

Evaluation of HDD SNR/Capacity Gains from 4KB-Block Format ECC

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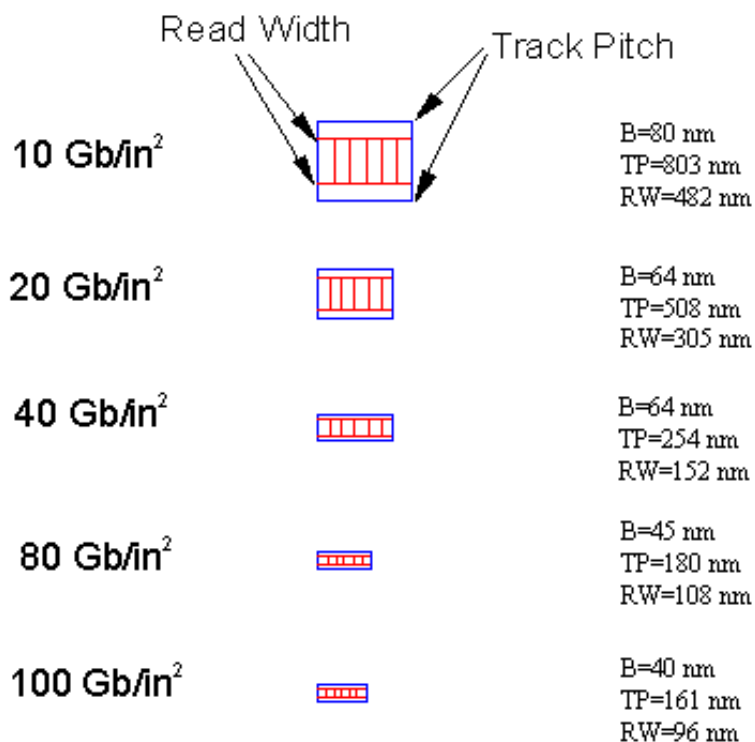
- **4K-Block Format Standard Chronology**
[1998-2005]
- **Motivation: AD-Growth Bottleneck**
[1998, IBM Task Force]
[S.McCarthy/Maxtor, 5/30/2001, Disk Con Presentation]
- **4K-Format Efficiency Gain Estimate**
- **4K-SNR (Signal-Processing) Gain Estimation**

4K-Block Format Standardization

- 1998 IBM Task Force Recommendation (M. Hassner)
- 1998 NSIC White Paper (D. Cheng, M. Hassner, B. Lamberts, and R. Wood)
 - 100 GB/in² recording → 6 db loss of SNR
 - Signal processing will recover 3 dB
 - Stronger ECC required to recover 3 dB → 4 KB block size
- 2000 IDEMA 4K Block Committee (E. Grochowski, M. Hassner)
- 2002 Hitachi proposal large block ATA standard (D. Colegrove)
- 2003 IDEMA Position Paper
 - Joint position of Hitachi GST, Seagate, Maxtor, and Fujitsu
 - Sent to Microsoft 11/19/2003
- 2004 Microsoft Support for 4K Block Format
 - Support for 4K block will be in “Longhorn” (6/4/2004)

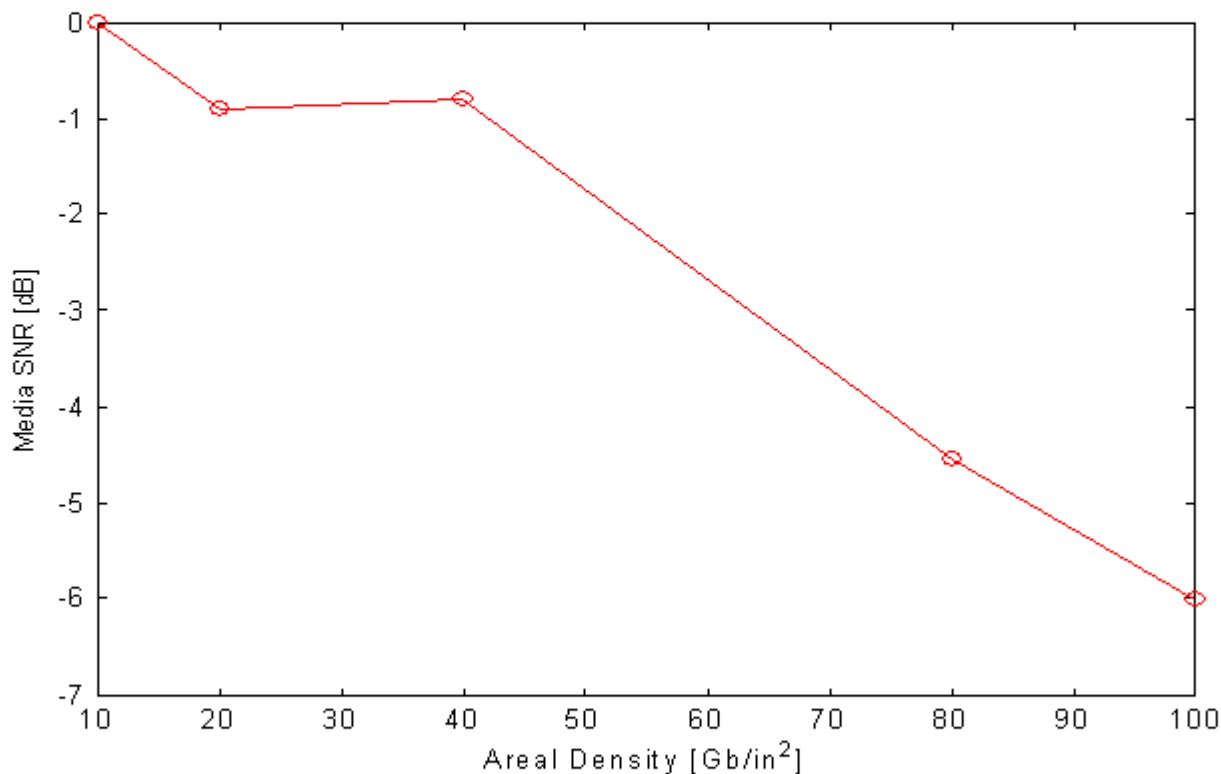
AD-Growth Bottle Bottleneck (I)

6 Bits and a Track at 10 to 100 Gb/in²



AD-Growth Bottle Bottleneck (II)

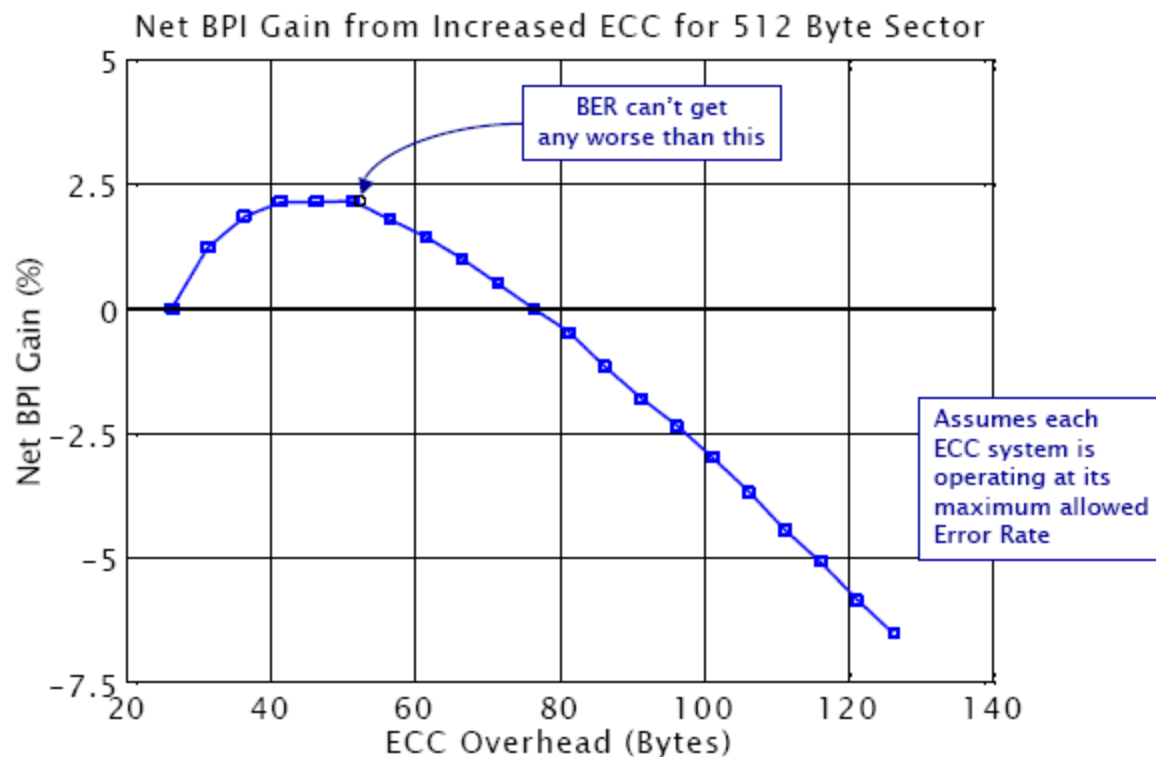
Media Noise at 10 to 100 Gb/in²



Motivation toward Long-Block Format (I)

Potential ECC Gains

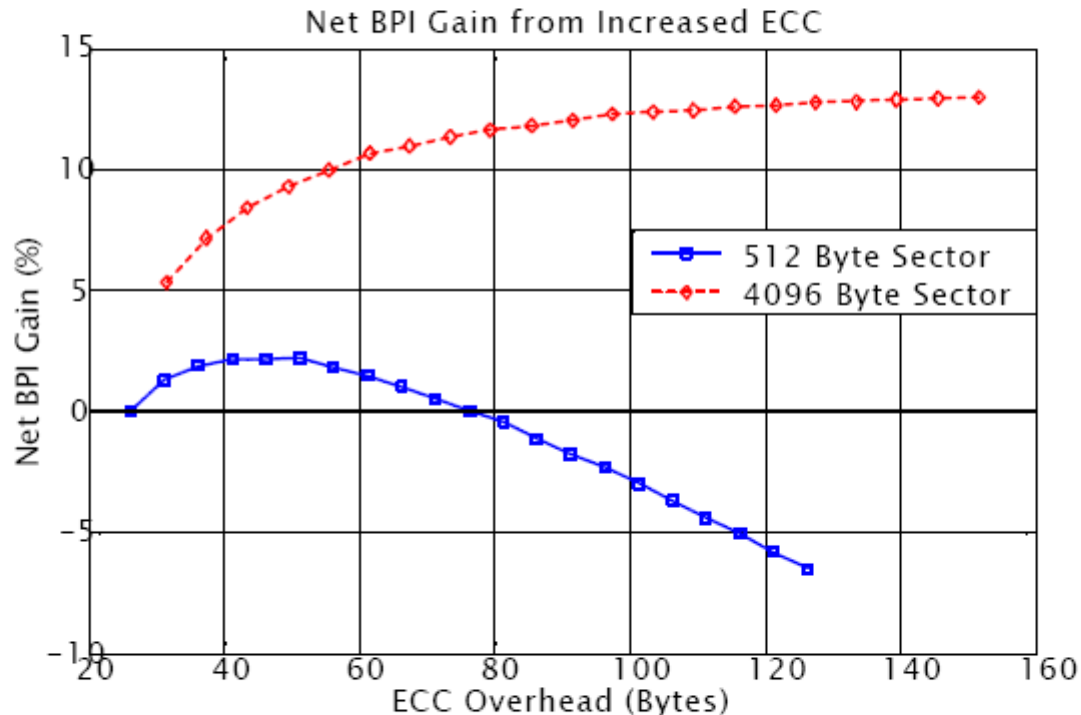
- Improvements in *Error Correction* on 512 Byte sectors are diminishing



Motivation toward Long-Block Format (II)

Increased Sector Size

- Longer Sectors improve *Error Correction* capability
 - Even with long sectors, *SNR* and *BER* will get worse



4K-Block Format Efficiency Gain

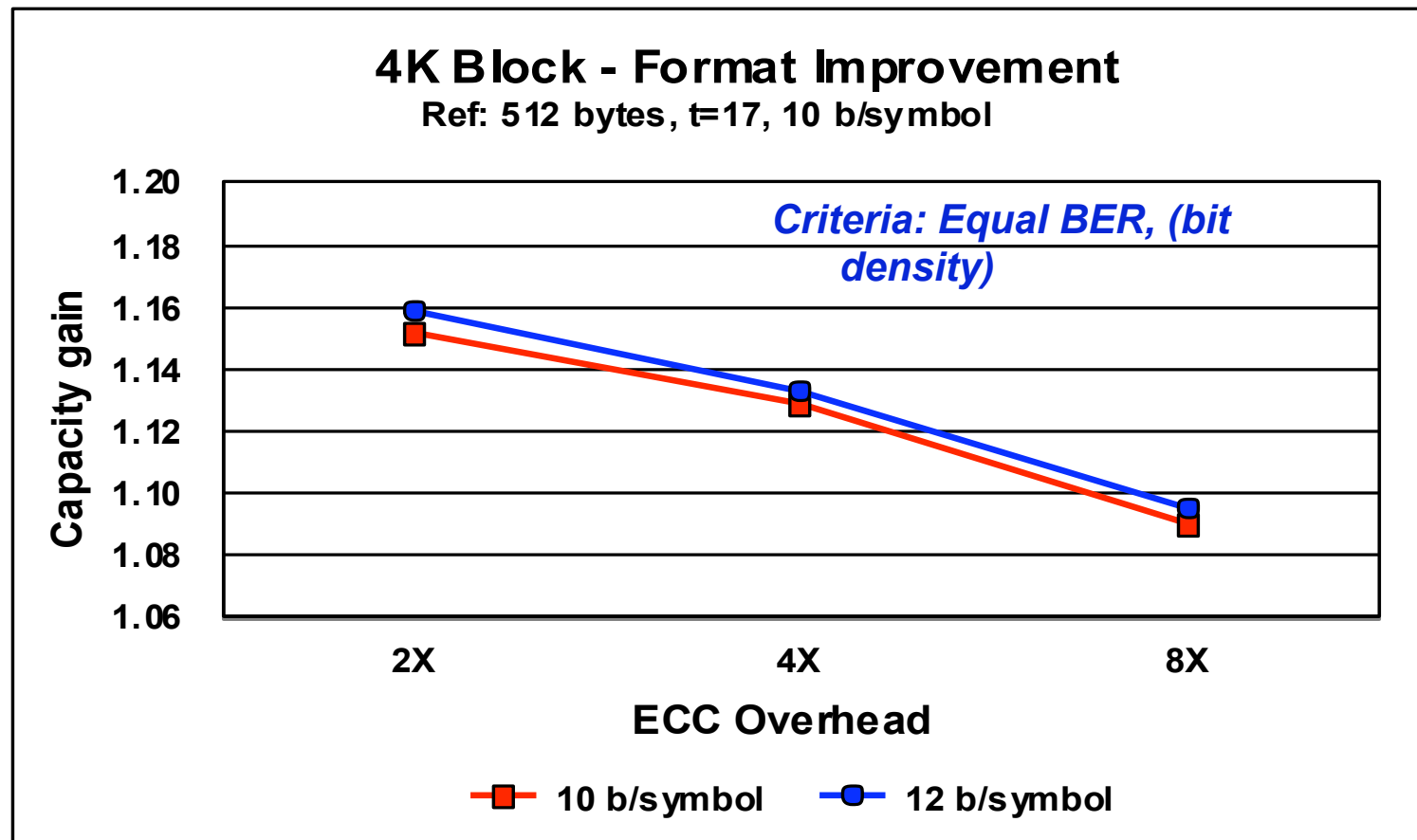
■ 512-Byte Sector Format

- Data is $\approx 80\%$ of Sector Size

■ 4K-Block Sector Format

- Data is 93-94% of Sector Size

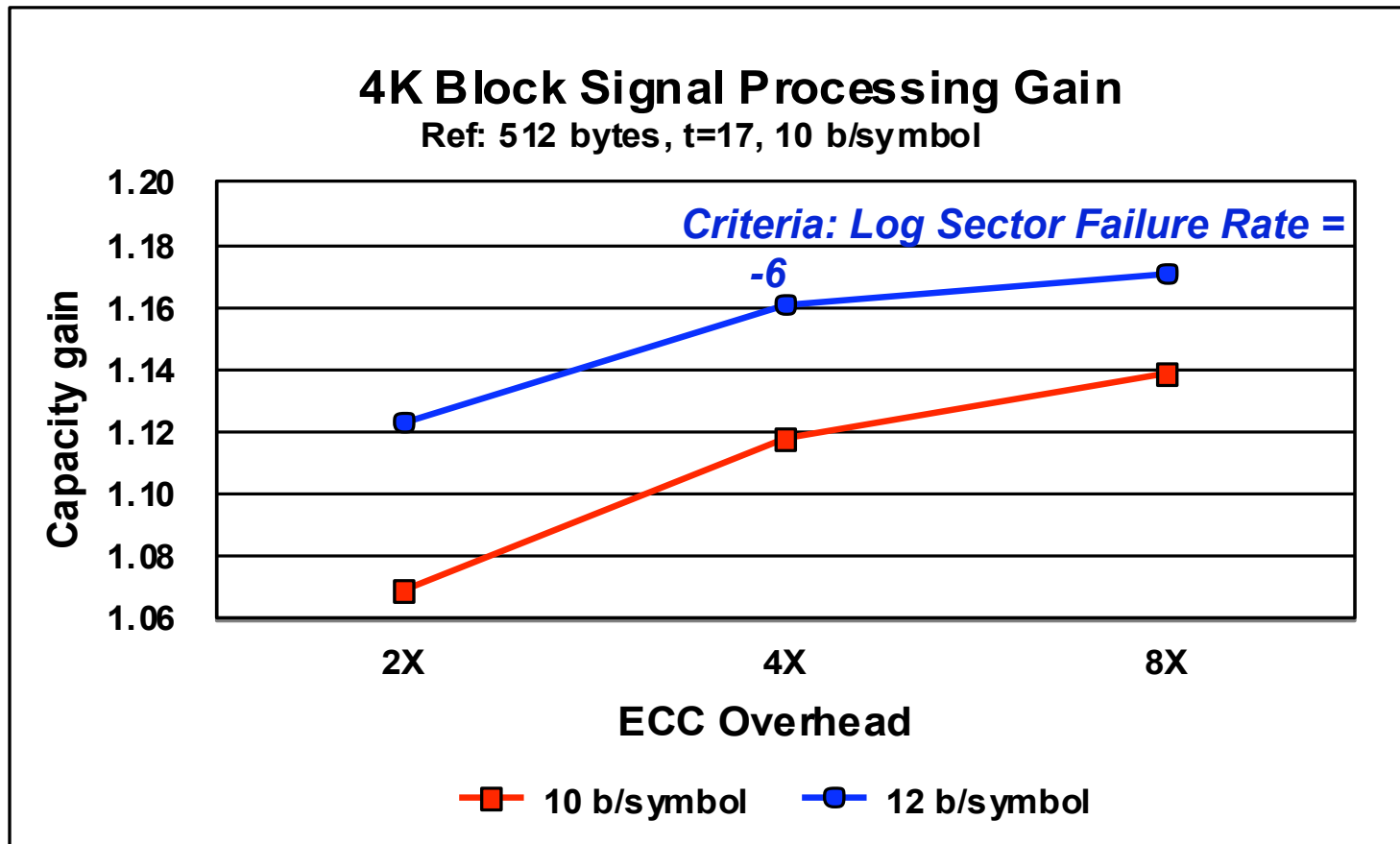
Capacity Gain Estimation from 4K-Block Format



- Reference: 512 byte, 10 b/symbol code & “1 x 17” ECC correction
- 2X, 4X, 8X ECC field size
- 1K x 4 interleave 10 b/symbol, 4K x 1 interleave 12 b/symbol

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Signal-Processing Gain from 4K-Block Format



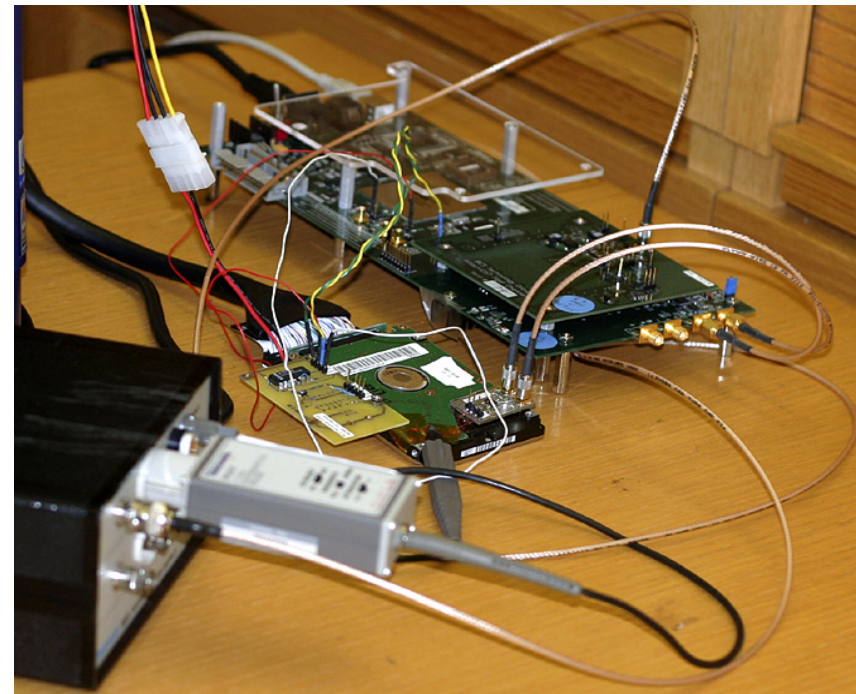
- Reference: 512 byte, 10 b/symbol code & “1 x 17” ECC correction
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SNR Gain Evaluation on Drive-Level Measurement

■ **Sector Failure Rate Evaluation using Drive-Tap setup**

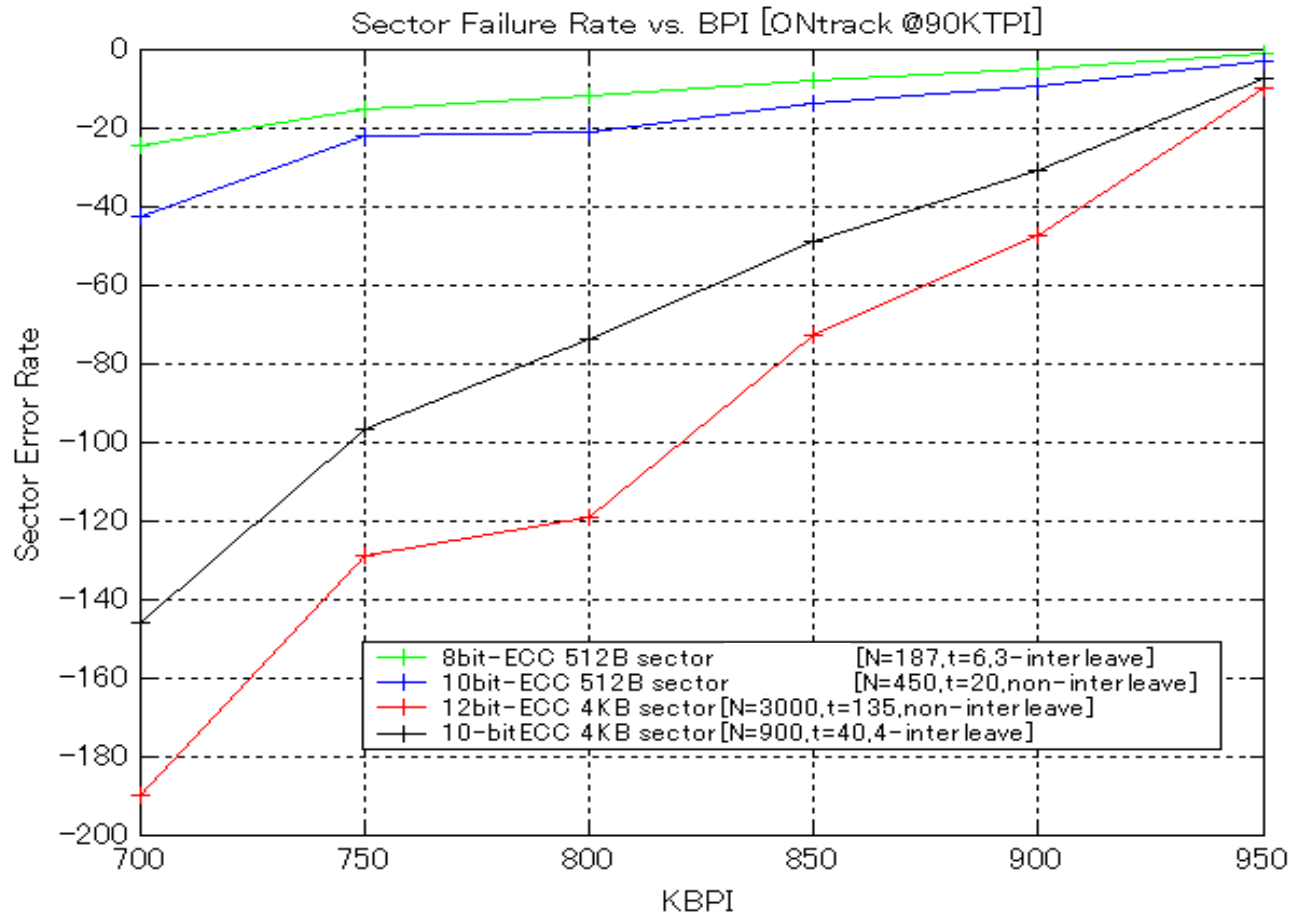
1. HDD measurement with BES channel evaluation board
 - Vary **kBPI**
 - Vary **OffTrack**
2. Burst error-event distribution measurement
3. Measured parameters in Multinomial Distribution Model^[1]
4. Sector Failure Rate (SFR) evaluation



[1] V. Y. Krachkovsky, Z. A. Keirn et al, in TMRC 2000
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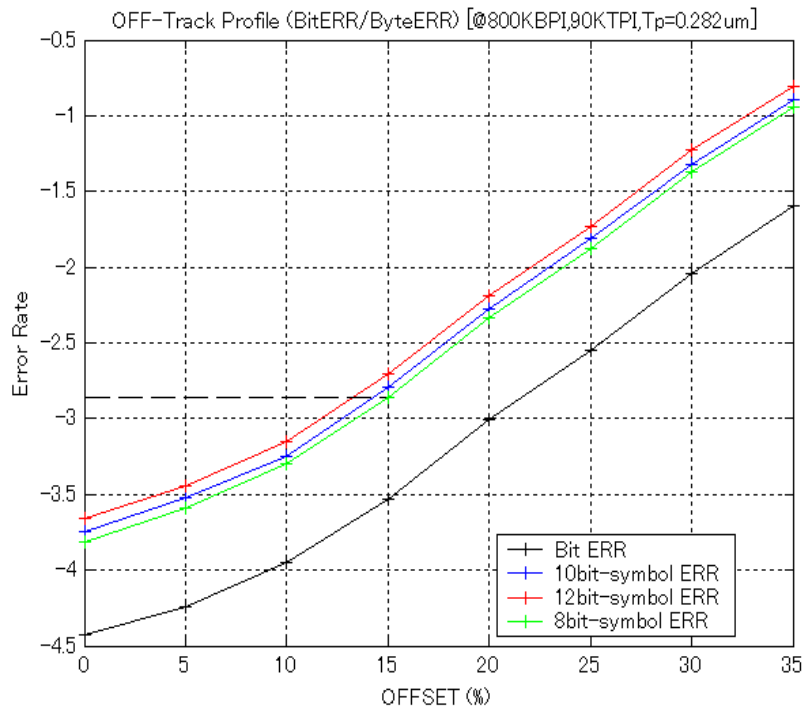
BPI-Gain Evaluation Results

■ ON track SER vs. BPI measurement (@90KTPI)

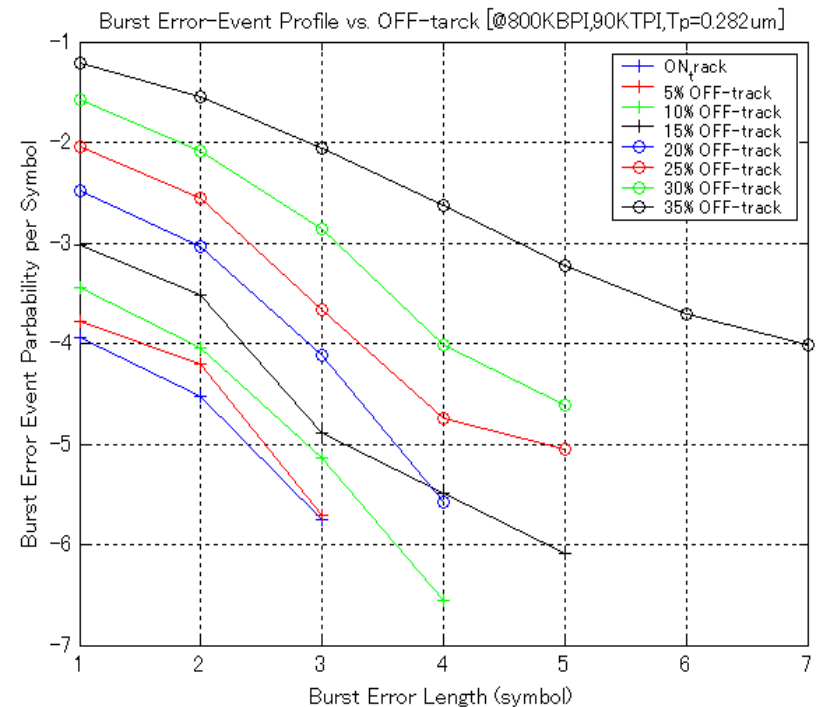


OFF-Track Tolerance Evaluation (I)

■ Error rate OFF-Track Profile (@800KBPI, 90KTPI, $T_p=0.282\mu\text{m}$)



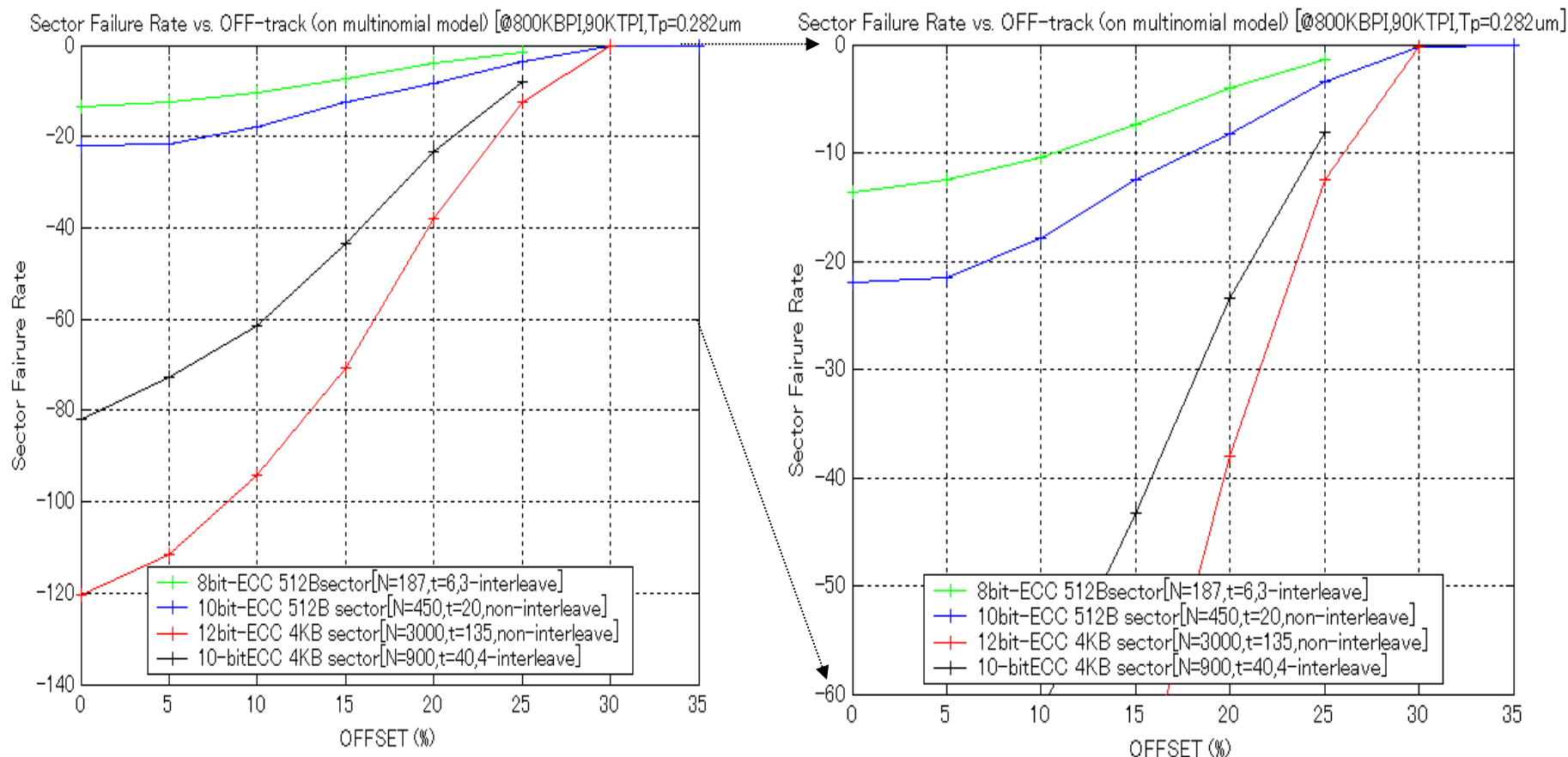
(1) Bit/Byte error rate



(2) Burst error statistics

OFF-Track Tolerance Evaluation (II)

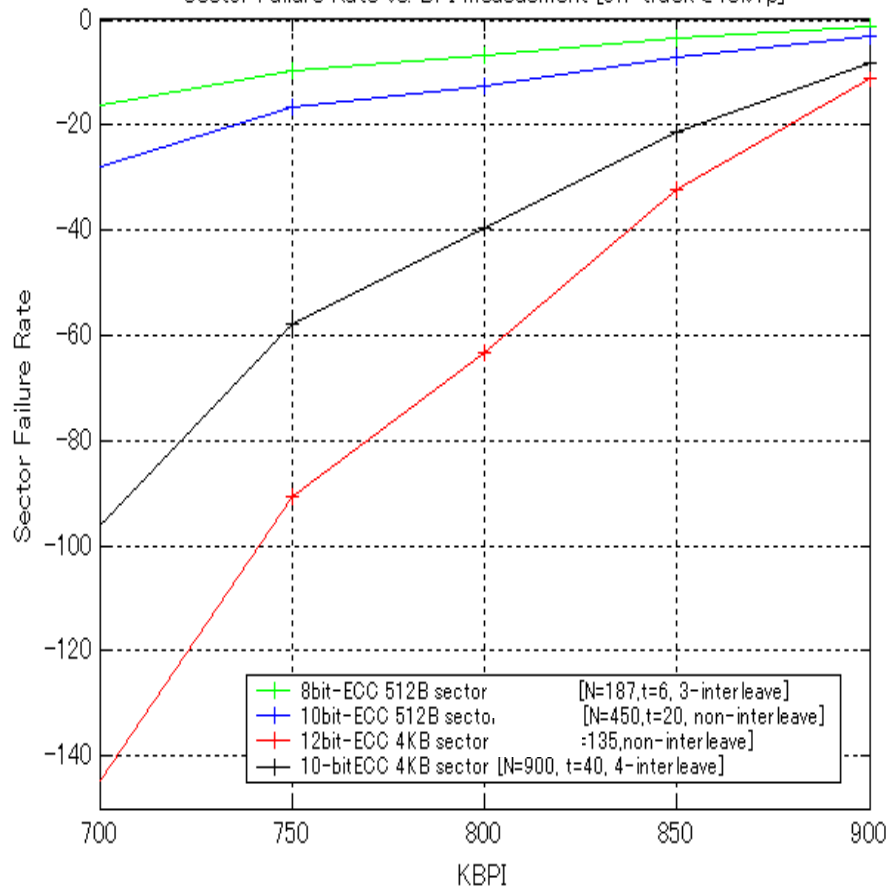
■ SFR OFF-Track Profile (@800KBPI,90KTPI,Tp=0.282um)



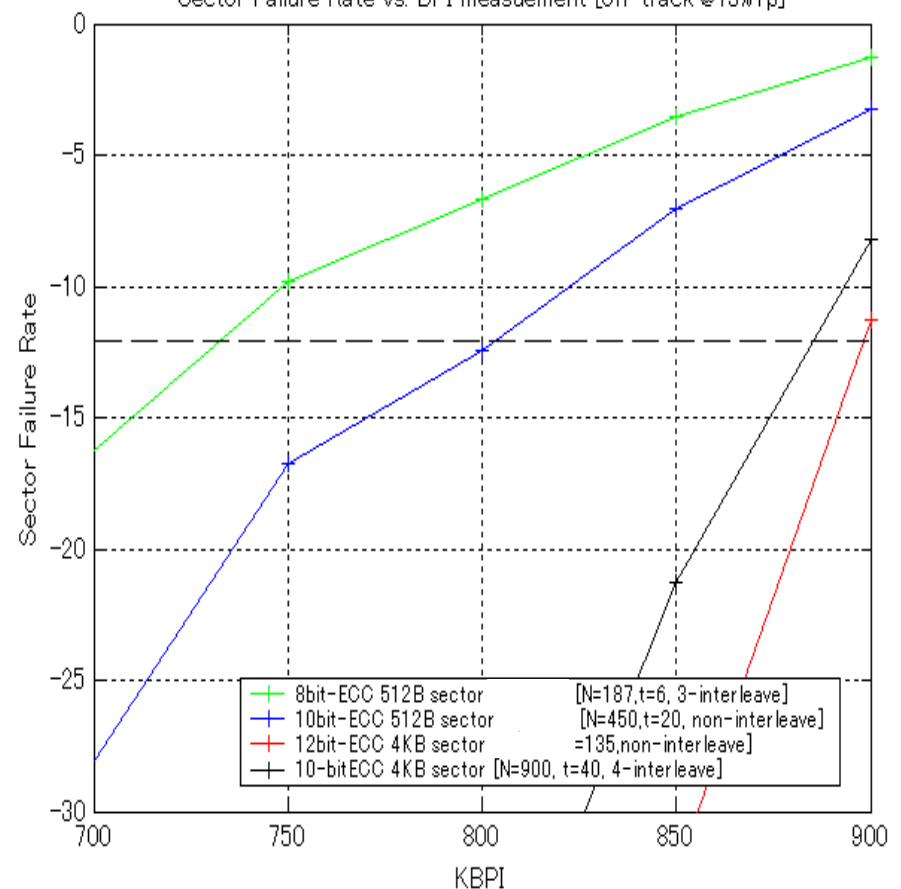
BPI-Gain Evaluation with Typical OffTrack

■ OFF track SFR vs. BPI measurement (@15%Tp offset)

Sector Failure Rate vs. BPI measurement [off-track @15%Tp]



Sector Failure Rate vs. BPI measurement [off-track @15%Tp]



4K-Block ECC SNR-Gain

□ BPI Gain $\approx 10\%$

- 10bit-ECC/800kBPI $\rightarrow$ 12bit-ECC/890kBPI**
- Maintain soft ERR $\approx 10^{-12}$**
- 9%-Overhead $\rightarrow$ 5%-Overhead**

□ OffTrack Tolerance Gain $\approx 10\%$ [@800kBPI**]**

- 10bit ECC &15% $\rightarrow$ 12bit-ECC&25%**
- Maintain soft ERR $\approx 10^{-12}$**
- 9%-Overhead $\rightarrow$ 5%-Overhead**

4K-Block 12-bit ECC Gains

- **512-Byte Sector Format**
 - 10-bit GF-Implementation/10-bit clock
 - 9%-**Overhead**
 - **ber** $10^{-5} - 10^{-6} \rightarrow$ **BER** $10^{-11} - 10^{-12}$
- **4K-Block Sector Format**
 - 12-bit GF-Implementation/12-bit clock
 - 5%-**Overhead**
 - **ber** $10^{-3.0} - 10^{-4} \rightarrow$ **BER** $10^{-11} - 10^{-12}$
 - **Format Efficiency Gain** 13 – 14%
 - **SNR Gain** 9%