Proposal for 400GBASE-ZR DWDM Optical Specs Baseline

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Introduction

- One of the main objectives for P802.3ct after the March Plenary is to define optical metrics for 400GBASE-ZR.

Status - High Level Decisions

		400 GbE
Channel Model		stassar_3ct_01_0319
# of Channels		?
Channel Spacing		100 GHz
Modulation Format		DP-16QAM
Frame Assumption		400GBASE-ZR PCS/PMA
FEC		CFEC
Tx Metric		lyubomirsky_3ct_01_0319 or stassar_3ct_01_0319
AUI Attachment		400G XS

dambrosia_3ct_01b_190404.pdf

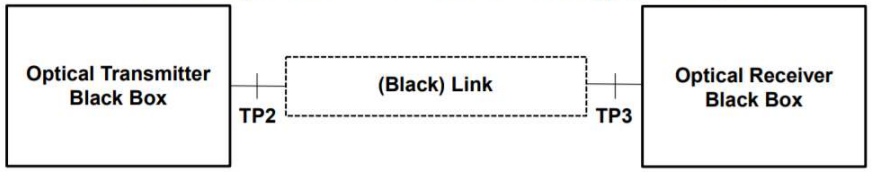
www.ieee802.org/3/ct/public/19_03/lyubomirsky_3ct_01a_0319.pdf
www.ieee802.org/3/ct/public/19_03/stassar_3ct_01_0319.pdf
http://www.ieee802.org/3/cn/public/adhoc/19_0502/zhang_3cn_01_190502.pdf

- We propose to build consensus using both OIF 400ZR Tx/Rx specs as well as ITU-T black link methodologies for the baseline of 400GBASE-ZR DWDM optical specs

Concerns on Previous proposal

From stassar_3ct_01_0319.pdf (slide #6 and #16)

Optical specification methodology principles



- Optical Transmitter is Black Box. Inside not specified. Implementation freedom
- At TP2 transmitter output signal is specified via (measurable) parameters and values
- The (black) link is characterized by its transfer characteristics as TP2 to TP3.
- Only limited link design elements are specified like maximum discrete reflectance.
- The optical signal at TP3 is created via "combining" optical signal at TP2 with link transfer characteristics TP2 to TP3.
- Optical receiver is also Black Box. Inside not specified. Implementation freedom.
- The only Receiver requirement: provide the specified Receiver performance under worst case receiver input optical signal at TP3.
- Example of non appropriate receiver parameter: receiver bandwidth.

Concern 1:

6

400GBASE-ZR receive characteristics

Parameter Name	Units	OIF Value	Alt Value
Maximum mean input power	dBm	0	
Minimum mean input power [amplified]	dBm	–12	
Minimum mean input power [unamplified]	dBm	–20	TBD
Minimum OSNR(193.6) [amplified]	dB (0.1 nm)	TBD	
Minimum OSNR(193.6) [unamplified]	dB (0.1 nm)	37	
Receiver OSNR tolerance(193.6)	dB (0.1 nm)	26	
Maximum reflectance of receiver	dB	–20	–27

Concern 2:

Concern 1: to comply at TP3, one would need a "black link emulator" with many statistical variables, which is challenging, if not impossible, to quantify as worst case. [E.g. there is no standards for PMD emulator for coherent]

Concern 2: the receiver spec table deviates from the current OIF 400ZR Rx specs. It's unclear how one could measure and be compliant with this "minimum OSNR (193.6) [amplified]" spec.

IEEE 802.3bs Rx specs and illustrative link budget

124.7.2 400GBASE-DR4 receive optical specifications

The 400GBASE-DR4 receiver shall meet the specifications defined in Table 124–7 per the definitions in 124.8. See NOTE at the end of 120.5.2 concerning the transition density of lanes operating at this nominal signaling rate.

Table 124–7—400GBASE-DR4 receive characteristics

Description	Value	Unit
Signaling rate, each lane (range)	53.125 ± 100 ppm	GBd
Modulation format	PAM4	—
Lane wavelengths (range)	1304.5 to 1317.5	nm
Damage threshold[a], each lane	5	dBm
Average receive power, each lane (max)	4	dBm
Average receive power, each lane[b] (min)	–5.9	dBm
Receive power (OMA_{outer}), each lane (max)	4.2	dBm
Receiver reflectance (max)	–26	dB
Receiver sensitivity (OMA_{outer}), each lane[c] (max)	–4.4	dBm
Stressed receiver sensitivity (OMA_{outer}), each lane[d] (max)	–1.9	dBm
Conditions of stressed receiver sensitivity test:[e]		
Stressed eye closure for PAM4 (SECQ), lane under test	3.4	dB
OMA_{outer} of each aggressor lane	4.2	dBm

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level. The receiver does not have to operate correctly at this input power.
[b]Average receive power, each lane (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.
[c]Receiver sensitivity (OMA_{outer}), each lane (max) is informative and is defined for a transmitter with SECQ of 0.9 dB.
[d]Measured with conformance test signal at TP3 (see 124.8.9) for the BER specified in 124.1.1.
[e]These test conditions are for measuring stressed receiver sensitivity. They are not characteristics of the receiver.

124.7.3 400GBASE-DR4 illustrative link power budget

An illustrative power budget and penalties for 400GBASE-DR4 channels are shown in Table 124–8.

124.8 Definition of optical parameters and measurement methods

All transmitter optical measurements shall be made through a short patch cable, between 2 m and 5 m in length, unless otherwise specified.

Table 124–8—400GBASE-DR4 illustrative link power budget

Parameter	Value	Unit
Power budget (for max TDECQ)	6.5	dB
Operating distance	500	m
Channel insertion loss[a]	3	dB
Maximum discrete reflectance	See 124.11.2.2	dB
Allocation for penalties[b] (for max TDECQ)	3.5	dB
Additional insertion loss allowed	0	dB

[a]The channel insertion loss is calculated using the maximum distance specified in Table 124–5 and cabled optical fiber attenuation of 0.5 dB/km at 1304.5 nm plus an allocation for connection and splice loss given in 124.11.2.1.
[b]Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

- *Specific Rx parameters are defined in the Rx characteristics table and detailed with definition of each item and their measurement methods.*
- *Illustrative link power budget table is shown with statement that “link penalties are not requirements and are not meant to be tested”.*

Our Proposal

- We propose to specifically mention the normative and informative parameters in the black link table

- We propose to keep as intact as possible the OIF 400ZR Rx specs (Iyubomirsky_3ct_01a_0319.pdf) which captures **measurable** individual impairment tolerance spec [as opposed to the minimum OSNR spec in stassar_3ct_01_0319.pdf]

- We therefore propose the 400GBASE-ZR line system operators comply to the black link table, and the transceiver suppliers comply to the Tx and Rx spec tables.

Black Link Channel Characteristics

Largely adopted from ***stassar_3ct_01_0319*** slide#17, changed into IEEE format.
Recommend the **line items highlighted in black** as normative spec parameters.
Recommend the **line items highlighted in green** as informative spec parameters.

Description	Value	Unit
Channel Spacing	100	GHz
Ripple (max)	***1.5***	dB
(Residual) chromatic dispersion (max)	1600	ps/nm
(Residual) chromatic dispersion (min)	0	ps/nm
Optical return loss at TP2 (min)	24	dB
Discrete reflectance between TP2 and TP3 (max)	-27	dB
Differential group delay (max)	33	ps
Polarization dependent loss (max)	2	dB
Polarization rotation speed (max)	50	krad/s
Inter-channel crosstalk at TP3 (max)	***-40***	dBc
Interferometric crosstalk at TP3 (max)	***-35***	dB
Optical path OSNR penalty (max) [a]	4	dB

a). Optical path OSNR penalty is a measure of the quality of the black link, using reference transmitter and receiver. The value is derived from Rx individual OSNR impairment penalty linearly added to ensure worst case and thus interoperability.

Rx Optical Specs

Description	Value	Unit
Input Power Range (min)	-12	dBm
Input Power Range (max)	0	dBm
Frequency Offset Tolerance (min)[a]	± 1.8	GHz
OSNR Tolerance (min)[b]	26	dB
CD Tolerance (min) [c]	1600	ps/nm
DGD (max)[d]	33	ps
SOPMD (max)[d]	272	ps^2
Peak PDL Tolerance (min)[e]	3.5	dB
Change in SOP Tolerance (min)[f]	50	rad/ms
Optical Power Transient Tolerance (min)[g]	± 2	dB
Optical return Loss (min)	20	dB
Optical filtering bandwidth tolerance (min)[h]	TBD	GHz

a). Rx must tolerate this amount of Tx frequency offset from the nominal ITU center frequency grid.
b). Minimum value of OSNR (referred to 0.1 nm noise bandwidth @ 193.6 THz) that can be tolerated while maintaining the maximum BER below the CFEC threshold. Must be met for a back-to-back measurement configuration at all input powers defined above.
c). Tolerance to chromatic dispersion with <0.5 dB OSNR penalty
d). Tolerance to max DGD and max SOPMD [according to 10ps mean PMD] with < 0.5 dB OSNR penalty and change in SOP < 1 rad/ms.
e). Peak PDL includes both transmitter polarization imbalance and black link PDL. Tolerance to peak PDL with < 1.3 dB OSNR penalty. Tested with noise injected after PDL emulator and PSP < 1 rad/ms.
f). Tolerance to change in SOP with < 0.5 dB OSNR penalty.
g). Tolerance to change in input power with < 0.5 dB OSNR penalty.
h). Tolerance to link bandwidth narrowing effect together with TX spectral excursion with <0.5dB OSNR penalty; bandwidth in GHz defined with double side band in regards to the ITU grid.

Tx Optical Specs I

Description	Value	Unit
Signaling rate, (range) per polarization	59.84375 +/-20ppm	GBd
Modulation Format	DP-16QAM	
Start Channel Frequency	191.3	THz
Stop Channel frequency	196.1	THz
Laser frequency accuracy	± 1.8	GHz
Laser line-width (max)[a]	500	kHz
Laser relative intensity noise (ave)[b]	-145	dB/Hz
Laser relative intensity noise (peak)[c]	-140	dB/Hz
Optical Output Power (max)	-6	dBm
Optical Output Power (min)	-10	dBm
Transmitter reflectance (min)[d]	***-20***	dB
Transmitter back reflection tolerance (min)[e]	***-24***	dB

a). Full Width Half Maximum (FWHM) high frequency component of the Tx laser phase noise.
b). Average over 0.2GHz < f < 10GHz.
c). Peak over 0.2GHz < f < 10GHz.
d). Optical power ratio of the reflected light of Tx output port back to fiber network vs. the external incident light into the Tx output port.
e). Maximum light power (relative in decibel w.r.t. Tx output) reflected back to transmitter while still meeting performance requirements.

Tx Optical Specs II

Description	Value	Unit
Transmitter polarization power imbalance	1.5	dB
In-band OSNR (min) per 0.1 nm[a]	34	dB
Out-of-band OSNR (min) per 0.1 nm[b]	23	dB
Total output power with transmitter disabled (min)	-20	dBm
Total output power during channel change (min)	-20	dBm
X-Y polarization skew	5	ps
I-Q DC offset[c]	-26	dB
Error Vector Magnitude (max)[d]	TBD	%
Spectral excursion (max)	**32**	GHz

a). Signal power over noise power in-band, measured with 12.5 GHz noise bandwidth.
b). Signal power over peak noise power in the whole frequency range, measured with 12.5 GHz noise bandwidth.
c). Ratio of unmodulated power to total signal power.
d). Currently the EVM spec is not in the normative spec yet in OIF 400ZR.

Conclusion

- We propose clear demarcation of 400GBASE-ZR optical spec ownership
  - the line system suppliers comply to the black link table
  - the transceiver makers comply to the Tx and Rx spec tables

- Recommend P802.3ct TF adopt the methodology defined in this proposal for baselining 400GBASE-ZR DWDM optical specs