Baseline Proposal: 400GBASE-ZR operation on 75GHz grid

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Framework of this baseline proposal

- The OIF 400ZR specification has already been defined for 100 GHz channel-spaced links
- In January, the 802.3ct (802.3cw) Task Force adopted a modified objective for 400Gb/s operation based on 75 GHz spacing
- This presentation includes a baseline proposal that includes modifications to the OIF specification based on the 75 GHz spacing and maps the parameters into the IEEE format as proposed in http://www.ieee802.org/3/ct/public/19_07/stassar_3ct_02_0719.pdf

400GBASE-ZR - 75GHz grid considerations

- 400GBASE-ZR operation on 75GHz Grid
  - Analysis
  - Penalties
- Mitigations
  - TX Spectral shaping
  - Filtering
- Baseline Proposal
  - Leverage OIF 400ZR IA
    - 100GHZ Grid parameters, modified for 75GHz Grid

Motivation and executive summary

- DCI demand for 75 GHz spacing is clear. See http://www.ieee802.org/3/ct/public/19_09/du_3ct_01b_0919.pdf
- This work explores the impact of 75 GHz spacing on inter-channel crosstalk between nearest neighbors
- Simulation and measurement work shows 75 GHz spacing is feasible without additional power required for digital spectral shaping.
- Affected Black Link parameters:
  - Maximum Spectral Excursion
  - Minimum Spectra Excursion
  - Crosstalk/Isolation
  - Ripple, etc… See also - http://www.ieee802.org/3/ct/public/19_07/deandrea_3ct_01_0719.pdf

Black link model

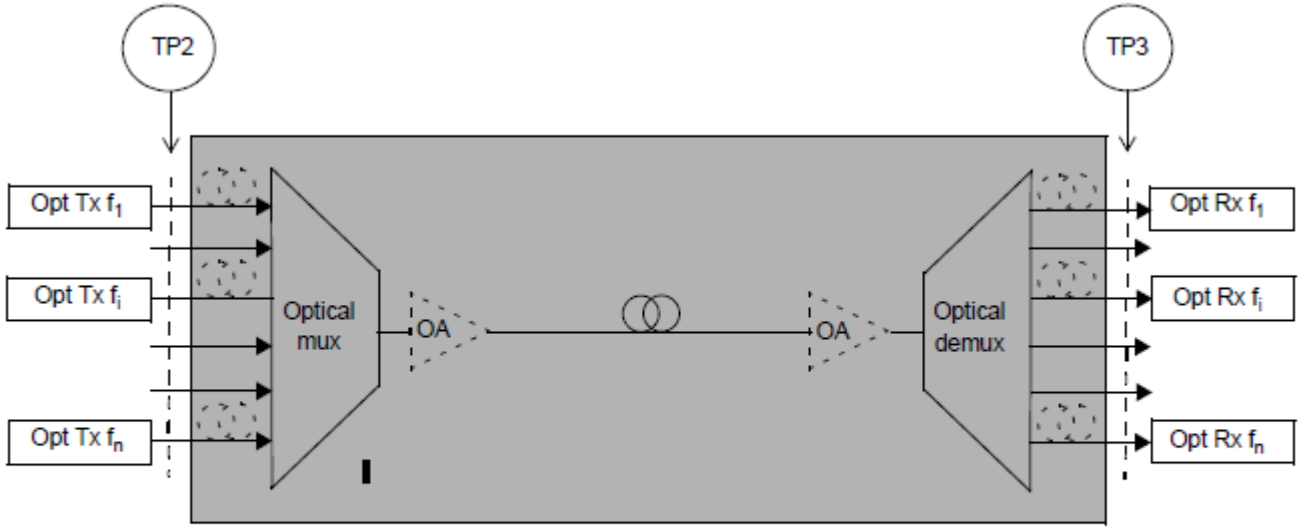
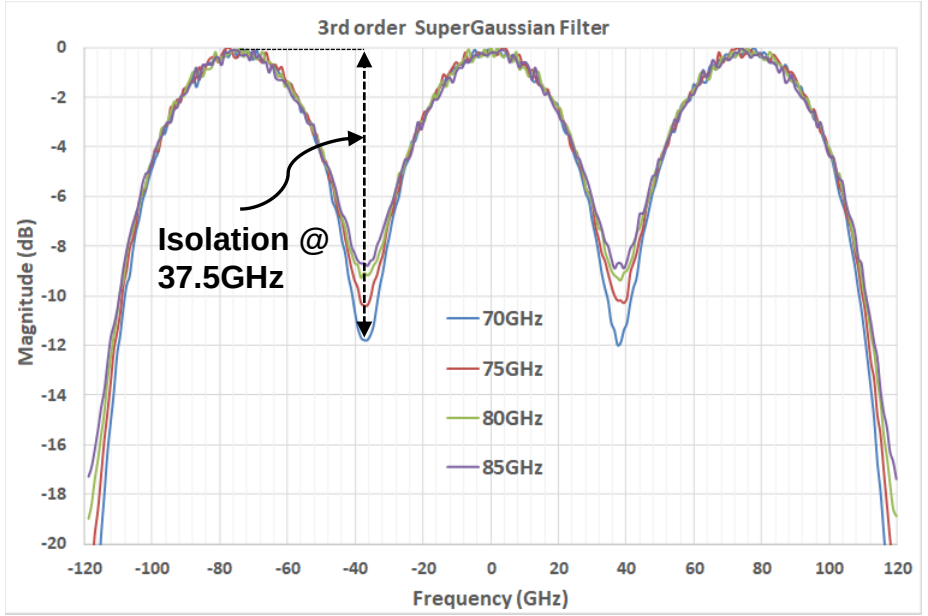


Figure 154–3—Example configuration of the black link approach

400GBASE-ZR 16QAM DP-QPSK, 75GHz spacing

- TX optical spectrum post mux. 3 separate 400G ZR signals multiplexed together with a spacing of 75GHz.
- Mux Filters are assumed to be 3rd order super-Gaussian filters. There is no laser frequency offset or filter offset.
- As the bandwidth of the filter is increased, the isolation between the channels decreases and hence the crosstalk increases.
- As the bandwidth of the filters is decreased, the signal spectrum is filtered and hence increases the ISI.
- Propose to define a TX Maximum Spectral Excursion and maximum inter-channel crosstalk value that results in minimal RX OSNR penalty for 75GHz Grid operation.

Optical spectra @ output of mux



Critical optical parameter definitions

Inter-channel crosstalk

Inter-channel crosstalk is defined as the ratio of total power in all of the disturbing channels to that in the wanted channel, where the wanted and disturbing channels are at different wavelengths.

Specifically, the isolation of the link shall be greater than the amount required to ensure that when any channel is operating at the minimum mean output power at point S_s and all of the others are at the maximum mean output power, then the inter-channel crosstalk at the corresponding point R_s is less than the maximum inter-channel crosstalk value.

(Definition copied from OIF-400ZR.01.0)

Critical optical parameter definitions – cont.

Optical path OSNR penalty

The optical path OSNR penalty is defined as:

- Lowest OSNR at R_S – Lowest OSNR at S_S

where:

- Lowest OSNR at TP2 is the lowest OSNR that meets the maximum BER of the application *before* transmission through the black link.
- Lowest OSNR at TP3 is the lowest OSNR that meets the maximum BER of the application *after* transmission through the black link.

The effects that contribute to the optical path OSNR penalty include:

- non-linear effects within the black link;
- inter-channel crosstalk;
- interferometric crosstalk;
- reflections from the optical path;
- polarization dependent loss.

(Definition modified from OIF-400ZR.01.0 for IEEE purposes)

Critical optical parameter definitions – cont.

Receiver OSNR tolerance

The receiver OSNR tolerance is defined as the minimum value of OSNR at point TP3 that can be tolerated while maintaining the maximum BER of the application. This must be met for all powers between the maximum and minimum mean input power with a transmitter with worst-case values of:

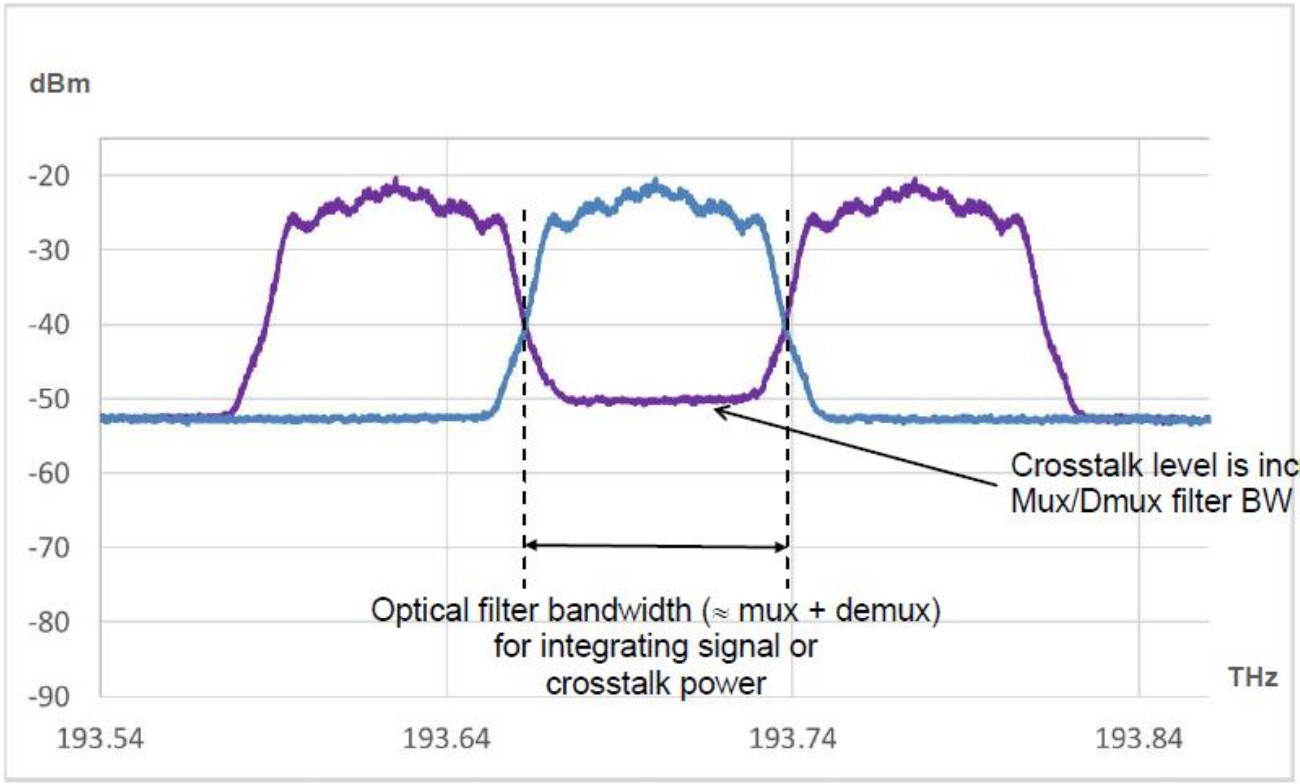
- EVMRMS for DP-16QAM signal classes,
- IQ offset for DP-D16QAM signal classes,
- optical return loss at point TP2,
- receiver connector degradations,
- measurement tolerances.

The receiver OSNR tolerance does not have to be met in the presence of chromatic dispersion, non-linear effects, reflections from the optical path, PMD, PDL or optical crosstalk; these effects are specified separately in the allocation of maximum optical path OSNR penalty.

(Definition modified from OIF-400ZR.01.0 for IEEE purposes)

Inter-channel crosstalk

Method 1 (VPI simulation)
– Three 75GHz-spaced channels with the same polarization



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NeoPhotonics

See way_3cw_01_200423.pdf

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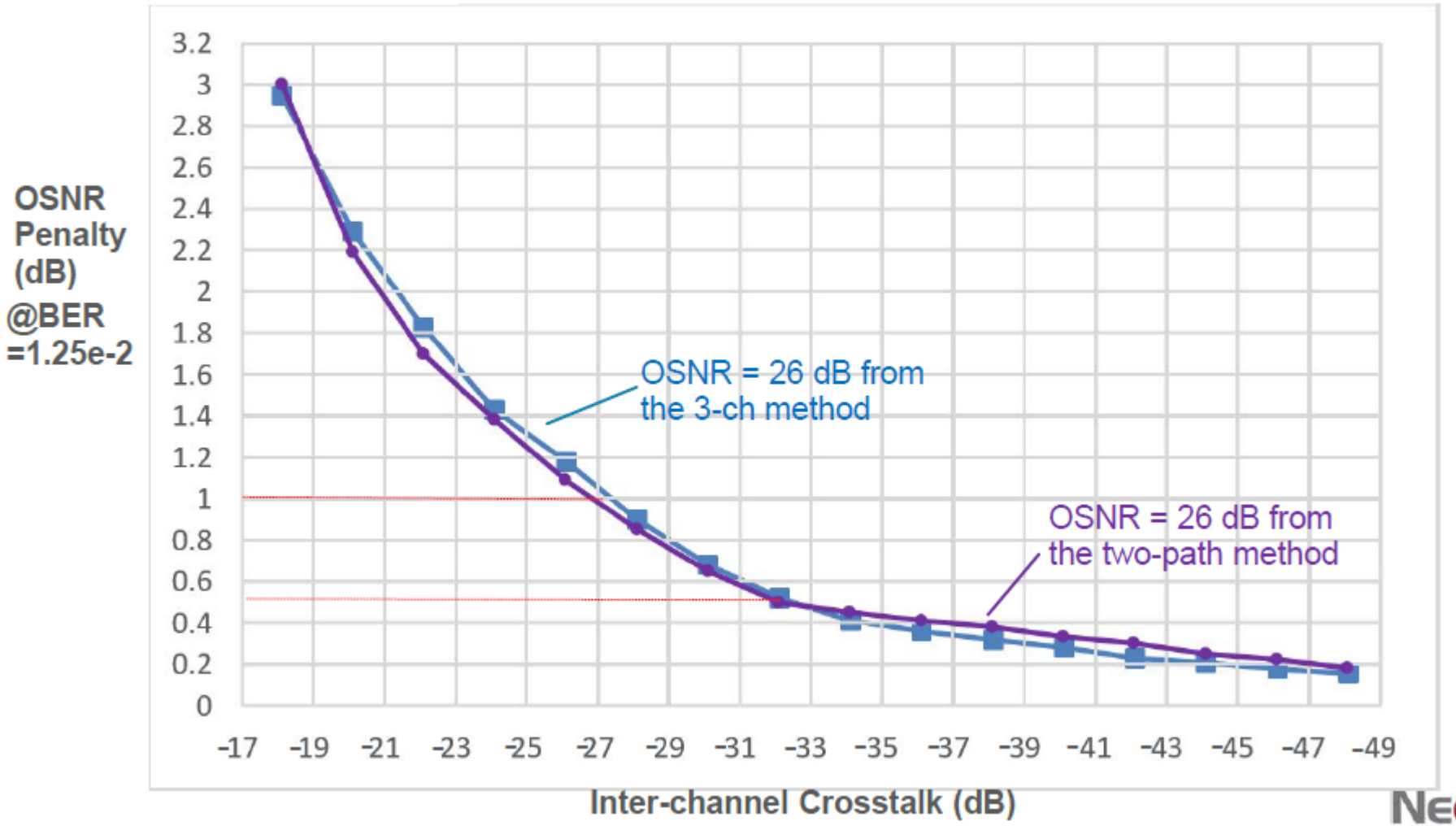
OSNR penalty due to inter-channel crosstalk



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See way_3cw_01_200423.pdf

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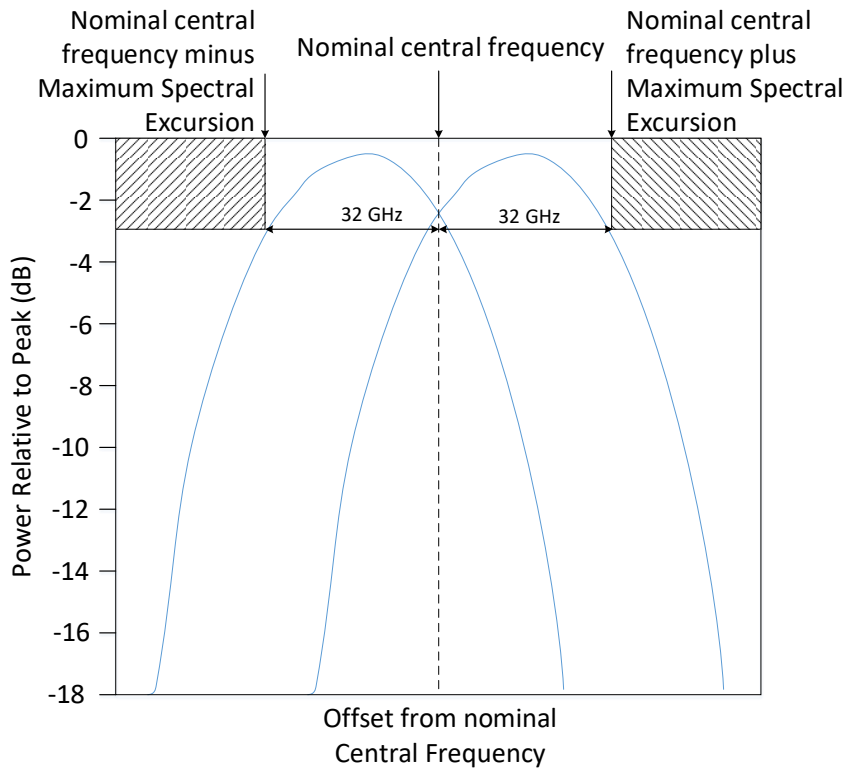
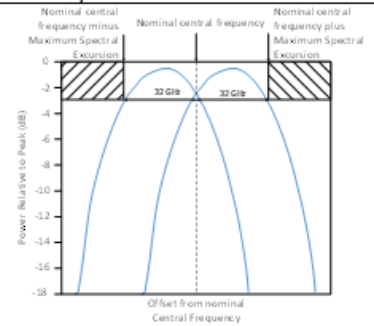
Optical parameter definitions

(Definition copied for reference from OIF-400ZR.01.0)

Maximum Spectral excursion (TX Spectrum Maximum mask)

Maximum Spectral excursion is defined as the difference between the nominal central frequency of the channel and the 3 dB point of the transmitter spectrum furthest from the nominal central frequency measured at point S_s. Including the laser frequency accuracy error value from the nominal center frequency.

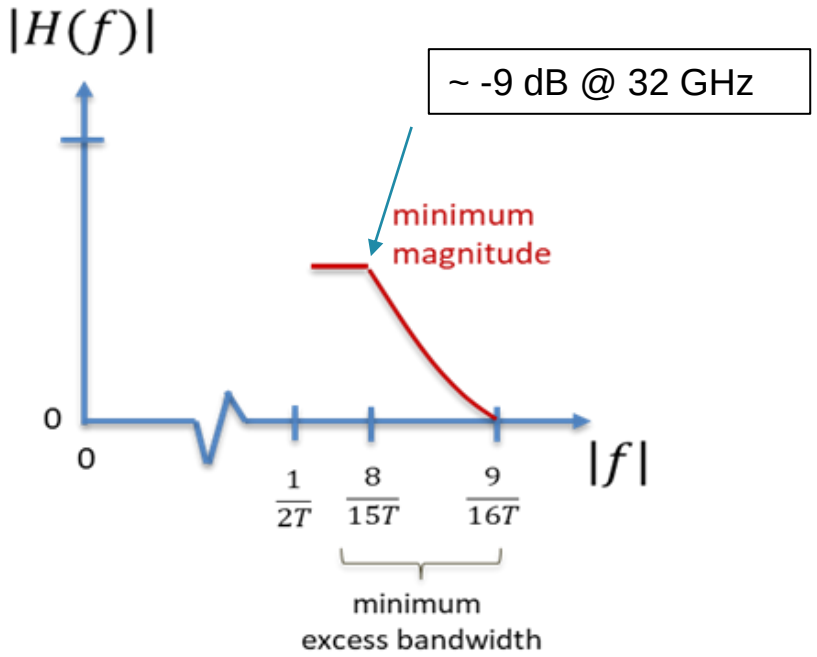


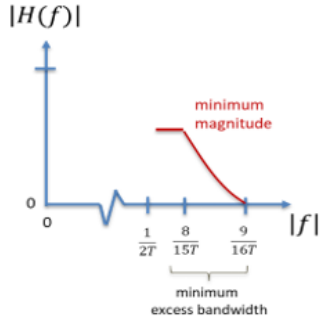
Ref.	Parameter	Min	Max	Unit	Conditions/Comments
13.1.200	Laser frequency accuracy	-1.8	1.8	GHz	Offset from channel frequency set point. The receiver LO has the same frequency accuracy.
13.1.201	Tx Spectral Excursion		32	GHz	 (See definition 13.3.2) Measured between the nominal central frequency of the channel and the -3.0dB points of the transmitter spectrum furthest from the nominal central frequency measured at point Ss. Includes Laser frequency accuracy (13.1.200) error value from nominal center frequency.

Optical parameter definitions – cont.

Minimum Excess Bandwidth (TX Minimum Spectra mask)

The minimum excess bandwidth is specified to guarantee multi-vendor clock recovery interoperability.



Ref.	Parameter	Min	Max	Unit	Conditions/Comments
13.1.215	Minimum Excess Bandwidth[1] (See Mask)	12.5		%	The baseband Tx spectral shape in this excess bandwidth shall meet or exceed the following conditions: The magnitude of the spectrum in the frequency range: $\frac{1}{2T} \le f \le \frac{9}{16T}$ shall meet $\lvert H(f)\rvert \ge H(0)\sqrt{\frac{1}{2}\left\{1+\cos\left[8\pi T\left(\left(\frac{8}{15T}\right)-\frac{7}{16T}\right)\right]\right\}}, \frac{1}{2T} \le \lvert f\rvert \le \frac{8}{15T}$ $\lvert H(f)\rvert \ge H(0)\sqrt{\frac{1}{2}\left\{1+\cos\left[8\pi T\left(\lvert f\rvert-\frac{7}{16T}\right)\right]\right\}}, \frac{8}{15T} \le \lvert f\rvert \le \frac{9}{16T}$ where T denotes the symbol period of the signal. 
13.1.220	Allowable output signal power window	-10	-6	dBm	Measured at optical connector.

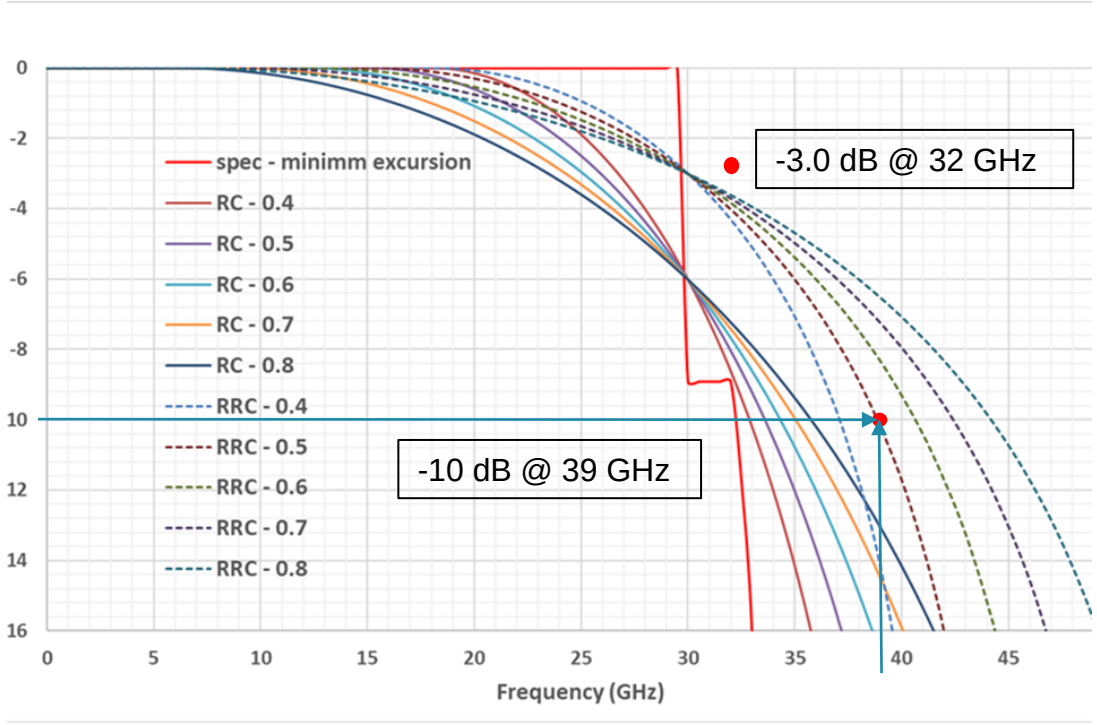
Note: The OIF is reviewing this specification in future maintenance. Minimum Excess Bandwidth may be modified or removed and replaced by a Tx Minimum spectrum mask.

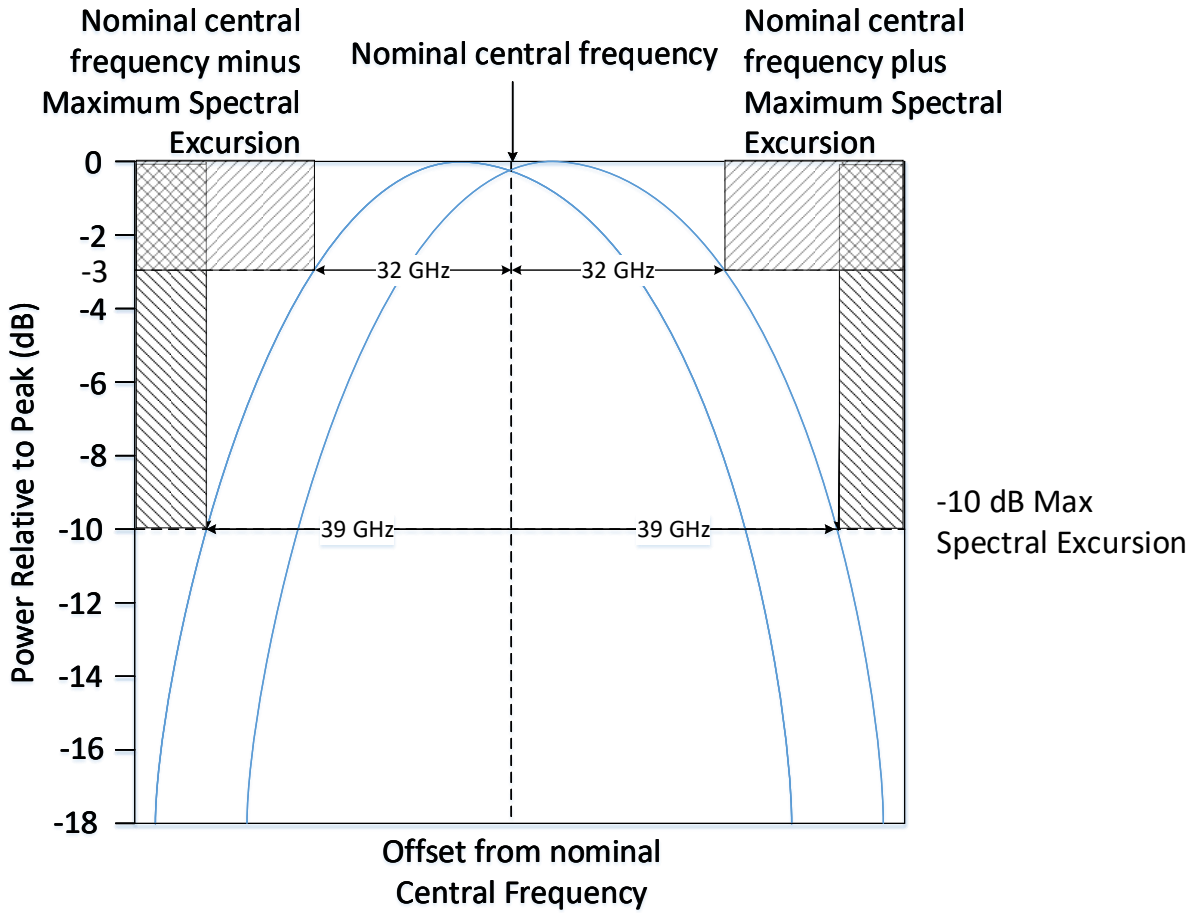
(Definition copied for reference from OIF-400ZR.01.0)

Proposed maximum spectral excursion

Proposed to define a point on the RRC=0.5 curve with inclusion of the frequency offset.

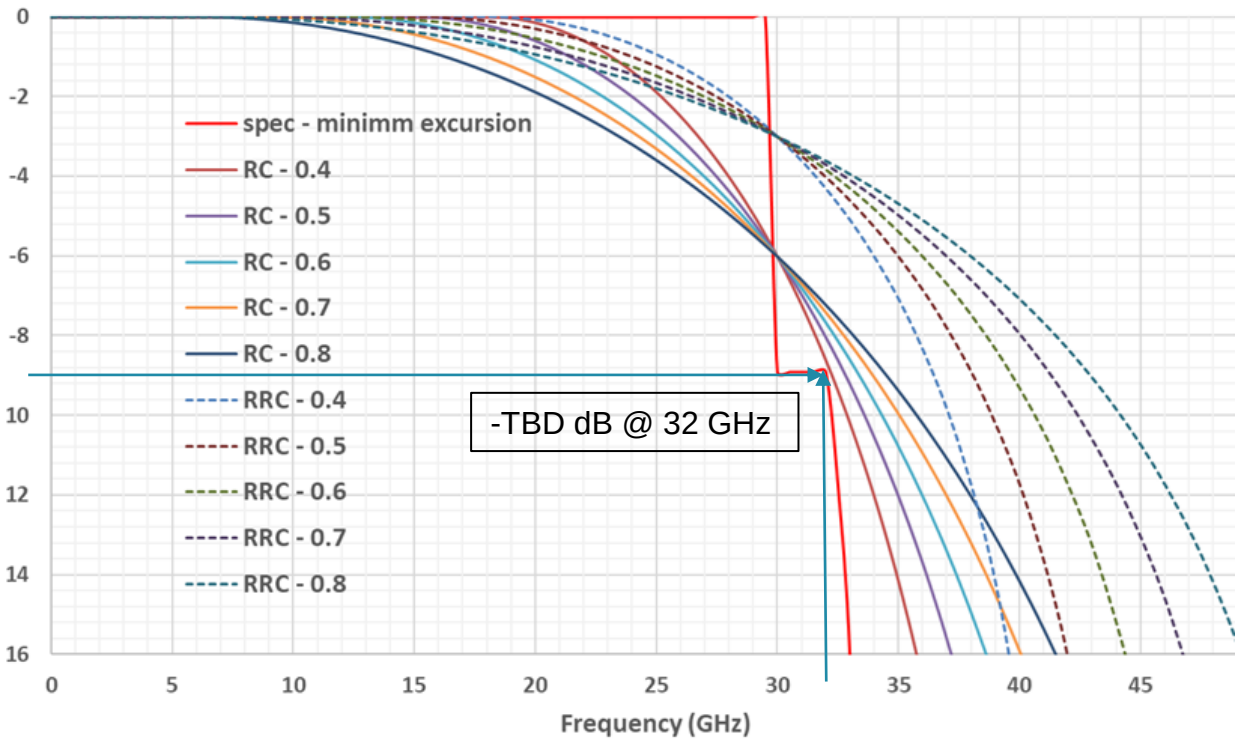
Addition of a 2nd point around -3dB could be considered.

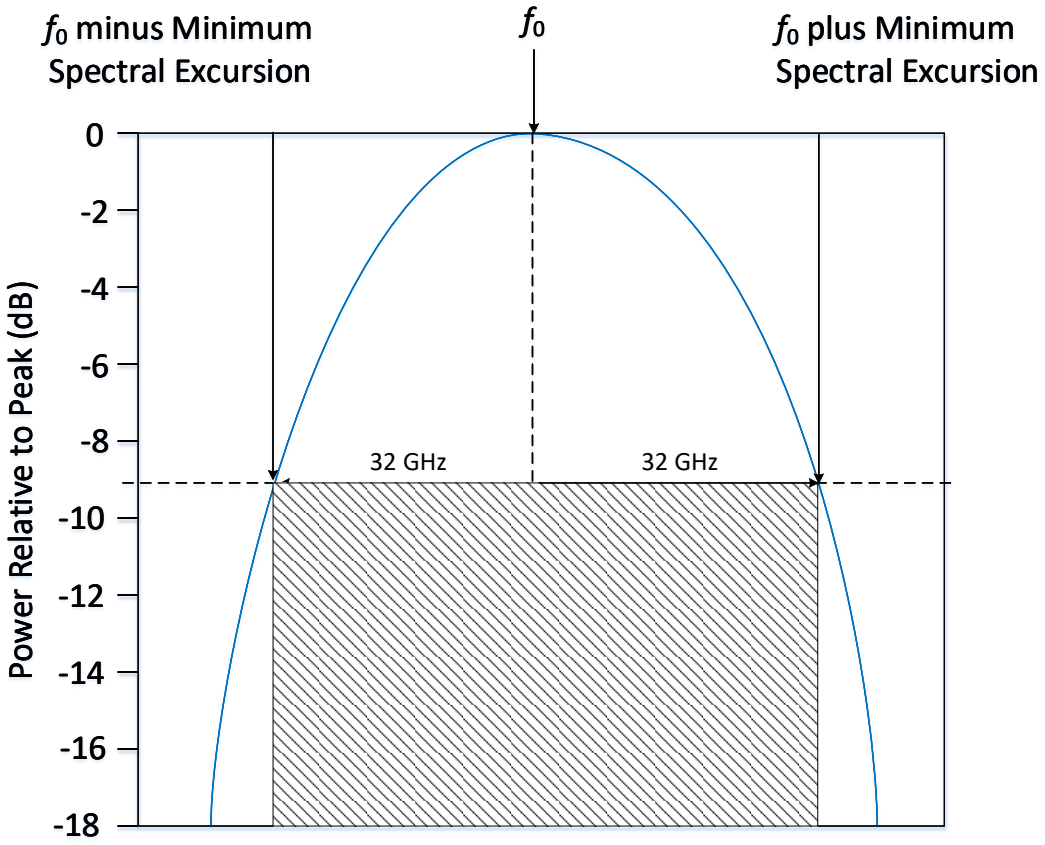




Proposed minimum spectra excursion

Proposed to define a Minimum Spectra Excursion for compatibility with Minimum Excess Bandwidth specification of OIF-400ZR-01.0





Transmitter optical specifications

Description	Value	Unit
Signaling rate (range)	59.84375 +/- 100ppm	GBd
Modulation format	DP-16QAM	-
Minimum Channel Spacing	75	GHz
Average channel output power (min)	-10	dBm
Average channel output power (max)	-6	dBm
Nominal center frequency	The frequency in Table 1xx-y corresponding to the variable Tx_optical_frequency_index (193.7)	THz
Spectral excursion (max) @ -3dB [a]	+/- 32	GHz
Spectral excursion (max) @ -10dB [b]	+/- 39	GHz
Spectra Excursion (min) [c]	+/- 32	GHz
Side-mode suppression ratio (SMSR), (min)	TBD	dBm
Laser linewidth (max)	500	KHz
Offset between the carrier and the nominal center frequency (max)	1.8	GHz

NOTE: Values in red are the values defined in OIF-400ZR-01.0 and included here for reference. (They are not part of the baseline proposal.)

a). Maximum acceptable difference between the nominal central frequency of the channel and the -3 dB points of the transmitter spectrum furthest from the nominal central frequency measured at TP2.
b). Maximum acceptable difference between the nominal central frequency of the channel and the -10 dB points of the transmitter spectrum furthest from the nominal central frequency measured at TP2.
c). Minimum acceptable difference between the transmitter f_0 and the -TBD dB point of the transmitter spectrum measured at TP2.

Transmitter optical specifications (cont.)

Description	Value	Unit
Power difference between X-Y polarizations (max)	1.5	dB
Skew between the X-Y polarizations (max)	5	ps
Error Vector Magnitude (max)	TBD	%
I-Q offset (max)	-26	dB
Transmitter Inband OSNR (193.6) (min) (193.7)	34	dB
Average launch power of OFF transmitter (max)	-20	dBm
Optical return loss tolerance (max)[a]	-24	dB
Transmitter reflectance (max)[b]	-20	dB
Laser relative intensity noise (avg)[c]	-145	dB/Hz
Laser relative intensity noise (max)[d]	-140	dB/Hz

NOTE: Values in red are the values defined in OIF-400ZR-01.0 and included here for reference. (They are not part of the baseline proposal.)

a). Maximum light power (relative in decibel w.r.t. Tx output) reflected back to transmitter while still meeting performance requirements.
b). 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.
c). Average over 0.2GHz < f < 10GHz.
d). Peak over 0.2GHz < f < 10GHz.

Proposed 400GBASE-ZR black link parameters

Description	Value	Unit
Channel spacing (min)	75 (100)	GHz
Ripple (max)[d]	2.5	dB
Optical path penalty OSNR (max)[e]	TBD[1] (0.5)	dB
Residual Chromatic dispersion (max)	2000 (2400)	ps/nm
Residual Chromatic dispersion (min)	-200	ps/nm
Optical return loss at TP2 (min)	24	dB
Differential Group Delay (DGD) (max)	28	ps
Discrete reflectance between TP2 and TP3 (max)	-27	dB
Polarization Mode Dispersion (avg)[a]	10	ps
Polarization Dependent Loss (max) [b]	2.0	dB
Polarization rotation speed (max)	50	krad/s
Inter-channel crosstalk at TP3 (max)	-27(-8)	dB
Interferometric crosstalk at TP3 (max)	-35	dB

NOTE: Values in red are the values defined in OIF-400ZR-01.0 and included here for reference. (They are not part of the baseline proposal.)

a). 10 ps of average PMD corresponds to max 33 ps of instantaneous DGD and max 500 ps^2 of SOPMD.
b). Does not include transmitter polarization imbalance.
c). Effective optical channel bandwidth (FWHM) due to DWDM optical filtering.
d). Peak-to-peak difference in insertion loss from TP2 o TP3.
e) Path penalty is the combined penalty caused by chromatic dispersion, polarization mode dispersion, in-band ripple, inter-channel crosstalk, and interferometric crosstalk.

[1]See definition. Maximum optical path penalty includes TBD dB due to inter-channel xtalk.

Rx optical specs

Description	Value	Unit
Signaling rate (range)	59.84375 +/- 100ppm	GBd
Modulation format	DP-16QAM	-
Nominal center frequency	The frequency in Table 1xx-y corresponding to the variable Tx_optical_frequency_index (193.7)	THz
Damage threshold	TBD	dBm
Average Input Power (max) [amplified]	0	dBm
Average Input Power (min) [amplified]	-12	dBm
Average Input Power (min) [unamplified]	-20	dBm
Receiver OSNR (193.6) (min)[a]	26	dB (0.1 nm)
OSNR Tolerance (193.6) (min)[b]	TBD	dB (0.1 nm)
Optical Return Loss (min)	20	dB

NOTE: Values in red are the values defined in OIF 400ZR and included here for reference. (They are not part of the baseline proposal.)

a). 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 in the presence of .
b). Minimum value of OSNR (referred to 0.1 nm noise bandwidth @ 193.6 THz) is equal to the minimum Receiver OSNR plus the maximum optical path penalty OSNR.

Conclusions:

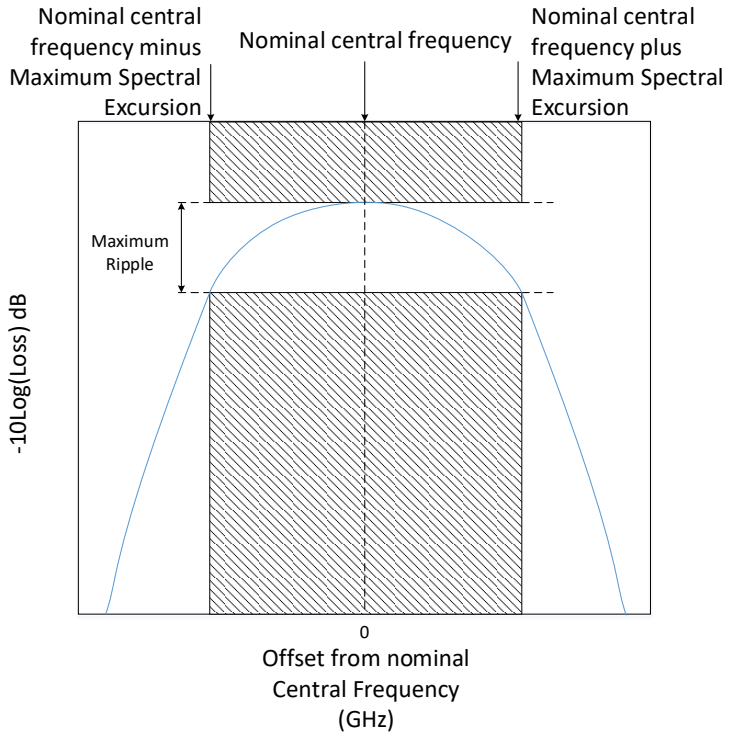
- Adopt Optical specifications defined on pages 17-20 as baseline.

Back-up slides

Optical parameter definitions.

Ripple

Ripple is defined over the entire black link from reference point TP2 to the Corresponding TP3. For any optical channel, it is the peak-to-peak difference in insertion loss between the input and output ports of the black link for that channel in the frequency range of the central frequency of the channel +/- the Maximum Spectral Excursion @ -3dB.



(Definition copied from OIF-400ZR.01.0 and modified for IEEE purposes)

Optical parameter definitions.

Minimum side mode Suppression ratio

The minimum side mode suppression ratio is the minimum value of the ratio of the largest peak of the total transmitter spectrum to the second largest peak. The spectral resolution of the measurement shall be better than the maximum spectral width of the peak. The second largest peak may be next to the main peak, or far removed from it.

(Adapted from ITU-T G.698.2 Clause 7.2.4)

Limiting Maximum I/Q offset maybe sufficient?