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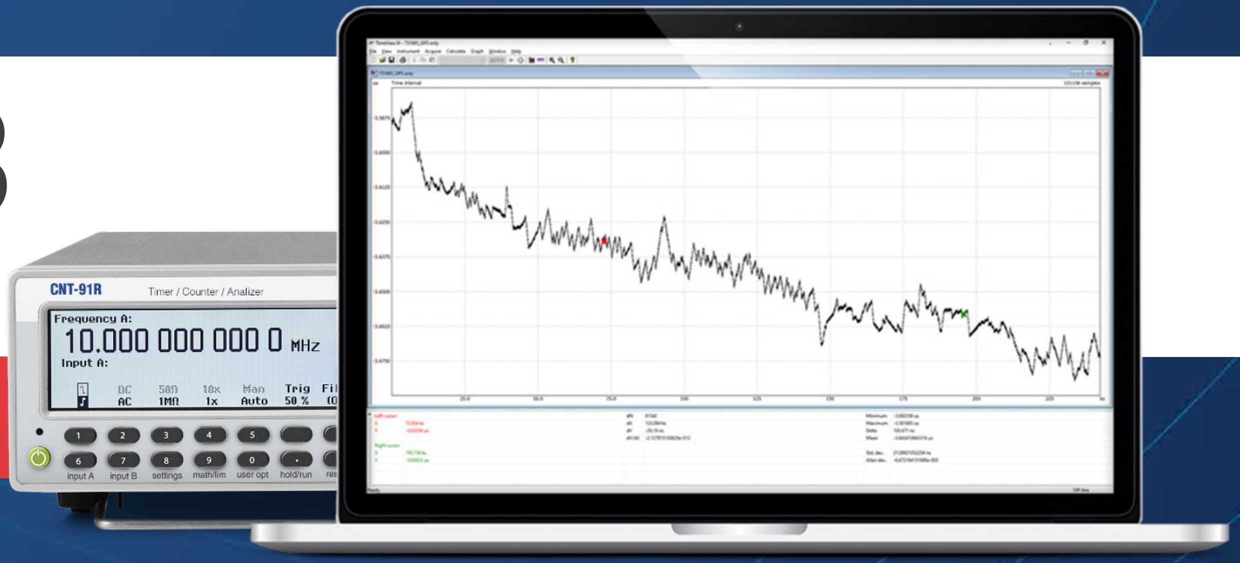
TimeView 3

Wander measurements



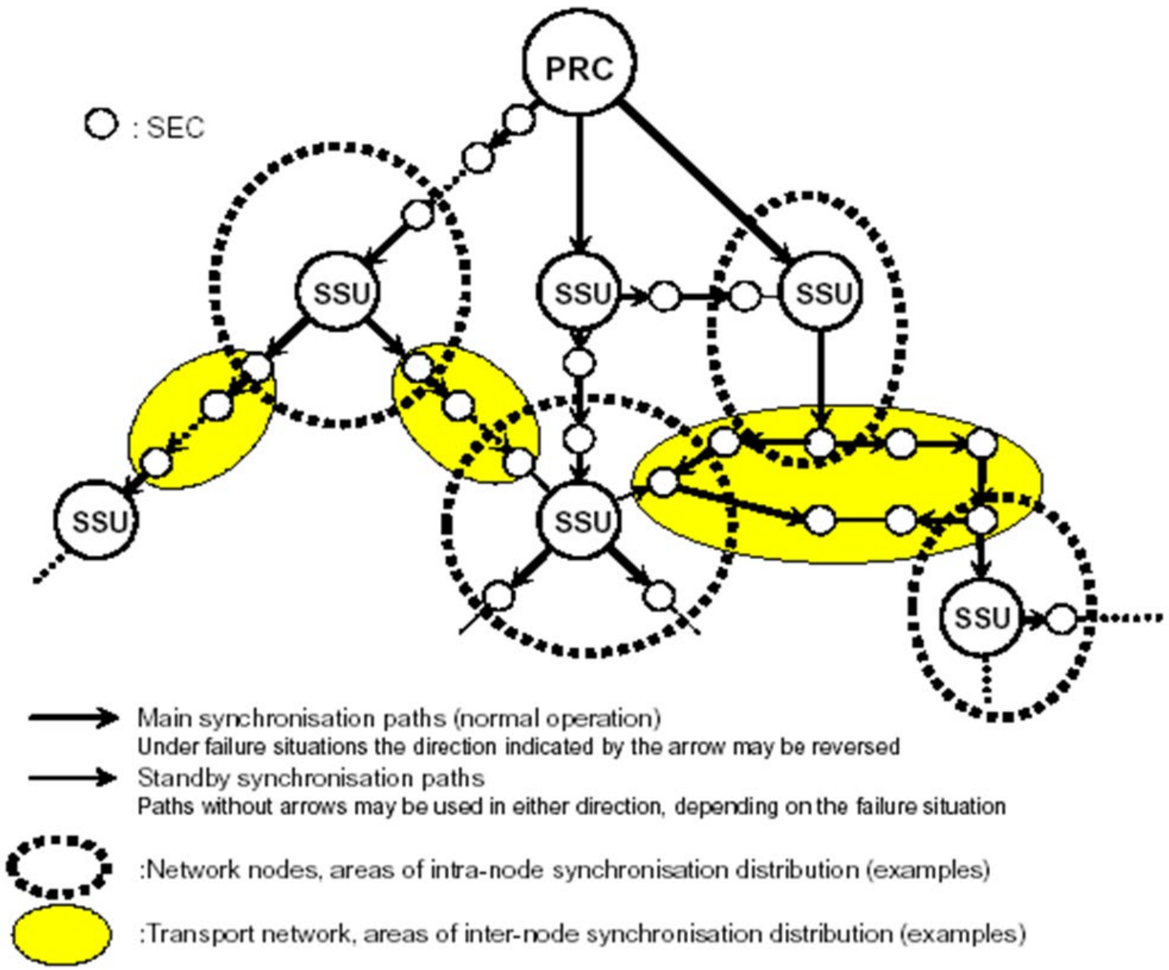
Jitter and Wander

- Jitter and Wander in network clocks or data signals = phase variation of the clock/data edges from the "ideal" signal
- Jitter is fast phase variations cycle to cycle, wander is slow variations
- The border between jitter and wander is 10 Hz phase variation
- Jitter and Wander are created in networks where a stable master clock is controlling/synchronizing remote less stable slave clocks
- Excessive jitter and wander can cause synchronization loss in slave nodes, bit errors, re-send messages, and more

Synchronized networks for voice, video and data

- SDH = Synchronous Digital Hierarchy
  - The network is synchronized from a 2.048 MHz master clock – the PRC (Cesium clock)
- PDH = Plesiochronous Digital Hierarchy
  - Predecessor to SDH. Sync via E1-clocks (2.048 MHz), but no hierarchy
- SONET
  - Similar to SDH, but basic clock frequency is 1.544 MHz
- IP Networks
  - By nature not synchronized – But new sync technologies like SyncE and/or PTP allows to transfer frequency and or time via slave clock disciplining
- GNSS synchronized Networks
  - Uses local GNSS receivers in network nodes for time/frequency synchronization

Example: Master-slave Synchronization in SDH



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Wander Facts – What can generate wander?

- Sources of wander
  - Slave clocks in network nodes (disciplined by incoming data)
  - Master clocks in networks (disciplined by GPS/GNSS)
  - Other clocks containing a Frequency Locked or a Phase Locked Loop for frequency control
  - Slow variations of delay time in the transmission network, e.g. due to temperature variation between day and night in long fibers (a change of fiber length due to temperature means a change of phase after transmission)
- Non-wander sources
  - All free-running oscillators without external frequency control in a stable temperature environment
    - *Cesium oscillators*
    - *Rubidium oscillators*
    - *OCXO:s*

The need for controlling synchronization

Transmission problems caused by wander (= bad synchronization)

- Voice > Sudden click sounds
- Data > Retransmission (lower throughput or even loss of data)
- GSM/3G/4G > Lost calls at handover
- Video > Pixel errors, frozen picture
- Fax > Unreadable characters
- Bad synchronization gives lower throughput in the network, and lower QoS
- Worst case; total loss of traffic

- *Unreliable network services →higher costs*
- *Reduced traffic volume →lower revenues*

Wander and CNT-91

- Wander of any clock (but not data signals) up to 160 MHz can be measured by CNT-91 and the TimeView 3 analysis SW.
- The basic measurement is **TIE**, i.e. the Time Interval Error between the clock edges of the DUT (Device under test), and the reference clock in CNT-91 (the "ideal clock").
- The "ideal" clock for comparison with the DUT frequency is created in SW, and TIE values are derived from the precise timestamps of the edges of the DUT (35 ps resolution).
- For this type of measurements, the CNT-91 must be very accurate, stable and have no wander of its own. This is achieved either using CNT-91R with integrated Rubidium clock or using an ultra-stable external reference.

TimeView post processing from TIE raw data

- Standard parameters acc. to ITU-T, ANSI and ETSI
    - MTIE, TDEV
- Parameters with compensation of frequency offset
    - RTIE, MRTIE
- Parameters for calculating other standard clock stability metrics (Allan Deviation and Modified Allan Deviation)
    - ADEV, MADEV

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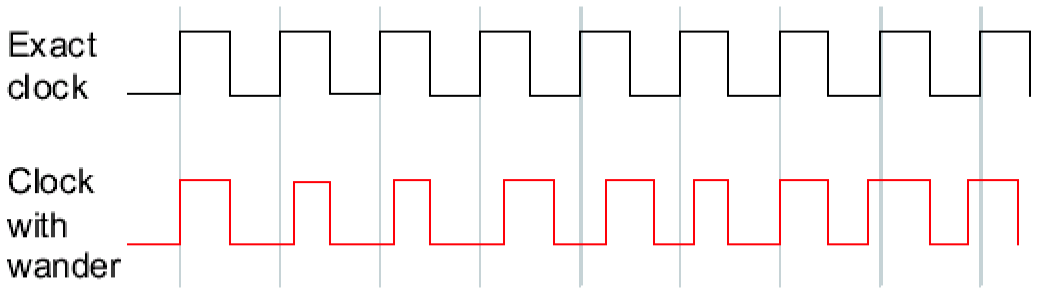
Wander Facts

- Wander = slow phase variation (below 10 Hz) of the synchronization clock (TIE);
- TIE = Time Interval Error between ideal and actual clock



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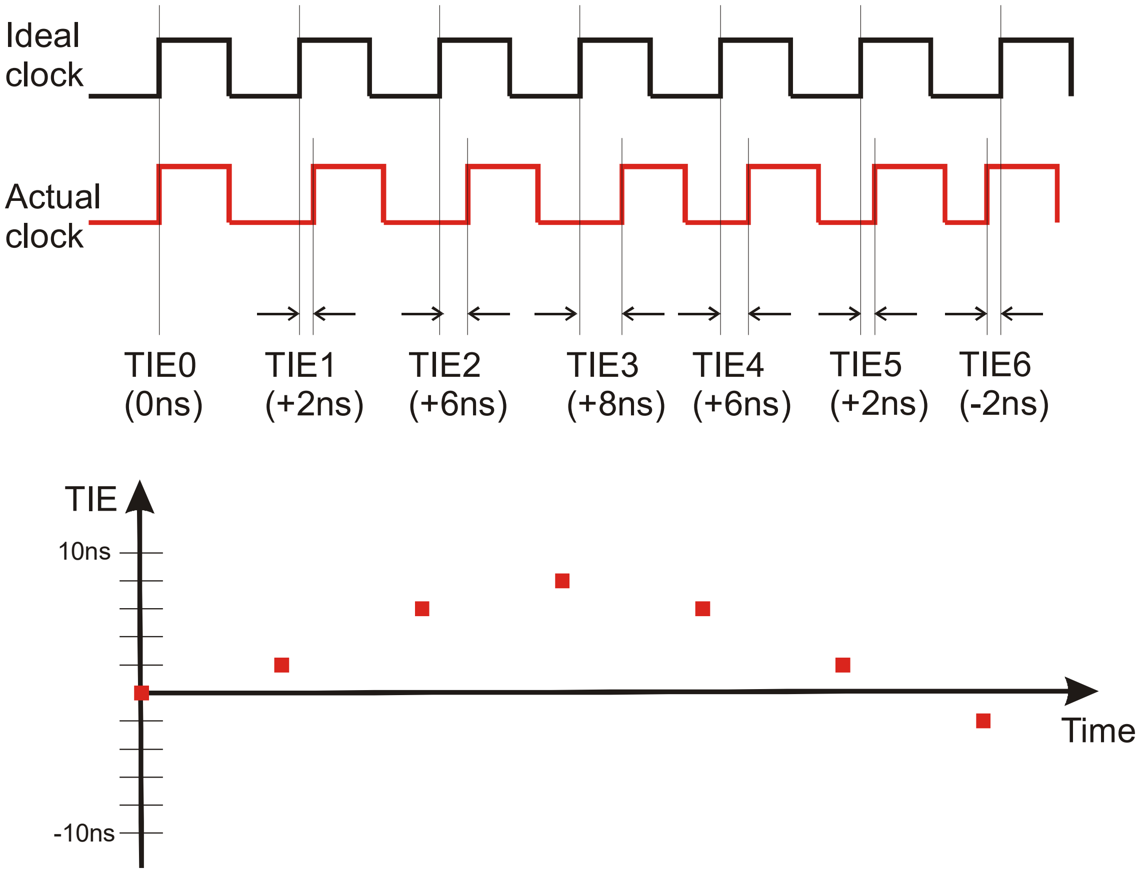
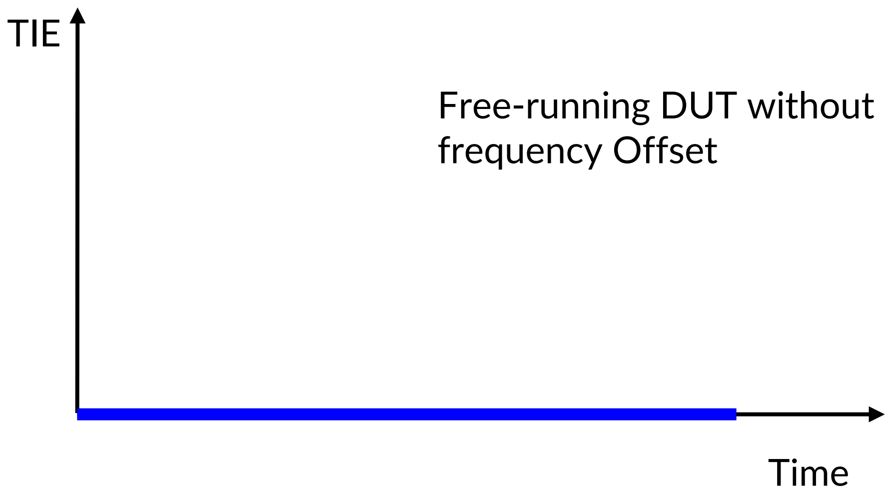
Simplified example TIE on a 1-pps signal



TIE for a perfect DUT

A very stable clock under test, that is free-running without any frequency offset, will result in a TIE-curve that is a straight line with a zero slope (TIE for first samples are the same as TIE for the last samples)

NOTE: a horizontal straight line demands that both the DUT and the CNT-91 reference ´timebase are “perfect”, meaning no frequency offset whatsoever



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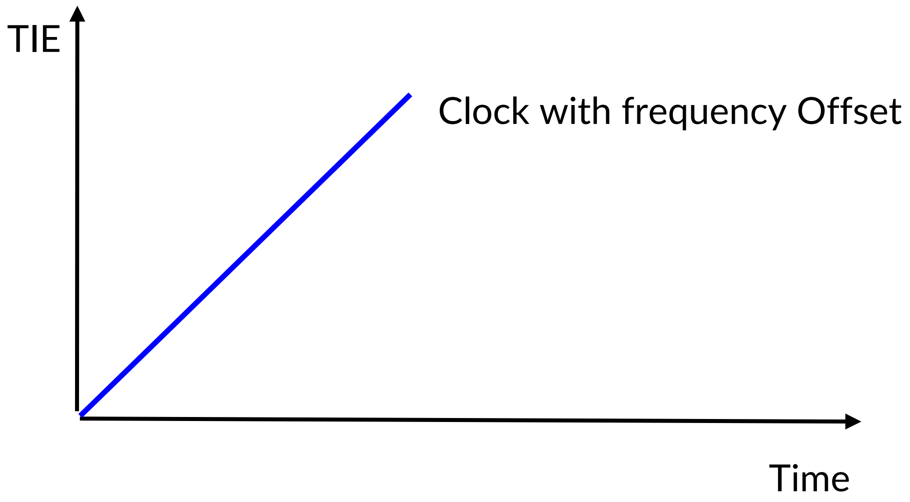
Frequency Offset

A stable but not exact clock under test, that is free-running with a frequency offset, will result in a TIE-curve that is a straight line with a slope ($\Delta TIE / \Delta t$) corresponding to the fractional frequency error ($\Delta f / f_{nom}$)

$f_{clock} = f_{nom} + \Delta f$

$TIE(t) = (\Delta f / f_{nom}) * t$

NOTE: the same straight line will appear if the DUT is perfect, but CNT-91 reference has an offset



Frequency Offset - RTIE

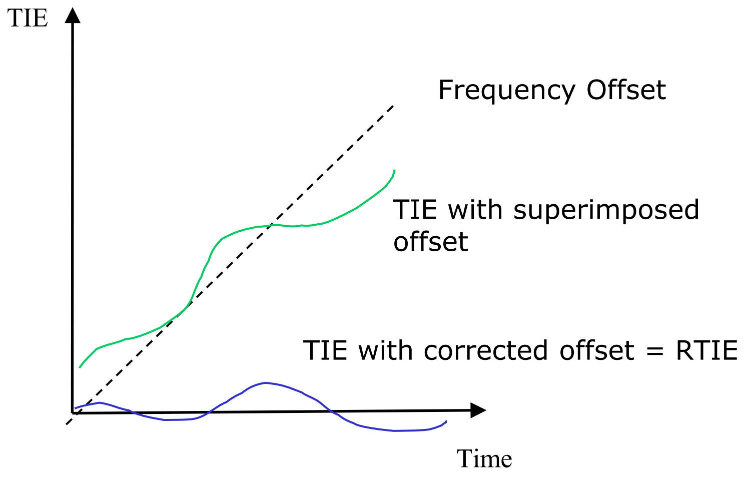
A network clock with wander (TIE) could show a frequency offset to the reference frequency used. This is the case:

A: When the clock itself has a frequency offset vs the Reference

B: When the Wander measurement tester has a built-in reference clock with an offset (e.g. when you have not calibrated the reference clock for a long time)

In either case the TIE-curve will show a combination of the frequency offset and the TIE variations

By eliminating the frequency offset from the TIE calculation, you will get RTIE = Relative TIE



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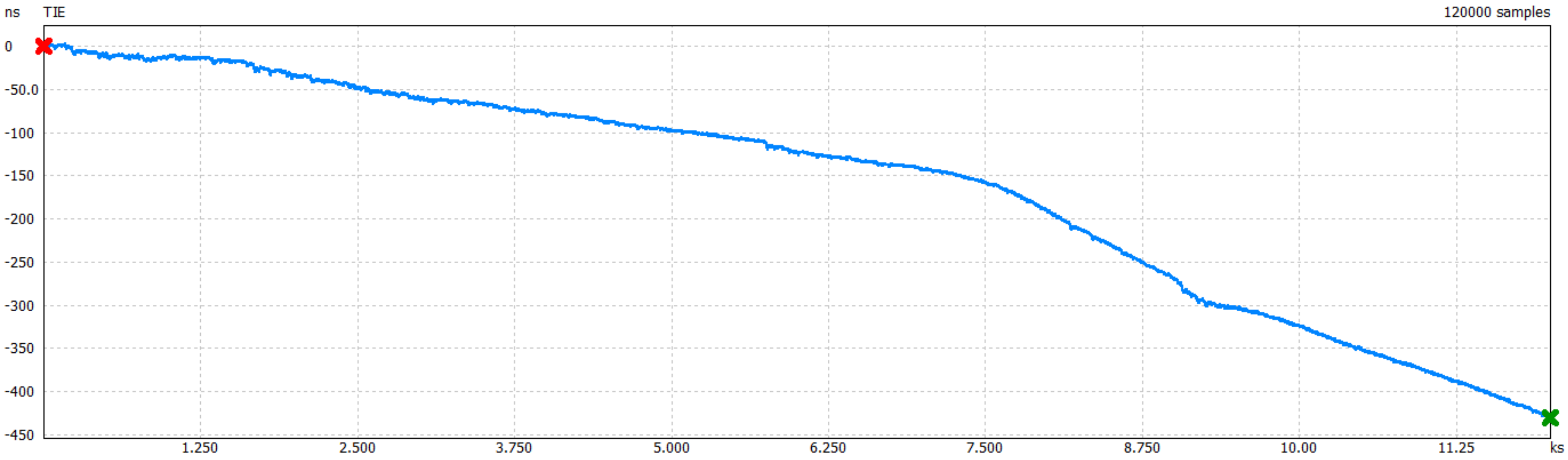
TIE example

This TIE graph shows the output of a GNSS controlled Rubidium oscillator over 12000s (3h and 20 minutes). There is a frequency difference between the DUT and the CNT-91R reference timebase of 3.5E-11, which explains the slope.



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Wander facts - MTIE

MTIE = Max TIE peak-peak

- MTIE expresses the worst-case phase error of the clock under test
- MTIE (τ) is the peak-peak phase error (TIE) variation (Max[TIE] – Min[TIE]) over observation periods (τ)
- A high MTIE means risk of frame slips (SDH/SONET)
- An MTIE increasing as a straight line is a sign of a frequency offset of the clock under test
- MTIE will reveal frequency drift of the clock under test

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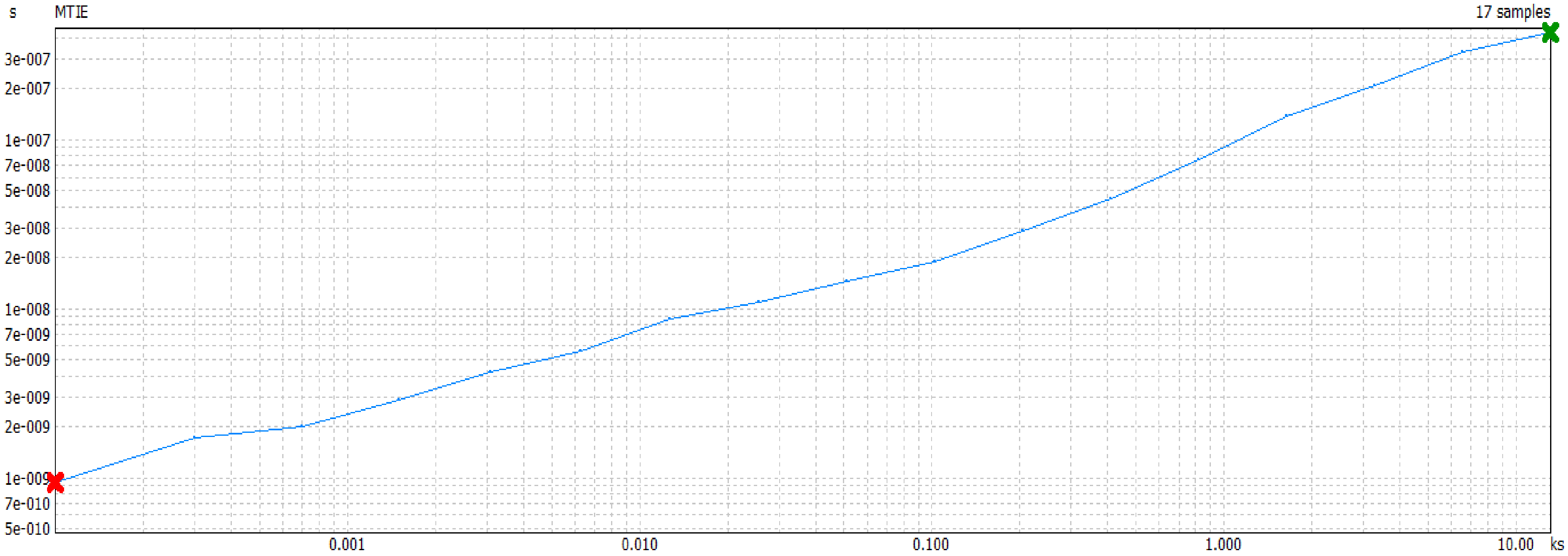
MTIE example

MTIE of the previous TIE measurement, MTIE is always a growing function (MTIE for a larger observation interval is always bigger than or equal to MTIE for a smaller interval).

MTIE at end of observation interval is 430 ns or 88% of a 2.048 MHz clock cycle



Wander Facts – TDEV

TDEV = Time Deviation

- TDEV(τ) expresses the short-medium stability of the clock under test
- TDEV = rms spread of the TIE samples over various observation periods (τ)
- TDEV shows short term stability such as random noise (but not freq offset)
- TDEV can show periodic modulation of the clock under test
- A high TDEV means risk of bit errors

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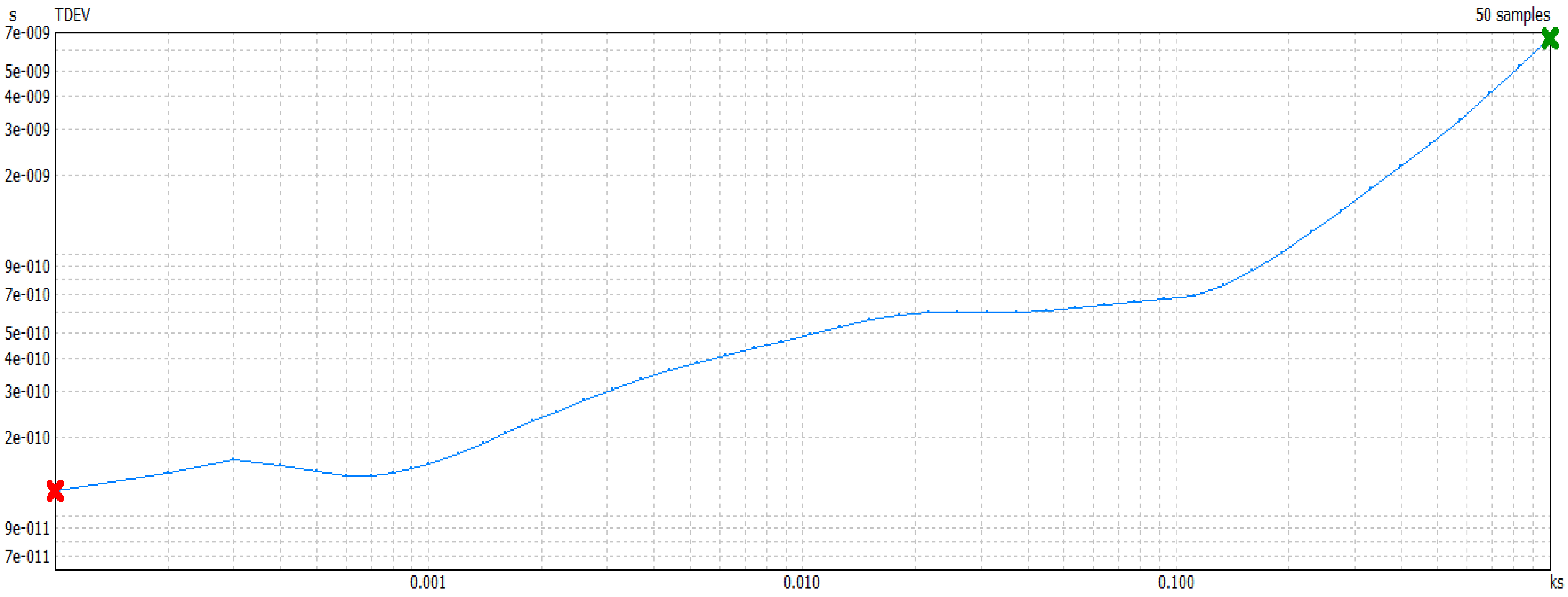
TDEV example

TDEV = Time Deviation

TDEV of the previous TIE measurement. TDEV can vary both up and down over the observation intervals.



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Wander Facts – RTIE

RTIE = Relative TIE

- RTIE is the phase variations, after removal of frequency offset
- A constant frequency offset between the reference clock and the clock under test will show up as a straight line
- $TIE(t) = \Delta F / F \cdot t$
- By subtracting the offset (the straight line) from the TIE data also small phase variations become visible
- Frequency offset could be present in the Clock under test (if it is free-running, and has lost lock), OR in the frequency reference used.
- Use RTIE with care! Do not use RTIE instead of calibrating the frequency reference! RTIE will effectively hide also frequency offset in DUTs

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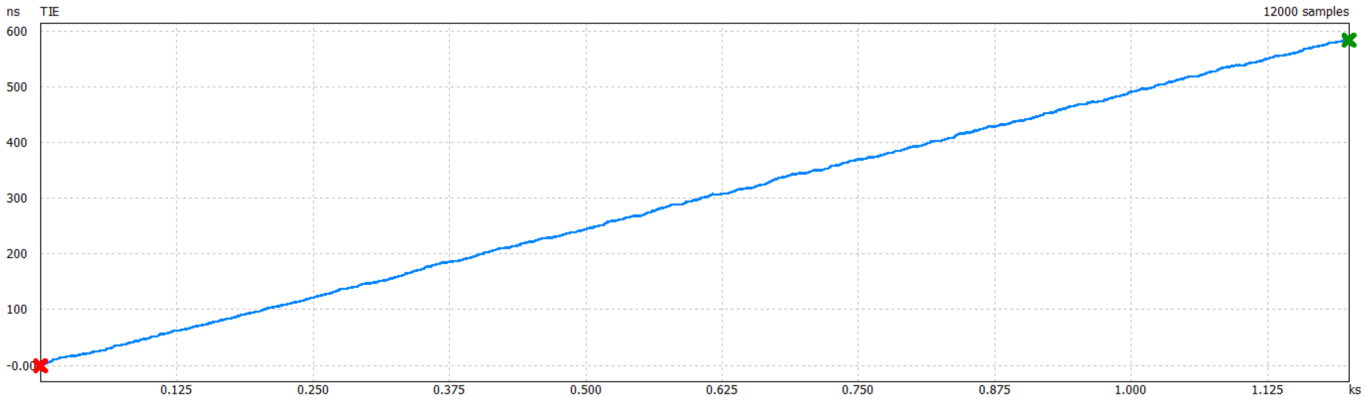
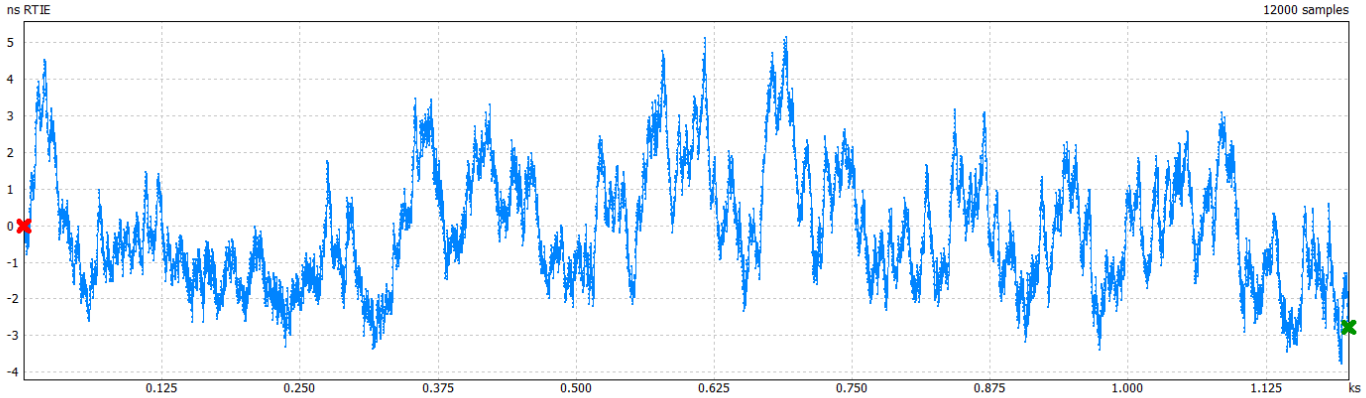
RTIE example

TIE: A high frequency offset indicates that either the frequency reference is offset, or the clock under test is free-running. The high offset will mask any phase variations.



RTIE will eliminate the effect of the frequency offset, and reveal the phase variations



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Frequency Offset - MRTIE

MRTIE (Maximum *Relative* Time Interval Errors). MRTIE = MTIE applied on RTIE data (compensated for frequency offset) instead of TIE data

Simpler instruments, with a less accurate Frequency reference use MRTIE instead of MTIE to hide the offset of the internal clock

The disadvantages with MRTIE compared to MTIE are:

- MRTIE will not detect unlocked network clocks with a drift
- MRTIE will not see the difference between wander and short-term frequency offset in locked clocks
- MRTIE values can not be used to validate MTIE masks according to ITU-T recommendations

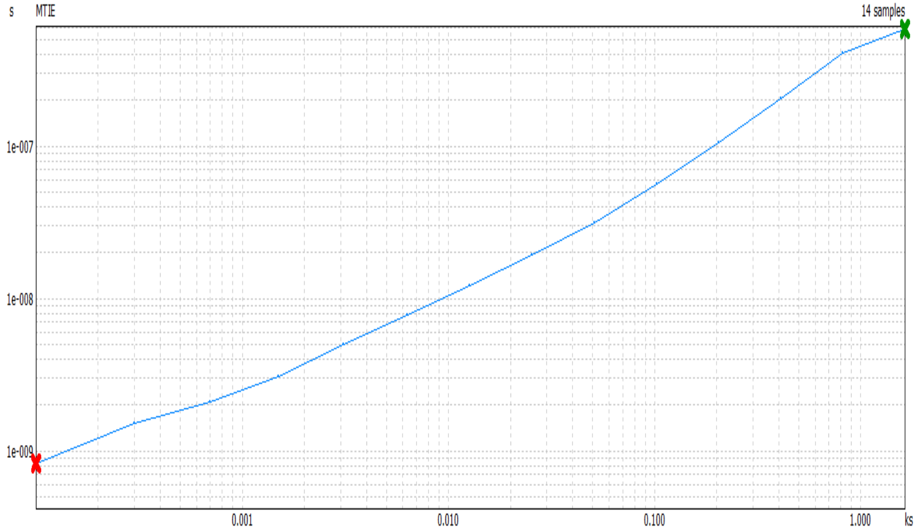
Conclusion:

- It is better to use a stable enough atomic frequency reference (Rubidium or external Cesium) and use MTIE as primary parameter in wander measurements.
- However, the MRTIE can give additional information of the DUT, if you are aware of the MRTIE limitations. Above all, the TIE variations due to disciplining are more clearly visible.

MRTIE example

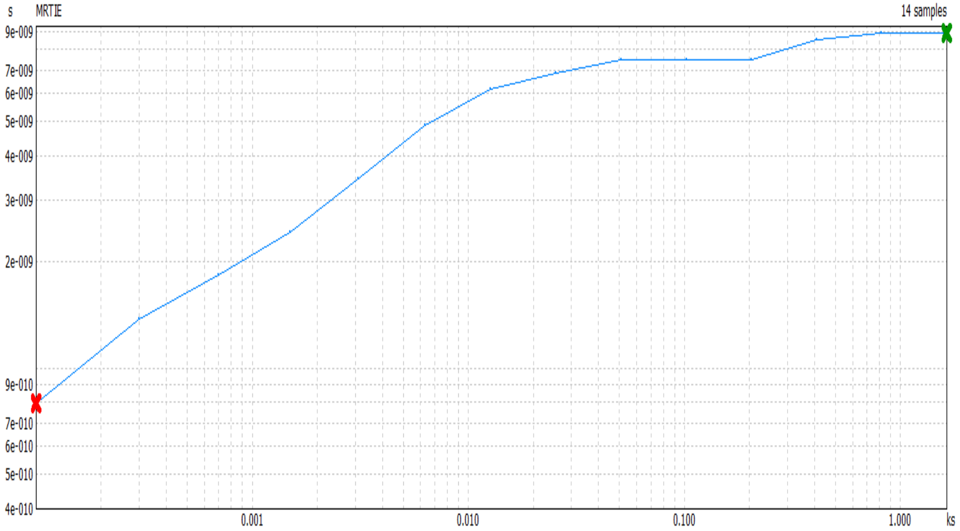
MTIE on signals with a high frequency offset will show up as an almost straight line with a slope for large observation times (tau).

MTIE at end of observation interval is 600 ns due to the high frequency offset



MRTIE show the actual MTIE wander of the same signals after removal of the frequency offset.

With frequency offset removed, MRTIE at end of observation interval is 9 ns, which is a better indication of ”true” MTIE performance.



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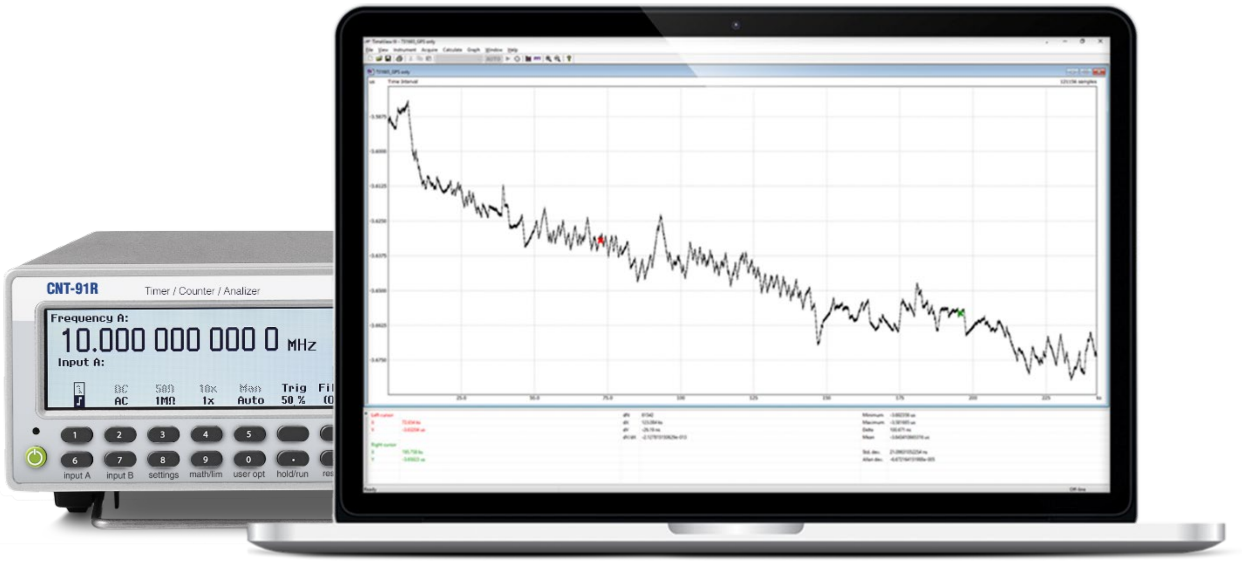
Wrap-up

Measuring wander is important for

- Network owners
- Oscillator manufacturers
- Telecom equipment manufacturers

CNT-91R +TimeView 3 is an excellent tool

- TIE measurements on any clock up to 160 MHz
- Calculation of MTIE, TDEV, RTIE and MRTIE
- Graphs with cursor readout & statistical calculation
- Export of CSV files for further analysis



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Questions and answers

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Thank you!

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