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BER/FLR Calculation Results for Multiplexing in PMA

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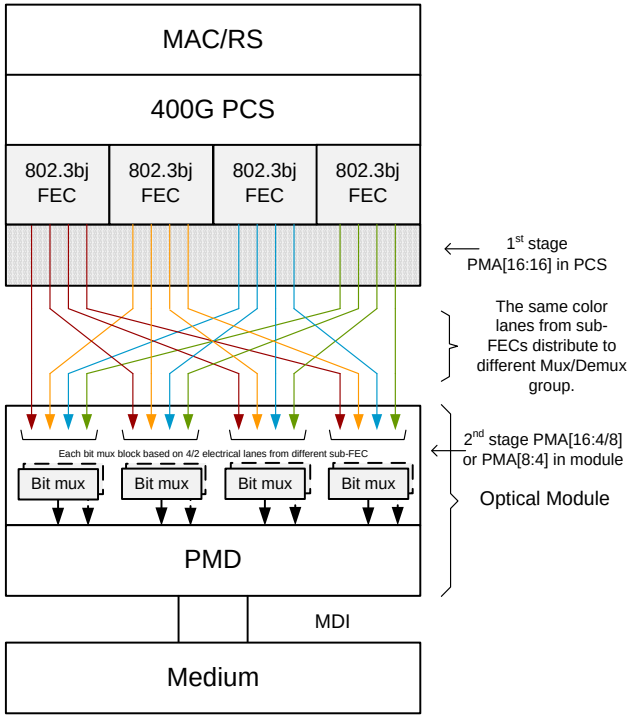
Background

- Based on evaluation method presented in May, (wang_t_3bs_01_0514), FEC performance with different burst error factors are explored; BERin requirements are listed for reference.

- KR4/KP4 FEC performance with all muxing methods are explored for comparison.



- Have minor updates on calculation method.
- Four muxing methods under investigation:
  - Orthogonal symbol mux
  - Orthogonal bit mux
  - Non-orthogonal symbol mux
  - Non-orthogonal bit mux
- Analysis of reusing gearbox for 400GbE and 4x100GbE, from BER performance perspective.

Updates in Calculation

- **For FEC incorporated 400GbE, FLR(frame loss rate) is more practical in evaluating MTTFPA performance. So we also use FLR equations from BER,**
  - http://www.ieee802.org/3/400GSG/public/adhoc/logic/jun26_13/anslow_01_0613_logic.pdf

$$FLR = 1-(1-BER)^{620}$$ Or approximately $$FLR = BER * 620$$

- **Update calculation programs**
  - Use SERin instead of BERin as $C_n^i = \binom{n}{i}$ function is based on symbols as well

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

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

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

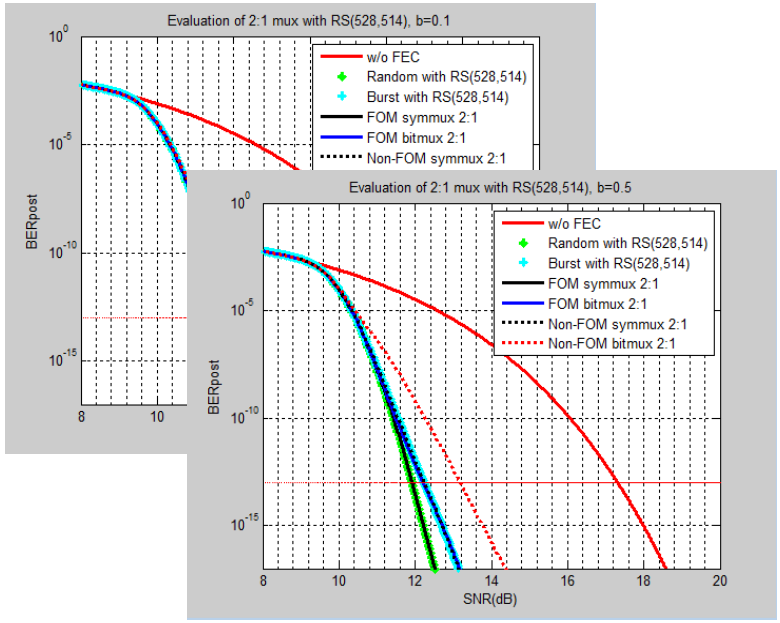
Probability of having two burst error whose total length is longer than *t+1* symbols

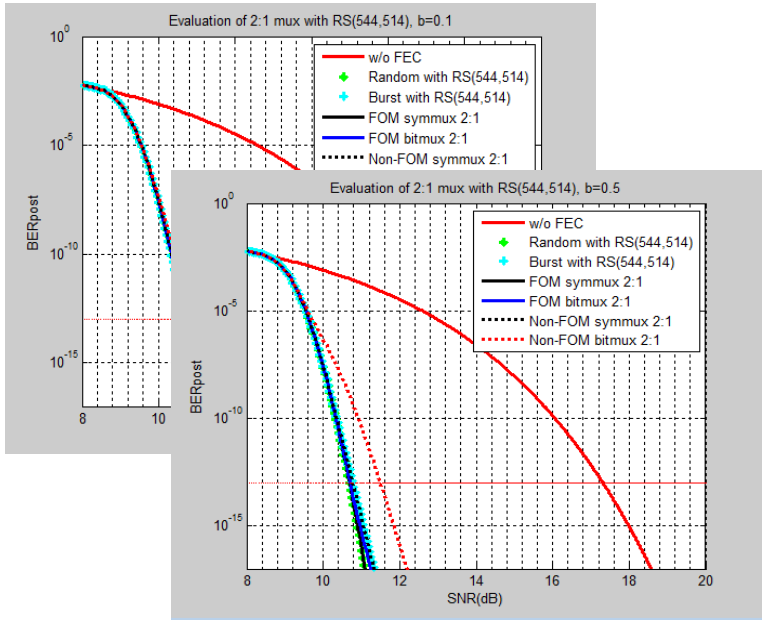
Probability of having a single burst error longer than *t+1* symbols

BER Evaluation (1)

- BER_{in} requirements for 2:1 mux are listed, assuming rllmax = 4bits

RS FEC	b	mux 2:1			
		FOM symbol mux	FOM bit mux	Non-FOM symbol mux	Non-FOM bit mux
RS(528,514)	b=0.1	3.75E-05	3.75E-05	3.56E-05	1.42E-05
	b=0.5	3.75E-05	2.19E-05	2.07E-05	2.38E-06
RS(544,514)	b=0.1	3.09E-04	3.09E-04	3.09E-04	2.23E-04
	b=0.5	3.09E-04	2.93E-04	2.63E-04	8.45E-05

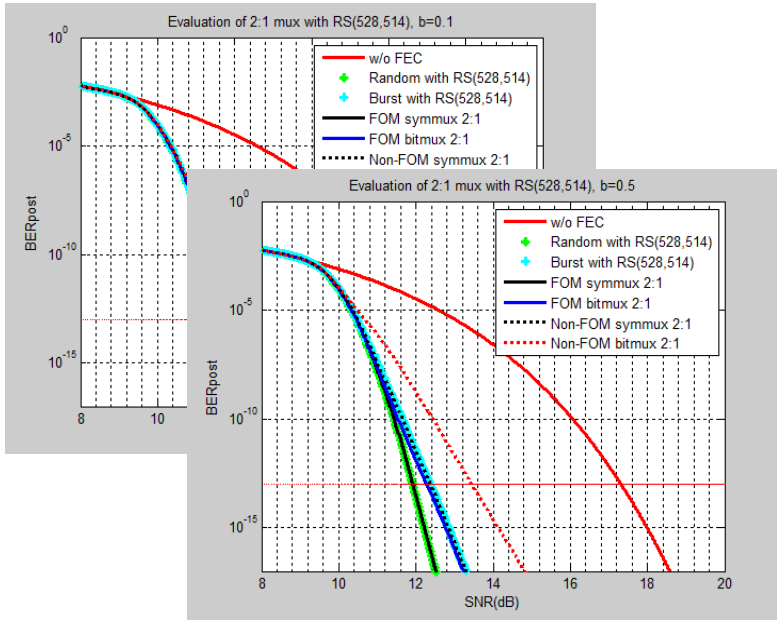


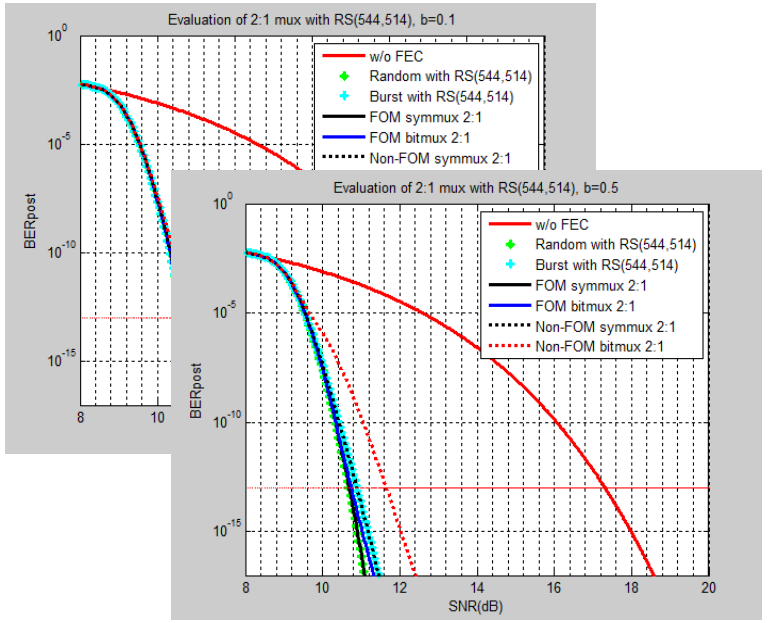


BER Evaluation (2)

- BER_{in} requirements for 2:1 mux are listed, assuming rllmax = 17bits

RS FEC	b	mux 2:1			
		FOM symbol mux	FOM bit mux	Non-FOM symbol mux	Non-FOM bit mux
RS(528,514)	b=0.1	3.75E-05	3.75E-05	3.56E-05	1.42E-05
	b=0.5	3.75E-05	1.86E-05	1.58E-05	1.25E-06
RS(544,514)	b=0.1	3.09E-04	3.09E-04	3.09E-04	2.23E-04
	b=0.5	3.09E-04	2.77E-04	2.23E-04	6.44E-05

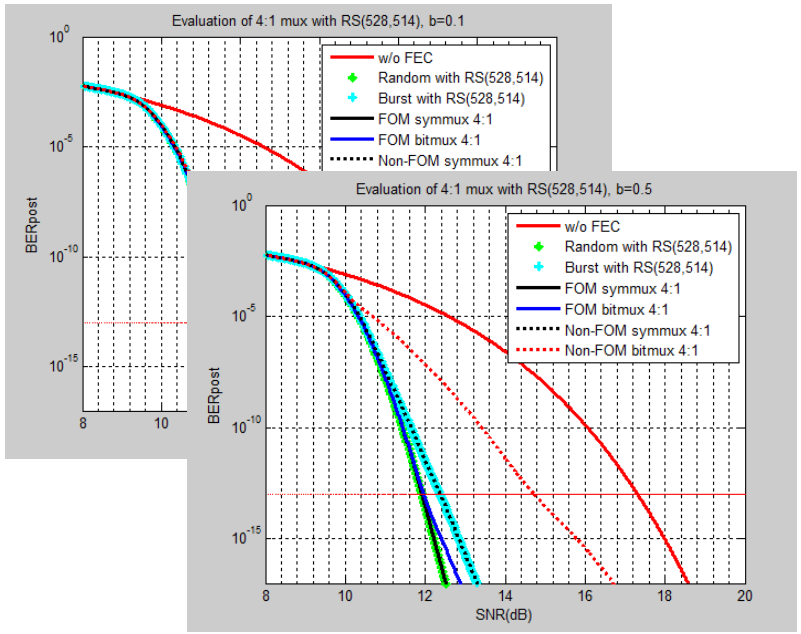


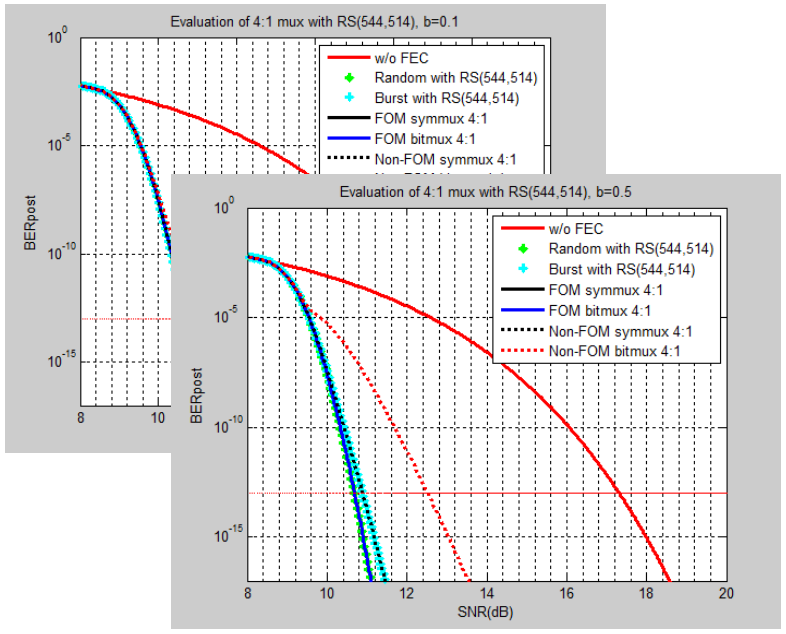


BER Evaluation (3)

- BER_{in} requirements for 4:1 mux are listed, assuming rllmax = 17bits

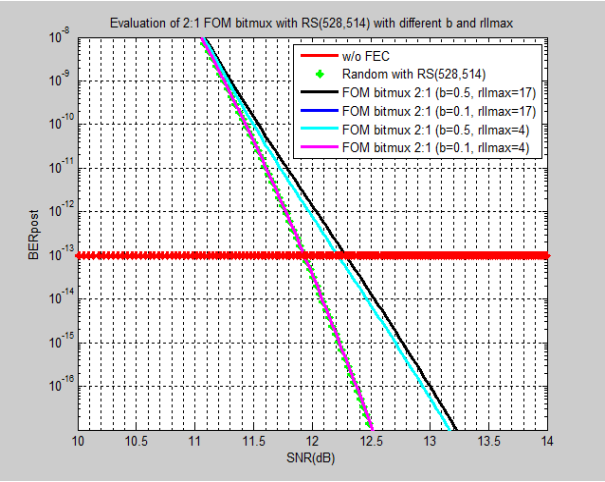
RS FEC	b	mux 4:1			
		FOM Symbol mux	FOM bit mux	Non-FOM symbol mux	Non-FOM bit mux
RS(528,514)	b=0.1	3.75E-05	3.75E-05	3.56E-05	4.10E-06
	b=0.5	3.75E-05	3.56E-05	1.58E-05	2.42E-08
RS(544,514)	b=0.1	3.09E-04	3.09E-04	2.93E-04	1.70E-04
	b=0.5	3.09E-04	3.09E-04	2.23E-04	1.14E-05



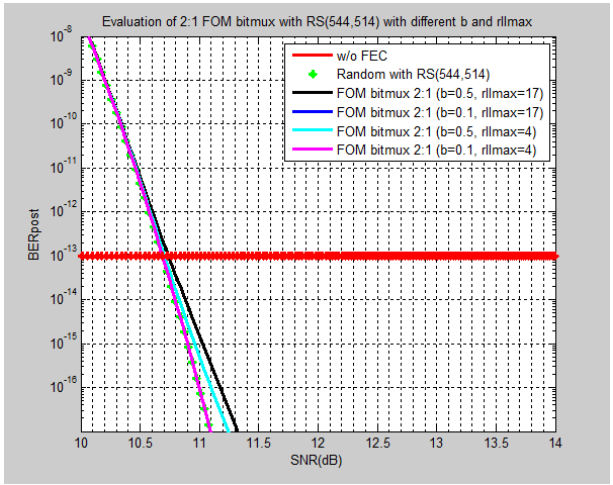


Effect of Parameters

- **b: “Prob of continuous error after a initial error bit”**
  - Smaller value of b, less probability for burst errors
- **Rllmax : “maximum burst error length”**
  - Larger rllmax increases probability for burst errors
- **Example with FOM bit mux 2:1 With different value of b and rllmax**

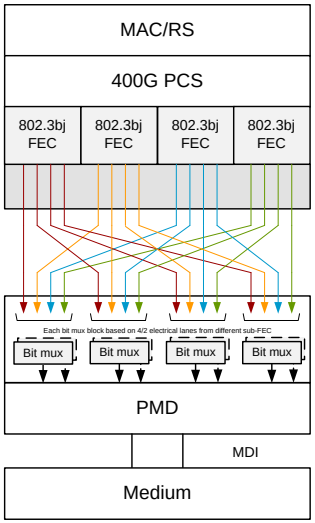


FOM bitmux with b=0.5/0.1, rll=17/4
For RSFEC(528,514)



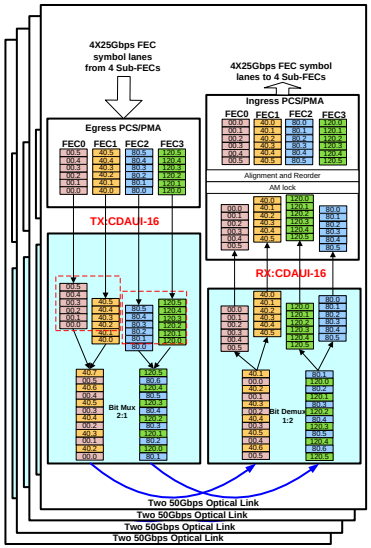
FOM bitmux with b=0.5/0.1, rll=17/4
For RSFEC(544,514)

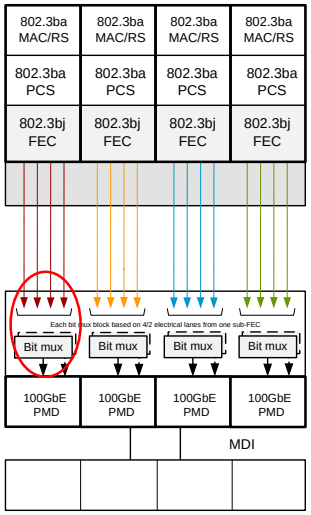
Compatible Gearbox - 1x400GbE vs. 4x100GbE



1X400GbE :

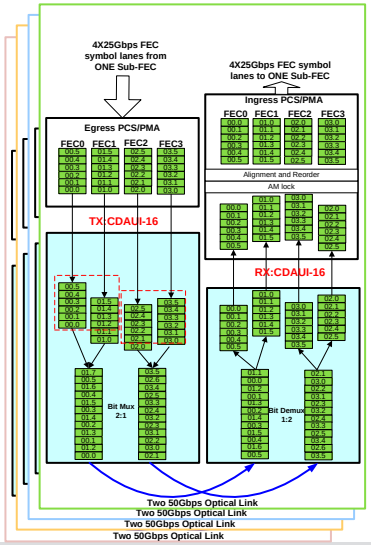
16X25G CDAUI with 8X50G PMD





4X100GbE :

4X(4X25G) CDAUI with 2X50G PMD

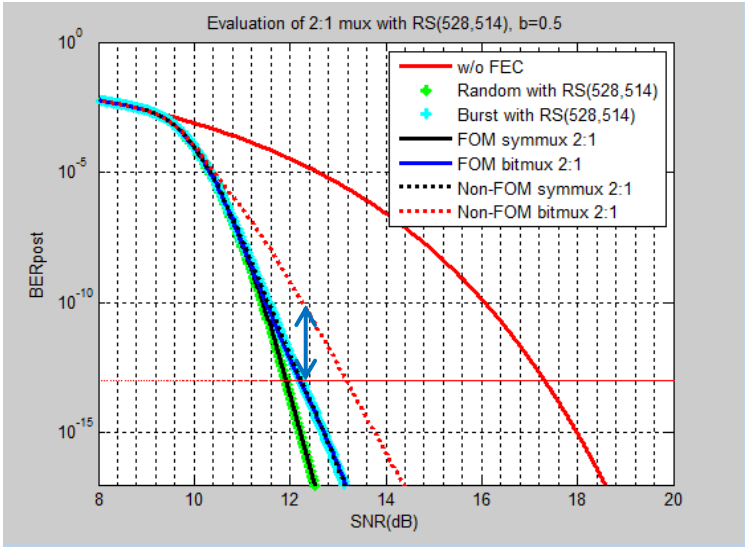


- Reuse compatible gearbox for 400GbE and 4x100GbE
  - Four groups of FOM mux in 400GbE.
  - Every 100GbE has mux within itself.
- MTTFPA Performance may be different for 400GbE and 100GbE, by using compatible gearbox.
  - How much difference?
  - Whether it is acceptable for MTTFPA requirement for both 400GbE/100GbE?

Performance Difference - 1x400GbE vs. 4x100GbE

- **While 400GbE has four parallel 100GBase-KR4/KP4 RSFEC and FOM mux options, if every individual 100GbE reuse one RSFEC encoder/decoder with only non-FOM mux options, what is the performance for 100GbE?**

- **Mux options:**
  - Bit mux
    - To reach BER_{post} = 1e-13 in 400GbE, SNR = 12.2dB,
      On each 100GbE,
      BER_{post} = 1e-10 (b=0.5, rll=4);
      = 5e-11 (b=0.1, rll=4)
      *MTTFPA = 10^{8} ~ 10^{10} years.
  - Symbol mux
    - To reach BER_{post} = 1e-13 in 400GbE, SNR=11.8dB,
      On each 100GbE,
      BER_{post} = 1e-12 (b=0.5, rll=4);
      = 1e-13 (b=0.1, rll=4)
      *MTTFPA = 10^{11} ~ 10^{13} years.



*refer to http://www.ieee802.org/3/bj/public/jan12/cideciyan_01_0112.pdf

Conclusions

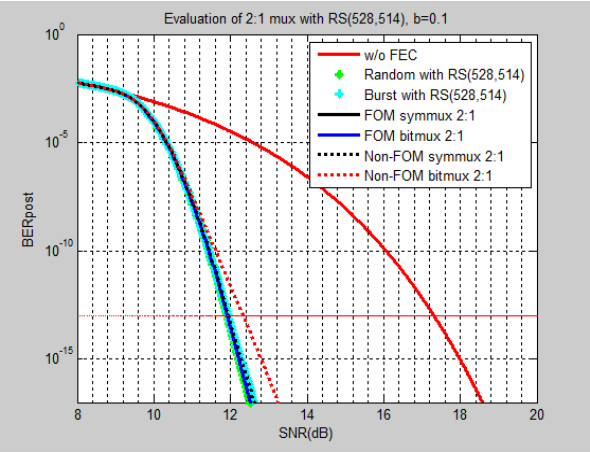
- **By using 100GBASE-KR4 RS(528,514) and FOM bit mux 2:1, BER_{in} should be 1.9e-5 to satisfy BER_{post} = 1e-13 objective in 400GbE, with coding gain of 5dB;**

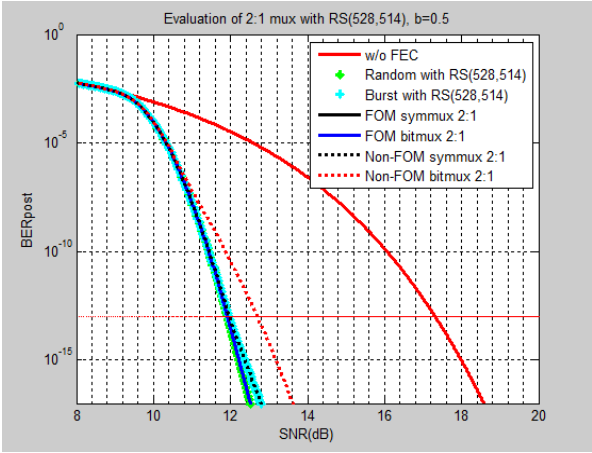
- **By using 100GBASE-KP4 RS(544,514) and FOM bit mux 2:1, It requires 2.8e-4 to meet BER_{post} = 1e-13 objective in 400GbE, with coding gain of 6.5dB;**

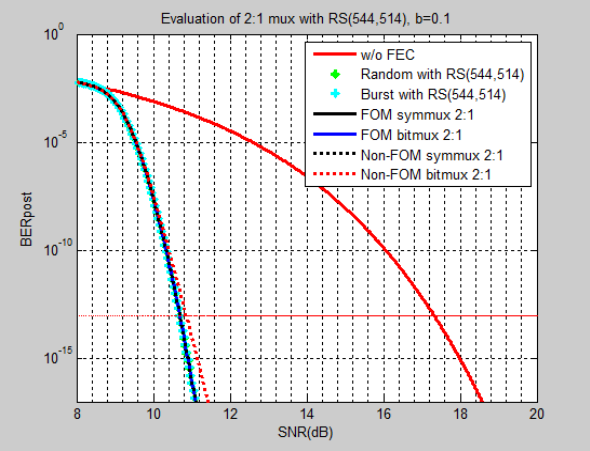
- **Supporting 400GbE and 4x100GbE compatible gearbox is possible with bitmux option, either accepting a certain degradation of performance according to the PMD features or we can put constraints on error propagation factors to keep MTTFPA.**

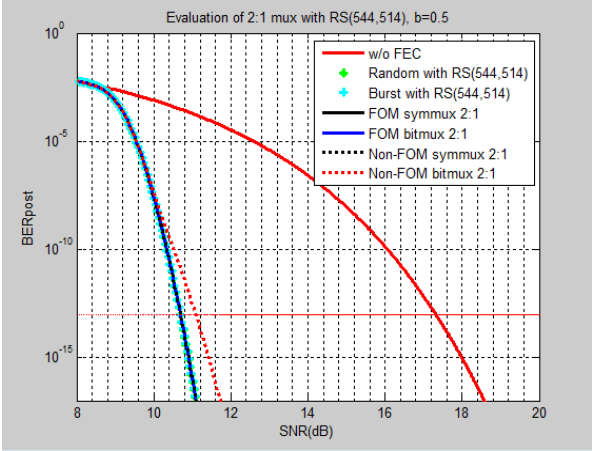
Thank you

BER Evaluation (2:1 mux ,rllmax=2 bits)









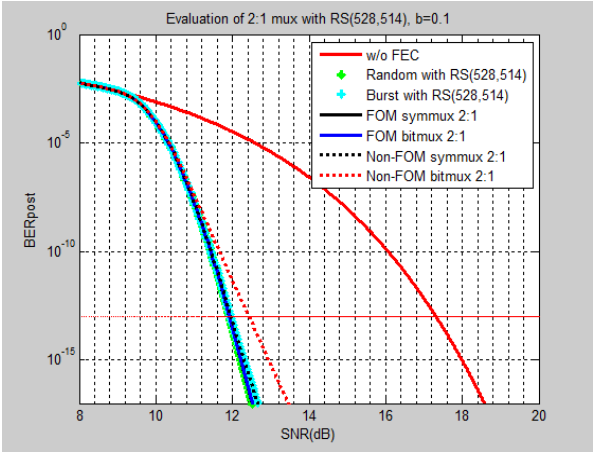
RS528,514	b=0.1				
BERpost	FLR	mux 2:1			
		FOM Symmux	FOM bitmux	Non-FOM sym	Non-FOM bit
1.00E-12	6.20E-10	5.19E-05	5.19E-05	4.92E-05	2.71E-05
1.00E-13	6.20E-11	3.75E-05	3.75E-05	3.56E-05	1.67E-05
1.00E-15	6.20E-13	2.07E-05	2.07E-05	1.86E-05	6.31E-06

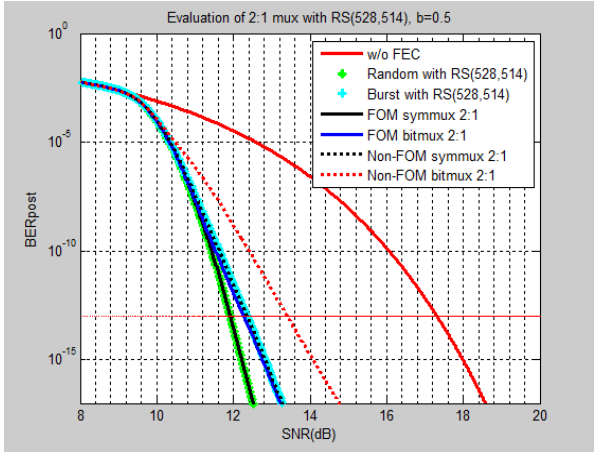
RS528,514	b=0.5				
BERpost	FLR	mux 2:1			
		FOM Symmux	FOM bitmux	Non-FOM sym	Non-FOM bit
1.00E-12	6.20E-10	5.19E-05	5.19E-05	4.92E-05	1.34E-05
1.00E-13	6.20E-11	3.75E-05	3.75E-05	3.37E-05	7.84E-06
1.00E-15	6.20E-13	2.07E-05	2.07E-05	1.58E-05	2.52E-06

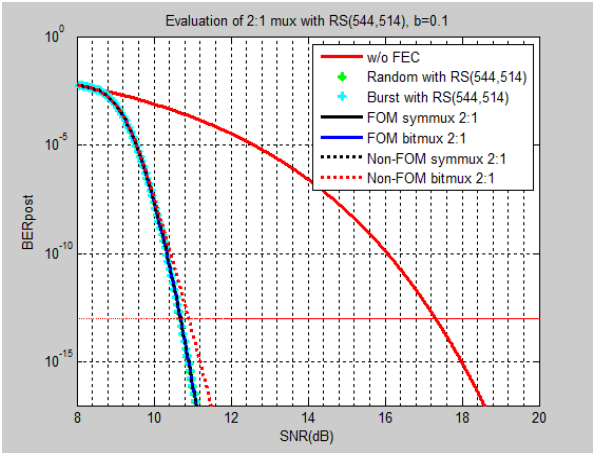
RS544,514	b=0.1				
BERpost	FLR	mux 2:1			
		FOM Symmux	FOM bitmux	Non-FOM sym	Non-FOM bit
1.00E-12	6.20E-10	3.63E-04	3.63E-04	3.63E-04	2.93E-04
1.00E-13	6.20E-11	3.09E-04	3.09E-04	3.09E-04	2.36E-04
1.00E-15	6.20E-13	2.23E-04	2.23E-04	2.23E-04	1.53E-04

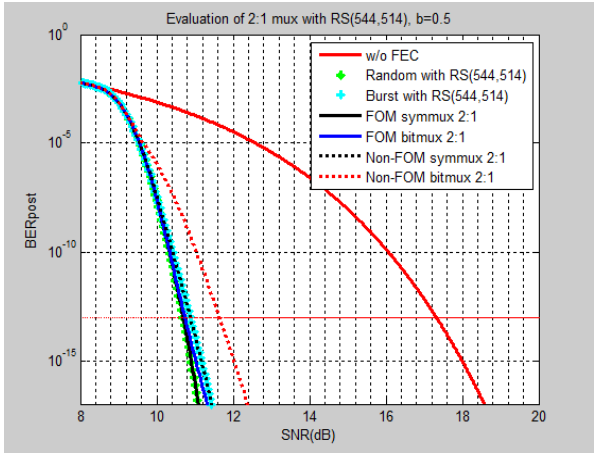
RS544,514	b=0.5				
BERpost	FLR	mux 2:1			
		FOM Symmux	FOM bitmux	Non-FOM sym	Non-FOM bit
1.00E-12	6.20E-10	3.63E-04	3.63E-04	3.63E-04	2.23E-04
1.00E-13	6.20E-11	3.09E-04	3.09E-04	3.09E-04	1.61E-04
1.00E-15	6.20E-13	2.23E-04	2.23E-04	2.23E-04	9.41E-05

BER Evaluation (2:1 mux ,rllmax=8 bits)









RS528,514 b=0.1

BERpost	FLR	No mux		mux 2:1			
		Random Err	Burst Err	FOM Symmux	FOM bitmux	Non-FOM sym	Non-FOM bit
1E-12	6.2E-10	5.19E-05	4.92E-05	5.19E-05	5.19E-05	4.92E-05	2.31E-05
1E-13	6.2E-11	3.75E-05	3.56E-05	3.75E-05	3.75E-05	3.56E-05	1.42E-05
1E-15	6.2E-13	2.07E-05	1.76E-05	2.07E-05	2.07E-05	1.76E-05	4.33E-06

RS528,514 b=0.5

BERpost	FLR	No mux		mux 2:1			
		Random Err	Burst Err	FOM Symmux	FOM bitmux	Non-FOM sym	Non-FOM bit
1.00E-12	6.20E-10	5.19E-05	2.57E-05	5.19E-05	3.19E-05	2.57E-05	3.13E-06
1.00E-13	6.20E-11	3.75E-05	1.58E-05	3.75E-05	1.96E-05	1.58E-05	1.39E-06
1.00E-15	6.20E-13	2.07E-05	5.98E-06	2.07E-05	6.67E-06	5.98E-06	1.99E-07

RS544,514 b=0.1

BERpost	FLR	No mux		mux 2:1			
		Random Err	Burst Err	FOM Symmux	FOM bitmux	Non-FOM sym	Non-FOM bit
1.00E-12	6.20E-10	3.63E-04	3.44E-04	3.63E-04	3.63E-04	3.44E-04	2.77E-04
1.00E-13	6.20E-11	3.09E-04	3.08E-04	3.09E-04	3.09E-04	3.08E-04	2.23E-04
1.00E-15	6.20E-13	2.23E-04	2.23E-04	2.23E-04	2.23E-04	2.23E-04	1.37E-04

RS544,514 b=0.5

BERpost	FLR	No mux		mux 2:1			
		Random Err	Burst Err	FOM Symmux	FOM bitmux	Non-FOM sym	Non-FOM bit
1.00E-12	6.20E-10	3.63E-04	2.77E-04	3.63E-04	3.44E-04	2.77E-04	9.41E-05
1.00E-13	6.20E-11	3.09E-04	2.23E-04	3.09E-04	2.77E-04	2.23E-04	6.45E-05
1.00E-15	6.20E-13	2.23E-04	1.50E-04	2.23E-04	1.80E-04	1.45E-04	3.19E-05