# Performance Analysis of Edge-based DFE

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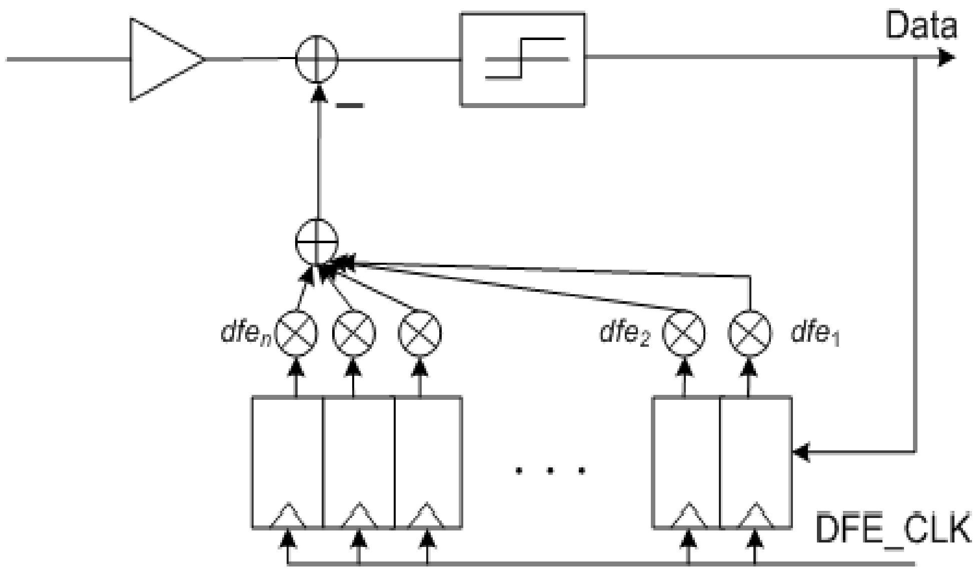
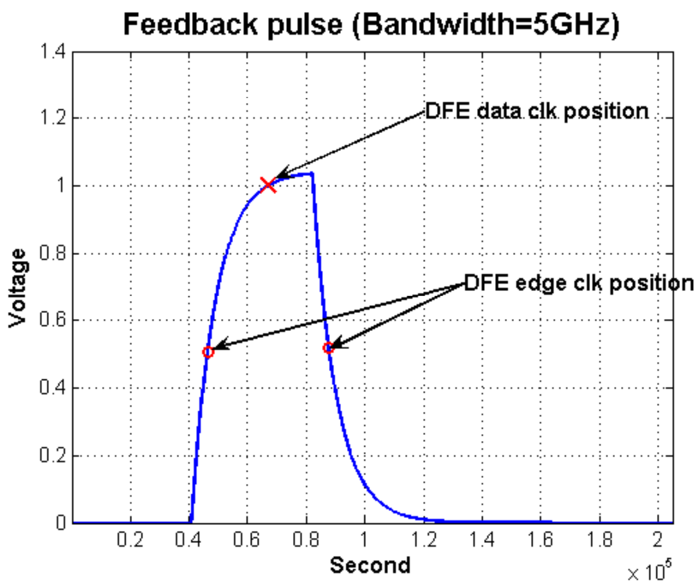
# Conventional DFE Architecture

- **Each DFE tap is an estimation of the ISI contribution from previous bits.**
- **DFE weights are current-summed with the received signal.**
- **DFE clock is adjusted so that the transitions of the DFE correction pulses are phase aligned with the transitions of the input data.**



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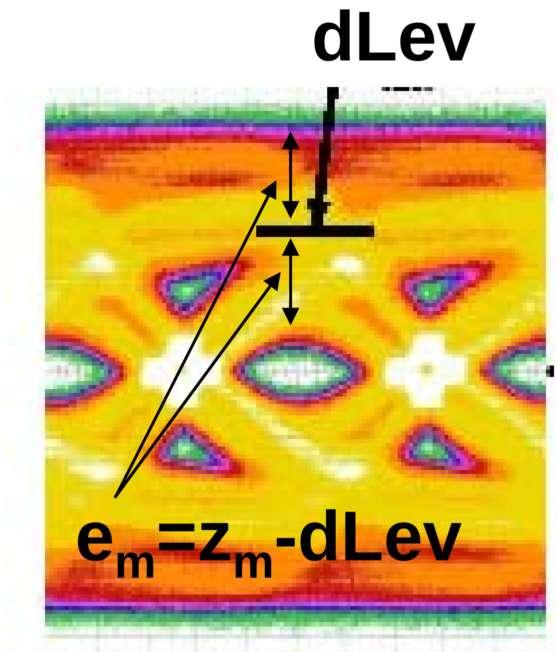
# Conventional Data-based DFE

- **DFE tap weights are directly estimated from ISI contributions at the data time.**

$$dfe_k^{j+1} = dfe_k^j + \mu \,\mathrm{sgn}(z_m - dLev^j)\,\mathrm{sgn}(a_{m-k})$$

$$dLev^{j+1} = dLev^j - \lambda \,\mathrm{sgn}(z_m - dLev^j)$$




- **DFE tap weights converges to the ISI components.**

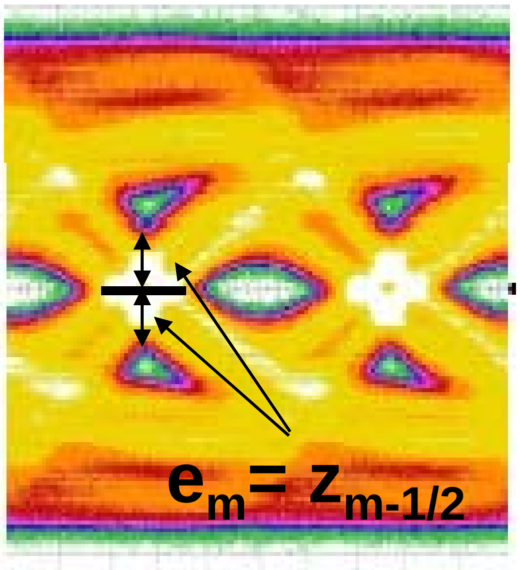
$$dfe_k = \varphi(t_s + kT)$$

- **Need an adaptive sampler placed at dLev to measure error signal.**

# Edge-based DFE (TI, designCon'04)

- **DFE tap weights are estimated from ISI contributions at the edge time.**

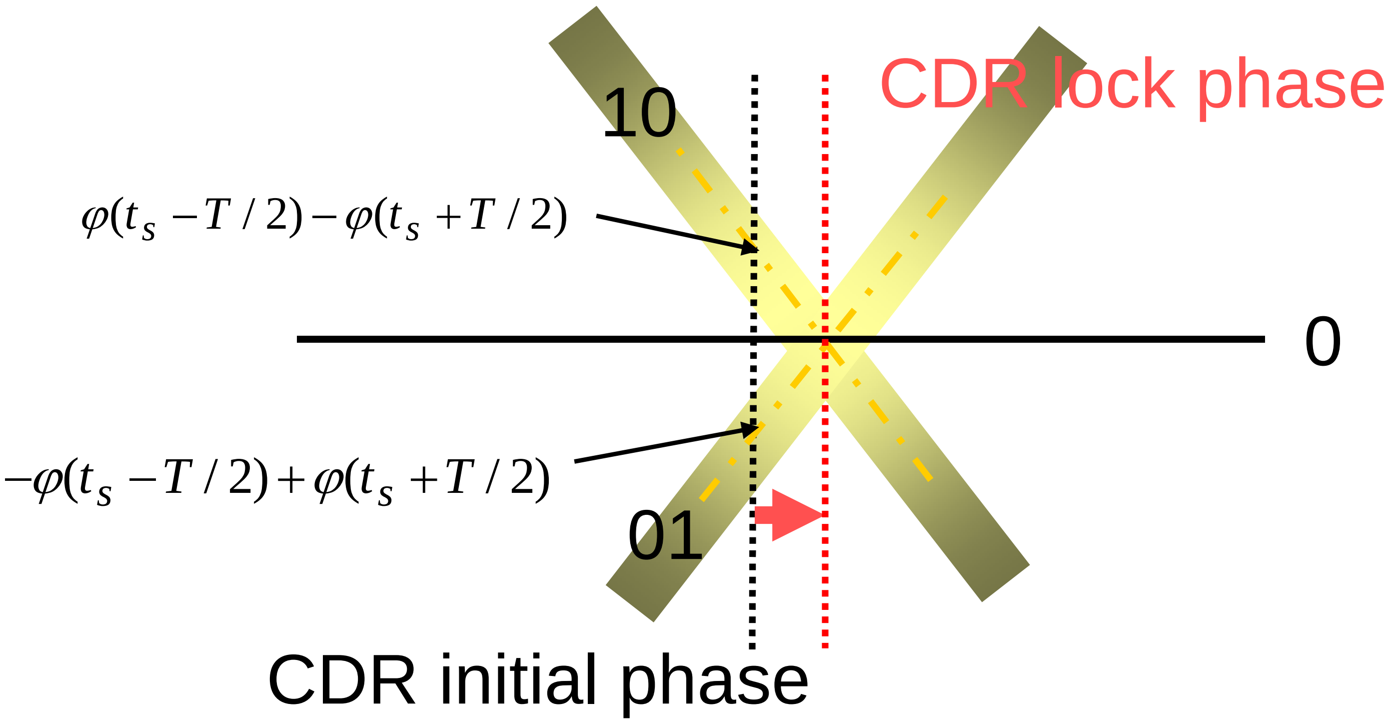
$$dfe_k^{j+1} = dfe_k^j + \mu \operatorname{sgn}(z_{m-1/2}) \operatorname{sgn}(a_{m-k} + a_{m-k-1})$$




- **DFE tap weights are adapted to minimize edge ISI.**
- **Less hardware compared with data-based DFE.**

# CDR Locking Phase

- **CDR locks to the phase where** $\varphi(t_S - T/2) - \varphi(t_S + T/2) = 0$



# E-DFE Steady-State Solution

- **The transition sample preceding the m-th data sample is:**

$$z_{m-1/2} = a_m \varphi(t_s - T/2) + a_{m-1}\{\varphi(t_s + T/2) - dfe_1/2\} + \sum_{k=1\ldots} a_{m-1-k}\{\varphi(t_s + T/2 + kT) - (dfe_k + dfe_{k+1})/2\}$$

- **The first DFE tap moves the CDR locking phase:**

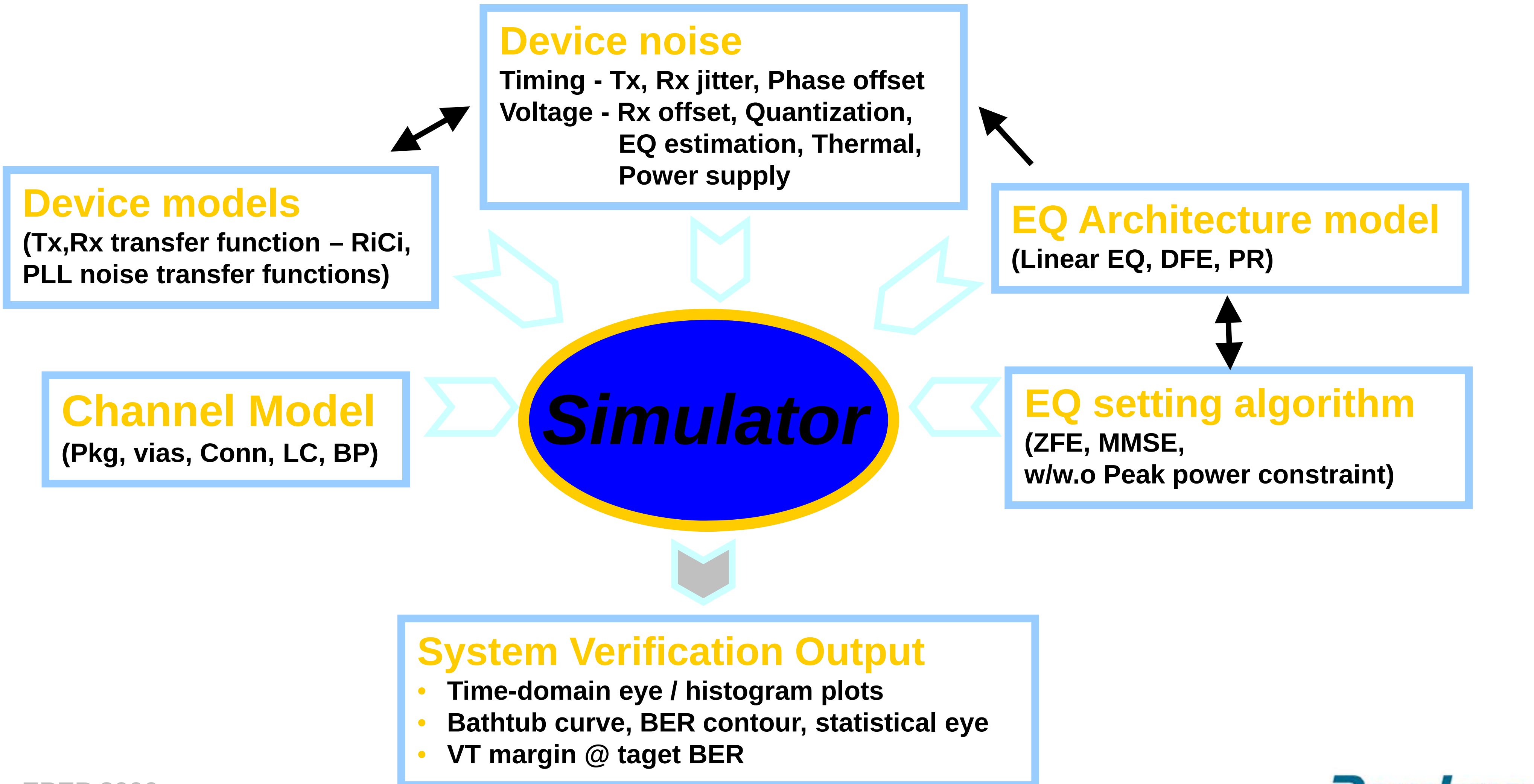
$$\varphi(t_s - T/2) - (\varphi(t_s + T/2) - dfe_1/2) = 0$$

- **The edges of the two adjacent DFE pulses are used to cancel one edge ISI.**

$$dfe_n = 2\varphi(t_s + T/2 + nT)$$
$$dfe_k = 2(\varphi(t_s + T/2 + kT) - dfe_{k+1}/2), \quad 1 \le k < n$$

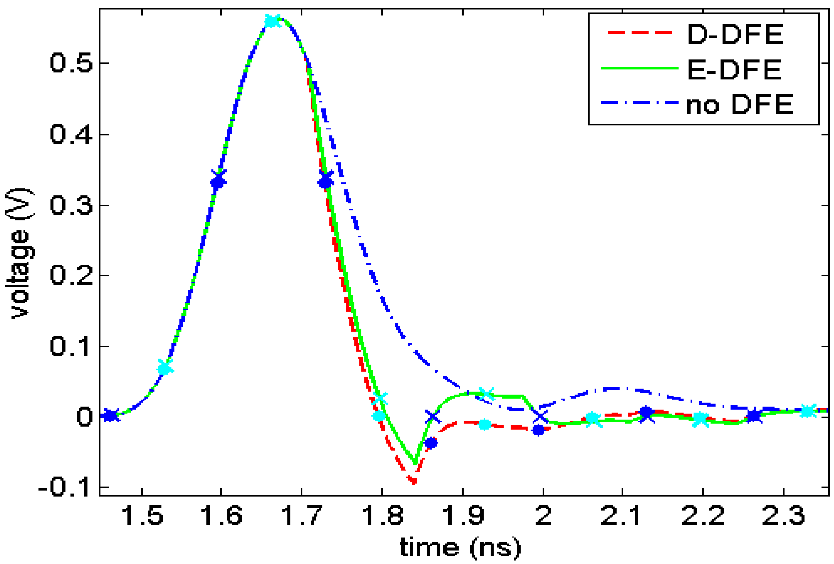
# Simulation Environment

- **Used in-house link performance analysis tool.**

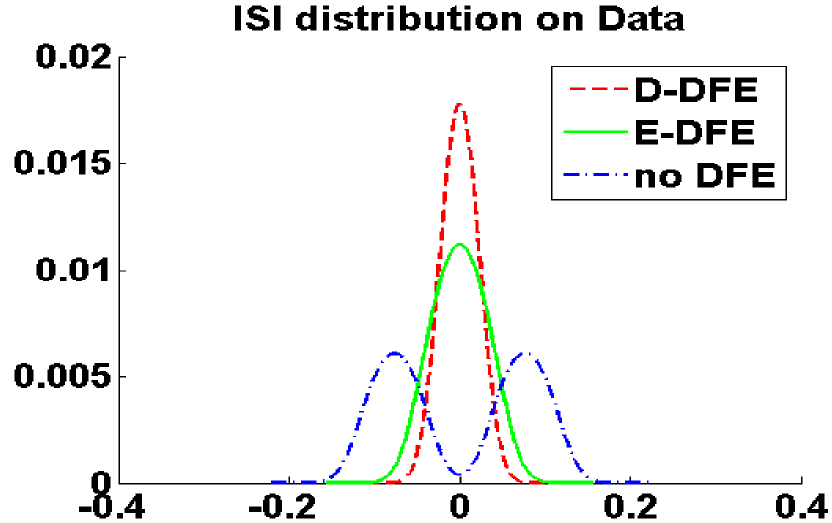


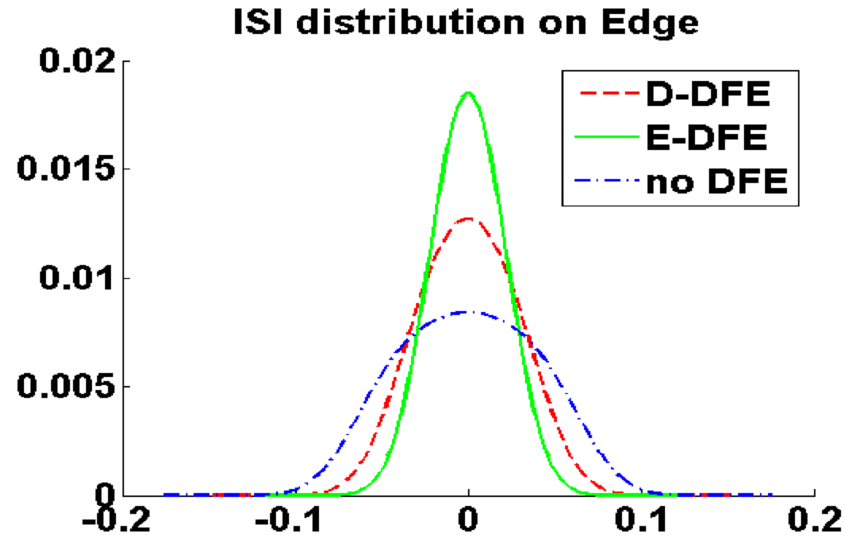
# Simulation Results (1)

## Single bit responses




**Blue markers: edge samples**
**Cyan markers: data samples**



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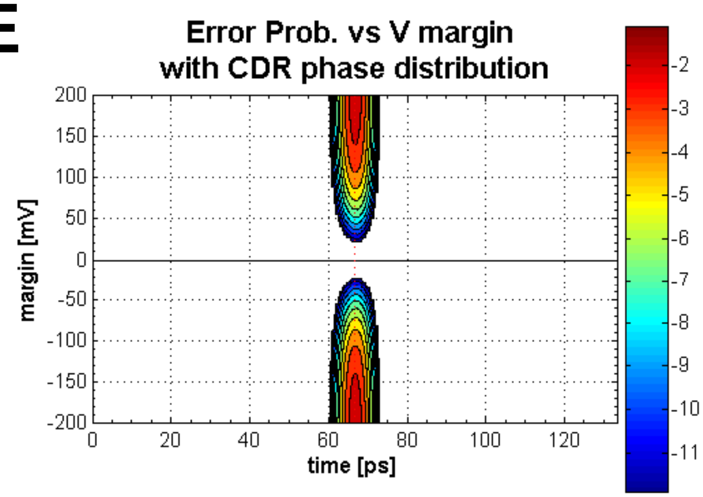
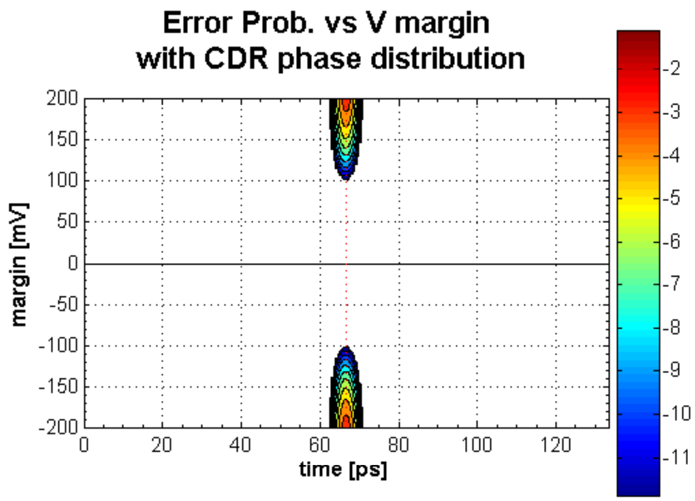
# Simulation Results (2)

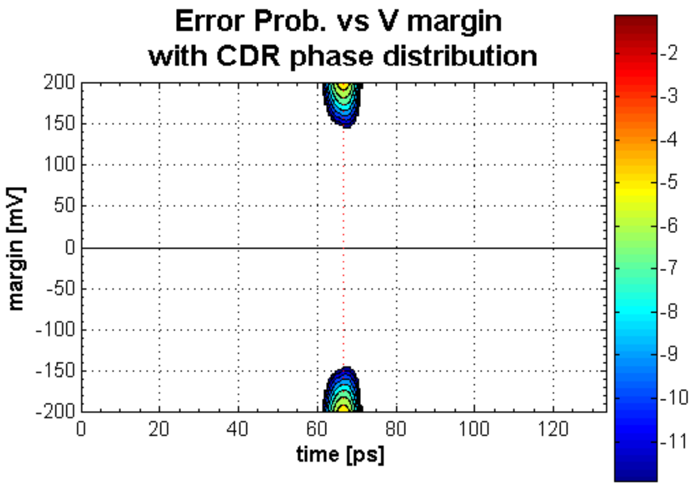
## no DFE




## E-DFE

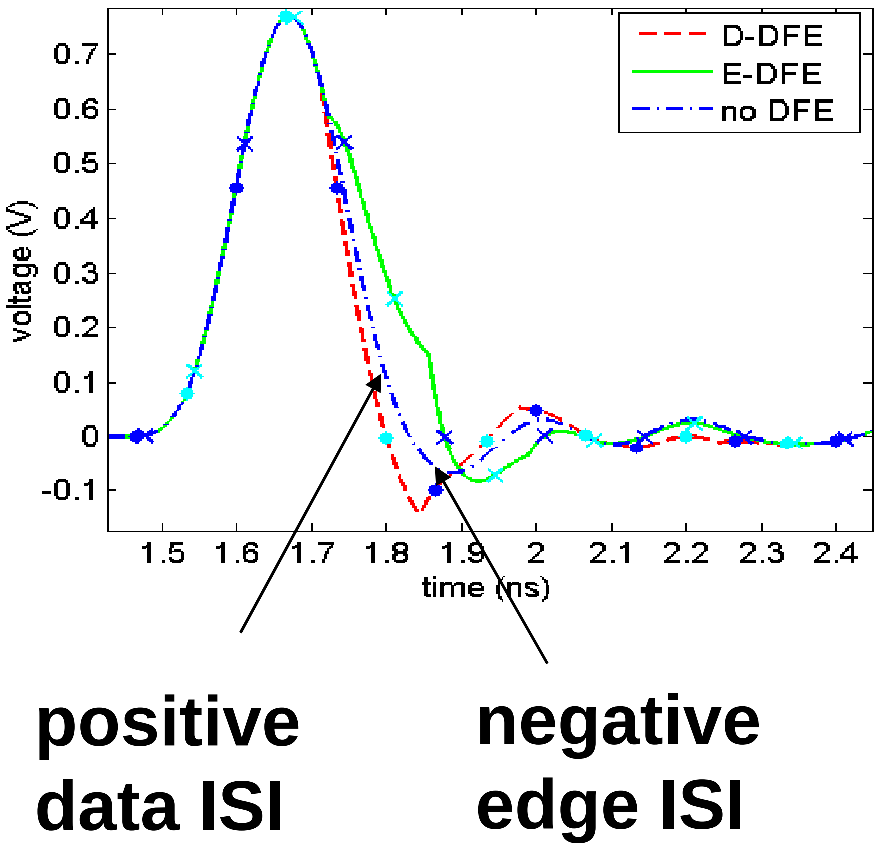



## D-DFE



# Simulation Results (3)

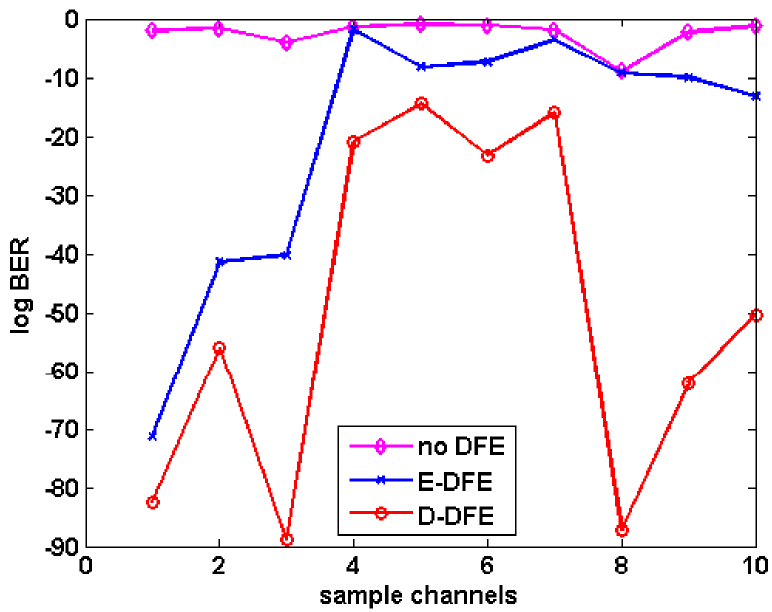
**Blue markers: edge samples**
**Cyan markers: data samples**



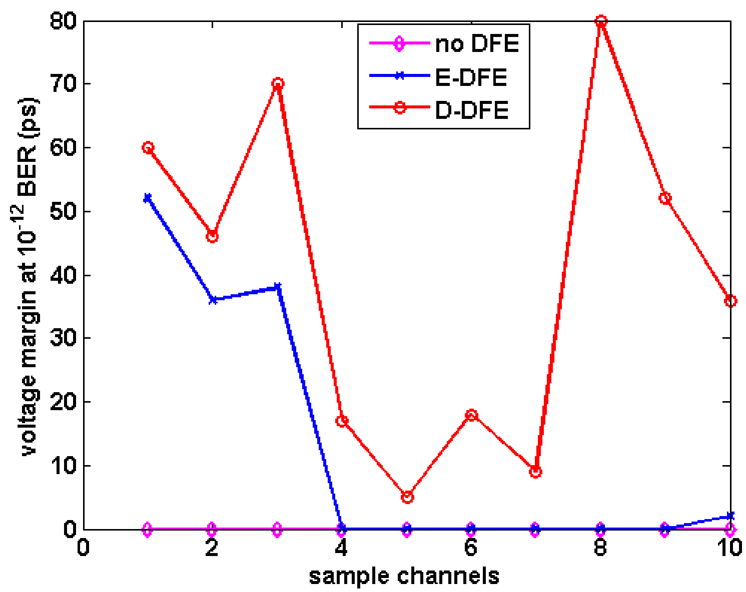

- **Edge ISI is not positively correlated with data ISI.**
- **Cancelling edge ISI results in adding more ISI to the data time.**
- **For this channel, E-DFE degrades BER.**

# Simulation Results (4)

**BER**




**voltage margin**




- **Regression data across 10 different channels at 7.5G (no linear EQ).**
- **E-DFE performs ok for some channels. For all the channels we've examined (with or without linear EQ), D-DFE outperforms E-DFE.**

# Conclusion

- **Simulation Results show that D-DFE offers better performance than E-DFE.**
- **E-DFE improves BER compared with no DFE in some channels.**
- **For some channels, E-DFE can even degrade the BER by introducing more ISI at the center of the eye.**