Using Data Dependent Noise to Aid Error Correction

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Presentation Overview

- Introduction and Motivation
- System Overview, Sources of Noise and Typical Detection/Decoding
- Modifications to the Viterbi and MAP Decoders : Asymmetric Decoders (AD)
- Results and Future Work
- Conclusion

1 Introduction and Motivation

- The classical Viterbi Algorithm[1] and Maximum *A Posteriori* (MAP)[2] detectors assumes that all symbols are equally likely and noise is data independent.
- Information storage channels are perturbed by data independent noise (Additive White Gaussian Noise, AWGN) and many data dependent sources of noise (signal jitter, media saturation, soft underlayer spike noise, etc)

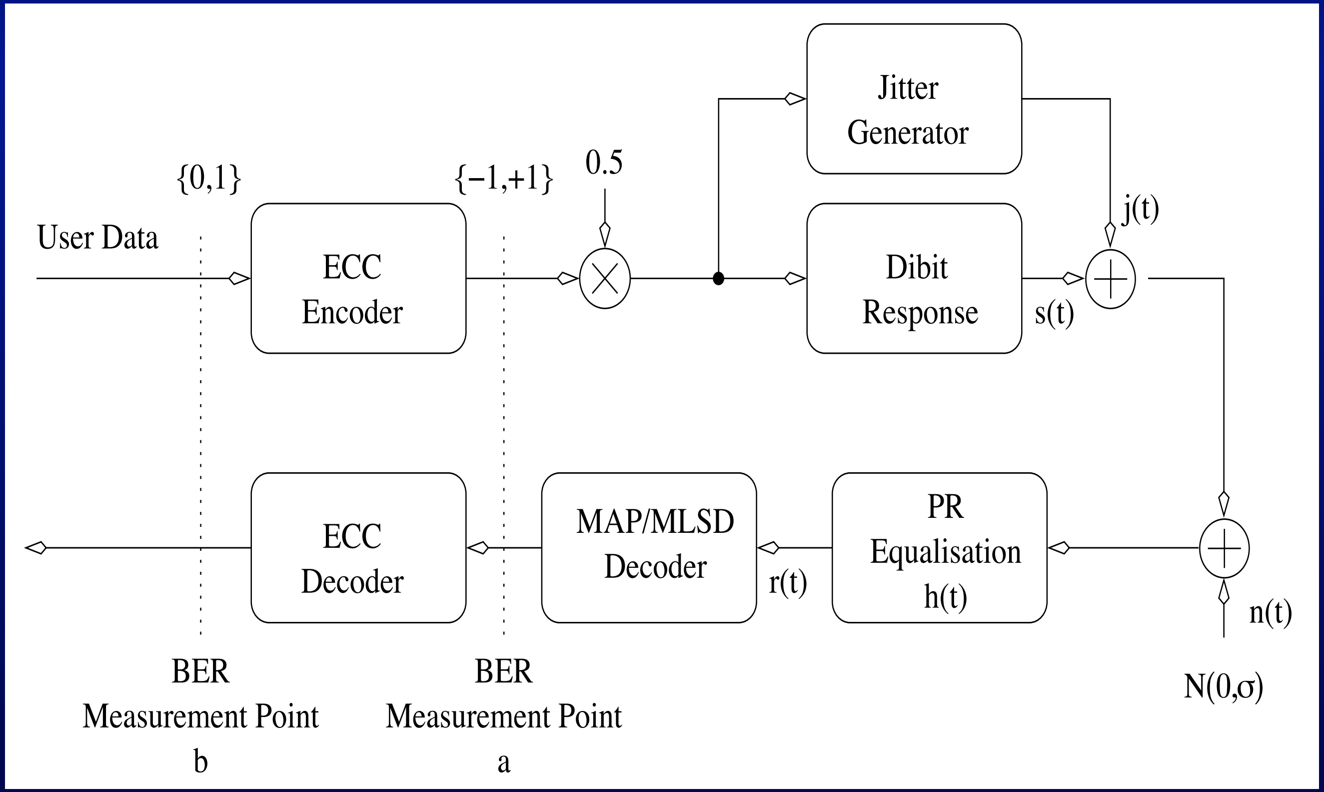
Extending and simplifying the proof of the classical Viterbi and MAP decoders to include channel data dependence was investigated. Results are presented in this talk.

2 System Overview and Sources of Noise

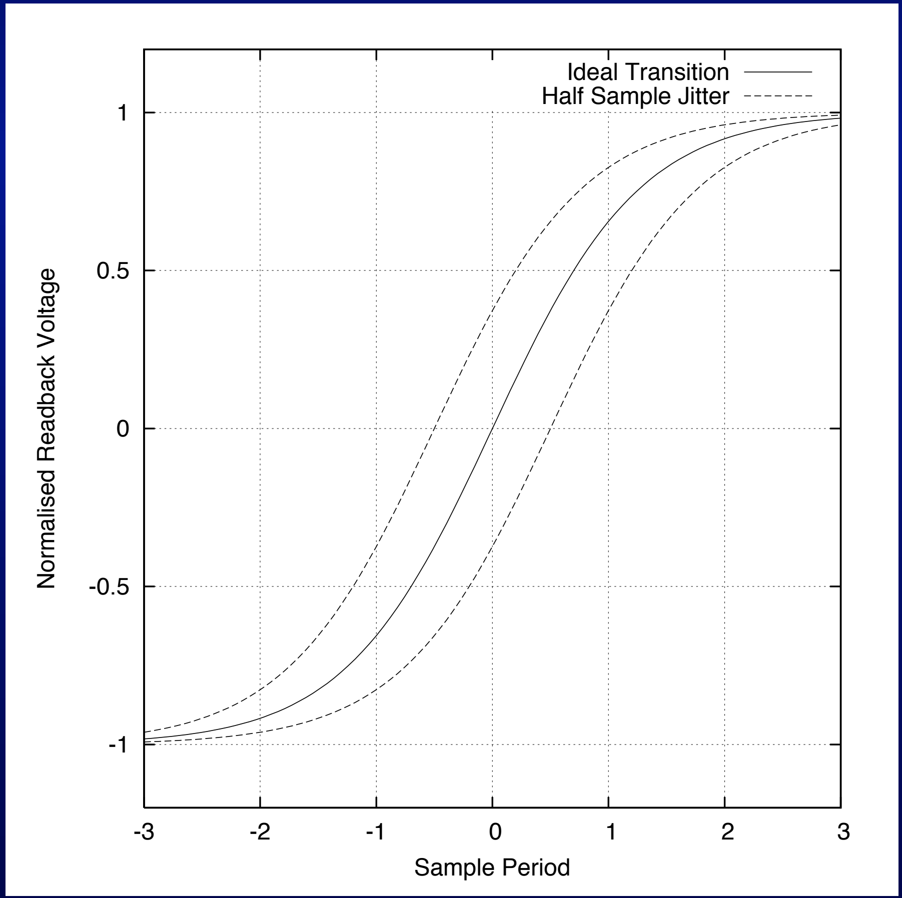
For simulation purpose, a perpendicular magnetic recording channel is assumed.

- The sources of noise include AWGN and Sampling Jitter, with Sampling Jitter seen as an additional (noisy) signal.
- The channel is equalised using Partial Response (PR) polynomials, and uses a Log-MAP decoder to decode the PR sequence.
- User data are recovered after the application of Error Correction Codes, in this particular case Low Density Parity Check (LDPC) codes are used[3].

3 Block Diagram - Perpendicular Recording



Jitter Noise



- For the perpendicular channel model, we assume a hyperbolic tangent readback signal from an isolated transition $u(t)$, given by

$$u(t) = \tanh\left(\ln(3)\frac{t}{D_{50}}\right)$$

where D_{50} is the normalised user density[4].

- The error correction code (ECC) is a (4096,3072) LDPC code.
- The received signal $r(t)$ can be described by the following equation

$$r(t) = h(t) * (s(t) + j(t) + n(t))$$

, where $h(t)$ is the impulse response of the PR equaliser, $s(t)$ is the channel readback waveform (with ISI), $j(t)$ is the transition jitter noise and $n(t)$ is AWGN, or the electronics noise and $*$ denotes convolution.

- Noise prediction is used within the decoder, resulting in the decoded signal being described as

$$r(t) = h(t) * s(t) + j(t) + n(t)$$

. Without noise prediction, the data dependence of the noise is lost.

4 Modifications to Trellis Decoders - Asymmetric Decoders (AD)

Typical expression in the Viterbi and Log-MAP decoders include an add–compare–select branch. For Viterbi decoders expressions like

$$\min\{S_a + (r_i - s_j)^2, S_b + (r_i - s_k)^2\}$$

occur in abundance, where S_a and S_b are state metrics, r_i is the received sample and s_j and s_k are ideal possibilities for r_i. This can be written using 1 multiplication, 2 additions and 1 compare as

$$\min\{S_a, S_b + r_i \cdot k_1 + k_2\}$$

where $k_1 = 2(s_i - s_j)$ and $k_2 = (s_j^2 - s_i^2)$

The modification required to this computation is

$$\min\{S_a + (r_i - s_j)^2, S_b + [(r_i - s_k)^2 \cdot \alpha + \beta]\}$$

where α and β can be precomputed depending on the statistics of the data dependent noise, and are constant as long as the statistics of the data dependent noise are constant. This can also be written as

$$\min\{S_a, S_b + r_i \cdot (r_i \cdot k_1 + k_2) + k_3\}$$

where $k_1 = \alpha - 1$, $k_2 = 2(s_i - \alpha \cdot s_j)$ and $k_3 = \alpha \cdot s_j^2 - s_i^2 + \beta$

This increases the computation by 1 additional multiplication and 1 additional addition for every metric computation compared to the classical Viterbi.

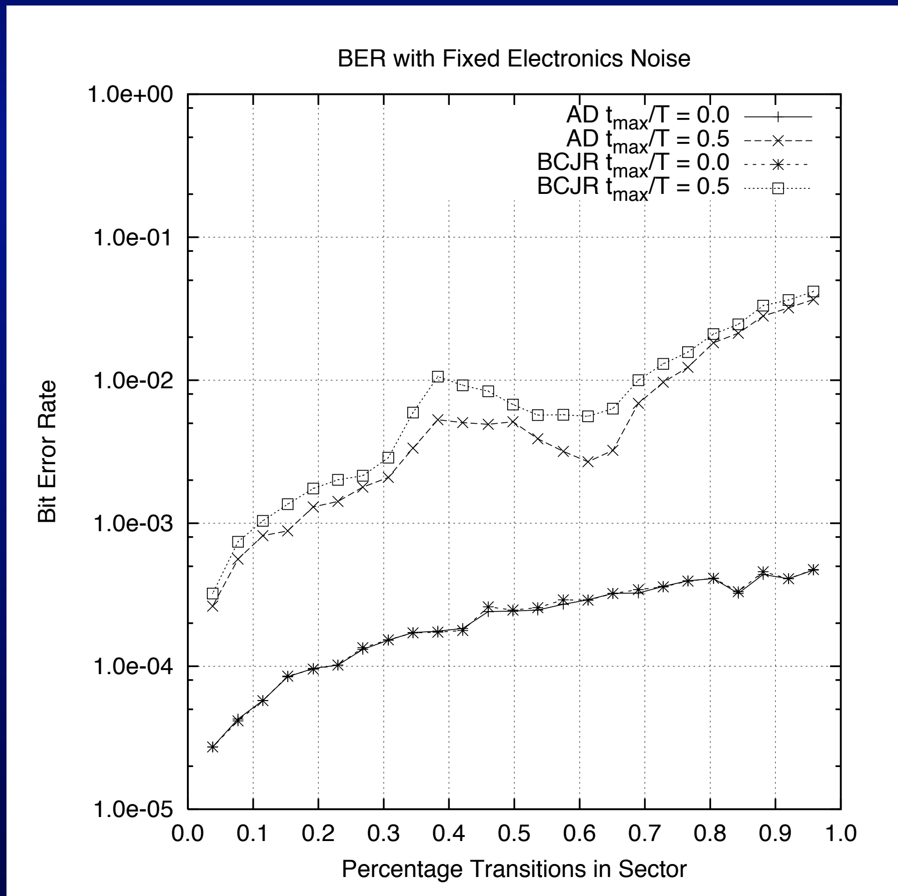
Similar computations can also be done for the Log-MAP decoder.

α depends on the statistics of the noise and β depends on the noise statistics and the probability of the ideal symbols s_i, s_j. A crucial aspect of the decoder is the dependence of α and β on the decoder output, so additional storage of all possibilities are required before any decision is made.

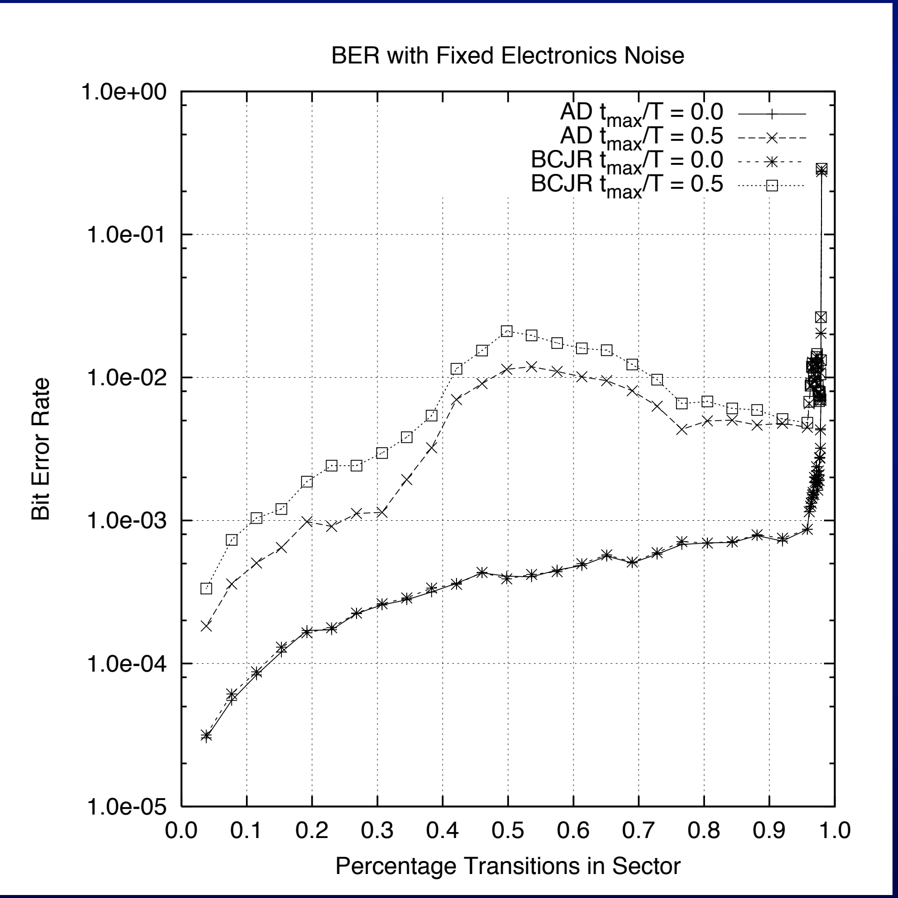
5 Results and Future Work

- The results compare fixed electronics SNR, and varying the maximum transition jitter within a sector of 4096 bits are shown for GPR[0.74,0.83,0.33,0.08,0.01] at different recording densities.
- Results without ECC are for SNR of 16dB and with ECC are at 12dB.
- Results are shown for increasing recording frequency.

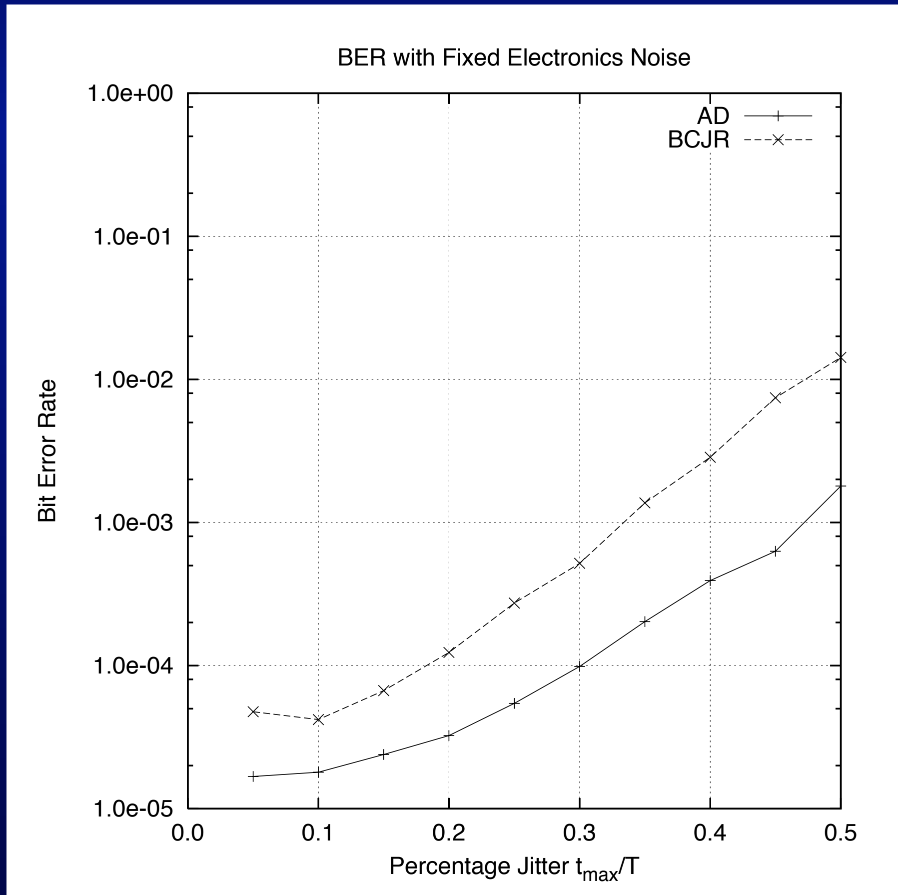
Results Before Error Correction - Low $D_{50} = 1.0$



Results Before Error Correction - High $D_{50} = 1.4$



6 Results After Error Correction - $D_{50} = 1.0$



- Results show promise especially in the presence of error correction.
- The effects of Inter–Symbol Interference in spreading the data dependance of sampling jitter at higher recording densities is very interesting and solvable, but computationally prohibitive at present.
- There appears to be pattern dependant errors at high frequency, possibly linked to ISI.
- The effect of new algorithms that produce near ML decoding using iterative algorithms[5] is also being investigated.

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