IEEE 802.3ap "Backplane Ethernet" Overview

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History of Backplane Ethernet

- **Ethernet previously did not standardize backplane interface as Ethernet traditionally focuses on the box interface.**
  - **Blade servers are changing the boundary of box / backplane interface**
  - **XAUI will be the closet standard in this space**
- **In Nov. 2003 IEEE 802.3 approved Backplane Ethernet Study group.**
- **In March 2004 Backplane Ethernet task force approved and 802.3ap officially started.**
- **Latest draft of 802.3ap is 0.9 and 0.91 will be available by June 6, located in member only area.**
  - **All the presentation and the task force material are available at http://www.ieee802.org/3/ap/index.html**

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What is Backplane Ethernet

- **Leverage Existing Ethernet fabric and MAC**

- **Use existing Ethernet standard to develop an interface optimized for backplane**

- **Not a chassis or connector specification**

- **Will not define mechanical, thermal, or material**

- **Primary area of focus will be:**
  - **Electrical specifications**
  - **Channel model specifications**

Justification for Backplane Ethernet

- **The convergence of network and computing created Blade-center.**

- **In blade center environment about half the Ethernet are internal and operates over the backplane.**

  – According to Gardner Report published IEEE Spectrum Apr. 2005 blade computing grows from $1.1B to $3.1B in 2009.

- **Already significant amount of blade computing are shipping.**

  – Many of these product use standard Ethernet chips and adopt them to operate over the backplane.

  – Majority of backplane Ethernet ports shipping with blade computing today is 1 Gig E but the migration to 10Gig E has started

    - At 10Gig commodity Ethernet chips may not operate reliably over the backplanes and proprietary solution will not have Ethernet economy of scale.
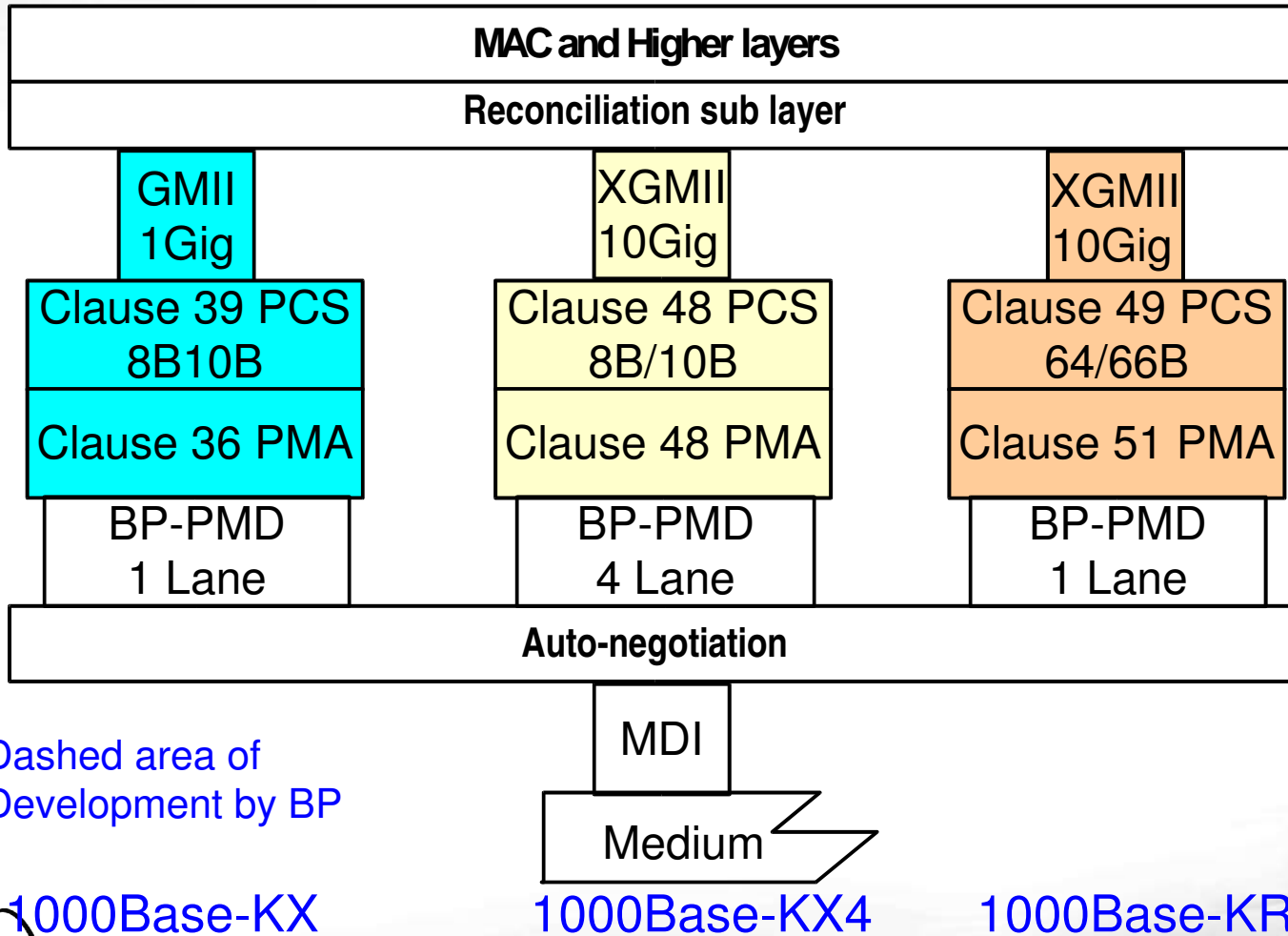
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IEEE 802.3ap Objective as Specified in the PAR

- **Preserve the 802.3 Ethernet frame format at the MAC client interface**

- **Preserve Min. and Max. frame size**

- **Support existing media independent interface**

- **Support operation over 1m of improved FR4 with 2 connectors**
  - **Define a 1 Gb/s PHY**
  - **Define a 10 Gb/s PHY**
    - **Single and 4 lane**

- **Automatic speed and feature negotiation.**

- **Support BER of 1E-12 or better**

- **Meet CISPR/FCC Class A.**

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Backplane Ethernet Layer Model

MAC and Higher layers
Reconciliation sub layer

GMII 1Gig	XGMII 10Gig	XGMII 10Gig
Clause 39 PCS 8B10B	Clause 48 PCS 8B/10B	Clause 49 PCS 64/66B
Clause 36 PMA	Clause 48 PMA	Clause 51 PMA
BP-PMD 1 Lane	BP-PMD 4 Lane	BP-PMD 1 Lane

Auto-negotiation

MDI

Medium

Dashed area of Development by BP

1000Base-KX   1000Base-KX4   1000Base-KR

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Auto-Negotiation

- IEEE 802.3ap defines scheme to Auto-Negotiate between KX, KX4, and KR.

- Auto-Negotiation is optional and host instead may use parallel detect

- Auto-Negotiation management definition is based on the IEEE Clause 28 " Definition of auto-negotiation for twisted-pair link Segment".

  - The actual signaling is not based on the Fast Link Pulses (FLPs or OOB), but instead is based on differential Manchester coding which is more suitable for high speed backplane.
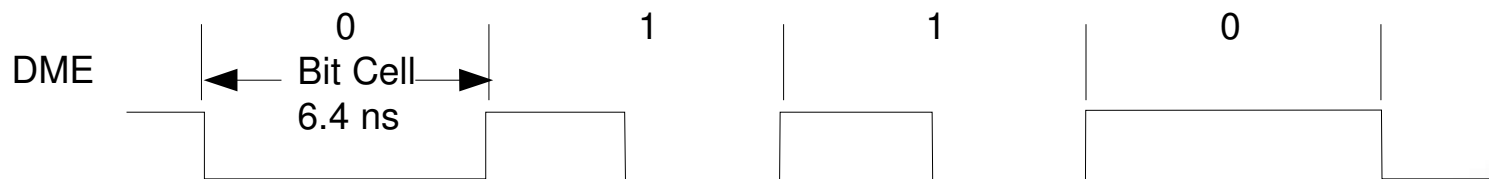
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XCVR Friendly Auto-neg

- **FLP "OOB" not XCVR Friendly for > 3 Gb/s**
  - Requires turning on/off transmitter very quickly ~100 ns pulse.
  - Receiver must have envelope detect to detect bursts.
  - PLL must acquire lock and adapt at the start of each training sequence
- **Attributes of XCVR Friendly Auto-neg**
  - Provide continuous clock information
  - DC balance
  - Baudrate low enough to operate on a untrained link
  - Higher that the signal minimum passband
  - Simple decode and encoder
  - Minimum additional requirement on the transceivers
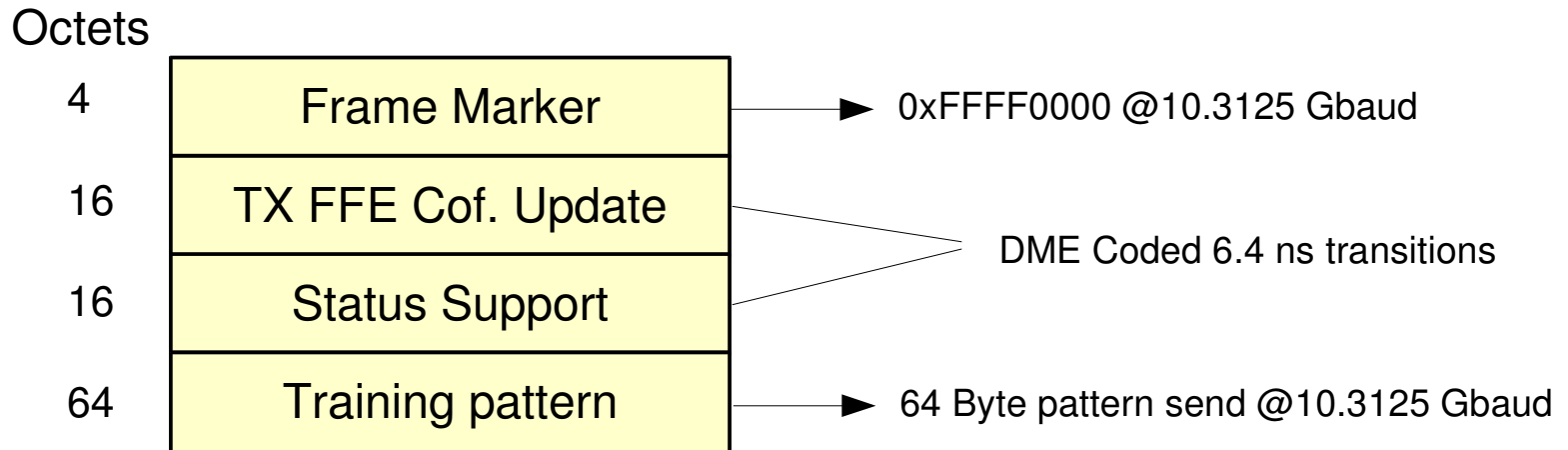- **6 Gig SAS can also benefit from a XCVR friendly Auto-Neg!**

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Auto-Neg Based on Differential Manchester Encoding (DME)

- **During Auto-neg DME operates at 312.5 Mbaud (6.4 ns ck-ck)**
  - **One symbol is equivalent to 33 symbols at 10.3125**
  - **Encoding rules bit cell always has transition**
  - **Generates DC-Balance signal at any one of the three rate currently defined**
  - **Bit cell center has transition for 1 but not for 0**
  - **Below example of DME signal**

```
                        0              1           1            0
DME
                  ◄─── Bit Cell ───►
                        6.4 ns
```

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Training Frame Structure

- **10GBASE-KR transmitter during training sends out DME codes at ¼ of baudrate of 10.3125 Gb/s.**

  – **Training frame structure is 100 octets in length as shown below:**

Octets

4	Frame Marker	→ 0xFFFF0000 @10.3125 Gbaud
16	TX FFE Cof. Update	
16	Status Support	DME Coded 6.4 ns transitions
64	Training pattern	→ 64 Byte pattern send @10.3125 Gbaud

Compliance Points

- **Transmitter – Normative**
  - **Must meet electrical, jitter, and min tap granularity**

- **Channel – Informative**
  - **Unlike Cat-x cable widely available in the market and standardized by the TIA you can't buy an IEEE / TIA complaint backplane.**
  - **In contrast to CAT-x and Single Mode Fiber (SMF) backplanes have significantly greater degree of freedom with variation due to material, trace geometry, and connectors.**
  - **IEEE BP has elected to be instead very precise regarding SerDes specifications so the designer can build manufacturable backplane**

- **Receivers – Normative**
  - **Must meet worst case electrical input, jitter, and impulse response**

Transmitter Architecture

- **At minimum a three tap FFE will be implemented**
  - **C-1 8 steps from 0 to -7/40**
  - **C1 16 steps from 0 to -15/40**

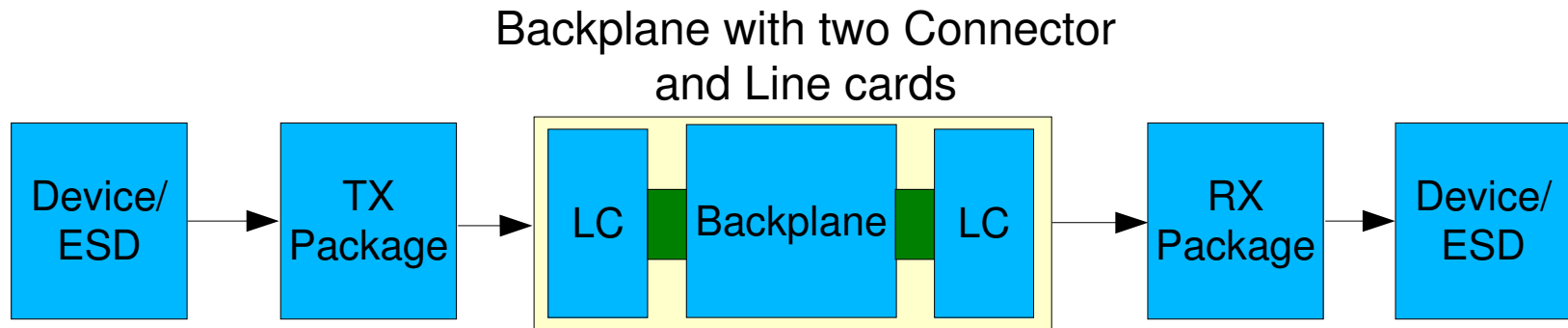**SAS 6Gig Meeting May 25-26 2005**
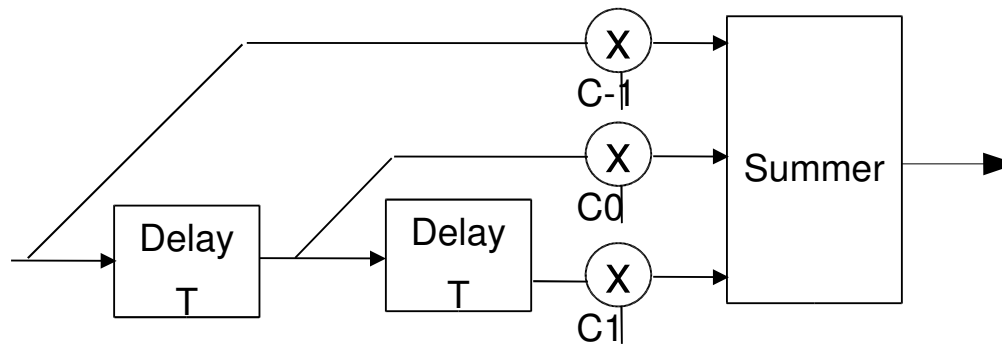
Receiver Compliance

- **IEEE does not specifically defines an receiver, most common implementations are FFE/DFE based.**

- **Receiver will be tested with a complaint transmitter plus channel stressor.**

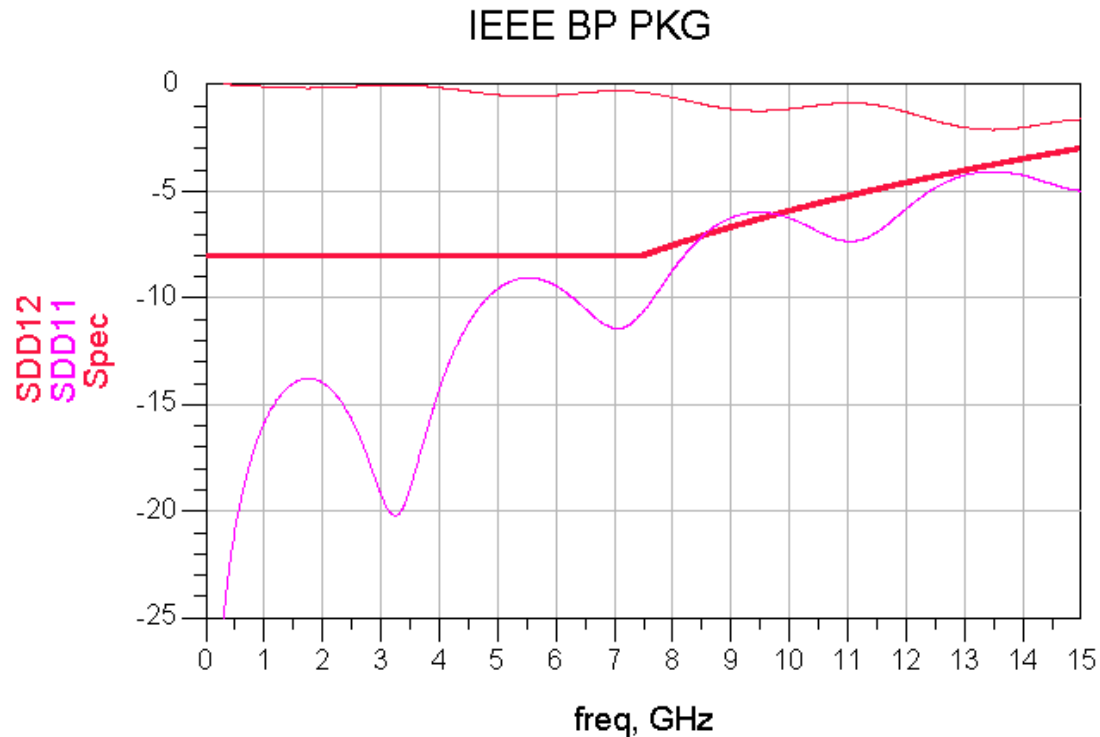 - **Receiver compliance testing still is under refinement, but it looks like:**
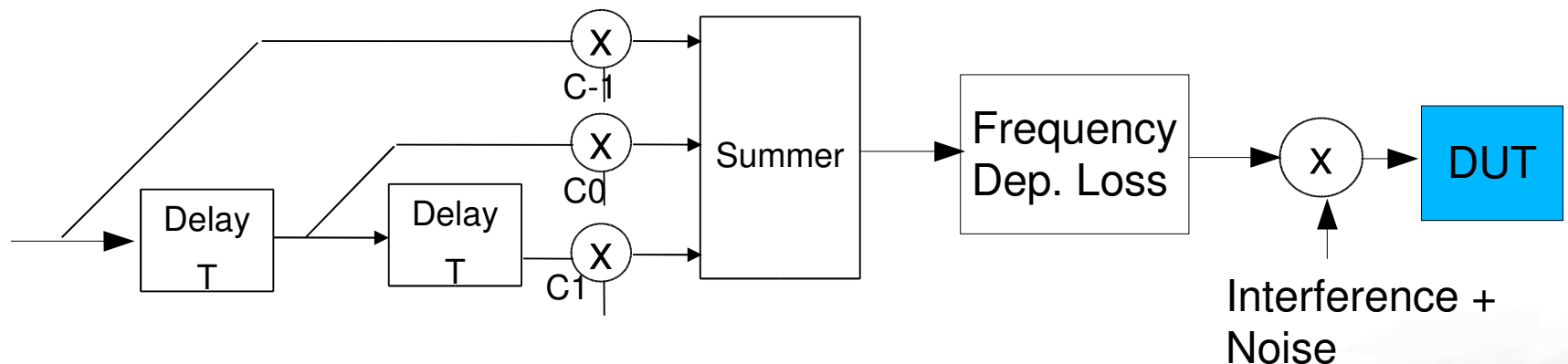
Channel Model

- **Through response is the cascaded s-parameters of each section**
  - **Aggressors are added to the receive signal.**

Backplane with two Connector
and Line cards

| Device/ESD | → | TX Package | → | LC | Backplane | LC | → | RX Package | → | Device/ESD |

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Proposed Package Model

- ## Capacitive package Model
  - ### Mask limits may change

IEEE BP PKG

Eqn Spec=if(freq<7.5e9)then -8 else (-8 + 16.67*log10(freq/7.5e9))

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BP Transmitter Electrical Specifications

Parameter	1000BASE-KX	10GBASE-KX4	10GBASE-KR	Units
Signaling Speed, Per Lane	1.25 ± 100 ppm	3.125 ± 100 ppm	10.3125 ± 100 ppm	GBd
Differential Peak-Peak Output Voltage	800 to 1600	800 to 1600	800-1200	mV
DC Common Mode Voltage	-0.4 to 1.2	-0.4 to 1.9	TBD	V
Differential Output Return Loss (Min)	10 [1]	10 [1]	8 [2]	dB
Output Jitter peak-peak (DJ)	0.1	0.17	0.15	UI p-p
Random Jitter (RJ)	NA	NA	0.15	UI p-p
Total Jitter	0.25	0.35	0.3	UI p-p

1. RL = 10 -10xLOG10(f/625), 625MHz <= f <= 2000 MHz

2. RL = 8 -16.6xLOG10(f/7.5), 7.5 GHz <= f <= 15 GHz

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BP Receiver Electrical Specifications

Parameter	1000BASE-KX	10GBASE-KX4	10GBASE-KR	Units
Signaling Speed, Per Lane	1.25 ± 100 ppm	3.125 ± 100 ppm	10.3125 ± 100 ppm	GBd
BER	1.00E-012	1.00E-012	1.00E-012	
Differential Input Sensitivity	200	TBD	TBD	mV
Receiver Coupling	AC	AC	AC	
Differential Input Peak-Peak Amplitude (max)	1600	1600	1200	V
Jitter Tolerance [1]	baud/1667	baud/1667	baud/1667	
Differential Output Return Loss (Min)	10 [2]	10 [3]	8 [4]	dB
Common Mode Return Loss	6 [2]	NA	NA	dB

1. Jitter tolerance mask -20 dB/Dec from baud/25000 to baud/1667, then 0.1 UP up to 20 Mhz.

0. From 50MHz to 625 MHz

0. (RL >625 MHz) = 10 -10xLOG10(f/625), 625MHz <= f <= 2000 MHz

Ref. 1 0. (RL >7.5 GHz) = 8 -16.6xLOG10(f/7.5), 7.5 Ghz <= f <= 15 GHz

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Overview of the IEEE Backplanes

STUB
DEPTH

50/178/35 mil

T1   T12   T20   T32

T1Synth   Tyco7   Tyco6

                        Mlx25st

6/76/18 mil

M1   M12   M20   M32

                         Mlx25bd
50/10/38 mil   B1   B12   B20   B32   Mlx1m
                                Tyco5   Tyco4   Tyco1 Tyco2 Tyco3

LC1 / BP / LC2

1 inch	20 inches	40 inches
Short Channel	CHANNEL LENGTH	Long Channel
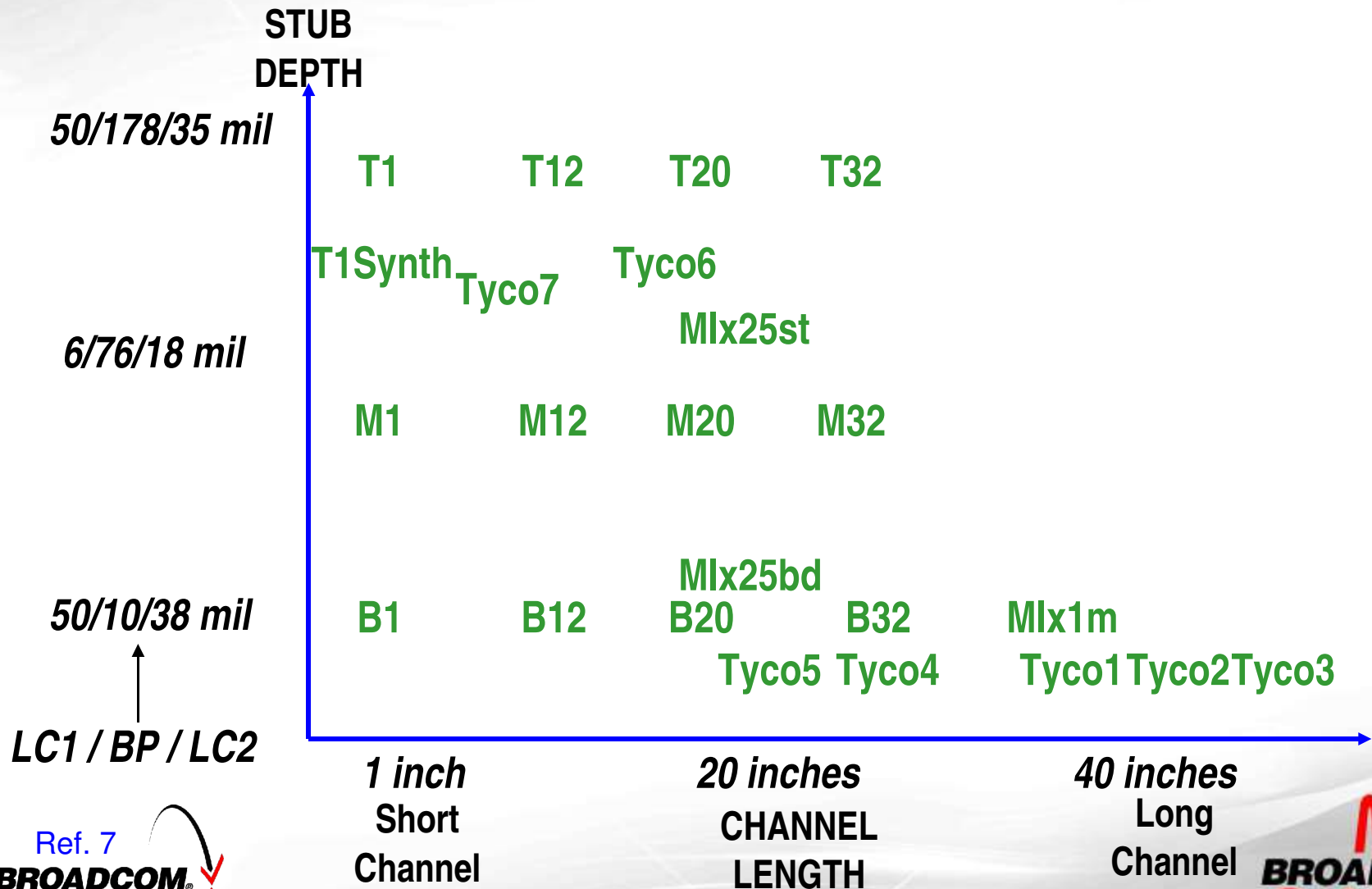
IEEE Tyco Channels

- **Return loss for several backplane including ATCA**
  - **Channel length 13-40" based on improved FR4**
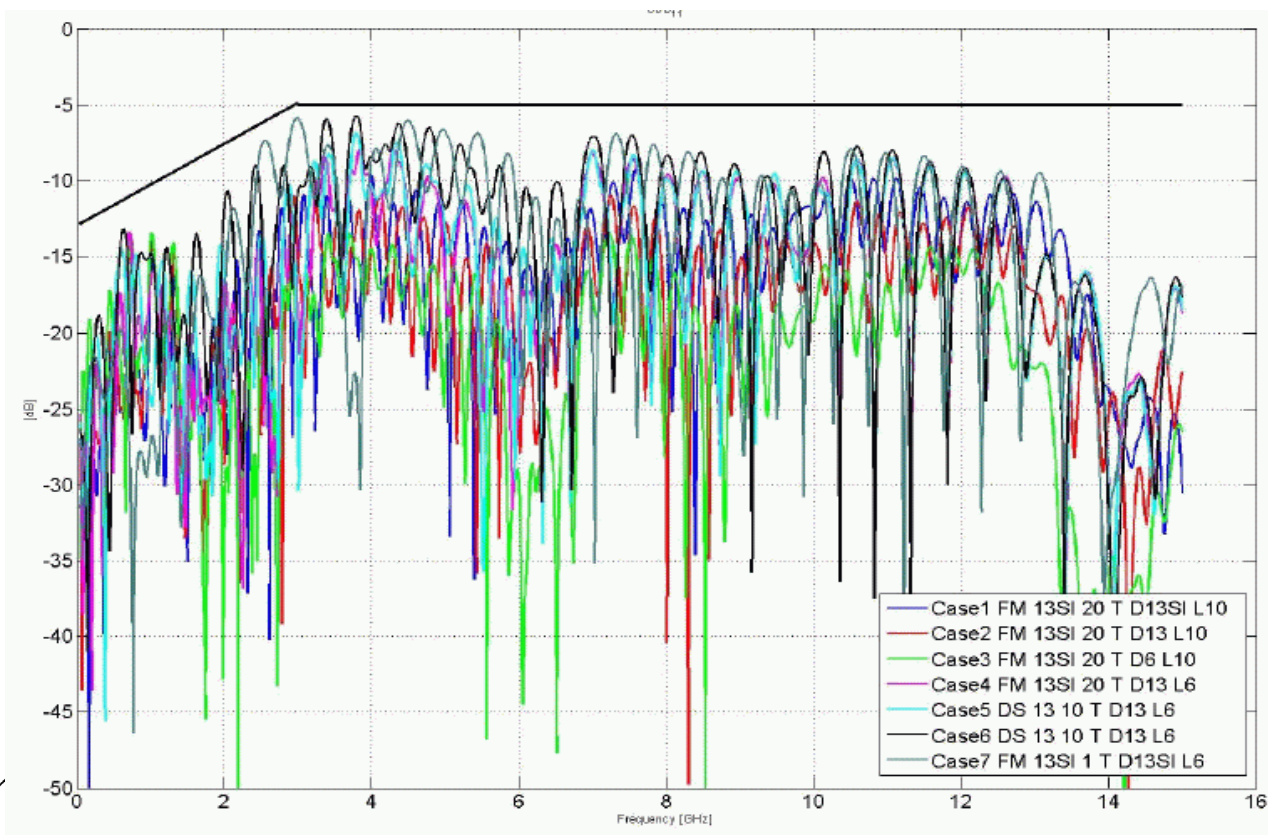
IEEE Intel Channels

- **Return loss for several ATCA Backplanes**
  - Channel length 1.25-32" based on improved FR4

Return loss: 1.25" and 32" backplanes
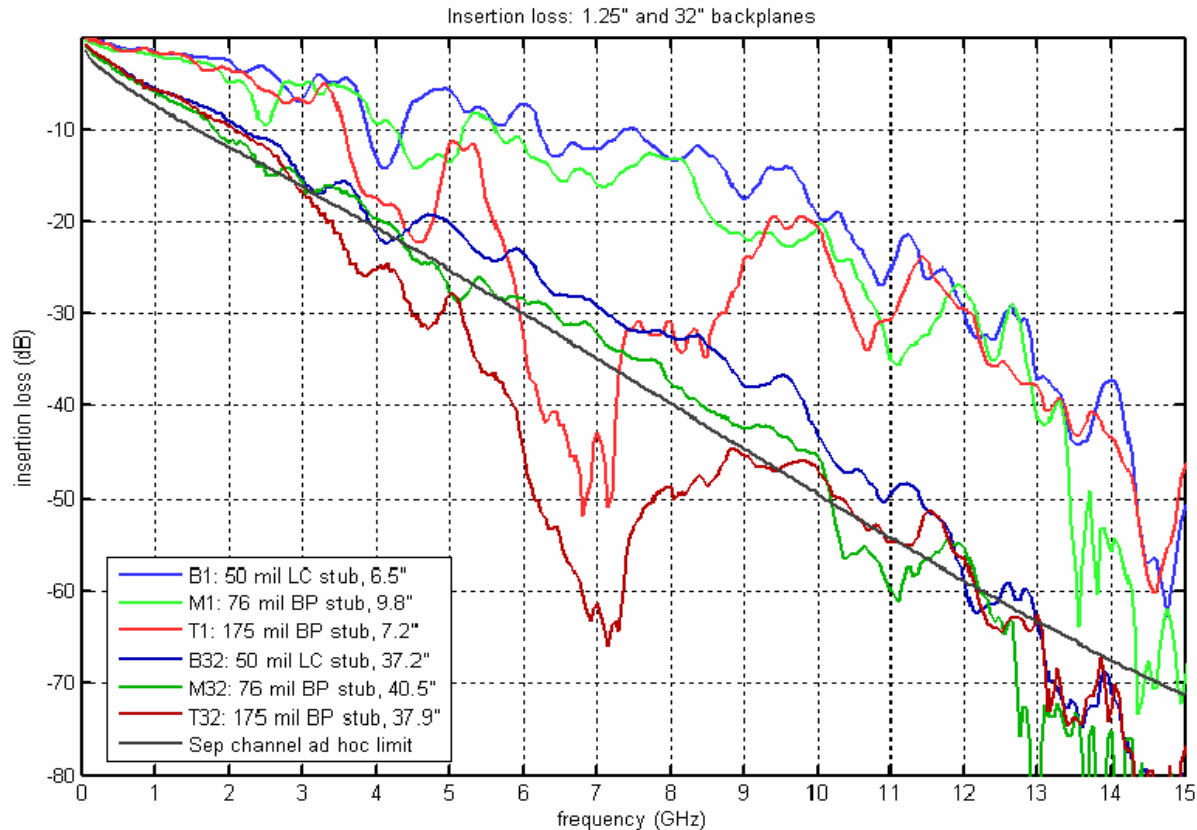
Legend:
- B1: 50 mil LC stub, 6.5"
- M1: 76 mil BP stub, 9.8"
- T1: 175 mil BP stub, 7.2"
- B32: 50 mil LC stub, 37.2"
- M32: 76 mil BP stub, 40.5"
- T32: 175 mil BP stub, 37.9"
- channel ad hoc limit
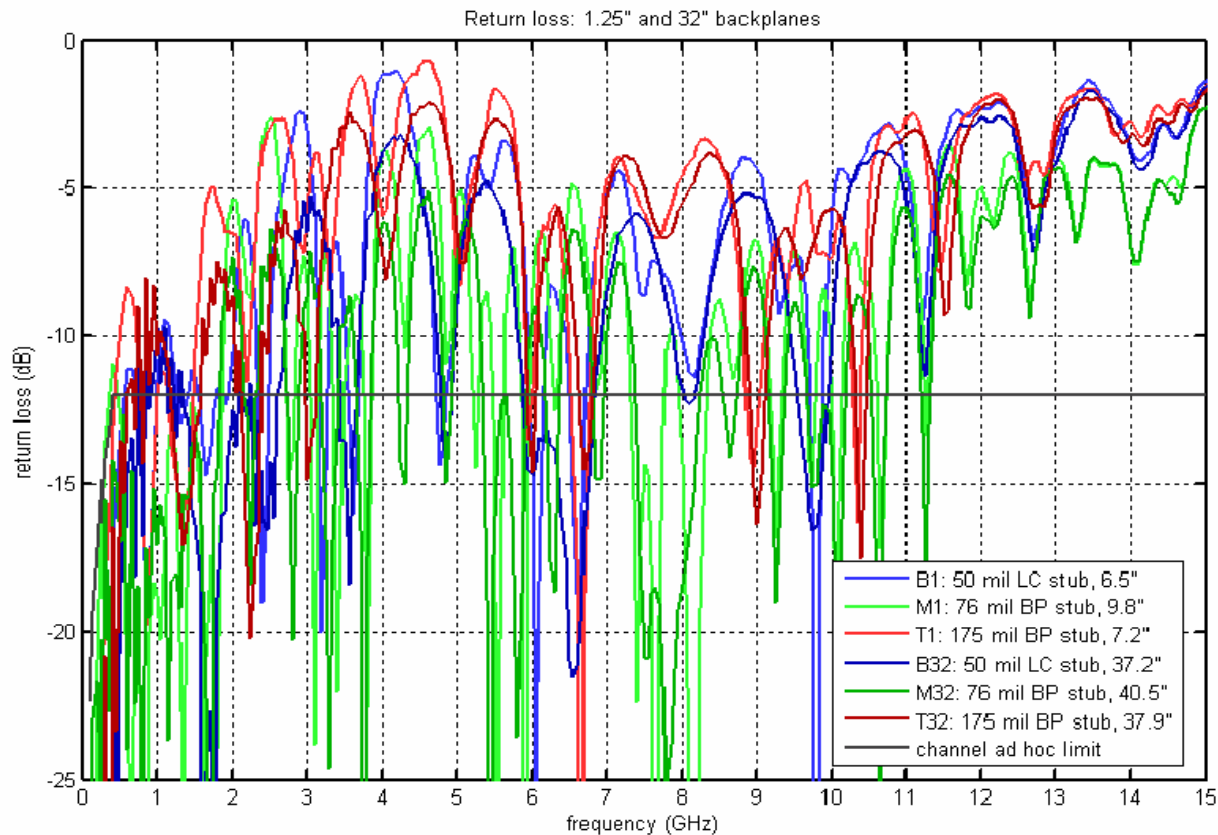
IEEE Intel Channels

- **Insertion Loss for several ATCA Backplanes**
  - **Channel length 1.25-32" based on improved FR4**

Insertion loss: 1.25" and 32" backplanes

Legend:
- B1: 50 mil LC stub, 6.5"
- M1: 76 mil BP stub, 9.8"
- T1: 175 mil BP stub, 7.2"
- B32: 50 mil LC stub, 37.2"
- M32: 76 mil BP stub, 40.5"
- T32: 175 mil BP stub, 37.9"
- Sep channel ad hoc limit

Vertical and Horizontal Eye Opening

NRZ 3-Tap FFE with 5-Tap DFE

Legend:
- Case1FM13SI20TD13SIL10.s4p
- Case2FM13SI20TD13L10.s4p
- Case3FM13SI20TD6L10.s4p
- Case4FM13SI20TD13L6.s4p
- Case5DS1310TD13L6.s4p
- Case6DS1310TD13L6.s4p
- Case7FM13SI1TD13SIL6.s4p
- FR408_25in_sj3k3g3h3_SPARS_BD.s4p
- FR408_25in_sj3k3g3h3_SPARS.s4p
- 1m_INBOUND/sj3k3g3h3_SPARS.s4p
- peters_01_0904_B1_thru.s4p
- peters_01_0904_B20_thru.s4p
- peters_01_0904_B32_thru.s4p
- peters_01_0904_M1_thru.s4p
- peters_01_0904_M20_thru.s4p
- peters_01_0904_M32_thru.s4p
- peters_01_0904_T1_thru.s4p
- peters_01_0904_T20_thru.s4p
- peters_01_0904_T32_thru.s4p
- T1_Synth_Causal
- peters_01_0904_B12_thru.s4p
- peters_01_0904_M12_thru.s4p
- peters_01_0904_T12_thru.s4p
- 0
- 0
- SPEC BOUNDS

Axis labels: Vertical Eye Vppd (y-axis), Horizontal Eye UI (x-axis)

Annotations: Intel Synthesized T1; Intel Top Layer Channels; Improvement from T1 to Synthesized T1

Ref. 7

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Eye Opening As Function of Channel and Stub Length

- **Stub length is the biggest obstacle for operating faster!**
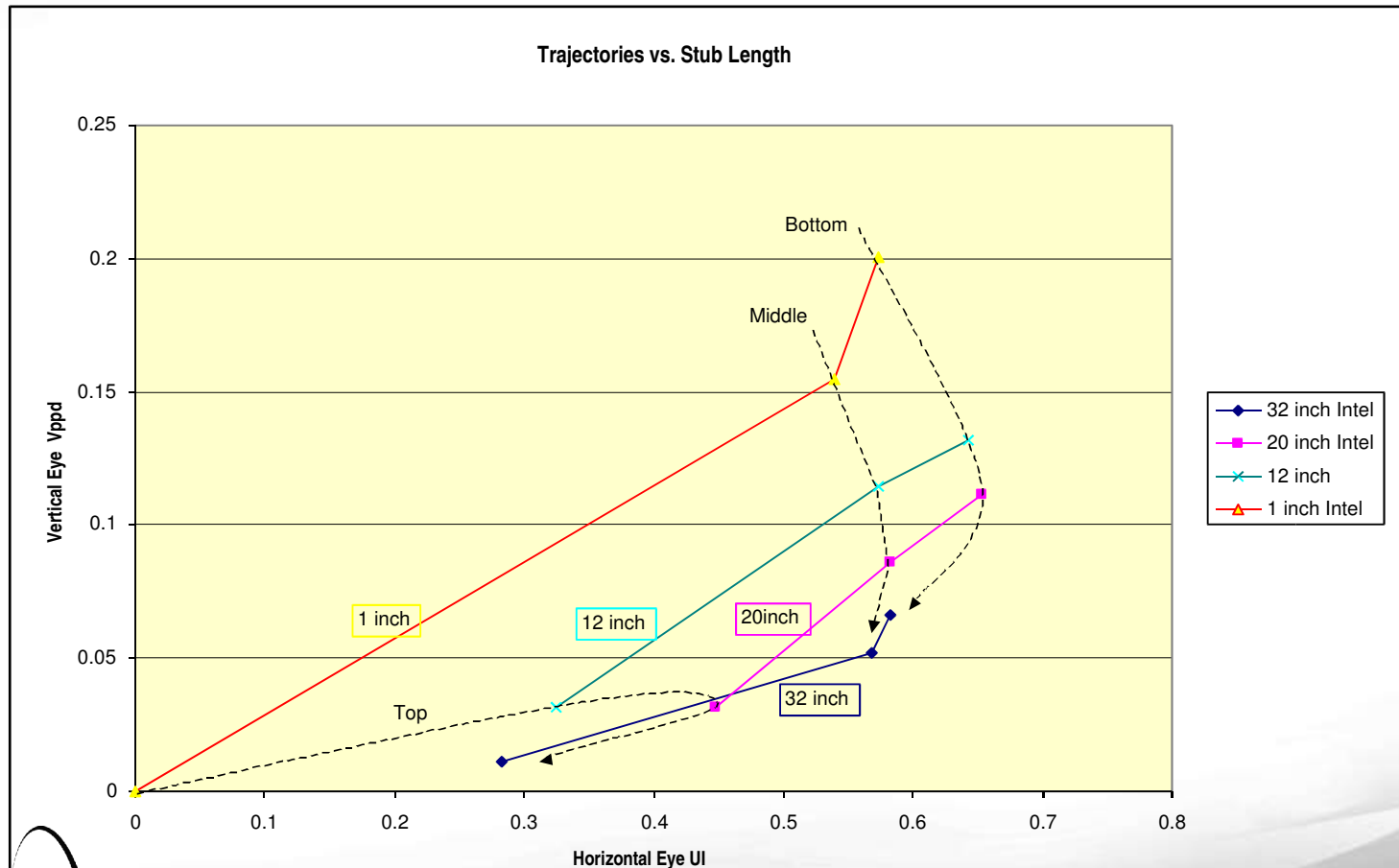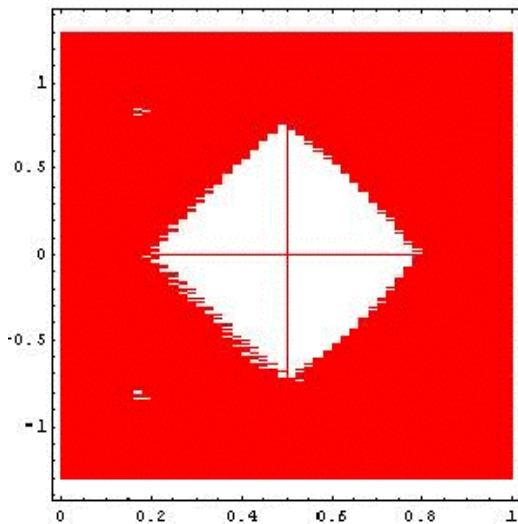

Trajectories vs. Stub Length

Eye Margin For Tyco #1

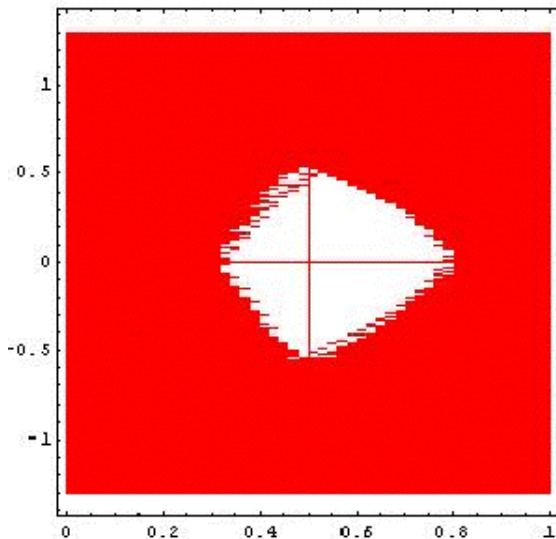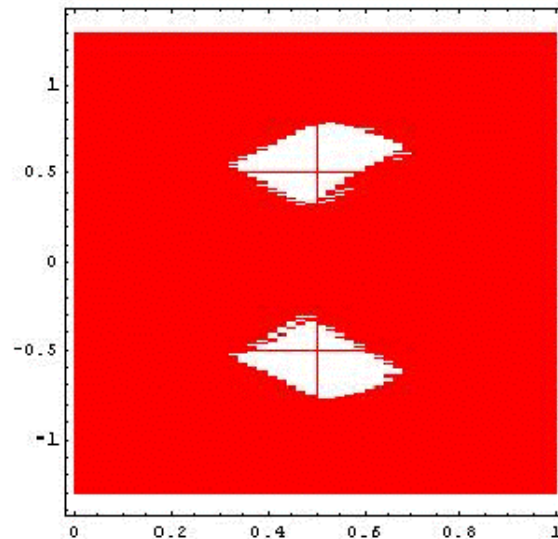- **Good channel, Eq with 4 Tap TX FIR and 5 Tap RX DFE.**

Ref. 4

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Eye Margin For Intel B12
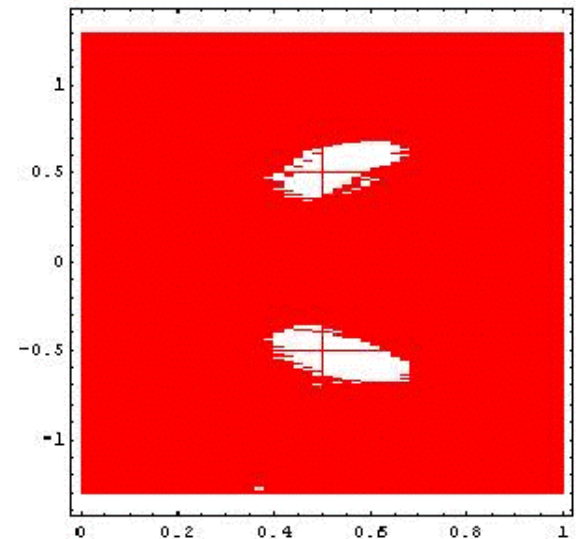
- **Good channel, Eq with 4 Tap TX FIR and 5 Tap RX DFE.**

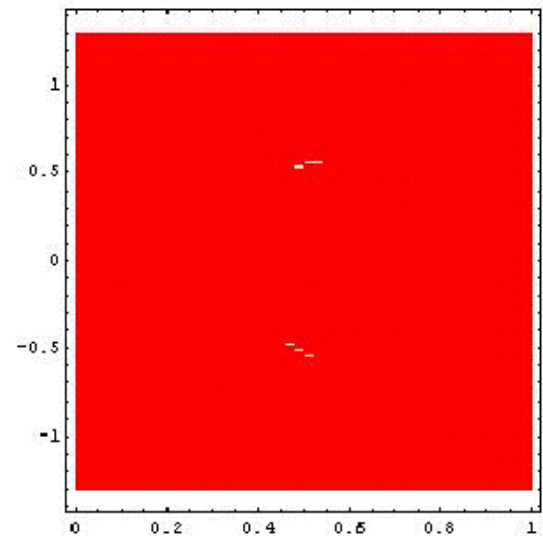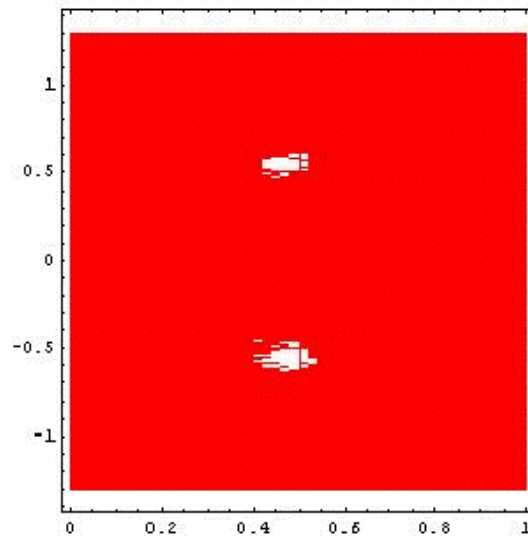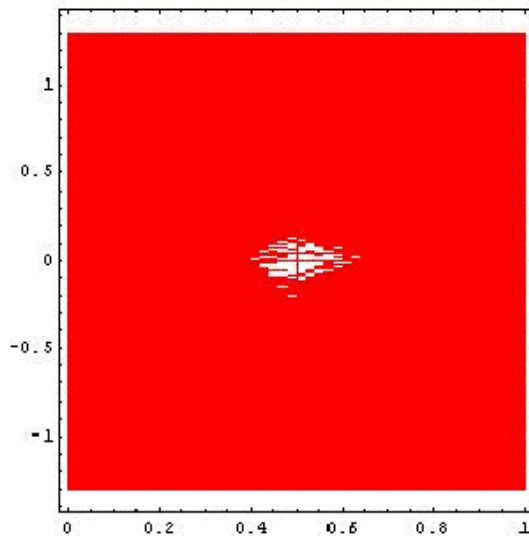NRZ Duobinary PR-4

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Eye Margin For Intel T1

- **Bad channel, Eq with 4 Tap TX FIR and 5 Tap RX DFE.**
  - No satisfactory solution with three signaling scheme below.

Ref. 4

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BP Summary

- **IEEE BP is scheduled to go to sponsor ballot by Jan 2006 and is expected to be approved June 2006.**

- **Methodology developed in IEEE Backplane Ethernet can assist development of SAS 6 Gig.**
    - **After more than 6 month of studying IEEE BP group selected NRZ signaling over PAM-4, PR2, and PR4.**

- **IEEE BP implementation based on NRZ signaling currently support**
    - **1.25 Gbaud 1-lane (8B10B)**
    - **3.125 Gbaud 4-lane (8B10B)**
    - **10.3125 Gbuad 1-lane (64/66B)**

- **SAS Auto-negotiation can leverage 802.3ap DME to overcome OOB limitations.**

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DFE Error Propagation

- **DFE are one of the common type of filter to equalize FR4 channels.**

- **DFE due to their feedback nature can propagate the error especially when the coefficient are large.**

- **CRC-32 can protect up to burst error of 3.**
  - **A 2 Tap DFE can generate burst of 3 error**
  - **A 4 Tap DFE can generate burst error >4.**

- **Three options exist for SAS 2.0**
  - **FEC probably too much latency**
  - **Add an additional CRC-8 to get total of 40 bits**
  - **Channel complexity is at level that DFE Tap <=2.**

An Eye Toward SAS 2.0 Requirements

- **Over-designing has an associated cost and power**
  - **Especially in SFF disk drives**

- **1st step Defining the Channel**
  - **26" vs 40"**
  - **Connector**
  - **FR4 type**
  - **Manufacturing practice and / or design role to manage stub length**
  - **Is there a need to operate a legacy 3 Gig SAS JBOD or Server at 6 Gig?**

- **OIF CEI 6 Gig LR may be overkill for 6 Gig SAS**

- **IEEE BP gives us path to 12 Gig SAS**

References

1. IEEE Draft 802.3ap Rev. 0.9 Ethernet Operation Over the Backplane, Apr 20, 2005.

2. Robert Brink, 10GBASE-KR transmitter Compliance Methodology proposal, brink_01_0505.pdf.

3. Pat Thaler, Transceiver friendly auto-negotiation signaling for 802.3ap, thaler_01_1104.pdf.

4. Spagna and Altmann, IEEE 802.3ap Simulation Results for 10Gb Serial Links, altman_02_0305.pdf

5. Peters, Chen, Gong, Cai, and Austin, ATCA Channel data for Backplane Ethernet Task Force, peters_01_0904.pdf.

6. John D'Ambrosia, Proposed Changes to the SDD11/SDD22 Return Loss mask, dambrosia_02_0904.pdf.

7. Steve Anderson, Signaling Method Performance Results, anderson_01_0305-1.pdf.

8. IEEE backplane Ethernet Website http://ieee802.org/3/ap

Acknowledgment's

1. Adam Healey, Chair IEEE 802.3ap (Backplane Ethernet).

2. Steve Anderson from Xilinx.

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