Performance of CSK Modulation with Various Lengths

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***Abstract*—This paper briefly introduces the transmitter of the GNSS signal to which CSK modulation is applied, and summarizes the CSK hard/soft decision demodulation method in the corresponding receiver. Based on the summarized method, we show the hard/soft decision demodulation performance and various analyzes in an environment similar to the existing GNSS signal.**

***Index Terms*—DSSS, PRN code, GNSS, CSK, Modulation**

I. Introduction

Recently, as the use of the global navigation satellite system(GNSS) increases, various services other than simple positioning services are appearing in the civilian and military fields. Therefore, the demand for data transmission is also increasing, which is the same as the demand for increasing the data rate of the navigation satellite [1], [2].

Since the satellite navigation system uses the direct-sequence spread spectrum(DSSS) method, a code-shift keying(CSK) modulation method has been proposed to increase the data rate in a limited band. The DSSS method of the existing GNSS transmits the pseudo-random noise(PRN) code in correspondence with each bit of a navigation message, but in the case of CSK modulation, the PRN code is cyclically shifted by the decimal value of several bits of a navigation message. Therefore, it is possible to increase the data rate in a limited band while maintaining the orthogonality of the PRN code [3].

In this paper, we briefly introduce the CSK modulation method used in GNSS signals, the corresponding transmitter/receiver, and the method of calculating hard/soft decision values. It concludes by showing the experimental results and analysis.

II. A CSK Modulation Applied GNSS Signal

Figure 1 shows the transmitter of the GNSS signal applied with the CSK modulation. A navigation messages pass through a channel encoder to generate a codeword, and the generated codeword is converted into a one symbol by m bits, and a PRN code having a length L is cyclically shifted by the decimal value $0 \leq i \leq M(= 2^m - 1)$ of the symbol and transmitted. At this time, $c_{csk,i}$ is a PRN code cyclically shifted by i. In the case of Japan's QZSS LEX signal, which is the first satellite signal to which CSK modulation has been applied, Reed-Solomon(RS) codes over $GF(2^8)$ are used as the channel codes, and Kasami code with a length of 10230 is used as the PRN code, and the symbol value of the RS code is used as a cyclic shift value [4]. Therefore, in this case, $m = 8$, $M = 255$, and $L = 10230$.

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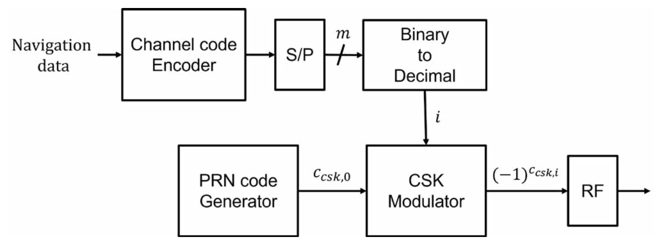
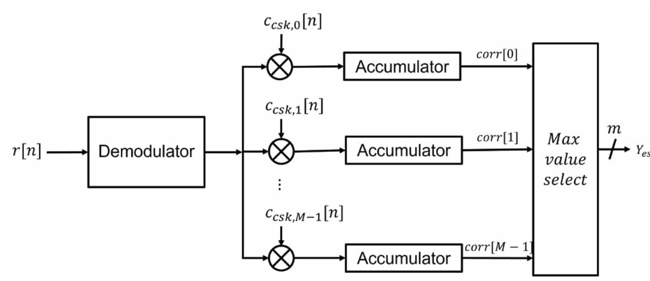
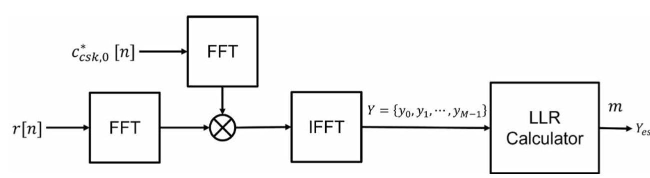


Fig. 1. A transmitter of GNSS signal with CSK modulation applied



(a) Hard decision demodulator



(b) Soft decision demodulator

Fig. 2. A demodulator of GNSS signal with CSK modulation applied

Figure 2 shows the demodulator of the GNSS signal receiver to which CSK modulation is applied. In [5], the CSK modulation hard decision demodulator is shown as (a), and in [6], [7], the CSK modulation soft decision demodulator is shown as (b). Depending on the channel decoder of the receiver, it receives the output value of the hard/soft decision demodulator as an input and performs a channel decoding.

III. Simulation Result and Conclusion

Figure 3 and 4 shows the performance according to the demodulation method shown in this article. In figure 3, the truncated Kasami code of length 10230 was used as the PRN code, and the performance was shown according to the length of $m = 7, 8$, and 9. According to [8], it was confirmed that the longer the length of m, the better the performance.

Figure 4 shows the results according to the PRN code length at the same number of CSK symbols or cyclic shift, i.e., $L = M$. Since the length of the Kasami code is $2^m - 1$ with even number m, similar to the de Bruijn sequence, we experimented with padding $'0'$ to make the length 2^m. Similar to Figure 3, the longer m shows the better performance. Comparing with $m = 8$ in Figure 3 and 4, in the case of $M = L$, about 0.2 dB is better at BER 10^{-3}. It is assumed that this is the energy difference per chip according to the PRN code length.

In the future, it is necessary to compare C/N_0, which is the FoM from the viewpoint of the receiver. In addition, we want to analyze the performance combined with channel coding. Algebraic codes can be decoded through a hard decision decoder [9], and probability-based codes (e.g., LDPC, Polar) can be decoded through a soft decision decoder [10]–[13].

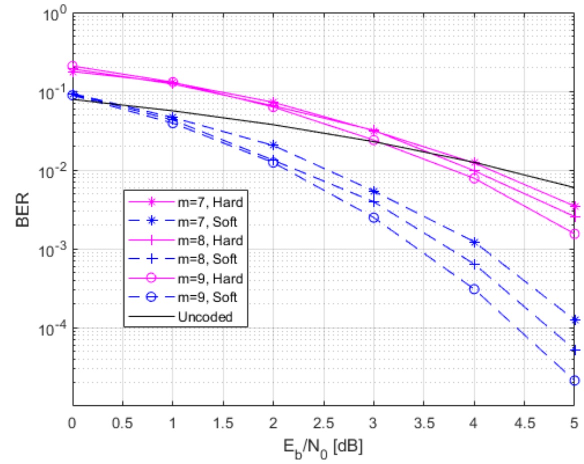


Fig. 3. The CSK modulation performance $(m = 7, 8, 9, L = 10230)$

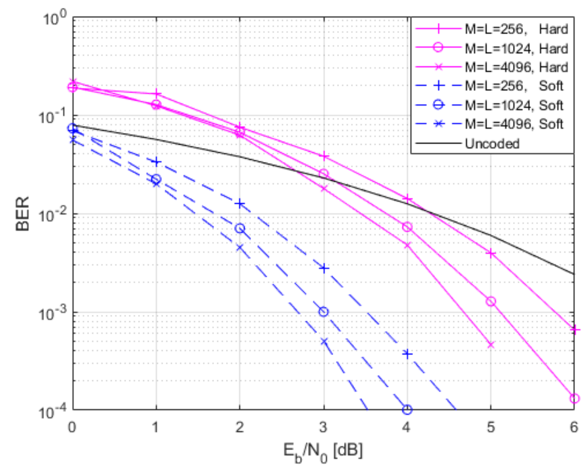


Fig. 4. The CSK modulation performance $(L = M = 2^m, m = 8, 10, 12)$

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