FEC Performance Analysis for 400GbE with FOM Bitmux

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Motivation

- KR4/KP4 RS FEC performance with Orthogonal/Non-Orthogonal bit mux methods are explored in “wang_t_3bs_01_0514” and “wang_t_3bs_01_0714”.
- FEC performance on multi-part links is investigate in “anslow_3bs_02_0714”.
- Some difference of FEC performance exists in these two slides due to distinction on worst case assumptions in evaluation.
- In these slides, we hope to further the investigation of FEC performance on bit multiplexing architecture,
  - Different assumptions of worse case in one-part link;
  - Comparison of KR4/KP4 FEC performance for one-part link;
  - A method to calculate FEC performance in two-part link with random error in one link and bursty errors in another;
  - KR4/KP4 FEC performance results by the method above.

FEC Performance Calculation

- **Calculation programs in “wang_t_3bs_01_0714”**

$$BER_{post} = \binom{n}{1} * M(t+1) * W(E) + \binom{n}{2} * \sum_{i=1}^{t} G(i) * M(t-i) * W(E) + \binom{n}{3} * \sum_{i=1}^{t} \sum_{j=1}^{t-i} G(i) * G(j) * M(t-i) * W(E) + \ldots + \sum_{i=t+1}^{n} \binom{n}{i} * G(i) * W(E)$$

Probability of having a single burst error longer than *t+1* symbols

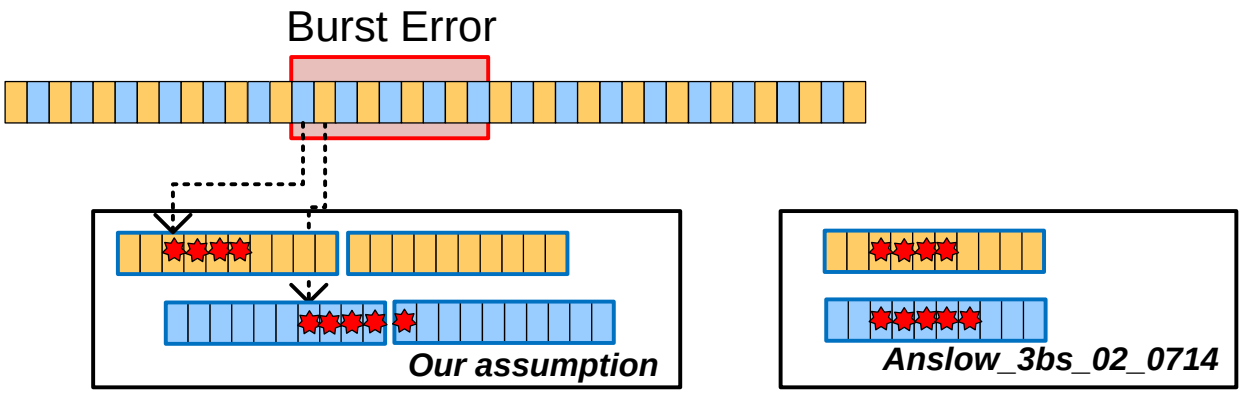
Probability of having two burst error whose total length is longer than *t+1* symbols

Probability of having three burst error whose total length is longer than *t+1* symbols

Probability of having more than *t+1* separate burst errors

- **The following assumptions affect the evaluation:**
  - Multiplexing symbol lanes without skews
  - Unbalanced error distribution after de-multiplexing
  - Permutation of burst error patterns

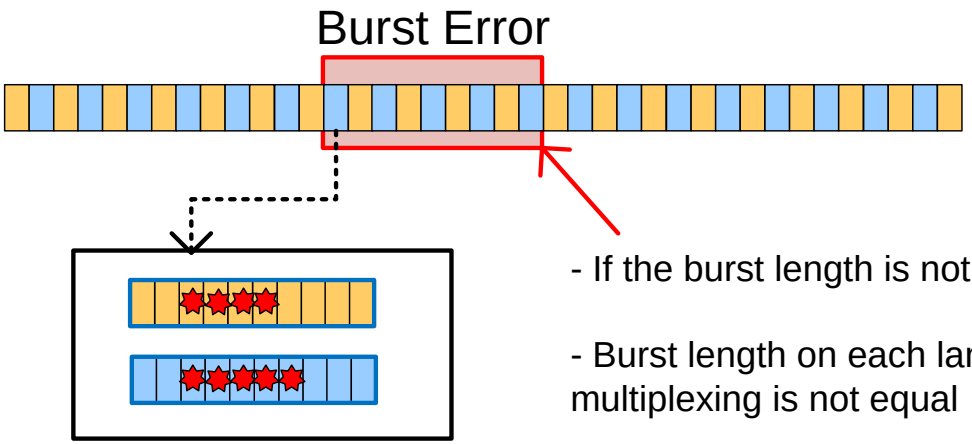
Assumption 1 : Multiplexing Symbol Lanes without Skews



- Our assumption was the symbol lanes are not aligned and it may have random offset from (0-9); however the offset could be any value in {0..9}, but it is fixed once the hardware layout is finished.

- “No skew” scenario from Anslow_02_bs_0714 is more realistic and simplified model, because layout skew difference is fixed yet unpredictable. We use this assumption in the following calculation.

Assumption 2：Unbalanced Error Distribution after De-Multiplexing



- If the burst length is not an even number:

- Burst length on each lane after de-multiplexing is not equal

- Our assumption:
  - Every FEC codeword has 50% chance with longer partial burst, and 50% chance to have short one.
- Otherwise:
  - Always calculate on the lane with longer partial burst error.

Assumption 3 : Burst Error Patterns Should be Counted

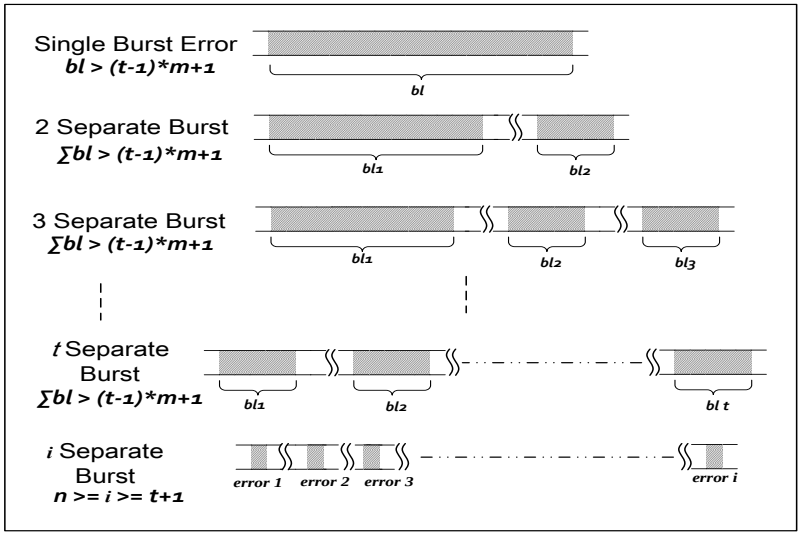


Figure 1

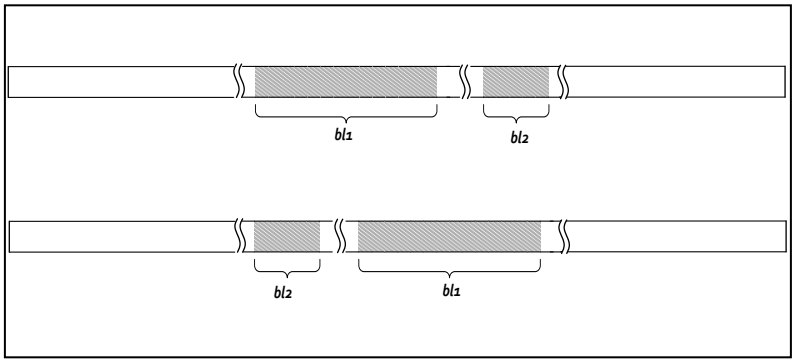


Figure 2

- All kinds of burst error patterns, longer than 8 symbols are counted. (As in Figure1 of “wang_t_3bs_01_0514”)
- The sequence of separate burst errors with different length should be considered, because it is another type of burst error occurrence, (Example in Figure2).
- The collective occurrence for all types of burst error affects the FEC performance.

FEC Performance on One-part Link

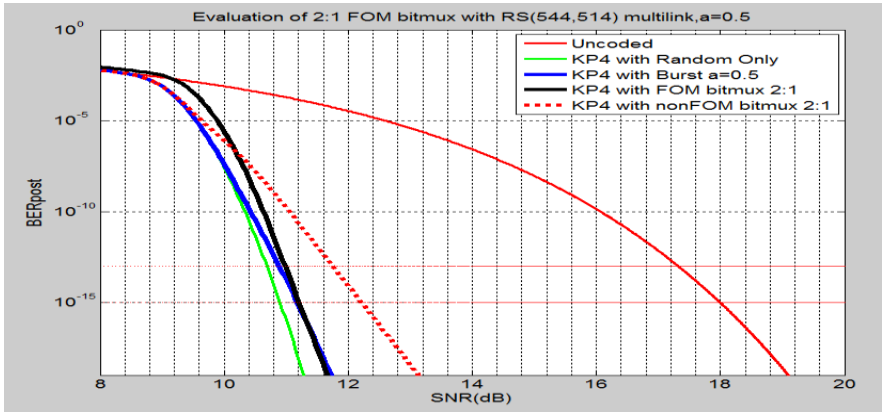
- KR4 FEC

	For FLR = 6.2E-11	For FLR = 6.2E-13
No FEC	1E-13	1E-15
1:2 Same FEC, a = 0.5	1.6E-7*	1.6E-8*
Burst, a = 0.5	9.6E-6*	3.3E-6*
1:2 Different FEC, a = 0.5	1.3E-5*	5.2E-6*
Random errors	3.8E-5	2.1E-5

	For FLR=6.2E-11	For FLR=6.2E-13
No FEC	**1E-13**	**1E-15**
Non FOM Bit Mux	**3.5E-7**	**3.5E-8**
Burst,a=0.5	**1.4E-5**	**6.3E-6**
FOM Bit Mux	**1.9E-5**	**8E-6**
Random errors	**4E-5**	**2.2E-5**

*Refer to **Anslow_3bs_02_0714***

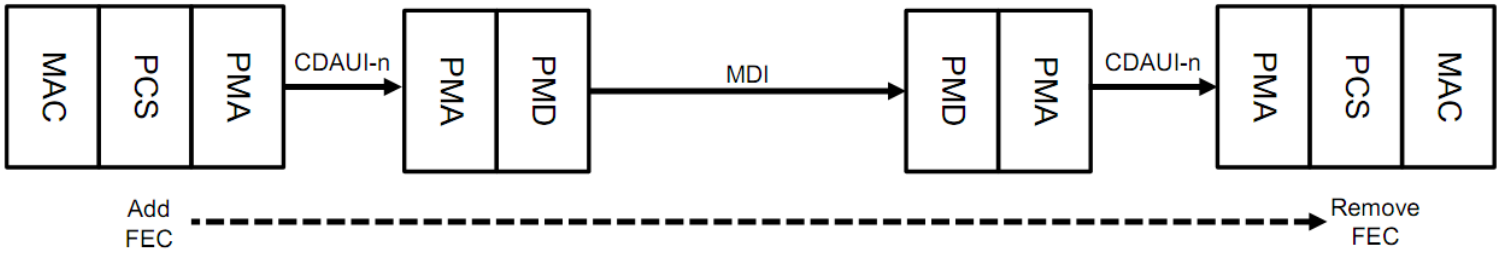
- KP4 FEC



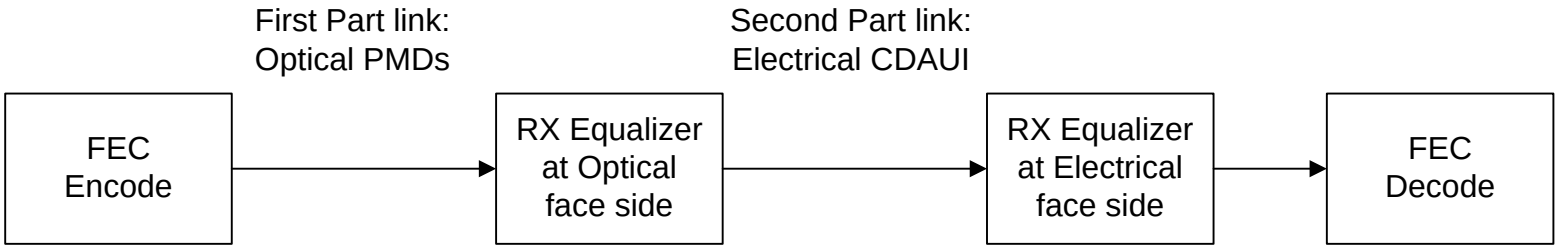
	For FLR=6.2E-11	For FLR=6.2E-13
No FEC	**1E-13**	**1E-15**
Non FOM Bit Mux	**5.5E-5**	**2.2E-5**
Burst,a=0.5	**2.4E-4**	**1.5E-4**
FOM Bit Mux	**2E-4**	**1.5E-4**
Random errors	**3E-4**	**2.3E-4**

FEC Performance on Two-part Link

- Method of FEC performance on multi-part links is stated in “anslow_3bs_02_0714”.
- FEC Strategies: End to End as in “gustlin_3bs_02_0714”:



- The error behavior of CDAUI-n interface in TX and RX are most likely similar. We can simplify the FEC performance model with the following two-part links at first and further investigation on the multi-part links as in real system.

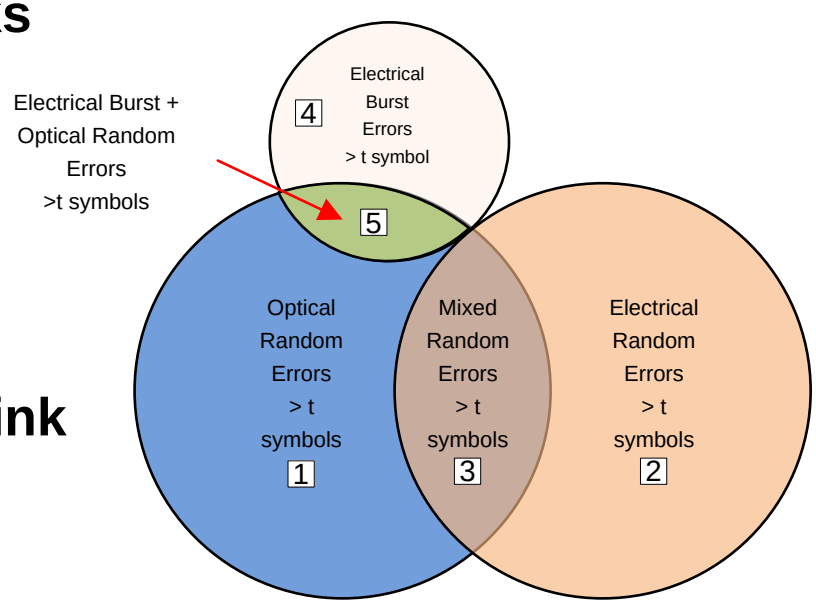


FEC Performance on Two-part Link (burst + random)

Random errors from two sub-links

$$\sum_{i=8}^{n} \binom{n}{i} SER^{i}(1-SER)^{n-i}$$

- Optical sub-link errors (1)
- Electrical sub-link errors (2)
- Optical + Electrical sub-link errors (3)



Burst errors from electrical sub-link

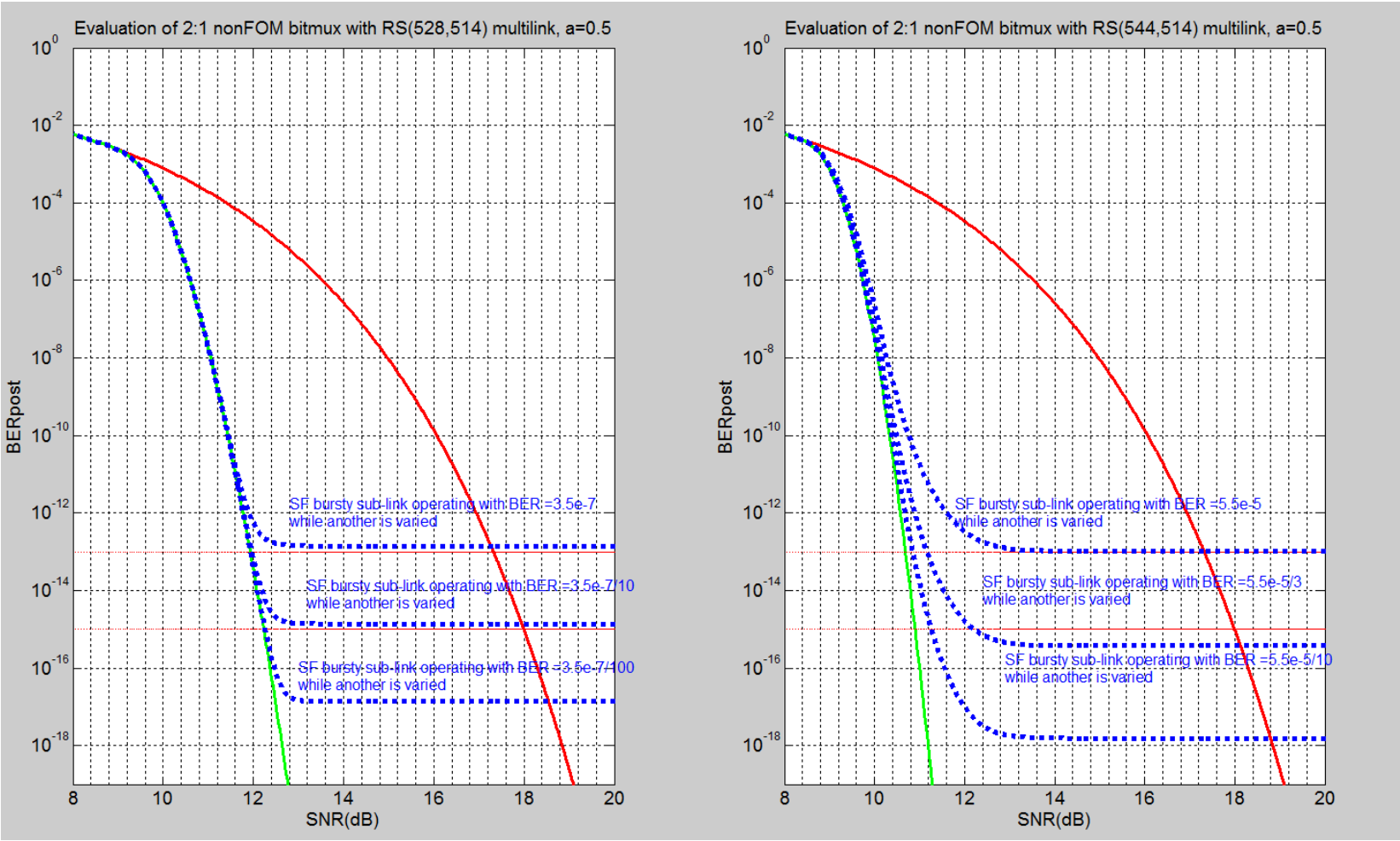
- One burst, two bursts, … seven bursts with total length > 8 symbols

$$Burst\ Error(8) = \binom{n}{1} * M(t+1) + \binom{n}{2} * \sum_{i=1}^{t} G(i) * M(t+1-i) + +... + \binom{n}{7} * \sum_{i_1=1}^{t} ... \sum_{i_6=1}^{t-i_1-i_2-..-i_5} G(i_1) * G(i_2) * M(t+1-i_1-i_2-..-i_6) \quad (4)$$

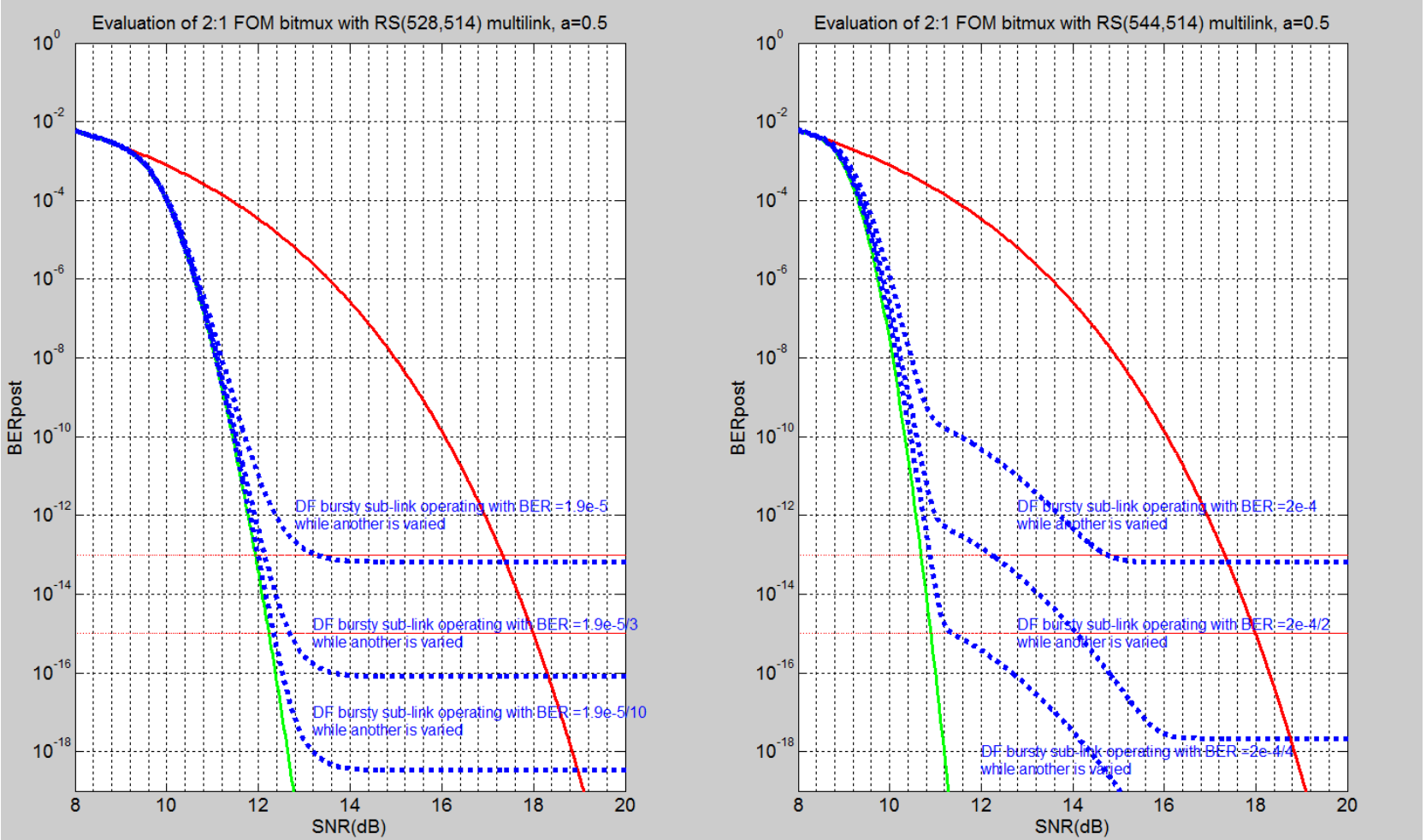
Mixed burst errors and random errors

$$\sum_{i=1}^{6} \binom{n}{i} SER^{i}(1-SER)^{n-i} * Burst\ Error(8-i) \quad (5)$$

Non-FOM Bit mux Result of KR4/KP4 FEC

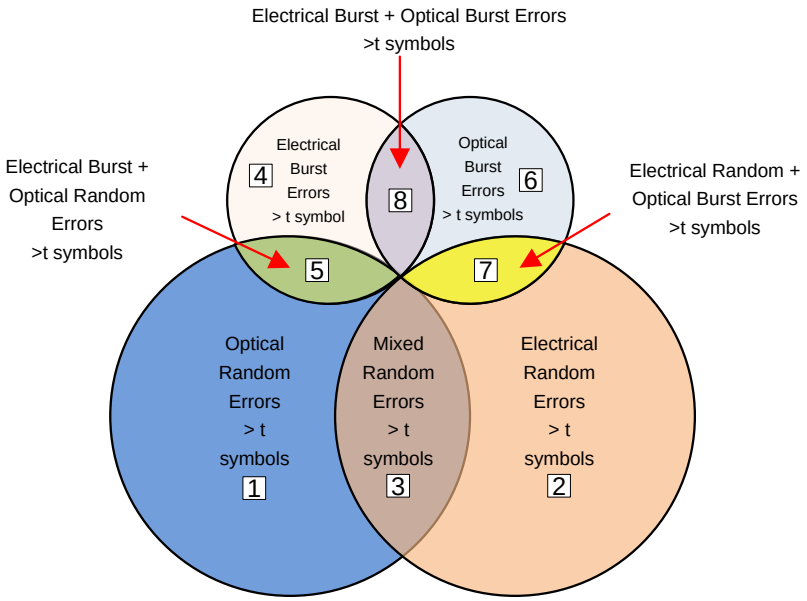


FOM Bit Mux Result of KR4/KP4 FEC



FEC Performance on Two-part Link (burst + burst)

- **Random errors from two sub-links**
  - Optical sub-link errors (1)
  - Electrical sub-link errors (2)
  - Optical + Electrical sub-link errors (3)
- **Burst errors from electrical sub-link**
  - One burst, two bursts, … seven bursts with total length > 8 symbols (4)
  - One burst, two bursts, … seven bursts with total length > 8 symbols (5)



- **Mixed burst errors and random errors from both sub-links**
  - Burst from optic and random from electrical link (6)
  - Burst from electrical and random from optic link (7)
- **Mixed burst errors from both sub-links**
  - Burst from both electrical and optic link (8)

Summary

- Evaluation assumptions are examined and compared with other methods.
- KR4 FEC Performance for one part link conforms by different contributions. Due to distinct assumptions and program method, KR4 FEC Performance for multi-part link has small difference.
- KP4 FEC Performance for one part link and multi-part link has been investigated.
- Multi-part link with Burst + Burst error model has been explored and result will be compared and presented later.

Thank you