I n t e r n a t i o n a l   T e l e c o m m u n i c a t i o n   U n i o n

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

G.8273.2/Y.1368.2

Amendment 2
(08/2015)

SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Packet over Transport aspects – Synchronization, quality and availability targets

SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

Internet protocol aspects – Transport

Timing characteristics of telecom boundary clocks and telecom time slave clocks

Amendment 2

Recommendation ITU-T G.8273.2/Y.1368.2 (2014) – Amendment 2

ITU-T

International Telecommunication Union

ITU-T G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

INTERNATIONAL TELEPHONE CONNECTIONS AND CIRCUITS	G.100–G.199
GENERAL CHARACTERISTICS COMMON TO ALL ANALOGUE CARRIER-TRANSMISSION SYSTEMS	G.200–G.299
INDIVIDUAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON METALLIC LINES	G.300–G.399
GENERAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON RADIO-RELAY OR SATELLITE LINKS AND INTERCONNECTION WITH METALLIC LINES	G.400–G.449
COORDINATION OF RADIOTELEPHONY AND LINE TELEPHONY	G.450–G.499
TRANSMISSION MEDIA AND OPTICAL SYSTEMS CHARACTERISTICS	G.600–G.699
DIGITAL TERMINAL EQUIPMENTS	G.700–G.799
DIGITAL NETWORKS	G.800–G.899
DIGITAL SECTIONS AND DIGITAL LINE SYSTEM	G.900–G.999
MULTIMEDIA QUALITY OF SERVICE AND PERFORMANCE – GENERIC AND USER-RELATED ASPECTS	G.1000–G.1999
TRANSMISSION MEDIA CHARACTERISTICS	G.6000–G.6999
DATA OVER TRANSPORT – GENERIC ASPECTS	G.7000–G.7999
PACKET OVER TRANSPORT ASPECTS	G.8000–G.8999
Ethernet over Transport aspects	G.8000–G.8099
MPLS over Transport aspects	G.8100–G.8199
Synchronization, quality and availability targets	**G.8200–G.8299**
Service Management	G.8600–G.8699
ACCESS NETWORKS	G.9000–G.9999

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

Recommendation ITU-T G.8273.2/Y.1368.2

Timing characteristics of telecom boundary clocks and telecom time slave clocks

Amendment 2

Summary

Amendment 2 to Recommendation ITU-T G.8273.2/Y.1368.2 (2014) introduces the following changes:

– adds Recommendation ITU-T G.703 as a normative reference in clause 2
– adds TDEV requirements in clauses 7.1.2 and C.2.1.2
– adds note in clauses 7.3.1 and C.2.3.1
– replaces clause 7.4.2 and subclauses 7.4.2.1 and 7.4.2.2
– replaces Annex B
– replaces clause C.2.4.2 and subclauses C.2.4.2.1 and C.2.4.2.2
– adds clause C.2.6
– replaces Appendix II
– removes Appendices IV and V.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T G.8273.2/Y.1368.2	2014-05-14	15	11.1002/1000/12196
1.1	ITU-T G.8273.2/Y.1368.2 (2014) Amd. 1	2015-01-13	15	11.1002/1000/12395
1.2	ITU-T G.8273.2/Y.1368.2 (2014) Amd. 2	2015-08-13	15	11.1002/1000/12543

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

Recommendation ITU-T G.8273.2/Y.1368.2

Timing characteristics of telecom boundary clocks and telecom time slave clocks

Amendment 2

1) Clause 2, References

Add the following references in clause 2:

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

[ITU-T G.8273] Recommendation ITU-T G.8273/Y.1368 (2013), *Framework of phase and time clocks*.

2) Clause 7.1.2, Dynamic time error low-pass filtered noise generation (dTEL)

Renumber NOTE 2 as NOTE, and replace the following text:

The applicable time deviation (TDEV) is for further study.

NOTE 1 – This Recommendation is expected to include a normative TDEV mask similar to that contained in Appendix IV in order to constrain the frequency distribution of the noise. It is strongly suggested that implementations based on this Recommendation limit dynamic time error noise generation to meet at least the requirements of the TDEV mask contained in Appendix IV.

With:

For a Class A or Class B T-BC containing an EEC-Option 1 clock and operating in locked mode synchronized to both a wander-free time reference at the PTP input and a wander-free frequency reference at the SyncE/SDH input, the TDEV at the PTP and 1 PPS outputs, measured through a first-order low-pass filter with bandwidth of 0.1 Hz, should meet the limits in Table 7-5 under constant temperature (within ±1K).

Table 7-5 – Dynamic time error noise generation (TDEV) for T-BC with constant temperature

TDEV limit [ns]	Observation interval τ [s]
4	$m < \tau \le 1000$ (Notes 1, 2)
NOTE 1 – The minimum τ value *m* is determined by packet rate of 16 packet per second (*m*=1/16) or 1 PPS signal (*m*=1) NOTE 2 – The values in this table are valid for 1 PPS, 1 GbE and 10 GbE interfaces. Interfaces for rates above 10 GbE are for further study.	

3) Clause 7.3.1, PTP to PTP noise transfer

Renumber NOTE as NOTE 1 and add the following note after the newly numbered note:

NOTE 2 – At all permissible noise input levels, the gain peaking of 0.1dB from PTP to PTP, or 0.2dB from physical layer frequency to PTP is far lower than the permitted noise generation of the clock at the PTP and 1pps outputs. Therefore it may be difficult to verify the gain peaking at either the PTP or 1pps outputs

4) Clause 7.4.2, Holdover performance

Replace clause 7.4.2 and subclauses 7.4.2.1 and 7.4.2.2 with the following text:

7.4.2 Holdover performance

When a T-BC loses its PTP input references, it enters the phase/time holdover state. Under these circumstances, the T-BC may either rely on the holdover of a local oscillator, or on a physical layer frequency assistance reference traceable to a primary reference clock (PRC), or on a combination of both.

This requirement reflects the performance of the clock in cases when the PTP input is ideal followed by disconnection of the PTP input. For the case of phase/time holdover requirements based on physical layer frequency (T-BC performance with physical layer frequency assistance during loss of PTP input reference), the frequency physical layer input is ideal.

This requirement 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.

7.4.2.1 T-BC holdover

The phase/time holdover requirements applicable to a T-BC are for further study.

7.4.2.2 T-BC performance with physical layer frequency assistance during loss of PTP input reference

The phase/time output will be measured through a first order low-pass filter with bandwidth of 0.1 Hz.

The phase/time performance during loss of PTP input reference requirements based on physical layer frequency applicable to a T-BC under constant temperature conditions is shown in Table 7-6. Under constant temperature conditions the maximum observation interval is 1000 seconds.

Table 7-6 – Performance allowance during loss of PTP input (MTIE) for T-BC with constant temperature

MTIE limit [ns]	Observation interval τ [s]
$22 + 40\ \tau^{0.1}$	$1 \le \tau \le 100$
$22 + 25.25\ \tau^{0.2}$	$100 < \tau \le 1000$

The phase/time performance during loss of PTP input reference requirements based on physical layer frequency applicable to a T-BC under variable temperature conditions is shown in Table 7-7. Under variable temperature conditions the maximum observation interval is 10000 seconds.

Table 7-7 – Performance allowance during loss of packet signal input (MTIE) for T-BC with variable temperature

MTIE limit [ns]	Observation interval τ [s]
$22 + 40\ \tau^{0.1} + 0.5\ \tau$	$1 \le \tau \le 100$
$72 + 25.25\ \tau^{0.2}$	$100 < \tau \le 1000$
for further study	$1000 < \tau \le 10000$

5) Annex B

Replace Annex B with the following text:

Annex B

Control of transient due to rearrangements in the synchronous Ethernet network

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

A T-BC shall properly limit the generation of phase/time error due to a rearrangement of the physical layer frequency transport (e.g., SyncE, SDH) by using ingress QL information (e.g., ESMC message). In the worst-case, the input SyncE frequency will experience a re-arrangement transient as detailed in Figure 12 of [ITU-T G.8262] and Figure 12 of [ITU-T G.813]. When a SyncE/SDH rearrangement occurs, the T-BC may experience an initial output transient when the SyncE/SDH loses PRC-traceability and a second output transient when or after the SyncE/SDH again becomes PRC-traceable. The absolute value of T-BC output phase error shall meet the following requirements when these transients occur:

a) The T-BC output phase error at the PTP and 1 PPS outputs shall not exceed the mask of Figure B.1 and Table B.1 below.

NOTE – The mask of Figure B.1 assumes that the SyncE signal loses PRC traceability at time zero and becomes traceable again at 15 s (i.e., the SyncE transient is completed by 15 s). The re-establishment of PRC-traceability will be earlier in smaller rings; the exact time depends on the number of EECs/SECs in the ring and the exact values of the SSM message delays. The mask is extended to 50 s to allow time for the T-BC to either re-acquire the SyncE signal or begin using the T-BC filter again after PRC-traceability has been re-established.

The SyncE transient test is done without a measurement filter and should exclude any constant time error. Ideally, the absolute value of unfiltered dTE is desired.

See Appendix II for background on the assumptions and derivations for the masks of Figure B.1 and Table B.1.

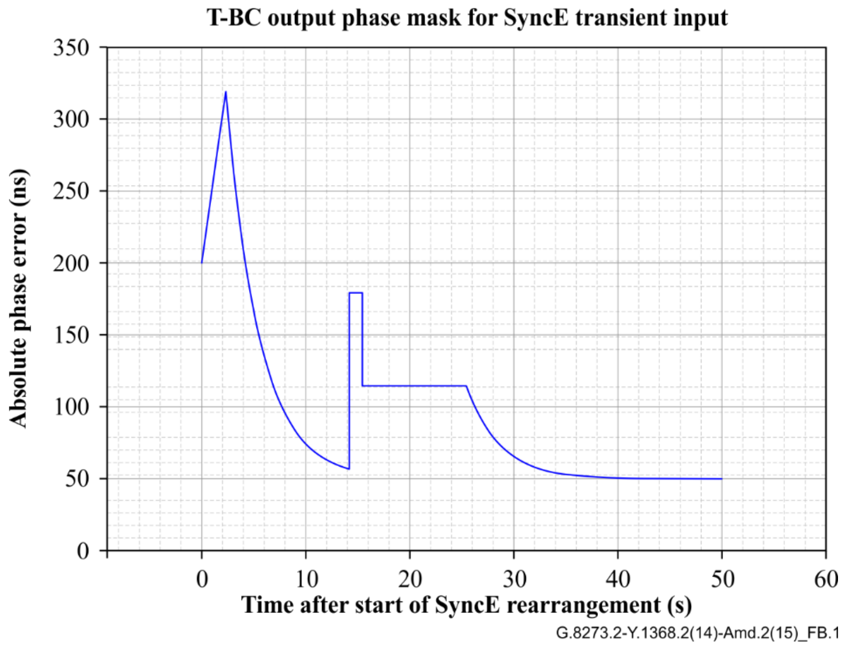

Figure B.1 – Phase error limit for output phase error transient after the start of the SyncE/SDH rearrangement

Table B.1 – T-BC output phase transient mask for output transient after start of SyncE/SDH rearrangement (at and just after loss of PRC-traceability by the SyncE/SDH signal)

Time *S* after start of SyncE/SDH rearrangement (s)	T-BC output absolute phase error (ns)
$0 \le S < 2.4$	$200 + 50S$
$2.4 \le S < 14.25$	$50 + 270\, e^{-2\pi(0.05)(S-2.4)}$
$14.25 \le S < 15.5$	180
$15.5 \le S < 25.5$	115
$25.5 \le S \le 50$	$50 + 65\, e^{-2\pi(0.05)(S-25.5)}$

NOTE – As per [ITU-T G.8264] SSM might be disabled by the operator. The impact on the mitigation of time error due to SyncE/SDH rearrangement when not using SSM is under the responsibility of the operator and is for further study.

6) Clause C.2.1.2, Dynamic time error low-pass filtered noise generation (dTEL)

i) Replace the following text:

The applicable TDEV is for further study.

NOTE 1 – This Recommendation is expected to include a normative TDEV mask similar to that contained in Appendix V in order to constrain the frequency distribution of the noise. It is strongly suggested that implementations based on this recommendation limit dynamic time error noise generation to meet at least the requirements of the TDEV mask contained in Appendix V.

With:

For a Class A or Class B T-TSC containing an EEC-Option 1 clock, and operating in locked mode synchronized to both a wander-free time reference at the PTP input and a wander-free frequency reference at the SyncE/SDH input, the TDEV at the 1 PPS output, measured through a first-order low-pass filter with bandwidth of 0.1 Hz, should meet the limits in Table C.5 under constant temperature (within ±1K).

Table C.5 – Dynamic time error noise generation (TDEV) for T-TSC with constant temperature

TDEV limit [ns]	Observation interval τ [s]
4	$1 < \tau \le 1000$

ii) Renumber NOTE 2 as NOTE

7) Clause C.2.3.1, PTP to 1 PPS noise transfer

Renumber NOTE as NOTE 1 and add the following note after the newly numbered note:

NOTE 2 – At all permissible noise input levels, the gain peaking of 0.1 dB from PTP to 1 PPS, or 0.2 dB from physical layer frequency to 1 PPS is far lower than the permitted noise generation of the clock at the PTP and 1 pps outputs. Therefore it may be difficult to verify the gain peaking at either the PTP or 1 pps outputs.

8) Clause C.2.4.2, Holdover performance

Replace clause C.2.4.2 and subclauses C.2.4.2.1 and C.2.4.2.2 with the following text:

C.2.4.2 Holdover performance

When a T-TSC loses its PTP input references, it enters the phase/time holdover state. Under these circumstances, the T-TSC may either rely on the holdover of a local oscillator, or on a physical layer frequency assistance reference traceable to a primary reference clock (PRC), or on a combination of both.

This requirement reflects the performance of the clock in cases when the PTP input is ideal followed by disconnection of the packet signal input. For the case of phase/time holdover requirements based on physical layer frequency (T-TSC performance with physical layer frequency assistance during loss of PTP input reference), the frequency physical layer input is ideal.

This requirement 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.

C.2.4.2.1 T-TSC holdover

The phase/time holdover requirements applicable to a T-TSC are for further study.

C.2.4.2.2 T-TSC performance with physical layer frequency assistance during loss of PTP Input Reference

The phase/time output will be measured through a first order low-pass filter with bandwidth of 0.1 Hz.

The phase/time performance during loss of PTP input reference requirements based on physical layer frequency applicable to a T-TSC under constant temperature conditions is shown in Table C.6. Under constant temperature conditions the maximum observation interval is 1000 seconds.

Table C.6 – Performance allowance during loss of PTP input (MTIE) for T-TSC with constant temperature

MTIE limit [ns]	Observation interval τ [s]
$22 + 40\tau^{0.1}$	$1 \le \tau \le 100$
$22 + 25.25\tau^{0.2}$	$100 < \tau \le 1000$

The phase/time performance during loss of PTP input reference requirements based on physical layer frequency applicable to a T-TSC under variable temperature conditions is shown in Table C.7. Under variable temperature conditions the maximum observation interval is 10000 seconds.

Table C.7 – Performance allowance during loss of PTP input (MTIE) for T-TSC with variable temperature

MTIE limit [ns]	Observation interval τ [s]
$22 + 40\tau^{0.1} + 0.5\tau$	$1 \le \tau \le 100$
$72 + 25.25\tau^{0.2}$	$100 < \tau \le 1000$
for further study	$1000 < \tau \le 10000$

9) Clause C.2.6

Add the following clause C.2.6 after clause C.2.5:

C.2.6 T-TSC performance measurement

It is necessary to provide means for measuring the T-TSC performance (including when deployed in the field.

The use of 1 PPS 50 Ω phase-synchronization measurement output physical interface is the recommended way to perform performance measurement and analysis of the T-TSC (see [ITU-T G.703]). When time of day information is to be tested other interfaces should be considered (e.g., 1 PPS V.11 interface, see [ITU-T G.703]).

NOTE 1 – For cases when provisioning of dedicated testing interface is not feasible (e.g., due to equipment dimension such as equipment related to small cell environments), other means should be provided. This is for further study.

NOTE 2 – It may be beneficial to also measure the performance at the output of the end application (e.g., in the case of radio base stations at the radio interface output), the definition of the related methods are under responsibility of the relevant standardization body.

10) Appendix II

Replace Appendix II with the following text:

Appendix II

Derivation of T-BC output transient mask due to SyncE/SDH rearrangement

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

The absolute value of T-BC output phase transient due to a SyncE/SDH rearrangement is derived for the following two mitigation schemes:

a) Reject the SyncE/SDH signal on receipt of the SSM that indicates the SyncE/SDH is no longer PRC-traceable, and

b) Turn off the T-BC filter on receipt of the SSM that indicates the SyncE/SDH is no longer PRC-traceable

In the derivation, the input transient is assumed to be as specified in Figure 12 of [ITU-T G.8262], with the initial 120 ns phase change starting at time zero and the final 120 ns phase change ending 15 s later. The output transients for schemes (a) and (b) are obtained and the transient mask is taken as the upper envelope of these two output transients.

II.1 Background on assumptions for and derivation of, T-BC output phase error due to a SyncE/SDH rearrangement

The T-BC output phase error mask of Figure B.1 of Annex B of this Recommendation is based on two possible techniques for mitigating the output phase error due to the HRM2 rearrangement. With the first technique, the EEC co-located with the T-BC informs the T-BC that the SyncE/SDH is no longer PRC-traceable when the EEC receives the SSM indicating this. When the T-BC is notified, it rejects the SyncE/SDH transient and operates in the pure PTP mode (i.e., without the use of SyncE/SDH to recover frequency). When the EEC switches a second time and is again PRC-traceable, it informs the T-BC. The T-BC then reacquires the SyncE/SDH signal. The T-BC typically waits at least 10 s after it is informed that the SyncE/SDH is again traceable to reacquire the SyncE/SDH, to ensure that the SyncE/SDH transient is completed; however, the important condition is that the mask of Figure B.1 is satisfied (i.e., the T-BC can reacquire the SyncE/SDH signal before 10 s have elapsed if it can satisfy the mask).

With the second technique, the T-BC filter is turned off when the T-BC is notified by the EEC that the SyncE/SDH is no longer traceable (i.e., when the EEC receives the SSM indicating this). The turning off of the filter means that it is no longer applied to the incoming PTP signal (as a low-pass filter) or to the SyncE/SDH signal (as a high-pass filter). When the T-BC is notified by the EEC that the SyncE/SEC is again traceable, the filter is again turned on. As with the first technique, the T-BC typically waits at least 10 s after it is informed that the SyncE/SDH is again traceable to turn the filter on, to ensure that the SyncE/SDH transient is completed; however, the important condition is that the mask of Figure B.1 is satisfied (i.e., the T-BC can turn the filter back on before 10 s have elapsed if it can satisfy the mask). To avoid a transient when the T-BC filter is turned back on, the filter continues to operate on the SyncE/SDH signal (with the SyncE/SDH transient present) and the PTP signal and the state of the filter is computed throughout the transient (i.e., at each sampling instant). However, the filter output is not used while the filter is turned off; the computations are done only so that the filter state will be known. When the filter is turned back on, the computed filter state at that instant is used as the initial state.

The mask of Figure B.1 is obtained by computing the absolute value of T-BC filter output phase error history, for each of the above techniques, assuming the SyncE/SDH undergoes the transient of Figure 12 of [ITU-T G.8262]. With each technique, it is found that the T-BC filter output history contains an initial transient when SyncE/SDH traceability is lost and a second transient when or shortly after SyncE/SDH traceability is regained. The actual duration of the time interval between the two transients depends on how large the EEC ring is (the interval is longer for larger rings). However, in Figure 12 of [ITU-T G.8262] the time interval between the start of the initial transient (i.e., the first 120 ns phase change at a rate of 7.5 ppm) and the start of the second transient (i.e., the second 120 ns phase change at a rate of 7.5 ppm) is 14.984 s.

The steady-state T-BC noise generation requirements are:

1) max|TE| limit of 100 ns for class A and 70 ns for class B (see Table 7-1 in clause 7.1).
2) cTE limit of ±50 ns for class A and ±20 ns for class B (see Table 7-2 in clause 7.1.1).
3) dTE MTIE limit of 40 ns, measured through a 0.1 Hz low-pass filter (see Table 7-3 in clause 7.1.2). This 40 ns includes the effect of EEC noise generation and timestamp granularity.
4) dTE high-frequency noise limit of 70 ns peak-to-peak, measured through a 0.1 Hz high-pass filter (see clause 7.1.3).

The SyncE transient test is done without a measurement filter and should exclude any constant time error. Ideally, the absolute value of unfiltered dTE is desired.

Simulations showed that the unfiltered dTE does not exceed 80 ns peak-to-peak. While selected results were not highly asymmetric, they did exhibit some asymmetry. To allow margin for some asymmetry, it will be assumed that the unfiltered dTE max|TE| is 50 ns. It is further assumed that the 50 ns maximum dTE is due to steady-state SyncE/SDH noise accumulation and timestamp granularity. Any phase error due to the SyncE/SDH rearrangement is added to this. Note that this value does not include the inherent random noise generation in the T-BC, as this has not yet been specified in [ITU-T G.8273.2]; once it is specified, it needs to be considered. In addition, this value does not include cTE. If it is not convenient to remove cTE, this must be added to the mask derived below, i.e., the total max|TE| from Table 1 (100 ns for class A and 70 ns for class B) must be used instead of the assumed 50 ns zero-to-peak for dTE.

In all cases, we assume the T-BC input is a PTP packet timing signal with mean Sync message rate of 16 messages/s. If other assumptions were made, e.g., if the input timing signal were 1 PPS instead of PTP, or if packet selection were performed that caused the mean rate of selected Sync message to be less than 16 messages/s, these cases would need to be analysed. In addition, the T-BC output phase computed is the actual phase (time) error; there is no additional measurement filter.

Note that in Figure III.2 of [ITU-T G.8273], which gives the input SyncE transient used in testing, the 120 ns phase changes and 50 ns/s phase rate of change are reduced to 104 ns and 45 ns/s respectively. This was done to allow some margin in the test. The mask is derived here using the input transient of Figure 12 of [ITU-T G.8262].

In addition, Appendix III of [ITU-T G.8273] presents three test methods. In the analysis here, we make conservative assumptions to produce a single mask that is applicable to all three methods. In particular, the input transient of Figure 12 of [ITU-T G.8262] is assumed to be the transient output of the EEC/SEC, which is input to the T-BC (but subject to the assumptions of the two schemes). This is subject to the assumptions that (a) in Method I of Appendix III of [ITU-T G.8273] the filtering of the EEC/SEC can be neglected, and (b) in Method II of Appendix III of [ITU-T G.8273] the output of the EEC/SEC does not exceed the mask of Figure 12 of [ITU-T G.8262] when the SyncE/SDH signal input to interface Y (Figure III.1 of [ITU-T G.8273]) is cut off. Method III of Appendix III of [ITU-T G.8273] is less stringent, because in this method the ESMC QL is changed but no SyncE/SDH transient is applied.

The following are the assumptions made in computing the T-BC output phase error due to the SyncE/SDH rearrangement, using the first technique, i.e., rejection of the SyncE/SDH transient:

a) The input transient to the T-BC at interface Y of Figure III of [ITU-T G.8273] is given by Figure 12 of [ITU-T G.8262].

b) The input PTP packet signal (i.e., carried by Sync and Delay_Req messages) is perfect, i.e., there is no phase error associated with this signal.

c) The T-BC filter bandwidth is 0.05 Hz. This is the minimum T-BC and T-TSC bandwidth. It is modelled as a first-order filter, and gain peaking is not modelled.

d) The EEC co-located with the T-BC receives an input SSM, indicating the SyncE signal is no longer PRC-traceable. This occurs 500-2000 ms after the transient begins and represents the holdover message delay, i.e., T_{HM}. Clause 5.14 of [ITU-T G.781] specifies that T_{HM} is in this range.

e) The EEC co-located with the T-BC sends to the T-BC, via interface Z of Figure III.1 of [ITU-T G.8273], an SSM indicating it is no longer PRC-traceable between 0 and 200 ms after it receives the changed SSM. This is the non-switching message delay (see clause 5.14 of [ITU-T G.781]). This delay is due to software processing in the EEC.

f) The SyncE/SDH transient is rejected by the T-BC after a time interval has elapsed following the receipt of the SSM. This delay is due to software processes in the T-BC; it is approximated as having an upper bound that is equal to the non-switching message delay, i.e., 200 ms in clause 5.14 of [ITU-T G.781] and a lower bound of zero.

g) There is a 30 ns phase jump at the T-BC input when the SyncE/SDH is rejected and a 60 ns phase jump when it is reacquired (simulations showed that max|TE| for HRM2, for a chain of 20 T-BCs, could be kept to within 200 ns with these phase jumps).

h) The initial part of the SyncE/SDH transient is a 7.5 ppm phase ramp over 16 ms, followed by a 50 ns/s phase ramp, followed by a 30 ns phase jump when the SyncE/SDH signal is rejected. Based on (d), (e), and (f), the earliest the rejection can occur is at 0.5 s (500 ms) after the PRC-traceability is lost. The latest the rejection can occur is at 2.4 s (2400 ms) after PRC-traceability is lost. The 30 ns phase jump can therefore occur anywhere between 500 ms and 2.4 s; to accommodate the worst case, we must take the envelope of all possibilities. For this envelope, we have an initial 7500 ns/s slope until the time error changes by 120 ns, followed by a 50 ns/s slope to time 500 ms, followed by a 30 ns phase step, followed by a 50 ns/s slope to time 2400 ms. A constant 50 ns phase is added to this entire transient to account for the phase error due to steady-state SyncE/SDH phase noise (see above).

i) The phase increases described in (g) are assumed to be rapid enough that they are above the 0.1 Hz T-BC filter corner frequency. Since the T-BC filter acts as a high-pass filter on the SyncE/SDH signal, this initial part of the SyncE/SDH transient is passed through the filter approximately unaffected, and the effect of the high-pass filtering can be ignored. This assumption is conservative, as accounting for the high-pass filter could only decrease the output phase error.

NOTE – There exist signals for which the zero-to-peak and peak-to-peak values are increased by high-pass filtering, e.g., a square wave whose period is much longer than the high-pass filter time constant, i.e., much smaller than the high-pass filter corner frequency. However, the signal of Figure 12 of [ITU-T G.8262] above is not in this category.

j) At 2.4 s, the SSM is received by the T-BC and the SyncE/SDH signal is rejected. The T-BC output phase error is an exponential decay with time constant 1/(2π*0.05 Hz) due to the relaxation of the filter.

k) At time 14.984 s after the start of the transient, the SyncE/SDH undergoes a 120 ns phase change, at a rate of 7.5 ppm, and is traceable again. Between 180 ms and 500 ms after this (this is the range for the switching message delay specified in clause 5.14.1 of [ITU-T G.781]), the EEC/SEC sends an SSM indicating this to the T-BC. At some time within 10 s of this, the SyncE signal is restored, and there is a 60 ns phase step, followed by an exponential decay with time constant 1/(2π*0.05 Hz) to the 50 ns level. The means that the 60 ns phase step can occur at any time between 14.984 s + 0.18 s = 15.164 s, and 14.984 s + 0.5 s + 10 s = 25.484 s. The resulting mask will be taken as the upper envelope of all possible 60 ns phase steps in the range 15.164-25.484 s, with each phase step followed by an exponential decay.

The following assumptions were made in computing the T-BC output phase error due to the SyncE/SDH rearrangement, using the second technique, i.e., turning off the T-BC filter:

l) This assumption is the same as assumption (a) above for rejection of the SyncE/SDH signal.

m) This assumption is the same as assumption (b) above for rejection of the SyncE/SDH signal.

n) This assumption is the same as assumption (c) above for rejection of the SyncE/SDH signal.

o) This assumption is the same as assumption (d) above for rejection of the SyncE/SDH signal.

p) This assumption is the same as assumption (e) above for rejection of the SyncE/SDH signal.

q) The T-BC filter is turned off after a time interval has elapsed following the receipt of the SSM. This delay is due to software processes in the T-BC; it is taken to have an upper bound equal to the non-switching message delay, i.e., 200 ms in clause 5.14 of [ITU-T G.781], and a lower bound of zero. When the next Sync message is received, an immediate correction to the time is made. While this Sync message carries the GM time, the T-BC phase error immediately after the correction is not zero because the most recent mean propagation delay computation was, in worst-case, based on previously received Sync and Delay_Req messages whose arrival and departure, respectively, were timestamped during the SyncE/SDH transient. The mean propagation delay is given by $[(T_4 - T_1) - (T_3 - T_2)]/2$. If we assume that the time interval between the receipt of the most recent Sync and the most recent Delay_Req is, in worst-case, two mean Delay_Req intervals, then the error in mean propagation delay is equal to the accumulated phase error over these two mean Delay_Req intervals, divided by 2. This value is (2)(0.0625 s)(50 ns/s)/2 = 3.125 ns. Then, the T-BC phase error due to the SyncE/SDH transient decreases to 3.125 ns above the 50 ns steady-state error, or 53.125 ns, when this next Sync message is received. This occurs at most 0.125 s later, or at 2.525 s (i.e., at most two mean Sync intervals, since it is assumed that the actual time between Sync messages is bounded by 2 mean Sync intervals). When the next Sync message after this one is received, which is at most 0.125 s after 2.525 s, or 2.65 s, the T-BC phase error decreases to 50 ns.

r) Between 2.65 s and when the SyncE/SDH signal is again traceable, at 14.984 s, the SyncE/SDH signal has a 50 ns/s frequency offset. This means that, since T-BC filtering is turned off, the T-BC phase error increases by (50 ns/s)(0.125 s) = 6.25 ns over the interval between successive Sync messages (the inter-message interval is taken as 0.125 s because clause 6.2.8 of [ITU-T G.8275.1] specifies that the actual Sync interval must not exceed two mean Sync intervals). When the next Sync message is received, this component of the phase error decreases to zero and then increases again until the next Sync message is received. The actual output transient over this time interval is a sawtooth. Since, as will be seen later, the time error for the first technique (i.e., rejecting the SyncE transient) is larger over most of the interval between 2.45 s and 14.984 s, we approximate this component of error by simply adding a constant 6.25 ns. Then, in (q) above, we approximate the error as 59.375 in the range 2.525-2.65 s, and 56.25 ns in the range 2.65-14.984 s.

s) When the SyncE/SDH is again traceable, at 14.984 s, the second 120 ns phase change over 16 ms interval (i.e., a 7500 ppm phase ramp) appears on the T-BC output. This 120 ns phase error lasts for at most 2 Sync intervals (i.e., as indicated above, this is the longest interval that elapses before the next Sync message is received, because clause 6.2.8 of [ITU-T G.8275.1] specifies that the actual Sync interval must not exceed two mean Sync intervals) and then the error is immediately corrected because the T-BC filter is still turned off. The SSM is received between 180 ms and 500 ms later (i.e., in the range 15.164-15.484 s) indicating the SyncE/SDH is again traceable and the T-BC filter is turned back on between 0 and 10 s later (i.e., in the range 15.164-25.484 s). As was the case when the T-BC filter was turned off (see (q) above), there is still phase error due to the fact that the most recent Sync and Delay_Req messages, which were used for the most recent propagation delay measurement, occurred during the transient when the SyncE/SDH reacquires its reference. In this case, the worst-case is when T_2 was taken just when the SyncE/SDH again became traceable, and T_3 was taken 0.125 s later. The phase error during this interval between the T_3 and T_2 timestamps is [(0.016 s)(7500 ns/s) + (0.125 s – 0.016 s)(0 ns/s)]/2 = 60 ns. Then, on receipt of the next Sync message after the T-BC filter is turned on, the T-BC phase error decreases to 56.25 ns + 60 ns = 116.25 ns. When the next Sync message is received 0.125 s after this, the T-BC phase error decreases to 50 ns.

The above assumptions (a) – (q) produce the T-BC output transients given in Tables II.1 and II.2. In addition to these assumptions, the SyncE/SDH signal was assumed to again be PRC-traceable after 15 s. The transients are continued to 50 s after the loss of traceability. The transients are shown in Figure II.1.

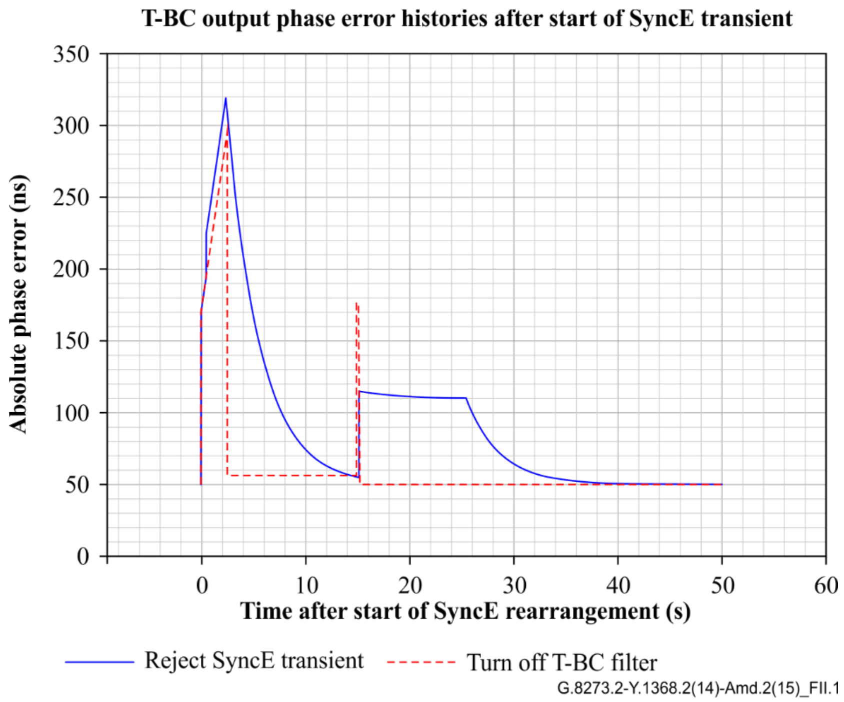

Figure II.1 – T-BC output phase error histories for each of the two techniques, assuming SyncE/SDH transient starts at time zero

Table II.1 – T-BC output phase error history using scheme (a) (rejection of SyncE/SDH transient)

Time *S* after start of SyncE/SDH rearrangement (s)	T-BC output absolute phase error (ns)
$0 \le S < 0.016$	$50 + 7500S$
$0.016 \le S < 0.5$	$170 + 50(S – 0.016)$
$0.5 \le S < 2.4$	$224.2 + 50(S – 0.5)$
$2.4 \le S < 15.164$	$50 + 269.2e^{-2\pi(0.05)(S-2.4)}$
$15.164 \le S \le 25.484$	$110 + 269.2\, e^{-2\pi(0.05)(S-2.4)}$
$25.484 \le S \le 50$	$50 + 60.193\, e^{-2\pi(0.05)(S-25.484)}$

Table II.2 – T-BC output phase error history using scheme (b) (turning off T-BC filter during SyncE/SDH transient)

Time *S* after start of SyncE/SDH rearrangement (s)	T-BC output absolute phase error (ns)
$0 \le S < 0.016$	$50 + 7500S$
$0.016 \le S < 2.525$	$170 + 50(S – 0.016)$
$2.525 \le S < 2.65$	59.375
$2.65 \le S < 14.984$	56.25
$14.984 \le S < 15.0$	$56.25 + 7500(S – 14.984)$
$15.0 \le S < 15.125$	176.25
$15.125 \le S < 15.25$	116.25
$15.25 \le S \le 50$	50

Figure II.1 and Table II.2 show that the output transient for scheme (b) (turning off the T-BC filter during the transient) contains a very sharp, narrow peak between 14.984 s and 15.25 s, i.e., over a period of 0.266 s. This peak is due to the second phase jump of 120 ns beginning at 14.984 s and ending at 15 s. In a test, the test set would have to begin and end the phase jump at exactly these times, otherwise the actual peak would occur at slightly different times and the equipment might fail. It would be desirable to allow some margin for the test set; this can be done by allowing the phase jump to begin as early as 14.5 s and end as late as 15.5 s (i.e., allow the phase jump to occur at any time during a 1 s interval). If this is done, the mask for scheme (b) must be computed as the envelope of all possible output transients with the second phase jump occurring during this interval. The modified output mask for scheme (b) is shown in Figure II.2 and Table II.3.

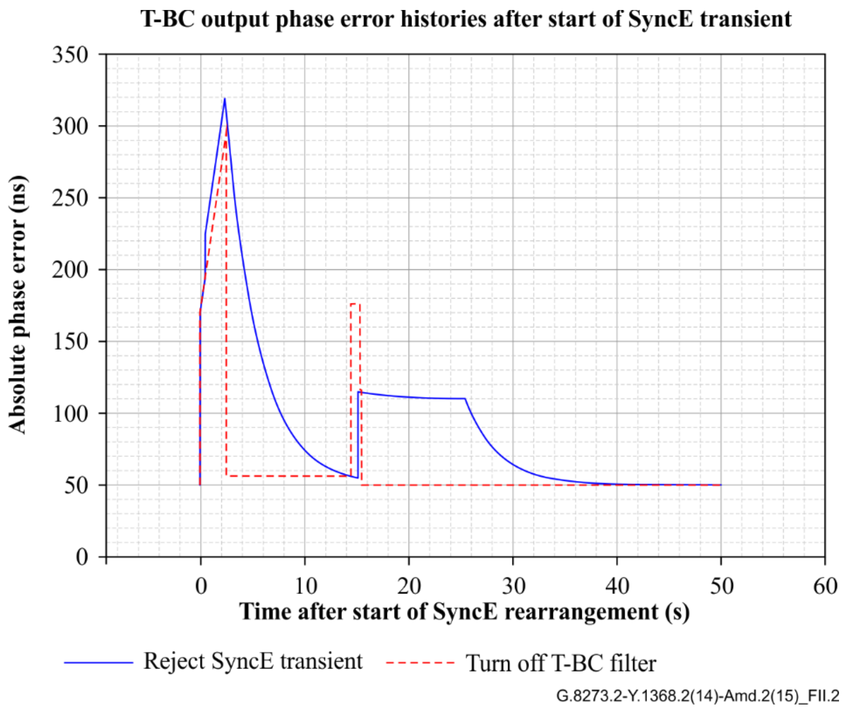

Figure II.2 – T-BC output phase error histories for each of the two techniques, assuming SyncE/SDH transient starts at time zero, and allowing 1 s of margin for the time of second 120 ns phase jump for scheme (b)

Table II.3 – Modified T-BC output phase error history using scheme (b) (turning off T-BC filter during SyncE/SDH transient), allowing 1 s of margin for time of second 120 ns phase jump

Time *S* after start of SyncE/SDH rearrangement (s)	T-BC output absolute phase error (ns)
$0 \le S < 0.016$	$50 + 7500S$
$0.016 \le S < 2.525$	$170 + 50(S - 0.016)$
$2.525 \le S < 2.65$	59.375
$2.65 \le S < 14.5$	56.25
$14.5 \le S < 14.516$	$56.25 + 7500(S - 14.5)$
$14.516 \le S < 15.375$	176.25
$15.375 \le S < 15.5$	116.25
$15.5 \le S \le 50$	50

Finally, note that the Figure II.2 and Table II.3 mask is still somewhat complex for observation intervals in the range 14.5-15.5 s. The mask can be simplified by allowing it to take on the maximum level in this range, i.e., 176.25 ns. The result is given in Figure II.3 and Table II.4.

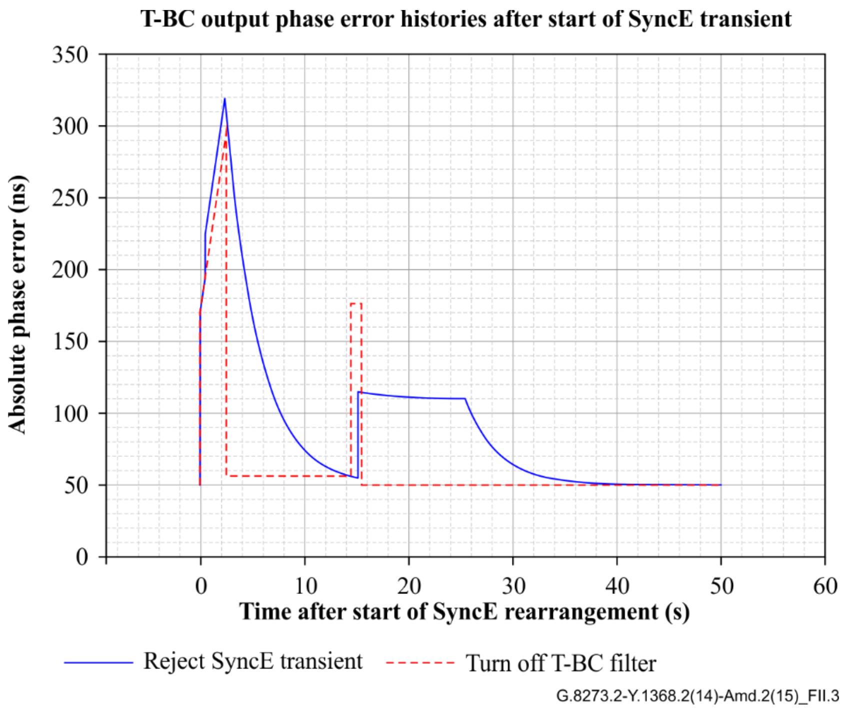

Figure II.3 – T-BC output phase error histories for each of the two techniques, assuming SyncE/SDH transient starts at time zero, and allowing 1 s of margin for the time of second 120 ns phase jump for scheme (b)

Table II.4 – Modified T-BC output phase error history using scheme (b) (turning off T-BC filter during SyncE/SDH transient), allowing 1 s of margin for time of second 120 ns phase jump

Time *S* after start of SyncE/SDH rearrangement (s)	T-BC output absolute phase error (ns)
$0 \le S < 0.016$	$50 + 7500S$
$0.016 \le S < 2.525$	$170 + 50(S – 0.016)$
$2.525 \le S < 2.65$	59.375
$2.65 \le S < 14.5$	56.25
$14.5 \le S < 15.5$	176.25
$15.5 \le S \le 50$	50

II.2 T-BC output phase transient mask

The T-BC output phase transient mask is taken as the upper envelope of the two output transients of Tables II.1 and II.4 and Figure II.3 above. This is given by the mask of Figure II.4 and Table II.5 below.

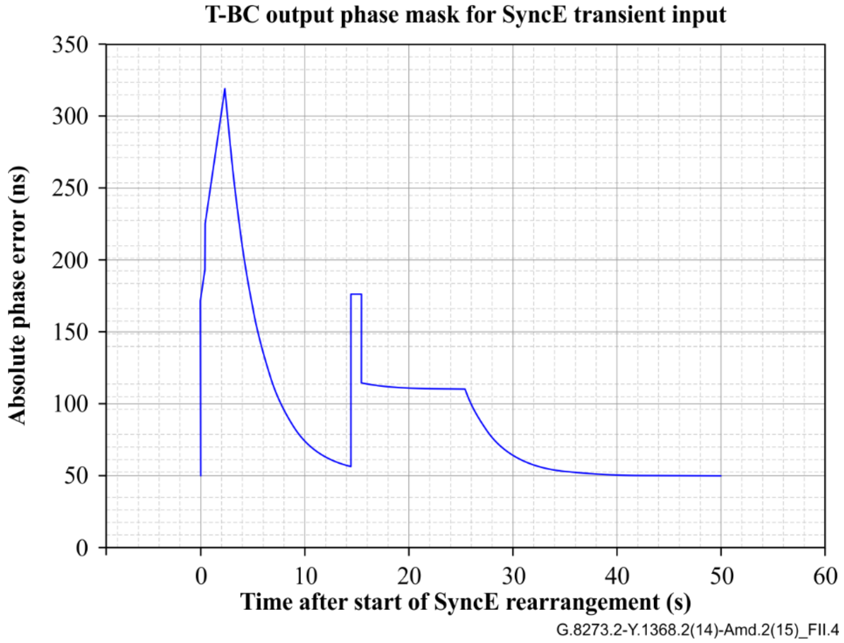

Figure II.4 – Upper envelope of masks of Figure II.3 and Table II.4

Table II.5 – Upper envelope of masks of Figure II.3 and Table II.4

Time *S* after start of SyncE/SDH rearrangement (s)	T-BC output absolute phase error (ns)
$0 \le S < 0.016$	$50 + 7500S$
$0.016 \le S < 0.5$	$170 + 50(S - 0.016)$
$0.5 \le S < 2.4$	$224.2 + 50(S - 0.5)$
$2.4 \le S < 14.3776$	$50 + 269.2e^{-2\pi(0.05)(S-2.4)}$
$14.3776 \le S \le 14.5$	56.25
$14.5 \le S < 15.5$	176.25
$15.5 \le S < 25.484$	$110 + 269.2\, e^{-2\pi(0.05)(S-2.4)}$
$25.484 \le S \le 50$	$50 + 60.193\, e^{-2\pi(0.05)(S-25.484)}$

Further simplifications are possible. First, in Figure II.4 and Table II.5, the limit of 56.25 ns for observation intervals between 14.3776 s and 14.5 s is of very short duration. The mask can be simplified by extending the limit of 176.25 ns, currently for observation intervals between 14.3776 s and 14.5 s, to the range 14.3776-14.5 s and rounding the lower end of the range to 14.25 s. The result is given by the mask of Figure II.5 and Table II.6 below.

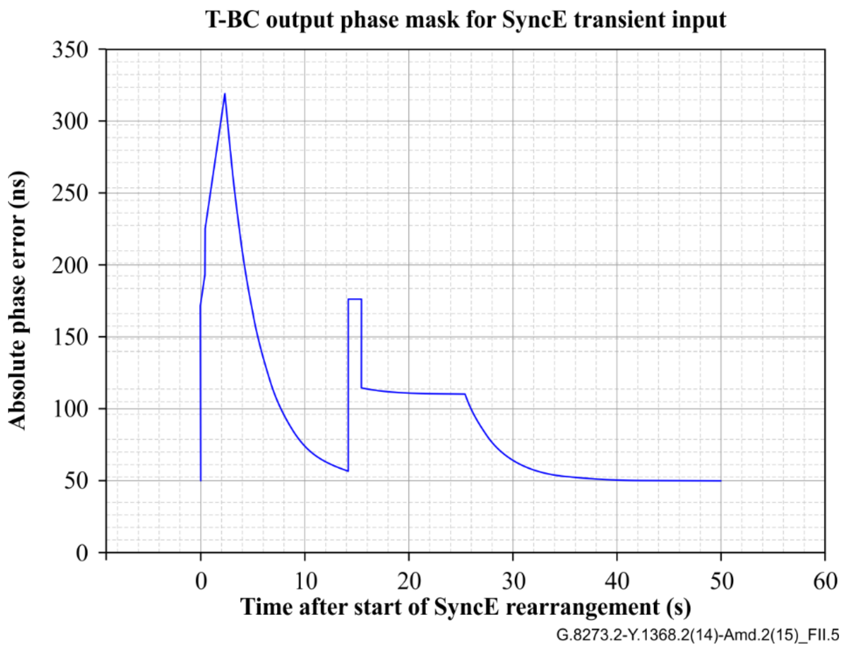

Figure II.5 – Upper envelope of masks of Figure II.3 and Table II.4 after applying simplifications in the range 14.25-14.5 s

Table II.6 – Upper envelope of masks of Figure II.3 and Table II.4 after applying simplifications in the range 14.25-14.5 s

Time *S* after start of SyncE/SDH rearrangement (s)	T-BC output absolute phase error (ns)
$0 \le S < 0.016$	$50 + 7500S$
$0.016 \le S < 0.5$	$170 + 50(S - 0.016)$
$0.5 \le S < 2.4$	$224.2 + 50(S - 0.5)$
$2.4 \le S < 14.25$	$50 + 269.2e^{-2\pi(0.05)(S-2.4)}$
$14.25 \le S < 15.5$	176.25
$15.5 \le S < 25.484$	$110 + 269.2\,e^{-2\pi(0.05)(S-2.4)}$
$25.484 \le S \le 50$	$50 + 60.193\,e^{-2\pi(0.05)(S-25.484)}$

Second, the portion of the mask in the third region, which extends from 0.5 s to 2.4 s, may be extended into the first two regions (0 to 0.5 s). This will increase the mask in the first two regions. However, note that the mask already increases rapidly during the first 0.5 s and that 170 ns of the increase occurs over the first 0.016 s. Third, values are rounded up to at most three significant figures. Fourth, the second to last region, which extends from 15.5 s to 25.484 s, is replaced by the maximum value of the mask in this region, i.e., 115 ns after the rounding up described above. This may be done because the total decay in the value of the mask in this region is less than 5 ns. The final result is given by the mask of Figure B.1 and Table B.1 of Annex B of this Recommendation.

11) Appendices IV and V

Remove Appendices IV and V.

ITU-T Y-SERIES RECOMMENDATIONS

GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

GLOBAL INFORMATION INFRASTRUCTURE	
General	Y.100–Y.199
Services, applications and middleware	Y.200–Y.299
Network aspects	Y.300–Y.399
Interfaces and protocols	Y.400–Y.499
Numbering, addressing and naming	Y.500–Y.599
Operation, administration and maintenance	Y.600–Y.699
Security	Y.700–Y.799
Performances	Y.800–Y.899
INTERNET PROTOCOL ASPECTS	
General	Y.1000–Y.1099
Services and applications	Y.1100–Y.1199
Architecture, access, network capabilities and resource management	Y.1200–Y.1299
Transport	**Y.1300–Y.1399**
Interworking	Y.1400–Y.1499
Quality of service and network performance	Y.1500–Y.1599
Signalling	Y.1600–Y.1699
Operation, administration and maintenance	Y.1700–Y.1799
Charging	Y.1800–Y.1899
IPTV over NGN	Y.1900–Y.1999
NEXT GENERATION NETWORKS	
Frameworks and functional architecture models	Y.2000–Y.2099
Quality of Service and performance	Y.2100–Y.2199
Service aspects: Service capabilities and service architecture	Y.2200–Y.2249
Service aspects: Interoperability of services and networks in NGN	Y.2250–Y.2299
Enhancements to NGN	Y.2300–Y.2399
Network management	Y.2400–Y.2499
Network control architectures and protocols	Y.2500–Y.2599
Packet-based Networks	Y.2600–Y.2699
Security	Y.2700–Y.2799
Generalized mobility	Y.2800–Y.2899
Carrier grade open environment	Y.2900–Y.2999
FUTURE NETWORKS	Y.3000–Y.3499
CLOUD COMPUTING	Y.3500–Y.3999

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

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series D	General tariff principles
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	**Transmission systems and media, digital systems and networks**
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Cable networks and transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant
Series M	Telecommunication management, including TMN and network maintenance
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Terminals and subjective and objective assessment methods
Series Q	Switching and signalling
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks, open system communications and security
Series Y	Global information infrastructure, Internet protocol aspects and next-generation networks
Series Z	Languages and general software aspects for telecommunication systems

Printed in Switzerland
Geneva, 2015