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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  
synchronous Ethernet technology**

Recommendation ITU-T O.174



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## **Recommendation ITU-T O.174**

### **Jitter and wander measuring equipment for digital systems which are based on synchronous Ethernet technology**

#### **Summary**

Recommendation ITU-T O.174 specifies test equipment used to generate and measure timing jitter and synchronization wander in digital systems based on synchronous Ethernet technology.

#### **History**

Edition	Recommendation	Approval	Study Group
1.0	ITU-T O.174	2009-11-13	15

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## Recommendation ITU-T O.174

### Jitter and wander measuring equipment for digital systems which are based on synchronous Ethernet technology

#### 1 Scope

The test equipment specified in this Recommendation consists principally of a jitter/wander measurement function and a jitter/wander generation function. Measurements can be performed at the physical layer of synchronous Ethernet systems. A bit error rate test set may be part of the same equipment or may be physically separate.

[ITU-T O.172] specifies the test equipment for generation and measurement of jitter and wander in digital systems based on the synchronous digital hierarchy (SDH).

[ITU-T G.8261], [ITU-T G.8262] and [ITU-T G.8264] should 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.

- [ITU-T G.691] Recommendation ITU-T G.691 (2006), *Optical interfaces for single channel STM-64 and other SDH systems with optical amplifiers.*
- [ITU-T G.703] Recommendation ITU-T G.703 (2001), *Physical/electrical characteristics of hierarchical digital interfaces.*
- [ITU-T G.705] Recommendation ITU-T G.705 (2000), *Characteristics of plesiochronous digital hierarchy (PDH) equipment functional blocks.*
- [ITU-T G.781] Recommendation ITU-T G.781 (1999), *Synchronization layer functions.*
- [ITU-T G.783] Recommendation ITU-T G.783 (2006), *Characteristics of synchronous digital hierarchy (SDH) equipment functional blocks.*
- [ITU-T G.810] Recommendation ITU-T G.810 (1996), *Definitions and terminology for synchronization networks.*
- [ITU-T G.811] Recommendation ITU-T G.811 (1997), *Timing characteristics of primary reference clocks.*
- [ITU-T G.812] Recommendation ITU-T G.812 (2004), *Timing requirements of slave clocks suitable for use as node clocks in synchronization networks.*
- [ITU-T G.813] Recommendation ITU-T G.813 (2003), *Timing characteristics of SDH equipment slave clocks (SEC).*
- [ITU-T G.822] Recommendation ITU-T G.822 (1988), *Controlled slip rate objectives on an international digital connection.*
- [ITU-T G.823] Recommendation ITU-T G.823 (2000), *The control of jitter and wander within digital networks which are based on the 2048 kbit/s hierarchy.*

- [ITU-T G.824] Recommendation ITU-T G.824 (2000), *The control of jitter and wander within digital networks which are based on the 1544 kbit/s hierarchy.*
- [ITU-T G.825] Recommendation ITU-T G.825 (2000), *The control of jitter and wander within digital networks which are based on the synchronous digital hierarchy (SDH).*
- [ITU-T G.957] Recommendation ITU-T G.957 (1999), *Optical interfaces for equipments and systems relating to the synchronous digital hierarchy.*
- [ITU-T G.959.1] Recommendation ITU-T G.959.1 (2008), *Optical transport network physical layer interfaces.*
- [ITU-T G.8010] Recommendation ITU-T G.8010/Y.1306 (2004), *Architecture of Ethernet layer networks.*
- [ITU-T G.8110.1] Recommendation ITU-T G.8110.1/Y.1370.1 (2006), *Architecture of Transport MPLS (T-MPLS) layer network.*
- [ITU-T G.8261] Recommendation ITU-T G.8261/Y.1361 (2008), *Timing and synchronization aspects in packet networks.*
- [ITU-T G.8262] Recommendation ITU-T G.8262/Y.1362 (2007), *Timing characteristics of synchronous Ethernet equipment slave clock (EEC).*
- [ITU-T G.8264] Recommendation ITU-T G.8264/Y.1364 (2008), *Distribution of timing information through packet networks.*
- [ITU-T O.3] Recommendation ITU-T O.3 (1992), *Climatic conditions and relevant tests for measuring equipment.*
- [ITU-T O.150] Recommendation ITU-T O.150 (1996), *General requirements for instrumentation for performance measurements on digital transmission equipment.*
- [ITU-T O.171] Recommendation ITU-T O.171 (1997), *Timing jitter and wander measuring equipment for digital systems which are based on the plesiochronous digital hierarchy (PDH).*
- [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).*
- [IEEE 802.3] IEEE Standard 802.3-2008, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications.*

### 3 Definitions

This Recommendation uses the following terms defined elsewhere:

- 3.1 Ethernet synchronization message channel:** [ITU-T G.8264].
- 3.2 non-sync operation mode:** [ITU-T G.8264].
- 3.3 synchronization network clock:** [ITU-T G.8261].
- 3.4 synchronous operation mode:** [ITU-T G.8264].
- 3.5 time interval error function:** [ITU-T G.810].
- 3.6 (timing) jitter:** [ITU-T G.810].



### 3.7 wander: [ITU-T G.810].

Note that [ITU-T G.810] and [ITU-T G.8261] provide additional definitions and abbreviations used in timing and synchronization Recommendations. They also provide background information on the need to limit phase variation and impairments on digital systems.

## 4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

EEC	synchronous Ethernet Equipment Clock
ESMC	Ethernet Synchronization Messaging Channel
ETH	Ethernet MAC layer network
ETY	Ethernet PHY layer network
GE	Gigabit Ethernet
IP	Internet Protocol
IWF	InterWorking Function
LPF	Low-Pass Filter
MTIE	Maximum Time Interval Error
MRTIE	Maximum Relative Time Interval Error
NE	Network Element
NRZ	Non Return to Zero
PDH	Plesiochronous Digital Hierarchy
PDU	Protocol Data Unit
PLL	Phase-Locked Loop
ppm	parts per million
PRBS	Pseudo Random Binary Sequence
PRC	Primary Reference Clock
QL	Quality Level
RTIE	Relative Time Interval Error
SDH	Synchronous Digital Hierarchy
SEC	Synchronous digital hierarchy Equipment Clock
SSM	Synchronization Status Message
SSU	Synchronization Supply Unit
STM-N	Synchronous Transport Module, level N
TDEV	Time DEVIation
TIE	Time Interval Error
UI	Unit Interval
UIpp	Unit Interval, peak-to-peak

## 5 Conventions

The jitter/wander measurement function in this Recommendation applies to synchronous Ethernet interfaces. Jitter measurement functions for legacy Ethernet are defined partly in [IEEE 802.3].

## 6 Functional block diagram

Figure 1 shows the general block diagram of the equipment and identifies the main functions covered in this Recommendation. The figure does not describe a specific implementation.

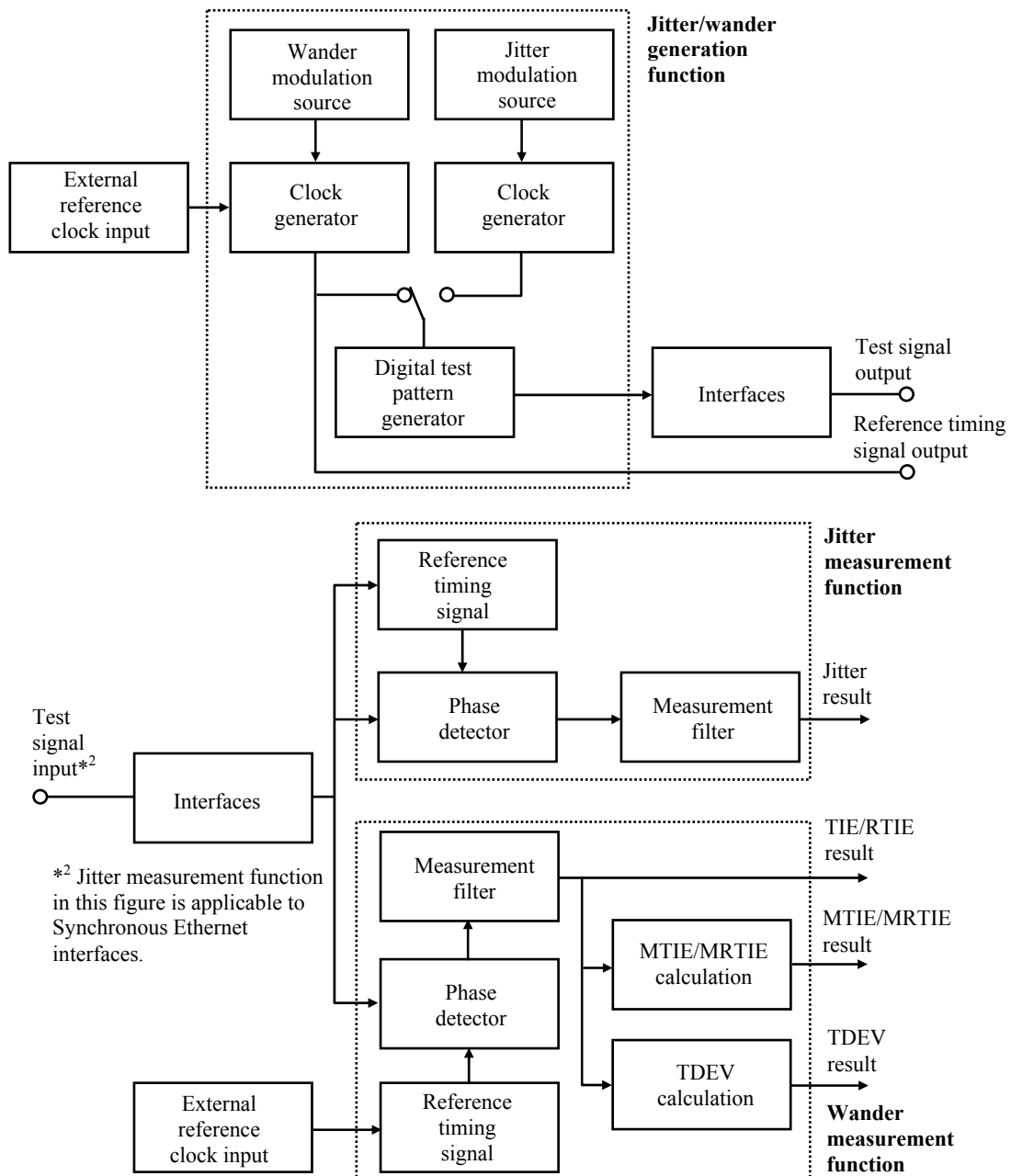


Figure 1 – Functional block diagram for jitter and wander test set

## **7 Interfaces**

### **7.1 Synchronous Ethernet interfaces**

The equipment shall be capable of operating at one or more of the following Ethernet interfaces. Table III.1 of [ITU-T G.8262] lists the interfaces supporting synchronous Ethernet.

### **7.2 External reference clock input**

The measuring equipment shall support reference data signals at bit rates of 1 544 kbit/s or 2 048 kbit/s. If 2 048 kbit/s can be accepted, the equipment shall also accept a clock signal at 2 048 kHz as a reference. The characteristics of clock signals shall be in accordance with [ITU-T G.703].

## **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 conforming to relevant Recommendations may be provided within the clock generator and/or digital test pattern generator, or may be provided separately. This Recommendation defines a sinusoidal modulation source for jitter generation. The modulation source for wander generation is defined as one of the following three signals.

- Sinusoidal.
- Time deviation (TDEV) wander (noise): White Gaussian noise filtered to obtain required TDEV characteristic.
- Maximum time interval error (MTIE) wander: Test signal to obtain required MTIE or maximum relative time interval error (MRTIE) characteristic.

The sinusoidal jitter/wander, TDEV wander and MTIE wander generation functions are defined in clauses 8.4, 8.5 and 8.6, respectively.

### **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 wander and the modulating frequencies shall meet the minimum requirements of Figure 2. The generated peak-to-peak jitter and the modulating frequencies for EEC options 1 and 2 shall meet [IEEE 802.3]. The Ethernet measurement methodology is defined in [IEEE 802.3]. The applicability to jitter measurement in a synchronization network environment is for further study.

#### **8.2.1 Accuracy of clock generator**

The frequency deviation of the internal clock signal from its nominal value shall be less than  $\pm 4.6$  ppm excluding locked operation.

As an option, the clock generator may provide adjustable frequency offset of sufficient magnitude to facilitate tests 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 listed in Table III.1 of [ITU-T G.8262].

It shall be possible to phase-lock the generation function to an external reference clock source of arbitrary accuracy; refer to clause 7.2.

### 8.3 Digital test pattern generator

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

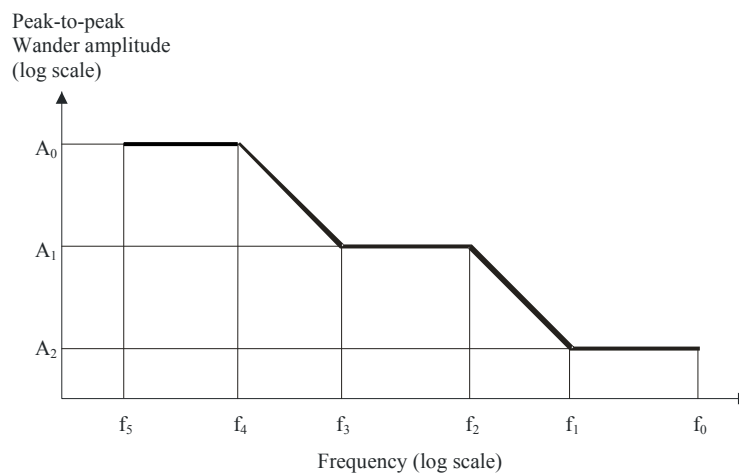
- a) Ethernet signal in accordance with [IEEE 802.3].
- b) Ethernet synchronous messaging channel protocol data unit (ESMC PDU) format signal in accordance with [ITU-T G.8264].

### 8.4 Sinusoidal jitter/wander generation function

The ability to generate sinusoidal wander for wander tolerance (MTIE) measurements as described in [ITU-T G.8262] may be provided. The following requirements shall be met to ensure sufficiently accurate, robust and consistent measurements.

#### 8.4.1 Minimum sinusoidal jitter/wander generation capability

The jitter/wander amplitude/frequency characteristics of the generation function shall meet the minimum requirements of Figure 2 for EEC signals.



Signal	Minimum peak-to-peak wander amplitude ( $\mu$ s)			Wander frequency breakpoints (Hz)					
	$A_0$	$A_1$	$A_2$	$f_5$	$f_4$	$f_3$	$f_2$	$f_1$	$f_0$
EEC	23.15	2.5	0.3	12 $\mu$	178 $\mu$	0.8m	16m	0.13	10
NOTE 1 – Values based on requirements of Table 8 of [ITU-T G.8262] for option 1.									
NOTE 2 – Jitter value is for further study.									

**Figure 2 – Minimum amplitude of adjustable generated sinusoidal wander amplitude versus wander frequency for EEC signals**

#### 8.4.2 Generation accuracy

The sinusoidal test signal source shall be compatible with the jitter/wander measurement function so 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 sinusoidal jitter/wander generation function depends on several factors, such as fixed intrinsic error, setting resolution, distortion and frequency response error. In addition, some error is a function of the actual setting.

### 8.4.2.1 Phase amplitude error

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

$$Q\% \text{ of setting } \pm 0.02 \text{ UI}_{pp}$$

Where  $Q$  is a variable error specified in Table 1 for EEC signals. The frequencies  $f_0$  and  $f_5$  used in Table 1 are defined in Figure 2.

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

**Table 1 – Variable error ( $Q$ ) of EEC signal jitter/wander generation**

Signal	Error, $Q$	Frequency range
EEC	$\pm 10\%$	$f_5$ to $f_0$
NOTE – Value of jitter range is for further study.		

### 8.4.2.2 Intrinsic jitter/wander of generation function

The intrinsic wander of the jitter/wander generation function measured in the bandwidth  $f_0$ – $f_5$ , as defined in Figure 2 with the amplitude set to zero, shall be less than:

$$0.04 \text{ UI}_{pp} \text{ for test signal defined in clause 8.3.}$$

## 8.5 TDEV wander generation function

The ability to generate TDEV wander (noise) for wander tolerance and wander transfer measurements as described in [ITU-T G.8262] may be provided. The following requirements shall be met to ensure sufficiently accurate, robust and consistent measurements:

- Wander generation function shall produce a test signal with TDEV within  $\pm 20\%$  of the applicable TDEV input tolerance mask. This accuracy shall be met when the measurement period  $T \geq 12\tau_{\max}$ , where  $\tau_{\max}$  is the largest value of  $\tau$  for the mask.
- The MTIE of the test signal shall not be greater than the upper limit defined in Annex C of [ITU-T O.172].
- The test signal shall be deterministic and repeatable, implying that the signal can start at the same point of the signal time function.

Clause II.2 of [ITU-T G.812] shows an example of an adequate implementation algorithm for generating a TDEV wander noise.

Clause II.1 of [ITU-T G.812] has additional information on application of TDEV wander noise.

NOTE – The signal may exceed the corresponding MTIE tolerance mask limits. Since both TDEV and MTIE requirements must be met for an input interface, the TDEV limits may be more stringent and therefore may exceed the MTIE values.

## 8.6 MTIE wander generation function

The ability to generate an MTIE wander signal for wander tolerance measurements as described in [ITU-T G.8262] may be provided. The following requirements shall be met to ensure sufficiently accurate, robust and consistent measurements:

- The wander generation function shall produce a test signal or set of test signals with MTIE within  $\pm 5\%$  of the applicable MTIE input tolerance mask. For a set of test signals, the MTIE will be considered to be the upper envelope of the set of corresponding MTIE curves.
- The jitter generated by the wander generation function shall not exceed the limits for the applicable network interface output jitter.

NOTE – When a test set is evaluated for compliance with these requirements, the generated wander must be measured using a low-pass filter (LPF) with adequate bandwidth so that its effect on the measured MTIE is less than 1%. See Appendix VI of [ITU-T O.172] for guidance on evaluating MTIE wander signal generation.

## 9 Jitter measurement function

The jitter measurement methodology for Ethernet interfaces is defined in [IEEE 802.3]. Ethernet assumes that there are essentially two jitter mechanisms: deterministic jitter and random jitter. Separate requirements are specified for transmitters and receivers. The jitter measurement for synchronous Ethernet according to [ITU-T O.172] is for further study.

## 10 Wander measurement function

The following measurement definitions, also applicable for synchronous Ethernet, are defined in clause 10 of [ITU-T O.172].

- Reference timing signal.
- Measurement of TIE.
- Measurement of transient TIE.
- Measurement of MTIE.
- Measurement of TDEV.
- Measurement of frequency offset.
- Measurement of frequency drift rate.

Appendices II, V and VI of [ITU-T O.172] provide further information about test configurations for measuring wander.

The MRTIE measurement function is defined in clause 10.1.

### 10.1 Measurement of maximum relative time interval error (MRTIE)

The ability to measure maximum relative time interval error (MRTIE), as defined in [ITU-T G.810] and [ITU-T G.823], may be provided.

MRTIE is a measure of wander that characterizes phase transients. It is a function of the parameter  $\tau$  called the observation interval.  $MRTIE(\tau)$  is the largest peak-to-peak relative TIE (RTIE), described in clause I.2.2.2 of [ITU-T G.823], in any observation interval of length  $\tau$ .

The MRTIE network limits of packet networks are specified in [ITU-T G.8261].

#### 10.1.1 Measurement and observation interval ranges

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

0.05 s to 1000 s for TIE as described in 10.2 of [ITU-T O.172].

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

100 000 ns

(corresponding to five times the maximum specification defined in [ITU-T G.823], for example).

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

### 10.1.2 Calculation algorithm accuracy

In some cases, the MRTIE calculation algorithm can be separated functionally from the TIE measurement, when 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 RTIE and MRTIE shall yield results within a certain error of the values calculated in accordance with the standard estimator formulas given in clauses II.2.2.2 of [ITU-T G.823] and II.5 of [ITU-T G.810].

The total MRTIE calculation error shall be less than:

$$\pm 2\% \text{ of MRTIE value } \pm Z_1(\tau)$$

where  $Z_1(\tau)$  is specified in Table 2 and  $\tau$  is the observation interval.

**Table 2 – Fixed error ( $Z_1$ ) of MRTIE calculation algorithm**

$Z_1(\tau)$ (ns)	Observation interval, $\tau$ (s)
$0.5 + 0.0055 \tau$	$0.05 \leq \tau \leq 1000$
NOTE – These requirements are based on [ITU-T G.823] and [ITU-T G.8261].	

### 10.1.3 Measurement result accuracy

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

$$\pm 7\% \text{ of MRTIE value } \pm Z_3(\tau)$$

where  $Z_3(\tau)$  is specified in Table 3 and  $\tau$  is the observation interval.

**Table 3 – Fixed error ( $Z_3$ ) of MRTIE measurement result**

$Z_3(\tau)$ (ns)	Observation interval, $\tau$ (s)
$3 + 0.033 \tau$	$0.05 \leq \tau \leq 1000$
NOTE – These requirements are based on [ITU-T G.823] and [ITU-T G.8261].	

## 11 Operating environment

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

## Appendix I

### Measurement guidelines for wander measurement

(This appendix does not form an integral part of this Recommendation)

#### I.1 TDEV/MTIE wander tolerance

##### I.1.1 Intent

The intent of this test procedure is to measure wander tolerance in terms of the TDEV/MTIE wander amplitude that, when applied to an equipment input, causes a designated degradation of error performance. TDEV/MTIE wander tolerance is a function of the amplitude and observation interval,  $\tau$ , of the applied TDEV/MTIE ( $\tau$ ) mask.

##### I.1.2 Apparatus

The following apparatus is required:

- External reference clock source.
- TDEV/MTIE wander modulation source.
- Clock generator.
- Digital signal generator.
- TDEV/MTIE wander measurement function (option).

##### I.1.3 Basic technique

The errors criterion for TDEV/MTIE wander tolerance measurements is defined as the largest amplitude of TDEV/MTIE mask that causes a cumulative total bit error rate of less than  $10^{-12}$ , where this total bit error rate has been summed over the measurement period of twelve times the observation interval.

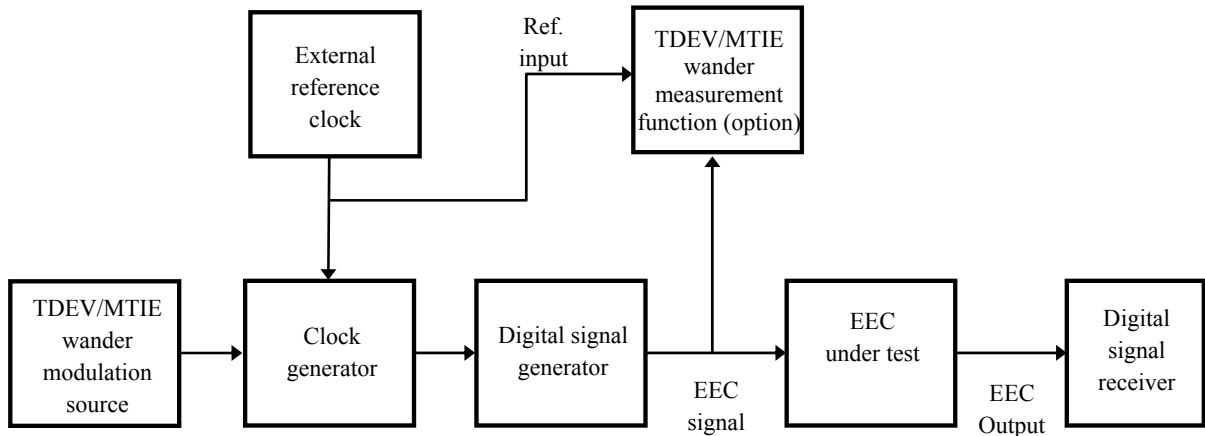
##### I.1.4 Equipment connection

Clauses I.1.5 and I.1.6 provide information on test configurations for TDEV/MTIE wander tolerance measurements that are in accordance with [ITU-T G.8262].

##### I.1.5 Measurement for EEC signal

Figure I.1 shows the test configuration for the input data signal of the EEC basic technique. The optional TDEV/MTIE wander measurement function is used to verify the amplitude of generated TDEV/MTIE wander on the input data signal.

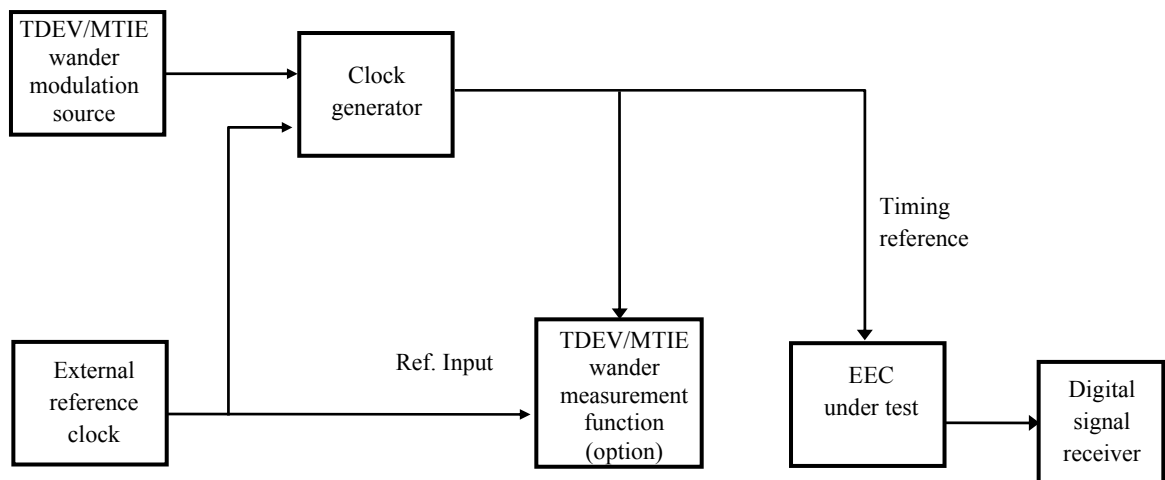




**Figure I.1 – TDEV/MTIE wander tolerance measurement configuration for EEC**

### I.1.6 Measurement for timing reference

Figure I.2 shows the test configuration for the input timing reference of the EEC basic technique. The optional TDEV/MTIE wander measurement function is used to verify the amplitude of generated TDEV/MTIE wander on the input timing reference signal.



**Figure I.2 – TDEV/MTIE wander tolerance measurement configuration for timing reference**

### I.1.7 Equipment settings

This technique involves setting a measurement period for TDEV/MTIE and determining the TDEV/MTIE wander amplitude of the data signal that satisfies the errors criterion. Specifically, this technique requires:

- 1) isolation of the TDEV/MTIE wander amplitude "transition region" (where error-free operation ceases);
- 2) performance of total bit error rate measurement, the measurement period of 12 times the observation interval in duration, for each incrementally added TDEV/MTIE wander amplitude from the beginning of this region;
- 3) determination of the largest TDEV/MTIE mask for which the cumulative total bit error rate is less than  $10^{-12}$ .

### **I.1.8 Measurement procedure**

- 1) Connect the equipment as shown in Figure I.1 or I.2. Verify proper continuity and error-free operation.
- 2) Set the initial TDEV/MTIE wander amplitude to 0 ns peak to peak.
- 3) Set the TDEV/MTIE wander amplitude for the desired TDEV/MTIE mask specified in the applicable standard.
- 4) Record the number of errors occurring during twelve times the TDEV/MTIE observation interval. Note that the initial measurement must be 0 errors.
- 5) Record the indicated TDEV/MTIE wander to characterize the TDEV/MTIE wander tolerance curve.

### **I.2 TDEV wander transfer**

Appendix II of [ITU-T G.812] describes how to measure noise transfer.



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