Implementors' Guide for ITU-T Recommendation G.168
(issue 2)

1 Introduction

This document contains technical corrections and clarification for the implementation of ITU-T Recommendation G.168 (06/02). This is an updated version of the Implementor’s Guide, issue 1 (January 2003).

1.1 References

[1] ITU-T Recommendation G.168 (06/02) - Digital network echo cancellers

1.2 Background

This guide is a compilation of reported defects, their resolutions and minor upgrades to the June 2002 edition of ITU-T Recommendation G.168 [1]. It includes all approved corrigenda and is intended to be an additional authoritative source of information for implementors to be read in conjunction with the Recommendation itself.

1.3 Scope of the guide

This guide records the resolutions of defects in the following categories:

- technical errors, such as omissions, inconsistencies, etc.
- ambiguities.

1.4 Document history

Version	Summary
Issue 1	Agreed at SG15 meeting, Geneva, 20-31 January 2003
Issue 2	Agreed at SG15 meeting, Geneva, 21-31 October 2003

2 Technical errors and ambiguities

2.1 Definition of echo return loss (ERL) (A_{ECHO})

Section 3.13 defines echo return loss. A note to this definition gives the impression that the only difference between ERL as defined in G.168 and echo loss as defined in ITU-T Recommendation G.122 is the point of measurement. This is not the case, and could cause confusion to people familiar with one definition but not the other.

The following modifications should therefore be made to the note following the definition of ERL:

NOTE – ERL is not the same as echo loss defined in ITU-T 2.2/G.122 since echo loss is a weighted integral of the loss/frequency function over the band 300-3400 Hz, and so has a fixed value for any particular echo path characteristic. Also, echo loss applies to loss of the a-t-b path viewed from the virtual switching point of the international circuit. The echo canceller may be located closer to the echo reflection point.

2.2 Test No. 2C: Convergence test in the presence of background noise

The reference to Figures 10 and 12 in 6.4.2.3.3 is incorrect. The correct reference should be to Figure 16.

2.3 Test No. 2C part (c) - Convergence test in the presence of background noise (NLP disabled)

There are a number of ambiguities associated with this test which should be corrected as follows:

- Add t_0 to Figure 13/G.168
- The convergence time allowed in Test 2C part (c) is 10
- The requirements graph in Figure 16/G.168 should be truncated after 10s + t_d since the steady state requirement for Test 2C is given in part (b)
- Add the following note under part (c):

NOTE: The method used to measure the noise in this test, results in fluctuating levels and can result in difficulty when performing this test.

2.4 Clarification of the measurement procedure for Tests 2C, 3A and 3B

In ITU-T Recommendation G.168 (06/02), a small change to the test method for Tests 2C(a), 2C(b), 3A and 3B has required the timing diagrams for these tests to be redrawn relative to the G.168 (04/00) version of the tests. In the earlier diagrams for Tests 2C and 3A, a delay was indicated between terminating the S_{gen} noise and starting the measurement of the signal at S_{out}. This delay is necessary if the level measurement device of section 6.4.1.2.1/G.168 is used for the measurements at S_{out}, otherwise S_{gen} noise energy stored in the bandpass filter and exponential filter of this measurement device will encroach into the measurement interval.

In G.168 (06/02) it is possible to overcome this problem in a number of different ways:

Option 1:

- A delay to the start of the measurement interval is re-introduced into the timing diagrams for Test 2C and also for Tests 3A and 3B if the 6.4.1.2.1 measurement method is used. The energy stored in the bandpass filter will propagate out in less than 13ms. The output from the exponential filter will decay by about 23dB in 187ms. Therefore, a total delay of 200ms before starting the measurement is more than adequate for tests 2C and 3A. This is shown in the modified Figures 13 and 17.

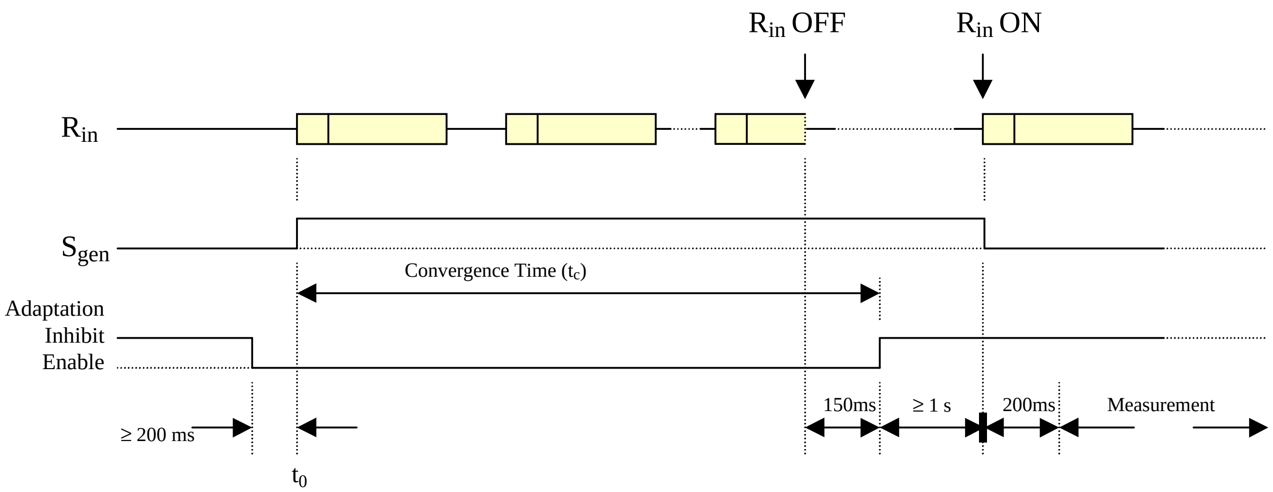

Figure 13/G.168 - Test No. 2C signal and time relationships

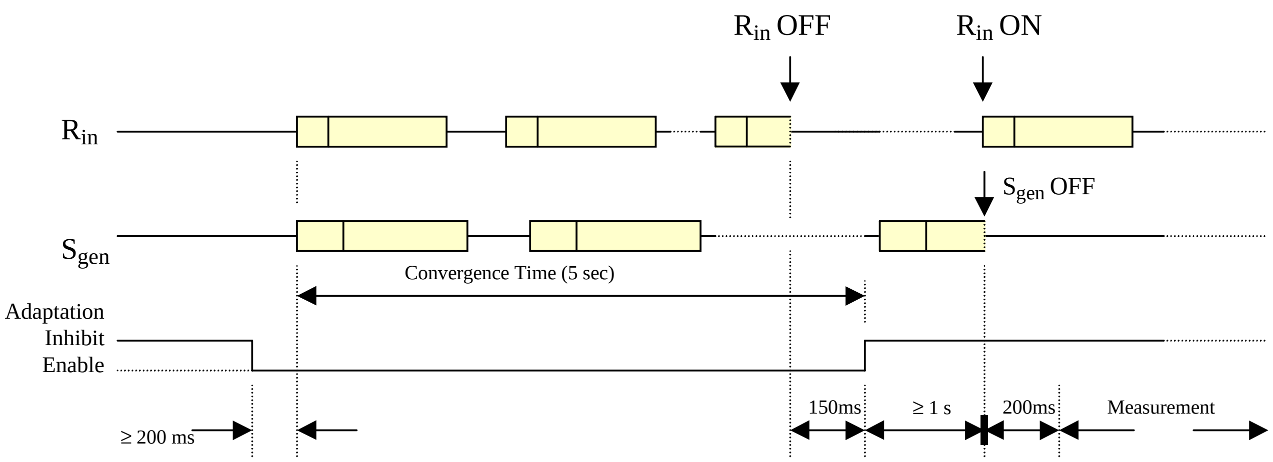

Figure 17/G.168 - Test No. 3A signal and time relationships

For Test 3B, the longest measurement delay is required when the test levels are $L_{Sgen,act}$ = 0dBm0 and $L_{Rin,act}$ = –30dBm0, and L_{RES} is at the threshold of failure (-45dBm0). In this situation, when the signal at S_{gen} is discontinued, the signal at R_{in} is reinstated and will rapidly exert an influence if echo path delay, t_d, is low. The output from the exponential filter will decay towards L_{RES}, becoming asymptotic to that level. Thus, to guarantee a pass result, in theory an infinite delay would be required before starting the measurements. In practice, bearing in mind that such a test result represents a borderline failure in any case, it is sufficient to ensure that the output from the exponential filter decays to a value indistinguishable from L_{RES} because of fundamental limitations due to noise and resolution. It is suggested that the chosen delay should allow the output from the exponential filter to decay, theoretically, to within 0.2 dB of L_{RES}. A total delay of 400ms (which includes 13ms to clear the history in the bandpass filter) would only allow the output from the exponential filter to decay to 1.76 dB of L_{RES}, and so this value of delay is insufficient. A total delay of 500ms (including 13ms to clear the history in the bandpass filter) would allow the output from the exponential filter to decay to 0.12 dB of L_{RES}, and so represents a suitable delay to the measurements. Hence Figure 18/G.168 is modified to show a delay of 500 ms between terminating the S_{gen} noise signal and starting the measurement of the signal at S_{out}.

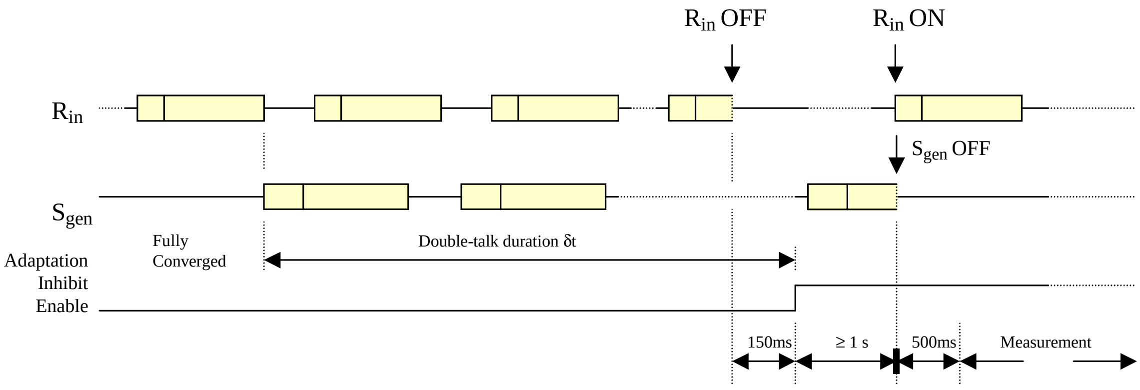

Figure 18/G.168 - Test No. 3B signal and time relationships

Option 2:

- The contents of the bandpass filter and exponential filter in the measurement device are set to zero (flushed) before any measurement is performed.

2.5 Clarification of the measurement method to be used for Tests 3, 4 and 6

In G.168 (04/97) only Tests 2A and 2B used the 35ms exponential filter. The filter was not specified for any other tests. Tests 3B, 3C, 4 and 6 referred back to Figures presented in Test 1, but since none of these tests used the exponential filter, there was no ambiguity.

In G.168 (06/02) Tests 1 and 2 are combined and there are three RMS measurement methods defined:

- the RMS method of section 6.4.1.2
- the level measurement device of section 6.4.1.2.1 (includes the 35ms exponential filter)
- the level measurement device for peaks of section 6.4.1.2.2.

Section 6.4.1.2 of G.168 (06/02) is titled “Measuring input and output levels”, and contains the following statements:

> *“For testing purposes, the method defined for measuring the input level of the composite source signals is a RMS method. Unless otherwise specified within a test, the RMS method should also be used for measuring the output levels at S_{out}.”*

> *“Some tests in this recommendation, e.g. Test No. 2, use the RMS value that is measured over the active portion of the CSS (i.e. excluding the pause in the CSS) only. The subscript ‘act’ in a signal level is used to denote the level measurement in this case. For example, if L_{Rin} is the RMS level of R_{in} including the pause, then $L_{Rin,act}$ is the RMS level of Rin excluding the pause.”*

From the example of Test 2 it may be concluded that, for CSS, $L_{Rin,act}$ should be specified wherever it is intended that S_{out} is measured using the level measurement device of 6.4.1.2.1. This has given rise to uncertainty regarding the intended method of RMS measurement for tests 3, 4 and 6 in G.168 (06/02) because these tests refer back to Figures in Test 2 that have the x axis labelled ‘$L_{Rin,act}$’.

Based on the above and the test specifications in G.168 (06/02), the measurement methods to be used for the individual tests are summarised in the list below. The list includes all tests that require level measurements at S_{out}. For most tests the required measurement technique is clear and unambiguous. Tests in which the requirement is not clear are underlined.

Test 2A: 6.4.1.2.1 and 6.4.1.2.2 and $L_{Rin,act}$ specified. No ambiguity.

Test 2B: 6.4.1.2.1 and 6.4.1.2.2 and $L_{Rin,act}$ specified. No ambiguity.

Test 2C: 6.4.1.2.1 and $L_{Rin,act}$ specified. No ambiguity.

Test 3A: 6.4.1.2 default method. {No mention of 6.4.1.2.1 or of $L_{Rin,act}$, therefore no ambiguity.}

<u>Test 3B:</u> 6.4.1.2 default method. {No mention of 6.4.1.2.1, but refers back to Figure 11 in which the x axis has been re-labelled $L_{Rin,act}$ in G.168 (06/02), therefore **the requirement is not clear.**}

<u>Test 3C:</u> 6.4.1.2 default method, and specific checks on peaks using 6.4.1.2.2 method. {No mention of 6.4.1.2.1, but refers back to Figure 9 in which the x axis has been re-labelled $L_{Rin,act}$ in G.168 (06/02), therefore **the requirement is not clear.}**

<u>Test 4:</u> 6.4.1.2 default method. {No mention of 6.4.1.2.1, but refers back to Figure 11 of Test 2 in which the x axis has been re-labelled $L_{Rin,act}$ in G.168 (06/02), therefore **the requirement is not clear.**}

Test 5: 6.4.1.2.1 and $L_{Rin,act}$ specified. No ambiguity.

<u>Test 6:</u> 6.4.1.2 default method. {No mention of 6.4.1.2.1, but refers to "the signal of Test 2" and Figure 11 of Test 2 in which the x axis has been re-labelled $L_{Rin,act}$ in G.168 (06/02), therefore **the requirement is not clear.**}

Test 7: 6.4.1.2.1 specified. No ambiguity.

Test 8: 6.4.1.2.1 specified. No ambiguity.

Test 9: 6.4.1.2 default method. {No mention of 6.4.1.2.1, therefore no ambiguity.}

Test 10A: 6.4.1.2.2 specified. No ambiguity.

Test 10B: 6.4.1.2.2 specified. No ambiguity.

Test 13: 6.4.1.2.2 specified, and 6.4.1.2.1 implied by reference to Tests 2A and 2B. No ambiguity.

Test 15: 6.4.1.2.1 and 6.4.1.2.2 and $L_{Rin,act}$ specified. No ambiguity.

The test list above shows that the measurement method for Test 3A is unambiguously defined according to the wording in G.168 (06/02). However, since Test 3A is similar in many respects to Test 3B, it is concluded that the same measurement method was intended for both. Therefore, the uncertainty regarding Test 3B reflects similar uncertainty on to Test 3A.

The main purpose of the exponential filter measurement method in G.168 (04/97) was to provide a short-term measurement so that the initial convergence of an echo canceller could be tracked with reasonable accuracy. In G.168 (06/02), the short-term level measurement device of 6.4.1.2.1 includes a bandpass filter primarily to eliminate the low-level D.C. bias that can occur with A-law encoding. Therefore, compared with the default 6.4.1.2 method, there seems no advantage in employing the 6.4.1.2.1 method in NLP-disabled tests when measurements are made after adaptation is inhibited. Test 3A, 3B, 4 and 6 fall into this category. However, the 6.4.1.2.1 bandpass filter may have some influence in NLP-enabled tests where it is anticipated that the Sout level may be in the region of –65dBm0 or below. Test 3C falls into this category.

In parts of Test 3C the 6.4.1.2.2 method for measuring signal peaks is specified, and so these regions are independent of the choice between 6.4.1.2 or 6.4.1.2.1 methods. In the region affected by the choice, the 6.4.1.2.1 method may lead to lower measured levels for short-term peaks, but the long averaging period of the default 6.4.1.2 method will reduce the influence of such peaks. Therefore, the effect on the pass or fail results for an echo canceller is likely to be small, and it is not clear that either method offers any particular advantage.

To remove the ambiguities outlined above, the 6.4.1.2.1 level measurement device should be used for Tests 3A, 3B, 3C, 4 and 6, except where otherwise specified in the test Requirement (e.g. Test 3C).

There are slightly more changes required for the double-talk tests (Test 3) since the specification of $L_{\text{Rin,act}}$ requires a corresponding specification of $L_{\text{Sgen,act}}$ in most cases, even if only to avoid specifying both L_{Rin} and $L_{\text{Rin,act}}$ in the same test. In the requirements below, $L_{\text{Sgen,act}}$ replaces nearly all instances of L_{Sgen} in the existing text, but reviewers are asked to give careful consideration to this aspect.

The following changes should be made to the requirements of each test:-

Test 3A: The Requirement is modified to read:

With the H register initially set to zero for all values of $L_{\text{Rin,act}} \geq -25$ dBm0 and ≤ 0 dBm0, $L_{\text{Sgen,act}} = L_{\text{Rin,act}} -15$ dB, ERL ≥ 6 dB and echo path delay, $t_d \leq \Delta$ ms, convergence should occur within 5 s and L_{RES} should be $\leq L_{\text{Sgen,act}}$. The level measurement device of section 6.4.1.2.1 should be used to measure the signal at S_{out}.

Test 3B: The Requirement is modified to read:

With the echo canceller initially in the fully converged state for all values of $L_{\text{Rin,act}} \geq -30$ dBm0 and ≤ 0 dBm0, and for all values of $L_{\text{Sgen,act}} \geq L_{\text{Rin,act}}$ and for all values of ERL ≥ 6 dB and echo path delay $t_d \leq \Delta$ ms, the residual echo level after the simultaneous application of R_{in} and S_{gen} for any time period should not increase more than 10 dB over the steady state requirements of Figure 11. The level measurement device of section 6.4.1.2.1 should be used to measure the signal at S_{out}.

Test 3C: The Requirement is modified to read:

With the H-register initially set to zero, for all values of $L_{\text{Rin,act}} \geq -25$ dBm0 and ≤ 0 dBm0, and for all values of $L_{\text{Sgen,act}} \geq L_{\text{Rin,act}}$ and for all values of ERL ≥ 6 dB and echo path delay td $\leq \Delta$ ms, any peaks (see 6.4.1.2.2) during period t_2 should not exceed the level $L_{\text{Sgen,act}}$ during period t_1. The residual echo level (measured using the level measurement device of section 6.4.1.2.1) during time period t3 should meet the requirements of Figure 9 with NLP enabled. During t_4 and t_5, no peaks (see 6.4.1.2.2) should exceed the level of $L_{\text{Sgen,act}} + 6$ dB.

Level offsets between L_{Rin} and L_{Sgen} can cause inappropriate operation of the NLP and can cause speech degradation and is for further study. Variation of CSS may be useful for this purpose.

Test 4: The Requirement is modified to read:

With the echo canceller initially in the fully converged state for all values of $L_{\text{Rin,act}} \geq -30$ dBm0 and ≤ 0 dBm0, two minutes after the removal of the R_{in} signal, the residual echo level should not increase more than 10 dB over the steady state requirement of Test No. 2 (Fig. 11). The level measurement device of section 6.4.1.2.1 should be used to measure the signal at S_{out}.

Test 6: The Requirement is modified to read:

The echo canceller is fully converged as in test 2 for all values of ERL ≥ 6 dB, and echo path delay $t_d \le \Delta$ ms. Once chosen, the echo path remains the same throughout the test. The sequence of tones of Table 2 (with the higher frequency 2 dB higher than the lower frequency for the dual tone combinations) is then applied for 5 s each to R_{in} such that $L_{Rin,act}$ ≥ -30 dBm0 and ≤ 0 dBm0. After the application of the tone sequence, the adaptation is inhibited. Using the same signal as in Test No. 2 the measured residual echo should not degrade more than 10 dB from the requirements of Figure 11 of Test No. 2. The NLP is disabled for this test. The level measurement device of section 6.4.1.2.1 should be used to measure the signal at S_{out}.

2.6 Test No. 6 – Non-divergence on narrow-band signals

It should be noted that the period of ≥ 1 second allowed following the adaptation inhibit command in G.168 tests should be applied to this test also.

2.7 Test No. 7 - Stability test

The requirements for Test No. 7 are given in Figure 22/G.168. This graph gives L_{RES} plotted against L_{Rin}. The graph is intended to be a straight line between the following two co-ordinates:

(-30, -55)

(+3, -27.5)

The graph in Figure 22 is correct at these two points, but due to unequal spacing, is incorrect everywhere else. Figure 22 should therefore be deleted and replaced with the following:

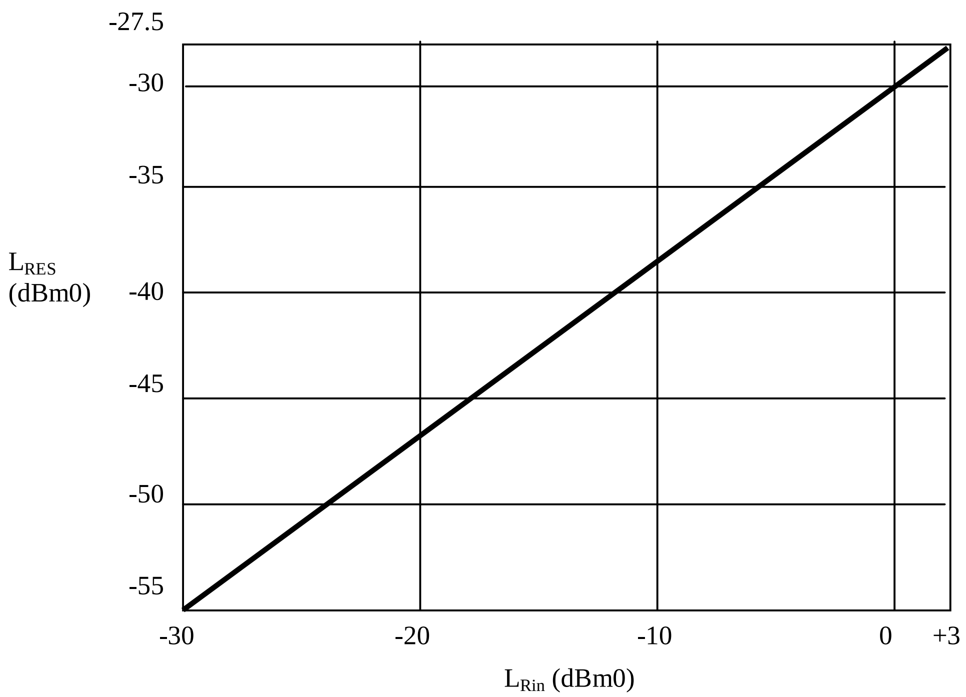

Figure 22/G.168 - Performance requirements for test 7

Note that the equation for the line in Figure 22 is: $L_{RES} = 0.83L_{RIN} - 30$

2.8 Test No. 9 - Comfort noise test

In the description of Test 9, the measurement method is specified, by default, to be the RMS method of section 6.4.1.2. However, the duration of the measurement is not specified.

The Requirement for Test 9 states:

L_{RET} should be within 2.0 dB of L_{Sgen}. Also, this value should hold as long as noise level L_{Sgen} remains constant.

Since a single, long-term measurement could hide unacceptable short-term level variations, in order to check the requirement it is necessary to specify a measurement duration, and to stipulate that this measurement be sequentially repeated over a longer period of time.

To obtain an acceptably accurate average value when measuring a noise signal, it may be necessary for the measurement period to be at least a few hundred milliseconds. An averaging period of 700ms is considered suitable for the measurement of L_{RET} in Test 9. To check that the level of L_{RET} does not fluctuate unacceptably, the measurement should be repeated sequentially over a minimum period of 8 seconds. All measurements should be within 2dB of L_{Sgen}.

The wording in the Test 9 Requirement should be modified as follows (3 places):

L_{RET} should be within 2.0 dB of L_{Sgen} when measured over a 700ms window. Also, this value should hold as long as noise level L_{Sgen} remains constant, and sequential 700ms measurements should be made over a minimum period of 8 seconds to check this.

2.9 Test No. 13 - Performance with ITU-T low bit rate coders in echo path (Optional, under study)

Test 13 requires that Tests 2A and 2B are performed with the echo canceller disabled in order to record a ‘baseline’. Tests 2A and 2B are then repeated with the echo canceller enabled, and the performance is compared with the baseline. The following aims to clarify the requirement for the recorded baseline.

Test 13 also requires that the measured peaks do not exceed 5dB above the “measured returned echo level”. The following also aims to clarify what is meant by “the measured returned echo level” in the context of the check on signal peaks.

When performed as tests in their own right, Tests 2A and 2B compare the measured level of the S_{out} signal with a mask. The measured level will change over time due to convergence of the echo canceller and due to the gaps in the CSS test signal. The mask contains a slope to accommodate the echo canceller convergence, but is otherwise flat for the first 10 seconds of the test.

In test 13, when the echo canceller is disabled, there will be no convergence, so the CSS peaks will all be at approximately the same level. It seems sensible, therefore, to set the baseline to the highest level recorded in the first stage of the test, as measured with the level measurement device of section 6.4.1.2.1. The baseline then becomes the mask for the second stage of the test, and the mask is flat throughout the test.

When running Tests 2A and 2B in their own right, the requirement for signal peaks (6.4.1.2.2) is with respect to a mask level that is flat over time. In Test 13, the requirement for signal peaks relative to “the measured returned echo level” is taken to mean relative to the baseline as discussed above.

For the reasons discussed above, the second paragraph under section 6.4.2.14 should be modified to read:

The test method is to place the echo canceller in the test configuration of Figure 28. Tests 2A and 2B are performed with the echo canceller disabled, and the residual echo level measured using a meter conforming to the characteristics of 6.4.1.2.1. The highest measured level is used as a baseline for the next stage of the test. Test 2A and test 2B are then repeated with the echo canceller enabled and the performance is compared with the baseline.

In addition, the first paragraph under the Requirement should be modified to read:

For the stated ITU-T coders, the residual echo power measured (see 6.4.1.2.1) with the echo canceller enabled should be equal to or less than the measured baseline with the echo canceller disabled. In addition, no peaks (see 6.4.1.2.2) are allowed that exceed 5dB above the measured baseline with the echo canceller disabled. The coders for which this test is applicable are to be stated by the user.

It should also be noted that a low bit rate coder exhibits a finite throughput delay. This throughput delay will be present in the echo path of the echo canceller and should be taken into account when performing this test, such that the overall delay in the echo path does not exceed the tail capacity of the echo canceller.

2.10 Test No. 15 - PCM offset test

The description of the test method for Test 15 currently makes no reference to Test 2B. Because of this, implementors may be confused by the description in the test Requirement since this fails to specify that adaptation should be re-enabled, and when re-enabling should occur.

To clarify this, the sentence at the end of the second paragraph under section 6.4.2.16 should be expanded to make reference to Test 2B, and should read:

The method consists of performing Test 2B, but with a DC offset applied at S_{in} *or* R_{in}.

In addition, the first part of the description under the Requirement should be modified to specify when adaptation should be re-enabled as follows:

For both Part 1 and Part 2 above, the H register is initially set to zero, or alternatively, with an open echo path resulting in $S_{in}=0$*, the H register content is converged to 0, and then the adaptation is inhibited. Adaptation is then enabled at least 200 ms before a DC offset at a level of –40 dBm0 is injected at either point A or point B in Figure 30 (for the Part 1 test) or Figure 31 (for the Part 2 test). The first CSS burst is applied to* R_{in} *at the same instant the DC offset is applied. With the NLP disabled, for all ....*

2.11 Section 6.4.2.11.1 Test No. 10A - Canceller operation on the calling station side

The vast majority of echo cancellers use some form of the least-squares algorithm to model the echo path impulse response. When a sinusoidal input signal is used as the input for the echo canceller, an exact model of the echo path is not possible. This response to a sinusoidal input signal is a well-known and understood consequence of the least-squares algorithm, and is precisely the behavior that can cause a problem with Test 10A.

In Test 10A, Region II starts during the application of the CED signal, and extends to the beginning of Sequence No. 1. Because of the response of least-squares-based algorithms to sinusoidal inputs, during that portion of Region II from the cessation of the CED signal to the beginning of Region III, the echo canceller may produce a residual echo that exceeds the recommendation limits at the end of the CED signal. The user should be aware that this may not be a failure of the echo canceller, but merely a response to the sinusoidal CED input signal. When this response occurs, additional investigation is warranted.

2.12 Section 6.4.2.11 Test No. 10 – Facsimile test during call establishment phase

When using the hybrid models given in Annex D, the K_i factors for tone signals given in Table D.1b should be used for this test.

2.13 Section 6.4.2.10 Test No. 9 – Comfort noise test

In item 4 of 6.4.2.10.1 Part 1 and 6.4.2.10.2 Part 2, "sure L_{RET} after 2 s" should be "Measure L_{RET} after 2 s".