

Measuring Time Error

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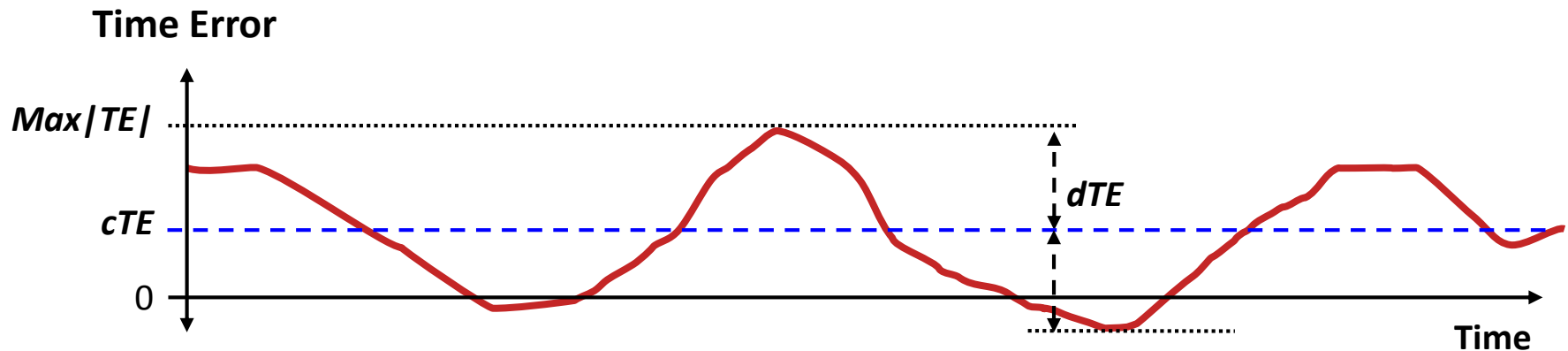
Presentation overview

- What is Time Error.
- Boundary Clocks & Slave Clocks, sources of uncertainty.
- G.8273.2 performance specification.
- Evaluation of Boundary Clocks & Slave Clocks.
- Example test results.

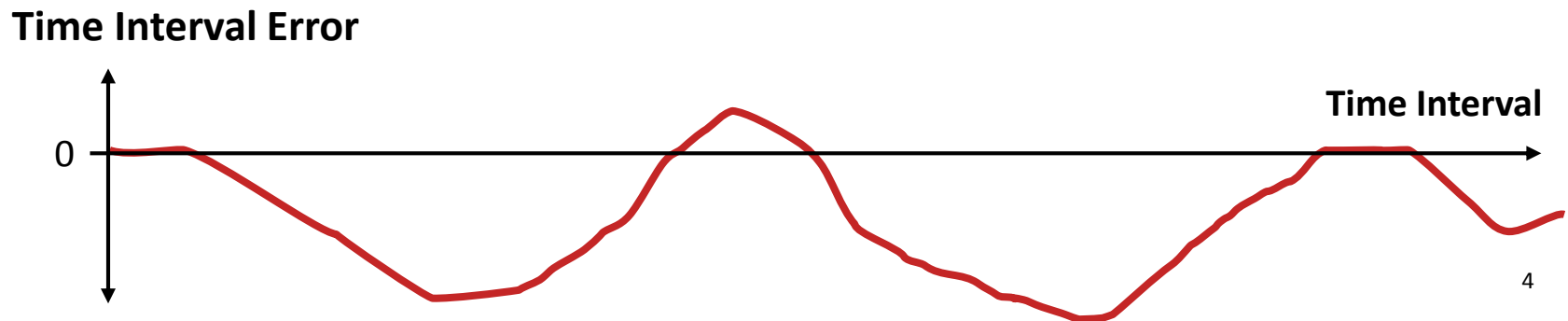
What is Time Error

Time Error and Time Interval Error (TIE)

- Time Error measures the time difference between two clocks



- Time Interval Error measures change of time error
 - Starts at zero by convention, then tracks the dynamic time error



Measuring Time Error

- Need an accurate time reference
 - Referenceless measurements can *estimate* change in time error, but can't *measure* time error.
- ***Max|TE|*** is defined as the maximum distance from zero of the time error function
 - Sign doesn't matter: excursions may be positive or negative
 - Unfiltered or filtered (0.1Hz) depending on application.
- ***cTE*** is defined as the mean of the time error function.
- ***dTE*** is analyzed using MTIE and TDEV of the time interval error function.

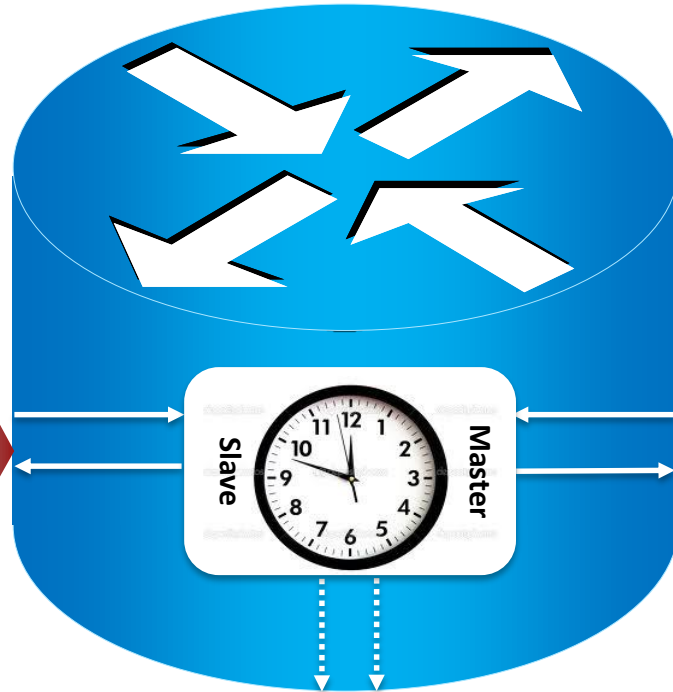
Time Error Specifications



- Time error generation of **equipment clocks** specified using three parameters:
 - Constant Time Error (**cTE**) - specified in nanoseconds.
 - Dynamic Time Error (**dTE**) - specified with MTIE & TDEV masks, data pre-filtered by 0.1Hz
 - Max absolute time error (**max|TE|**) - specified in nanoseconds, **data unfiltered**
- **Network limits** on time error at reference points specified using two parameters:
 - Dynamic Time Error (**dTE**) - specified with MTIE & TDEV masks, data pre-filtered by 0.1Hz
 - Max absolute time error (**max|TE|**) - specified in nanoseconds, **data pre-filtered by 0.1Hz**

Boundary and Slave Clocks

Boundary Clock, T-BC



Frequency (T1/E1/SyncE) Time/Phase (1pps)

Boundary Clocks reduce PDV accumulation by:

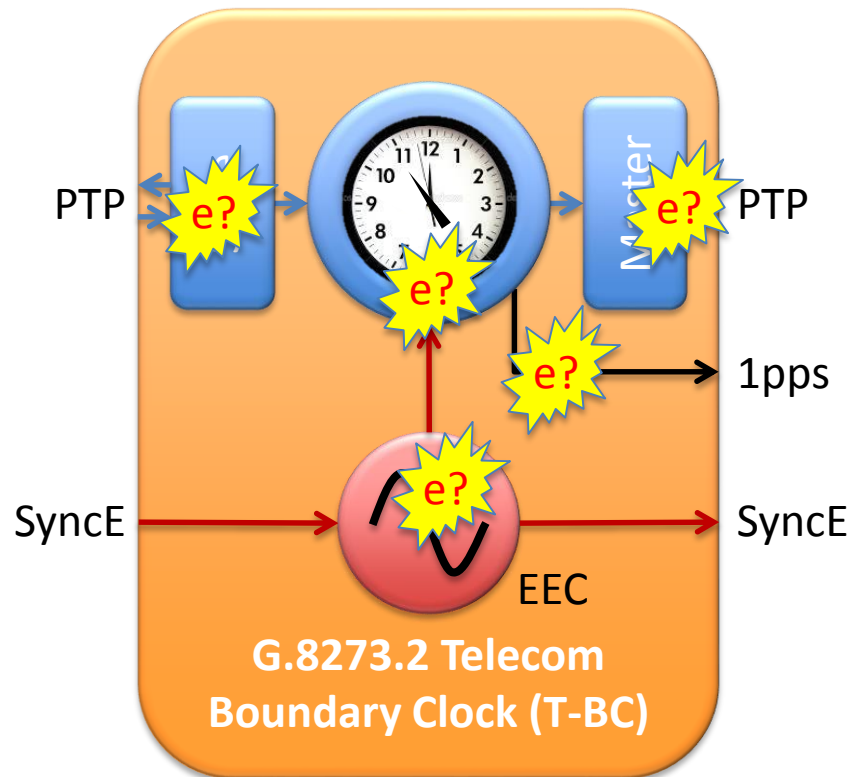
- Terminating the PTP flow and recovering the reference time
- Generating a new PTP flow using the recovered time
- No direct transfer of PDV
- Slave/Master combination

Telecom BCs (T-BCs) use SyncE to:

- Improve stability
- Improve holdover

T-BCs specified in ITU-T Recommendation G.8273.2

T-BC sources of uncertainty



Sources of uncertainty:

- Timestamp noise in slave
- Phase noise and distortion in internal oscillator
- SyncE phase wander
- Path delay uncertainty in 1pps signal path
- Timestamp noise in master

Time Error is the combination of all these uncertainties

Time Slave Clocks, T-TSC

- Similar to the T-BC, but without the PTP master element
- Performance measured at the 1pps output
- Most performance requirements similar to the boundary clock:
 - Noise generation
 - Noise Tolerance
 - Noise transfer
 - Transient response
- Holdover specification will be stricter (*currently for further study*)
- T-TSC specified in Annex C of G.8273.2

T-BC Clock Specification G.8273.2

G.8273.2 T-BC Specification



Five key elements to every ITU-T clock specification:

- **Noise generation**
 - The intrinsic noise generated by the clock itself with an “ideal” reference at the input
- **Noise tolerance**
 - The maximum amount of noise the clock can tolerate at its input
- **Noise transfer**
 - The transfer function of the clock; usually defined as the bandwidth
- **Transient response**
 - The response of the clock to a transient at its input
- **Holdover**
 - How long a clock should maintain its output within specification after loss of the input signal

For time clocks, “noise” means time error.



- Max|TE| specification: 100ns (class A), or 70ns (class B) (*unfiltered*)
- cTE specification: 50ns (class A), or 20ns (class B) (*mean over 1000s*)
- dTE specification: 40ns MTIE, 4ns TDEV (*after filtering by 0.1Hz*)



- No alarms are generated
- Clock does not switch references or go into holdover
- *There are no performance limits to check*

G.8273.2 Noise Tolerance Limits

PTP Noise tolerance:

- T-BCs must tolerate the maximum dTE accumulation over the chain of T-BCs
- Specified using an MTIE mask in G.8271.1 Section 7.3:

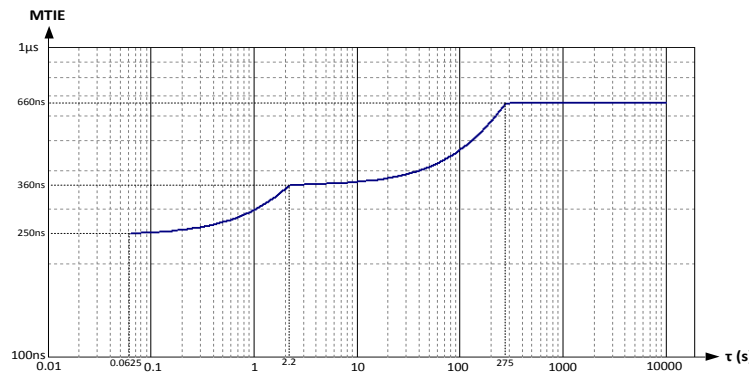


Figure 2 from G.8271.1:
dTE network limit

SyncE Noise tolerance as defined in G.8262:

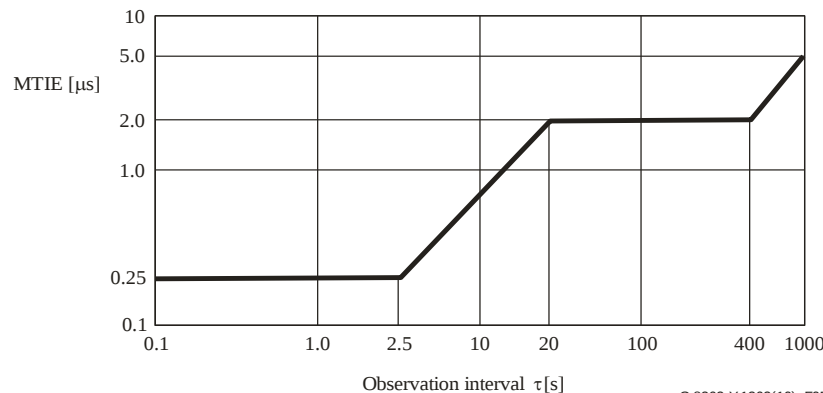
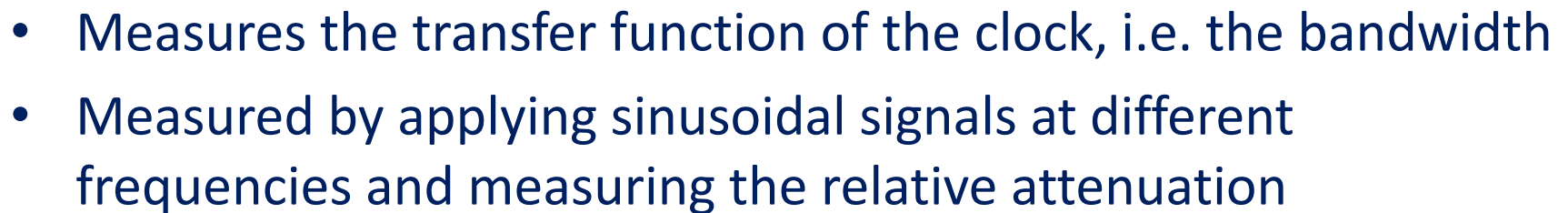
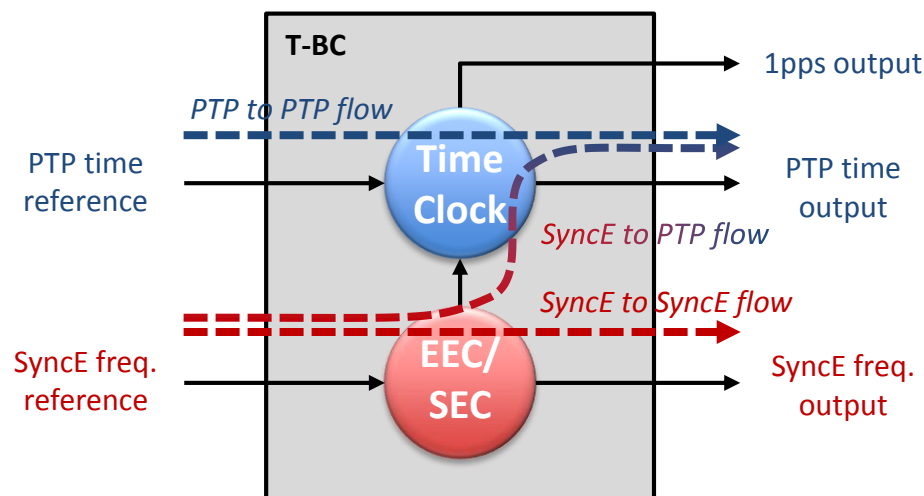


Figure 5 from G.8262:
Input wander tolerance
for EEC Option 1



G.8273.2: Noise Transfer



PTP input is:

- Noisy at high frequencies (*e.g. packet jitter, timestamp quantization*)
- Quiet at low frequencies (*because traceable to a time reference*)

Time Clock is a phase (time) locked loop:

- Smooths out packet noise at high frequencies by following SyncE or local osc. (*i.e. PTP input is low-pass filtered*)
- follows PTP input at low frequencies, correcting SyncE or oscillator wander (*i.e. SyncE/oscillator noise is high-pass filtered*)

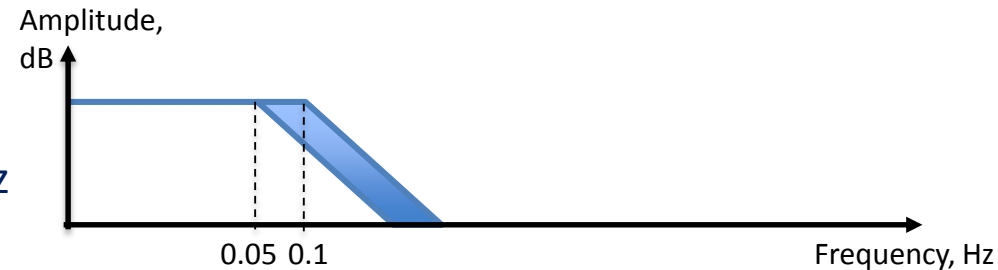
SyncE input low-pass filtered by EEC, then high-pass filtered by Time Clock

- Net result is a band-pass filter

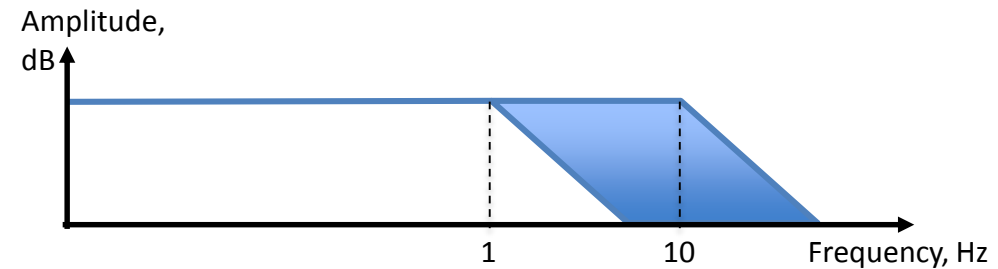
G.8273.2: T-BC Clock Bandwidth

Noise Transfer

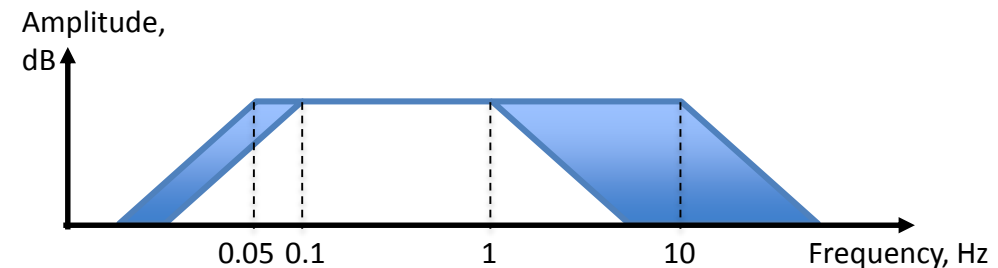
- **PTP to PTP:**
Low pass filter,
bandwidth between 0.05 to 0.1Hz



- **SyncE to SyncE (G.8262):**
Low pass filter,
bandwidth between 1 to 10Hz



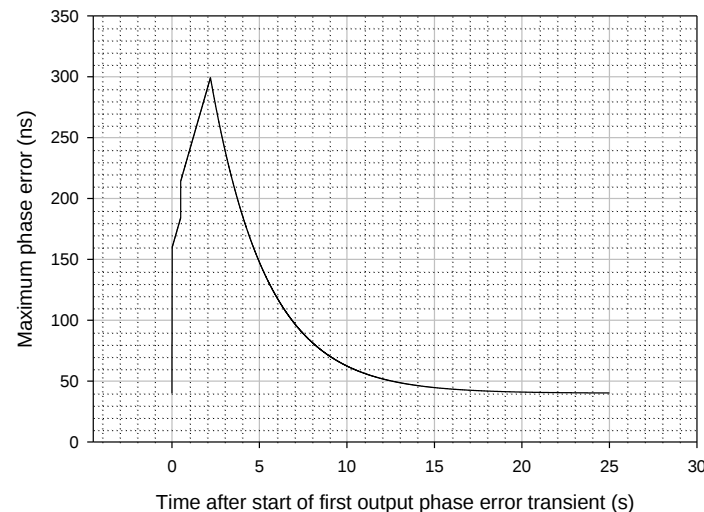
- **SyncE to PTP:**
Bandpass filter,
lower cutoff 0.05 to 0.1Hz,
upper 1 to 10Hz



G.8273.2 Transient response

- G.8273.2 specifies that a T-BC should “reject” a SyncE transient on its input
 - This means it should not follow the SyncE input until the signal is restored
 - Determined by monitoring the QL of the SyncE signal
- Defines an acceptable transient mask that the T-BC should remain within when a SyncE transient is applied at the input

T-BC output phase mask for first output phase error transient after start of SyncE rearrangement

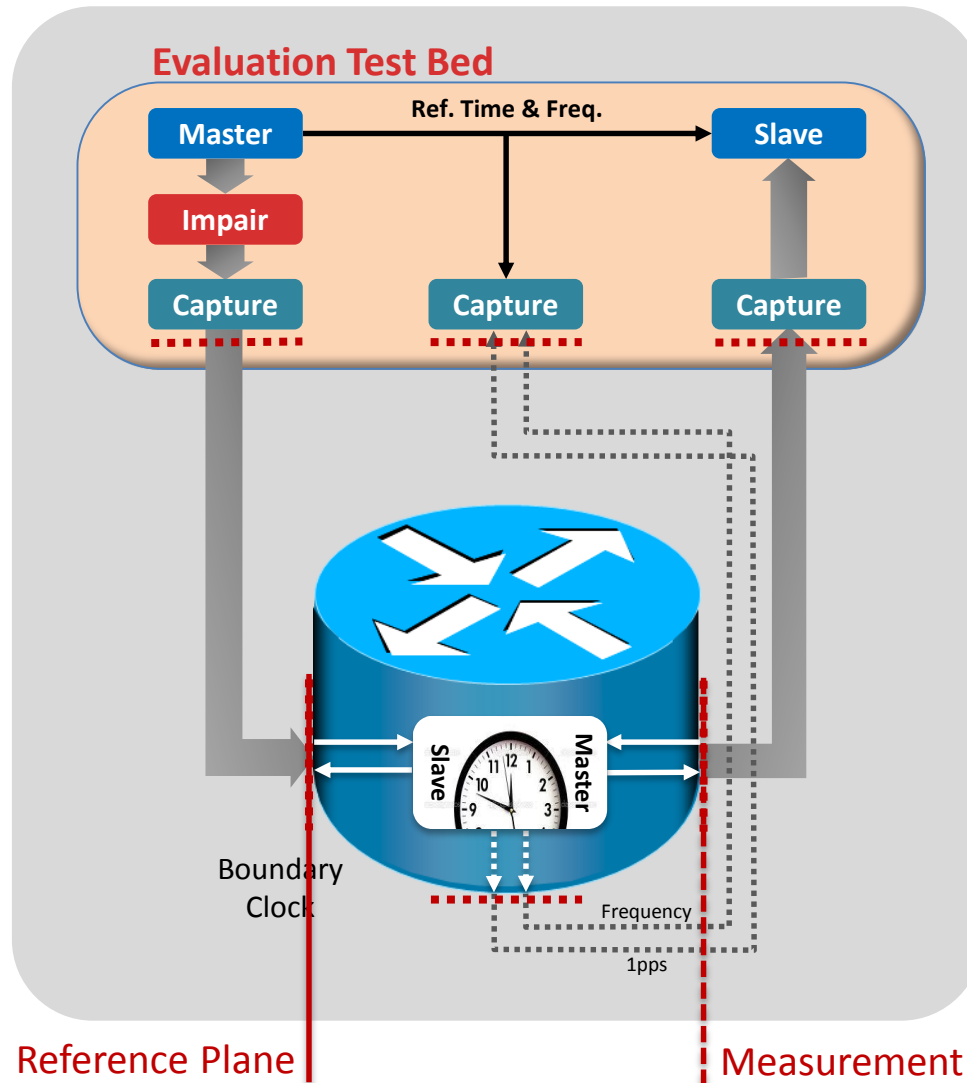


G.8273.2 Holdover Specification

- G.8273.2 does not yet define holdover period for a T-BC
- Holdover provided at the end node rather than at each T-BC
- “Assisted” holdover may be provided using SyncE
 - Long term stability of the SyncE signal helps output to remain within specification
 - Even with assisted holdover, the clock will not remain in specification for more than a few seconds

T-BC & T-TSC evaluation

T-BC Time Error Evaluation



TE: Difference between egress time to ingress time;

- Max |TE| (unfiltered)
- Constant TE
- Dynamic TE (MTIE/TDEV)

a) Measure Egress PTP

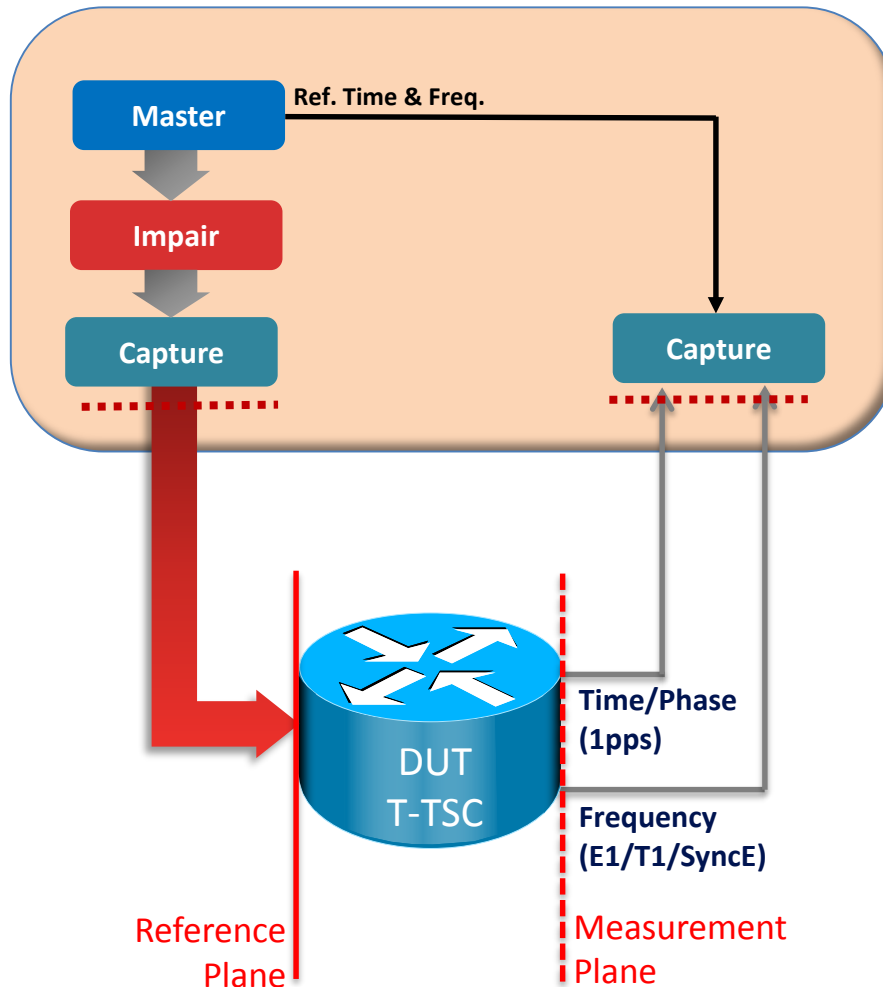
- Analyse timestamps to determine TE of T-BC.
- Important to verify egress PTP as this is the signal used to transfer Time downstream.

b) Measure 1pps

- Once deployed 1pps is the monitor point to indicate what is happening on the egress PTP
- Must verify it accurately reflects actual performance on the egress PTP

T-TSC Time Error Evaluation

Evaluation Test Bed



TE: Difference between time output to ingress time;

- **Max|TE|** (unfiltered)
- **Constant TE**
- **Dynamic TE** (MTIE/TDEV)

a) Measure 1pps;

- Analyse 1pps output to determine performance of T-TSC

Example Test Results

Unfiltered Two Way Time Error



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Averaged (10s) Two Way Time Error



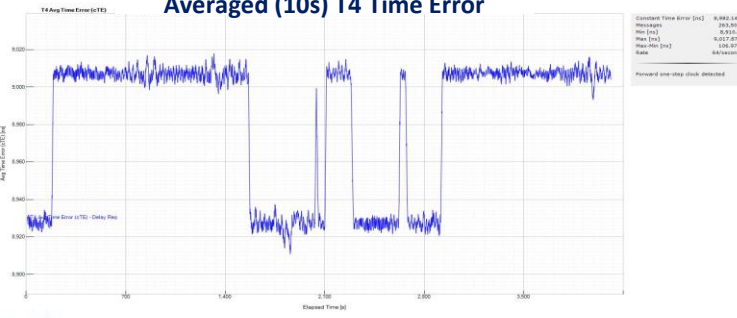
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Averaged (10s) T1 Time Error



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Averaged (10s) T4 Time Error



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T-BC: Example results, Device A



- Raw Time Error: Pk-to-pk Time Error is over 1μsec with single packet events clearly visible.

1pps Time Error

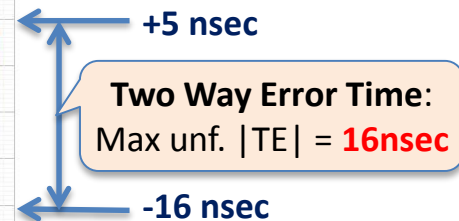
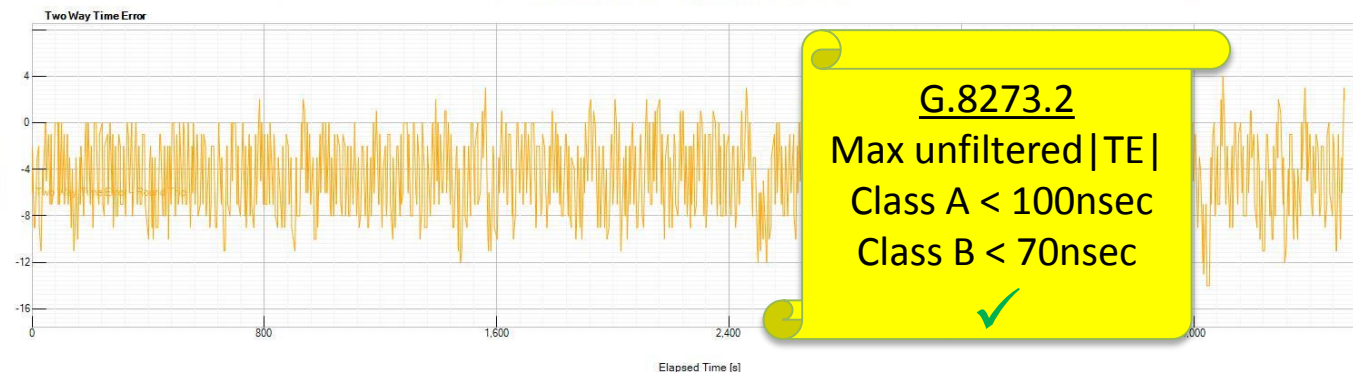
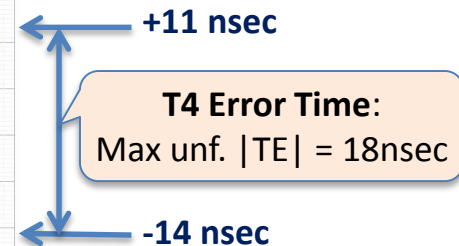
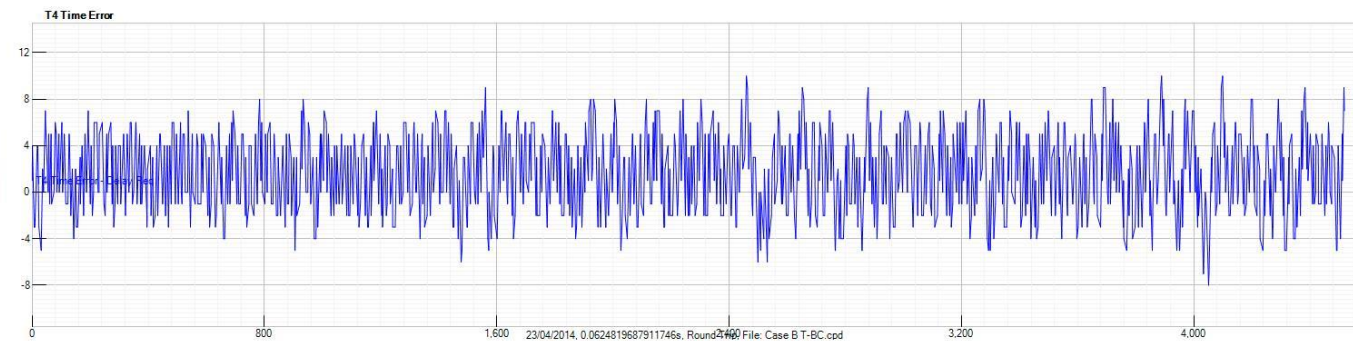
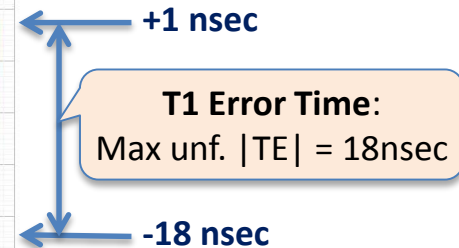
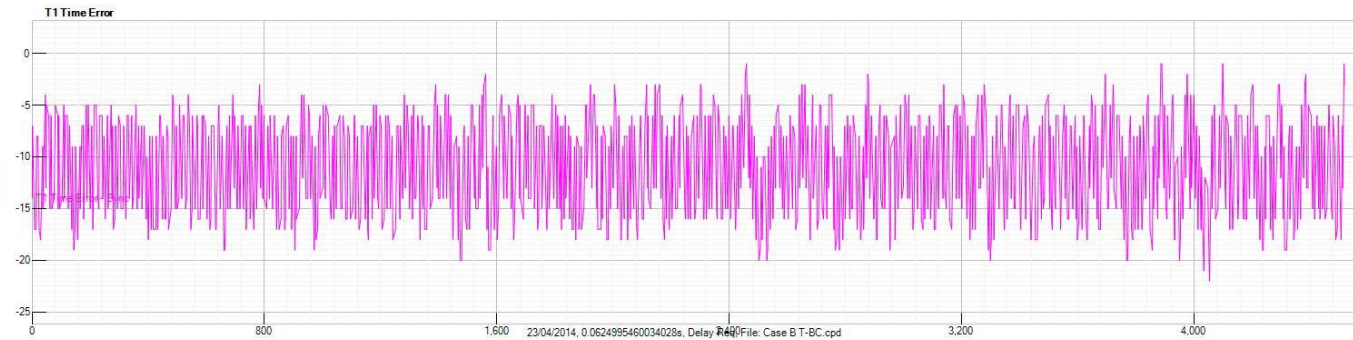


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- Removing the pkt-to-pkt noise, it becomes more obvious what the underlying phase movement is that could impact the terminating devices.
- Compare the 1588v2 vrs 1pps Time Error
- Understand packet effects affected 1588v2 Time Error.

T-BC: Example results, Device B

Max Unfiltered Time Error

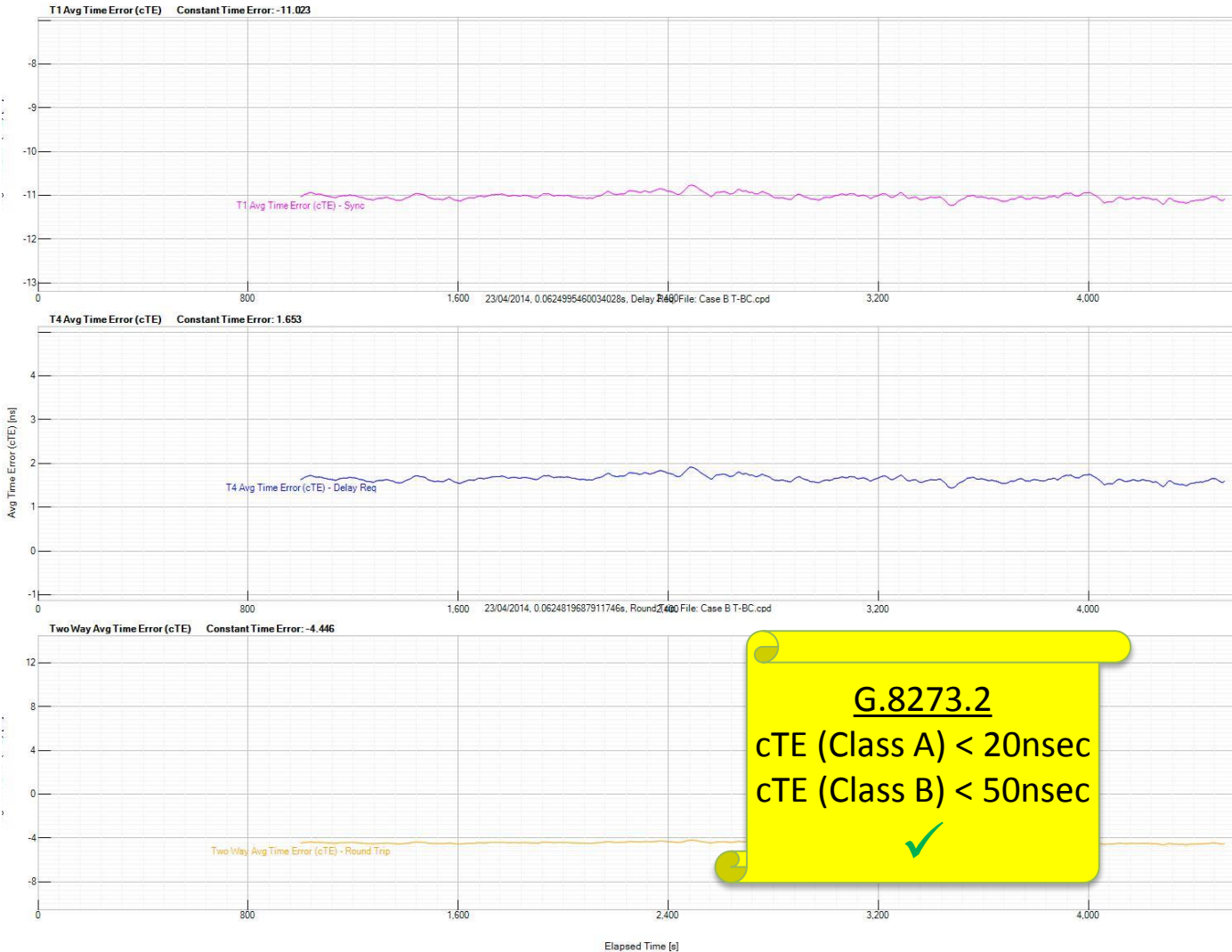


G.8273.2
Max unfiltered |TE|
Class A < 100nsec
Class B < 70nsec



T-BC: Example results, Device B

Constant Time Error (1000sec averaging)



-10.76 nsec

T1 Constant Error Time:
cTE = -11.02 nsec

-11.23 nsec

+1.44 nsec

T4 Constant Error Time:
cTE = 1.65nsec

+1.92 nsec

G.8273.2
cTE (Class A) < 20nsec
cTE (Class B) < 50nsec



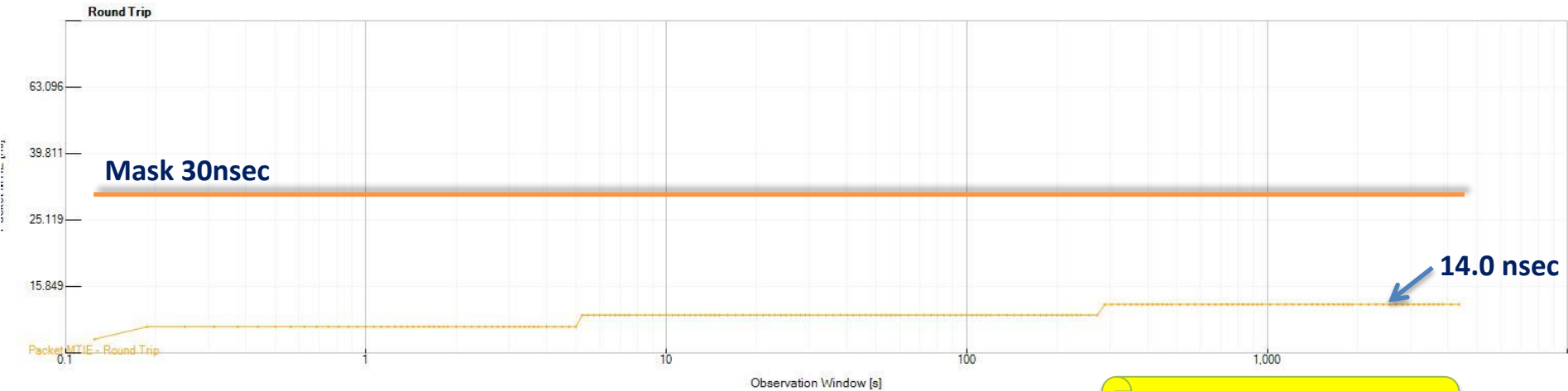
-4.65 nsec

Two Way Constant Error Time:
cTE = -4.45nsec

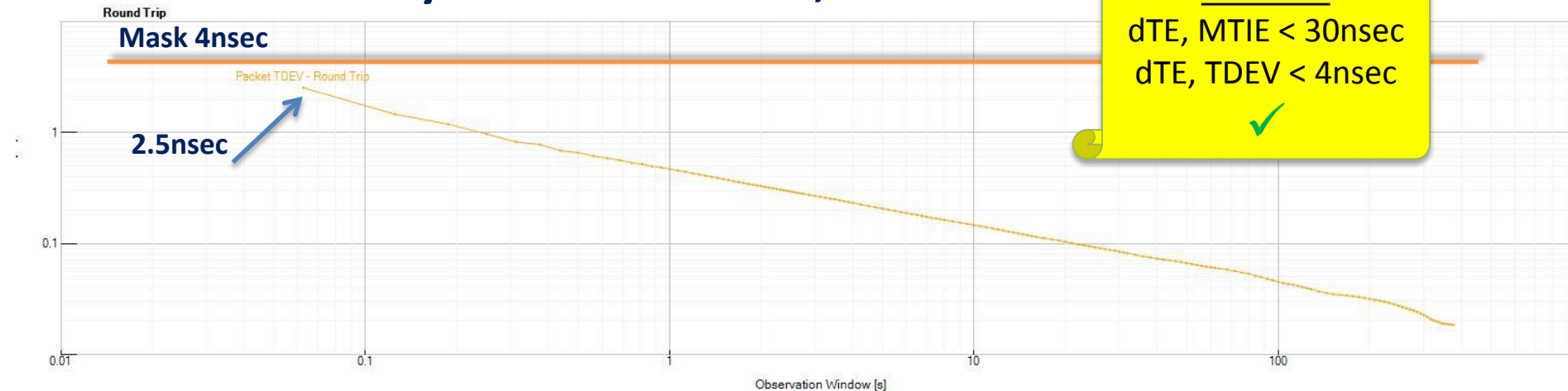
-4.19 nsec

T-BC: Example results, Device B

Dynamic Time Error, MTIE



Dynamic Time Error, TDEV



G.8273.2
dTE, MTIE < 30nsec
dTE, TDEV < 4nsec



Summary

- Time Error Metrics
 - Max $|TE|$
 - Constant TE, cTE
 - Dynamic TE, dTE, (MTIE & TDEV)
- G.8273.2; Both T-BC and T-TSC performance parameters specified.
 - Noise Generation
 - Noise Tolerance
 - Noise Transfer
 - Transient Response
 - Holdover
- Proving performance
 - High-accuracy measurement so all sources of Test-bed accuracy need to be considered.

Wednesday Night ... What a Night!



Hollywood's finest will be back (if released!)