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Chaos modulation in semiconductor laser with optoelectronic feedback

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Abstract. The experimental and numerical study of chaos modulation will be presented in two stats, first, when the frequency of the external perturbation is varied, secondly, when the amplitude of this perturbation is changed. The dynamics of the laser output are analyzed by Fast Fourier Transformation, attractors and bifurcation Diagram. Some frequencies could be hidden other appeared, when the frequencies are hidden, the communication link considered as secure.

1. Introduction

Chaos can be defined as a term utilized to represent the irregular behavior related to the dynamical systems that arise out of strictly deterministic time evolution with no external stochasticity or source of noise [1]. Sensitive dependency on initial conditions implies that in the case when two chaotic temporal series are starting from extremely close yet a little different initial conditions, at the start, the 2 series act in the same way, it implies that they will be starting to differ exponentially in time and the same behavior will not be shown again [2]. Semiconductor lasers (SL) were used to be related devices in studying chaos dynamical systems [3]. As the configuration system of SL is often used in data-storage and communication technologies, it has gained much popularity. they may yield conceptual realization of important semiconductor laser dynamics [4]. Three dynamic equations can describe the chaotic systems using semiconductor lasers, in the case when a semiconductor is put through at least one perturbation like: Optoelectronic feedback (OEFB), it can express nonlinear dynamics involving chaos [5-7]. three-fold dimensionality and Nonlinearity are necessary conditions to form chaos in SLs [8]. So, in the case when the laser's non-linearity is not strong enough, it can be enhanced with delayed loops of feedbacks [9]. One of the key requirements in communication are that data transfer must be quickly done and with very low distortion [10]. The goal of implementing chaos communication device has one out of two chaotic phenomena: control of chaos or synchronization. For implementing chaos communication, two chaotic oscillators are required as a transmitter or receiver. A message will be added to chaotic signal in the transmitter and will be masked in the signal. Since it carries data, the chaotic signal is called the chaotic carrier [10]. Chaotic Modulation (CM) is the Method of sending messages by OEFB-induced chaos which depends on the system utilized for coding and decoding the message [11]. A message and chaotic carrier in CM, obey a new chaotic oscillation in the non-linear system. In the nonlinear oscillator, a message will be mixed with a chaotic carrier and the two signals correspond a new chaotic state that is dissimilar from the original one. The message's amplitude should be small enough in regards to the carrier wave when the decoding process of ordinary message is being used. Moreover, the transmission degree that is related to security becomes of inferior quality in the case when there is high-level of signal messages. So, the message's amplitude in CM should also be small [10]. Amplitude modulation (AM) can be defined as a modulation approach that is utilized in information transmission . In AM, the amplitude (signal strength) related to the carrier wave is different in relation to that of the transmitted message signal. Frequency modulation(FM), in which the frequency of carrier signal is varied while the amplitude fixed[12]. Chaotic dynamics is related with temporal regularity that is related to the output laser power of system for a specified value of its feedback strength [13,14]. This phenomenon happens when an external frequency is utilized to the chaotic system [15]. Theoretically and Experimentally, Al Naimee et al. stated some researches on chaos generation using various methods such as optoelectronic [7,16] and optical feedback [17,18] with different control parameters. The associated dynamics were examined numerically and experimentally and considered to be chaotic in explored ranges of OEFB strength and bias current [19]. Sora et al. studied the changing in the dynamical state of a nonlinear system (semiconductor laser) by adding noise. These changes dependencies on the noise amplitude [13].

In this study, an experimental setup was implemented for studying the control and modulation of chaos in SL with ac coupled optoelectronic delay feedback. Modulation is an important characteristic of the chaotic systems that enable encrypting data in chaos communication, in which data could be encoded and modulated in chaos carrier. Finally, this work will show hidden and appeared frequencies by changing the amplitude or frequency of the modulating signal.

2. Experimental work and discussion

Figure 1 display the diagram related to the experimental setup, involves a single SL (hp / Agilent model 8150A optical signal source) with ac-coupled optoelectronic feedback. The laser provides an emission with a 850 nm wavelength and continuous output power of 2mW. The output laser beam is sent through an optical fiber to a photo detector, where the optical signal is converted to electrical signal. The generated electrical current is considered to be proportional to optical intensity. Then the electrical signal passes through a variable gain amplifier. The amplifier gain is used for determining the feedback strength. After that, the electrical signal is feedback to the semiconductor laser. The external signal from function generator modulates laser output.

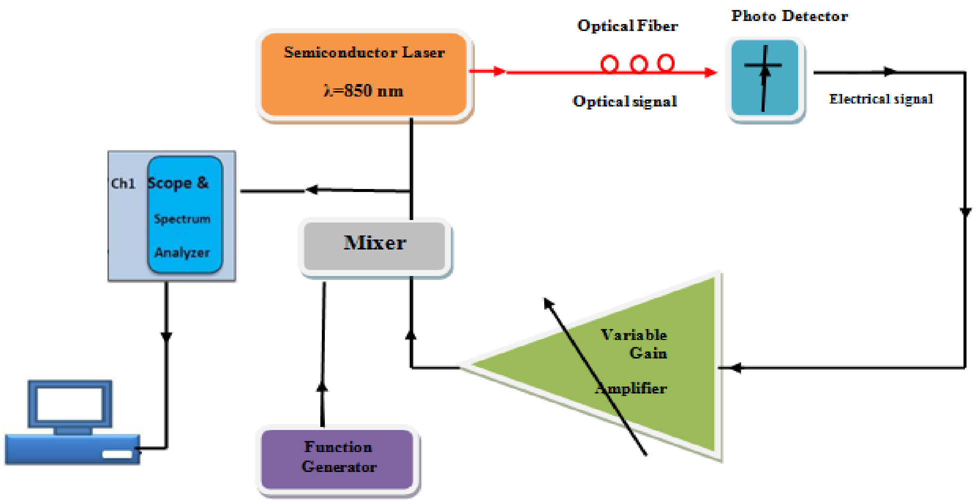

Figure 1. The sketch diagram of the experimental setup of chaos modulation

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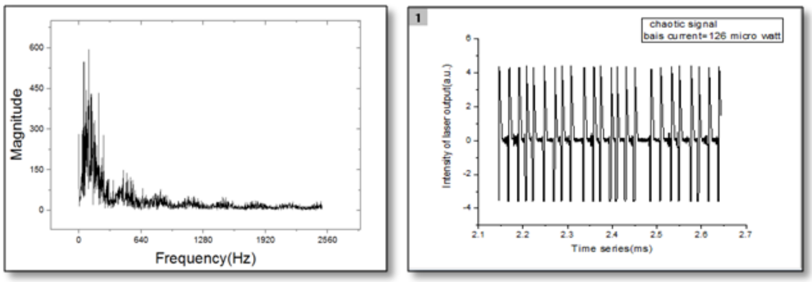
The first step of experimental work is the variation of the laser bias current. It was accomplished that a time series for each observed set of data from the chaotic signals. The laser diode's value power defined as a control parameter related to chaotic spike evolution as displayed in Figure1. Then analysis the time series and FFT of chaotic systems which show the maximum value of frequencies in chaotic region, and taken the amplitude of time series for studying the best modulation in chaotic region.



(b) (a)

Figure 2. Time series and FFT of Chaotically spiking.

As shown in figure 2b the maxima value of the frequency is 2.5 KHz and we will take the amplitude of the chaotic signal around 800mv r.m.s. The carrier, that hold considerably higher frequency and amplitude than the message signal, carries information. Then we calculate the ratio of the massage and the carries (chaos signal). The FFT frequency range is(0- 2500)HZ ,This result rout to the 10% from 2500 is 250 Hz and 20% from 2500 is 500 and so on .The amplitude of the chaos is 800 mv r.m.s , the10% of 800mv is 80mv(0.08v)and 20% from 800mv is 0.16 v and so on .

First step is to start with AM ,the amplitude (signal strength) related to the carrier wave is varied in relation to that of the transmitted message signal.

Then the output signal (sinusoidal signal) perturbation is added to the chaotic signal which has two control parameters amplitude and frequency. At first, it was observed, the dynamical sequence that contains FFT of different amplitude values where the frequency has been fixed at166Hz (7%from chaos signal). By gradually increasing in the amplitude of the perturbation (0.06,0.08,0.1…..… 0.8) volt show the hidden frequency in the first step, then appearing the frequency and increasing in it is amplitude at FFT, then frequency is fixed as shown in figure 3.

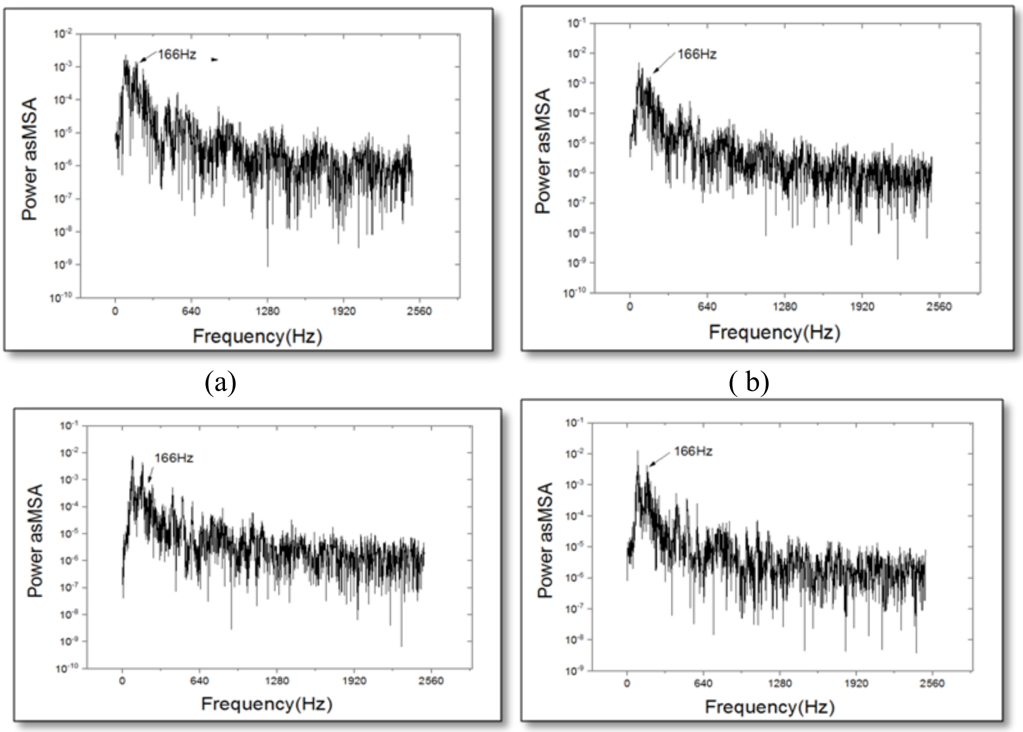
When frequency is fixed at 250(10% from chaos signal) and changing amplitude until frequency appear, then fixed frequency at (275,300,325,….2500)Hz and changing amplitude and plot these data to distinguished the region that could hide the frequency (satisfied the security) which is stable(green color) and the region that cannot hidden the frequency (unstable(red region)) and the critical region (yellow color) as shown in figure 4.

Second, when the amplitude of perturbation has been fixed at 0.08v (10% from chaos Amplitude) with gradually increasing in the frequency, the dynamical sequence has (been shown the hidden frequency in all the frequencies value as demonstrated in figure 5.

Now The amplitude is fixed at 0.12 (15% from chaos Amplitude)) and changing frequency(166,191,216,241..………1725) until frequency appear, then the amplitude is fixed at 0.16 (20% from chaos Amplitude)and changing frequency(166,191,216,241,………1600) Hz until frequency appear, plotting the data to distinguished the region that could hide the frequency (satisfied the security) which is stable (green color) and the region that cannot hide the frequency (unstable(red color)) and the critical region (yellow color) as shown in figure 6.

As shown in figure 6 the green region could hide the information and red region appear it, so we must avoid values that represented the red region.

The plots in figures 5, 6 are very important because it tell as the value, we can use it with the safety.



(a) (b)

(c) (d)

Figure 3. Power spectra with different modulation amplitude
(a) 0.08v, (b) 0.12v, (c) 0.48v,(d)0.62 v.

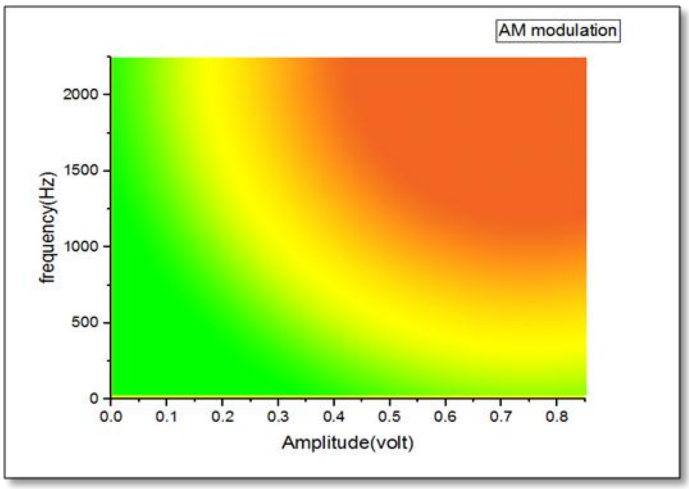


Figure 4. AM modulation (stability and instability region).

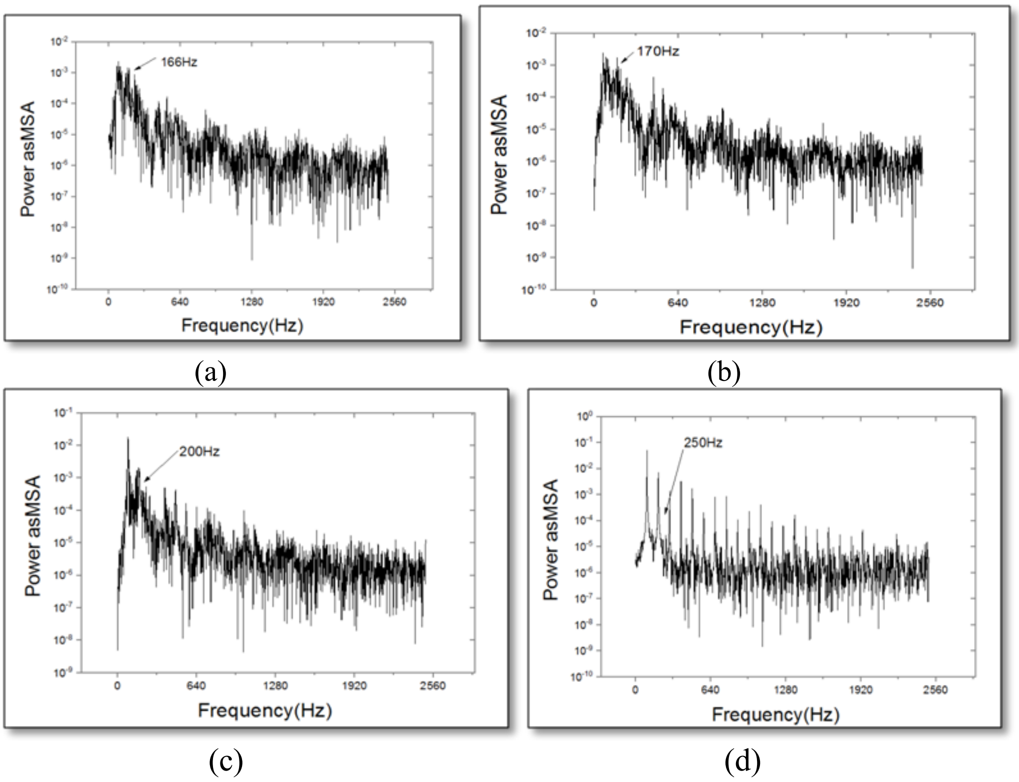


Figure 5. Power spectra with different modulation frequency
(a) 166Hz, (b) 170Hz, (c) 200Hz (d)250Hz.

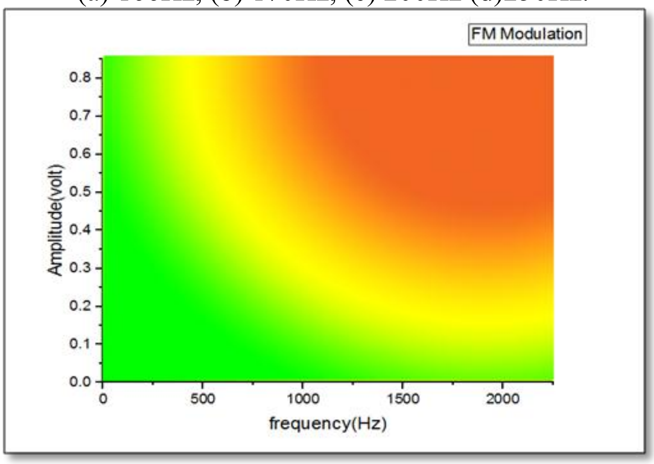


Figure 6. FM modulation (stability and instability region).

3. Conclusions

Chaotic dynamics are a good candidate for hiding information, which are a significant part for encrypting data in optical communications. Various frequencies were utilized as control parameters, appearance and hidden of such frequencies is implemented for the security of chaos communication. From the results of this study we noted that we cannot apply certain frequencies (red region) for security communication since we cannot hide these frequencies in high and low amplitude.

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