral connection (δ=0.35) is added. Figure 4(b) shows the change in synchronization rate when a lateral connection (δ=0.70) is added.

From Fig. 4, it is confirmed that the change in synchronization rate varies depending on the location where the connections are added, even in the same layer. It also is confirmed that the synchronization rate increases when lateral connections are added at locations (8-9) where there are more connections.



(a) lateral connection (δ=0.35).



(b) lateral connection (δ=0.70).

Figure 4. The change in synchronization rate when a lateral connection is added.

IV. CONCLUSION

In this study, it is confirmed the change in synchronization rate when lateral connection is added to chaotic circuits coupled with non-uniform coupling strength. As a result, it is confirmed that the change in synchronization rate varies depending on the layer to which the lateral connection is added. In addition, even in the same layer, the synchronization rate varies depending on the location where the lateral connection is added. It is considered that the number of connections that the location where the lateral connection is added influences the synchronization rate.

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