PAM8 Draft v0.1 Summary

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Agenda

- High-Level Summary and comparison to Phoenix PAM8 baseline proposal
- Draft structure
- High-level walkthrough of subclauses
- Backup slides

High-Level Summary and comparison to Phoenix PAM8 baseline proposal

- Most of the Phoenix proposal was adopted in the draft. Some of the items needed more detail that were added.

- For now, we call this new Phy, **100GBase-MR**

- The EEE spec is only in form of place holder, TBD.

- Most of the time, when there is a "TBD" in the spec, the suggested value is also specified.

- Below is what was changed in the draft compared to Phoenix proposal
  - For the multi-layer coding, the outer 802.3bj 100GBase KR4 FEC code was replaced with bch(8072,7968,T=8,m=13)
  - The DSQ-32 option is not detailed in the Draft v0.1
  - The TX Transmit characteristics and the RX tests are not exactly as specified in the Phoenix proposal. (See the following slides for details)

High-Level Summary and comparison to Phoenix PAM8 baseline proposal

Draft Amendment to IEEE std 802.3 — IEEE *Draft* P802.3bm/D0.1
IEEE P802.3bm 40 Gb/s and 100 Gb/s Fiber Optic Task Force — May-2013

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)	96.3.10.5	-0.78	dBm
Average launch power of OFF transmitter (max)		-30	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
Output waveform Define linear fit parameters here	96.3.10.9		
Output jitter and linearity Clock random jitter, RMS Clock deterministic jitter, peak-to-peak Signal-to-noise-and-distortion ratio	 96.3.10.10 96.3.10.10 96.3.10.11	 0.01 0.08 8.8	 UI UI dB

High-Level Summary and comparison to Phoenix PAM8 baseline proposal

Draft Amendment to IEEE std 802.3 | IEEE *Draft* P802.3bm/D0.1
IEEE P802.3bm 40 Gb/s and 100 Gb/s Fiber Optic Task Force | May-2013

96.3.10.12 100GBASE-MR receive optical specifications

The 10GBASE-MR receiver shall meet the specifications defined in Table 96-11 per measurement techniques defined in 96.3.10.13 to 96.3.10.18.

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)		-35	dB
Interference tolerance	96.3.10.17	See subclause	
Jitter tolerance	96.3.10.18	See subclause	

High-Level Summary and comparison to Phoenix PAM8 baseline proposal

Table 96–12—100GBase-MR Fiber optic cabling (channel)

Description	100GBase-MR	Unit
Operating distance (min)	2	m
Operating distance (max)	500	m
Channel insertion loss (max)	4	dB
Positive dispersion (max)	1.0	ps/nm
Negative dispertion (max)	-2.0	ps/nm
Optical return Loss (min)[a]	29	dB
DGD_max[b]	1.5	ps

[a] Based on 35 dB RL for connectors per ISO/IEC 11801, dual-trunk architecture model having up to 8 connectors with a mix of APC and non-APC types.
[g] Differential Group Delay (DGD) is the time difference between the fractions of a pulse that are transmitted in the two principal states of polarization of an optical signal. DGD_max is the maximum differential group delay that the system must tolerate.

96.8.1 Optical fiber and cable

The fiber optic cable shall meet the requirements of IEC 60793-2 and the requirements of Table 96-13.

Table 96–13—100GBase-MR Optical fiber and cable characteristics

Description	100GBase-MR	Unit
Fiber cable attenuation (max)	0.4[a] or 0.5[b]	dB/km
Zero dispersion wavelength(λ_0)	$1300 \leq \lambda_0 \leq 1324$	nm
Dispersion slope (max) (S_0)	0.093	ps/nm^2 km

[a]For the single-mode case, the 0.4 dB/km attenuation for optical fiber cables is defined in ITU-T G.652.
[b]For the single-mode case, the 0.5 dB/km attenuation is provided for Outside Plant cable as defined in ANSI/TIA/EIA

High-Level Summary and comparison to Phoenix PAM8 baseline proposal

Editorial issue with the draft

- The original file format of the draft is not Adobe FrameMaker. The document is written in Microsoft Word.

- Some of the diagrams are screen shots rather than detailed drawings.

- The draft document is also provided in the Adobe PDF format.

The Author understands this shortcoming and apologizes to 802.3bm editorial team. This issue will be fixed in the subsequent version of the draft.

Draft Structure

96. Physical Medium Attachment (PMA) sublayer, Physical Medium Dependent (PMD) sublayer, and baseband medium, type 100GBASE-MR

96.1 Overview: Associated clauses and relationship to OSI layers
96.2 Physical Medium Attachment (PMA) service interface: Details the Overhead frame structure and PAM8 encoding. Also defines test patterns.
96.3 Physical Medium Dependent (PMD) Sublayer: Defines test points, 100GBase-MR reach, Transmit and receiver characteristics and associated tests.
96.4 Environmental specifications: Defines General safety and Laser safety.
96.5 Environment: Defines Electromagnetic emission, temperature, humidity and handling.
96.6 PMD labeling requirements: Defines PMD labeling requirements.
96.7 Fiber optic cabling model: Defines the cable model.
96.8 Characteristics of the fiber optic cabling (channel): Defines channel, optical fiber cable, optical fiber connection and connector reflection requirements.
96.9 Protocol implementation conformance statement (PICS) proforma for Clause 96, Physical Medium Dependent (PMD) sublayer and baseband medium, type 100GBASE-MR

High-level walkthrough of subclauses

96.1 Overview

Draft Amendment to IEEE std 802.3 IEEE *Draft* P802.3bm/D0.1
IEEE P802.3bm 40 Gb/s and 100 Gb/s Fiber Optic Task Force May-2013

96. Physical Medium Attachment (PMA) sublayer, Physical Medium Dependent (PMD) sublayer, and baseband medium, type 100GBASE-MR

96.1 Overview

This clause specifies the Physical Medium Attachment (PMA) sublayers, Physical Medium Dependent (PMD) sublayer, and medium for the 100GBASE-MR PHY. A 100GBASE-MR physical shall include the required sublayers and may include the optional sublayers specified in Table 96–1.

Table 96–1—Physical Layer clauses associated with the 100GBASE-MR PMD

Associated Clause	100GBase-MR
81-RS	Required
81-CGMII[a]	Optional
82-PCS for 100GBase-R	Required
83A-CAUI	Optional
xx-MLC-FEC	Required
96-PMA	Required
96-PMD	Required
78-Energey-Efficient-Ethernet	Optional

[a]The CGMII is an optional interface. However, if the CGMII is not implemented, a conforming implementation must behave

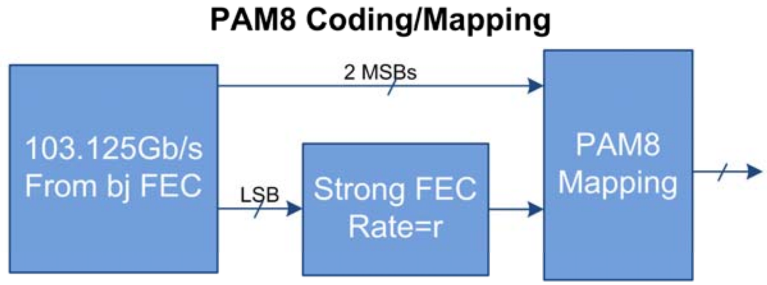
- The current draft does not include the subclause xx-MLC-FEC.

- The Draft v0.1 MLC FEC has some differences with Phoenix proposal which is detailed in the subsequent pages.

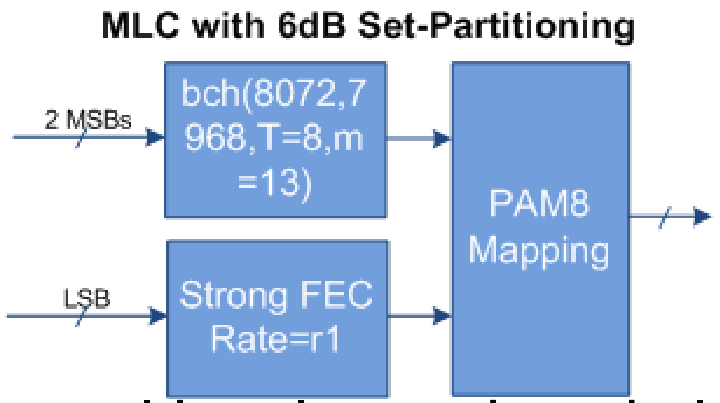
High-level walkthrough of subclauses

MLC FEC

•Phoenix Proposal used 802.3bj KR4 FEC as outer code



• Draft V0.1 uses bch(8072,7968,T=8,m=13) as MSB FECs



•The new proposal has lower decode latency, better coding gain and lower Baud-rate!

High-level walkthrough of subclauses

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

High-level walkthrough of subclauses

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	Phoenix proposal	Draft v0.1
MLC coding scheme	6dB set partitioning	6 dB set partitioning
257b/256b transcoding	Required	Required
Baud rate	40.4296875Gbaud	39.55078125Gbaud
Required SNR for 1E-15	19.6dB	<19.6dB
Encoder latency	25ns	25ns
Decoder latency	350ns to 405ns	330ns

High-level walkthrough of subclauses

96.2 Physical Medium Attachment (PMA) service interface

• Most of the spec was leveraged from 802.3bj 100GBase-KP4 by reducing the number of lanes from 4 to 1.

• The EEE support is not included. It is TBD as place holder.

• The 56-bit overhead insertion, partial gray coding and unipolar PAM8 mapping scheme is completely defined

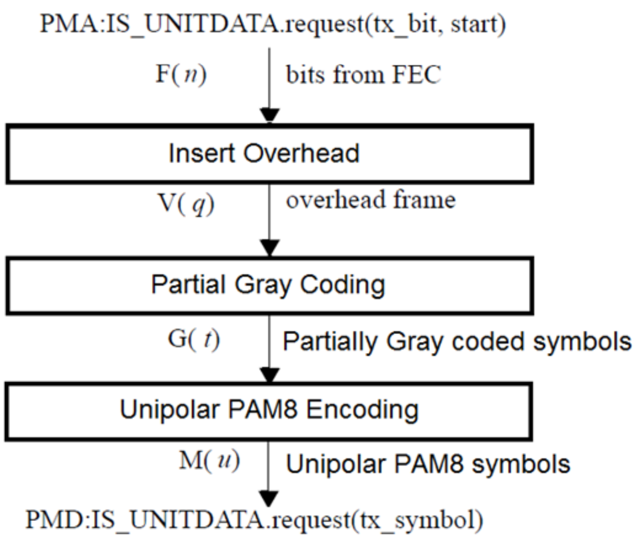


Figure 96–2—Transmit adaptation process diagram

High-level walkthrough of subclauses

96.2 Physical Medium Attachment (PMA) service interface

Test patterns

- JP03A and JP03B is adopted from 100GBase KP4. They are called JP07A and JP07B. These are clock outputs used for jitter measurement.

- JP07C is added . It is a PRBS31 used for average power measurement

- JP07D is added. It is a low speed clock used for OMA measurement

- QPRBS31 is adopted from 100GBase KP4. It is called Octal_PRBS31. It is used for SNDR measurement and receiver test

High-level walkthrough of subclauses

96.3 Physical Medium Dependent (PMD) Sublayer

96.3.5.1 PMD link block diagram

For purposes of system conformance, the PMD sublayer is standardized at test points TP2 and TP3 as shown in Figure 94-4. The optical transmit signal is defined at the output end of a patch cord (TP2), between 2 and 5 m in length, of a type consistent with the link type connected to the transmitter. Unless specified otherwise, all transmitter measurements and tests defined in 96.3.10 are made at TP2. The optical receive signal is defined at the output of the fiber optic cabling (TP3) connected to the receiver. Unless specified otherwise, all receiver measurements and tests defined in 96.3.10 are made at TP3.

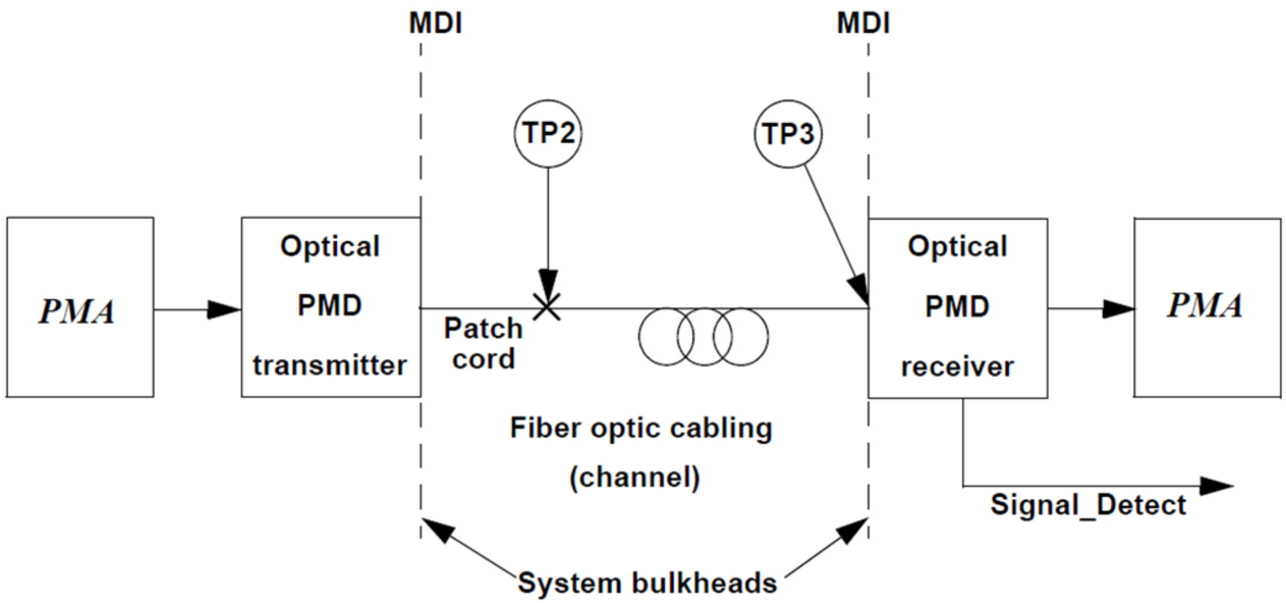


Figure 96–4—PMD link Block diagram

High-level walkthrough of subclauses

96.3 Physical Medium Dependent (PMD) Sublayer

Transmitter characteristics and transmit output test

- Transmitter output launch power, OMA, Extinction Ratio and transition time is measured similar to 10GBase-LR spec and the values are in accordance with Phoenix proposal.

- Transmitter output jitter and linearity test is done similar to 100GBase-KP4
  - Linear fit is used to measure the TX SNDR. This will result in averaging of the RIN.
  - Clock pattern (JP07A) is used to measure Clock-Random-Jitter (CRJ) and Clock-Deterministic-Jitter (CDJ)
  - This is a similar spec (but not exactly equivalent) to the Phoenix proposal
  - Tests are in electrical domain by converting Unipolar Optica PAM to bipolar electrical PAM

High-level walkthrough of subclauses

96.3 Physical Medium Dependent (PMD) Sublayer

TDP has been replaced with Linear fit test and Clock jitter test

- Section 96.3.10.9 explains linear fit method similar to 100G Base-KP4 to test the output of transmitter at TP2

- TP2 includes modulator driver electrical noise/jitter in addition to Laser RIN

- Test equipment connected to TP2 will most likely require conversion of optical signal to electrical signal which adds to TP2
    - Test equipment channel insertion loss
    - Shot noise
    - Test equipment TIA thermal noise

96.3.10.2 Test Fixture

Figure 96-5 shows the test fixture. A waveform from TP2 of the system under test is captured for analysis using an oscilloscope having a fourth order (TBD), 20 GHz (TBD) Bessel-Thomson (TBD) responses.

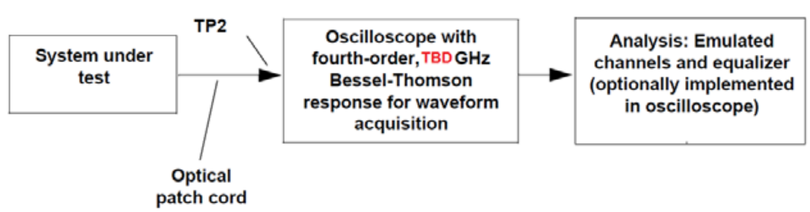


Figure 96–5—Transmitter test fixture and test points

High-level walkthrough of subclauses

Linear fit test and Clock jitter test

Assuming :

• Minimum TX average launch power of -0.78dBm per 96.3.10.5, Flat laser RIN=-142dB/Hz and modulator linearity of 34dB Peak_Signal/Noise_average ratio, 2ps sinusoidal TX DJ and 250fs TX RJ
•Test equipment channel insertion loss=1dB, TIA NEP=15pA/sqrt(Hz) and Test Equipment BW>20GHz
• Test pattern is Octal_PRBS

Results in:

The linear fit error σ(e)=0.0468 normalized to signal peak for 96.3.10.9 and SNDR=8.8dB per 96.3.10.11

Assuming:

• Minimum TX average launch power of -0.78dBm per 96.3.10.5, Flat laser RIN=-142dB/Hz , modulator linearity of 34dB Peak_Signal/Noise_average ratio, 2.5ps sinusoidal TX DJ and no TX RJ
• Test equipment channel insertion loss=1dB, TIA NEP=15pA/sqrt(Hz) and Test Equipment BW>20GHz
• Test pattern is 20GHz clock JP07A

Results in:

CDJ=0.08UI and CRJ=0.015UI. Section 96.3.10.10 lists CDJ=0.08UI and CRJ=0.01UI

High-level walkthrough of subclauses

96.3 Physical Medium Dependent (PMD) Sublayer
TX Output jitter and linearity

Phoenix proposal

Transmitter Output Jitter

Parameter	Limit	Test Pattern Condition	Unit
TWDP [1]	2	PRBS15	dBo
Qsq (linear)	32	68.6.7	NA
DCD	0.035	Clock 8 ones/8 zeros	UI
Effective Random Jitter (1 σ) [1,2]	0.015	PN15 PAM-2	UI
Effective Deterministic Jitter (p-p) [1,2]	0.15	PN15 PAM-2	UI

1. Waveforms and jitter are captured with reference CDR having loop BW of Fbaud/40430
2. Effective random jitter and deterministic jitter is the Dual-Dirac fitted parameters from Q=2 to Q=5 with minimum of 64 kbits of samples or equivalent edges

Draft v0.1

Transition time (20-80%, min), no equalization	96.3.10.8	13.8 (TBD)	ps
Output waveform Define linear fit parameters here	96.3.10.9		
Output jitter and linearity Clock random jitter, RMS Clock deterministic jitter, peak-to-peak Signal-to-noise-and-distortion ratio	 96.3.10.10 96.3.10.10 96.3.10.11	 0.01 (TBD) 0.08 (TBD) 8.8 (TBD)	 UI UI dB

High-level walkthrough of subclauses

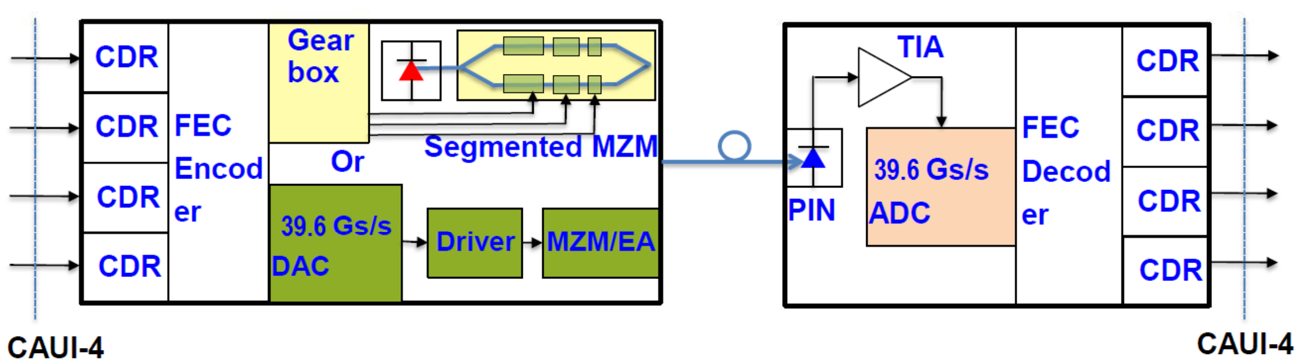
96.3 Physical Medium Dependent (PMD) Sublayer

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 for TX implementation (Same as Phoenix proposal).

Phoenix presentation page 5

PAM-8 Block Diagram

- Showing segmented modulator and traditional MZM/EA



High-level walkthrough of subclauses

96.3 Physical Medium Dependent (PMD) Sublayer

Receiver characteristics and receiver test

• Receiver spec with the exception of the receiver tolerance test was adopted from the Phoenix proposal

• For receiver tolerance test, and interference tolerance and jitter tolerance is defined but the spec is not fully populated.

-The objective is to define a similar test to 100GBase-KP4 that stresses the receiver using Octal_PRBS13

- The test includes modeling of all relevant noise sources, including MPI

96.3.10.13 Comprehensive stressed receiver sensitivity and overload test block diagram

Figure 96-8 shows the reference block diagram for the comprehensive stressed receiver test. As shown in the figure, an electrical signal is created using a pattern generator with pattern Octal_PRBS13 (see 96.2.8.5), and impaired by the following:

a) Gaussian low-pass filter

b) Gaussian white noise source

c) Intersymbol interference (ISI)

NOTE—Gaussian noise that extends, positively and negatively, to at least seven times its rms value is adequate.

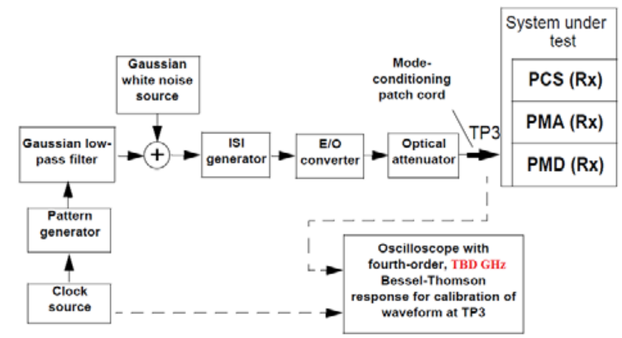


Figure 96–8— Reference measurement configuration for comprehensive stressed receiver sensitivity and overload test

High-level walkthrough of subclauses

96.4 Environmental specifications
96.5 Environment
96.6 PMD labeling requirements

The spec is adopted from 10GBase-LR with appropriate changes.

High-level walkthrough of subclauses

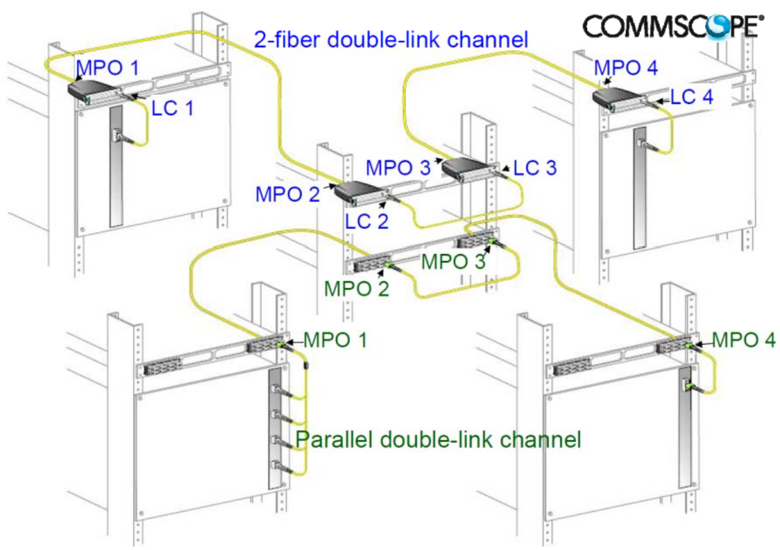
96.7 Fiber optic cabling model

The section is not populated.

Recommended to be based on dual-trunk architecture model having up to 8 connectors with a mix of APC and non-APC types.

http://www.ieee802.org/3/bm/public/mar13/kolesar_02_0313_optx.pdf page 3

Double-link cabling channels



High-level walkthrough of subclauses

96.8 Characteristics of the fiber optic cabling (channel)

The section is adopted from 10GBase-LR4 with actual values coming from Phoenix proposal.

Table 96–12—100GBase-MR Fiber optic cabling (channel)

Description	100GBase-MR	Unit
Operating distance (min)	2	m
Operating distance (max)	500	m
Channel insertion loss (max)	4	dB
Positive dispersion (max)	1.0	ps/nm
Negative dispertion (max)	-2.0	ps/nm
Optical return Loss (min)[a]	29	dB
DGD_max[b]	1.5	ps

[a] Based on 35 dB RL for connectors per ISO/IEC 11801, dual-trunk architecture model having up to 8 connectors with a mix of APC and non-APC types.
[B] Differential Group Delay (DGD) is the time difference between the fractions of a pulse that are transmitted in the two principal states of polarization of an optical signal. DGD_max is the maximum differential group delay that the system must tolerate.

96.8.1 Optical fiber and cable

The fiber optic cable shall meet the requirements of IEC 60793-2 and the requirements of Table 96-13.

Table 96–13—100GBase-MR Optical fiber and cable characteristics

Description	100GBase-MR	Unit
Fiber cable attenuation (max)	0.4[a] or 0.5[b]	dB/km
Zero dispersion wavelength(λ_0)	$1300 \le \lambda_0 \le 1324$	nm
Dispersion slope (max) (S_0)	0.093	ps/nm^2 km

[a] For the single-mode case, the 0.4 dB/km attenuation for optical fiber cables is defined in ITU-T G.652.
[b] For the single-mode case, the 0.5 dB/km attenuation is provided for Outside Plant cable as defined in ANSI/TIA/EIA

High-level walk through of subclauses

96.9 Protocol implementation conformance statement (PICS) proforma for Clause 96, Physical Medium Dependent (PMD) sublayer and baseband medium, type 100GBASE-MR

This section is not populated. It is TBD.

Backup slides

Phoenix Proposal: Low-Latency PAM-8 Strong FEC

- Block size: 8280
- Code Rate: 119/207
- Number of Extra OH bits: 200
- Code rate including extra OH: 38/69 (Approximately 0.55)

- Spectral Efficiency (Excluding bj FEC): 1+1+38/69=176/69 (Approximately 2.55)
- Baud-Rate=103.125*69/176=40.4296875 Gs/s

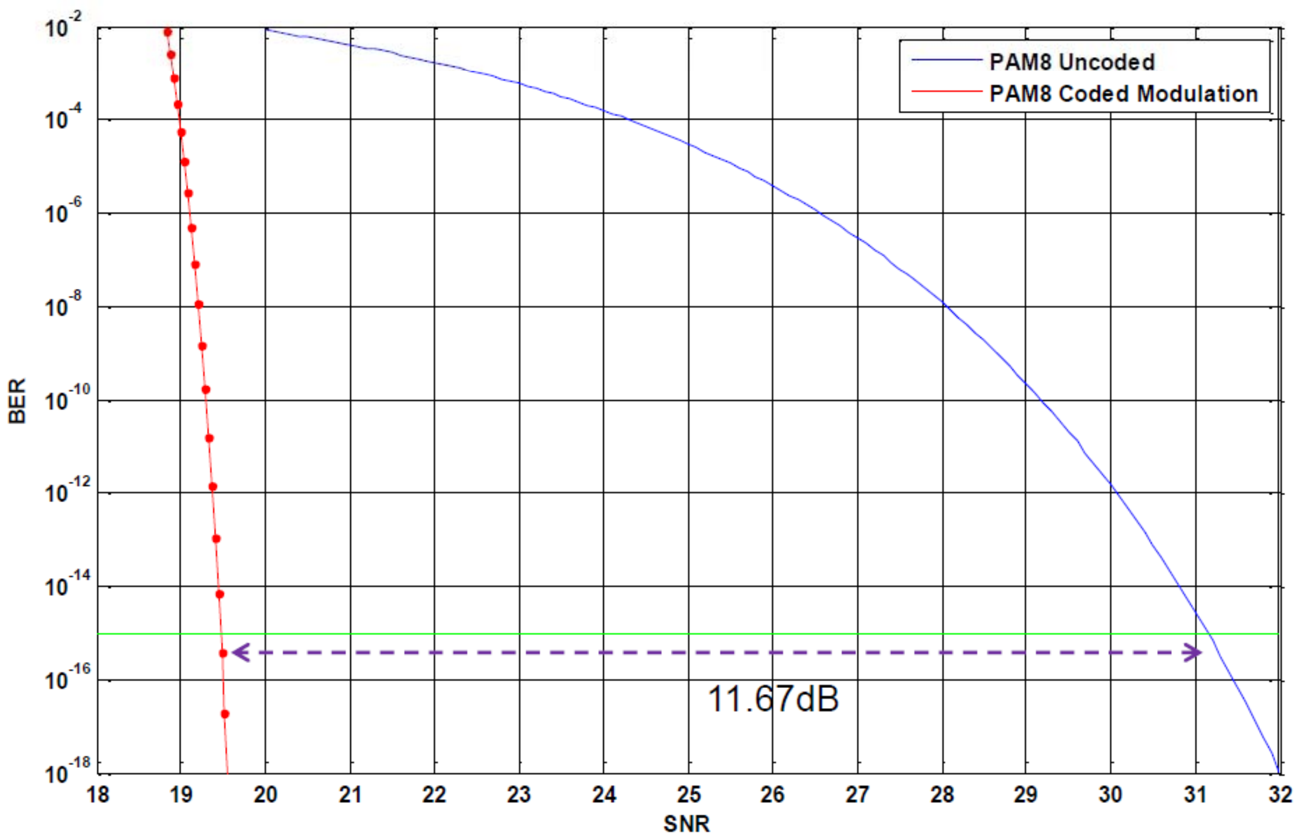
- CAUI-4 clock to PAM-8 clock conversion ratio: **69/44**
  - This is a simple multiple of 156.25MHz. 100G Base KP4 is using a similar 2 digit ratio

- PAM-8 SNR for 1E-15 BER: **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+100ns=305ns
  - Extra latency required for bj FEC Decoder.
  - If the bj FEC decoder is implemented in the ASIC, latency is 100ns
  - If the bj FEC decoder is implemented in the module, latency is 45ns

Phoenix proposal Page-16

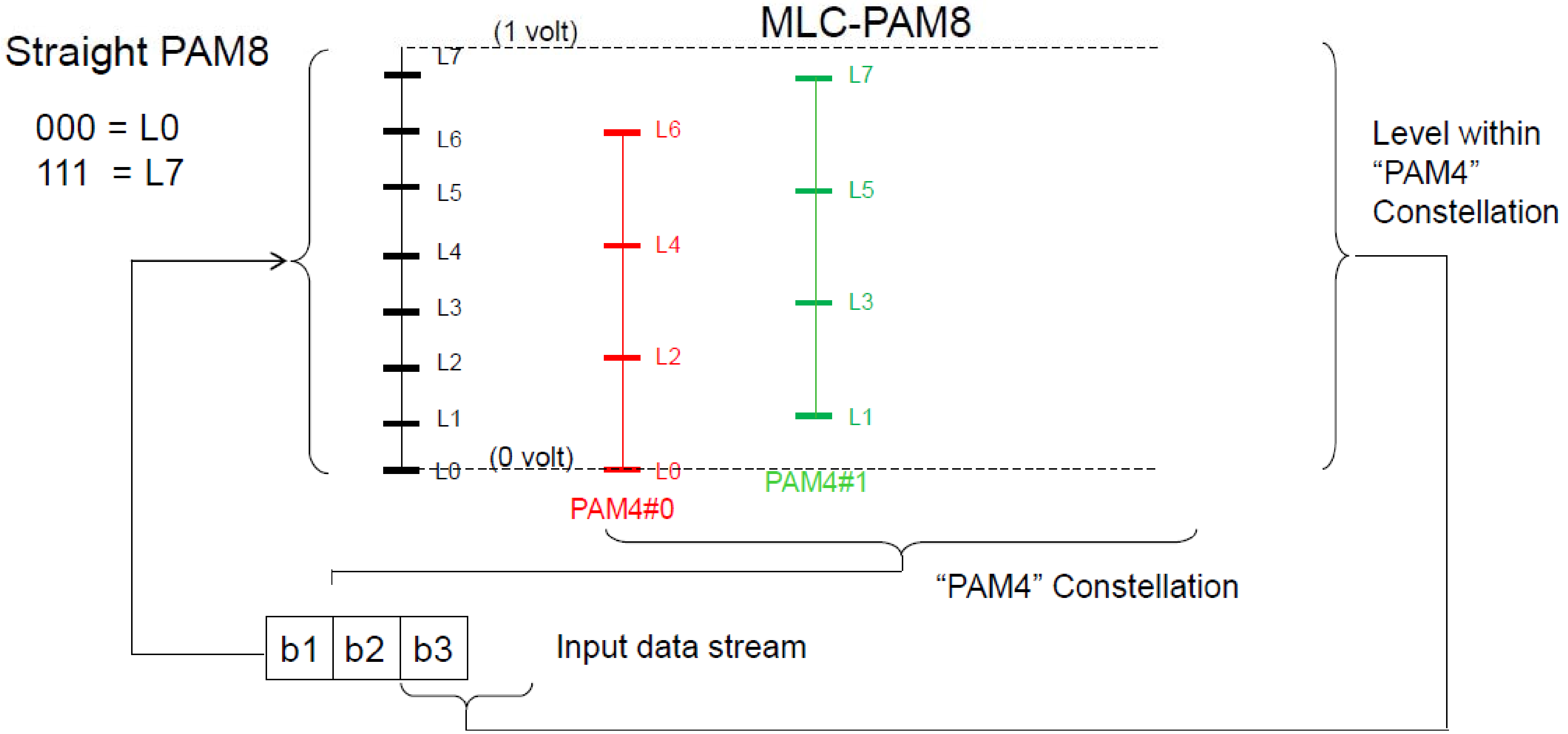
Example Coded Modulation Sim Results



- PAM8 coded modulation FEC delivers 11.67dB coding gain

Phoenix proposal Page-20

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