Jitter and Wander Measurements in Synchronous Ethernet Networks

Andreas Alpert

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Agenda

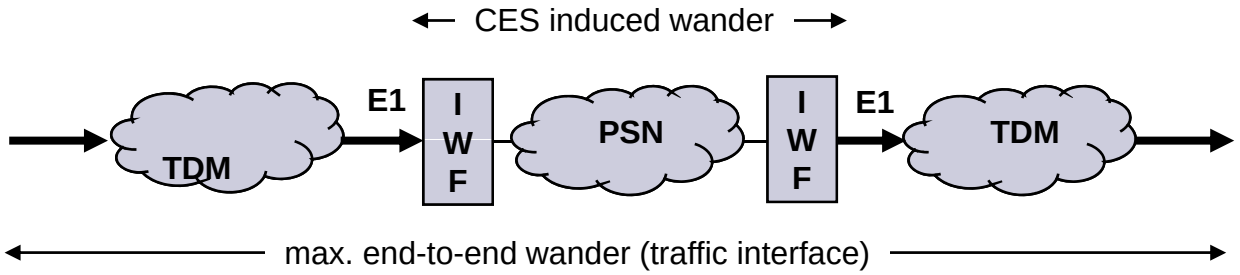
- Introduction
- Synchronous Ethernet
- Jitter and Wander Aspects
- Test Applications in SyncE
- Conclusion

Introduction

Migration to Ethernet-based packet networks

- Migration from TDM networks to packet-switched networks (PSN) based on Ethernet
- TDM is frequency synchronized at the physical layer
- Ethernet is working in asynchronous mode and not designed for the transport of synchronization
- TDM emulation (CES) requires a synchronized frequency that the timing of the signal is similar on both ends of the packet network
- Synchronization can be applied to Ethernet-based packet networks using Synchronous Ethernet (SyncE)

TDM signals have to meet jitter and wander performance:

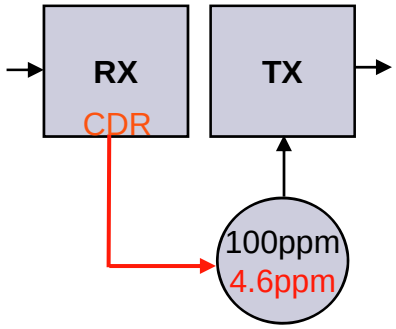


CES Circuit Emulation Services
IWF Inter Working Function

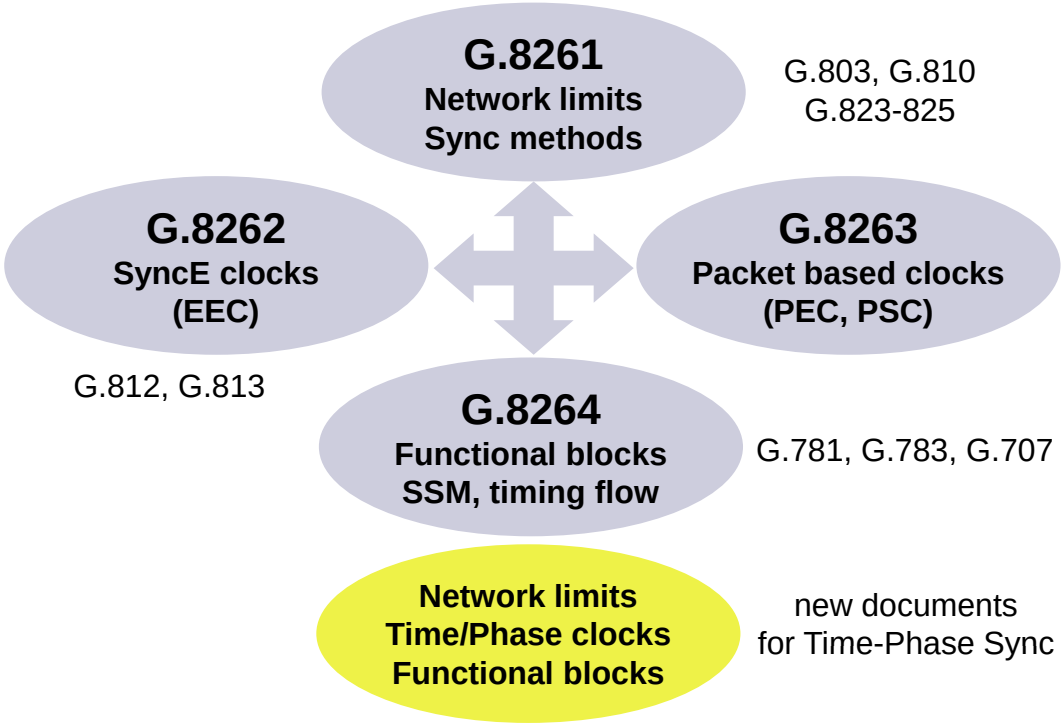
Synchronous Ethernet

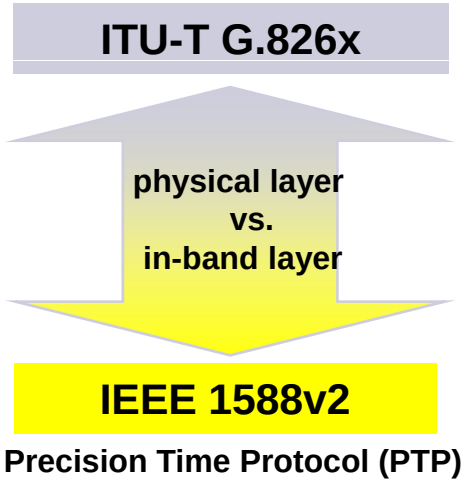
What is Synchronous Ethernet ?

- SyncE enables the migration to packet networks
- Synchronizes the Ethernet physical layer by BITS/SSU or line-timed as done in SDH/SONET
- Replaces 100ppm Ethernet clock
- Does not impact any IEEE standards



SyncE PHY clocking





Precision Time Protocol (PTP)

Inter-working of Ethernet and SyncE in frequency

Ethernet interfaces according to IEEE 802.3

- are non-synchronous - do not carry synchronization
- work with ±100ppm as max. frequency offset

SyncE interfaces in non-sync operation mode (identical to IEEE 802.3)

- RX does not pass the recovered clock to the system clock
- TX might be synchronized to the EEC, but remains unknown for RX

SyncE interfaces in sync operation mode

- RX derives the frequency from the input and passes it to the system clock
- TX is locked to the system clock with ± 4.6 ppm max. frequency offset

ITU-T G.8261 Annex A

Interface type	Operation mode	Frequency		
		Maximum output frequency deviation	Input tolerance	
			for data recovery	for clock recovery
Ethernet	non-sync mode	+/- 100 ppm	+/- 100 ppm	n/a
SyncE		Locked to the EEC or, if not, be within +/- 100 ppm		
SyncE	sync mode	Locked to the EEC (in the worst case +/- 4.6 ppm)		Max. +/- 4.6 ppm

Inter-working of Ethernet and SyncE in noise

- Ethernet specifies jitter according to IEEE
- Wander is not an issue for Ethernet traffic operation
- Jitter/wander for synchronous interfaces is specified acc. to ITU-T
- For Synchronous Ethernet interfaces in synchronous operation mode the relevant requirements are specified in G.8261 and G.8262

ITU-T G.8261 Annex A

Interface type	**Operation mode**	**Noise**					
		Maximum output noise generation		Equipment input noise tolerance			
		Jitter	Wander	for data recovery		for clock recovery	
				Jitter	Wander	Jitter	Wander
Ethernet	non-sync mode	Acc. to IEEE	n/a	Acc. to IEEE	n/a	n/a	n/a
SyncE							
SyncE	sync mode	According to G.8261 (Network) G.8262 (Equipment)				According to G.8262	

Related jitter and wander measurements

- **Jitter measurements of Ethernet ports refer to IEEE**

G.8261 Annex A

Interface type	Operat. mode	Jitter input tolerance	Jitter noise generation	Jitter noise transfer	Network limits
Ethernet	non-sync mode	according to IEEE	according to IEEE	n/a	n/a
SyncE					
SyncE	sync mode	for further study, see Appendix X for Jitter measurements			

- **Wander requirements are not specified for Ethernet interfaces**

G.8261 Annex A

Type of interface	Operat. mode	Wander input tolerance	Wander noise gen.	Wander noise transf.	Network limits
Ethernet	non-sync mode	n/a			
SyncE					
SyncE	sync mode	for further study; see Appendix X for Jitter measurements			

- **ITU-T methodologies in comparison with IEEE jitter measurements**

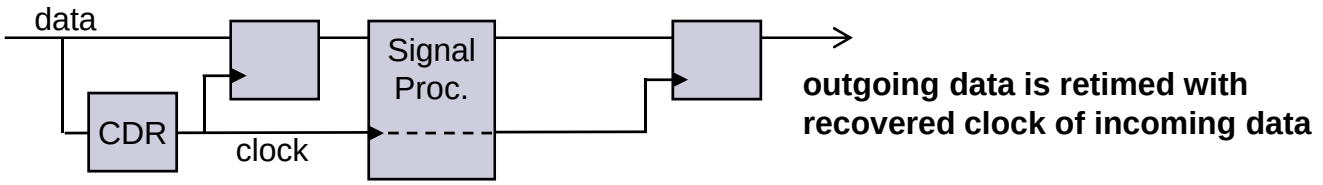
G.8261 Appendix X

	SDH	Ethernet
Network standard Test equipment standard	ITU-T G.783, G.825 ITU-T O.172	IEEE 802.3
Jitter applications	Jitter generation Jitter input tolerance Jitter transfer	see Note 1(BERT scan) see Note 2 (SRS) ---

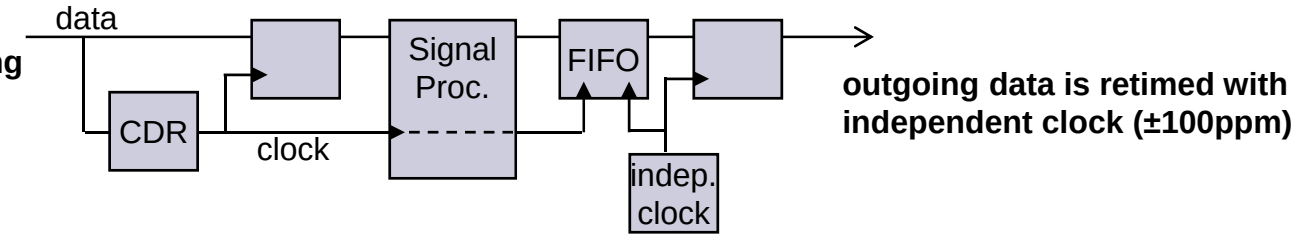
Difference in clocking of SDH/SONET and Ethernet

- The specifications and test methodologies for jitter on Ethernet differ from those for SDH/SONET because different timing methods are used
- In Ethernet, the jitter generated by components must be limited, but the jitter transferred from one component to another is less important than for synchronous systems where jitter can increase from component to component

SDH/SONET
= synchronous clocking

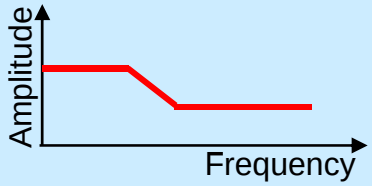
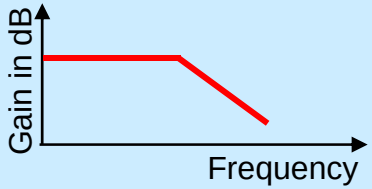


Ethernet
= asynchronous clocking



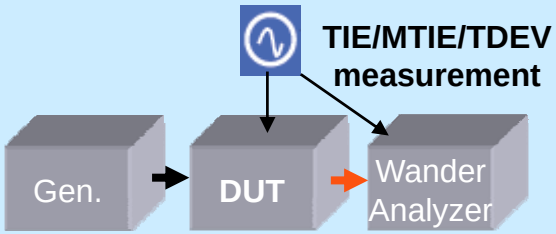
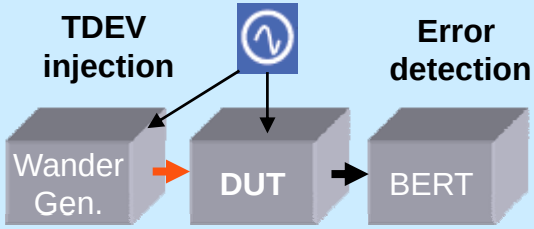
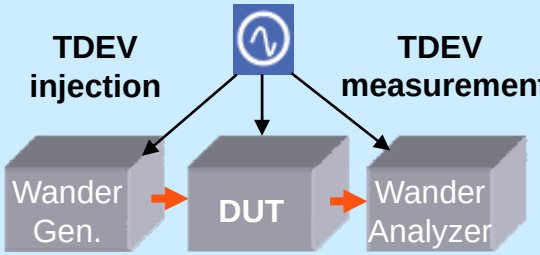
Jitter and Wander Aspects

Views of jitter

Application \ Technology	**SDH/SONET/SyncE** **Synchronous Architecture acc. ITU-T, Telcordia, ANSI**	**Ethernet** **Asynchronous Architecture acc. IEEE 802.3**
Jitter Generation	**Peak-Peak-Jitter measurement** Gen. → DUT → Jitter Analyzer Generation	**BERT scan (Bathtub curve)** Gen. → DUT → BERT Generation
Jitter Tolerance 	**Jitter injection** → DUT → **Error detection** Jitter Gen. → DUT → BERT Tolerance	**Impairment injection** → DUT → **Error detection** Stressed Eye → DUT → BERT SRS
Jitter Transfer 	**Jitter injection** → DUT → **Select. Jitter measurement** Transfer Jitter Gen. → DUT → Jitter Analyzer for calibration	**not applicable** DUT Device Under Test

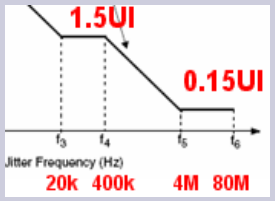
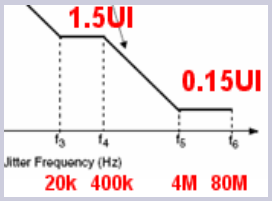
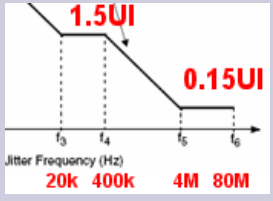
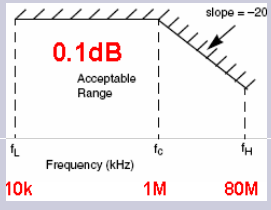
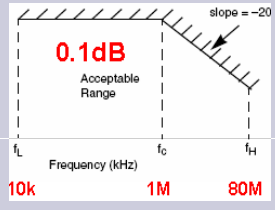
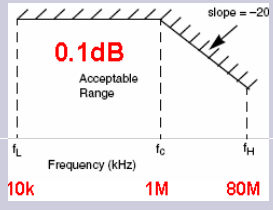
ITU-T (timing) jitter: short-term variations with frequency greater than or equal to 10 Hz

Views of wander

Technology / Application	**SDH/SONET/SyncE** **Synchronous Architecture acc. ITU-T, Telcordia, ANSI**	**Ethernet** **Asynchronous Architecture acc. IEEE 802.3**
Wander Generation		**not applicable**
Wander Tolerance		**not applicable**
Wander Transfer		**not applicable** DUT Device Under Test

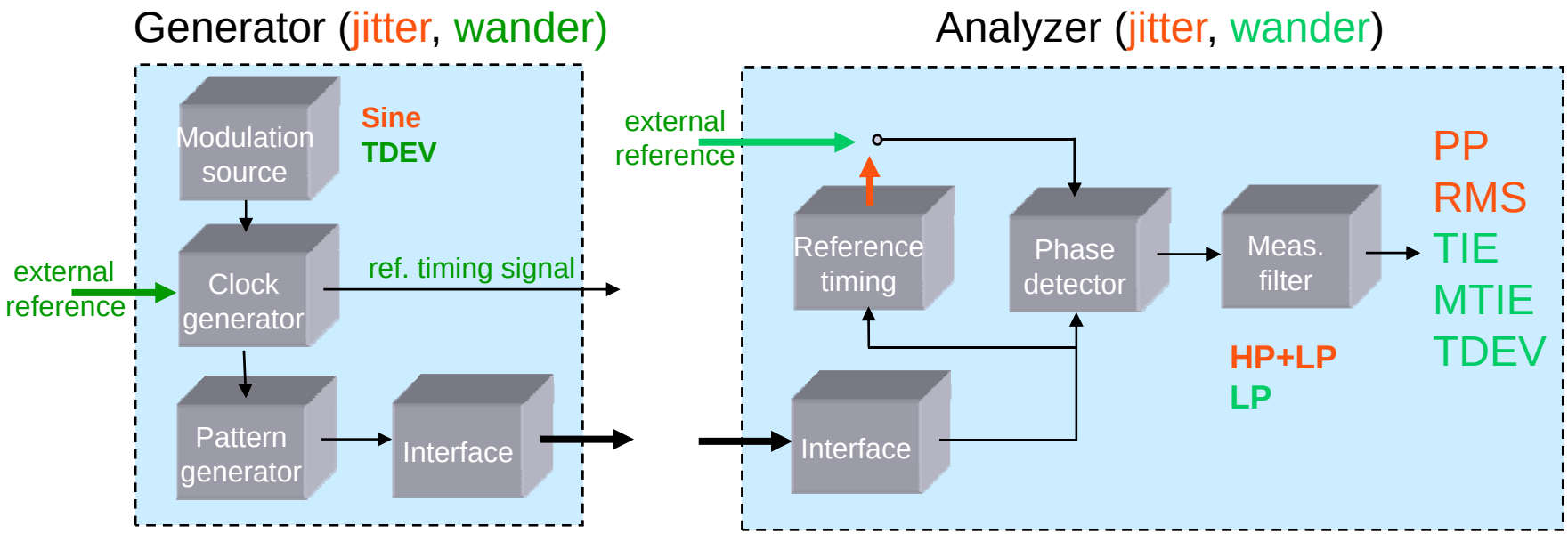
ITU-T wander: long-term variations with frequency less than 10 Hz

Example: Jitter standards for STM-64/OC-192/OTU2

	Network Equipment			Test Equipment	
	SONET OC-192	SDH STM-64	OTN OTU2	SDH STM-64	OTN OTU2
	Telcordia GR-253	ITU-T G.825	ITU-T G.8251	ITU-T O.172	ITU-T O.173
Generation	20k-80M 300 mUI 4M-80M 100 mUI	20k-80M 300 mUI (G.813) 300 mUI (G.783) 4M-80M 100 mUI	20k-80M 300 mUI 4M-80M 100 mUI	Receiver fixed error W 20/50k-80M 100 mUI 4M-80M 35 mUI	20k-80M 100 mUI 4M-80M 35 mUI
Tolerance					
Transfer					

ITU-T Recommendations for jitter test equipment

O.171	Jitter and wander measuring equipment for PDH
O.172	Jitter and wander measuring equipment for SDH
O.173	Jitter measuring equipment for OTN
O.packetjitter	Jitter and wander measurements for packet networks

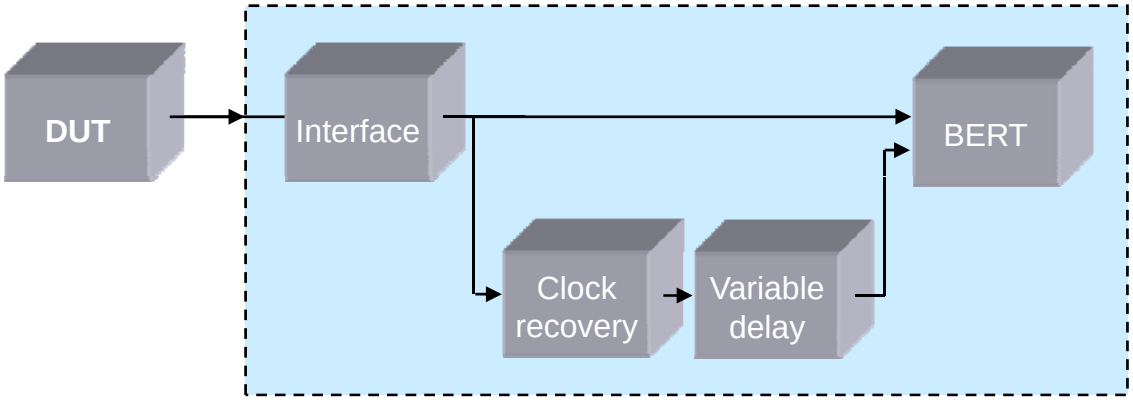


IEEE Recommendations for jitter generation

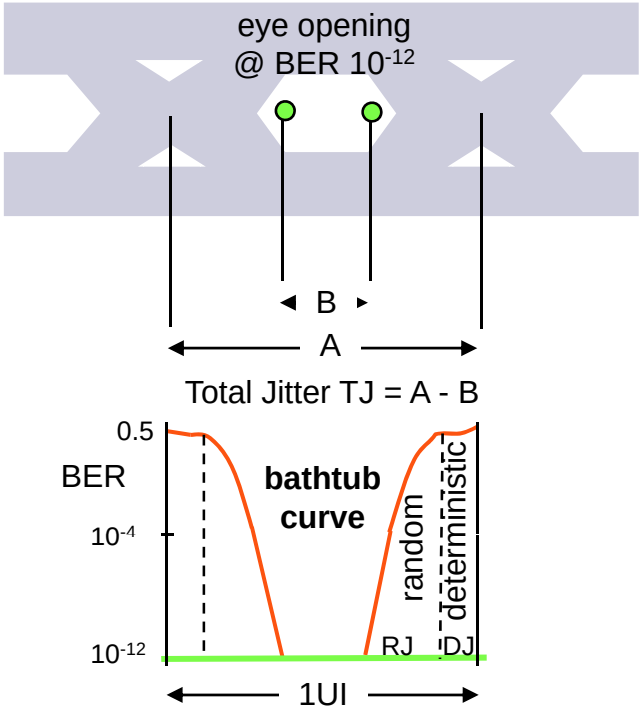
Jitter output test methodologies (IEEE 802.3ae Annex 48B.3)

- Time domain measurement using an oscilloscope to characterize the data eye
- Time domain measurement using BERT scan by moving of the data sampling point within the data eye
- Time interval analysis based on accurate measurement of the time interval between threshold crossings of the transmitter waveform

- Example: BERT scan method



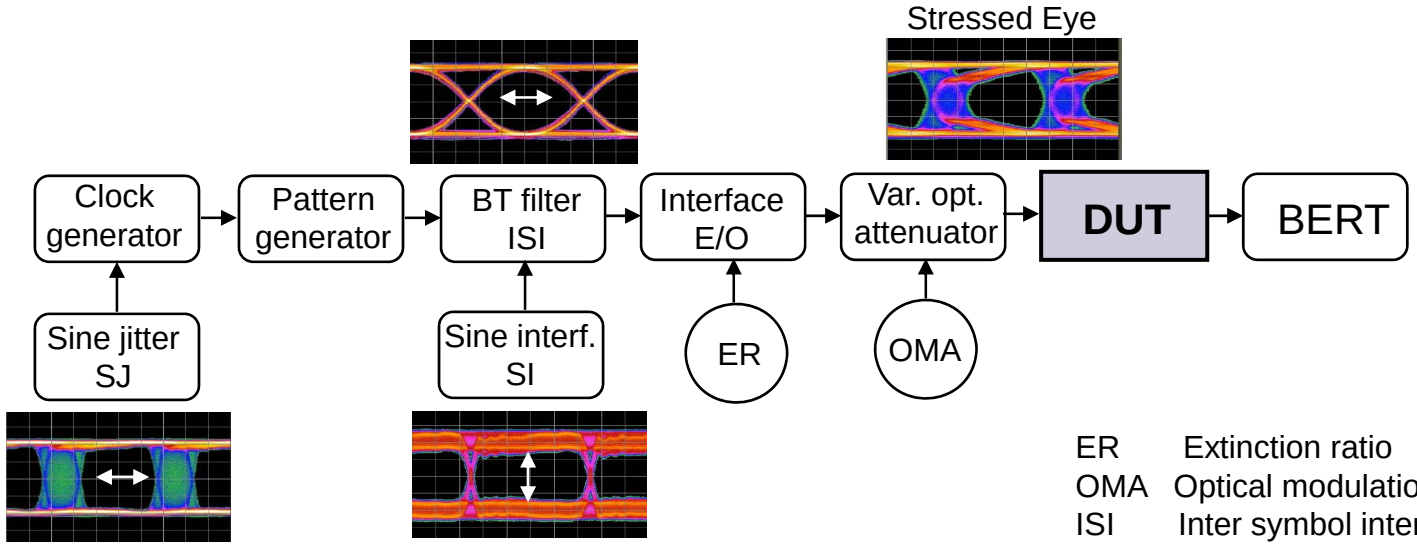
BER (Bit Error Ratio) is recorded as a function of decision circuit time position, varied over one Unit Interval (= one bit period)



IEEE Recommendations for jitter tolerance (SRS)

- In SDH/SONET, Jitter tolerance is using sinusoidal jitter
- In Ethernet, combination of impairments create the stressed signal

Stressed receiver sensitivity test (SRS)
= Stressed eye test (SE)
= Stressed receiver conformance test (SRCT)



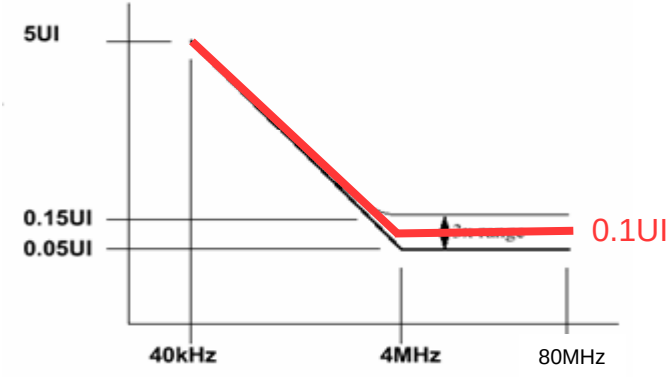
ER Extinction ratio
OMA Optical modulation amplitude
ISI Inter symbol interference
BT Bessel-Thompson 4th order
VECP Vertical eye closure penalty

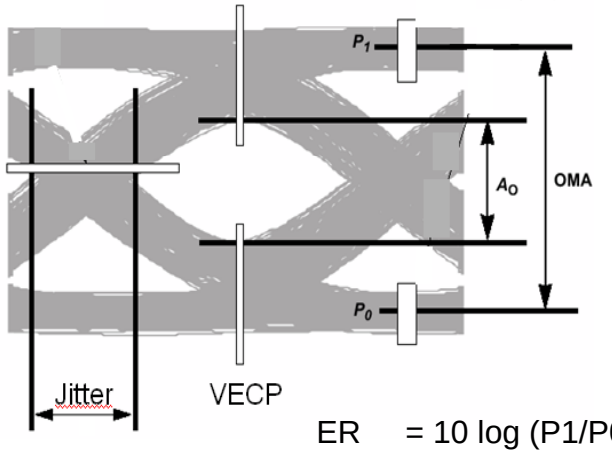
Stressed receiver conformance test (IEEE 802.3ae)

- Create stressed signal
  - Control of OMA and ER
  - Inject of VECP and Jitter

Test conditions 10GE	850 nm	1310 nm	1550 nm
ER (dB)	3	3.5	3
OMA (dBm)	-7.5	-10.3	-11.3
VECP (dB)	3.5	2.2	2.7
Jitter (UIpp)	0.3	0.3	0.3

- Sweep SJ frequency
  - Receivers must operate with BER < 10^{-12}





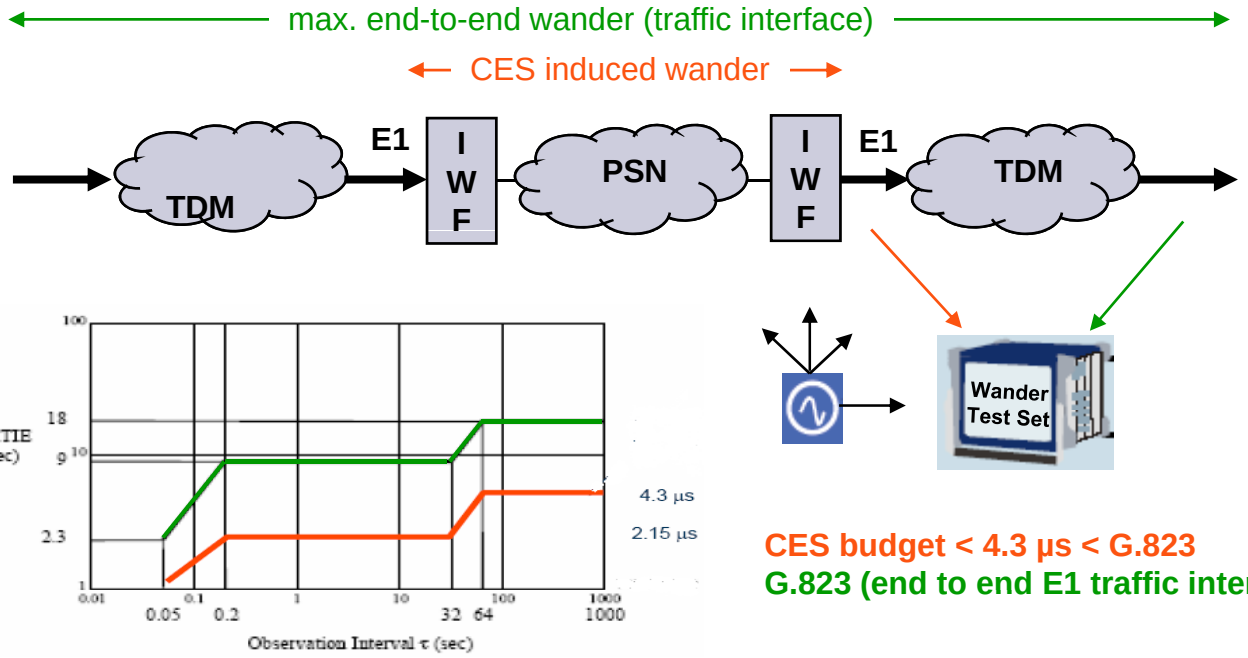
ER = 10 log (P1/P0)
OMA = P1-P0
VECP = 10 log (OMA/A0)
P0/P1 = optical power for 0/1

Test Applications in SyncE

CES network limits defined in G.8261

Example: Support of CES via SyncE

- The CES segment is located as an island between TDM segments
- CES for TDM requires that the timing of the signal is similar on both ends of the packet network
- The jitter and wander limits for E1(DS1) traffic interfaces carried over the CES segment are based on G.823 (G.824)

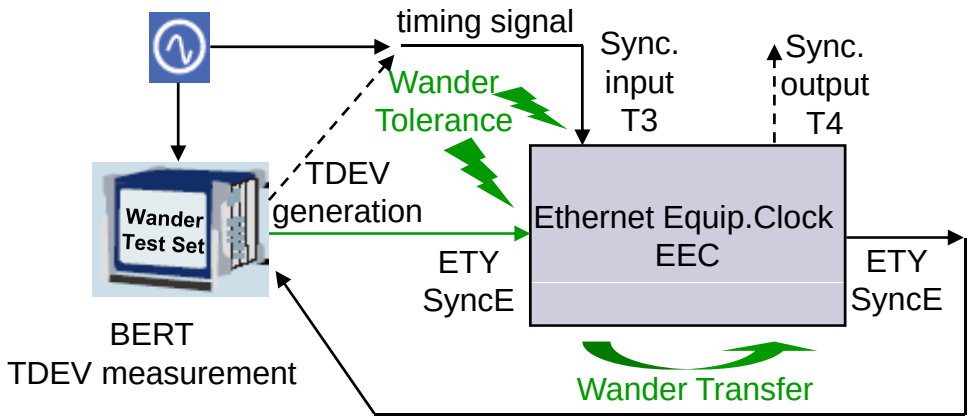


CES budget < 4.3 µs < G.823
G.823 (end to end E1 traffic interface) < 18 µs

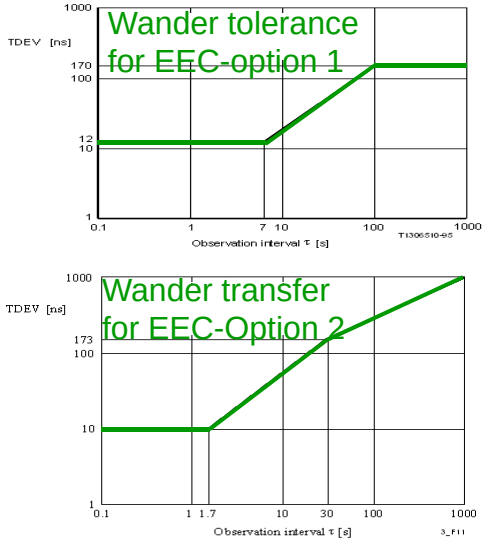
Ethernet Equipment Clock limits defined in G.8262

- EEC recovers the line timing from the incoming bit stream
- EEC injects timing onto the outgoing bit stream
- EEC is specified in G.8262 which is based on SDH standard G.813
- Two EEC-Options: Option 1 for 2048 kb/s and Option 2 for 1544 kb/s
- G.8262 defines requirements for clock accuracy, noise transfer, noise tolerance, noise generation, holdover performance

Example: Wander TDEV Tolerance/Transfer measurement configuration for the line signal and timing signal



ETY Ethernet PHY layer network



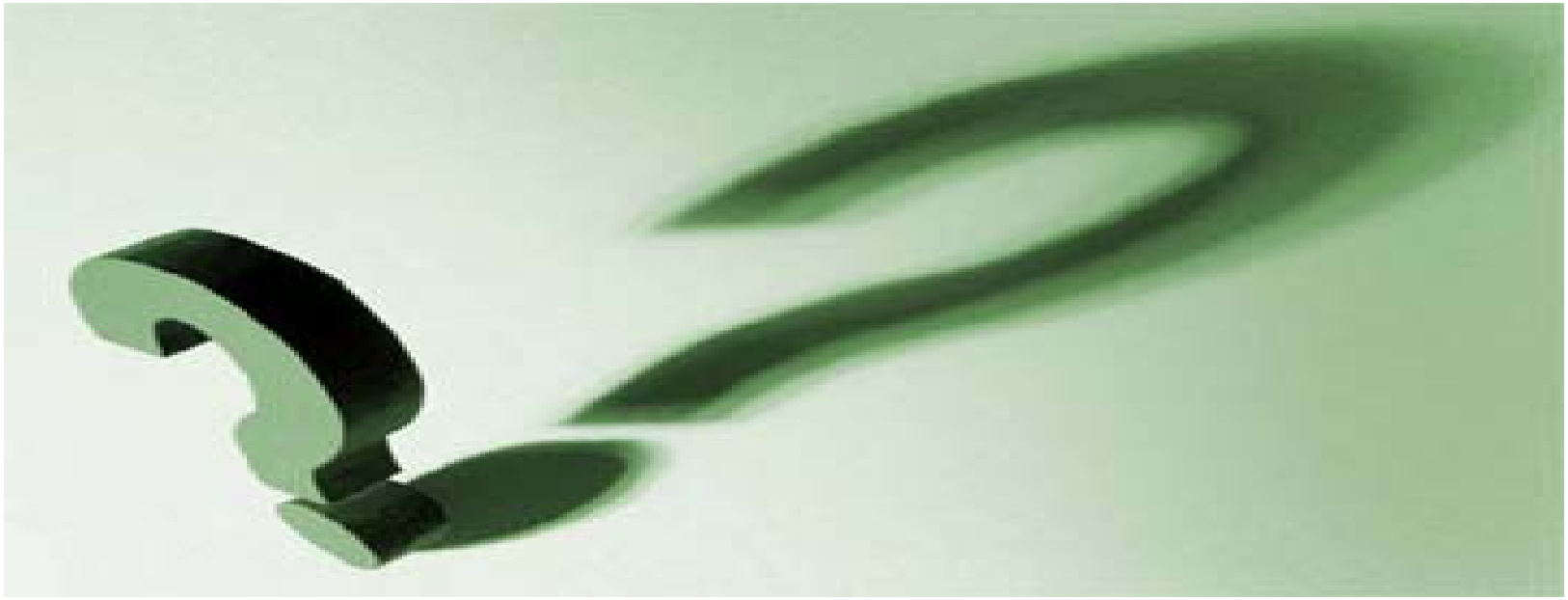
Conclusion

Conclusion

- Migration from TDM networks to packet-switched networks (PSN) based on Ethernet
- Need for timing and synchronization to ensure that all clocks in the network operate at the same frequency to avoid errors and service disruptions
- The specifications and test methodologies for jitter on Ethernet differ from those for SDH/SONET because different timing methods are used
- New ITU-T Recommendations G.826x define jitter/wander for synchronous interfaces and networks according to existing ITU-T Recommendations
- New ITU-T Recommendation for SyncE test equipment is in preparation

Q & A

Thank you
for your attention



andreas.alpert@jdsu.com