The impact of the LDPC-coded PR17PP processing technique on the SIL recording performance with NA 1.84

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ABSTRACT

The signal quality was examined at the recording densities higher than 100 Gbit/in^2 in our SIL recording system with NA 1.84. We applied the LDPC-coded PR17PP processing unit to our system, and the advancement of recording density by around 35% was confirmed. The recording power tolerance in this arrangement was ± 8.1% at a recording density of 109 Gbit/in^2. This recording density is equivalent to 151 GB for a 12cm-diameter disc, assuming the redundancy that is specified in the Blu-ray disc format.

Key words: near-field, signal processing, partial response, LDPC, recording density

1. INTRODUCTION

For a high-density optical storage system, we have proposed a super-hemisphere solid immersion lens (SIL) with a numerical aperture (NA) of 1.84 [1]. This NA 1.84 realizes an areal recording density 4.5 times of the Blu-Ray disc which has a NA of 0.85. A low bit error rate of 4.5×10^{-5} was confirmed at a recording density of 80.7 Gbit/in^2 [1]. On the other hand, several approaches in signal processing have been also examined for the purpose of improving the recording density [2-4]. Miyauch et al. [2] have demonstrated that a novel trellis decoding technique for the 17PP code is effective for increasing the recording density of the Blu-ray disc. Ohkubo et al. proposed a new LDPC-coded PR17PP system [4]. They showed that their system would make it possible to increase the recording capacity of the Blu-ray disc up to 36GB. This article is a brief report on the result of applying the LDPC-coded PR17PP system to our SIL system. The adjustment of parameters for decoding and the improvement in the recording capacity will be discussed.

2. EXPERIMENTAL

The designed NA of the objective lens was 1.84, which was achieved by a combination of a super-spherical SIL and an aspherical objective lens. The recording stack structure, which was of a phase-change material of GeSbTe alloy, was equivalent to that of a conventional Blu-ray disc. To change the recording density we adjusted the linear velocity, keeping the channel clock constant at 66MHz. The laser power and the write-strategy pattern were optimized for each recording density. We adopted the Sequenced Amplitude Margin Quasi-Error estimation (SAMQES) value [5] and bit error rate as evaluation indexes. These values were measured by our signal-processing system. Figure 1 is a block diagram of our experimental setup, consisting of the recording system, the equalizer board and the LDPC board [6]. For recording and playback the signals on the discs, we used the conventional PULSTEC ODC-1000 recording tester, which was adjusted for SIL evaluation. On the equalizer board, the second-order adaptive Volterra filter proposed by Kajiwara et al.[7] was implemented in the equalizer circuit for the purpose of compensating for the large amplitude asymmetry. After analog processing on the equalizer board, the readout signal was forwarded to the LDPC board. The signal was digitized and was decoded as PR code or LDPC code. To measure the bit error rate, a series of data of about 300k bits was fed into and analyzed by the LDPC board.

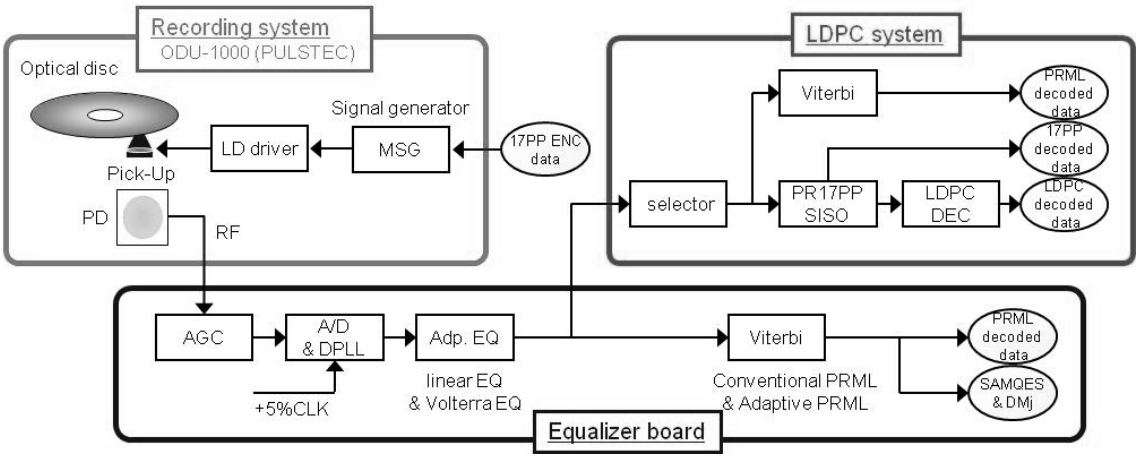

Fig. 1. Block diagram of the recording system, equalizer board and LDPC board.

3. RESULTS AND DISCUSSION

In order to evaluate the impact of the equalizing circuit and the PR classes, we measured the recording power dependence of SAMQES values at recording densities of 72.0 Gbit/in^2 and 100.8 Gbit/in^2. Results are shown in Fig.2. We varied the irradiation laser power, maintaining the ratio of the high laser power to the low laser power. Random data of 17PP code were recorded on the center track of three consecutive tracks. When we measured SAMQES value, we chose the kind of the equalizer types (linear or Volterra) and the class of the PR code (PR1221 or PR12221). Because asymmetric mark will be written by an excess laser, it is expected that the Volterra equalizer will work effectively in the excessive laser power region. In Fig.2-(a), it is actually found that Volterra equalizer has the effect of expanding the power tolerance. The other remarkable feature is the bottom SAMQES value. In the case of bit density of 72.0 Gbit/in^2, the decoded result by PR1221 is better than that by PR12221. However, it is found that PR12221 has an advantage in the case of recording density of 100.8 Gbit/in^2. Thus, we can understand that PR12221 is more suitable for higher density recording. Hereafter we fixed PR12221 and Volterra equalizer as the decoding parameters.

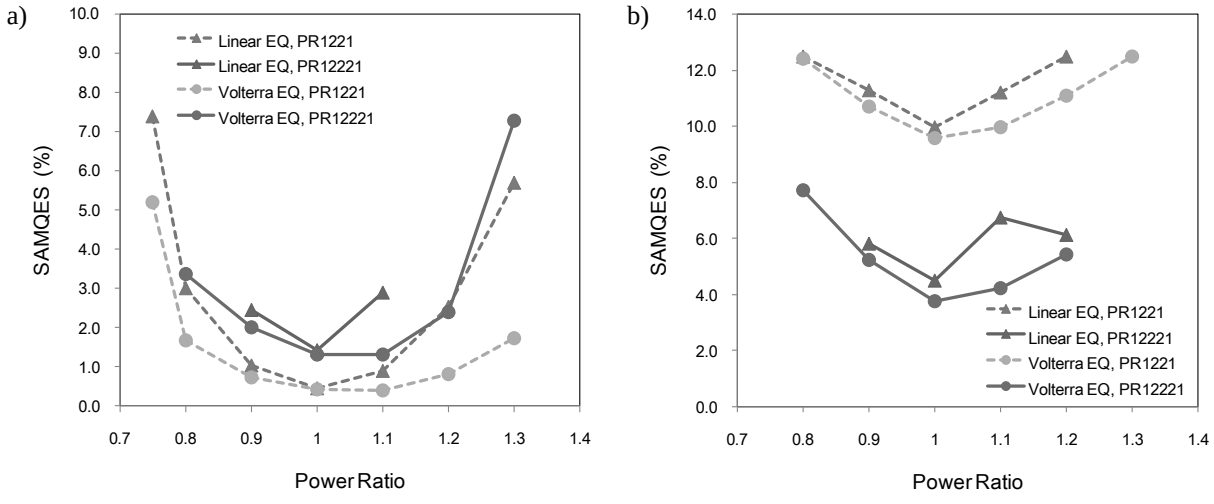

Fig. 2. The recording power dependence of SAMQES values on three consecutive tracks. (a) 72.0 Gbit/in^2 (b) 100.8 Gbit/in^2.

We evaluated the decoding performance of the PRML, observing the bit error rate of the decoded signals at various recording densities ranging from 72.0 Gbit/in^2 to 113 Gbit/in^2. The results are shown in Fig.3. If the bit error rate of 1x10^{-3} would be considered as a criterion for recovering by ECC, it is considered that a recording density of 100 Gbit/in^2 is feasible. Judging from the correlation between the SAMQES value and the decoded bit error rate, the SAMQES value should be less than 3.0. In Fig.3, the bit error rate obtained by use of the LDPC decoding is also plotted. When the LDPC was employed for decoding, no error was observed for the area densities below 109 Gbit/in^2. From these results, we concluded that the upper limit of the recording density was around 109 Gbit/in^2, when our SIL recording system of 1.84 NA was combined with the LDPC-coded PR17PP system.

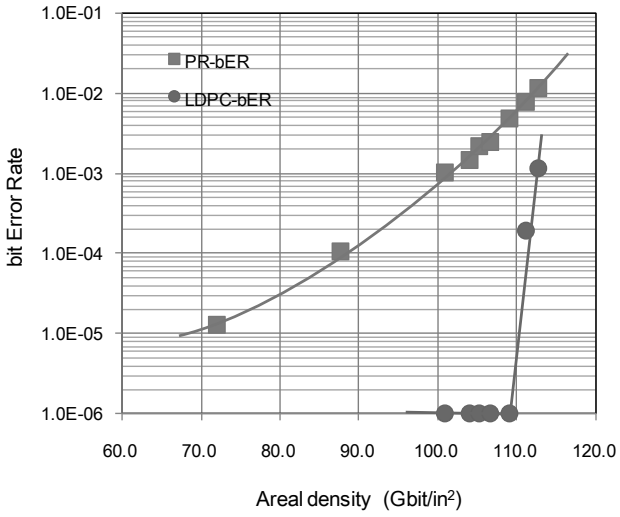

Fig. 3. Dependence of the bit error rate on the areal recording density.

The recording power tolerance was measured at the area density of 109 Gbit/in^2. In Fig.4, the dotted curve shows the SAMQES dependence and solid curve indicates the LDPC result. Due to instability of PLL, the bit error rate through LDPC at the excessive laser power region turned out to be worse regardless of those SAMQES values that enable data recovery in our conventional decoding system. Nevertheless, we obtained a sufficient wide power tolerance of ± 8.1%, which is defined to be the laser power range for error-fee region.

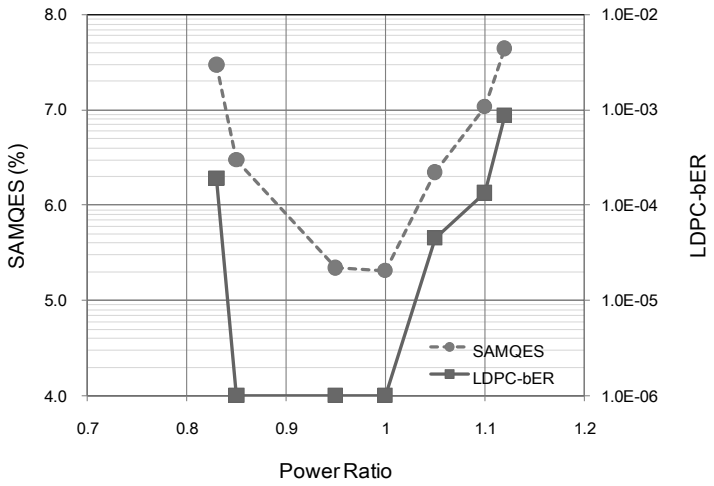

Fig. 4. Recording power tolerance of a phase-change disc at an areal density of 109 Gbit/in^2.

4. CONCLUSION

We succeeded in raising the recording density of our SIL system with 1.84 NA, applying the LDPC-coded PR17PP that employed the Volterra type equalizer and PR12221 code. The upper limit of the recording density was estimated to be 109 Gbit/in^2 and we obtained a practical power tolerance of ± 8.1% at this density. This recording density is equivalent to 151 GB on a 12cm-diameter disc if the redundancy of the Blu-ray disc format is assumed.

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Biographies

I joined Sony in 1985. I have engaged in optical disc development.

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