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ITU-T

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G.8266/Y.1376

Amendment 1

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Timing characteristics of telecom grandmaster clocks for frequency synchronization

Amendment 1

Summary

Recommendation ITU-T G.8266/Y.1376 specifies the requirements for packet master clocks suitable for frequency synchronization in packet networks.

Amendment 1 provides the following updates:

– Changes the scope to include the grandmaster (GM) with embedded primary reference time clock (PRTC);
– Changes clause 8.1 to account for the GM with embedded PRTC;
– Replaces text and provides additional material to Appendix I.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T G.8266/Y.1376	2016-11-13	15	11.1002/1000/13106
1.1	ITU-T G.8266/Y.1376 (2016) Amd. 1	2018-03-16	15	11.1002/1000/13548

Keywords

Frequency synchronization, packet master clock.

* 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.

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Timing characteristics of telecom grandmaster clocks for frequency synchronization

Amendment 1

Editorial note: This is a complete-text publication. Modifications introduced by this amendment are shown in revision marks relative to Recommendation ITU-T G.8266/Y.1376 (2016).

1 Scope

This Recommendation defines the minimum requirements for the timing functions of the telecom grandmaster clocks that operate in the network architecture as defined in [ITU-T G.8265] and the related profile defined in [ITU-T G.8265.1]. It supports frequency synchronization distribution when using packet-based methods. It allows for proper network operation when a telecom grandmaster clock is timed from a physical frequency source traceable to a primary reference clock (PRC) or primary reference time clock (PRTC) according to the architecture defined in [ITU-T G.803].

~~The case of a telecom grandmaster whose frequency is provided by an embedded PRTC or PRC function is for further study.~~

This Recommendation focuses on the types of networks corresponding to the HRM-1 and HRM-2 as defined in [ITU-T G.8261.1].

The HRM-2 type of network is for further study in the current version of this Recommendation. Other types of networks are out of the scope of this Recommendation.

This Recommendation includes clock accuracy, noise tolerance, noise transfer, noise generation, and holdover specifications for the telecom grandmaster clocks for frequency synchronization. These requirements apply under the normal environmental conditions specified for the equipment.

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.703] Recommendation ITU-T G.703 (2016), *Physical/electrical characteristics of hierarchical digital interfaces*.

[ITU-T G.803] Recommendation ITU-T G.803 (2000), *Architecture of transport networks based on the synchronous digital hierarchy (SDH).*

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

[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.8260] Recommendation ITU-T G.8260 (2015), *Definitions and terminology for synchronization in packet networks.*

[ITU-T G.8261.1] Recommendation ITU-T G.8261.1 (2012), *Packet delay variation network limits applicable to packet based methods (Frequency synchronization).*

[ITU-T G.8262] Recommendation ITU-T G.8262 (2015), *Timing characteristics of a synchronous Ethernet equipment slave clock*.

[ITU-T G.8265] Recommendation ITU-T G.8265 (2010), *Architecture and requirements for packet-based frequency delivery.*

[ITU-T G.8265.1] Recommendation ITU-T G.8265.1 (2014), *Precision time protocol telecom profile for frequency synchronization*.

[ITU-T G.8272] Recommendation ITU-T G.8272 (2015), *Timing characteristics of primary reference time clocks*.

3 Definitions

The terms and definitions used in this Recommendation are contained in [ITU-T G.810] and [ITU-T G.8260].

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

GM Grandmaster

GNSS Global Navigation Satellite System

MTIE Maximum Time Interval Error

NE Network Element

PEC-M-F Packet-based Equipment Clock – Master – Frequency

PRC Primary Reference Clock

PRTC Primary Reference Time Clock

PTP Precision Time Protocol

SyncE Synchronous Ethernet

TDEV Time Deviation

ToD Time of Day

5 Conventions

The telecom grandmaster clock for frequency synchronization (PEC-M-F) is based on [ITU-T G.812]. The packet-based equipment clock – master – frequency (PEC-M-F) conforms to one of [ITU-T G.812] Type I, Type II or Type III specifications with additional requirements or modifications as listed in this recommendation:

– A PEC-M-F Type I is based on [ITU-T G.812] Type I

– A PEC-M-F Type II is based on [ITU-T G.812] Type II

– A PEC-M-F Type III is based on [ITU-T G.812] Type III.

6 Frequency accuracy

The PEC-M-F should comply with [ITU-T G.812] clause 6 for its respective clock Type.

7 Pull-in, hold-in, and pull-out ranges

The PEC-M-F should comply with [ITU-T G.812] clause 7 for its respective clock Type.

8 Noise generation

8.1 Wander in locked mode

The PEC-M-F should comply with [ITU-T G.812] clause 8.1 for its respective clock Type.

The PEC-M-F PTP port output is measured through a first order low-pass filter with bandwidth of 0.1 Hz, and only observation intervals above 1s are considered.

For the case of telecom grandmaster whose frequency is provided by an embedded PRTC, the PEC-M-F should comply with clause 6.2 of [ITU-T G.8272].

8.2 Jitter

A PEC-M-F operating in a locked mode synchronized to a noise-free frequency reference at the SyncE/SDH input, should comply with:

– [ITU-T G.812] clause 8.3.1, when measured at a 2048 kHz or 2048 kbit/s output interface
– [ITU-T G.812] clause 8.3.2, when measured at a 1544 kbit/s output interface
– Peak-to-peak time error of less than 70 ns, when measured at a precision time protocol (PTP) output interface through first-order high-pass filter of 0.1 Hz over a measurement interval of 1000 s.

9 Noise tolerance

9.1 Wander tolerance

The measurement method of clause 9.1.3 is recommended for wander tolerance testing.

9.1.1 MTIE wander tolerance

The PEC-M-F complies with [ITU-T G.812] clause 9.1.1 for its respective clock Type.

9.1.2 TDEV wander tolerance

The PEC-M-F complies with [ITU-T G.812] clause 9.1.2 for its respective clock Type.

9.1.3 Sinusoidal wander tolerance

The PEC-M-F complies with [ITU-T G.812] clause 9.1.3 for its respective clock Type.

9.2 Jitter tolerance

The PEC-M-F should comply with the jitter tolerance requirements of:

– [ITU-T G.812] clause 9.2.1, applied at a 2048 kHz or 2048 kbit/s input interface
– [ITU-T G.812] clause 9.2.2, applied at a 1544 kbit/s input interface
– [ITU-T G.8262] clause 9.2, applied at a synchronous Ethernet input interface.

10 Noise transfer

The PEC-M-F should comply with [ITU-T G.812] clause 10 (a) for its respective clock Type.

Guidance on the measurement techniques for these requirements is given in Appendix I.

NOTE – The noise transfer measurement technique must account for the allowed noise generation (e.g., wander and timestamp noise) of the clock.

11 Transient response and holdover performance

In each of the following clauses, the PEC-M-F PTP output interface is measured through a first order low-pass filter with bandwidth of 0.1 Hz, and only observation intervals above 1 s are considered.

11.1 Short-term phase transient response

If the frequency reference of a PEC-M-F Type I clock is a physical layer clock, the output 2048 kHz and 2048 kbit/s interfaces should comply with the requirements of [ITU-T G.812] clause 11.1.1. The output PTP interface should also comply with the 2048 kHz and 2048 kbit/s requirements of [ITU-T G.812] clause 11.1.1. The output SyncE interface should comply with the STM-N requirements of [ITU-T G.812] clause 11.1.2.

If the frequency reference of a PEC-M-F Type II or Type III clock is a physical layer clock, the output 1544 kbit/s interface should comply with the requirements of [ITU-T G.812] clause 11.1.3. The output PTP interface should also comply with the 1544 kbit/s requirements of [ITU-T G.812] clause 11.1.3. The output SyncE interface should comply with the STM-N requirements of [ITU-T G.812] clause 11.1.4.

11.2 Long-term phase transient response (hold-over)

The PEC-M-F should comply with [ITU-T G.812] clause 11.2 for its respective clock Type.

11.3 Phase discontinuity

The PEC-M-F should comply with [ITU-T G.812] clause 11.4 for its respective clock Type.

12 Interfaces

The requirements in this Recommendation are related to reference points internal to the network elements (NEs) in which the clock is embedded and are therefore not necessarily available for measurement or analysis by the user. Therefore the performance of the [ITU-T G.812] clock is not defined at these internal reference points, but rather at the external interfaces of the equipment.

Note that not all of the interfaces below need to be implemented on all equipment.

The external input and output are:

– 2 048 kHz interfaces according to [ITU-T G.703] with additional jitter and wander requirements as specified herein;
– 2 048 kbit/s interfaces according to [ITU-T G.703] with additional jitter and wander requirements as specified herein;
– 1 544 kbit/s interfaces according to [ITU-T G.703] with additional jitter and wander requirements as specified herein;
– Ethernet interface carrying PTP messages;

  NOTE 1 – This interface is only used for output.

– Synchronous Ethernet (SyncE) interfaces;

  NOTE 2 – Ethernet interfaces can combine Synchronous Ethernet for frequency and PTP messages.

Other interfaces are for further study.

Annex A

Telecom grandmaster clock functional model

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

Figure A.1 illustrates a telecom grandmaster clock functional model.

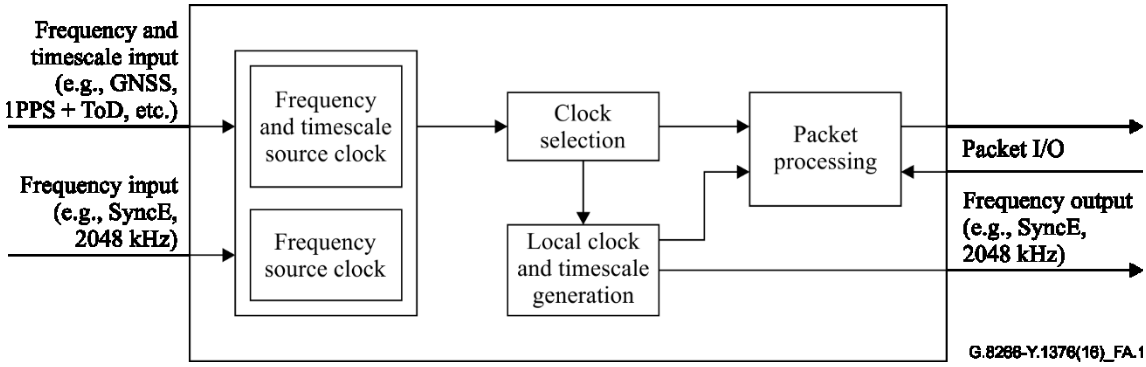

Figure A.1 – PEC-M functional model

NOTE 1 – This diagram is a functional model. It is not intended to specify any specific implementation. Any implementation specific detail is outside the scope of this Recommendation.

NOTE 2 – Not all interfaces are mandatory to be present in an implementation.

NOTE 3 – Not all functional blocks are mandatory to be present in an implementation.

Table A.1 describes the functionality of the blocks depicted in Figure A.1.

Table A.1 – Proposed clock model functional blocks

Functional block label	Functionality
Frequency & Timescale Source Clock	Synchronizes to a frequency & timescale input reference (e.g., GNSS, 1PPS and ToD, etc.) and provides this as a reference to the clock selection block.
Frequency Source Clock	Synchronizes to a frequency input reference (e.g., SyncE, 2048 kHz, etc.) and provides this as a reference to the clock selection block.
Clock Selection	Selects the local source clock to be used, from amongst the various possible available inputs. The selected local source clock is input to the local timescale generation block.
Local Clock & Timescale Generation	Generates the local clock and time scale of the clock using the selected local source clock information supplied by the clock selection block. Provides the local time scale information to the Packet Processing block. NOTE – Timescale generation is only used for the PTP output.
Packet Processing	Acting as a packet master clock (PTP master), will process ingress PTP packets and generate egress PTP packets according to the PTP profile. Timestamps PTP packets using the local timescale generation information, where required by the PTP profile.

Table A.2 describes the functionality of the interfaces depicted in Figure A.1.

Table A.2 – Proposed clock model external interfaces

External interfaces label	Functionality
Packet I/O	Packet interface to transmit and receive PTP packets from the packet processing block. It will interact with external PTP slave devices.
Frequency & Timescale Input (e.g., GNSS, 1PPS+ToD, etc.)	Interface to receive information from applicable interfaces available on the clock (e.g., GNSS, 1PPS input and ToD serial time information, etc.). Provides timing information to the frequency & timescale source clock block.
Frequency Input (e.g., SyncE, 2048 kHz)	Frequency input from applicable interfaces available on the clock (e.g., SyncE, [ITU-T G.703], 2048 kHz). Provides frequency information to the frequency source clock block.
Frequency Output (e.g., SyncE, 2048 kHz)	Frequency output (e.g., SyncE, [ITU-T G.703], 2048 kHz) provides frequency information. Generated by the local timescale generation block.

Appendix I

Measurement method for wander transfer

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

The clock specification in [ITU-T G.812] used wideband noise, defined as a TDEV mask, as an input stimulus to measure the wander transfer of a clock. However, this method is unsuitable for use with a packet interface because the timestamp noise is likely to be larger than the 2% margin allowed between the input and output masks.

For this Recommendation it is proposed to use sinusoidal tones at different frequencies across the frequency response of the clock. Such tones can be generated very accurately and therefore can be used for measuring gain-peaking, provided the noise generation (e.g., wander and timestamp noise) is properly considered.

[ITU-T G.812] defines only the bandwidth and the gain peaking of the filter and does not define the response at frequencies above the nominal bandwidth. However, this can be inferred by comparing the TDEV wander limit defined in [ITU-T G.812] clause 10 (b) with the input stimulus defined in [ITU-T G.812] clause 9.1.2. Plotted as a ratio of the two limits in dB, this shows that the expected frequency response of a [ITU-T G.812] clock (and therefore a ITU-T G.8266 clock) is as shown in Figure I.1.

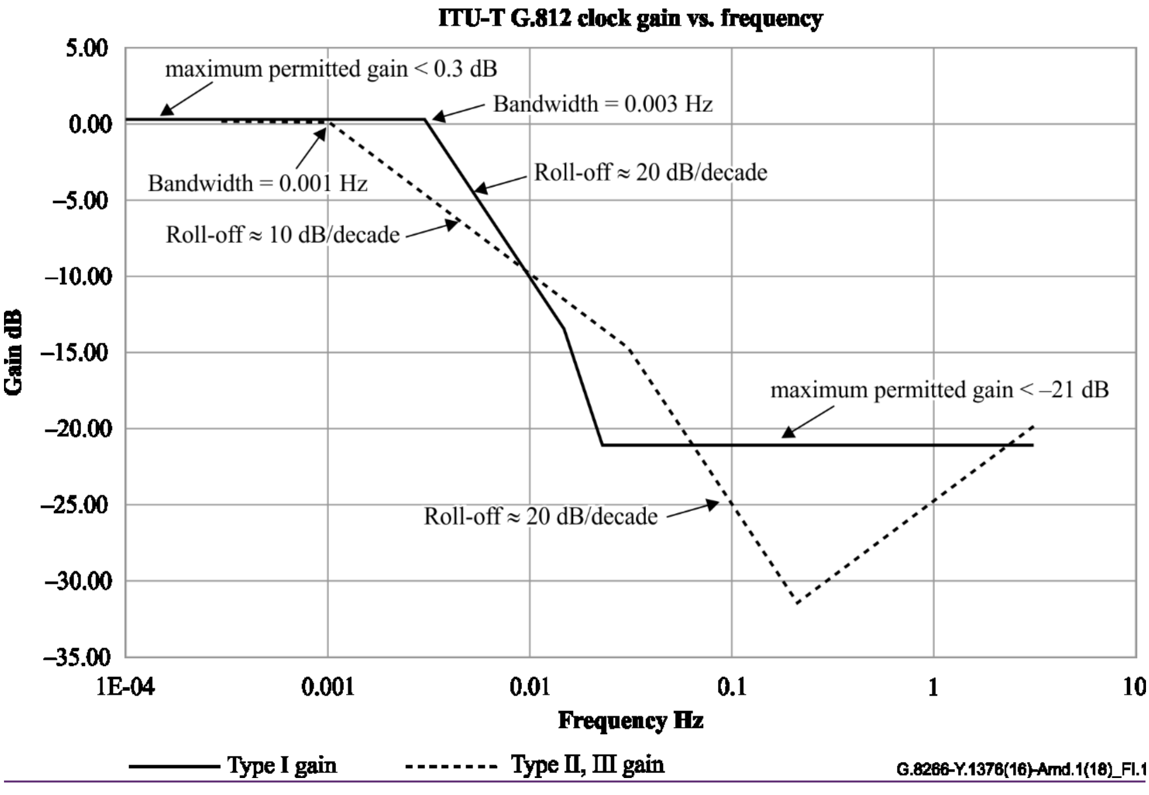

Figure I.1 – ITU-T G.812 clock gain vs. frequency plot

Using these values, it is possible to calculate the maximum output amplitude expected from a sinusoidal input at a given frequency.

Tables I.1 and I.2 show input tone frequencies that could be used, and the expected maximum gain of the clock based on the characteristics given above. The input tone frequencies and amplitudes are taken from clause 9.1.3 of [ITU-T G.812] (Sinusoidal wander tolerance).

Table I.1 – Option I clocks (bandwidth 3 mHz, gain peaking 0.2 dB)

Tone frequency (Hz)	Input tone amplitude (peak to peak, ns)	Maximum output tone amplitude (peak to peak), ns	Minimum output tone amplitude (peak to peak), ns
0.1	750	145	n/a
0.043	750	145	
0.016	2000	435	
0.003	2000	2230	
0.0008	2000	2230	1800
0.00032	5000	5335	4740

Table I.2 – Option II and III clocks (bandwidth 1 mHz, gain peaking 0.2 dB)

Tone frequency (Hz)	Input tone amplitude (peak to peak, ns)	Maximum output tone amplitude (peak to peak), ns	Minimum output tone amplitude (peak to peak), ns
0.1	310	130	n/a
0.01	400	230	
0.00143	1000	955	
0.001	1001	1125	
0.0001	1037	1160	915

~~[ITU-T G.812] only defines the bandwidth and the gain peaking of the filter, and does not define the response at frequencies above the nominal bandwidth. The choice of sinusoidal tone frequencies, input signal amplitudes, and associated output signal amplitudes are for further study.~~

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