

NRZ Simulation over Ad Hoc pre-selected Channels

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Outline

- Objectives and motivation
- Simulations Environment
- Tyco cases 1-7 simulation results
- PETER's channels simulation results
- Analysis
- Summery

Objectives and Motivation

- Simulate NRZ signal on Ad-Hoc pre-selected channels
- Use small size (taps) equalizer: 3 FFE, 5 DFE.
- Use Signed-LMS for adaptation.
- Define the list of channels that NRZ, with minimum hardware, can solve.

- Motivation: demonstrate that NRZ signaling with optimized (small number of taps) equalizer can resolve most channels.
- Motivation: define equalizer architecture that is simple to implement in low cost CMOS technology.
- Motivation: suggest channels that can be solved with NRZ signaling, to prevent over design.

Method

- Simulation environment for NRZ signaling, including impairments: Jitter, NEXT, FEXT, package, AC coupling, white noise.
- Simulate over the Tyco cases 1-7.
- Simulations of PETER's channels.
- Analyze results.

Computing BER

- BER calculation under the assumption of worst case Gaussian noise.

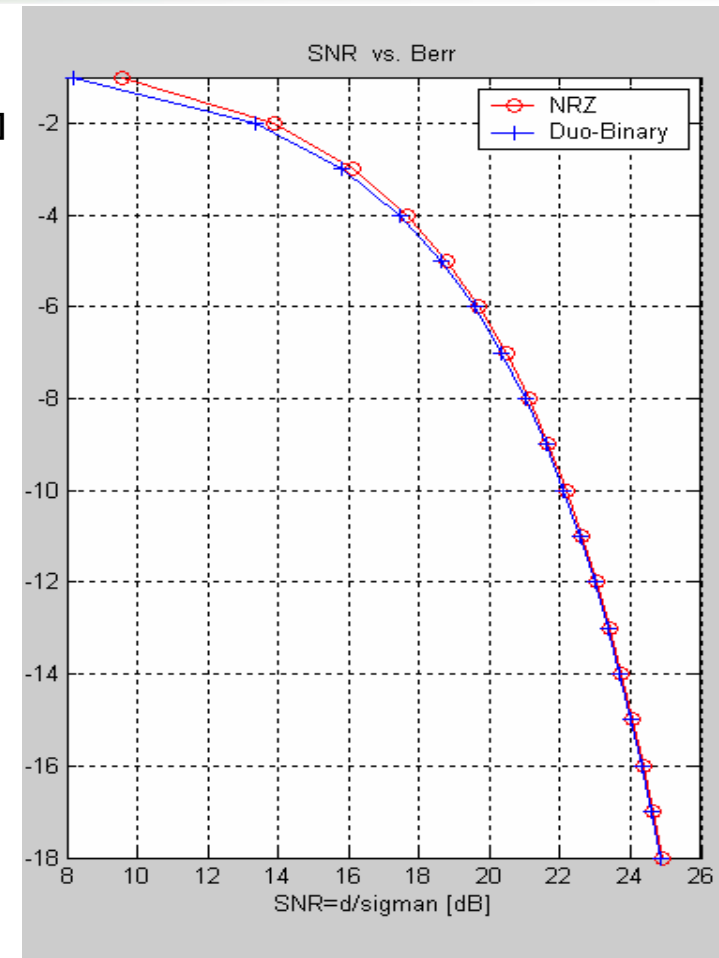
$$BER_{NRZ} = Q\left(\frac{d_{\min}}{2\sigma_n}\right)$$

- dmin**= Minimum distance between “symbols” at point where decision is made.

- $SNR = \frac{d_{\min}^2}{\sigma_n^2}$ = noise variance at slicer input.

- BER=10e-12 requires SNR = ~23dB
- BER=10e-15 requires SNR = ~24dB
- BER=10e-18 requires SNR = ~25dB

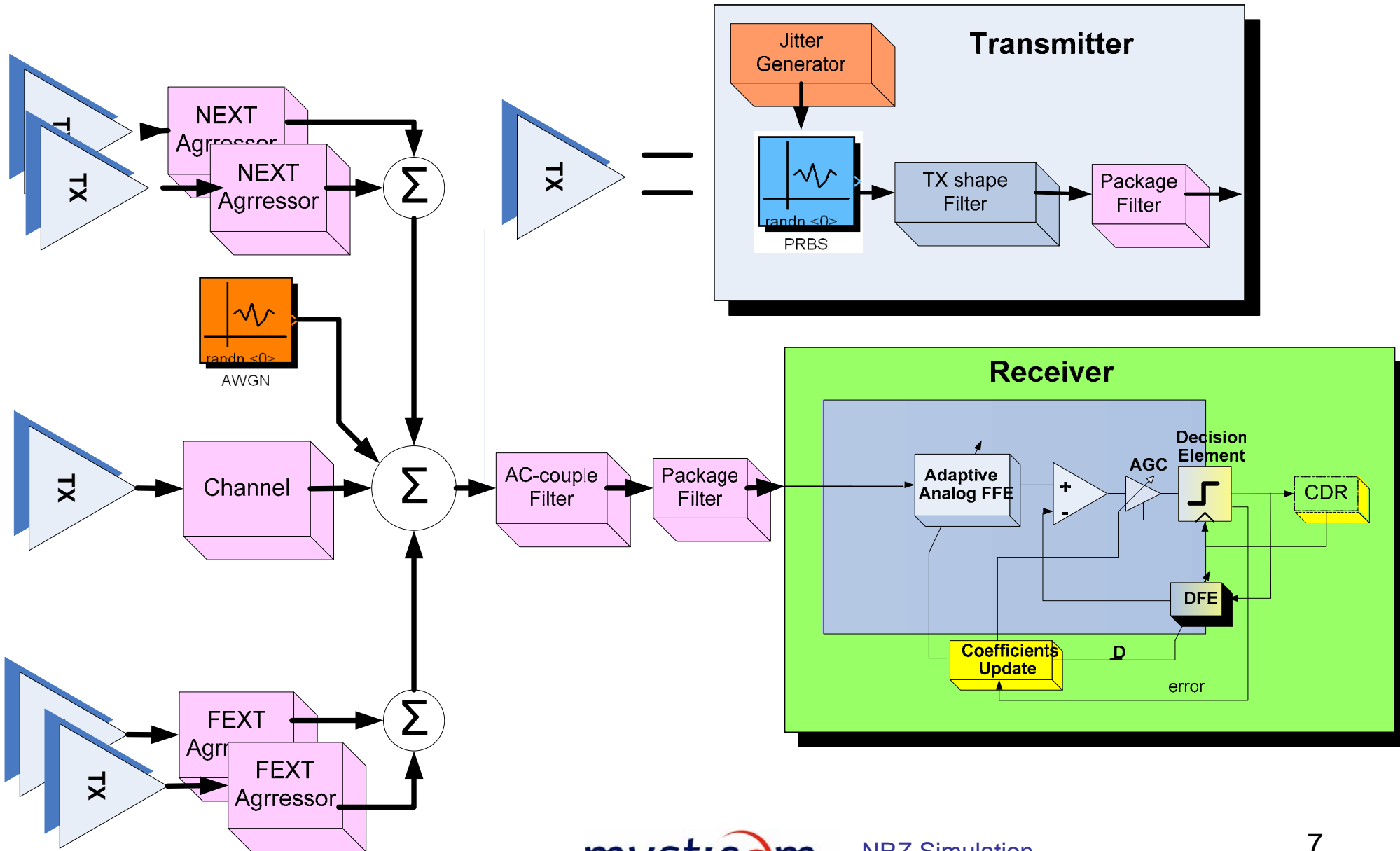
BER [10^Y]



Simulation Tool

- Internal tool that was developed in Mysticom, called X-system.
- Tool is based on C++, with Simulink as its GUI.
- Simulations are in the time domain. S-param models are translated into Impulse response and implemented as a filter in the time domain.
- Tools was validated on previous silicon and products (1000Base-T, XAUI, CX4,...) - showed very good correlation between lab measurements and simulation results.

Simulation Environment Block Diagram



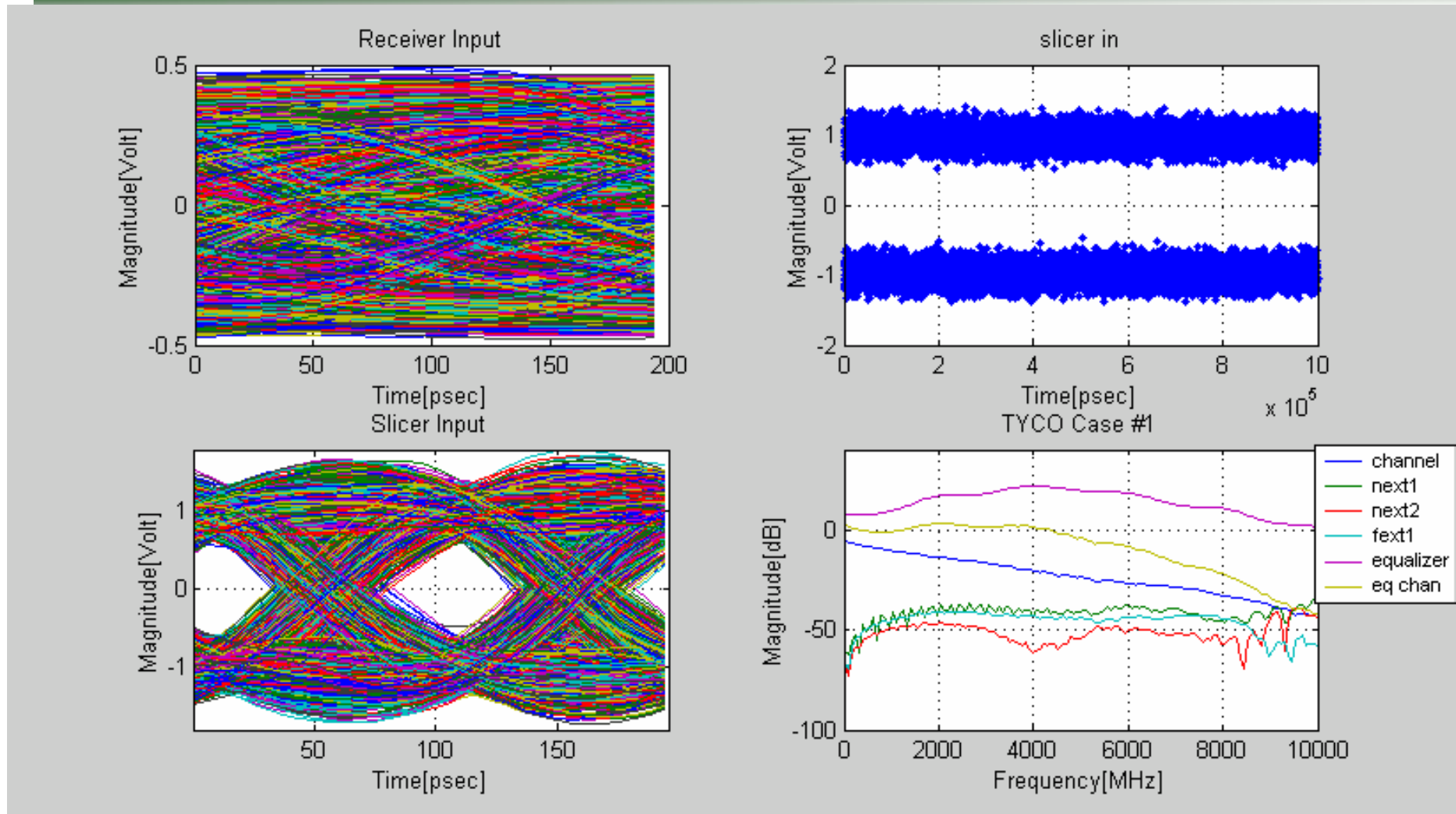
Simulation Parameters

- **Launch amplitude:** 1 Vp-p differential
- **Transmitter DJ set to maximum:** 0.17 UIpp
- **Transmitter RJ set to maximum:** 0.0071 UIrms (0.1UIpp @ 10-12 bits)
- **Data rate:** 10.3 Gbps
- **Receiver offset:** 0 ppm
- **Data pattern:** PRBS15
- **Random noise:** 1.46mV rms
- **AC coupling:** 4.7nf
- **Simulate across package types :** Spec_RL_cap_like
- **Simulating continues time by using simulation clock which is 16 times faster than the bit rate (160GHz).**

Equalizer Parameters

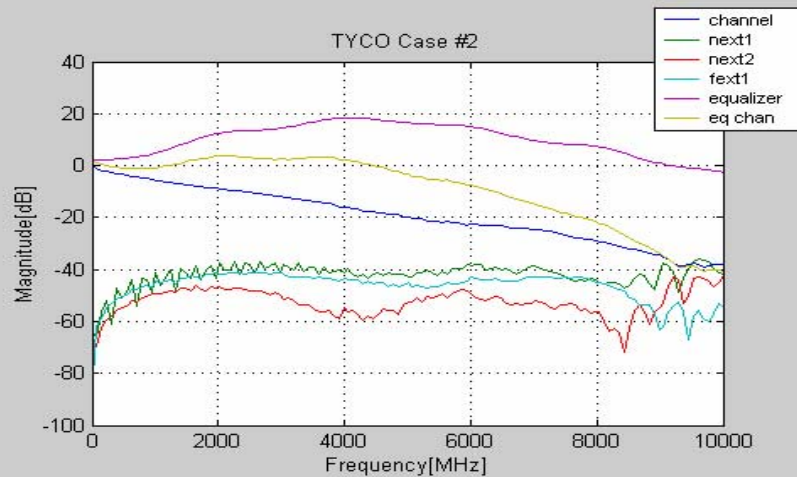
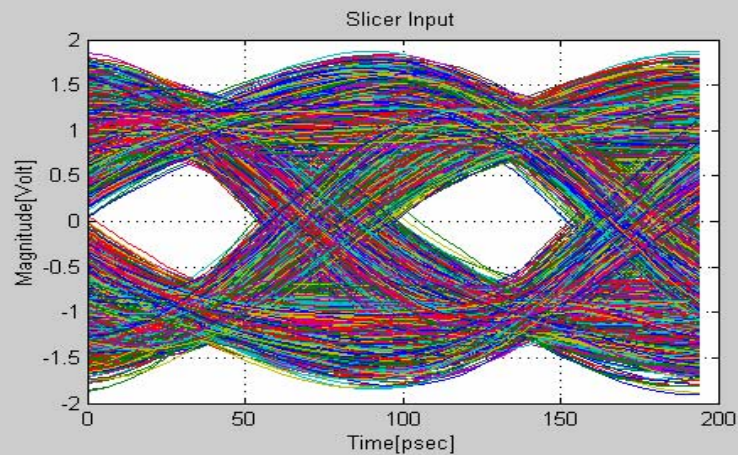
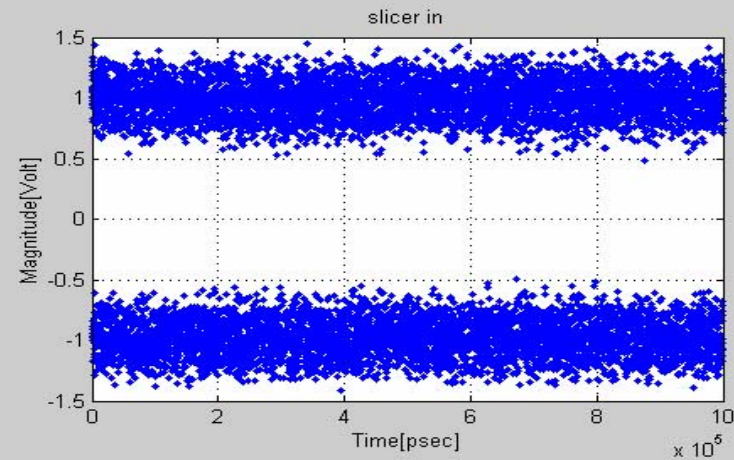
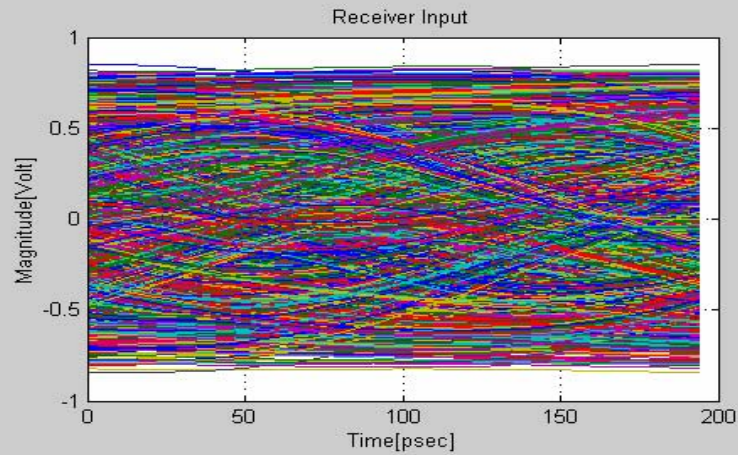
- FFE :
 - 3 Taps length.
 - 1 pre-cursor, main-tap, 1 post-cursor.
 - Analog tap delay line of $T/2$ space.
 - Signed-LMS adaptation.
- DFE:
 - 5 Taps length.
 - Non overlapped with FFE.
 - T-space CML.
 - Signed-LMS adaptation

TYCO Case #1



- SNR =24.86dB
- Horizontal margin = 21.8psec
- Vertical margin =96mV

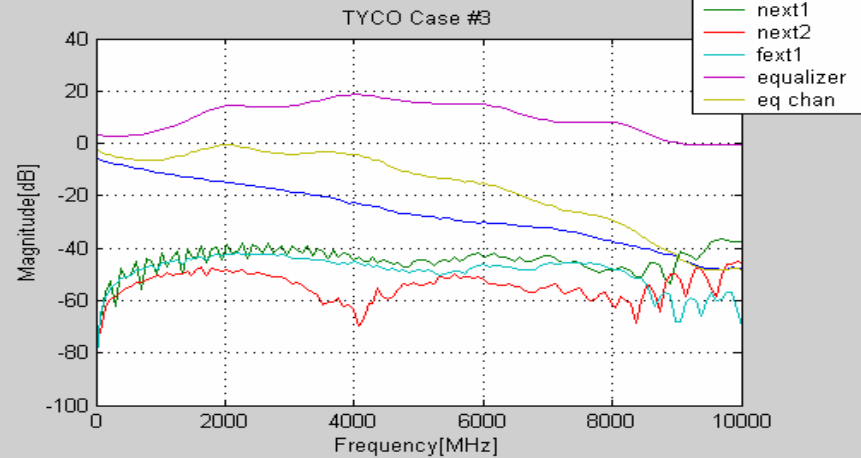
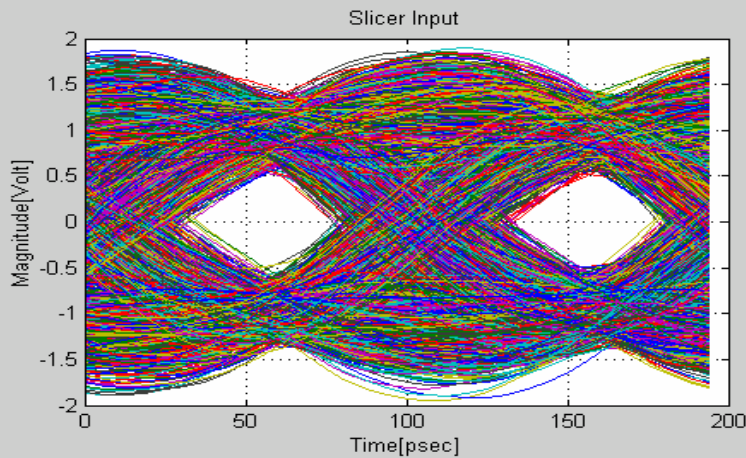
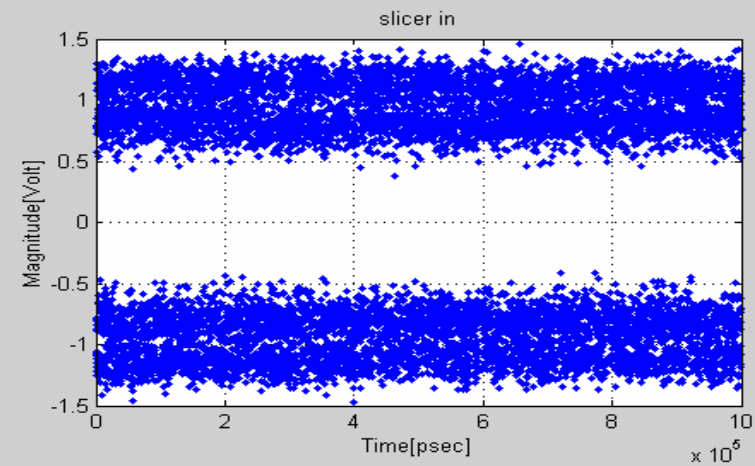
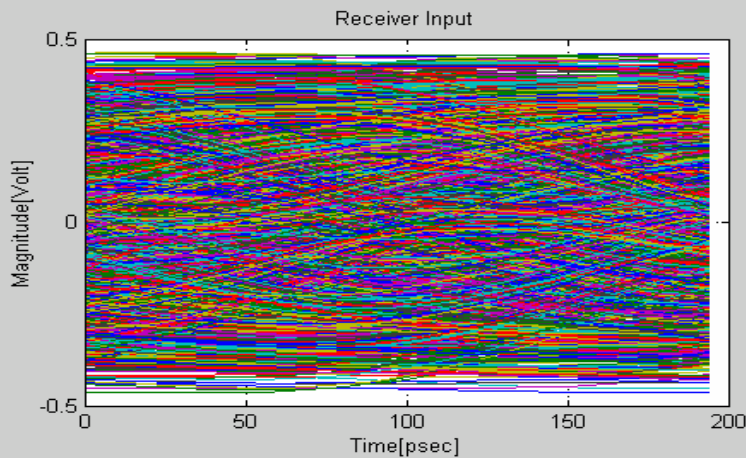
TYCO Case #2



- SNR=25.74dB
- Horizontal margin =28psec
- Vertical Margin=40.7mV

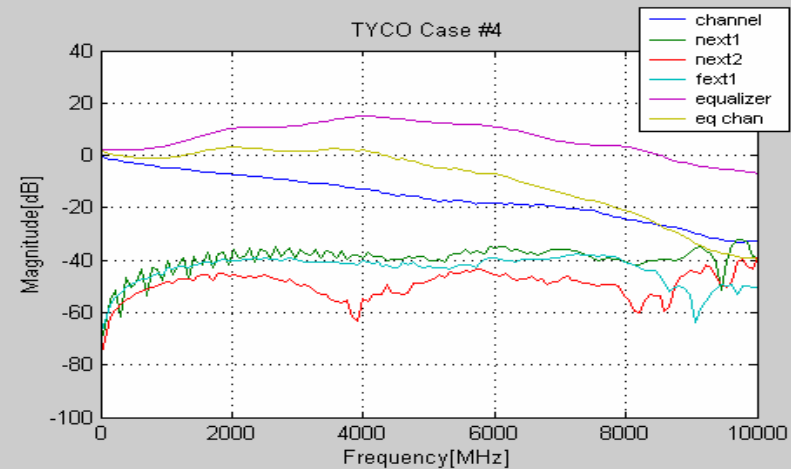
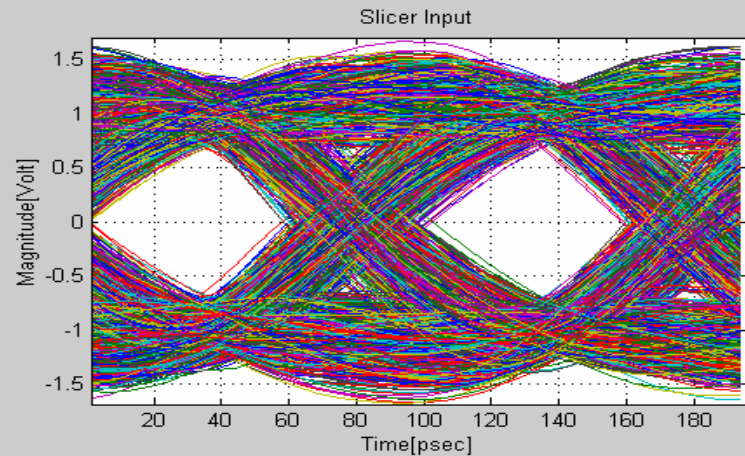
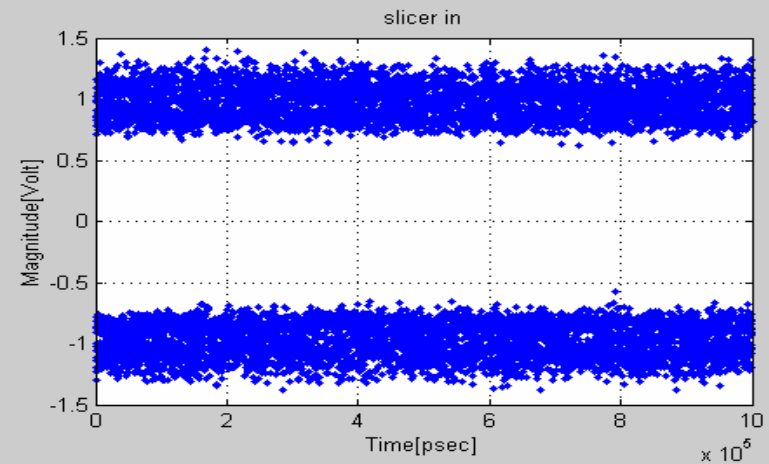
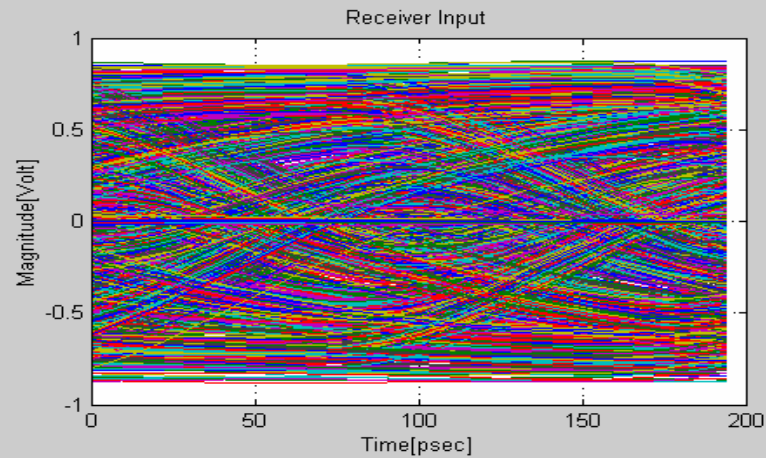


TYCO Case #3



- SNR=23.15dB
- Horizontal margin =5psec
- Vertical Margin=8.6mV

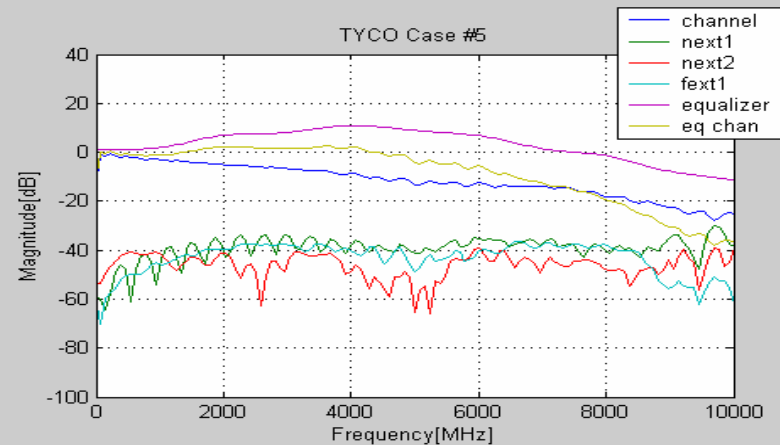
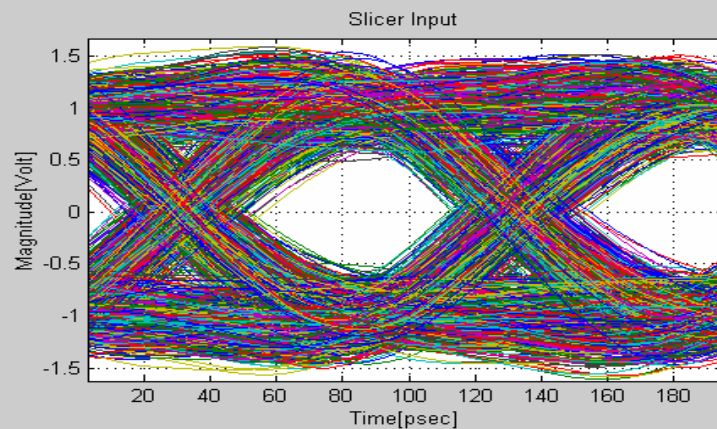
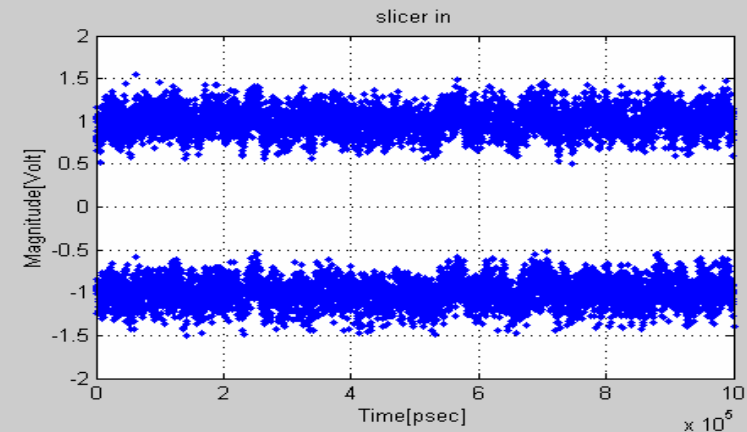
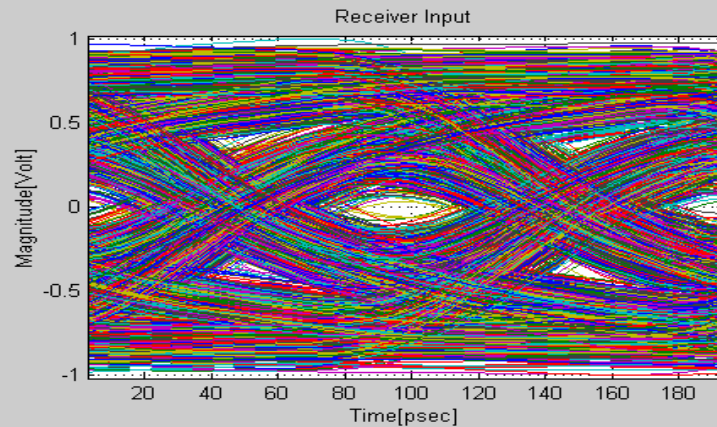
TYCO Case #4



- SNR=25.55dB
- Horizontal margin =25psec
- Vertical_margin=47.6mV

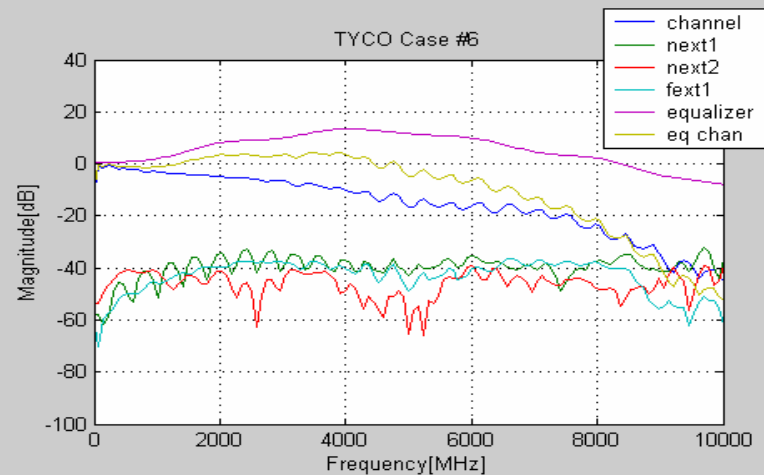
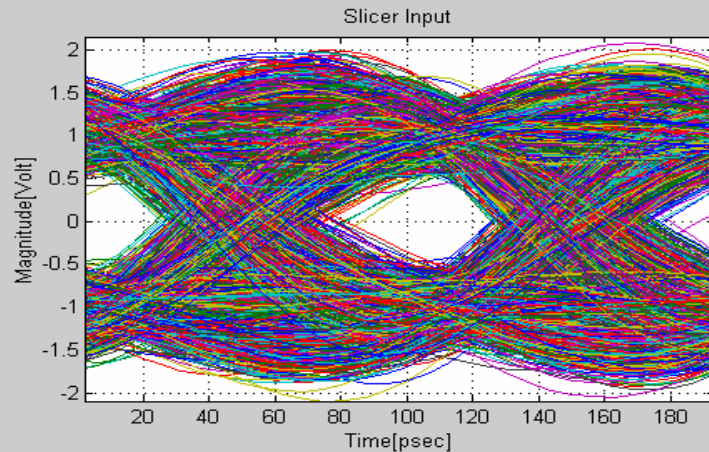
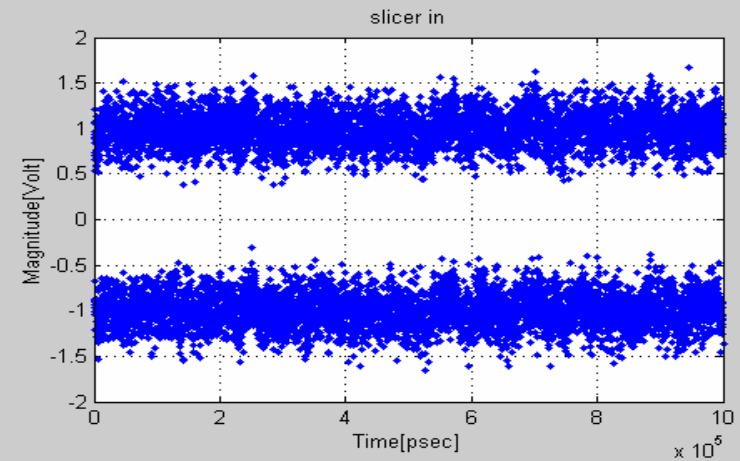
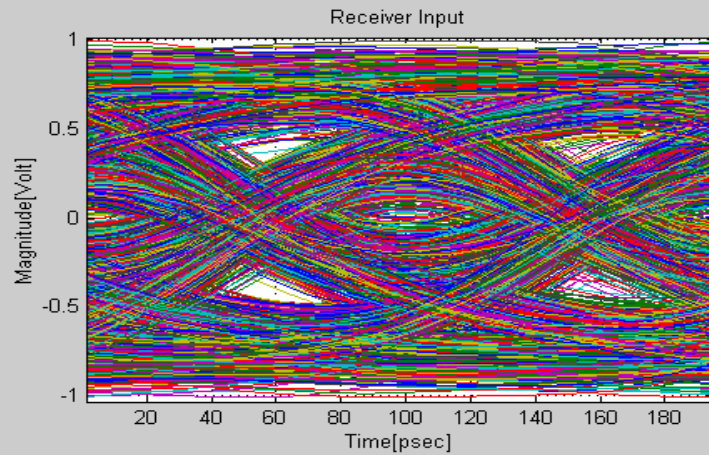


TYCO Case #5



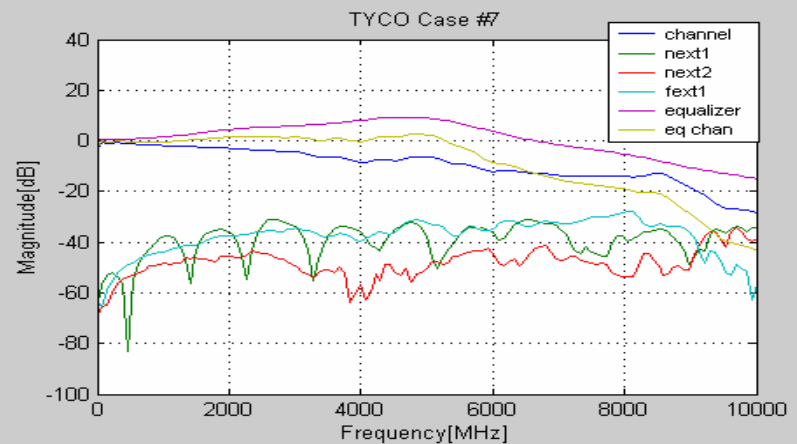
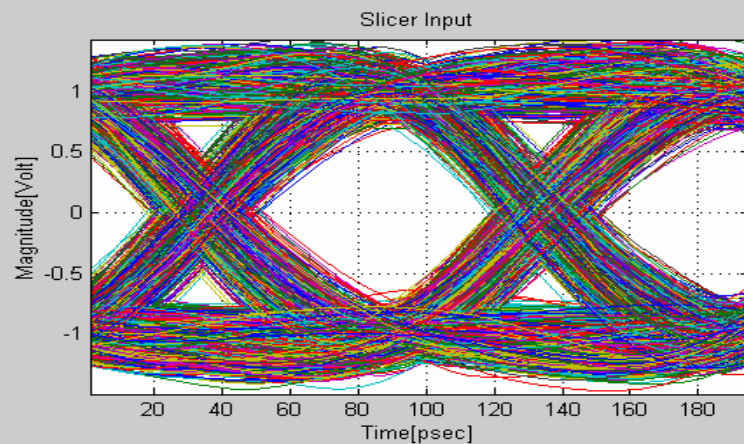
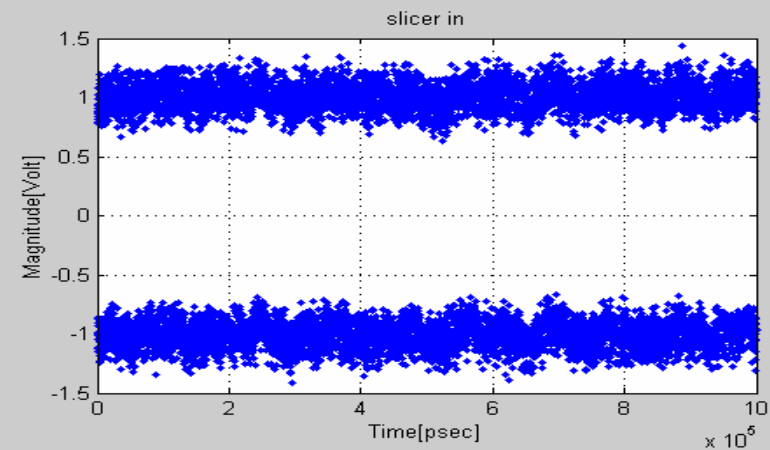
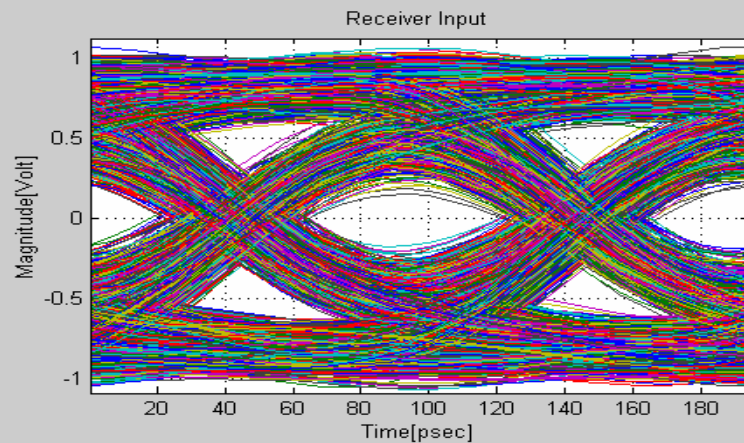
- SNR=25.14dB
- Horizontal margin =29psec
- Vertical_margin=68.8mV

TYCO Case #6



- SNR=23.71dB
- Horizontal margin =6psec
- Vertical_margin=19.6mV

TYCO Case #7



- SNR=25.44dB
- Horizontal margin =50psec
- Vertical_margin=112.5mV

NRZ Results over TYCO channels

SIGNALING	FILE	SNR[dB]	V_MRG[mV]	H_MRG[psec]
NRZ	Case #1	24.86	96	21.8
NRZ	Case #2	25.74	40.7	28
NRZ	Case #3	23.15	8.6	6
NRZ	Case #4	25.55	47.7	25
NRZ	Case #5	25.14	68.8	29
NRZ	Case #6	23.71	19.6	6
NRZ	Case #7	25.44	112.5	50

NRZ Over PETER's Channels

SIGNALING	FILE	SNR[dB]	V_MRG[mV]	H_MRG[psec]
NRZ	B1	23.21	4.2	13
NRZ	B12	24.69	31.8	46.87
NRZ	B20	24.29	24.3	25
NRZ	B32	23.17	2.4	3.13
NRZ	M1	22.6	0	0
NRZ	M20	24.78	27.4	37.5
NRZ	M32	22.21	0	0
NRZ	T1	19.21	0	0
NRZ	T12	13.97	0	0
NRZ	T20	15.57	0	0
NRZ	T32	17.24	0	0

Results analysis

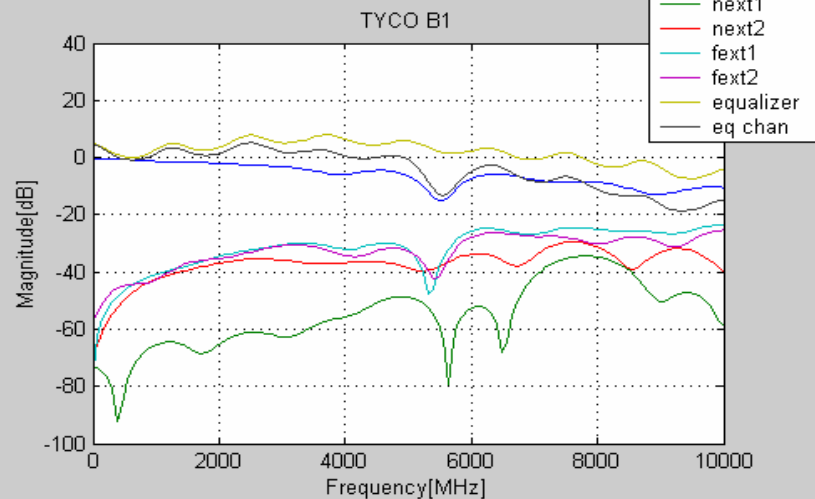
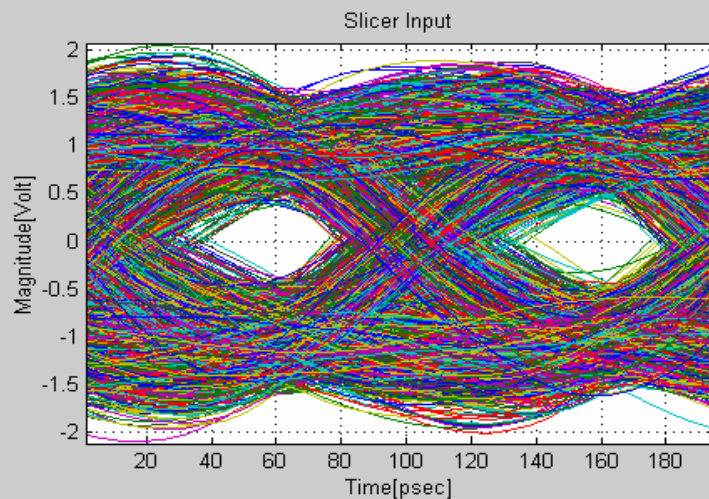
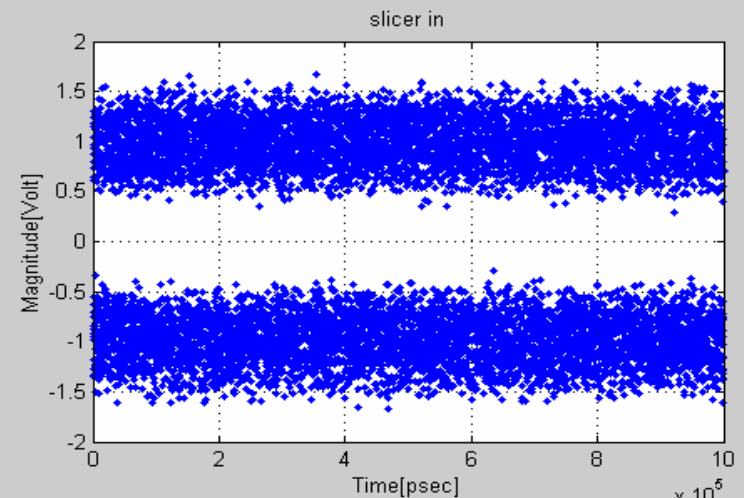
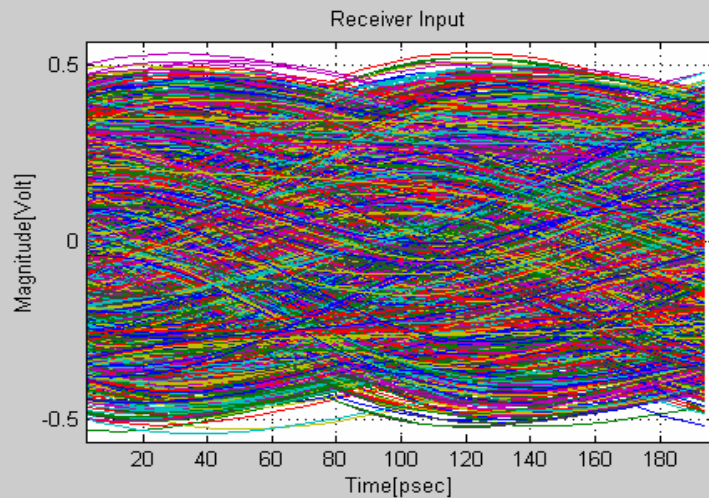
- **TYCO channels**
 - All channels can be resolved for BER of better than $10e-12$.
 - Cases #3 and #6 have lower margin.
- **PETER's channels**
 - B channels:
 - Can be resolved for BER of $10e-12$
 - Channel B32 has lower margin
 - M channels:
 - M20 can be resolved for BER of better than $10e-12$
 - M1,M12,M32 hard to meet BER target
 - T channels
 - Far from target ,BER is less than $10E-7$
- **Complete results are provided in spreadsheet**

Summary

- **Signaling**
 - NRZ with Analog FFE(3 taps), and DFE(5 taps), with Sign-LMS adaptation can resolve most channels.
- **Channel model**
 - Tyco channels can be solved.
 - Portion of Peter's channel can be solved with the current architecture.

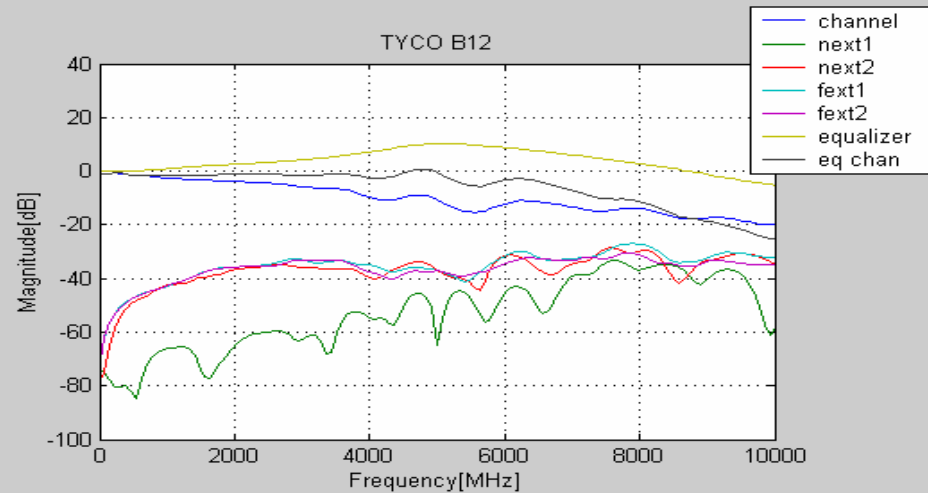
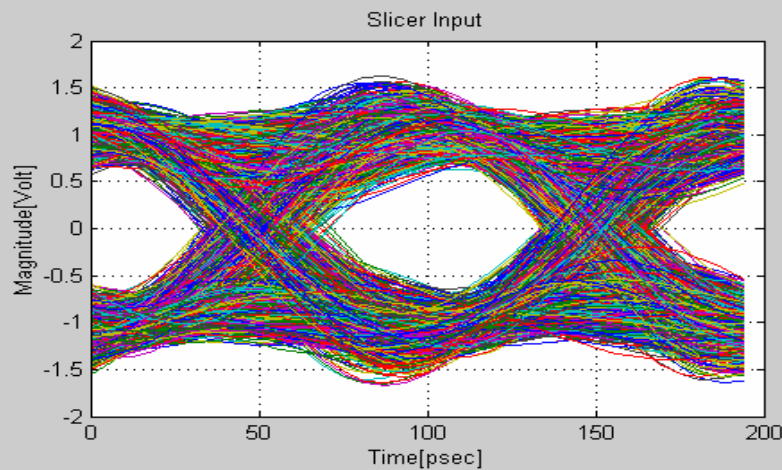
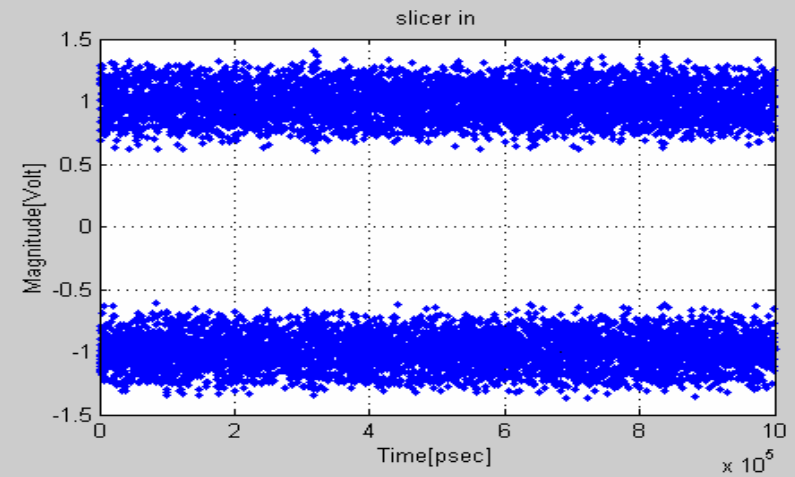
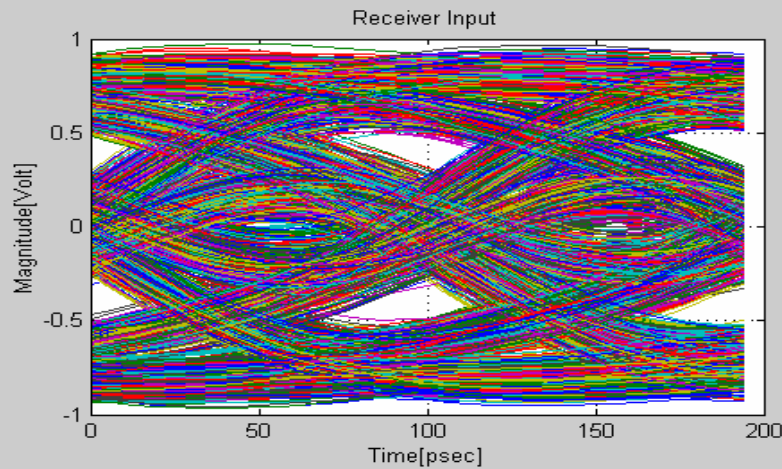
Backup

B1



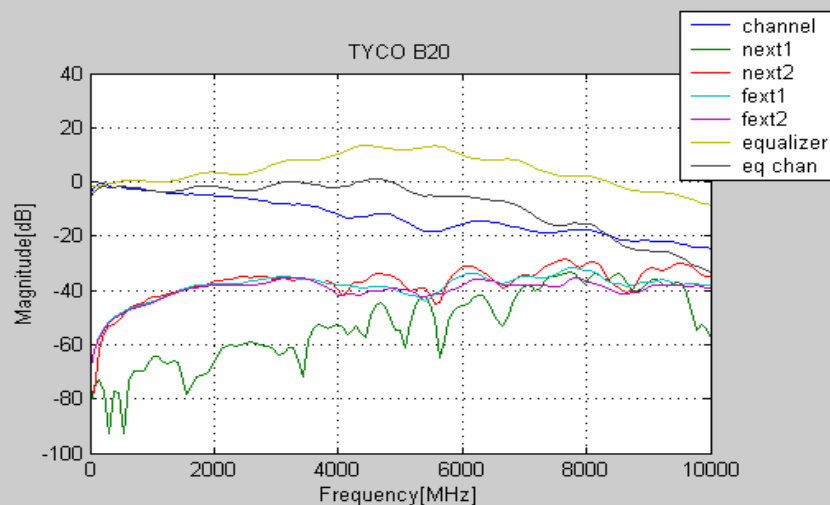
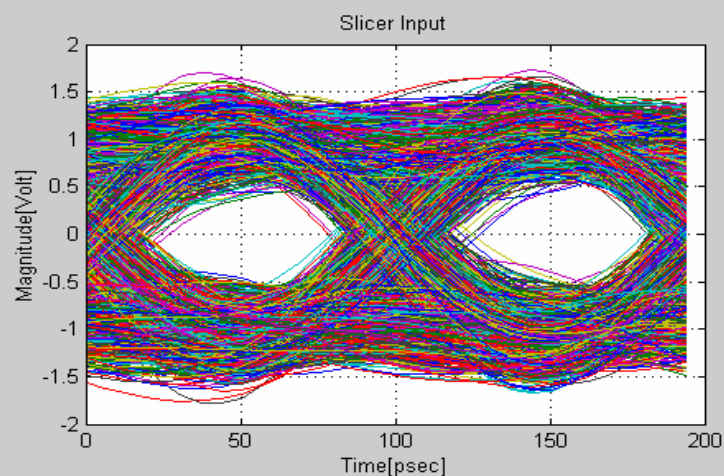
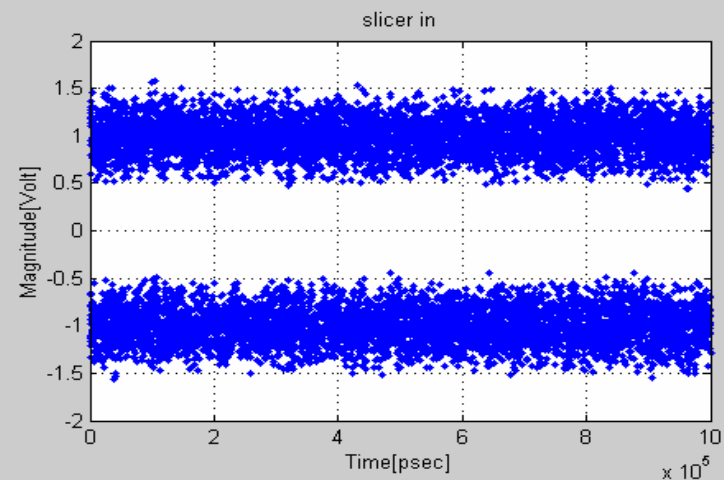
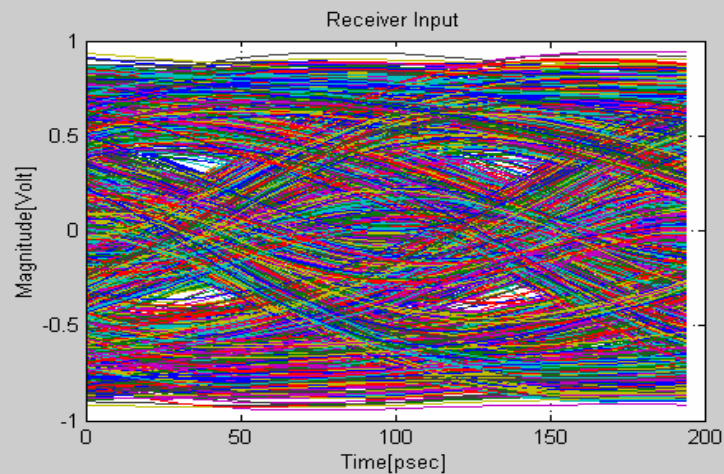
- SNR=23.21dB
- Horizontal margin =13psec
- Vertical_margin=4.2mV

B12



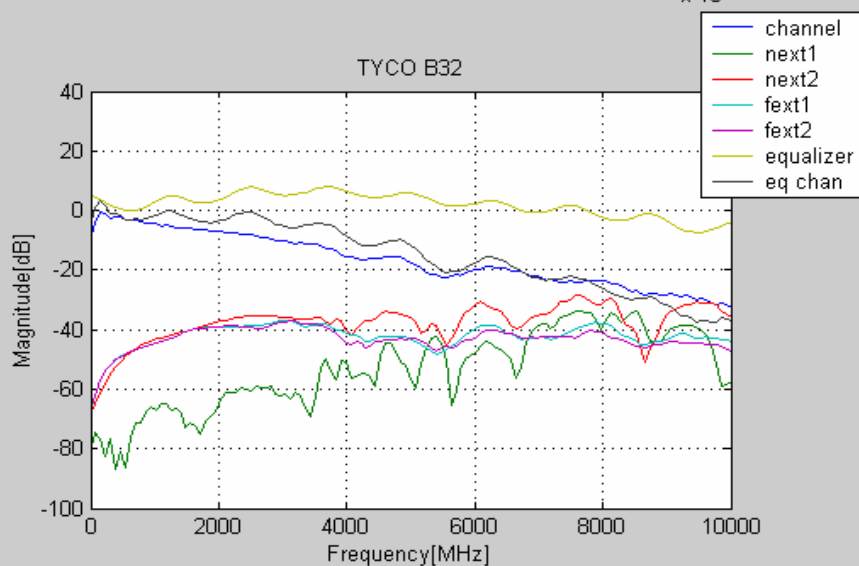
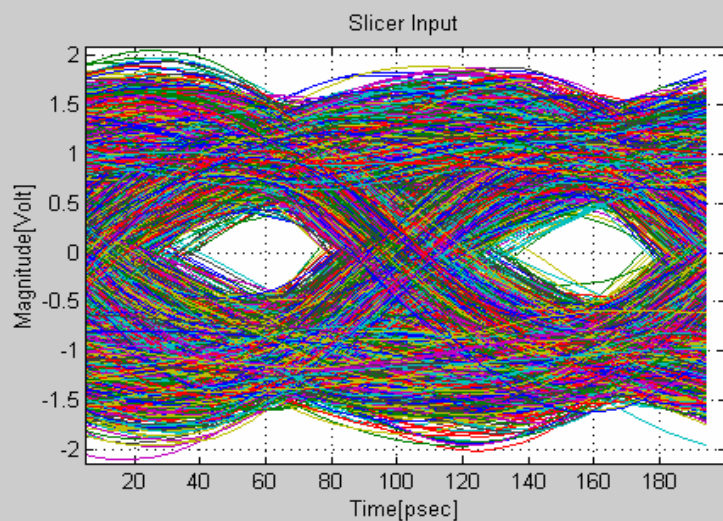
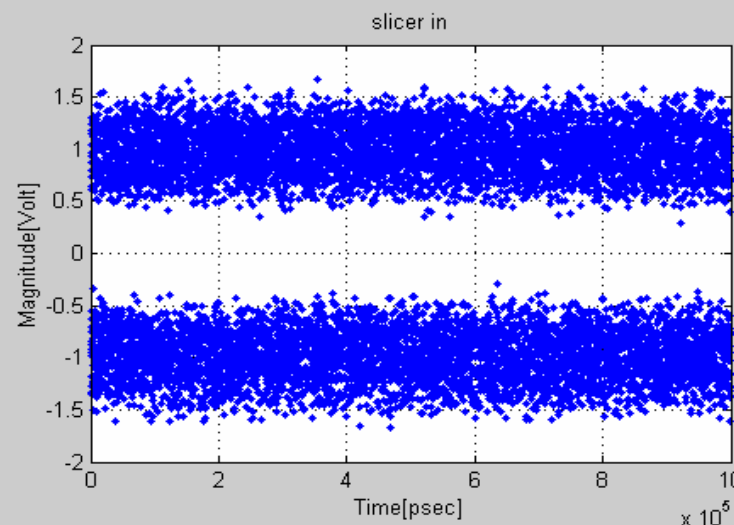
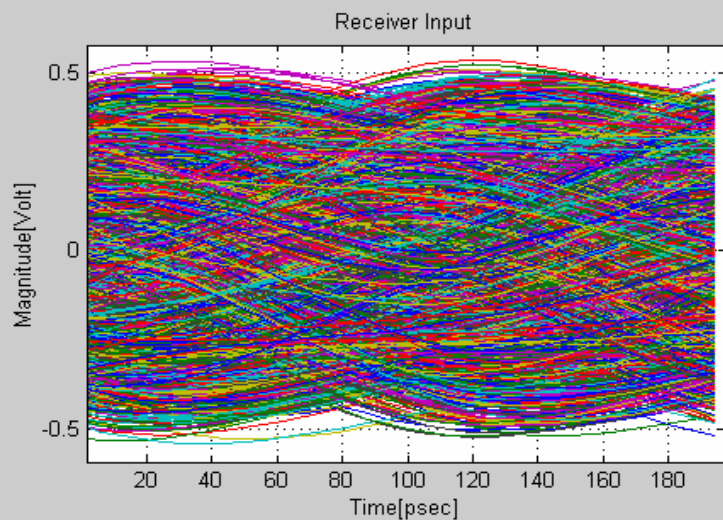
- SNR=24.69dB
- Horizontal margin =46.87psec
- Vertical_margin=31.8mV

B20



- SNR=24.29dB
- Horizontal margin =25psec
- Vertical_margin=24.3mV

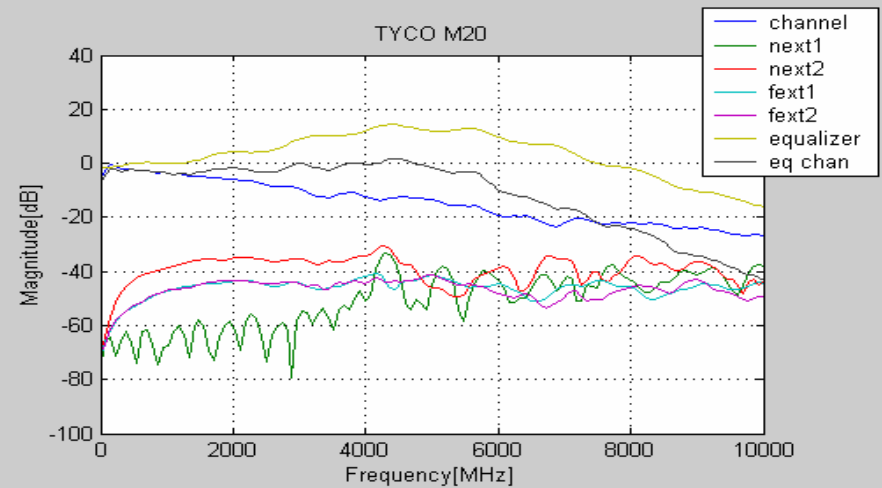
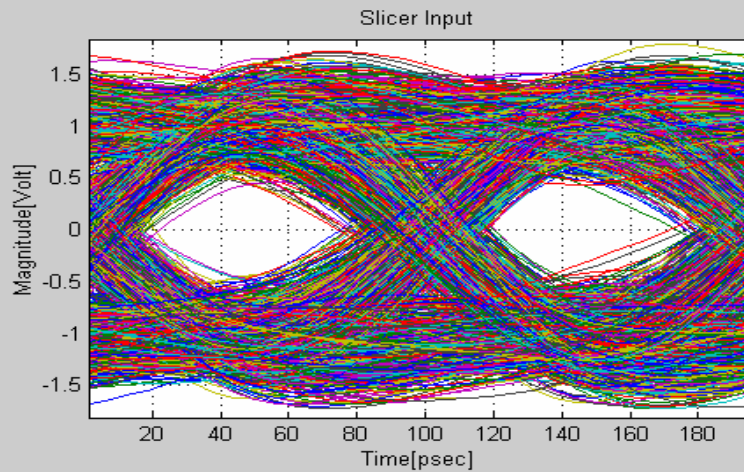
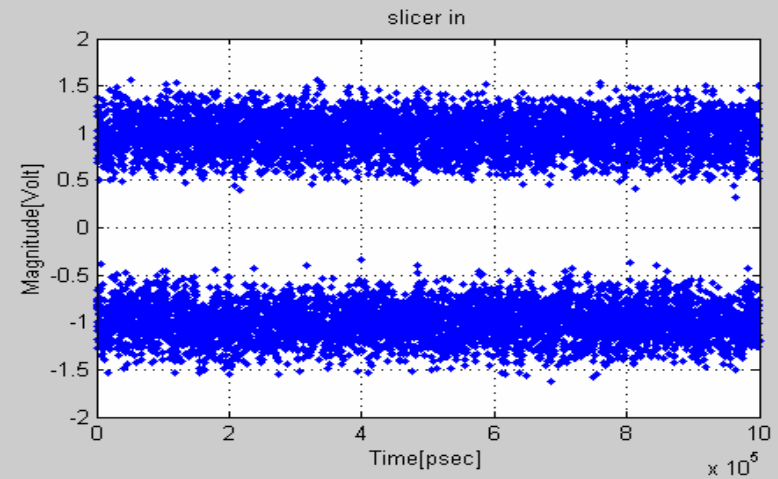
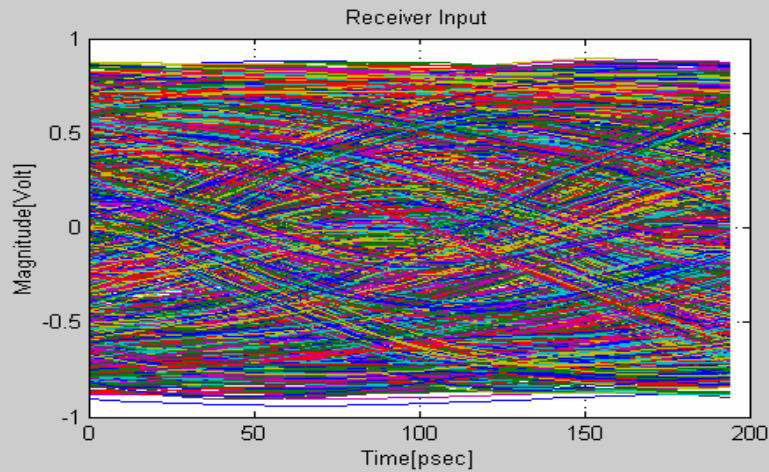
B32



- SNR=23.17dB
- Horizontal margin =3.13psec
- Vertical_margin=2.4mV



M20



- SNR=24.78dB
- Horizontal margin =37.5psec
- Vertical_margin=27.4mV

Impulse Response and cursors position

