EXPERIMENTAL EVIDENCE OF DETECTING HIDDEN FREQUENCY IN CHAOS COMMUNICATIONS

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Abstract
We introduce a methodology to obtain the hidden frequencies in a dynamical system by utilizing just a single variable.By embedding the data in multidimensional spaces, and recording the density of points that the trajectory encounters as it evolves, it is possible, through a spectral analysis to apply a variable frequency over this density time series, to determine the real frequencies of the system hidden in the chosen variable.

Key words
Chaos Communication, Time-series, Embedding Frequencies, Synchronization

1 Introduction

Chaotic communications based on semiconductor lasers have excited incredible research interest since the 1990s. Physical-layer encryption using chaotic lasers is another option to transmit a message quickly and secretly. There are some practical devices and setups for chaotic optical communications, which are instinctively thought to be secure. However, there is the absence of an arrangement of security assessment rules for these communication setups(Zhao and Yin 2010, Chang, Chen et al. 2013). The whole spectrum of frequencies obtained numerically in Lorenz dynamical system by using only one variable(Ortega 1995). Also, an adequate amount of noise causes a more ordered behaviour in many fields and optical systems (Lang and Kobayashi 1980, McNamara, Wiesenfeld et al. 1988, Jung and Hänggi 1989, Gang, Ditzinger et al. 1993, Pikovsky and Kurths 1997, Barbay, Giacomelli et al. 2000, Giacomelli, Giudici et al. 2000, Marino, Giudici et al. 2002, Buldu, Garcia-Ojalvo et al. 2004, Arecchi and Meucci 2009, Sora F. Abdalah and Riccardo Meucci 2012).

In this paper ,we present an experimental technique for chaotic optical communications (chaos with embedded frequency) in a system operating in a high chaotic spiking rate(Rasheed, Aljaff et al. 2016) , a semiconductor laser with optical feedback ,to break the security and point out a new way to get the exactly embedded frequency (i.e. reduce the security).

We have inserted a range of frequencies besides the embedded frequency by means of external sinusoidal function generators to the driving current of SL.
This criterion and the suggested rule are very helpful in embedding data in secure communication systems using chaotic lasers.

2 The experimental setup

We consider (Rasheed, Aljaff et al. 2016) a semiconductor laser subject to optical feedback from an optical fiber closed loop. The experimental setup Fig.1 consists of a single-mode semiconductor laser (1550 nm wavelength). The pigtailed laser output is connected to two1x2 directional couplers (1x2 DC, 90%:10% and 1x2YC, 50%:50%) to form a fiber loop mirror. We realize the loop by connecting the two output branches of the Y-coupler. The reflected light from coupler is split into two parts; the first one provides the optical feedback to the cavity of the semiconductor laser whilst the other is connected to a high-speed InGaAs photodetector with response time <1 ns. The photodetector is connected to a sampling digital storage scope (LeCroy 500 MHz).
The principle of weak signal detection based on the change of phase trace is described as follows, The laser has been modulated by using two frequencies one of them was weak and embedded with an amplitude of 50microvolt, and the other was a range of frequencies of 10mv amplitude.

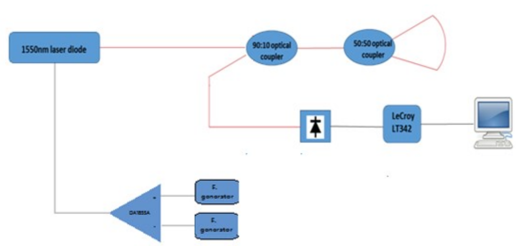

Figure 1. The experimental setup of a semiconductor laser with optical feedback.

3 Results and discussion

In the absence of an external range of frequencies, the output intensity is chaotic and we don't see any frequency in the FFT spectrum analyzer (Fig.1b). As the external range of frequencies is introduced into the system, we notice the appearance of the embedded 50MHz frequency (Fig 2b).
The appearance or synchronization of the embedded frequency was observed in the value equal to the first one Fig. 4.

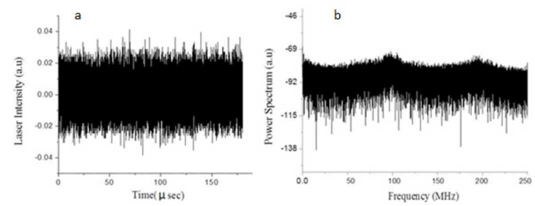

Figure 2. Time evolution(a) and corresponding FFT characteristic(b) without external frequencies and with embedded 50MHz periodic signal

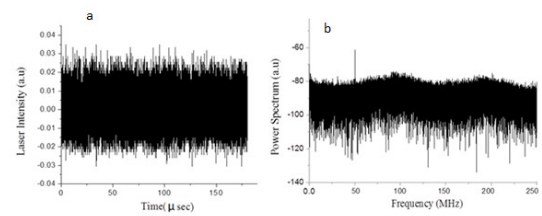

Figure 3. Time evolution(a) and corresponding FFT characteristic(b) with applied range of frequencies

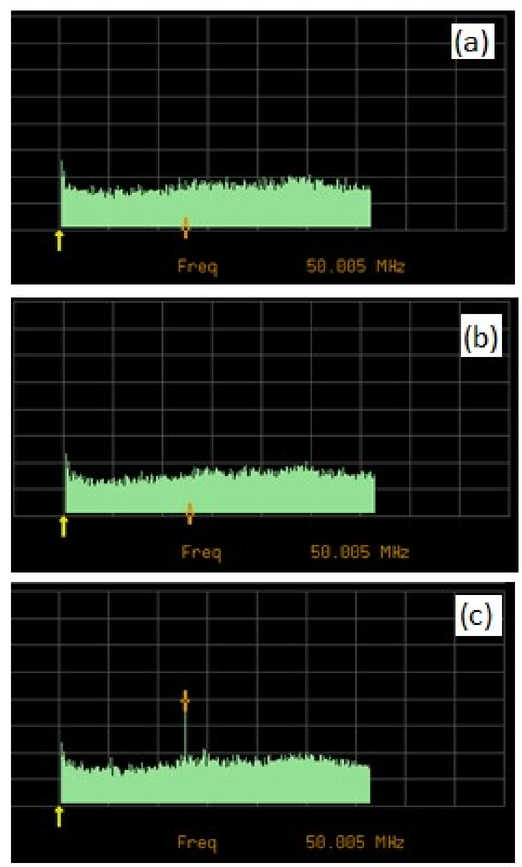

Figure 4. FFT characteristic of embedded 50MHz periodic signal (a)without external frequency,(b)with 10MHz external frequency,(c) with 50MHz external frequency.

Simulation experiments show that the oscillator is sensitive to the small signal having the tiny frequency difference with the referential (embedded) signal and immune against the random frequency and interference signal having larger frequency difference with the referential signal.

3 Conclusions

Through analyzing the modulated chaos of laser with optical feedback, we found that the system output is an intermittent chaotic signal when input frequency deviates the compulsory drive frequency slightly, and the deviation can be estimated by the statistic characteristic of output chaotic signal. Experimental results show that the signal with low Signal/chaos can be detected by this method. The hidden frequency in a chaotic environment could be extracted in the receiving part without synchronization; this could open a novel way in chaos communications.

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