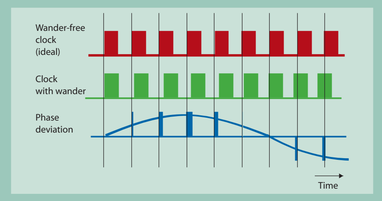
Real-Time Wander Measurement

ONT-506 / ONT-512 / ONT-503

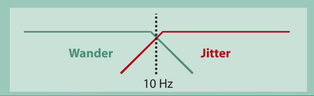
T-BERD / MTS-8000

What is Wander?

Wander is the long-term variation of the significant instances of a digital signal from their ideal position in time, where "long-term" implies that these variations are of frequency less than 10 Hz. That means Wander is a phase variation at slow frequencies of DC to 10Hz.



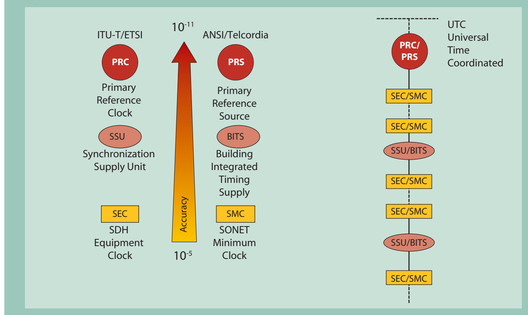
What is the difference between Wander and Jitter?



Frequency range	0 - 10 Hz	>10 Hz
Primary disruption	Synchronization problems	Causes bit errors
Reference clock source for measurement	Absolutely necessary	Not required
Unit for amplitude	Time (ns, µs, ...)	Unit Interval (UI)
Test time	Long-term measurement (hours, days)	Minutes

Asynchronous system: Only jitter is of interest. PLLs track the slow phase variations (wander).
Synchronous system: Both wander and jitter are of interest. PLLs for clock recovery are sensitive to jitter. FIFOs operate open loop and are sensitive to wander.

Clock Hierarchies and Synchronization Reference Chain



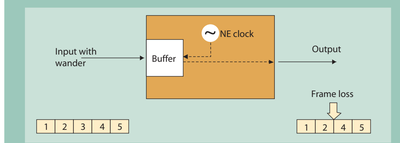
Clock Specifications

ANSI/ Telcordia clock	Stratum 1 (PRS) [T1.101]	Stratum 2 [T1.101]	Not defined	Not defined	TNC [T1.101]	Stratum 3E [T1.101] (BITS)	Not defined	Stratum 3 [T1.101]	Not defined	SMC [T1.105.09, Telcordia]	Stratum 4 [T1.101]
ITU-T clock	PRC [G.811]	Type II [G.812]	Type I [G.812]	Not defined	Type V [G.812]	Type III [G.812]	Type VI [G.812]	Type VI [G.812]	Option 1 [G.813]	Option 2 [G.813]	Not defined
ETSI clock	EN 300 462-6-1	Not defined	EN 300 462-4-1	EN 300 462-7-1	Not defined	Not defined	Not defined	Not defined	EN 300 462-5-1	Not defined	Not defined
Accuracy	1×10^{-11}	1.6×10^{-8}	ND	ND	1×10^{-7} [*] ND [**]	4.6×10^{-6}	ND	1×10^{-11}	4.6×10^{-6} *f/s*	2.0×10^{-5}	3.2×10^{-5}
Fractional frequency offset at the end of 24 hours of holdover [note 1]	ND	1×10^{-10}	2.7×10^{-8}	2.7×10^{-8}	1.5×10^{-8}	1.2×10^{-8}	3×10^{-8}	3.9×10^{-7}	2×10^{-6}	4.6×10^{-6}	ND
Implied bandwidth	ND	≤ 1 mHz	≤ 3 mHz	≤ 20 mHz	≤ 0.1 Hz	≤ 1 mHz	≤ 0.1 Hz	≤ 3 Hz [note 2]	1 - 10 Hz	≤ 0.1 Hz	ND

ND = not defined [**] ITU-T [*] ANSI TNC = Transit Node Clock ffs = for further study

Note 1: Includes (a) initial frequency offset, (b) linear frequency drift rate (aging), and (c) temperature component, except that the temperature component is not applicable (NA) for the type V and type VI clocks (reference table A.18/G.812).
Note 2: Where stratum 3 clock is used in a SONET NE, its bandwidth is ≤ 0.1 Hz.

How does Wander Affect Data Transmission?



Wander causes underflow or overflow of the network element's buffer leading to loss of signal bits. The system contains an integrated mechanism which avoids loss of synchronization and removes the entire frame.

What are the consequences for the user?

Problem list (protocol dependent)	
Voice	Audible click
Data	Retransmitted and/or damaged data
Video	Frozen and/or loss of image
Mobile phone	Dropped calls
Internet	Packet loss
Fax	Loss of scan lines

Wander Standards

Wander Generation at Network Interfaces

Application	ITU-T	ANSI	Telcordia	ETSI
	G.823 (G.825)	---	---	EN 300 462-3-1 EN 302 084
SONET	G.824 (G.825)	T1.101	---	---
1,5 Mb/s hierarchy	G.824	T1.403	---	---
PDH 2 Mb/s hierarchy	G.823	---	---	EN 302 084
Synchronization	G.823 G.824	T1.101	---	EN 300 462-3-1

Wander Generation at Equipment Interfaces

Application	ITU-T	ANSI	Telcordia	ETSI
SDH/SONET (TM, ADM, DXC etc.)	G.813	T1.105.05	GR-253	EN 300 462-5-2
PRC clock	G.811	T1.101	GR-2830	EN 300 462-6-1
SSU/BITS clock	G.812	T1.101	GR-1244	EN 300 462-4-1 EN 300 462-7-1
SDH/SONET clock	G.813	T1.105.09	GR-253	EN 300 462-5-1

Mapping/Pointer Wander

Application	ITU-T	ANSI	Telcordia	ETSI
SDH/SONET equipment	G.783	T1.105.03	GR-253	---

Wander Tolerance

Application	ITU-T	ANSI	Telcordia	ETSI
SDH/SONET	G.825	T1.101	GR-253	EN 302 084
1.5 Mb/s hierarchy	G.824	---	---	---
PDH 2 Mb/s hierarchy	G.823	---	---	EN 302 084
SSU/BITS clock	G.812	T1.101	GR-1244	EN 300 462-4-1 EN 300 462-7-1
SDH/SONET clock	G.813	T1.101	---	EN 300 462-5-1

Wander Transfer

Application	ITU-T	ANSI	Telcordia	ETSI
SDH/SONET	---	T1.101	GR-253	---
SSU/BITS clock	G.812	T1.101	---	EN 300 462-4-1, EN 300 462-7-1
SDH/SONET clock	G.813	---	---	EN 300 462 5-1

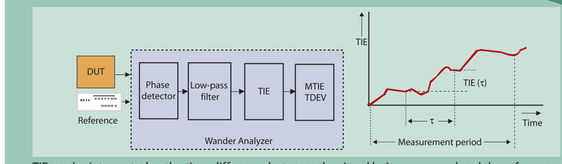
Definitions and Terminology

Application	ITU-T	ANSI	Telcordia	ETSI
Synchronization networks	G.810	T1.101	---	EN 300 462 1-1

Wander Measurement Equipment

PDH equipment	(O.171)	---	---	---
SDH equipment	O.172	---	---	---

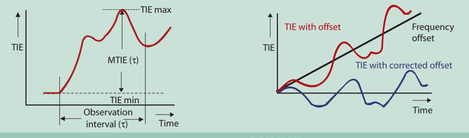
TIE (Time Interval Error)



TIE can be interpreted as the time difference between the signal being measured and the reference clock. It is typically measured in nanoseconds and set to zero at the start of the measurement period. TIE gives the timing change since the measurement began.

Application	Sampling time	Low-pass filter	Measurement range
Standard TIE acc. to O.172	1/30 s	10 Hz	$\pm1\times10^{9}$ ns
Transient TIE acc. to O.172	1/1000 s	100 Hz	$\pm1\times10^{9}$ ns

MTIE (Maximum Time Interval Error) and MRTIE



MTIE is a measure of wander that characterizes frequency offsets and phase transients. It is a function of a parameter τ called the observation interval. MTIE (τ) can be said to be the largest peak-to-peak TIE in any observation interval of length τ.

MRTIE (Maximum relative time interval error). If during wander analysis the reference is not available (due to spatial separation for example), the MTIE analysis can have a frequency offset imposed on it. This frequency offset is subtracted from the result so that the network wander is displayed.

TDEV (Time Deviation)

TDEV is a measure of wander that characterizes its spectral content. It is a function of a parameter τ called the observation interval. TDEV(τ) can be said to be the RMS of filtered TIE, where a band-pass filter is centered on a frequency of 0.42/τ.

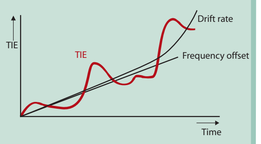
Frequency Offset and Frequency Drift Rate

Frequency offset (in ns/s): (is the first time derivative of phase)

$$y(n\tau_0) = \frac{6}{N\tau_0}\sum_{i=1}^{N} \chi^{n+i}\left[\frac{2i}{N^2-1} - \frac{1}{N-1}\right]$$

Frequency drift rate (in ns/s²): (is the second time derivative of phase)

$$D(n\tau_0) = \frac{60}{N\tau_0^2}\sum_{i=1}^{N} \chi^{n+i}\left[\frac{6i^2}{N^4-5N^2+4} - \frac{6i}{N^3-N^2-4N+4} + \frac{1}{N^2-3N+2}\right]$$



τ_0 is the sampling interval in seconds

N is the number of phase samples in the measurement period

$T = N\tau_0$ is the measurement period in seconds

$t = n\tau_0$ is the time at the beginning of the measurement period

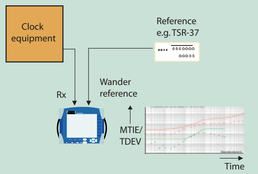
χ_i are the phase samples in ns

Wander Measurements

Clock Stability Measurement

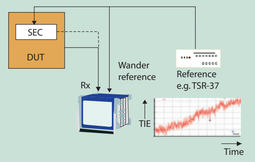
The accuracy of the reference clock should be better than the clock equipment.

Recommendations:
ITU-T O.172/G.810
ETSI EN 300 462-1-1



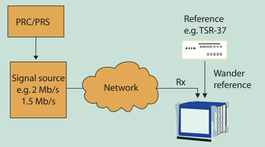
Wander Generation of DUTs (TIE/MTIE/TDEV)

Recommendations:
ITU-T O.172/G.810
ETSI EN 300 462-1-1



Wander Measurement for Synchronous Signals (TIE/MTIE/TDEV)

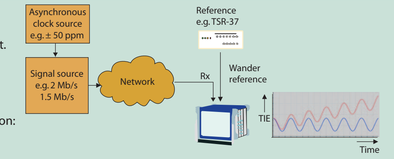
Recommendations:
ITU-T O.172/
G.810/G.823/G.824/G.825
ETSI EN 300 462-1-1



Wander Measurement for Asynchronous Signals (MRTIE)

Elimination of phase ramp caused by offset.

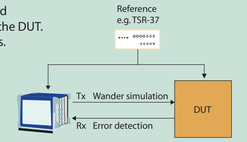
Recommendation:
ITU-T G.823



Wander Tolerance Measurement (WTM)

A test signal with pre-defined frequency and amplitude wander values is transmitted to the DUT. Received signals are then checked for errors.

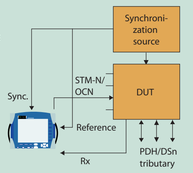
Recommendations:
ITU-T G.823/G.824/G.825/
O.172, ETSI EN 302 084



Pointer Wander Measurement (MTIE)

Pointer wander is the simultaneous occurrence of mapping wander and pointer wander in synchronous network elements at plesiochronous interfaces. Both types of wander only occur at tributary interfaces of SDH/SONET network elements.

Recommendations:
Telcordia GR-253 (2005), section 5.7
ANSI T1.105.03 (2002)
ITU-T G.783 (2000)



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