Modal noise measurements relevant to 400G-SR4.2

Re: Comment IDs 1 and 7 against D1.2

Yi Sun (OFS), Earl Parsons (CommScope) and Robert Lingle Jr (OFS)

IEEE P802.3cm Vancouver, Canada, March 2019

Supports and their affiliation

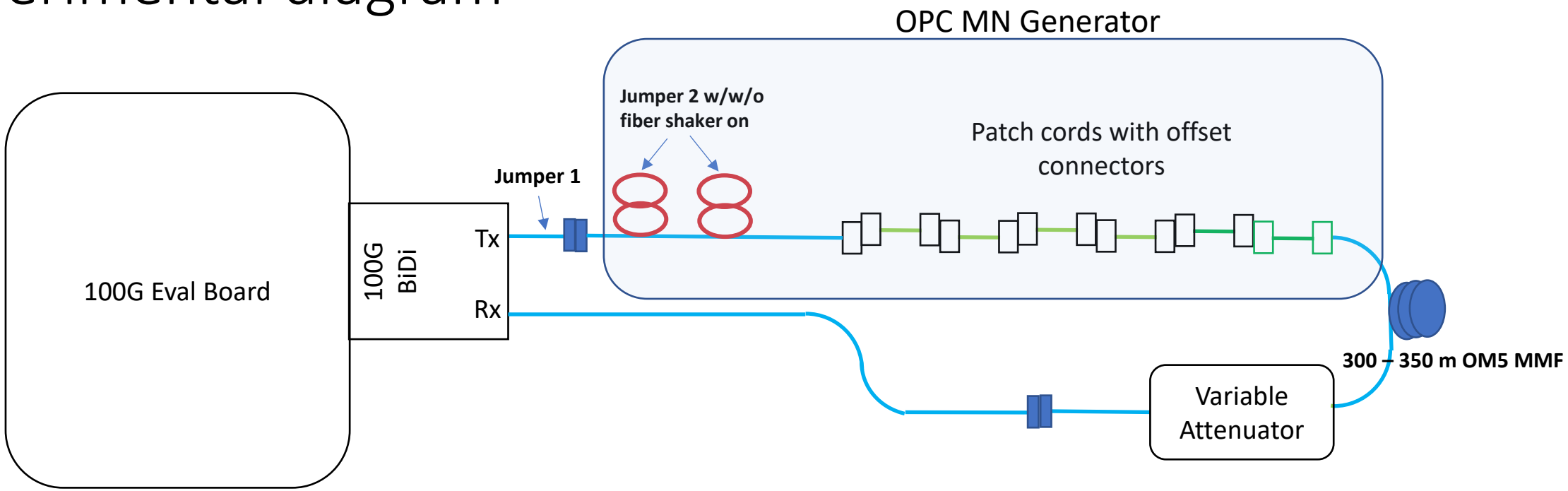
- Greg Le Cheminant Keysight Technologies

Overview

- The purpose of this study is to measure penalties due to modal noise, using real parts, in back-to-back (BtB) and long length regimes
- Back-to-back (BtB) and transmission experiments carried out with offset jumpers and fiber shaker
- Two 100G BiDi transceivers used along with fiber near minimum OM5 compliance
- 300 to 350m fiber is used to create near-worst case eye closure as measured by SECQ, as well as create a σ_{rms}*CD*length product near worst-case
- Received power measurements are not better than ± 0.1 dB and perhaps higher
- Small power penalties from modal noise generation are observable at BER 1e-5 and 1e-6. But it is not obvious that penalties are beyond the measurement error at 2.4e-4, where they are generally smallest.
- These data show no evidence of “falling off a cliff” when modal noise is introduced with near worst-case eye closure.

Same as sun_3cm_01a_0119

Experimental diagram



Two 100G BiDi transceivers tested
Errors estimated by FEC decoder
Look at power penalty at 2.4e-4 BER
Received power is measured by the power detector built into Rx
Offset jumpers on slide 8-11:

- ***4 connections w/ 1.5 dB total EF insertion loss***
- ***2-6 µm offset per connection***
- ***~100 offset connectors were produced***
- ***4 provided large offsets***

Worst-case 850nm fiber had EMB of 4875 MHz-km, compared to 4700 MHz-km OM4 and OM5 spec limit

Lowest BW 910nm fiber had EMB of ~3900 MHz-km, compared to ~3100 MHz-km for OM5

Offset jumper on slide 12 courtesy of Jose Castro at Panduit. EF loss is 1.1 dB, recommended by Jose for use with other jumpers and shaker to sum up to near 1.5 dB

Longer fiber is used to mimic worst-case eye closure

	TX A		TX B	
Wavelength (nm)	857	906	857	907
RMS spectral width (nm)	0.3	0.34	0.29	0.37
Tx TDECQ (dB)	3.0	2.6	2.7	2.7
Tx SECQ (dB)	1.7	1.4	1.5	1.4
Tx SECQ 310 m w/ Offset Jumpers (dB)	3.9	4.6	3.8	4.4
Tx SECQ 360m w/ Offset Jumpers (dB)			4.3	

- The two 100G BiDi transceivers do not have worst-case TDECQ or spectral width
- However by using long fiber with low bandwidth, we can achieve SECQ values near 4.5 dB and test modal noise with near worst-case eye closure

TDECQ and SECQ results continued
(measurements requested at 2/28 ad hoc call)

	Tx A		Tx B	
Wavelength (nm)	857	906	857	907
Tx TDECQ (dB)	3.0	2.6	2.7	2.7
Tx SECQ (dB)	1.7	1.4	1.5	1.4
Tx SECQ w/ Offset Jumpers (dB)	1.8	1.4	1.6	1.5
Tx SECQ w/ Long Fiber	3.1	4.3	3.3	4.3
Tx SECQ w/ Long Fiber and Offset Jumpers (dB)	3.7	4.8	3.8	4.5
Tx SECQ w/ Long Fiber and Offset Jumpers (dB)	3.9	4.6	3.8	4.4
Tx SECQ w/ Long Fiber and Offset Jumpers and Shaker On (dB)	4.4	4.8	4.3	4.7

Long Fiber is 310 m except for Tx B at 850 nm where it is 360 m

Encircled flux results for each transmitter

	Tx A		Tx B		Standard
Wavelength (nm)	857	906	857	907	
Flux in					
4.5 µm (%)	9.2	11.9	8.7	14.4	< 30
19 µm (%)	95	95.8	91.7	95.3	> 86

Encircled flux standard for connectors

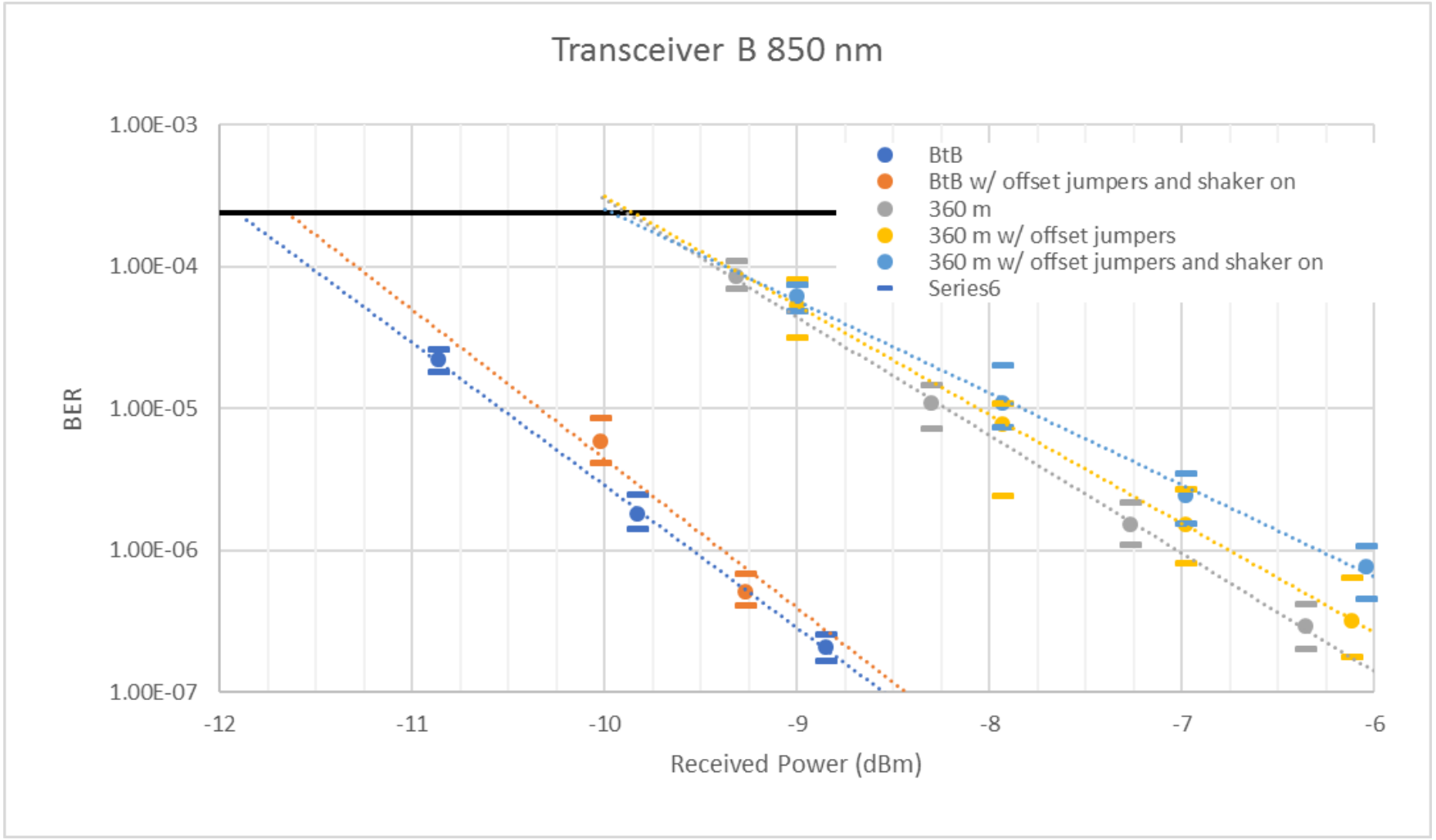
Flux in	IEC Standard
10 µm (%)	33.5
15 µm (%)	65.5
20 µm (%)	91.91
22 µm (%)	97.51

Offset jumpers and fiber shaker introduce at most 0.25 dB penalty, comparable to measurement repeatability

TDECQ = 3.0 dB
SECQ @ 310 m = 3.9 dB

Circles are average BER
Bars are max and min BER

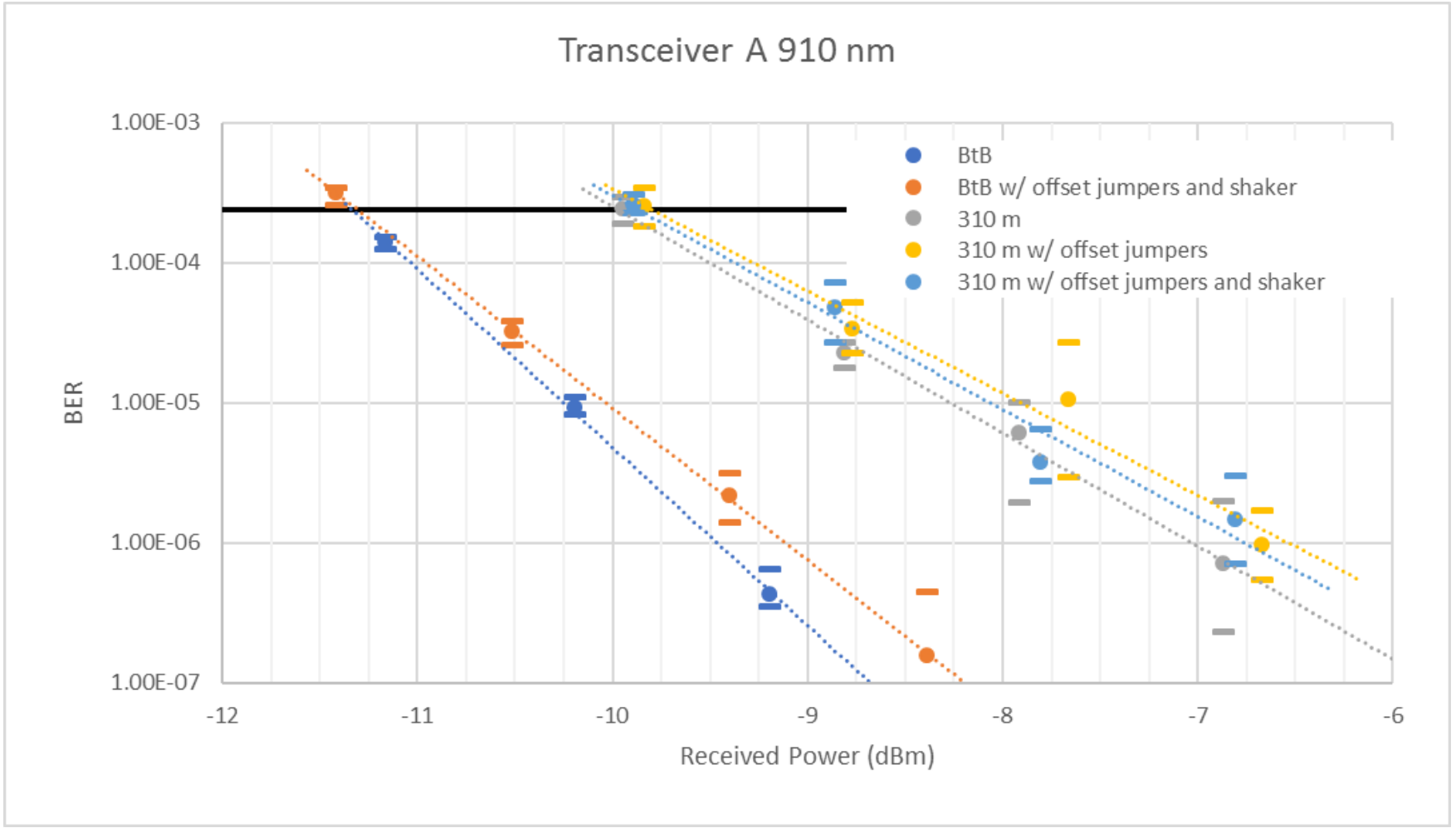
Offset jumpers and fiber shaker introduce at most 0.25 dB penalty, comparable to measurement repeatability



TDECQ = 2.7 dB
SECQ @ 350 m = 4.3 dB

Circles are average BER
Bars are max and min BER

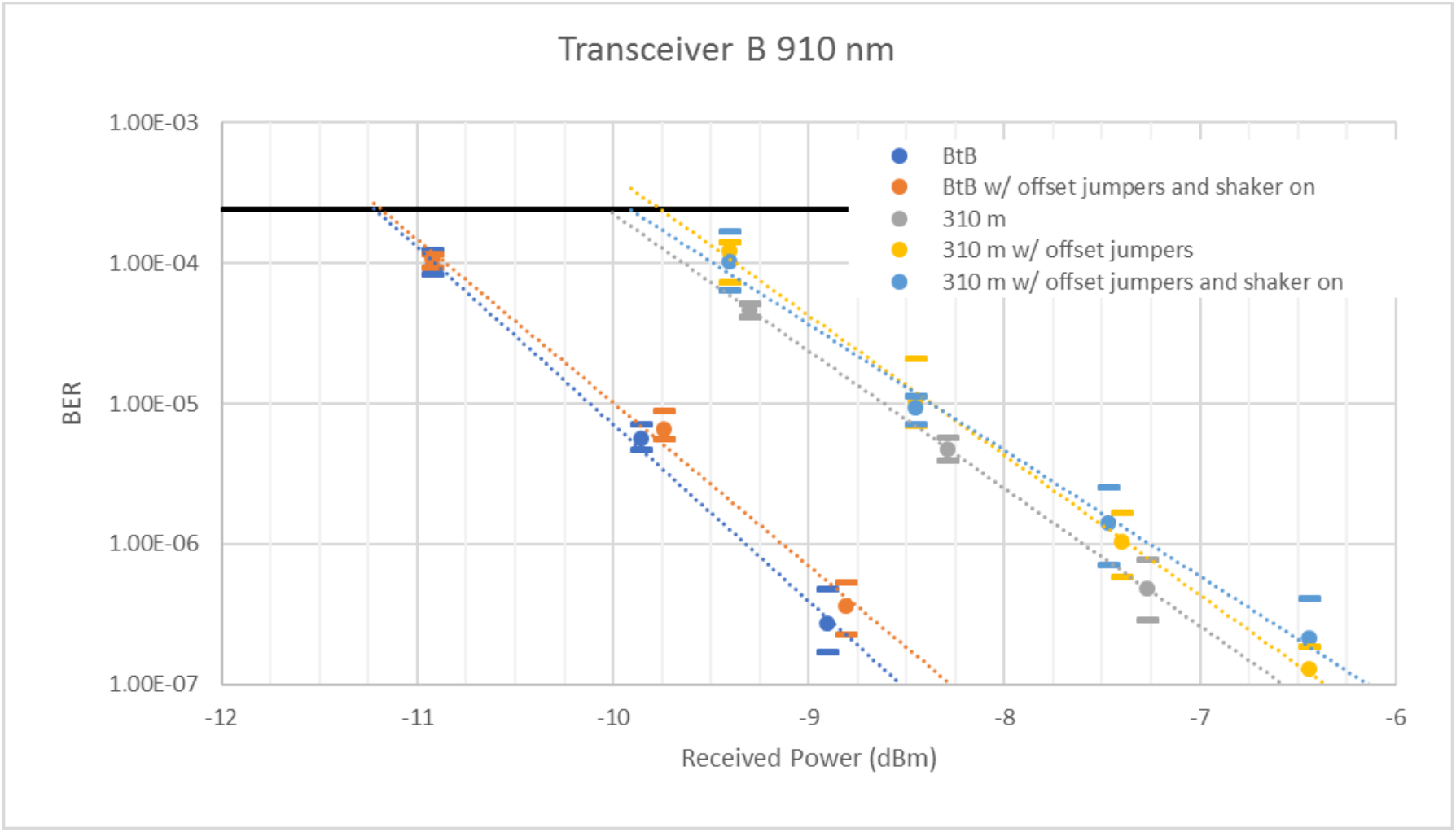
Offset jumpers and fiber shaker introduce at most 0.25 dB penalty, comparable to measurement repeatability



TDECQ = 2.6 dB
SECQ @ 300 m = 4.6 dB

Circles are average BER
Bars are max and min BER

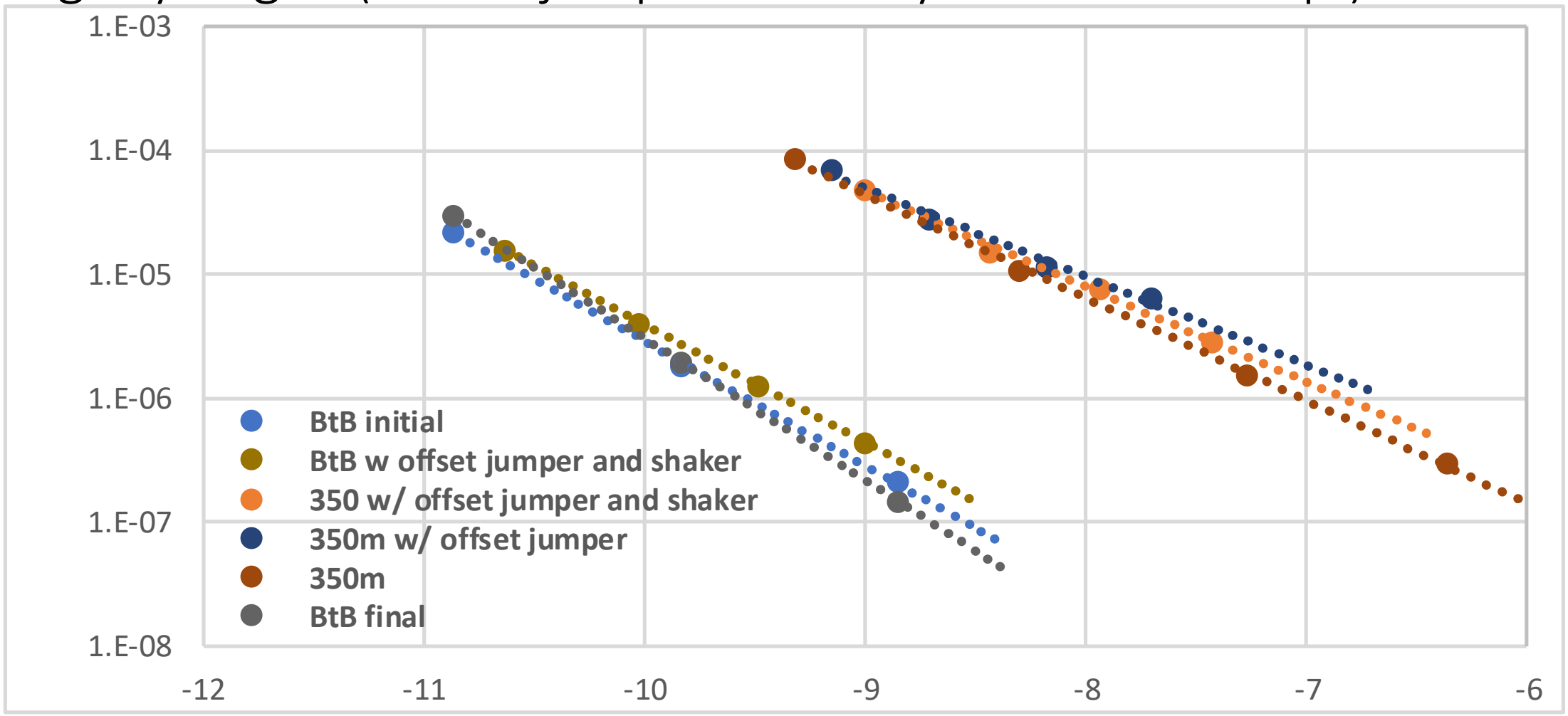
Offset jumpers and fiber shaker introduce at most 0.25 dB penalty, comparable to measurement repeatability



TDECQ = 2.68 dB
SECQ @ 300 m = 4.43 dB

Circles are average BER
Bars are max and min BER

BtB modal noise penalties at 1e-5 and 2e-4 are within measurement error. MN penalties with 350m fiber are only slightly larger. (1.1 dB jumper courtesy of Panduit Corp.)



Conclusions

- Measured modal noise penalties at BER 2.4e-4, measured with real parts, are at most 0.25 dB, and not obviously inconsistent with the allocation in the draft.
- Modal noise penalty comparable to measurement repeatability.
- Modal noise penalties BtB and over fiber are a few tenths of a dB in links with 300 to 350m low bandwidth fiber, where SECQ is near 4.5 dB, indicating little “Pcross” effect