IEEE 802.3ap

Proposal for 10Gbps Serial Backplane PHY using Unified Signaling

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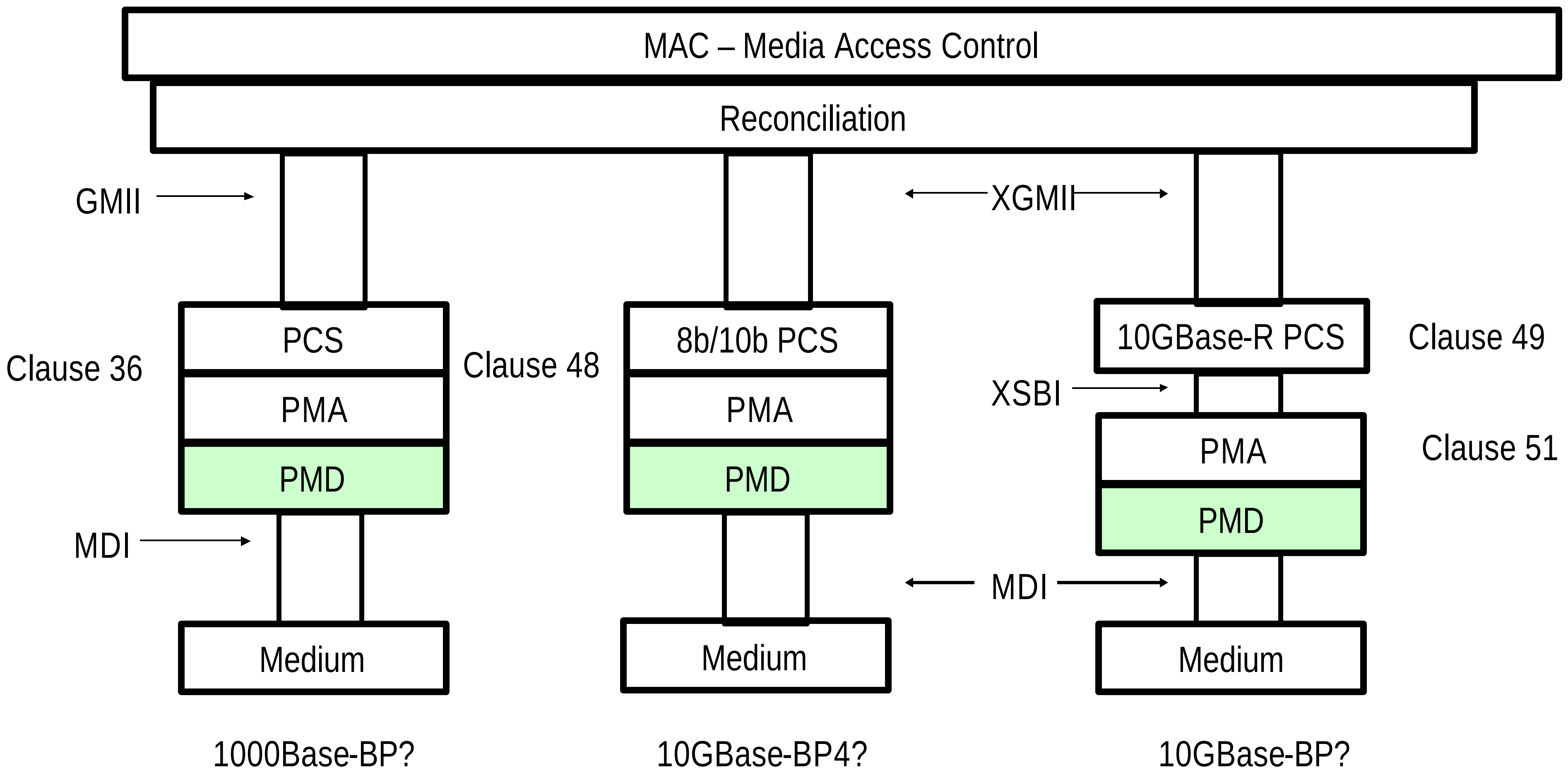
Objectives

- Propose a new PMD sublayer for 10Gbps Serial link across proposed channel using NRZ or DuoBinary signaling
- The presentation allows flexibility in the implementation.
- Leverage existing PCS and PMA sublayers Clause 49 and 51

Agenda

- Overview
- TX specifications
- RX specifications
- Channel Model
- Simulation Data
- Auto-negotiation
  - Clause 28 Based
  - Clause 37 Based
- Conclusion

Layer Model

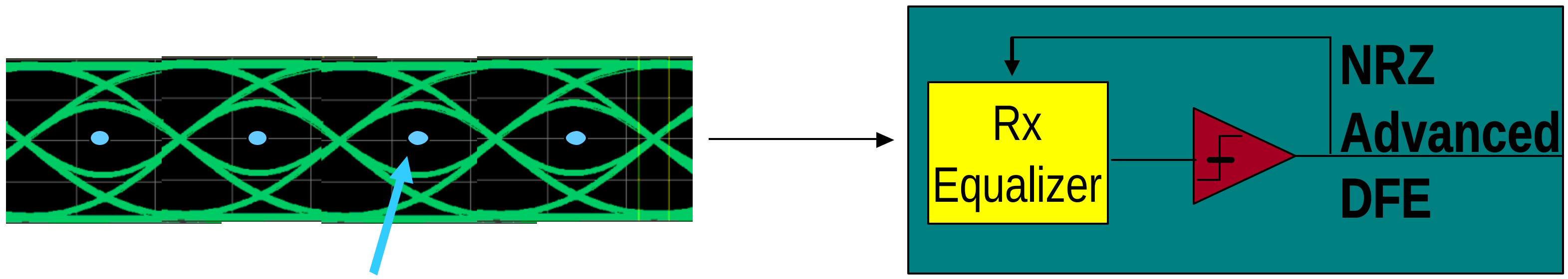


MAC – Media Access Control
Reconciliation
GMII
XGMII
Clause 36
PCS
PMA
PMD
Clause 48
8b/10b PCS
PMA
PMD
10GBase-R PCS
Clause 49
XSBI
PMA
PMD
Clause 51
MDI
MDI
Medium
Medium
Medium
1000Base-BP?
10GBase-BP4?
10GBase-BP?

Overview

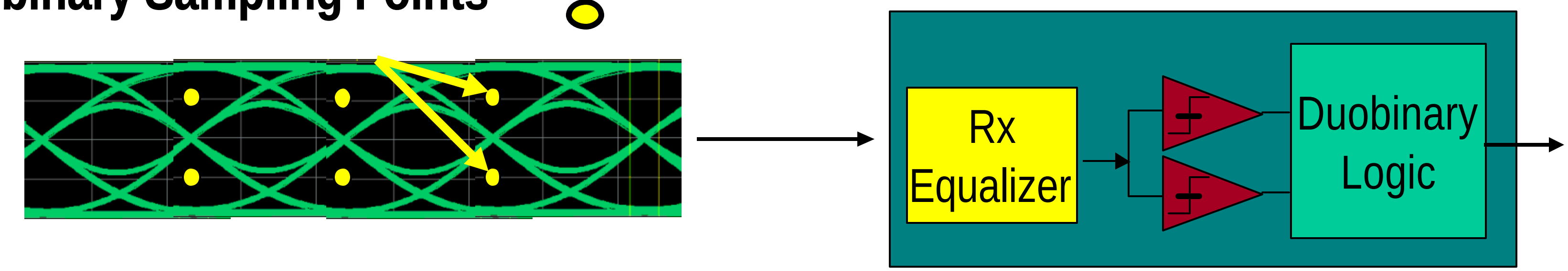
- Use Existing Clause 51 and 49 for PMA and PCS layer
- Define Transmitter characteristics
  - Based on TX mask, output amplitude, jitter, etc
- Adopt a Normative Channel Model
- Defined receiver characteristics
  - Jitter tolerance, return loss, etc.
  - Require operation with compliant TX over normative channel.
  - Similar approach as 1000BT, CX4 and XAUI
  - Allows implementation flexibility in RX
    - NRZ with Equalization
    - DuoBinary
    - Hybrid Architectures

Same Signal
Different Sampling Points

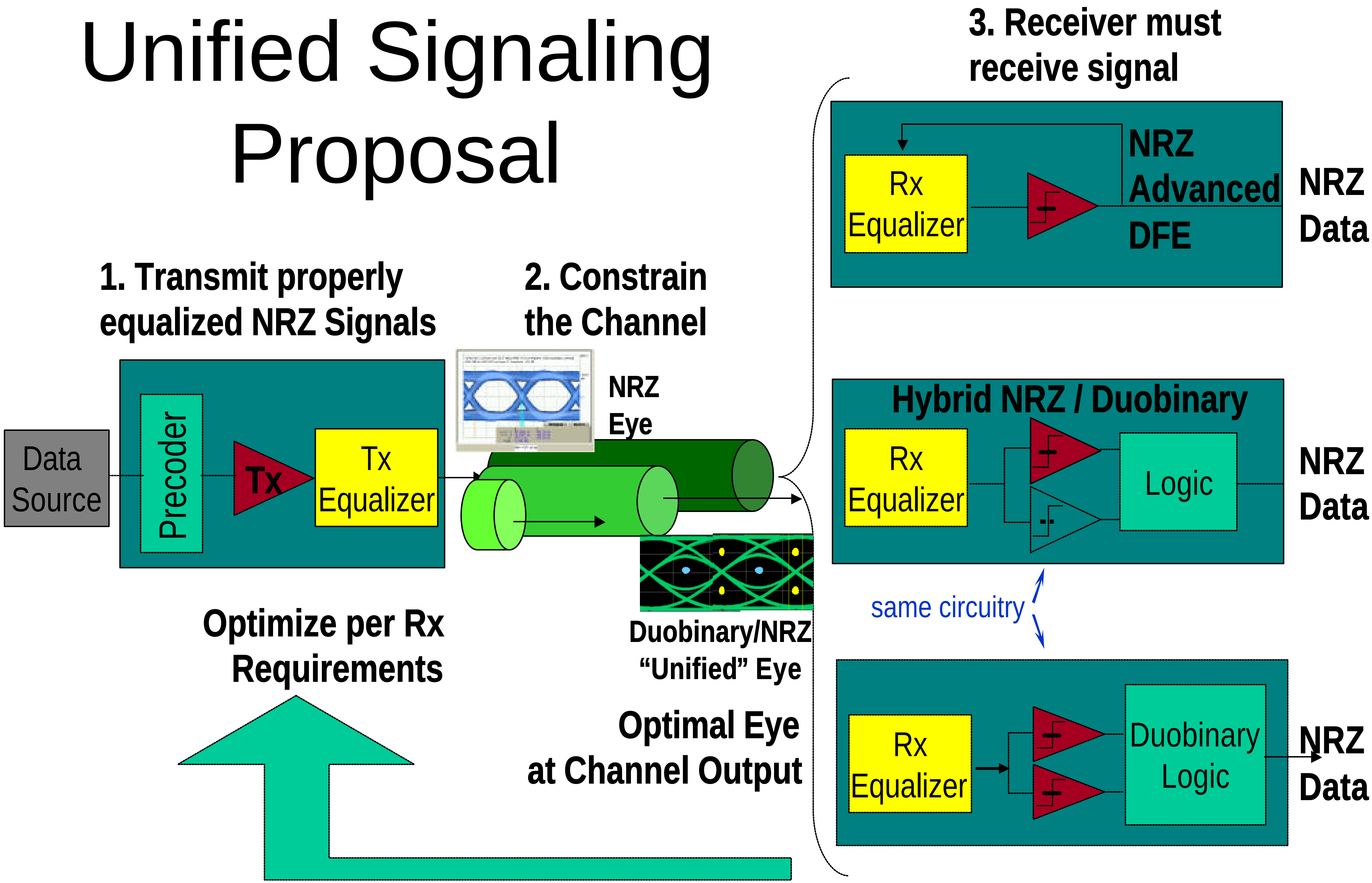


Traditional NRZ Sampling Point

Duobinary Sampling Points



Unified Signaling Proposal



Overview (Cont.)

- TX Equalization can be controlled by RX via Auto-negotiation protocol.
  - Protocol independent
    - Clause 28 State Machines with SSP similar to (szczepanek_01_0704.pdf)
    - Clause 37 based Auto negotiation
  - Inc/Dec control over TX Equalizer taps.
    - Allow the RX to choose optimal TX equalization for RX technology.
    - Efficient TX and RX implementations
  - Selectable Tx Precoding for DuoBinary Receivers
    - Easy to implement, Enables simplified DuoBinary RX

TX specification

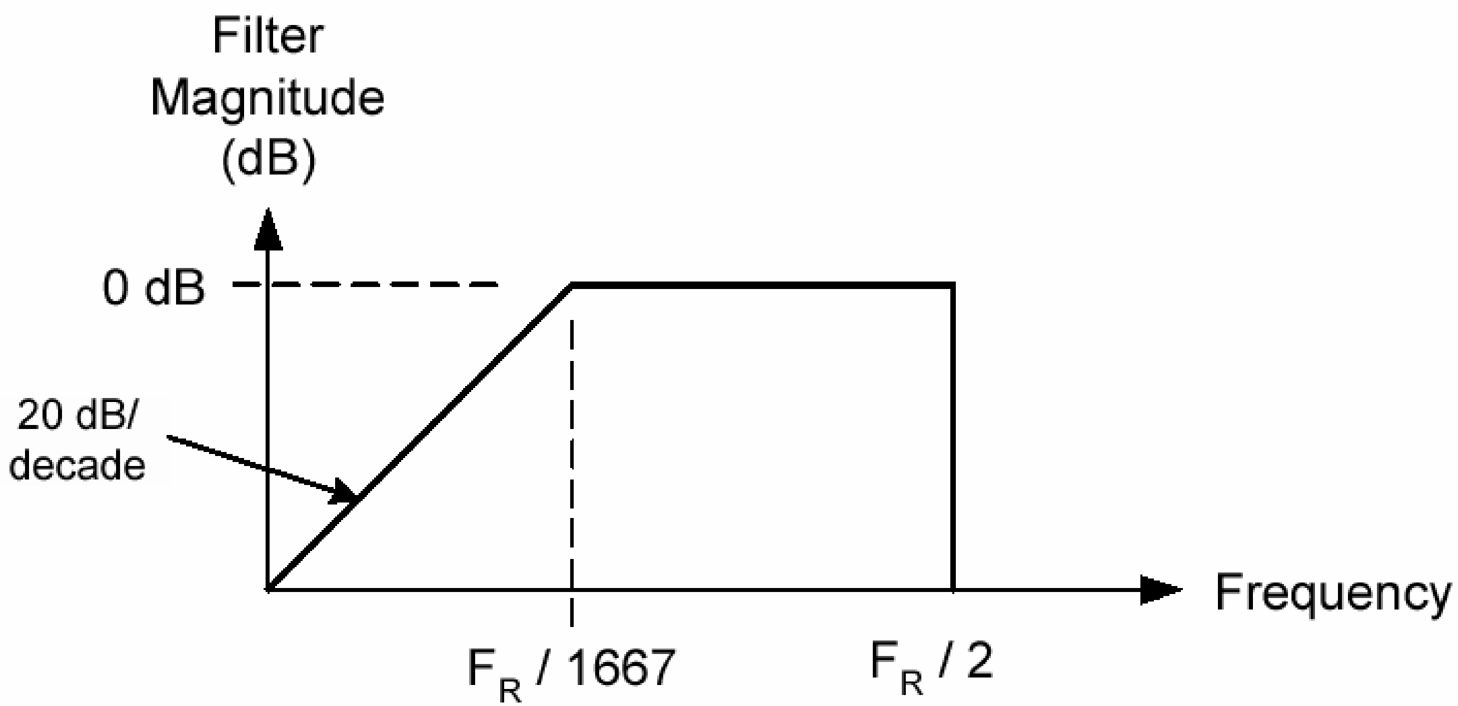
- Equalized TX mask
  – Must meet mask with at least one value of its EQ.
- Actual TX EQ implementation not defined!
  – Implementation is bounded by mask tests

Driver Characteristics Table

Parameter	Value	units
Baud rate tolerance	10.3125GBd +/- 100ppm	GBd
Diff. Amplitude (1) maximum minimum	1200 800	mVp-p mVp-p
Common-Mode Voltage	TBD	V
Diff. Output Return Loss minimum	Figure	dB
Output Template	Figure	V
Transition Time min Measured between 20% and 80%	24	ps
Output Jitter (2) Random Deterministic Total	 .15 0.15 0.3	 UIp-p UIp-p UIp-p

(1) Measured at Peak of the Output Waveform
(2) With Jitter Filter Applied

TX Jitter Filter

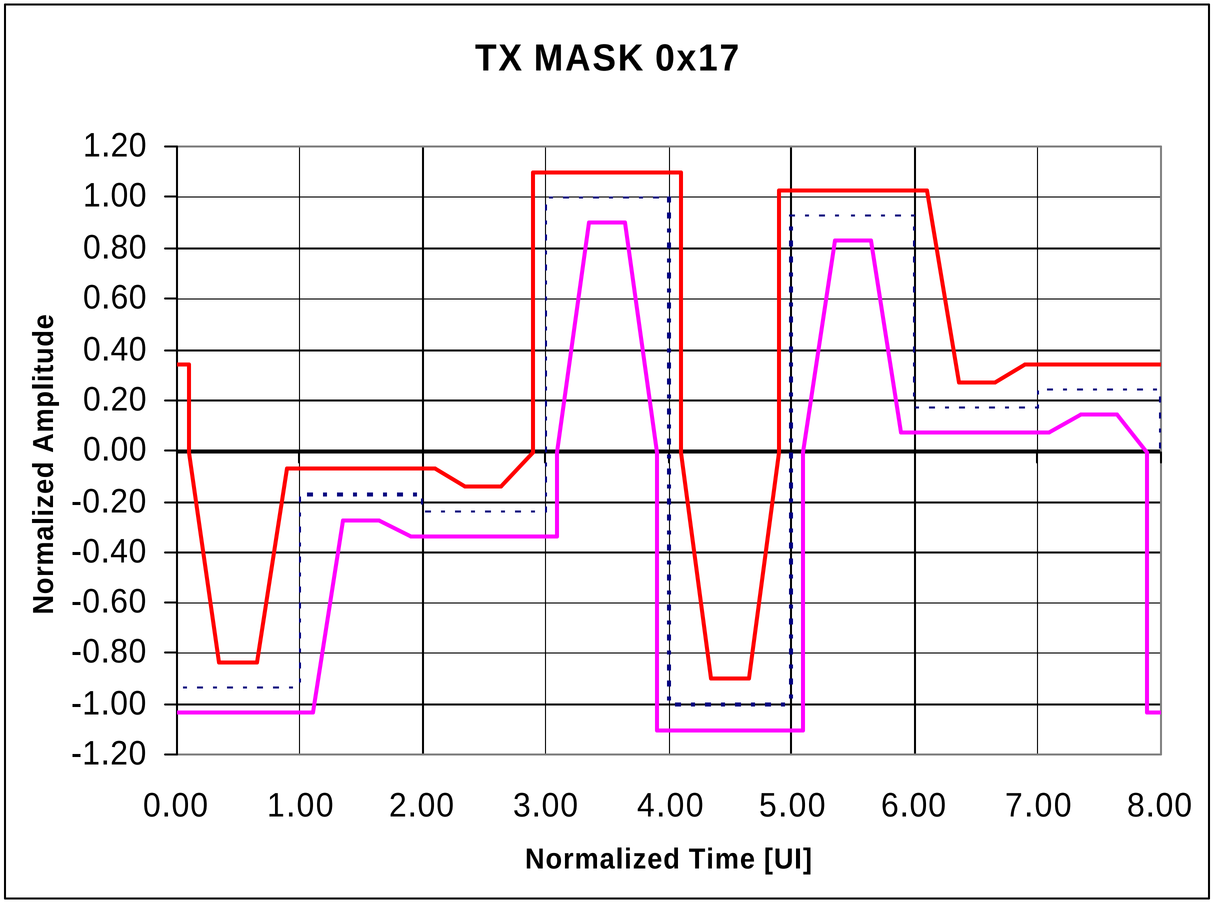


Note: F_R is bit rate

TX Mask

Test pattern is 0x17 repeating pattern

Masked based on tap values shown in simulation section of presentation



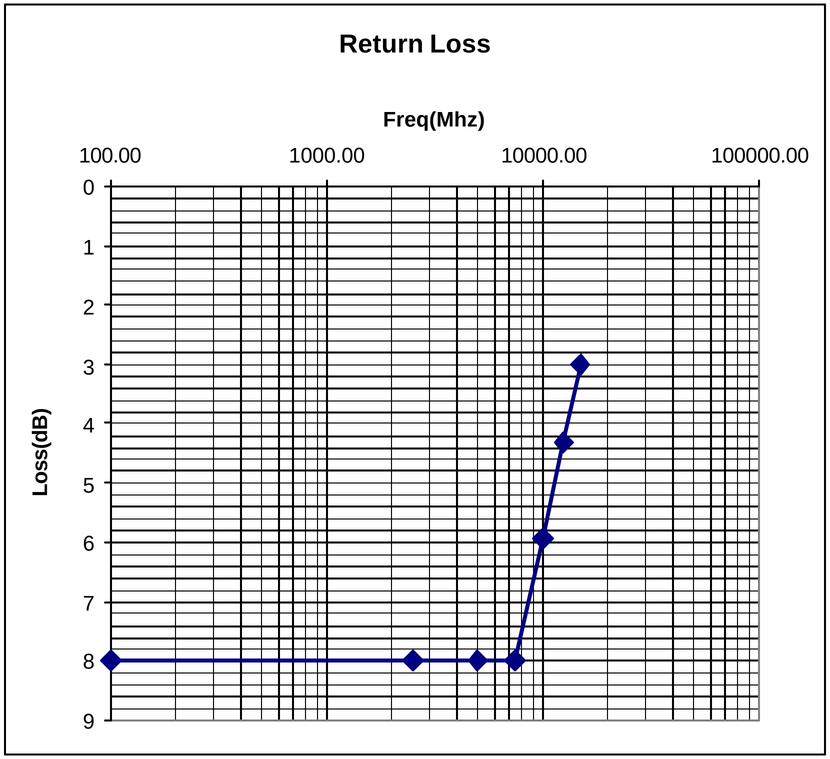
Differential Return Loss

Return Loss(f) = 8

For 100Mhz = f < 7.5 Ghz

Return Loss(f) = $8 - 16.6 * \log\left(\frac{f}{7.5Ghz}\right)$

For 7.5Ghz = f < 15Ghz



RX specification

Bit error ratio

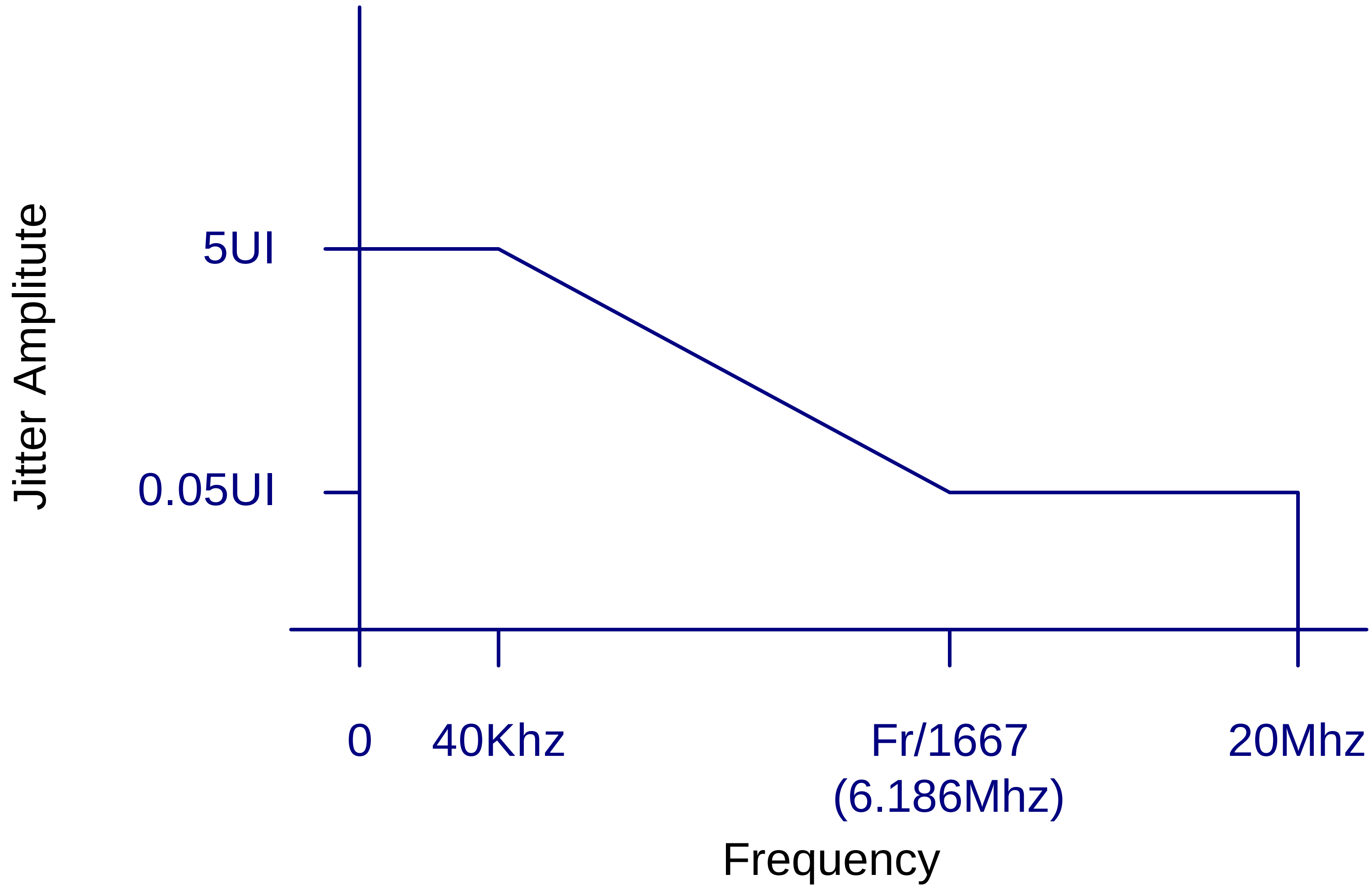
The receiver shall operate with a BER of better than 10 .12 when receiving a compliant transmit signal, as defined in X,through a compliant channel as defined in Y.

Paraphrased from 54.6.4.1 of IEEE802.3ak-2004

RX Characteristics Table

Parameter	Value	units
Baud rate tolerance	10.3125GBd +/- 100ppm	GBd
Diff. Peak Amplitude maximum	1600	mVp-p
Error Rate	10^-12	
Diff. Return Loss minimum	See TX Ret. Loss	dB
Jitter Tolerance	See Figure	UI

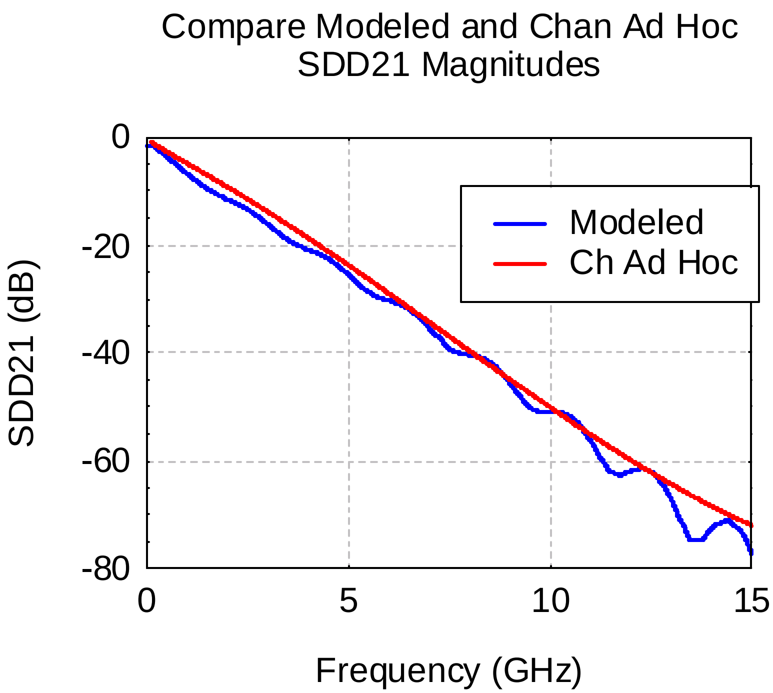
RX Sinusoidal Jitter Tolerance

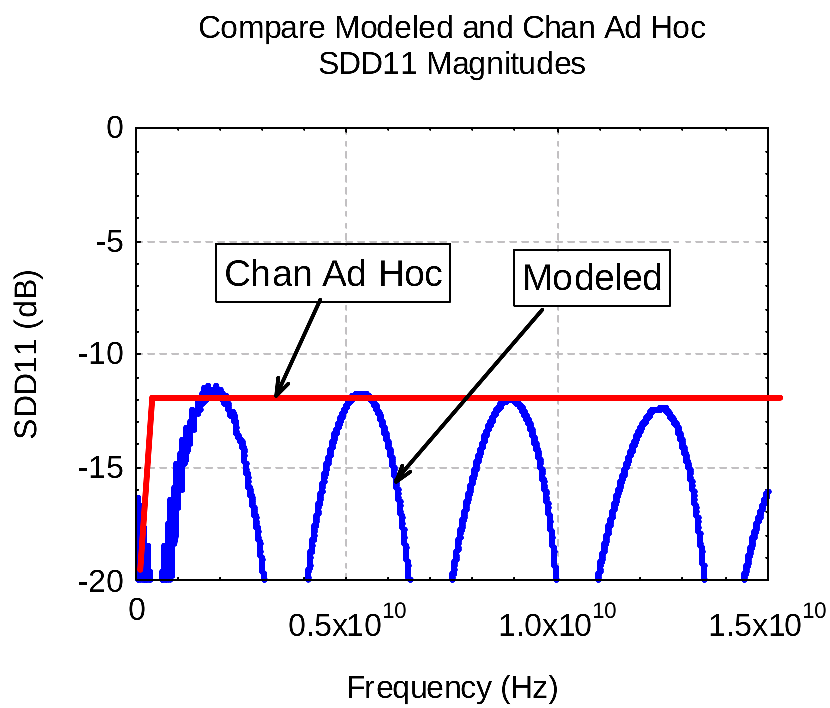


Channel Model

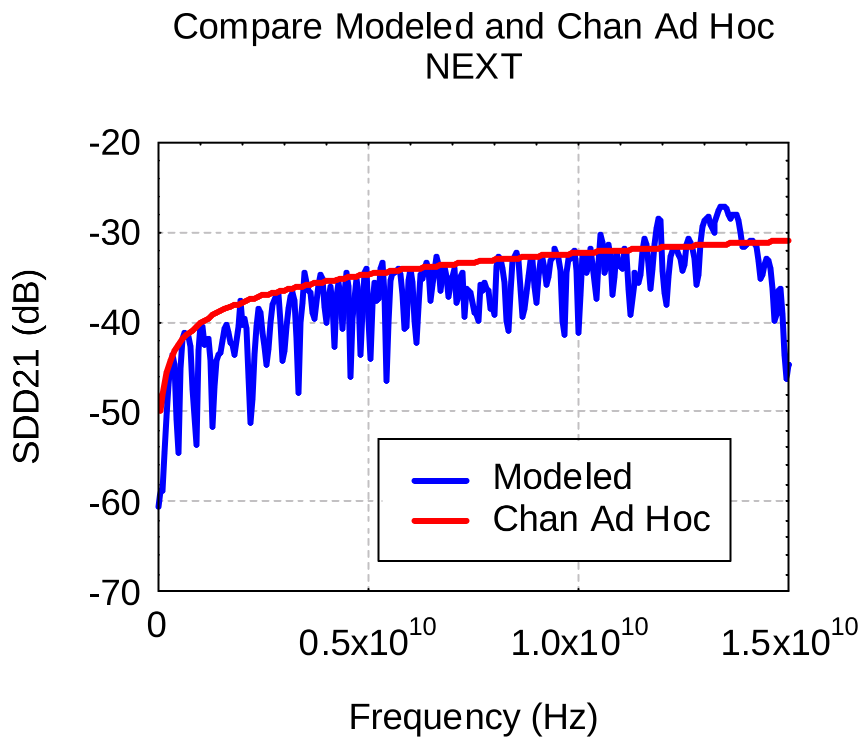
- The Channel Model is Normative
- Informative channel model developed by Channel Ad Hoc determines the bounds of the normative model.
- Proposed specification is subject to change based on ongoing work by the Channel Ad Hoc.

Channel Model (2)

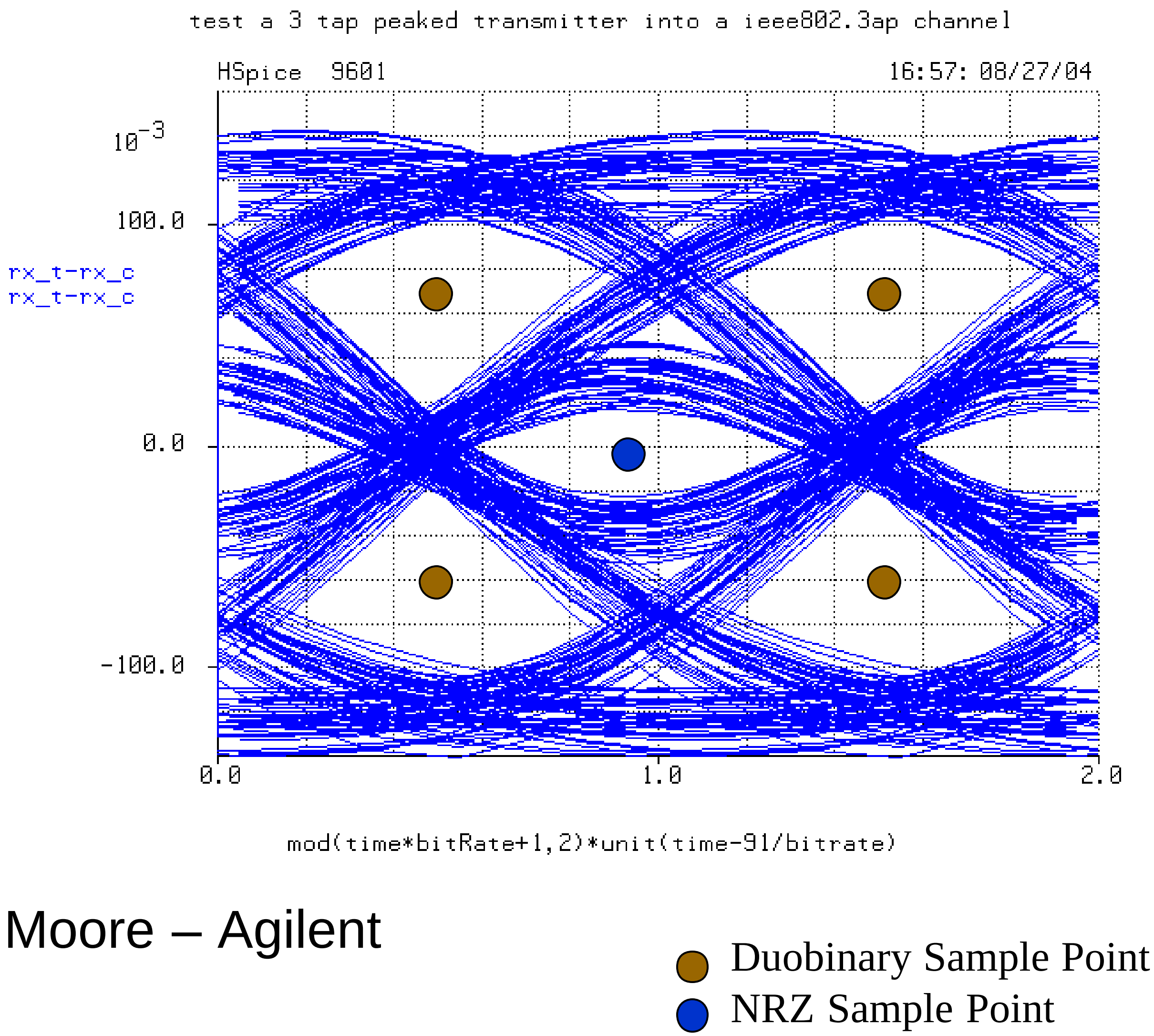




Channel Model (3)



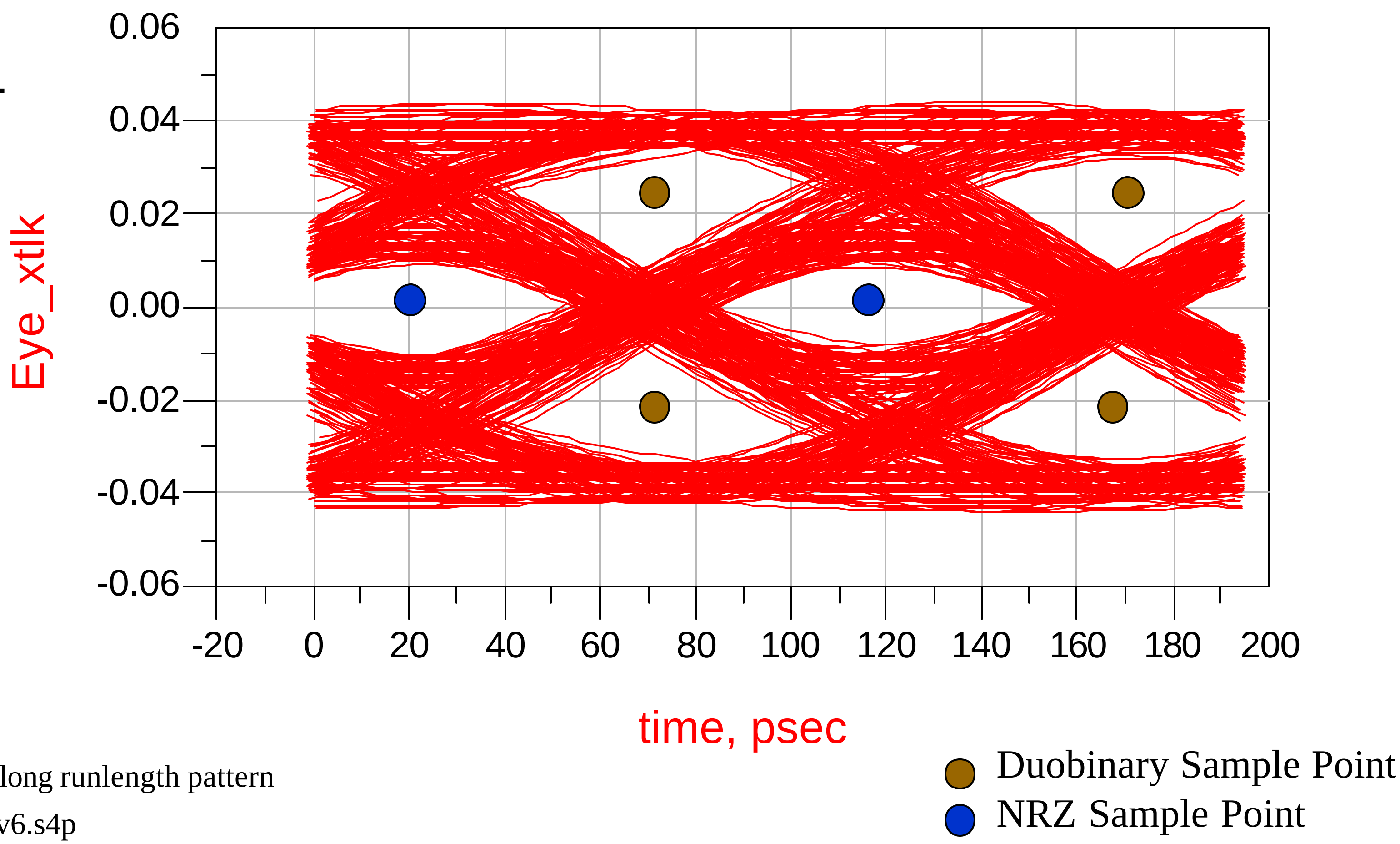
Simulation Data



- 1Vp-p Output Amp
- 3 tap
  - C(-1) = -0.035
  - C(0) = 0.585
  - C(1) = -0.380
- Data provided by Charles Moore – Agilent

IEEE chan 10.3125Gbs Received eye .2UI jitter with xtlk

- C[-1]=.071
- C[0]=1
- C[1]=-.67



10.3125Gbs

.2 UI jitter

1000bits Pseudo-random w/ long runlength pattern

Xtlk with 8 agressor xtlk_rev6.s4p

Clause 28 – SSP based Auto Negotiation

Signaling

- SSP (Symbol Sequence Pulse) replaces FLP

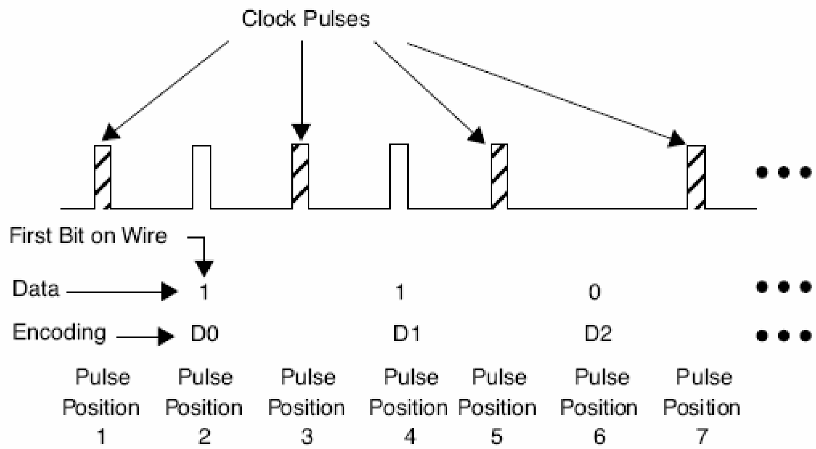


Figure 28–4—Data bit encoding within FLP Bursts

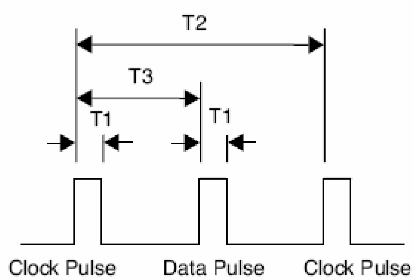


Figure 28–5—FLP Burst pulse-to-pulse timing

Insert Training Pattern

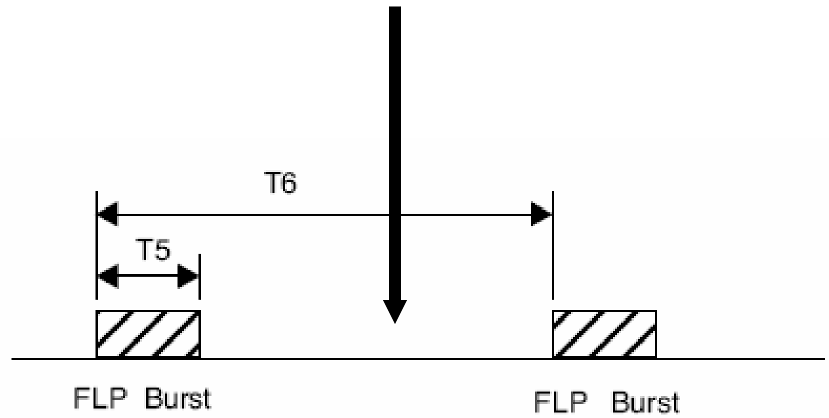
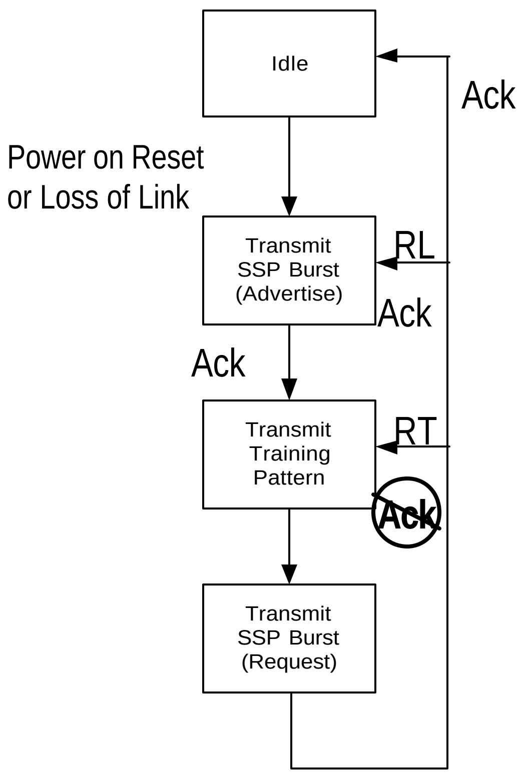


Figure 28–6—FLP Burst to FLP Burst timing

Signaling Timing (proposed new Timing)

	Parameter	Min	Typ	Max	Units
T1	Pulse width		100		ns
T2	Clock pulse to clock pulse		1		us
T3	Clock pulse to Data pulse		500		ns
T4	Pulses in burst	33		97	#
T5	Burst width		48.5		us
T6	Burst to Burst		1		ms

Negotiation Sequence



Sent SSP burst until Ack received

Minimum 6ms

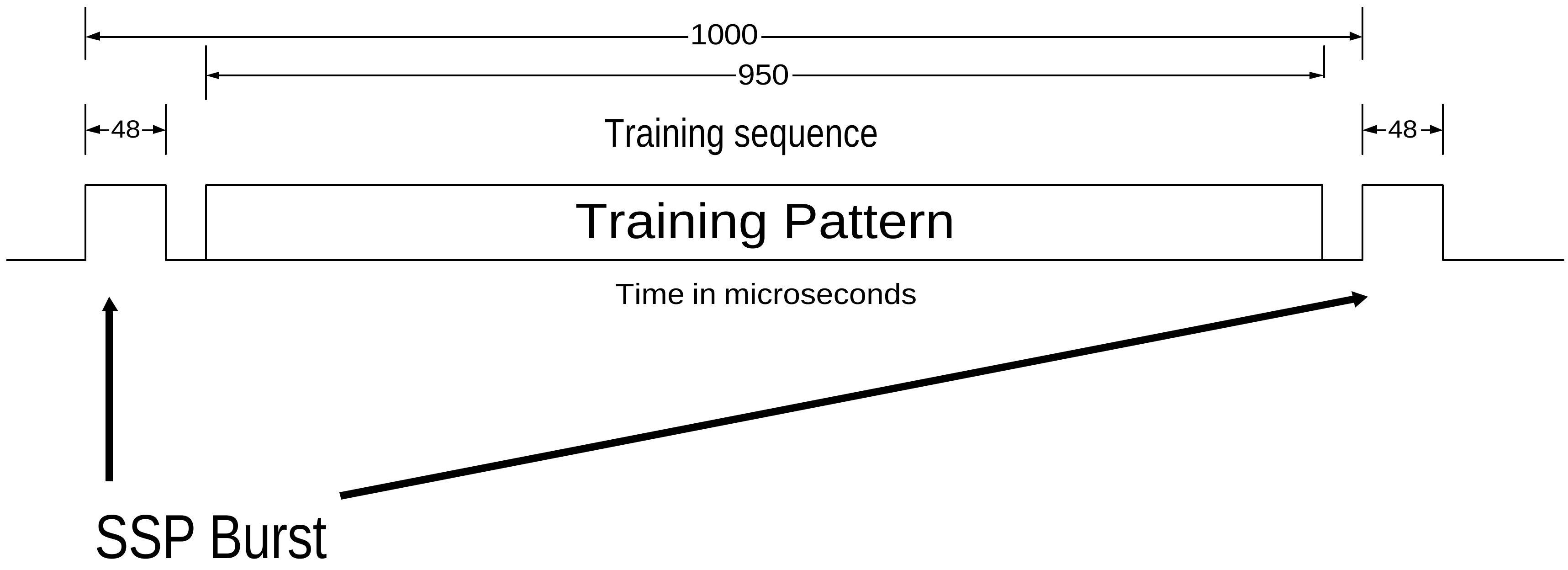
Send Training pattern

Send SSP burst with requested EQ/PC

Minimum 1ms

- Per Clause 28: Must receive 3 identical SSP Bursts to be considered valid then transmit Ack. Ack bit must be received for 3 SSP Burst minimum as well.

Negotiation Diagram



- Pattern will be sent with default TX Equalization settings on first attempt.
- Subsequent attempts would use adjusted values received via SSP Burst
- 950us = 9.8 million bits
- Training pattern will be designed to enable fast CDR lock and TX Equalization convergence

Auto Negotiation Base Page

Selector Field					Ability Field										
S0	S1	S2	S3	S4	A0	A1	A2	A3	A4	A5	LS0	LS1	RF	Ack	NP
D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15

- New Selector field value = 4 : IEEE802.3ap
- Ability bits
  - A0 – 1Gbps Capable
  - A1 – 4x3Gbps Capable
  - A2 – 10Gbps Capable
  - A3-A5 : Reserved for future
- LS0-LS1 : Lane selection
- RF: Remote Fault
- Ack : Acknowledge
- NP : Next Page

Auto Negotiation (Next Page)

Coefficient Update Field															
C^{-1}		C0		C1		C2		C3		C4		C5		C6	
D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15

R	R	R	R	R	R	R	R	PC	R	R	R	R	RT	RL	P
D16	D17	D18	D19	D20	D21	D22	D23	D24	D25	D26	D27	D28	D29	D30	D31

- 2 bits for Coefficient Update
  - 00 : Hold
  - 01 : Decrement
  - 10 : Increment
  - 11 : Reserved
  - Taps will increment or decrement until max or min value and then hold
- Upto 8 tap coefficients (Baseline is 3)
- Assume 1 UI granularity between taps

- R : Reserved for future
- PC : Precode Turns on TX Precoding for Duobinary RX
- RT: Resend Training Patterns
- RL: Indicates failure to Equalize/Re-Advertise
- Parity

Clause 37 – based Auto Negotiation

Clause 37 AutoNegotiation

- Key Objectives
  - Support speed selection among Clause 37 AN enabled devices and non-AN enabled (legacy) devices
  - Support AN transparently over optical or electrically redriven channels
  - Provide mechanism to automatically configure transmitter settings
    - Optimize for minimum calibration time
  - Minimize or eliminate PHY layer circuitry specific to AN
- Key Features
  - Clause 37 based AN speed selection
    - Default selections for non-AN based devices
    - Low speed (Baud/8) mode for 10Gbps serial AN, eliminating need for PHY to support 1.25Gbps solely for AN
  - Clause 37 based transmitter configuration passing in Baud/8 mode
    - Full baud-rate training pattern
    - Eliminates need for PLL switching and relocking between training and parameter passing
- Summary Proposal
  - Complete details in contribution xxxx.xx

Figure 37-5 Modification

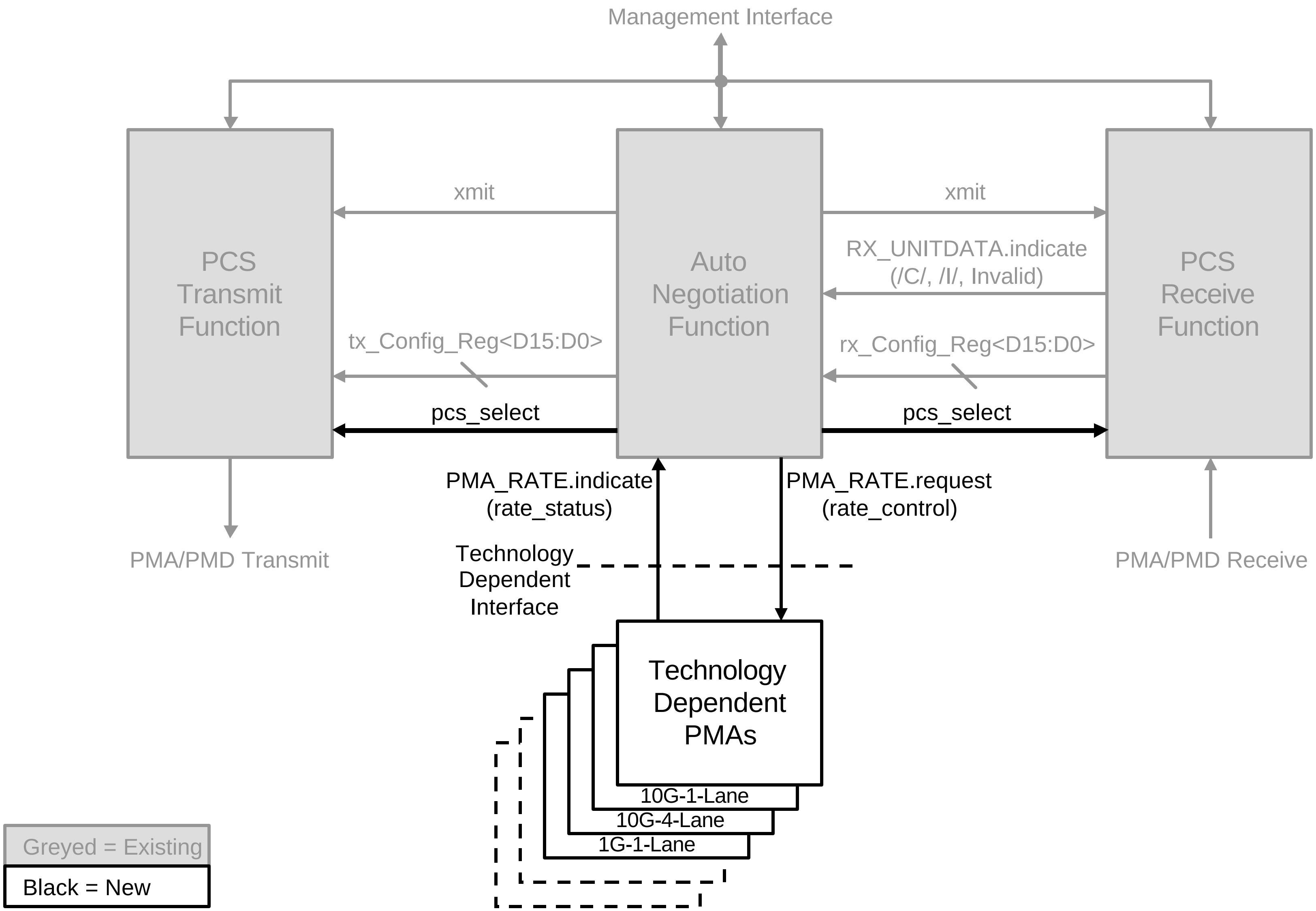


Figure 37-6

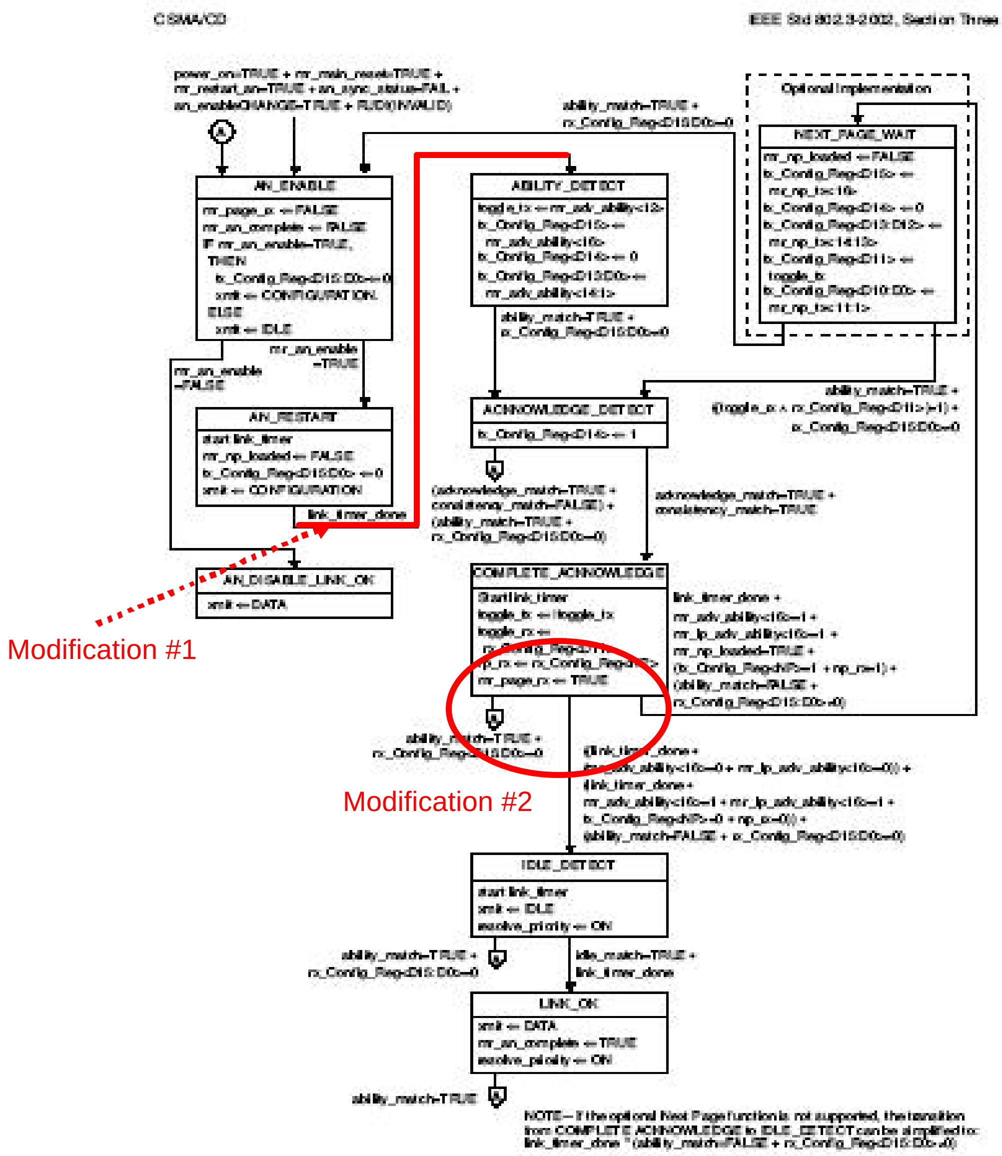


Figure 37–6 —Auto-Negotiation state diagram

L

Extended Next Page Possibility

Name	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15
Base Page	Res	Res	Res	Res	Res	FD	HD	PS1	PS2	Res	Res	EN	RF1	RF2	Ack	NP
	D32	D33	D34	D35	D36	D37	D38	D39	D40	D41	D42	D43	D44	D45	D46	D47
EoBP Next Page	0	1	0	1	0	0	0	0	0	0	0	T	Ack2	MP	Ack	NP
	D16	D17	D18	D19	D20	D21	D22	D23	D24	D25	D26	D27	D28	D29	D30	D31
	TC		PC	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	10G1	10G4	1G1
	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15
	C(-1)		C(0)		C(1)		C(2)		C(3)		C(4)		C(5)		C(6)	

EN	Extend Next Page Capable
1G1	1G-1-Lane capable
10G4	10G-4-Lane capable
10G1	10G-1-Lane capable

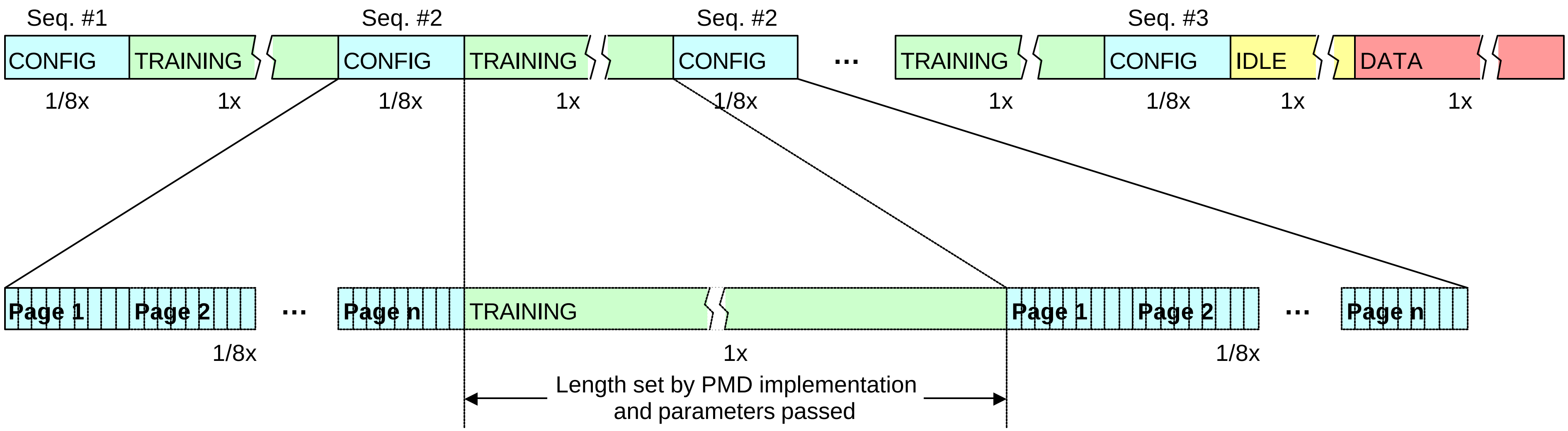
TC		
0	0	Send Training Pattern
0	1	Training Pattern Follows
1	0	Training Done
1	1	Reserved

PC	
0	No Tx Precoding
1	Turn Duobinary precoding on

C(n)		Action
0	0	Hold
0	1	Decrement
1	0	Increment
1	1	Hold

- Taps will increment or decrement until their min or max values are reached and then they hold
- Up to 8 coefficients (baseline is 3)
- Assume 1 UI between taps

Training Sequence Example



<u>Auto-Negotiation sequence 1</u>

Base Page
Message Page
Speed Ability Page
Tx FFE Pre-Cursor Ability #1 Page
Tx FFE Post-Cursor Ability #1 Page
Tx Train Control, TR=1 Page
Tx Train Control, TR=0 Page
TRAINING pattern

<u>Auto-Negotiation sequence 2</u>

Base Page
Message Page
Speed Ability Page
Tx FFE Pre-Cursor Adjust #1 Page
Tx FFE Post-Cursor Adjust #1 Page
Tx Train Control, TR=1 Page
Tx Train Control, TR=0 Page
TRAINING pattern

<u>Auto-Negotiation sequence 3</u>

Base Page
Message Page
Speed Ability Page
Tx FFE Pre-Cursor Adjust #1 Page
Tx FFE Post-Cursor Adjust #1 Page
Last Page
IDLE
DATA

Line Rates: Both Sides Auto-Negotiation

Local Phy	Link Partner	Initial Rate Local / Remote	CONFIG. Rate	TRAINING Rate	IDLE & DATA Rate
1G1	1G1 10G4+1G1 10G1+1G1	1.25G / 1.25G 1.25G / 1.25G 1.25G / 1.25G	1.25G	-	1.25G
10G4+1G1	10G1+1G1	1.25G / 1.25G	1.25G	-	1.25G
10G4	10G4 10G4+1G1 10G1+10G4	1.56G / 1.56G 1.56G / 1.25G 1.56G / 1.56G	1.56G	3.125G	3.125G
10G4+1G1	10G4+1G1 10G1+10G4	1.25G / 1.25G 1.25G / 1.56G	1.56G	3.125G	3.125G
10G1	10G1 10G1+1G1 10G1+10G4	1.29G / 1.29G 1.29G / 1.25G 1.29G / 1.56G	1.29G	10G1	10G1
10G1+10G4	10G1+1G1 10G1+10G4	1.56G / 1.25G 1.56G / 1.56G	1.29G	10G1	10G1
10G1+1G1	10G1+1G1	1.25G / 1.25G	1.29G	10G1	10G1

Line Rates: One Side Auto-Negotiation

Local Phy No A-Neg	Link Partner	Initial Rate Local / Remote	Config. Rate	TRAINING Rate	IDLE & DATA Rate
1G1	1G1 10G4+1G1 10G1+1G1	1.25G / 1.25G 1.25G / 1.25G 1.25G / 1.25G	-	-	1.25G
10G4	10G4 10G4+1G1 10G1+10G4	3.125G / 1.56G 3.125G / 1.25G 3.125G / 1.56G	-	-	3.125G

Conclusion

- The proposal meets objective for 10Gbps Serial PMD
- Specified in a manner that is consistent with existing IEEE 802.3 PMD clauses
- Maintains compatibility with other 10Gbps serial electrical standards
- Does not specify a specific implementation
- Provides a mechanism for the channel to be optimally equalized using either Auto-negotiation protocols