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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 and wander measuring equipment for  
digital systems which are based on the  
synchronous digital hierarchy (SDH)**

ITU-T Recommendation O.172

(Previously CCITT Recommendation)

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ITU-T O-SERIES RECOMMENDATIONS  
**SPECIFICATIONS OF MEASURING EQUIPMENT**

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## **ITU-T RECOMMENDATION O.172**

### **JITTER AND WANDER MEASURING EQUIPMENT FOR DIGITAL SYSTEMS WHICH ARE BASED ON THE SYNCHRONOUS DIGITAL HIERARCHY (SDH)**

#### **Summary**

This Recommendation specifies instrumentation that is used to generate and measure jitter and wander in digital systems based on the SDH. Measurement requirements for both SDH line interfaces and SDH tributary interfaces operating at PDH bit rates are addressed in this Recommendation.

The requirements for the characteristics of the jitter and wander 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.172 was prepared by ITU-T Study Group 4 (1997-2000) and was approved under the WTSC Resolution No. 1 procedure on the 26th of March 1999.

#### **Keywords**

Input jitter tolerance, Input wander tolerance, Jitter generation, Jitter measurement, Jitter transfer function, Output jitter, Output wander, Phase transients, Pointer jitter, Pointer sequence generation, Wander generation, Wander measurement, Wander noise transfer.

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## **Introduction and Background**

The timing and synchronization performance of SDH networks and SDH network equipment elements is specified in a number of ITU-T Recommendations, using jitter and wander parameters. This Recommendation specifies the various characteristics of jitter/wander measuring equipment, which are needed in order to support the requirements of these ITU-T Recommendations and to perform other test and measuring tasks.

This Recommendation has been developed to ensure maximum compatibility with the relevant SDH network and equipment measurement requirements, whilst maintaining backwards compatibility with the associated PDH test equipment requirements of Recommendation O.171 [17] where possible.

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 O.172

# JITTER AND WANDER MEASURING EQUIPMENT FOR DIGITAL SYSTEMS WHICH ARE BASED ON THE SYNCHRONOUS DIGITAL HIERARCHY (SDH)

(Geneva 1999)

## 1 Scope

This Recommendation specifies test instrumentation that is used to generate and measure timing jitter and synchronization wander in digital systems based on the Synchronous Digital Hierarchy (SDH).

This Recommendation also specifies requirements for the measurement of SDH tributaries operating at PDH bit rates. Where possible, Recommendation O.171 [17] is referenced for use at such interfaces, but where new requirements exist, they are specified in this Recommendation.

The test instrumentation consists principally of a jitter/wander measurement function and a jitter/wander generation function. Measurements can be performed at the physical layer of SDH systems. 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.

Test instrumentation for the generation and measurement of jitter and wander in digital systems based on the Plesiochronous Digital Hierarchy (PDH) is specified in Recommendation O.171 [17].

It is recommended that Recommendations G.783 [5], G.812 [8], G.813 [9], G.825 [12] and G.958 [14] 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; all 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.

### 2.1 Normative references

- [1] ITU-T Recommendation G.691<sup>1</sup> (1998), *Optical interfaces for single channel SDH systems with optical amplifiers, and STM-64 systems.*
- [2] ITU-T Recommendation G.703 (1998), *Physical/electrical characteristics of hierarchical digital interfaces.*
- [3] ITU-T Recommendation G.707 (1996), *Network node interface for the synchronous digital hierarchy (SDH).*
- [4] ITU-T Recommendation G.772 (1993), *Protected monitoring points provided on digital transmission systems.*

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<sup>1</sup> Presently at the stage of draft.

- [5] ITU-T Recommendation G.783 (1997), *Characteristics of synchronous digital hierarchy (SDH) equipment functional blocks.*
- [6] ITU-T Recommendation G.810 (1996), *Definitions and terminology for synchronization networks.*
- [7] ITU-T Recommendation G.811 (1997), *Timing characteristics of primary reference clocks.*
- [8] ITU-T Recommendation G.812 (1998), *Timing requirements of slave clocks suitable for use as node clocks in synchronization networks.*
- [9] ITU-T Recommendation G.813 (1996), *Timing characteristics of SDH equipment slave clocks (SEC).*
- [10] ITU-T Recommendation G.823 (1993), *The control of jitter and wander within digital networks which are based on the 2048 kbit/s hierarchy.*
- [11] ITU-T Recommendation G.824 (1993), *The control of jitter and wander within digital networks which are based on the 1544 kbit/s hierarchy.*
- [12] ITU-T Recommendation G.825 (1993), *The control of jitter and wander within digital networks which are based on the synchronous digital hierarchy (SDH).*
- [13] ITU-T Recommendation G.957 (1995), *Optical interfaces for equipments and systems relating to the synchronous digital hierarchy.*
- [14] ITU-T Recommendation G.958 (1994), *Digital line systems based on the synchronous digital hierarchy for use on optical fibre cables.*
- [15] CCITT Recommendation O.3 (1992), *Climatic conditions and relevant tests for measuring equipment.*
- [16] ITU-T Recommendation O.150 (1996), *General requirements for instrumentation for performance measurements on digital transmission equipment.*
- [17] ITU-T Recommendation O.171 (1997), *Timing jitter and wander measuring equipment for digital systems which are based on the plesiochronous digital hierarchy (PDH).*
- [18] ITU-T Recommendation O.181 (1996), *Equipment to assess error performance on STM-N interfaces.*
- [19] ITU-R Recommendation F.750-3 (1997), *Architectures and functional aspects of radio-relay systems for SDH-based networks.*

## **2.2 Informative references**

- [20] ANSI T1.105.03-1994, *Telecommunications – Synchronous Optical Network (SONET) – Jitter at Network Interfaces.*
- [21] ANSI T1.105.06-1996, *Telecommunications – Synchronous Optical Network (SONET) – Physical Layer Specifications.*

## **3 Definitions**

For the purpose of this Recommendation, the following definitions apply (refer to Recommendation G.810 [6]):

**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).

**3.3 time interval error (function):** The difference between the measure of a time interval as provided by a clock and the measure of that same time interval as provided by a reference clock.

It may be useful to note that Recommendation G.810 [6] 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

This Recommendation uses the following abbreviations:

AU-n	Administrative Unit, level n
CMI	Coded Mark Inversion
MTIE	Maximum Time Interval Error
NRZ	Non Return to Zero
PDH	Plesiochronous Digital Hierarchy
PJE	Pointer Justification Event
PLL	Phase-Locked Loop
ppm	parts per million
PRBS	Pseudo Random Binary Sequence
RMS	Root-Mean-Square
SDH	Synchronous Digital Hierarchy
STM-N	Synchronous Transport Module, level N
TDEV	Time Deviation
TIE	Time Interval Error
TSS	Test Signal Structure
TU-m	Tributary Unit, level m
UI	Unit Interval
UIpp	Unit Interval, peak-to-peak

## 5 Conventions

For the purposes of this Recommendation, the following conventions are adopted:

- a) Particular interface signals used are denoted either by their standardized signal formats, e.g. STM-1 or by their bit rate, e.g. 139 264 kbit/s. The default physical format of SDH interfaces is considered to be optical and the default physical format of PDH interfaces is considered to be electrical.
- b) Where the electrical form of an SDH interface is specifically used in this Recommendation, the interface is denoted by "e", e.g. STM-1e (refer also to clause 7).

- c) Particular interface signals used may be categorized either as SDH line interfaces, or as SDH tributary interfaces. In this Recommendation, SDH line interfaces refer to those which support STM-N signals, whilst SDH tributary interfaces refer to those which support signals operating at PDH bit rates.

## 6 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.

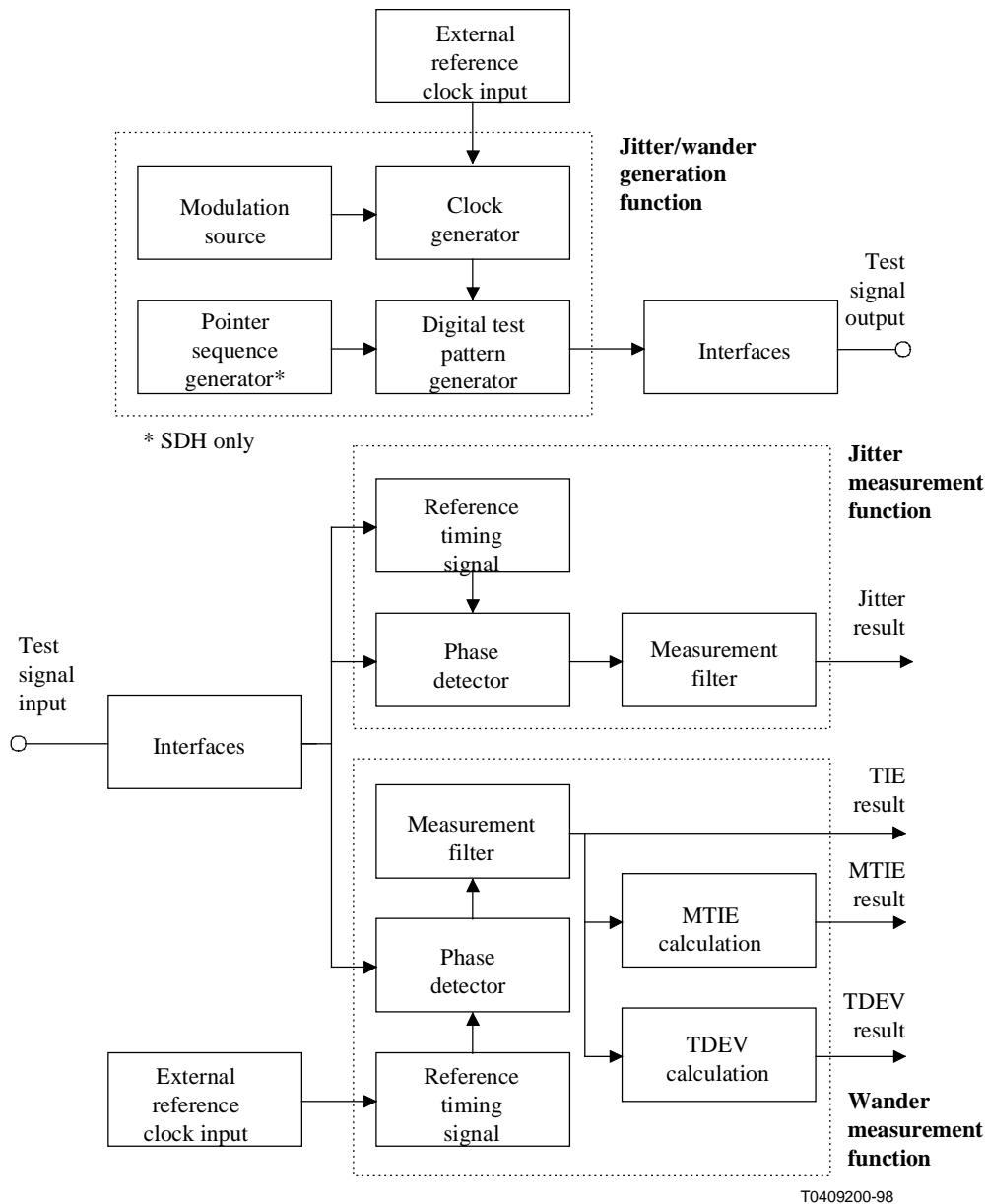


Figure 1/O.172 – Functional block diagram for jitter and wander test set

## 7 Interfaces

### 7.1 Optical interfaces

The instrumentation shall be capable of operating at one or more of the following bit rates and corresponding optical interface characteristics as defined in the appropriate clauses of Recommendations G.957 [13] and G.691 [1] and also ANSI T1.105.06 [21] (for 51 840 kbit/s interfaces).

- STM-0 51 840 kbit/s
- STM-1 155 520 kbit/s
- STM-4 622 080 kbit/s
- STM-16 2 488 320 kbit/s
- STM-64 9 953 280 kbit/s

### 7.2 Electrical interfaces

The instrumentation shall be capable of operating at one or more of the following bit rates and corresponding electrical interface characteristics as defined in the appropriate clauses of Recommendation G.703 [2] and also ITU-R Recommendation F.750-3 [19] (for 51 840 kbit/s electrical interfaces). However, for all bit rates the signal applied to the input of the jitter/wander measuring circuit shall be a nominal rectangular pulse. Other signal shapes may produce inter-symbol interference – which cannot be corrected by simple line equalization – thus affecting measurement accuracy.

- 1544 kbit/s
- 2048 kbit/s
- 6312 kbit/s
- 34 368 kbit/s
- 44 736 kbit/s
- 51 840 kbit/s, STM-0e
- 139 264 kbit/s
- 155 520 kbit/s, STM-1e

The jitter/wander measurement function input and jitter/wander generation function output ports shall have a return loss as specified in the appropriate clauses of Recommendation G.703 [2].

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

### 7.3 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 Recommendation G.703 [2].

## **7.4 Input interface sensitivity**

The jitter/wander measurement function is required to operate satisfactorily under the following input conditions:

- a) the specification for equipment optical interfaces defined in Recommendations G.957 [13] and G.691 [1];
- b) the specification for equipment electrical interfaces defined in Recommendation G.703 [2];
- c) protected monitoring points as defined in Recommendation G.772 [4].

## **8 Jitter/wander generation function**

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

### **8.1 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. However, other stimuli may be required for certain tests.

### **8.2 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/wander and the modulating frequencies shall meet the minimum requirements of Table 3 and Figure 3.

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  $\Omega$  or 0.25 Volt peak-to-peak into 50  $\Omega$ .

#### **8.2.1 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.  $\pm 10$  ppm to  $\pm 100$  ppm, as defined for the various bit rates in Recommendations G.703 [2] and G.813 [9].

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

### **8.3 Digital test pattern generator**

The jitter/wander measurement function will normally be used in conjunction with any suitable digital test pattern generator providing the following facilities.

### 8.3.1 Digital test patterns

The digital test pattern generator shall be capable of providing one or more of the following signals, for use at STM-N bit rates:

- a) framed SDH signals in accordance with Recommendation G.707 [3];
- b) structured test signals in accordance with Recommendation O.181 [18], dependant on the type of network element to be tested;
- c) structured test signals defined in Annex A.

### 8.3.2 Digital test patterns for SDH tributary signals

Digital test patterns appropriate for testing SDH tributary interfaces operating at PDH bit rates of 1544 kbit/s, 2048 kbit/s, 6312 kbit/s, 34 368 kbit/s, 44 736 kbit/s and 139 264 kbit/s are defined in 7.3.1/O.171 [17].

## 8.4 Pointer sequence generator

In order to test the effect of pointer justification events (PJE) on SDH desynchronizer equipment, the digital test pattern generator shall be capable of generating complete test sequences of pointer justifications in accordance with the appropriate clauses of Recommendation G.783 [5].

As an option, the equipment may provide additional PJE control functions to facilitate further pointer jitter testing.

Appendix III provides further information regarding the test set configuration and capability for testing using pointer sequences.

### 8.4.1 Pointer test sequence generation capability

The equipment shall provide a minimum set of pointer test sequences applicable at particular SDH tributary bit rates, denoted by "X" in Table 1, in accordance with clause 10/G.783 [5].

For particular SDH tributary bit rates, the pointer adjustments shall be applied either to the AU-n or the TU-m pointers, as shown in Table 1. The direction or polarity of the pointer test sequence shall be selectable between incrementing or decrementing pointer values.

The test procedure specified in clause 10/G.783 [5] shall be followed.

**Table 1/O.172 – G.783 pointer test sequence description**

G.783 pointer test sequence		SDH tributary bit rate (kbit/s) and SDH container					
		1544	2048	6312	34 368	44 736	139 264
ID	Description	TU-11	TU-12	TU-2	TU-3	AU-3	AU-4
a	Single Alternating		X		X		X
b	Regular + Double		X		X		X
c	Regular + Missing		X		X		X
d	Double Alternating				X		X
e	Single	X		X		X	
f	Burst	X		X		X	
g1	Periodic 87-3					X	X
g2	Periodic 87-3 with Add					X	X

**Table 1/O.172 – G.783 pointer test sequence description (concluded)**

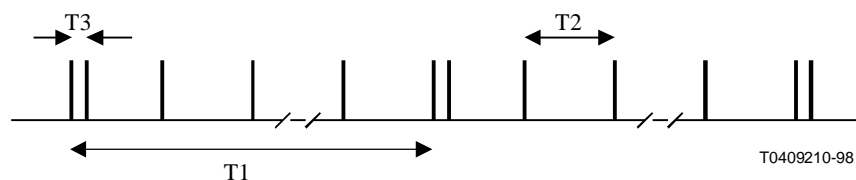
G.783 pointer test sequence		SDH tributary bit rate (kbit/s) and SDH container					
		1544	2048	6312	34 368	44 736	139 264
ID	Description	TU-11	TU-12	TU-2	TU-3	AU-3	AU-4
g3	Periodic 87-3 with Cancel					X	X
h1	Periodic	X		X		X	
h2	Periodic with Add	X		X		X	
h3	Periodic with Cancel	X		X		X	

The time intervals between PJE's within a test sequence depend on the particular sequence and the bit rate of the SDH tributary under test. Recommendation G.783 [5] shall be consulted for precise detail of the pointer sequences applicable to a particular tributary bit rate. Table 2 specifies the time intervals that shall be provided between PJE's for particular SDH tributary bit rates, and which are illustrated in a generic fashion in Figure 2. Time intervals T1 and T2 may be adjustable to values greater than the minimum shown in Table 2.

**Table 2/O.172 – Time intervals between G.783 pointer justification events**

Time Interval	SDH tributary bit rate (kbit/s)					
	1544	2048	6312	34 368	44 736	139 264
T1 (minimum)	30 s	10 s	30 s	10 s	30 s	10 s
T2 (minimum)	1 s	750 ms	1 s	34 ms <sup>a)</sup>	34 ms	34 ms <sup>a)</sup>
T3	2 ms	2 ms	2 ms	0.5 ms <sup>a)</sup>	0.5 ms	0.5 ms <sup>a)</sup>

<sup>a)</sup> Value is for further study in Recommendation G.783 [5].



**Figure 2/O.172 – Generic G.783 pointer sequence, illustrating the time intervals of Table 1**

## 8.5 Minimum generation capability

### 8.5.1 Jitter/wander generation capability for SDH line signals

The jitter/wander amplitude/frequency characteristic of the generation function shall meet the minimum requirements of Table 3 and Figure 3.



**Table 3/O.172 – Minimum amplitude of adjustable generated jitter/wander amplitude versus jitter/wander frequency**

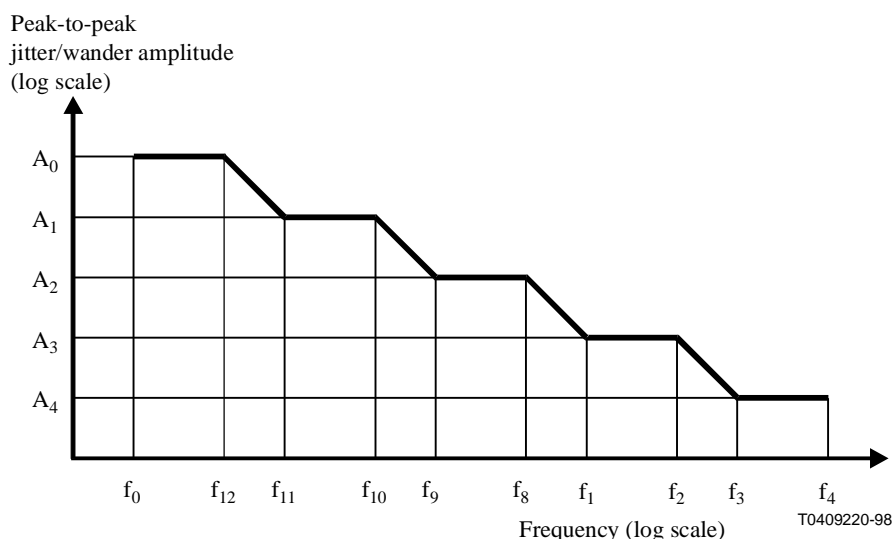
Signal	Minimum peak-to-peak jitter/wander amplitude (UIpp)					Jitter/wander frequency breakpoints (Hz)									
	A <sub>0</sub>	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>4</sub>	f <sub>0</sub>	f <sub>12</sub>	f <sub>11</sub>	f <sub>10</sub>	f <sub>9</sub>	f <sub>8</sub>	f <sub>1</sub>	f <sub>2</sub>	f <sub>3</sub>	f <sub>4</sub>
STM-0e, STM-0	*	*	20	2	0.2	*	*	*	*	10	30	300	2 k	20 k	400 k
STM-1e	3 600	400	50	2	0.1	12 μ	178 μ	1.6 m	15.6 m	125 m	19.3	500	3.25 k	65 k	1.3 M
STM-1	3 600	400	50	2	0.2	12 μ	178 μ	1.6 m	15.6 m	125 m	19.3	500	6.5 k	65 k	1.3 M
STM-4	14 400	1 600	200	2	0.2	12 μ	178 μ	1.6 m	15.6 m	125 m	9.65	1 k	25 k	250 k	5 M
STM-16	57 600	6 400	800	2	0.2	12 μ	178 μ	1.6 m	15.6 m	125 m	12.1	5 k	100 k	1 M	20 M
STM-64	230 400	25 600	3 200	2	0.2	12 μ	178 μ	1.6 m	15.6 m	125 m	6.05	10 k	400 k	4 M	80 M

NOTE 1 – Values denoted by "\*" are not defined.

NOTE 2 – Values are based on the requirements of Table 2/G.825 [12] and Figure 2/G.825 [12].

NOTE 3 – Values for STM-0 are based on the requirements of ANSI T1.105.03 [20].

NOTE 4 – Values for STM-64 are to be considered provisional, since network requirements are not yet defined in Recommendation G.825 [12].



**Figure 3/O.172 – Generated jitter/wander amplitude versus jitter/wander frequency**

### 8.5.2 Jitter/wander generation capability for SDH tributary signals

Requirements relating to SDH tributary interfaces operating at PDH bit rates of 1544 kbit/s, 2048 kbit/s, 6312 kbit/s, 34 368 kbit/s, 44 736 kbit/s and 139 264 kbit/s are defined in 7.2/O.171 [17].

## 8.6 Generation accuracy

The test signal source shall be compatible with the jitter/wander 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/wander applied to the unit under test using a corresponding jitter/wander measuring device.

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

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

$$\pm Q\% \text{ of setting } \pm 0.02 U_{\text{Ipp}}$$

where Q is a variable error specified in Table 4 and the frequencies  $f_0$ ,  $f_1$ ,  $f_4$  and  $f_9$  used in Table 4 are defined in Table 3.

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

**Table 4/O.172 – Variable error (Q) of SDH line jitter/wander generation**

Signal	Error, Q	Frequency range
STM-0e, STM-0	FFS	$f_9-f_1$
	$\pm 8\%$	$f_1-f_4$
STM-1e, STM-1	FFS	$f_0-f_1$
	$\pm 8\%$	$f_1-500 \text{ kHz}$
	$\pm 12\%$	$500 \text{ kHz}-f_4$
STM-4, STM-16, STM-64	FFS	$f_0-f_1$
	$\pm 8\%$	$f_1-500 \text{ kHz}$
	$\pm 12\%$	$500 \text{ kHz}-2 \text{ MHz}$
	$\pm 15\%$	$2 \text{ MHz}-f_4$
NOTE 1 – FFS denotes that the value is for further study.		
NOTE 2 – Values for STM-64 are to be considered provisional, since network requirements are not yet defined in Recommendation G.825 [12].		

### 8.6.1 Intrinsic jitter/wander of generation function

The intrinsic jitter of the jitter/wander generation function measured in a bandwidth  $f_1-f_4$  with the amplitude set to zero shall be less than:

0.04  $U_{\text{Ipp}}$  for an output signal with structure defined in Annex A; or

0.02  $U_{\text{Ipp}}$  for a clock signal.

The specification for maximum allowable intrinsic wander is for further study.

## 9 Jitter measurement function

### 9.1 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.

### 9.2 Measurement capabilities

#### 9.2.1 Measurement range

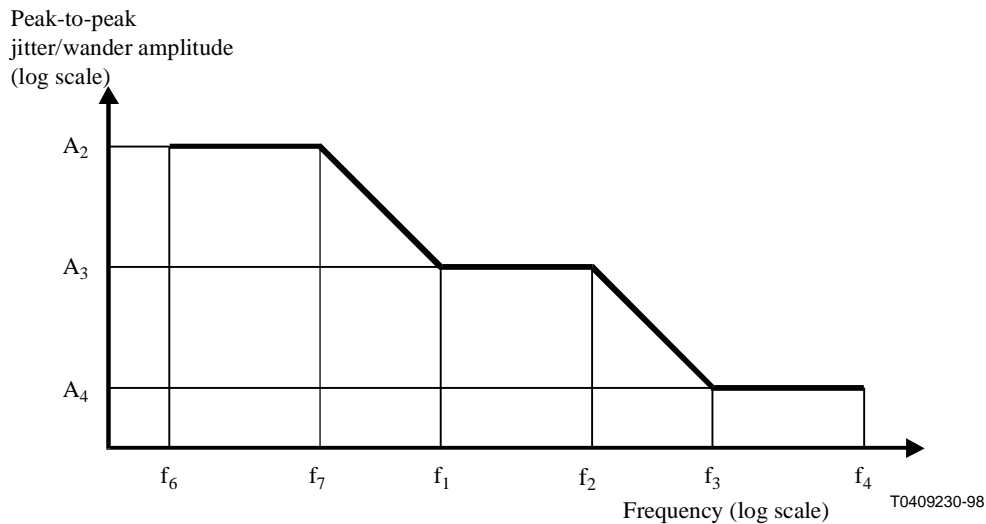
The jitter measurement function shall be capable of measuring peak-to-peak jitter. The measurement ranges to be provided are optional but for reasons of compatibility the jitter amplitude/jitter frequency characteristic of the jitter measurement function shall meet the minimum requirements of Table 5 and Figure 4. The frequencies  $f_6$  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  $f_6$  to  $f_4$  is optional.

**Table 5/O.172 – Minimum amplitude of measured jitter versus jitter frequency**

Signal	Minimum peak-to-peak jitter amplitude (UIpp)			Jitter frequency breakpoints (Hz)					
	A <sub>2</sub>	A <sub>3</sub>	A <sub>4</sub>	f <sub>6</sub>	f <sub>7</sub>	f <sub>1</sub>	f <sub>2</sub>	f <sub>3</sub>	f <sub>4</sub>
STM-0e, STM-0	20	2	0.2	10	30	300	2 k	20 k	400 k
STM-1e	50	2	0.1	10	19.3	500	3.25 k	65 k	1.3 M
STM-1	50	2	0.2	10	19.3	500	6.5 k	65 k	1.3 M
STM-4	200	2	0.2	*	10	1 k	25 k	250 k	5 M
STM-16	800	2	0.2	10	12.1	5 k	100 k	1 M	20 M
STM-64	2000	2	0.2	*	10	10 k	400 k	4 M	80 M

NOTE 1 – Values denoted by "\*" are not defined.  
 NOTE 2 – The accuracy of the instrument is specified between frequencies  $f_1$  and  $f_4$ .  
 NOTE 3 – Values for STM-0 are based on the requirements of ANSI T1.105.03 [20].  
 NOTE 4 – Values for STM-64 are to be considered preliminary, since requirements are not yet specified in Recommendation G.825 [12].



**Figure 4/O.172 – Measured jitter amplitude versus jitter frequency**

### 9.2.2 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 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.

### 9.2.3 Measurement of RMS jitter

Measurement of RMS jitter may be performed internally within the instrumentation, or externally using the analogue output mentioned in 9.5.1.

### 9.2.4 Measurement capability for SDH tributary signals

Requirements relating to SDH tributary interfaces operating at PDH bit rates of 1544 kbit/s, 2048 kbit/s, 6312 kbit/s, 34 368 kbit/s, 44 736 kbit/s and 139 264 kbit/s are defined in 8.2/O.171 [17].

In addition, the following requirements apply:

The test set shall tolerate input sinusoidal phase variation at particular tributary bit rates, according to the following frequency/amplitude specifications of Table 6. These frequency/amplitude values represent the relevant worst-case pointer test sequences defined in Recommendation G.783 [5].

**Table 6/O.172 – Input phase tolerance of test set when measuring SDH tributary jitter**

Bit rate (kbit/s)	Input phase variation	
	Amplitude (UIpp)	Frequency (Hz)
1 544	FFS	FFS
2 048	30	0.5
6 312	FFS	FFS
34 368	22	5.0
44 736	FFS	FFS
139 264	75	1.5
NOTE – FFS denotes that the value is for further study.		

In this context, tolerate means that the test set shall measure within the accuracy specified in this Recommendation, considering that the input phase variation may have been attenuated by the applied measurement filters.

### 9.3 Measurement bandwidths

The measurement bandwidth shall be limited in order to measure the specified jitter spectra as defined in relevant Recommendations and for other uses. The bandwidth  $f_1$ - $f_4$  or  $f_3$ - $f_4$  of the jitter measurement function shall be in accordance with Table 7.

**Table 7/O.172 – Jitter measurement function bandwidth**

Signal	Jitter measurement bandwidth (–3 dB cut-off frequencies)		
	$f_1$ (Hz) high-pass	$f_3$ (Hz) high-pass	$f_4$ (Hz) low-pass
STM-0e, STM-0	100	20 k	400 k
STM-1e, STM-1	500	65 k	1.3 M
STM-4	1 k	250 k	5 M
STM-16	5 k	1 M	20 M
STM-64	10 k	4 M	80 M
NOTE 1 – Values for STM-0 are based on the requirements of ANSI T1.105.03 [20].			
NOTE 2 – Values for STM-64 are to be considered provisional, since network requirements are not yet defined in Recommendation G.825 [12].			

### 9.3.1 Frequency response of jitter measurement function for SDH line signals

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 9.4).

For all SDH line 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 single-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 7 and the  $-3$  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 7 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 Recommendation G.825 [12].

### 9.3.2 Frequency response of jitter measurement function for SDH tributary signals

Requirements relating to SDH tributary interfaces operating at PDH bit rates of 1544 kbit/s, 2048 kbit/s, 6312 kbit/s, 34 368 kbit/s, 44 736 kbit/s and 139 264 kbit/s are defined in 8.3/O.171 [17].

In addition, for all SDH tributary bit rates, the following requirements apply to the jitter measurement function when the measurement filter at frequency  $f_1$  is used:

- a) The high-pass measurement filters with cut-off frequency  $f_1$  have a first-order characteristic and a roll-off of 20 dB/decade.
- b) The nominal  $f_1$  cut-off frequency for each bit rate is specified in Table 4/O.171 [17] and the  $-3$  dB point of the measurement filters shall be at a frequency  $f_1 \pm 10\%$ .
- c) The frequency response error of the measurement filters below  $f_1$  shall be as defined in Table 6/O.171 for frequency  $f_1$ . In addition the gain accuracy of  $\pm 5\%$  as defined in 8.4.1/O.171 [17] shall apply at frequencies less than  $f_1$ .
- d) A second filter pole is allowed at a frequency of less than 0.1 Hz, where the roll-off characteristic can increase to 40 dB/decade.
- e) The maximum attenuation of the measurement filters shall be at least 60 dB.

These jitter measurement functional requirements are compatible with Recommendation G.783 [5].

Appendix IV illustrates how these filter requirements and the specifications of the following subclauses may be combined into a total jitter measurement function response.

## 9.4 Measurement accuracy

When not specified in the following subclauses, jitter measurement accuracy requirements relating to SDH tributary interfaces operating at PDH bit rates of 1544 kbit/s, 2048 kbit/s, 6312 kbit/s, 34 368 kbit/s, 44 736 kbit/s and 139 264 kbit/s are defined in 8.4/O.171 [17].

### 9.4.1 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 various bit rates in Recommendations G.703 [2], G.813 [9] and G.958 [14].

The measurement accuracy is specified using an input signal with structure defined in Annex A and physical characteristics of either:

- a) an electrical signal in conformance with Recommendation G.703 [2] having the nominal terminated signal level and with no additional frequency-dependent loss; or
- b) an optical signal in conformance with Recommendation G.957 [13] or G.691 [1] and with a nominal power in the range  $-10$  dBm to  $-12$  dBm.

The total error at 100 kHz jitter frequency (excluding the frequency response error specified in 9.4.4) shall be less than:

$$\pm 5\% \text{ of reading} \pm W$$

where  $W$  is the fixed error of Table 8 or Table 9, which includes any contribution from the internal timing extraction function.

NOTE – The fixed error term  $\pm W$  used in this Recommendation is equivalent to the combination of fixed error terms  $\pm X \pm Y$  that are used in Recommendation O.171 [17].

### 9.4.2 Fixed error of SDH line jitter measurements

For the STM-N bit rates and for the indicated digital signals, the fixed error of the jitter measurement function shall be as specified in Table 8 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 8 are defined in Table 7.

**Table 8/O.172 – Fixed error (W) of SDH line jitter measurements**

Signal	Maximum peak-to-peak jitter error (UIpp) for given digital signals			
	Structured signal		Clock signal	
	$f_1$ - $f_4$	$f_3$ - $f_4$	$f_1$ - $f_4$	$f_3$ - $f_4$
STM-0e	FFS	FFS	FFS	FFS
STM-0	0.07	0.05	0.05	0.03
STM-1e	0.07	0.025	0.05	0.02
STM-1	0.07	0.05	0.05	0.03
STM-4	0.1	0.05	0.05	0.03
STM-16	0.1	0.05	0.05	0.03
STM-64	FFS	FFS	FFS	FFS

NOTE 1 – FFS denotes that the value is for further study.  
 NOTE 2 – Structured digital signals are defined in Annex A.  
 NOTE 3 – Clock interfaces are optional.

### 9.4.3 Fixed error of SDH tributary jitter measurements

For the tributary bit rates and for the indicated digital signals, the fixed error of the jitter measurement function shall be as specified in Table 9 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 9 are defined in Table 3/O.171 [17].

**Table 9/O.172 – Fixed error (W) of SDH tributary jitter measurements**

Bit rate (kbit/s)	Maximum peak-to-peak jitter error (U <sub>pp</sub> ) for given digital signals			
	Pseudo-random signal		Clock signal	
	$f_1$ - $f_4$	$f_3$ - $f_4$	$f_1$ - $f_4$	$f_3$ - $f_4$
1 544	0.04	0.025	0.015	0.01
2 048	0.04	0.025	0.015	0.01
6 312	0.04	0.025	0.015	0.01
34 368	0.04	0.025	0.03	0.02
44 736	0.04	0.025	0.03	0.02
139 264	0.04	0.025	0.03	0.02

NOTE 1 – Pseudo-random digital signals are defined in 8.3.1.  
NOTE 2 – Clock interfaces are optional.

### 9.4.4 Frequency response error

At jitter frequencies between  $f_1$  and  $f_4$  other than 100 kHz, the error additional to that specified in 9.3.1 and 9.4.1 above shall be as specified in Table 10. Frequencies  $f_1$  and  $f_4$  used in Table 10 are defined in Table 7.

Requirements relating to SDH tributary interfaces operating at PDH bit rates of 1544 kbit/s, 2048 kbit/s, 6312 kbit/s, 34 368 kbit/s, 44 736 kbit/s and 139 264 kbit/s are defined in 8.4.3/O.171 [17].

**Table 10/O.172 – Frequency response error**

Signal	Additional error	Frequency range
STM-0e, STM-0	FFS	$f_1$ - $f_4$
STM-1e, STM-1	±2%	$f_1$ -300 kHz
	±3%	300 kHz-1 MHz
	±5%	1 MHz- $f_4$
STM-4	±2%	$f_1$ -300 kHz
	±3%	300 kHz-1 MHz
	±5%	1 MHz-3 MHz
	±10%	3 MHz- $f_4$



**Table 10/O.172 – Frequency response error (concluded)**

Signal	Additional error	Frequency range
STM-16, STM-64	±2%	f <sub>1</sub> -300 kHz
	±3%	300 kHz-1 MHz
	±5%	1 MHz-3 MHz
	±10%	3 MHz-10 MHz
	±15%	10 MHz-f <sub>4</sub>
NOTE 1 – FFS denotes that the value is for further study.		
NOTE 2 – Values for STM-64 are to be considered provisional, since network requirements are not yet defined in Recommendation G.825 [12].		

#### 9.4.5 Digital test signal-dependent error

The accuracy requirements stated in previous subclauses shall be met when digital test signals defined in Annex A are used to perform the jitter measurement. When using other structured signals, pseudo-random or random signals, larger measurement errors could be expected. Considering the measurement bandwidths specified above, signals with a higher "zero" or "one" content (i.e. fewer signal transitions) may even infringe the sampling theorem which – for theoretical reasons – makes it impossible to meet the specified accuracy requirements.

### 9.5 Additional facilities

#### 9.5.1 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 an RMS meter.

## 10 Wander measurement function

Appendix II provides further information regarding the test configurations for measurement of wander.

### 10.1 Reference timing signal

For the testing of wander, it shall be possible to phase-lock the measurement function to an external reference clock source of arbitrary accuracy; refer also to 7.3.

### 10.2 Measurement of TIE (Time Interval Error)

The instrumentation shall be capable of measuring Time Interval Error (TIE) as defined in Recommendation G.810 [6]. TIE is the basic function whereby many different stability parameters (such as MTIE and TDEV) may be calculated.

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

### 10.2.1 Sampling interval

In order to calculate and estimate the various wander parameters specified in following subclauses, TIE is treated as a sampled parameter since continuous knowledge of the time interval error is not practically attainable (refer to Recommendation G.810 [6]).

The maximum sampling time  $\tau_0$ , of TIE shall be:

$$1/30 \text{ s}$$

in accordance with Recommendations G.813 [9] and G.812 [8].

### 10.2.2 Measurement bandwidth

Wander shall be measured through an equivalent 10 Hz, first-order, low-pass measurement filter, in accordance with Recommendations G.813 [9] and G.812 [8], and with the following characteristics:

- a) The low-pass measurement filter has a single-order characteristic and a roll-off of  $-20$  dB/decade. The  $-3$  dB point of the measurement filter shall be at a frequency  $10 \text{ Hz} \pm 10\%$ .
- b) The amplitude of pass-band ripple in the range 1 to 10 Hz shall be less than  $\pm 0.2$  dB (relative to the gain at 0.1 Hz) and the maximum attenuation of the measurement filter shall be at least 30 dB.

### 10.2.3 Measurement range

The dynamic range of the TIE measurement shall be a minimum of:

$$\pm 1 \times 10^9 \text{ ns}$$

(corresponding, for example, to a frequency offset of  $\pm 4.6$  ppm for 200 000 seconds or over 55 hours).

### 10.2.4 Measurement result accuracy

The measuring accuracy of the wander measurement function is dependent upon several factors such as the magnitude of the reading, fixed intrinsic error, frequency response and TIE sampling interval.

For each measurement of TIE over an Observation Interval  $\tau$ , the total TIE measurement error shall be less than:

$$\pm 5\% \text{ of the measured TIE value } \pm Z_0(\tau)$$

where  $Z_0(\tau)$  is based on the measurement requirements of Recommendation G.811 [7] and is specified in Table 11.

**Table 11/O.172 – Fixed error ( $Z_0$ ) of TIE measurement**

$Z_0(\tau)$ (ns)	Observation Interval, $\tau$ (s)
$2.5 + 0.0275 \tau$	$0.05 \leq \tau \leq 1000$
$29 + 0.001 \tau$	$\tau > 1000$

NOTE – There is an additional frequency-dependent error term above 1 Hz due to the measurement filter response (refer to 10.2.2).

### 10.3 Measurement of MTIE (Maximum Time Interval Error)

The capability of measuring Maximum Time Interval Error (MTIE) as defined in Recommendation G.810 [6] may be provided.

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

#### 10.3.1 Measurement and observation interval ranges

In order to support the MTIE specifications of various ITU-T Recommendations, it shall be possible to measure MTIE over a range of observation intervals at least from:

0.05 s to 10 000 s

The maximum range of calculated MTIE results shall be at least:

50 000 ns

(corresponding to 10 times the maximum specification defined in Recommendation G.813 [9], for example).

NOTE – The minimum measurement period  $T$  for  $MTIE(\tau)$  is the observation interval (i.e.  $T = \tau$ ).

#### 10.3.2 Calculation algorithm accuracy

In certain cases, the MTIE calculation algorithm can be functionally separated from the TIE measurement, in which case the following accuracy requirements apply to the standalone algorithm.

When provided with a given set of TIE measurement data, an algorithm used to calculate MTIE shall yield results within a certain error of the values calculated in accordance with the standard estimator formula given in II.5/G.810 [6].

The total MTIE calculation error shall be less than:

$\pm 2\%$  of the MTIE value  $\pm Z_1(\tau)$

where  $Z_1(\tau)$  is specified in Table 12 and  $\tau$  is the observation interval.

**Table 12/O.172 – Fixed error ( $Z_1$ ) of MTIE calculation algorithm**

$Z_1(\tau)$ (ns)	Observation Interval, $\tau$ (s)
$0.5 + 0.0055 \tau$	$0.05 \leq \tau \leq 1000$
$5.8 + 0.0002 \tau$	$\tau > 1000$
NOTE – These requirements are based on a consideration of Recommendation G.811 [7].	

In order to verify the accuracy of a stand-alone MTIE calculation algorithm, a defined TIE noise source can be used, which is described in Appendix V.

#### 10.3.3 Measurement result accuracy

The total measurement error (i.e. including error from a TIE measurement and error from the MTIE calculation algorithm) shall be less than:

$\pm 7\%$  of the MTIE value  $\pm Z_3(\tau)$

where  $Z_3(\tau)$  is specified in Table 13 and  $\tau$  is the observation interval.

**Table 13/O.172 – Fixed error ( $Z_3$ ) of MTIE measurement result**

$Z_3(\tau)$ (ns)	Observation Interval, $\tau$ (s)
$3 + 0.033 \tau$	$0.05 \leq \tau \leq 1000$
$35 + 0.0012 \tau$	$\tau > 1000$
NOTE – These requirements are based on a consideration of Recommendation G.811 [7].	

#### 10.4 Measurement of TDEV (Time Deviation)

The capability of measuring Time Deviation (TDEV) as defined in Recommendation G.810 [6] may be provided.

TDEV is a measure of wander that characterizes its spectral content. It is a function of a parameter  $\tau$  called the Observation Interval. TDEV( $\tau$ ) can be said to be the RMS of filtered TIE, where a band-pass filter is centred on a frequency of  $0.42/\tau$ .

##### 10.4.1 Measurement and observation interval ranges

In order to support the TDEV specifications of various ITU-T Recommendations, it shall be possible to measure TDEV over a range of observation intervals at least from:

0.05 s to 10 000 s

The maximum range of calculated TDEV results shall be at least:

10 000 ns

(corresponding to 10 times the maximum specification defined in Recommendation G.813 [9], for example).

NOTE – The minimum measurement period  $T$  for TDEV( $\tau$ ) is twelve times the observation interval (i.e.  $T = 12\tau$ ), in accordance with Recommendations G.813 [9], G.812 [8] and G.811 [7].

##### 10.4.2 Calculation algorithm accuracy

In certain cases, the TDEV calculation algorithm can be functionally separated from the TIE measurement, in which case the following accuracy requirements apply to the stand-alone algorithm.

When provided with a given set of TIE measurement data, an algorithm used to calculate TDEV shall yield results within a certain error of the values calculated in accordance with the standard estimator formula given in II.3/G.810 [6].

The total TDEV calculation error shall be less than:

$\pm 2\%$  of the TDEV value  $\pm Z_2(\tau)$

where  $Z_2(\tau)$  is specified in Table 14 and  $\tau$  is the observation interval.

**Table 14/O.172 – Fixed error ( $Z_2$ ) of TDEV calculation algorithm**

$Z_2(\tau)$ (ns)	Observation Interval, $\tau$ (s)
0.06	$0.05 \leq \tau \leq 100$
$0.0006 \tau$	$100 < \tau \leq 1000$
0.6	$1000 < \tau \leq 10\ 000$
NOTE – These requirements are based on a consideration of Recommendation G.811 [7].	

In order to verify the accuracy of a stand-alone TDEV calculation algorithm, a defined TIE noise source can be used, which is described in Appendix V.

### 10.4.3 Measurement result accuracy

The total measurement error (i.e. including error from a TIE measurement and error from the TDEV calculation algorithm) shall be less than:

$$\pm 7\% \text{ of the TDEV value } \pm Z_4(\tau)$$

where  $Z_4(\tau)$  is specified in Table 15 and  $\tau$  is the observation interval.

**Table 15/O.172 – Fixed error ( $Z_4$ ) of TDEV measurement result**

$Z_4(\tau)$ (ns)	Observation Interval, $\tau$ (s)
0.36	$0.05 \leq \tau \leq 100$
$0.0036 \tau$	$100 < \tau \leq 1000$
3.6	$1000 < \tau \leq 10\,000$
NOTE – These requirements are based on a consideration of Recommendation G.811 [7].	

## 11 Operating environment

The performance requirements shall be met when operating within the climatic conditions as specified in 2.1/O.3 [15].

## ANNEX A

### Structured test signals for the measurement of jitter

#### A.1 Introduction

It is important to define the test signals to be used when performing jitter tests. This is of particular importance when testing SDH optical systems, since the scrambling system does not limit the length of runs of zeros/ones that can exist on a line signal, i.e. the maximum time period without any data transitions in the scrambled signal. Recommendation G.707 [3] provides further information regarding SDH signal structure and payload scrambling.

For example, if the traffic in an STM-N signal emulates the scrambling pattern, then many bytes of all zeros/ones will appear in the coded line signal. As the extreme cases of this will be rare occurrences, and also as it will be very difficult for a jitter test set to continue to perform accurate measurements under these conditions, it is important that a representative worst-case signal is defined for the purposes of test set specification.

##### A.1.1 Payload test conditions

Concatenated payloads provide the worst-case scenario for STM-N 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 30 consecutive identical zeros/ones (i.e. there will be 30 clock periods with no transitions on the line signal). For non-concatenated payloads generated by SDH test sets, the byte interleaving of the VC-4 containers reduces the maximum length of runs produced.

### A.1.2 SDH overhead byte conditions

Care shall be taken in selecting the binary content of the J0 and Z0 bytes and of the bytes reserved for national use which are excluded from the scrambling process of the STM-N signal, to ensure that long sequences of "1"s or "0"s do not occur.

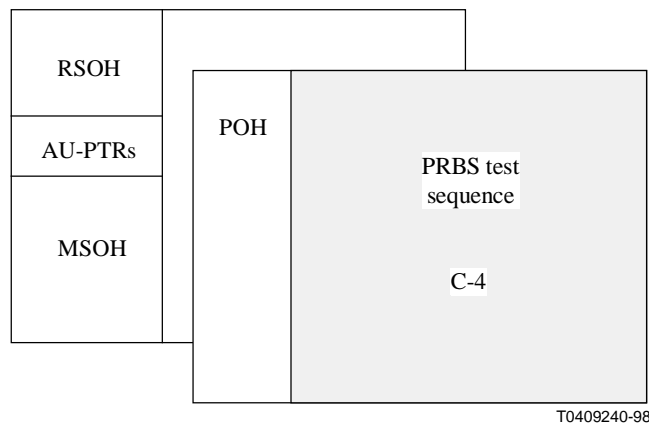
The content of these overhead bytes shall be set to a "10101010" (AA<sub>H</sub>) pattern.

## A.2 Test signal structure for STM-N signals

### A.2.1 STM-1 signal

The STM-1 test signal structure illustrated in Figure A.1 consists of a PRBS test sequence of length  $2^{23} - 1$  bits according to Recommendation O.150 [16], which is applied to all bytes of the C-4 container.

NOTE – This is equivalent to Test Signal Structure 1 (TSS1) defined in Annex C/O.181 [18].



**Figure A.1/O.172 – Test signal structure for jitter testing of STM-1 interface**

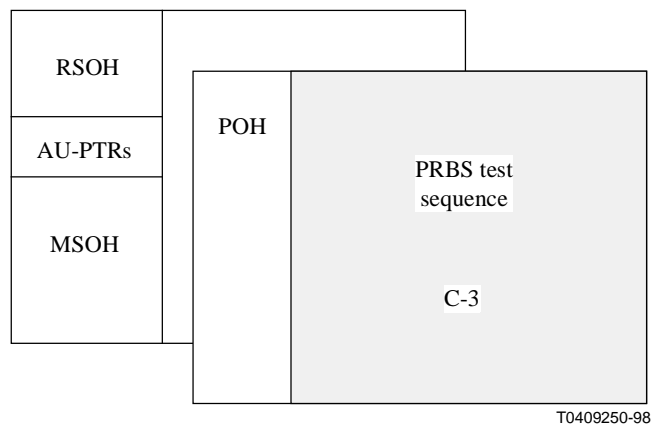
### A.2.2 STM-N signal (N ≥ 4)

The test signal TSS1 described in A.2.1 shall be used.

The (N-1) C-4 payload containers which do not contain the test signal shall contain an all "0" or all "1" fixed byte pattern or may contain an unequipped VC-4 as defined in Recommendation G.783 [5].

### A.2.3 STM-0 signal

The STM-0 test signal structure illustrated in Figure A.2 consists of a PRBS test sequence of length  $2^{23} - 1$  bits according to Recommendation O.150 [16], which is applied to all bytes of the C-3 container.

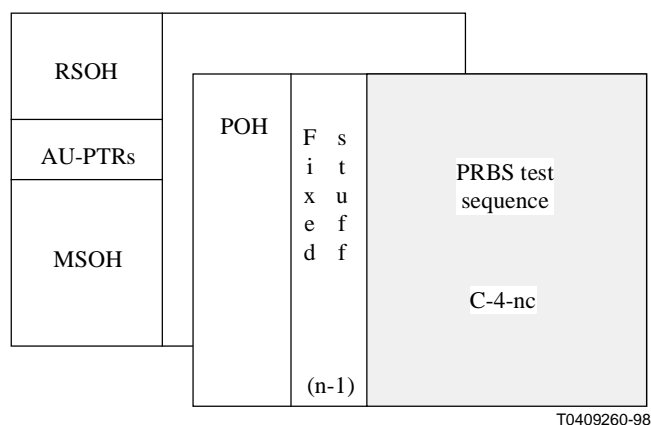


**Figure A.2/O.172 – Test signal structure for jitter testing of STM-0 interface**

### A.3 Test signal structure for concatenated STM-N signals

#### A.3.1 STM-N signal ( $N \geq 4$ )

The STM-N test signal structure illustrated in Figure A.3 is a PRBS test sequence of length  $2^{23} - 1$  bits according to Recommendation O.150 [16], which is applied to all bytes of the C-4-nc concatenated container.



**Figure A.3/O.172 – Test signal structure for jitter testing of concatenated STM-N interface**

## APPENDIX I

### Guidelines concerning the measurement of jitter in SDH systems

Appendix I/O.171 [17], "Guidelines concerning the measurement of jitter", although appropriate for PDH systems, may also be consulted for guidance on the general principles of measuring jitter in SDH systems.

## Guidelines concerning the measurement of wander in SDH systems

### II.1 Wander measurements

#### II.1.1 General considerations on wander measurement configurations

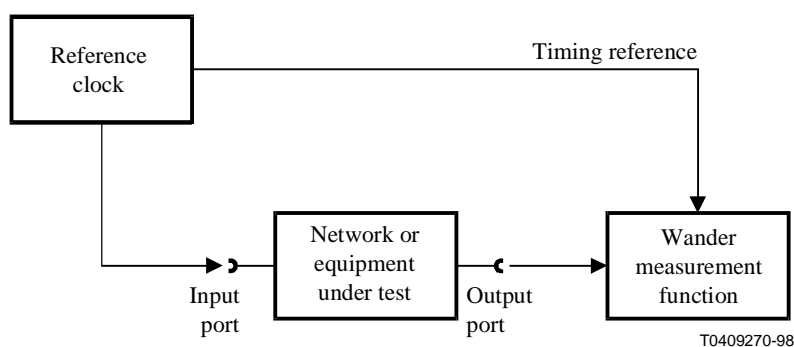
Due to the low frequency of the phase variations to be evaluated (refer to definition in clause 3), wander is a quantity which requires a special test configuration. When performing jitter measurements, the required reference timing signal is normally produced locally – by means of a phase-locked loop (PLL) within the test set; it is derived from the average phase of the signal to be measured. Such a PLL cannot be realized to cope with the requirements of wander measurements.

Therefore, wander measurements always require an external reference clock signal of adequate stability.

Subclauses II.1.2 and II.1.3 contain information on test configurations for wander measurements that are in accordance with Recommendation G.810 [6].

#### II.1.2 Synchronized wander measurements

Figure II.1 shows in a very general form the functional block diagram required for the synchronized measurement of wander.



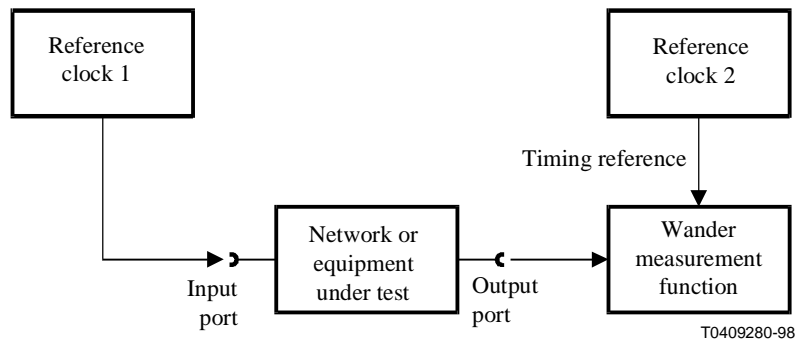
**Figure II.1/O.172 – Synchronized wander measurement configuration**

This configuration is applicable if the timing signals required to perform the measurement can be derived from a common reference clock. This means that only loop measurements – where input and output ports of the unit-under-test are accessible at the same location – can be carried out in this way. In this set-up, the measurement result is not affected by phase variations of the reference clock. Thus, the requirements on the stability of the reference clock are not very high and are achievable in portable test instrumentation.



### II.1.3 Non-synchronized wander measurements

The block diagram for non-synchronized wander measurements is illustrated in Figure II.2.

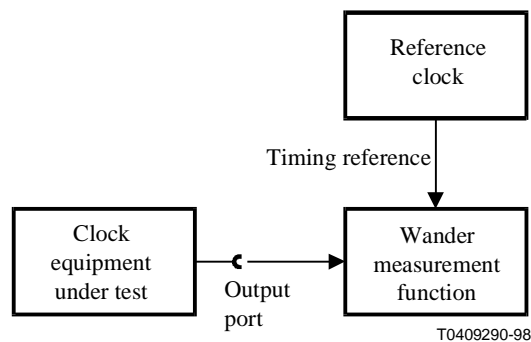


**Figure II.2/O.172 – Non-synchronized wander measurement configuration**

This configuration is applicable to wander measurements in cases where both input and output ports of the network or equipment under test are not available at the same location (e.g. end-to-end measurements). In this set-up, the measurement result is affected by any frequency/phase drift of the two clocks involved in the measurement. This means that the stability of the two clocks has to be at least one order of magnitude better than the quantity to be measured. Such reference clocks may not be provided in portable test instrumentation in which case synchronization to an external reference is required.

### II.2 Clock stability measurements

If the stability of a clock is to be measured, the measurement set-up is similar to that described above in II.1.3. It is illustrated in Figure II.3.



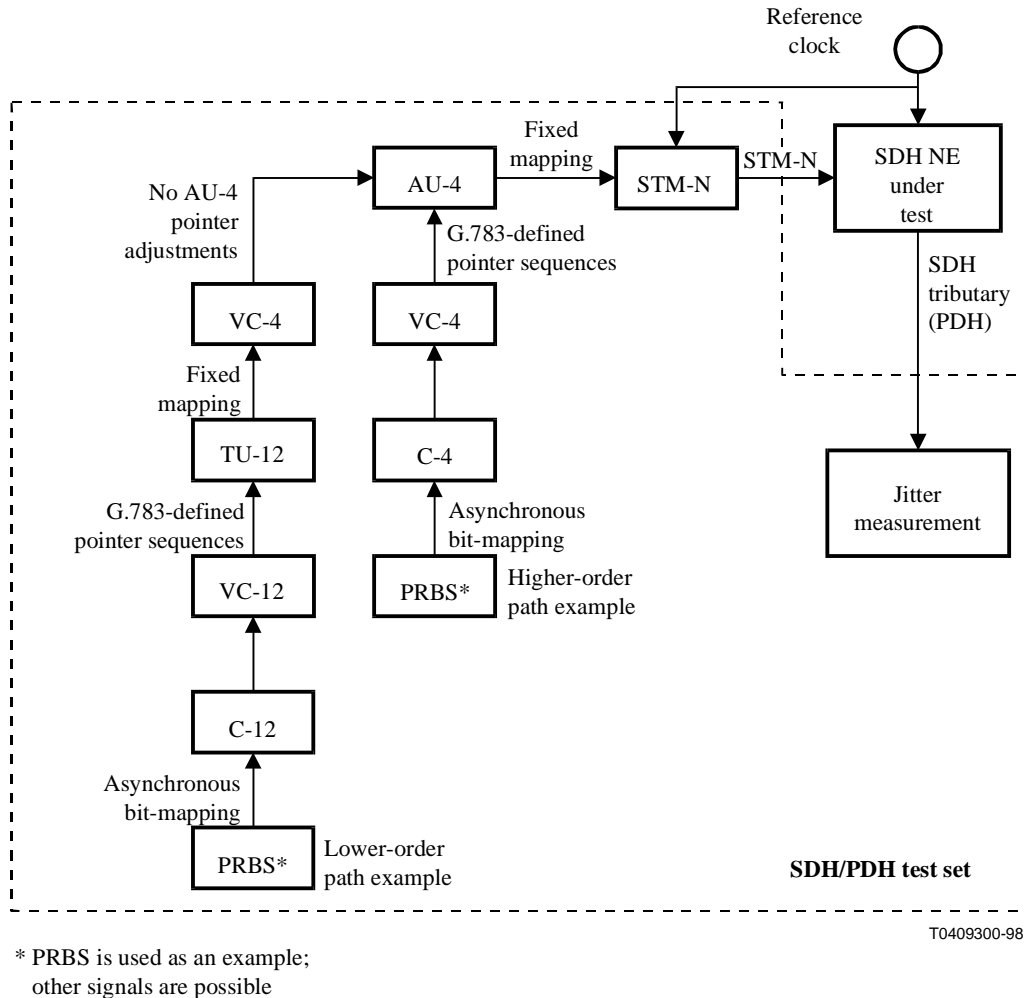
**Figure II.3/O.172 – Clock stability measurement configuration**

Also in this configuration, the measurement result is affected by any frequency or phase drift of the reference clock involved in the measurement. The same considerations as described in II.1.3 apply in this case.

## APPENDIX III

### Guidelines concerning the generation of pointer test sequences

The following functional block diagram of Figure III.1 and text, outline a method for generating the pointer test sequences defined in Recommendation G.783 [5] and which are described in 8.4.1. This figure does not describe a specific implementation.



**Figure III.1/O.172 – Functional block diagram  
of pointer test sequence generation**

In order to generate a Recommendation G.783 [5] pointer test sequence, the following considerations shall be taken into account by the test set capabilities, the test configuration and the user of the test set:

- a) The SDH/PDH test set and the network element should be synchronized from the same reference clock, to eliminate any uncontrolled pointer justification events that would interfere with the results.
- b) To measure combined pointer and mapping jitter, it should be possible to set the frequency of the PDH PRBS within the PDH offset ranges defined in Recommendation G.703 [2].
- c) To measure only mapping jitter, it should be possible to suppress pointer justification actions.

- d) To generate the bit-stuffing sequence for asynchronous bit-mapping, justifications of a single polarity should be generated at regular intervals.
- e) To create lower-order TU-m pointer test sequences, the higher-order AU-n pointer should be fixed.
- f) The "pointer sequences" and the "bit-mapping" functions imply frequency offsets between the clocks which drive the various functional blocks.

APPENDIX IV

**Total jitter measurement function response**

**IV.1 Introduction**

Subclause 9.3.2 specifies filters for SDH tributary jitter measurement. These specifications are in terms of limits on individual filter parameters such as  $-3$  dB cut-off frequency, gain tolerance, pass-band ripple, etc.

These parameters imply that some equivalent limits on the total frequency responses of the jitter measurement functions exist. This appendix illustrates how the individual filter parameters can be combined into a single frequency response, whose characteristic is bounded by mask limits.

**IV.2 Measurement filter parameters**

Table IV.1 summarizes the measurement filter parameters and their definitions. In the following descriptions of mask limits, if the value of a particular parameter is not specified in a filter description, then the default value given in Table IV.1 should be used.

**Table IV.1/O.172 – Summary of measurement filter specification parameters**

Measurement filter parameter	Parameter definition
n	Order of the filter (n = 1 is first-order, n = 3 is third-order).
$f_x$	Nominal $-3$ dB cut-off frequency or bandwidth.
a	Fractional cut-off frequency tolerance ( $\pm$ ). Default: no specification.
$f_p$	Second filter pole frequency. Default: 0 for high-pass, $\infty$ for low-pass.
g	Fractional gain tolerance of 9.3.2 (c).
r	Pass-band ripple ( $\pm$ ) in dB. Default: 0.
c	Minimum maximum attenuation in dB. Default: no specification.

### IV.3 Mask limits for high-pass measurement filter response

The upper and lower mask limits for the frequency response are  $Upper(f)$  and  $Lower(f)$  as defined below. These masks apply to the frequency range  $f < 10 f_x$ .

$$Upper(f) = \begin{cases} U(f) + r, & f > f_x \\ -c, & U(f) < -c \\ U(f), & \text{otherwise} \end{cases}$$

where:

$$U(f) = 20 \log \left[ \frac{((1+g)f)^n}{\sqrt{f^{2n} + ((1-a)f_x)^{2n}}} \right] \quad [IV-1]$$

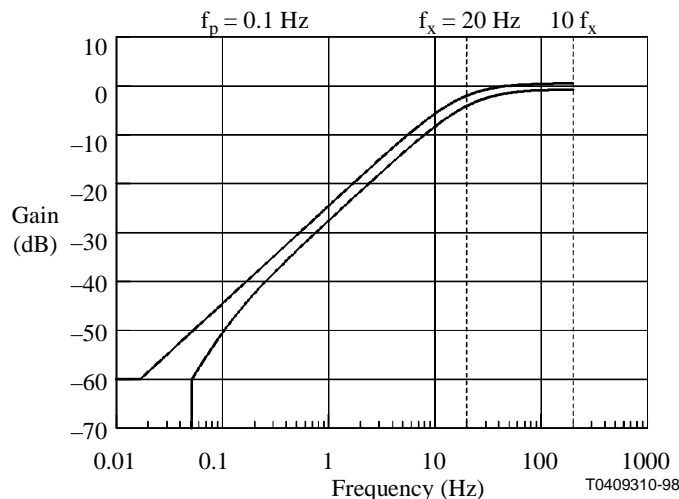
$$Lower(f) = \begin{cases} L(f) - r, & f > f_x \\ -\infty, & L(f) < -c \\ L(f), & \text{otherwise} \end{cases}$$

where:

$$L(f) = 20 \log \left[ \frac{((1+g)f)^n}{\sqrt{f^{2n} + ((1-a)f_x)^{2n}}} \frac{f}{\sqrt{f^2 + f_p^2}} \right] \quad [IV-2]$$

#### IV.3.1 SDH tributary jitter measurement high-pass filter

As an example, the SDH tributary jitter measurement filter specified for 2048 kbit/s has parameters  $n = 1$ ,  $f_x = 20$  Hz,  $a = 0.1$ ,  $f_p = 0.1$  Hz,  $g = 0.07$ ,  $r = 0$ , and  $c = 60$  dB. Then the upper and lower mask limits for the jitter measurement function frequency response are as illustrated in Figure IV.1.



**Figure IV.1/O.172 – Mask limits for 2048 kbit/s jitter measurement high-pass filter at 20 Hz**

## Verification of MTIE and TDEV calculation algorithms

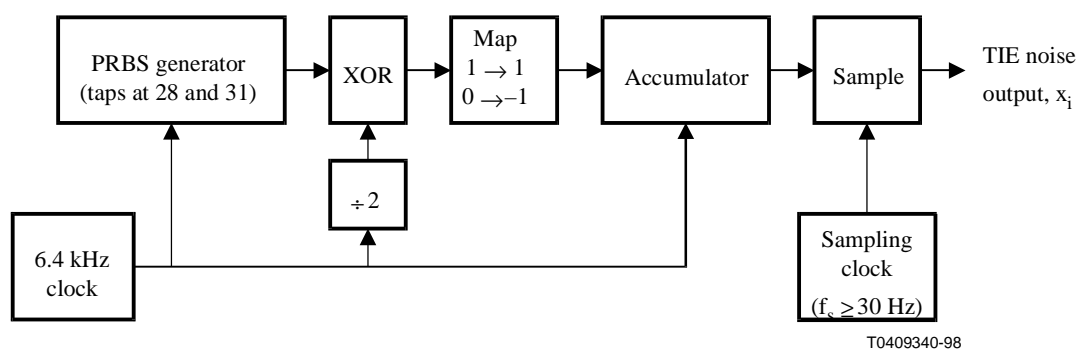
### V.1 TIE noise source functional description

In order to verify the accuracy of standalone MTIE and TDEV calculation algorithms (refer to 10.3.2 and 10.4.2), a defined TIE noise source can be used.

The MTIE and TDEV calculation algorithm accuracy specifications (refer to 10.3.2 and 10.4.2) nominally apply to all possible TIE waveforms from which MTIE and TDEV are calculated. Since it is impractical to test for many waveforms, the TIE pattern generator described here can be used to verify the algorithm accuracy. It generates a "random-walk" phase noise that is typical of wander encountered in an SDH network. A functional block diagram is illustrated in Figure V.1.

The TIE generator is based on a pseudo-random binary sequence (PRBS) generator that is 31 stages long. The output of the PRBS generator is a pseudo-random sequence of 1s and 0s. The output of the TIE generator is a series of numbers  $x_i$  at a rate  $f_s$ , where the numbers represent nanoseconds (ns), and  $f_s$  is not less than 30 Hz.

The resulting TIE waveform has a  $1/f^2$  power spectral density and a normal (i.e. Gaussian) distribution out to  $2.5\sigma$ , where  $\sigma$  is the standard deviation. Note that although the system clock is 6.4 kHz, the numbers  $x_i$  are generated at a lower rate of  $f_s$  through sub-sampling. Since this source produces a TIE noise signal that repeats after 671 000 seconds, it is valid for testing TDEV algorithms to Observation Intervals,  $\tau$ , as large as 56 000 seconds.



**Figure V.1/O.172 – TIE noise source used for verifying MTIE and TDEV calculation algorithms**



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