

Article

A New Jounce Chaotic System: Dynamical Analysis, Adaptive Synchronization and Switching Parameter Modulation Applications

Abdul-Basset A. Al-Hussein ¹, Fadhil Rahma Tahir ¹, Ghaida A. Al-Suhail ², Mariam H. Abd ³
and Viet-Thanh Pham ^{4,*}

¹ Department of Electrical Engineering, University of Basrah, Basrah 61004, Iraq; abdulbasset.jasim@uobasrah.edu.iq (A.-B.A.A.-H.); fadhil.rahma@uobasrah.edu.iq (F.R.T.)

² Department of Computer Engineering, University of Basrah, Basrah 61004, Iraq; ghaida.suhail@uobasrah.edu.iq

³ Infrastructure Directorate, Department of Engineering Works, Al Nasiriya 64001, Iraq; mariam876am@gmail.com

⁴ Faculty of Electronics Technology, Industrial University of Ho Chi Minh City, Ho Chi Minh City 70000, Vietnam

* Correspondence: phamvietthanh@iuh.edu.vn

Abstract

This paper presents and analyzes a new four-dimensional (4D) jounce hysteresis chaotic dynamical system and investigates its application to robust communication. An adaptive chaotic synchronization scheme is developed based on the proposed 4D jounce system, in which an adaptive controller is designed at the receiver to achieve robust synchronization between the master and slave systems in the presence of uncertain system parameters. Lyapunov stability theory is employed to derive the adaptive control laws and parameter-update rules required for online estimation of the uncertain receiver-side parameters. For chaos-based communication, multiple information signals are encoded by modulating selected parameters of the chaotic transmitter system. At the receiver, the adaptive parameter estimator tracks the transmitted time-varying parameter, enabling reliable information recovery through a midpoint-thresholding decision scheme after the initial transient period. The performance and robustness of the proposed communication framework are evaluated through comprehensive numerical simulations under additive white Gaussian noise (AWGN) at different noise levels. The results demonstrate accurate chaotic synchronization, reliable information recovery, and robustness against channel noise, indicating the potential of the proposed 4D jounce chaotic system for robust and noise-tolerant communication applications.

Keywords: jounce chaotic system; synchronization; adaptive control; chaos-based communication; switching parameter modulation

MSC: 93C10; 93C40



Academic Editor: Jonathan Blackledge

Received: 20 August 2026

Revised: 23 September 2026

Accepted: 24 September 2026

Published: 27 September 2026

Copyright: © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

1. Introduction

Over the past several decades, chaotic systems have attracted increasing attention in both theoretical research and practical circuit implementation because of their distinctive nonlinear dynamics and broad range of applications. They have been investigated extensively in various fields, including engineering [1–3], biology and ecological models [4,5],