OVERSAMPLED TIMING RECOVERY FOR MAGNETIC RECORDING CHANNELS

Piya Kovintavewat[1], M. Fatih Erden[2], Erozan Kurtas[2], and John R. Barry[1]
(1) Georgia Institute of Technology, Atlanta, GA 30332 (2) Seagate Technology, Pittsburgh, PA 15222

Timing recovery (TR) is a crucial component of a magnetic recording channel detector. It has shown in [1] that a fractionally-spaced equalizer (FSE) performs better than a T-spaced equalizer (TSE), where T is a bit period, due to its insensitivity to the choice of sampling phase used. To improve TR performance, we take advantage of an FSE to propose the oversampled TR (OTR) in the applications of longitudinal and perpendicular recording channels. Its performance will be with the symbol-rate TR (STR). The readback signal, $r(t)$, in Fig. 1 can be expressed as

$$r(t) = \sum_k a_k \left\{ g(t - kT - \tau_k - |b_k/2| \cdot \Delta t_k) - g(t - (k+1)T - \tau_k - |b_{k+1}/2| \cdot \Delta t_{k+1}) \right\} + n(t), \quad (1)$$

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, $g(t)$, for longitudinal recording is taken as $g(t) = 1/(1+(2t/PW_{50})^2)$ where PW_{50} is the width of $g(t)$ at half of its peak value, whereas that for perpendicular recording is $g(t) = \mathrm{erf}(\sqrt{\ln 16}\, t/PW_{50})$ 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 an i.i.d. sequence with a Gaussian distribution with zero mean and variance σ_j^2 (i.e., $\mathrm{N}(0, \sigma_j^2)$) truncated to $T/2$. The clock jitter noise, τ_k, is modeled as a random walk, i.e., $\tau_{k+1} = \tau_k + \mathrm{N}(0, \sigma_w^2)$. The readback signal is filtered by a low-pass filter whose cutoff frequency is at $N/(2T)$ and then sampled at $t_m = mT/N + \hat{\tau}_k$, where $k = \lfloor m/N \rfloor$ and $\lfloor \bullet \rfloor$ takes on the smallest integer value. 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. The STR ($N = 1$) employs an M&M TED [2], whereas the OTR with $N = 2$ uses an early-late TED [2]. The received sequence, z_m, is equalized by a T/N-spaced equalizer, $F(D)$, and downsampled by N to obtain a T-spaced sequence, y_k. The equalizer shapes the signal to a general partial response (GPR) target. The design of the GPR target and its corresponding equalizer can be found in [3]. Eventually, the VD performs Viterbi detection.

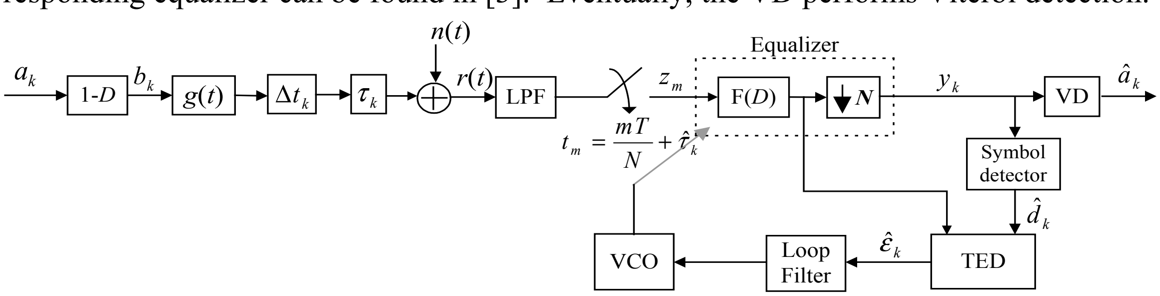

Figure 1. System model.

Results

We consider a normalized recording density ND = PW_{50}/T = 2.5 for both longitudinal and perpendicular recording channels with σ_j/T = 3% media jitter noise, σ_w/T = 0.5% clock jitter noise, and 0.4% frequency offset. The SNR is defined as SNR = $10\cdot\log_{10}(V^2/\sigma^2)$ in dB, where V is the signal peak amplitude (assumed to be 1). The 5-tap GPR target and a 21-tap equalizer are designed at SNR required to achieve BER = 10^{-5}. We use a linearized model of PLL [2] to design α and β assuming that there is no noise in the system and the S-curve slope of TED [2] is equal to one at the origin. The PLL gain parameters were then designed to recover phase and frequency changes in "Tss" bit periods (the smaller the Tss, the faster the convergence rate). Same PLL gain parameters were used during acquisition and tracking modes. Each BER point was computed using as many data packets as needed to collect at least 1000 error bits. One data packet consists of a preamble of length Tss and a 4096-bit input data sequence.

Fig. 1 (left) indicates that the OTR performs better than the STR for all cases in londitudinal recording, especially when Tss is small (i.e., when operating in a system that requires a fast convergence rate). In perpendicular recording, the OTR yields a small gain over the STR when using α and β designed for Tss = 256, as depicted in Fig. 1 (right). Nevertheless, a large gain is obtained when utilizing α and β designed for Tss = 100 and Tss = 50. Thus, the OTR performs better than the STR in both longitudinal and perpendicular magnetic recording systems, especially when fast convergence (small Tss) is required.

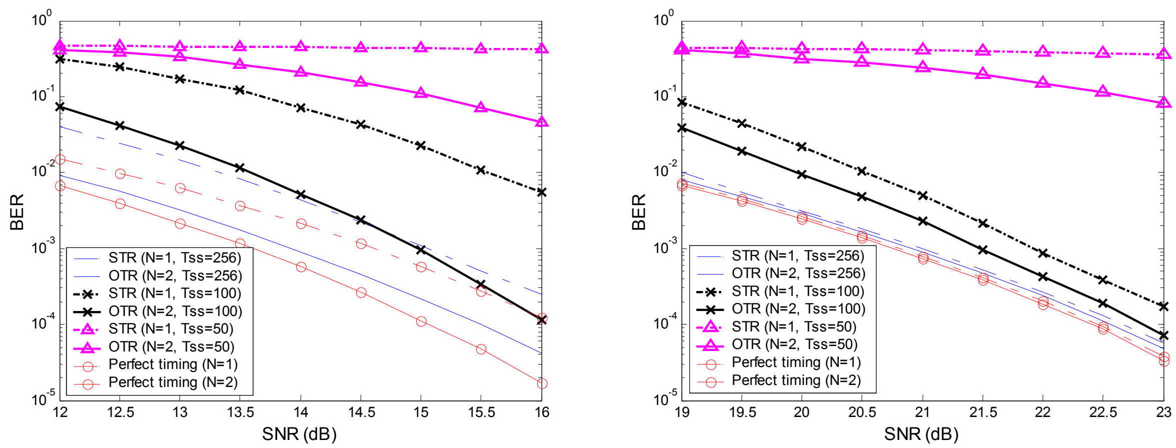

Figure 1. Performance comparison using PLL gain parameters designed to achieve diffirent convergence rates for longitudinal (left) and perpendicular (right) recording channels at ND = 2.5.

References

[1] G. Ungerboeck, "Fractionally tap-spacing equalizer and consequences for clock recovery in data modem," *IEEE Trans. on communications*, Vol. COM-24, No. 8, pp. 856-864, August 1976.

[2] Jan W. M. Bergmans, *Digital baseband transmission and recording*, Kluwer academic publishers, Boston/London/Dordrecht, 1996.

[3] Jaekyun Moon and Weining Zeng, "Equalization for maximum likelihood detector," *IEEE Trans. on Magnetics*, Vol. 31, No. 2, March 1995, pp. 1083-1088.