Continued simulating media noise list detector. Written a brief document describing the media noise detector (you should already have a soft copy, but in case you do not here it is again).

Experimented with number of best paths passed to non-linear PP by linear PP. Observed that Viterbi output + best error event is enough to get the gain. There is almost no gain by further increasing number of errors in the list.

Added a single bit parity code to the media noise detector. Observed that there is no gain due to the parity code in terms of BER (over uncoded media noise detector). If you remember the system we used at ultra high UBD ("extended target in a PP") also does not give any gain if parity is added. I think this is due to the fact that most of the error events corrected by the parity PP, have been already fixed by utilizing non-linear info or, as in the case of "extended target", better noise whitening. So maybe we should look at multiparity???

Increased number of states in the non-linear PP (by adding some future/past bits). This did not give any gain.

Read Lucent's patent on media noise detector more carefully. It seems that Lucent did not patent list detector (since this was presented by K. Knudson, et al GLOBCOM'93), instead they patented the media noise PP as a whole, i.e. the system comprising of linear Viterbi and beefed-up PP which utilizes some extra information not used by Viterbi (e.g. non-linear noise, extended whitening filter, etc. And of course as I mentioned earlier, Kavcic detector is also patented.

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Detection in the Presence of Media Noise

Greg Burd

1.0 Introduction

This paper considers a problem of signal detection for Inter-symbol Interference (ISI) channels with pattern dependent media noise. Maximum A Posteriori detector for such channels was developed by Kaucic and Moura, see [1] for more details. Even though Kaucic’s detector provides significant gains over conventional Viterbi detector in the presence of media noise, it is not very appealing due to implementation complexity. This paper presents a sub-optimal version of Kaucic’s detector which provides nice trade-off between the performance and complexity of original algorithm.

2.0 Non-linear channel model

Figure 1 shows a typical magnetic recording system

Here the channel is modeled as non-linear ISI channel with signal dependent media noise. Let \( h(D) = h_0 + h_1 D + h_2 D^2 + h_3 D^3 + h_4 D^4 \) be Viterbi target polynomial. Let \( x(D) \) represent channel input and \( y(D) \) be its output. For the non-linear channel \( y(D) \) is modeled by

\[
y_j(x(D)) = \tilde{y} + m_t(x(D)) + n_j \tag{EQ 1}
\]

where \( \tilde{y} = \sum_{k=0}^{4} x_{i-k} h_k \), and \( m_t(x(D)) \) is the non-linear pattern dependent media noise contribution. The noise term, \( n_j \), is Markov process with memory \( L \),

\[
n_j(x(D)) = \sum_{j=1}^{L} f_j(x(D)) n_{k-j} + \sigma(x(D)) N(0, 1) \tag{EQ 2}
\]

It will be further assumed that all pattern dependent parameters are causal function of \( x(D) \) with the memory equals that of the channel, i.e.
\[ m_f(x(D)) = m\left( x_{i-4} x_{i-3} x_{i-2} x_{i-1} x_i \right) \] (EQ 3)

\[ \sigma_f(x(D)) = \sigma\left( x_{i-4} x_{i-3} x_{i-2} x_{i-1} x_i \right) \] (EQ 4)

\[ f_j(x(D)) = f_j\left( x_{i-4} x_{i-3} x_{i-2} x_{i-1} x_i \right), \text{ for } j=1,..,L \] (EQ 5)

The corresponding non-linear Viterbi Branch Metric (BM) is given by

\[ BM = \sigma^2_{\text{max}} \ln(\sigma^2) + \left[ y - (\bar{y} + m) - \sum_{j=1}^{L} f_j(x(D))n_{\tilde{k}-j} \right] \cdot \left( \frac{\sigma^2_{\text{max}}}{\sigma^2} \right) = \alpha + \left[ y - (\bar{y} + m) - \sum_{j=1}^{L} f_j(x(D))n_{\tilde{k}-j} \right] \cdot \beta^2 \] (EQ 6)

3.0 Media Noise List Detector

The proposed Media Noise detector consists of linear Viterbi detector, Linear Post Processor (linear PP), and non-linear Post Processor (non-linear PP)

**FIGURE 2. Media noise detector diagram**

Linear PP takes sampled channel output and Viterbi decisions as inputs and filters for the dominant error events (a typical list of dominant error events for magnetic recording system includes \{+, -, +-, ++\}, \{+,-,+-,++\}, \{+-,-+,+-+-\}, error events). For each block of length \(C\), linear PP identifies (but does not correct) a list of \(N\) least reliable Viterbi decisions (including location, error type, and polarity) by considering linear Maximum Likelihood Distance Penalty (MLDP) associated with an error event,

\[ MLDP_{lin}(error) = PM_{lin}(\text{viterbi out + error}) - PM_{lin}(\text{viterbi out}) \] (EQ 7)

Linear PP then passes the list to the Non-linear PP which in turn computes MLDP for each error event in the list using non-linear Path Metric of EQ6. Note that
\[
MLDP_{\text{nlin}}(\text{error}) = PM_{\text{nlin}}(\text{viterbi\_out+\text{error}}) - PM_{\text{nlin}}(\text{viterbi\_out}) = \\
\sum (BM_{\text{nlin}}(\text{viterbi\_out+\text{error}}) - BM_{\text{nlin}}(\text{viterbi\_out}))
\]  
(EQ 8)

Figure 3 shows a filter implementing MLDP calculation with non-linear metric.

**FIGURE 3.** MLDP penalty filter

The non-linear PP is then chooses the error event with the smallest non-linear MLDP. Finally the correction is made if this error event has

\[ MLDP(\text{error}) < \text{threshold} < 0 \]  
(EQ 9)

### 4.0 Performance

To study the performance of proposed detector a bit-by-bit simulation have been done at UBD=2.2, with 50/50 media noise as defined in [2], with Viterbi target={4,-3,-2,-3,-2}. The linear PP screens for {+,+-,+-+,+-} error events. The detector parameters are L=3, N=2. Figure 4 shows that proposed list detector is only 0.3 dB away from the optimal Kavcic detector, and gives 1.1dB gain over the conventional linear Viterbi detector.
FIGURE 4.

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Non-Linear detector
UBD=2.2, 50/50 media noise

- Viterbi
- Linear PP
- kavčić\((l=4, L=3)\)
- non-linear Viterbi\((\sigma)\)
- kavčić PP

BER

SNR

18.5
19
19.5
20
20.5
21
21.5