Journal of Engineering and Development
www.jead.org
Vol. 20, No.1, January 2016
ISSN 1813-7822

MODIFIED MAXIMUM AUTO-CORRELATION ESTIMATION FOR CHAOTIC INITIAL CONDITION MODULATION SCHEME

*Dr. Hikmat Najem Abdullah[1], Ibrahim Fahmi Ali[2]

1) Prof., Information and Communication Engineering Department, Al-Nahrain University, Baghdad, Iraq.
2) M. Sc. Student, Electrical Engineering Department, Al-Mustansiryah University, Baghdad, Iraq.

(Received:15/06/2015 ; Accepted:23/09/2015)

Abstract: In this paper, an efficient technique for initial condition estimation of chaotic map in binary phase shift keying initial condition modulation (BPSK-ICM) scheme is proposed. This technique is named maximum autocorrelation estimation (MACE). The proposed scheme reduces the complexity of the chaotic demodulator thereby minimizing the hardware implementation cost. Simulation results confirm that the proposed technique outperforms the conventional technique used in direct sequence spread spectrum (DS-SS) system. In AWGN channel and at bit error rate (BER) of 10^{-3}, the results showed that the proposed BPSK-ICM scheme achieves a gain in E_b/N_0 of 1.5 dB over DS-SS system with the same value of the processing gain for both systems.

Keywords:*chaotic communication, parameter modulation, BPSK Modulation, maximum autocorrelation estimation*

كشف تضمين الشرط الابتدائي الفوضوي باستخدام طريقة معدلة لتخمين القيمة القصوى للارتباط الذاتي

الخلاصة: في هذا البحث تم اقتراح طريقة كفوءة لتخمين للقيم الابتدائية للسلسلة الفوضوية في منظومة تضمين القيم الابتدائية ذات تزحيف القدح الثنائي للطور(BPSK-ICM). ولقد تم تسمية هذه الطريقة بطريقة تخمين الارتباط الأكبر (MACE) . إن الطريقة المقترحة تقلل من تعقيدية حلال التضمين الفوضوي في المستلم وبالتالي تقليل كلفة البناء المادي للمنظومة. ولقد أكدت نتائج المحاكاة ان الطريقة المقترحة تتفوق في أدائها على منظومة الطيف المنتشر بالسلسلة المباشرة التقليدية (DS-SS) ، حيث حققت الطريقة المقترحة ربحا مقداره 1.5 ديسبل بنسبة قدرة الإشارة الى قدرة الضوضاء مقارنة بنظام (DS-SS) التقليدي عندما كان معدل الخطأ لبتات الارسال 10^{-3} في قناة كاوس الضوضائية وباستخدام قيمة ربح العملية نفسه لكلا النظامين.

1. Introduction

Recently, chaotic signals are used in communication systems due to their unique characteristics such as wide bandwidth, low power spectral density and low cross-correlation values[1]. Different chaotic modulation systems have been proposed[2-8], these systems exploit different properties of a chaotic dynamical system to obtain the aim of spread spectrum (SS) transmission. One of the most important chaotic modulation systems is chaotic parameter modulation (CPM). In CPM schemes, the information signal is modulated by merging it into the chaotic map parameters to

**Corresponding Author* hikmat_04@yahoo.com

achieve the aim of SS transmission for both analog and digital communication [9]. The chaotic signal parameters that are usually need to be estimated are the bifurcation factor and the initial condition. CPM schemes offer several benefits in comparison with traditional SS systems based on spreading codes, these are: CPM systems does not require synchronization process for data demodulation and has potential of higher system capacity compared to the traditional SS techniques. However, in general CPM systems, the problem is how to make accurate parameter estimation at the receiver thereby retrieving the transmitted information signal in an optimal manner. Therefore, CPM schemes need a demodulator which has an ability to estimate and track the parameters of a chaotic map. Many estimators include various adaptive filtering algorithms such as least mean square (LMS), recursive least square (RLS) and extended Kalman filter (EKF) are found not working efficiently in high noise level situation thereby cannot guarantee to build a reliable and practical communication system[10]. Hence, a new chaotic estimation technique is necessary to be developed.

2. Binary Phase Shift Keying Chaotic Initial Condition Modulation (BPSK-ICM) Scheme

In this section, a spread spectrum (SS) chaotic modulation scheme named BPSK-ICM is proposed for data demodulation. This scheme is a special case of the our proposed scheme in[11]where instead of using quadrature amplitude modulation (QAM) in M-ary ICM system, BPSK modulation as signal constellation is applied to reduce system complexity. The constellation diagram of BPSK modulation is illustrated in Fig.1.

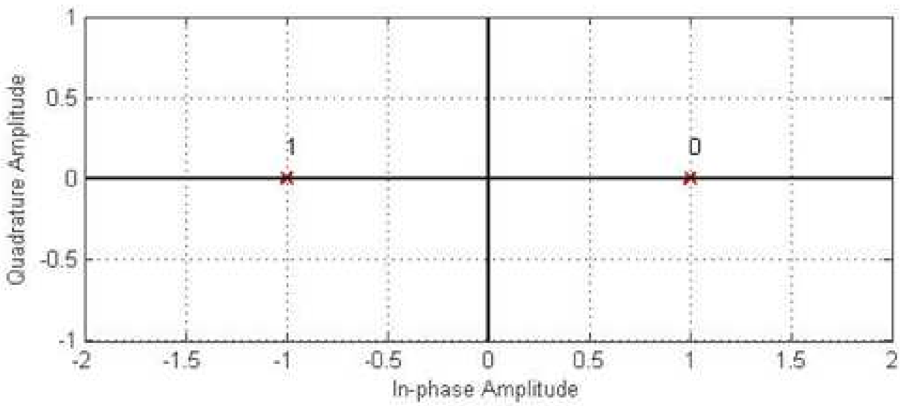

Figure 1.Constellation mapping for BPSK modulation

2.1. *Design of BPSK-ICM Transmitter*

Fig.2 shows the block diagram of BPSK-ICM scheme. At the transmitter side, a binary information signal is first constellation mapped using BPSK modulation. Hence, the resulted information is mapped to "+1" and "-1" symbols. In M-ary ICM scheme, the two output vectors produced from the in phase and quadrature channels are used as initial conditions to the two chaotic generators. In fact, the output obtained from the constellation mapping of BPSK modulation consists of the real part only. Hence, only one chaos generator is used. Therefore, the main advantage of this technique is its simplicity. After the chaotic sequence is multiplied by a weight w to increase the system security, this chaotic sequence is sent to the radio frequency (RF) modulator for wireless transmission.

2.2. *Design of BPSK-ICM Receiver*

At the receiver side, the received sequence r(n), n=1,....,N, is observed after RF demodulator, where η(n) is the additive channel noise component. As the estimation problem is not required to estimate large number of possible states, but only two values as "+1" and "-1". Therefore, maximum autocorrelation estimation (MACE) technique is applied to obtain the estimated vectors that have maximum autocorrelation value with the received noisy signal. After the estimated vectors are found, the initial condition can be retrieved accurately; thereby, determining the original information. In this simulation, cubic chaotic map as chaotic sequence generator is used. The processing gain of this scheme is 32 chaotic samples.

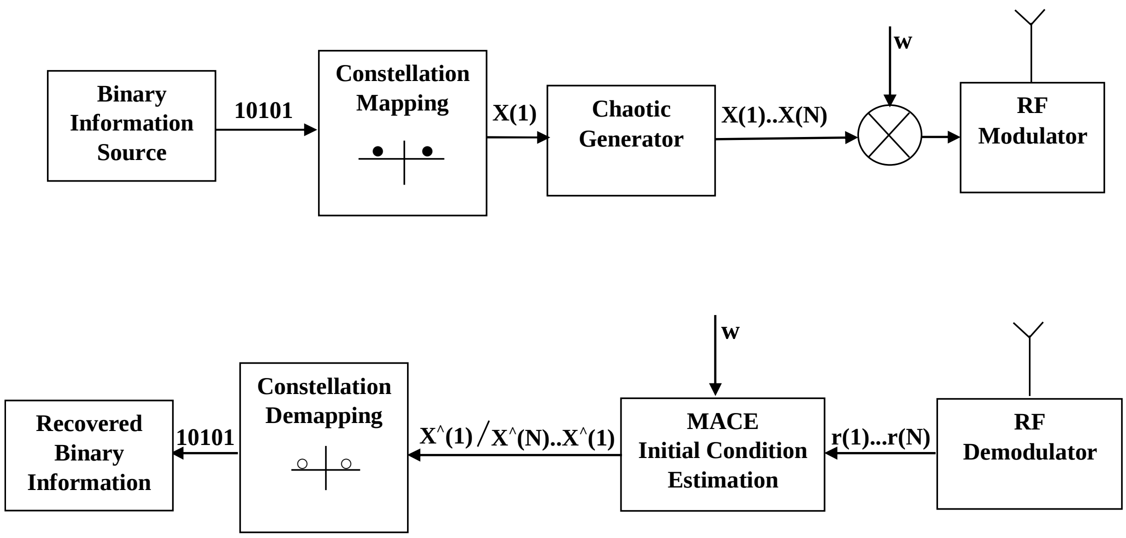

Figure 2. Block diagram of BPSK-ICM scheme

3. Simulation Results of BPSK-ICM in AWGN Channel

In this section, the BER performance of the BPSK-ICM system in AWGN channel is evaluated. The same cubic chaotic map is used to generate the chaotic sequence. Fig.3 shows the simulation results of BPSK-ICM in comparison with conventional DS-SS BPSK system in AWGN channel. DS-SS BPSK system uses imperfect channel estimation with ML estimation technique, while BPSK-ICM uses MACE technique for data demodulation. From the simulation results shown in Fig.3, it is clear that at BER = 10^{-3}, the E_b/N_0 level of BPSK-ICM system is about 9.5 dB. BPSK-ICM achieves a gain in E_b/N_0 of about 1.5 dB, as compared with conventional DS-SS system. But the performance of DS-SS BPSK system is better when using perfect channel estimation as shown in Fig.4. The main advantage of the BPSK-ICM scheme is the elimination of the synchronization process; hence, its demodulator is very simple.

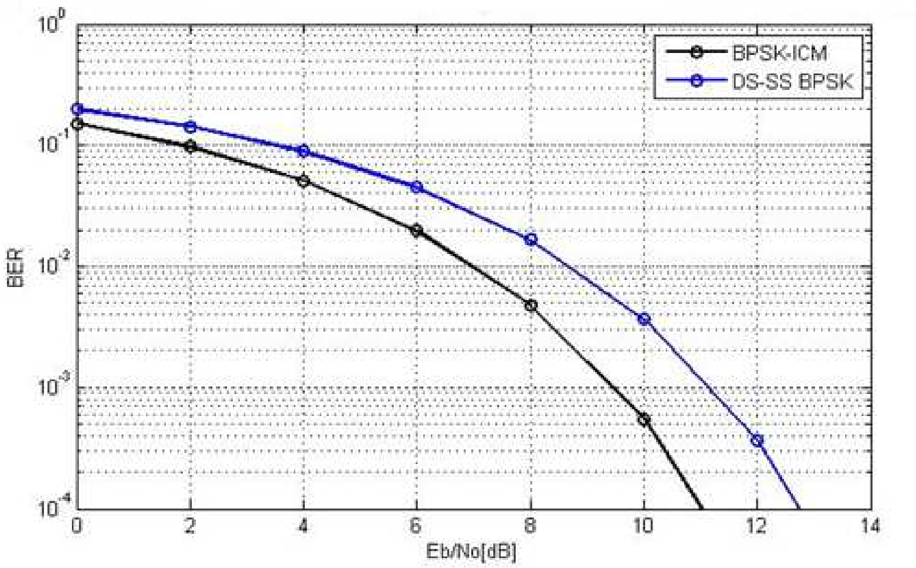

Figure 3. BER performance comparison of conventional DS-SS BPSK and BPSK-ICM systems in AWGN channel (using MACE estimation).

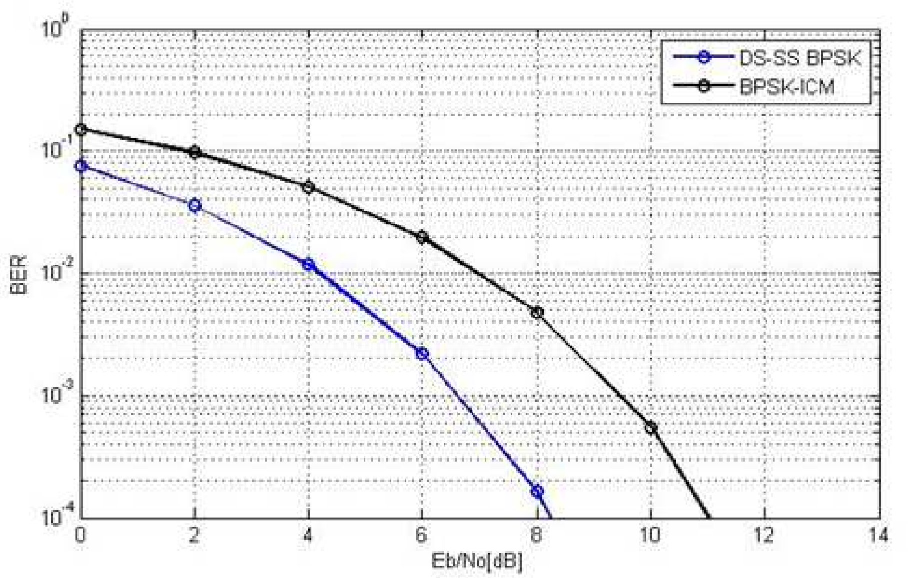

Figure 4. BER performance comparison of conventional DS-SS BPSK and BPSK-ICM systems in AWGN channel (using perfect channel estimation).

From the simulation results shown in Fig.4, it is clear that, at BER $=10^{-3}$, the E_b/N_0 level of DS-SS BPSK system is about 6.7 dB. DS-SS BPSK system achieves a gain in E_b/N_0 of about 2.8 dB, as compared with BPSK-ICM system. Hence, BER performance of DS-SS BPSK system is better than BPSK-ICM system only when using perfect channel estimation.

4. Conclusions

In this paper, a new binary phase shift keying initial condition modulation (BPSK-ICM) scheme is proposed for data demodulation. The main advantage of BPSK-ICM scheme is that it involves a simple parameter estimation algorithm without need for synchronization process, which reduces the complexity of the demodulator. Simulation results show that, BPSK-ICM outperforms the conventional DS-SS BPSK system when channel estimation error is negligible due to the superior cross-correlation properties of chaotic sequences. However, in the presence of perfect channel estimation, the performance DS-SS BPSK becomes relatively better than the proposed due the digital nature of the PN sequence used in DS-SS BPSK. This is due to Therefore, BPSK-ICM scheme is a good substitution to the conventional DS-SS system in AWGN channel.

References

1. Eisencraft,M. and Kato, D. (2009).*Spectral properties of chaotic signals with applications in communications.* Elsevier journal of Nonlinear Analysis: Theory, Methods & Applications, Vol.71, No.12, pp.2592-2599.
2. Yu, H. and Leung, H. (2001).*"A comparative study of different chaos basedspread spectrum communication systems"*. Proceedings of IEEE International Symposium on Circuits and Systems ISCAS, Sydney, Vol.3, pp. 213-216.
3. Xiang, Y., Tse, C. and Lau, F.(2005). *Performance of Frequency-modulated Differential-Chaos-Shift-Keying Communication System over Multipath Fading Channels with Delay Spread*. International Journal of Bifurcation and Chaos, Vol.15, No.12, pp.212-2-19.
4. Tian, Z. (2010). *"Power Spectrum Mask in Chaotic Secure Communication"*.Proceedings of International Conference on Computer Application and System Modeling ICCASM, Taiyuan, Vol.6, pp.418-421.
5. Majumdar, D., Moritz, R, Leung, H. and Maundy, B. (2010).*"An Enhanced Data Rate Chaos-based Multilevel Transceiver Design Exploiting Ergodicity "*. IEEE Military Communication Conference-MILCOM, San Jose, Vol.1, pp.1256 - 1261.
6. Quyen, N.,Yem, V. and Hoang, T. (2013). *"A Chaos-Based Secure Direct-Sequence/Spread-Spectrum Communication System"*.Hindawi Publishing Corporation: Abstract and Applied Analysis, Vol.2013, pp. 97-107.
7. Marino, I., Ullner, E and Zaikin, A. (2013). *"Parameter Estimation Methods for Chaotic Intercellular Networks"*, Scribendi Academic Editing PLOS ONE, Vol.8, No.11.
8. He, J. andCai, J. (2014). *Parameter modulation for secure communication via the synchronization of Chen hyperchaotic systems.* Journal of Systems Science & Control Engineering, Vol.2, No.1, pp.712-726.

9. Xu, M. and Leung, H. (2010).*A Novel High Data Rate Modulation Scheme Based on Chaotic Signal Separation*. IEEE Transactions on communications, Vol. 58, No.10, pp.2855-2860.
10. Leung, H. and Lam, J. (1997). *Design of demodulator for the chaotic modulation communication system*.IEEE Transactions on Circuits and SystemsI: Fundamental Theory and Applications, Vo1.44, No.3, pp.262-267.
11. Abdullah, H. N. and Ali, I. F. (2015). *Initial Condition Chaotic Modulation Scheme using Maximum Auto Correlation Estimation.* International Journal of Engineering Research and Industrial Applications, Vol.8, No.2, pp. 13-29.