Proceedings of the 4th International Conference on Computing Innovation and Applied Physics
DOI: 10.54254/2753-8818/80/2025.GL20476

Receive-decrypt Circuit Design for Encrypted Signal Processing

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Abstract: In today's society where the Internet and information networks are so developed, the need for confidentiality of information transmission is more and more important, no matter whether it is in the business sector, the military, medical care, or individuals. In this paper analyses the basic working principles of four different communication systems, namely, the high-dimensional chaotic laser communication system, the chaotic synchronous confidential communication system based on the reserve pool calculation, the ultra-chaotic system based on the amnesia, and the communication system based on the Duffing vibrator array, from encrypting the signal and sending it from the transmitting end to receiving, demodulating and converting the encrypted signal from the receiving end. The differences between the different parts of each system are compared. Finally, it is found that today's communication systems have the disadvantages of poor confidentiality, weak anti-jamming, high cost, low accuracy, etc., respectively, and suggestions for modification are made. Finally, the future development of communication is looked forward to.

Keywords: Cryptosystems, chaotic signals, chaotic encryption

1. Introduction

In today's social environment of high-speed development of the Internet, whether it is the military, politics and business or each individual is using the Internet for efficient transmission of information, so it also leads to many potential risks in the process of transmission of information such as information in the process of transmission is intercepted, or stolen and so on [1].

Therefore, this paper focuses on the process of signal processing and reception of four kinds of communication systems, namely, high-dimensional chaotic laser communication system, amnesia-based chaotic control and application of hyper chaotic system, amnesia-based chaotic control and application of hyper chaotic system, and communication system based on Duffing vibronic array, and summarizes the advantages and disadvantages of each communication system, and the reception and decoding of each communication system, and the advantages and disadvantages of each communication system, and the reception and decoding of each communication system. The advantages and disadvantages of each system in the transmission process, and the differences in the methods of receiving, demodulating and converting the encrypted signals at the receiving end. It also summarizes the advantages and disadvantages of each system and the improvement methods of each system.

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2. Encrypted Signal Application Scenario Analysis

2.1. High-dimensional chaotic laser communication systems

High-dimensional chaotic laser communication systems are effective in long-distance communications in terms of rate and confidentiality, and are mainly used in military classified communications, satellite communications, and optical communications between data centers.

Military communications use high-dimensional chaotic lasers as a transmitting source to generate complex and unpredictable optical signals for data modulation and encryption. At the receiving end, the data is restored by specific decoding algorithms. Its strong anti-jamming and stealthy nature prevents eavesdropping by the enemy, and its suitability for long-distance transmission matches well with the special characteristics of military communications [2].

Satellite communication can be achieved through high-dimensional chaotic laser transmission signals to achieve encrypted communication between satellites and ground stations. The high-dimensional characteristics of chaotic laser signals can resist space noise interference. It improves the confidentiality and anti-interference of satellite communication and maintains stable transmission in the harsh space environment.

Optical communication in data centres requires the integration of high-dimensional chaotic lasers in the optical fiber network to generate signals that are difficult to decipher to ensure the secure transmission of data between data centres. High data transmission rates and low BER provide encrypted high-speed transmission links for financial and medical industries.

2.2. Chaotic synchronous secure communication system based on reserve pool computation

The Chaotic Synchronous Confidential Communication System based on Reserve Pool Computing is mainly used in the encrypted communication of IoT devices, remote medical data transmission, smart city security monitoring and so on. The IoT device deploys reserve pool computing module at the sending end and receiving end respectively, transmits data synchronously using the chaotic signal it generates, and then decodes the accurate data through the synchronization mechanism at the receiving end. It can effectively improve the confidentiality and security of communication between devices, prevent hacking, and enhance data protection in IoT networks.

For remote medical data, the reserve pool chaotic signal is embedded in the patient data transmission link, and the receiving end receives and decodes it synchronously to ensure the confidentiality of medical data. While ensuring the accuracy of data transmission, it protects the patient's private data and prevents the leakage of sensitive information [3].

Urban security monitoring can apply reserve pool computing to the communication link in the monitoring system to transmit monitoring data through chaotic signals. This in turn improves the security of security communication, prevents hijacking or tampering of surveillance video, and enhances the privacy of urban security data transmission.

2.3. Amnesia-based Chaos Control for Hyper Chaotic Systems and Applications

Hyper chaotic systems based on amnesia Chaos control and applications of hyper chaotic signals are unpredictable and highly confidential, so they are usually used in sensitive information and important information transmission. Examples include data encryption in military communications, communication control of drone swarms, and encrypted data transmission between financial institutions.

The military adds a memristor module to the encryption device, generating a hyper chaotic signal for data modulation, and transmitting data through unpredictable multi-dimensional chaotic signals

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[4]. Ultra chaotic signals have extremely high encryption strength, ensuring that sensitive military data is difficult to decrypt or intercept, and meeting the demand for high confidentiality.

The use of amnesia hyper chaos signals in UAVs to regulate communication between UAVs ensures that the information received by each UAV is independently encrypted, which enhances the anti-jamming and security of the communication link, and is especially suitable for UAV mission execution in hostile environments.

The addition of the super chaotic signal generated by the amnesia to the financial data transmission encrypts the sensitive financial data through the unpredictable signal, ensures the security of the financial data, prevents the data from being eavesdropped during transmission, and is suitable for application in the transnational financial transaction network.

2.4. Communication system based on Duffing vibrator array

The communication system based on Duffing vibrator array is used in deep sea communication, radar signal processing, and signal analysis in geological exploration because of its sensitivity to small signal changes.

In the deep sea, it can use Duffing vibrator array to detect and amplify the weak deep-sea signals, enhance the quality and stability of signal transmission, and can be stable in the deep-sea noise environment to transmit signals, improve the sensitivity of the signal detection, suitable for submarine or deep-sea instrument communication.

Duffing oscillator is used in the signal receiving system of radar to detect the radar echo signal with high sensitivity and enhance the recognition rate of weak signals. It enhances the radar system's ability to capture low-signal targets and is suitable for target detection in complex battlefield environments.

In geological exploration, Duffing vibrators are used to analyses underground weak signals to help detect resource distribution [5]. In complex geological environments, it improves detection accuracy and signal processing capability, and is suitable for applications such as mineral resource detection.

3. Receive decryption circuit principal analysis

3.1. Generation and reception of encrypted signals

3.1.1. Similar process

In the high-dimensional chaotic laser communication system, chaotic synchronous secure communication system based on reserve pool computing, the generation and reception of encrypted signals are the same, first of all, it generate chaotic signals through the laser at the transmitting end, and encrypt the chaotic signals by applying the chaotic mask method to superimpose the chaotic signals and the information signals we want to transmit, and then we use the laser to convert the encrypted signals into optical signals to be transmitted through optical fiber or free space to the receiving end. to the receiving end.

In the memristor-based hyper chaotic system, the encryption of the information we use the memristor to change the chaotic system into a hyper chaotic system because of its peculiar memory and nonlinear characteristics, and because the essential characteristic of the hyper chaotic system is its strong nonlinear behavior, and the memristor can be naturally introduced into the circuit with this kind of nonlinear, so we can use it to help generate the hyper chaotic behavior [6]. At the same time, the normalization and feedback of mixed signals (encrypted signals) are introduced at the receiving and transmitting ends respectively, so that both the receiving and transmitting ends can be driven by the same mixed signals, and then return the original information to the transmitting end after

DOI: 10.54254/2753-8818/80/2025.GL20476

normalization and feedback. The encrypted signal is sent through the channel to the receiving end for decryption.

In the communication system based on Duffing oscillator array, the generation of encrypted signals is consistent with the high-dimensional chaotic laser communication system and the chaotic synchronous secure communication system based on the reserve pool computation, but we use the duffing oscillator to detect the signals, which is a kind of oscillator with the ability to respond to the small changes, and has the natural immunity to the external noise, which is very strong anti-interference ability. Duffing oscillators are oscillators that respond to small changes and are naturally immune to external noise, making them highly resistant to interference. We use the unique nonlinear dynamics of the duffing oscillator and its sensitivity to the phase of the signal to detect chaotic signals without the need for synchronization equipment [7]. The duffing oscillator shows different trajectory patterns for signals of different frequencies and phases in the chaotic state, so when the chaotic signal is transmitted, the duffing oscillator can respond to the signal through the change of phase trajectory, so that the system can detect the existence and content of the chaotic signal. And because a single duffing oscillator has a limited reception range of the initial phase of the signal and cannot receive the full 360° phase space, we form an array of same-frequency duffing oscillators by using multiple same-frequency duffing oscillators, and through the collaborative work of multiple oscillators, this paper realizes the coverage of the signal's full 360° phase space. So that the array can receive the whole content of the signal without distortion and avoid signal loss.

3.1.2. Difference

In the high-dimensional chaotic laser communication system, based on the reserve pool calculation of chaotic synchronous confidential communication system, we found that the laser synchronisation disadvantage in the production process cannot guarantee that the transmitter and receiver lasers to achieve the exact same, so that most of the cases we send and receive the two ends of the generalised synchronisation rather than the complete synchronisation. This method has problems such as the information signal is not fully integrated into our chaotic signal, but similar to ‘floating’ in the chaotic signal carrier, and also after the combination of the transmission process of our chaotic signal is similar to the noise has similar noise characteristics are very susceptible to external noise interference, so the external noise and channel distortion of these factors produce negative impacts. The interaction of negative signals generated by these factors will greatly interfere with the synchronous transmission of our information [8]. And very small noise has the danger of directly destroying the original signal synchronisation effect of the system, and increase the BER, which leads to low precision and inaccuracy of the reply signal. So, in this method, there is a possibility that the energy of the mixed signal is not enough to accurately drive the receiver to synchronise with the signal transmitter.

In amnesia based hyper chaotic system we improve the difficulty, complexity and secrecy of the system by changing the chaotic system into hyper chaotic system. Ultra chaotic signals are more difficult to predict in real time, which also leads to a much higher performance and prediction accuracy of the ultra-chaotic secure communication system synchronisation, and by normalising the original information and returning it to the sender after feedback, it is possible to solve the problem of fusion of the two signals as well as to greatly enhance the confidentiality of the system and its ability to resist noise and interference. Moreover, the amnesia can effectively increase the number of state variables and dynamic complexity of the system, so that the system has multiple equilibrium points and multiple stability, thus enhancing the complexity of the system [9]. The parameters of the amnesia can also be adjusted to regulate the dynamical behaviour of the system, so as to flexibly control the frequency, amplitude and other characteristics of the hyperchaotic system.

In the communication system based on duffing oscillator array we use duffing oscillators that are able to distinguish small changes in the signal state due to their parameter-sensitive nonlinear

DOI: 10.54254/2753-8818/80/2025.GL20476

dynamics. This property makes them more resistant to interference and accurate in recognising and demodulating chaotic signals. Compared to conventional systems, the non-coherent demodulation method of Duffing arrays avoids the complexity of chaotic synchronisation and exhibits lower BER in response to noise interference.

3.2. Demodulation process of encrypted signal

In the high-dimensional chaotic laser communication system at the receiving end we convert the received optical signals into electrical signals by means of photodetectors and decrypt them by means of a demodulator, the principle of which is to subtract the chaotic signals generated at the receiving end from the encrypted signals and then get the original information signals.

The difference between the chaotic synchronised secure communication system based on reserve pool computation and the high-dimensional chaotic laser communication system is that the signal is synchronised using the reserve pool computation, and when the encrypted signal is received by the RC system, a large number of nodes in the reserve pool can predict the chaotic carrier at the transmitter side [10]. The reason for this is that at the receiving end of the RC have trained its internal parameters in advance with some of the known chaotic carriers so that it can predict the unknown chaotic carriers. This paper also uses the cross-prediction method to reduce the prediction error so as to achieve highly accurate chaotic synchronisation. Then it directly subtract the chaotic carrier in the encrypted signal from the chaotic carrier predicted by our receiver to get the original information signal.

In the amnesia-based hyper chaotic system, we use a one-way coupling controller to keep the chaotic system at the transmitter and receiver side synchronised, and at the receiver side, we use the similarity between the synchronised chaotic signal and the encrypted signal to separate the information signal we want to transmit from the chaotic background, so as to demodulate the original signal. And the unidirectional coupling synchronisation controller can effectively cope with the multidimensionality, sensitivity and anti-interference requirements of the hyper chaotic system, and it only needs to transmit the information from the transmitting end to the receiving end, and there is no need to return the signal, which guarantees the security of communication to a certain extent. In addition, the unidirectionality prevents the signal feedback from influencing the chaotic state at the transmitter [11].

In the signal demodulation process of the communication system based on the Duffing vibrator array, the phase trajectory pattern of the Duffing vibrator is used to identify the phase change of the chaotic signal and then decode the original information. And the system is immune to signals with arbitrary initial phases, which enables stable non-coherent demodulation.

3.3. Signal conversion and output

High-dimensional chaotic laser communication systems use filters to remove noise and extract the effective signal, then increase the signal strength by means of erbium-doped fibre amplifiers, and finally use a decoder to output the adjusted electrical signals through output devices such as loudspeakers or displays. The erbium-doped fibre amplifier plays an important role in this process by compensating for the loss of the signal during transmission and ensuring the signal strength [12].

Chaotic synchronous secure communication system based on reserve pool computation, the super chaotic system based on memristor decrypts and transmits the signal by outputting the demodulated signal into readable signal through analogue-to-digital converter and other components.

The communication system based on Duffing vibrator array smoothes the demodulated signals according to the roughness characteristics of the phase trajectory, and finally outputs stable electrical signals. At the same time, the phase trajectory is analysed by a domain segmentation detector to

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optimize the phase trajectory recognition rate under the addition of white noise and improve the overall anti-interference performance of the signal.

4. Analysis of challenges and optimization directions

4.1. Deficiencies

The high cost of lasers and associated equipment for high-dimensional chaotic laser communication systems, especially for large-scale deployments, may limit their application. Furthermore, lasers cannot be perfectly synchronised due to process or error, which results in flawed or incomplete demodulation of the information leading to communication failure or decoding errors. Laser signals are extremely sensitive to the environment, and the propagation of laser signals in the atmosphere may be affected by weather, air quality, and other factors, resulting in signal attenuation and unstable transmission.

The chaotic synchronisation of the reserve pool based secure communication system requires a high degree of consistency in the computation process between the sender and the receiver, and any lack of synchronisation will lead to communication failure. Moreover, the reserve pool computation still requires a certain number of computational resources and memory support, especially when dealing with complex data [13]. Implementing the complexity of reserve pooling for the prediction of chaotic signals requires the accurate design and training of reserve pooling neural networks, which can be complex and time-consuming in some applications.

The main difficulty for amnesia-based hyper chaotic systems is in the important component, the amnesia. The amnesia technology is still in the developmental stage and the manufacturing accuracy and cost can be difficult points. The high-dimensional nature of hyperchaotic signals makes it almost impossible to decipher the data during transmission, but their design and control is relatively complex and requires a high technological threshold. It still needs longer time as well as more experiments and tests to verify its long-term stability and reliability.

Communication systems based on Duffing vibrator arrays are capable of detecting weak signals, but may not perform as stably as other systems in high signal strength or high-speed communication scenarios. Since the output signals of Duffing vibrators are usually complex, efficient signal processing techniques are required to extract the effective information, and their nonlinear characteristics may lead to signal distortion in some applications, especially in multipath propagation or frequency mismatch.

4.2. Optimization directions

For high dimensional chaotic laser communication systems can develop lower cost lasers, for example by using new materials and applying them. For inaccurate synchronisation we can use more advanced algorithms to compensate for hardware synchronisation errors. For environmental interference we can optimise the channel, e.g. by burying the channel underground and isolating it from the outside world or by developing more stable lasers to reduce the effect of the environment on the signal.

For chaotic synchronous secure communication systems based on reserve pool computing we can use advanced synchronisation algorithms to reduce the time delay and frequency offset between the transmitter and receiver, and introduce adaptive synchronisation mechanisms so that the system can be dynamically adapted to cope with synchronisation problems in unstable or interfering environments. For computational resource consumption we can choose to use hardware acceleration to accelerate the reserve pool computation process and reduce the demand for computational resources [14]. Or use lightweight neural network models to reduce the computational complexity of the reserve pool computation, especially in embedded systems with limited resources.

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For the super chaotic system based on amnesia we adopt advanced nanotechnology and materials for amnesia to improve the fabrication precision and reliability of amnesia and reduce the fabrication cost. And we study the simplified structure of hyper chaotic system to reduce the dimension and complexity of the system, so that the design is more flexible and easier to implement.

Communication systems based on Duffing vibrator arrays are weak in detecting high signal strength situations We can combine Duffing vibrators with other types of communication systems in conjunction with multimode signal processing techniques to broaden their applicability scenarios. The use of hardware acceleration to accelerate the signal processing process, reduce the signal processing delay to improve the signal processing ability, and then introduce error correction algorithms, in the signal decoding process to automatically correct the error caused by non-linearities to reduce the distortion of the signal.

5. Conclusion

At present, we have discussed the basic working principles of four systems, namely, high-dimensional chaotic laser communication system, chaotic synchronous secure communication system based on reserve pool computation, amnesia-based hyperchaotic system, and communication system based on Duffing oscillator arrays. From encrypting the signals at the transmitting end to the synchronisation, demodulation, and conversion of the signals at the receiving end, we have listed the differences and advantages and disadvantages of each system, and give the solution. However, nowadays, because of the high cost of these solutions, the complexity of technology and algorithms, the consumption of resources, and the lack of maturity of various technologies and other factors, it is still not possible to further improve the system. So, it hopes that in the near future we can use the communication system with stronger confidentiality, accuracy, and lower cost.

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