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| Please don’t change the structure of this table, just insert the necessary information. | | | | |

# Abstract

This document contains the draft of the ITU-T Amendment 1of the Recommendation G.8273.2/Y.1368.2 as agreed at the meeting in in Geneva, 19-30 June 2017.

Editor’s notes were removed from this revision.

This Amendment 1 to Recommendation G.8273.2/Y.1368.2 is proposed for consent at the SG15 plenary meeting in Geneva, 19-30 June 2017.

Draft Amendement 1 to ITU-T Recommendation G.8273.2/Y.1368.2

Timing characteristics of telecom boundary clocks  
and telecom time slave clocks

**Amendment 1**

Summary

This Amendment add a paragraph in the Scope, adds a note in Clause 7.1, replaces text in clause 7.3.1, clause 7.4, Annex A, Clause C.2.3.1, Clause C.2.4, Appendix I, Appendix II, and Appendix III. It also adds Appendix VI.

Note to ITU Editor: All the Figures in Appendix III have been changed from the published version by editing it as a picture, since the source for the published version is not available. Please, ensure that the new version of the figures are used (i.e. please, don’t put back the original figures from the current published version).

Draft Amendement 1 ITU-T Recommendation G.8273.2/Y.1368.2

Timing characteristics of telecom boundary clocks  
and telecom time slave clocks

**Amendment 1**

# Clause 1

In the scope, add the following paragraph at the end of Scope before the note:

“For information on the applicability of G.8273.2 requirements to a standalone T-TSC or a T-TSC embedded in an end application, refer to clause 7 of [ITU-T G.8271.1].”

# Clause 7

Add the following note at the end of Clause 7:

“Note: The impact on PTP performance due to 1000BASE-T and 10GBASE-T link renegotiation is for further study.”

# Clause 7.3.1

Replace the following text in clause 7.3:

“In the passband, the phase gain of the T-BC should be smaller than 0.1 dB.”

With:

“In the passband, the phase gain of the T-BC should be smaller than 0.1 dB (1.1%).”

# Clause 7.4

Replace Clause 7.4 with the following text:

## 7.4 Transient response and holdover performance

### 7.4.1 Transient response

#### 7.4.1.1 PTP Output and 1PPS Output transient response due to rearrangement of physical layer frequency transport and PTP network

The transient response of the T-BC due to a simultaneous or nearly coincident rearrangement of both the PTP network and the physical layer frequency transport is for further study.

#### 7.4.1.2 PTP Output and 1PPS Output transient response due to rearrangement of PTP network

The PTP to PTP and PTP to 1PPS transient response requirements, due to a rearrangement of the PTP network, applicable to a T-BC are for further study.

#### 7.4.1.3 PTP Output and 1PPS Output transient response due to rearrangement of physical layer frequency transport

The physical layer frequency to PTP and physical layer frequency to 1PPS transient response due to a rearrangement of the physical layer frequency transport is specified in Annex B.

#### 7.4.1.4 PTP Output and 1PPS Output transient response due to long term rearrangement of physical layer frequency transport

The response to an interruption or degradation of the physical layer frequency input for a period longer than specified in Annex B is specified in this clause. In this case, the T-BC may rely on a phase and time input.

This requirement reflects the performance of the clock in cases when the physical layer frequency input is ideal followed by disconnection of the physical layer frequency input. The PTP input is ideal.

The T-BC performance requirements when the physical layer frequency assistance is lost are for further study.

### 7.4.2 Holdover performance

The requirements in this clause bound the maximum excursions in the PTP and 1PPS output signal during loss of PTP input and/or physical layer frequency input. Additionally, it restricts the accumulation of the phase movement during input signal impairments or internal disturbances.

#### 7.4.2.1 T-BC performance during loss of physical layer frequency assistance and loss of phase and time input reference

When a T-BC loses all its physical layer frequency and phase and time inputs, it enters the phase/time holdover state. Under these circumstances, the T-BC may rely on a local oscillator.

This requirement reflects the performance of the clock in cases when the PTP input and physical layer frequency input are ideal followed by disconnection of the PTP input and physical layer frequency input.

The phase/time holdover (both physical layer and PTP inputs are lost) 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

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

This requirement reflects the performance of the clock in cases when the PTP input is ideal followed by disconnection of the PTP input. The physical layer frequency input is ideal.

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 and Figure 7-1. Under constant temperature conditions (within ±1K) 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 τ0.1 | 1 ≤ τ ≤ 100 |
| 22 + 25.25 τ0.2 | 100 < τ ≤ 1000 |



Figure 7-1 – Performance allowance during loss of PTP input (MTIE)   
for T-BC with constant temperature

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 and Figure 7-2. 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 τ0.1 + 0.5 τ | 1 ≤ τ ≤ 100 |
| 72 + 25.25 τ0.2 | 100 < τ ≤ 1000 |
| for further study | 1000 < τ ≤ 10000 |



Figure 7-2 – Performance allowance during loss of PTP input (MTIE)   
for T-BC with variable temperature

NOTE – Guidelines for variable temperature testing are described in Appendix I of [ITU-T G.8273].

# Annex A

Change the title of Annex A from:

“Telecom boundary clock model”

To:

“Telecom boundary clock and Telecom slave clock models”

Change the first sentence in Annex A from:

Figure A.1 illustrates a telecom boundary clock model.

To:

Figure A.1 illustrates a telecom boundary clock and telecom slave clock models.

Add the following sentence to Note 3:

“SYNCE output is optional for T-TSC”

So it reads:

“NOTE 3 – T-BC functional model is also applicable to the T-TSC, except for the PTP master side (the T‑TSC functional model includes the 1 PPS and ToD interface). SyncE output is optional for T-TSC.”

# Annex C.2

Add the following text in Clause C.2:

“See Appendix III for background information on performance requirements of the T-TSC

Note: The impact on 1PPS performance due to 1000BASE-T and 10GBASE-T renegotiation is for further study.”

# Annex C.2.3.1

Replace the following text in clause C.2.3.1:

“In the passband, the phase gain of the T-TSC should be smaller than 0.1 dB.”

With

“In the passband, the phase gain of the T-TSC should be smaller than 0.1 dB (1.1%).”

# Annex C.2.4

Replace Annex C.2.4 with the following text:

## C.2.4 Transient response and holdover performance

### C.2.4.1 Transient response

#### C.2.4.1.1 1PPS Output transient response due to rearrangement of physical layer frequency transport and PTP network

The transient response of the T-TSC due to a simultaneous or nearly coincident rearrangement of both the PTP network and the physical layer frequency transport is for further study.

#### C.2.4.1.2 1PPS Output transient response due to rearrangement of PTP network

The PTP to 1PPS transient response requirements, due to a rearrangement of the PTP network, applicable to a T-TSC are for further study.

#### C.2.4.1.3 1PPS Output transient response due to rearrangement of physical layer frequency transport

The physical layer frequency to 1PPS transient response due to a rearrangement of the physical layer frequency transport is specified in Annex B.

#### C.2.4.1.4 1PPS Output transient response due to long term rearrangement of physical layer frequency transport

The response to an interruption or degradation of the physical layer frequency input for a period longer than specified in Annex B is specified in this clause. In this case, the T-TSC may rely on a phase and time input.

This requirement reflects the performance of the clock in cases when the physical layer frequency input is ideal followed by disconnection of the physical layer frequency input. The PTP input is ideal.

The T-TSC performance requirements when the physical layer frequency assistance is lost are for further study.

### C.2.4.2 Holdover performance

The requirements in this clause bound the maximum excursions in the 1PPS output signal during loss of PTP input and/or physical layer frequency input. Additionally, it restricts the accumulation of the phase movement during input signal impairments or internal disturbances.

#### C.2.4.2.1 T-TSC performance during loss of physical layer frequency assistance and loss of phase and time input reference

When a T-TSC loses all its physical layer frequency and phase and time inputs, it enters the phase/time holdover state. Under these circumstances, the T-TSC may rely on a local oscillator.

This requirement reflects the performance of the clock in cases when the PTP input and physical layer frequency input are ideal followed by disconnection of the PTP input and physical layer frequency input.

The phase/time holdover (both physical layer and PTP inputs are lost) 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

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

This requirement reflects the performance of the clock in cases when the PTP input is ideal followed by disconnection of the PTP input. The physical layer frequency input is ideal.

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 and Figure C.1. Under constant temperature conditions (within ±1K) 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 τ0.1 | 1 ≤ τ ≤ 100 |
| 22 + 25.25 τ0.2 | 100 < τ ≤ 1000 |



Figure C.1 – Performance allowance during loss of PTP input (MTIE)   
for T-TSC with constant temperature

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 and Figure C.2. 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 τ0.1 + 0.5 τ | 1 ≤ τ ≤ 100 |
| 72 + 25.25 τ0.2 | 100 < τ ≤ 1000 |
| for further study | 1000 < τ ≤ 10000 |



Figure C.2 – Performance allowance during loss of PTP input (MTIE)   
for T-TSC with variable temperature

NOTE – Guidelines for variable temperature testing are described in Appendix I of [ITU-T G.8273].

# Appendix I

In Appendix I, change the following paragraph from:

“Specifically, the SyncE/SDH signal is rejected when the SSM indicating the SyncE/SDH signal is no longer PRC-traceable is received by the EEC collocated with that T-BC, and the SyncE/SDH signal is again used at a time *Treacq* after receipt of the SSM indicating the SyncE signal is again PRC-traceable is received by the EEC/SEC collocated with that T-BC.”

To:

Specifically, the SyncE/SDH signal is rejected when the SSM indicating the SyncE/SDH signal is no longer PRC-traceable is received by the EEC collocated with that T-BC or T-TSC, and the SyncE/SDH signal is again used at a time *Treacq* after receipt of the SSM indicating the SyncE signal is again PRC-traceable is received by the EEC/SEC collocated with that T-BC or T-TSC.

Change the last sentence in Appendix I from:

“This is true whether or not the SyncE/SDH transient is rejected at each T-BC.”

To:

“This is true whether or not the SyncE/SDH transient is rejected at each T-BC/T-TSC.

# Appendix II

Change the title of Appendix II from:

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

To:

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

Add the following note at the beginning of Appendix II:

Note: The derivation of T-BC output transient mask due to SyncE/SDH rearrangement explained in this Appendix is also applicable to case of the T-TSC.

# Appendix III

Replace Appendix III with the following text:

“Appendix III  
  
Background to performance requirements of the T-BC/T-TSC

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

Annex A describes a detailed model of a telecom boundary clock and telecom slave clock. Figure III.1 is a simpler representation showing the timing signal flows between the main functional blocks during normal operation.

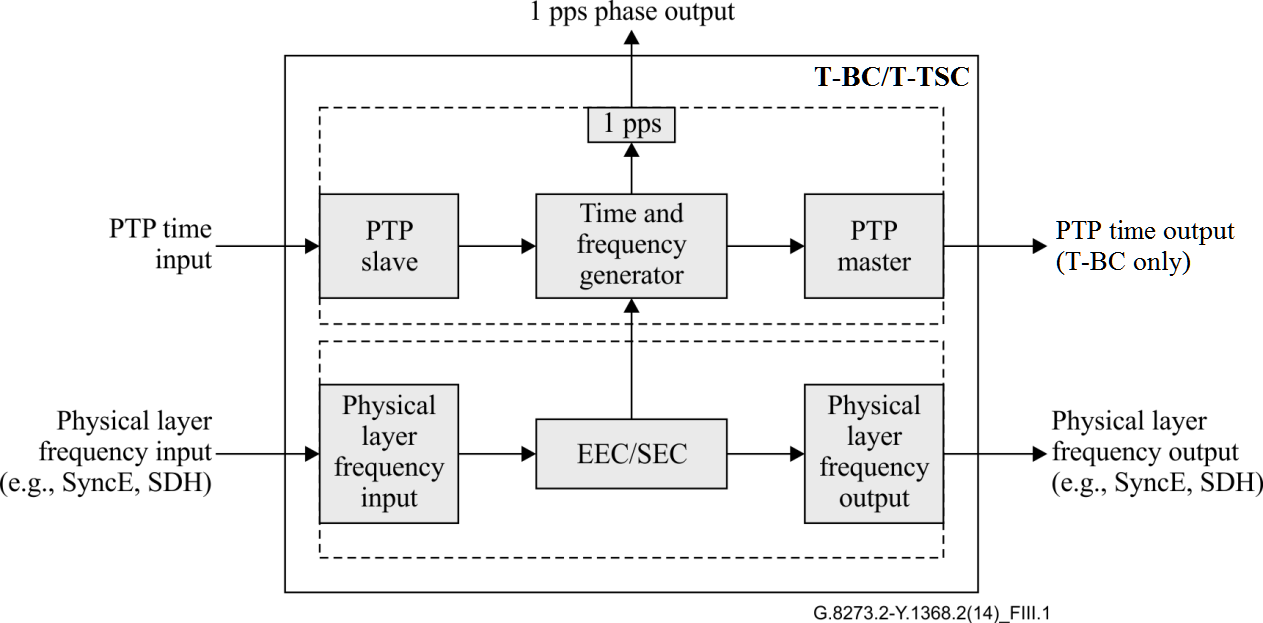


Figure III.1 – Model of T-BC/T-TSC showing signal flows in normal operation

“NOTE: the term “PTP output” only applies to T-BC in this appendix”.

From this diagram, it can be seen that there are basically two clocks in a T-BC/T-TSC, a frequency clock locked to the physical layer frequency input, and a time clock locked to the PTP input. In most cases, the frequency reference is SyncE based rather than SDH or PDH, and hence the frequency clock is an EEC. The two clocks are shown in Figure III.2:

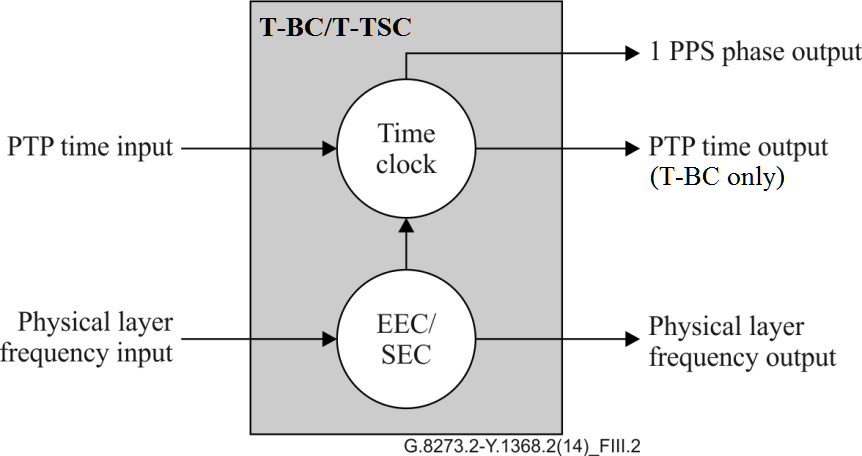


Figure III.2 – Simplified model of T-BC/T-TSC showing clocks

Since the 1 PPS output is a measurement point intended to reflect the performance of the time clock, it is expected that it should be broadly equivalent to the PTP output, aside from the different noise characteristics of the respective signal types.

Therefore there are three primary timing flows in a T-BC/T-TSC:

1) PTP time input to PTP and 1 PPS time/phase outputs;

2) physical layer frequency input to physical layer frequency output;

3) physical layer frequency input to PTP and 1 PPS outputs.

## III.1 Noise generation requirements

The noise generation of a clock is defined as the noise (normally phase wander) at the output of the clock, with a wander-free reference at the input of the clock.

The noise generation at the physical layer frequency output is only affected by the physical layer frequency input, and is defined by [ITU-T G.8262] and [ITU-T G.813], the clock specifications for an EEC or SEC respectively.

The PTP and 1 PPS signals are the output of the time clock within the T-BC/T-TSC. For these outputs noise basically means time error. This can be defined by three parameters:

1) cTE – the mean value of the time error function, measured over a long observation interval;

2) dTE – the variation of the time error function;

3) maximum time error (max|TE|) – the maximum absolute value of the time error.

For a T-BC/T-TSC, the maximum noise generation is defined in terms of cTE and dTE. The max|TE| parameter is generally used for network limits.

There are two inputs that can affect the output of the Time Clock, the physical layer frequency input and the PTP input. Therefore the noise generation at the PTP and 1 PPS outputs is defined as the noise present at the output with a time-error free time reference at the PTP input, and a wander-free frequency reference at the physical layer frequency input. This is shown in Figure III.3:

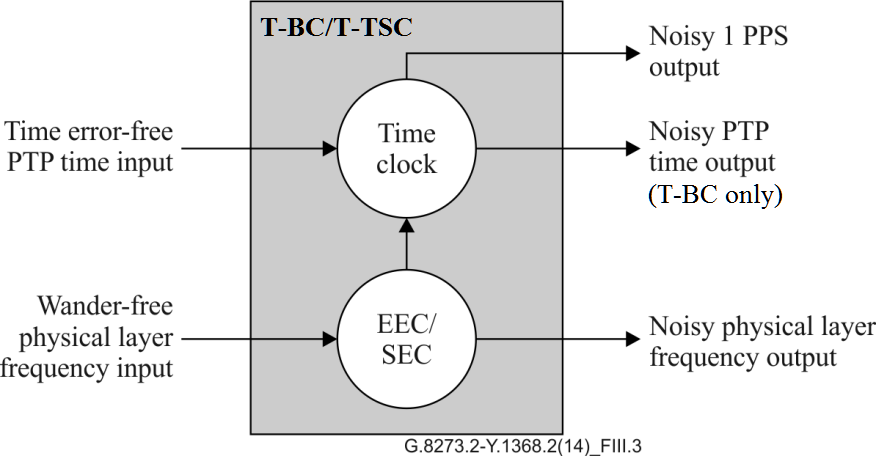


Figure III.3 – Noise generation of a T-BC/T-TSC

## III.2 Noise tolerance

The noise tolerance of a T-BC/T-TSC is the maximum level of noise at the inputs of a T-BC/T-TSC that must be tolerated while continuing to work normally. In the real network, both inputs of a clock may be noisy at the same time, therefore the noise tolerance requirements are defined to apply simultaneously on both inputs.

For the PTP input, noise tolerance is defined in terms of the dTE of the input signal. cTE is not considered, since PTP is effectively "blind" to cTE; it cannot detect constant time error at its input without additional information (e.g., asymmetry measurements). The amount of dTE is based on network limit in [ITU-T G.8271.1].

For the physical layer frequency input, the maximum phase wander that should be tolerated is described in [ITU-T G.8262].

There are no output performance requirements on the output of the T-BC/T-TSC during a noise tolerance test. This is because the T-BC/T-TSC is a node within a chain. The noise accumulation through the chain is governed by the noise generation of the clock, and the network limits provide the overall limit on the performance of the chain. A clock is merely expected to work normally during a noise tolerance test, i.e., not switch references, generate any alarms, or go into holdover.

Noise tolerance is shown in Figure III.4:

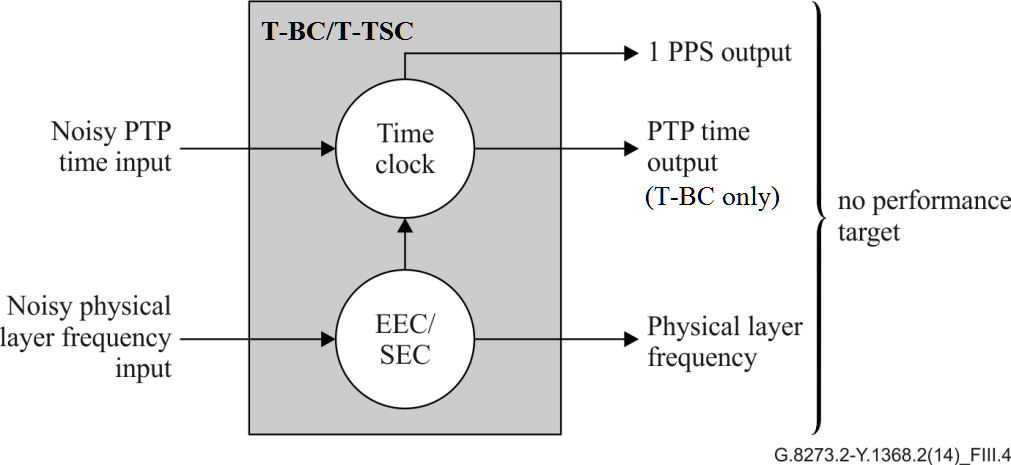


Figure III.4 – Noise tolerance of a T-BC/T-TSC

## III.3 Noise transfer

The noise transfer of a clock describes how any noise present on the input of a clock is passed to the output of the clock. It is basically the transfer function of the clock, and is usually expressed in terms of bandwidth, since the clock acts a filter to the noise.

As discussed before, there are three primary signal flows through a T-BC/T-TSC, as shown in Figure III.5:

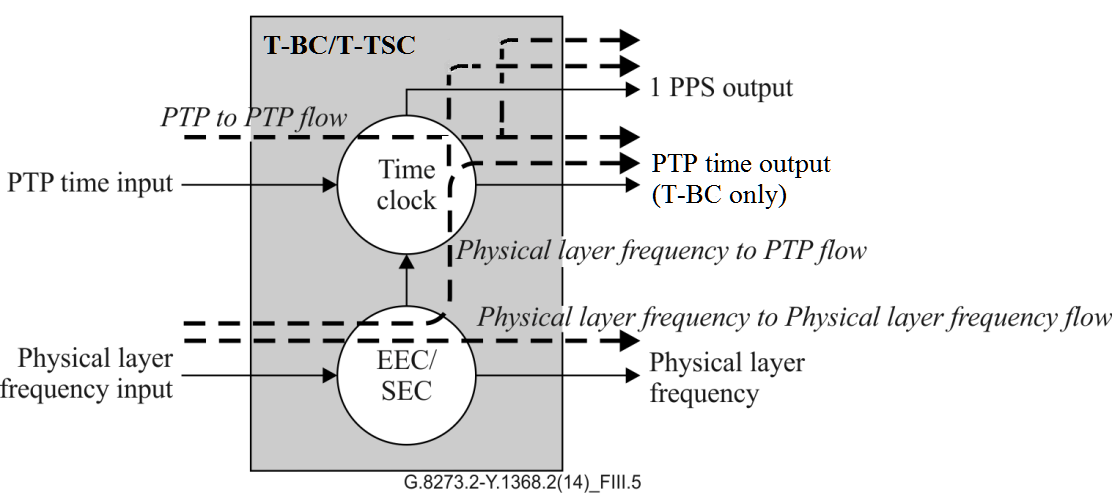


Figure III.5 – Signal flows through a T-BC/T-TSC

Each of these flows has a bandwidth associated with it. The PTP to PTP (and PTP to 1 PPS) bandwidth is explicitly defined in clause 7.3.1, as a low-pass filter with a maximum bandwidth of 0.1 Hz, and a minimum bandwidth of 0.05 Hz.

The physical layer to physical layer frequency bandwidth is defined in [ITU-T G.8262] and [ITU‑T G.813], as this is a standard EEC and SEC function respectively. This is also a low-pass filter, with a maximum bandwidth of 10 Hz, and a minimum bandwidth of 1 Hz.

For the physical layer frequency to PTP (and physical layer frequency to 1 PPS) path, the physical layer frequency signal is first low-pass filtered by the EEC or SEC, then high-pass filtered by the time clock. This is because the time clock acts a low-pass filter to its time input, but a high-pass filter to its frequency input. This is a natural consequence of how the clock functions – basically it follows the time input at low frequencies, to stay locked to the time reference, but follows the frequency input at high frequencies (e.g., in between PTP packets, the frequency input provides the "ticking" to maintain the time output).

Therefore the cumulative effect is a band-pass function, with the lower cutoff at 0.05-0.1 Hz, and the upper cutoff at 1-10 Hz. Table III.1 summarizes the transfer functions, while Figure III.6 shows generalized schematics of the transfer functions.

Table III.1 – Transfer functions applicable to a T-BC/T-TSC

|  |  |
| --- | --- |
| Input/output on the T-BC/T-TSC | Transfer function |
| PTP input to PTP output  PTP input to 1 PPS output | 0.05-0.1 Hz low-pass filter |
| Physical layer frequency input to physical layer frequency output | 1-10 Hz low-pass filter |
| Physical layer frequency input to PTP output  Physical layer frequency input to 1 PPS output | [0.05-0.1; 1-10] Hz band-pass filter (NOTE 1) |

NOTE 1 – The band-pass filter description of the system behaviour from physical layer input to PTP/1\_PPS output is representative of the expected behaviour. See Notes in Clause 7.3.2 and Clause C.2.3.2.

a) PTP to PTP (or 1 PPS) transfer function schematic

b) Physical layer frequency to physical layer frequency transfer function schematic

c) Physical layer frequency to PTP (or 1 PPS) transfer function schematic

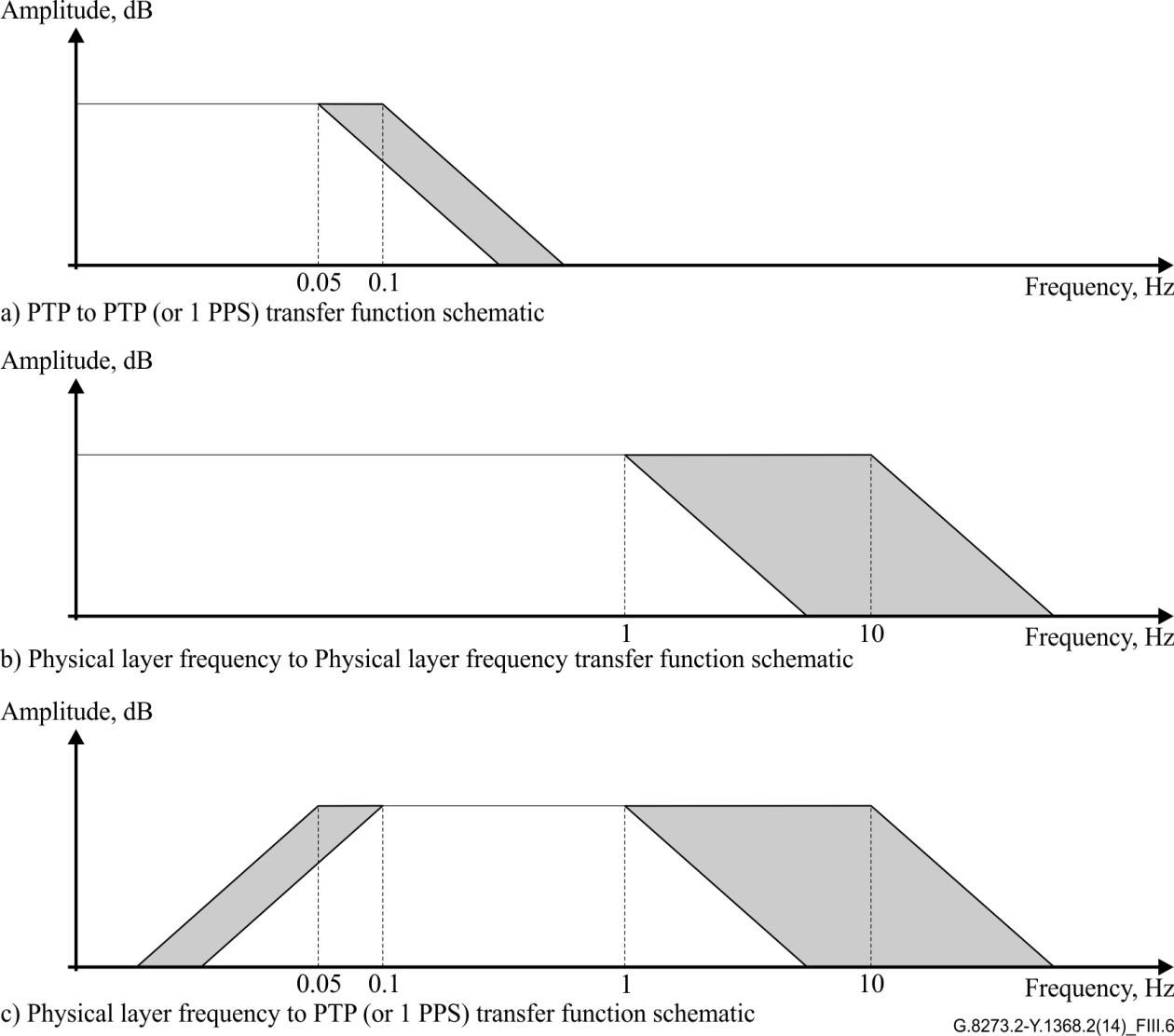


Figure III.6 – Generalized transfer function schematics of a T-BC/T-TSC

It should be noted that the diagrams in Figure III.6 are generalized schematics. The actual transfer function will be more rounded, and include the gain peaking defined in clause 7.3. In particular, the band-pass filter may not contain a flat area due to the closeness of the low-pass and high-pass corner frequencies.

## III.4 Holdover

There are two types of holdover available in a T-BC/T-TSC. The first is where the T-BC/T-TSC loses its PTP time reference, but not the physical layer frequency reference, as shown in Figure III.7. In this case, the stable frequency reference is used to keep the time output "ticking" at approximately the correct rate. Since the long-term frequency of the physical layer frequency is traceable to a PRC, this is likely to maintain the correct time over a reasonable period of time.

The performance requirements to be met in this physical layer frequency-assisted holdover mode are not defined at present, and are for further study.

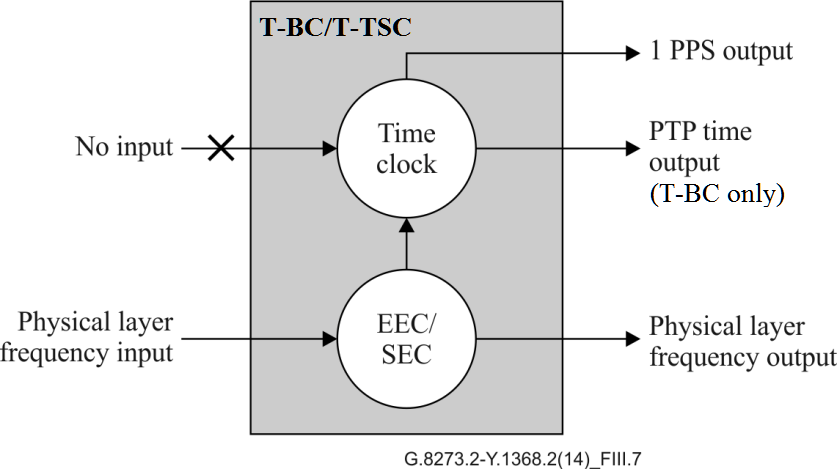


Figure III.7 – Physical layer frequency-assisted holdover

The second type is where both inputs are lost simultaneously, as shown in Figure III.8. The time output is then maintained using the local oscillator, but this is not expected to maintain accurate time for more than a few seconds, due to the drift rate of the oscillator. The performance requirements to meet in unassisted holdover are for further study.

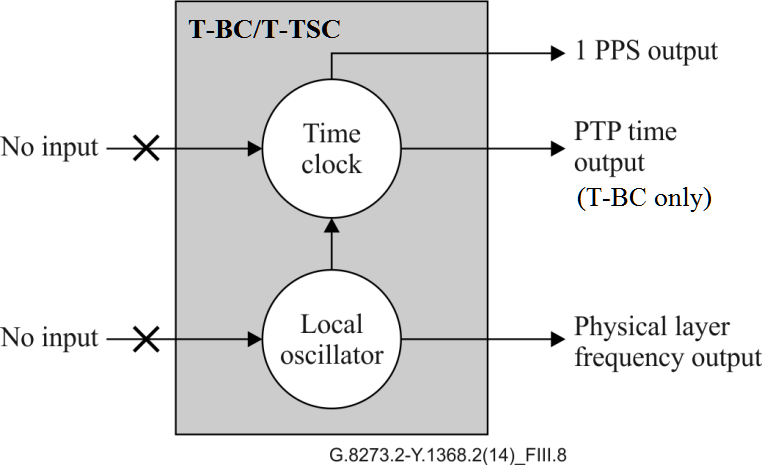


Figure III.8 – Unassisted holdover”

# Appendix VI

Add the following Appendix VI with the following text:

Appendix VI  
  
Choice of Frequencies for Measuring Noise Transfer

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

Note 1 in clause 7.3 provides some guidelines on the choice of frequencies used to measure the noise transfer of a T-BC. These guidelines are intended to ensure that the measured results properly reflect the response of the T-BC, and are not compromised by the presence of sub-Nyquist artefacts.

Sub-Nyquist artefacts are described in the paper by Isaac Amidror [*b-Amidror*]. This paper shows that where a tone frequency is sampled at a closely related frequency, a “sub-Nyquist artefact” frequency exists at a frequency *ε*, where

where:

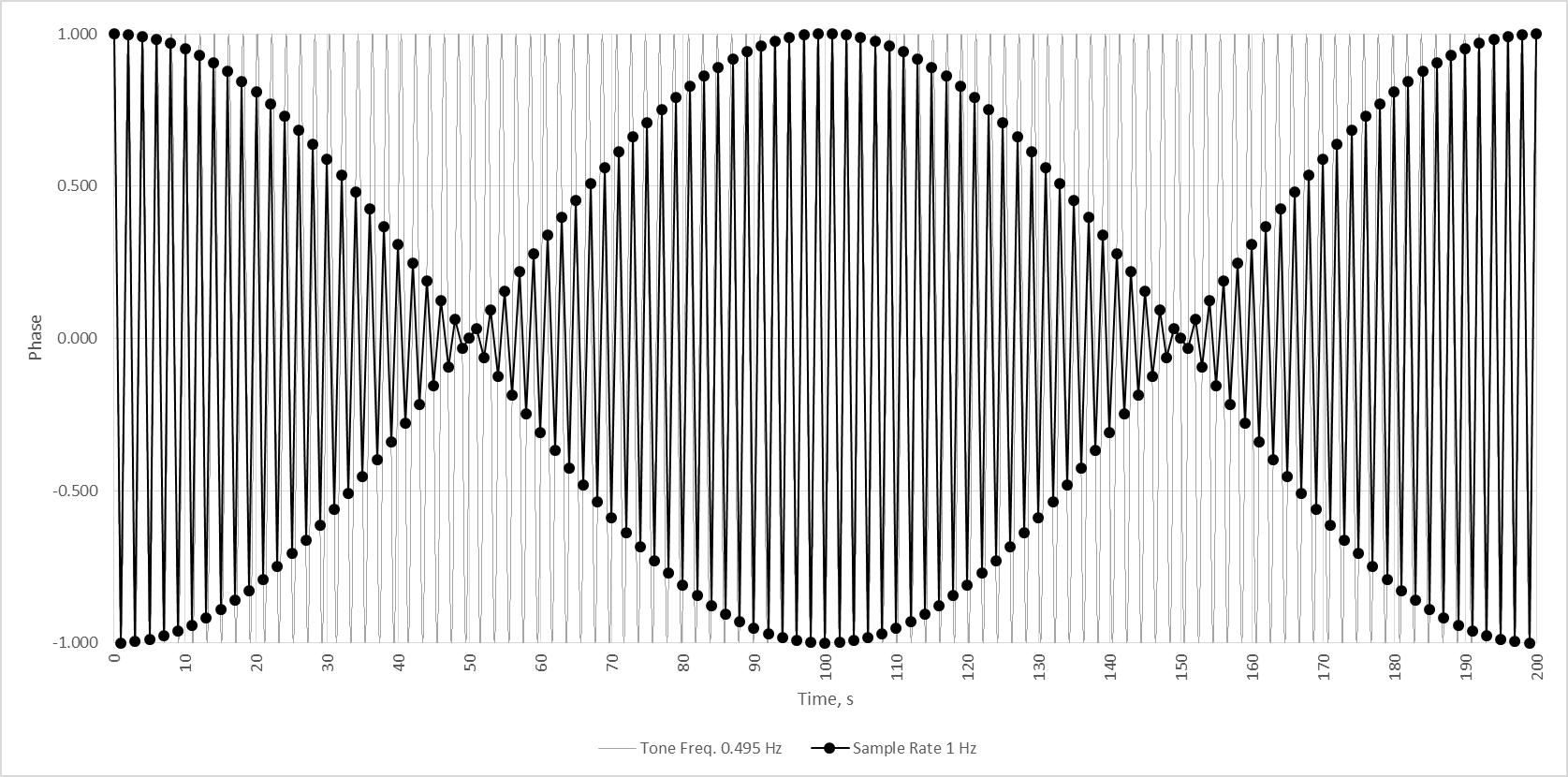
*ft* = tone frequency

*fs*= sampling frequency

*m, n* are small integers

*ε* is a small frequency difference, and can be positive or negative

This can be seen in Figure VI.1. Here, the sampling frequency *fs* = 1Hz, and the tone frequency *ft* = 0.495 Hz, giving *m* = 1, *n* = 2, and *ε* = -0.005 Hz:

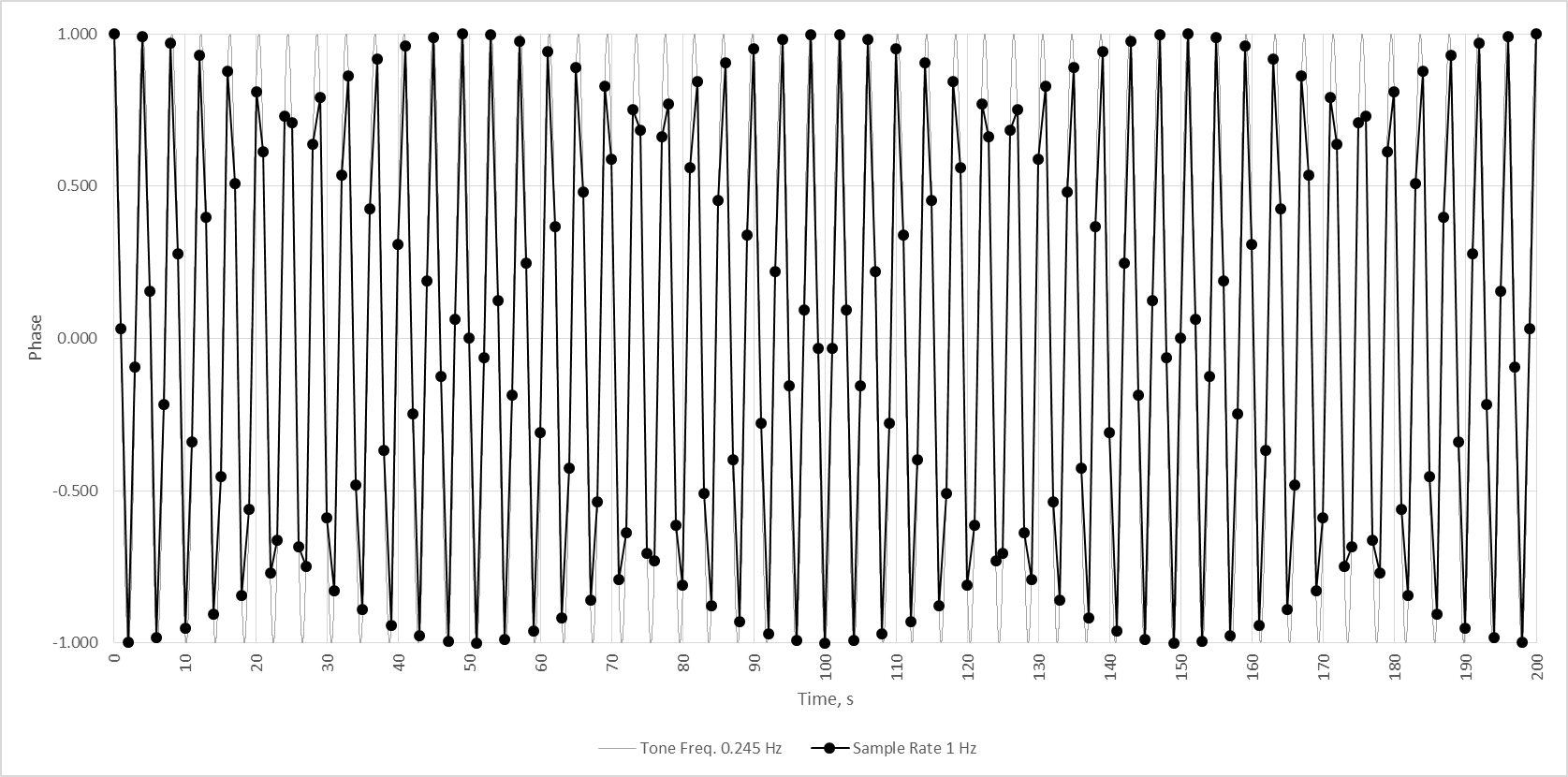


**Figure** VI.**.1: Sub-Nyquist Artefact for *m* = 1, *n* = 2, *ε* = -0.005 Hz**

## Envelope Repeat Frequency

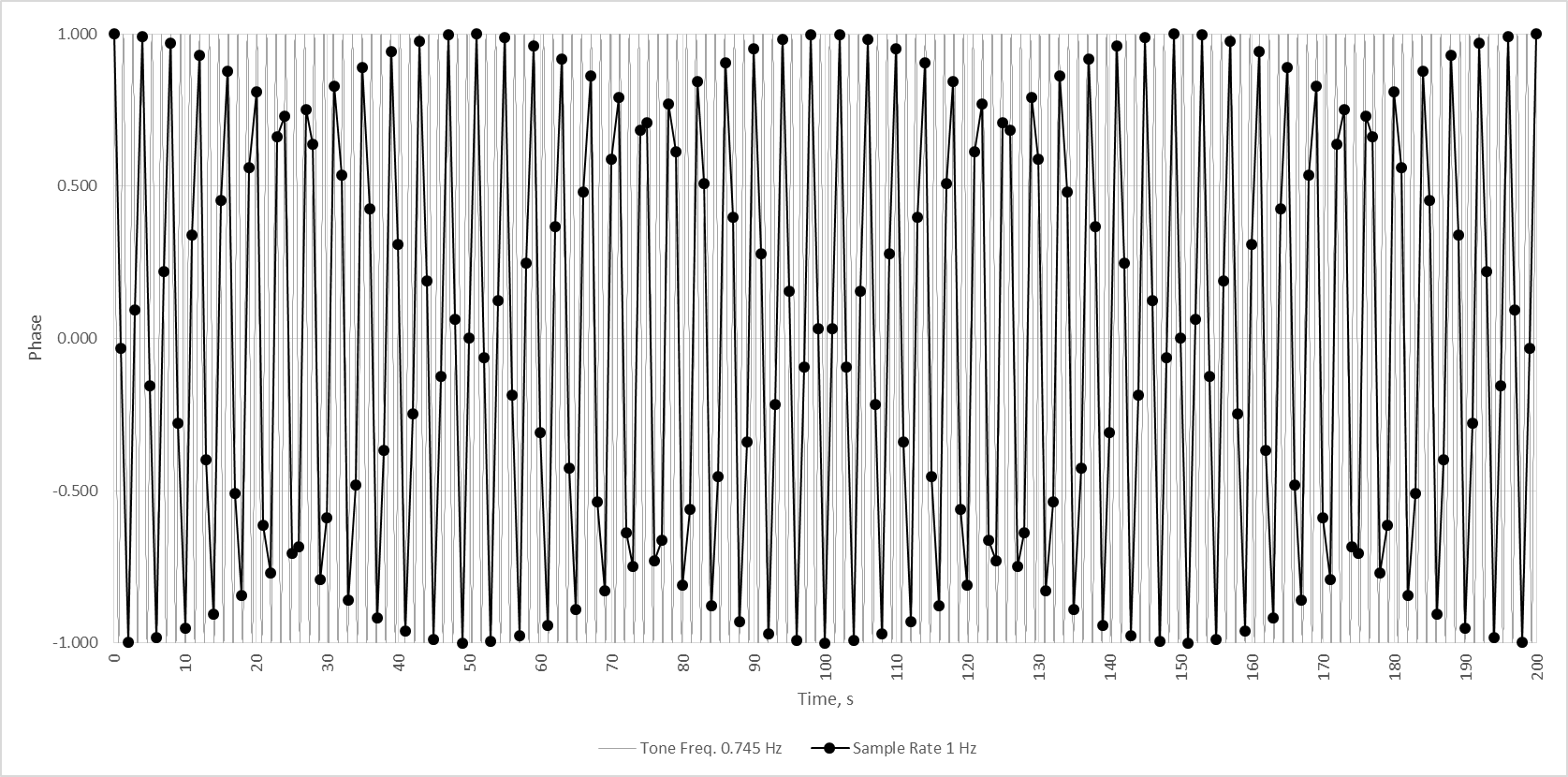
In Figure VI.1 it can be seen that while the artefact itself follows a frequency of 0.005 Hz (period of 200s), there is an envelope pattern that repeats at 0.01Hz (period of 100s). In fact, this envelope pattern repeats at a frequency of

Figure VI.2 shows *m* = 1, *n* = 4 and *ε* = -0.005 Hz, giving a tone frequency of 0.245Hz. It can be seen that this time the envelope repeats at a frequency of 0.02Hz:[[1]](#endnote-1)



**Figure** VI**.2: Sub-Nyquist Artefact for *m* = 1, *n* = 4, *ε* = 0.005 Hz**

Figure VI.3 shows *m* = 3, *n* = 4 and *ε* = -0.005 Hz. Again, the envelope repeats at 0.02Hz (*n* \* *ε*), but the tone frequency is now 0.745Hz because of the different value of *m*.

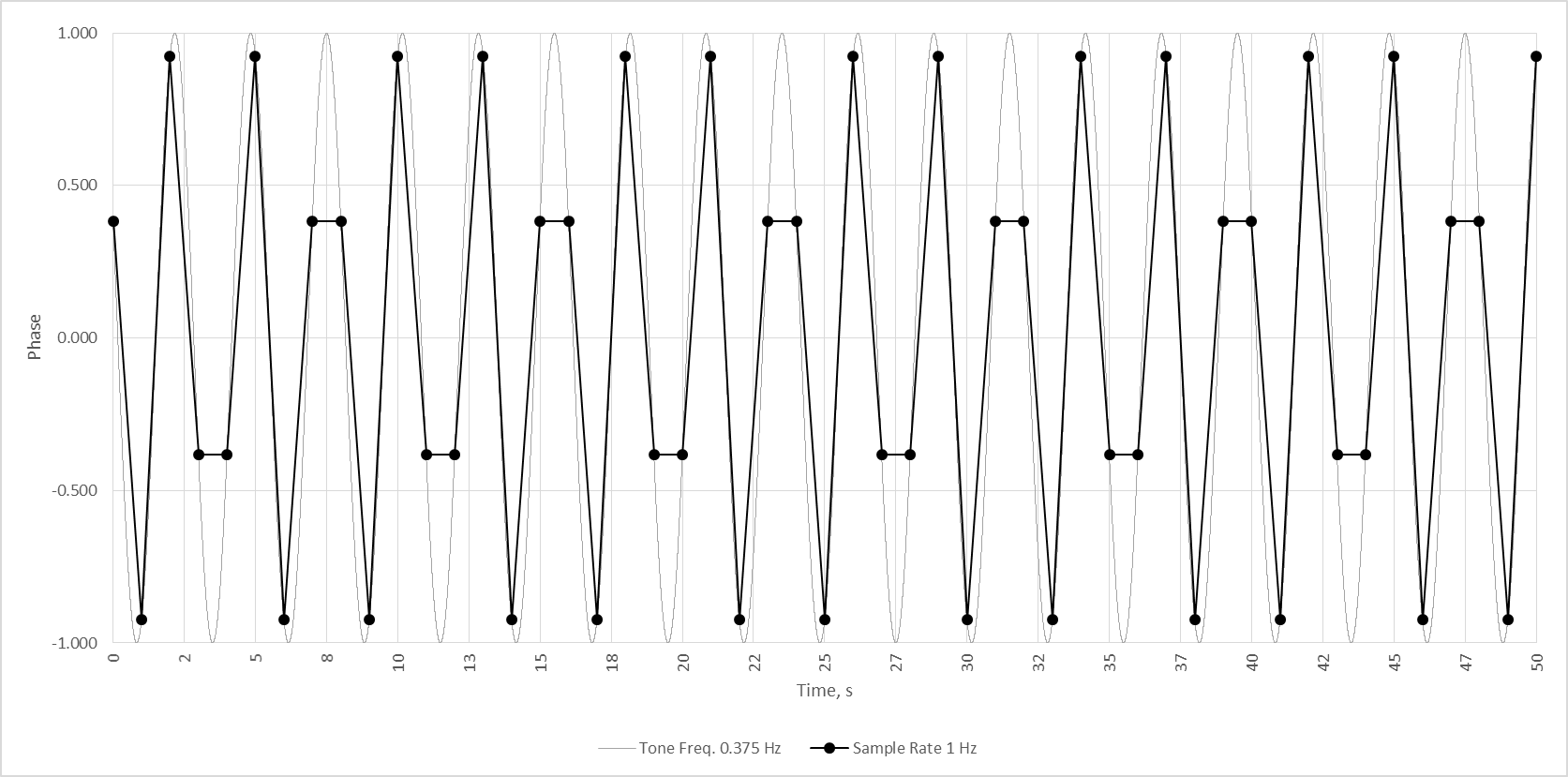


**Figure** VI**.3: Sub-Nyquist Artefact for *m* = 3, *n* = 4, *ε* = -0.005 Hz**

When measuring noise transfer, it is the peak-to-peak magnitude of the output response that is measured. Therefore, the frequency of the envelope repeat should be high enough to give sufficient repeats of the envelope in a reasonable measurement period. Since this is related to the artefact frequency *(ε)*, it can be controlled by setting the artefact frequency appropriately. It should be noted that where *n* is large, the envelope repeat frequency may approach or even exceed the tone frequency. In these cases, it loses its meaning.

## Choice of Artefact frequency

Care should be taken that the artefact frequency is chosen correctly. For example, in Figure VI.4, *m* = 1, *n* = 2, and *ε* = 0.125 Hz. In this case, the envelope never quite gets to +1 or -1 at its peak values, resulting in about a 0.7dB loss in amplitude.



**Figure** VI.**4: Sub-Nyquist Artefact for *m* = 1, *n* = 2, *ε* = 0.125 Hz**

This is because the artefact frequency is both too high relative to the sample rate (i.e. there are not enough samples in each artefact period), and also it is an integer divisor of the sampling rate (1/8), therefore every 16th sample occurs at the same phase of the artefact frequency.

Therefore, the artefact frequency should be chosen against the following criteria:

* Low frequency relative to both the sampling rate and tone frequency, to ensure sufficient points in each period
* Not close to an integer divisor of the sampling rate
* High enough that the envelope repeat period is reasonable, ensuring measurement times are not excessively long

## Possible Frequencies

The following table shows tone frequencies that could potentially be used to measure the transfer response of a T-BC. These tone frequencies assume a PTP event message rate (Sync and Delay\_req) of precisely 16.000 Hz.  When the message rate is not precisely 16.000 Hz (the allowed range in the standard is 16 Hz ± 30% for Sync and 16 Hz +0% to -30% for Delay\_req),  this will generate sub-Nyquist artefacts at different frequencies, and therefore will require different input tone frequencies than shown in the table.

These tone frequencies have been chosen according to the following criteria:

1. The tone frequencies are separated by approximately a factor of two, giving both good coverage of the frequency space, and equal spacing on a logarithmic axis
2. The artefact frequency *ε* is fixed at 0.015 times the nominal tone frequency, to ensure enough points in each artefact period.
3. The envelope frequency is fixed at 0.015Hz at the 1pps output, to permit reasonable measurement times (200s per frequency, apart from the lowest frequencies which require longer measurement times)
4. The range of frequencies extends more than a decade either side of the specified T-BC filter bandwidth range of 0.05 to 0.1Hz
5. For frequencies 0.03125Hz and below, the *n* value is greater than 16 even for the 1pps output. Therefore there is no requirement to adjust the nominal tone frequency.
6. The same frequencies may be used to measure at both the PTP and 1pps outputs, to allow the tests to be conducted concurrently

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Nominal Frequency, Hz | Tone Frequency, Hz | 16pkts/s PTP | | | 1pps output | | |
| *m, n* | epsilon, Hz | envelope, Hz | *m, n* | epsilon, Hz | envelope, Hz |
| 0.00390625 | **0.00390625** | No requirement to adjust the nominal frequency (*n* ≥ 32) | | | No requirement to adjust the nominal frequency (*n* ≥ 32) | | |
| 0.0078125 | **0.0078125** |
| 0.015625 | **0.015625** |
| 0.03125 | **0.03125** |
| 0.0625 | **0.0615625** | 1, 256 | -0.0009375 | n/a  (>0.5\**ft*) | 1, 16 | -0.0009375 | -0.015 |
| 0.125 | **0.123125** | 1, 128 | -0.001875 | 1, 8 | -0.001875 | -0.015 |
| 0.25 | **0.24625** | 1, 64 | -0.00375 | 1, 4 | -0.00375 | -0.015 |
| 0.5 | **0.4925** | 1, 32 | -0.0075 | -0.24 | 1, 2 | -0.0075 | -0.015 |
| 1 | **0.985** | 1, 16 | -0.015 | -0.24 | 1, 1 | -0.015 | Aliased component at 0.015Hz |
| 2 | **1.985** | 1, 8 | -0.015 | -0.12 | 2, 1 | -0.015 |
| 4 | **3.985** | 1, 4 | -0.015 | -0.06 | 4, 1 | -0.015 |
| 8 | **7.985** | 1, 2 | -0.015 | -0.03 | 8, 1 | -0.015 |

**Table** VI**.1: Possible Tone Frequencies for Measuring Frequency Response of T-BCs**

## Expected Filter Response (PTP to PTP and PTP to 1pps Noise Transfer)

The frequency response of the clock is not completely defined in clause 7.3.1. In order to evaluate the performance of the clock, the following criteria are recommended.

1. The minimum implementation should have a gain reduction of at least that of a first-order, -20dB/decade filter for frequencies above the maximum permitted bandwidth.
2. The maximum permitted gain peaking for frequencies below the maximum permitted bandwidth should be 0.1dB.
3. The maximum attenuation for frequencies below the minimum permitted bandwidth should be 3dB.
4. The attenuation at the maximum permitted bandwidth point should be at least 3dB.
5. The maximum attenuation at frequencies above the minimum permitted bandwidth should be undefined.

The maximum and minimum acceptable gain at different frequencies is given in Tables VI.2 and VI.3, and shown in Figure VI**.5**. Any measured response within the grey zone is considered acceptable. This is before taking into account any noise generation of the clock.

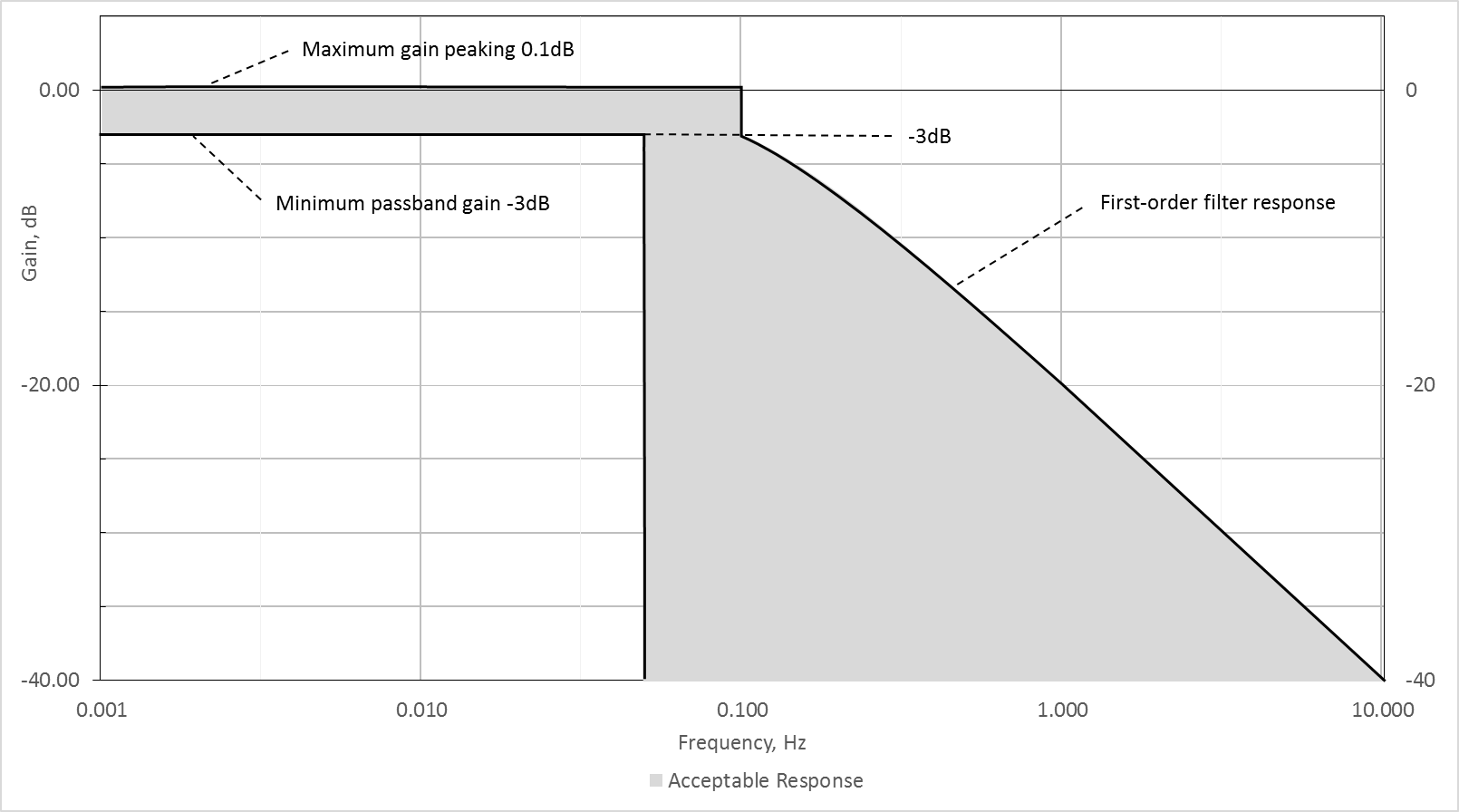
Although Figure VI.5 could be interpreted as having a ‘range’ of acceptable frequency responses in the passband, once the filter response of the implementation has been established, it is expected that the frequency response will not change over time.

|  |  |  |
| --- | --- | --- |
| **Frequency range, Hz** | **Maximum gain, dB** | **Notes** |
| *f* < 0.1 | 0.1 | 1 |
| *f* ≥ 0.1 |  | 2 |
| NOTE 1: This is the maximum phase gain in the passband, per clause 7.3.1  NOTE 2: Formula is based on a first-order low-pass filter response, using the maximum bandwidth from clause 7.3.1 | | |

**Table** VI**.2:** Maximum Gain for PTP to PTP Filter Implementation

|  |  |  |
| --- | --- | --- |
| **Frequency range** | **Minimum gain, dB** | **Notes** |
| *f* < 0.05 | -3dB | 1 |
| *f* > 0.05 | no minimum gain specified |  |
| NOTE 1: This is the minimum gain in the pass band | | |

**Table** VI**.3:** Minimum Gain for PTP to PTP Filter Implementation

****

**Figure** VI**.5**: Frequency Response of Acceptable PTP to PTP Filter Implementation

When measuring the performance of the clock, the noise generation of the clock must be taken into account. There are several methods that can be used to do this.

1. Allow up to ±50ns for noise generation. This is based on the difference between the maximum absolute time error and the constant time error a T-BC of 50ns (100ns and 50ns respectively for Class A T-BCs; 70ns and 20ns respectively for Class B T-BCs).
2. Measure the actual noise generation of the T-BC, and use this as the allowance. For example, the allowance could be ±*x* ns, where *x* is the peak to peak amplitude of the measured noise generation.   
   This has the potential to be more accurate than the first method, but there is a risk that the DUT may be falsely declared as failing the test if the noise generated during the noise transfer test is different from when the noise generation was measured. Note that the test failure is caused by this method, not caused by the tested clock.
3. Use a least-squares estimation algorithm to remove the noise generation of the clock, and estimate the output amplitude of the sine wave test tone. This is capable of estimating the amplitude to a reasonable precision with a good level of confidence, provided the added noise is white phase modulation. The accuracy of this method when the added noise has different characteristics (e.g. random walk, other power-law noise types, or sinusoidal noise) is for further study.
4. Use a pulse-amplitude modulation method to re-construct the original signal. This involves taking a Fourier transform of the output to recover the tone frequency and its amplitude.

Table VI**.**4 lists each test frequency, with the permitted gain and expected output amplitude, both with and without added noise. The amount of noise, *N*, is dependent on which of the four methods is being used. The input tone amplitude used is 200ns, based on the PTP noise tolerance of the clock. This table could be used as pass/fail criteria for the noise transfer of the clock.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Frequency, Hz | **Peak-to-peak Input Amplitude, ns** | **Permitted gain, dB** | | **Peak-to-peak Output amplitude (clean), ns** | | **Peak-to-peak Output amplitude, with ±*N* ns added noise, ns** | |
| Maximum | Minimum | Maximum | Minimum | Maximum | Minimum |
| 0.00390625 | 200 | 0.1 | -3 | 205 | 140 | 205 + *N* | 140 – *N* |
| 0.0078125 | 200 | 0.1 | -3 | 205 | 140 | 205 + *N* | 140 – *N* |
| 0.015625 | 200 | 0.1 | -3 | 205 | 140 | 205 + *N* | 140 – *N* |
| 0.03125 | 200 | 0.1 | -3 | 205 | 140 | 205 + *N* | 140 – *N* |
| 0.0615625 | 200 | 0.1 | n/a | 205 | n/a | 205 + *N* | n/a |
| 0.123125 | 200 | -4 | 130 | 130 + *N* |
| 0.24625 | 200 | -8.5 | 80 | 80 + *N* |
| 0.4925 | 200 | -14 | 40 | 40 + *N* |
| 0.985 | 200 | -19.9 | 25 | 25 + *N* |
| 1.985 | 200 | -26 | 15 | 15 + *N* |

**Table** VI**.4:** Maximum and Minimum Expected Output Amplitudes at Test Frequencies for PTP-to-PTP and PTP-to-1pps Noise Transfer Measurement

NOTE 1 – The frequencies in the above table assume an input PTP event message rate of precisely 16.00 messages/s. For other rates, different tone frequencies should apply as described earlier.

NOTE 2 – The maximum amplitude values in the table have been rounded up to the nearest 5ns in order to account for measurement equipment accuracy, while the minimum amplitude values have been rounded down to the nearest 5ns.

## Expected Filter Response (SyncE to PTP and SyncE to 1pps Noise Transfer)

The frequency response of the clock is completely not defined in clause 7.3.2. In order to evaluate the performance of the clock, the following criteria are recommended.

1. The minimum implementation should have a gain reduction of at least that of a first-order, -20dB/decade filter for frequencies below the minimum permitted lower corner frequency, and above the maximum permitted upper corner frequency.
2. The maximum permitted gain peaking for frequencies between the minimum permitted lower corner frequency and the maximum permitted upper corner frequency should be 0.2dB.
3. The maximum attenuation for frequencies between the maximum permitted lower corner frequency and the minimum permitted upper corner frequency should be 3dB.
4. The attenuation at the maximum permitted upper and minimum permitted lower corner frequencies should be at least 3dB.
5. The maximum attenuation at frequencies below the maximum permitted lower corner frequency and above the minimum permitted upper corner frequency should be undefined.

The maximum and minimum acceptable gain at different frequencies is given in Tables VI.5 and VI.6, and shown in Figure VI.6. This figure represents the bandpass frequency response when the T-BC or T-TSC is assisted by a physical layer clock specified in [ITU-T G.8262] option 1. The response when the T-BC or T-TSC is assisted by a different physical layer, such as [ITU-T G.812] Type I, is for further study.

Any measured response within the grey zone is considered acceptable. This is before taking into account any noise generation of the clock.

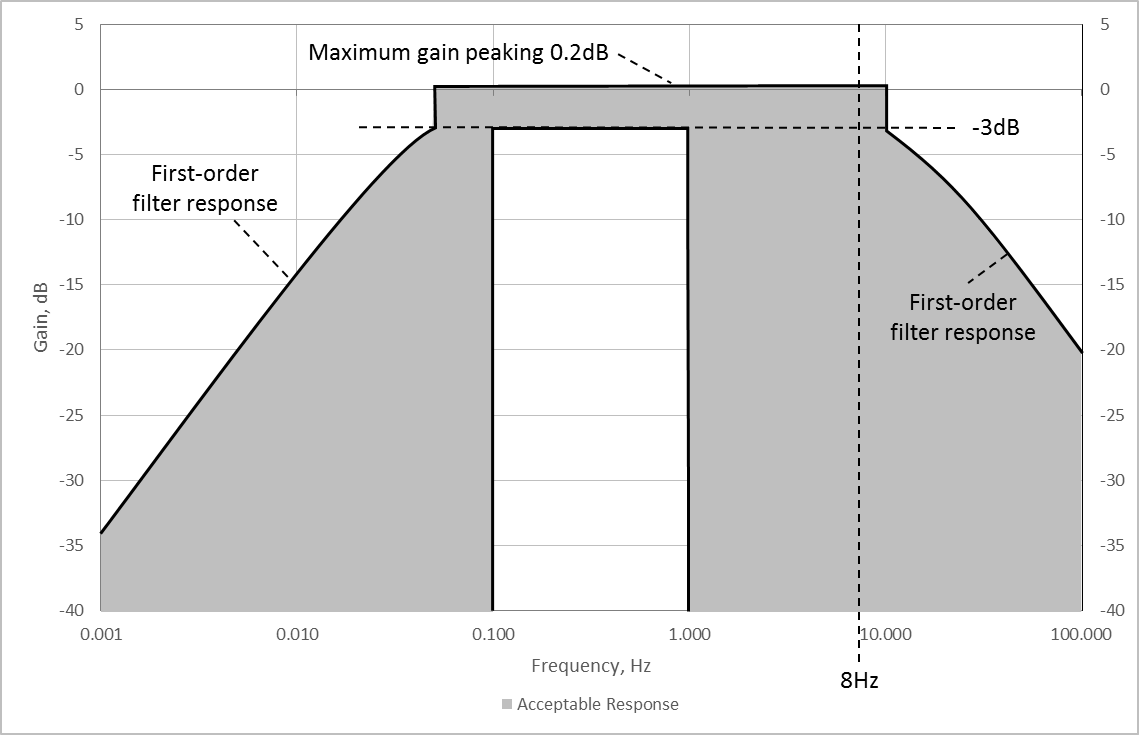
Although Figure VI.6 could be interpreted as having a ‘range’ of acceptable frequency responses in the passband, once the filter response of the implementation has been established, it is expected that the frequency response will not change over time.

|  |  |  |
| --- | --- | --- |
| **Frequency range, Hz** | **Maximum gain, dB** | **Notes** |
| *f* ≤ 0.05 |  | 1 |
| 0.05 < *f* < 10 | 0.2 | 2 |
| *f* ≥ 10 |  | 3 |
| NOTE 1: Formula is based on a first-order high-pass filter response, using the minimum bandwidth from clause 7.3.2  NOTE 2: This is the maximum phase gain in the passband, per clause 7.3.2  NOTE 2: Formula is based on a first-order low-pass filter response, using the maximum bandwidth from clause 7.3.2 | | |

**Table** VI**.5:** Maximum Gain for SyncE to PTP Filter Implementation

|  |  |
| --- | --- |
| **Frequency range** | **Minimum gain, dB** |
| *f* < 0.1 | No minimum gain specified |
| 0.1 ≤ *f* ≤ 1 | -3 |
| *f* > 1 | no minimum gain specified |

**Table** VI**.6:** Minimum Gain for SyncE to PTP Filter Implementation

****

**Figure** VI**.6**: Frequency Response of Acceptable SyncE to PTP Filter Implementation

NOTE – Since the PTP message rate is 16Hz, it will not be possible to measure the frequency response above the Nyquist rate of 8Hz. This means it might not be possible to verify the upper corner frequency of the bandpass filter.

When measuring the performance of the clock, the noise generation of the clock must be taken into account. The same methods as described above may be used to do this.

The input tone amplitude used is 250ns, based on the noise tolerance of the EEC. This table could be used as pass/fail criteria for the noise transfer of the clock.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Frequency, Hz | **Peak-to-peak Input Amplitude, ns** | **Permitted gain, dB** | | **Peak-to-peak Output amplitude (clean), ns** | | **Peak-to-peak Output amplitude, with ±*N* ns added noise, ns** | |
| Maximum | Minimum | Maximum | Minimum | Maximum | Minimum |
| 0.00390625 | 250 | -22.3 | n/a | 20 | n/a | 20 + *N* | n/a |
| 0.0078125 | -16.3 | 40 | 40 + *N* |
| 0.015625 | -10.6 | 75 | 75 + *N* |
| 0.03125 | -5.6 | 135 | 135 + *N* |
| 0.0615625 | 0.2 | 260 | 260 + *N* |
| 0.123125 | -3 | 175 | 175 – *N* |
| 0.24625 |
| 0.4925 |
| 0.985 |
| 1.985 | n/a | n/a | n/a |
| 3.985 |
| 7.985 |

**Table** VI**.5:** Maximum and Minimum Expected Output Amplitudes at Test Frequencies for SyncE-to-PTP and SyncE-to-1pps Noise Transfer Measurement

NOTE 1 – The frequencies in the above table assume an input PTP event message rate of precisely 16.00 messages/s. For other rates, different tone frequencies should apply as described earlier.

NOTE 2 – The maximum amplitude values in the table have been rounded up to the nearest 5ns in order to account for measurement equipment accuracy, while the minimum amplitude values have been rounded down to the nearest 5ns.

Bibliography

[b-Amidror] Isaac Amidror, *“Sub-Nyquist Artefacts and Sampling Moiré Effects”*, Royal Society Open Science, 2015 March, 2(3): 140550, published online March 18, 2015, available at <http://rsos.royalsocietypublishing.org/content/2/3/140550>

i Some literature (e.g. the Amidror paper) refer to the pattern as consisting of several interlaced envelopes at the artefact frequency, ε. In this document, the envelope repeat period refers to the period between crests of the overall envelope pattern.

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1. [↑](#endnote-ref-1)