Single Fiber, Single wavelength, GbE / FE transceiver

ODN requirements & performance measurements

ODN = Optical Distribution Network

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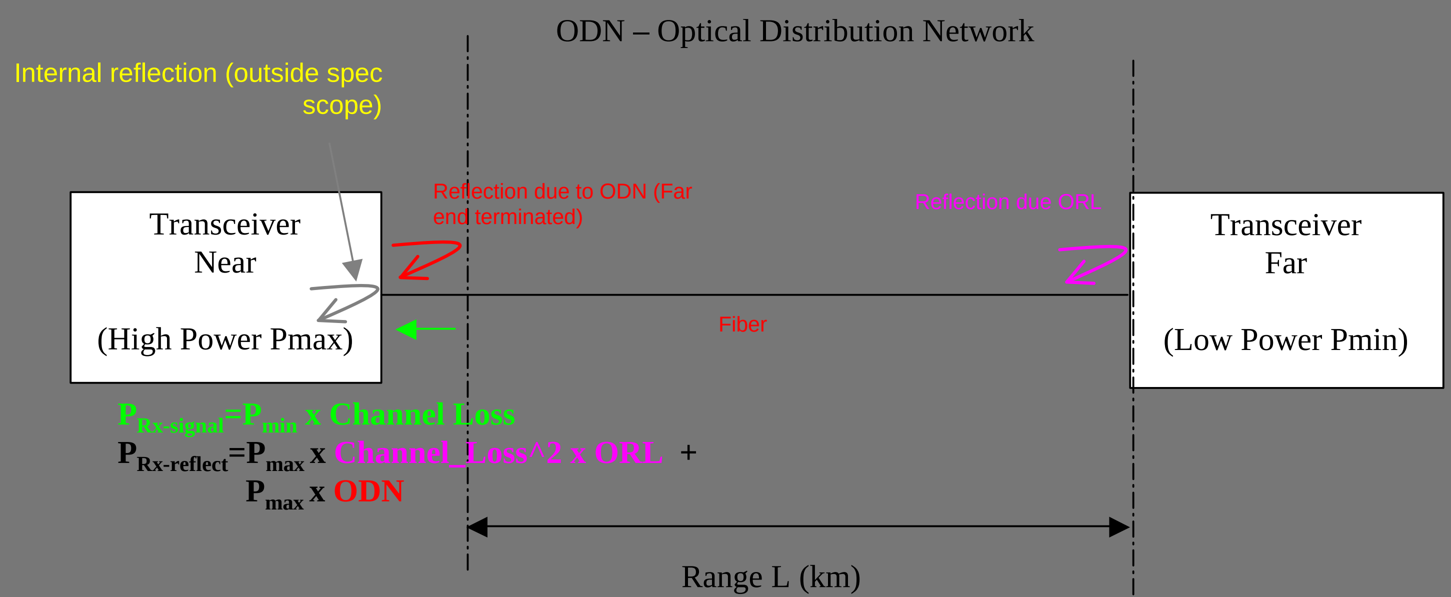
IEEE 802.3 ah interim
May 2002

Dependence on cable plant return loss (action item 4)

- Current plant data
- Measurements
  - Self reflection Rx interference
  - Self reflections Tx interference

Link reflections – P transmit issues



$P_{Rx\text{-}signal} = P_{min} \times \text{Channel Loss}$

$P_{Rx\text{-}reflect} = P_{max} \times \text{Channel\_Loss}^2 \times \text{ORL} +$
$P_{max} \times \text{ODN}$

Channel Loss:
* Fiber attenuation (0.5dB/km x 10km)
* Connector (0.5 dB x 4)

Link Penalty:
* MPN and others – 3dB allotment

ODN ORL - Background

- From major carriers:
  - Current networks are >30dB ORL
  - “Old” networks can be as “bad” as > 20 dB
- Common SC-PC connections are specified >35 (or 40) db
- Low ORL in the ODN “disaster waiting to happen” (= cold solder joint)
- ODN ORL of 20dB allows 23 CURRENT worst-case connectors

The maximum link distances for single-mode fiber are calculated based on an allocation of 2.0 dB total connection and splice loss. For example, this allocation supports four connections with an average insertion loss per connection of 0.5 dB. Connections with different loss characteristics may be used provided the requirements of Table 38–11 and Table 38–12 are met.

38.11.2.2 Connection return loss

The return loss for multimode connections shall be greater than 20 dB.

The return loss for single-mode connections shall be greater than 26 dB.

GR909 specifies <-40 dB ORL per connection

Single Fiber links - Message (Plain Text)

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From: muneer.zuhdi@marconi.com   Sent: Mon 3/4/2002 4:06 PM

To: Meir Bartur; Thomas.murphy@infineon.com

Cc: george.buabbud@marconi.com; debra.wawro@marconi.com

Subject: Single Fiber links

Tom and Meir,

Your EFM presentation was forwarded to me by George BuAbbud I have a point that I would like to raise. You mentioned that major carriers are spec'ing ORL of -30 dB in new networks, and -20 dB in old networks. You also referenced 802.3-2000 which spec a reflection of 26 dB per connection.

My understanding is that all major carriers in the US follow Telecordia spec GR909 in their network specifications. The telecordia spec indicates that connections along the optical path should have a reflection of <-40 dB each.

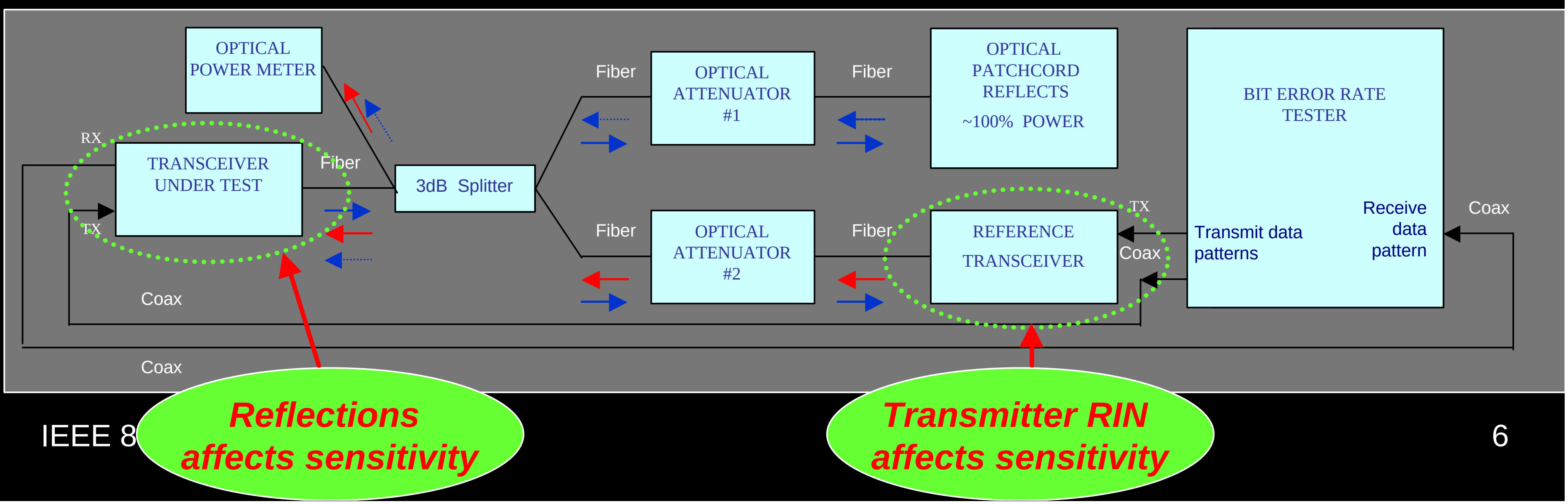
I'm not familiar with 802.3-2000, but I thought that GR909 would be the appropriate reference for the optical path parameters.

Regards

Muneer Zuhdi

Example: Generalized Sensitivity measurement Variable Optical Return Signal

- Measure Transceiver Under Test (TUT) output power P_0, ER, t_r, t_f, etc.
- Use calibrated symmetric 2 way splitter combiner (~3.5dB)
- Increase the optical attenuation of the reflection leg (#1) to max.
- Measure sensitivity by adjusting attenuator #2 (no reflections)
- Turn ref. Tx off and reduce reflectance leg attenuator (#1) until power meter reads the desired P_0 – target_ORL
- Turn ref. Tx on and re-measure sensitivity under ORL condition

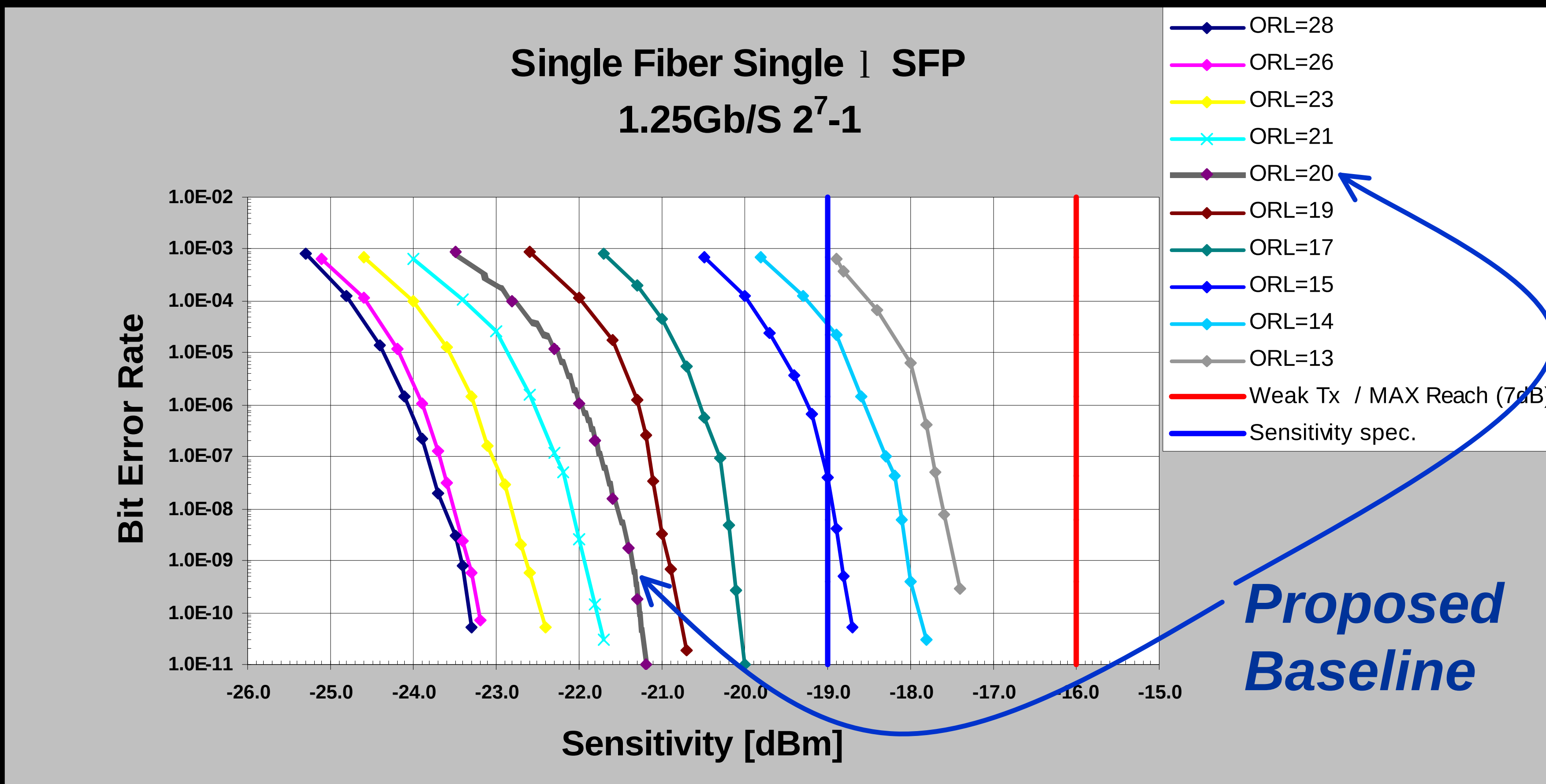


Measurements: Rx effects

- Test 1
  - Pout = - 6dBm
  - Measured sensitivity (no reflections)

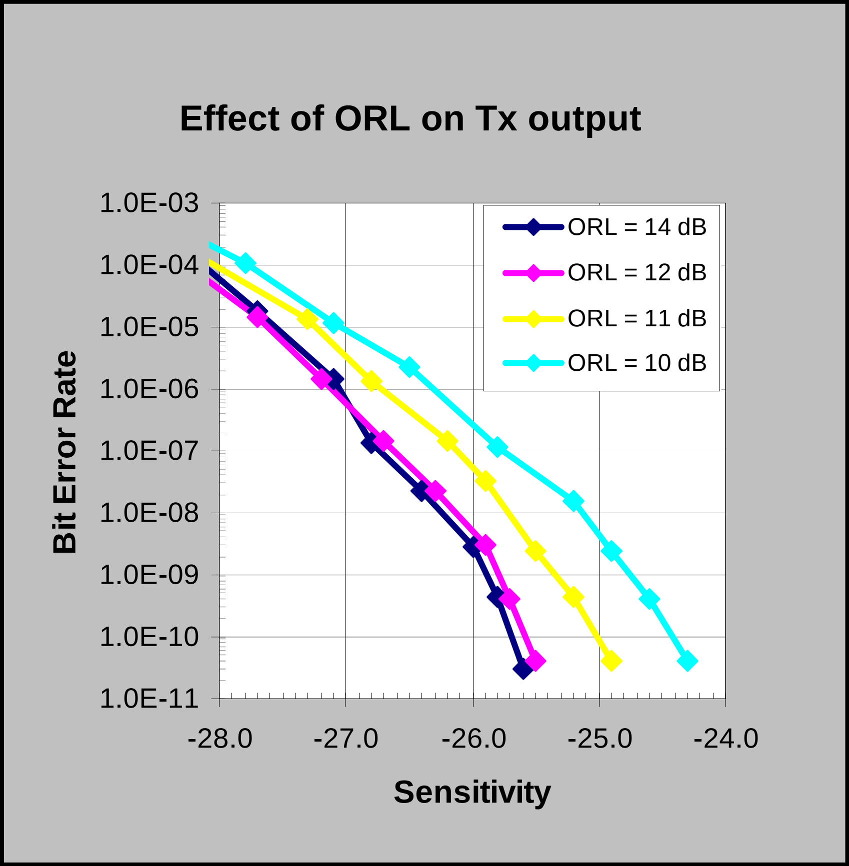
    –23 dBm (model predicts –23.5 dBm; 0.5dB loss due to electrical cross-talk?)
  - Introduce ODN reflection 21.4 ORL (-27.4dBm)
  - Sensitivity measured –22dBm (model predicts–22 dBm)
- Test 2
  - Signal –18dBm; Sensitivity –22.8dBm
  - Reflection to cause 1E-12 BER   –22.7dBm
  - Signal/Reflection 4.7dB both predicted and measured
- Theoretical predictions are accurate and reliable!

Rx Sensitivity –
Self Tx signal interference with remote signal due to ORL



Lowest sensitivity SFP in-house

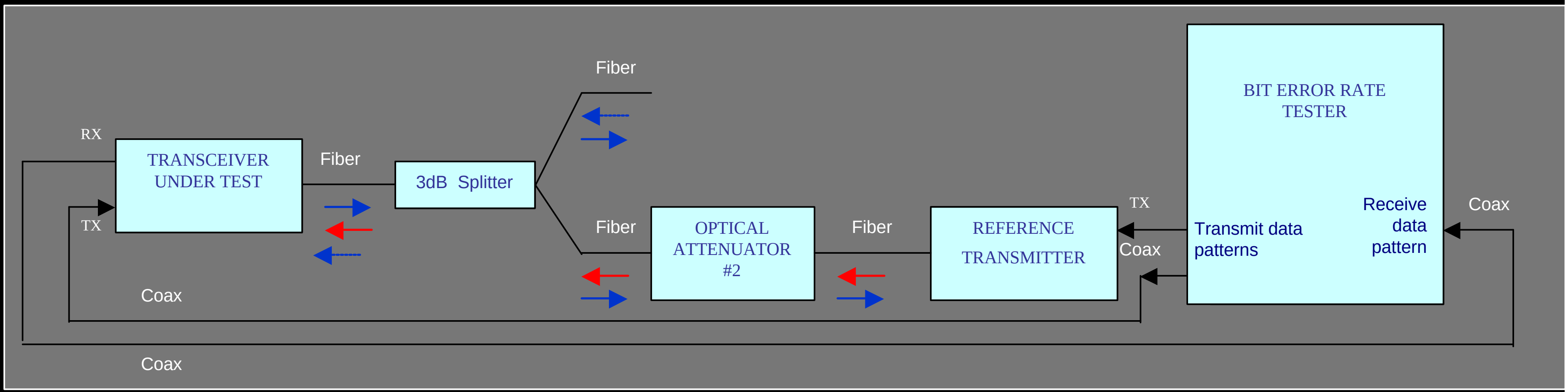
Tx output –
Self Tx signal interference – results in higher RIN and degrades Rx sensitivity



- Non – issue for FP lasers. Current 1000Base-LX specifications are or 12 dB ORL.

Demonstration

- Utilize 3 dB splitter with un-terminated connection.
- Total ORL = ~ 21dB
- This setup tests both effects (on the receiver when "weak" remote signal arrives AND on the transmitter effective RIN)



Summary

- Single wavelength link with maximum ORL of the ODN –20 dB is easily achievable with FP lasers
- ODN reflections sensitivity – is much more acute problem for DFB (even for dual wavelength solution) and VCSEL (data required)

VCSEL sensitivity to reflections

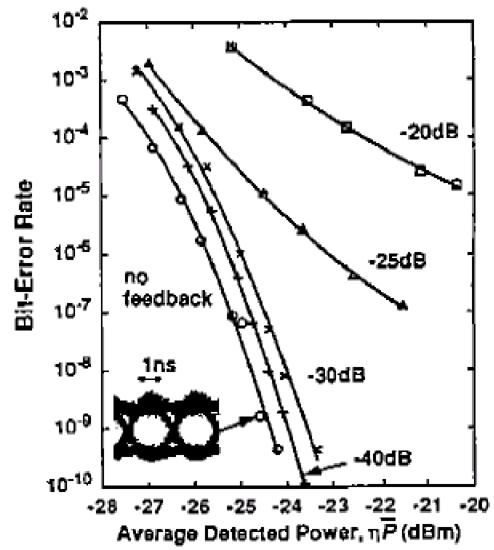


Figure 5.13 Experimentally measured BER at 500 Mb/s for a VCSEL under optical feedback. The BER is measured at several feedback levels. (After Ref. [131]. ©1993 IEEE. Reprinted with permission.)

[131] K.-P. Ho, J. D. Walker, and J. M. Kahn, *IEEE Photon. Technol. Lett.* **5**, 892 (1993).

Figure 5.13 shows the results of the BER measurements for a VCSEL operating at 958 nm. Such a laser operates in a single longitudinal mode because of an ultrashort cavity length ($\sim 1\ \mu$m) and exhibits a RIN near -130 dB/Hz in the absence of reflection feedback. However, the RIN increases by as much as 20 dB when the feedback exceeds the -30-dB level. The BER measurements at a bit rate of 500 Mb/s show a power penalty of 0.8 dB at a BER of 10^{-9} for -30-dB feedback, and the penalty increases rapidly at higher feedback levels [131].

SFWG - Single Fiber Single Wavelength GbE
Theoretical treatment Appendix

- Vipul paper "*Cross-Talk in Bi-Di Single Wavelength Single fiber GbE*" Demonstrated feasibility

http://grouper.ieee.org/groups/802/3/efm/public/jul01/presentations/bhatt_1_0701.pdf

- Reflections - Link "Engineering" issues
- Test methodology examples
- Results

Link “Engineering” – Vipul’s model adaptation

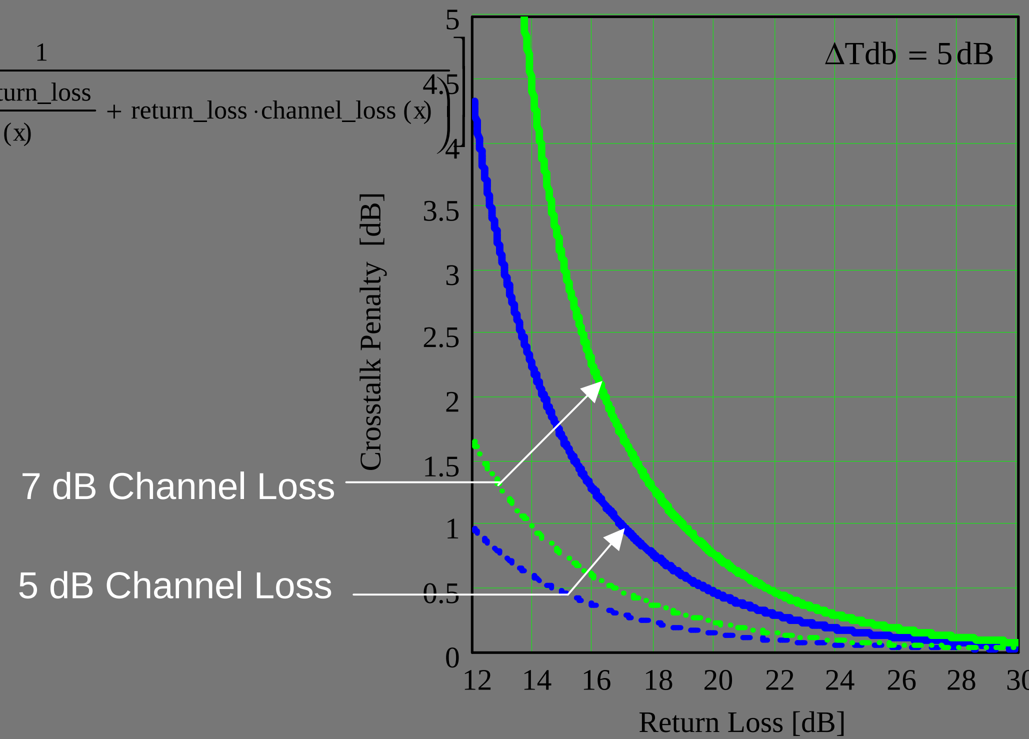
Design Recommendations

Modify the receiver design to add an offset to the receiver threshold. Keep the return loss of transceiver-cable interface to at least 5 dB higher than the total channel insertion loss, so as to keep the Crosstalk Penalty to well under 2 dB.

- Include Transmitter power range (e.g. 5 dB)
- Include worst case reflections condition (short link with minimal losses)
- Treat two distinct parameters:
  - Transceiver ORL
  - ODN ORL

Effect of 5 dB P transmit power range ($P_{max} – P_{min}$)

$$\text{Xtalk\_Penalty1}(x) := 10\cdot\log\left[\frac{1}{1-(1+\Delta T)\cdot\left(\frac{\text{XTALK}+\text{ODNreturn\_loss}}{\text{channel\_loss}(x)}+\text{return\_loss}\cdot\text{channel\_loss}(x)\right)}\right]$$



ODN ORL – Open end

- Worst Case (un-intended loopback):
  - All lumped at the interface (no link loss)
  - Open Fiber yields –14dB reflection
  - High power Tx (P_{max})

  SD - Signal Detect (assert) = LOS – Loss Of Signal (de-assert)
- Attenuation Link budget (10km) - 7dB
- Min power received P_{min} – 7dB
- SD should be set < P_{min} – 7dB
- Max reflection P_{max} – 14dB
- SD should be set > P_{max} – 14dB

$$P_{max} - 14dB < SD < P_{min} - 7dB$$

Setting at the Tx SD during mfg. will guarantee no un-intended loopback

ORL total

- To enable simple installation worst case reflections (for connected link) should not assert SD
- SD_{assert} = Pmin - $Channel\_Loss_{max}$ – XdB
- SD_{assert} > $Reflection_{worst\ case}$
- $Reflection_{worst\ case}$ = Pmax * (10^-.1*ODN_ORL + 10^-.1* ORL)

- Example
  - Pmin = - 9dBm; $Channel\_Loss_{max}$= 7dB; Pmax = - 4 dBm
  - ODN_ORL = 20dB ; ORL = 17 dB (- total ORL = 15.2 dB)
- *Since total ORL < Open Connector ORL SD issues are not relevant.*

Sensitivity under reflection is treated next.

Transceiver ORL

- Worst case situation for 0 dB link insertion loss
- SIGNAL/Reflection = Pmin - (Pmax-ORL)
  - Pmax – Pmin = 5dB
  - For SIGNAL/Reflection = 10 dB requires ORL = 15 dB
- Vipul have shown that SIGNAL/Reflection = 5 dB at the far end results in penalty < 1.6 dB
- Our measurement shows 1dB penalty for SIGNAL/Reflection = 5.4 dB
- ***CONCLUSION: ORL of 17dB has plenty of margin***