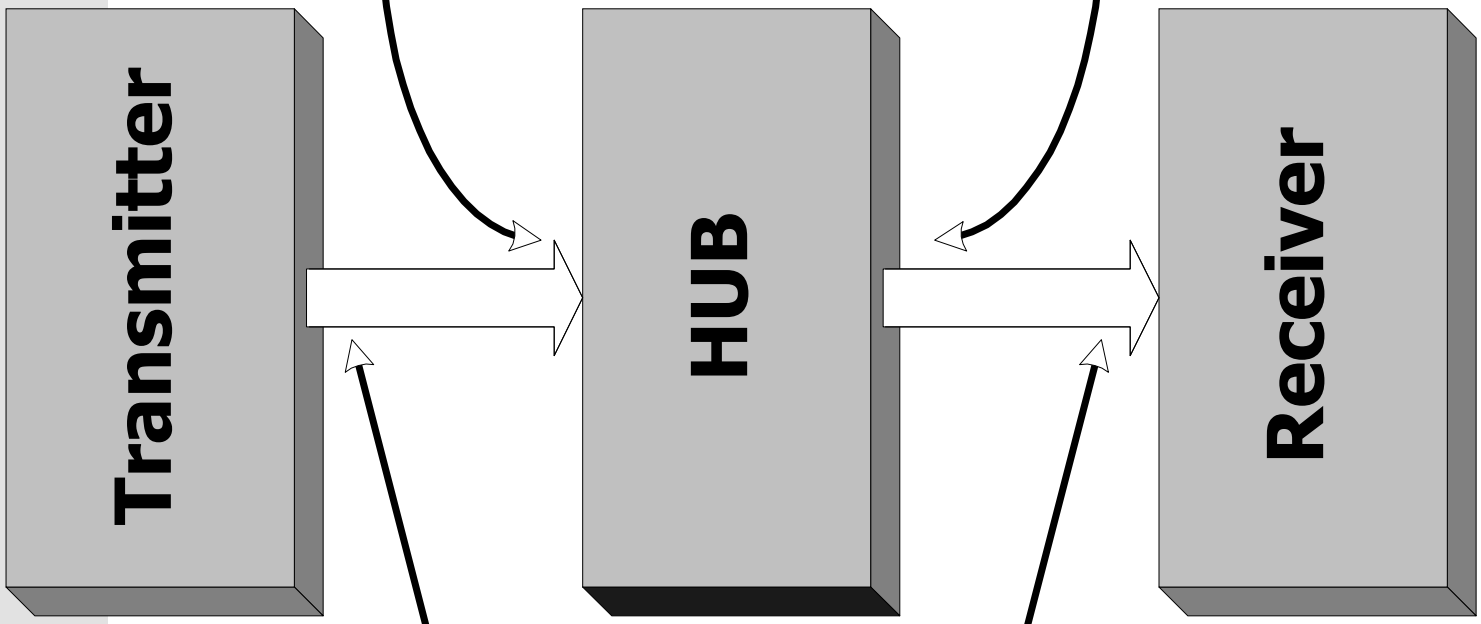
Jitter Analysis of Data Communication Devices

Intro to Jitter Analysis

- Why test for Jitter?
  - Device Speeds are exceeding 1GHz
  - Studies show a clear link between jitter and overall device reliability
  - Jitter Testing is faster and more conclusive than production bit error rate testing
    - Fibre Channel specifications call for 14 σ reliability
  - Jitter contributing significantly to timing errors
    - 1 ns of jitter = 10% problem in 100baseT device
    - 1 ns of jitter = 100% problem in Fibre Channel & Gigabit Ethernet devices

Introduction to Jitter

Jitter Transfer is measured as the net gain between these two points.



Jitter Output is measured at this point.

Jitter Tolerance is measured at this point.

Example of FC Link

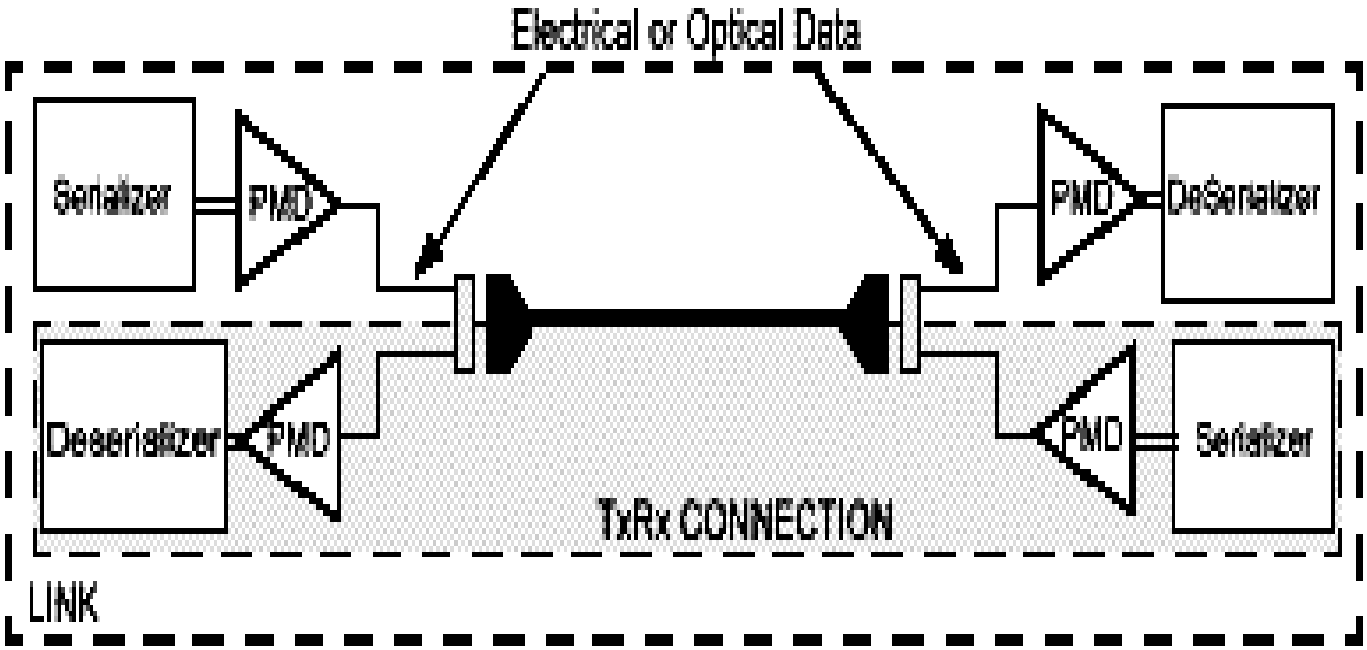
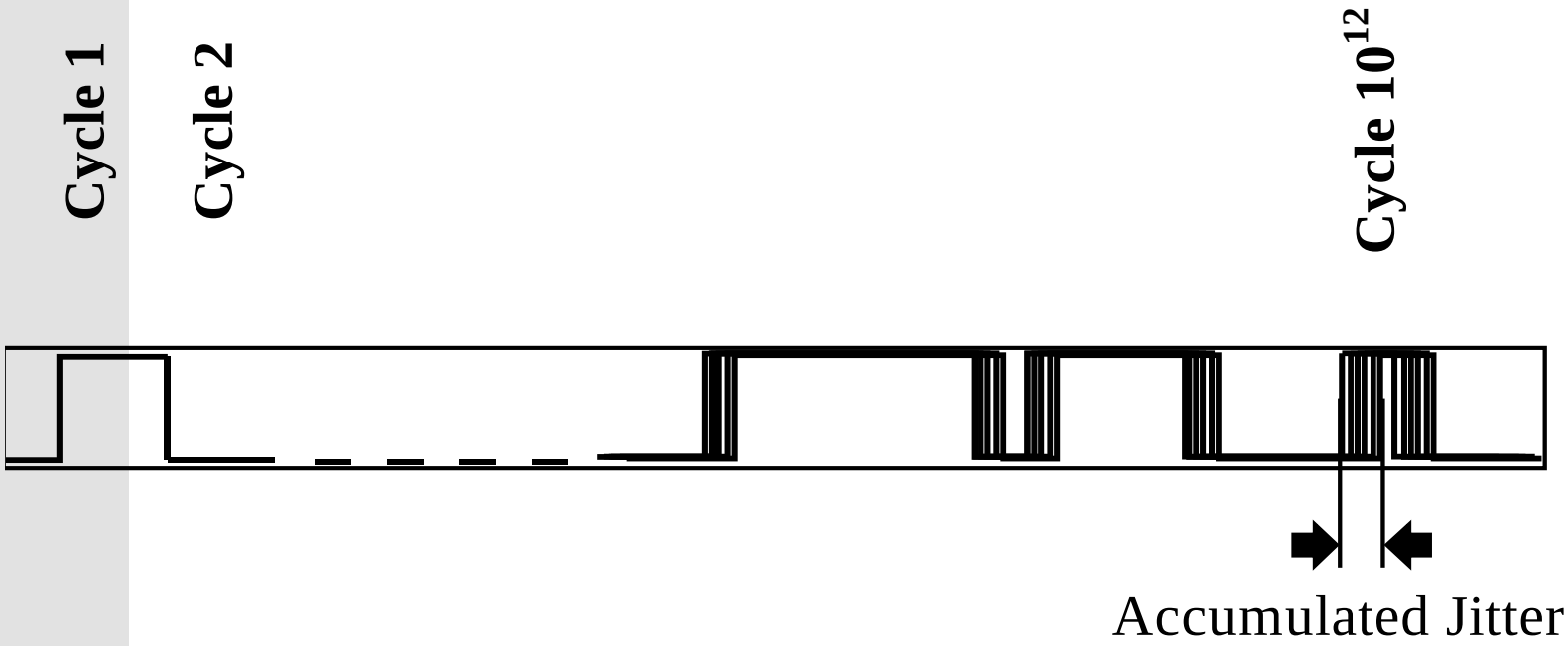


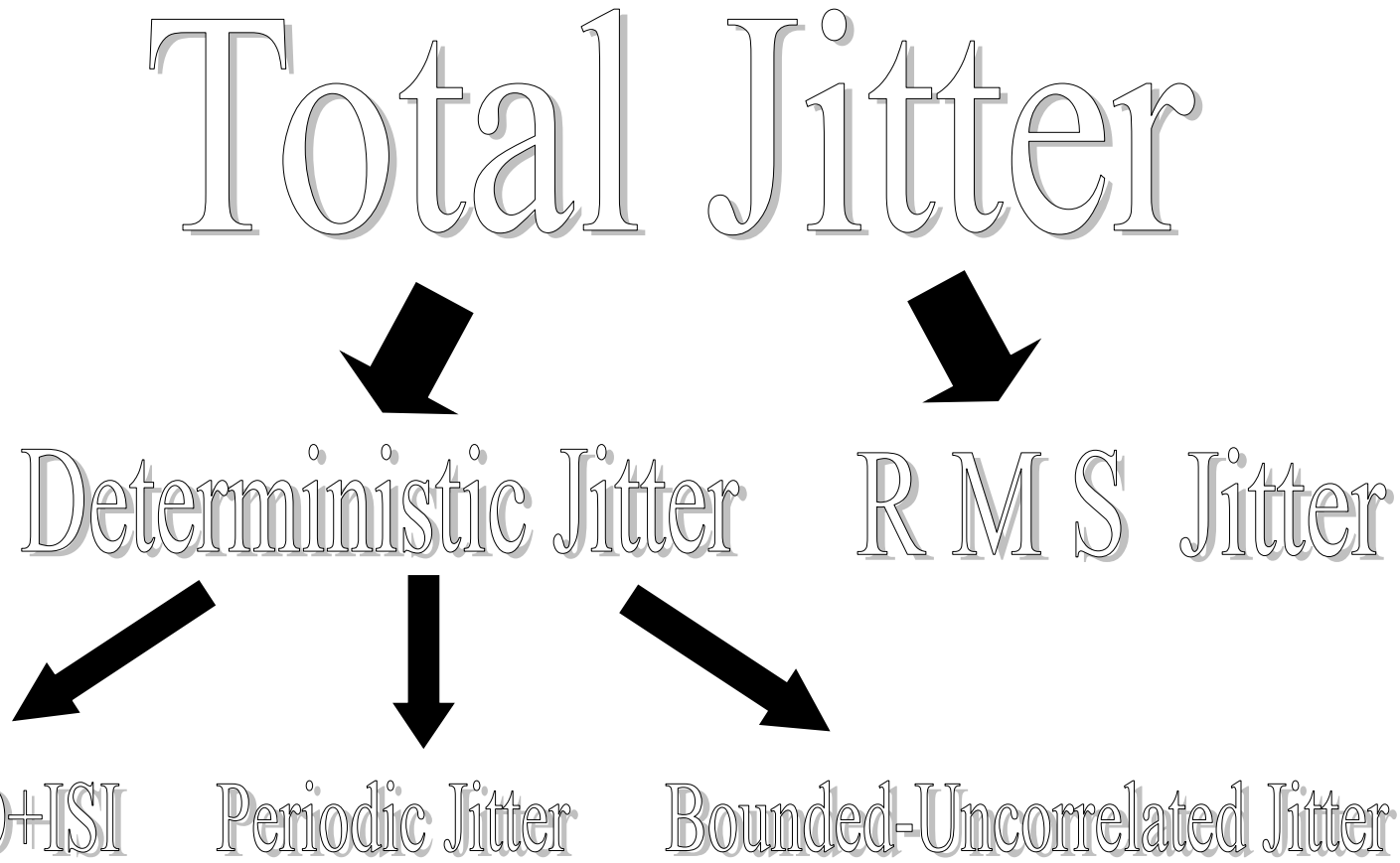
Figure 5 – Fibre channel link

Jitter Terminology Review

Total Jitter After 10^{12} Cycles



Jitter Terminology Review



Jitter Terminology Review

- Total Jitter :
  - *"The total jitter is the sum of the peak to peak values of deterministic jitter and random jitter."* Fibre Channel MJS-7, page 8.
  - *"Jitter is the mis-positioning of the significant edges in a sequence of data bits from their ideal positions. Sufficiently gross mis-positioning results in data errors."* Fibre Channel MJS-7 page 7.
- RMS Jitter (RMSJ) or Random Jitter (RJ)
  - Stochastic in nature. Typically characterized by a Gaussian Distribution
  - Unbounded in Nature

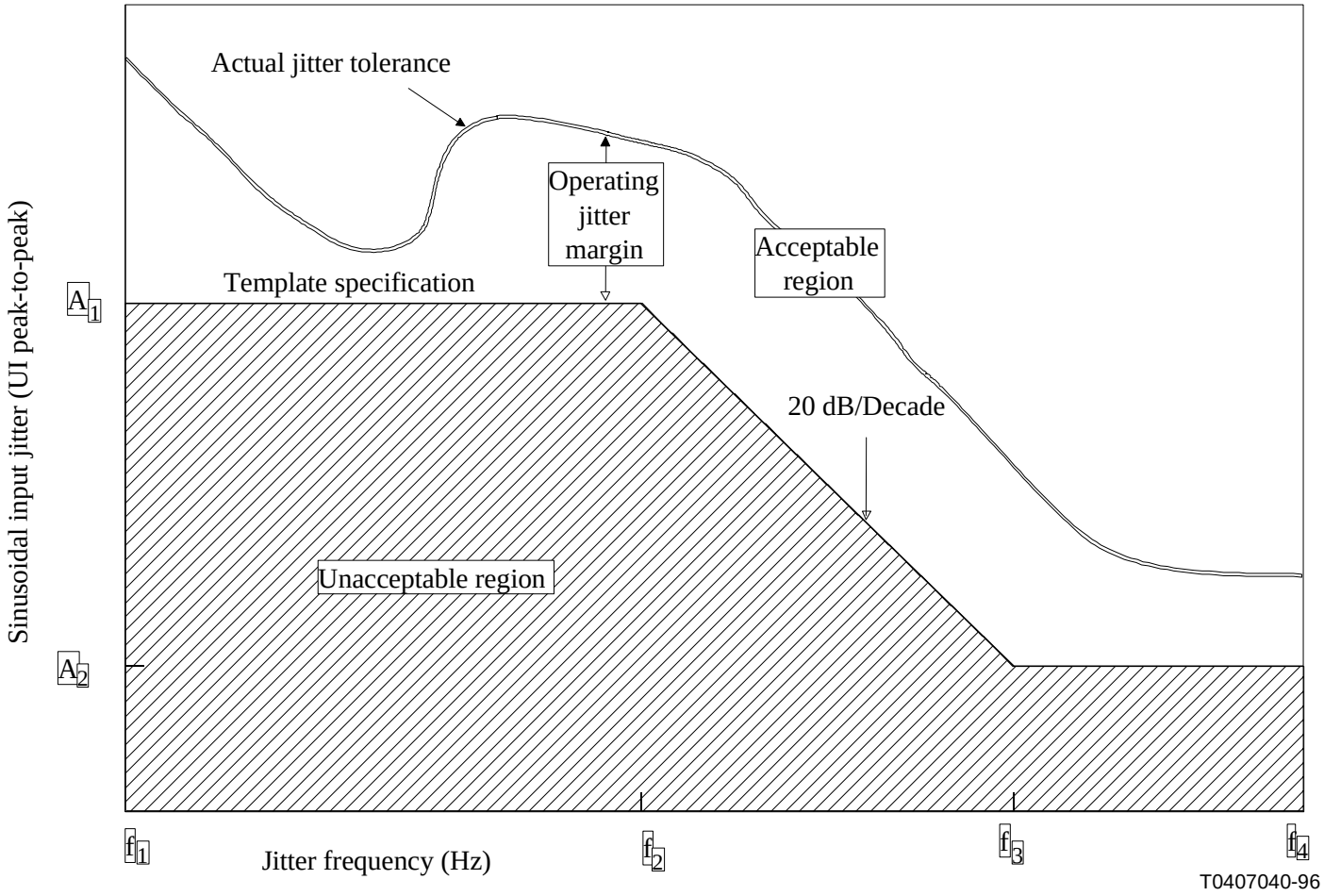
Jitter Terminology Review

- Deterministic Jitter (DJ)
  - Composed of Duty Cycle Distortion (DCD), Inter-Symbol Interference (ISI), Periodic Jitter (PJ) and Bounded Uncorrelated Jitter (BUJ)
  - DJ is bounded and effects short term stability
  - DCD + ISI
    - Can quantify the quality of the interface and the Input and Output impedance matching
  - PJ
    - Can quantify crosstalk effects from EMI sources and adjacent or nearby signal paths and quality of clock source

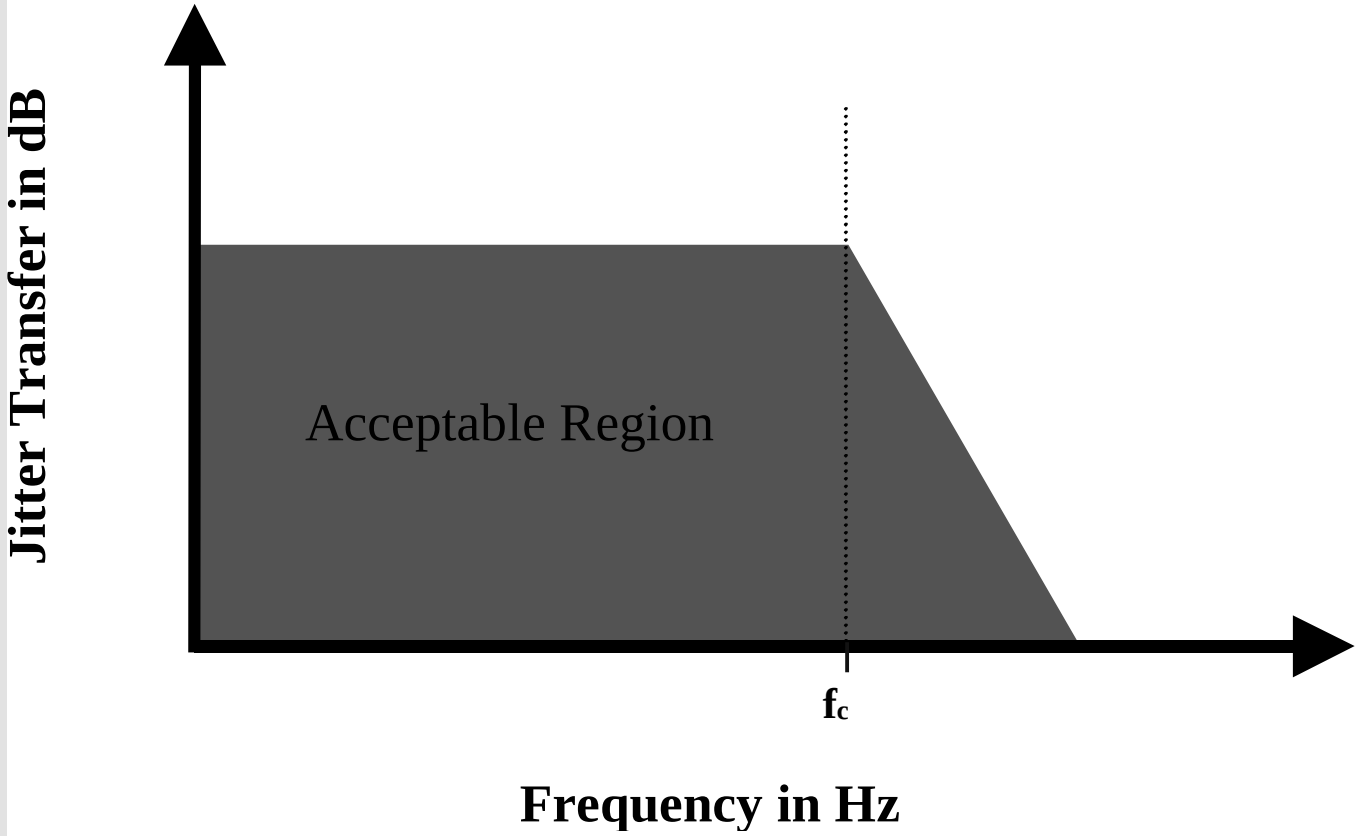
Jitter Specifications

- Serial Data Communications Standards to be discussed:
  - **SONET**
  - **Fibre Channel-Gigabit Ethernet**

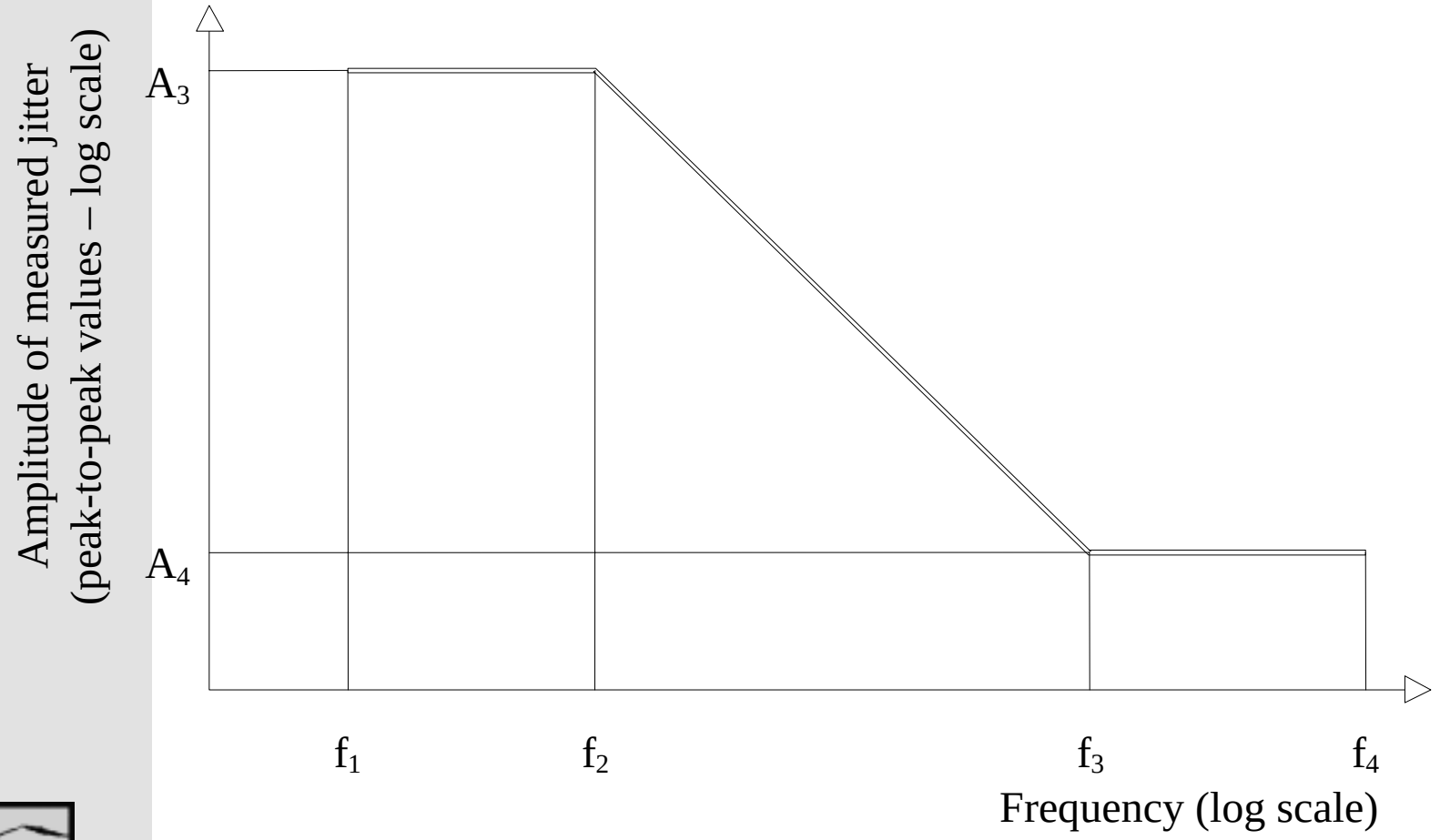
SONET - Jitter Tolerance



SONET - Jitter Transfer



SONET - Jitter Generation



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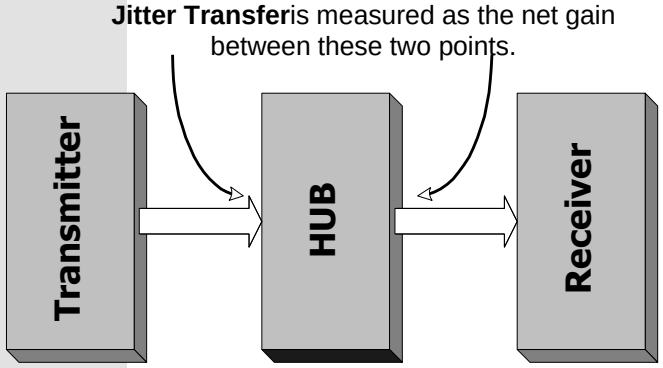
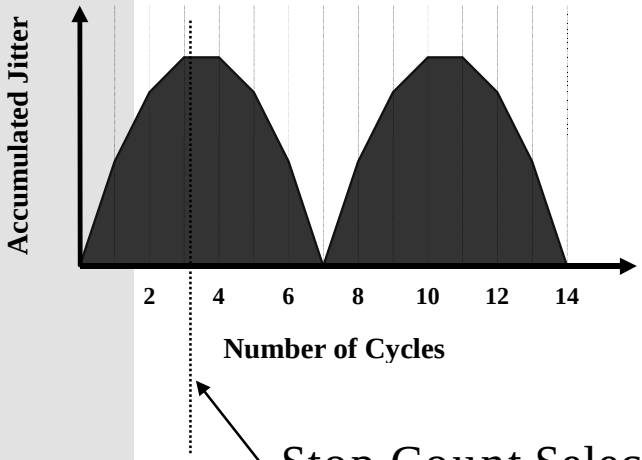
SONET - Production Tests



Jitter Analysis Graph with Period as Function

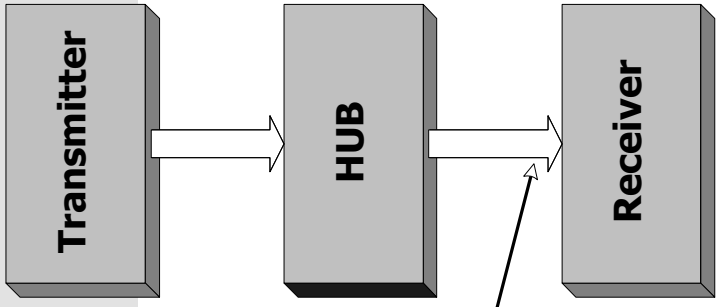


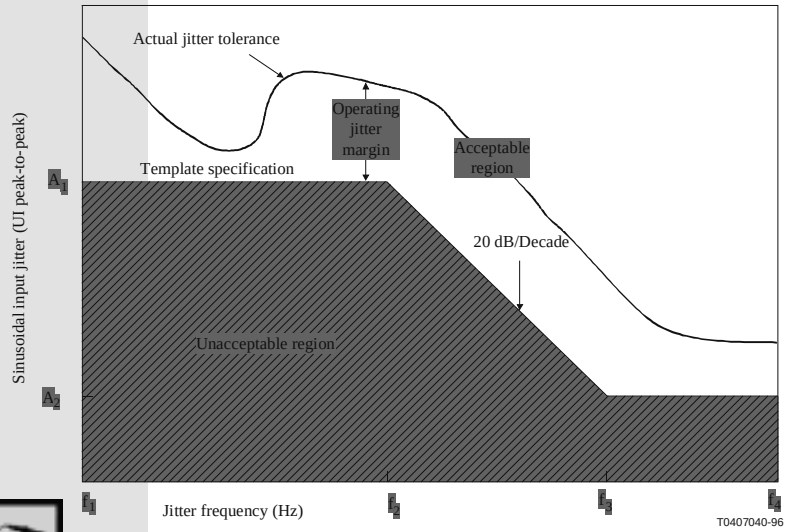
JITTER TRANSFER -

- Measure 1σ input jitter from jitter source using stop count equal to: $F_C / (2*F_{MOD})$ where F_C is the carrier frequency and F_{MOD} is the modulation frequency
- Measure 1σ output jitter with same stop count.
- Transfer function is calculated from

$$J_{TRAN} = 20 \log_{10}\left(\frac{1\sigma \text{ result at Input}}{1\sigma \text{ result at Output}}\right)$$

SONET - Production Tests

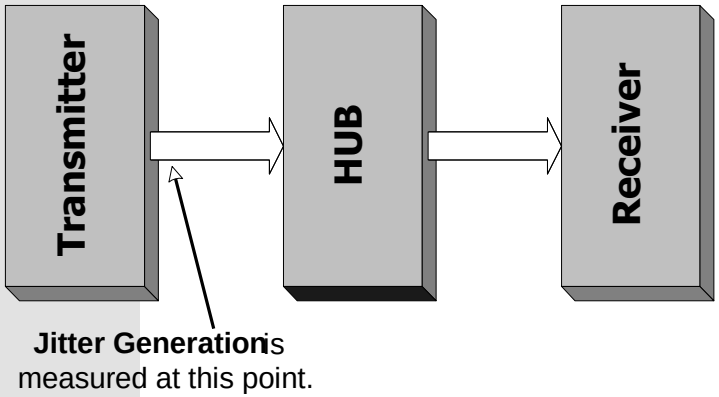


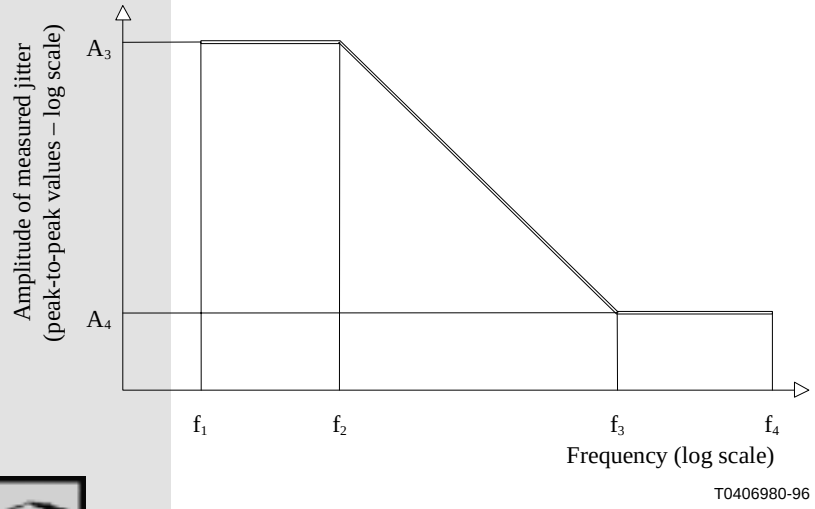


JITTER Tolerance -

- Typically, test critical frequencies and measure Bit Error Rate.
- This is done by inducing modulation on input of receiver.
- Use DTS550, AWG or other Pattern Modulation source (many protocol analyzers now have output modulation control as well.)

SONET - Production Tests





JITTER Generation -

- Use Bandpass filter (either DSP or real) for limiting input bandwidth.
- DSP approach limits hardware involved on load board.
- DTS207x has built in band pass capability.

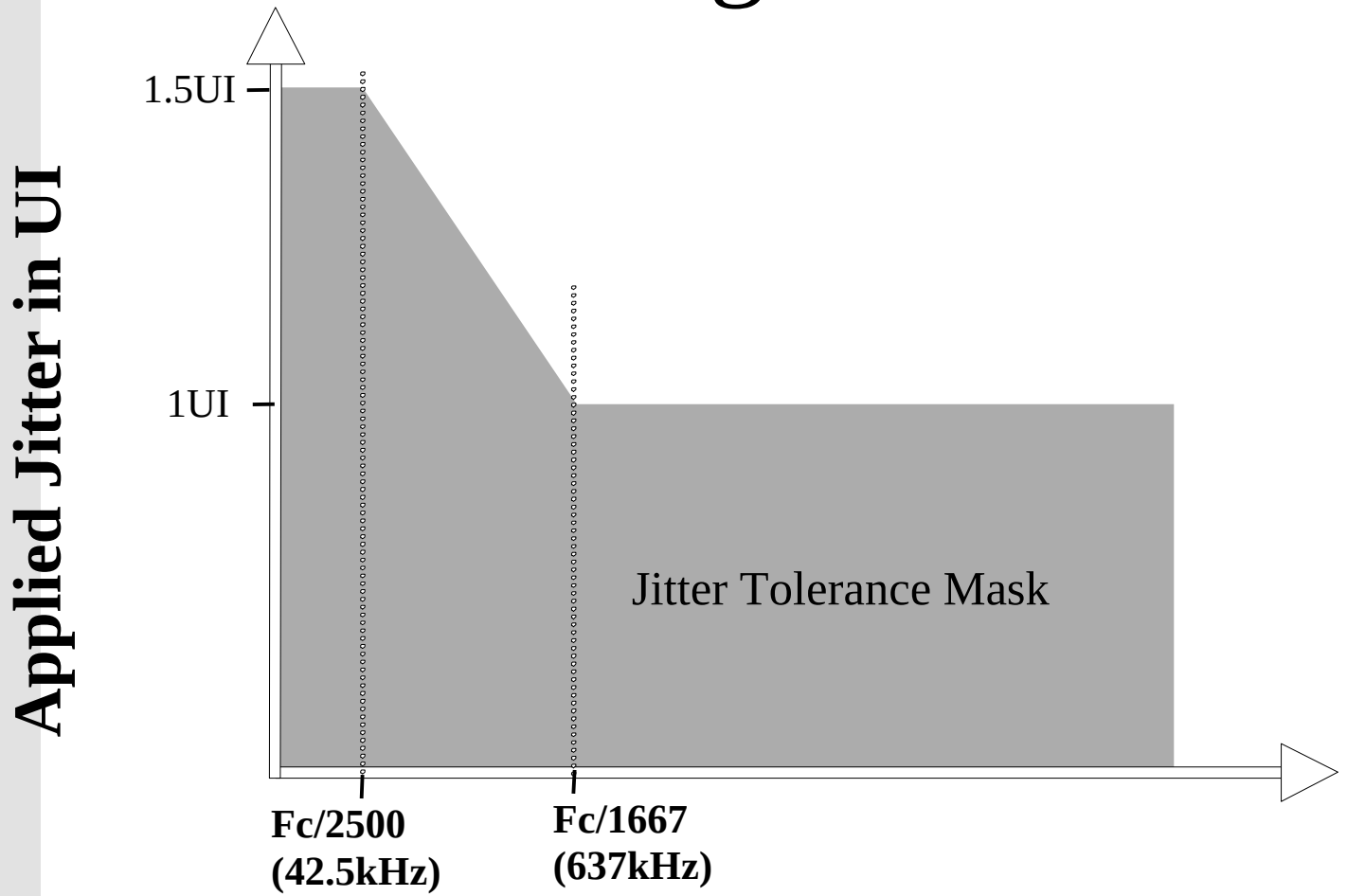
High Pass Filter:

$$\text{Stop count} = F_C / F_3$$

Low Pass Filter:

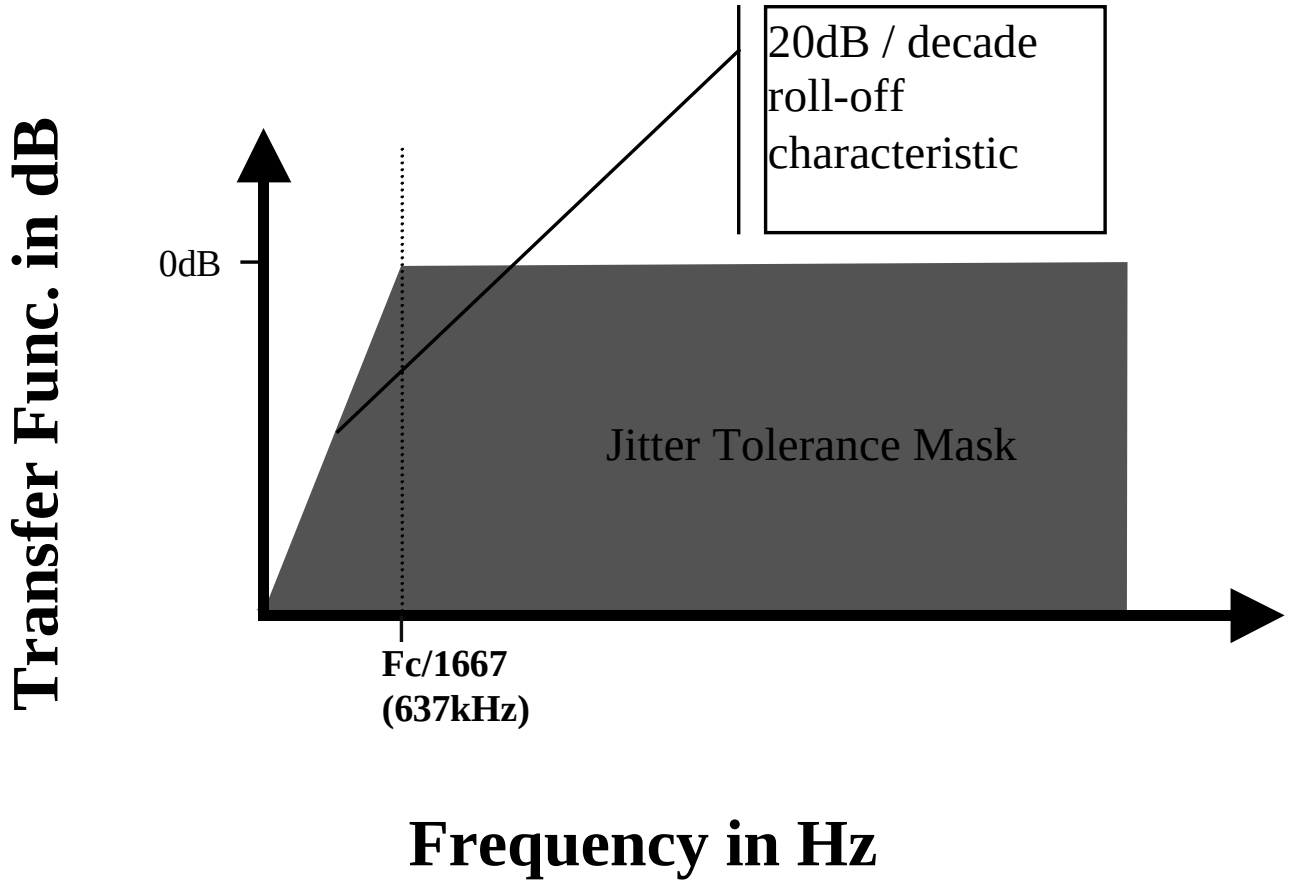
$$\text{Increment} = F_C / F_4$$

Fibre Channel-Gigabit Ethernet



FC - Output Jitter

(High Pass Filter Function)



FC - Total Jitter Calculation
(Using Golden PLL and Eye-Histogram™)

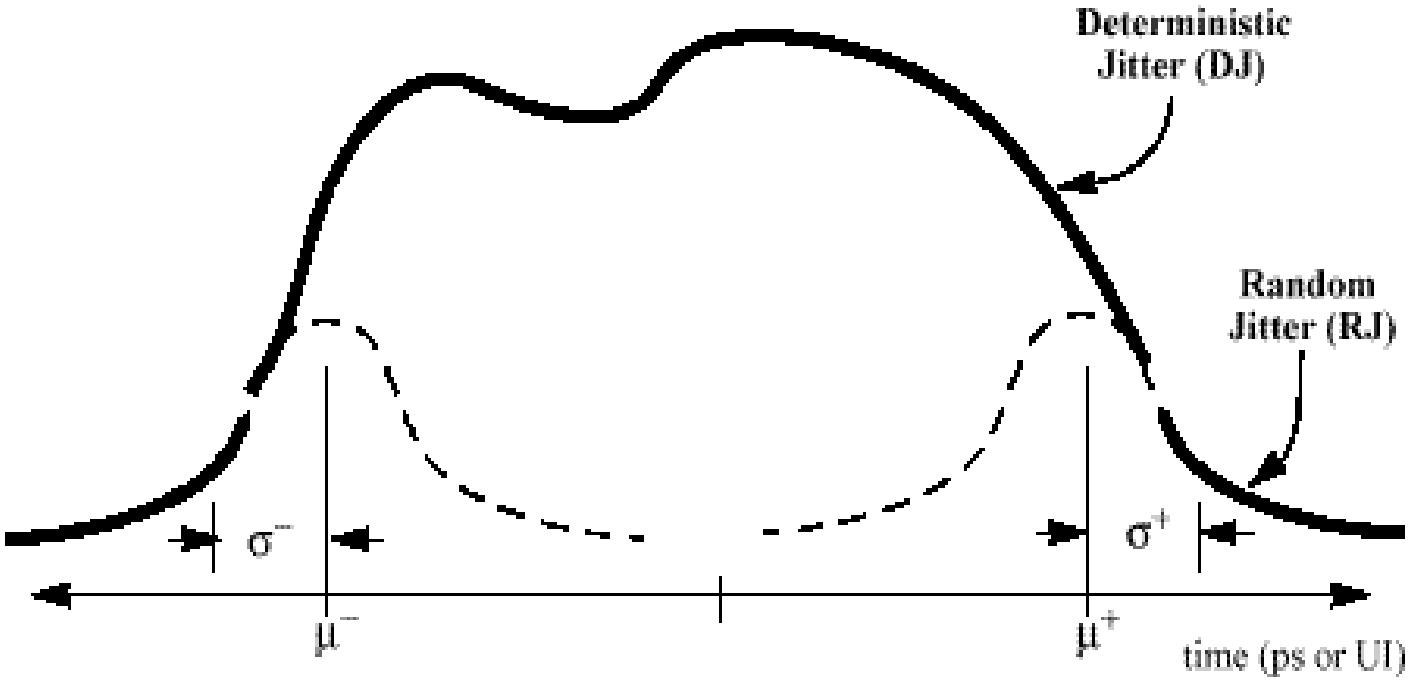
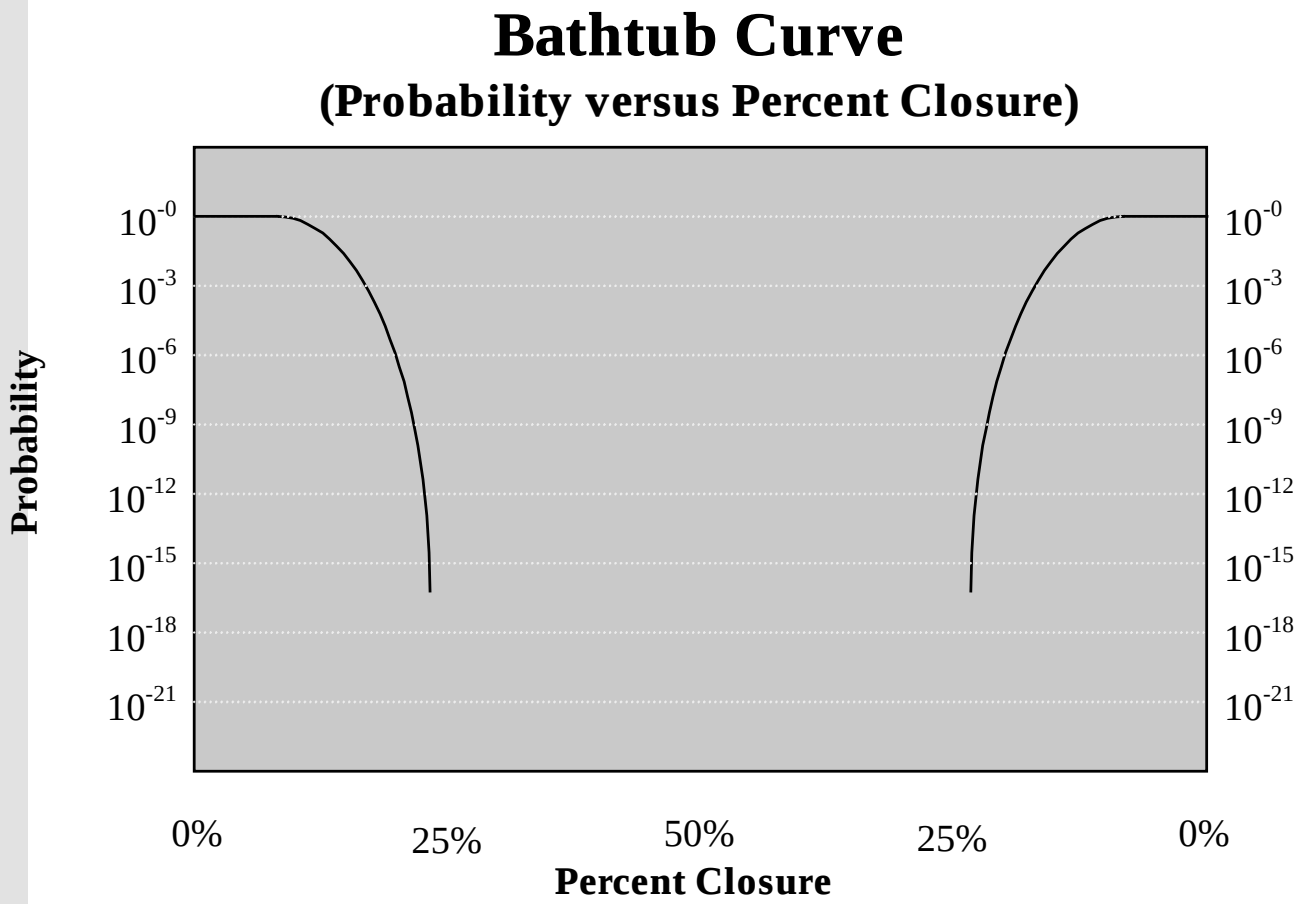


Figure D.1 – Time Domain Total Jitter Calculation

FC-Total Jitter Calculation
("Clockless" using BERT or VI™)



Production Testing

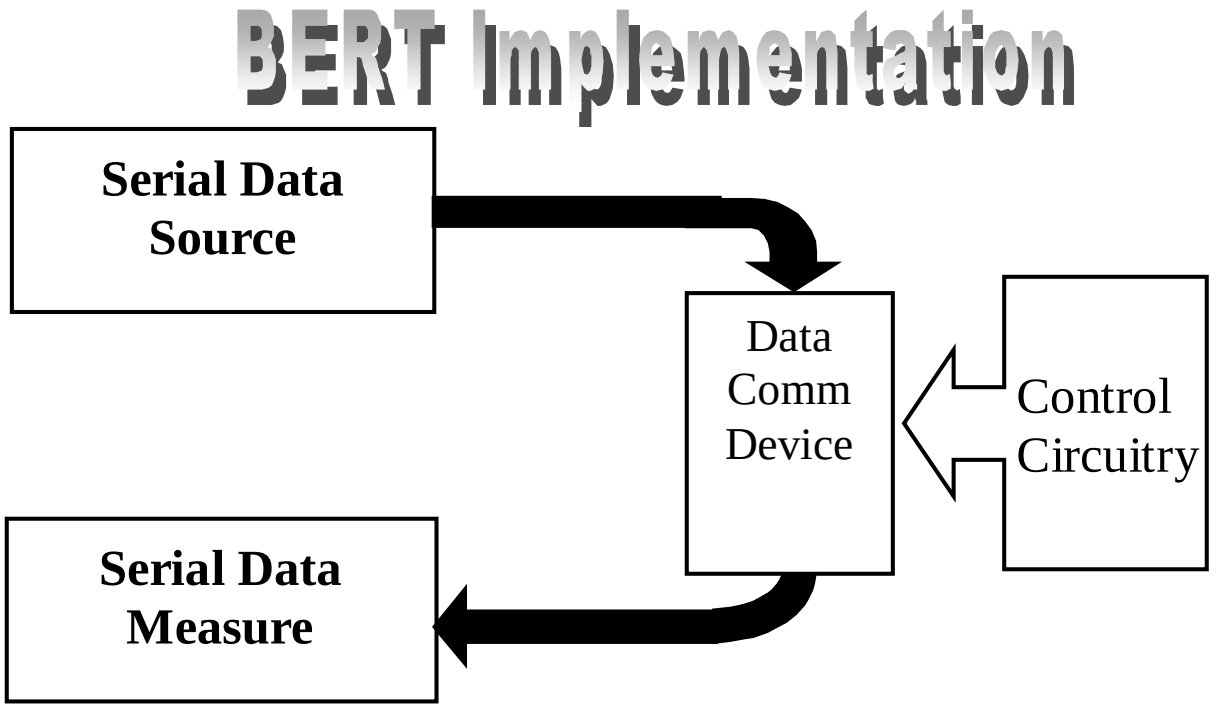
- Fibre Channel
  - To guarantee 14 σ reliability in production, the Eye opening at the threshold can be calculated from: TJ = DJ + 14xRJ
  - Alternatively, all 10^{12} cycles can be tested for data accuracy at various timing settings.
    - For Fibre Channel, this would take 942 seconds per pass.

Available Test Methods

- Three Common methods for Jitter Analysis of Data Communications
  - Bit Error Rate Tester (BERT)
  - Digital Sampling Oscilloscope (DSO)
  - Wavecrest Digital Time System (DTS)

- All methods can detect a jitter problem, but, only one method can isolate the necessary jitter components to meet ANSI specifications.

Available Test Methods



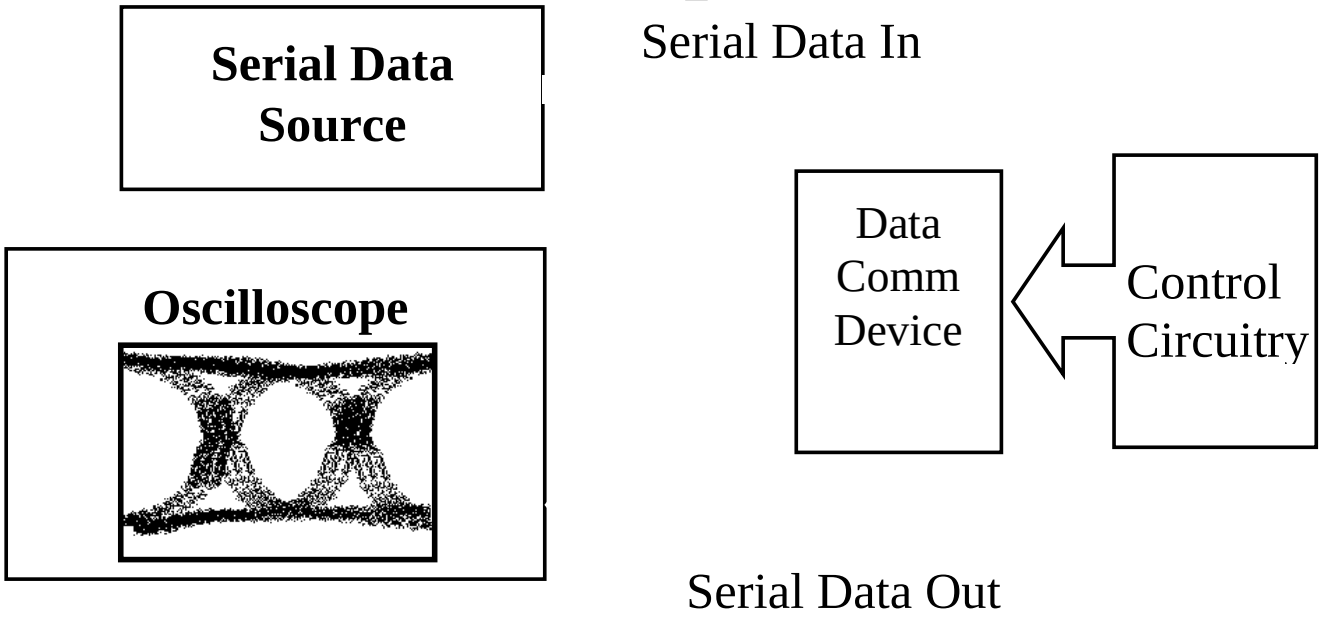
Available Test Methods

- Bit Error Rate Test (BERT) Systems
  - Ensure comparitor timing is phased lock to device output
  - Using random pattern, place comparison marker at various locations within device period to uncover pass / fail point.
  - Be sure to execute through entire reliability level desired (for 14 σ reliability, test at least 10^{12} cycles of data)
    - for Fibre channel, each pass = 941.7 seconds
    - may take several passes to find pass / fail boundary

Result = Total Jitter

Available Test Methods

DSO Implementation



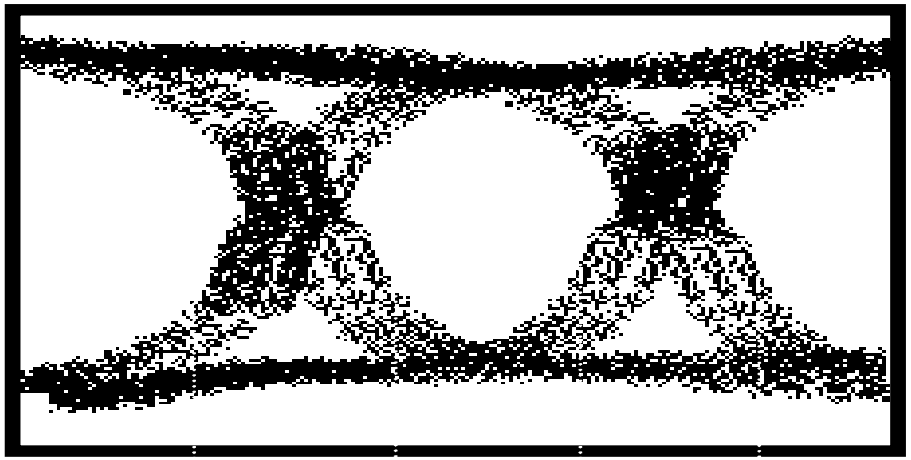
Available Test Methods

- Using an Oscilloscope
  - Not as accurate as a BERT solution alone
  - Uses golden PLL to extract implied clock from data stream or trigger source from BERT system.
  - Can Generate Eye Diagram Based on Trigger
    - shows the existence of jitter
    - difficult to quantify jitter and cannot extract necessary jitter components.
  - Uses test Masks to perform Pass / Fail testing

Cannot Isolate RJ for Reliability Testing

Available Test Methods

- Evaluating an Eye Diagram
  - Generate Histogram of threshold crossings
  - Histogram will show the existence of jitter

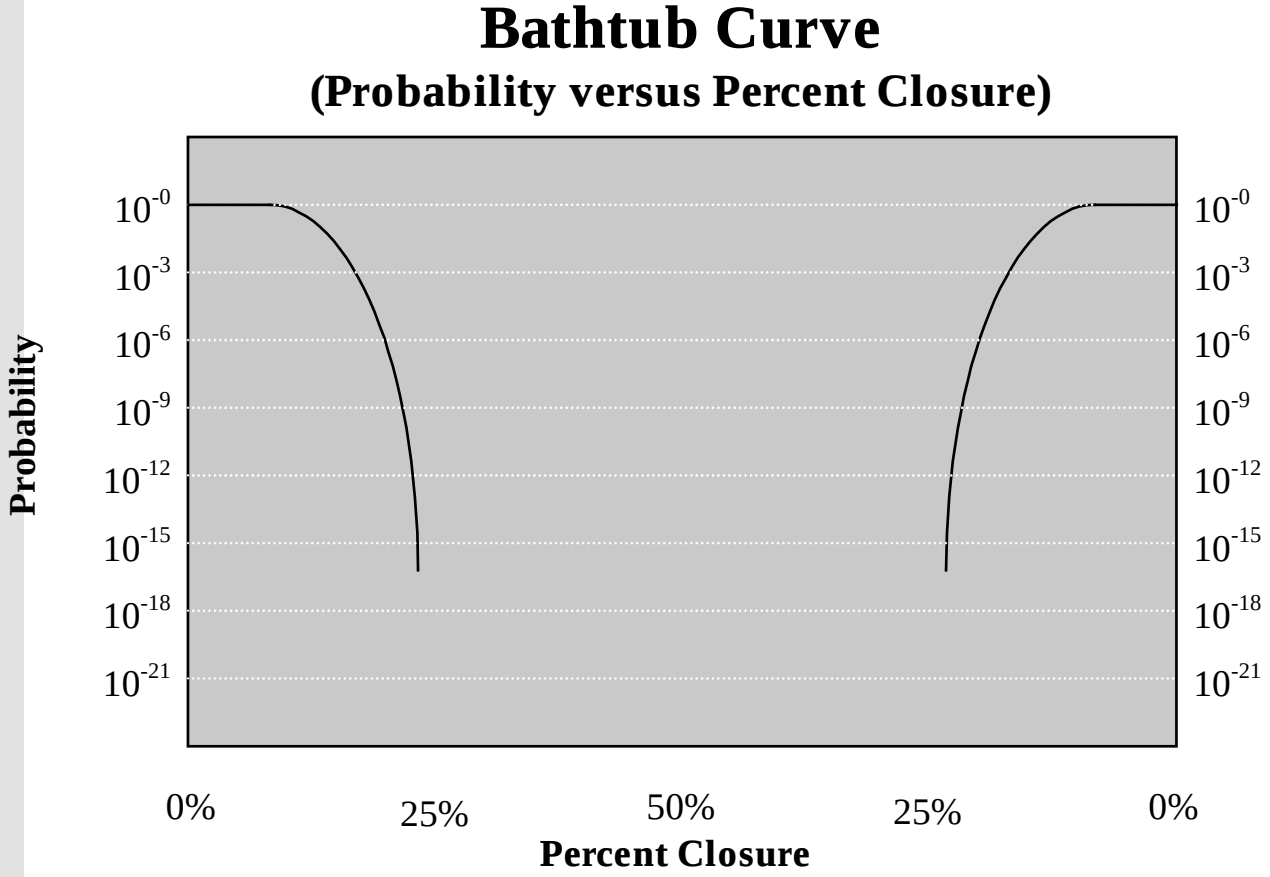


The VI™ dataCOM Advantage

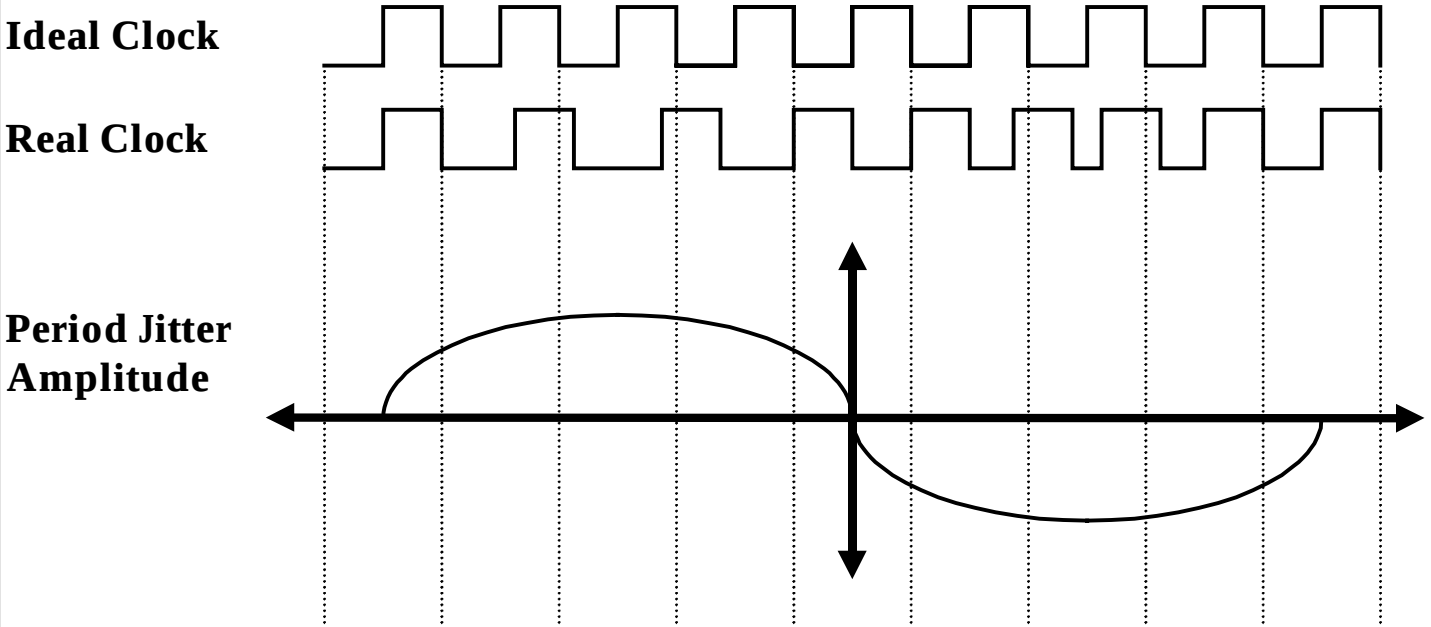
- Separation of Jitter Components
  - RJ, DCD+ISI,PJ and BUJ
- Quick Correlation
  - Laboratory, Production and Customer Application Card
  - Share Setup files and data files to compare various setups
  - Minimize operator setup error
- Characterize PLL Bandwidth and Loop-Feedback Response Time

The VI™ dataCOM Advantage

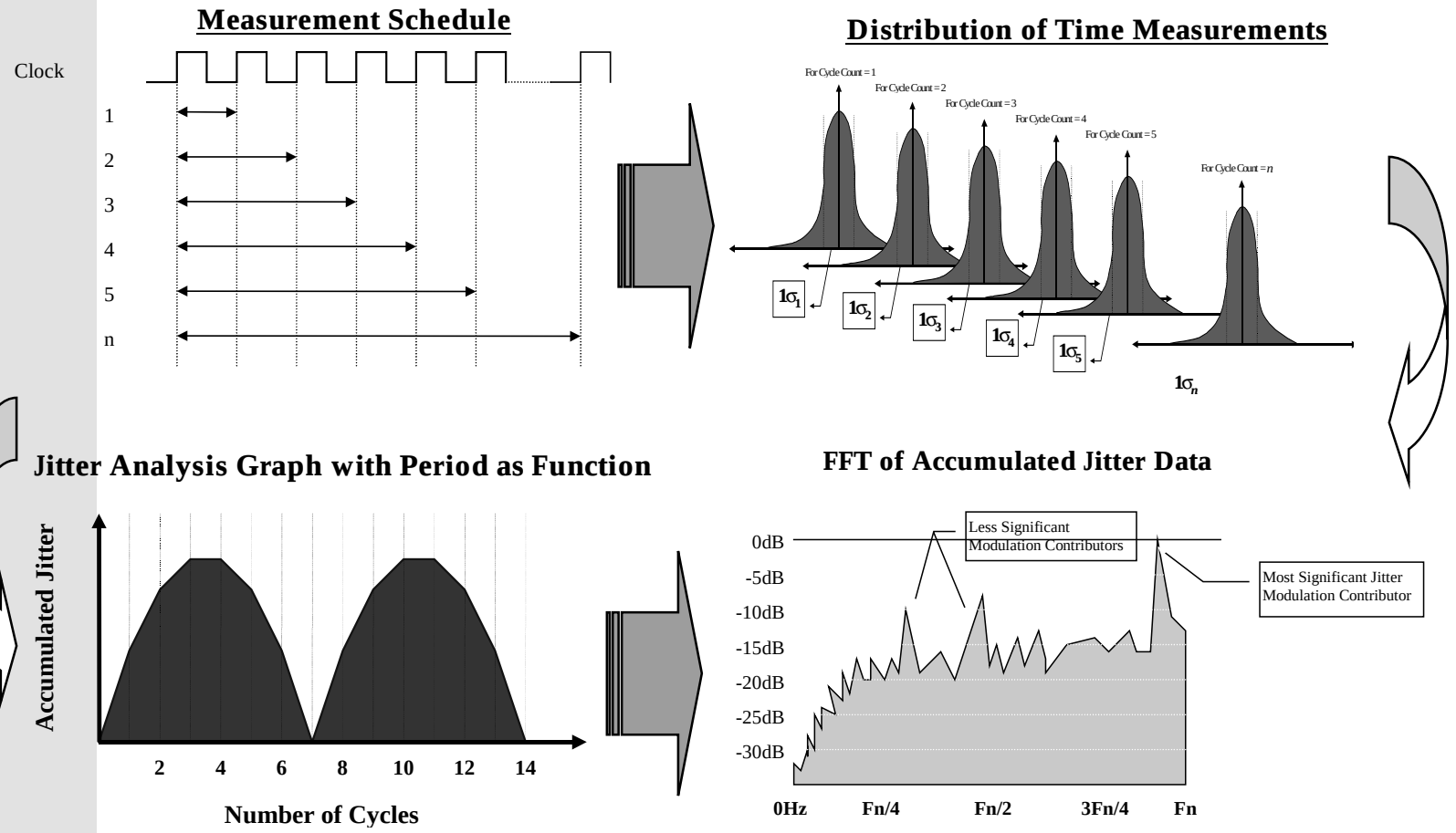
- **Evaluating the Bathtub Curve**



Accumulated Time Analysis™

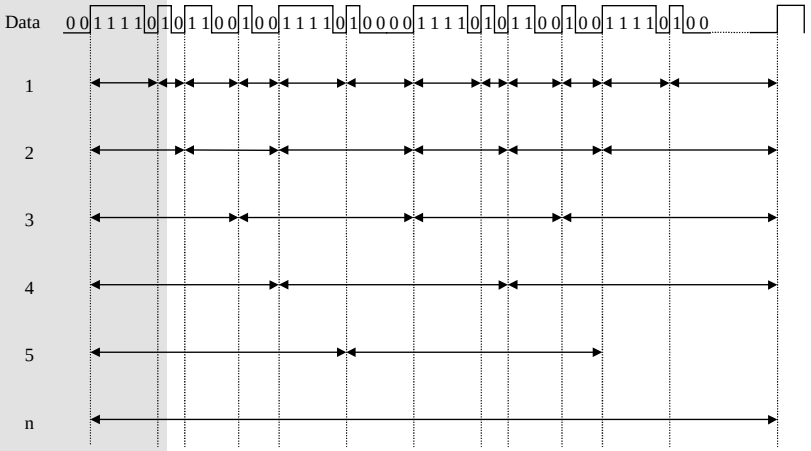


Accumulated Time Analysis™

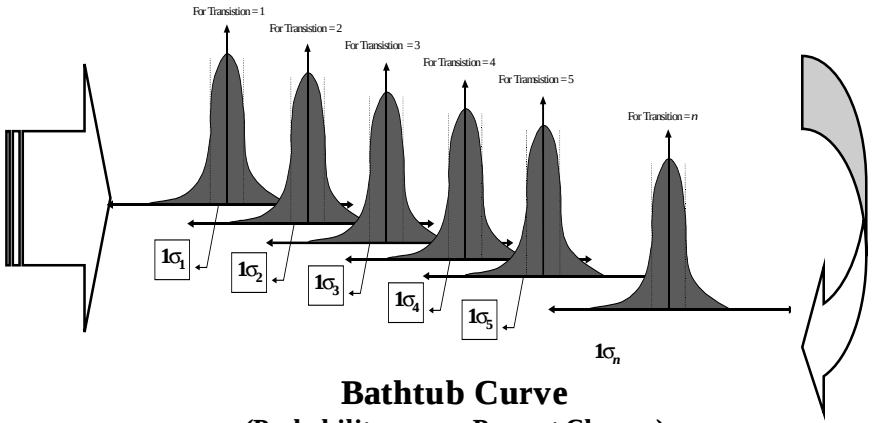


Fn = Apparent Nyquest Frequency

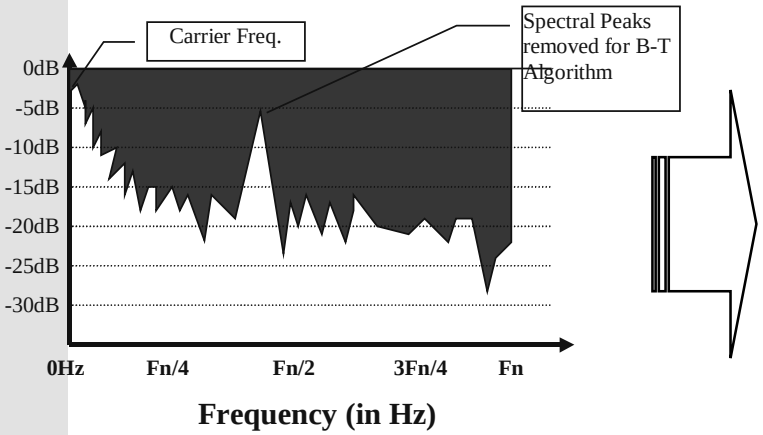
VI™ DataCOM Random Pattern Theory of Operation



Measurements Binned to Closest UI Boundary

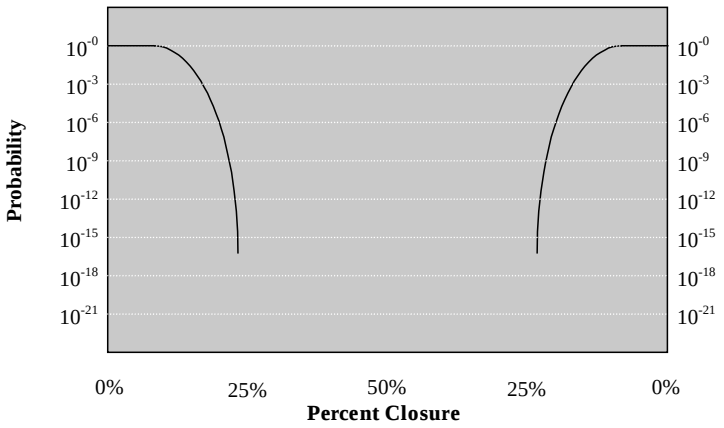


FFT of Binned Array Data using ATA

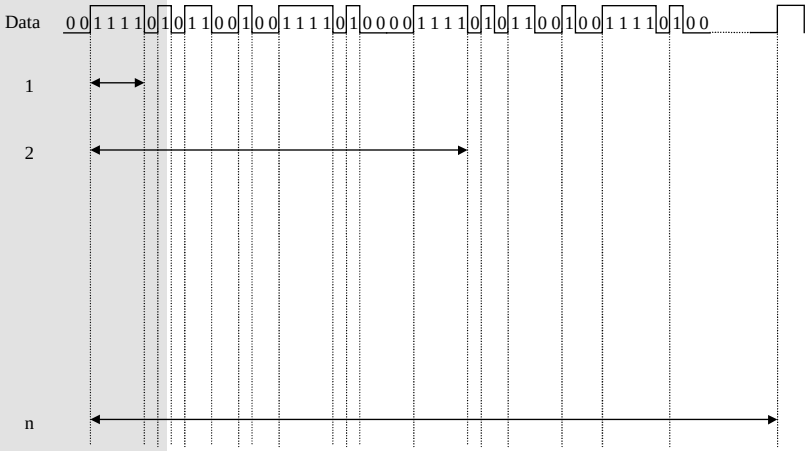


Fn = Apparent Nyquest Frequency

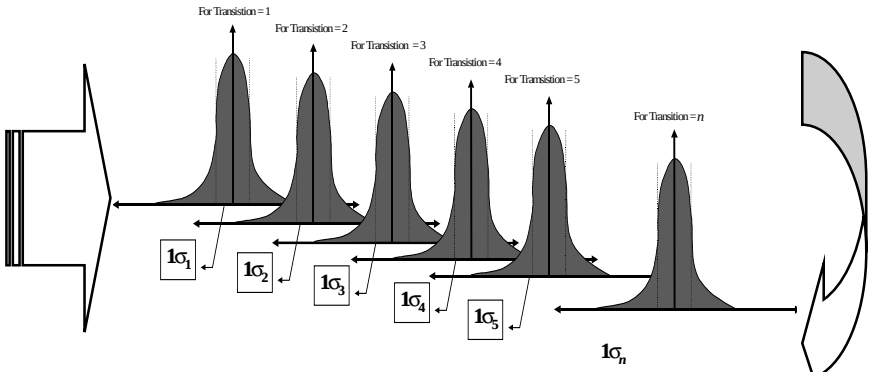
Bathtub Curve
(Probability versus Percent Closure)



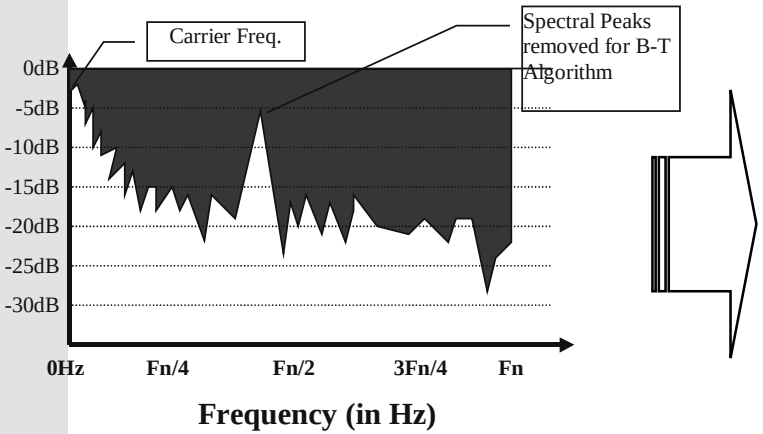
VI™ DataCOM Known Pattern - Theory of Operation



Transition Distributions

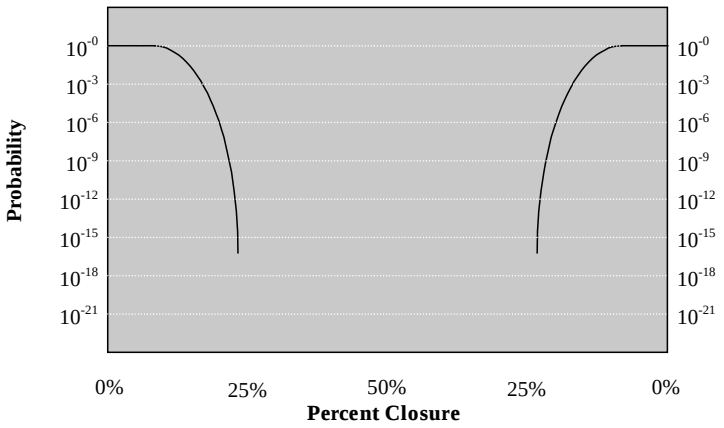


FFT of Binned Array Data using ATA

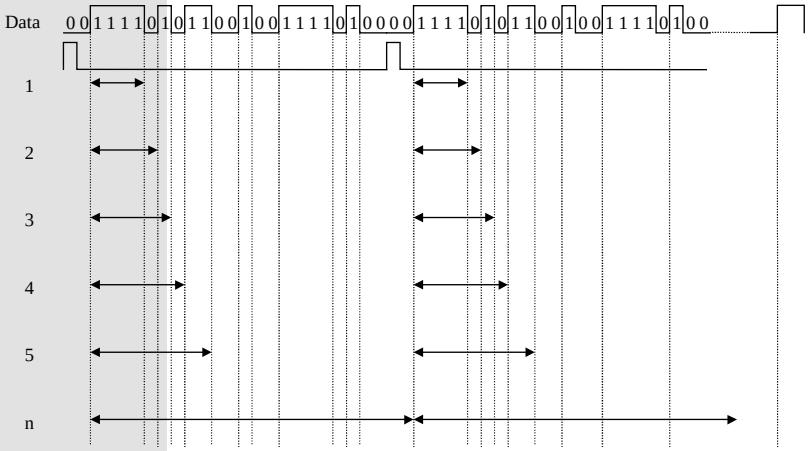


Fn = Apparent Nyquest Frequency

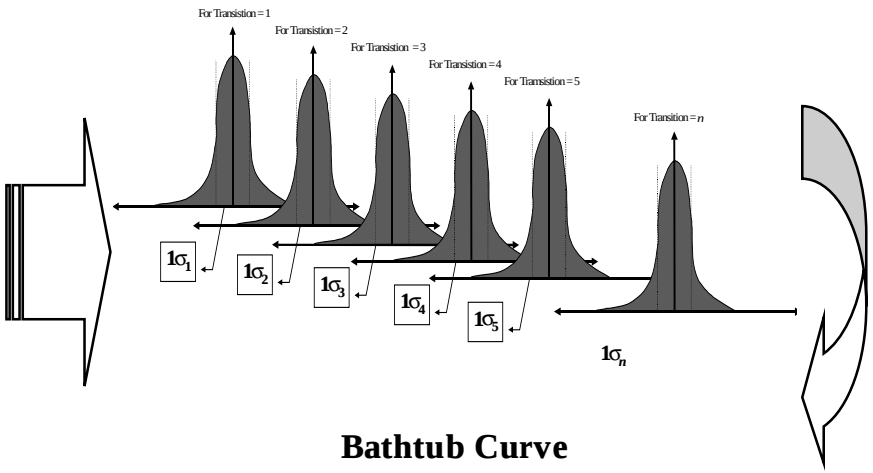
Bathtub Curve
(Probability versus Percent Closure)



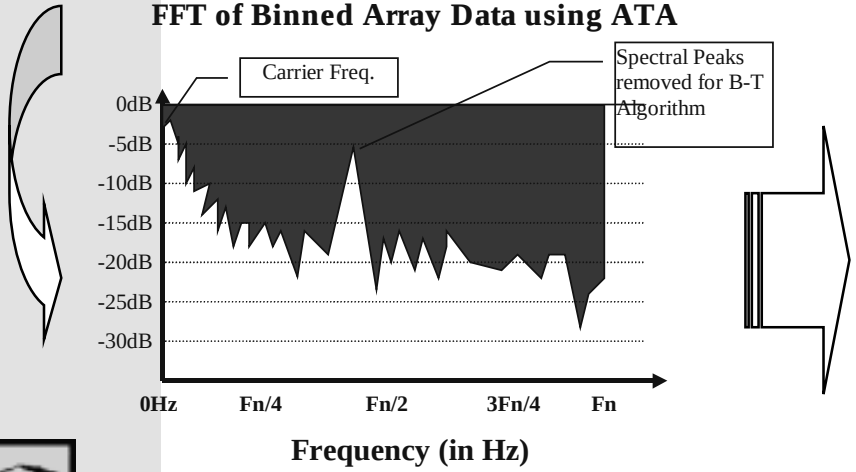
VI™ DataCOM Known Pattern & Pattern Marker - Theory of Operation



Transition Distributions



FFT of Binned Array Data using ATA



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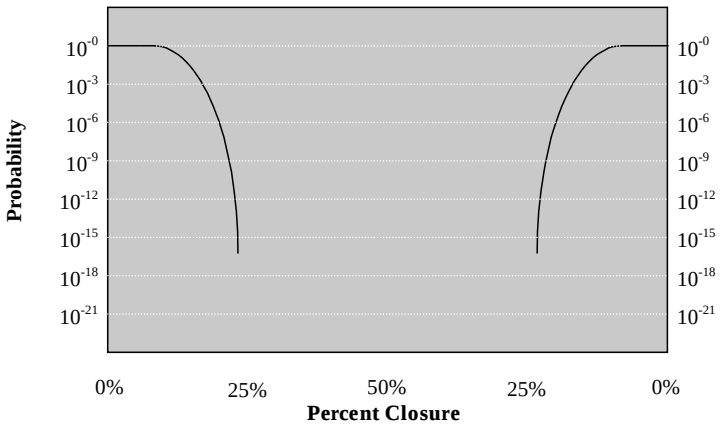
Bathtub Curve
(Probability versus Percent Closure)



Understanding the Alternatives

- BERT
  - Extremely long characterization times
- Eye Diagram
  - will not be able to filter out frequency components below cutoff frequency
    - Device should be able to track low frequency jitter
  - will not be able to separate Random Jitter from Deterministic Jitter
- Wavecrest DTS
  - Fast, Reliable & Production Worthy

Understanding the Alternatives

BERT	O'scope	DTS
Advantages		
• Accurate Device Verification with some jitter detection	• Using clock recovery circuit, peak to peak jitter measurement available	• Can separate RJ, PJ, DCD+ISI and BUJ • Fast, Production Worthy Solution • Accurate and Repeatable
Disadvantages		
• Extremely long test times • Very expensive solution	• Cannot filter frequency components • No RJ,PJ,DCD+ISI separation • Underestimates Total Jitter