Jitter Measurements in Telecom Transmission Systems — Improving Accuracy and Repeatability

By Andreas Alpert

Telecom transmission systems

In today's Telecom transmission systems voice, data, and video are transported together. Network operators compete by offering these new services with improved performance and lower cost, increased reliability and flexibility. These trends have technical consequences, including higher data rates and more complex network topologies. Synchronous optical transport networks based on SONET/SDH and OTN technology are best suited to meet these requirements, and are now commonplace in transmission applications.

Timing and synchronization

However, these modern networks make great demands on synchronization and thus the phase stability of clock and data signals. In real life, interfering factors such as crosstalk, clock degradation, noise, bandwidth limitations, mapping and framing prevent perfect synchronization. This transmission anomaly is called jitter. Jitter must be considered when designing, developing, deploying, interconnecting, and maintaining every network. Jitter can cause bit errors, slips, and data loss, thereby impairing transmission quality.

Recommendations for network and test equipment

Network specifications, such as the ITU-T G-series or Telcordia GR-series, describe the jitter performance of networks and network equipment and set limits on the amount of jitter that devices may generate, tolerate and transfer. These requirements are referenced by test equipment specifications, such as the ITU-T O-series, and are usually taken as a minimum requirement.

New issues in calibration and verification

Recognizing that, the ITU-T O-series recommendations did not include a method for verifying receiver accuracy, the ITU-T proposed the implementation of a receiver-only test to improve the accuracy and repeatability of jitter testing. This "Method for Verification of Measurement Result Accuracy and Intrinsic Fixed Error" was formalized in Appendix VII of O.172. A reference transmitter, which is key to the O.172 Appendix VII, is used to ensure that jitter test instrument receivers are calibrated to measure all jitter the same way regardless of the nature of the jitter event. The accuracy maps that are created using the reference transmitter make it possible to compare jitter measurement characteristics of different instruments and to standardize the results.

New issues with jitter generation

One of the most difficult tasks is the correct measurement of jitter generation, also known as output jitter or intrinsic jitter, because of the very small amounts of jitter that must be accurately measured. A common value for OC-192/OC-48 network elements (NE) is the 100 mUI peak-to-peak intrinsic jitter limit defined in Telcordia GR-253. The 100 mUI limit is becoming an ever more important issue with the increased use of pluggable optics like XFP transceivers. These low-cost modular devices integrate optical transmitter and receiver in a compact form factor, but as a consequence produce higher levels of pattern-dependent jitter. The need to ensure increased margin to the 100 mUI industry standard requires accurate and repeatable jitter measurements.

Contents

This paper is organized in six chapters.

Chapter 1 describes jitter in SONET/SDH/OTN applications.

Chapter 2 summarizes the measurement accuracy for test equipment.

Chapter 3 describes the new Appendix VII of ITU-T O.172.

Chapter 4 analyzes the new Appendix VIII of ITU-T O.172.

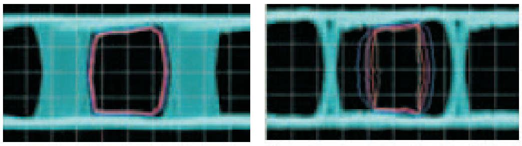
Chapter 5 explains high-accuracy jitter test equipment.

Chapter 6 discusses differential jitter testing of XFP transceivers.

1. Jitter in SONET/SDH/OTN applications

Jitter definition

The overall performance of SONET, SDH, and OTN transport networks depends heavily on the relative timing of accurate stable clocks. The jitter analysis for these networks focuses on contributions of jitter in the frequency domain. In an eye diagram, jitter is the movement of the pulse edges on the horizontal time axis.



Closing the eye opening causes wrong bit sampling

Sinusoidal jitter

Random jitter

Figure 1: Jitter as seen on the eye diagram using an oscilloscope

Jitter is defined as the short term variation of the significant instants of a digital signal from their ideal position in time. Jitter is concerned with non-cumulative variations above 10 Hz and measured in unit intervals (UI). 1 UI corresponds to an amplitude of one bit per clock period and is independent of bit rate and signal coding.

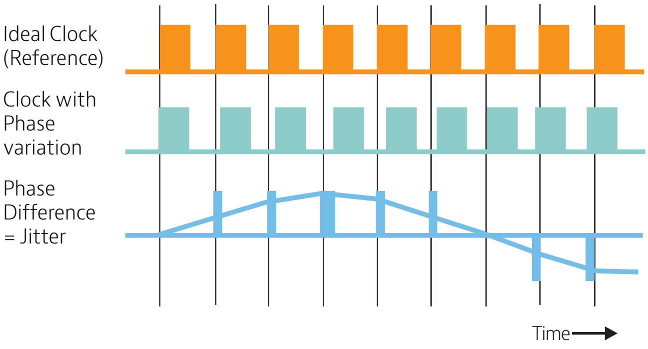


Figure 2: Jitter is the deviation of clock transitions from an ideal square wave

The result is displayed as a peak-to-peak value or as a root mean square (rms) value over a band-limited frequency range. Peak-to-peak results give a better measure of the effect on performance, as the extremes are what can cause errors, while rms values give information about the total amount of average jitter.

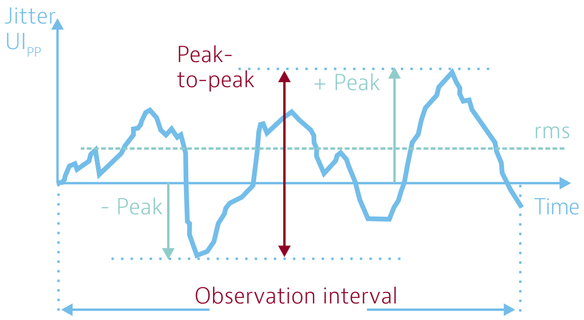


Figure 3: Definition of jitter amplitudes Peak-to-peak, +Peak, and -Peak

The rms value of the jitter signal provides an indication of the jitter noise power. Peak values that cause bit errors are not identified by a rms measurement. Peak values are momentary values, whereas rms values represent the average power during a certain integration period. The relation between rms and peak-to-peak values is not fixed and depends on the time function of jitter. Particularly with noise-like signals with small and high peak amplitude, the relation becomes high compared to the well known relation of sinusoidal signals (peak = rms × √2 , e.g. 28 mUI_{pp} = 10 mUI_{rms}).

The rms jitter is defined for an integration period of *T* and is calculated as the square root over the mean value of the squared signal:

$$J_{rms} = \sqrt{\frac{1}{T}\int_0^T [j(t)]^2\, dt}$$

Jitter measurements

There are three relevant measurements that define the jitter performance of a network element or a transmission system: output jitter (intrinsic jitter or jitter generation), jitter tolerance, and jitter transfer. Figure 4 shows where these required measurements are performed in a network.

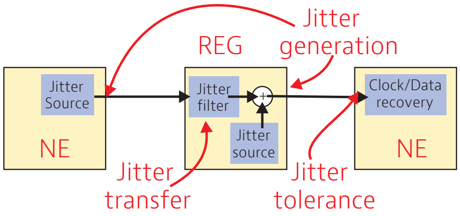


Figure 4: Jitter measurements required in a network

Jitter standards

Jitter is always present within devices, systems, and networks. In order to ensure interoperability between devices and to minimize signal degradation due to jitter accumulation, it is important that there are limits for the maximum level of jitter at an output interface and for the maximum level that can be tolerated at an input interface.

These limits have been determined by Telcordia and ITU-T and have been implemented in several standards for different types of devices and interfaces. Network specifications, such as the ITU-T G-series or Telcordia GR-series, describe the jitter performance by giving limits on the amount of jitter generation, tolerance, and transfer.

Figure 5: Standard bodies and standard categories

Standard Categories
- Line equipment
- Network interface
- Test equipment
  ITU-T O.171 for PDH test equipment
  ITU-T O.172 for SDH test equipment
  ITU-T O.173 for OTN test equipment

ITU-T has published three jitter recommendations for test equipment, O.171, O.172, and O.173. O.171 covers PDH systems, whereas O.172 is primarily concerned with SDH systems and also addresses requirements for SDH tributaries. O.173 deals with the control of jitter within the optical transport network (OTN).

The OTN frame structure and layered architecture are similar to SONET/SDH but there are significant differences which affect jitter performance and measurements of networks.

1.1 Output jitter

Output jitter is the overall jitter measured at the output of a system. A certain amount of jitter will appear at the output port of any network element, even if an entirely jitter-free digital signal or clock is applied to its input. The network element itself produces this intrinsic jitter, for example, due to clock thermal noise and drift in clock oscillators and clock data recovery circuits. Output jitter, which is also referred to as intrinsic jitter or jitter generation, is the jitter generated by a component or a device under test (DUT) when the input has no jitter. Jitter generation is based on band limited peak-to-peak and rms values without separating jitter generation into its random (noise) and deterministic components.

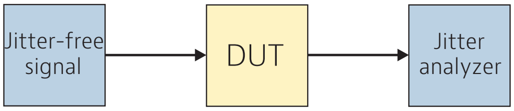


Figure 6: Intrinsic jitter produced by a network element

Standards for jitter generation

Table 1 shows the jitter generation limits of SDH network equipment interfaces according to ITU-T G.783 requirements.

Table 1: Jitter generation limits of SDH network equipment interfaces

	Measurement Band (–3 dB Frequencies)		
Interface	**High-Pass (kHz)**	**Low-Pass (MHz)**	**Limit Peak-Peak Amplitude (UI)**
STM-1 optical	0.5 65	1.3 1.3	0.30 0.10
STM-4 optical	1 250	5 5	0.30 0.10
STM-16 optical	5 1000	20 20	0.30 0.10
STM-64 optical	20 4000	80 80	0.30 0.10
STM-256 optical*	80 16000	320 320	0.30 0.10

* values are provisional

Table 2 shows the jitter generation limits of SONET network equipment interfaces according to ANSI T1.105.03 requirements:

Table 2: Jitter generation limits of SONET network equipment interfaces

	Measurement Band (–3 dB Frequencies)		
Interface	**High-Pass (kHz)**	**Low-Pass (MHz)**	**Limit Peak-Peak/rms Amplitude (UI)**
OC-1, STS-1	12	0.4	0.1 /0.01
OC-3, STS-3	12	1.3	0.1 /0.01
OC-12	12	5	0.1 /0.01
OC-48	12	20	0.1 /0.01
OC-192	20 4000	80 80	0.3 0.1

Jitter generation of SONET OC-192 network equipment interfaces according to Telcordia generic requirements (GR) are defined differently from ITU-T and ANSI.

Table 3: Jitter generation limits according to Telcordia GR-253
GR-253 (R5-258) defines:

Interface	Measurement Band (–3 dB Frequencies)		Limit Peak-Peak/rms Amplitude (UI)
	High-Pass (kHz)	Low-Pass (MHz)	
OC-192	50	80	0.1 /0.01

When the Telcordia recommendation was written it was noted that for OC-192 it may not be feasible for test equipment to support the capability to provide accurate measurements.

Frame pattern jitter

Output jitter measurements at network interfaces typically use a live traffic signal. This technique involves demodulating the jitter from the live traffic at the output of a network interface, high-pass and low-pass filtering of the jitter, and measuring the peak-to-peak and the rms amplitude of the jitter over the specified measurement time interval (60 seconds). Output jitter results are strongly influenced by the contents of the data being carried. Test results for a 1010 pattern can vary widely from those for a PRBS (pseudo-random binary sequence).

In SONET/SDH/OTN technology the payload is scrambled to prevent long strings of logic zeros or ones, but the header of the SONET/SDH/OTN frame is not scrambled. Frame pattern jitter is the phenomenon that causes pattern-dependent jitter due to the unscrambled part of the SONET/SDH frame. Such intrinsic jitter cannot be completely avoided in clock recovery circuits of network elements. Network elements with excessive pattern jitter generation may exhibit jitter peaks which have to be recognized correctly by test instruments.

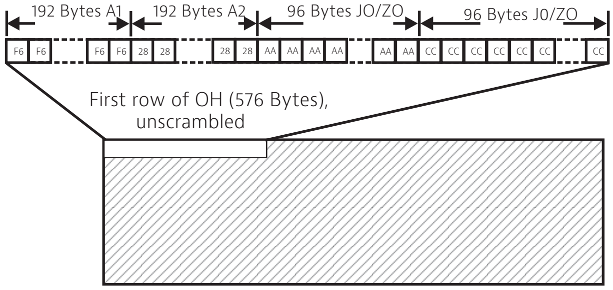


Figure 7: SONET/SDH frame structure with unscrambled bytes (example OC-192/STM-64)

The unscrambled part of the SONET/SDH frame contains specific repeating bit patterns, such as the frame alignment bytes A1 and A2 and the remaining Z0 bytes in the first row of the overhead. The "1" density is significantly different between the A1 ($F6_{hex}$) and A2 (28_{hex}) bytes. The Z0 bytes in SDH systems should be set to a repeating 1010 (AA_{hex}) pattern (ITU–T G.783) and in SONET systems to a repeating 1100 (CC_{hex}) pattern (ANSI T1.105).

This leads to different average values of the signal amplitude and may cause different phase shifts of the signal transitions during the occurrence of these bytes. The spectral base line is 5 GHz for AA_{hex} and 2.5 GHz for CC_{hex}. Due to band limiting effects of the transmission channel the AA_{hex} pattern may be more affected compared to the CC_{hex} pattern. This again may cause a specific phase shift of the signal transitions during the occurrence of this pattern. These phase shifts are measured as jitter since the duration of these time periods is long enough to be fully detected in the 80 MHz bandwidth of the jitter measuring filter.

The resulting data-dependent deterministic jitter can dominate the system. The peak-to-peak jitter is dependent on the unused bytes (see evaluation for three examples 01_{hex}, AA_{hex}, CC_{hex}). Thus accurate measurement of peak-to-peak jitter is key to the characterization of SONET/SDH/OTN networks and the network elements. For this it is necessary to use framed SONET/SDH/OTN signals for accurate jitter measurements. A jitter test instrument must sample the SONET/SDH/OTN frame completely for jitter without any gaps to ensure measurement of transients moving over the whole frame.

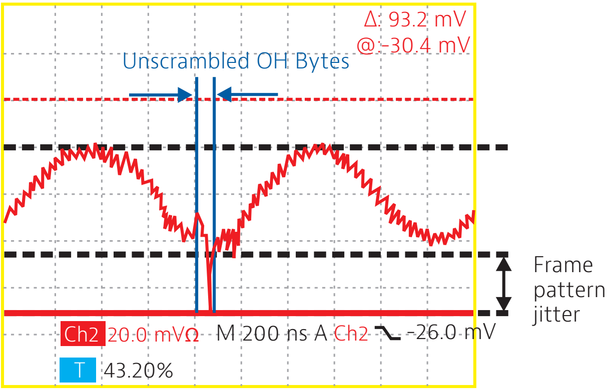


Figure 8: Frame pattern jitter at the demodulator output of a jitter receiver

The following example shows that during the time period of the unscrambled bytes different jitter pulses are generated depending on the bit pattern contents of these bytes. In this case the AA_{hex} bytes cause a negative jitter peak, the CC_{hex} bytes a positive peak, whereas the A1/A2 pattern shows similar jitter results for both cases. The remaining periodic jitter is due to the repeating PRBS pattern. When measuring the jitter of the above evaluated OC-192/STM-64 transmit signal, the result shows similar asymmetrical +peak and –peak values as expected from the independent evaluation.

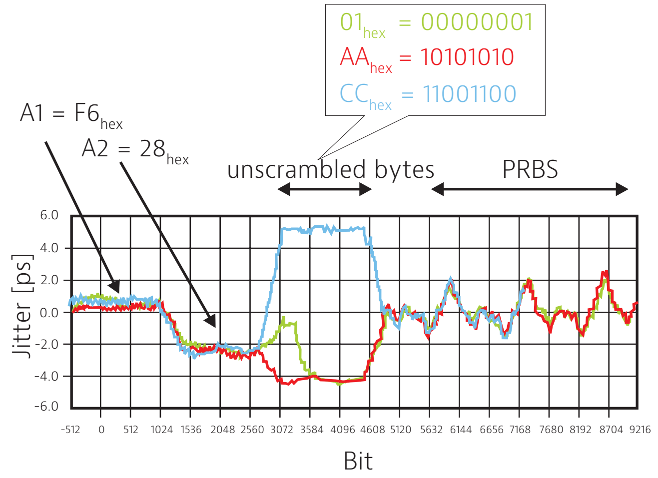


Figure 9: Pattern-dependent jitter generated by the unscrambled bytes

Transient peak detection

The international standardization bodies such as ITU-T, Telcordia or ANSI have specified various limits for the amount of output jitter occurring in a SONET/SDH transmission system. It is the goal of the system design to keep the jitter parameters below the recommended thresholds. ITU-T O.172 describes two test procedures for transient peak detection, a peak-to-peak detection and in addition an optional phase hit detection:

- Peak-to-peak detection

The jitter measurement function shall be capable of measuring peak-to-peak jitter addressed by peak-peak detection over a time frame of one minute. The measurement fails if the jitter has exceeded the limit no matter if it happened for the entire observation period or if a single jitter peak has occurred.

- Phase hit detection

When measuring peak-to-peak jitter it shall be possible to count the number of occasions and the period of time for which a given selectable threshold of jitter is exceeded. It shall be possible to record these events by means of an external counter, or an internal counter as an option. It shall be possible to set the threshold at any selected value within the measuring range of the jitter measurement function.

What kind of detection is applied in the Viavi Solutions jitter test sets?

Viavi uses two separate peak detectors:

- Detector for the peak-to-peak jitter
- Detector for phase hits

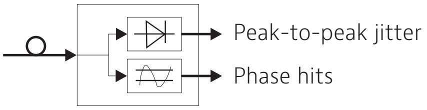
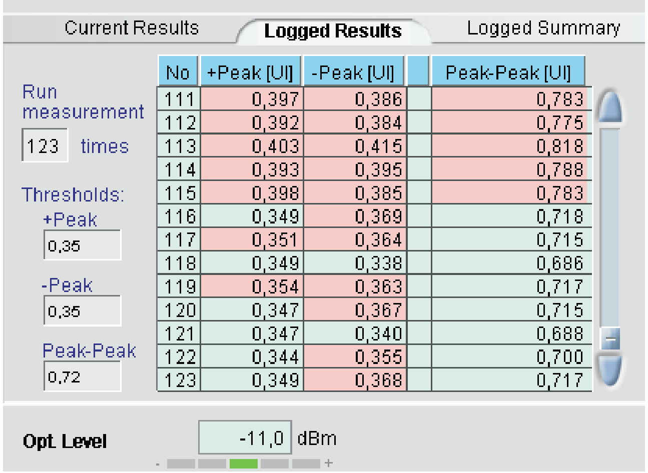


Figure 10: Detection of peak-to-peak jitter and phase hits

The peak-to-peak detector measures current values which are continuously displayed, and maximum values if the measurement is started. Viavi ONT test equipment allows the user to keep a log of maximum results if a measurement is started repeatedly.



Run measurement 123 times

Thresholds:
+Peak 0,35
-Peak 0,35
Peak-Peak 0,72

No	+Peak [UI]	-Peak [UI]		Peak-Peak [UI]
111	0,397	0,386		0,783
112	0,392	0,384		0,775
113	0,403	0,415		0,818
114	0,393	0,395		0,788
115	0,398	0,385		0,783
116	0,349	0,369		0,718
117	0,351	0,364		0,715
118	0,349	0,338		0,686
119	0,354	0,363		0,717
120	0,347	0,367		0,715
121	0,347	0,340		0,688
122	0,344	0,355		0,700
123	0,349	0,368		0,717

Opt. Level -11,0 dBm

Figure 11: ONT implementation

- logged results for repetitive jitter measurements
- colored bar for received input power (green portion shows the recommended power range)

To detect phase hits, the received jitter amplitude is compared with a selected jitter amplitude threshold and sampled to obtain the number of events exceeding the threshold. A counter then displays the number of such events (phase hits). Both positive and negative counts can be monitored.

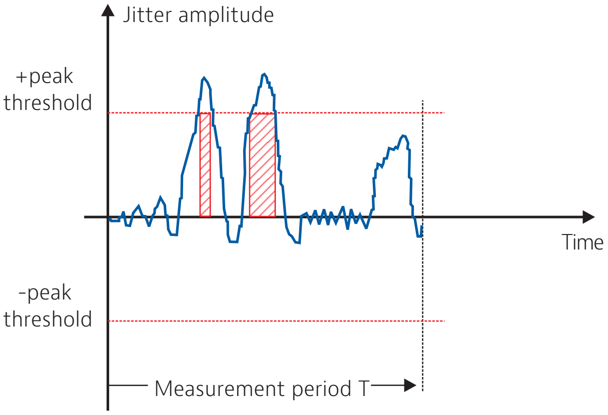


Figure 12: Phase hit detection

The better way to get an answer on the nature of the tested jitter is offering a "jitter over time" measurement, a graphical representation of output jitter results over observation time. This test application allows the user to determine the "burstiness" of the jitter, which can be hardly determined by the phase hit measurement alone. The following figure shows an example, realized in Viavi's ONT family:

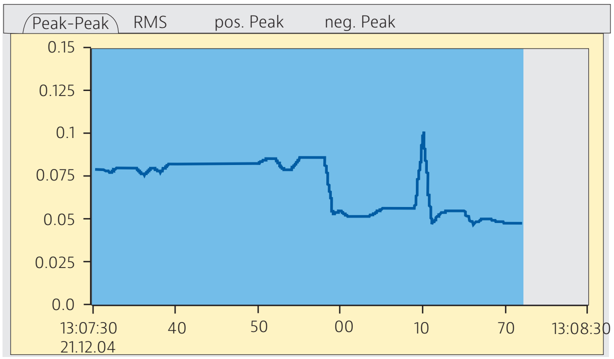


Figure 13: Jitter vs. time measurement to determine the burstiness of jitter

1.2 Jitter tolerance

Jitter tolerance is the ability of a given device under test (DUT) at the receiving end to tolerate large amounts of jitter without degrading the BER (bit error rate).

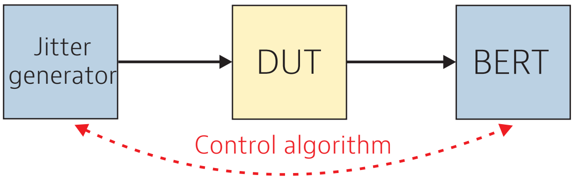


Figure 14: Jitter tolerance testing

Jitter tolerance of SONET/SDH network equipment interfaces is defined according to ITU-T G.825/ ANSI T1.105.03 and Telcordia GR-253 requirements:

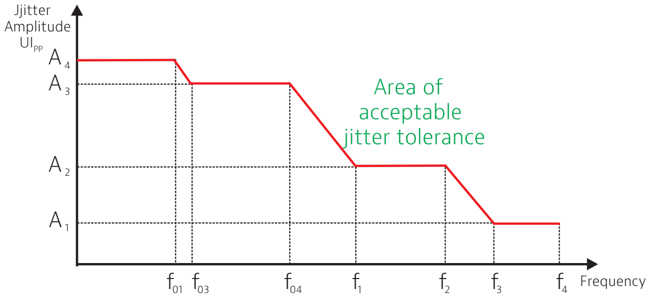


Figure 15: Jitter tolerance mask

The jitter tolerance measurement can be done by different methods:

- Automatic determination of maximum tolerable jitter (MTJ)
- Automatic check of the values on the limit curve of maximum tolerable jitter (Fast MTJ)
- BER penalty method by using a degraded signal-to-noise ratio

Automatic determination of maximum tolerable jitter (MTJ)

Jitter tolerance is a measurement to check the resilience of equipment to input jitter. This measurement is required to confirm that network elements (NEs) in the transmission system can operate without errors in the presence of the worst case jitter from preceding sections. Jitter tolerance is one of the most important characteristics of the clock recovery and input circuitry of network equipment.

To test jitter tolerance, a signal is generated with sinusoidal jitter added sequentially at a number of different frequencies and is fed to the DUT where the transmission signal is swept in a controlled phase-transient-free sequence.

In the real world, jitter is unlikely to be sinusoidal, but such jitter is easy to generate and gives repeatable results. It allows the results for different systems to be compared and makes it possible to write system specifications, usually in the form of a jitter tolerance mask. To test the maximum jitter tolerated, the amplitude of the jitter tester is increased at each frequency until transmission errors or alarms are detected. The receiver checks for errors and alarms and the transmitter increments or decrements the jitter amplitude using a control algorithm, re-testing for errors and alarms at the frequency point until the MTJ result is found. This is repeated for each subsequent jitter frequency. The control algorithm used to detect the maximum tolerance employs successive approximation.

Testing the full jitter specification defined by the jitter mask requires a large number of measurements. Automation and the selection of the correct test conditions are therefore essential to minimize the test time.

After any change of jitter amplitude, or after moving to the next frequency point, a settling time is allowed before the gate time for the new measurement cycle starts. This is important, as some DUTs need some time to recover from error or alarm conditions caused by jitter exceeding the tolerance margin. The transmission error measurement is made during the gate time period, and the threshold used for detection of jitter tolerance may simply be the detection of any transmission errors or alarms, or a defined number of bit errors. The gate time and number of bit errors can be varied.

Automatic limit testing of maximum tolerable jitter (Fast MTJ)

This extremely fast measurement tests the device under test for conformance to the standard tolerance mask limits for maximum tolerable jitter. The editable frequency/amplitude values are set sequentially and the test pattern monitored for the permitted error count by the receiver. The result of each measurement is shown in a table as the status message.

BER penalty method

The BER penalty method (ITU-T O.171 Appendix A) tests the jitter tolerance by using a degraded signal-to-noise ratio (SNR). It sets up a BER test under no-jitter conditions, then it reduces the optical power level at the DUT's optical input, using an external optical attenuator, until a BER of very low error ratios is measured by the analyzer (e.g., ratio of 4E-10, approximately 1 errors per second, for OC-48/STM-16). Then the SNR is improved 1 dB by reducing attenuation (1 dB power penalty) with a resultant reduction in BER. Jitter is then applied using the MTJ method, as previously described, to find the level of jitter that causes the same BER as the 1 dB power penalty, and this is repeated at other jitter frequencies.

1.3 Jitter transfer function (JTF)

Jitter transfer function or JTF measures the clock recovery performance of a network element as a function of jitter frequency. It is measured by applying sinusoidal jitter of specified amplitude and frequency to the data and measuring the output jitter amplitude at that frequency.

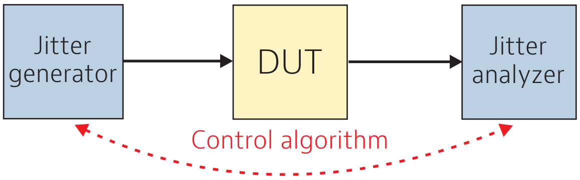


Figure 16: Determining the jitter transfer function

Figure 17 shows Jitter transfer function of SONET/SDH network equipment interfaces according to ITU-T G.783/ ANSI T1.105.03 requirements.

Jitter transfer is a measure of how much jitter is transferred from the input to the output of the network equipment. JTF is important for cascaded clock recovery circuits in long-distance transmission systems with regenerators and line terminals. As a signal traverses a network, the jitter generated by the equipment becomes the input jitter to the next part of the network. If this jitter is amplified, it can exceed the jitter tolerance of the subsequent equipment. In this way, excessive jitter may accumulate and cause errors as the signal progresses through the network equipment. Jitter transfer measurement is required to confirm that there is no amplification of jitter by network elements (NEs) in the transmission system.

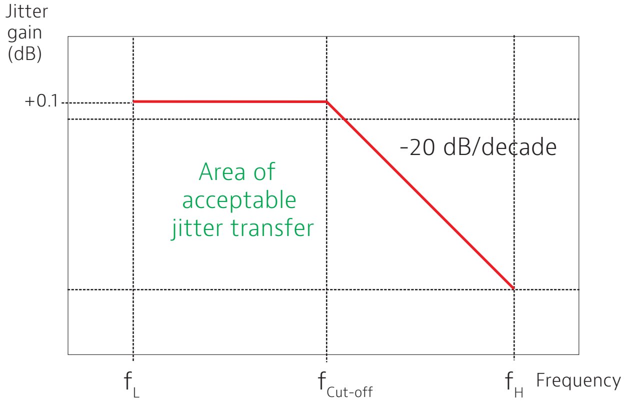


Figure 17: Jitter transfer mask

The jitter transfer measurement is performed by comparing the absolute level of jitter being transmitted into the DUT with an absolute measure of the jitter output from the DUT. JTF is defined as the ratio of the output jitter to the applied input jitter as a function of frequency:

$$H(f) = 20 \times \log(\text{output jitter}/\text{input jitter})\ [\text{dB}]$$

The standard jitter tolerance mask is usually used to set the input jitter level during the jitter transfer test. Sinusoidal jitter is applied sequentially at a number of different frequencies and amplitudes within the mask during the measurement process. The jitter receiver tracks the applied jitter frequency and makes a measurement of the level. To achieve the necessary accuracy a very narrow-band tracking filter method is employed.

To ensure optimum accuracy, the transmitter/receiver of the test set can be normalized by performing a loop-back calibration, prior to making DUT measurements.

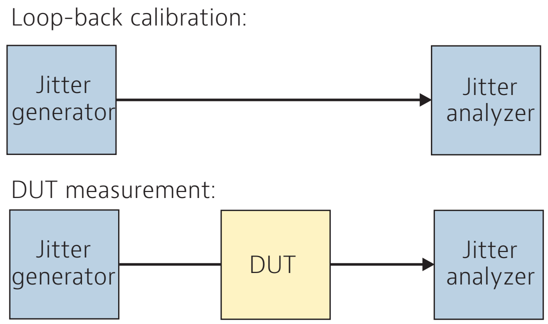


Figure 18: Performing loop-back calibration prior to test jitter ensures optimum accuracy

Measurement resolution and repeatability can be improved by increasing the rms integration period and settling time. The rms integration period is the time spent for the measurement at each point. The purpose of the settling time is to allow the DUT to settle after changes, and before making the measurement.

Viavi's ONT offers user-defined jitter masks that can be edited, allowing for jitter transfer measurements with increased jitter amplitude at low frequencies to improve the measurement noise floor margin . Before performing jitter transfer measurements, the jitter generation and jitter tolerance requirements for the DUT should have been checked and met. It is important that the DUT meets the jitter generation requirements, as any phase noise which correlates to a jitter transfer test point frequency could affect the accuracy of the measurement.

2. Measurement accuracy for test equipment (recent addendum to ITU-T O.172)

The industry requires reliable, accurate and repeatable jitter measurement instruments. Accuracy limits for jitter test equipment are defined in ITU-T O.172. The following figure shows the block diagram of the instrumentation in general form, identifying the main functions that are addressed in the recommendation.

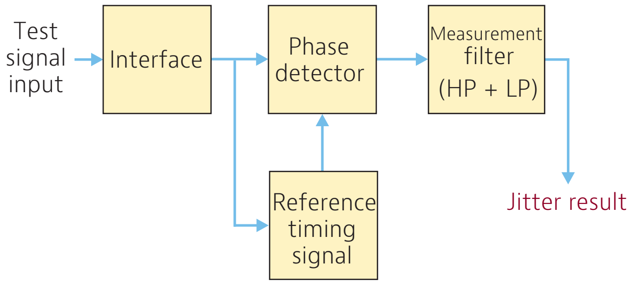


Figure 19: Block diagram for a jitter measurement function

The measurement bandwidth shall be limited in order to measure the specified jitter spectra as defined in relevant recommendations. The bandwidth $f_1 - f_4$, $f_{12} - f_4$, or $f_3 - f_4$ of the jitter measurement function shall be in accordance with Table 4.:

Table 4: Jitter measurement bandwidth

	Jitter measurement Bandwidth (–3 dB Cut-Off Frequencies)			
Signal	**f_1 (Hz) High-Pass**	**f_{12} (Hz) High-Pass**	**f_3 (Hz) High-Pass**	**f_4 (Hz) Low-Pass**
STM-0e, STM-0	100	–	20 k	400 k
STM-1e	500	–	65 k	1.3 M
STM-1	500	12 k	65 k	1.3 M
STM-4	1 k	12 k	250 k	5 M
STM-16	5 k	12 k	1 M	20 M
STM-64	20 k	50 k*	4 M	80 M
STM-256	80 k	–	16 M	320 M

f_{12} is optional, *value is provisional

The accuracy of the jitter measurement function is dependent upon several factors such as the fixed intrinsic error of the receiver, the frequency response and the digital test pattern-dependent error of the internal reference timing circuits. In addition there is an error that is a function of the actual reading.

The measurement accuracy is specified using an input signal with a structure defined in O.172 Annex A for SDH line signals and for pseudo-random sequences for SDH tributary signals and physical characteristics of either:

- an electrical signal in conformance with Recommendation G.703 having the nominal terminated signal level and with no additional frequency-dependent loss; or
- an optical signal in conformance with Recommendation G.957 or G.691 and with a nominal power in the range –10 dBm to –12 dBm. Operation at higher input power levels may be permitted at STM-64 and STM-256 in accordance with the mean launch powers specified in Recommendation G.693.

The total measurement error shall be less than:

$$\pm R\% \text{ of reading} \pm W$$

where *R* is the variable error (frequency response) and *W* is the fixed error (intrinsic error) of the measuring device input.

Table 5: Fixed error W

	Maximum Peak-to-Peak Jitter Error (UI_{pp})					
	Structured Signal			**Clock Signal**		
Signal	**f_1 to f_4**	**f_{12} to f_4**	**f_3 to f_4**	**f_1 to f_4**	**f_{12} to f_4**	**f_3 to f_4**
STM-0e	ffs	–	ffs	ffs	–	ffs
STM-0	0.07	–	0.035	0.05	–	0.03
STM-1e	0.07	–	0.025	0.05	–	0.02
STM-1	0.07	0.035	0.035	0.05	0.03	0.03
STM-4	0.1	0.035	0.035	0.05	0.03	0.03
STM-16	0.1	0.035	0.035	0.05	0.03	0.03
STM-64	0.1	0.035*	0.035	0.05	–	0.03
STM-256	0.15	–	0.05	0.05	–	0.03

f_{12} is optional, *value is provisional, ffs: for further study

Table 6: Variable error R

Signal	Error R	Frequency Range
STM-0e, STM-0	ffs	f_1 to f_4
STM-1e, STM-1	± 7% ± 8% ± 10%	f_1 –300 kHz 300 kHz – 1 MHz 1 MHz – f_4
STM-4	± 7% ± 8% ± 10% ± 15%	f_1 – 300 kHz 300 kHz – 1 MHz 1 MHz – 3 MHz 3 MHz – f_4
STM-16, STM-64, STM-256	± 7% ± 8% ± 10% ± 15% ± 20%	f_1 – 300 kHz 300 kHz – 1 MHz 1 MHz – 3 MHz 3 MHz – 10 MHz 10 MHz – f_4

Example calculation:

The output jitter of a DUT is 80 mUI at OC-192/ STM-64 with 4 MHz to 80 MHz filter bandwidth.

Measured jitter = M = 80 mUI

R = 20% (refer to table 6)

W = 35 mUI (refer to table 5)

Max. measurement error = $E_{max} = \pm((R \times M) + W)$
$= \pm ((0.20 \times 80 \text{ mUI}) + 35 \text{ mUI}) = \pm 51 \text{ mUI}$

Result range (uncertainty) = $M \pm E_{max}$ = 80 mUI ± 51 mUI

This example shows that for a measurement result, the uncertainty range is wide even if the test equipment complies with ITU-T O.172. The measurement uncertainty will make it impossible to give a correct pass/fail evaluation of the device under test. The error limits in O.172 for the test equipment are not sufficient for high-accuracy jitter measurements.

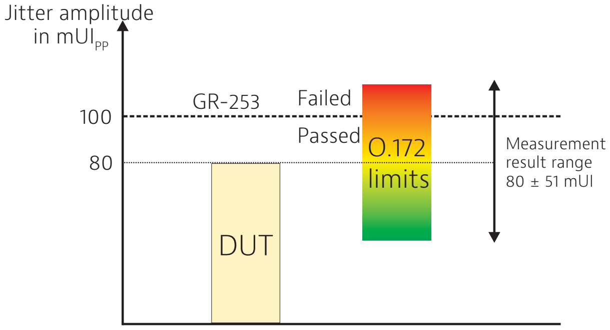


Figure 20: Measurement uncertainty range

Therefore there is a need for high-accuracy jitter measurement equipment providing much lower intrinsic jitter (receiver fixed error W). For example minimizing W from 100 mUI (common in legacy jitter measurement devices) to 15 mUI reduces the measurement uncertainty by a factor of 7.

3. Method to verify the measurement result accuracy (ITU-T O.172 Appendix VII)

Another challenge is how to prove the accuracy of a jitter receiver and how to guarantee consistency between different test sets and also different test set vendors. The only way to get confidence is by verifying the different test sets against a standard jitter free reference according to a standard evaluation method. The existing ITU-T O.172 recommendation for jitter test sets defines fixed intrinsic error limits for jitter measurement receivers. However, this recommendation does not describe a method for verifying receiver accuracy.

To address the industry needs for accurate and repeatable jitter measurements, ITU proposed the O.172 Appendix VII "Method for Verification of Measurement Result Accuracy".

The test procedure ITU-T O.172 Appendix VII recommends a method and defines example implementations to verify and characterise the measurement result accuracy of receivers used for jitter measurements. This method allows the user to effectively de-embed error contributions of the test equipment from the signal being measured. It defines the requirements of a high quality 'golden' optical data signal—a reference transmitter—with the capability to add pulse transient sinusoidal modulation. The reference transmitter along with the added pulse transient sinusoidal modulation enables the generation of an almost infinite range of jitter possibilities and ensures precise characterization of a receiver for all types of jitter.

3.1 Reference transmitter with negligible jitter

The reference transmitter provides a low-noise signal. The pattern-dependent jitter contribution of the reference transmitter can be considered as negligible and therefore may be removed from the error calculation. The scheme uses a high quality optical transmitter and pattern generator with minimal pattern-dependent jitter at the line rate under test. A target would be less than 10 mUI peak-peak measured in bandwidth f_1 to f_4. This source can be used for calibration of jitter receivers.

Figure 21: Reference transmitter used for calibration of jitter receivers

The block diagram for a reference transmitter and a verification system consists of three main parts.

Part 1: Precision clock and modulation generation section

Part 2: Precision optical data generation section

Part 3: Jitter calibration section

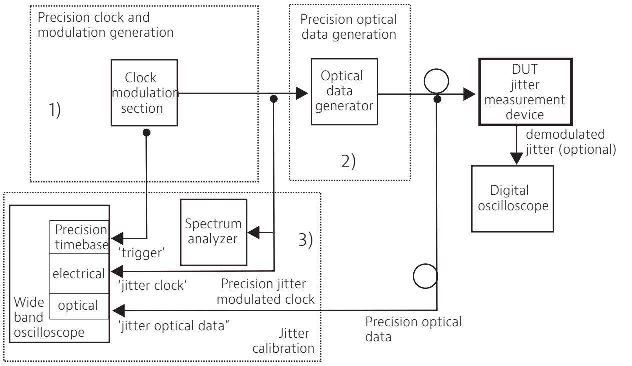


Figure 22: Block diagram for a reference transmitter and a verification system

The following figure is a block diagram of an example implementation of the optical data generation section (Part 2).

The optical data generation section consists of a traditional pattern generator coupled to a double optical modulation scheme to perform an optical retiming function. The data modulator operates as a traditional modulator that has pattern-dependent jitter. In order to remove this jitter, a second modulator performs an optical retiming operation using an optical "AND" function with a clock pulse of reduced width. This method is called "pulse carving". This clock pulse has no pattern dependence. The resulting data output has the jitter properties of the retiming clock pulse with the data information—this is a return-to-zero (RZ) data pulse. The RZ data is pulse stretched into pattern-dependent jitter free non-return-to-zero (NRZ) data. The pulse stretcher does not add jitter to the output because of an all-optical solution splitting the optical signal and delaying without conversion to an electrical signal and without pulse distortion.

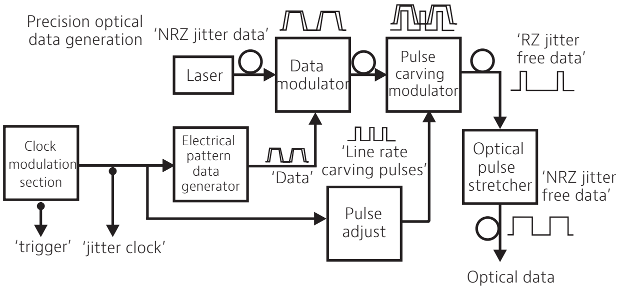


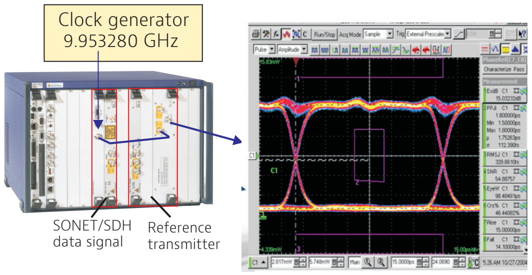
Figure 23: Example block diagram for optical data generation

How does Viavi address the reference transmitter?

In order to verify the performance of jitter receivers, Viavi implements the newest verification procedures in their development and manufacturing processes. As a key contributor to the ITU recommendation, including the latest appendices, Viavi has established itself as a leader in high-accuracy jitter measurement.

Viavi designed and manufactured a reference transmitter which exceeds the minimum accuracy requirements set by ITU-T. The generated reference signal ensures highest accuracy and is virtually free of pattern-dependent jitter. Variations of the digital test pattern or overhead bytes, also including the unscrambled part, do not affect the outgoing jitter. The reference transmitter enables Viavi to provide a jitter receiver-only calibration and verification in the manufacturing process allowing the industry's highest receiver-to-receiver consistency and absolute accuracy.

The error associated with the pattern-dependent jitter of the reference transmitter is verified by a wide band eye measurement and by the Appendix VIII analysis. The jitter phase pulse performance is verified by a reference phase discriminator. The jitter phase transfer to the data output is verified using a 1010 data pattern and a reference O/E.



Eye diagram of the optical data signal

Figure 24: Viavi in-house reference transmitter used to develop and manufacture industry-leading jitter solutions

3.2 Accuracy map covers all types of jitter

A jitter receiver has to work with all practical jitter signals from continuous sinusoidal to bursts and pulses. The Appendix VII defines a set of jitter waveforms to represent all these types. A generic jitter modulator is described with the capability to generate pulse sinusoidal jitter. This implementation gives test equipment vendors and users the ability to accurately characterise jitter measurement equipment.

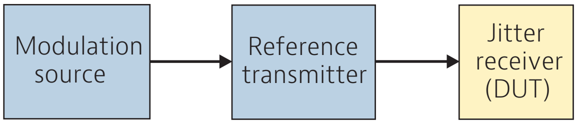


Figure 25: Reference transmitter modulated by sinusoidal bursts

The following figure is a block diagram of an example implementation of the clock and modulation generation section (Part 1).

This section consists of two high quality synthesizers to generate the line rate clock and sinusoidal jitter phase modulation. The relative amplitude levels of these oscillators determines the generated jitter amplitude, the relative frequencies and the jitter modulation.

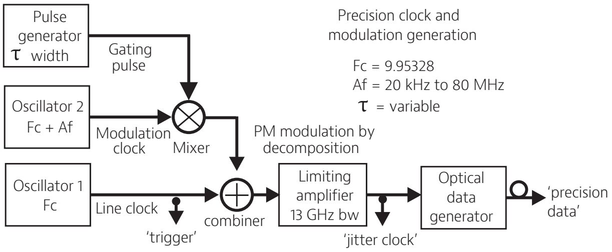


Figure 26: Block diagram of clock and modulation generation section

The described verification system can be used to test varying modulation pulse widths and repetition rates. The user of the system has control over the area to be characterized to verify compliance with O.172. At each modulation frequency point an accuracy map can be produced with varying transient widths and repetition rates.

The following figure shows an example of a sinusoidal burst with the parameters modulation frequency, jitter amplitude A, burst width and burst repetition rate.

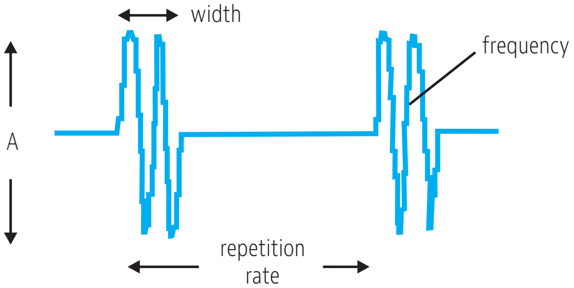


Figure 27: Example of a sinusoidal burst for clock modulation

The range of modulation frequencies, burst widths and repetition rates depend on the jitter measurement bandwidth, which is related to the applied bit rate. A possible combination of modulation frequencies, burst widths and repetition rates is given in Appendix VII.

Table 7: Combination of modulation frequency and burst width

Signal	Modulation Frequency f_m	Minimum Burst Width t_{min}	Burst Width > t_{min}				
STM-1	1 kHz *	2 ms	–	–	–	–	–
	65 kHz *	31 µs	–	–	–	100 µs	1 ms
	300 kHz	6.7 µs	–	–	–	100 µs	1 ms
	1.3 MHz	1.5 µs	–	–	10 µs	100 µs	1 ms
STM-4	10 kHz *	200 µs	–	–	–	–	1 ms
	250 kHz *	8 µs	–	–	–	100 µs	1 ms
	1 MHz	2 µs	–	–	10 µs	100 µs	1 ms
	5 MHz	400 ns	–	–	10 µs	100 µs	1 ms
STM-16	50 kHz *	40 µs	–	–	–	100 µs	1 ms
	1 MHz *	2 µs	–	–	10 µs	100 µs	1 ms
	5 MHz	400 ns	–	–	10 µs	100 µs	1 ms
	20 MHz	100 ns	–	1 µs	10 µs	100 µs	1 ms
STM-64	200 kHz *	10 µs	–	–	–	100 µs	1 ms
	3 MHz *	667 ns	–	–	10 µs	100 µs	1 ms
	20 MHz	100 ns	–	1 µs	10 µs	100 µs	1 ms
	80 MHz	25 ns	100 ns	1 µs	10 µs	100 µs	1 ms

* Applicable only when high-pass f_1 is used for the measurement

Remarks for the test procedure:

- The burst repetition rate shall be in the range from 10 Hz to 10 kHz.
- Minimum burst repetition rate of 10 Hz is chosen for measurement repeatability and is based on test pattern PRBS repetition.
- Burst widths of 100 μs and 1 ms can only be used with burst repetitions less than 10 kHz and 1 kHz respectively.
- The measurement period should be 60 s.

Table 8: Example table for OC-192/STM-64 and modulation frequency of 3 MHz

	Burst Width	667 ns	0.01 ms	0.1 ms	1 ms
Repetition Rate	Cycles Burst Period	2	30	300	3000
10 Hz	100 ms				
100 Hz	10 ms				
1 kHz	1 ms				*
10 kHz	0.1 ms			*	n/a

* sine-wave

Appendix VII defines an amplitude A of 100 mUI peak-to-peak jitter modulation. An ideal jitter receiver should measure 100 mUI peak-to-peak of jitter for all burst widths and repetition rates. The measurement results for each different parameter are recorded in an accuracy map. The ideal accuracy map would be flat reporting 100 mUI for all waveforms regardless of how frequently or how long the jitter signal occurs. The degree of flatness is a measure of the accuracy of the jitter receiver.

The following diagram shows an example accuracy map:

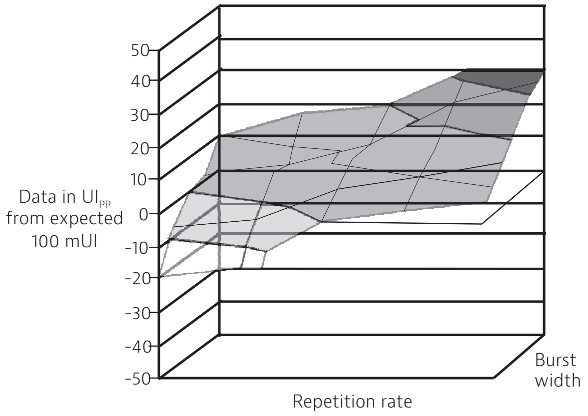


Figure 28: Example jitter measurement accuracy map

How does Viavi address the accuracy map?

Viavi uses a reference transmitter with a modulation section that exceeds the minimum accuracy requirements set by ITU-T. The Viavi reference transmitter uses the "pulse carving" method to generate a virtually jitter-free reference signal that is then modulated with a sinusoidal burst of 100 mUI. The "pulse carving" method provides the pattern independence necessary to ensure that the only jitter at the output is the jitter that is purposely added by the modulation section.

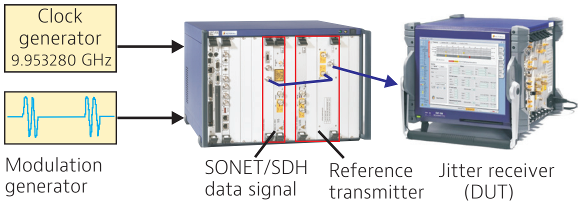


Figure 29: Addressing the accuracy map

Accuracy map test procedure for OC-192/ STM-64:

- Modulate the reference transmitter by a short sinusoidal burst (e.g., 3 MHz)
- Vary the burst width from 667 ns to 1 ms and vary the repetition rate of the modulation from 10 Hz to 10 kHz
- Measure for 1 min with different values
- Repeat the procedure for a number of tests

Repeating the above procedure will provide consistency in the results.

The following figure shows an accuracy map taken from ONT product for OC-192/STM-64:

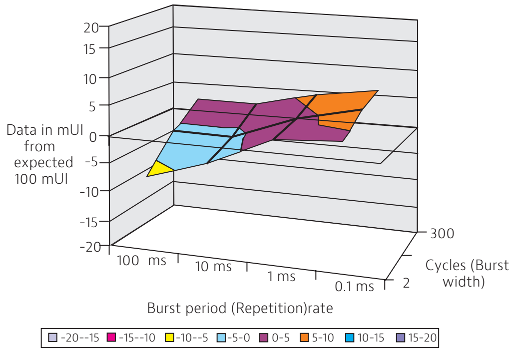


Figure 30: Typical accuracy map for OC-192/STM-64 with modulation frequency 3 MHz

The Viavi high-accuracy jitter test solution provides accurate and repeatable jitter results and shows consistency when repeating the test procedure. Jitter peaks are detected reliably, regardless of their frequency. The Viavi accuracy map option for the high-accuracy jitter equipment provides detailed jitter accuracy profiles plotted for each individual jitter receiver.

The accuracy map is a useful tool to compare the accuracy and repeatability of different jitter receivers. Jitter instruments with a flat accuracy map can provide a large cost saving to the user by saving time in design, troubleshooting, and reducing the occurrence of "marginal" pass/fail cases in production.

The product quality improvements gained by using the most accurate test solutions also helps equipment manufacturers and network providers improve the quality of the products they produce, increase customer satisfaction, lower rework and improve top and bottom line growth.

4. Method to characterize the intrinsic jitter of a transmitter (ITU-T O.172 Appendix VIII)

The test procedure described in ITU-T O.172 Appendix VIII recommends a method and implementation to verify and characterize a transmitted signal with a specific jitter test pattern. This technique may be used to help de-embed transmit and receive components of jitter test equipment. It is a method to determine the rms and peak-to-peak values of a transmitted signal with a defined test pattern.

The technique requires a fixed, repeating SONET/SDH-like test frame. This test frame is used as a diagnostic tool and is not intended for use to characterise network equipment or devices under test. This technique can be applied to verify the pattern-dependent jitter and the random jitter contribution of the low jitter data source defined in Appendix VII (reference transmitter).

This method requires the use of a data signal, a clock signal and a high quality pattern frame trigger. The long-term phase drift between clock and data is recognized as a source of potential error and should be considered in any measurement. The calculation of the peak-to-peak value is done by using the probability distribution function (PDF).

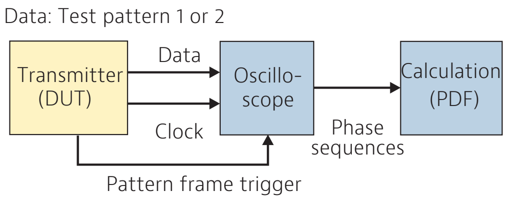


Figure 31: Principal method for characterization of transmit intrinsic jitter

The following figures show the defined diagnostic test patterns. These are suitable for use at OC-192/STM-64 and OC-48/STM-16 line rates.

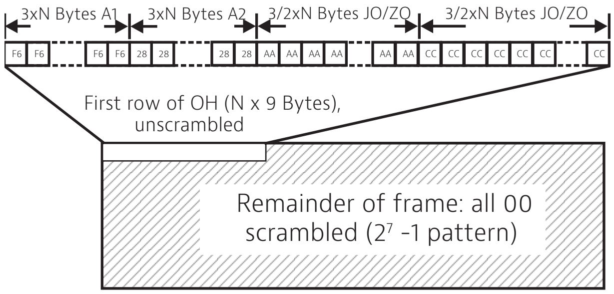


Figure 32: Diagnostic test pattern 1

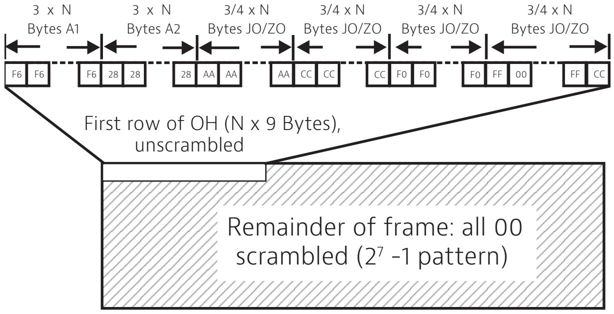


Figure 33: Diagnostic test pattern 2

Step 1: Measurement of test frame with pattern-dependent jitter

1. Set a transmitter to produce a framed test signal with test pattern 1 or 2 (as in the figures above).
2. Use an oscilloscope to extract the data and clock waveforms.
3. Set the acquisition to average over at least 64 traces to eliminate random phase noise. Adjust the phase of the clock rising edge to coincide exactly with the signal edges. Measure the time (in UI) between the rising edge of the clock and the corresponding signal edge (within ±0.5 UI). This forms a sequence of pattern-dependent phase values χi.

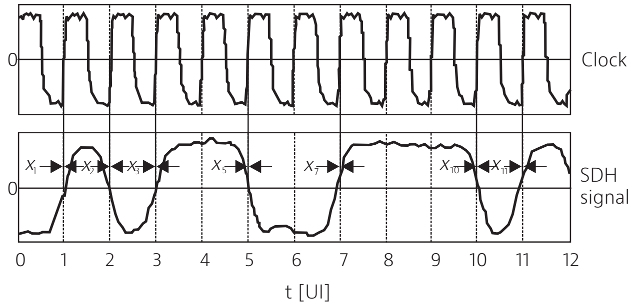


Figure 34: Measurement of the pattern-dependent phase sequences

4. If there is no corresponding signal edge for a particular i, assign to $\chi_i = 0$. Measure χ_i to cover one period of the frame, i.e., the size of the data set, [χ_i to χ_N] is $N = 125 \times 10^6 \times f_0$, where f_0 is the corresponding bit rate. Then generate mathematically a new sequence by using the following formulae:

$$\chi'_i = \frac{\sum_{n=1}^{24} \chi_{i-n}}{\sum_{n=1}^{24} p_{i-n}}$$

where p_i represents the pattern density information. Assign $p_i = 1$ when an edge exists, assign $p_i = 0$ when no transition data is present. Substitute χ'_i values into series χ_i where no measured edge value exists.

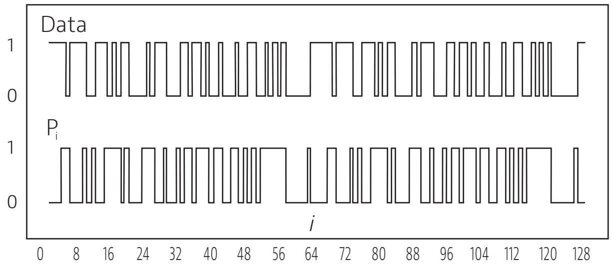


Figure 35: Example – Data pattern and transition density p_i

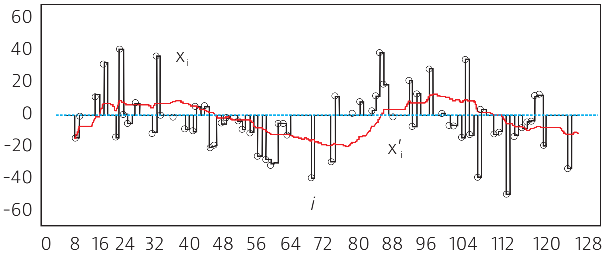


Figure 36: Example – Unfiltered phase values χ_i and χ'_i

5. Filter the sequence χ_i mathematically with the appropriate high-pass and low-pass filters to form the sequence of pattern-dependent jitter values y_i.

6. Use histogram methods to determine the probability distribution function PDFy of the sequence y_i.

7. From PDFy, calculate the rms of the sequence y_i. This value σ_{PD} is the rms of the pattern-dependent jitter.

Step 2: Measurement of clock random jitter

1. Set the transmitter to produce a 1010... data sequence. (This eliminates pattern-dependent jitter.)

2. Apply the signal to a spectrum analyzer, in the case of an optical signal use a wide-bandwidth O/E converter.

From the SSB noise on one side of the half-baud component, determine the power spectral density PSD_{RP} of the random phase noise. (In converting the SSB noise to UI^2/Hz, remember that one cycle of the half-baud component is 2 UI.)

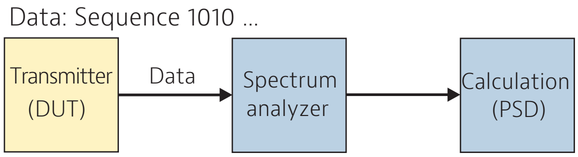


Figure 37: Block diagram for measurement of clock random jitter

3. Mathematically apply the appropriate high-pass and low-pass filtering to the PSD_{RP} to get the power spectral density PSD_{RJ} of the random jitter noise.

4. Integrate PSD_{RJ} over all ƒ and take the square root to get the rms σ_R of the random jitter noise.

Step 3: Estimate of total jitter using the PDF

1. The rms of the total jitter is $\sigma_T = [\sigma_{PD}{}^2 + \sigma_R{}^2]^{0.5}$.

2. Assuming the random jitter noise is Gaussian, use σ_R to get the probability density function PDF_R of the random jitter noise.

3. Convolve the pattern-dependent PDFy with the random PDF_R to get the probability distribution function PDF_T of the total jitter.

4. Calculate the average peak-to-peak jitter from PDF_T, from the bandwidth of the jitter, and from the measurement interval using the following calculation.

Calculation of peak-to-peak value from the probability distribution function (PDF)

From the probability distribution function $p(\chi)$ of a time function χ the expected peak-to-peak value of χ, knowing that χ is about white out to a bandwidth BW, can be calculated for a measurement interval *T*.

A time function χ that is white out to a bandwidth BW has about $N = 2 \cdot BW \cdot T$ independent values in the interval *T*. Then the probability of not exceeding some value χ during the interval *T* is the probability of *N* independent values all not exceeding that χ. But the probability of not exceeding χ on one try is the cumulative distribution function $c(\chi)$, where $c(\chi)$ is the integral of $p(\chi)$. Then the probability of not exceeding χ in *N* independent tries is $c_{max}(\chi) = c(\chi)N$. Since this is the probability that the maximum value will not exceed χ, $c_{max}(\chi)$ is the cumulative distribution function of the maximum value. Then the probability distribution function $p_{max}(\chi)$ of the maximum is the derivative of $c_{max}(\chi)$. The average (or expected) value of the maximum is the integral of $\chi \cdot p_{max}(\chi)$ over all of χ.

As an example, the following figure shows these functions for the case of a Gaussian $p(\chi)$ with an rms of unity. If the bandwidth of χ is BW = 80 MHz and the measurement interval is T = 60 seconds, then $N = 9.6 \times 109$. Raising $c(\chi)$ to this power pushes the rise of the $c_{max}(\chi)$ out beyond 6. $p_{max}(\chi)$ is the derivative of $c_{max}(\chi)$. From $p_{max}(\chi)$ we calculate the expected maximum of 6.43.

In a similar manner, the minimum of χ can be found. In this symmetrical case, the expected minimum is −6.43, and the expected peak-to-peak value is 12.86.

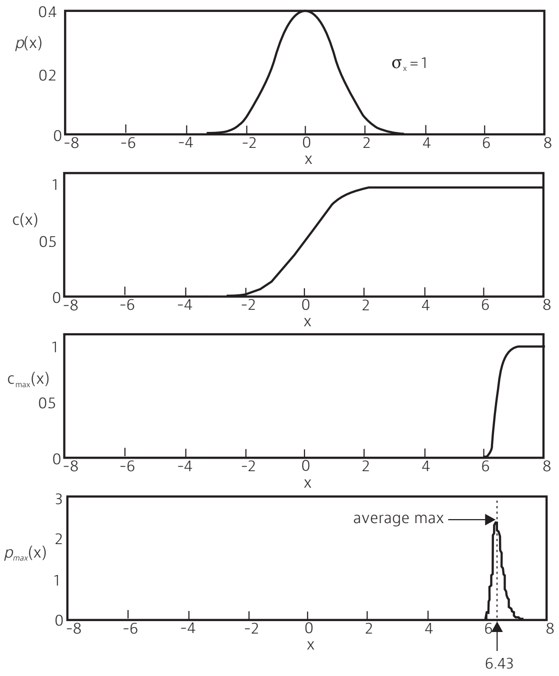


Figure 38: Gaussian example of finding the expected maximum of x from the PDF of x

Restrictions of the Appendix VIII method

The method requires a fixed, repeating SONET/SDH-like test frame which is used as a potential diagnostic tool and is not intended for use to characterize network equipment or device under test. This method requires a high-quality frame trigger. The long-term phase drift between clock and data and the phase insertion algorithm are recognized as a source of potential error and should be considered in any measurement.

The data acquisition is done by a high-quality oscilloscope. The bandwidth of the O/E module and the precision time base are sources of potential errors.

How does Viavi address the Appendix VIII?

Viavi uses the Appendix VIII method to qualify the intrinsic jitter of the reference transmitter (described in Appendix VII). This is a standard part of the Viavi jitter receiver calibration.

The test procedure compares the phase difference of data signal and the reference clock signal with a digital sampling oscilloscope. A phase analysis software calculates the deterministic intrinsic jitter. Random jitter is excluded by averaging many traces.

The following figure shows the characterisation of the reference transmitter (10 Gbps with measurement bandwidth 20 kHz to 80 MHz):

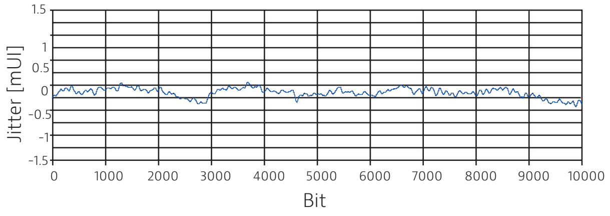


Figure 39: Pattern-dependent jitter of the reference transmitter

How does Viavi calibrate the jitter generator?

For the calibration of the jitter generator, the Bessel zero method is generally used. The spectrum of a sinusoidal phase modulated carrier signal (clock) is characterized by the Bessel functions. The carrier amplitude as a function of the modulation amplitude is expressed by the Bessel Function of zero order (J_0). The first sidelines in a distance of $\pm f_m$ (modulation frequency) are expressed by the Bessel function of first order (J_1, J_{-1}).

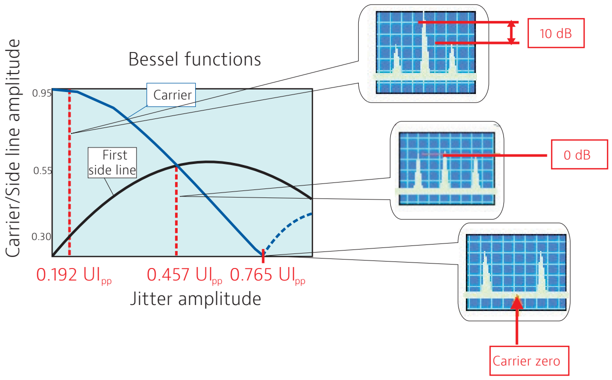


Figure 40: Spectral result of a jitter modulated clock

The figure shows the spectral result of the jitter modulated clock for different characteristic jitter amplitudes. For 0.192 UI_{pp} the relation between carrier and first sidelines is exactly 10 dB. At 0.457 UI_{pp} both, the carrier and sideline amplitudes are exactly equal (0 dB). The carrier disappears completely at 0.765 UI_{pp} (first Bessel zero). Table 9 shows a selection of those calibration values.

Table 9: Calibration values

Jitter (UI_{pp})	**Carrier/Sideline (dB)**	**Carrier Zero**
0.100	15.97	–
0.192	10.0	–
0.457	0.0	–
0.765	–	Zero No. 1

5. Industry leading accuracy for jitter testing of SONET/SDH and OTN

With the ONT family of products Viavi delivers a state-of-the-art jitter test solution for SONET/SDH and OTN networks that meets or exceeds all of the latest industry standards. All functions are fully compliant to the requirements of ITU-T Recommendation O.172/ O.173 and are recognized for excellent accuracy, repeatability and reliability.

Due to the market need for sufficient margin to validate very low level jitter generation according to rms (below 10 mUI) and peak-peak jitter (below 100 mUI) Telcordia GR-253 requirements, Viavi has significantly improved the jitter hardware in the ONT family in order to enhance the intrinsic jitter performance. By widening network equipment design margins, the need to retest marginal cases is reduced, resulting in less cost and faster time to market.

These enhancements offer significant reduction of pattern-dependent and random jitter and lead to

- Lower intrinsic peak-to-peak jitter
- Lower intrinsic rms jitter.

The following graphs show the guaranteed jitter receiver accuracy specification (fixed error W) of the high-accuracy ONT solution as compared to the ITU recommendation and standard ONT solution. The latest enhancements give the Viavi ONT jitter solution an accuracy that exceeds the ITU requirements by a factor of greater than 6 and the standard ONT by a factor of greater than 3 for peak-to-peak measurements.

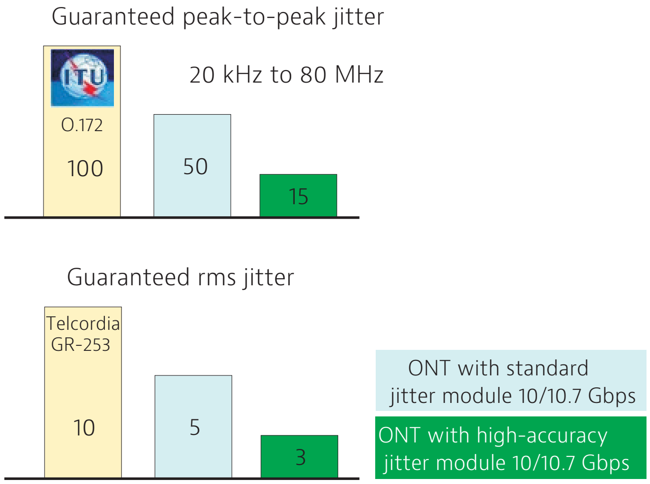


Figure 41: Guaranteed jitter receiver accuracy specification of ONT product

The O.172 Appendix VII recommendation is implemented as standard on the ONT jitter products. Calibration and verification of all jitter receivers is done by the reference transmitter. Accuracy maps are supplied as an option. These detailed graphs provide individual accuracy performance of the jitter receiver that customers can use to compare the results of different test tools.

Key jitter features

- Fully standards compliant SONET/SDH jitter testing to ITU-T O.172 and OTN jitter testing to ITU-T O.173
- Industry leading jitter measurement accuracy through new design and O.172 Appendix VII calibration and characterization
- Receiver-only, fixed jitter accuracy specification of 15 mUI across entire filter range
- Programmable jitter tolerance and jitter transfer masks
- Jitter testing for optical and electrical interfaces
- Wander test from 10/10.7 Gbps, MTIE/TDEV online analysis
- Wander sample rates up to 1000 samples in compliance with ITU Recommendation O.172

6. Electrical differential jitter testing of XFP transceivers

Pluggable optics are quickly becoming the standard for all optical network interfaces and are quickly replacing legacy optical front ends. This technology has a lot of advantages like low cost, extremely compact, easy exchange among many vendors, hot-pluggable, etc. With more than 80 component vendors standardizing the parameters of pluggable optics through the Multi Source Agreement (MSA), it is easy to see why this technology is gaining industry wide acceptance so quickly.

The XFP is one of these pluggable optical modules for 10 Gbps supporting established Telecom standards 9.95 Gbps SONET-OC192/SDH-STM-64, and supporting emerging applications 10.31 Gbps Ethernet LAN, 10.7 Gbps G.709 FEC, 10.52 Gbps Fiber Channel, and 11.09 Gbps Ethernet over G.709 FEC. XFP manufacturers have to perform compliance tests to each of the related standards for different applications.

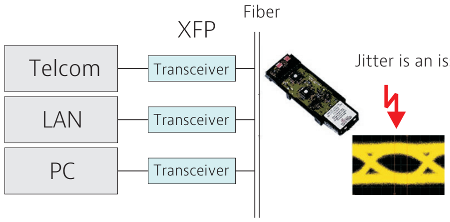


Figure 42: Pluggable optics – XFP transceivers for 10 Gbps applications

The increased use of pluggable optics and the pressure to reduce the cost and also component size of these devices has led to jitter becoming an even more important issue than it was in the past. The Telcordia GR-253-CORE specified 100 mUI limit for network equipment is becoming a very challenging requirement to meet and consequently requires accurate test equipment to determine if the device meets this specification.

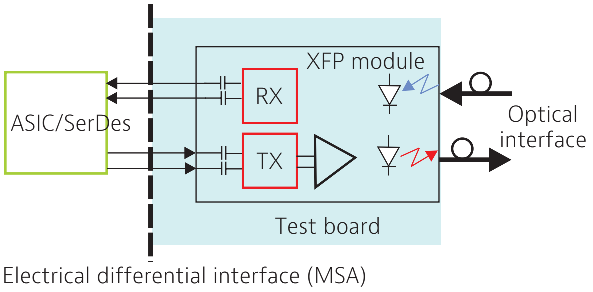


Figure 43: Differential I/O interface of a XFP transceiver

The XFP modules feature a 10 Gbps differential I/O interface. This is a high-speed serial electrical interface based on low voltage AC coupled logic with a nominal differential impedance of 100 Ω.

The electrical differential I/O creates new requirements like jitter generation and jitter tolerance measurements.

How does Viavi support electrical differential jitter testing?

Viavi provides a solution for electrical jitter and BER testing of XFP modules at differential interfaces. This testing module supports differential input/output connected to the interface under test and single-ended input/output connected to the jitter generator and analyzer of the ONT. The jitter module has low intrinsic jitter generation and high receiver accuracy that guarantees highly accurate measurement results on XFP modules. The following figure shows the jitter test set ONT with an electrical differential module connected to a test board with XFP.

Jitter measurements as for optical front ends have to be performed like jitter generation and jitter tolerance.

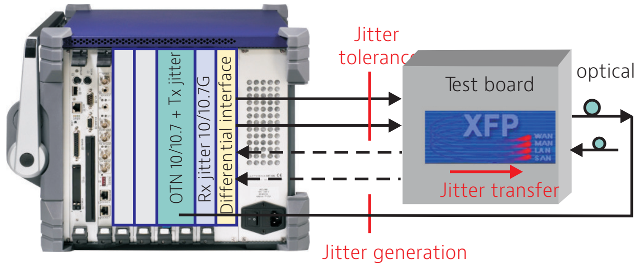


Figure 44: XFP transmitter measurements

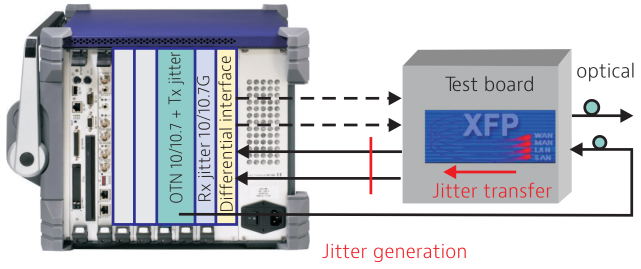


Figure 45: XFP receiver measurements

Electrical differential tests are important to component manufacturers who have to perform optical and differential compliance tests according to existing Telecom standards and also according to MSA specifications.

Conclusion

Network equipment manufacturers who are responsible for verifying that equipment adheres to strict jitter limits need highly accurate repeatable test results that verify design conformance to the 100 mUI industry standard.

As more and more high-speed, time-sensitive services are implemented, the impact of jitter escalates, requiring new methods to minimize its presence early in the equipment design stage.

This has pushed the International Telecommunications Union Technology Standardization Sector (ITU-T) to develop new recommendations for jitter test equipment. The ITU proposed the implementation of a receiver-only test to improve the accuracy and repeatability of jitter testing. This “Method for Verification of Measurement Result Accuracy and Intrinsic Fixed Error” was formalized in ITU-T O.172 Appendix VII that defines recommended test parameters to ensure that a jitter receiver can measure all types of jitter, including transient and continuous jitter. A reference transmitter, which is key to the O.172 Appendix VII recommendation, is used to ensure that a reference jitter receiver is calibrated to measure all jitter the same way regardless of the nature of the jitter event. The accuracy map makes it possible to compare jitter characteristics of different instruments and to normalize the results. This eliminates the problem of different jitter test sets giving different measurement results.

Viavi actively participates in the ITU-T recommendation committees, helping to craft the standards. Subsequently, it became one of the first test instrument manufacturers to implement the Appendix VII standard into a new reference transmitter that uses a reference source to generate an “ideal” signal virtually free of pattern-dependent jitter. Viavi took the initiative and implemented accuracy requirements that exceeded those set by the ITU-T in its ONT product family. The results are increased receiver-to-receiver consistency and absolute accuracy. Using Viavi solutions with this new level of test accuracy enables the user to perform high-quality device characterization while speeding the development, integration and production of new products.

Hence the ONT increases the design margins, saves R&D time, reduces production waste and improves profitability.

Viavi continues to contribute to the standardization of network test equipment in order to ensure that we continue to provide the most accurate and consistent products to our demanding customer base. This enables the design, production, installation, and support of faster, more reliable optical networks.

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