“And One Large Sector Size for All”

Greg Silvus
Andrei Vityaev
Broadcom Corporation

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Outline

- Gains of the 4 kB sector format
- Signal processing for 4 kB vs 512 B sector
- Conclusions

4 kB Density Gain Breakdown

	Density Gain	Explanation
12-bit ECC random error correction capability	**3.0%** **(“BPI gain”)** **4.5%**	*With same % overhead, 12-bit ECC corrects more errors, allowing higher linear density*
12-bit ECC overhead for random errors		*To achieve same Sector Error Rate, 12-bit ECC requires fewer ECC symbols*
Defect/TA/burst ECC overhead	**8.1%**	*Additional fixed number of ECC symbols required for defect/ TA/burst correction is a smaller percentage of 4 kB sector*
Drive format		*Fewer sector gaps, preambles, sync marks in the case of 4 kB sector size*
TOTAL	**15.6%**	

- Typical split of the “BPI gain” is

7.5% = 3% (higher bit density) + 4.5% (less ECC overhead for random errors)

- Results are from a drive-tap + multinomial model; confirmed by simulations
- The split depends on operating conditions. In simulations, optimum ECC configuration had

a bigger portion of the “higher bit density” portion of the gain

Predicting the Format Penalty

Assume 1 Sector of Data Written at 700 Mbps with no ECC takes up this much space

Writing data at 740 Mbps takes up less space

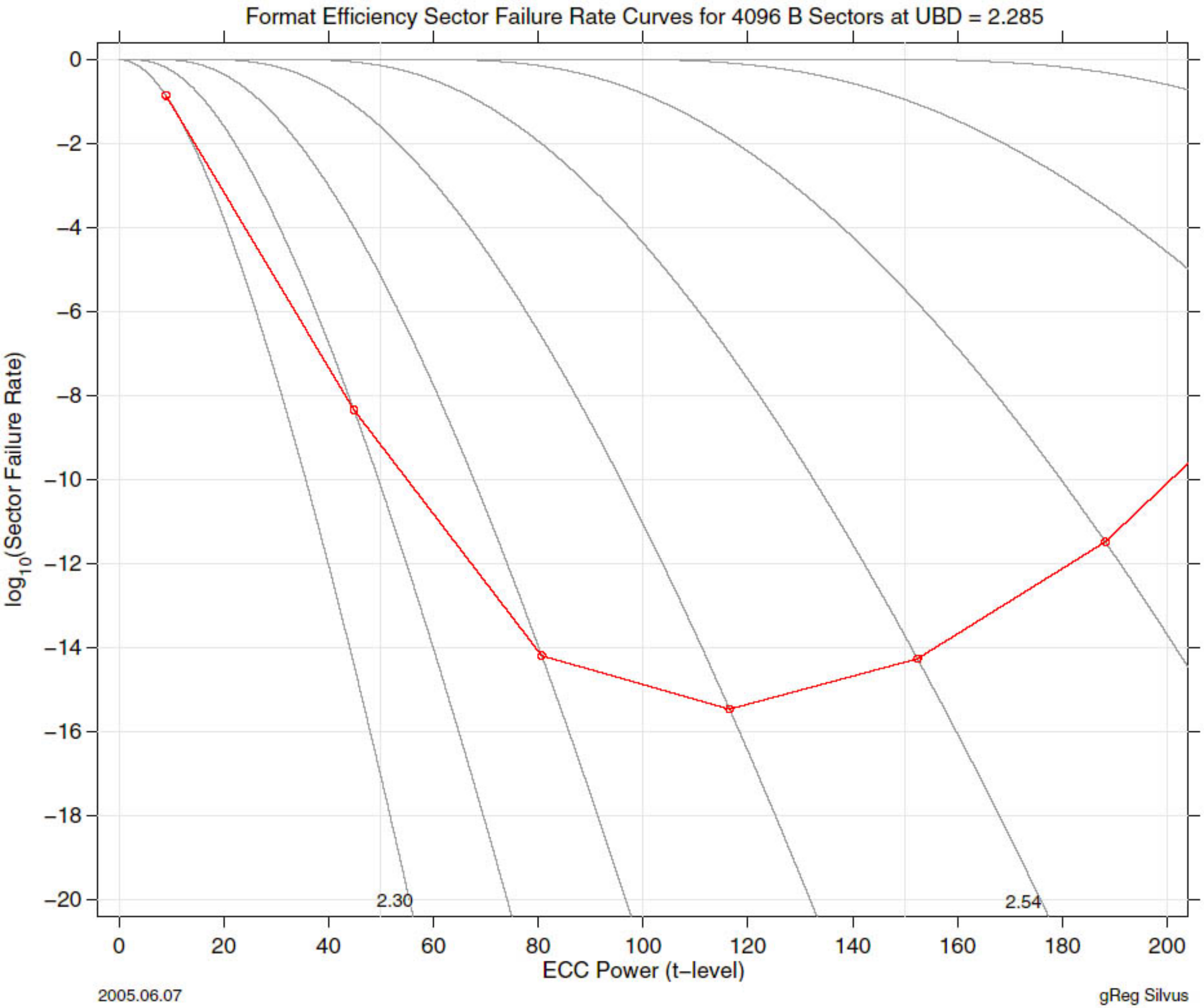
Leaving this much space for ECC Parity

Determine number of symbols left over and apply it to ECC

Higher data rate means: More ECC
Same Capacity
Poorer Raw Error Rate

Optimum ECC: Simulations

- **Baseline UBD = 2.285**
- **UBD = 2.42 supports t ~ 80**
- **Min Point at t ~ 120 corresponds to $\log_{10}$(bER) ~ -2.5 (UBD = 2.48)**
- **4096 B, S=12, I=1**



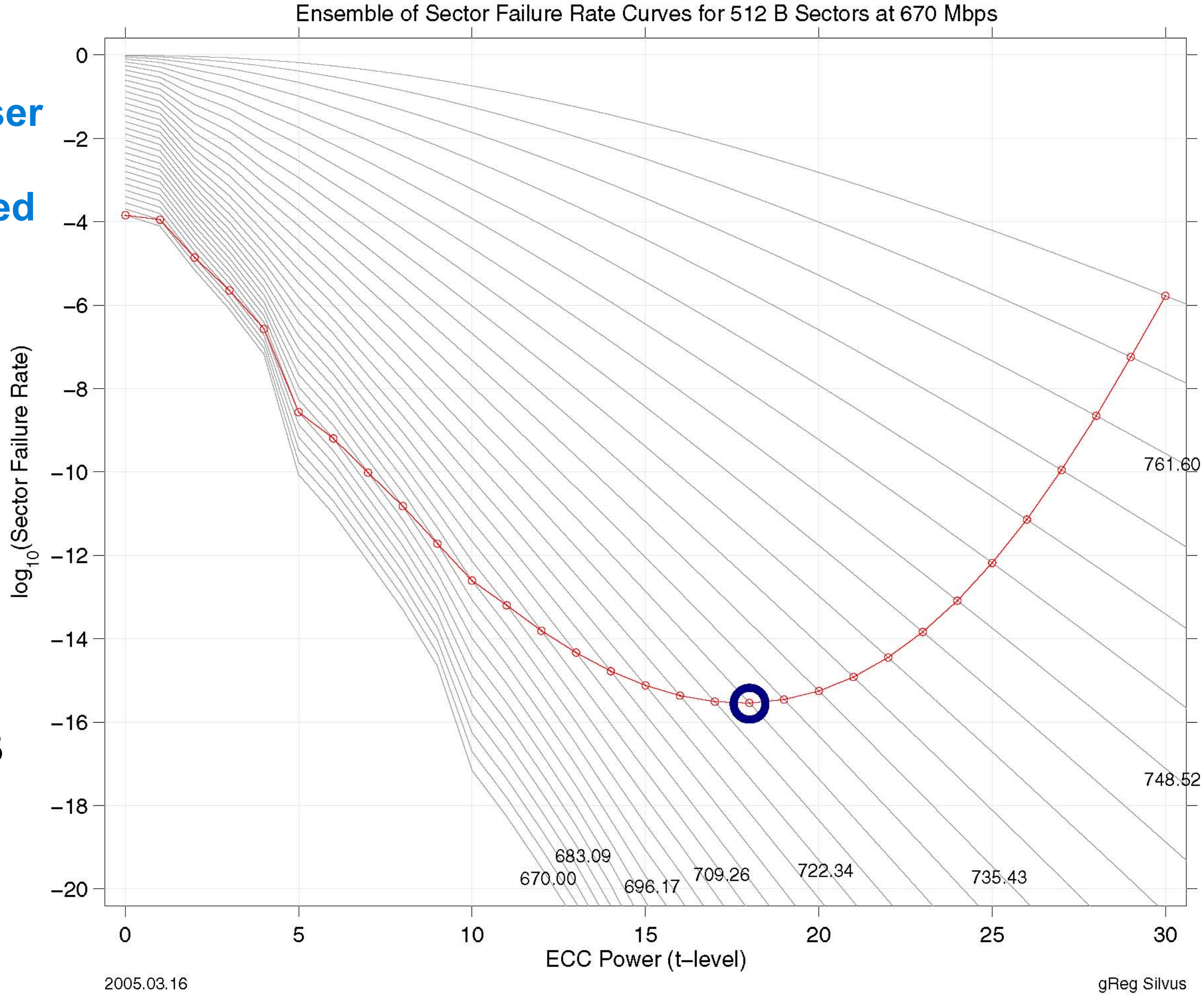
Connecting everything™

Measurement using drive X

- Optimum t-level curve for drive X
- For 512 B sector, user data rate of 670 Mbps can be achieved
- Optimum “t” is at bER of 1E-4.3

- Combination of multinomial model and bER measurements

- **Drive X has very high code-rate penalty, 1%~0.3dB**

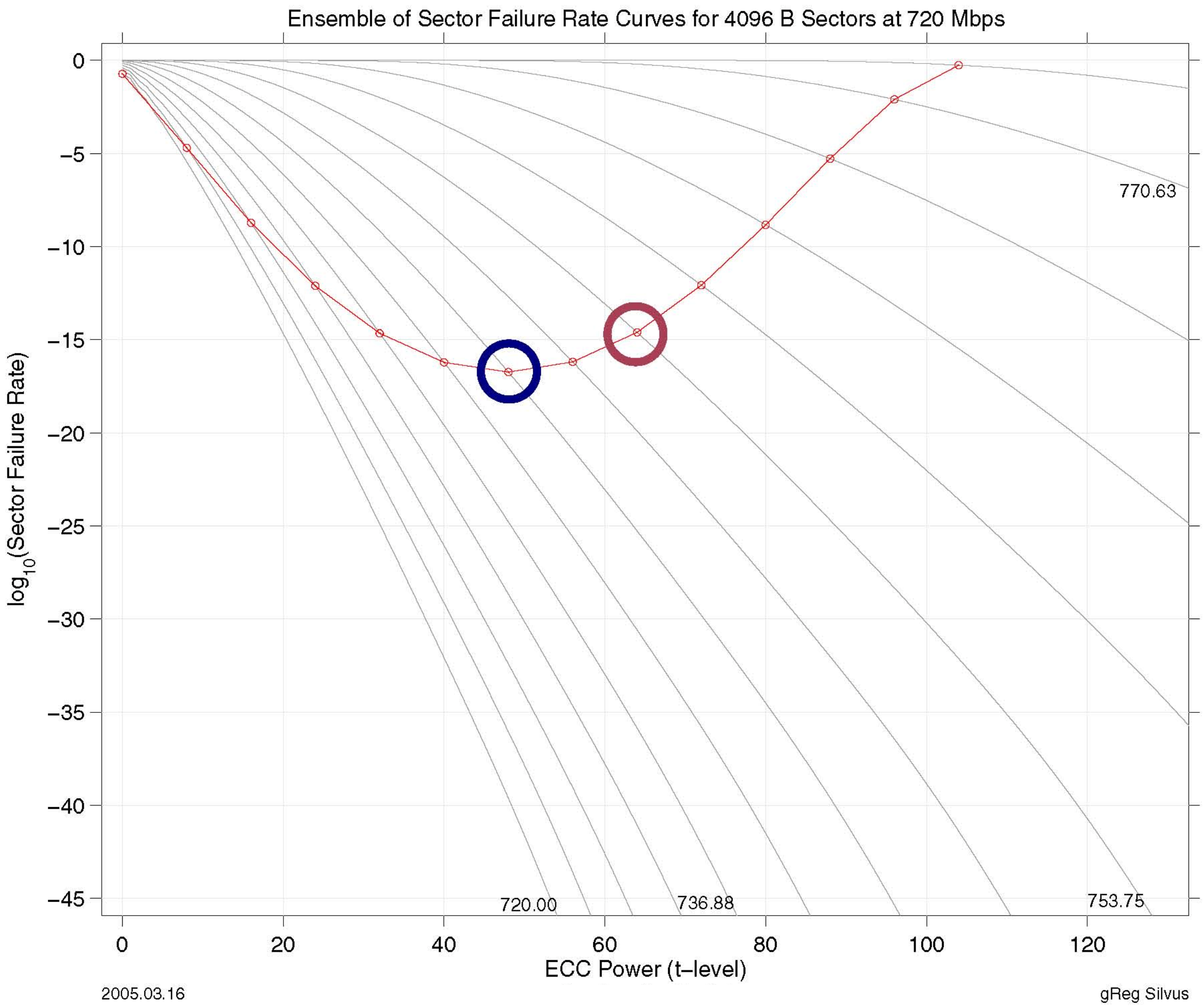


Connecting everythi

Measurement using drive X

- Optimum t-level curve for drive X
- For 4 kB sector, user data rate of 720 Mbps can be achieved
- 7% Capacity increase vs 512 B sector (format efficiency gain excluded)
- Optimum “t” is at bER of 1E-3.5

- Drive X has very high code-rate penalty, 1%~0.3dB



Connecting everything

Signal Processing for 4 kB vs 512 B physical sectors

512B sector size and 4 kB sector size require different signal processing to be implemented in HDD hardware

- **Different Error-Correction-Code**
  - Reed-Solomon code based on 12-bit arithmetic for 4 kB sectors
  - Reed-Solomon code based on 10-bit arithmetic for 512 B sectors
- **Different read channel signal processing algorithms**
  - Previous curves show different optimal read channel SNR/bit-Error-Rate (bER) operating points for 4 kB and 512 B sectors
    - Example of Drive X measurement: bER=1E-4.3 for 512 B and bER=1E-3.5 for 4 kB sectors
    - Different SNR leads to different signal processing algorithms (some algorithms that have performance gain at better SNR/bER show no performance gain at worse SNR/bER)
- **Optimum support for both 4 kB and 512 B sectors leads to two different read channels combined into one**

Conclusions

- **Broadcom investigation confirms the gains of the 4 kB sector format in HDD capacity**
- **Broadcom is designing HDD ICs that support 4 kB**
- **Optimum support for both 512 B and 4 kB physical sector size results in significant Area/Power/Cost penalty in HDD SOC**
  - SOC designed to be optimal for 4 kB physical sectors can have "sub-optimal" (few % less drive capacity) support for 512 B physical sectors
- **Support for single 4 kB physical and dual 4 kB/512 B logical sector format is possible without significant Area/Power/Cost penalty**
  - Engineering issues and risk with Firmware and Hard-disk-controller IC design remain
- **Broadcom's recommendation is to migrate all drives, OS and BIOS to single 4 kB Physical and Logical sector format**
  - "And One Large Sector Size for All"