Optik 155 (2018) 43–49

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Full length article

Research on laser coded signal extraction technology based on stochastic resonance

Yufa Zhang*, Xiaoquan Sun

State Key Laboratory of Pulsed Power Laser Technology, Electronic Engineering Institute, Hefei 230037, China

ARTICLE INFO

Article history:
Received 26 August 2017
Accepted 1 November 2017

Keywords:
Laser guidance
Laser coding
Stochastic resonance
Signal detection

ABSTRACT

The coded laser signal with low energy for irradiation the target is proposed for countermining laser warning system and laser protection technology. Meanwhile, the stochastic resonance technology is applied to extract and recognize the weak laser encoded signal. The principle of stochastic resonance technique is analyzed, and the process of the extraction of low signal to noise ratio (SNR) of the normal periodic code signal, binary signal and four coded signal are simulated. The results show that, in the case of suitable parameters, the low SNR laser coded signal can be effectively extracted by the stochastic resonance system. Stochastic resonance technique is one of an important method for extracting the signal with low SNR.

1. Introduction

With the characteristics of high precision and great power, the Laser precision guided weapons are playing more and more important roles in modern warfare. Existing laser guided weapons use laser beams to illuminate targets by means of precise frequency codes and pseudo random codes. The laser seeker receives and recognizes signals reflected by the target [1,2].

However, the final effect of laser coded signals is that the guidance laser is irradiated to the target with high power at present. When the alarm system intercepts laser with threatening properties, the target can be protected by camouflage and many other protective measures quickly. In comparison, the aim for countermining laser warning and protection system can be achieved by reducing the amount of laser energy emitted, that is, the laser with low energy is adopted, which can reduce the probability of intercepting the laser signal by laser warning system. As a result, the combat effectiveness of precision guided weapons is maximized. However, the reduction of the emitted laser energy will inevitably lead to very weak signal retroreflect to the laser guidance seeker, and special signal detection methods are required for weak signal extraction [3–5].

Currently, echo signal detection methods are related to correlation detection, matching filter and other linear detection technology. However, correlation detection and matching filter are difficult to extract signal effectively under the conditions of low SNR or lack of prior knowledge of signal and noise. It means that the linear detection technique is difficult for low SNR signal detection. At present, the development and application of non-linear detection technology make it possible to extract and identify the low SNR signal. The rapid development of weak signal detection technology based on stochastic resonance technology provides one of important means for low SNR signal extraction. With in-depth study, stochastic

* Corresponding author.
E-mail address: zyf9180@163.com (Y. Zhang).

https://doi.org/10.1016/j.ijleo.2017.11.001
0030-4026/© 2017 Published by Elsevier GmbH.

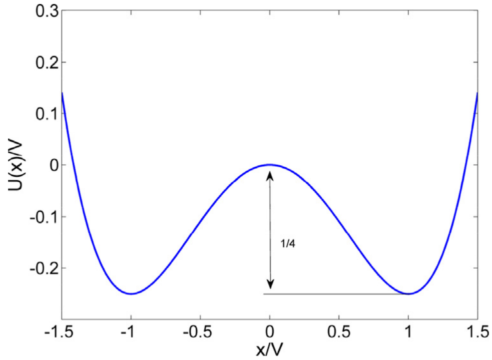

Fig. 1. Potential function curve.

resonance technology has been applied to the weak signal amplification and signal transmission, and the technology plays an increasingly important role in communication, radar, biological system, image processing and so on [6–12].

2. The theory of stochastic resonance system

When a weak signal is imported to the nonlinear stochastic resonance system, part of the background noise energy of signal can be transformed into useful signal energy. The maximal SNR signal can be achieved when the signal, noise and nonlinear system are coordinated in the system.

After studying the principle of stochastic resonance system, the most typical and concise description of the nonlinear bistable system is the Langevin equation, the dynamic equation can be expressed as [10–12]:

$$\frac{dx}{dt} = ax - bx^3 + s(t) + n(t) \tag{1}$$

Among them, x is the output of the system, $s(t)$ is the input signal, $n(t)$ is the noise. The potential function of the system is:

$$U(x) = -\frac{1}{2}ax^2 + \frac{1}{4}bx^4 \tag{2}$$

Where a and b are structural parameters of the nonlinear system.

As shown in Fig. 1, a bistable system has two potential wells and a potential barrier. The stochastic resonance system describes the process of signal and noise passing from one potential well to the other potential well when the signal is compensated by noise energy.

The Langevin equation, which describes the random motion, is a special class of nonlinear stochastic differential equations. The analytic expression of the equation is inaccurate but the method of numerical simulation is an effective solution. The Runge-Kutta algorithm is used to solve this problem for higher precision in engineering. The algorithm can be expressed as:

$$x_{n+1} = x_n + \frac{1}{6}(k_1 + 2k_2 + 2k_3 + k_4) \tag{3}$$

$$\begin{aligned} k_1 &= h(ax_n - bx_n^3 + p_n) \\ k_2 &= h[a\left(x_n + \frac{k_1}{2}\right) - b\left(x_n + \frac{k_1}{2}\right)^3 + p_n] \\ k_3 &= h[a\left(x_n + \frac{k_2}{2}\right) - b\left(x_n + \frac{k_2}{2}\right)^3 + p_{n+1}] \\ k_4 &= h[a(x_n + k_3) - b(x_n + k_3)^3 + p_{n+1}] \end{aligned} \tag{4}$$

Where x_n and p_n are the sampled value of the signal $s(t)$ and the input $p(t) = s(t) + n(t)$ respectively. The time step is $h = 1/f_s$, f_s is the sampling frequency.

3. Simulation analyze

The laser signal received by the detection system is easily disturbed by various facts in environment, and the laser radiation should be prevented from being intercepted by the opposing detecting equipment. Therefore, it is necessary to encode the emitted laser. The binary coded sequence is used to simulate the laser coded signal. After the laser coded signals are overwhelmed by strong noise, the encoded signals are recovered by stochastic resonance system in the following.