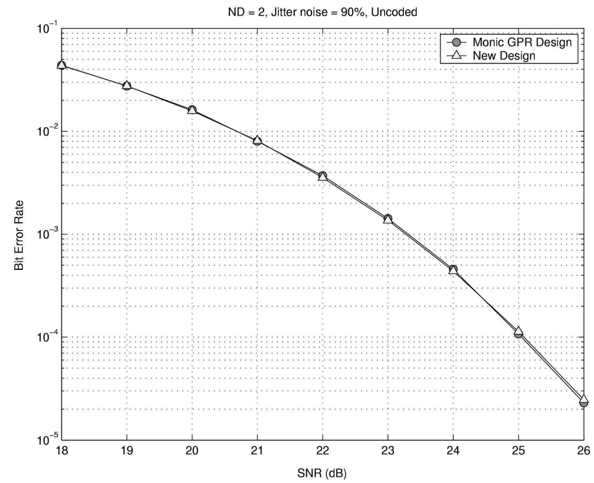
GQ-11

Optimal Equalizers and Targets for Detection in ISI Channels.

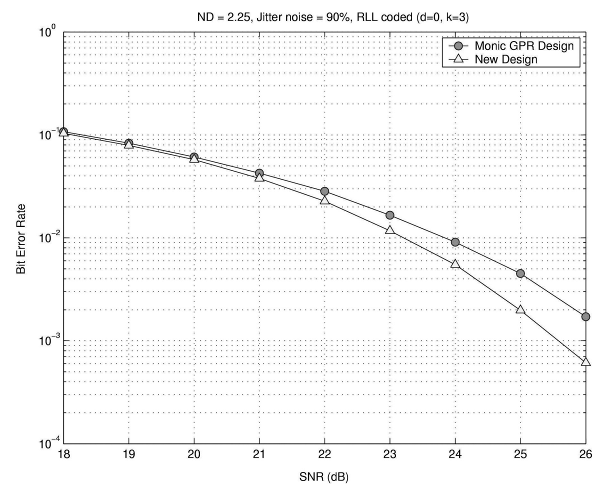
R. Venkataramani[1] and F. Erden[1]
1. Seagate Technology, Pittsburgh, PA, USA

Introduction: The equalizer is an important functional block in read channel architecture of magnetic recording systems. The function of the equalizer is to modify the channel response to reduce the length of the intersymbol interference (ISI) in the system. This, in turn, reduces the complexity of the sequence detector. Traditionally, the equalizer is designed so that the equalized channel response approximates a pre-specified target response which is a short FIR sequence.
Two commonly studied equalizers are the zero-forcing equalizer (ZFE) and the minimum mean-squared error (MMSE) equalizer. The ZFE forces the equalized channel response to match the target response exactly. The undesired effect of zero forcing is that it colors the noise spectrum and may amplify the noise significantly. In contrast, the MMSE equalizer minimizes the variance of the equalization error. The equalization error is spectrally white but signal dependent. In both cases the goal is to make the equalized channel response close to the target response. In particular, the MMSE equalizer designed in conjunction with a monic generalized partial response (GPR) target [1] has been observed to perform extremely well in practice.
In this paper we consider the alternate approach of designing the equalizer and target jointly so that they minimize the overall bit-error rate in the system. Our main result is theoretical analysis that shows that the MMSE equalizer and the monic GPR target do indeed perform the best (compared to other designs) for uncoded inputs. However, for spectrally shaped coded inputs, the proposed design produces filters that are different from those GPR design. Thus, we predict a gain with the new design over the monic GPR design for coded signals.
Simulation Results: We apply our results to the magnetic recording channel. The magnetic recording medium is modeled as an ISI channel with additive Gaussian electronic noise and transition jitter noise [2]. The transition jitter noise is modeled as a truncated Gaussian random variable. For perpendicular recording, the transition response is an error function. We adopt the signal-to-noise ratio (SNR) used in [2, chapter 6].
We design length-31 MMSE DFE equalizers and length-3 targets monic GPR targets [1] and compare their performance to the proposed design. We compute the resulting bit error rate by simulations for both target and equalizer design algorithms at various SNRs. We first consider uncoded (IID) inputs applied to a channel operating at a normalized density of 2 and 90% jitter noise. Figure 1 shows the resulting BER performance. As predicted, both design algorithms perform nearly identically and optimally. Next, consider a run-length limited (RLL) (0,3) code [3] with a code rate of 8/9 applied to a channel with 90% jitter noise and a normalized density of 2.25 to still keep the user density 2. Figure 2 shows the BER at the output of the Viterbi detector. We clearly see the performance gain of the proposed design over the monic GPR design. This is consistent with our prediction that the monic GPR design is suboptimal for colored inputs.

[1] J. Moon and W. Zeng, "Equalization for maximum likelihood detectors," IEEE Trans. Magnetics, vol. 31, no. 2, pp. 1083—88, March 1995.
[2] Bane Vasic and Erozan Kurtas, Eds., Coding and Signal Processing for Magnetic Recording Systems, CRC Press, 2005.
[3] K. A. Schouhamer Immink, Codes for Mass Data Storage Systems, Shannon Foundation Publishers, 1999.



BER performance for IID inputs at 90% jitter noise.



BER performance for RLL coded inputs at 90% jitter noise.