25Gbps PMA for PON

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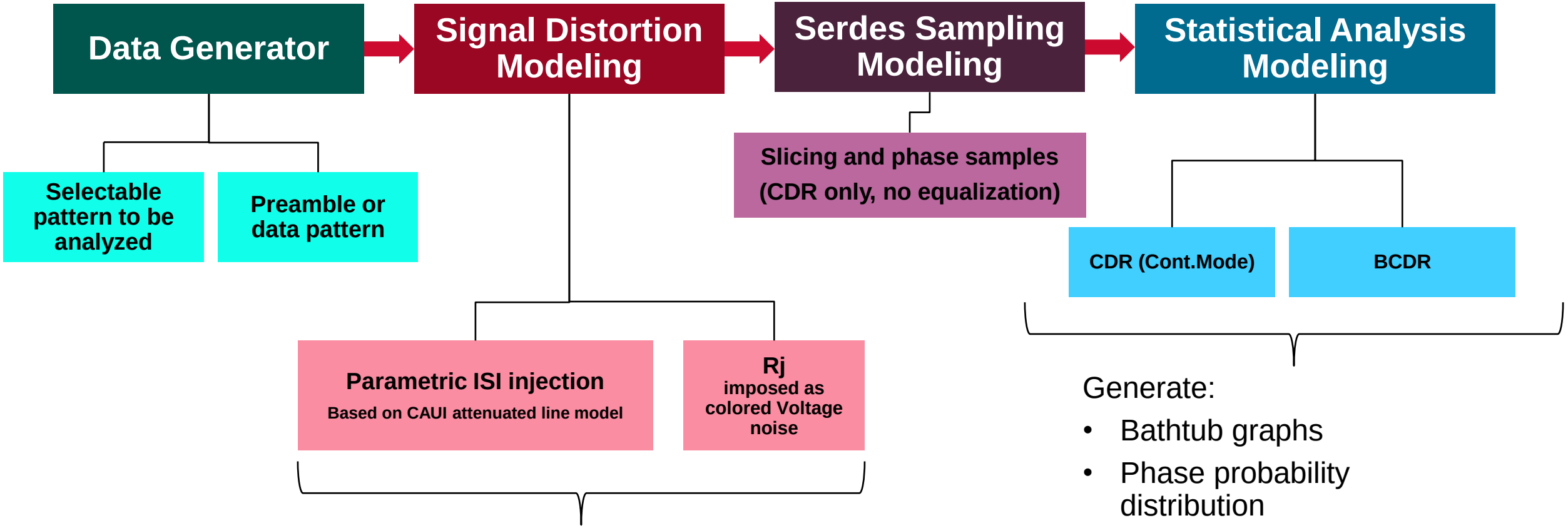
PMA conceptual block diagram



Generate:

- Bathtub graphs
- Phase probability distribution

Generate statistical noise in the phase domain

R(j) and D(j) to generate target BER

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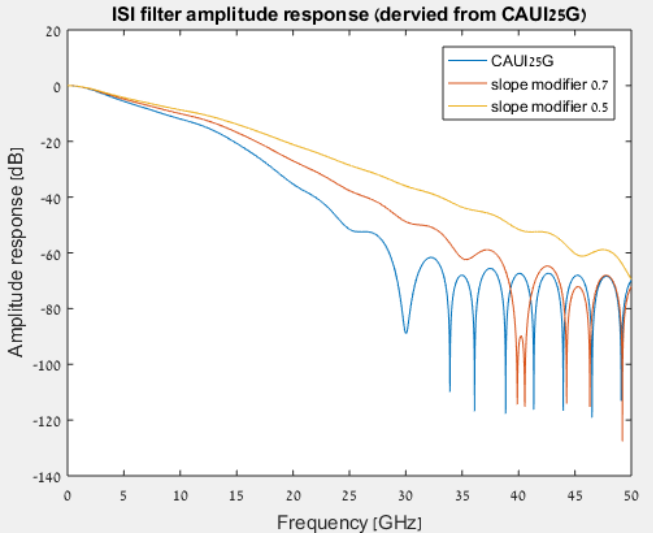
Model overview

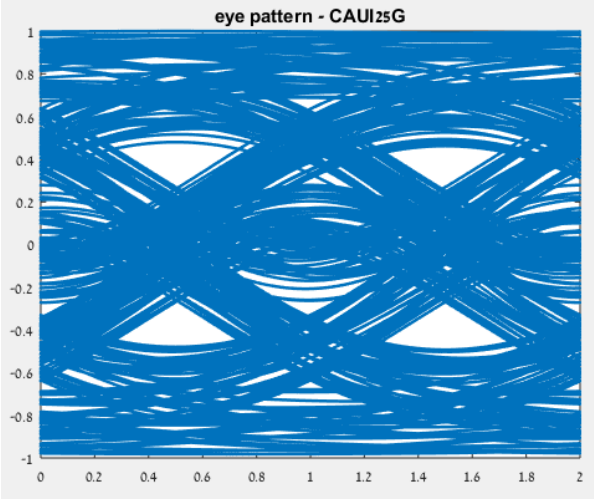
- Data Pattern
  - Random data pattern
- Received signal modeling
  - Optical eye pattern
  - Receiver filter (e.g. 4th order Bessel filter).
  - ISI generation via line insertion loss
    - Currently weighted CAUI25G based
    - Modeling residual ISI only. SERDES equalization not modeled.
- Random Jitter model
  - Modeled as voltage noise.
  - AWGN through receiver filter
  - RMS is based on target input BER of the received signal.

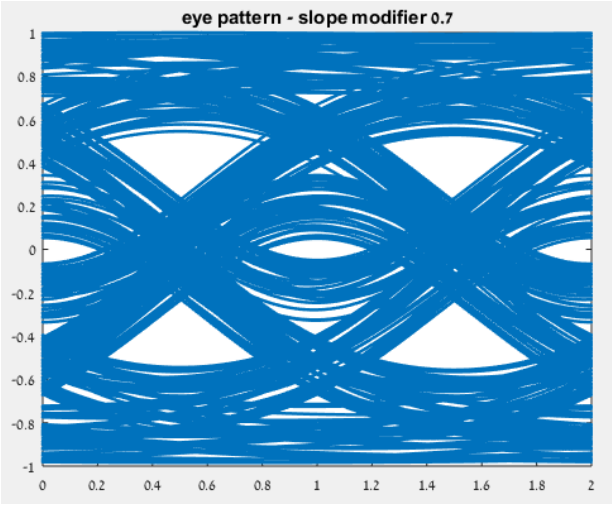
CDR Statistical Model

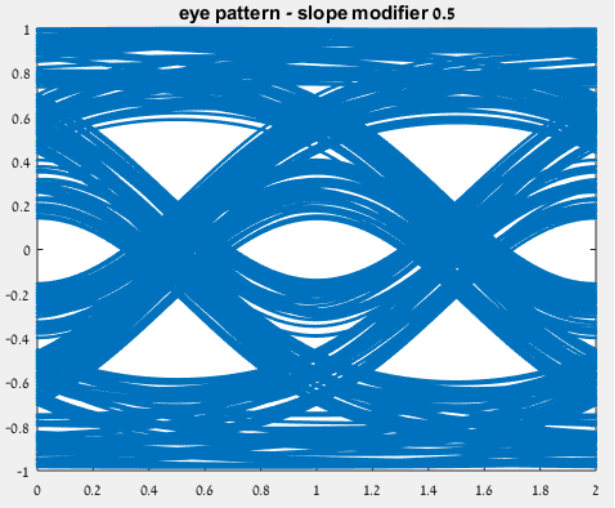
- Statistical model
  - Loop bandwidth configuration
  - Evaluate different control algorithms for phase acquisition and tracking.
- Results
  - Calculate bathtub curve of input eye
    - Probability curve of bit errors based on input ISI and RJ
  - Calculate the phase probability distribution
    - Estimates the quality of the SERSES lock in the presence of noise
  - Calculate the effect of input BER on output BER
    - Estimates the non-ideal effects due to noise and CDR loop BW

ISI modeling (derived from CAUI25G PCB model)









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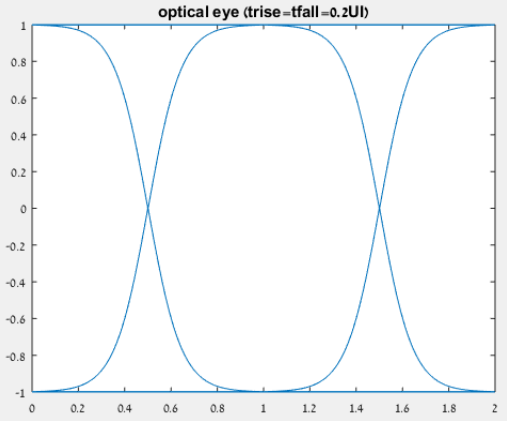
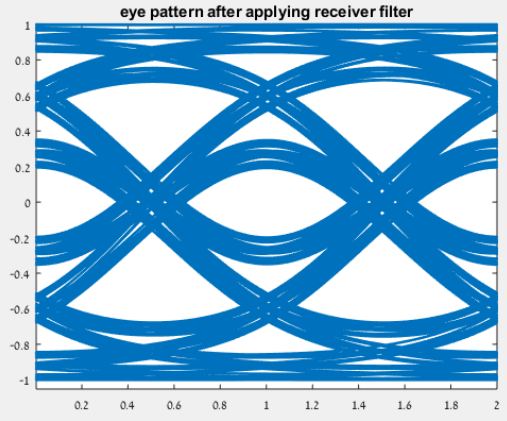
Example of Eye “Flow” through the stages:

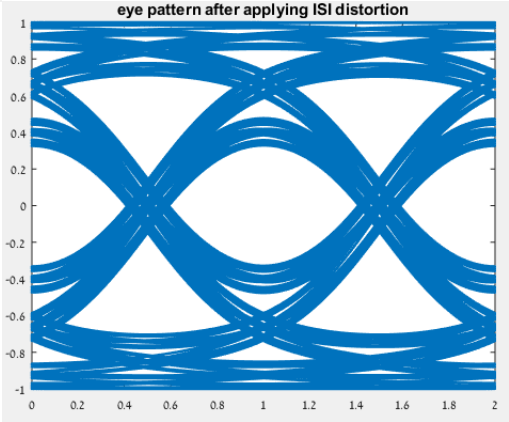
input eye



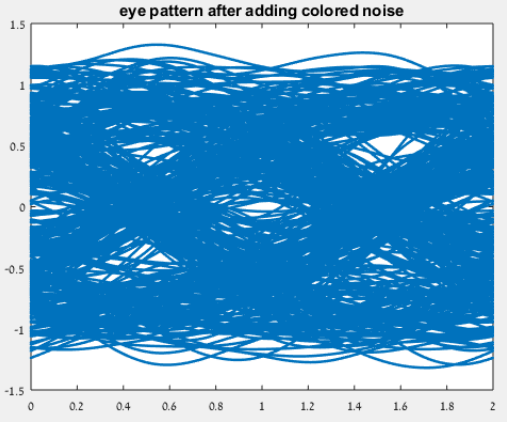
receiver filter



ISI model



adding colored noise



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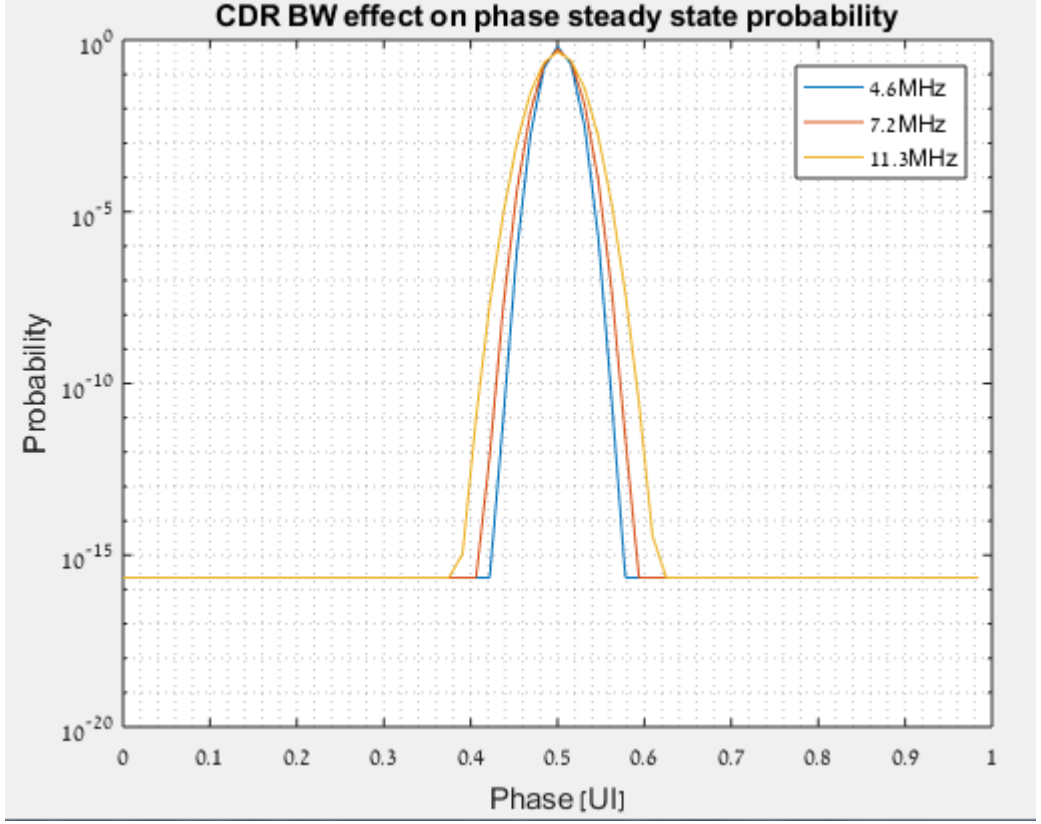
Phase Probability Distribution

- "Lock" probability
  - Phase position of CDR is calculated statistically
  - Position indicates the quality of lock
  - Lower BW will lock more precisely due to higher integration (expected)
  - Multiplying the phase error probability times the bathtub results in the expected output BER
  - Input BER is ideal and taken at center of eye(bottom of bathtub).
  - Example shows 0.56% errors introduced by SERDES @ 11.3MHz Loop BW

(Floor set to 1e-16 to speedup simulation time)



ISI 0.3UIp-p, Input BER=5.6e-3

BW [MHz]	Out BER / In BER
4.6	1.0026
7.2	1.0037
11.3	1.0056

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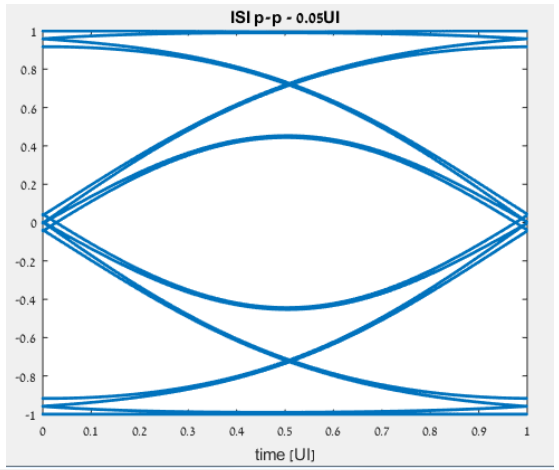
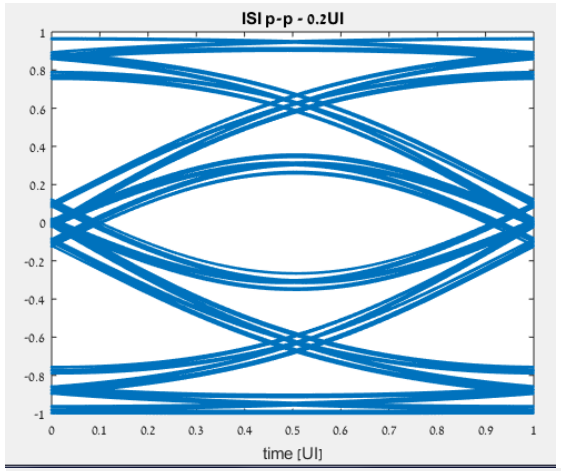
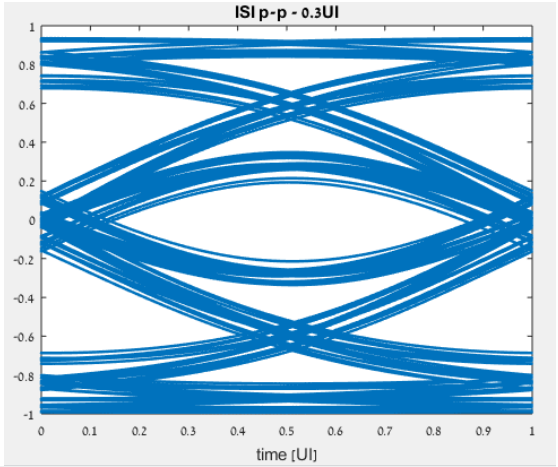
Example ISI @ Input BER 5.6e-3

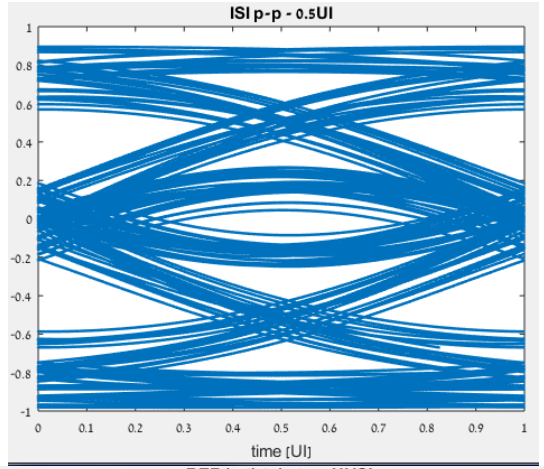
- Adjust Rj for constant BER with different ISI/DJ.
- Noise RMS is computed to achieve target BER per signal ISI condition.
- Bathtub curve calculated from eye

Eye with ISI (no RJ)

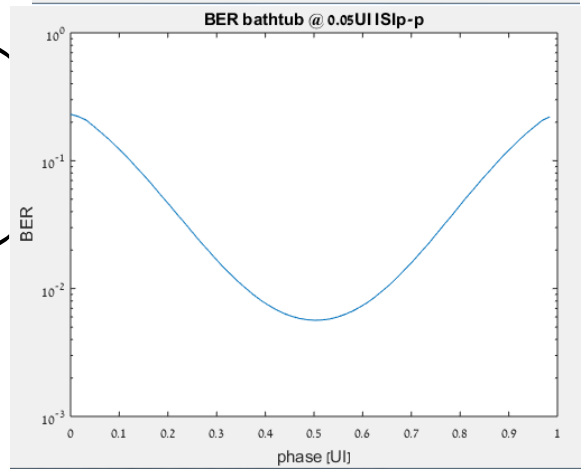


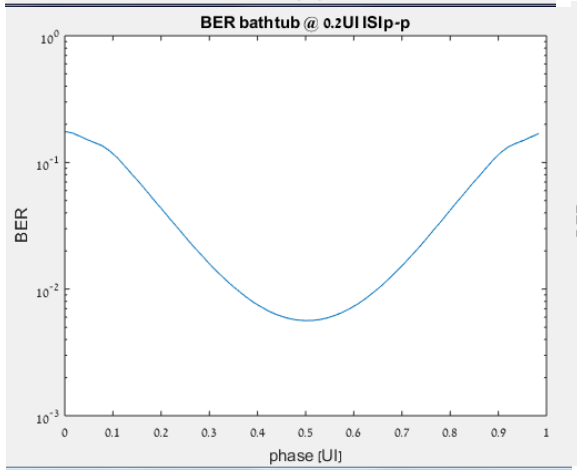


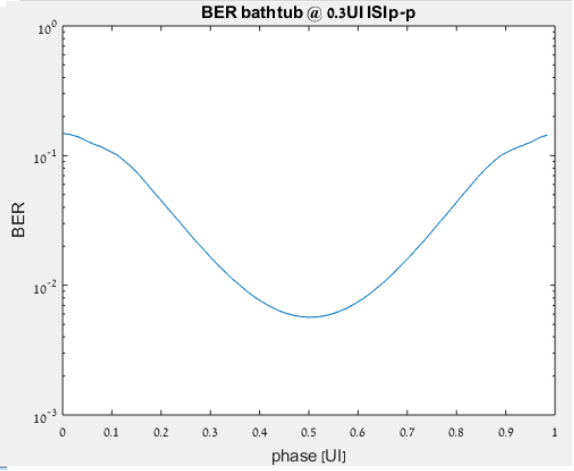


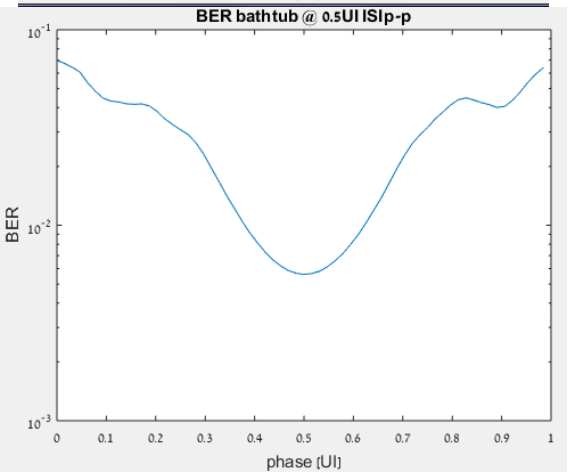


Bathtub(with RJ)









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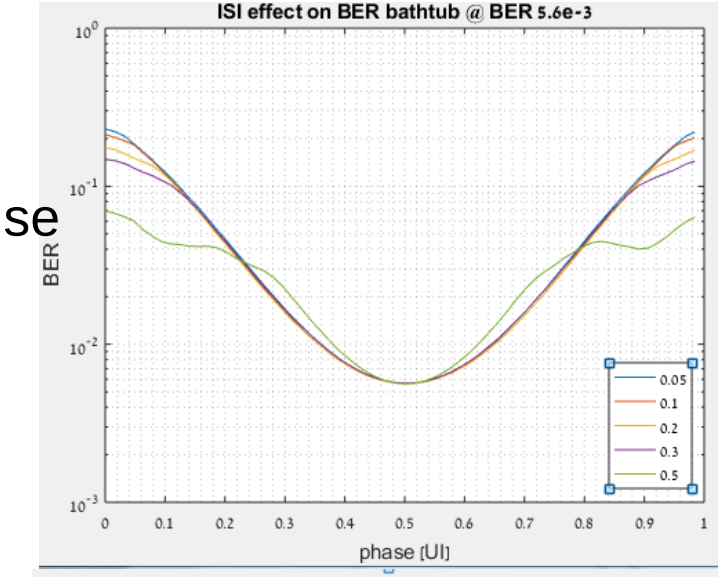
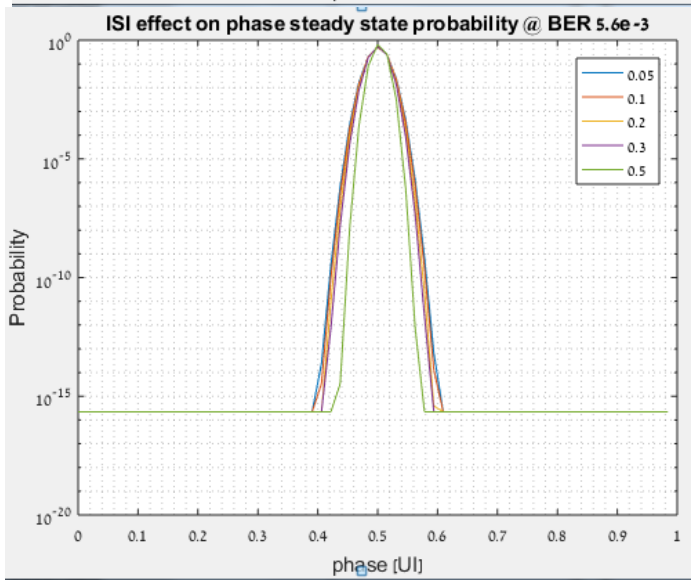
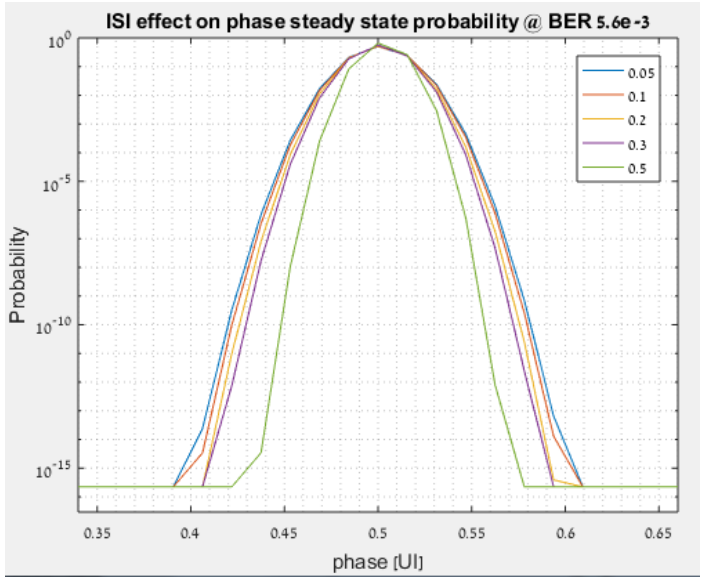
Sweep ISI @ Input BER 5.6e-3

- Results of sweeping ISI/RJ
  - Worst case is small ISI, high RJ
  - Expected since ISI is bounded noise under constant BER

ISI p-p	Noise/Noise @ISI=0.05 [dB]	Out BER / In BER
0.05	0	1.0045
0.1	-1.322	1.0040
0.2	-3.399	1.0038
0.3	-4.839	1.0037
0.5	-12.884	1.0035







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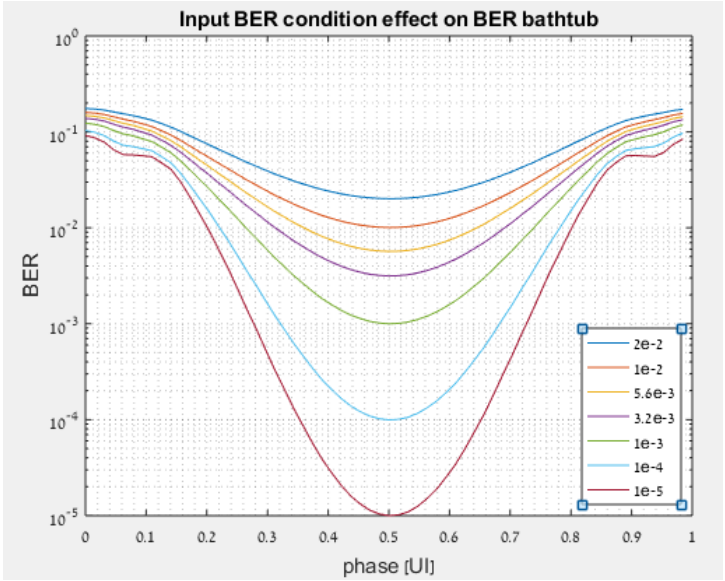
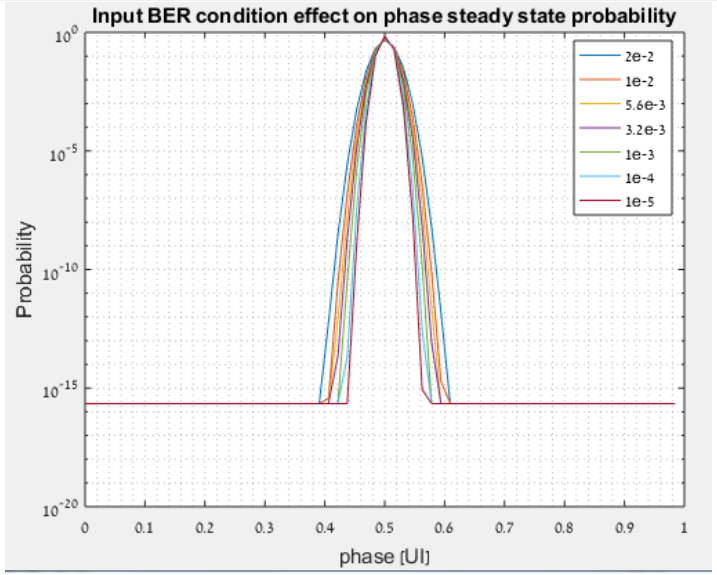
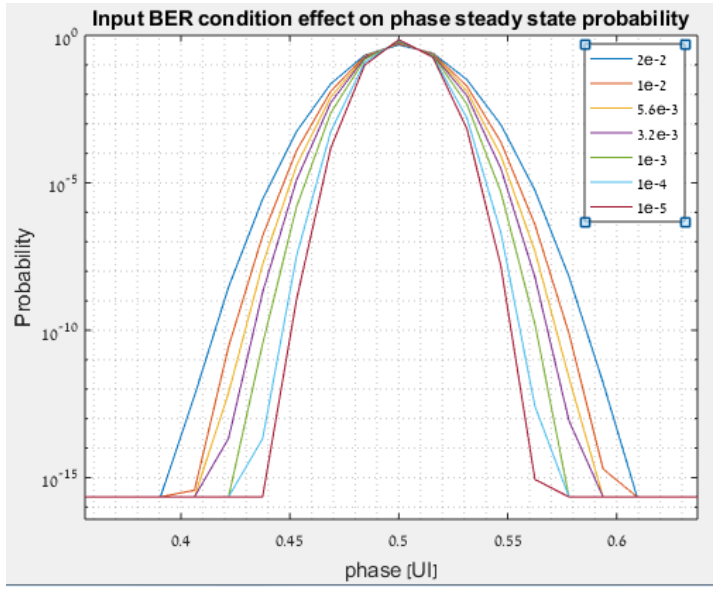
Sweep Input BER @ ISI 0.3UIp-p

- Results of BER
  - Ratio of BER Out to BER In is decreasing with increasing BER
  - Unexpected. This is due to flattening of bathtub curve.

In BER	Out BER / In BER
2e-2	1.0030
1e-2	1.0033
5.6e-3	1.0037
3.2e-3	1.0041
1e-3	1.0048
1e-4	1.0062
1e-5	1.0075







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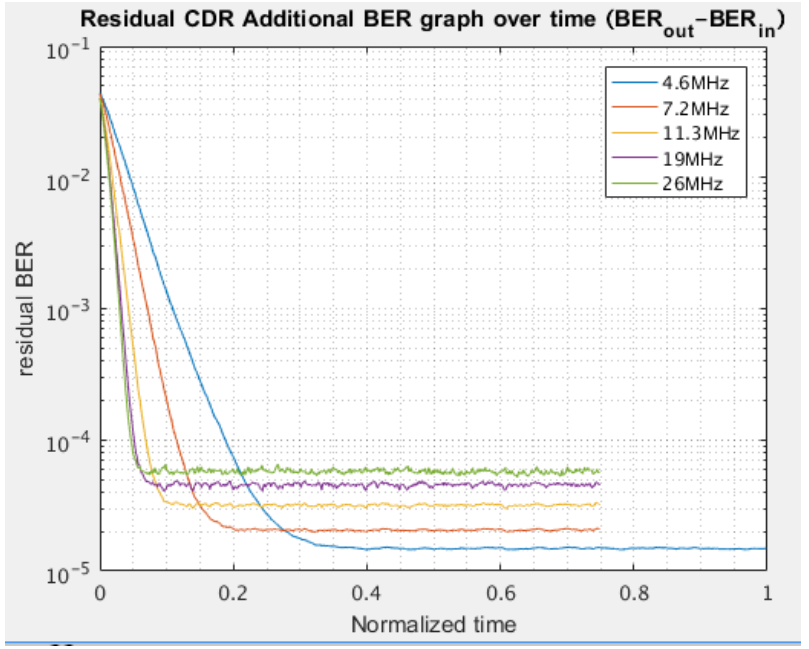
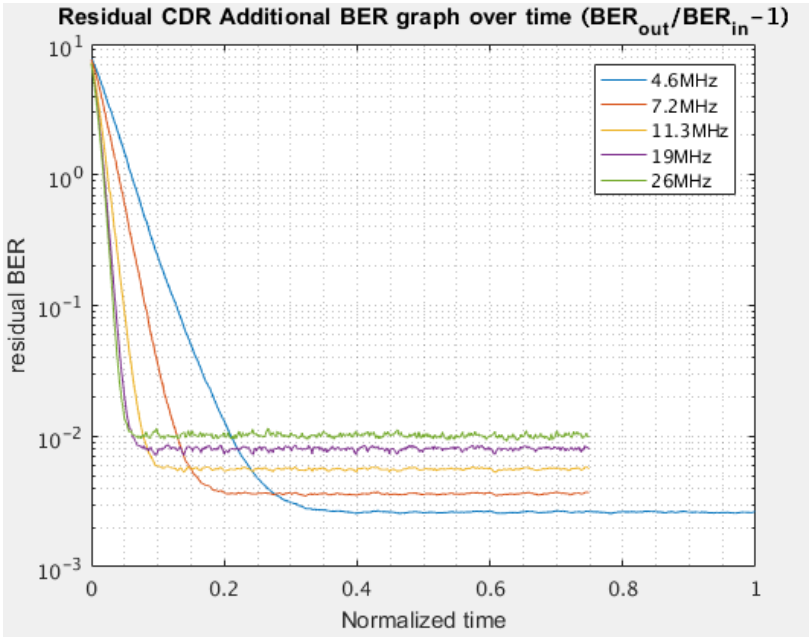
BCDR mode

- Locking accuracy is tied to the statistical confidence of the phase error
  - Recall that more integration time (lower loop BW) is required to filter the tail of the RJ probability curve.
  - Inverse of loop BW is time.
    - i.e.10MHz = 100ns(0.1 simulation time)
  - The loop filter is reset at the beginning of a burst since phase position in unknown.
    - Starts integration time of loop filter
- This is not the CDR lock time
  - This does not include initial eye centering
  - This does not include AGC, equalization, or other settling time effects.
- Summary
  - Accuracy is statistically limited at the start of burst
  - Higher BER until loop BW target is achieved





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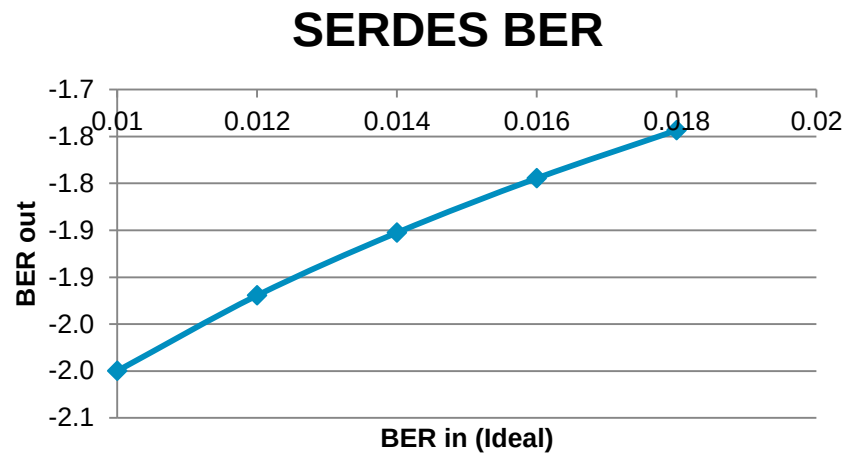
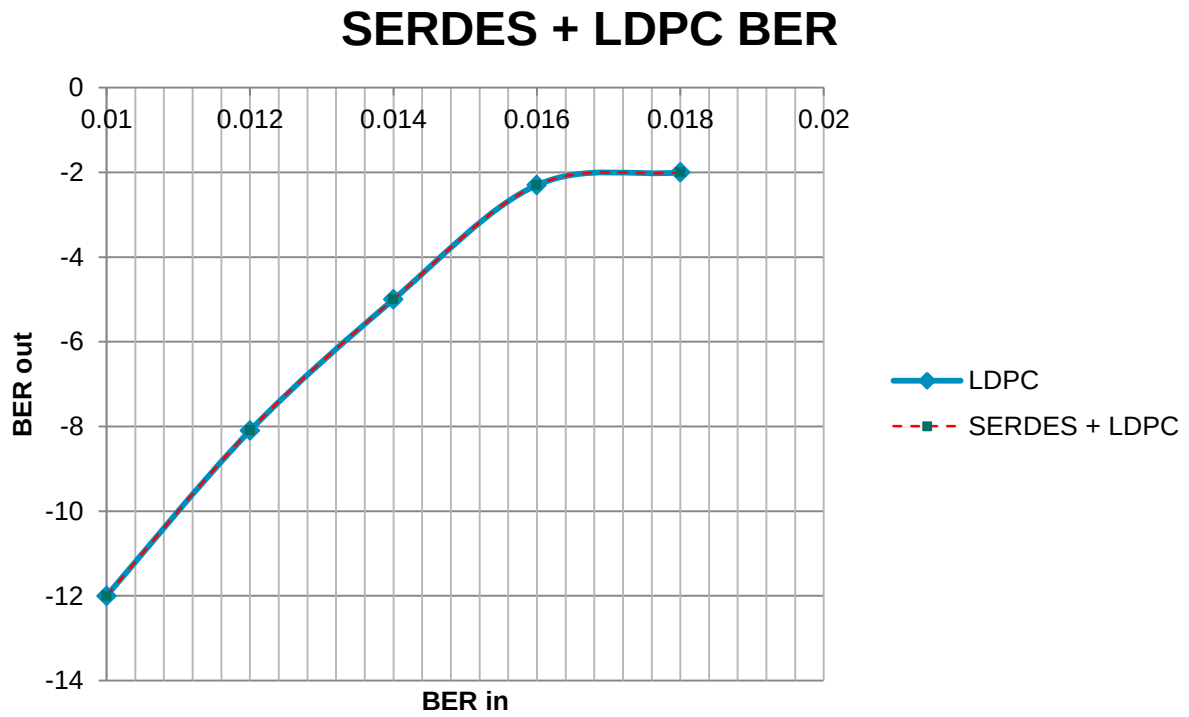
Impact on FEC

- Adding SERDES BER to LDPC gain curve show virtually no impact to system performance.

(Shifts curve 0.4% to the left)





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Summary

- CDR performance
  - CDR remains locked with >1E-15 probability
  - Errors introduced by non-ideal sampling of CDR is small <0.4%
  - Errors have negligible impact on FEC gain
- BCDR performance
  - BER is influenced by sync time
  - Effectively increases loop BW.
  - Incremental increase in BER is small.
- Operating at BER 1E-2 is not a problem
  - SERDES will lock
  - Additive BER by SERDES is small