ICCD 2003

Paradigm Shift For Jitter And Noise In Design And Test > 1 Gb/s Communication Systems

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Purposes

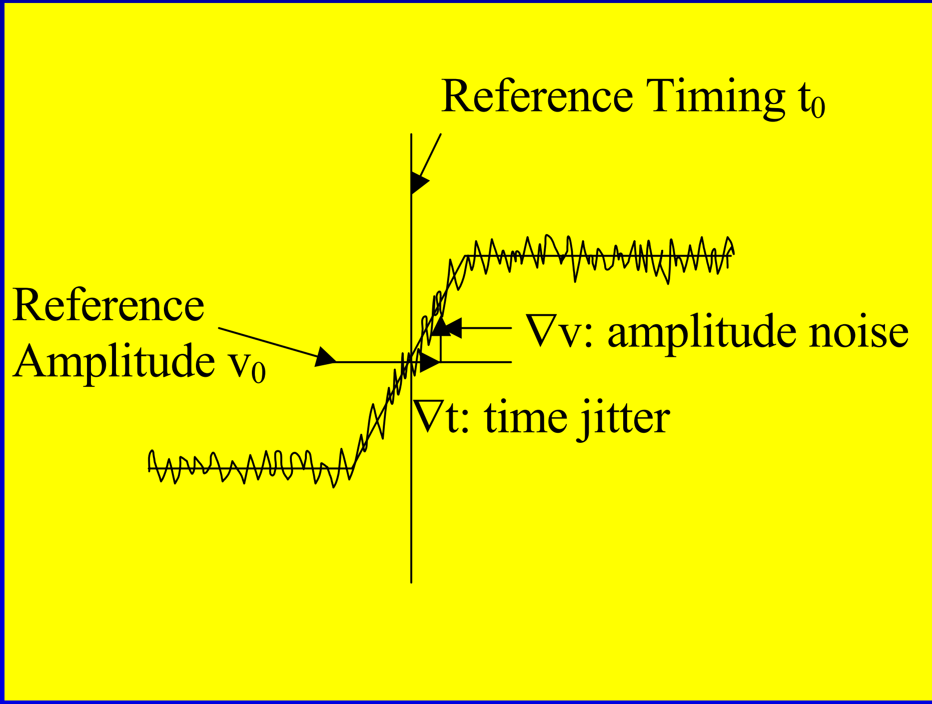
- Illustrate the shortfalls of simple parametric based jitter/noise analysis methods (Peak-to-Peak or RMS only)
- Introduce the PDF and CDF based statistical jitter/noise analysis methods
- Introduce the jitter/noise transfer function and its role in serial data link
- Apply both statistical analysis and transfer function for jitter, noise, and BER in modeling and testing > 1 Gb/s systems

Outline

- Overview of jitter and noise basic
- Shortfalls for parametric peak-to-peak
- PDF and CDF functions jitter, noise, and BER
- Overview of serial communication systems
- Jitter/noise transfer function
- Methods for estimating and testing jitter, noise, and BER
- Conclusion

Jitter And Noise Basics

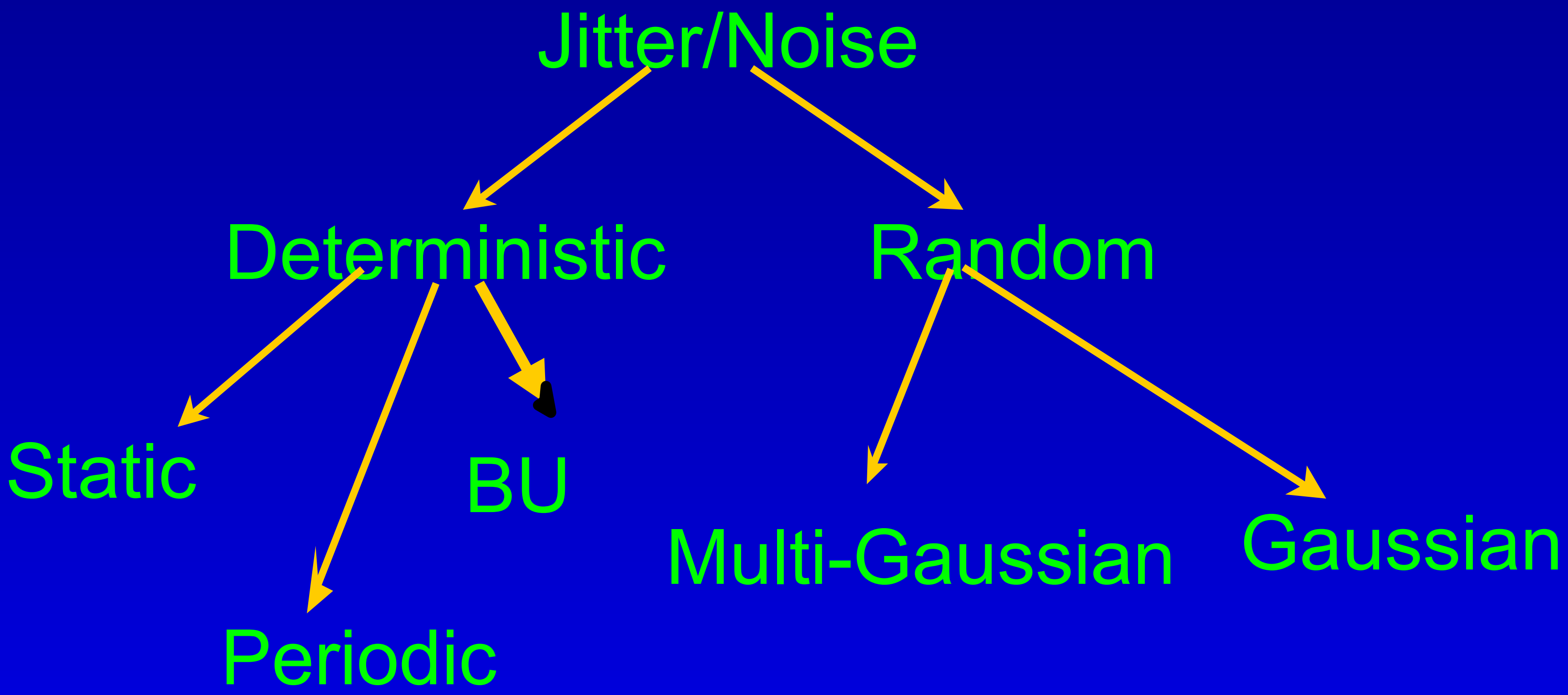
- Timing Jitter : Any deviation from ideal timing
- Amplitude Noise: Any deviation from ideal amplitude
- Timing jitter occurs when there is an edge transition
- Amplitude noise is a constant activity



Jitter And Noise Viewed From Signal Theory

- Jitter/noise is a statistical process
- Jitter/noise has a distribution
- Jitter/noise has many different components
- Jitter/noise can only be completely quantified by its PDF !!!

Jitter Classification Scheme (Statistical Based)



BU: Bounded uncorrelated

Relationship Between Total PDF And Component PDFs: ***Convolution***

- An example for timing jitter PDF

$$p_{TJ}(t) = p_{RJ}(t) * p_{DJ}(t)$$

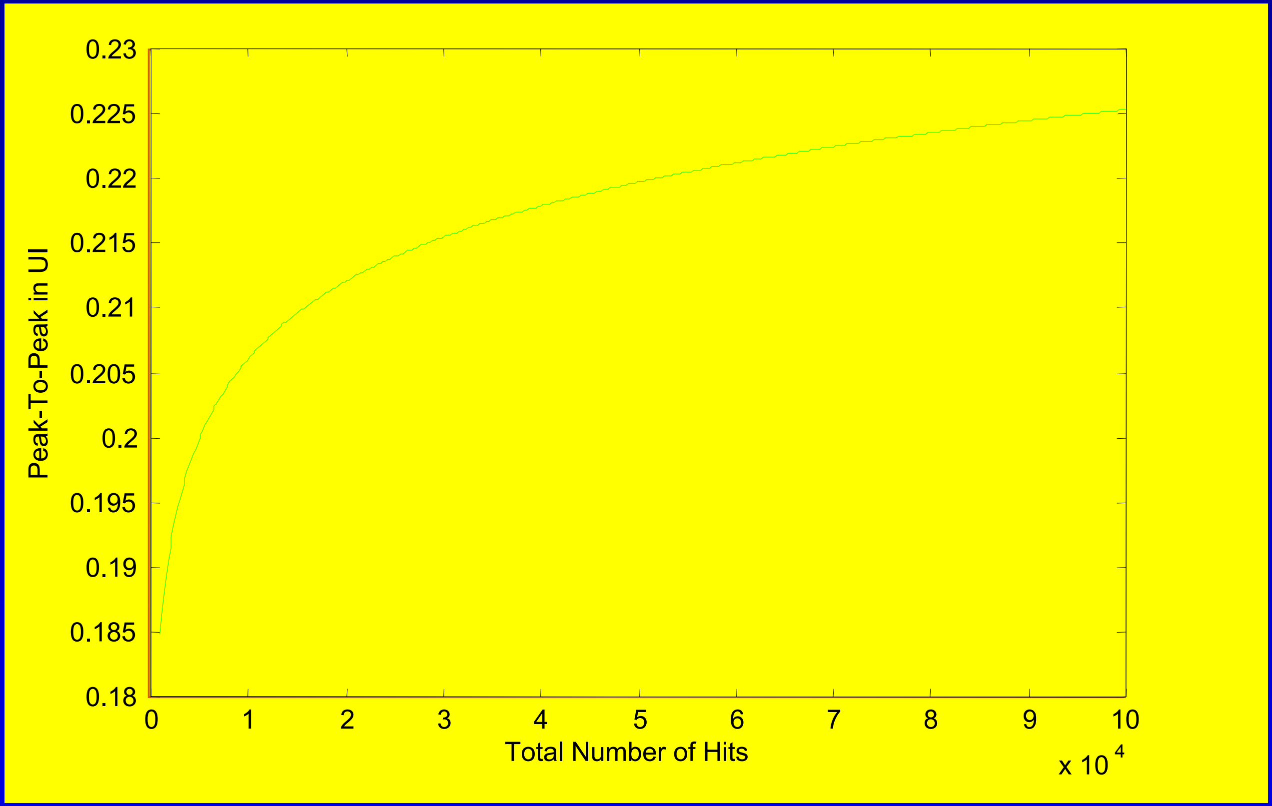
$$= \int_{-\infty}^{\infty} p_{DJ}(\tau) p_{RJ}(t-\tau) d\tau$$

Why *Deterministic* Parametric (i.e, Peak-To-Peak or RMS) No Longer Sufficient?

- Peak-to-peak or RMS alone ***cannot*** determine a general PDF
- Peak-to-peak will be an ***unstable*** and size ***sample size dependent*** estimation in the presence of random component
- RMS will be an ***inaccurate*** estimation for a Gaussian random in the presence of deterministic component

A Peak-To-Peak Shortfall Case Study

- Sample Size Dependency

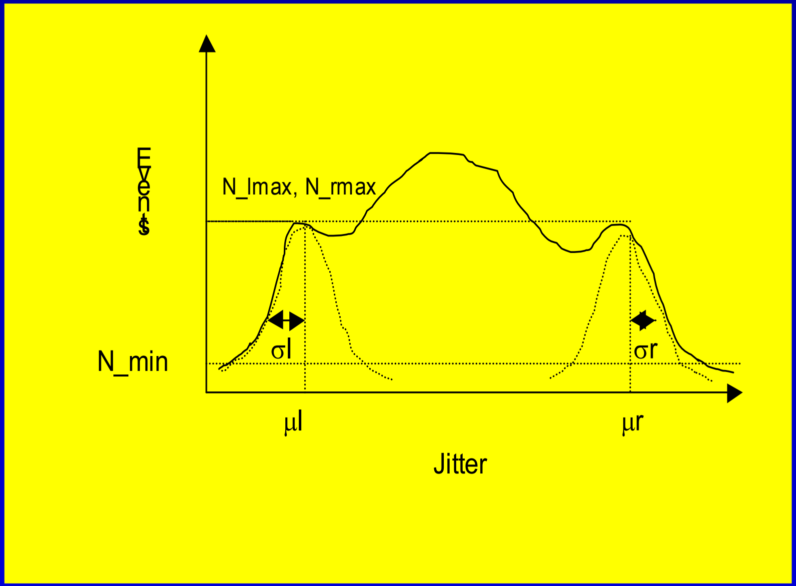


A RMS Shortfall Case Study

RMS ≠ RJ sigma

$$RMS = \sqrt{\frac{1}{N-1}\sum_{n=1}^{N} (\overline{\Delta t} - \Delta t_i)^2}$$

$$> \quad \sigma$$

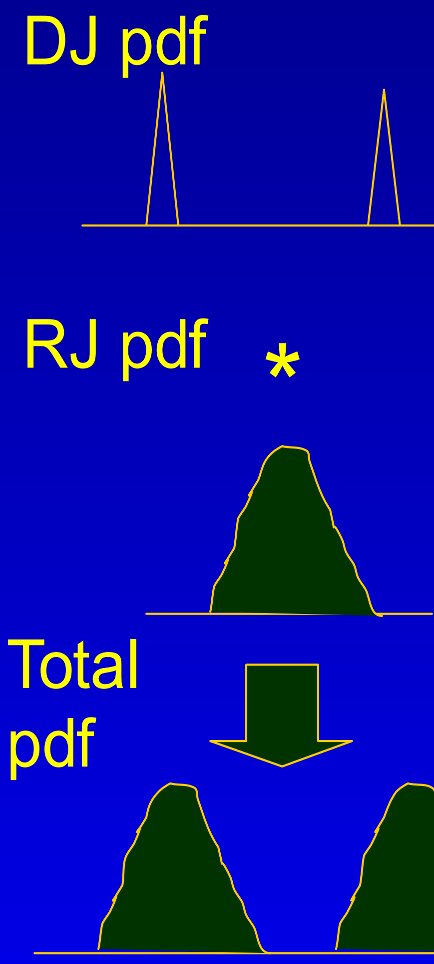


A Deterministic And Random PDF Estimation Method: TailFit (Patented)

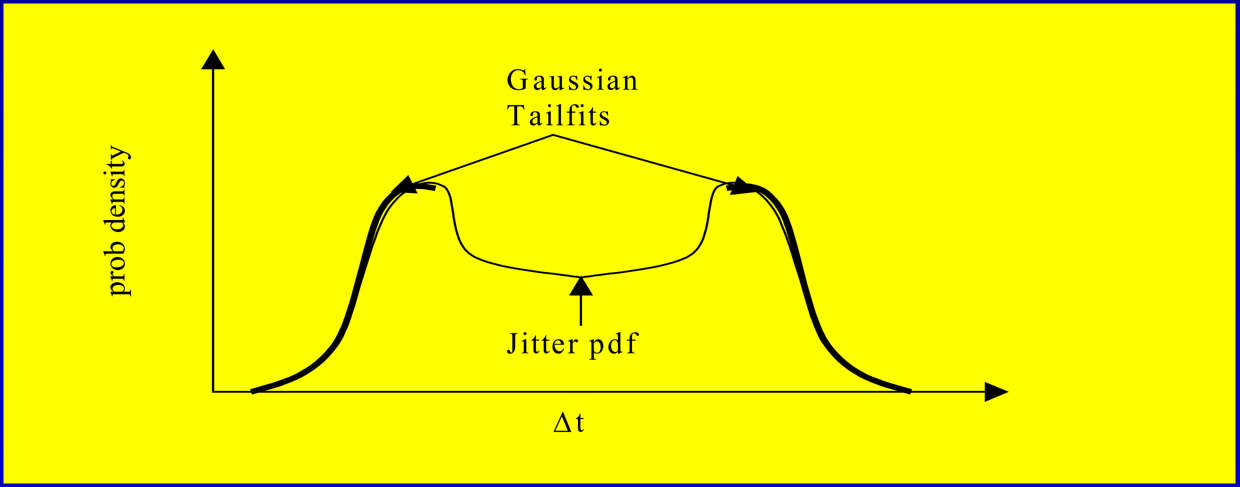
- Total jitter PDF = DJ PDF * RJ PDF
- RJ PDF is a Gaussian

$$p(\Delta t)=\frac{1}{\sqrt{2\pi}}e^{-\frac{(\Delta t-\mu)^2}{2\sigma^2}}$$

- ***Tail parts*** of distribution preserve information on RJ process.

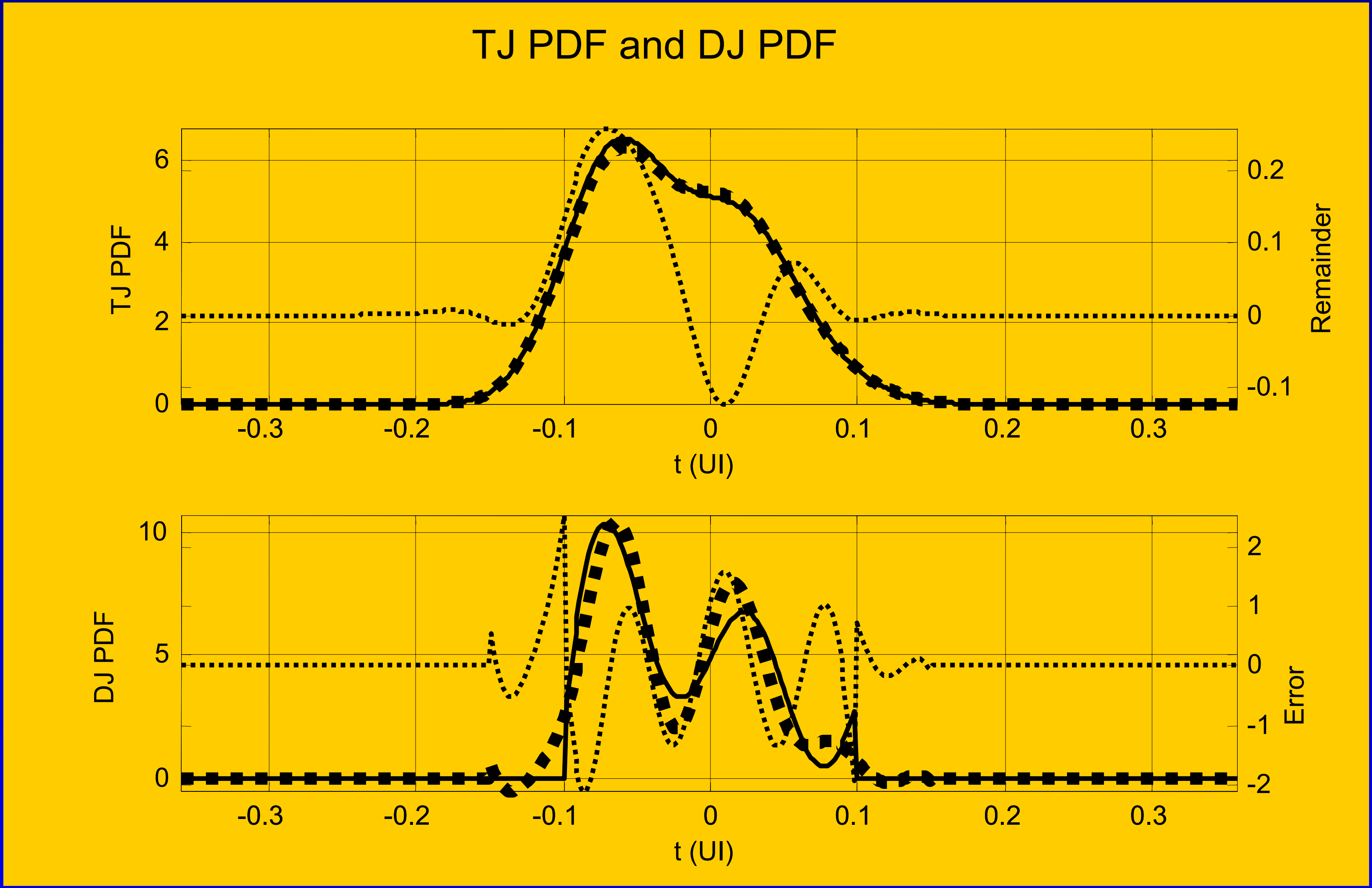


What Does The “TailFit” Offer ?

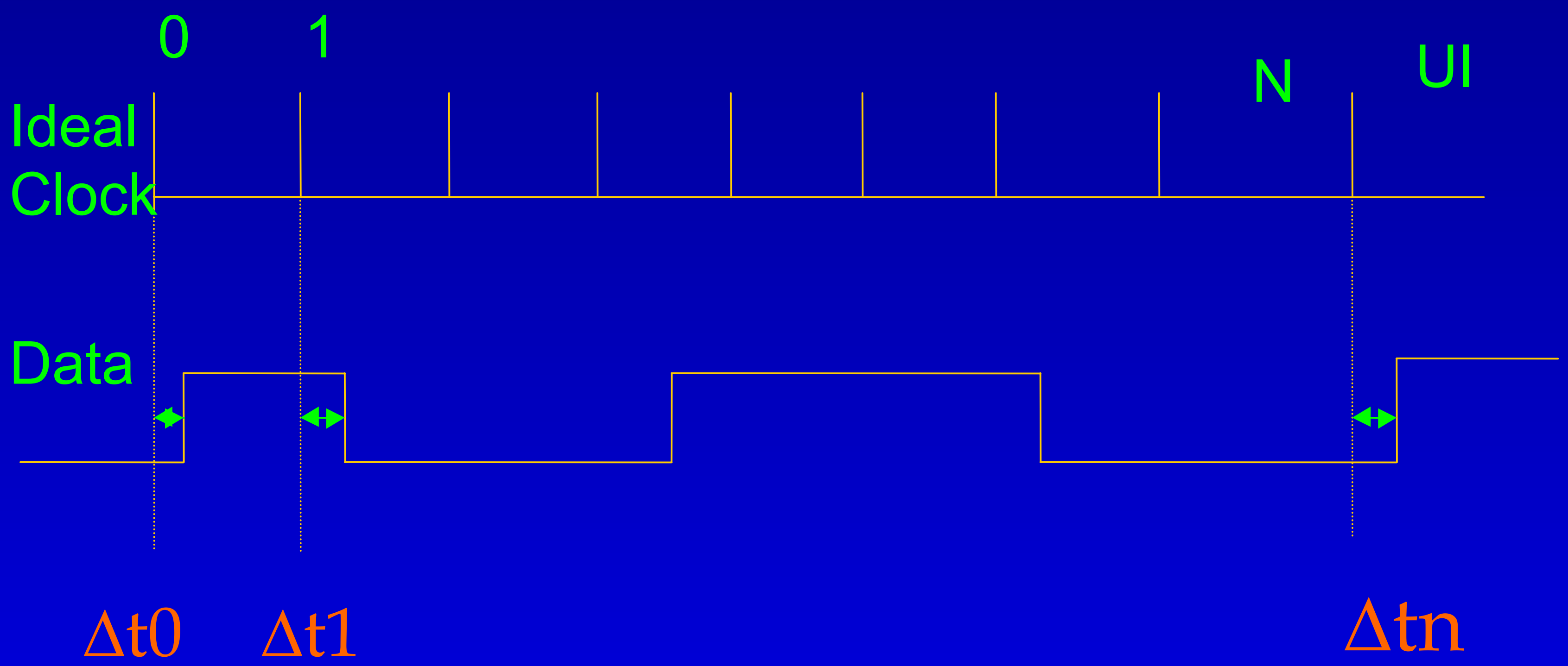


- RJ PDFS
- DJ PDF (via deconvolution)
- Subspace statistical parameters

DJ PDF Via Deconvolution

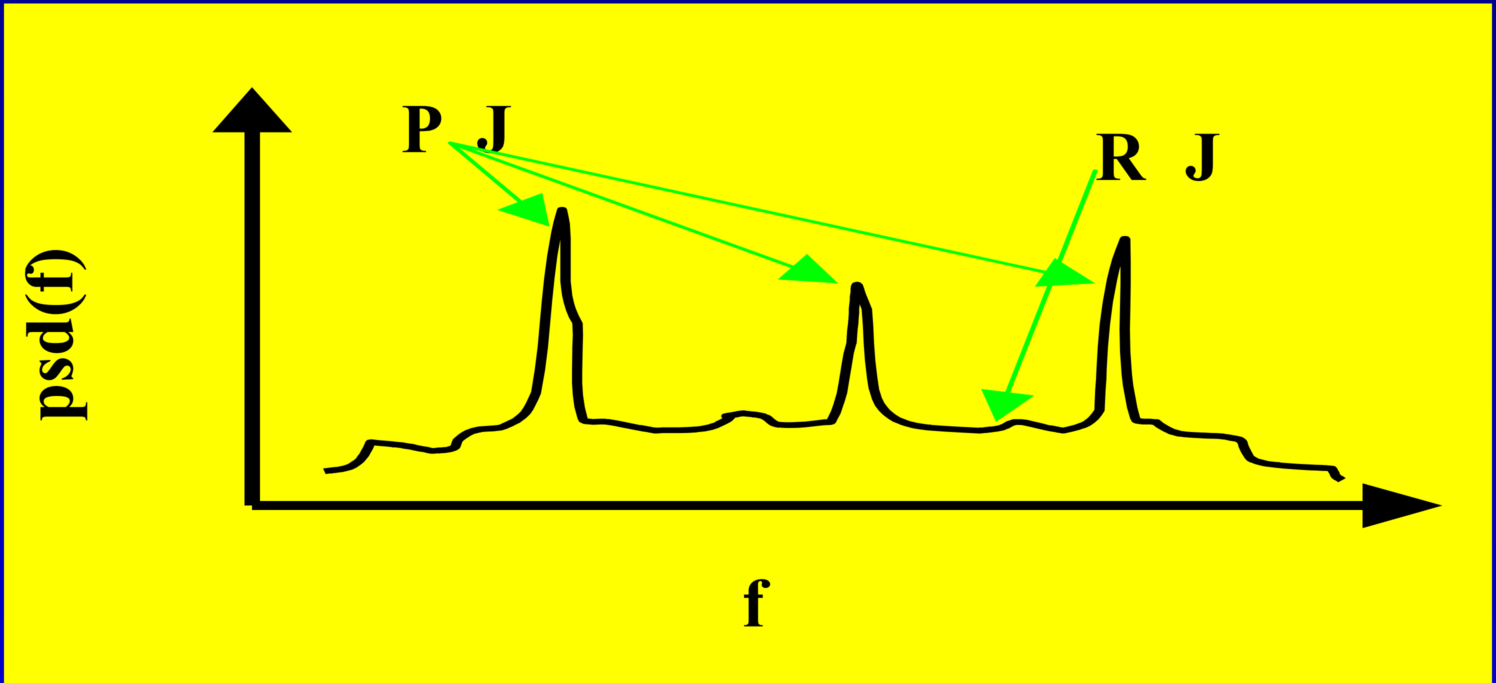


A Jitter/Noise Spectrum Estimation Method: Autocorrelation (Patented)



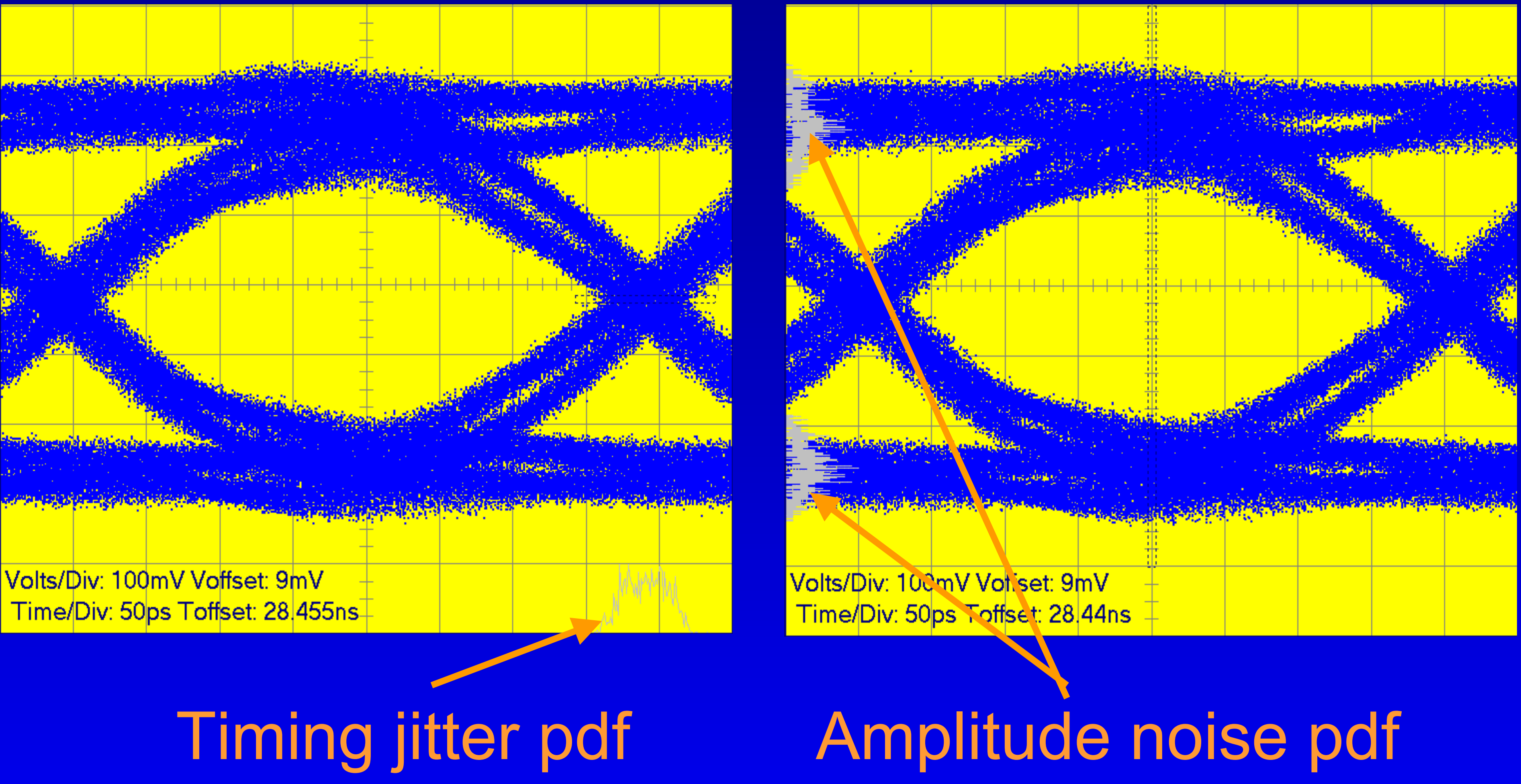
$$PSD(f) = FFT(c - 2 * Rxx(\Delta t(n)))$$

What Does The "Autocorrelation" Offer ?

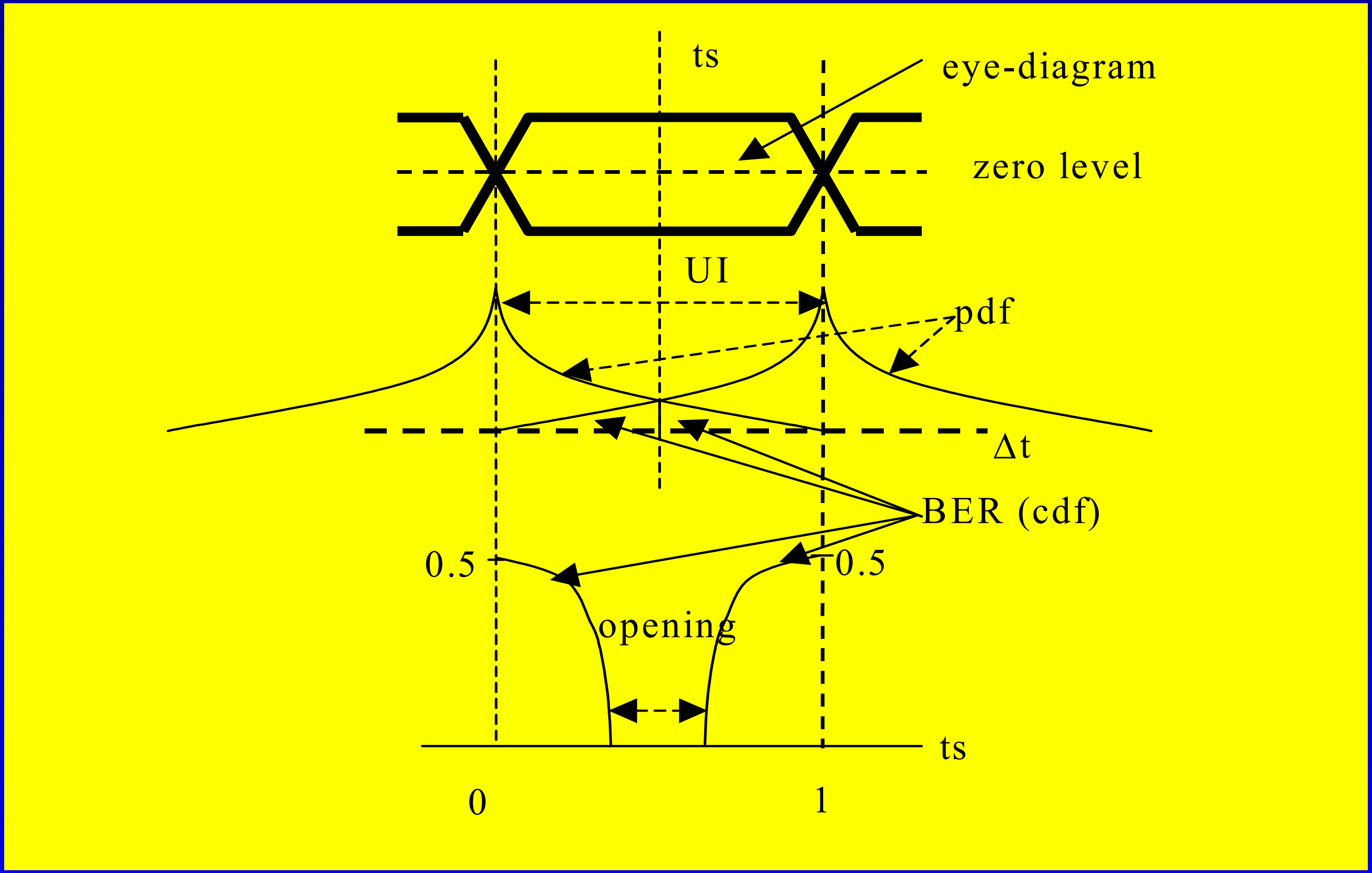


- RJ PSD
- PJ PSD
- DDJ (DJ without PJ and BUJ) PSD

Jitter And Noise In One View: Eye-Diagram



Jitter, Noise, And BER

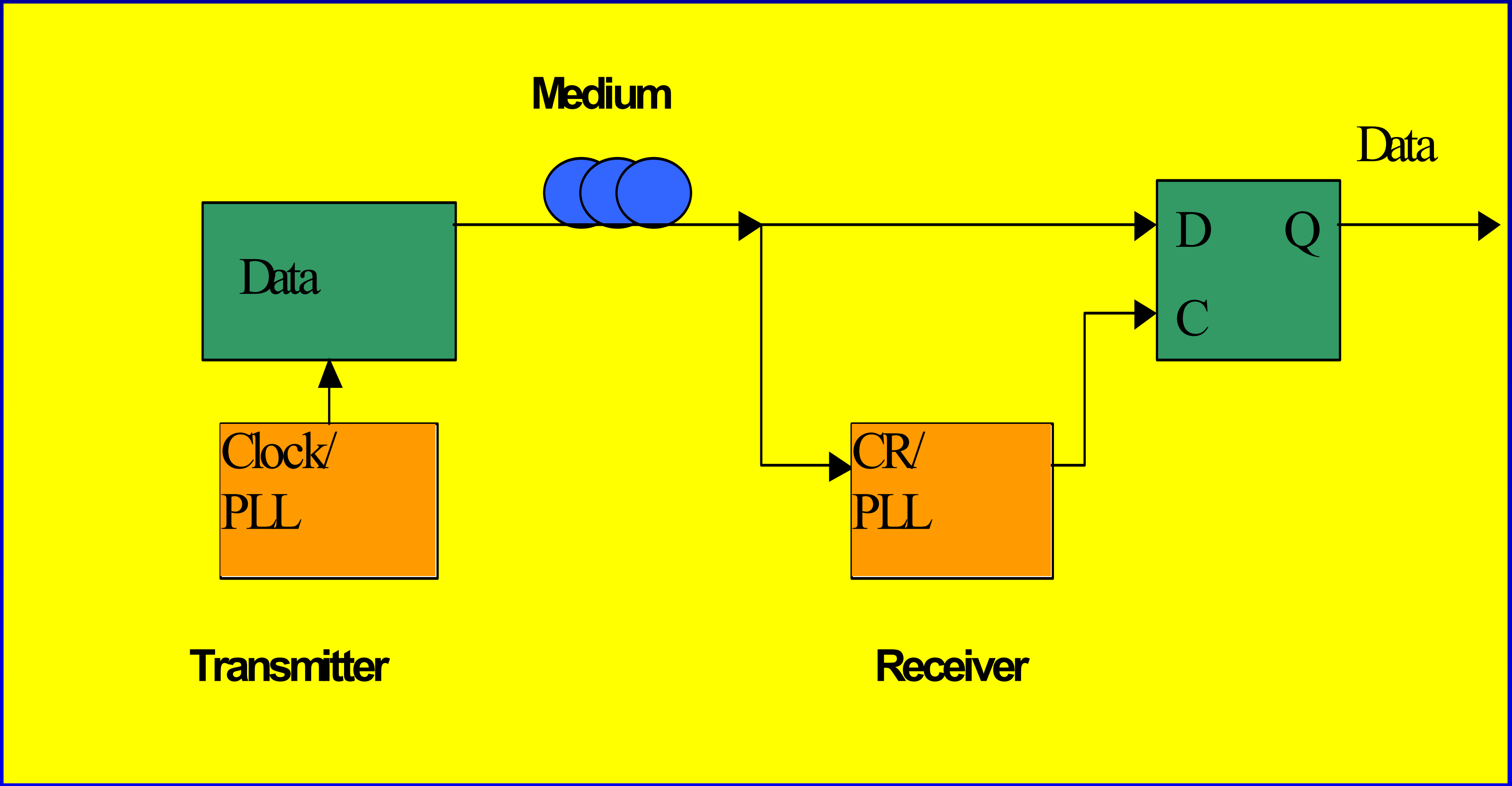


Jitter, Noise, And BER Cont…

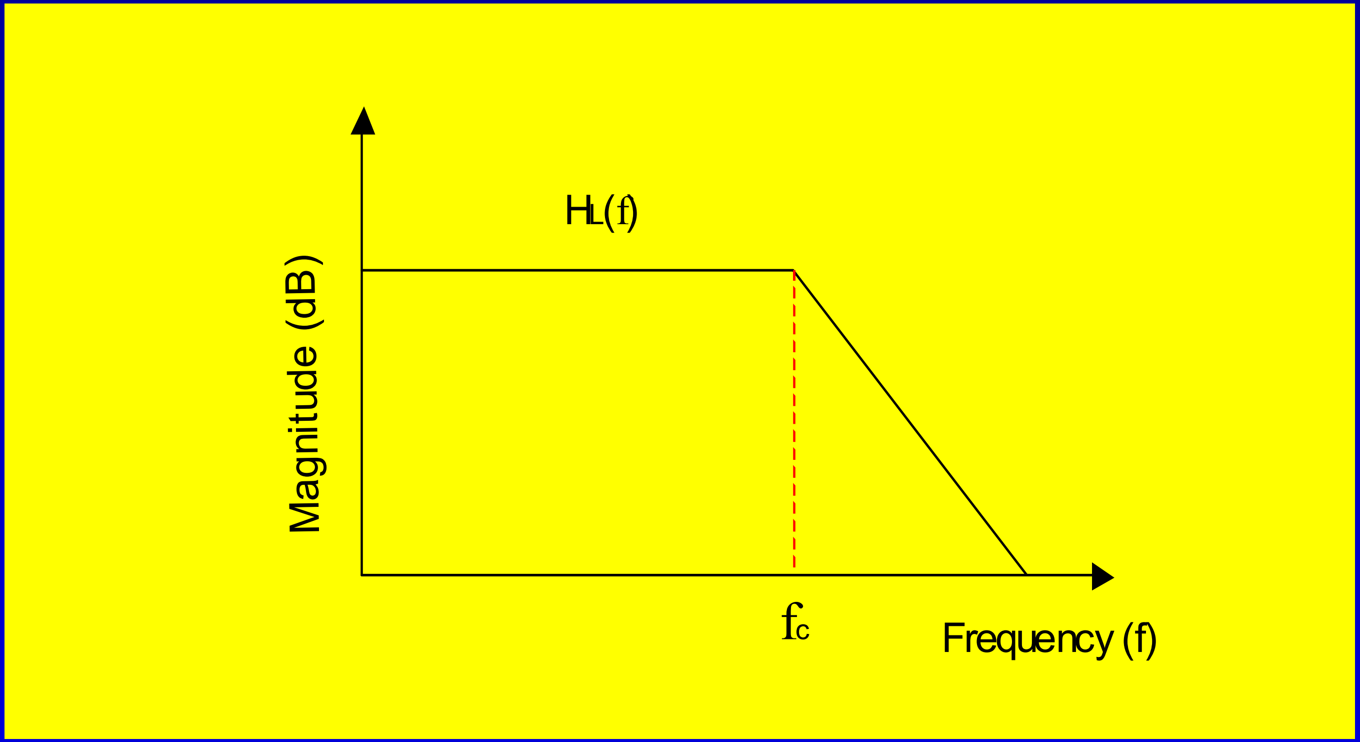
- BER: metric for overall system performance
- BER: CDF from jitter and noise PDFS

$$BER(t_s) = CDF(t_s) = \frac{1}{2}[\int_{t_s}^{\infty} P_{tl}(\Delta t)d(\Delta t) + \int_{-\infty}^{t_s} P_{tr}(\Delta t)d(\Delta t$$

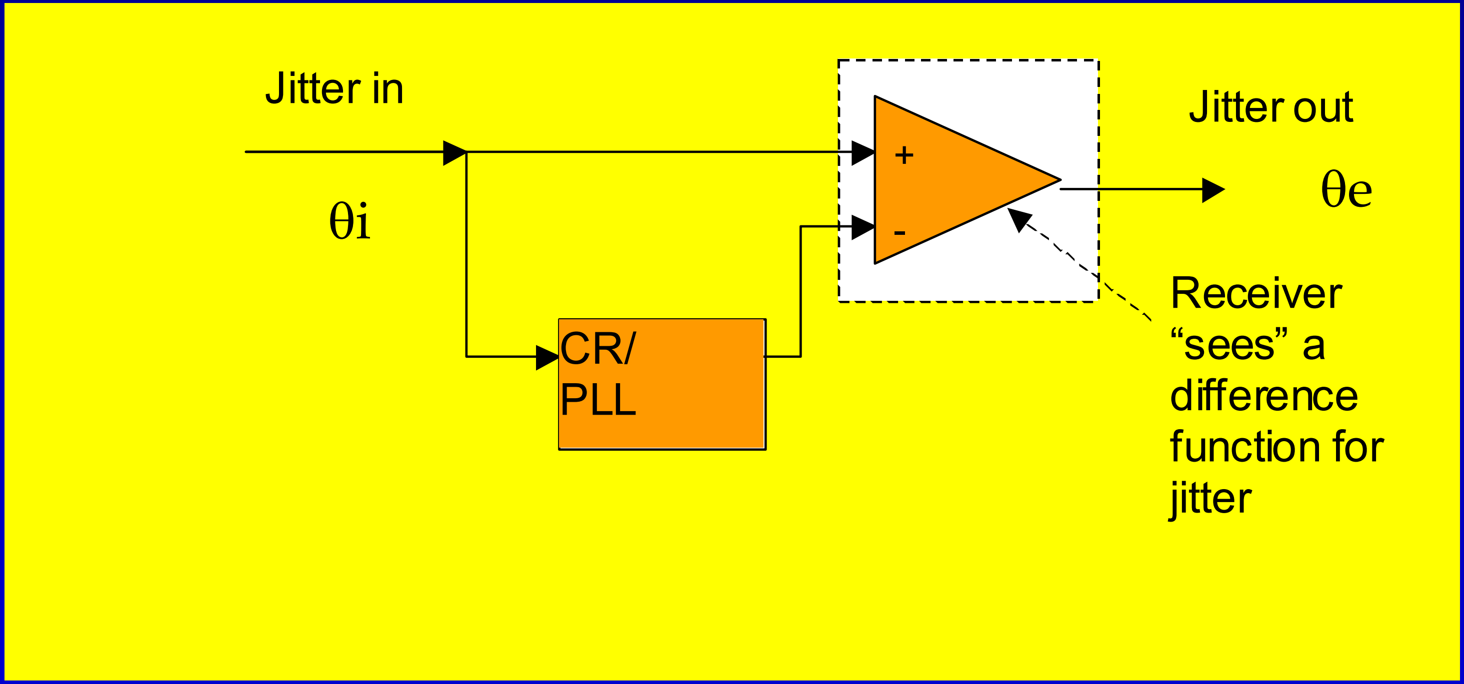
A Serial Data Communication System



A PLL Frequency Response Function



Receiver Jitter Transfer Function

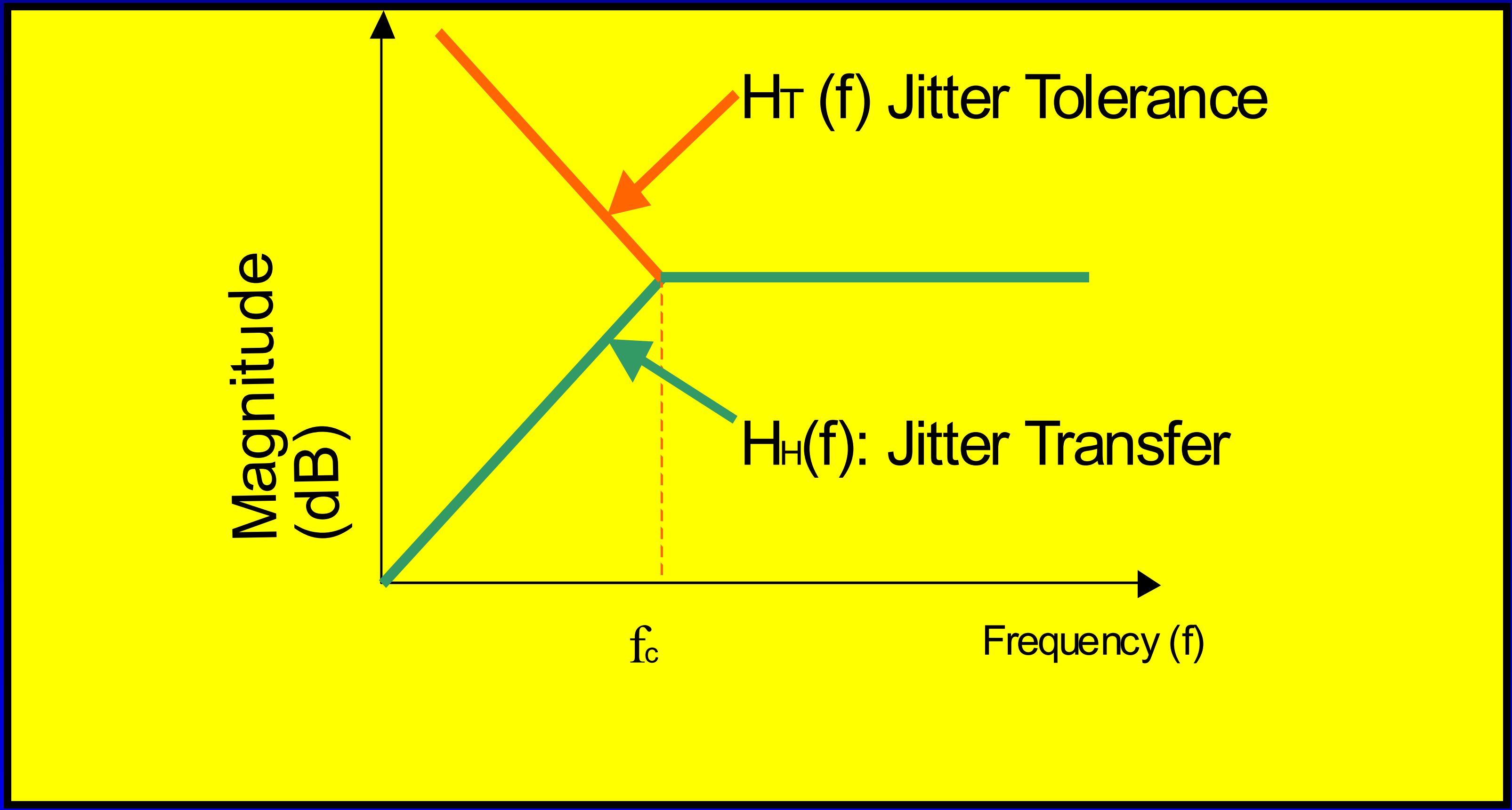


- A "difference" function

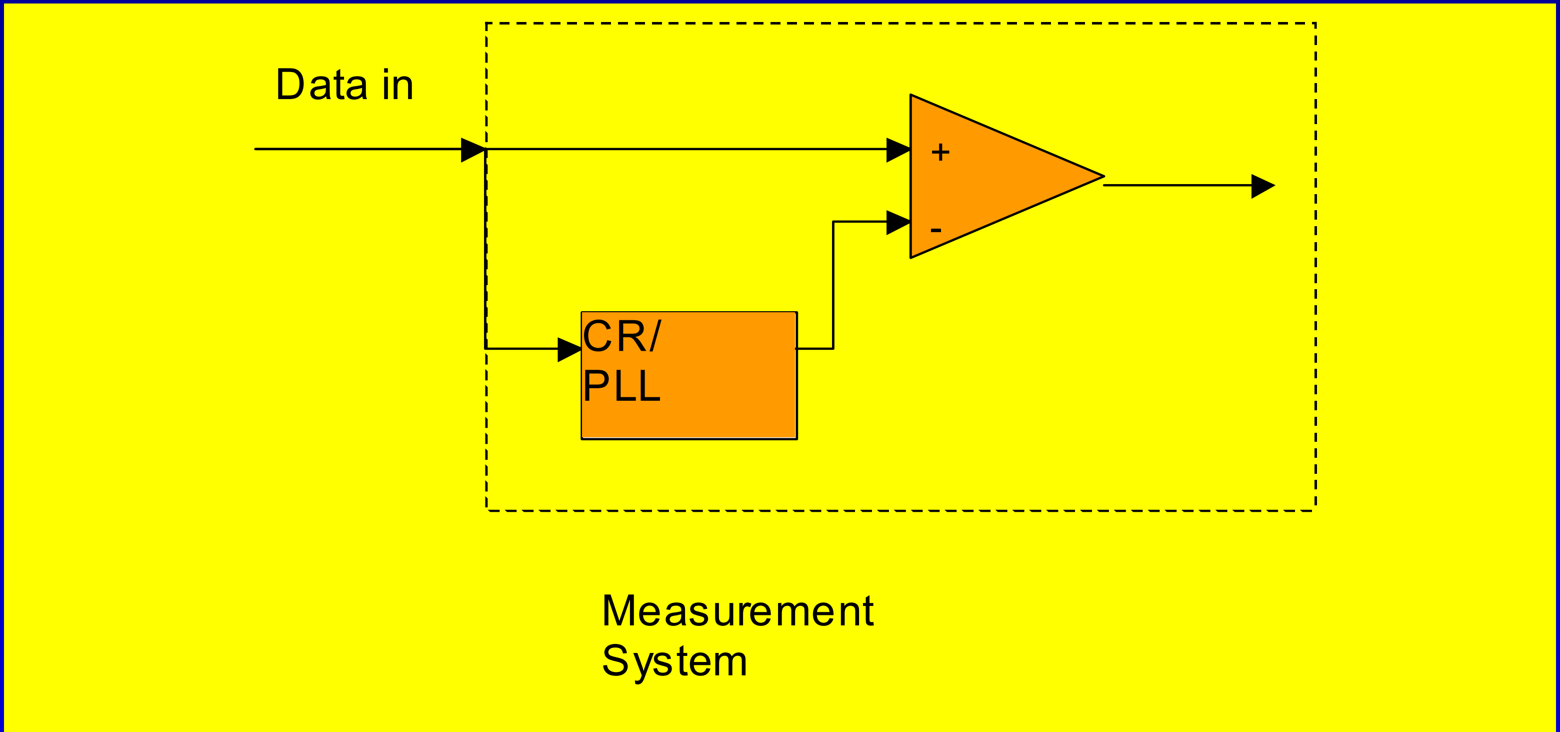
What Does A Difference Function Mean?

- Jitter is referenced to a recovered bit clock
- Receiver has a jitter transfer function
- “Intrinsic” jitter referenced to an ideal bit clock is not the jitter “seen” by the receiver
- BER of the system should be estimated based on jitter “seen” by the receiver

Jitter Transfer/Tolerance Functions For Data Recovery



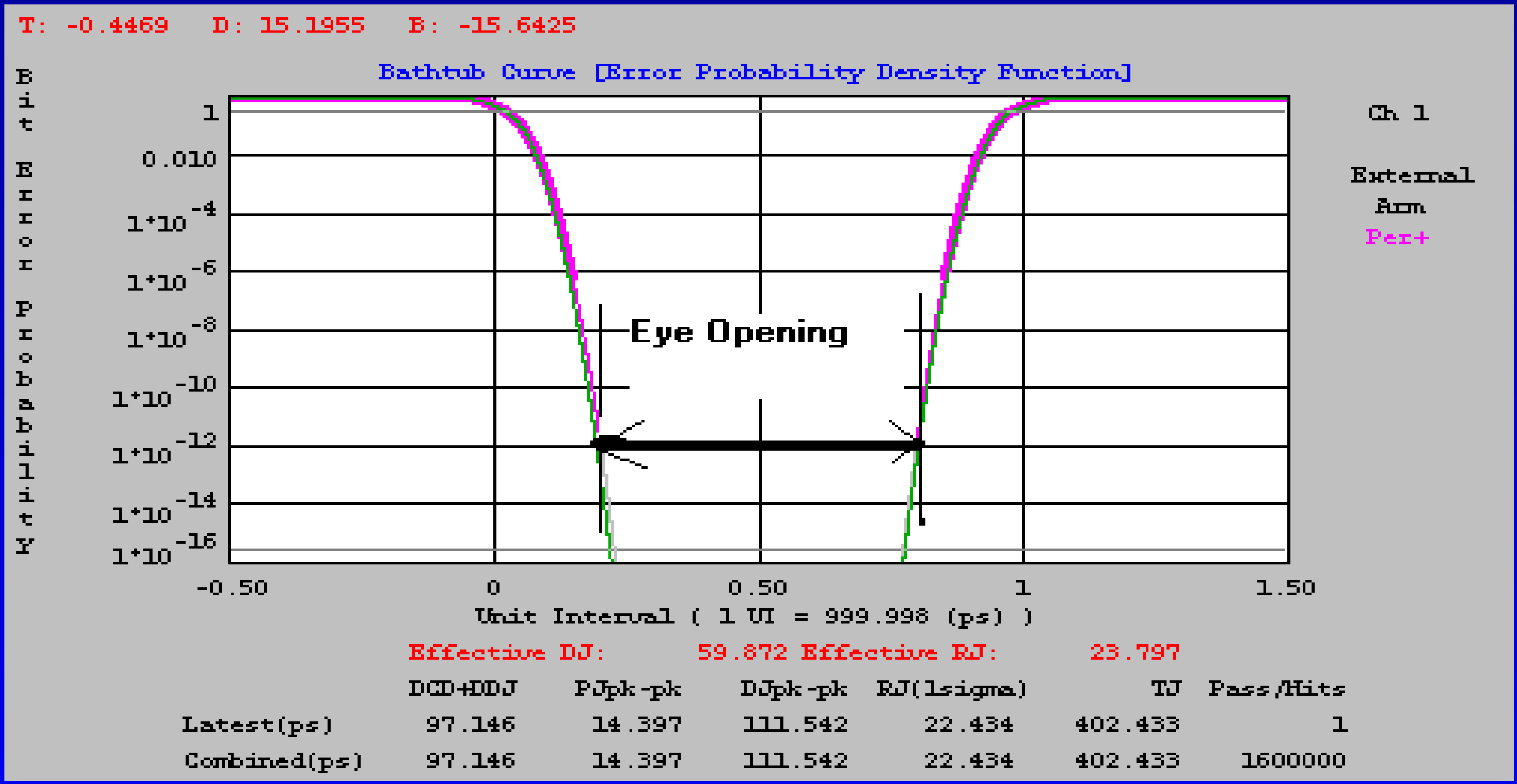
What Constitutes A Valid Jitter Estimating/Testing Method?



- Estimate the jitter as the receiver “sees” !!!
- CR/PLL and difference functions or their equivalents are required

Compliance Estimating/Testing: Total Jitter And BER Function

- Total jitter = UI – eye opening @ $\mathbf{10^{-12}}$



A Valid Jitter Estimating/Testing Method For Serial Links

Estimating/testing total jitter PDF via an appropriate bit clock reference

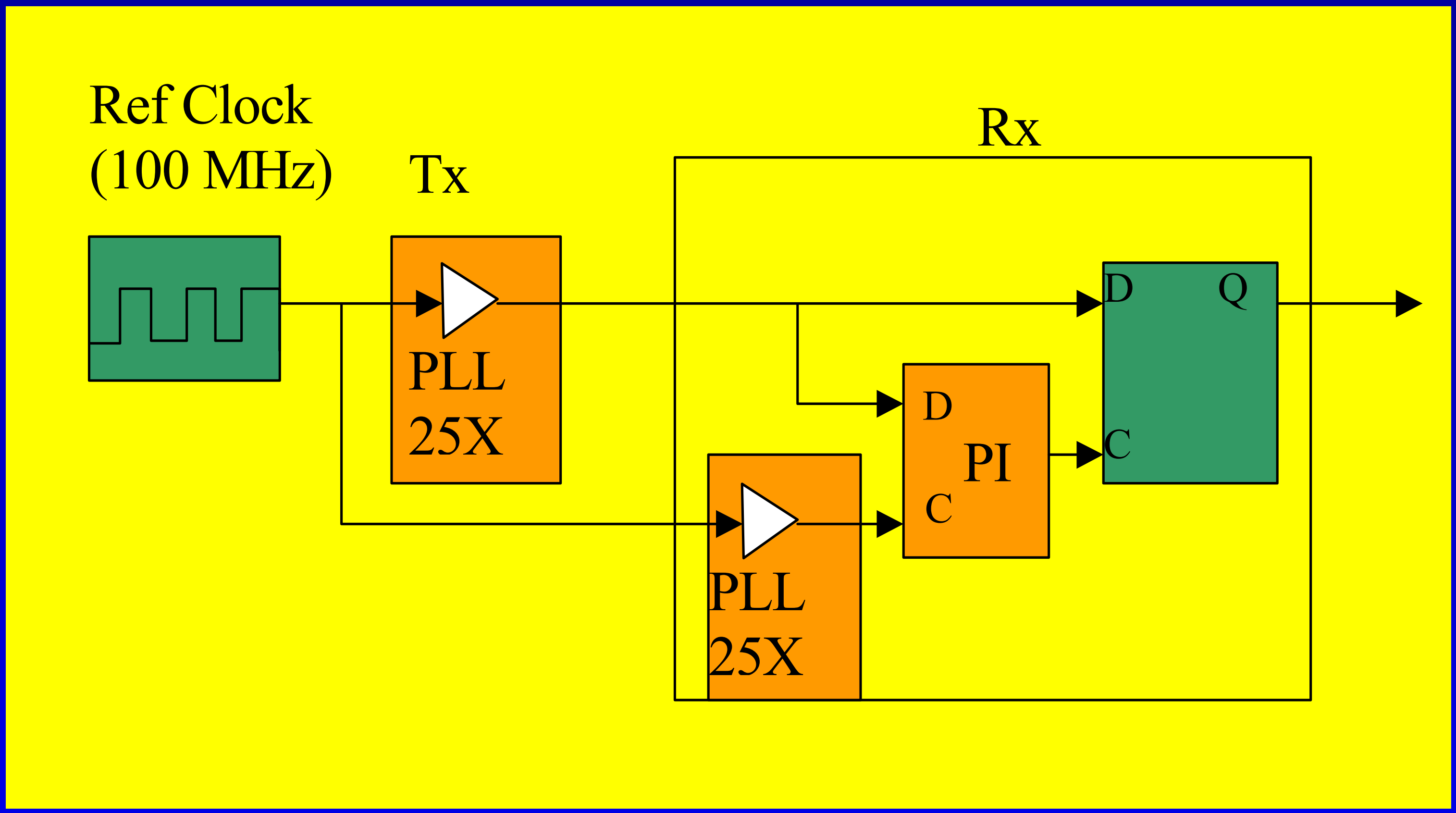
Estimating/Testing BER function to $< 10^{-12}$

Estimating/Testing total jitter @ BER = 10^{-12} or smaller

Pass/Fail

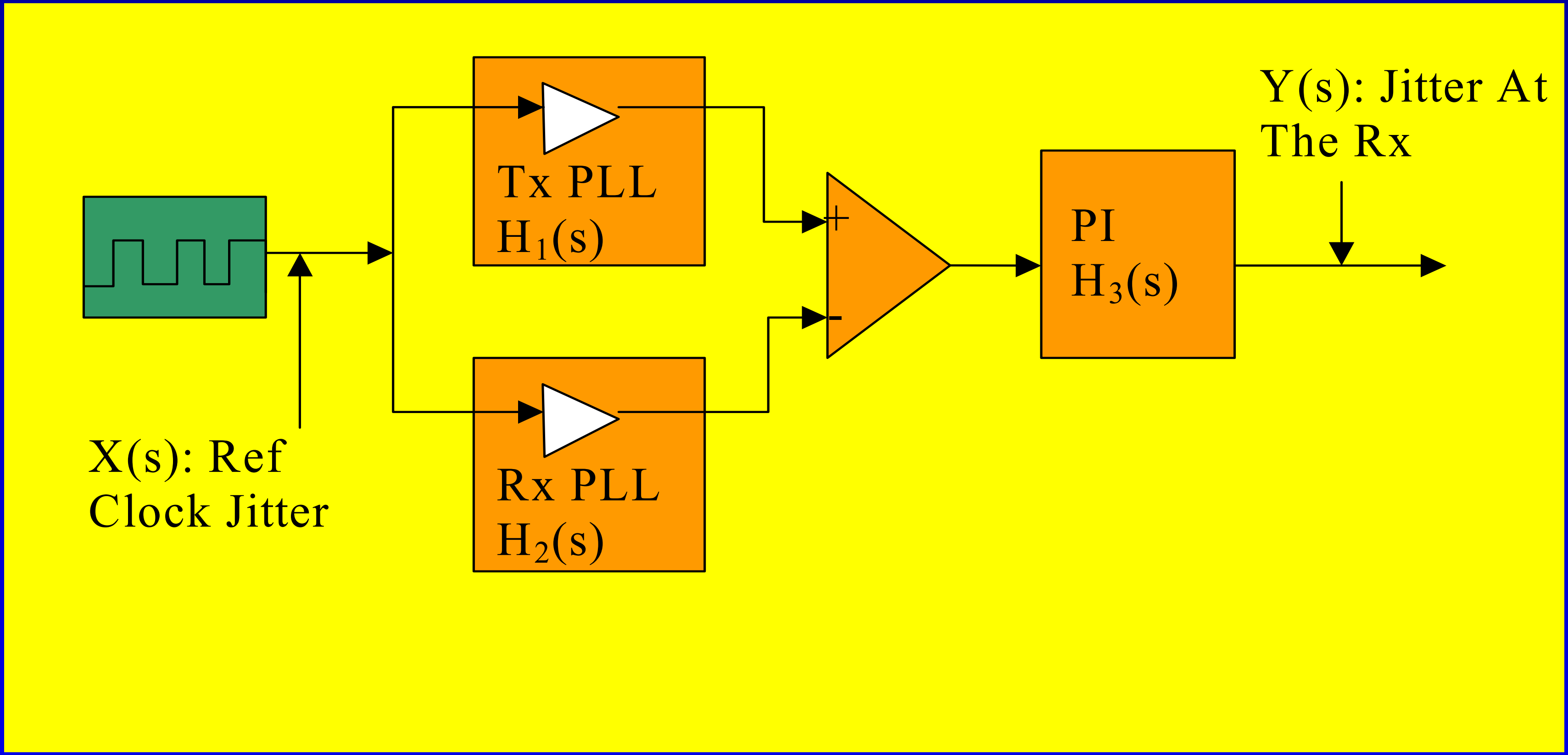
Jitter Transfer Function For PCI Express

- System block diagram for common clock mode



Jitter Transfer Function For PCI Express Cont..

- System Transfer Function Block Diagram



Jitter Transfer Function For PCI Express Cont..

- Math Relationships

$$H_t(s) = (H_1(s) - H_2(s)) \bullet H_3(s)$$

$$Y(s) = H_t(s) \bullet X(s)$$

Summary And Conclusion

- Deterministic parametric methods for jitter and noise ***no longer sufficient*** (e.g., Peak-to-Peak)
- ***Statistical functional (PDF/CDF) methods*** are required for jitter, noise, and BER estimation/test
- “Tailfit” offers deterministic and random ***PDF/CDF*** estimation/test
- “Autocorrelation” offers PSD for periodic and random components
- ***Transfer function*** is required in estimating relevant jitter, noise, and BER for the system
- ***Statistical PDF/CDF + transfer function*** gives a ***complete and accurate*** system performance estimation/testing