ROBUSTNESS OF PER-SURVIVOR ITERATIVE TIMING RECOVERY IN PERPENDICULAR RECORDING CHANNELS

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Per-survivor iterative timing recovery was proposed in [1] to jointly perform timing recovery, equalization, and error-correction decoding. In this paper, we investigate the robustness of per-survivor iterative timing recovery against thermal asperity (TA) [2] and in ultra-high media noise environment in perpendicular recording channels. The readback signal, $p(t)$, in Fig. 1 can be written as

$$p(t)=\sum_k \left(a_k/2\right)\left\{g(t-kT-\Delta t_k-\tau_k)-g(t-(k+1)T-\Delta t_{k+1}-\tau_k)\right\}+n(t)\,, \qquad (1)$$

where $a_k \in \{\pm 1\}$ is a binary input sequence with bit-period T and $n(t)$ is AWGN with power σ^2. The transition response is given by $g(t) = \mathrm{erf}(\sqrt{\ln 16}\, t/\mathrm{PW}_{50})$ where $\mathrm{erf}(\cdot)$ is an error function and PW_{50} is the width of the derivative of $g(t)$ at half its maximum. The media jitter noise, Δt_k, is modeled as a random shift in the “transition position” with a Gaussian probability distribution function with zero mean and variance $|b_k|\sigma_j^2$ (i.e., $\Delta t_k \sim \mathcal{N}(0, |b_k|\sigma_j^2)$) truncated to $T/2$. The clock jitter noise, τ_k, is modeled as a random walk, i.e., $\tau_{k+1} = \tau_k + \mathcal{N}(0,\sigma_w^2)$. The readback signal is filtered by a seventh-order Butterworth low-pass filter and is sampled at time $kT + \hat{\tau}_k$, where $\hat{\tau}_k$ is an estimate of τ_k. The sampler output s_k is then equalized to a predetermined target. The sampling phase offset is updated by a second-order PLL according to $\hat{\tau}_{k+1} = \hat{\tau}_k + \alpha\hat{\varepsilon}_k + \hat{\theta}_k$, where $\hat{\theta}_k = \hat{\theta}_{k-1} + \beta\hat{\varepsilon}_k$, and α and β are PLL gain parameters. In the conventional receiver, conventional timing recovery is followed by a turbo equalizer, which iteratively exchanges soft information between a soft-in soft-out (SISO) equalizer and an SISO decoder.

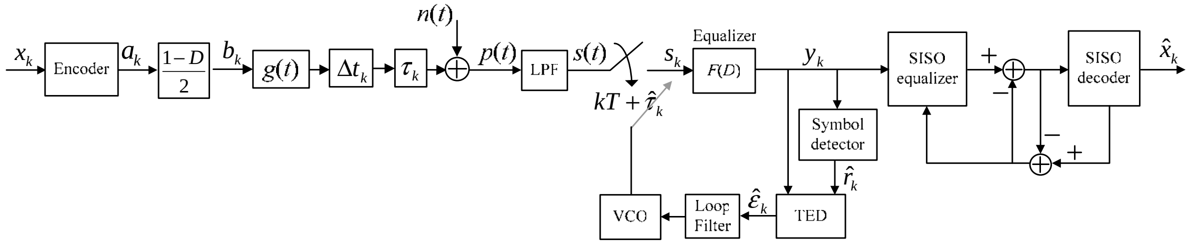

Figure 1. System model.

Results

We consider a rate-8/9 coded system in which a block of 3640 message bits, $\{x_k\}$, is encoded by a regular (3, 27) LDPC code, resulting in a coded block length of 4095 bits, $\{a_k\}$. The SISO equalizer is implemented based on a soft-output Viterbi algorithm, and the SISO decoder is implemented based on the message passing algorithm with 5 internal iterations. To account for a coded system, we define a *user density*, D_u, as D_u = ND/code rate. Also, we consider a perpendicular recording channel with σ_w/T = 0.5% clock jitter noise and 0.2% frequency offset. The SNR is defined as SNR = $10\cdot\log_{10}(E_i/N_0)$ in dB, where E_i is the energy of the channel impulse response (the derivative of the transition response scaled by 2). The GPR target and a 21-tap equalizer are designed at SNR required to achieve BER = 10^{-5}.

First, we investigate the robustness of per-survivor iterative timing recovery in the presence of TA after applying the TA detection and correction algorithm [2]. The TA signal is generated according to [2] and is added to $p(t)$ before low-pass filtering. Fig. 2(a) compares the performance of different iterative timing recovery schemes at the 5-th iteration for D_u = 2, σ_j/T = 3% media jitter noise, and a 3-tap GPR target. Clearly, per-survivor iterative timing recovery is more robust against TA than the conventional receiver. This is because it can automatically correct a cycle slip, as opposed to the conventional receiver.

Noise in magnetic recording channels is also *data-dependent*, whose severity depends on the data pattern written on the disk. A *pattern-dependent noise-predictive* (PDNP) technique [3] has been proposed to combat with the data-dependent noise. Hence, we apply the PDNP technique in PSP-SOVA [1], resulting in PSP-SOVA-PDNP. This scheme has high complexity because it requires trellis expansion. To reduce its complexity, we perform the PDNP technique in a per-survivor manner [1], resulting in PSP-SOVA-PDNP-MO, which requires no trellis expansion. Fig. 2(b) compares the performance of different iterative timing recovery schemes when they have *same* complexity for D_u = 3, σ_j/T = 10%, and a 4-tap GPR target. It can be shown that 1 iteration of per-survivor iterative timing recovery using PSP-SOVA-PDNP has the complexity approximately equal to 4 iterations of the conventional receiver, and 8 iterations of per-survivor iterative timing recovery using PSP-SOVA-PDNP-MO. Apparently, per-survivor iterative timing recovery using PSP-SOVA-PDNP-MO performs better than other schemes.

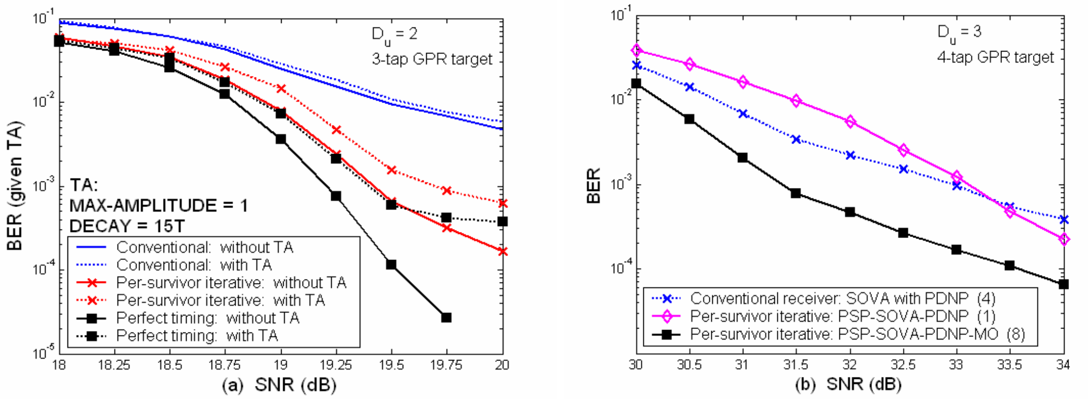

Figure 2. Performance comparison.

References

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