MINIMUM MEAN SQUARE ERROR CHANNEL TRUNCATION FOR MAGNETIC CHANNELS

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Basic Idea

To achieve higher data densities while maintaining a low bit error probability, many systems incorporate an equalizer. We present a non-traditional design criterion for use in a magnetic data recording system. This criterion is different from the standard minimum mean square error (MMSE), zero-forcing (ZF), or target-based (such as EPR4 targets) designs that have appeared in the literature. The critical idea is to relax traditional constraints and allow *any* intersymbol interference (ISI) within a certain time-window. The resulting equalizer has less noise gain leading to a lower bit error rate for a given signal-to-noise ratio than the traditional equalizers when each is used with a companion sequence detector.

Notation

We introduce the following notation for the magnetic storage channel as in Figure 1 wherein: s_k is a zero mean, independent, identically distributed (iid) source sequence; x_k is the channel output sequence; n_k is a zero mean, iid noise sequence; $C = [c_0 \ c_1 \ \dots \ c_n]^T$ is the length $n+1$ channel impulse response vector (here a Lorentzian is used); $D = [d_0 \ d_1 \ \dots \ d_m]^T$ is the length $m+1$ equalizer tap weight vector (to be designed); y_k is the equalizer output sequence. We assume that the equalizer output y_k is then input to some limited complexity detector (Viterbi like) matched to the combined channel-equalizer impulse response.

Figure 1: System Block Diagram

Equalizer Design Criterion

The standard MMSE criterion minimizes squared difference between the equalizer output y_k and some previous source symbol $s_{k-\Delta}$ with $J_{MSE} = \mathcal{E} \{ (y_k - s_{k-\Delta})^2 \}$. Given that we have a limited complexity detector following the equalizer, we may allow a limited number (L) of post-cursor ISI components without cost penalty. L is chosen based on the complexity of detector. Thus, we choose the equalizer design cost function as

$$J_{CT} = \mathcal{E} \left\{ \left(y_k - \left(s_{k-\Delta} + \sum_{\ell=1}^L h_{\ell} s_{k-\Delta-\ell} \right) \right)^2 \right\}$$

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calling this the "channel-truncation" cost function. The terms h_{ℓ} (which denote the combined channel-equalizer response) are allowed to take *any* value. This is different than target-based designs which mandate *a priori* selection of the desired channel-equalizer response. Let C denote channel convolution matrix. The optimal equalizer with the new criterion is,

$$D_{opt} = \left(C^* M C^T + \frac{\sigma_n^2}{\sigma_s^2} I \right)^{-1} \tilde{C}^*$$

where M is the identity matrix with the $\Delta+1$ through $\Delta+L$ diagonal elements set to zero and $\tilde{C}^* = [c_{\Delta}^* \ \dots \ c_{\Delta-L-m}^*]$.

Performance Results

We compare the performance of magnetic systems using the channel-truncation criterion compared with a MMSE based on a EPR4 target for a Lorentzian pulse channel. We choose $\beta/T = 2.7$ (density parameter). The performance figure of merit is denoted $FOM = \frac{80}{NG \times ISI}$ where $SG = \sum_{i=\Delta}^{\Delta+L} |h_i|^2$ (signal gain), $NG = \sum_{i=0}^m |d_i|^2$ (noise gain), $ISI = \sum_{i=0}^{\Delta-1} |h_i|^2 + \sum_{i=\Delta+L+1}^{\infty} |h_i|^2$ (isi). (Consider the signal power entering the detector (SG) a useful quantity, while the noise gain (NG) and isi outside of the detector's "window" (ISI) have deleterious effects.) The channel-truncation criterion has a better performance metric over a wide range of SNR's. A point of interest around 20dB SNR shows approximately a 2.5dB FOM improvement (Figure 2b shows $FOM_{CT} - FOM_{MMSE}$).

Figure 2: Performance Comparison & Improvement of Using New Criterion

References

- [1] P. Melsa, R. Younce, C. Rohrs, "Impulse Response Shortening for Discrete Multitone Transceivers", *IEEE Trans on COMM*, Vol 44, No 12, Dec 96.
- [2] J. P. LeBlanc, S. W. McLaughlin, "Enhanced RAM-based Equalizers for Nonlinear Channels" *32nd Asilomar Conference on Signals, Systems, and Computers*, Asilomar, CA, Nov. 1998