100GBase-PAM8

Baseline proposal update

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IEEE Next Gen 100G Optical Ethernet Task Force

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About this presentation

- This presentation explains and provides supporting notes for the draft clause for 100GBASE-PAM8.
- The actual Baseline Proposal on which the draft is based is http://www.ieee802.org/3/bm/public/jan13/bhatt_01_0113_optx.pdf
- It was co-authored and supported by the following members:
- Chris Bergey (Luxtera), Vipul Bhatt (Cisco), Sudeep Bhoja (Inphi), Arash Farhood (Cortina), Ali Ghiasi (Broadcom), Dave Lewis (JDSU), Beck Mason (JDSU), Gary Nicholl (Cisco), Torben Nielsen (Acacia), Dan Stevens (Fujitsu Semiconductor), Norm Swenson (Clariphy), Andre Szczepanek (InPhi), Vivek Telang (Broadcom), Matt Traverso (Cisco), Zhongfeng Wang (Broadcom), Brian Welch – Luxtera

Agenda

- High-Level Summary of changes
- High-level walkthrough of changes
- Backup slides

High-Level Summary of changes

- Added Octal PRBS test pattern to be used for TX tests and RX stressed sensitivity tests
- Added informative RIN-OMA spec to TX Characteristics
- Added OMA spec to TX and RX Characteristics
- Replaced TX Linear-Fit test with TWDP
- Added receiver sensitivity and stressed sensitivity values in OMA
- Other Receiver Characteristic changes:
  - Added receiver damage threshold spec
- Completed the fiber Optic Cabling section
  - Kept the link budget at 4dB and allocated total of 3.54dB to Connection/Splice loss per Paul Kolesar calculation posted on the reflector

High-Level walkthrough of changes

Octal PRBS patter (OPRBS13)

• The OPRBS13 test pattern is generated prior to Unipolar PAM8 encoding. When the OPRBS13 test pattern is enabled, it replaces the signal from the Partial Gray Coder.

• The OPRBS13 test pattern is a repeating 8191 symbol test pattern. Three full cycles of a PRBS13 pattern generator are used to produce the OPRBS13 test pattern.

• Bits in the first and third cycles, R(1:8191) and R(16383:24573), are not inverted, and bits in the second cycle, R(8192:16382) are inverted. Triplets of bits R(3j-2:3j), j=1 to 8191, are mapped to partially Gray-coded symbols, as defined in 96.2.2.4.

• The PRBS13 pattern generator has generator polynomial $g(x)=1+x+x^2+x^{12}+x^{13}$.

High-Level walkthrough of changes

TX characteristics

Table 96–10—100GBase-MR transmit characteristics

Description	**Subclause reference**	**100GBase-MR**	**Unit**
Signaling speed (nominal)	96.3.10.3	39.55078125	GBd
Signaling speed variation from nominal (max)	96.3.10.3	+/-100	ppm
Center wavelength (range)	96.3.10.4	1300 to 1320	nm
Average launch power (max)	96.3.10.5	3	dBm
Average launch power (min)[a]	96.3.10.5	-0.78	dBm
Average launch power of OFF transmitter (max)	96.3.10.5	-30	dBm
OMA (min)	96.3.10.7	0	dBm
Extinction ratio (min)	96.3.10.6	6	dB
Optical Return Loss Tolerance (max)	96.8	29	dB
Transmitter reflectance (max)		-35	dB
Transition time (20-80%, min), no equalization	96.3.10.8	13.8	ps
$RIN_{29}OMA$ (max)[b]	96.3.10.9	-139	dB/Hz
Transmitter output waveform and dispersion penalty (TWDP)	96.3.10.10	TBD	dB
Output jitter Clock random jitter, RMS Clock deterministic jitter, peak-to-peak	 96.3.10.11 96.3.10.11	 0.01 0.08	 UI UI

[a]Average launch power (min) is informative and not the principal indicator of signal strength.
[b]$RIN_{29}OMA$ (max) is informative and not the principal indicator of signal quality.

High-Level walkthrough of changes

TWDP test

• Replaced the Linear-Fit/SNDR test with TWDP very similar to 10GBase-LRM TWDP

• The TWDP test along with the jitter test can comprehensively test TP2.

• TWDP measurement procedure

The 100GBase-MR TWDP measurement procedure is similar to the TWDP measurement procedure described in 68.6.6.1. The system under test repetitively transmits the OPRBS13 test pattern define in 96.2.8.5, and the waveform is captured with an effective sample rate of at least seven samples per unit interval. The waveform is to be captured without averaging.

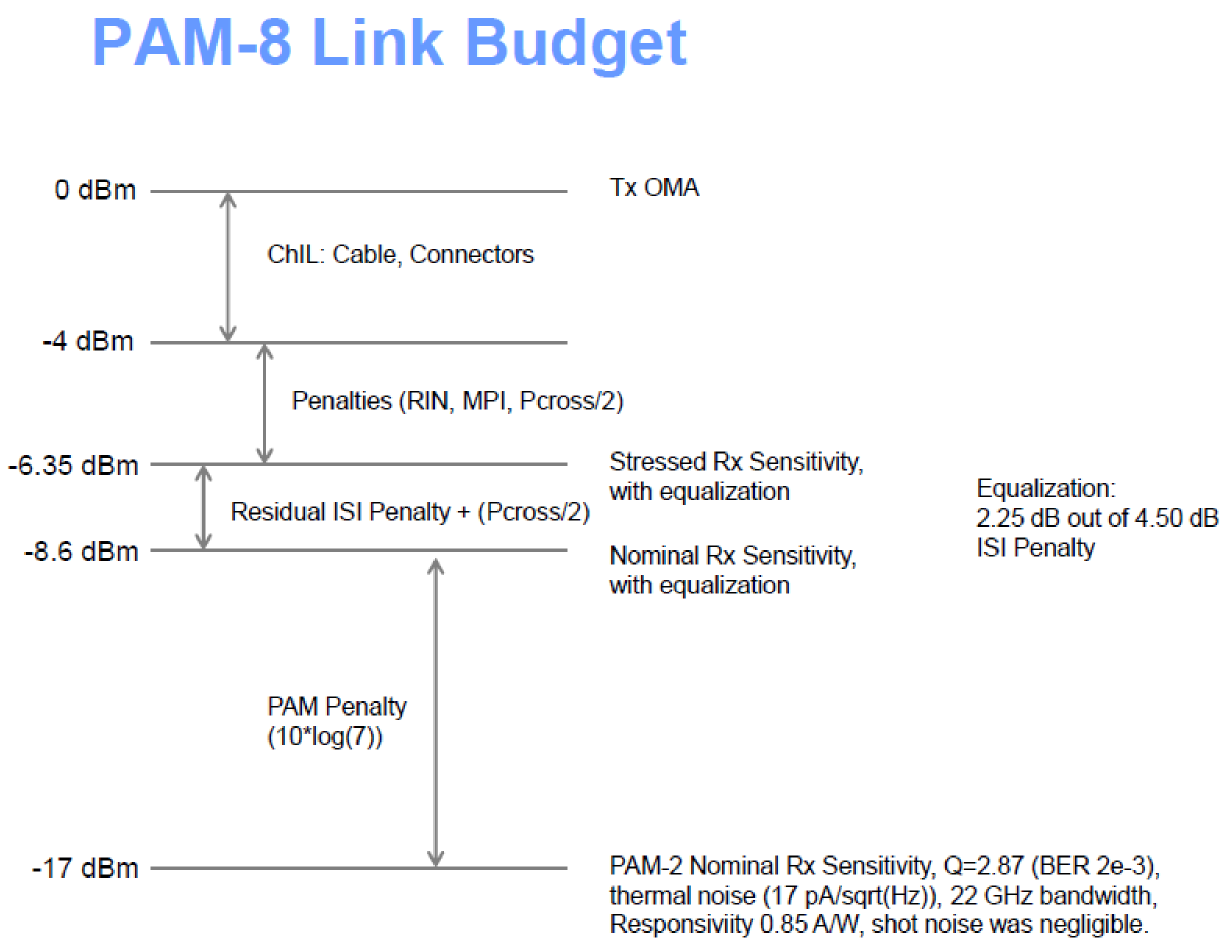
The algorithm processes the captured waveform to determine a reference FFE-MMSE equalizer, with tap number and spacing TBD. This is not intended to represent the equalizer used within an optical receiver, but is intended to provide uniform measurement conditions at the transmitter.

The captured waveform is then processed by the reference equalizer, and the per-level noise variances are estimated at the slicer. A semi-analytical method is then used to map the noises variances to an effective transmitter signal-to-noise ratio.

High-Level walkthrough of changes

Receiver sensitivity

From Phoenix base-line proposal page-7



High-Level walkthrough of changes

RX characteristics

Table 96–11—100GBase-MR receive characteristics

Description	Subclause reference	100GBase-MR	Unit
Signaling speed (nominal)	96.3.10.14	39.55078125	GBd
Signaling speed variation from nominal (max)	96.3.10.15	+/-100	ppm
Center wavelength (range)	96.3.10.15	1300 to 1320	nm
Average receive power (max)	96.3.10.16	3	dBm
Average receive power (min)	96.3.10.16	-4.78	dBm
Receiver reflectance (max)	96.8.2.2	-35	dB
Damage threshold [a]		5.5	dBm
Receiver sensitivity in OMA (max) [b]	96.3.10.19	-8.6	dBm
Receiver comprehensive stressed receiver sensitivity in OMA (max)		-6.35	dBm
Conditions for comprehensive receiver stressed sensitivity test	96.3.10.17	See subclause	
Jitter tolerance	96.3.10.18	See subclause	

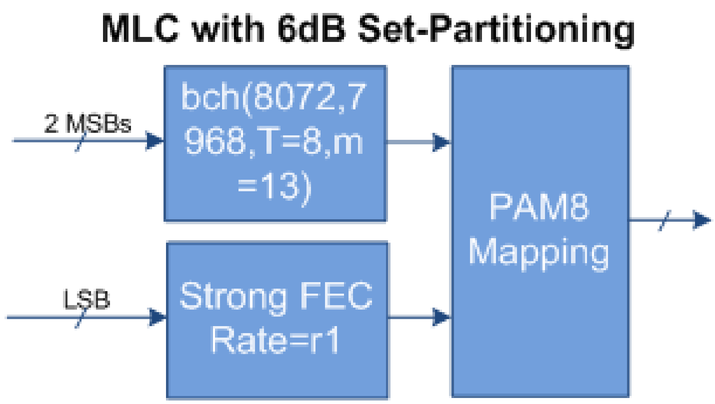
[a] The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level.

[b] Receiver sensitivity in OMA (max) is informative

Backup Slides

MLC FEC

- Draft V1.0 uses bch(8072,7968,T=8,m=13) as MSB FECs



MLC FEC

- LSB Block size 8100 bits
- LSB code rate: 1156/2025 (approximately 0.571)
  MSB block size:8072 bits
- MSB code rate: 996/1009 (approximately 0.987)

- Number of extra unused overhead bits in the MSB block: 56 (detailed mapping is specified in the draft subclause 96.2.2.2)

- Combined Code Rate including extra overhead: 1028/1215 (approximately 0.846)

- Like Phoenix proposal, the MLC-FEC requires transcoding change from 64b/66b to 256b/257b

- PAM8 symbol rate including the transcoding: 39.55078125 Gbaud (Phoenix proposal was 40.4296875)

- CAUI-4 clock to PAM-8 clock conversion ratio: 135/88

MLC FEC

•PAM-8 SNR for 1E-15 BER: better than **19.6dB** (Phoenix proposal was 19.6dB)

- The 6dB Set-Partition gain does not fully materialize because some of the optical noise sources are amplitude dependent (such as RIN).
- If the noise was AWGN, then the PAM-8 SNR for 1E-15 BER should have been 19.3dB. So there is a loss of 0.3dB due to non-AWGN noise effect

- Encoder latency: 25ns
- Decoder latency: Block receive time + Decode time = 205ns+125ns=330ns (A minimum saving of 20ns compared to Phoenix proposal!)

Description	Draft v1.0
MLC coding scheme	6 dB set partitioning
257b/256b transcoding	Required
Baud rate	39.55078125Gbaud
Required SNR for 1E-15	<19.6dB
Encoder latency	25ns
Decoder latency	330ns

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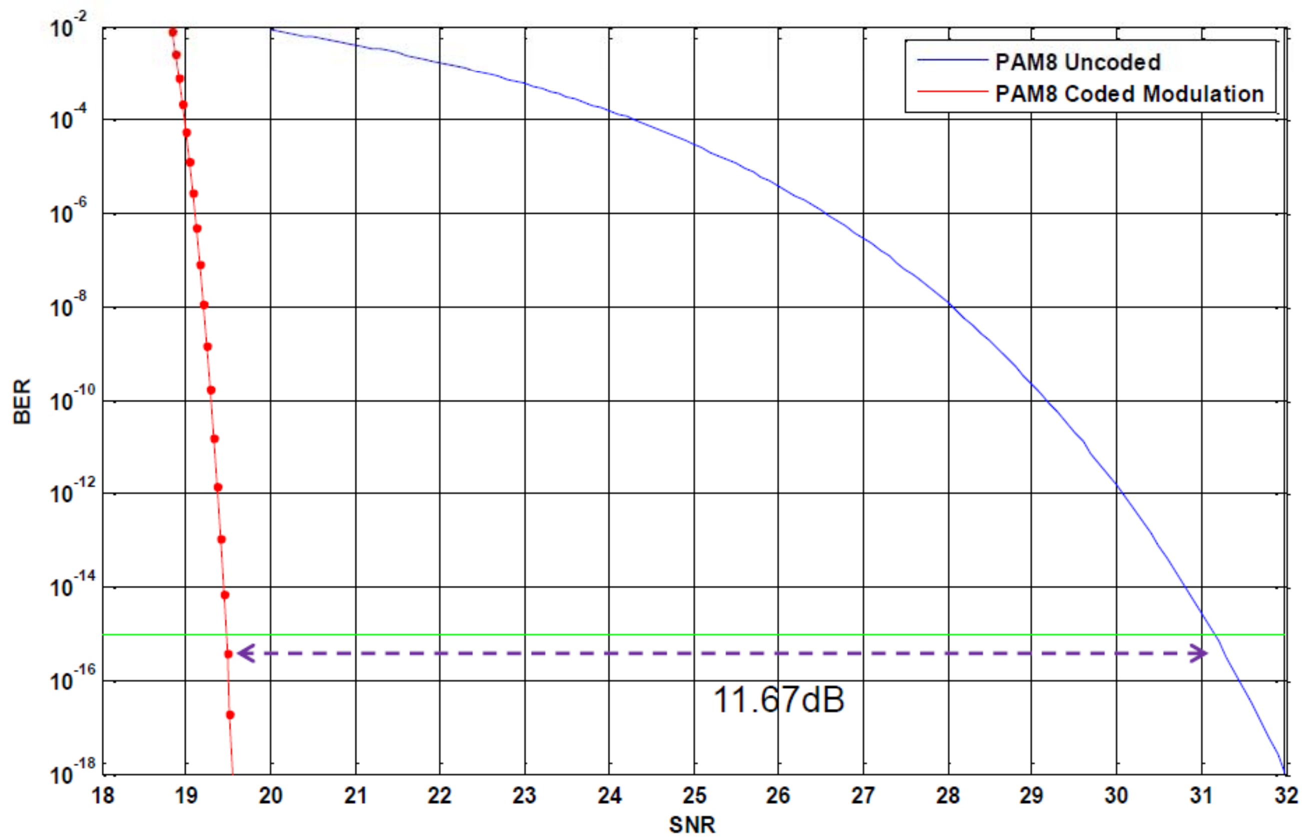
Example Coded Modulation Sim Results



- PAM8 coded modulation FEC delivers 11.67dB coding gain

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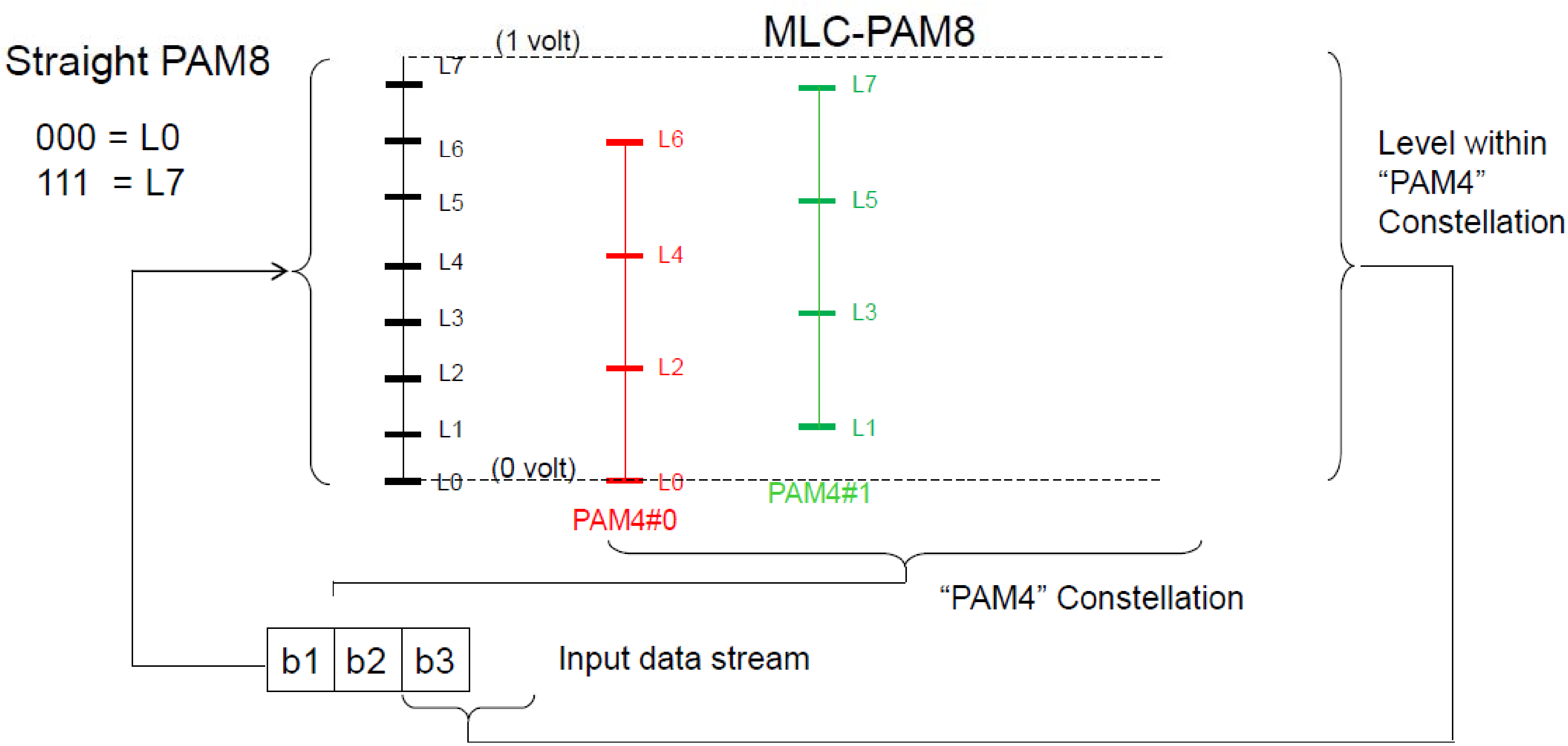
Multi Level Coding (MLC)



- MLC – Not all bits are equal. Focus FEC overhead/gain where it adds most value
- Treat one bit b1 as "PAM8". Treat lower two bits (b2,b3) as "PAM4"
- Target all FEC overhead/gain to protecting the upper bit, and no FEC to lower two bits
- Enables higher FEC coding gain without bumping up the symbol (data) rate
- A 10% overhead FEC (on aggregate) results in 30% overhead FEC on upper bit

96.3 Physical Medium Dependent (PMD) Sublayer

The transmitter spec does not define transmit filter and the transmitter test allows for certain amount of static non-linear compensation (on the receive side). This is to enable various options such as EML/DML and SiPhotonic modulators for TX implementation

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PAM-8 Block Diagram

- Showing segmented modulator and traditional MZM/EA