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SERIES O: SPECIFICATIONS OF MEASURING EQUIPMENT

Equipment for the measurement of digital and analogue/digital parameters

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Jitter measuring equipment for digital systems which are based on the optical transport network

Recommendation ITU-T O.173

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Recommendation ITU-T O.173

Jitter measuring equipment for digital systems which are based on the optical transport network

Summary

Recommendation ITU-T O.173 specifies instrumentation that is used to generate and measure jitter in digital systems based on the optical transport network (OTN). Measurement requirements for client interfaces, e.g., SDH line interfaces are not addressed in this Recommendation.

The requirements for the characteristics of the jitter measuring equipment that are specified in this Recommendation must be adhered to in order to ensure consistency of results between equipment produced by different manufacturers.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T O.173	2003-03-29	4
2.0	ITU-T O.173	2007-03-16	4
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3.0	ITU-T O.173	2012-02-13	15

Keywords

Input jitter tolerance, input wander tolerance, jitter, jitter generation, jitter measurement, jitter transfer function, output jitter.

FOREWORD

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Introduction

The timing performance of OTN networks and OTN equipment elements is specified in [ITU-T G.8251], using jitter and wander parameters. This Recommendation specifies the various characteristics of jitter measuring equipment, which are needed in order to support the requirements of [ITU-T G.8251] and to perform other test and measuring tasks.

While functional and characteristic requirements are given for the measuring equipment, the realization of the equipment configuration is not covered and should be given careful consideration by the designer and user. In particular, it is not required that all features described in this Recommendation shall be provided in one piece of equipment. Users may select those functions which correspond best to their applications.

Recommendation ITU-T O.173

Jitter measuring equipment for digital systems which are based on the optical transport network

1 Scope

This Recommendation specifies test instrumentation that is used to generate and measure timing jitter in digital systems based on the optical transport network (OTN).

The test instrumentation consists principally of a jitter measurement function and a jitter generation function. Measurements can be performed at the physical layer of OTN network node interfaces (NNIs). A bit error rate test set may also be required for certain types of measurements; this may be part of the same instrumentation or it may be physically separate.

It is recommended that [ITU-T G.8251] and [ITU-T G.709] are read in conjunction with this Recommendation.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.693] Recommendation ITU-T G.693 (2009), *Optical interfaces for intra-office systems*.

[ITU-T G.703] Recommendation ITU-T G.703 (2001), *Physical/electrical characteristics of hierarchical digital interfaces*.

[ITU-T G.709] Recommendation ITU-T G.709/Y.1331 (2009), *Interfaces for the Optical Transport Network (OTN).*

[ITU-T G.810] Recommendation ITU-T G.810 (1996), *Definitions and terminology for synchronization networks*.

[ITU-T G.959.1] Recommendation ITU-T G.959.1 (2009), *Optical transport network physical layer interfaces*.

[ITU-T G.8251] Recommendation ITU-T G.8251 (2010), *The control of jitter and wander within the optical transport network (OTN).*

[ITU-T O.3] Recommendation ITU-T O.3 (1992), *Climatic conditions and relevant tests for measuring equipment*.

[ITU-T O.172] Recommendation ITU-T O.172 (2005), *Jitter and wander measuring equipment for digital systems which are based on the synchronous digital hierarchy (SDH).*

[ITU-T O.182] Recommendation ITU-T O.182 (2007), *Equipment to assess error performance on Optical Transport Network interfaces.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 (timing) jitter [ITU-T G.810]: The short-term variations of the significant instants of a timing signal from their ideal positions in time (where "short-term" implies that these variations are of frequency greater than or equal to 10 Hz).

3.1.2 wander [ITU-T G.810]: The long-term variations of the significant instants of a digital signal from their ideal position in time (where "long-term" implies that these variations are of frequency less than 10 Hz).

NOTE – It may be useful to note that [ITU-T G.810] provides additional definitions and abbreviations used in timing and synchronization Recommendations. It also provides background information on the need to limit phase variation and the impairments on digital systems.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

OPUk	Optical channel Payload Unit-k
OTN	Optical Transport Network
OTUk	completely standardized Optical channel Transport Unit-k
OTL	Optical channel Transport Lane
ppm	parts per million
PRBS	Pseudo Random Binary Sequence
SDH	Synchronous Digital Hierarchy
UI	Unit Interval
UIpp	Unit Interval peak-to-peak

5 Functional block diagram

Figure 1 shows the block diagram of the instrumentation in general form, identifying the main functions that are addressed in this Recommendation. The figure does not describe a specific implementation.

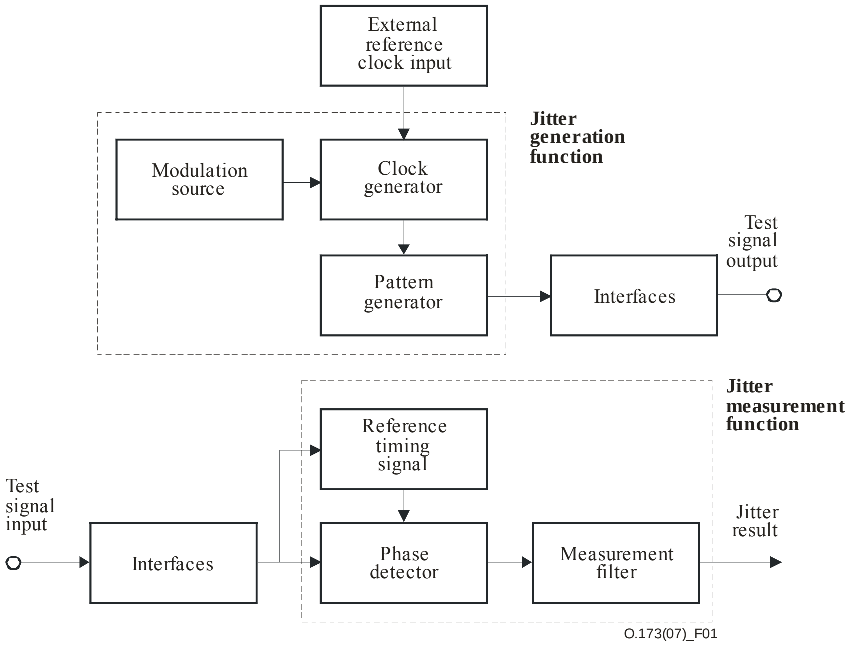

Figure 1 – Functional block diagram for jitter test set

6 Interfaces

6.1 Optical interfaces

The instrumentation shall be capable of operating at one or more of the following OTUk and OTLk.4 bit rates and corresponding optical interface characteristics as defined in the appropriate clauses of [ITU-T G.959.1].

–	OTU1	255/238 * 2 488 320 kbit/s	≈ 2 666 057.143 kbit/s
–	OTU2	255/237 * 9 953 280 kbit/s	≈ 10 709 225.316 kbit/s
–	OTU3	255/236 * 39 813 120 kbit/s	≈ 43 018 413.559 kbit/s
–	OTL3.4	43.018 Gbit/s divided by 4	≈ 10.754 Gbit/s
–	OTL4.4	111.809 Gbit/s divided by 4	≈ 27.952 Gbit/s

6.2 Electrical interfaces

As an option, the jitter measurement function shall be capable of measuring jitter at an electrical clock output port when such an access is provided on digital equipment.

6.3 External reference clock input

The measuring equipment shall accept data signals at bit rates of 1544 kbit/s or 2048 kbit/s as a reference. If 2048 kbit/s can be accepted, the equipment shall also accept a clock signal at 2048 kHz as a reference. The characteristics of the clock signals shall be in accordance with [ITU-T G.703].

6.4 Input interface sensitivity

The jitter measurement function is required to operate satisfactorily under the input conditions as specified in [ITU-T G.959.1] and [ITU-T G.693].

7 Jitter generation function

Tests of OTN equipment may be made with either a jittered or a non-jittered digital signal. This will require the digital test pattern generator, clock generator and modulation source shown in Figure 1.

7.1 Modulation source

The modulation source, required to perform tests in conformance with relevant Recommendations, may be provided within the clock generator and/or digital test pattern generator or it may be provided separately. In this Recommendation, the modulation source is defined to be sinusoidal.

7.2 Clock generator

It shall be possible to phase-modulate the clock generator from the modulation source and to indicate the peak-to-peak phase deviation of the modulated signal.

The generated peak-to-peak jitter and the modulating frequencies shall meet the minimum requirements of Table 1 and Figure 2.

If the output interfaces for the modulated clock signal and/or the external timing reference signal are provided, the minimum amplitude shall be 1 volt peak-to-peak into 75 Ω or 0.25 volt peak-to-peak into 50 Ω.

7.2.1 Accuracy of the clock generator

The frequency deviation of the internal clock signal from its nominal value shall be less than:

±4.6 ppm

As an option, the clock generator may provide adjustable frequency offset of sufficient magnitude to facilitate testing across the clock tolerance range of the equipment-under-test, e.g., ±10 ppm to ±100 ppm.

It shall be possible to phase-lock the generation function to an external reference clock source of arbitrary accuracy; refer also to clause 7.3.

7.3 Digital test pattern generator

The digital test pattern generator (see Annex A) shall be capable of providing OTUk signals with a frame structure and payload mapping of a NULL client or PRBS test signal into OPUk in accordance with clauses 17.5.1 and 17.5.2 of [ITU-T G.709].

7.4 Minimum jitter generation capability

The jitter amplitude/frequency characteristic of the generation function shall meet the minimum requirements of Table 1 and Figure 2.

Table 1 – Minimum amplitude of adjustable generated jitter amplitude versus jitter frequency for OTUk and OTLk.4 signals

Signal	Minimum peak-to-peak jitter amplitude (UIpp)			Jitter frequency breakpoints (Hz)				
	A_1	A_2	A_3	f_0	f_1	f_2	f_3	f_4
OTU1	20	2	0.2	500	5 k	100 k	1 M	20 M
OTU2	20	2	0.2	2 k	20 k	400 k	4 M	80 M
OTL3.4	80	8	–	2 k	20 k	33 k	4 M	–
OTL4.4	20	8	–	20 k	50 k	83 k	10 M	–
OTU3	20	8	0.2	8 k	20 k	480 k	16 M	320 M

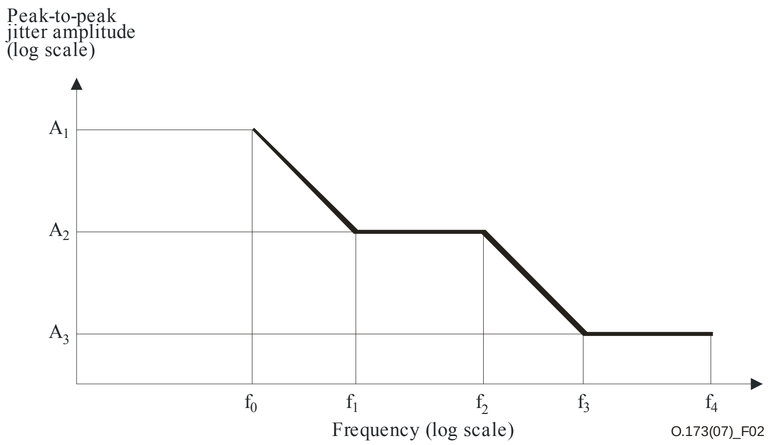

Figure 2 – Generated jitter amplitude versus jitter frequency

7.5 Generation accuracy

The test signal source shall be compatible with the jitter measurement function in such a way that the overall measuring accuracy is not substantially deteriorated. The generation accuracy may be increased by measuring the jitter applied to the unit under test using a corresponding jitter measuring device.

The generating accuracy of the jitter generation function is dependent upon several factors such as fixed intrinsic error, setting resolution, distortion and frequency response error. In addition, there is an error that is a function of the actual setting.

7.5.1 Phase amplitude error

The amplitude error of sinusoidal jitter generation shall be less than:

$$\pm Q\% \text{ of setting } \pm 0.02 \text{ UIpp}$$

where Q is a variable error specified in Table 2.

NOTE – This Recommendation excludes any wideband intrinsic jitter/wander components.

Table 2 – Variable error (Q) of OTUk and OTLk.4 jitter generation

Signal	Error, Q	Frequency range
OTU1	±10%	500 Hz to 5 kHz
	±8%	>5 kHz to 500 kHz
	±12%	>500 kHz to 2 MHz
	±15%	>2 MHz to 20 MHz
OTU2	±10%	2 kHz to 20 kHz
	±8%	>20 kHz to 1 MHz
	±12%	>1 MHz to 4 MHz
	±15%	>4 MHz to 80 MHz
OTL3.4	±10%	2 kHz to 20 kHz
	±8%	>20 kHz to 33 kHz
	±12%	>33 kHz to 4 MHz
OTL4.4	±10%	20 kHz to 50 kHz
	±8%	>50 kHz to 83 kHz
	±12%	>83 kHz to 10 MHz
OTU3	±8%	>20 kHz to 1 MHz
	±12%	>1 MHz to 4 MHz
	±15%	>4 MHz to 80 MHz
	±15%	>16 MHz to 320 MHz

7.5.2 Phase slope error

The band-limited peak-to-peak phase slope error in UI/s shall be less than:

$$\frac{(\pm 2.5 \cdot \text{Q\% of setting} \pm 0.05\,\text{UIpp}) \cdot 2\pi f_m}{\sqrt{1+(f_m / f_{3\text{dB}})^2}}$$

over the range:

$$10\text{ Hz} \leq f_m \leq 2 \cdot f_3$$

where f_m is the modulation frequency, $f_{3dB} = 2 \cdot f_3 \pm 10\%$ is the bandwidth of the low-pass filter, f_3 is defined in Table 1, and Q is a variable error specified in Table 2.

See Annex B of [ITU-T O.172] for the definition of band-limited peak-to-peak phase slope error.

NOTE – This Recommendation includes modulation harmonics (within the low-pass filter bandwidth) due to distortion, but it excludes any wideband intrinsic jitter components.

7.5.3 Intrinsic jitter/wander of generation function

The intrinsic jitter of the jitter generation function measured in a bandwidth f_1-f_4 as defined in Table 1 with the amplitude set to zero shall be less than:

0.04 UIpp for an output OTUk signal with a frame structure defined in clause 7.3 and for an output OTLk.4 signal.

0.02 UIpp for a clock signal.

8 Jitter measurement function

8.1 Reference timing signal

A reference timing signal for the phase detector is required. For end-to-end measurements of jitter, it may be derived in the jitter measurement function from the input digital test pattern. For looped measurements, it may be derived from a suitable clock source.

8.2 Measurement capabilities

8.2.1 Measurement range

The jitter measurement function shall be capable of measuring peak-to-peak jitter. The measurement ranges to be provided are optional but for reasons of compatibility the jitter amplitude/jitter frequency characteristic of the jitter measurement function shall meet the minimum requirements of Table 3 and Figure 3. The frequencies f_0 to f_4 define the range of jitter frequencies to be measured; capability to measure the range of frequencies lower than f_1 is optional.

NOTE – Operation of the jitter measurement function over one continuous frequency range f_0 to f_4 is optional.

Table 3 – Minimum measured jitter amplitude versus jitter frequency for OTUk and OTLk.4 signals

Signal	Minimum peak-to-peak jitter amplitude (UIpp)			Jitter frequency breakpoints (Hz)				
	A_1	A_2	A_3	f_0	f_1	f_2	f_3	f_4
OTU1	20	2	0.2	500	5 k	100 k	1 M	20 M
OTU2	20	2	0.2	2 k	20 k	400 k	4 M	80 M
OTL3.4	80	8	–	2 k	20 k	33 k	4 M	–
OTL4.4	20	8	–	20 k	50 k	83 k	10 M	–
OTU3	20	8	0.2	8 k	20 k	400 k	16 M	320 M

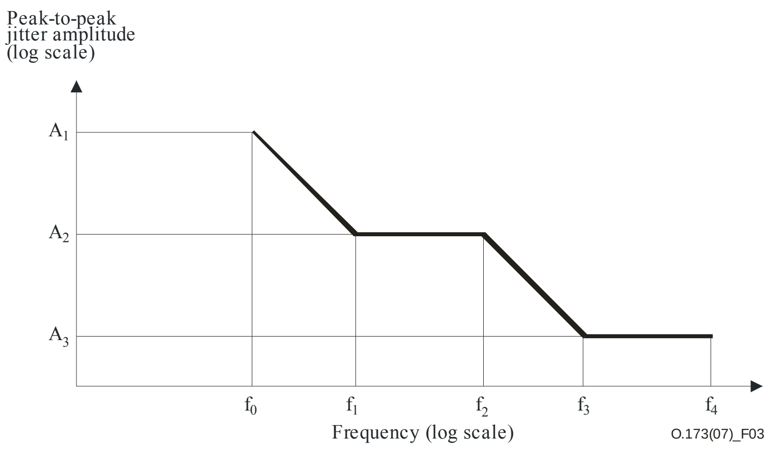

Figure 3 – Measured jitter amplitude versus jitter frequency

8.2.2 Selectable threshold

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 occasions 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.

8.3 Measurement bandwidths

The measurement bandwidth shall be limited in order to measure the specified jitter spectra as defined in [ITU-T G.8251]. The bandwidth f_1-f_4 or f_3-f_4 of the jitter measurement function shall be in accordance with Table 4.

Table 4 – Jitter measurement function bandwidth for OTUk and OTLk.4 signals

Signal	Jitter measurement bandwidth (–3 dB cut-off frequencies)		
	f_1 (Hz) high-pass	f_3 (Hz) high-pass	f_4 (Hz) low-pass
OTU1	5 k	1 M	20 M
OTU2	20 k	4 M	80 M
OTL3.4	20 k	–	80 M
OTL4.4	50 k	–	200 M
OTU3	20 k	16 M	320 M

8.3.1 Frequency response of jitter measurement function

The response of all filters within the pass band shall be such that the accuracy requirements of the jitter measurement function are met (refer to clause 8.4).

For all OTUk and OTLk.4 bit rates, the following requirements apply to the jitter measurement function when the measurement filters at frequencies f_1, f_3 and f_4 are used:

a) The high-pass measurement filters with cut-off frequencies f_1 and f_3 have a first-order characteristic and a roll-off of 20 dB/decade.

b) The nominal f_1 and f_3 cut-off frequencies for each bit rate are specified in Table 4 and the nominal –3 dB point of the measurement filters shall be at frequencies $f_1 \pm 10\%$ and $f_3 \pm 10\%$, respectively.

c) The low-pass measurement filter with cut-off frequency f_4 has a maximally-flat, Butterworth characteristic and a roll-off of –60 dB/decade.

d) The nominal f_4 cut-off frequency for each bit rate is specified in Table 4 and the –3 dB point of the measurement filter shall be at a frequency $f_4 \pm 10\%$.

e) The maximum attenuation of the measurement filters shall be at least 60 dB.

These jitter measurement functional requirements are compatible with [ITU-T G.8251].

8.4 Measurement accuracy

8.4.1 Measurement result accuracy

The measuring accuracy of the jitter measurement function is dependent upon several factors such as fixed intrinsic error, frequency response and 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 accuracy of the jitter measurement shall not be affected by frequency offset on the input signal that is within the limits defined for the OTUk and OTLk.4 bit rates in [ITU-T G.8251].

The measurement accuracy is specified using an input signal with a structure defined in Annex A and the physical characteristics of an optical signal in conformance with [ITU-T G.959.1] with a nominal power in the range −10 dBm to −12 dBm. Operation at higher input power levels may be permitted at OTU3 in accordance with the mean launch powers specified in [ITU-T G.693].

The total measurement error shall be less than:

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

where R is the variable error specified in Table 6 and W is the fixed error of Table 5, which includes any contribution from the internal timing extraction function.

8.4.2 Fixed error

For the OTUk and OTLk.4 bit rates and for the indicated digital signals, the fixed error of the jitter measurement function shall be as specified in Table 5 within the frequency ranges f_1-f_4 and f_3-f_4. Indicated frequencies f_1, f_3 and f_4 used in Table 5 are defined in Table 3.

Table 5 – Fixed error (W) of OTUk and OTLk.4 jitter measurements

Signal	Maximum peak-to-peak jitter error (UIpp) for given digital signals			
	OTUk and OTLk.4 signal		Clock signal	
	f_1-f_4	f_3-f_4	f_1-f_4	f_3-f_4
OTU1	0.1	0.035	0.05	0.03
OTU2	0.1	0.035	0.05	0.03
OTL3.4	0.1	–	0.05	–
OTL4.4	0.2	–	0.05	–
OTU3	0.2	0.05	0.05	0.03

NOTE 1 – OTUk signals are defined in Annex A.

NOTE 2 – Clock interfaces are optional.

NOTE 3 – In OTU3 the objective is to reduce the fixed error W within the frequency ranges f_1-f_4 and f_3-f_4 to 0.1 UIpp and 0.035 UIpp.

8.4.3 Variable error

At jitter frequencies between f_1 and f_4, the variable error R additional to that specified in clause 8.4.2 shall be as specified in Table 6. Frequencies f_1 and f_4 used in Table 6 are defined in Table 3.

Table 6 – Variable error (R) of OTUk and OTLk.4 jitter measurements

Signal	Error, R	Frequency range
OTU1	±7%	5 kHz to 300 kHz
	±8%	>300 kHz to 1 MHz
	±10%	>1 MHz to 3 MHz
	±15%	>3 MHz to 10 MHz
	±20%	>10 MHz to 20 MHz
OTU2	±7%	20 kHz to 300 kHz
	±8%	>300 kHz to 1 MHz
	±10%	>1 MHz to 3 MHz
	±15%	>3 MHz to 10 MHz
	±20%	>10 MHz to 80 MHz
OTL3.4	±7%	2 kHz to 20 kHz
	±8%	>20 kHz to 33 kHz
	±10%	>33 kHz to 4 MHz
OTL4.4	±7%	20 kHz to 50 kHz
	±8%	>50 kHz to 83 kHz
	±10%	>83 kHz to 10 MHz
OTU3	±7%	20 kHz to 300 kHz
	±8%	>300 kHz to 1 MHz
	±10%	>1 MHz to 10 MHz
	±15%	>10 MHz to 80 MHz
	±20%	>80 MHz to 320 MHz

8.5 Analogue output

The jitter measurement function may provide an analogue output signal to enable measurements to be made externally to the jitter measurement function, e.g., by using an oscilloscope or a spectrum analyser.

8.6 Jitter transfer measurement accuracy

The specification of OTN equipment jitter transfer characteristics in [ITU-T G.8251] (see Note) uses a gain-versus-frequency mask to limit the maximum transfer gain (P) and the maximum transfer bandwidth (f_C). This mask is specified in-between the frequency range f_L to f_H. The accuracy of the jitter transfer measurement depends on several factors: the repeatability of the jitter generator's performance, the linearity and repeatability of the jitter measurement equipment's performance, and the noise floor of the measurement. Where the jitter frequency f_m is less than f_C, the measurement accuracy affects the determination of whether the gain limit P has been met. Where the jitter frequency f_m is greater than f_C, the measurement accuracy affects the determination of whether the bandwidth limitation mask above f_C is not exceeded.

The total measurement error in the jitter frequency range $f_L = 0.01 \cdot f_C$ and $f_H = 100 \cdot f_C$ or f_4, if f_4 is lower than $100 \cdot f_C$ when using input jitter amplitude equal to the applicable jitter tolerance masks, shall be less than:

$$\pm 0.05 \text{ dB} \pm 0.12 \cdot g$$

where g is the measured jitter transfer gain at the jitter frequency f_m in dB, and f_L, f_C, and f_H are according to Table A.7-2 of [ITU-T G.8251]. This measurement error applies for g greater than or equal to –45 dB. No accuracy is specified for g less than –45 dB.

NOTE – Table A.7-1 of [ITU-T G.8251], ODCb jitter transfer requirement, is a specification for internal equipment that does not have an interface that can be measured. Consequently, Table A.7-1 of [ITU-T G.8251], ODCb jitter transfer requirement, is excluded from this Recommendation, and only Table A.7-2 of [ITU-T G.8251], ODCr jitter transfer requirement, is targeted.

9 Operating environment

The performance requirements shall be met when operating within the climatic conditions as specified in clause 2.1 of [ITU-T O.3].

Annex A

OTUk test signals for jitter measurement

(This annex forms an integral part of this Recommendation.)

A.1 Introduction

It is important to define the test signals used when performing jitter tests. This is especially important when testing OTN systems because the scrambling system does not limit the length of consecutive 0s/1s that can exist in a line signal, meaning the maximum time period without any data transitions in the scrambled signal is unlimited. [ITU-T G.709] provides further information about OTN signal structure and payload scrambling.

For example, if the traffic in an OTN signal emulates the scrambling pattern, many bytes of consecutive 0s/1s will appear in the coded line signal. Extreme cases are rare, but it is very difficult for a jitter test set to continue to perform accurate measurements under these conditions, so it is important to define a representative worst-case signal for a test set specification.

A.1.1 Payload test conditions

A.1.1.1 OPU1

Concatenated payloads provide the worst-case scenario for OPUk test signals. For bulk-filled concatenated signals with a $2^{23}-1$ PRBS filling the container, the result of scrambling this data is a worst-case run of 31 consecutive identical 0s/1s (meaning 31 clock periods with no transitions in the line signal).

A.1.1.2 OPU2/OPU3

Concatenated payloads provide the worst-case scenario for OPUk test signals. For bulk-filled concatenated signals with a $2^{23}-1$ (OPU2) or $2^{31}-1$ (OPU2,3) PRBS filling the container, the result of scrambling this data is a worst-case run of 39 consecutive identical 0s/1s (meaning 39 clock periods with no transitions in the line signal).

A.2 Test signal structure for OTN signals

A.2.1 Mapping of PRBS test signal into OPUk

The OPUk test signal structure shown in Figure A.1 consists of a PRBS test sequence of length $2^{31}-1$ bits according to [ITU-T O.182], which is mapped into the OPUk payload.

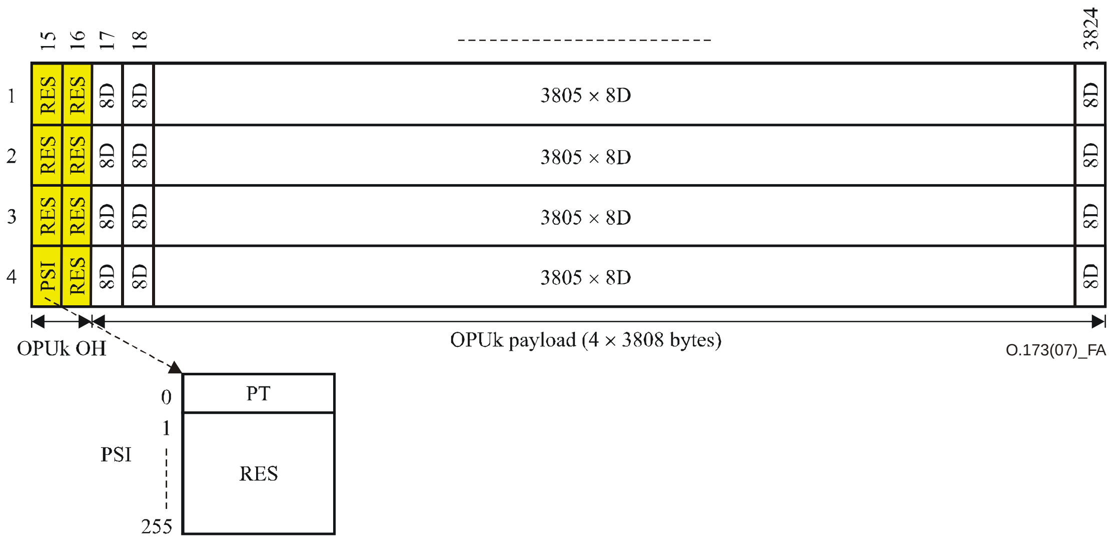

Figure A.1 – Test signal structure for jitter testing of OTN signal

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