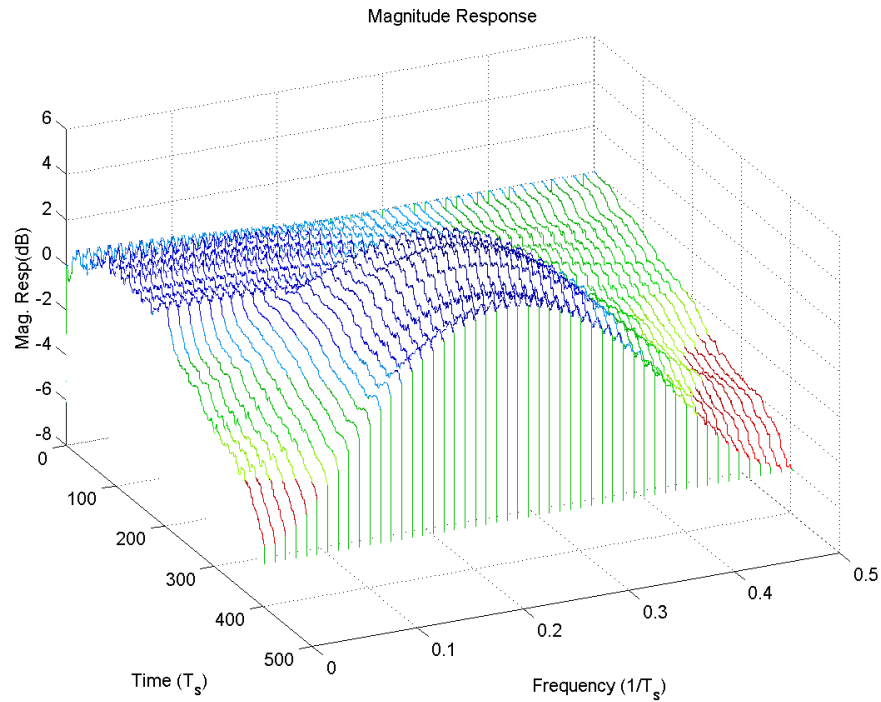
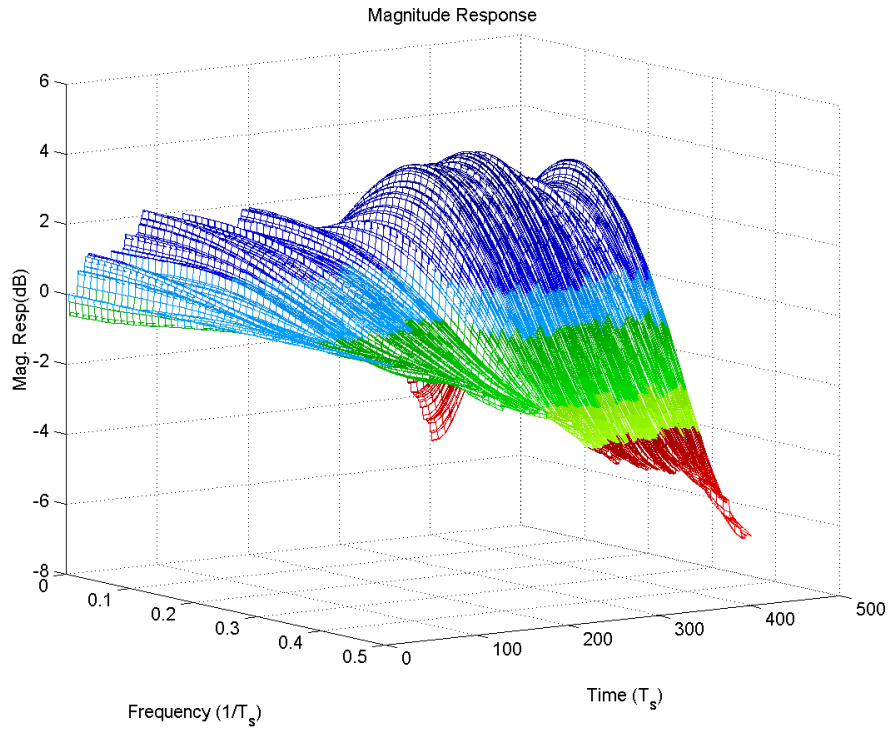


PRML_{pro}TM

A powerful, practical, easy-to-use signal creation, signal analysis and read channel simulation tool for magnetic disk, tape and optical channels.



Head / Media Engineering

Head/media engineers use PRMLpro™ to predict and analyze how their new head/media designs will work with target channels. They use meaningful channel-level metrics such as mean squared error (MSE), Viterbi difference metric (similar to SAM, Sequenced Amplitude Margin) and bit error rate (BER). PRMLpro™ has the flexibility to enable engineers to create their own proprietary performance measures, as well.

Read / Write Channel Engineering

Read channel engineers typically have very accurate, custom, in-house models of the channels they are using. PRMLpro™ does not compete with the channel-specific accuracy and custom features of in-house models. Instead, PRMLpro™ offers read/write engineers a simple way to create noisy, distorted input waveforms for their models. It also can serve as an independent benchmark for evaluating in-house channel models. By following the PRMLpro™ naming conventions and file formats, PRMLpro™'s extensive post-processing analysis and graphics can be applied to the output of in-house models. Furthermore, PRMLpro™ can be used to determine initial conditions for in-house simulations.

By calibrating PRMLpro™'s output to in-house channel models and to current hardware channels, read/write engineers can supply support groups with an easy-to-use, cost-effective channel model. This can empower the field applications engineers and failure analysis engineers to do their jobs better and faster, while freeing the read/write group from providing "help desk" support for their own in-house, high-end, very sophisticated simulations.

Field Applications and Failure Analysis Engineering

Customers want to know what filter cut-off value to select for a new head/media combination. They want your help to determine why their optimization routine has picked vastly different FIR taps after they implemented a drive design change that "shouldn't have affected the channel." The factory has experienced a drop in drive yields and you must determine the cause.

PRMLpro™ can be your first line of analysis for these issues. It provides well-planned graphical output that often speaks for itself. Furthermore, if your customer also uses PRMLpro™, you can exchange files and analysis easily via e-mail. In this way PRMLpro™ facilitates a rich level of communication between you and your customer (or between you and the factory) that was not possible before.

Production technicians can be empowered to capture signals from the problem drive zones and perform initial investigations with PRMLpro™. When they e-mail these PRMLpro™ screens to failure analysis engineering, much more information and insight into the problem is immediately available.

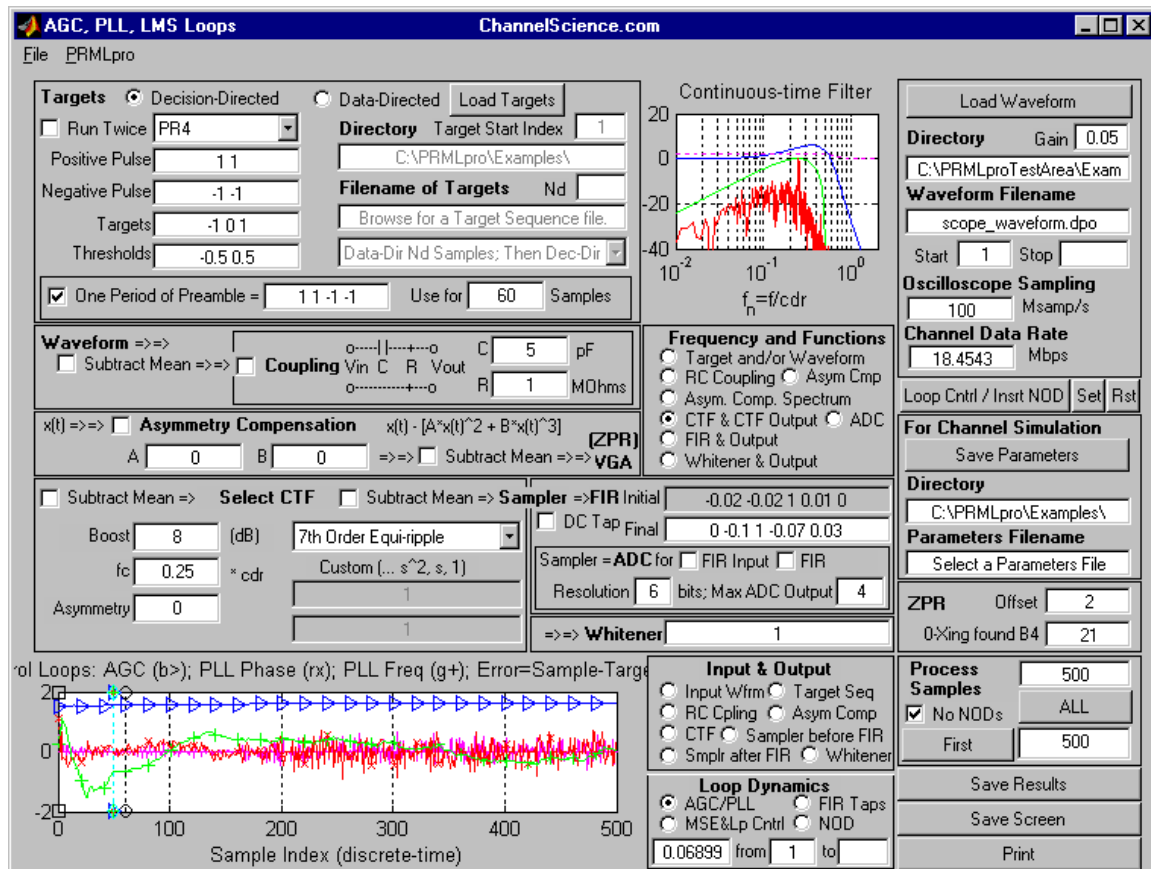
Customer-driven, Customer-supported Enhancements

ChannelScience thanks our customers who have partnered with us and provided financial support to enhance PRMLpro™. We have added key features for optical, tape and disk drives that come directly from working engineers' requests. The best part is getting comments that PRMLpro™ is fun to use!

Please call us (972-814-3441) to discuss customizing PRMLpro™ to meet your company's needs.

AGC, PLL, LMS Loops Screen: The Read Channel Front-end

The AGC, PLL, LMS Loops screen of PRML^{pro}™ provides AC coupling, (G)MR asymmetry compensation, continuous-time filtering (CTF), automatic gain control (AGC), 2nd-order PR4 phase-locked loop (PLL) with zero phase restart (ZPR), least mean square (LMS) adaptation of any size finite impulse response (FIR) discrete-time filter and sample whitening. Both decision-directed (slicer) and data-directed adaptation modes are provided.



The smaller figure in the screen above shows the magnitude and group delay of the CTF. The partial-response target spectrum and the spectrum of the signal at the output of the CTF are also shown. The larger figure provides the loop dynamics of the AGC and the frequency correction applied by the PLL. Also shown in the figure are the phase error and the sample error that drives the phase error. Vertical markers indicate important channel events such as switching from acquisition mode to tracking mode.

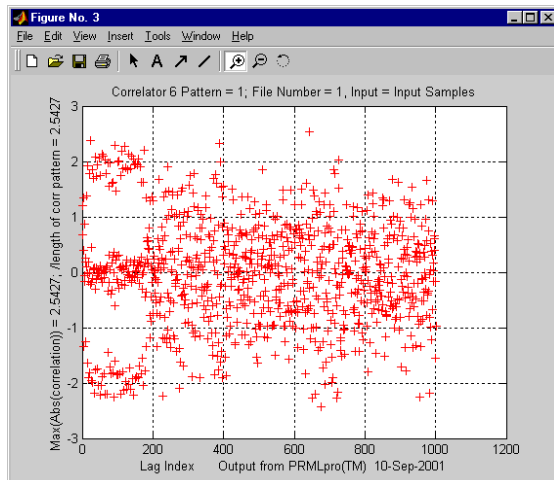
Pressing the “Loop Cntrl / Insert NOD” pushbutton opens a second screen that provides precise control of the AGC, PLL and LMS parameters. It also provides 28 ways to insert noise, offset, and delay (“NOD”) at various key locations in the channel. Gaussian, uniform and additive white binary noise sources are provided.

Every PRML^{pro}™ figure supports zooming in and out. Every PRML^{pro}™ figure can be opened in a larger, individual window that fills the whole screen -- and supports zooming. In this way, even the smallest figures can yield clear, detailed information.

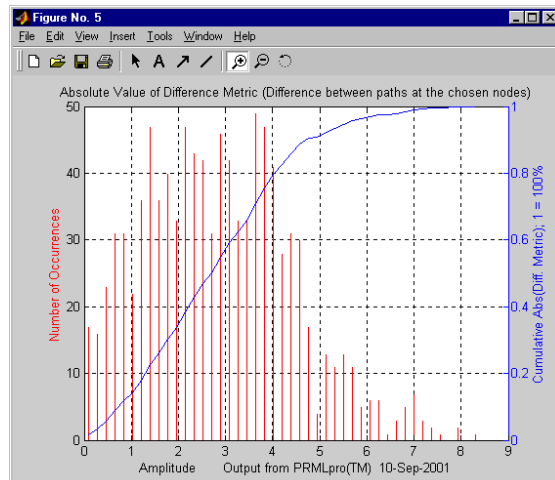
Channel Simulation (BER) Screen: The Viterbi Algorithm and Analysis

The Channel Simulation (BER) screen of PRMLpro™ provides data detection through a generalized Viterbi detector, post-coder and fault-tolerant sync detector. Numerous output analysis options are available for individual files including custom correlators, histograms and cumulative distribution plots. The correlators can be specified to analyze input samples, detector-determined target sequences, sample errors, difference metrics and detector decisions. This simplifies searching for error patterns. Multiple files can be processed to yield BER vs. SNR (signal-to-noise ratio) plots.

Sample Value Plot (Correlator = "1")

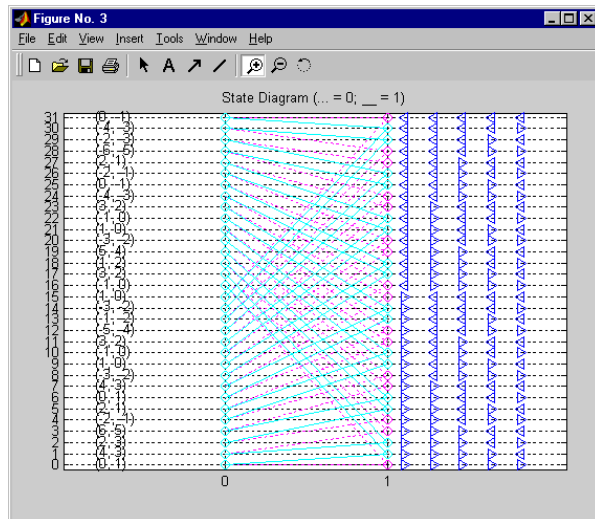
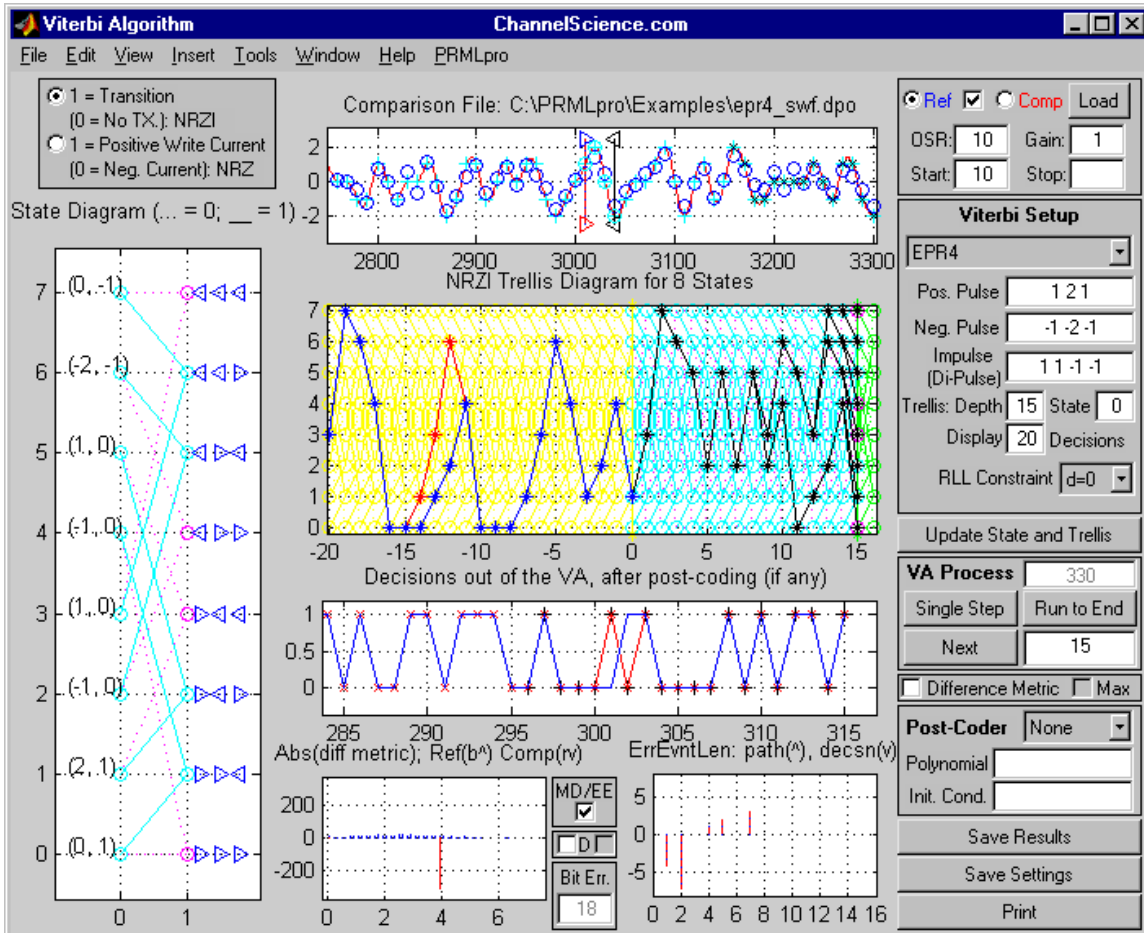


Histogram and Cumulative Distribution



Viterbi Algorithm (VA) Screen: Detailed Analysis of Error Events and Statistics

“What is the bit error rate?” Engineering analysis goes beyond questions like this to “Why is this the bit error rate and what can be done to improve it?” PRMLpro™’s VA screen finds error events and indicates their location in the sample sequence, the Viterbi trellis path and the detected data sequence. Distributions of errors, samples, targets, difference metrics, error events and error event lengths are provided. PRMLpro™ even supports generalized detector targets requiring 32-states or more.

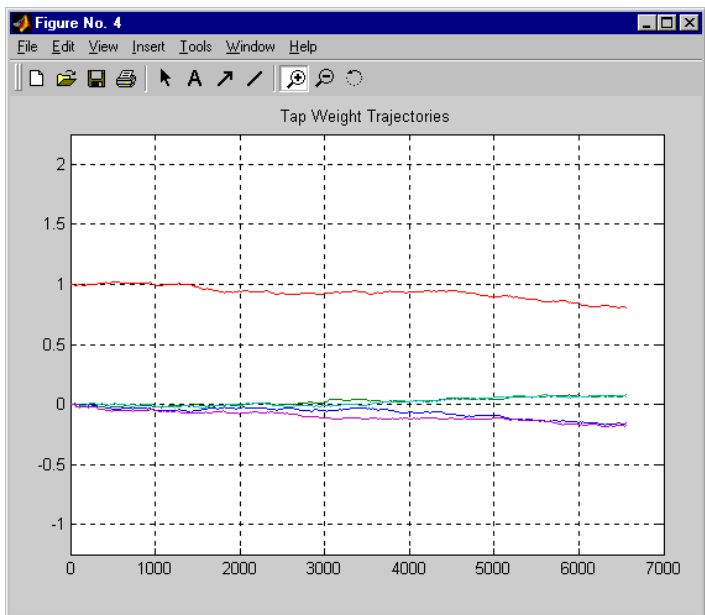
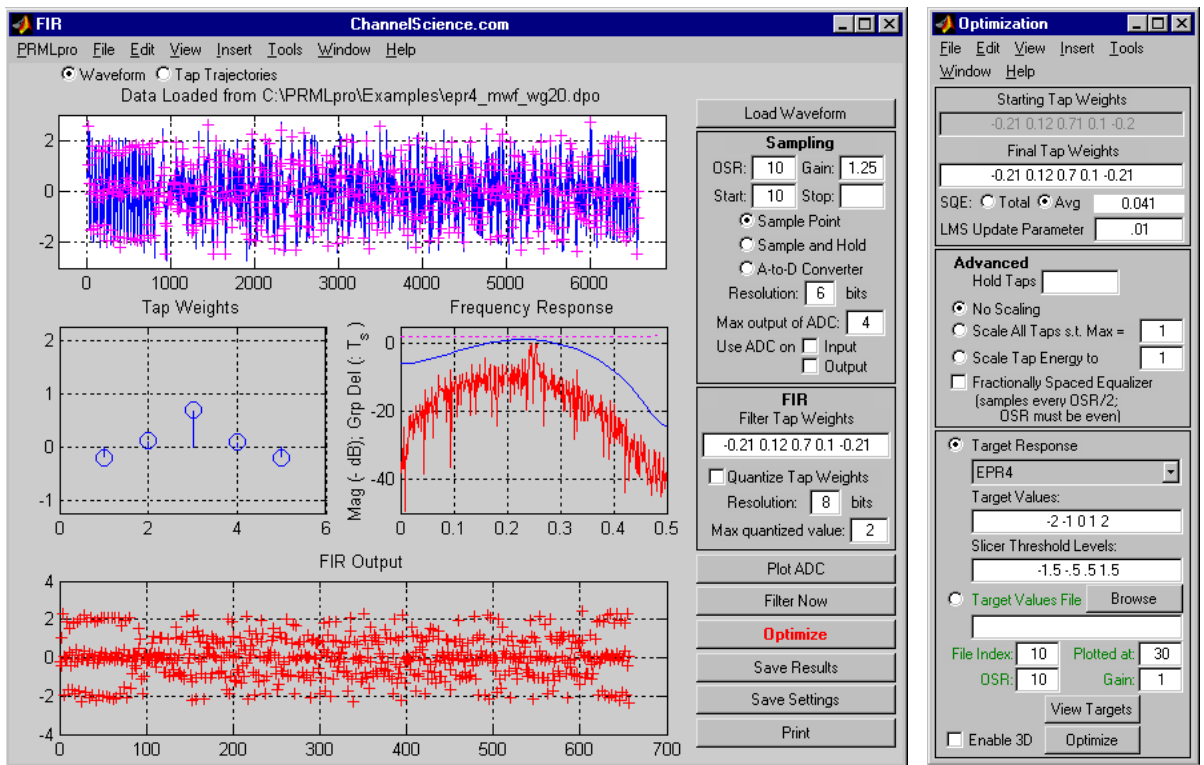


To the left is the state diagram for a 32-state “EEEEPR4” detector. Any depth trellis can be specified. The target values for each path are automatically determined for either NRZ or NRZI interpretations.

The triangles to the right of the figure indicate the condition on the media that each state represents. For magnetic media specifically, this shows the last 5 directions of magnetization.

FIR and LMS Optimization Screens: Any Length FIR, Data- or Decision-directed Adaptation

The Discrete-time Filter (FIR) screen provides time- and frequency-domain insight into FIR filtering. In the figure below, a 5-tap fir is applied to samples of the noisy input waveform. The FIR's output approaches the desired EPR4 target response. Clicking and dragging tap weights results in the recalculation and re-display of the magnitude and group delay plots for the FIR. This helps build intuition about how the FIR is affecting your signal. Analog-to-digital conversion (ADC) is also provided.

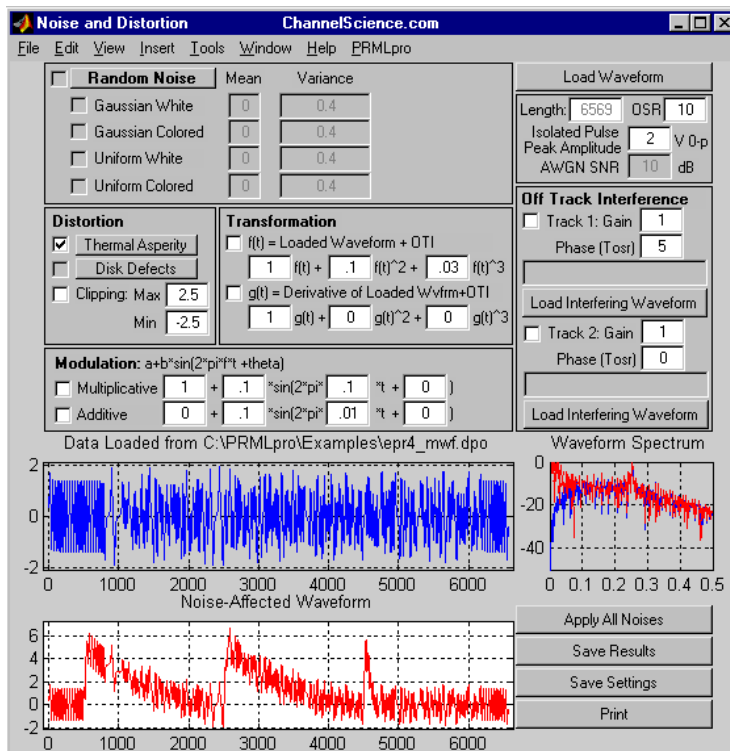
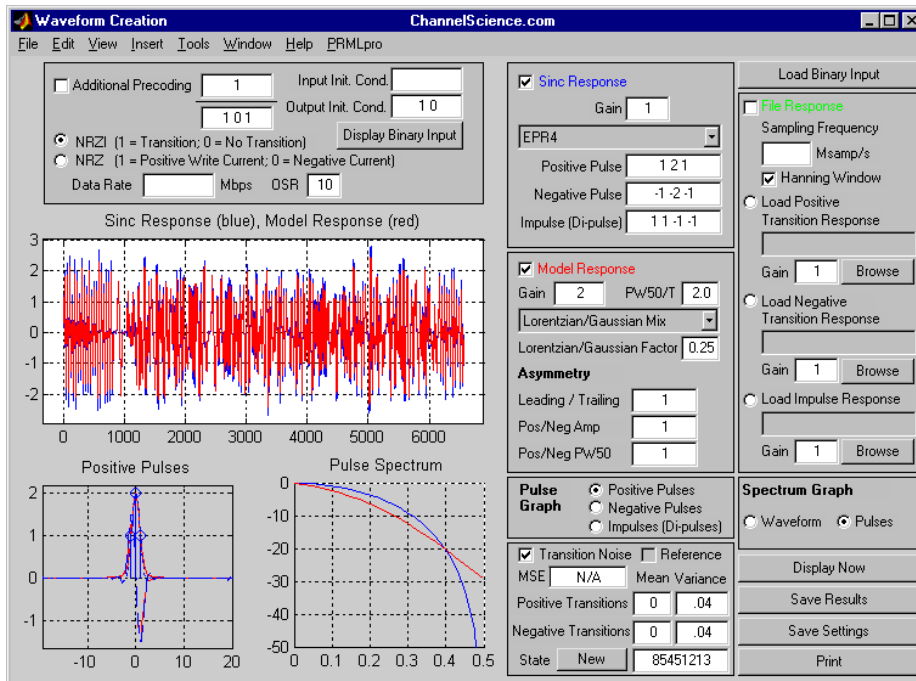


The tap weight trajectories for the 5-tap FIR are shown in the figure to the left. The center tap started at 1, the other taps started at 0. LMS drives the taps to new values based on the input waveform samples and their corresponding target values. Target values can be determined by a slicer (decision-directed mode) or by a file of ideal target samples (data-directed mode).

Repeating adaptation runs, beginning at the previous run's ending values, is an easy way to determine FIR tap settings. Any of the taps, as well as the overall tap weight energy, can be held constant.

Waveform Creation Screen: Modeled or Captured Pulses, with Media Noise

Load in a binary sequence and specify whether it is to be interpreted as NRZ or NRZI. Three waveforms can be created simultaneously, based on this binary sequence. First a flexible sinc model response is provided for standard partial-response, or custom, pulse shapes. Second, popular models for magnetic and optical recording pulses are used. Third, pulse files captured from an oscilloscope or created by your own sophisticated micro-magnetic model can be used to generate a waveform. In addition, a transition-jitter media noise model is available in NRZI mode.



These waveforms can be saved and then input to the Noise and Distortion screen for further processing. This includes adding white and colored noises, thermal asperities (as shown to the left), disk defects, clipping, polynomial transformations, adding interfering waveforms and multiplicative and additive modulation.

Consulting and Customization

ChannelScience offers world-class read channel consulting expertise. We can help you with chip architectures, algorithm development, software simulations, market analysis, patent review, competitive analysis, hardware evaluation and drive-level performance tuning. Our goal is to save you time or save you money or, best of all, both.

We welcome partners for PRML pro TM including hardware and complementary software products such as micro-magnetic and optical signal models. Watch for upcoming announcements of new alliances for PRML pro TM products.

If there are features that you would like to see included in future releases of PRML pro TM, please let us know. Often customers find it advantageous to provide financial support for such additions to more quickly get precisely what they want.

The PRML pro TM Product Family for Microsoft Windows 95/98/NT

PRML pro TM for MATLAB®

PRML pro TM is written in MATLAB®. It can operate from the MATLAB® command window and shares variable with the workspace. All files are in MATLAB® format. Graphs on the GUI can be changed and your own data can be plotted on top of PRML pro TM plots. If you are a MATLAB® user, PRML pro TM for MATLAB® is the right product for you.

PRML pro TM StandAlone

PRML pro TM is written in MATLAB®, but the software can be compiled to executable C and linked with special MATLAB® libraries from The MathWorks. You do not need to purchase MATLAB® in order to use PRML pro TM StandAlone.

PRML pro TM Student Edition

This version is available as a 30-day free trial download from www.ChannelScience.com. A license for the Student Edition is only available to participants in the class "PRML Lab," written by ChannelScience and offered through KnowledgeTek, Inc. The Student Edition is similar to PRML pro TM StandAlone except for certain limitations on file size and access to advanced features.

The Student Edition is also available to universities, at a very low price. Call 972-814-3441 for details.

References

For details on the front-page images see: C.H.Sobey and B.S. Russell, "LMS Filter Adaptation in PRML Channels," *Data Storage Magazine*, August 2000, pp. 15 - 22. Available at www.DataStorge.com.

Sequenced Amplitude Margin (SAM) Reference: Tim Perkins and Zak Keim, "A Window-Margin-Like Procedure for Evaluating PRML Channel Performance," *IEEE Trans. Magn.*, vol. 31, no.2, pp. 1109-1114, March 1995.

Additive White Binary Noise Reference: J.L. Sonntag and N. Sayiner, "Using Additive White Binary Noise to Marginalize Read Channels," *IEEE Trans. Magn.*, Vol. 34. No. 1, January, 1998, pp. 178-180.

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