100GBASE-DR Link Budget Considerations

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Background and Motivation

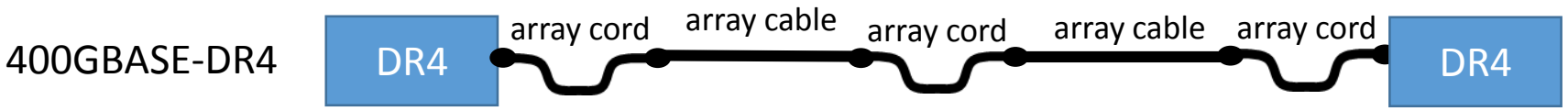
- One of IEEE 802.3cd objectives is to *'define a single lane 100 Gb/s PHY for operation over duplex SMF with lengths up to at least 500 m, consistent with IEEE P802.3bs Clause 124'* (400GBASE-DR4).
- In the adopted 100GBASE-DR baseline of traverso_3cd_03a_0916, it was stated: "with penalties consistent with a channel allowing up to 4 discrete reflectances of -35 dB" – This means an additional ~0.2 dB MPI penalty needs to be included in the link budget.
- No consensus has been reached as how to split this 0.2 dB between Tx and Rx.

- As the additional MPI penalty is primarily due to the high reflectance LC connectors in 100GBASE-DR links, which also have lower insertion loss, high MPI penalty and high link loss do not occur at the same time.
- In this presentation, we propose to use the total of link loss and MPI penalty for 100GBASE-DR link budget (vs. considering them separately) and show this would support more link usage cases with the same total budget as 400GBASE-DR4.

Methodologies Used in This Analysis

1) Show conforming link topologies comparing with 3.0 dB link loss.
   - Referencing kolesar_3bs_01_0514 for MPO/LC loss statistics and model
     - Assume MPO mean loss = 0.35 dB (stdev = 0.25 dB), and
       LC mean loss = 0.2 dB (stdev = 0.15 dB).
   - Referencing anslow_03_1107.xls for SMF attenuation
   - Highlighting breakout topologies for information.
2) Calculate MPI penalties for link topologies in (1)
   - Referencing king_01a_0116_smf for MPI calculation
   - Highlighting breakout topologies for information
   - Show link topologies that are narrowly omitted by 3.1 dB budget

400GBASE-DR4 Reference



500m Double link with 4 MPO connectors

Connector Losses =2.65 dB,
Fiber loss = 0.25dB,

-> Link Loss =2.9dB (rounded to 3dB)

MPI Penalty = 0.1 dB
Agreed Budget = 3.1 dB

500m Link Loss & MPI Penalties vs. # of LC/MPO Connectors

Link Loss	0 MPO	1 MPO	2 MPO	3 MPO	4 MPO	5 MPO
0 LC	0.25	1.23	1.83	2.38	**2.9**	3.4
1 LC	0.83	1.53	2.11	2.65	3.16	n.c.
2 LC	1.18	1.82	2.38	2.91	3.41	n.c.
3 LC	1.5	2.1	2.65	3.16	n.c.	n.c.
4 LC	1.8	2.38	2.91	3.42	3.91	n.c.
5 LC	2.09	2.65	3.17	n.c.	n.c.	n.c.
6 LC	2.37	2.91	3.42	n.c.	n.c.	n.c.
7 LC	2.64	3.17	n.c.	n.c.	n.c.	n.c.
8 LC	2.91	n.c.	n.c.	n.c.	n.c.	n.c.

Green cells = Margins w/respect 3.0 dB link loss

Yellow cells = Less than 0.2dB margin w/respect 3.0dB Link loss

Orange cells = Not supported by 3.0dB link loss

Blue = 400GBASE-DR4 link loss

Red = considered main topology for 100GBASE-DR double link

MPI penalty	0 MPO	1 MPO	2 MPO	3 MPO	4 MPO	5 MPO
0 LC	n.c.	n.c.	n.c.	n.c.	**0.1**	n.c.
1 LC	n.c.	n.c.	n.c.	0.07	0.06	n.c.
2 LC	n.c.	n.c.	0.13	0.11	0.12	n.c.
3 LC	n.c.	0.2	0.19	0.18	n.c.	n.c.
4 LC	n.c.	0.33	0.26	n.c.	n.c.	n.c.
5 LC	n.c.	0.36	0.35	n.c.	n.c.	n.c.
6 LC	0.55	0.43	n.c.	n.c.	n.c.	n.c.
7 LC	0.55	n.c.	n.c.	n.c.	n.c.	n.c.
8 LC	0.55	n.c.	n.c.	n.c.	n.c.	n.c.

Green cells = MPI penalty < 0.3dB

Orange cells = MPI penalty > 0.3dB

Blue = 400GBASE-DR4 agreed MPI penalty (calculated is < 0.1dB)

- High link loss and high MPI penalty not always occur at the same time.

Independent Link Loss & MPI Penalty vs. Total Budget

3.3 dB Total Budget (3 dB Loss + 0.3 dB MPI Penalty)

Loss only	0 MPO	1 MPO	2 MPO	3 MPO	4 MPO
0 LC	-	-	n.c.	n.c.	2.90
1 LC	-	n.c.	n.c.	2.65	3.16
2 LC	n.c.	n.c.	2.38	2.91	3.41
3 LC	n.c.	2.10	2.65	3.16	n.c.
4 LC	1.80	2.38	2.91	n.c.	n.c.
5 LC	2.09	2.65	3.17	n.c.	n.c.
6 LC	2.37	2.91	n.c.	n.c.	n.c.
7 LC	2.64	3.17	n.c.	n.c.	n.c.
8 LC	2.91	n.c.	n.c.	n.c.	n.c.

Green Cells: Meet both 3dB link loss and 0.3dB MPI Penalty

Orange cells: OK with 3dB link loss but MPI penalty > 0.3 dB

3.1 dB Total Budget

Loss+MPI	0 MPO	1 MPO	2 MPO	3 MPO	4 MPO
0 LC	-	-	n.c.	n.c.	3.00
1 LC	-	n.c.	n.c.	2.72	3.16
2 LC	n.c.	n.c.	2.51	3.02	3.41
3 LC	n.c.	2.30	2.84	3.34	n.c.
4 LC	n.c.	2.71	3.17	n.c.	n.c.
5 LC	n.c.	3.01	3.52	n.c.	n.c.
6 LC	2.92	3.34	n.c.	n.c.	n.c.
7 LC	3.19	n.c.	n.c.	n.c.	n.c.
8 LC	n.c.	n.c.	n.c.	n.c.	n.c.

Green Cells: Meeting 3.1 dB total budget

Yellow Cells: Can be covered with an extra 0.2 dB

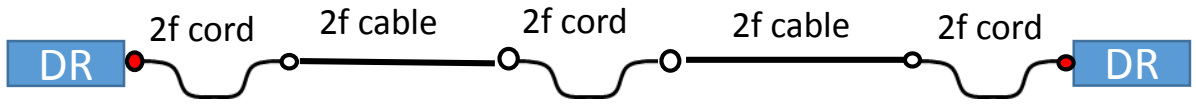
But 2 cases are for DR4-DR only

- Consistent with previous methods
- Less usage case covered
- Different optical specs for DR (4xDR) and DR4

- Consider the total budget of (loss + MPI penalty)
- More usage case covered
- Same optical specs for DR, DR4 (4xDR)

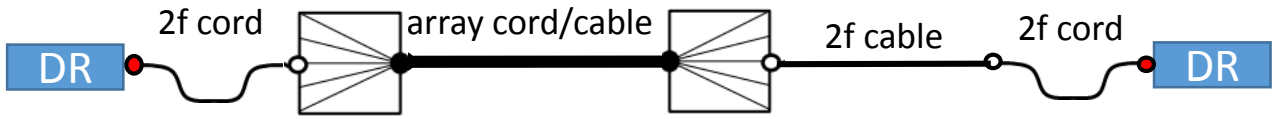
DR – DR 500m Usage Cases Covered by 3 dB Link Loss

A



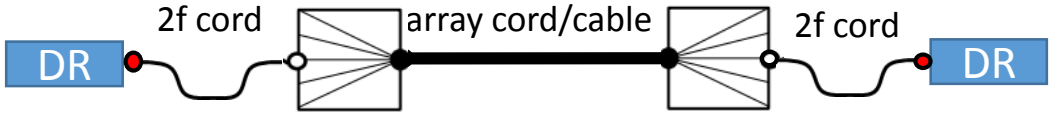
4 LCs
Link Loss = 1.8 dB

C



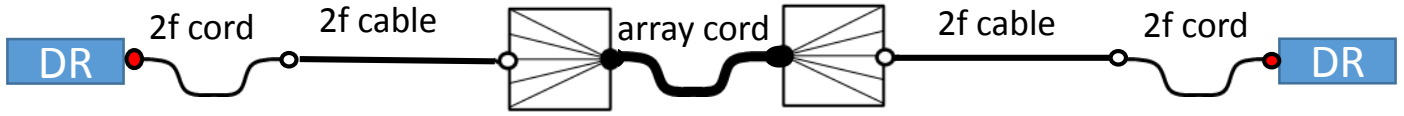
2 MPOs + 3 LCs MPI Penalty = 0.19 dB
Link Loss = 2.65 dB

D



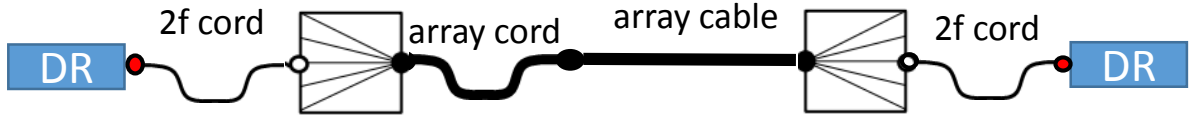
2 MPOs + 2 LCs MPI Penalty = 0.13 dB
Link Loss = 2.38 dB

K



2 MPOs + 4 LCs MPI Penalty = 0.26 dB
Link Loss = 2.91 dB

M

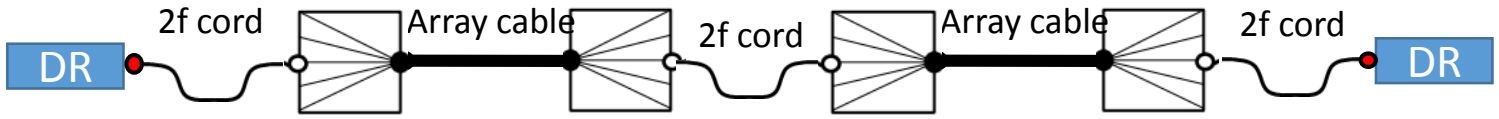


3 MPOs + 2 LCs MPI Penalty = 0.11 dB
Loss = 2.91 dB

Cases K = Narrowly missed 3.1 dB total budget

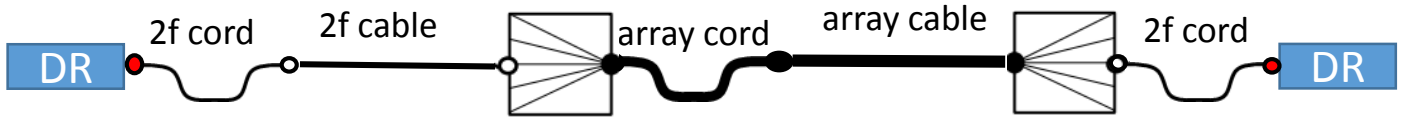
DR-DR 500m Links Excluded by 3.0 dB Budget

B



4 MPOs + 4 LCs
Link Loss = 3.91 dB

L



3 MPOs + 3 LCs
Link Loss = 3.16 dB

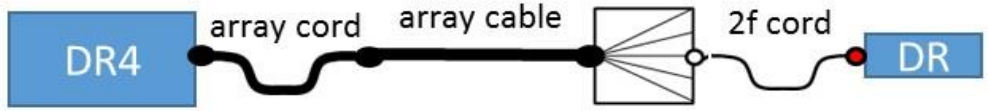
N

4 MPOs + 2 LCs
Link Loss = 3.41 dB

Case B was discussed to be one of the most representative topologies, but can't be considered in 100BASE-DR links due to its high loss

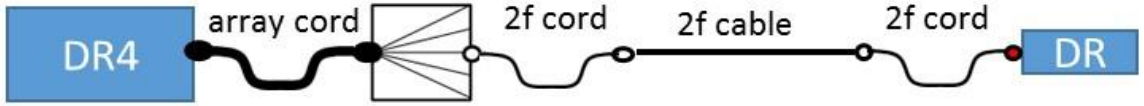
Informative: DR4 (4xDR) Breakout to 100GBASE-DR

E



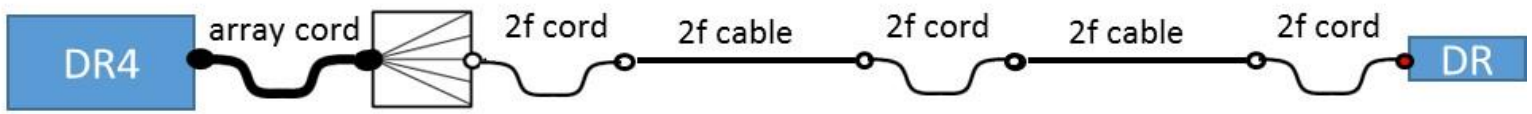
2 MPOs + 1 LCs
Link Loss = 2.11 dB

F



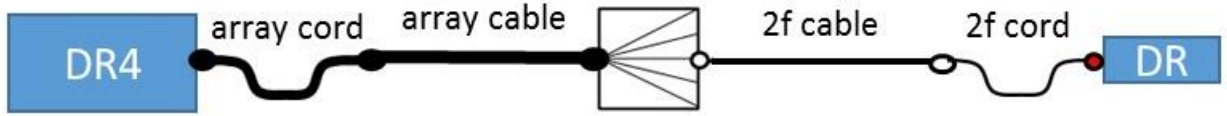
1 MPOs + 3 LCs
Link Loss = 2.1 dB
MPI Penalty = 0.2 dB

H



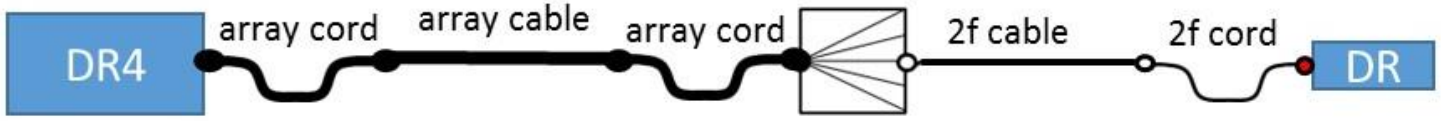
1 MPOs + 5 LCs
Link Loss = 2.65 dB
MPI Penalty = 0.36 dB

J



2 MPOs + 2 LCs
Link Loss = 2.38 dB
MPI Penalty = 0.13 dB

I



3 MPOs + 2 LCs
Loss = 2.91 dB
MPI Penalty = 0.11 dB

All breakout usage cases are covered by 3.1 dB link loss + MPI Penalty

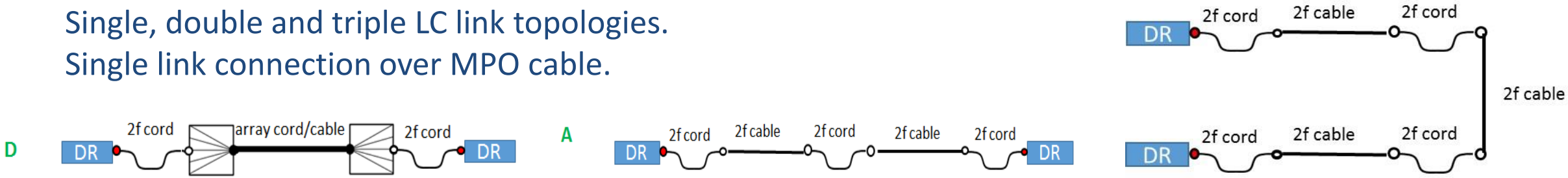
Main Link Topologies Supported by 3.1 dB Total Budget

Assuming 3.1dB total budget for 100GBASE-DR, we can include below topologies:

100GBASE-DR over 100GBASE-DR

Single, double and triple LC link topologies.

Single link connection over MPO cable.



Breakout: 4x100G-DR (DR4-like) over 100GBASE-DR

Single, double links connection for most representative break-out cases.

100GBASE-DR (4xDR) optical interface specifications identical to 400GBASE-DR4 specifications

Summary

- Proposed to use the total of link loss and MPI penalty in 100GBASE-DR link budget consideration, which would support more usage cases

- Increasing the link budget by another 0.2 dB (to account for the additional MPI penalty) only gives limited additional benefits in usage case.

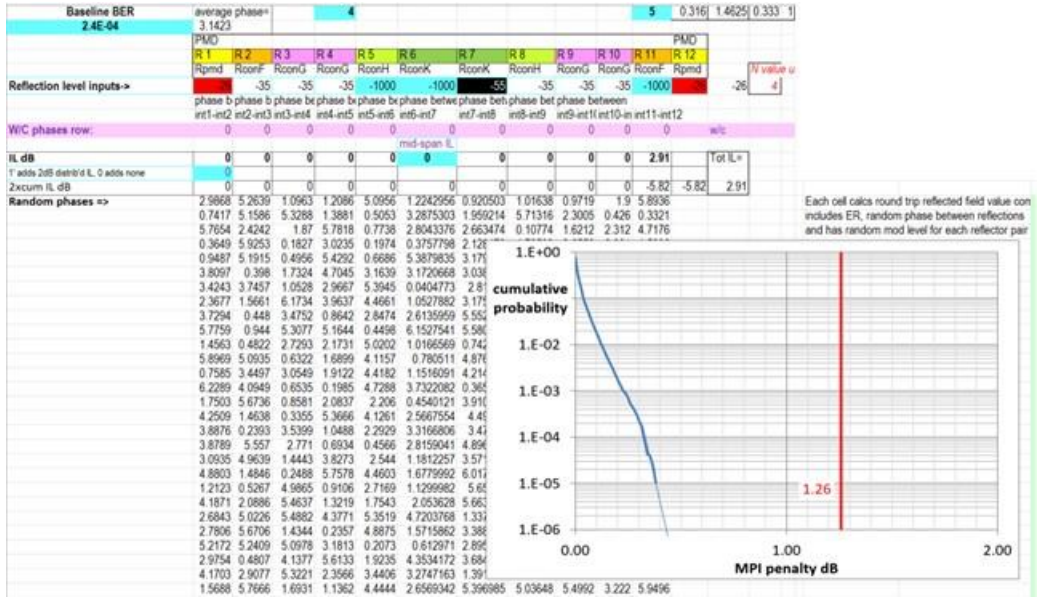
- Recommend to keep the Tx OMA(min) and Rx sensitivity specs unchanged from 400GBASE-DR4 specifications.

Issues to be considered

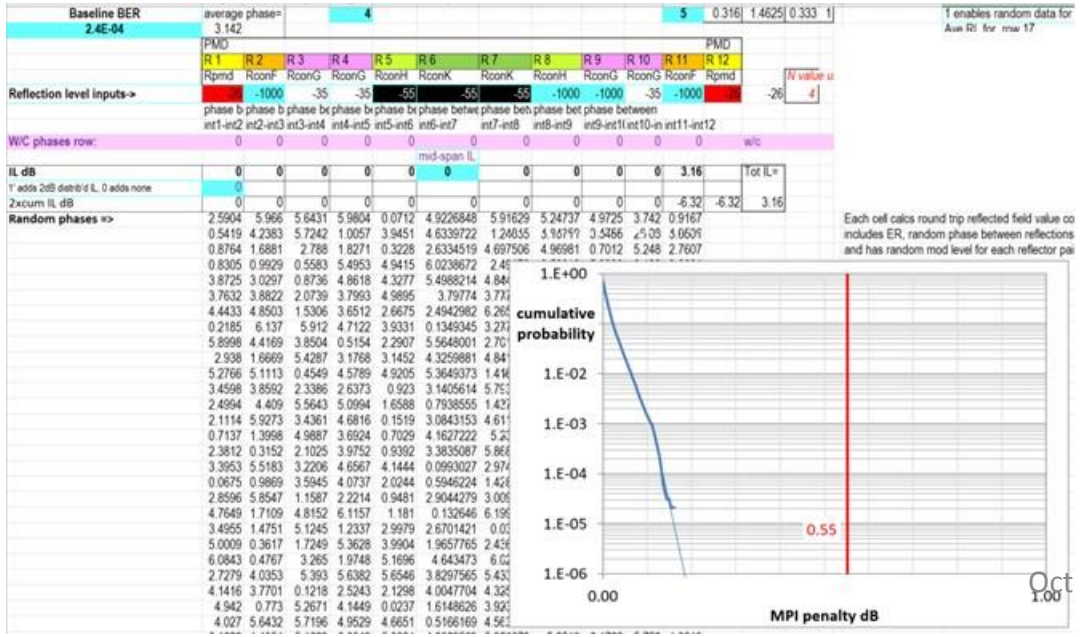
- Specifications for reflection tolerance, RIN, Optical Return loss, etc.

Back-Up

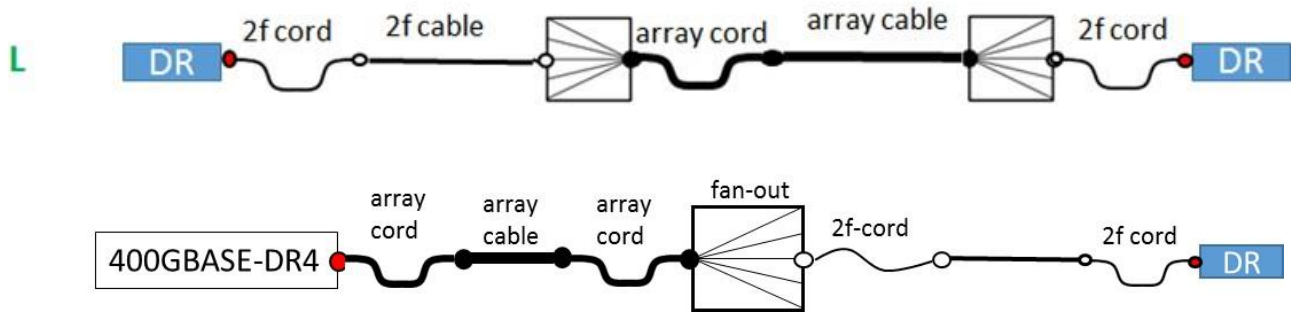
Applicable 100GBASE-DR topologies assuming 3.3dB budget (with MPI penalty).



6LC, 1MPO -> 0.43dB MPI penalti, budget of 3.34dB

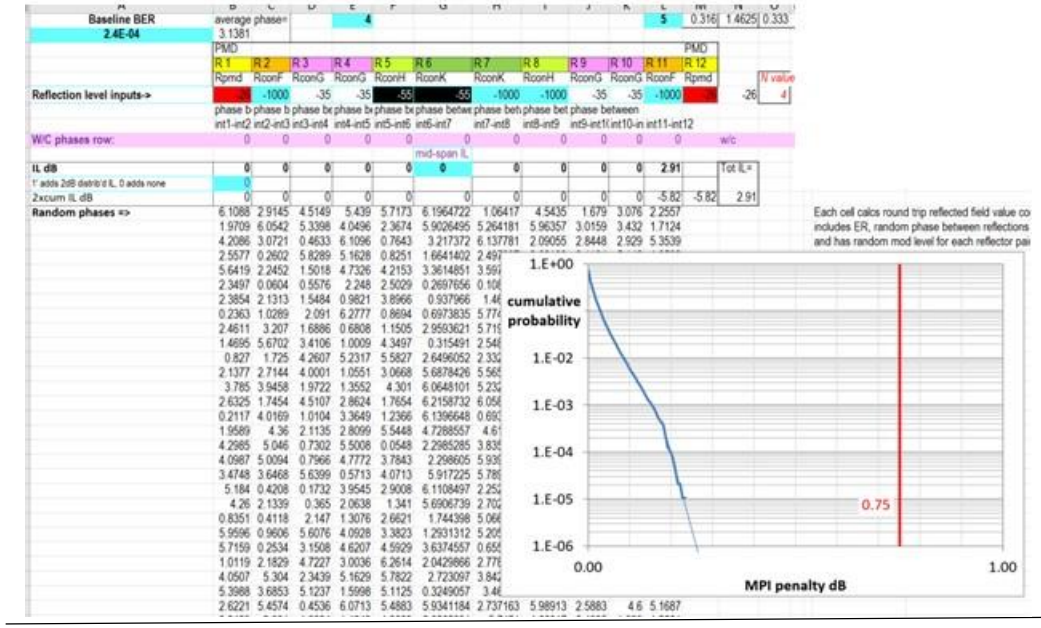


Case L-DL (3LC, 3MPO) -> 0.18dB MPI penalty, budget of 3.34dB



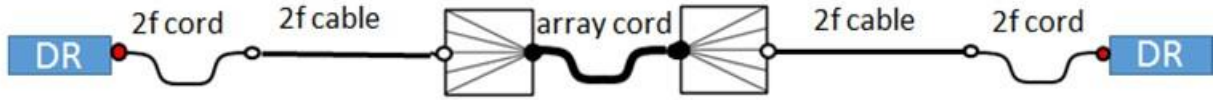
Note that to support the break-out, the 100GBASE-DR specs should be specified to go beyond 3.34dB budget.

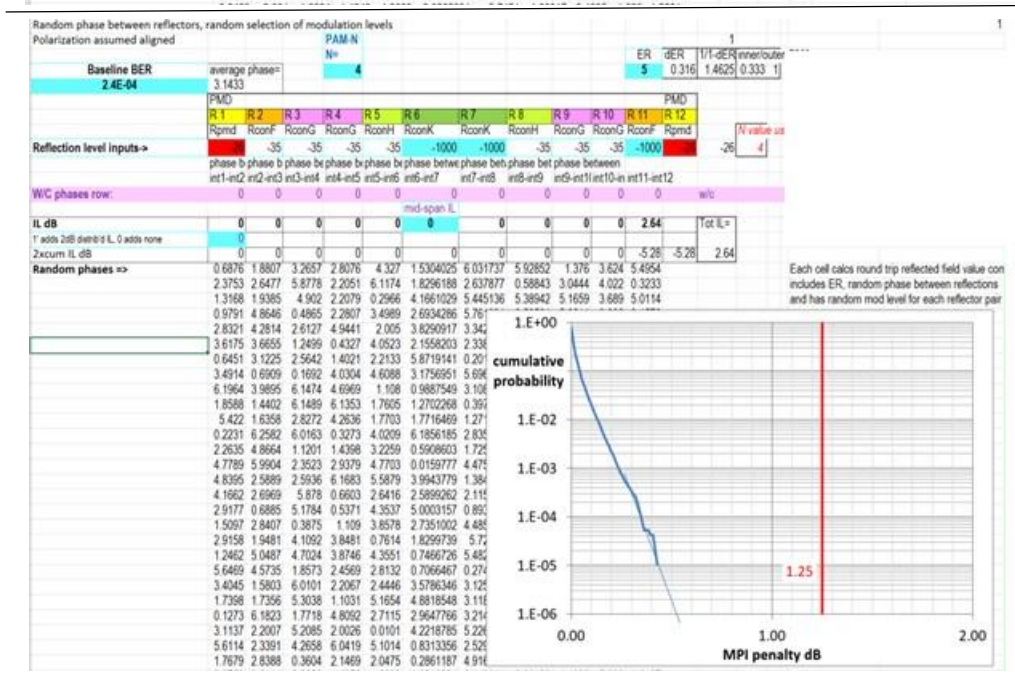
Applicable 100GBASE-DR/breakout topologies with 3.2dB budget (with MPI penalty).



Case K-DL (4LC, 2MPO) -> 0.26dB MPI penalty, budget of 3.17dB

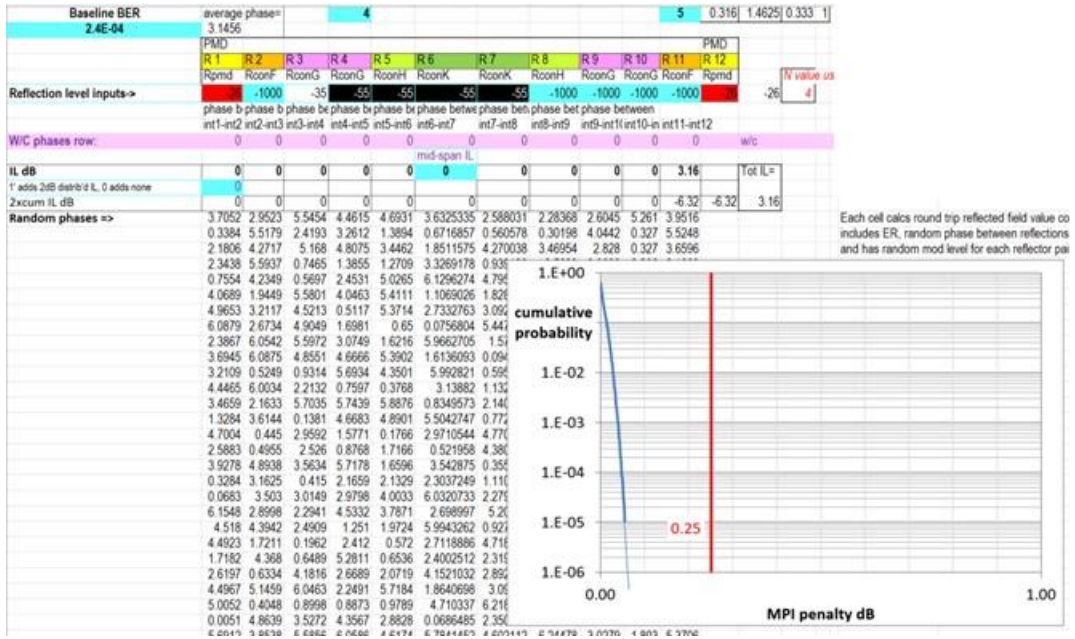
K



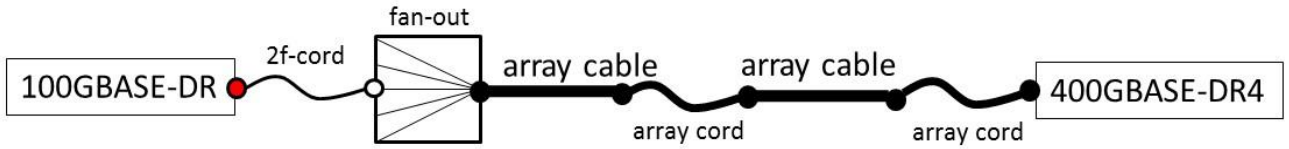


7LC -> 0.55dB MPI penalty, budget of 3.19dB

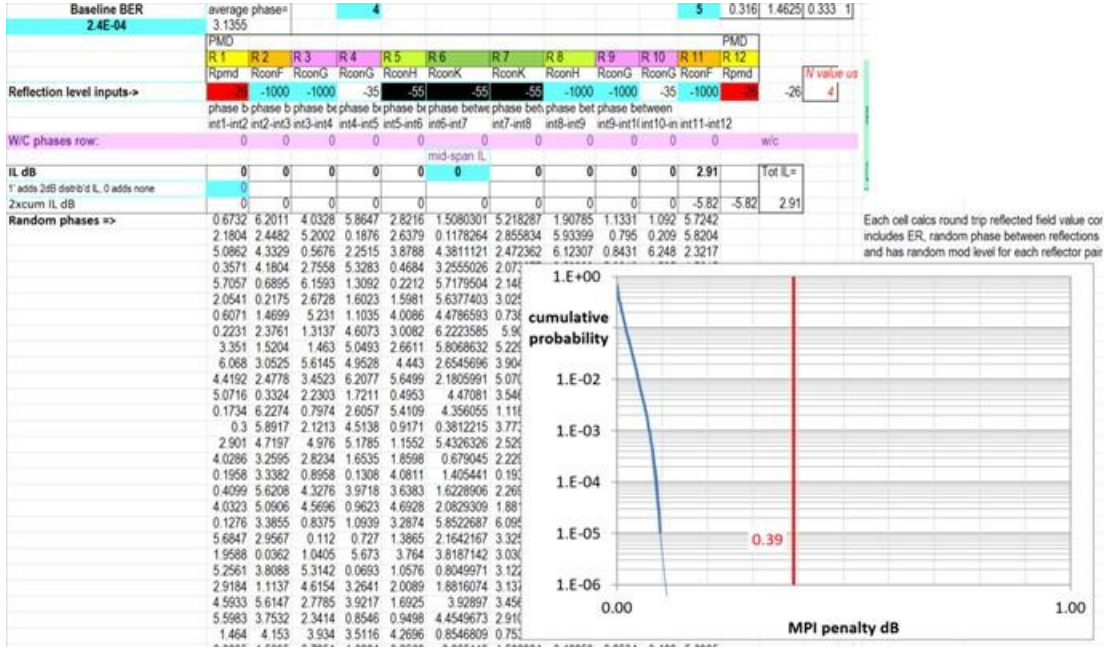
Applicable 100GBASE-DR/breakout topologies with 3.2dB budget (with MPI penalty).



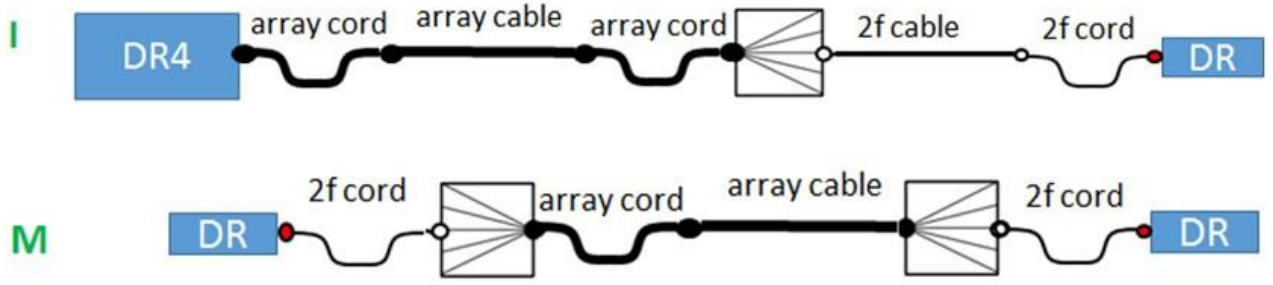
1LC, 4MPO -> 0.06dB MPI penalty, budget of 3.22dB

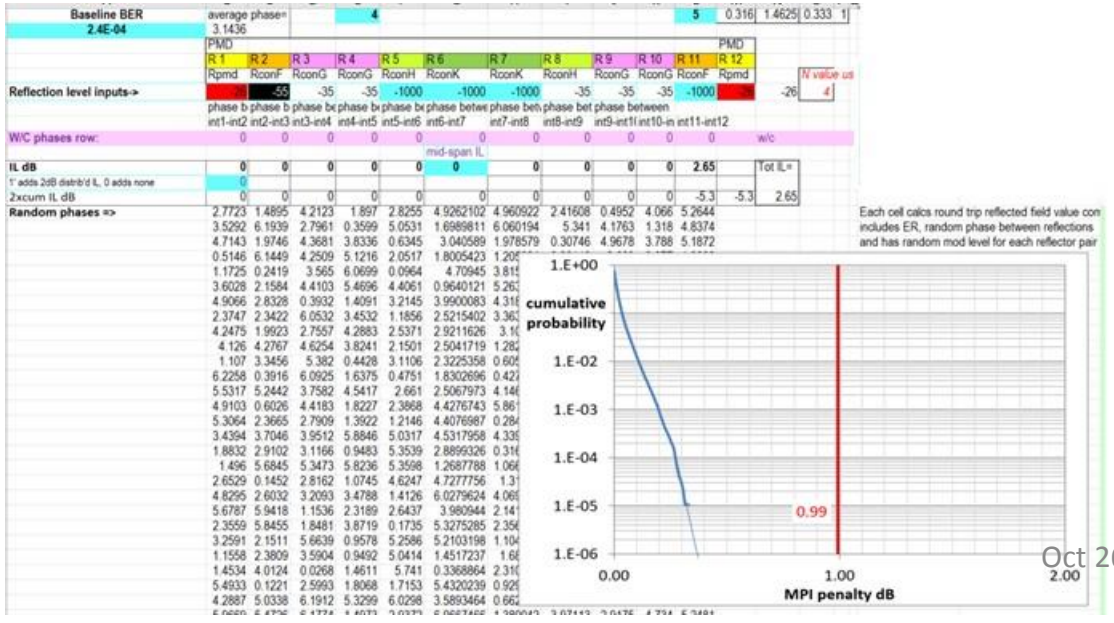


Applicable 100GBASE-DR/breakout topologies with 3.1dB budget (with MPI penalty).

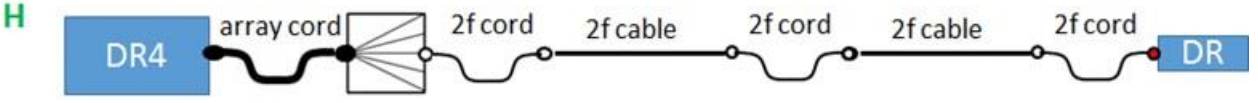


Case M-SL, I-DL (2LC, 3MPO) -> 0.11dB MPI penalty, budget of 3.02dB

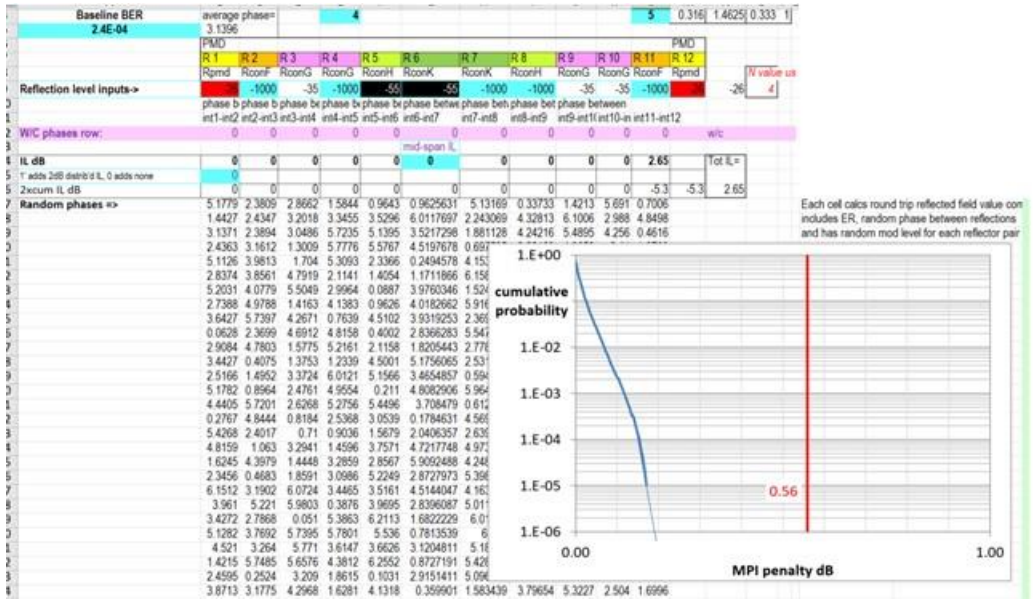




Case H-DL (5LC, 1MPO) -> 0.36dB MPI penalty, budget of 3.01dB

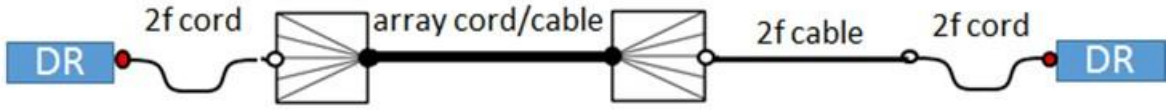


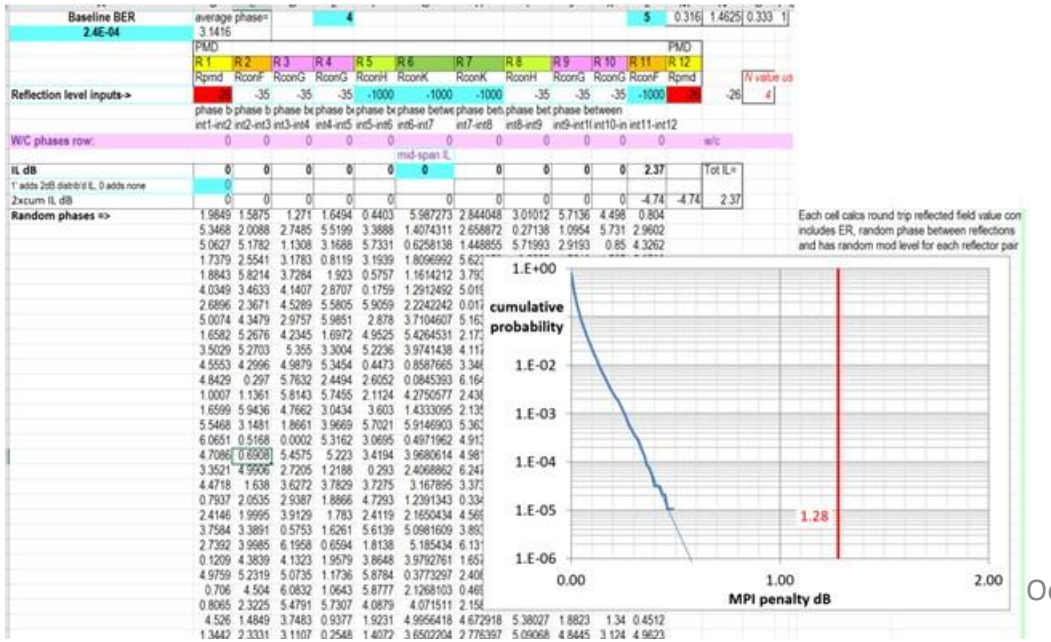
Applicable 100GBASE-DR/breakout topologies with 3.1dB budget (with MPI penalty).



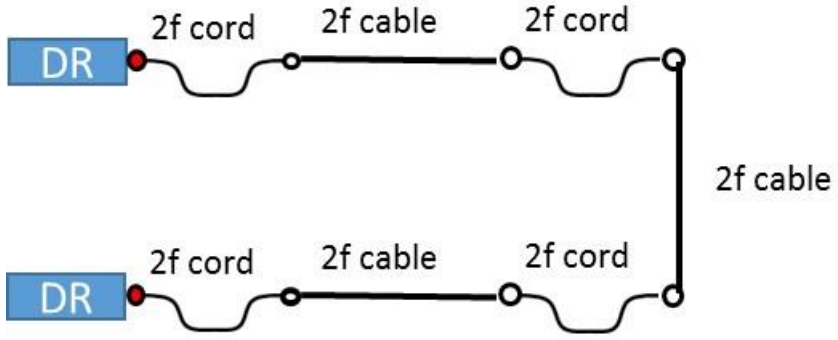
Case C-SL (3LC, 2MPO) -> 0.19dB MPI penalty, budget of 2.84dB

C

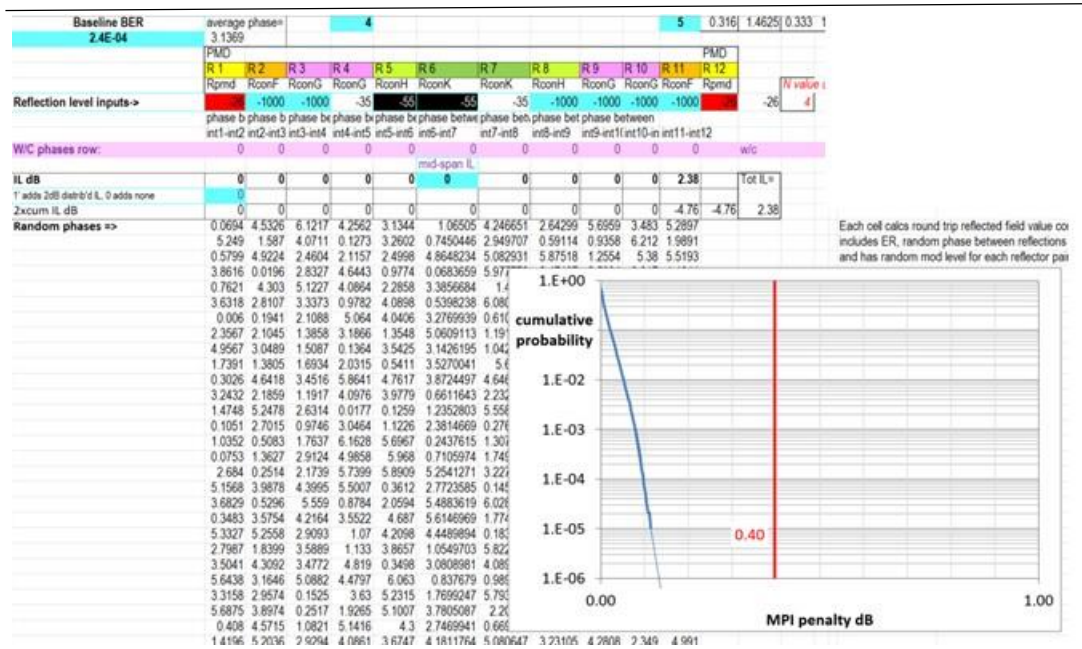




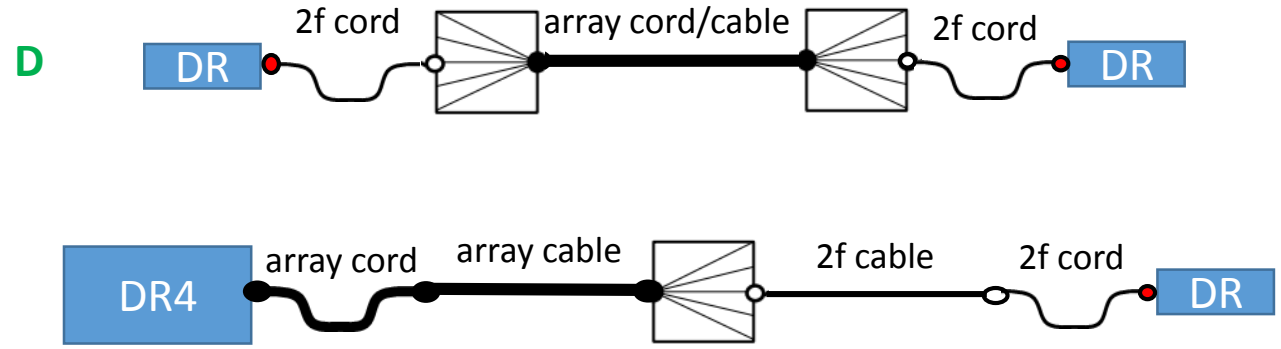
6LC -> 0.55dB MPI penalty, budget of 2.92dB

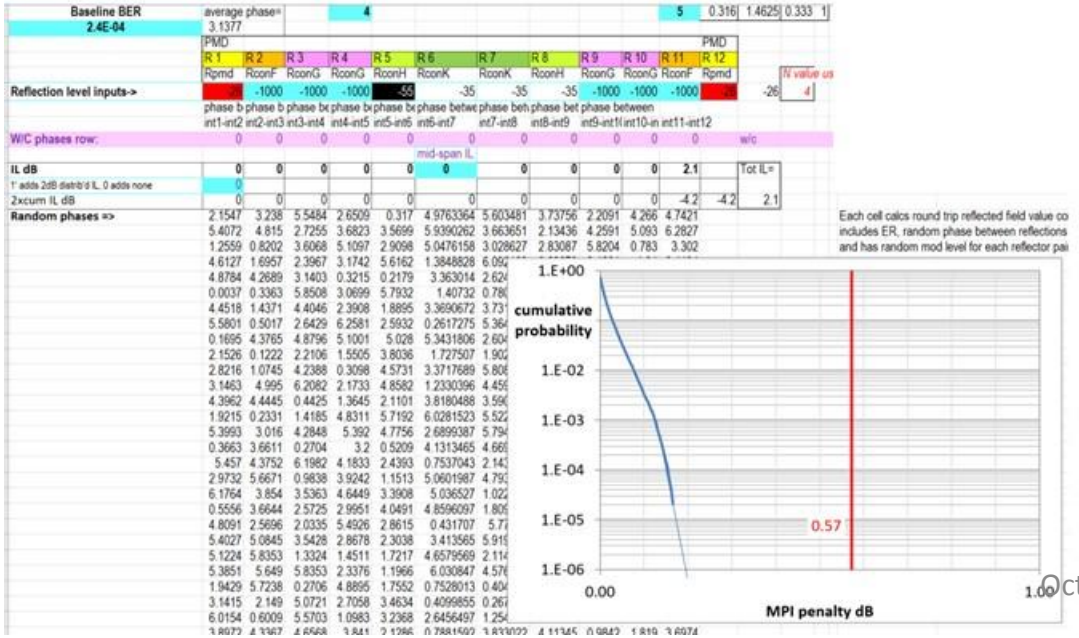


Applicable 100GBASE-DR/breakout topologies with 3.1dB budget (with MPI penalty).

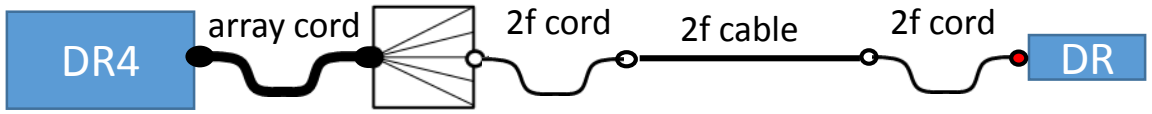


Case D-SL, J-DL (2LC, 2MPO) -> 0.13dB MPI penalty, budget of 2.51dB

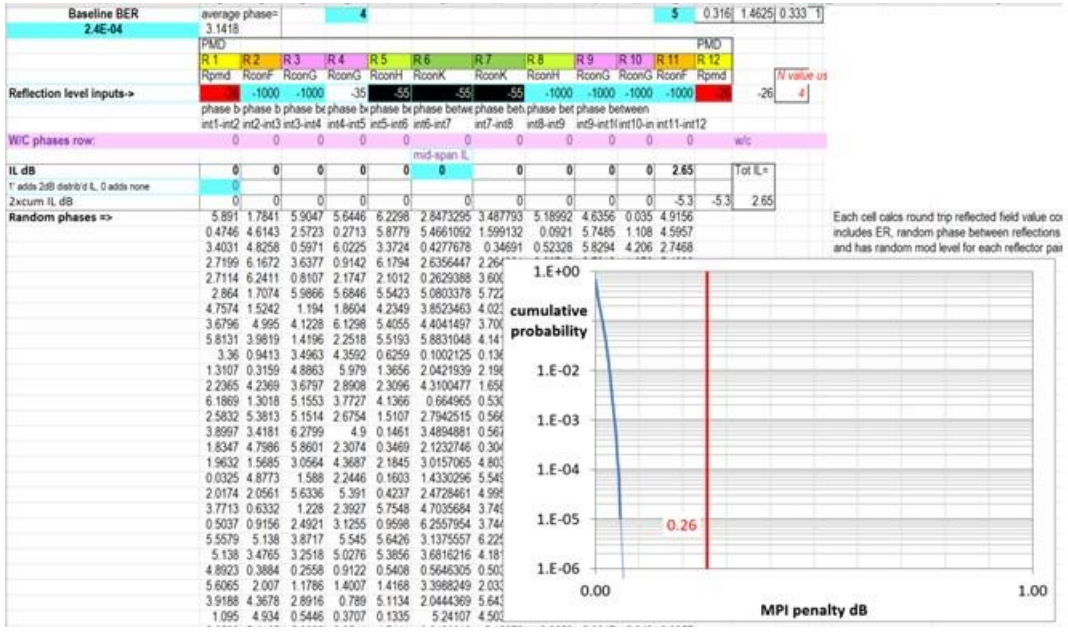




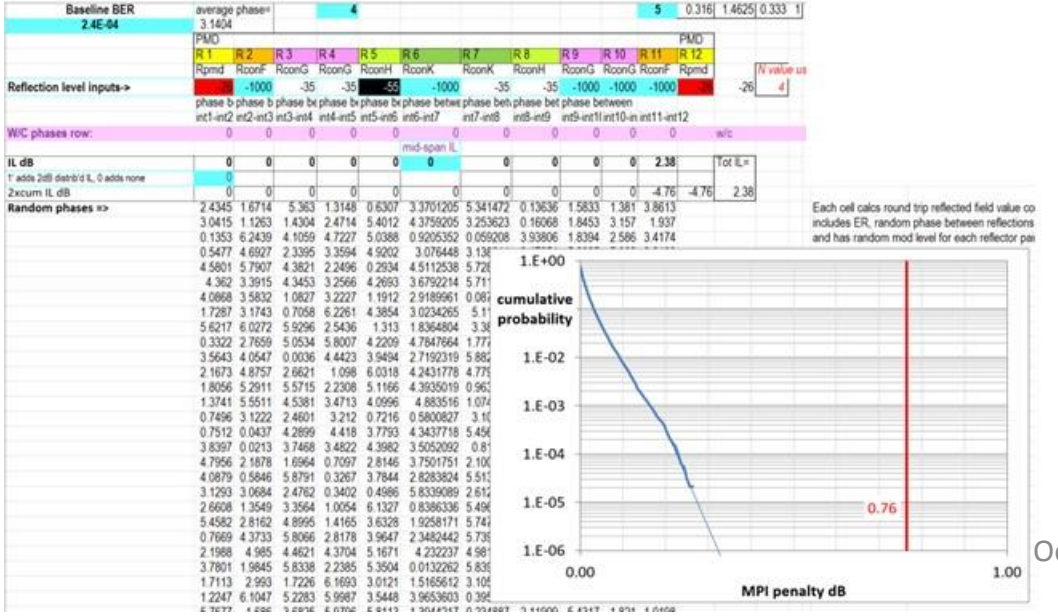
Case F-SL (3LC, 1MPO) -> 0.2dB MPI penalty, budget of 2.3dB



Applicable 100GBASE-DR/breakout topologies with 3.1dB budget (with MPI penalty).

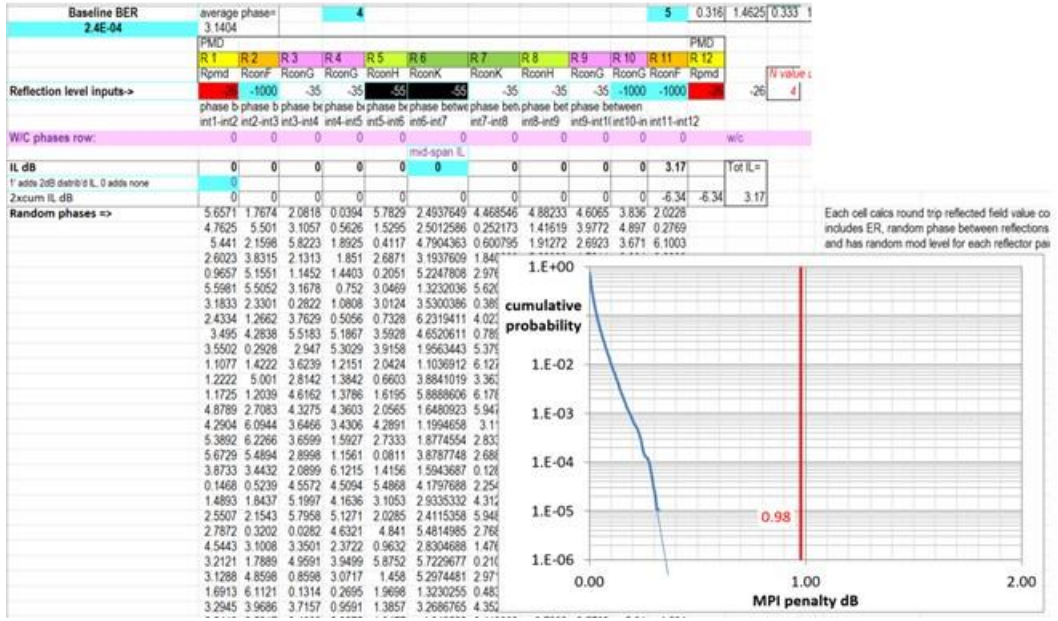


1LC, 3MPO -> 0.07dB MPI penalty, budget of 2.72dB

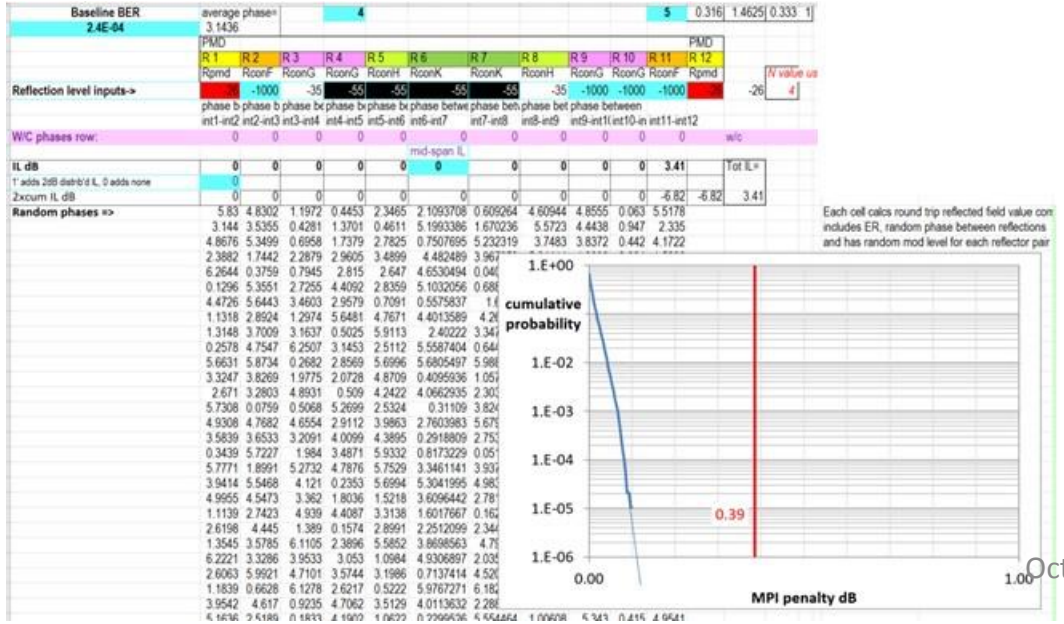


4LC, 1MPO -> 0.33dB MPI penalty, budget of 2.71dB

Applicable 100GBASE-DR/breakout topologies with 3.5dB budget (with MPI penalty).



5LC, 2MPO -> 0.35dB MPI penalty, budget of 3.52dB



Case N-DL (2LC, 4MPO) -> 0.12dB MPI penalty, budget of 3.53dB