Synchronization Effects during the Interaction of Complex Nonlinear Systems

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Abstract

Stochastic Resonance (SR) is a phenomenon where the addition of an optimal level of white noise to a nonlinear system can amplify a signal so weak that a sensor could not previously detect it. By transferring a specific amount of energy from the broad spectrum of noise, the signal-to-noise ratio increases, making the original signal more discernable. This effect is frequently utilized in nonlinear, bistable systems.

The paper also explores the essence and significance of synchronization. Through numerical simulations, frequency synchronization in the Van der Pol model and phase synchronization in the Adler equation are demonstrated.

Furthermore, wavelet coherence analysis revealed the time and frequency-dependent relationships between solar activity indices (sunspot number, 10.7 cm radio flux) and Earth's magnetic field. Periods of high coherence coincide with the phases of solar maxima, indicating that solar activity exerts a significant influence on Earth's magnetosphere. The obtained results confirm that cyclic solar variations drive geomagnetic fluctuations, clearly illustrating the close, dynamic link between the magnetic fields of the Sun and Earth.

Keywords: Stochastic Resonance, Nonlinear Systems, Frequency Synchronization, Phase Synchronization, Van der Pol Model, Adler Equation, Wavelet Coherence, Solar Activity, Geomagnetic Fluctuations

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