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Nonlinear Dynamics of Chaotic Optical Communication Systems: Signal Processing and Cybersecurity

ELENA V BAKUNINA[1], OLEG V. DYKYI[1] AND ARTEM V. VITAVETSKY[1*]

1. National University "Odessa Law Academy", 28, Rishel'evskaya str., Odessa, 65012
2. Odessa State Environmental University, Mathematics Depr., L'vovskaya str. 15, 65009, Odessa
* Presenting Author

Abstract: A chaos–geometric approach to investigation of complex chaotic dynamical systems is applied to an analysis, modeling and processing the time series of emission intensities of chaotic transmitter/receiver systems (two unidirectionally coupled semiconductor laser systems in the all-optical scheme) suited for encoding at rates of GBit/s. The problem of a signal processing is directly connected with the corresponding cybersecurity in some chaotic optical communictaion systems. The estimated values for the dynamic and topologic invariants such as the correlation and Kaplan-York dimensions, Lyapunov indicators, Kolmogorov entropy etc for investigated chaotic signal time series of two unidirectionally coupled semiconductor laser systems are obtained. For the first time it is constructed a numerical prediction model for the corresponding chaotic signal time series. The obtained data on the chaotic dynamical parameters can be utilized for indirect estimate of a privacy in the communication as the higher the complexity of the carrier the more difficult is to decode a message without the appropriate receiver.

Keywords: chaotic optical communictaion systems, nonlinear dynamics, invariants

1. Introduction. Nonlinear Dynamics of Chaotic Optical Communication Systems

At present time there are carried out the intensive investigations in the field of signal processing and cybersecurity in different optical chaos communictaion systems that is provided by a great importance and interst due to its technical applications [1,2]. One should note that a message could be encoded and decoded within a high dimensional chaotic carrier in devices with using coupled single-mode semiconductor lasers subjected to coherent optical feedback or injection, or fiber ring lasers. The important feature of such scheme is connected with successful possibility to synchronize two spatially separated chaotic semiconductor lasers to each other. The authors [1] have presented a review of the main characteristics for emitter/receiver devices concentrating on two kind of chaotic systems: a semiconductor laser subject to a delayed all-optical feedback and a semiconductor lasers subject to a delayed non-linear electro-optical feedback. It has been shown: i) there is generated a direct-chaotic carrier in dynamics of both systems; ii). availability of chaotic regime in system is sufficient to provide a privacy in the communication as the higher the complexity of the chaotic carrier the more difficult is to decode the message without the appropriate receiver [1].

In this paper an effective chaos –geometric approach [2-5] is applied to analysis, modeling and processing the time series of emission intensities of chaotic transmitter/receiver systems (two unidirectionally coupled semiconductor laser systems in the all-optical scheme) suited for encoding at rates of GBit/s. There are listed the estimated values for the dynamic and topologic invariants such as the correlation and Kaplan-York dimensions, Lyapunov indicators, Kolmogorov entropy etc for investigated chaotic signal time series.

2. Results and Discussion

Using a chaos geometric approach in versions [2-5] there are obtained the numerical data of analysis and modeling time series of emission intensities of chaotic transmitter/receiver systems (two coupled semiconductor laser systems in the all-optical scheme). The concrete step is an analysis of the corresponding time series with $8x10^3$ points and Δt=0.0125 ns. The corrective algorithms have been used in order to reconstruct the missing time series terms. There is an important chaos emergency parameter such as the Gottwald-Melbourne $E_{gm} \leq 1$.

The calculation allows to get the following values of the main topologic and dynamic invariants, namely, the time lag ν=8, the embedding dimension D_E=5, the correlation dimension D_C=3.2, the Kaplan-York dimension: D_L=2.3, the positive and negative Lyapunov indicators δ_1=0.233, δ_2=0.003, δ_3=-0.004,…, the Kolmogorov entropy: E_K=0.236.

The performed calculation allows to pay attention at a few important dynamic features in the system. Firstly, availability of two positive Lyapunov indicators is an evidence of a chaos availability in the temporal dynamics and existence of the respective strange attractor in a phase space. It is important to underline that the Kaplan-York dimension is very close to the correlation dimension, but indeed is smaller than the embedding dimension. The latter confirms the correctness of the choice of the latter.

It is important to underline that a changing the governed parameters in a system will result in changing the main dynamic and topologic parameters and can be performed in regime of the numerical experiment. As the problem of a signal processing in investigated chaotic optical communictaion system is directly connected with the corresponding cybernetic security, it is obvious that the obtained data on the chaotic dynamic parameters and carrier can be utilized for indirect estimate of a privacy in the communication as the higher the complexity of the carrier the more difficult is to decode a message without the appropriate receiver [2].

3. Concluding Remarks

In order to conclude, a chaos–geometric approach (in versions [2-5]) has been applied to investigation of complex chaotic optical communication dynamical systems with the aim of modeling and processing data of the time series for emission intensities of chaotic transmitter/receiver systems. The values of some dynamic and topologic invariants such as the correlation and Kaplan-York dimensions, Lyapunov indicators, Kolmogorov entropy etc are obtained. These data on the chaotic dynamical parameters can be utilized for indirect estimate of a privacy in the communication.

References

[1] MIRASSO C, FISCHER I, PEIL M AND LARGER L: Optoelectronic Devices For Optical Chaos Communications. *Proc. Spie* 5248, *Semiconductor Optoelectronic Devices For Lightwave Communication*, 2003.

[2] BAKUNINA E AND DYKYI O: Signal processing and cybersecurity in some chaotic optical communictaion systems. *Photoelectronics*. 2020, 29:45-51.

[3] GLUSHKOV AV: *Methods of a Chaos Theory*. Astroprint: Odessa, 2012

[4] GLUSHKOV A, SVINARENKO A, BUYADZHI V, ZAICHKO P AND TERNOVSKY V: Chaos-geometric attractor and quantum neural networks approach to simulation chaotic evolutionary dynamics during perception process. In: BALICKI J (ED) *Advances in Neural Networks, Fuzzy Systems and Artificial Intelligence, Series: Recent Advances in Computer Engineering*. WSEAS: Gdansk, 2014, **21**:143-150.

[5] GLUSHKOV A, IGNATENKO A, KUZNETSOVA A, BUYADZHI A, MAKAROVA A AND TERNOVSKY E: Nonlinear dynamics of atomic and molecular systems in an electromagnetic field: Deterministic chaos and strange attractors. In: AWREJCEWICZ J (Ed.) *Perspectives in Dynamical Systems II: Mathematical and Numerical Approaches.* Series: *Springer Proceedings in Mathematics & Statistics*. 2021, **363**:Ch.11.