INTERNATIONAL TELECOMMUNICATION UNION

TELECOMMUNICATION STANDARDIZATION SECTOR

STUDY PERIOD 2017-2020

SG15-LS181

STUDY GROUP 15

Original: English

Question(s):	6/15	6 May 2019

LS
(Ref.: TD165/WP2)

Source:	ITU-T Study Group 15
Title:	LS/r on request for information on test results of maximum spectral excursion performance

LIAISON STATEMENT

For action to:	-
For comment to:	-
For information to:	IEEE 802.3 Ethernet Working Group IEEE P802.3ct Task Force
Approval:	By correspondence via Q6 exploder (6 May 2019)
Deadline:	-

Contact:	Peter Stassar Huawei Technologies Co., Ltd. P.R. China	Tel: +31 20 4300832 Email: peter.stassar@huawei.com

Q6/15 thanks IEEE 802.3 for their Liaison Statement, agreed to at the IEEE 802.3 Plenary meeting, Vancouver, BC, Canada, 14th March 2019, which we reviewed via correspondence.

In your liaison statement you asked if Q6 could share any multi-vendor test results on transmitter maximum spectral excursion performance carried out within ITU-T SG15 that would be relevant to the development of DWDM optical interface specifications for DP-DQPSK at 100 Gb/s and DP-16QAM at 400 Gb/s.

In the annex we provide a summary of the concluding report on the analysis of spectral excursion for primarily the 100 Gbit/s DP-QPSK modulation format presented at the June/July 2015 SG15 Plenary Meeting.

As Q6 progresses its work on future revisions of Recommendation ITU-T G.698.2, to include 200G and 400G application codes, we will be happy to provide suitable results on transmitter maximum spectral excursion performance for DP-16QAM at 400 Gb/s with IEEE 802.3 as soon as they have become available.

ANNEX

Summary of spectral excursion testing & analysis for advanced modulation formats in Q6/15

Introduction

This Annex provides a summary of spectral excursion testing & analysis for advanced modulation formats carried out in Q6/15 and completed at the SG15 Plenary Meeting June/July 2015. It contains an extract from the results as reported in TD 175 (WP2) to the SG15 Plenary Meeting, June/July 2015.

The following companies have contributed to this effort: ADVA, Alcatel-Lucent, Ciena, Cisco, Deutsche Telecom, Ericsson, FiberHome and Huawei.

DP-QPSK analysis

Measurement results for 100 Gbit/s DP-QPSK had been reported in various contributions:

- Contribution 1 100G DP-QPSK through concatenated WSS's
- Contribution 2 100G DP-QPSK through a tunable band pass filter
- Contribution 3 100G DP-QPSK through concatenated Wave Shaper filters
- Contribution 4 100G PDM-RZ-QPSK through concatenated WSS's and interleavers
- Contribution 5 100G DP-QPSK through a cascade of WSS filters
- Contribution 6 100G DP-NRZ-QPSK through groups of cascaded waveshapers
- Contribution 7 100 G DP-DQPSK through a WaveShaper filter
- Contribution 8 100G DP-QPSK through a tunable band pass filter

In Contribution 1 results were provided for 1 pass, 11 passes and 16 passes through the WSS.

In Contribution 2 results were provided for filter -2 dB bandwidths of both 330 pm and 240 pm.

In Contribution 3 results were provided for 1, 2, 4, 8, 12 and 16 filters in series.

In Contribution 4 results were provided for 1 WSS, 1 WSS + interleaver and 13 WSS's + interleaver.

In Contribution 5 results were provided for 1, 2, 4, 6, 8, 12, and 16 passes through the WSS.

In Contribution 6 results were provided for 1, 4, 8, and 16 filters in series.

In Contribution 7 results were provided for 50, 40 and 30 GHz optical filters.

In Contribution 8 results were provided for filter -2 dB bandwidths of both 330 pm and 240 pm.

Taken together, this gives 30 curves of penalty vs offset for 8 different implementations of DP-QPSK transmitter and 28 different filter arrangements. For each curve, the OSNR penalty was measured, as the centre wavelength of the signal was tuned within the filter bandwidth. Figure 1 shows, as an example, the OSNR penalty (triangle markers and black line) as a function of the frequency offset. Also shown are the filter shape (blue) with red markers (x) for the 2.5 dB isolation points and two curves representing the signal spectrum (grey), when tuned to frequency offset values such that one of the -2.5 dB points of the spectrum (+ markers) coincides with one of the 2.5 dB isolation points of the filter. These frequency offset values are also marked by red vertical lines. Figure 1 also marks by arrows the width between the frequency offset limits (red) as well as the actual tuning width for which the OSNR penalty stays below 1 dB (black). The smallest of the two differences between the red lines and the adjacent 1 dB penalty point is referred to later as the "minimum gap between limit and 1 dB penalty point".

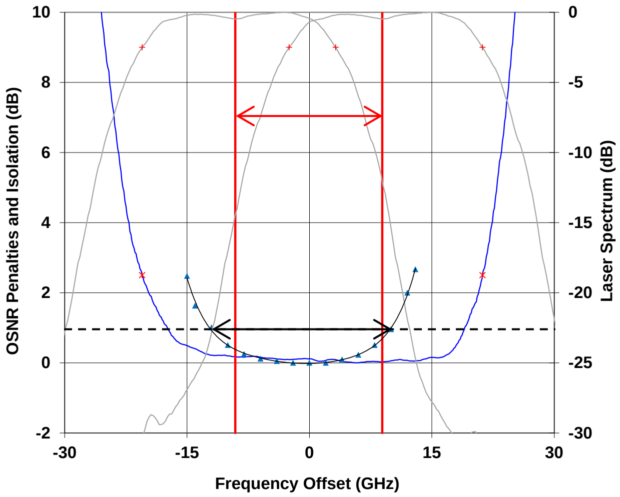


Figure 1 – Example signal spectrum (grey curves) with -2.5 dB points (+), isolation of filter arrangement (blue curve) with 2.5 dB points (x), and OSNR penalty (black curve, triangles) as functions of offset from centre frequency.

As all of the results except for those in Contributions 1, 7 and 8 were normalised to 0 dB minimum penalty for each offset curve, the results from these three contributions have been modified here to use the same normalisation.

The analysis of the available data has been done in a manner equivalent to that done around 2005 for NRZ signals.

It has been proposed to use the Tx spectrum -3 dB points with a 3 dB filter ripple. Figure 2 shows a plot of OSNR penalty vs. transmitted spectrum –x dB points for 3 dB filter ripple for all 30 measurements. Similarly, Figure 3 shows a plot of OSNR penalty vs. filter ripple for transmitted spectrum –3 dB points.

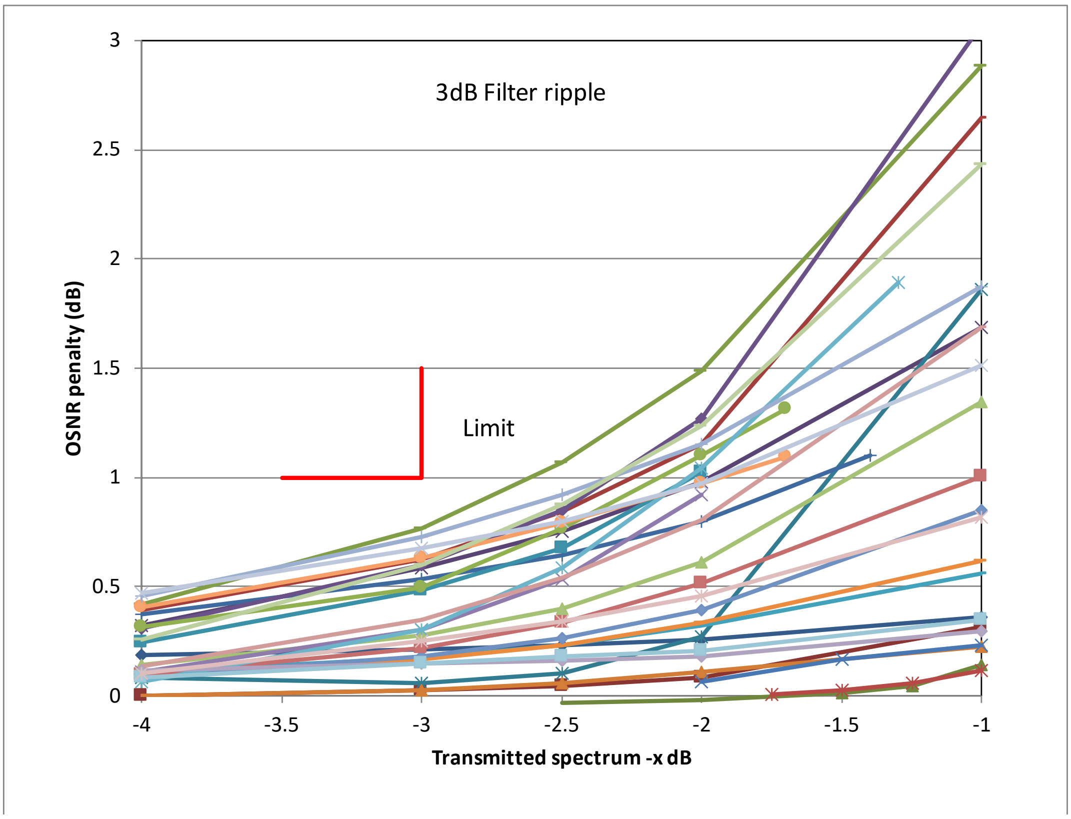


Figure 2 – OSNR penalty vs. transmitted spectrum –x dB points for 3 dB ripple

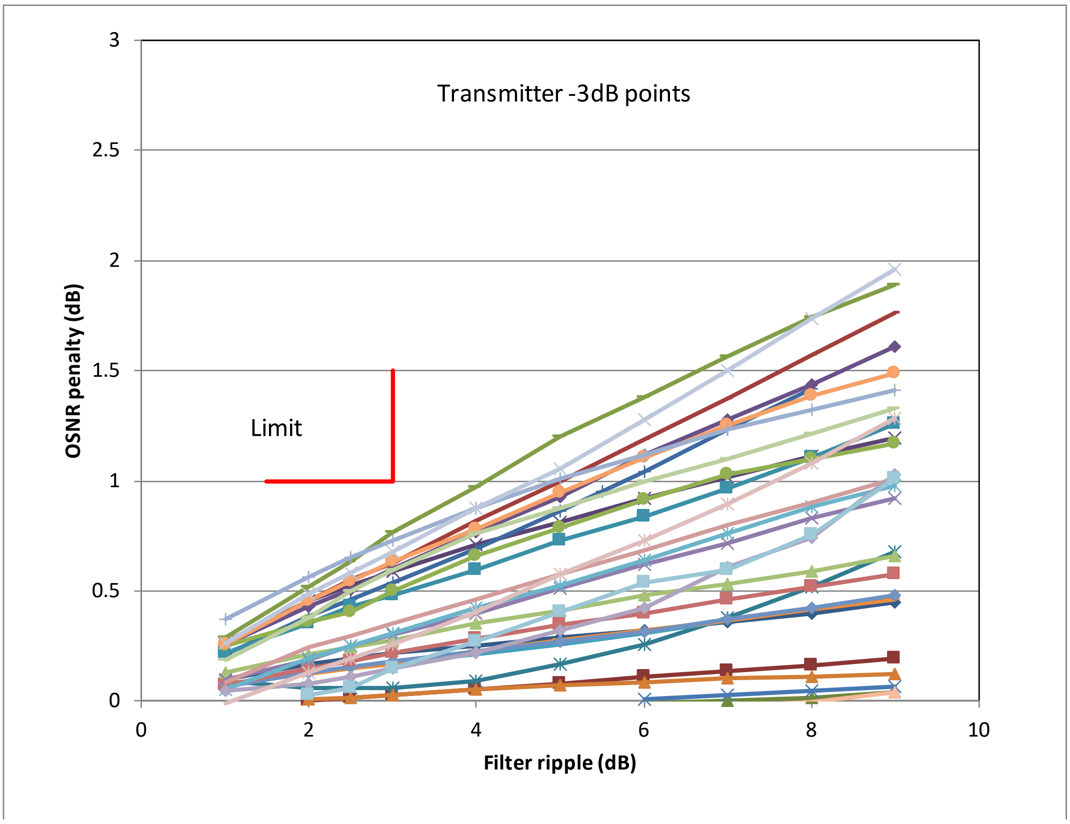


Figure 3 – OSNR penalty vs. filter ripple for transmitted spectrum –3 dB points

As can be seen from Figure 2 and Figure 3, within this data set the OSNR penalty remains below 1 dB as long as the transmitted spectrum -3 dB points remain within the end-to-end filter function -3 dB points. Figure 4 plots the difference in frequency between the two limits for this criterion vs. the difference in frequency between the actual 1 dB OSNR penalty points.

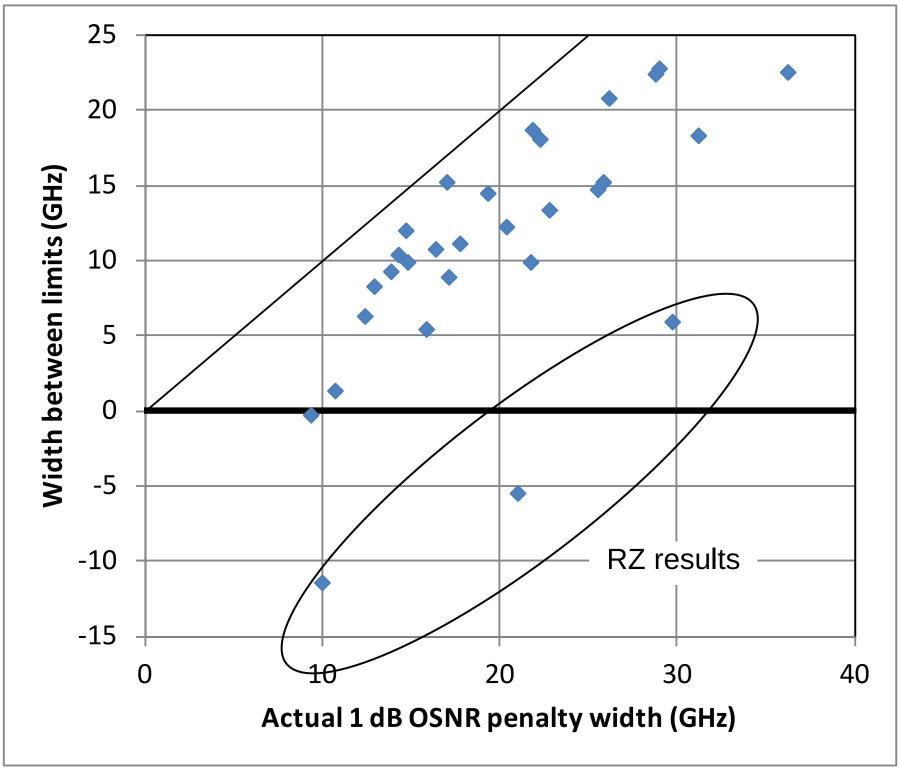


Figure 4 – Difference between the (-3 dB, 3 dB) points vs. the actual 1 dB OSNR penalty width

As expected, this plot shows a significant difference between some of the "width between limits" values and the actual 1 dB penalty width.

The three 100G PDM-RZ-QPSK results are separated from the NRZ results by a sufficiently large amount to suggest that the criterion for this format needs to be different from the criterion for NRZ. Of course many more results for RZ would be needed to be able to define what this should be.

To explore the exact values of the criterion further, Figure 5 shows the difference in frequency between the two limits for a (-2 dB, 2 dB) criterion vs. the difference in frequency between the actual 1 dB OSNR penalty points and Figure 6 shows the same for a (-2.5 dB, 2.5 dB) criterion.

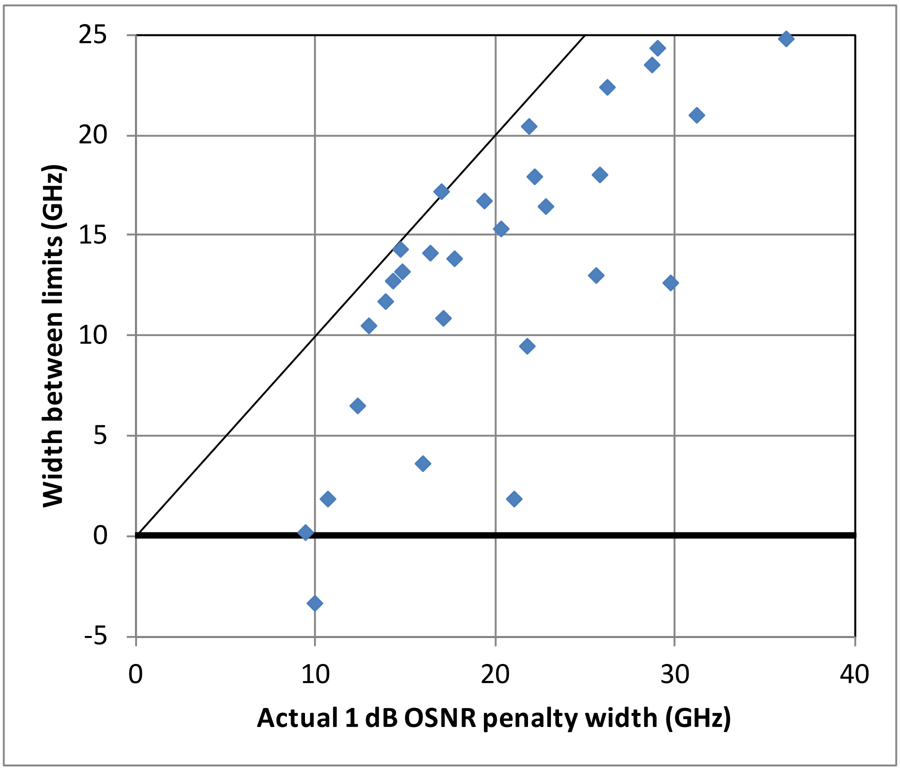


Figure 5 – Difference between the (-2 dB, 2 dB) points vs. the actual 1 dB OSNR penalty width

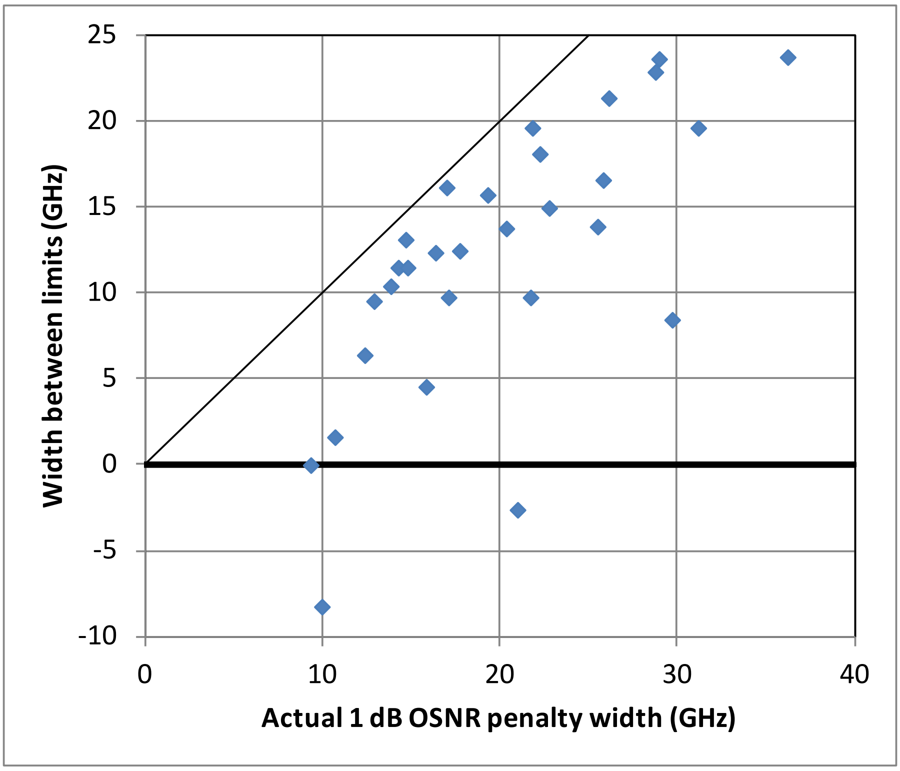


Figure 6 – Difference between the (-2.5 dB, 2.5 dB) points vs. the actual 1 dB OSNR penalty width

While the (-2 dB, 2 dB) criterion leaves less of a gap between the limits and the actual performance, some points are on or slightly over the 1:1 line showing that some combinations of transmitter and filter will exceed 1 dB OSNR penalty with this criterion.

The (-2.5 dB, 2.5 dB) criterion shown in Figure 6 also reduces the gap while preserving the 1 dB OSNR penalty as shown in Figures 7 and 8.

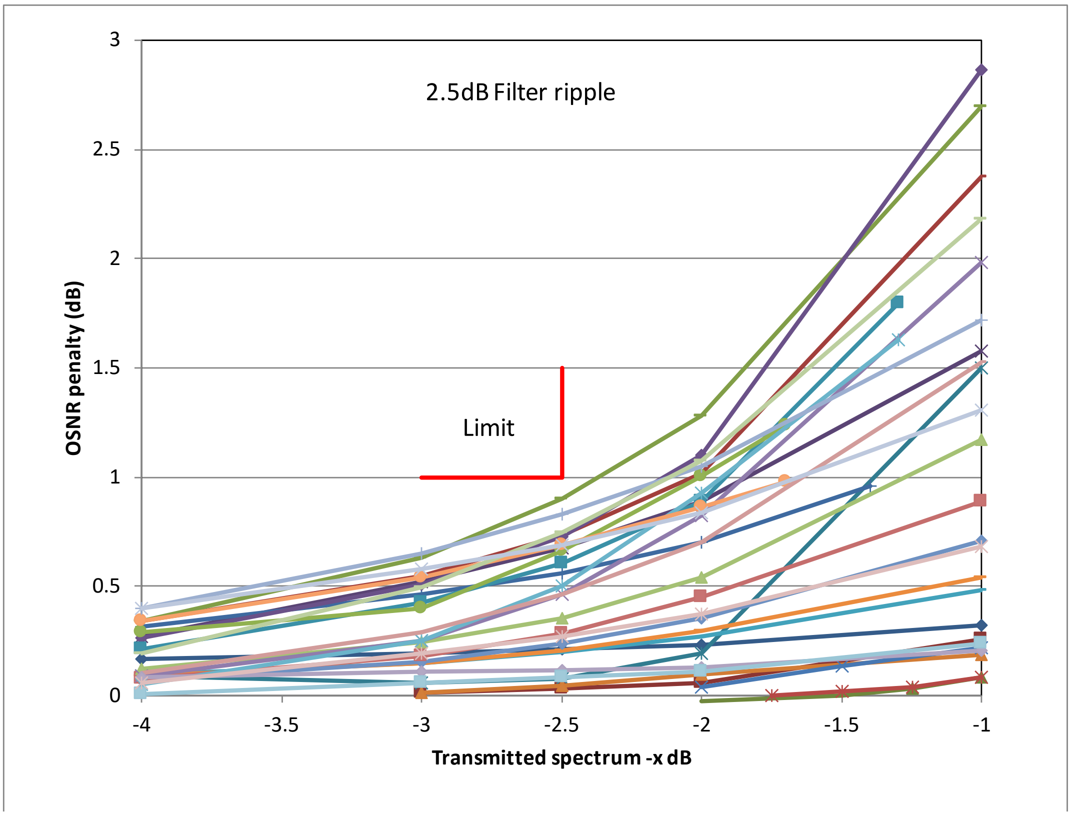


Figure 7 – OSNR penalty vs. transmitted spectrum –x dB points for 2.5 dB ripple

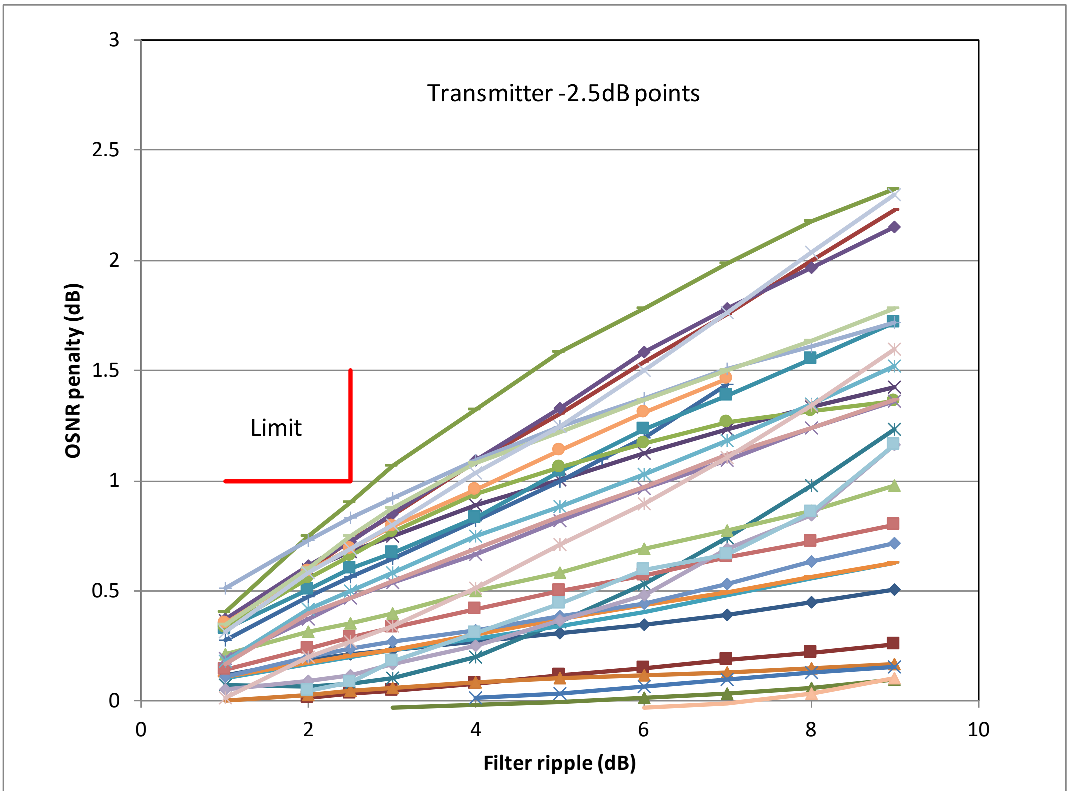


Figure 8 – OSNR penalty vs. filter ripple for transmitted spectrum –2.5 dB points

Another way to look at the same data is shown in Figure 9 which plots the minimum gap between the (-3 dB, 3 dB) limit point and the 1 dB OSNR penalty point vs. the actual 1 dB penalty width and Figure 10 which is the same for the (-2.5 dB, 2.5 dB) limit points.

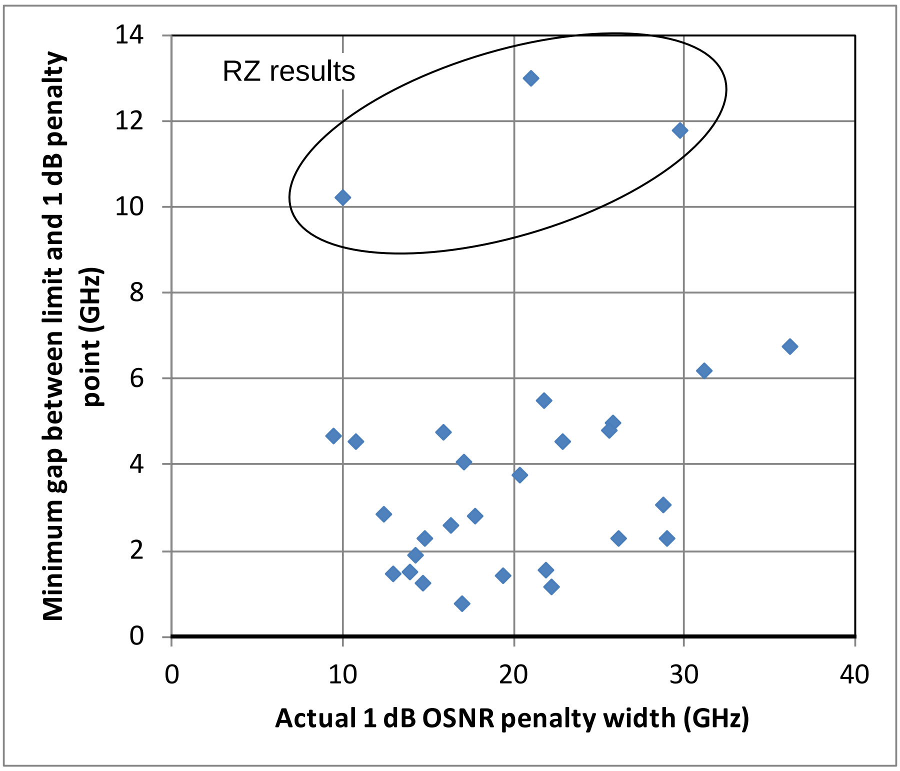


Figure 9 – Minimum gap between the (-3 dB, 3 dB) limit point and the 1 dB OSNR penalty point

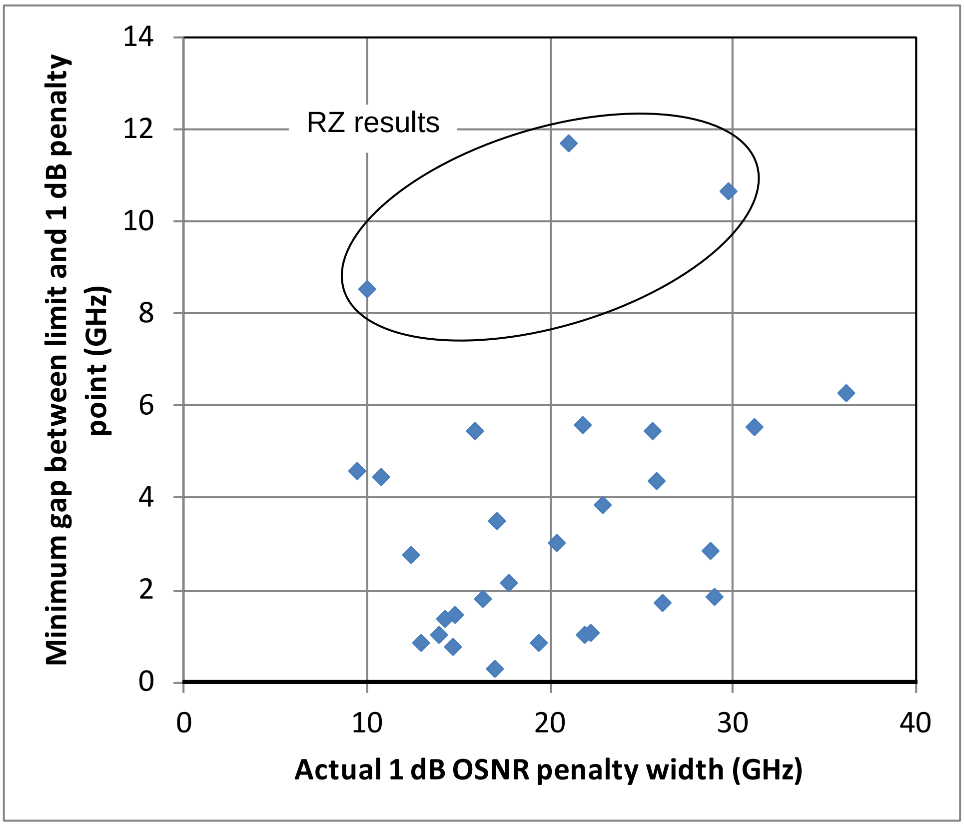
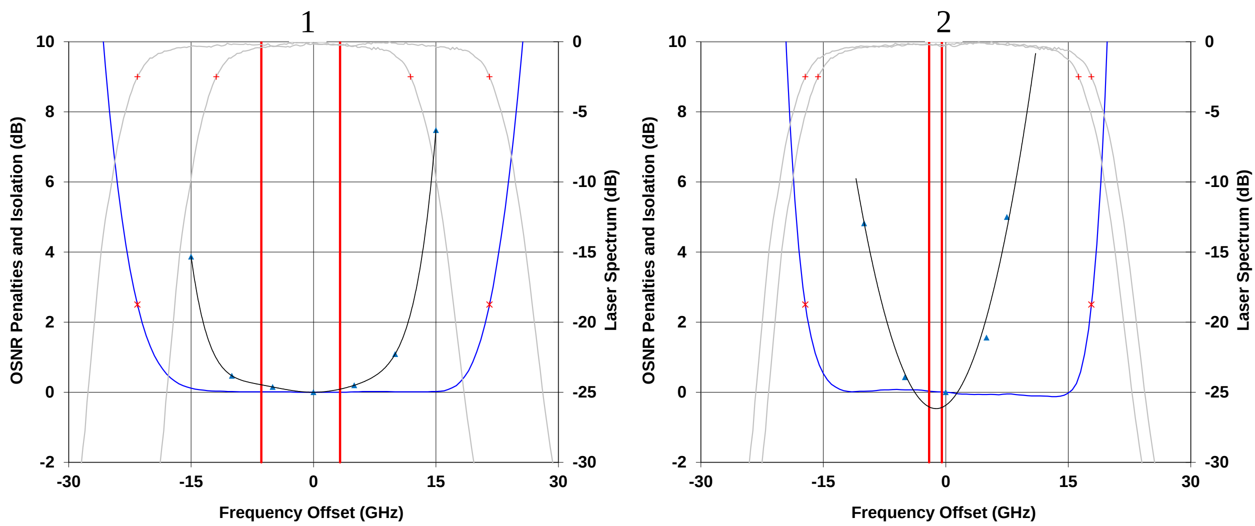


Figure 10 – Minimum gap between the (-2.5 dB, 2.5 dB) limit point and the 1 dB OSNR penalty point

The individual plots for the -2.5 dB, 2.5 dB limit points are shown below for all 100 Gbit/s NRZ DP-QPSK results with less than 1 dB penalty.



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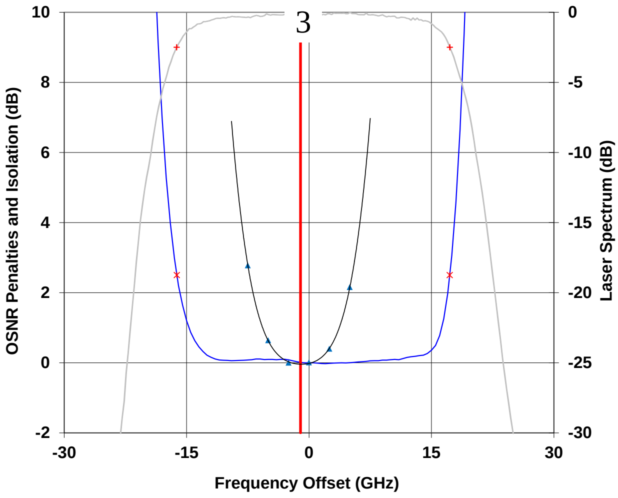
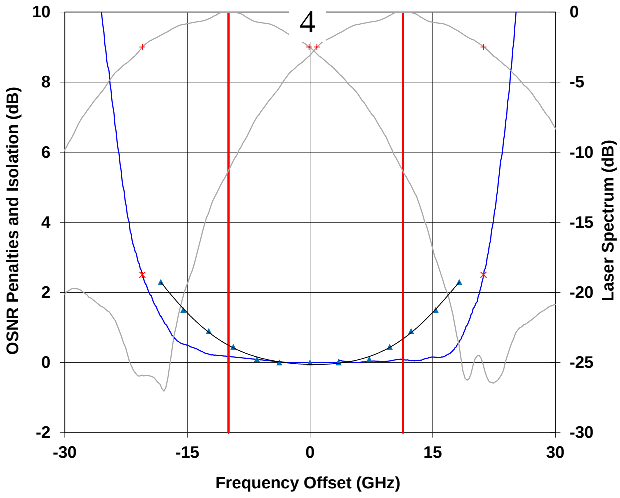

OSNR Penalties and Isolation (dB)
Laser Spectrum (dB)
Frequency Offset (GHz)

4


OSNR Penalties and Isolation (dB)
Laser Spectrum (dB)
Frequency Offset (GHz)

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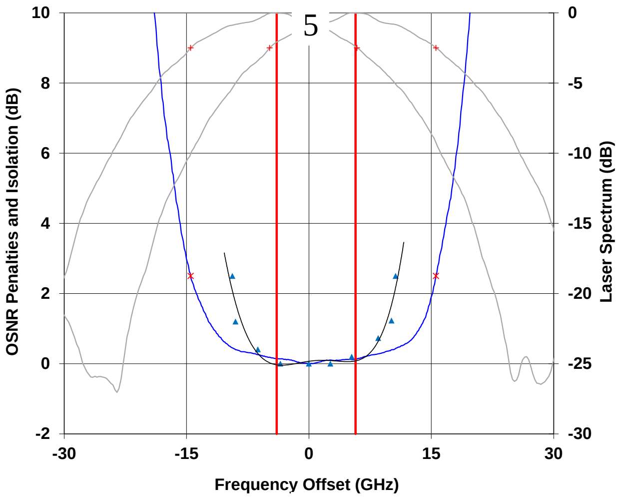
OSNR Penalties and Isolation (dB)
Laser Spectrum (dB)
Frequency Offset (GHz)

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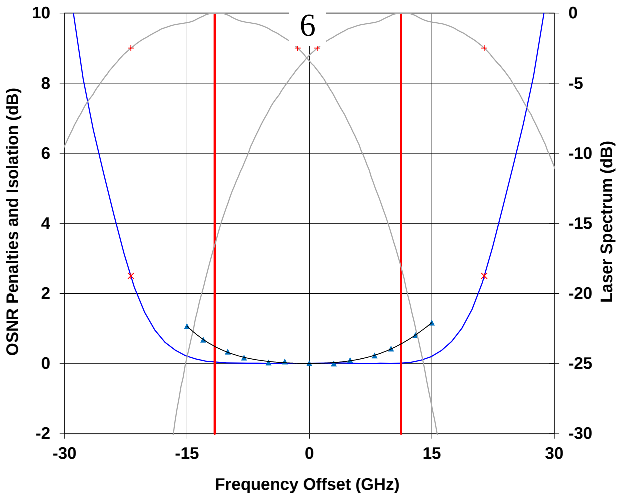
OSNR Penalties and Isolation (dB)
Laser Spectrum (dB)
Frequency Offset (GHz)

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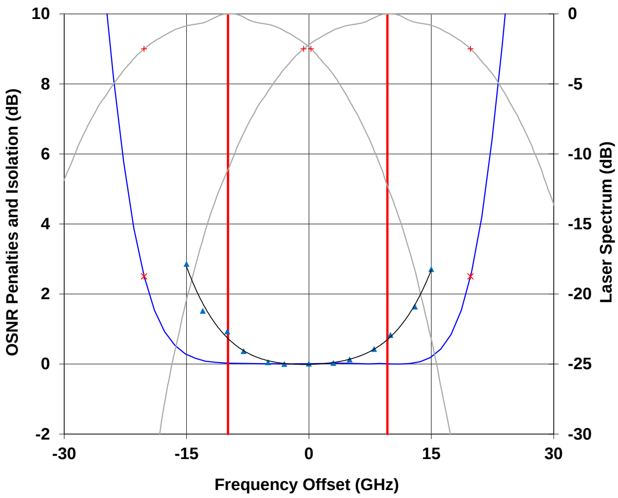
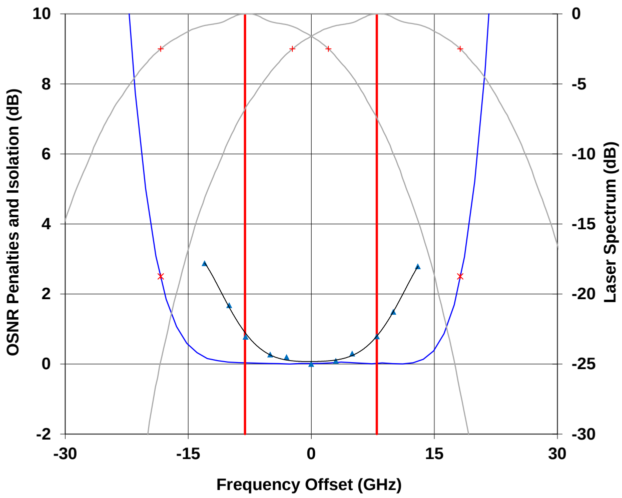

OSNR Penalties and Isolation (dB)
Laser Spectrum (dB)
Frequency Offset (GHz)


OSNR Penalties and Isolation (dB)
Laser Spectrum (dB)
Frequency Offset (GHz)

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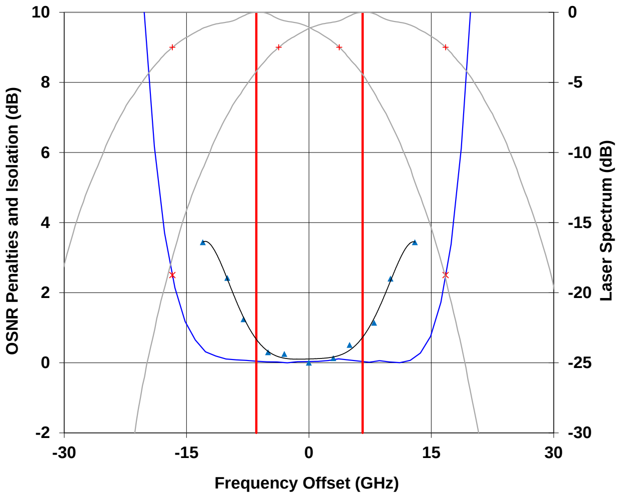
OSNR Penalties and Isolation (dB)
Laser Spectrum (dB)
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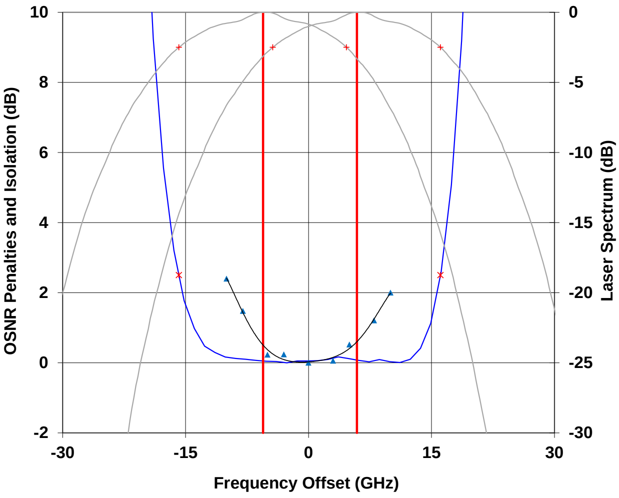
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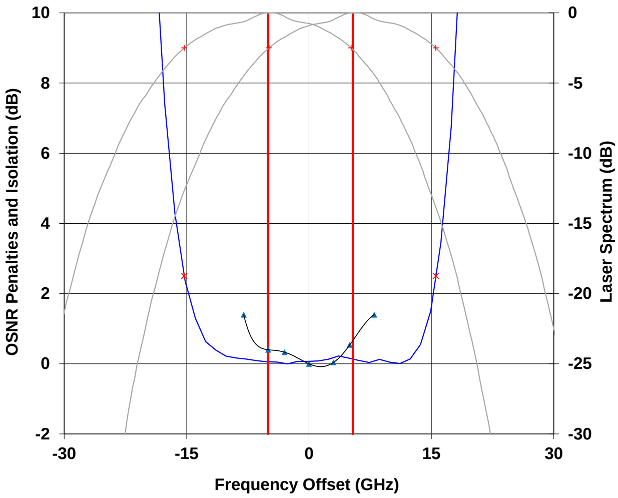
Laser Spectrum (dB)
Frequency Offset (GHz)


OSNR Penalties and Isolation (dB)
Laser Spectrum (dB)
Frequency Offset (GHz)

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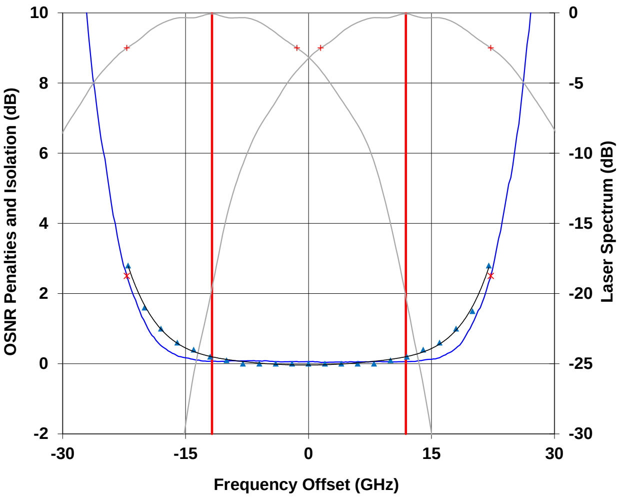
OSNR Penalties and Isolation (dB)
Laser Spectrum (dB)
Frequency Offset (GHz)

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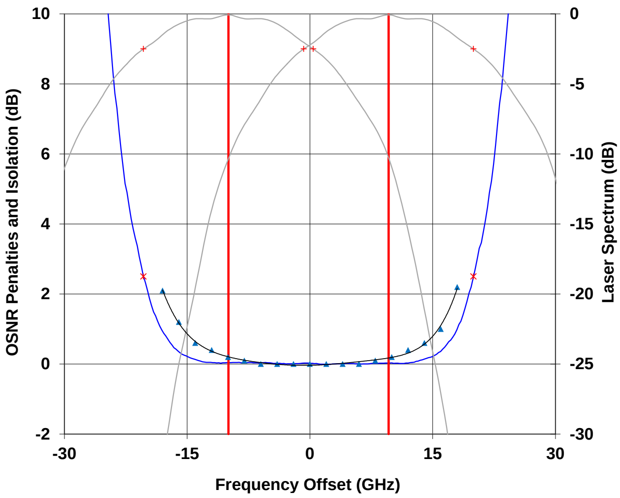
OSNR Penalties and Isolation (dB)
Laser Spectrum (dB)
Frequency Offset (GHz)

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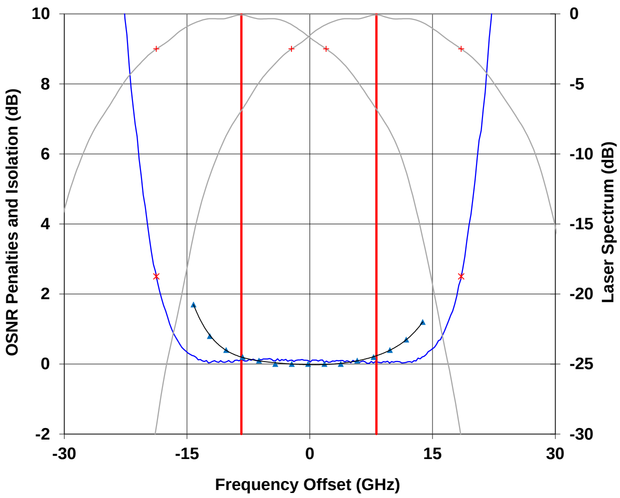
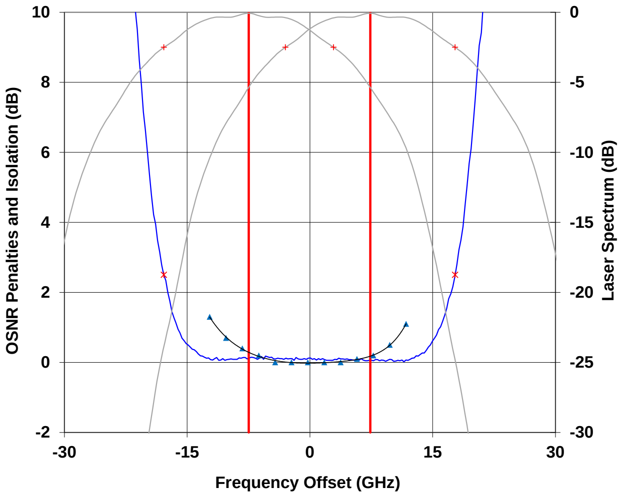

OSNR Penalties and Isolation (dB)
Laser Spectrum (dB)
Frequency Offset (GHz)

16


OSNR Penalties and Isolation (dB)
Laser Spectrum (dB)
Frequency Offset (GHz)
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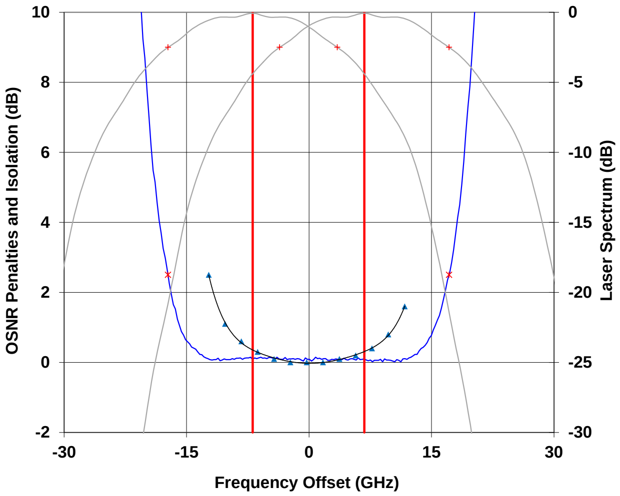
OSNR Penalties and Isolation (dB)
Laser Spectrum (dB)
Frequency Offset (GHz)
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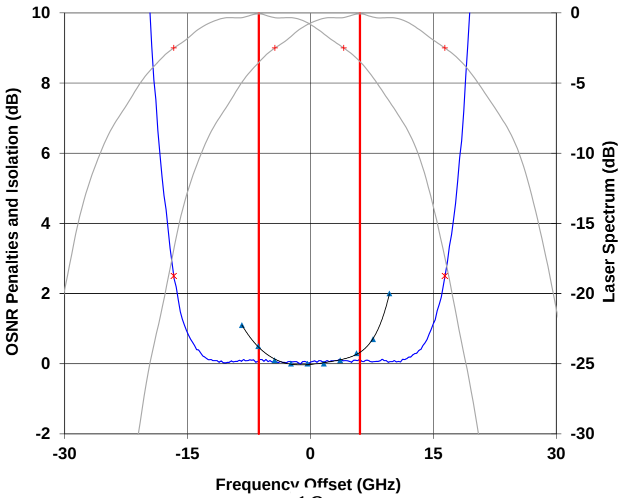
OSNR Penalties and Isolation (dB)
Laser Spectrum (dB)
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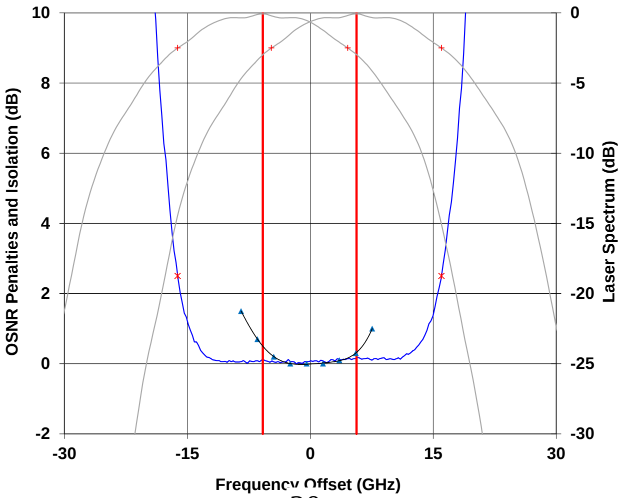
OSNR Penalties and Isolation (dB)
Laser Spectrum (dB)
Frequency Offset (GHz)
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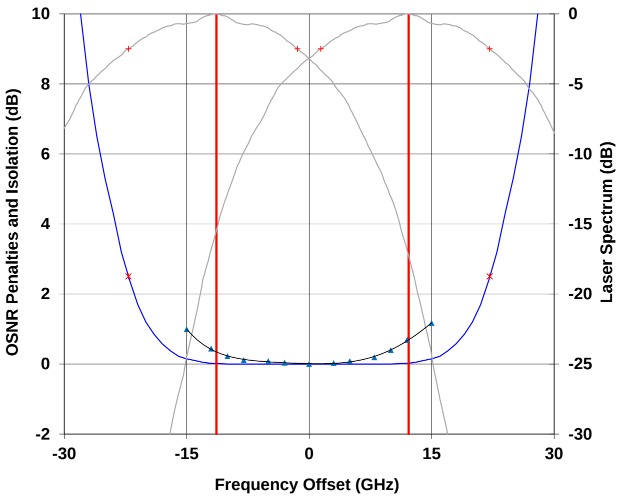
OSNR Penalties and Isolation (dB)
Laser Spectrum (dB)
Frequency Offset (GHz)
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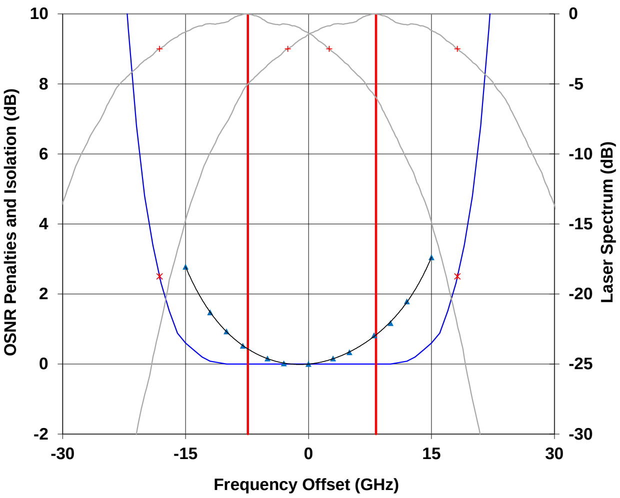
OSNR Penalties and Isolation (dB)
Laser Spectrum (dB)
Frequency Offset (GHz)
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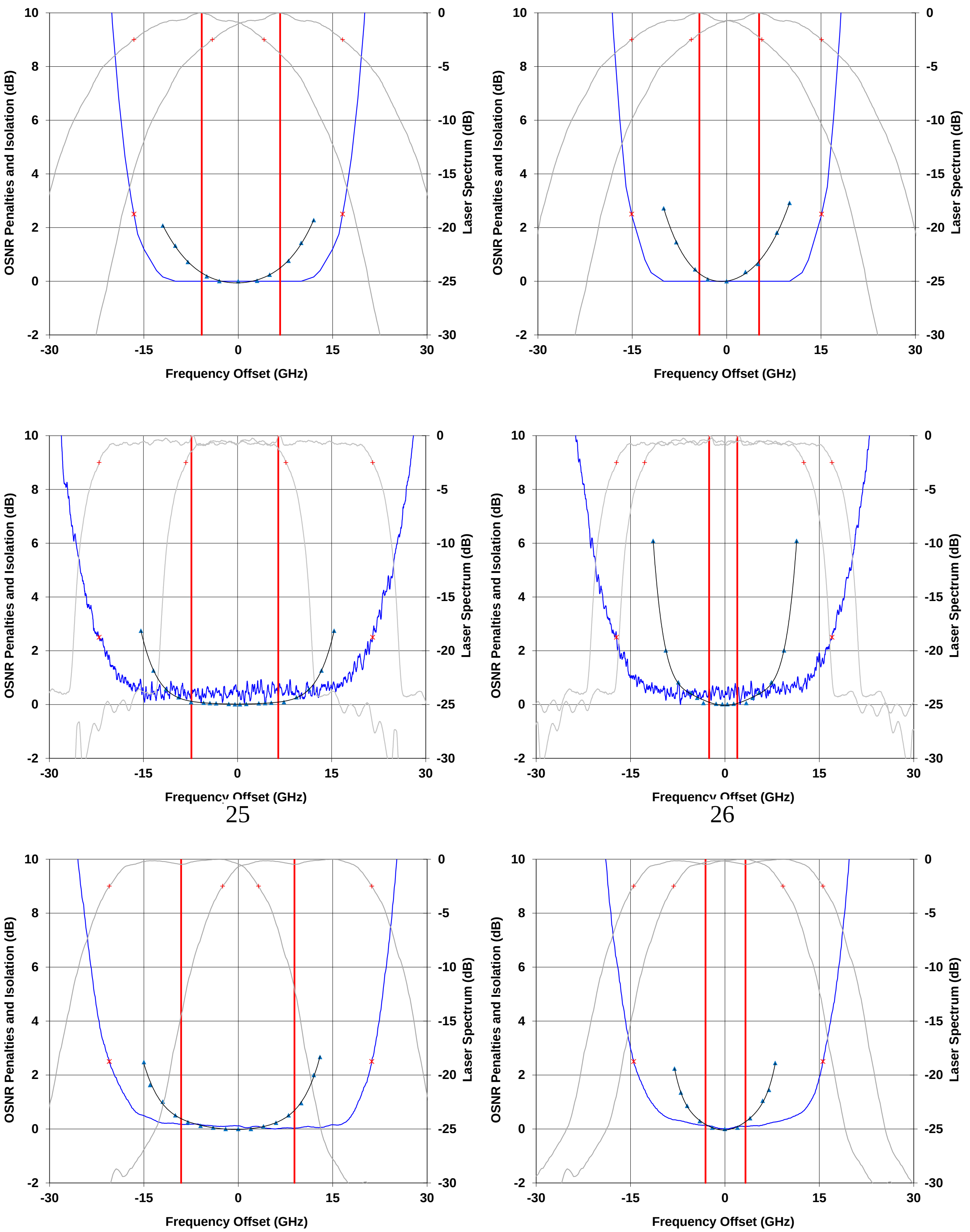

Figure 11 - Signal spectrum (grey curves) with -2.5-dB points (+), isolation of filter arrangement (blue curve) with 2.5-dB points (x), and OSNR penalty (black curve, triangles) as functions of offset from centre frequency.

Conclusions

With these measurement data it was possible to reach some conclusions regarding the spectral excursion criterion for 100G DP-QPSK.

For these results, the OSNR penalty remains below 1 dB as long as the transmitted spectrum -3 dB points remain within the end-to-end filter function -3 dB points. This condition may, however, be somewhat conservative and disallow systems that would operate satisfactorily.

Changing the criterion to be that the transmitted spectrum -2.5 dB points remain within the end-to-end filter function -2.5 dB points reduces the gap between the limit and the actual 1 dB penalty point while preserving the 1 dB OSNR penalty.

These conclusions are based on 27 measurements of 100G NRZ DP-QPSK with different filters and with six different DP-QPSK transmitters.

The results for 100G PDM-RZ-QPSK show a much larger gap between the limits and the actual 1 dB penalty points which suggests that the criterion for this format needs to be different from the criterion for NRZ. More results for RZ would be needed to be able to define what this should be.

As a result of this analysis Q6/15 agreed to use the -2.5dB/-2.5dB conditions at a maximum OSNR penalty of 1dB for 100G application codes in G.698.2.