2004 RISP International Workshop on Nonlinear
Circuit and Signal Processing (NCSP'04)
Hawaii, USA, Mar. 5-7, 2004.

Research on Noncoherent Detection for Chaos Shift Keying

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1. Introduction

An optimal noncoherent detection technique for Chaos Shift Keying (CSK) digital communication system is important for chaos-based communication [1]-[3]. However, calculation in the optimal noncoherent detection becomes complicated when chaotic sequence length becomes large. Therefore, computing cost in the optimal noncoherent detection becomes too large. Also, whether the optimal noncoherent detection would also suffer from a decrease in performance for long chaotic sequence length is uncertain.

In this study, to improve the computing cost as keeping a good bit error rate, we propose a very simple detection method for CSK which can decode even if chaotic sequence length becomes long. As varying the length of the chaotic sequence and E_b/N_0 of the channel, the bit error rate is evaluated by computer simulations.

2. System Model

We consider a discrete-time binary CSK communication system, as shown in Figure 1.

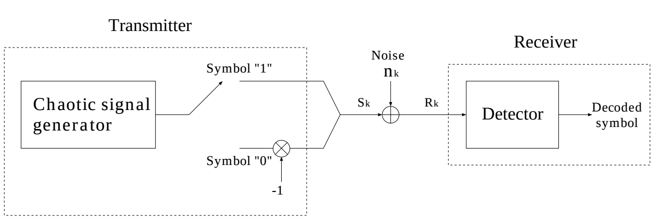


Figure 1: Block diagram of a discrete-time binary CSK communication system

2.1. Transmitter

In the transmitter, a chaotic sequence is generated by a chaotic map. In this study, signals are generated from the following skew tent map.

$$x_{n+1} = \begin{cases} \dfrac{2x_n + 1 - a}{1 + a} & (-1 \leq x_n \leq a) \\ \dfrac{-2x_n + 1 + a}{1 - a} & (a < x_n \leq 1) \end{cases} \quad (1)$$

This is expressed in Fig. 2. If the imformation symbol

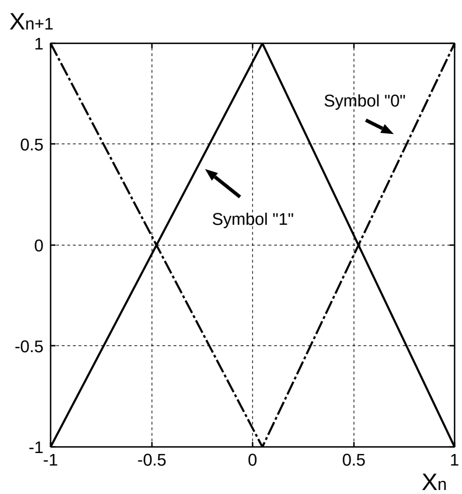


Figure 2: Skew Tent Map

"1" is sent, Formula (1) is used, and if "0" is sent, the reversed function of Formula (1) is used. In order to transmit a 1-bit signal, N chaotic signals are generated, where N is chaotic sequence length. Therefore the transmitted signal is denoted by vector $\mathbf{S} = (S_1\ S_2\ \cdots\ S_N)$.

2.2. Channel and Noise

In the channel, noise is assumed additive white Gaussian noise (AWGN) and is denoted by the noise vector by $\mathbf{n} = (n_1\ n_2\ \cdots\ n_N)$. Thus, the received signal block is given by $\mathbf{R} = (R_1\ R_2\ \cdots\ R_N) = \mathbf{S} + \mathbf{n}$.

2.3. Receiver

Detection method executes the following steps, as shown in Fig. 3.

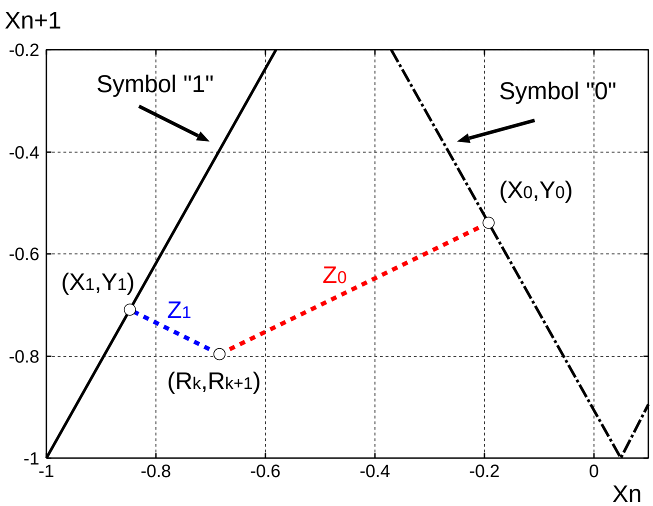


Figure 3: Detection method

1. The received signals R_k and R_{k+1} give a point on the skew tent map, as $(X_n, X_{n+1}) = (R_k, R_{k+1})$.

2. From the point, we find a point to possess the shortest distance with two functions of Formula 1 and the reversed function of it, as $(X_n, X_{n+1}) = (X_i, Y_i)$. The point is obtained as Formula (2),

$$\begin{cases} X_i = \dfrac{A}{A^2+1}\left(\dfrac{R_t}{A} + R_{t+1} - B\right) \\ Y_i = \dfrac{A^2}{A^2+1}\left(\dfrac{R_t}{A} + R_{t+1} - B\right) + B \end{cases} \quad (i = 0, 1) \tag{2}$$

where A is the gradient of the two functions, B is the intercept.

3. The shortest distance Z_i is obtained than Formula (3).

$$Z_i = \left| \sqrt{(X_i - R_t)^2 + (Y_i - R_{t+1})^2} \right| \quad (i = 0, 1) \ . \tag{3}$$

The decoded symbol is decided as "1" or "0" depending on Z_1 being smaller or larger than Z_0.

3. Simulation result

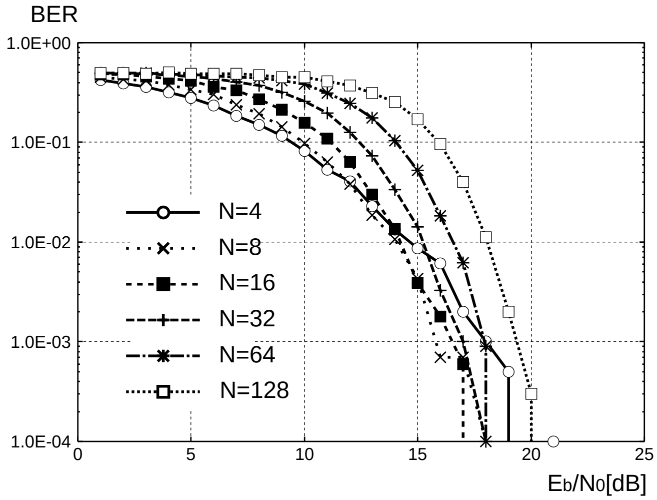
We have developed computer programs to compute (2) and (3). Chaotic sequence length N ranging from 4 to 128 are used. In simulation, 10^4 symbols are transmitted and the bit error rate (BER) is recorded for various E_b/N_0 values, where E_b denotes the average energy per bit. The simulation time (cpu-time) is also noted in each case. In addition, the optimal detection simulates with the same condition, too

3.1. Chaotic sequence length constant and $\mathbf{E_b/N_0}$ change

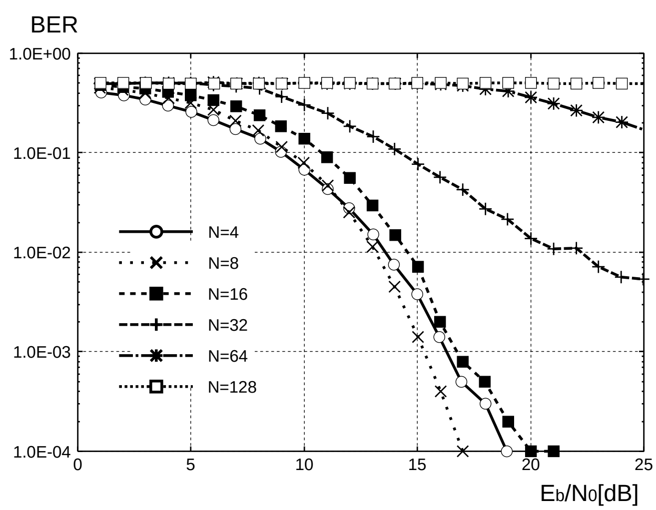
Figures. 4(a) and 4(b) plots the BERs versus E_b/N_0 for different chaotic sequence length N. Both the detection method, when E_b/N_0 value is small, the BER performance degrades. However, when E_b/N_0 value is large, it can be observed that the BER performance of proposed method improves than the optimal detection.

3.2. Chaotic sequence length change and $\mathbf{E_b/N_0}$ constant

Figures. 5(a) and 5(b) plot the BERs versus chaotic sequence length N for different E_b/N_0 values. When chaotic sequence N of optimal detection becomes long, the BER performance degrades, as shown in Fig 5(b). even if chaotic sequence N of proposed method, as shown in Fig 5(a). However, even if N becomes long, proposed method doesn't degrade than optimal detection, as shown in Fig. 5(a). It can be said from a Fig. 5(a) that the BER of the proposed method becomes very small when $N = 8 \sim 16$.

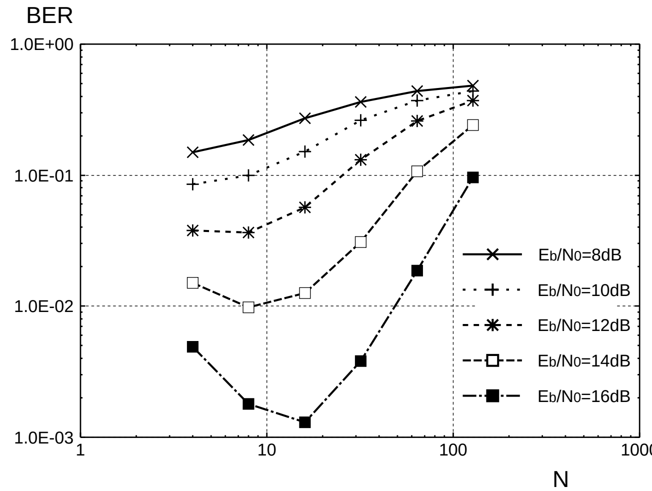


(a) Proposed method

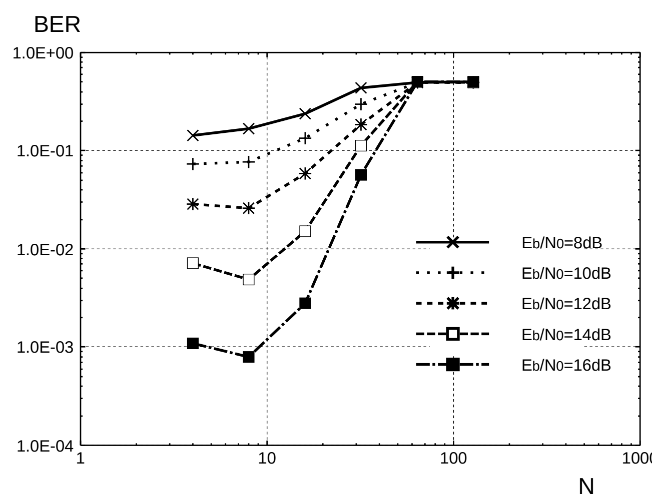


(b) The optimal detection

Figure 4: BERs versus E_b/N_0 for chaotic sequence length N 4 to 128 for a CSK system



(a) Proposed method



(b) The optimal detection

Figure 5: BERs versus chaotic sequence N for defferent E_b/N_0 values for a CSK system

3.3. Simulation time

In Table 1, the simulation time is tabulated against the chaotic sequence N. In both method, simulation time also becomes long as N becomes long. When we compare the same N, it turns out that simulation time of the proposed method is far quick. Therefore, in simulation time, the proposed method could be said as excellent.

Table 1: Simulation time

N	Proposed method [sec]	Optimal Detector [sec]
4	0.07	44.57
8	0.17	79.12
16	0.35	149.39
32	0.72	289.66
64	1.45	573.07
128	2.92	1130.78

4. Conclusions

In this study, to improve the computing cost as keeping a good bit error rate, we proposed a very simple detection method for CSK which can decode even if chaotic sequence length becomes long. As a result, we obtained a good result to even a simple method.

Acknowledgement

This work was partly supported by The Telecommunications Advancement Foundation's Resarch Grant.

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[3] F. C. M. Lau and C. K. Tse, "Approximate-Optimal Detector For Chaos Communication Systems," Int. journal of Bifurcation and Chaos, Vol. 13, No. 5 pp. 1329-1335, 2003.