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Rikitake Attractor and It's Synchronization Application for Secure Communication Systems

Ihsan Pehlivan and Yilmaz Uyaroğlu
Department of Electrical and Electronics Engineering, Faculty of Engineering,
Sakarya University, Esentepe, Sakarya, Turkey 54040

Abstract: The Rikitake chaotic dynamical system is a model which attempts to explain the irregular polarity switching of the geomagnetic field. The system exhibits Lorenz-type chaos and orbiting around two unstable fixed points. In the present study, chaotic Rikitake attractor's electronic circuit was implemented and it is addressed suitable for chaotic synchronization circuits to secure communication using Matlab-Simulink and Pspice programs.

Key words: Rikitake attractor, synchronization, secure communication

INTRODUCTION

One model which attempts to explain the reversal of the Earth's magnetic field is the Rikitake system (Rikitake, 1958). This system describes the currents of two coupled dynamo disks (Ito, 1980; McMillen, 1999). The governing equations are:

$$\begin{aligned} \dot{x} &= -\mu \cdot x + z \cdot y \\ \dot{y} &= -\mu \cdot x + (z - a) \cdot x \\ \dot{z} &= 1 - x \cdot y \end{aligned} \qquad (1)$$

Here a and μ are parameters which we will assume to be nonnegative. Synchronization of chaotic systems has in recent years become an area of active research. Different approaches are proposed and being pursued. Among themes the technique of Pecora-Carroll (Pecora and Carroll, 1990), who show that, when a state variable from a chaotically evolving system is transmitted as an input to a replica of part of the original system, the replica subsystem (receiver) sometimes synchronizes to the original system (sender). They and others suggest that this phenomenon of chaos synchronism may serve as the basis for new ways to achieve secure communication (Carroll and Pecora, 1993), (Cuomo and Oppenheim, 1993). This study focuses on the identical synchronization using Pecora-Carroll technique to Rikitake system for secure communications.

Simulink and Pspice simulations of Rikitake attractor: Using Matlab Simulink modeling of Rikitake Attractor in Fig. 1., Poincare maps in the xy, xz and yz planes are attained in Fig. 2.

Figure 3 shows the circuit schematic for implementing the Rikitake Eq. (1). We use TL084 opamps, the Analog Devices AD633JN multipliers, appropriate valued resistors and capacitors for Pspice simulations. The circuit is supplied ±12 V power supplies. Acceptable inputs to the AD633 multiplier IC are -10 to +10 V. The resistors R_1-R_7,

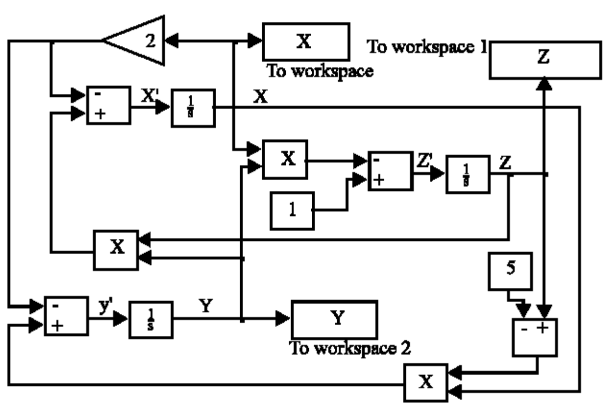

Fig. 1: Matlab-Simulink model of Rikitake attractor

Corresponding Author: Yilmaz Uyaroglu, Department of Electrical and Electronics Engineering, Faculty of Engineering, Sakarya University, Esentepe, Sakarya, Turkey 54040

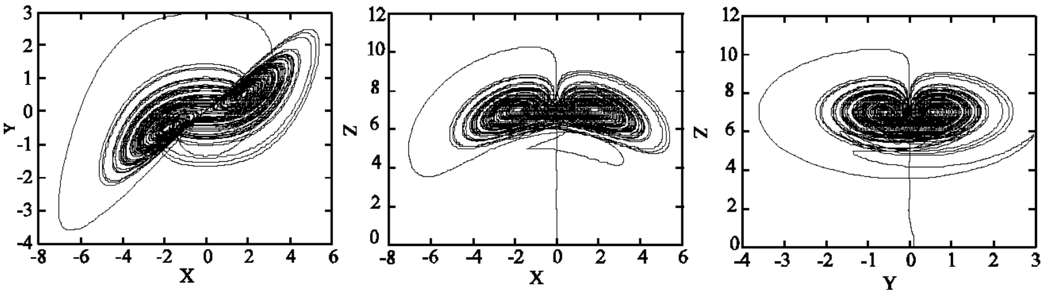

Fig. 2: Phase portraits of the Rikitake attractor when $\mu = 2$, $a = 5$, $x_0 = 0$, $y_0 = 0.1$ and $z_0 = 0$

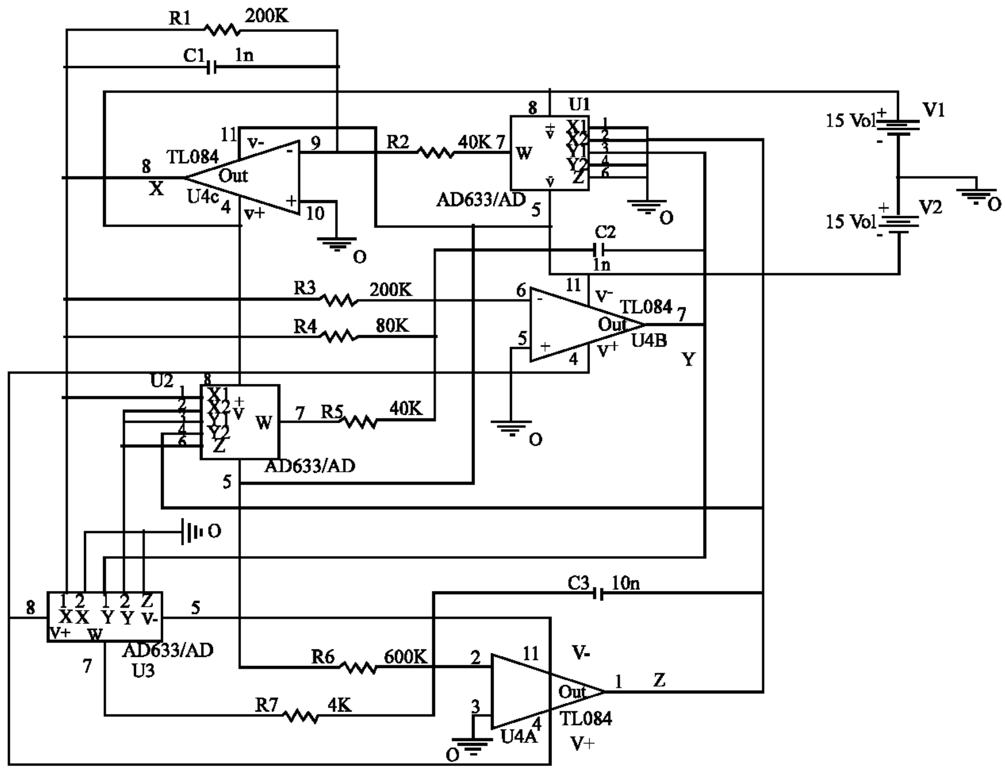

Fig. 3: Circuit scheme of Rikitake Attractor

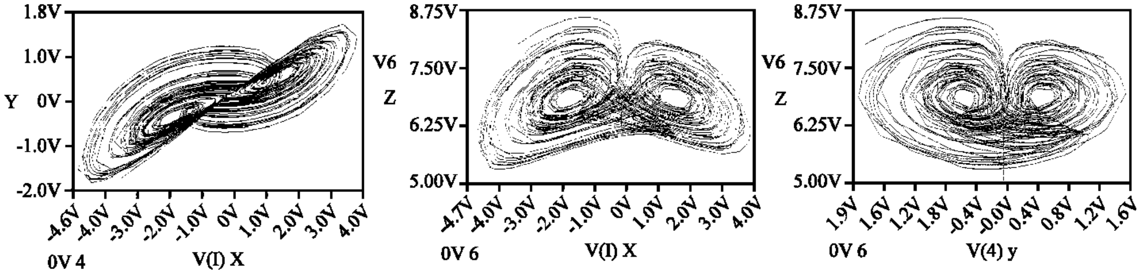

Fig. 4: The Pspice simulation results of the Rikitake attractor circuit. (a) x, y phase portrait (b) x, z phase portrait (c) y, z phase portrait

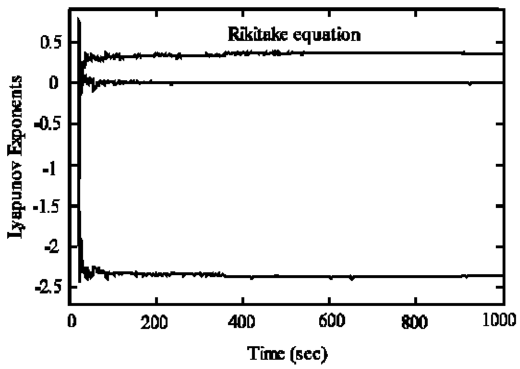

Fig. 5: Lyapunov exponents of the Rikitake system (1) for merely parameters μ = 2, a = 5

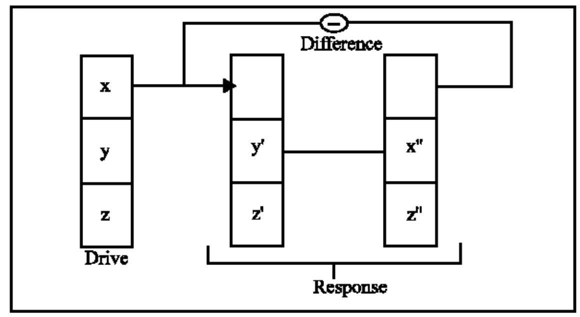

Fig. 6: Block diagram of a cascaded synchronization system

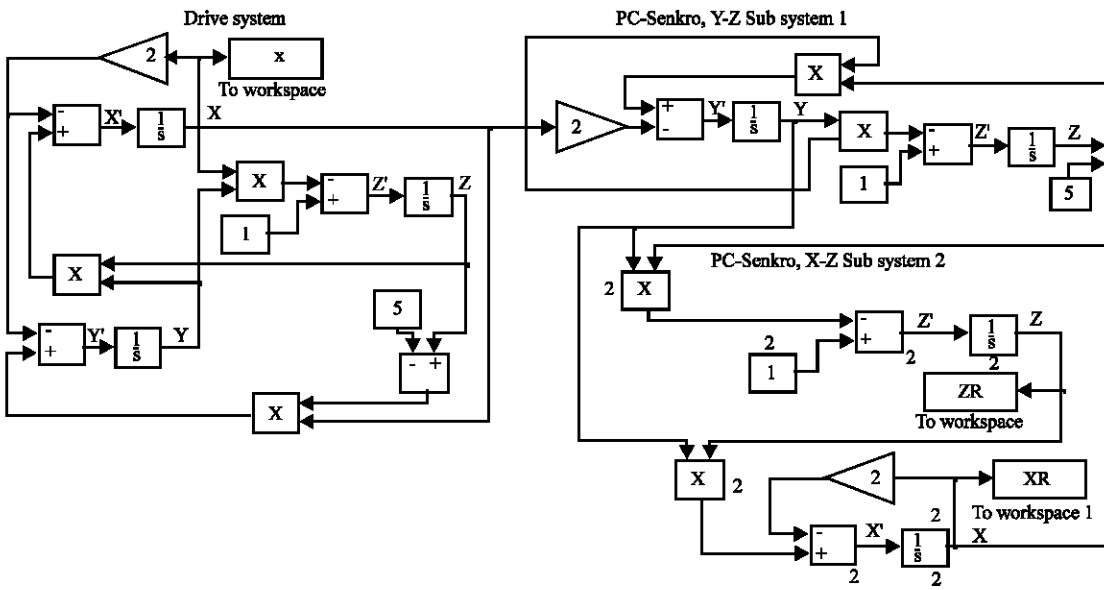

Fig. 7: Simulink Modeling of Pecora-Carroll Synchronization of Rikitake Attractor

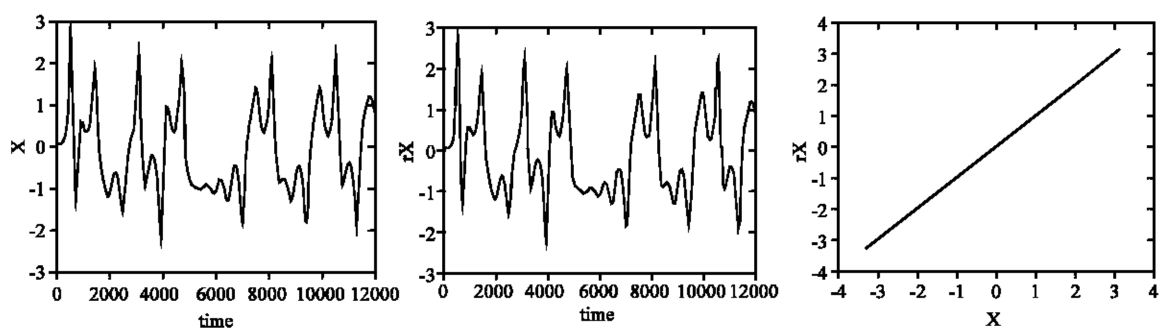

Fig. 8: Simulink outputs of Pecora-Carroll Synchronization of Rikitake Attractor a) Drive system X signal b) Response system Xr signal c) Synchronization between X and Xr

are all shown with nominal values in Fig. 3. Figure 4 shows Pspice simulation results of this circuit. Pspice and Matlab-Simulink simulations (Fig. 2) give the same conclusions.

Figure 5 shows the calculus of the Lyapunov Exponents performed the Rikitake system in the case of $\mu = 2$, $a = 5$. It is worth noting that only one positive LE is present.

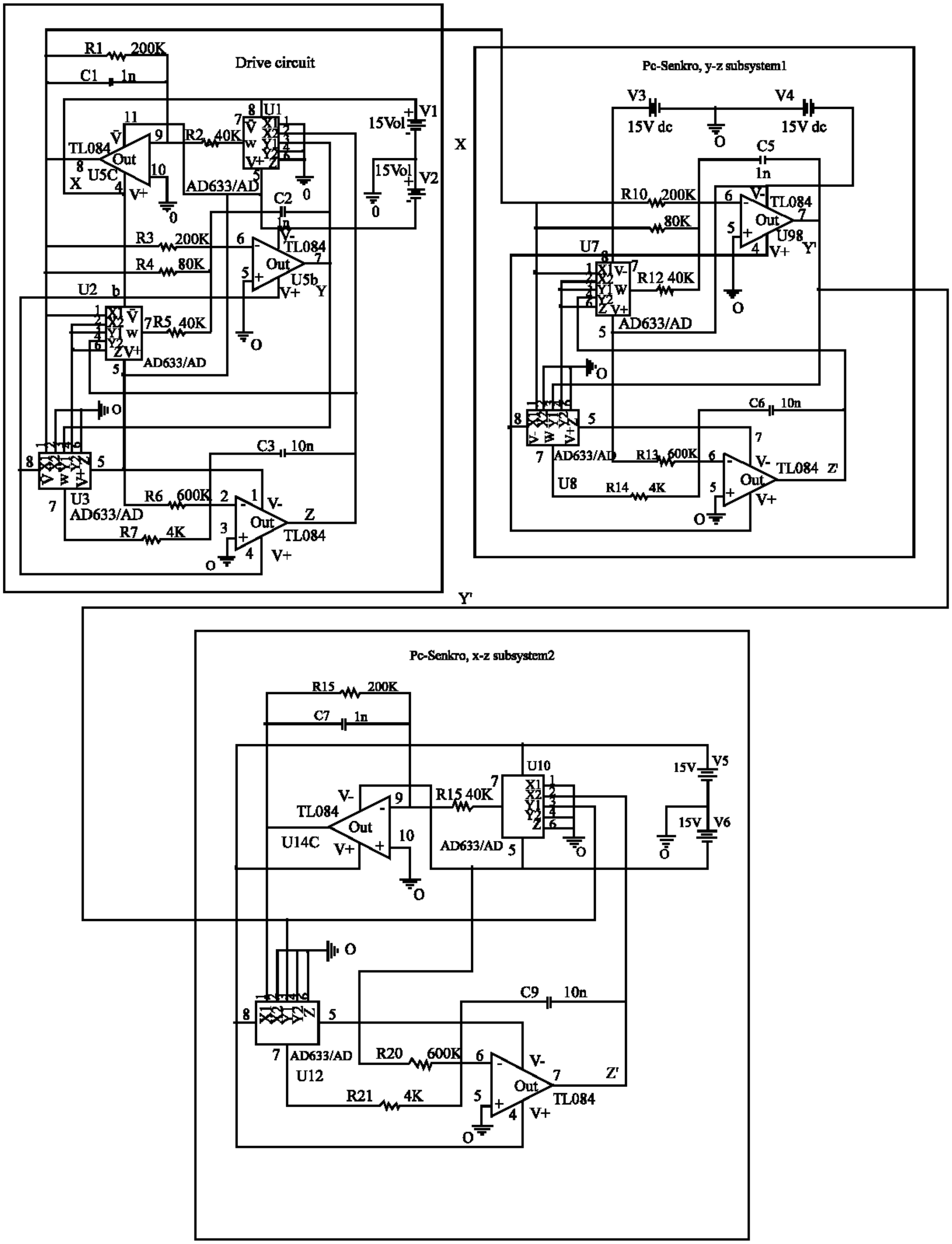

Fig. 9: Pspice Circuit of Pecora-Carroll Synchronization of Rikitake Attractor

Synchronization of the Rikitake system: Synchronization between chaotic systems has received considerable attention and led to communication applications. There are two major methods for coupling and synchronizing

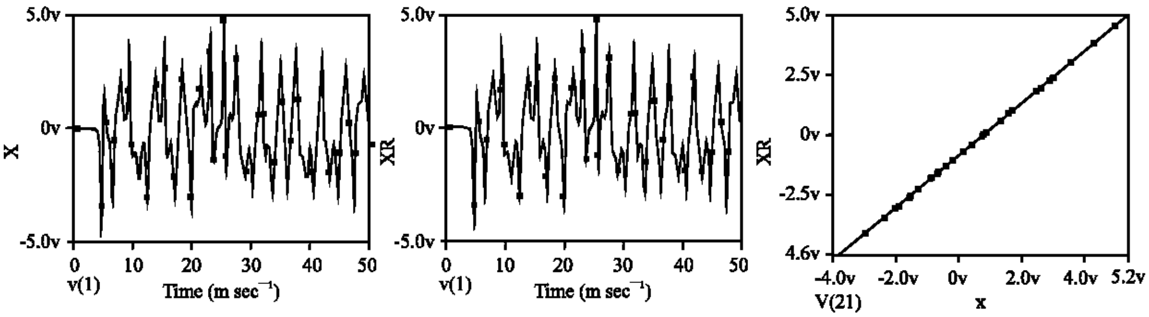

Fig. 10: Pspice simulation outputs of Pecora-Carroll Synchronization of Rikitake Attractor Circuit a) Drive system X signal b) Response system Xr signal b) Synchronization between X and Xr

identical chaotic systems, the cascading method and the one-way coupling method. With these methods, a message signal sent by a transmitter system can be reproduced at a receiver under the influence of a single chaotic signal through synchronization. This paper presents the study of numerical simulation of chaos synchronization for chaotic Rikitake System. The method of synchronization is Pecora-Carroll method; drive subsystem and response subsystem were constructed. Figure 6 shows block diagram of a cascaded synchronization system. Figure 7 pointed out simulation modeling of P-C Synchronization of Rikitake Attractor.

There are two major methods in chaos synchronization of coupled identical systems; the cascading method and the one way coupling method. The idea of the methods is to reproduce all the signals at the receiver under the influence of a single chaotic signal from the driver. Therefore, chaos synchronization provides potential applications to communications and signal processing. However, to build secure communications system, some other important factors, need to be considered. Simulations of synchronization of Rikitake Attractor are presented as shown in Fig. 8.

Figure 9 shows the circuit schematic for implementing the Rikitake attractor's Pecora-Carroll Synchronization. We use TL081 opamps, the Analog Devices AD633JN multipliers, appropriate valued resistors and capacitors for Pspice simulations. The circuits are supplied ±12 V power supplies. Figure 10 shows Pspice simulation results of this circuit. Pspice and Matlab-Simulink simulations (Fig. 8) give the same conclusions.

CONCLUSIONS

In this study, we have studied applications of chaos synchronization. Method is the one-way coupling method, the idea is using a parameter to couple two identical chaotic systems and makes them synchronizing. But this coupling is not mutual. The behavior of the response system depends on the behavior of the drive system but not invertible. We have demonstrated in simulation that chaos can be synchronized and applied to secure communication schemes. This paper focuses on the identical synchronization for secure communications. Chaos synchronization was investigated using Matlab-Simulink and Pspice programmes. Related Fig. 2, 4, 8 and 10) show that Pspice and Matlab-Simulink simulations give the same conclusions.

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