RF chaos communication system based on optoelectronic feedback

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The experimental results of wireless analog information transmission in RF band via chaos using optoelectronic feedback are reported. The chaotic carrier is generated by an optoelectronic feedback of single mode semiconductor laser and injected, in addition to a constant bias current, to a voltage control oscillator (VCO) to produce an RF carrier for transmission. The RF chaotic is detected and fed to the semiconductor laser in the receiver part to generate synchronization chaos for decoding the transmitted information. The results show the chaotic carrier has been successfully and efficiently used for the transmission and recovery RF message with security communication system.

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Keyword: Security communication, Optoelectronic feedback, RF, Optoelectronic chaos

1. Introduction

In recent years, secure communication systems based on chaotic dynamics have attracted much attention and an increasing interest in electronics optics and optoelectronics [1-3]. In chaotic systems, the information is put into the chaotic signal by modulating either the chaotic source parameters or the chaotic signal after it is generated by the source. Consequently, information is retrieved from the chaotic signal without intermediate heterodyning [4]. A chaos-based communications system could also improve privacy, security, and probability of interception, inasmuch as chaotic sequences, unlike pseudorandom sequences, can be made completely nonperiodic [5]. Semiconductor diode lasers have been widely used for the study of optical chaotic dynamics. Such lasers may be rendered chaotic through optical or optoelectronic feedback. Optoelectronic feedback is performed using electronic components such as amplifiers and filters [6]. The basic idea behind the use of chaos to transmit messages is to mask a message within a chaotic carrier before transmission and makes the presence of the signal difficult to detect in either the time or frequency domain [2, 7]. The use of chaotic signals on which to modulate and demodulate information may be quite attractive from the point of view of the efficiency of the use of communications channel bandwidth or possibly for reasons of power efficiency in the design and use of a transmitter [8]. Performance of chaotic communication in radio-over-fiber (ROF) transmission based on optoelectronic feedback semiconductor lasers has been studied numerically by Fan-Yi Lin and Meng-Chiao Tsai in 2007 [9]. The generation of chaotic signals is well understood for low-speed circuits, 1 i.e., for devices with characteristic frequencies in the Hz or kHz range. However, there is considerable interest in generating high-speed chaos because of promising applications such as random signal radar/lidar, random number generation, and communications [10, 11]. In this paper, the RF chaotic communication system is studied experimentally based on the optoelectronics feed back.

2. Experimental work

A schematic diagram of our experimental setup for the investigation of semiconductor lasers with delayed optoelectronic feedback to generate RF chaotic signal is shown in Fig. 1.

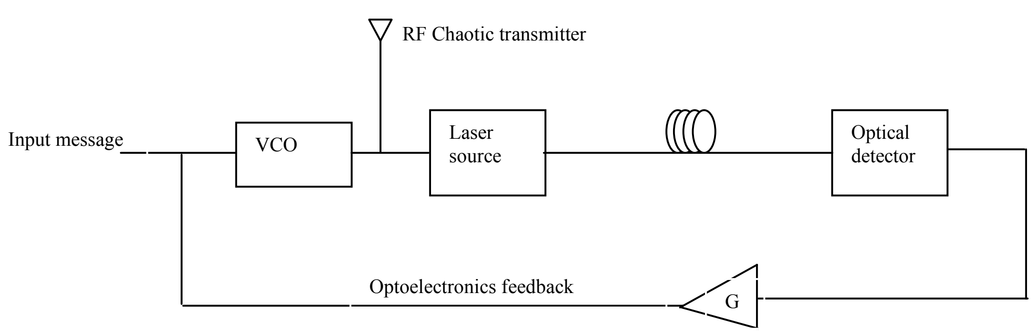


Fig. 1. The experimental setup of the RF transmitter chaotic.

A voltage controlled oscillator (VCO) is used to generate a FM signal which is fed to the semiconductor laser. The semiconductor laser used in this work is a multiple quantum well laser HFCT-5205. The package of this laser is designed to allow repeatable coupling into single mode optical fiber and to operate at a nominal wavelength of 1310 nm. This laser has a 7.7 nm spectral width (RMS), with an optical rise time of 2 nsec, and the average optical output power is 0 dBm. The laser is driven by a DC bias current and lasers in a single mode. The output light is received and converted to a current by the HP A8951 PIN photodetector. The current is subsequently amplified and added as a feedback to the VCO by adding it to the injection current, resulting in a delayed positive feedback. Because the photodetector responds only to the intensity of the laser output, the feedback signal contains the information on the variations of the laser intensity which is proportional to the photon density in the laser cavity. The optoelectronic feedback is driven by a base-band chaotic signal, thus generating at its output a chaotic FM carrier from the output of the VCO. The module output signal, a mixture of chaotic and information signals, modulates the amplitude of RF-band oscillations. The oscillations are then transmitted by RF transmitter. The demodulation of the signal in the received part was achieved by subtraction the transmitted RF chaotic from receiver's chaos generation as shown in Fig. 2.

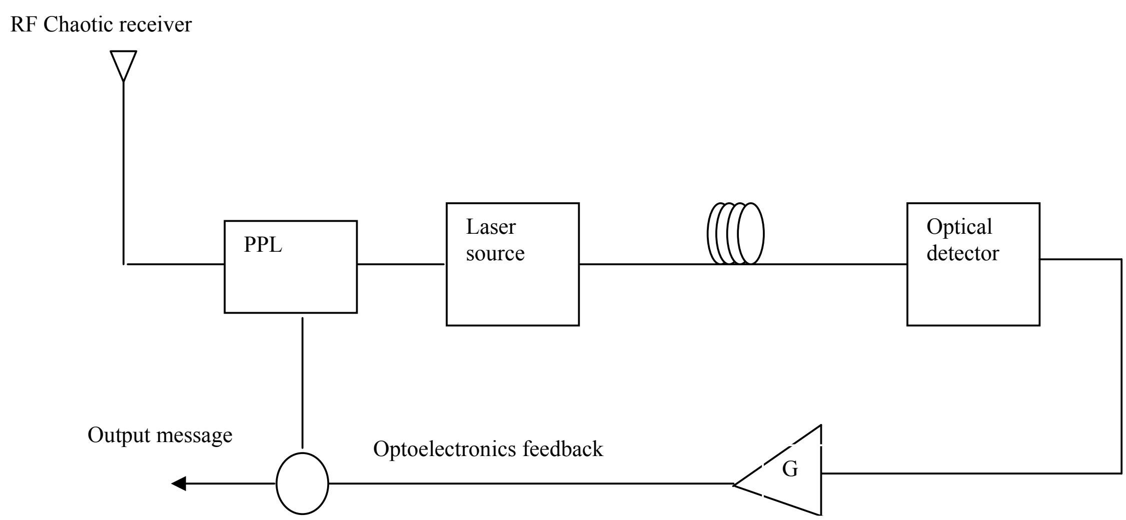


Fig. 2. The experimental setup of the RF receiver chaotic.

3. Results and discussion

Optoelectronic feedback caused by the light from a semiconductor laser enters a detector which generates an electrical signal and then is summed back into the power source that drives the laser. This process causes a delayed feedback due to the time taken by the electrical signals to travel around the feedback loop.

Although the signals travel at the speed of light, the delay time is significant enough to create the nonlinear dynamics. The experimental results of temporal waveform and corresponding attractor of periodic, quasiperiodic, and chaotic pulsing are shown in Fig. 3.

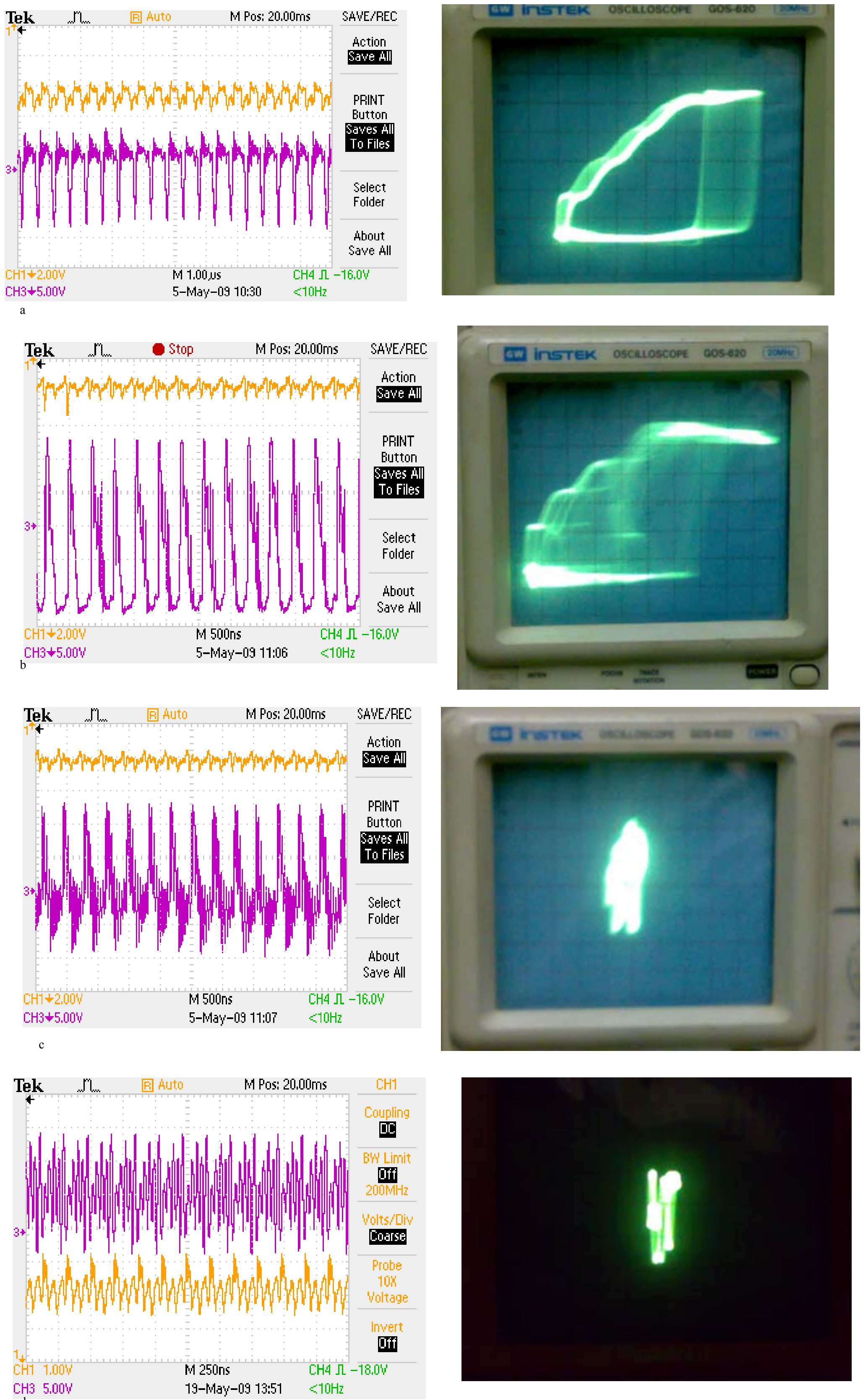
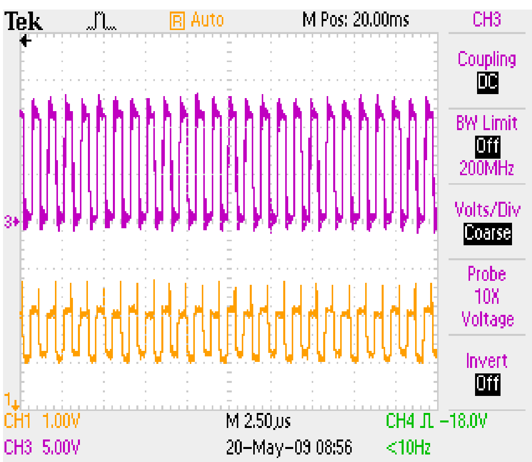


Fig. 3. The waveform and corresponding attractor of periodic, quasiperiodic, and chaotic pulsing.

These figures show the time series (left) and attractor (right) of the output power of the laser under optoelectronics feedback operation. It can be noticed that when the feedback photocurrent level is low, the laser is oscillated periodically as in Fig. 3-a. When the level of the photocurrent level increased, the time series will mix spectrum with a strong periodic peaks with broad high frequency to generate a quasiperiodic as in Fig. 3-b. The high frequency chaotic is mainly generated due to bifurcation of the oscillating laser mode in the laser cavity when the feedback reaches a certain value as in Fig. 3-c. When increasing the optoelectronic feedback gain through the tunable gain of the RF driver, it is possible to obtain numerous dynamical regimes as typically observed in nonlinear delayed feedback oscillators as in Fig. 3-d; their amplitudes increase with increasing feedback loop gain.

The chaotic signal in this work was observed when the semiconductor laser operated just above the threshold current >13mA and the feedback photocurrent from the detector is controlled by the electrical amplifier. In the same time it was noticed that the variation of the laser injected current as well lead to missing the chaotic which need to play with the feedback current to find it again. This means that the coupling coefficient between the amplitude and the feedback current is stronger than the coupling with the population inversion. Because chaotic signals are generated by deterministic dynamical systems, two coupled chaotic systems are synchronized in the receiver part to produce identical chaotic oscillations to provide the key recovery of information that is modulated onto a chaotic carrier. A comparison between the transmitted and received signals is illustrated in figure.



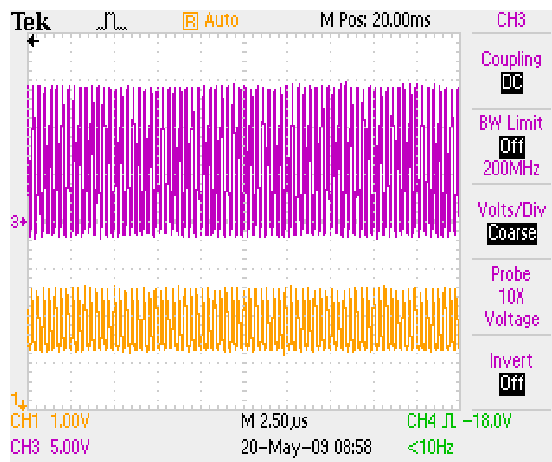


Fig. 4. A comparison between the transmitted and received signals.

4. Conclusions

A simple, low-cost and high-speed setup has been designed, constricted and operated for nonlinear dynamics RF chaotic communication system based on the optoelectronic feedback process. This chaos could be demodulated by subtracting the transmitter chaos from that receiver chaos signals. With this operation, such setup may be efficiently used for secure communication system.

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