2007 RISP International Workshop on Nonlinear Circuits and Signal Processing (NCSP'07)
Shanghai Jiao Tong University, Shanghai, China, Mar. 3-6, 2007

Research on Differential Chaos Shift Keying Changing Deviation of Chaotic Sequence

Shintaro ARAI and Yoshifumi NISHIO

Department of Electrical and Electronics Engineering
Tokushima University
2-1 Minami-Josanjima, Tokushima 770-8506, Japan
Phone:+81-88-656-7470, Fax:+81-88-656-7471
Email: {arai, nishio}@ee.tokushima-u.ac.jp

Abstract

This paper investigates a performance of Differential Chaos Shift Keying (DCSK) using the chaotic sequence with biased values. In other words, a transmitted signal is changed by the deviation of the output of chaos depending on transforming a chaotic map. We carry out computer simulations and compare its performance to the conventional DCSK system.

1. Introduction

Recently, a noncoherent receiver for digital communication systems using chaos is studied actively[1]-[7]. Especially, it is attracted to develop noncoherent detection systems which does not need to recover a basis signals (unmodulated carries) at the receiver. The differential chaos shift keying (DCSK) [1] and the optimal receiver [2] are well known as a typical noncoherent system.

In our previous research, we proposed a transmitter changing a chaotic sequence depending on an initial value for a suboptimal receiver [6], where the suboptimal receiver has a performance similar to the optimal receiver, and this algorithm is simpler than the optimal receiver. As a simulation result, it could be observed that its performance was better than that of the conventional transmitter for the suboptimal receiver. From this result which changes the performance depending on the initial value, we expected that the values included in the chaotic sequence influenced the noncoherent chaos communication performance greatly.

In this study, we investigate a performance of the chaotic sequence with biased values using DCSK as the noncoherent chaos communication. In other words, a transmitted signal is changed by the deviation of the output of chaos depending on transforming a chaotic map. We carry out computer simulations and compare its performance to the conventional DCSK system.

2. Differential Chaos Shift Keying (DCSK)

Figure 1 shows the block diagram of the DCSK transmitter (a) and receiver (b). This system is well-known as the typical correlation-based noncoherent chaos communication. The modulation scheme and the detection method are described below.

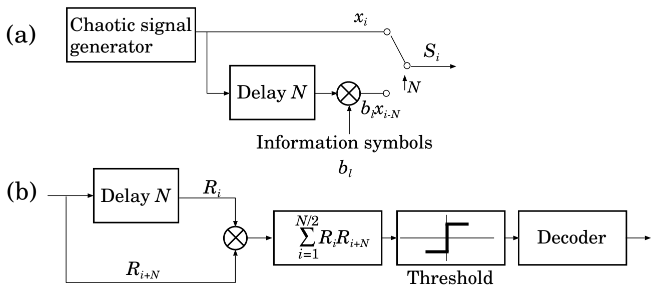


Figure 1: DCSK operation. (a) transmitter. (b) receiver.

In this scheme, the transmitter outputs a chaotic sequence x_i followed by the same sequence multiplied by the information symbol $b_l(\pm 1)$. In order to transmit 1-bit information, N chaotic signals are generated, where N is the chaotic sequence length. Therefore, the transmitted signal is given by

$$S_i = \begin{cases} x_i & (1 \le i \le N) \\ b_l x_{i-N} & (N+1 \le i \le 2N) \end{cases} \quad (1)$$

Also, the transmitted signal can be written as $\mathbf{S} = (S_1\ S_2\ \cdots\ S_{2N})$ by vector.

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

On the receiving side, it is evaluated by the correlation of 2 signals which are divided from the received signals into the half (N). Thus, the output of the correlation can be written as

$$C_1 = \sum_{i=1}^{N} R_i R_{N+i} \tag{2}$$

The decoded symbol is decided as "+1" or "−1" depending on C_1 being larger or smaller than 0.

In order to generate the transmitted signal, the DCSK transmitter needs to switch correctly by the chaotic sequence length N. Therefore, the sophisticated switch is required, and it is regarded as the important issue to design DCSK.

3. Chaotic Map With Different Slopes

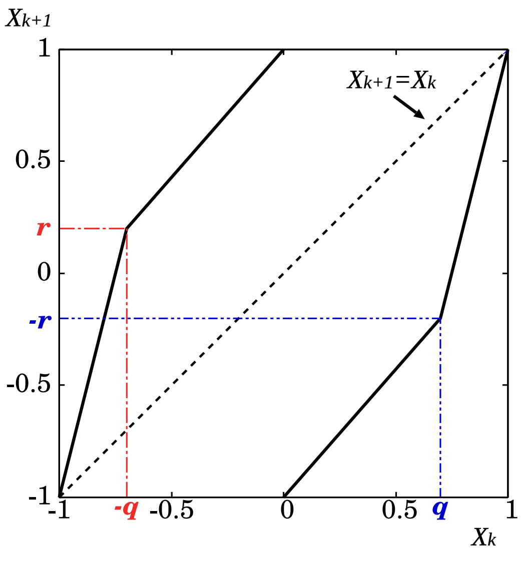
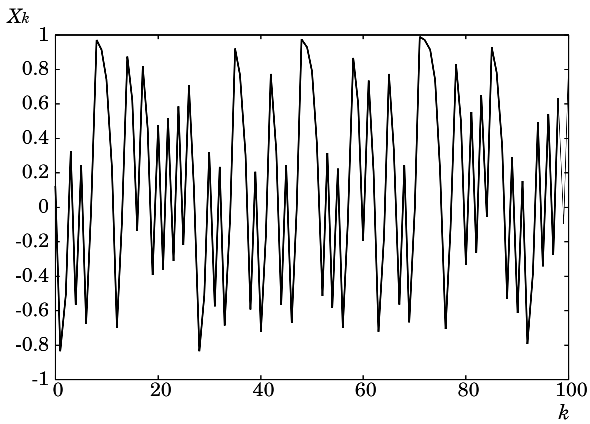


Figure 2: Chaotic map with different slopes.

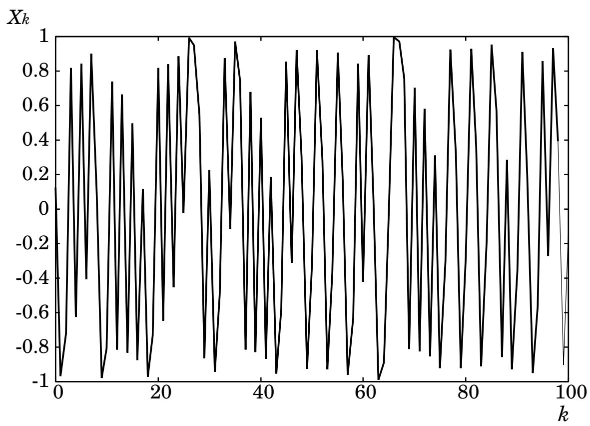
In order to generate the chaotic sequence with biased values, we use the chaotic map shown in Fig. 2. This map was made from the Bernoulli shift map well known as a typical 1-dimensional map based on the reference [7] and is described by Eq. (3). As one can see, the slopes of the map can be changed by deciding parameters q $(0.5 \leq q \leq 1.0)$ and r $(0.0 \leq r \leq 1.0)$.

$$x_{k+1} = \begin{cases} \dfrac{(1+r)x_k + q + r}{1-q} & (-1 \leq x_k \leq -q) \\ \dfrac{(1-r)x_k + q}{q} & (-q < x_k \leq 0) \\ \dfrac{(1-r)x_k - q}{q} & (0 < x_k \leq q) \\ \dfrac{(1+r)x_k - q - r}{1-q} & (q < x_k \leq 1) \end{cases} \tag{3}$$

As an example, chaotic sequences are shown Figs. 3(a) and (b) in the case of $(q, r) = (0.6, 0.2)$ and $(0.8, 0.8)$. From these figures, It can be observed that the chaotic sequence includes many values near 1.0 (or -1.0) as both q and r approach 1.0, namely, it can be said that deviation was made to the values of the chaotic sequence. In addition,



(a) $(q, r) = (0.6, 0.2)$.



(b) $(q, r) = (0.8, 0.8)$.

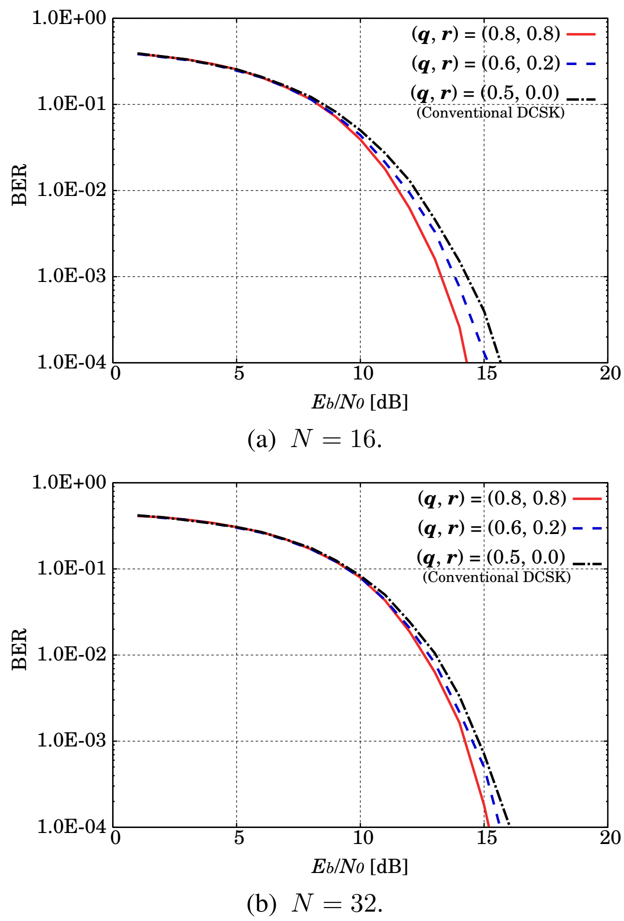
Figure 3: Chaotic sequences for each parameter.

when $(q, r) = (0.5, 0.0)$, the corresponding map becomes the Bernoulli shift map. In this study, the parameters q and r of this map is changed and the performance of DCSK system is investigated.

4. Simulation Result

In this section, we study the performance of the DCSK communication system using the chaotic map with the different slopes by computer simulation. The simulation conditions are as follows.

On the transmitting side, the chaotic sequence length N are 16 and 32. In addition, the parameters q and r deciding the slope of map is used the case of $(q, r) = (0.6, 0.2)$ and $(0.8, 0.8)$. The noise is assumed to be only AWGN in the channel. Hence, the noises at the transmitter and receiver are not considered. On the basis of these conditions, the system performance is evaluated by plotting BER against E_b/N_0 when 10^4 bits of information are transmitted. Also we estimate the chaotic sequence of each parameter by calculating the autocorrelation and the cross-correlation property.

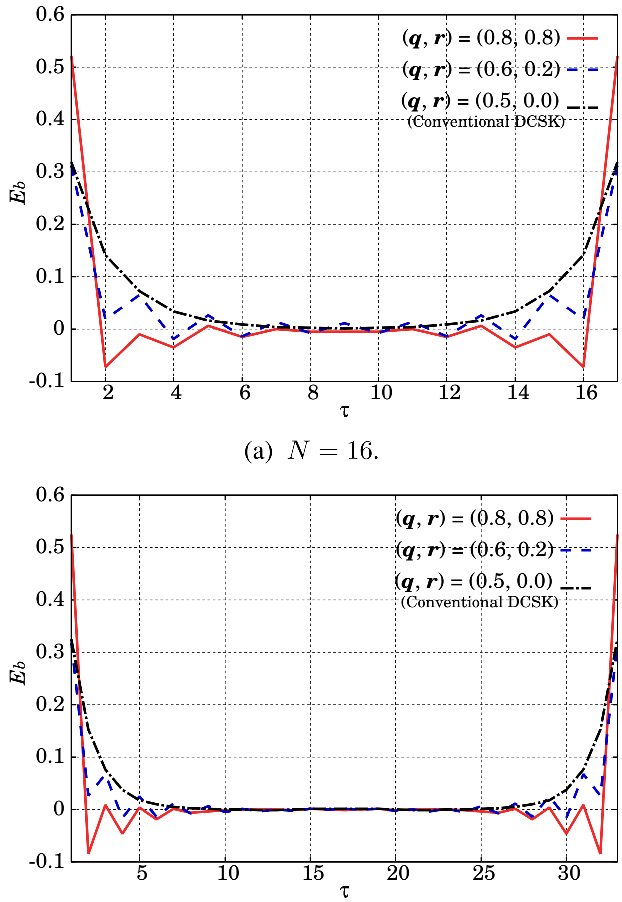


(a) $N = 16$.

(b) $N = 32$.

Figure 4: Bit Error Rate (BER).

Figure 4 plots the BERs versus E_b/N_0 for each parameter. In order to compare the performance of the chaotic sequence with biased values, Fig. 4 shows the performance of the conventional DCSK (i.e. $(q, r) = (0.5, 0.0)$) together. As one can see, we find that the BER performance improves as both q and r approach 1.0. That both parameters approach 1.0 means using the chaotic sequence including many values near 1.0 (or -1.0), as shown in Fig. 3. From this result, we consider that it is because the chaotic sequence became strong to interference of the noise by including many values near 1.0 (or -1.0).

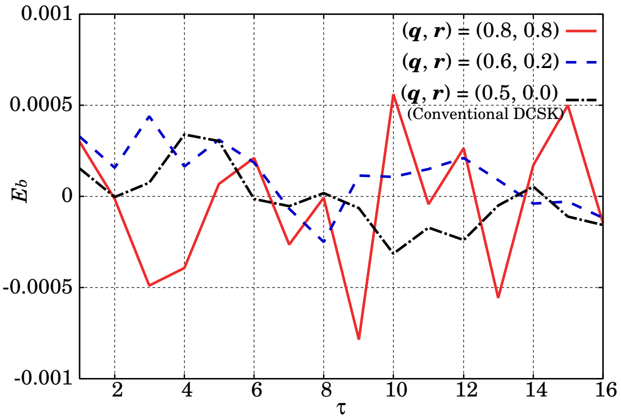


(a) $N = 16$.

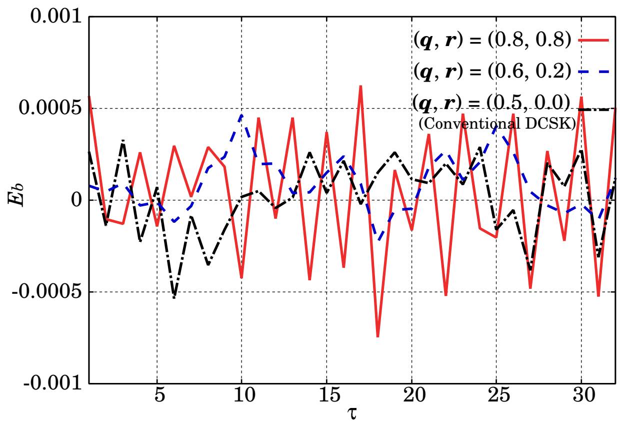
(b) $N = 32$.

Figure 5: Autocorrelation property.

Next, let us observe the property of the chaotic sequence having the deviation of values. Figures 5 and 6 show the autocorrelation and the cross-correlation property, respectively. As one can see the autocorrelation property, it can be said that the property improve as both q and r approach 1.0. Namely, we can confirm the reason that the BER has been improved as shown in Fig. 4. However, the cross-correlation property got worse to the contrary. It is because many similar values included in the chaotic sequence by having many values near 1.0. In other words, in the case where both parameters q and r are very close to 1.0, its sequence will become unsuitable for multiplexing. Hence, it is an important future problem to generate the chaotic sequence suitable for communication which considered the balance of the parameters q and r.



(a) $N = 16$.



(b) $N = 32$.

Figure 6: Cross-correlation property.

5. Conclusions

In this paper, we investigated the performance of the chaotic sequence with biased values using DCSK. As a results, we found that the chaotic sequence suitable for communication can be generated by conditioning the deviation of the values. Based on this result, investigating further the chaotic map used by this study is our future work.

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