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European Standard (Telecommunications series)

Transmission and Multiplexing (TM); Generic requirements for synchronization networks; Part 7-1: Timing characteristics of slave clocks suitable for synchronization supply to equipment in local node applications

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Contents

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Foreword

This European Standard (Telecommunications series) has been produced by ETSI Technical Committee Transmission and Multiplexing (TM), and is now submitted for the Vote phase of the ETSI standards Two-step Approval Procedure.

The present document is part 7-1 of a multi-part deliverable covering Transmission and Multiplexing (TM); Generic requirements for synchronization networks, as identified below:

Part 1-1: "Definitions and terminology for synchronization networks";

Part 2-1: "Synchronization network architecture";

Part 3-1: "The control of jitter and wander within synchronization networks";

Part 4-1: "Timing characteristics of slave clocks suitable for synchronization supply to Synchronous Digital Hierarchy (SDH) and Plesiochronous Digital Hierarchy (PDH) equipment";

Part 4-2: "Timing characteristics of slave clocks suitable for synchronization supply to Synchronous Digital Hierarchy (SDH) and Plesiochronous Digital Hierarchy (PDH) equipment; Implementation Conformance Statement (ICS) proforma specification";

Part 5-1: "Timing characteristics of slave clocks suitable for operation in Synchronous Digital Hierarchy (SDH) equipment";

Part 6-1: "Timing characteristics of primary reference clocks".

Part 6-2: "Timing characteristics of primary reference clocks; Implementation Conformance Statement (ICS) proforma specification";

Part 7-1: "Timing characteristics of slave clocks suitable for synchronization supply to equipment in local node applications".

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1 Scope

The present document outlines requirements for timing devices called Synchronization Supply Units for local node applications (SSU-Ls). This SSU is used in synchronizing network equipment in the Synchronous Digital Hierarchy (SDH) transport network, in the Public Switched Telephone Network (PSTN) and in the Public Land Mobile Networks (PLMN) for local node applications.

The last SSU in a Synchronization chain, irrespective of the traffic network, provides the applications for this type of clock.

NOTE: The requirements in the present document apply under environmental conditions according to one of the environmental classes defined in ETS 300 019 [1], unless stated otherwise. The manufacturer will need to specify to which specific environmental class the equipment belongs.

A description of the Synchronization Supply Unit (SSU) logical function is given in figure 1 in EN 300 462-2-1 [3]. In general, the SSU will have multiple timing reference inputs and in the event that all timing references fail, the SSU should be capable of maintaining operation (holdover) within prescribed performance limits as detailed in the present document. The requirements laid down in the present document describe the minimum performance of an SSU applied as a local node clock (SSU-L). Requirements for transit node clock applications for SSU's are described in EN 300 462-4-1 [5].

The SSU-L function can be implemented in a separate piece of equipment called a Stand-Alone Synchronization Equipment (SASE) or it can form a logical function of another equipment such as a telephony exchange or an SDH cross-connect.

The requirements specified in the present document refer to the design of new synchronization networks and consequently they do not necessarily represent the performance of existing synchronization network and equipment.

A timing device within SDH equipment can also conform to EN 300 462-5-1 [6].

The characteristics related to holdover and noise generation performance make this type of clock also suitable for application in the GSM radio sub-system (see GSM 05.10 [7]). In particular as a clock used by a Base Station Controller (BSC) or by a Mobile Switching Centre (MSC), further synchronizing (typically via a traffic link) the Base Station (BS). The characteristics of this clock are not optimized for a clock to be implemented in the BS.

In order to fulfil the frequency accuracy requirements required in the GSM radio interface, this clock should be connected to a synchronization network that is properly designed and correctly operating.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication and/or edition number or version number) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

[1] ETSI ETS 300 019: "Equipment Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment".

[2] ETSI EN 300 462-1-1: "Transmission and Multiplexing (TM); Generic requirements for synchronization networks; Part 1-1: Definitions and terminology for synchronization networks".

[3] ETSI EN 300 462-2-1: "Transmission and Multiplexing (TM); Generic requirements for synchronization networks; Part 2-1: Synchronization network architecture".

[4] ETSI EN 300 462-3-1: "Transmission and Multiplexing (TM); Generic requirements for synchronization networks; Part 3-1: The control of jitter and wander within synchronization networks".

[5] ETSI EN 300 462-4-1: "Transmission and Multiplexing (TM); Generic requirements for synchronization networks; Part 4-1: Timing characteristics of slave clocks suitable for synchronization supply to Synchronous Digital Hierarchy (SDH) and Plesiochronous Digital Hierarchy (PDH) equipment".

[6] ETSI EN 300 462-5-1: "Transmission and Multiplexing (TM); Generic requirements for synchronization networks; Part 5-1: Timing characteristics of slave clocks suitable for operation in Synchronous Digital Hierarchy (SDH) equipment".

[7] GSM 05.10: "Digital cellular telecommunications system (Phase 2+); Radio subsystem synchronization (GSM 05.10)".

[8] ETSI ETS 300 166: "Transmission and Multiplexing (TM); Physical and electrical characteristics of hierarchical digital interfaces for equipment using the 2 048 kbit/s - based plesiochronous or synchronous digital hierarchies".

[9] ITU-T Recommendation G.825: "The control of jitter and wander within digital networks which are based on the synchronous digital hierarchy (SDH)".

[10] ITU-T Recommendation G.823: "The control of jitter and wander within digital networks which are based on the 2 048 kbit/s hierarchy".

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

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in EN 300 462-1-1 [2] apply.

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

BS	Base Station
BSC	Base Station Controller
GSM	Global System for Mobile communications
ITU-T	International Telecommunications Union-Telecommunications Standardization Sector
MSC	Mobile Switching Centre
MTIE	Maximum Time Interval Error
NE	Network Element
PDH	Plesiochronous Digital Hierarchy
ppm	parts per million
PSTN	Public Switched Telephone Network
SASE	Stand Alone Synchronization Equipment
SDH	Synchronous Digital Hierarchy
SSU	Synchronization Supply Unit
SSU-L	SSU Local
STM-1opt	Optical STM-1 interface
STM-1el	Electrical STM-1interface
STM-N	Synchronous Transport Module-N
TDEV	Time DEViation
UI	Unit Interval
UIpp	Unit Interval peak to peak

A full list of abbreviations used in timing and synchronization is listed in EN 300 462-1-1 [2].

4 Frequency accuracy

The long-term frequency accuracy normally applies when operating in long term free running conditions. Since the SSU-L is a slave clock, then the normal operating modes are either locked or holdover. The frequency accuracy specification in holdover mode is specified in clause 9.

5 Pull-in and pull-out ranges

The minimum pull-in range shall be ±0,5 ppm, whatever the internal oscillator frequency offset may be. The pull-out range is for further study.

6 Noise generation

The noise generation of an SSU-L represents the amount of phase noise produced at the output when there is an ideal input reference signal or the clock is in holdover state. A suitable reference, for practical testing purposes, implies a performance level at least 10 times more stable than the output requirements. The ability of the clock to limit this noise is described by its frequency stability. The measures MTIE and Time Deviation (TDEV) are useful for characterization of noise generation performance.

For observation intervals, τ, between 0,1 and 10 000 s, Maximum Time Interval Error (MTIE) and Time DEViation (TDEV) are measured through an equivalent 10 Hz, first order, low-pass measurement filter, at a maximum sampling time τ_0 of 1/30 s. The minimum measurement period, T, for TDEV is twelve times the observation interval ($T = 12\tau$). Further guidance is provided in clause A.2 of EN 300 462-3-1 [4].

6.1 Wander in locked mode

When the SSU is in the locked mode of operation, the MTIE and TDEV measured using the synchronized clock configuration defined in figure 1a) of EN 300 462-1-1 [2] shall have the limits in tables 1 and 2, if the temperature is constant (±1 K).

Table 1: Wander in locked mode for constant temperature specified in TDEV

Requirement (ns)	Observation interval (s)
3 ns	$0,1 < \tau \leq 25$ s
$0,12\tau$ ns	$25 < \tau \leq 100$ s
12 ns	$100 < \tau \leq 10\,000$ s

Table 2: Wander in locked mode for constant temperature specified in MTIE

Requirement (ns)	Observation interval (s)
24 ns	$0,1 < \tau \leq 9$ s
$8\tau^{0,5}$ ns	$9 < \tau \leq 400$ s
160 ns	$400 < \tau \leq 10\,000$ s

The thick solid lines in figures 1 and 2 show the resultant requirements.

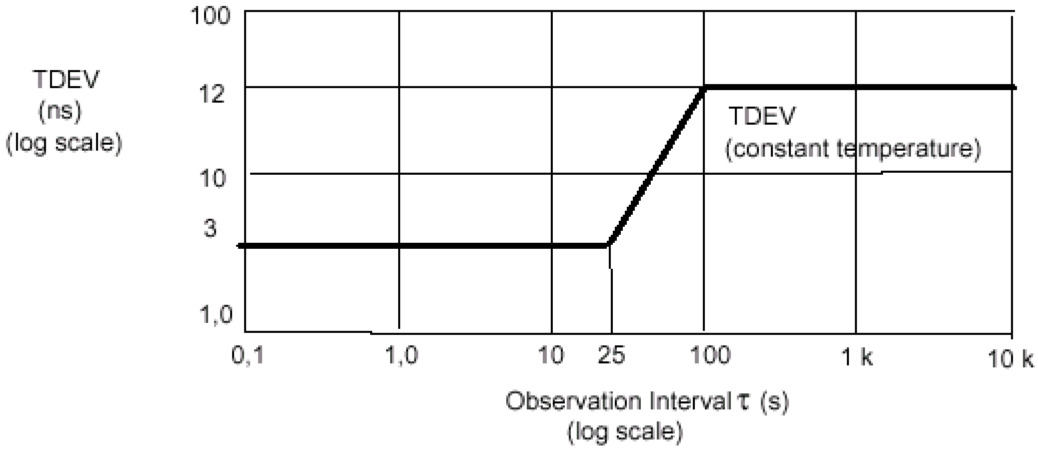

Figure 1: TDEV as a function of an observation interval τ

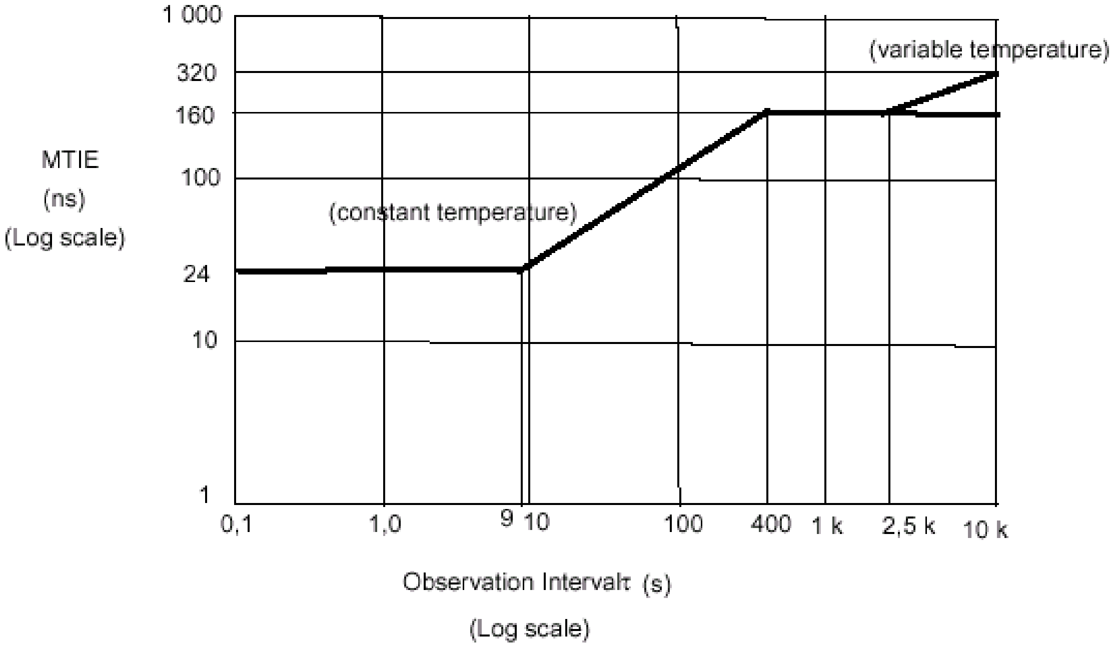

Figure 2: MTIE as a function of an observation interval τ

When temperature effects are included of which the limits and rate of change are defined in ETS 300 019 [1], corresponding to the environmental class to which the equipment belongs, the allowance for the total MTIE contribution of a single SSU-L is given by the values in table 3.

Table 3: Total Wander in Locked Mode for variable temperature specified in MTIE

Requirement (ns)	Observation interval (s)
$3{,}2\ \tau^{0{,}5}$	$2\,500 < \tau \leq 10\,000$

NOTE: For observation intervals greater than 10 000 s the MTIE is expected not to exceed 320 ns.

The upper solid line in figure 2 shows the resultant requirement.

6.2 Non-locked wander

When a clock is not locked to a synchronization reference, the random noise components are negligible compared to deterministic effects like initial frequency offset. Consequently the non-locked wander effects are included in clause 9.2.

6.3 Jitter

While most specifications in the present document are independent of the output interface at which they are measured, this is not the case for jitter production; jitter generation specifications shall utilize existing specifications that are currently specified differently for different interface rates. These requirements are stated separately for the interfaces identified in clause 10. To be consistent with other jitter requirements the specifications are in UIpp, where the UI corresponds to the reciprocal of the bit rate of the interface.

Due to the stochastic nature of jitter, the peak-to-peak values given in this clause eventually are exceeded. The requirements shall therefore be fulfilled with a probability of 99 %.

The functional description for measuring output jitter at a digital interface can be found in ITU-T Recommendation O.172 [11] and instrumentation in accordance with this Recommendation is appropriate for measurement of jitter in SDH systems.

The high-pass measurement filters of the following clauses have a single-order characteristic and a roll-off of 20 dB/decade. The low-pass measurement filters have a maximally flat, Butterworth characteristic and a roll-off of 60 dB/decade. Further specifications for the frequency response of the jitter measurement function such as measurement filter accuracy and additional allowed filter poles are given in ITU-T Recommendation O.172 [11].

6.3.1 Output jitter at a 2 048 kHz and 2 048 kbit/s interface

In the absence of input jitter, the intrinsic jitter at a 2 048 kHz or 2 048 kbit/s output interface as measured over a 60 seconds interval shall not exceed 0,05 UIpp when measured through a band-pass filter with corner frequencies at 20 Hz and 100 kHz.

6.3.2 Output jitter at a Synchronous Transport Module N (STM-N) interface

In the absence of input jitter at the synchronization interface, the intrinsic jitter at STM-N output interfaces as measured over a 60 seconds interval shall not exceed the limits given in table 4.

Table 4: Output jitter requirements for STM-N interfaces

Interface	Measuring filter Hz	Peak-to-peak amplitude UI
STM-1el.	500 to 1,3 M	0,50
	65 k to 1,3 M	0,075
STM-1opt.	500 to 1,3 M	0,50
	65 k to 1,3 M	0,10
STM-4	1 k to 5 M	0,50
	250 k to 5 M	0,10
STM-16	5 k to 20 M	0,50
	1 M to 20 M	0,10
NOTE: for STM-1: 1 UI = 6,43 ns; for STM-4: 1 UI = 1,61 ns; for STM-16: 1 UI = 0,40 ns.		

7 Noise tolerance

Noise tolerance of an SSU-L indicates the minimum phase noise level at the input of the clock that should be accommodated whilst:

- maintaining the clock within prescribed performance limits in locked mode of operation;
- not causing any alarms;
- not causing the clock to switch reference;
- not causing the clock to go into holdover.

In general, the noise tolerance is the same as the network limit for the synchronization interface in order to maintain acceptable performance. The jitter and wander tolerances given in clauses 7.1 and 7.2 represent the worst levels that a synchronization carrying interface should exhibit.

NOTE: Clocks may be used to monitor, in-service, the phase noise on an incoming timing reference signal. For such purposes different observation intervals and sampling times can be used. Guidance is provided in clause A.2 of EN 300 462-3-1 [4].

Combining the most stringent requirements from each specific data interface and presenting them as a single specification, which defines the performance of the SSU-L, have derived the requirements in clause 7.1. It is not expected that every synchronization interface should tolerate the full requirements in figure 3. Consequently when testing a specific interface (e.g. an STM-N), the interface is also bound by the jitter and wander tolerance limits defined in ITU-T Recommendations G.823 [10] and G.825 [9].

7.1 Jitter tolerance

The lower limits of maximum tolerable sinusoidal input jitter for signals carrying synchronization to SSU-Ls is given in figure 3 and table 5.

Table 5: Lower limit of maximum tolerable input jitter

Requirement (ns)	Frequency interval (Hz)
750	$1 < f \leq 2\ 400$
$1{,}8 \times 10^6\ f^{-1}$	$2\ 400 < f \leq 18\ 000$
100	$18\ 000 < f \leq 100\ 000$

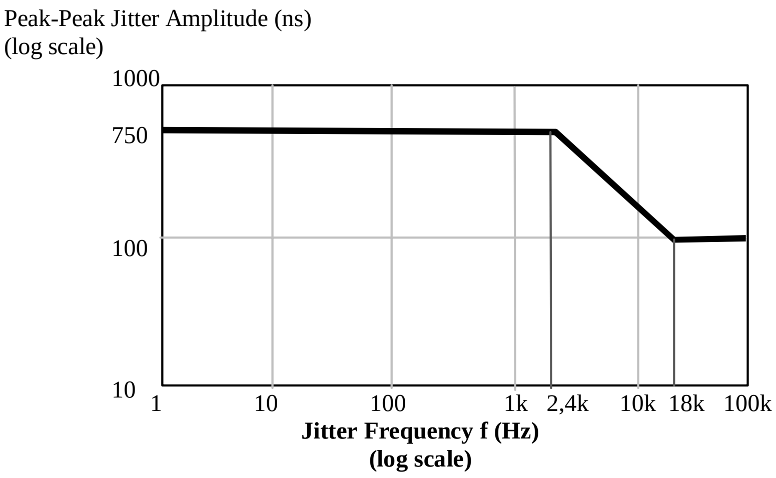

Figure 3: Lower limit of maximum tolerable sinusoidal input jitter

7.2 Wander tolerance

The clock shall tolerate input wander as specified in tables 6 and 7 (figures 4 and 5 respectively). The templates in these figures are intended to represent the cumulative network wander at the SSU-L clock input, i.e. for synchronization inputs the required wander tolerance is equal to the maximum expected network limit in the field.

For observation intervals of 0,1 s to 10 000 s, MTIE and TDEV shall be measured through an equivalent 10 Hz, first-order, low-pass measurement filter, at a maximum sampling time τ_0 of 1/30 seconds. The minimum measurement period T for TDEV is twelve times the observation interval τ.

Table 6: Input wander tolerance specified in TDEV

Requirement (ns)	Observation interval (s)
34	$0,1 < \tau \leq 20$
$1,7\tau$	$20 < \tau \leq 100$
170	$100 < \tau \leq 1\,000$
$5,4\tau^{0,5}$	$1\,000 < \tau \leq 10\,000$

Table 7: Input wander tolerance (MTIE)

Requirement (µs)	Observation interval (s)
0,75	$0,1 < \tau \leq 7,5$
$0,1\tau$	$7,5 < \tau \leq 20$
2	$20 < \tau \leq 400$
$0,005\tau$	$400 < \tau \leq 1\,000$
5	$1\,000 < \tau \leq 10\,000$

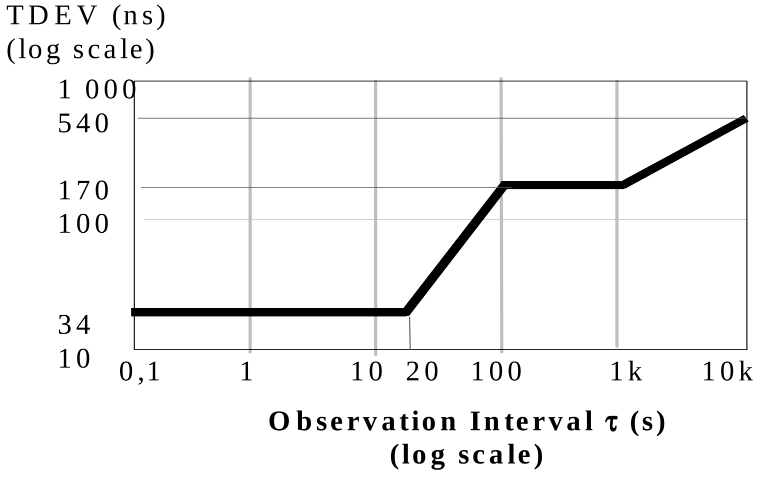

Figure 4: Input wander tolerance (TDEV)

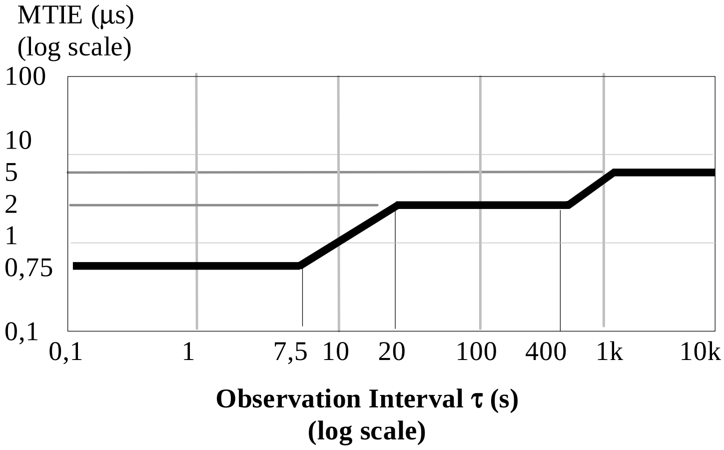

Figure 5: Input wander tolerance (MTIE)

While suitable test signals that check conformance to the masks in figure 5 are being studied, test signals with a sinusoidal phase variation can be used, according to the levels in table 8 and figure 6.

Table 8: Input wander Tolerance specified in Sinusoidal Input wander

Requirement (µs)	Frequency interval (Hz)
5	$0,000\ 012 < f \leq 0,000\ 32$
$0,001\ 6\ f^{-1}$	$0,000\ 32 < f \leq 0,000\ 8$
2	$0,000\ 8 < f \leq 0,016$
$0,032\ f^{-1}$	$0,016 < f \leq 0,043$
0,75	$0,043 < f \leq 1$

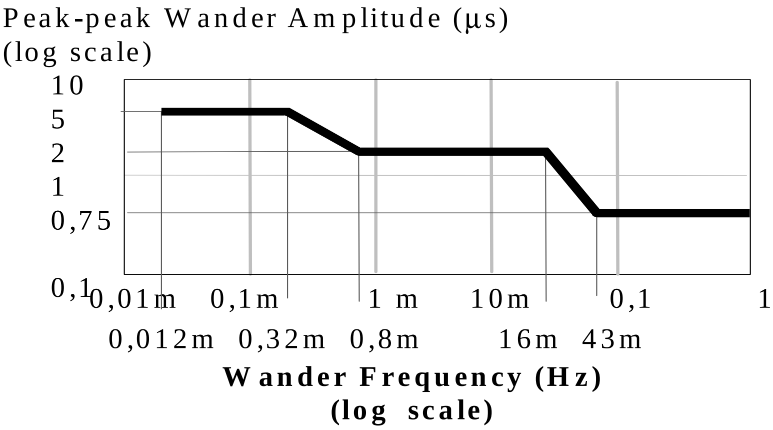

Figure 6: Lower limit of maximum tolerable sinusoidal input wander

8 Transfer characteristic

The transfer characteristic of the SSU-L determines its properties with regard to the transfer of excursions of the input phase relative to the phase modulation. Noise transfer can be described in two ways:

a) the SSU-L can be viewed as a low-pass filter for the differences between the actual input phase and the ideal input phase of the reference. The allowed bandwidth for this low-pass filter behaviour is:

- the maximum bandwidth of an SSU-L is 20 mHz;
- there is no limit specified for the minimum bandwidth.

In the pass band the maximum allowed phase gain of the SSU-L shall be smaller than 0,2 dB (2,3 %).

b) noise transfer describes the amount of noise impairment observed at the output, as a result of noise introduced at the input of the clock. The SSU-L clock, when subjected to a wideband noise signal shaped as prescribed in clause 7.2 (i.e. the TDEV input tolerance specification), shall produce an output signal that lies within the limits specified in table 9 and figure 7.

NOTE: The output wander mask shall include both intrinsic noise and pass-band phase gain.

Guidance on the measurement techniques for these requirements is given in annex B of EN 300 462-5-1 [6].

For observation intervals of 0,1 s to 10 000 s, MTIE and TDEV shall be measured through an equivalent 10 Hz, first-order, low-pass measurement filter, at a maximum sampling time τ_0 of 1/30 s. The minimum measurement period T for TDEV is twelve times the observation interval τ.

Table 9: Output wander mask specified in TDEV

TDEV limit (ns)	Observation interval τ (s)
3	$0,1 < \tau \leq 1,6$
$0,2 + 1,76\ \tau$	$1,6 < \tau \leq 100$
176	$100 < \tau \leq 1\ 000$
$5,58\ \tau^{0,5}$	$1\ 000 < \tau \leq 10\ 000$

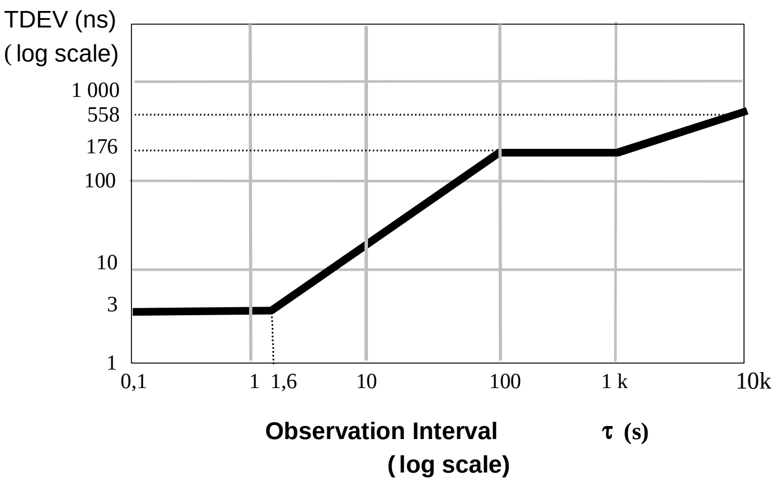

Figure 7: Output wander mask (TDEV)

9 Transient response and holdover performance

The specifications in this clause apply to situations where the input signal is affected by disturbances or transmission failures (e.g. short interruptions, switching between different synchronization signals, etc.) that result in phase transients at the SSU-L output (see clause 10). The ability to withstand specified disturbances is necessary to avoid transmission defects or failures. Transmission failures and disturbances are common stress conditions in the transmission environment.

To ensure transmission integrity it is recommended that all the phase movements at the output of the SSU-L stay within the level described in the following clauses.

9.1 Phase response during input reference switching

The present document reflects the performance of the clock in cases when the (selected) input reference is lost due to a failure in the reference path and a second reference input signal, traceable to the same reference clock, is available simultaneously or shortly after the detection of the failure (e.g. in cases of autonomous restoration). The output phase variation, relative to the input reference before it was lost, is bounded by the following requirements.

The phase error should not exceed 240 ns over the period T_y between the loss of reference and locking to an alternative reference. During T_y two-phase jumps are allowed that may occur upon loss of the current reference and the locking to a new reference. Each phase jump should not exceed 60 ns, with a temporary offset of no more than 7,5 ppm. During the rest of the duration of T_y, the frequency offset shall not exceed 1 x 10^{-9}.

The resultant overall specification is summarized in figure 8.

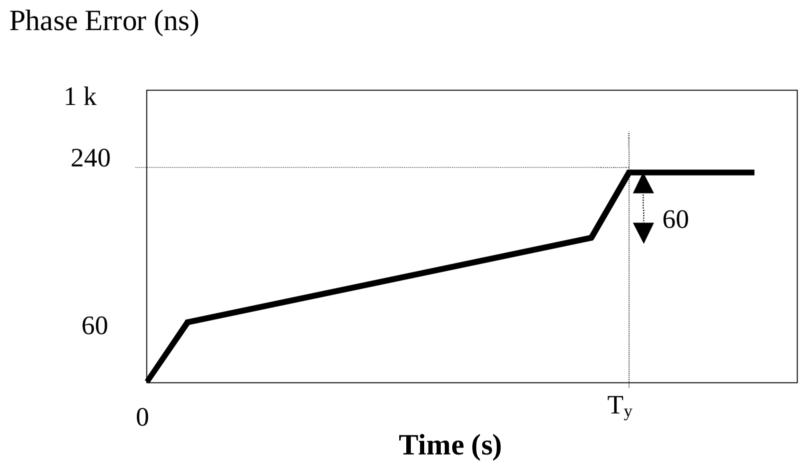

Figure 8: Maximum phase transient at the output due to reference switching

The figure is intended to depict the worst-case phase movement (240 ns) attributable to an SSU reference clock switch.

NOTE: Output phase excursion, when switching between references which are not traceable to the same clock, are for further study.

9.2 Phase response during Hold-over operation

The present document bounds the maximum excursions in the output timing signal. Additionally, it restricts the accumulation of the phase movement during input signal impairments or internal disturbances.

When an SSU-L loses its reference, it is said to enter the hold-over state. The phase error, ΔT, at the output of the SSU-L relative to the input at the moment of loss of reference should not exceed the following limit:

$$\Delta T(S) = \{(\boldsymbol{a_1} + \boldsymbol{a_2})\, S + 0{,}5\, \boldsymbol{b}\, S^2 + \boldsymbol{c}\} \text{ ns (see note 5);}$$

where:

Table 10: Transient response specification during hold-over

$\boldsymbol{a_1}$ (ns/s)	1,0 (see note 1)
$\boldsymbol{a_2}$ (ns/s)	10 (see note 2)
$\boldsymbol{b}$ (ns/s^2)	1,16 x 10^{-5} (see note 3)
$\boldsymbol{c}$ (ns)	60 (see note 4)

NOTE 1: The frequency offset $\boldsymbol{a_1}$ represents an initial frequency offset, corresponding to 1 x 10^{-9} (0,001 ppm).

NOTE 2: The frequency offset $\boldsymbol{a_2}$ accounts for temperature variations after the clock went into holdover and corresponds to 1 x 10^{-8} (0,01 ppm). If there are no temperature variations, the term $\boldsymbol{a_2}$ S should not contribute to the phase error.

NOTE 3: The drift $\boldsymbol{b}$ is caused by aging: 1,16 x 10^{-5} ns/s^2 corresponds to a frequency drift of 1 x 10^{-9}/day (0,001 ppm/day). This value is derived from typical aging characteristics after 60 days of continuous operation. It is not intended to measure this value on a per day basis as the temperature effect will dominate.

NOTE 4: The phase offset $\boldsymbol{c}$ takes care of any additional phase shift that may arise during the transition at the entry of the holdover state. During the transition, the temporary frequency offset on SDH output interfaces shall not exceed 7,5 ppm.

NOTE 5: During the period of holdover, with the exception of the period of transition into holdover (see note 4), the temporary frequency offset after S seconds shall not exceed ($\boldsymbol{a_1} + \boldsymbol{a_2} + \boldsymbol{b}$ S).

9.3 Phase response to input signal interruptions

For short term interruptions on synchronization input signals, that do not cause reference switching, the output phase variation is for further study.

9.4 Phase discontinuity

In cases of infrequent internal testing or other internal disturbances (including major hardware failures, that would give rise to clock equipment protection switches) within the SSU-L, the following conditions should be met on 2 Mbit/s and 2 MHz synchronization output interfaces:

- the phase variation over any period S up to 1 ms should not exceed 60 ns;
- the phase variation over any period S up to 4 s should not exceed 120 ns;
- for periods greater than 4 s, the phase variations should not exceed a total amount of 240 ns.

In case the SSU-L clock is built-in into SDH equipment, the temporary frequency offset at any STM-N output interface shall never exceed 7,5 ppm.

10 Interfaces

The requirements in the present document are related to reference points internal to the equipment or Network Element (NE) in which the clock is embedded and are therefore not necessarily available for measurement or analysis by the user. Therefore the performance of the SSU-L is not specified at these internal reference points, but rather at the external interfaces of the equipment, that are used for synchronization. The input and output interfaces are:

- 2 048 kHz external interfaces according to ETS 300 166 [8];
- 2 048 kbit/s interfaces according to ETS 300 166 [8];
- STM-N traffic interfaces.

NOTE: All of the above interfaces may not be implemented on all equipment. These interfaces should comply with the additional jitter, wander and frequency accuracy requirements as defined in the present document.

Annex A (informative): Bibliography

ETSI EN 300 462-6-1: "Transmission and Multiplexing (TM); Generic requirements for synchronization networks; Part 6-1: Timing characteristics of Primary Reference Clocks".

ITU-T Recommendation G.812 (1997): "Timing requirements of slave clocks suitable for use as node clocks in synchronization networks".

History

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