DESIGN, SIMULATION AND REALIZATION OF THE RIKITAKE ATTRACTOR’S CHAOTIC OSCILLATOR CIRCUIT

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Abstract

In this paper, Rikitake Attractor’s chaotic oscillator circuits were designed and simulated using Matlab-Simulink® and Orcad-PSpice® programs. Also real electronical experimental circuit of Rikitake attractor was realized. Simulation and oscilloscope outputs are used to illustrate the accuracy of the designed and realized Rikitake chaotic circuits.

Keywords: Chaotic system, Chaotic attractor, Chaotic circuit, Rikitake attractor, Rikitake oscillator.

Anahtar kelimeler: Kaotik sistem, Kaotik çekici, Kaotik devre, Rikitake çekicisi, Rikitake osilatörü.

2. Design And Simulations Of The Rikitake Attractor’s Chaotic Oscillator Circuit

The Rikitake chaotic dynamical system is a model which attempts to explain the irregular polarity switching of the earth’s geomagnetic field [9-10]. The system exhibits Lorenz-type chaos and orbiting around two unstable fixed points. This system describes the currents of two coupled dynamo disks. Following nonlinear autonomous ordinary differential equations are the Rikitake chaotic system:

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

Here \(a\) and \(\mu\) are parameters which we will assume to be nonnegative. The Lyapunov exponents of the Rikitake Attractor are 0.232, 0, and -1.232. Namely, only one positive LE is present. The Figure 1. and Figure 2. show the Simulink modeling and the simulation results of the Rikitake Attractor respectively.

Figure 1. Matlab-Simulink Model of the Rikitake Attractor

This paper focuses on the design and realization of Rikitake Attractor’s chaotic oscillator circuits. The brief is organized as follows. In Section II, Simulink modeling and PSpice circuit design and their simulations of the Rikitake system are obtained. In Section III, real chaotic electronical experimental circuits of the Rikitake system are realized. Section IV contains conclusions.
Figure 2. Phase portraits of the Rikitake attractor when $\mu = 2$, $a = 5$, $x_0 = 0$, $y_0 = 0.1$, and $z_0 = 0$.

Figure 3 shows the circuit schematic for implementing the Rikitake equations (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 R1 - R7, are all shown with nominal values in Figure 3. Figure 4 shows Pspice simulation results of this circuit. Pspice and Matlab-Simulink simulations (Fig. 2, 4) give the same conclusions.

Figure 3. Designed Circuit Schematic of the Rikitake Attractor

Figure 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.
2. Design And Simulations Of The Rikitake Attractor’s Chaotic Oscillator Circuit

The designed circuit schematic of the Rikitake Attractor is implemented with electronics components for initial conditions $x_0=0$, $y_0=0$, $z_0=0$, that can be used to study chaotic phenomena. The circuit employs simple electronic elements such as resistors, and operational amplifiers, and is easy to construct.

Experimental electronic circuit realization of the Rikitake system is seen in Figure 5. Oscilloscope outputs of electronic circuit of the Rikitake system are seen in Figure 6. and 7. Chaotic $x$, $y$, $z$ signals vs. time are seen in Figure 6. a, b, c. Respectively. Also chaotic xy, xz, yz attractors are seen in Figure 7. a, b, c respectively.

Figure 5. Experimental electronic circuit realization of the Rikitake Attractor

![Figure 5](image1)

Figure 6. Oscilloscope outputs of electronic circuit of the Rikitake system. Chaotic $x$, $y$, $z$ signals vs. time respectively

![Image 1](image2)  
![Image 2](image3)  
![Image 3](image4)
Figure 7. Oscilloscope outputs of electronic circuit of the Rikitake system. Chaotic xy, xz, yz attractors respectively

4. Conclusions

Rikitake chaotic system is one simple three-dimensional quadratic autonomous chaotic system, which can generate complex 2-scroll chaotic attractors simultaneously. This paper focuses on the Rikitake Attractor’s chaotic oscillator circuits. Rikitake Attractor’s chaotic oscillator circuits were designed and simulated using Matlab-Simulink and PSpice programmes. Also, real electronic experimental circuit of the Rikitake attractor was realized. Related Figures (Figures 2, 4 and 7) point out that Matlab-Simulink, Pspice and also real oscilloscope outputs prove the same conclusions. The study of chaotic oscillators is of interest in electrical engineering education. To implement as electronics of the Rikitake chaotic system is very easy, due to having zero initial conditions. Introducing a laboratory project that integrates experimental and simulation results may prove an exciting experience.

References