Chaotic Wireless Communication Systems Using Combination of LMS and RLS Adaptive Equalizer

Behnam Kojouri[1], Ammar Hasanvand[1], Vahid Asadpour[1]
1- Department of Electrical Engineering, Sadjad Institute of higher Education, Mashhad, Iran
Email: behnam.9471@gmail.com

Received: May 4, 2013 Revised: June 5, 2013 Accepted: June 12, 2013

ABSTRACT:
In recent years, a variety of communications systems based on chaos and nonlinear dynamics have been proposed. However, most of these algorithms not working under realistic channel conditions. This paper presents a channel equalization scheme for chaotic communication systems based on a Logistic Chaos map. The dynamic representation of Logistic map is exploited to allow a straightforward and efficient implementation. Equalizer filter coefficients are updated using a new combination of RLS and LMS by partitioned the main frame of data into subsequent frames, the first frame which include the training sequence is fed to RLS for better convergence speed, however switch to LMS for low complexity.

KEYWORDS: Chaotic Wireless Communication, Equalizer filter, Adaptive Equalizer, CSK

1. INTRODUCTION

Chaos theory, a branch of the theory of the interesting nonlinear systems, exhibits an interesting nonlinear phenomenon and has been intensively studied in the past four decades. Initially, it was studied by researchers with strong mathematical background rather than circuit-designers or electronic engineers/ scientists. Chaos appears as a perfect solution to data transmission. Chaos communications systems offer the promise of inherent security, resulting from the broadband and "noise-like" appearance of chaotic signals, and efficiency, since systems could be allowed to operate in their natural nonlinear states. Generations of chaotic maps came from many different directions. It can be a complex or simple control system, a mathematical equation such as a differential equation, or a simple circuit modelling like Chua circuit. A variety of approaches to chaotic communications have been proposed, including chaotic modulation, masking, and spread-spectrum [1, 2].

Fig. 1 shows a generic chaotic communications system. In such a system the information bits to be transmitted must first be encoded in the signal waveform generated by the chaotic system using logistic map. Rather than using structured signals, such as rectangular pulses or sinusoids, to denote '0's and '1's, these communications systems embed the information in the time evolution, or dynamics, of the transmitted signal. The process of mapping the information bits to the state of the chaotic system is termed chaotic modulation.

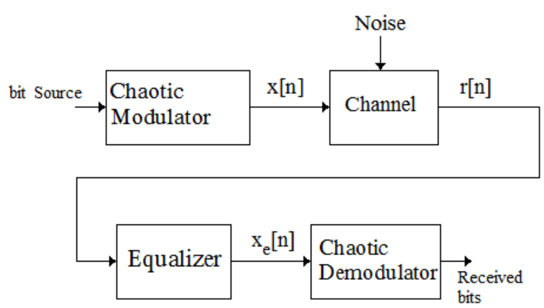

Fig. 1. Generic chaotic communications system

This assignment of information bits to state should not be arbitrary, and the greatest efficiency is achieved when the information transmission rate matches the topological entropy of the chaotic system [2]. Next, the chaotic sequence is transmitted through the channel. The effect of the channel is to distort the transmitted sequence and corrupt it with additive noise. The purpose of the equalizer is to undo the distortions caused by the channel. Equalizer used here combination of RLS and LMS is presented by partitioned the main frame of data into subsequent frames, the first frame which include the training sequence is fed to RLS for better convergence speed, however switch to LMS for low complexity[3]. Finally, the recovered chaotic sequence is passed through a chaotic demodulator to obtain an estimate of the transmitted bit sequence from the symbolic dynamics of the reconstructed signal. Although there have been many algorithms proposed for using chaotic signals for communications purposes, there remain several basic issues that need to be addressed. First of all, almost all of these algorithms disregard channel effects or fail to work under realistic channel conditions. There has been some research into equalization algorithms for chaotic communications systems [4, 5, 6]. In [4], a self-synchronization-based channel equalizer was proposed. However, this approach has limited utility because most chaotic systems do not self-synchronize. In [5], a technique for the blind identification of autoregressive (AR) systems driven by a chaotic signal was proposed. Finally, lack of efficiency and speed is a severe limitation for many of the existing chaotic communications schemes.

In this paper, we present a framework to address all of these important problems. The proposed equalization algorithm is able to compensate for the effects of a fading dispersive channel with AWGN. Simple techniques are also proposed for chaotic modulation and demodulation at the maximum possible information rate. Additionally, alternative representations of the proposed chaotic systems provide a means for implementation in finite precision arithmetic. Chaotic communications systems are often said to be secure because the transmitted signal has a random appearance with little further justification. Finally, it is shown that the proposed algorithms are fast, accurate, and efficient.

Section 2 provides information on of chaotic system that will be considered. Then, equalization algorithms are presented in Section 3. Simulations and results for the proposed algorithms are given in Section 4.

2. CHAOTIC SYSTEM

Here the first, we explain the method of chaotic signals generated by Logistic map, then we explain Chaos Shift Keying (CSK).

2.1. Logistic map

Dynamic system that is capable of exhibiting chaotic properties for spreading spectrum communication is proposed in which:

$$g_{n+1} = a g_n (1 - g_n) \qquad (1)$$

Where a is the bifurcation parameter (or control) parameter, which is considered to be in the interval of $3.75 < a \leq 4$; for a non-period chaos system.

In this work, the bifurcation parameter is identified as the 'security key' of the system. This security key can only be known to the authorized user. Without this key the transmitted signal cannot be demodulated. Due to its bifurcation behavior, the chaotic sequence is very sensitive to the initial condition chosen. An exact value must be known in the receiver side to be able to demodulate the transmitted CSK signal [7, 8].

2.2. Chaos Shift Keying (CSK)

The demodulation process is a simple coherent correlator at the receiver as shown in Fig. 2

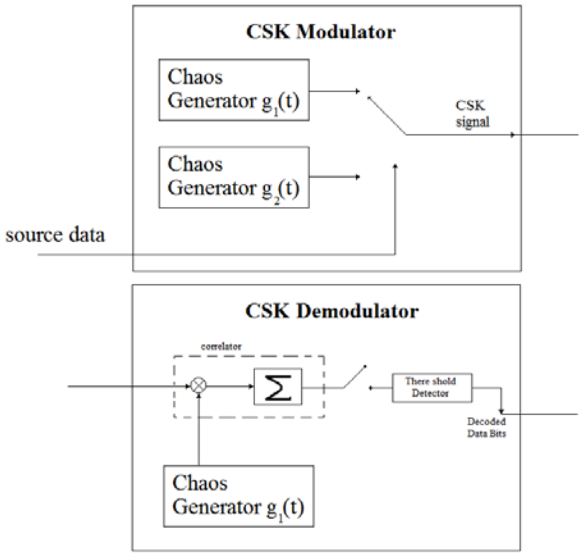

Fig. 2. CSK Modulator and De-modulator

In binary chaos shift keying modulation [2], chaotic signals carrying different bit energies are used to transmit the binary information. An information signal is encoded by transmitting one chaotic signal g_1 or g_2 at a time. For example, if the information signal binary bit "1" occurs at time, the chaos signal g_1 is to be sent, and for information bit "0", the chaos signal g_2 is to be sent. The two chaotic signals can come from two different chaos systems or the same system with different parameters. The transmitted signal is given by

$$s(t) = \begin{cases} g_1(t) \text{ , symbol "1" is transmitted} \\ g_2(t) \text{, symbol "0" is transmitted} \end{cases}$$

(2)

The chaotic sequence for CSK g_1 and g_2 can be generated in three different ways. First method: it uses two different chaotic generators. Second method: generating the two sequences using different initial conditions of the same chaotic generator. And the last method: the two sequences are generated by the same chaotic generator with the same initial condition but multiplied by two different constants.

3. EQUALIZER SYSTEM

At this point, it should be clear how chaotic modulation and demodulation are performed, an equalizer is needed to recover the transmitted chaotic sequence such that the demodulator gives the correct bit sequence. This section looks at the equalizer component of the block diagram. For simplification, a discrete-time representation will be used.

Fig. 3 shows the equalizer and chaotic demodulator. In this block diagram, r[n] represents the output of the channel, which is a distorted chaotic sequence. Equalized sequences, with the training data d[n], denoted by m[n]. Then, equalized signals by filter LMS, with the training data x[n]. The x[n] is chaotic signal that obtained after threshold. In Section 2 and thresholded by correlaor-demodulator to demodulate the chaotic sequence.

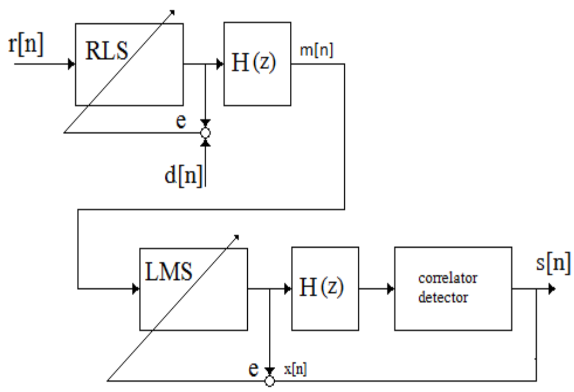

Fig. 3. Combination of LMS and RLS Adaptive Equalizer

3.1. Least-Mean Square Adaptive Algorithm

In the adaptive LMS algorithm [9], the coefficients (weights vector) H(n) of the FIR filter are updated according to the following formula:

$$H(n) = H(n-1) + \mu e(n) y(n)$$
(3)

Where $H(n) = [H_0(n) H_1(n) \ldots H_M(n)]$ (M + 1 being the filter length), μ is the convergence parameter (sometimes referred to as step-size), $e(n) = d(n) - z(n)$ is the output error (z(n) being the filter output), and d(n) is the reference signal. Note that $z(n) = H(n-1) y^T(n) = \hat{x}(n)$, where ˆx(n) is the original signal and y(n) = [y(n) y(n − 1)...y(n −M)] is the filter input signal.

3.2. The RLS Algorithm

As compared to the LMS algorithm, the RLS algorithm has the advantage of fast convergence [9], but this comes at the cost of increasing the complexity. The RLS algorithm consumes longer computation time and has a higher sensitivity to numerical instability than the LMS algorithm. In this paper, we consider the RLS algorithm in the following form:

$$z(n) = H(n-1) y^T(n)$$
(4)

$$e(n) = d(n) - z(n)$$
(5)

$$k(n) = \frac{P(n-1) z(n)}{\lambda + z^h(n) P(n-1) z(n)}$$
(6)

$$p(n) = \frac{P(n-1) - P(n-1) z^h(n) k(n)}{\lambda}$$
(7)

$$p(n) = \frac{P(n-1) - P(n-1) z^h(n) k(n)}{\lambda}$$
(8)

$$H(n) = H(n-1) + e(n) k(n)$$
(9)

Where h indicates the Hermitian property.

4. SIMULATIONS AND RESULTS

To simulate the proposed algorithm, are used Riley fading channel. It was also assumed that the channel adds white Gaussian noise, n[n], to the signal. The signal at the output of the channel can be written as:

$$r[n] = c[n] * x[n] + n[n]$$
(10)

Where x[n] is the output of the chaotic modulator.

In this paper, CSK modulation of signals for chaos generated by logistic map different parameters, respectively α1 = 3.6 and α2 = 3.9 for zero and one bits are used. Distortion are plotted in under figures to illustrate the unstructured nature of these signals.

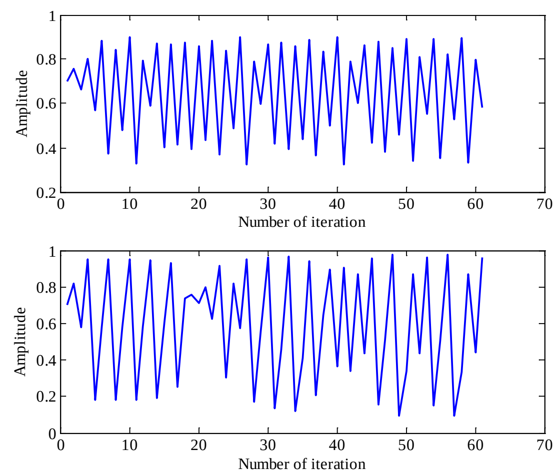

Fig. 4. Signal when the bit is 1 and 0

Also length of the signal is SF, that called the spreading factor.

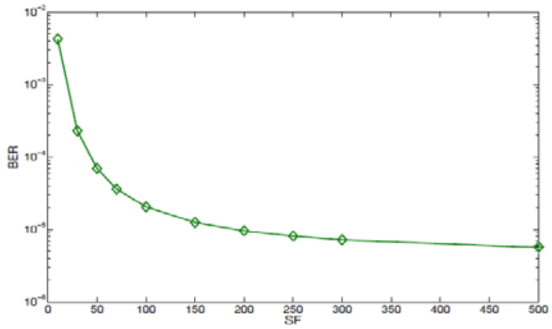

Fig. 5. BER performance for CSK with 10 dB for different SF [2].

In Fig. 5 shows the performance is improved for higher SF.

Adaptation starts with a training sequence, i.e., a known sequence of information bits, to get an initial estimate of the filter coefficients. The mean-square error is plotted for the first 2500 iterations in Fig. 6 with a noise variance of 0.01. Fig. 7 shows a BER performance of RLS-LMS equalization algorithm also Fig. 8 shows a BER performance for different SF. as you can see performance is improved for higher SF.

In Fig. 9 shows a BER performance of algorithm in riley and rician channels for SF=60 as you can see performance of algorithm in rician channel is better than performance of algorithm in riley channel.

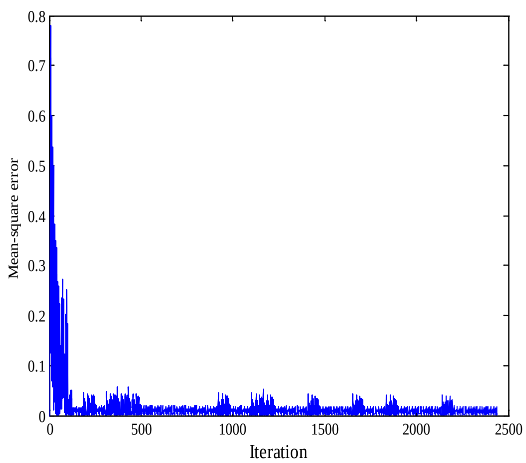

Fig. 6. Mean-square error for the first 2500 iterations.

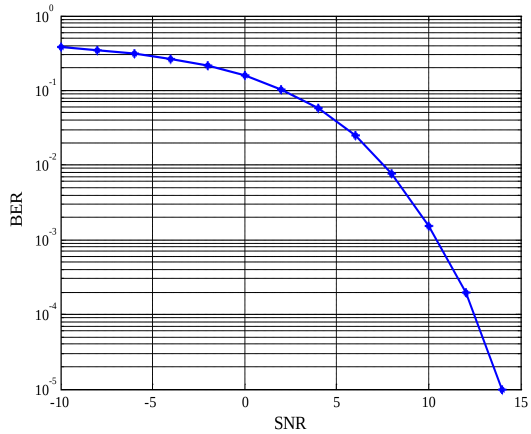

Fig. 7. BER performance of RLS-LMS equalization algorithm in riley channel

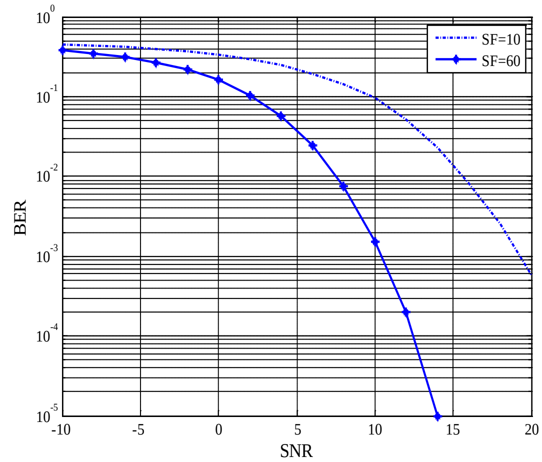

Fig. 8. BER performance of RLS-LMS equalization algorithm for SF=10, 60 in riley channel

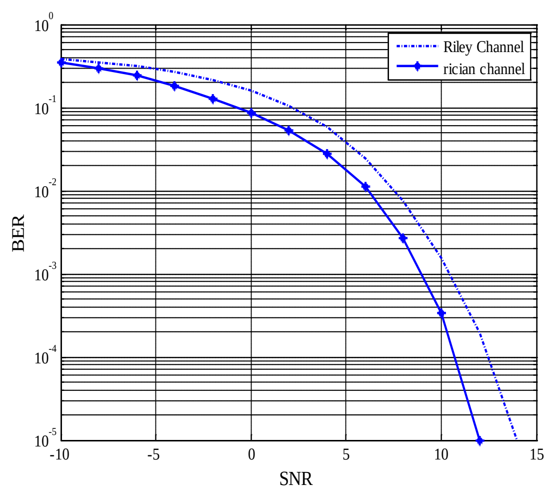

Fig. 9. BER performance of algorithm in riley and rician channels for SF=60

Finally In Fig. 10 we plot bit error rate versus signal-to-noise ratio for both types of RLS-LMS equalization algorithm compared to the LMS equalization algorithm for SF=60.

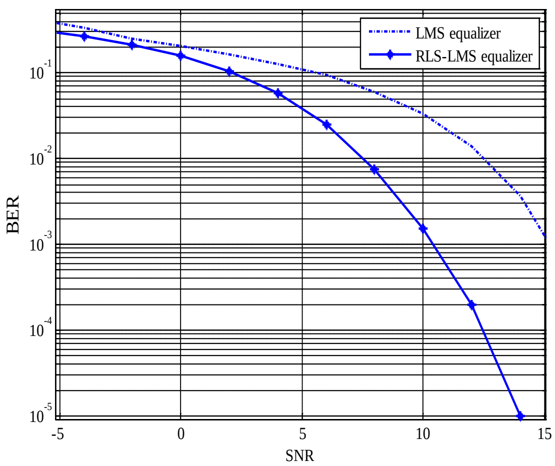

Fig. 10. Bit-error rate performance of RLS-LMS equalization algorithm compared to the LMS equalization algorithm.

5. CONCLUSIONS

This paper has described equalization algorithm for chaotic communications systems. The logistic map was shown to be the key that makes possible chaotic modulation, demodulation, and equalization. Simulation results showed that the performance of the equalization algorithm improved significantly, moreover, the proposed algorithm is fast and efficient. Finally, the extension to higher dimension chaotic systems is straightforward.

REFERENCES

[1] Mahmut Cifrci, and Douglas B. Williams, **"A NOVEL CHANNEL EQUALIZER FOR CHAOTIC DIGITAL COMMUNICATIONS SYSTEMS, "** IEEE International Conference on Acoustics, Speech, and Signal Processing, vol. 3, pp. 1301-1304, 1999.

[2] Yuu-Seng Lau, **"Techniques in Secure Chaos Communication,"** A PhD Thesis, University of RMIT, Melbourne, February 2006.

[3] Mahmood Farhan Mosleh, and Aseel Hameed AL-Nakkash, **"Combination of LMS and RLS Adaptive Equalizer for Selective Fading Channel,"** European Journal of Scientific Research, 2010.

[4] K. M. Cuomo, A. V. Oppenheim, and R. J. Barron, **"Channel equalization for self-synchronizing chaotic systems,"** Proceedings of International Conference on Acoustics, Speech, and Signal Processing, 1996.

[5] H. Leung, **"System identification using chaos with application to equalization of a chaotic modulation system,"** IEEE Transactions on Circuits and Systems-I: Fundamental Theory and Applications, vol.45, no. 3, pp. 314-320, 1998.

[6] Mahmut Ciftci, and Douglas B. Williams, "**Iterative Equalization For Chaotic Communications Systems,"** IEEE International Conference on Acoustics, Speech, and Signal Processing, Vol. 4, pp. iv/165 - iv/168, March 2005

[7] H.-B. Ghobad and C. D. McGillem, "A chaotic direct-sequence spread- specturm communication system," IEEE Trans. Communications, vol. 42, no. 234, pp. 1524- 1527, Feb/Mar/Apr. 1994.

[8] H.-B. Ghobad and C. D. McGillem, "Chaotic sequences for spread spec trum: an alternative to PN-sequences," in Proc ICWC, pp. 437-440, Jun. 1992.

[9] S. Haykin, Adaptive Filter Theory, Prentice Hall, 1986.