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# O.173

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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 (OTN)**

ITU-T Recommendation O.173

ITU-T O-SERIES RECOMMENDATIONS

**SPECIFICATIONS OF MEASURING EQUIPMENT**



*For further details, please refer to the list of ITU-T Recommendations.*

# ITU-T Recommendation O.173

## Jitter measuring equipment for digital systems which are based on the Optical Transport Network (OTN)


### Summary

This Recommendation specifies instrumentation that is used to generate and measure jitter in digital systems based on the 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.



### Source

ITU-T Recommendation O.173 was prepared by ITU-T Study Group 4 (2001-2004) and approved under the WTSA Resolution 1 procedure on 29 March 2003.



### Keywords

Input jitter tolerance, Input wander tolerance, Jitter generation, Jitter measurement, Jitter transfer function, Output jitter.

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## CONTENTS

## Introduction

The timing performance of OTN networks and OTN equipment elements is specified in ITU-T Rec. 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 Rec. 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.

# ITU-T Recommendation O.173

## Jitter measuring equipment for digital systems which are based on the Optical Transport Network (OTN)

## 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 (NNI). 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 Recs G.8251 [1] and G.709 [5] be 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.


[1] ITU-T Recommendation G.8251 (2001), *The control of jitter and wander within the Optical Transport Network (OTN)*.

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

[3] ITU-T Recommendation G.959.1 (2001), *Optical transport network physical layer interfaces*.

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

[5] ITU-T Recommendation G.709/Y.1331 (2003), *Interfaces for the Optical Transport Network (OTN)*.

[6] ITU-T Recommendation O.172 (2001), *Jitter and wander measuring equipment for digital systems which are based on the Synchronous Digital Hierarchy (SDH)*.

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


## 3 Definitions

For the purposes of this Recommendation, the following definitions apply (refer to ITU-T Rec. G.810 [2]):

**3.1 (timing) jitter**: The short-term variations of the significant instances of a digital signal from their ideal positions in time (where "short-term" implies that these variations are of frequency greater than or equal to 10 Hz).

**3.2 wander**: The long-term variations of the significant instances of a digital signal from their ideal position in time (where "long-term" implies that these variations are of frequency less than 10 Hz).

It may be useful to note that ITU-T Rec. G.810 [2] 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:

OPUk Optical Channel Payload Unit-k

OTN Optical Transport Network

OTUk completely standardized Optical Channel transport Unit-k

ppm parts per million

PRBS Pseudo Random Binary Sequence

SDH Synchronous Digital Hierarchy

UI Unit Interval

$UI_{pp}$ 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.

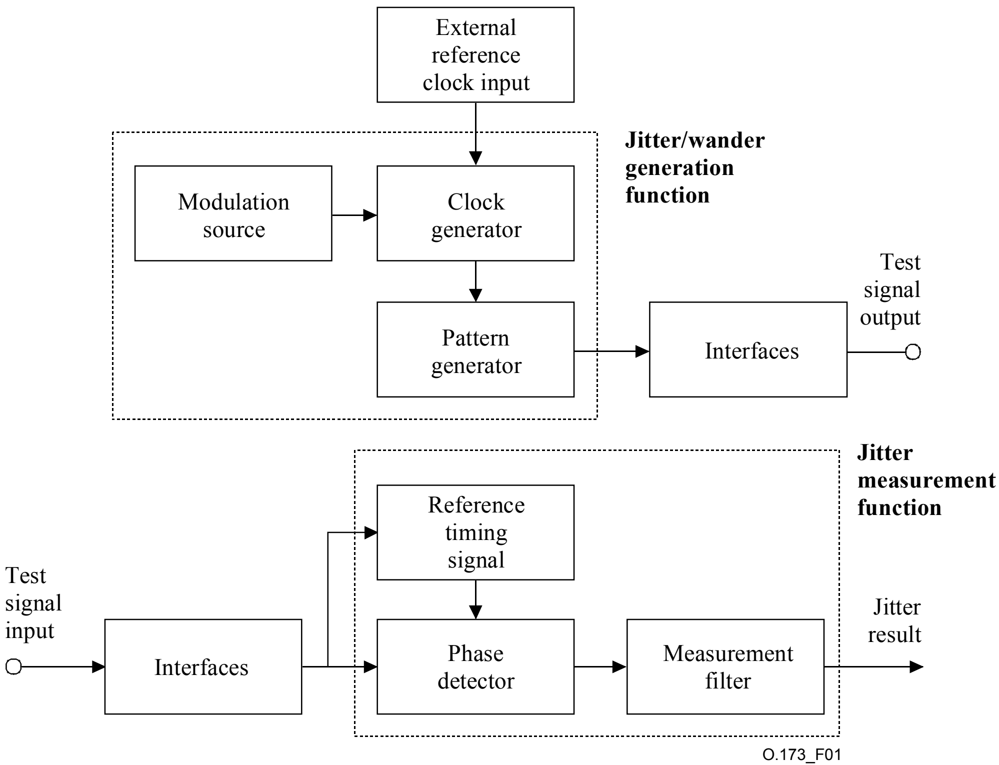


**Figure 1/O.173 – Functional block diagram for jitter test set**

## 6 Interfaces

### 6.1 Optical interfaces

The instrumentation shall be capable of operating at one or more of the following OTUk bit rates and corresponding optical interface characteristics as defined in the appropriate clauses of ITU-T Rec. G.959.1 [3].

- 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

### 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 Rec. G.703 [4].

### 6.4 Input interface sensitivity

The jitter measurement function is required to operate satisfactorily under the input conditions as specified in ITU-T Rec. G.959.1 [3].

## 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 1.

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:

$$\pm 4.6 \text{ ppm}$$

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 7.3.

### 7.3 Digital test pattern generator

The digital test pattern generator 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 ITU-T Rec. G.709/Y.1331 [5], clauses 17.4.1 and 17.4.2.

### 7.4 Minimum jitter generation capability

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

**Table 1/O.173 – Minimum amplitude of adjustable generated jitter amplitude versus jitter frequency for OTUk 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 |
| OTU3 | 20 | 8 | 0.2 | 8 k | 20 k | 400 k | 16 M | 320 M |

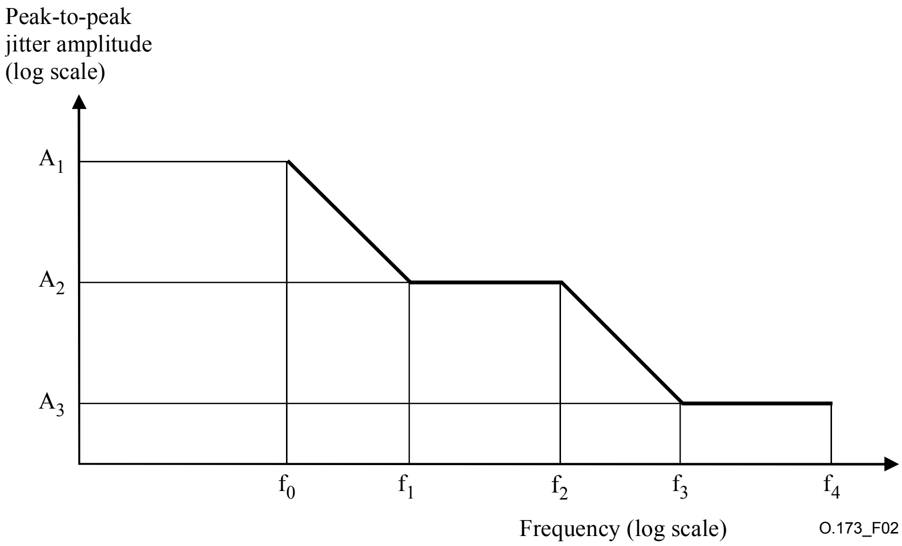


**Figure 2/O.173 – Generated jitter amplitude versus jitter frequency**

### 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/O.173 – Variable error (Q) of OTUk 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 500 kHz |
| | ±12% | > 500 kHz to 2 MHz |
| | ±15% | > 2 MHz to 80 MHz |
| OTU3 | FFS | FFS |
| NOTE – FFS denotes that the value is for further study. | | |

### 7.5.2 Phase slope error

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

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

over the range:

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

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/O.172 [6] 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 7.3.

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 Figure 3 and Table 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/O.173 – Minimum measured jitter amplitude versus jitter frequency for OTUk 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 |
| OTU3 | 20 | 8 | 0.2 | 8 k | 20 k | 400 k | 16 M | 320 M |

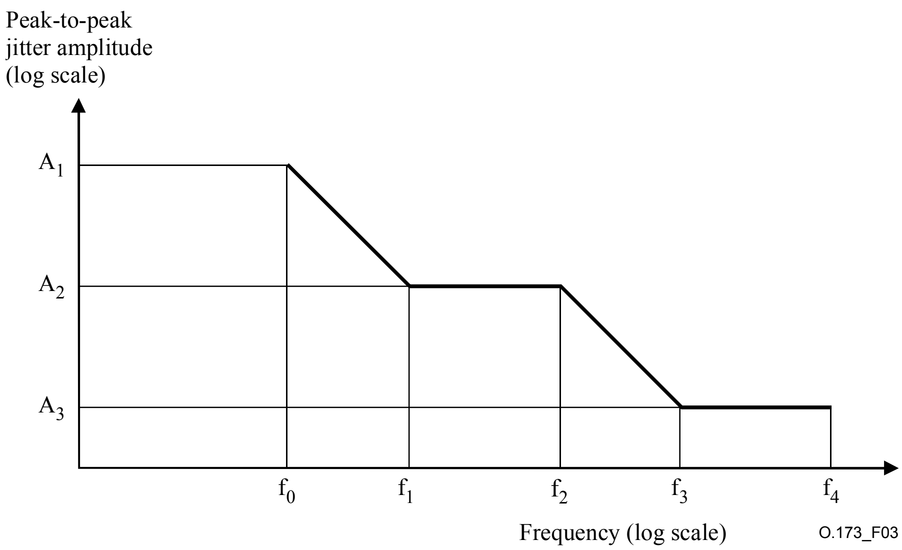


**Figure 3/O.173 – Measured jitter amplitude versus jitter frequency**

#### 8.2.2 Selectable threshold

When measuring peak-to-peak jitter, it shall be possible to count the number of events 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.

### 8.3 Measurement bandwidths

The measurement bandwidth shall be limited in order to measure the specified jitter spectra as defined in ITU-T Rec. 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/O.173 – Jitter measurement function bandwidth for OTUk 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 |
| 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 8.4).

For all OTUk 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 $f_1$ ±10% and $f_3$ ±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 $f_4$ ±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 Rec. G.8251 [1].

### 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 bit rates in ITU-T Rec. G.8251 [1].

The measurement accuracy is specified using an optical signal in conformance with ITU-T Rec. G.959.1 [3] with a nominal power in the range −10 dBm to −12 dBm, and a signal structure defined in 7.3.

The total measurement error shall be less than:

±R% of reading ±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 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 4.

**Table 5/O.173 – Fixed error (W) of OTUk jitter measurements**

| Signal | Maximum peak-to-peak jitter error (UIpp) for given digital signals | | | |
|---|---|---|---|---|
| | OTUk signal | | Clock signal | |
| | $f_1$-$f_4$ | $f_3$-$f_4$ | $f_1$-$f_4$ | $f_3$-$f_4$ |
| OTU1 | 0.1 | 0.05 | 0.05 | 0.03 |
| OTU2 | 0.15 | 0.05 | 0.05 | 0.03 |
| OTU3 | 0.2 | 0.05 | 0.05 | 0.03 |

### 8.4.3 Variable error

At jitter frequencies between $f_1$ and $f_4$, the variable error R additional to that specified in 8.3.1 shall be as specified in Table 6. Frequencies $f_1$ and $f_4$ used in Table 6 are defined in Table 4.

**Table 6/O.173 – Variable error (R) of OTUk jitter measurements**

| Signal | Error, R | Frequency range |
|---|---|---|
| OTU1 | ±7% | 5 kHz ≤ f ≤ 300 kHz |
| | ±8% | 300 kHz < f ≤ 1 MHz |
| | ±10% | 1 MHz < f ≤ 3 MHz |
| | ±15% | 3 MHz < f ≤ 10 MHz |
| | ±20% | 10 MHz < f ≤ 20 MHz |
| OTU2 | ±7% | 20 kHz ≤ f ≤ 300 kHz |
| | ±8% | 300 kHz < f ≤ 1 MHz |
| | ±10% | 1 MHz < f ≤ 3 MHz |
| | ±15% | 3 MHz < f ≤ 10 MHz |
| | ±20% | 10 MHz < f ≤ 80 MHz |
| OTU3 | FFS | FFS |
| NOTE – FFS denotes that the value is for further study | | |

### 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 analyzer.

### 8.6 Jitter transfer measurement accuracy

The specification of OTN equipment jitter transfer characteristics in ITU-T Rec. G.8251 [1] 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. This measurement error applies for $g$ greater of equal to –45 dB. No accuracy is specified for $g$ less than –45 dB.

## 9 Operating environment

The performance requirements shall be met when operating within the climatic conditions as specified in 2.1/O.3 [7].

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