ON THE RECORDING CODE WHICH IMPROVES THE GROOVE PARAMETER

K. TANAKA, H. MIZUNO and T. TAKADA

Teikyo University of Technology, Japan

Abstract - In order to increase the recording capacity the mark edge recording and (1,7)RLL code are employed in the second generation ISO/IEC optical disk standard. However this recording method degrades groove parameter at ROM area because (1,7)RLL code has long T_{max} which causes recording pattern of combination of long pits and short spaces. New (2,5)RLL code whose T_{max} is small were developed. Because T_{max}/T_{min} gets close to unity, the information capacity of the code is small so that detection window width becomes narrow. Because narrow band signal to noise ratio is large and jitter is small in ROM area, the window margin of (2,5)RLL code written in ROM area is same as that of (1,7)RLL code written in MO area when both codes are recorded in the same recording density. The window width of (2,5)RLL code is 0.4Tb and T_{min} is 1.2Tb where Tb is one bit length of information bit.
KEYWORDS: RECORDING CODE, OPTICAL DISK, OPTICAL ROM, PRE-PIT

INTRODUCTION

In order to increase the recording capacity the mark edge recording and (1,7)RLL code are employed in the second generation ISO/IEC optical disk standard.[1] However, this recording method degrades groove parameter at ROM area where data is written in pre-pit form. It imposes difficulty on the drive design. This paper describes new recording code which improves groove parameter at the ROM area.

IMPROVEMENT OF GROOVE PARAMETER

When the reflected beam from land area decreases due to the existence of the pits in ROM area, groove parameters such as cross track signal (CTS) and push-pull signal are degraded so that optical head seek control becomes difficult. This is severe in the combination of the mark edge recording and (1,7)RLL code. The worst case of it is the case where there is repetition of 7T,2T pattern and 7Ts correspond

to the pits and 2Ts do to the spaces. Where T represents one channel bit length. The repetition of 8T,2T dose not occur in present (1,7)RLL code fortunately. Fig. 1 shows relationship between groove parameters and pit density.

Fig.1: Relationship between groove parameters and pit density

The definition of pit density is the percentage of pit area in length on the land. Because the pit density of the worst case is 0.8, the worst case CTS dose not satisfy the criteria

specified by ISO/IEC. In order to solve this problem re-synch byte is used to control DSV(Digital Sum Variance) of channel bits so that long term average of the cross track signal barely meet the specification. However, there is still place where the CTS dose not meet the specification in short term average. It still gives burden to the seek control of drives.

One of the method to improve CTS is to employ mark position recording. However, employment of mark edge recording is preferable from the recording density point of view if it is possible. Most of the recording codes have been developed only to increase recording density. The code developed with giving consideration to both groove parameter and recording density can solve the problem.

When a code, whose T_{max} is short and T_{min} is long, is employed, the degradation of the groove parameter by the presence of pits can be eased. Because size of encoding and decoding circuitry of recording code are small compared with rest of whole circuit in optical disk drive, employment of recording code, different from that in MO area, in ROM area is acceptable.

THE RECORDING CODE

Coding/Decoding Circuit and Code Parameter

A couple of types of (2,5)RLL codes, whose combination of T_{max} and T_{min} is better than that of (1,7)RLL code, were developed and studied. Among them Fixed block type was selected. The conversion table is shown in Table 1. The code parameters are listed in Table 2. Where Cap. stands for Shannon capacity of

the code. (2,5)RLL code can be coded using sliding block

Table1 : Encoding algorithm of fixed block (2,5)RLL code

Input bits	Channel bits		
	* Preceding channel bits		
	00	10	01
0000	0100010000	←	0000100100
0001	0100001000	←	0001001001
0010	0100010001	←	0000010001
0011	1000100001	→	0000100001
0100	1000010000	→	0001000100
0101	1000001000	→	0001001000
0110	0100010010	←	0000010010
0111	0100100010	→	0001000001
1000	1000100100	→	0010000100
1001	1001001000	→	0010001000
1010	1000010001	→	0010010001
1011	1000100010	→	0000100010
1100	1001000100	→	0010010000
1101	0100001001	→	0010001001
1110	1000010010	→	0010010010
1111	1001000010	→	0001000010

Table2:Code Parameter of (2,5)RLL Code

Item	Value	Item	Value
m	2	T_{min}	1.2
n	5	T_{max}	2.4
d	2	DR	1.2
k	5	DSV	∞
$T\omega$	0.4	Cap.	0.465

method as shown in Fig. 2. Coding algorithms is shown in Annex 1. Decoding is the inverse process of encoding so that it can be done in similar way. Fig. 3 shows run length distribution when random data is encoded. When

Fig.2: Encoding circuit of (2,5)RLL code

Fig.3 : Run length distribution

occurrence probability of run length of 3,4 are large, the code has good recording and play back characteristics. Fig. 4 illustrates error propagation characteristics when one bit

Fig.4: Error propagation characteristics

shift takes place in play back signal. The maximum and average propagation are less than 6T and 1.2T respectively so that burden to the EDAC is small.

Groove Parameter

The worst case is repetition of 5T,3T pattern so that the pit density is 0.6. The groove parameter can be dramatically improved. Fig. 5 and 6 show computer simulated pattern of pit and space pattern of (1,7)RLL code and that of (2,5)RLL code. The black part corresponds to the pit. The picture shows pattern in the middle of the zone of Zone Constant Angular Velocity (ZCAV) so the edge of the zone is not shown. There is re-synch. byte which controls DSV in the middle of each tack. Therefore, left part of the picture is the worst combination while right half is the best combination. Small pits are homogeneously distributed on the track in (2,5)RLL. This is the cause of good groove signal.

Fig.5: The worst case pit pattern of (1,7)RLL code

Fig.6: The worst case pit pattern of (2,5)RLL code

Window Margin

As seen from Table 2 Tmin and Detection window width (Tw) of (2,5)RLL code are shorter than that of (1,7)RLL code. This comes from smallness of Shannon capacity of (2,5)RLL code.[2] When (2,5)RLL code is used in

pre-pit area the recording density shall not be smaller than that when (1,7)RLL code is recorded in MO area. The narrow band signal to noise ratio (NBSNR) of pre-pit signal is better than that of MO signal. This largeness of NBSNR saves the smallness of the capacity of (2,5)RLL code. The window margin of (2,5)RLL when it is recorded in pre-pit area and that of (1,7)RLL code recorded in MO area were compared. The standard deviation of jitter as a percentage of detection window width of both (2,5)RLL code and that of (1,7) are listed in Table 3. The jitter of (1,7)RLL was experimental value. The jitter caused by noise of (2,5)RLL code was calculated from NBSNR, and that caused by Inter-Symbol Interference (ISI) of (2,5)RLL pre-pit recording was obtained by computer simulation. The indicial response was calculated by program computing optical diffraction at pit area. The indicial responses were added according to the evaluation pit pattern. The pit pattern were 8*3T, 6T, 3T, 6T, 3T, 3T, 6T, 3T, 6T, 3T, where 8*3T means eight times repetition of 3T interval. The read out signal was processed by the direct slicing method, and the jitter was measured. [3] The optical condition for comparison were same for both code. That is wave length of the

laser beam was 780 nm, NA of the object lens was 0.55, and recorded in 1773 bit/mm.

Table3: Jitter of (2,5)RLL and (1,7)RLL code caused by noise and ISI

Code	Noise	ISI+Noise
(2,5)RLL	2.8%	5.9%
(1,7)RLL	4.9%	5.3%

CONCLUSION

In order to improve groove parameter at ROM area with mark edge recording, new (2,5)RLL code whose Tmax is small were developed. Improvement of groove parameter was achieved.

ACKNOWLEDGEMENT

The authors wish to express thank to MCC to supply data of CTS shown in Figure 1.

REFERENCE

- [1] ISO/IEC DIS-13842, 1994.
- [2] K. A. S. Immink "Coding Techniques for Digital Recorders," Prentice Hall, 1991.
- [3] T. Maeda et al. "Read Channel and Format for High Density Magneto-Optical Disk System, Th2.3 ISOM/ODS'93, PP. 59-60, 1993.2

Information data $D_1 \sim D_4$ is encoded into channel data $M_1 \sim M_{10}$

$$M_1 = \bar{Y}_1 \cdot \bar{Y}_2 \cdot (\bar{D}_1 \cdot \bar{D}_4 + \bar{D}_1 \cdot \bar{D}_2 \cdot \bar{D}_3 + \bar{D}_2 \cdot \bar{D}_3 \cdot \bar{D}_4 + \bar{D}_1 \cdot \bar{D}_2 + \bar{D}_1 \cdot \bar{D}_3)$$

$$M_2 = \bar{Y}_2 \cdot (\bar{Y}_1 \cdot \bar{D}_1 \cdot \bar{D}_2 \cdot \bar{D}_3 \cdot \bar{D}_4 + \bar{D}_1 \cdot \bar{D}_2 \cdot \bar{D}_4 + \bar{D}_1 \cdot \bar{D}_2 \cdot \bar{D}_3 + \bar{Y}_1 \cdot \bar{D}_1 \cdot \bar{D}_2 \cdot \bar{D}_3 + \bar{D}_1 \cdot \bar{D}_3 \cdot \bar{D}_4)$$

$$M_3 = \bar{D}_1 \cdot (\bar{Y}_1 \cdot \bar{Y}_2 \cdot \bar{D}_4 + \bar{Y}_1 \cdot \bar{Y}_2 \cdot \bar{D}_4 + \bar{Y}_1 \cdot \bar{Y}_2 \cdot \bar{D}_3 + \bar{Y}_1 \cdot \bar{Y}_2 \cdot \bar{D}_3)$$

$$M_4 = \bar{Y}_1 \cdot \bar{Y}_2 \cdot \bar{D}_1 \cdot \bar{D}_3 \cdot (\bar{D}_2 \cdot \bar{D}_4 + \bar{D}_2 \cdot \bar{D}_4) + \bar{Y}_1 \cdot \bar{Y}_2 \cdot \bar{D}_1 \cdot \bar{D}_2 \cdot (\bar{D}_3 + \bar{D}_4) + \bar{Y}_1 \cdot \bar{Y}_2 \cdot (\bar{D}_1 \cdot \bar{D}_2 \cdot \bar{D}_3 + \bar{D}_1 \cdot \bar{D}_3 \cdot \bar{D}_4 + \bar{D}_2 \cdot \bar{D}_3 \cdot \bar{D}_4) + (\bar{Y}_1 + \bar{Y}_2) \cdot \bar{D}_1 \cdot \bar{D}_2 \cdot \bar{D}_3 \cdot \bar{D}_4$$

$$M_5 = \bar{Y}_1 \cdot \bar{D}_2 \cdot \bar{D}_3 \cdot \bar{D}_4 \cdot (\bar{Y}_2 \cdot \bar{D}_1 + \bar{Y}_2 \cdot \bar{D}_1) + \bar{Y}_1 \cdot \bar{Y}_2 \cdot \bar{D}_1 \cdot \bar{D}_3 \cdot \bar{D}_4 + (\bar{Y}_2 + \bar{Y}_1) \cdot \bar{D}_2 \cdot \bar{D}_3 \cdot \bar{D}_4$$

$$M_6 = \bar{Y}_2 \cdot \bar{D}_4 \cdot (\bar{Y}_1 \cdot \bar{D}_1 \cdot \bar{D}_2 + \bar{Y}_1 \cdot \bar{D}_1 + \bar{D}_1 \cdot \bar{D}_2 + \bar{D}_3) + \bar{Y}_1 \cdot \bar{D}_4 \cdot (\bar{Y}_2 \cdot \bar{D}_1 \cdot \bar{D}_2 + \bar{D}_3)$$

$$M_7 = \bar{D}_3 \cdot \bar{D}_4 \cdot (\bar{Y}_1 + \bar{Y}_2)$$

$$M_8 = \bar{D}_3 \cdot \bar{D}_4 \cdot (\bar{Y}_1 \cdot \bar{Y}_2 \cdot \bar{D}_1 \cdot \bar{D}_2 + \bar{Y}_1 \cdot \bar{Y}_2 \cdot \bar{D}_1 + \bar{Y}_1 \cdot \bar{Y}_2 \cdot \bar{D}_1 + \bar{Y}_1 \cdot \bar{D}_1 \cdot \bar{D}_2 + \bar{Y}_2 \cdot \bar{D}_1 \cdot \bar{D}_2)$$

$$M_9 = \bar{D}_3 \cdot (\bar{Y}_1 \cdot \bar{D}_1 \cdot \bar{D}_4 + \bar{Y}_1 \cdot \bar{D}_2 \cdot \bar{D}_4 + \bar{Y}_2 \cdot \bar{D}_1 \cdot \bar{D}_4 + \bar{Y}_2 \cdot \bar{D}_2 \cdot \bar{D}_4 + \bar{Y}_1 \cdot \bar{Y}_2 \cdot \bar{D}_2)$$

$$M_{10} = \bar{Y}_1 \cdot \bar{D}_2 \cdot \bar{D}_3 \cdot \bar{D}_4 + \bar{Y}_2 \cdot \bar{D}_2 \cdot \bar{D}_3 \cdot \bar{D}_4 + \bar{Y}_1 \cdot \bar{Y}_2 \cdot \bar{D}_1 \cdot (\bar{D}_2 \cdot \bar{D}_4 + \bar{D}_2 \cdot \bar{D}_3 + \bar{D}_3 \cdot \bar{D}_4) + \bar{Y}_1 \cdot \bar{Y}_2 \cdot \bar{D}_1 \cdot \bar{D}_3 \cdot \bar{D}_4 + \bar{Y}_1 \cdot \bar{D}_1 \cdot \bar{D}_2 \cdot \bar{D}_3 \cdot \bar{D}_4 + \bar{Y}_2 \cdot \bar{D}_1 \cdot \bar{D}_2 \cdot \bar{D}_3 \cdot \bar{D}_4 + \bar{Y}_2 \cdot \bar{D}_1 \cdot \bar{D}_2 \cdot \bar{D}_3$$

Annex1: Encoding rule of (2,5)RLL code