Transmitter Spectral Mask and DWDM Black Link Spectral Definitions

Eric Maniloff - Ciena

Tom Williams - Cisco (Acacia)

Gary Nicholl – Cisco

Winston Way - Neophotonics

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Supporters

Atul Srivastava – NEL

Charles Park – Juniper

Mike Sluyski – Cisco (Acacia)

Mark Nowell – Cisco

Peter Stassar – Huawei

Hideki Isono – Fujitsu

Tomoo Takahara – Fujitsu

Markus Weber – Cisco (Acacia)

Jeff Maki - Juniper

Pavel Zivny - Tektronix

David Lewis - Lumentum

Ray Nering – Cisco

Massimo Sorbara - Global Foundries

John DeAndrea – II-VI (Finisar)

Background

Note – comments on this topic have been submitted against 802.3cw D1.0.

An approach to define a methodology for specifying inter-channel crosstalk in DWDM systems has been developed.

This approach provides a means of defining the required parameters to bound adjacent channel crosstalk and filtering penalty.

The issues associated with inter-channel crosstalk definitions are detailed in:
https://www.ieee802.org/3/cw/public/adhoc/21_0201/maniloff_3cw_01a_210201.pdf

The modifications in this proposal are based on the approach in:
https://www.ieee802.org/3/cw/public/adhoc/21_0312/maniloff_3cw_01a_210312.pdf

This presentation includes a summary of the recommendations for methodology and parameters

Black Link approach in IEEE P802.3ct

- Transmitter parameters are specified
  - EVM along with reference receiver definition is used as a transmitter metric
- OSNR is provided for back-to-back measurements
- DWDM black link parameters are specified (see G698.2)
- OSNR Penalty is defined based on black link

- This provides a mechanism for testing that a given receiver is compliant
  - Individual black link parameter penalties are not specified.

Problem Statement

- Conventionally Inter-channel crosstalk is defined as the ratio of the integrated power of aggressor channels to the power of the signal channel
  - This definition does not include spectral dependence of the noise power relative to the signal power
  - Previous coherent applications at 100Gb/s such as those in IEEE 802.3ct or ITU-T G698.2 had excess margin, and hence did not require this level of detail.
- Coherent optical receivers perform spectral filtering of the received signal
  - The impact of inter-channel crosstalk depends on its spectral content, rather than simply its integrated power
- Calculation of inter-channel crosstalk penalty requires information on more than the integrated crosstalk power – its spectral distribution is needed
  - With a proper weighting function, the integrated optical crosstalk penalty can be calculated.

Specifying the required parameters

- Important points:
  - Key parameters (Tx, DWDM black link) should be independently specified & measurable
  - Parameters should be sufficiently well defined to allow Rx design to meet spec requirements
  - The method developed must be compatible with the black link approach adopted in 802.3ct.

Methodology overview

- The following will be defined:
  - Transmit Spectral mask Max and Min
  - DWDM channel passband
  - DWDM black link adjacent channel spectral attenuation
- Details of these are provided in this contribution, as well as in references.
- Defining both the transmit spectrum and the spectral properties of the black link allows calculation of the filtering penalty and the inter-channel crosstalk spectral distribution.

Transmit Spectrum

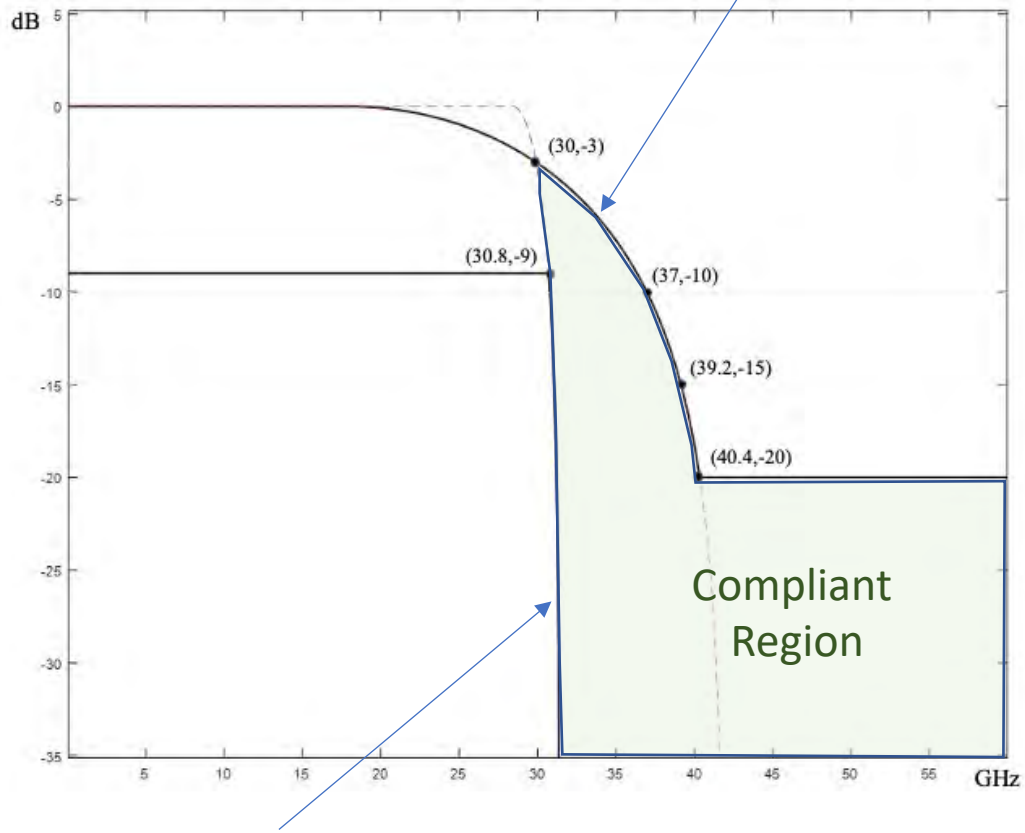
- It is proposed that 802.3cw specifies:
  - The maximum transmit spectrum based on an RRC curve
    - Roll-off (ß) = $ß_{Max}$
    - Floor
  - Defined as a continuous spectrum
    - Using discrete points can be discussed in the future
  - The minimum transmit Spectrum based on an RRC curve
    - Roll-off (ß) = $ß_{Min}$

Transmit Spectral mask (Max and Min)

The solid curves define the upper and lower limits of the mask.

Dashed lines show RRC with roll-offs $ß_{Max}$ =0.4 ,floor = -20 dB, and $ß_{Min}$ =0.05

This is following the specifications in: https://www.ieee802.org/3/ct/public/20_11/way_cw_01b_201116.pdf



802.3cw D1.0 - Transmit Spectrum

Table 156–6—400GBASE-ZR transmit characteristics

Description	Value	Unit
Signaling rate (range)	59.84375 +/– 20ppm	GBd
Modulation format	DP-16QAM	—
Minimum channel spacing	75	GHz
Average channel output power (max)	–6	dBm
Average channel output power (min)	–10	dBm
Nominal center frequency	The frequency in Table 156–4 where the channel index number equals the variable Tx_optical_channel_index	THz
Spectral excursion (max)	TBD	GHz
Side-mode suppression ratio (SMSR) (min)	TBD	dB
Laser linewidth (max)	500	kHz

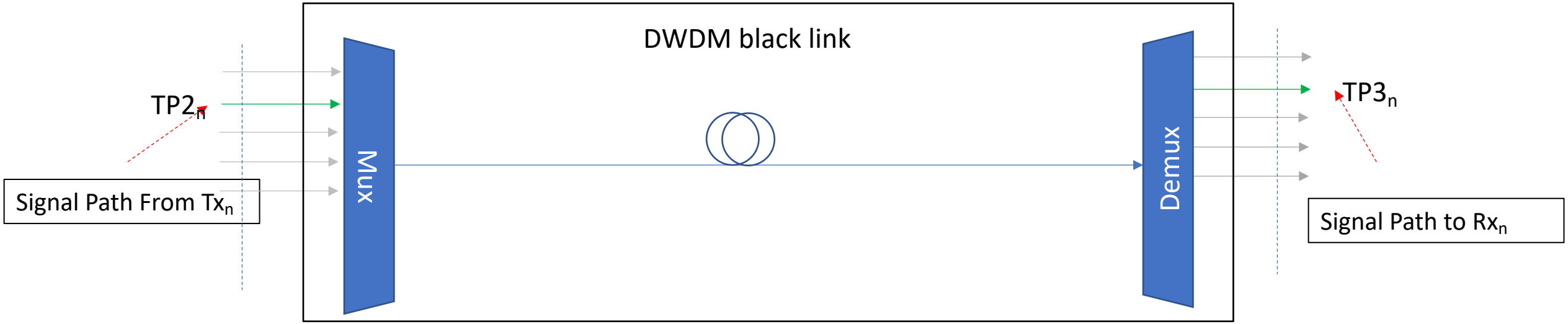
Recommendation for Transmit Spectrum with zero frequency shift

- Replace Spectral Excursion (max) (GHz) with:
  - Transmit Spectrum (max): 0.4 RRC Roll-Off
    - For frequencies > -3dB point
  - Transmit Spectrum (min): 0.05 RRC Roll-Off
    - For frequencies > -9dB point
  - Spectral Floor: -20 dB

DWDM Channel Passband

- 802.3ct used a ripple spec to define both loss variations within the passband and the passband
- Calculation of filtering penalty requires a more complete passband definition
- The passband can be defined based on based on a knowledge of the mux and demux filter properties, including roll-off and spectral offset

DWDM Channel Passband



- The DWDM channel passband ($TP2_n$ to $TP3_n$) can be calculated based on mux and demux filter assumptions
  - Filter Bandwidths, roll-offs, and frequency offsets can be defined to calculate a spectral mask for the signal channel

DWDM Channel Passband

Table 156–8—400GBASE-ZR DWDM black link characteristics

Description	Value	Unit
Channel spacing (min)	75	GHz
Ripple (max)	TBD	dB
Average output power at TP3 (max)	TBD	dBm
Average output power at TP3 (min): for OSNR at TP3 < 35 dB (12.5 GHz) for OSNR at TP3 ≥ 35 dB (12.5 GHz)	 TBD TBD	 dBm dBm
OSNR at TP3 (min)	TBD	dB (12.5 GHz)

DWDM Channel Passband Specification

- Define DWDM channel passband specifications in place of using ripple to define the passband
  - Note: Ripple spec will be maintained to bound allowable loss variation within passband

- Specify at discrete points
  - Define the specs relative to averaged loss across a bandwidth around f_0

DWDM channel Passband: Recommended parameters

- DWDM channel passband width is specified to the center of the channel f_0
  - The passband is specified by defining attenuation at discrete frequencies relative to f_0
- The following parameters for Mux & Demux will be used to derive the DWDM channel passband:
  - BW min = 70GHz
  - BW max = 76GHz
  - Filter order = 3
  - |Maximum center frequency variation| ≤ 4 GHz
- DWDM channel spectral attenuation relative to the attenuation at the center channel frequency (f_0)

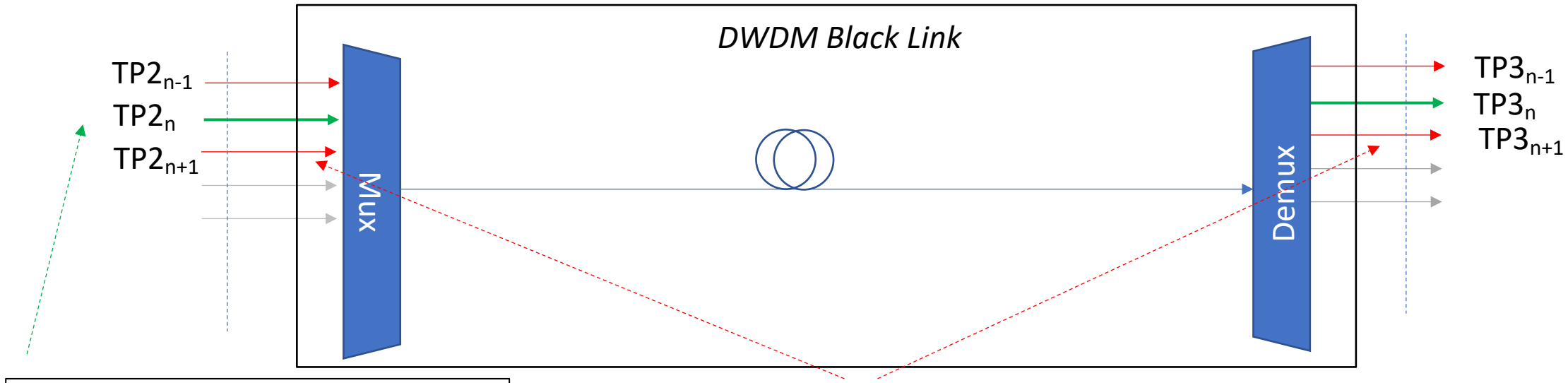
Attenuation (dB)	Full Width Min (GHz)	Full Width Max (GHz)
0.5	42	50
3	60	68
20	84	93

Inter-channel Crosstalk

Table 156–8—400GBASE-ZR DWDM black link characteristics

Description	Value	Unit
Polarization rotation speed (max)	50	krad/s
Inter-channel crosstalk at TP3 (max)	TBD	dB

Adjacent DWDM channel spectral attenuation



- Adjacent channel spectral attenuation defines the spectral attenuation between port n and the adjacent ports, n±1
- Adjacent channel spectral attenuation can be combined with Transmit spectrum to calculate the spectral distribution of the inter-channel crosstalk

Inter-channel Crosstalk specification

- Add adjacent channel spectral attenuation
  - Needs DWDM black link clarification to include port indexing

- Specification will be:
  - The spectral attenuation for frequencies at Demux port n, will be defined for light transmitted into the adjacent channels (n ± 1)
  - Attenuation will be defined relative to the attenuation at the center of the measurement channel

Adjacent channel attenuation specification

- Filter parameters can be used to calculate the adjacent channel attenuation in a black link approach
- The following parameters for Mux & Demux will be used to derive the DWDM black link adjacent channel spectral attenuation:
  - BW max = 76GHz
  - Filter order = 3
  - |Maximum center frequency variation| ≤ 4 GHz
  - Insertion loss variation ≤ 1.5dB
  - Adjacent channel floor > 30dB

Specification for adjacent channel attenuation

- Specification can be defined:
  - The spectral attenuation from an adjacent channel frequency divided by the attenuation at the center frequency of a signal channel will be less than (values to be filled in)

Frequency Offset	Isolation (dB)
0	-TBD
±15	
±20	
±25	
±30	
±35	
±40	
±45	
±50	
±55	
±60	
±65	
±70	
±75	

Summary

- A new approach is proposed to constrain the link penalty due to crosstalk between adjacent DWDM channels within the DWDM black link.
- This approach requires the addition of the following new parameters and their associated definitions:
  - Transmit spectral mask (Max and Min)
  - DWDM channel passband
  - DWDM black link adjacent channel spectral attenuation
- Recommended parameter values are included in this proposal. It is anticipated the Task Force will be able to modify these values as further analysis becomes available once full baseline is adopted.

Thanks!