TECHNICAL REPORT

TR-138
Accuracy Tests for Test Parameters

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Executive Summary

This Broadband Forum Technical Report is part of the Broadband Access Suite. Its key value is in loop qualification, loop troubleshooting and in gathering accurate network statistics and related network optimization. Service Providers rely on these functionalities in network operations and management, for which the ADSL and VDSL2 test parameters are the underlying source of information. The key values of this Technical Report also allow the consumer to benefit by enabling DSL service installation, and better service optimization and troubleshooting.

On one hand, this information derived from the test parameters is useful only if these test parameters are reported by DSL equipment with sufficient accuracy. On the other hand, it is important for silicon and equipment vendors that the required accuracy is also feasible within reasonable implementation complexity. It is to reflect the industry consensus on this key tradeoff, that the Broadband Forum has released this Technical Report. This Technical Report provides test setup, methodology and expected results, as to determine whether or not the accuracy requirements defined in ITU-T Recommendations are met.

This Technical Report accompanies TR-100 (ADSL2/ADSL2plus interoperability test plan) and TR-114 (VDSL2 interoperability test plan). Where these Broadband Forum deliverables define rate/reach performance requirements under various loop and noise conditions, this Technical Report TR-138 defines the tests for verification of actual accuracy provided by implementations, in reporting loop and noise characteristics, against the accuracy requirements defined in the ITU-T DSL Recommendations. The ITU-T DSL Recommendations G.992.3 (ADSL2 transceivers), G.992.5 (ADSL2plus transceivers) and G.993.2 (VDSL2 transceivers) define several test parameters that are reported by the transceivers to the management system as defined in G.997.1 (Physical Layer OAM).

The test parameters covered in this Technical Report represent the subset of the transceiver test parameters from G.997.1 that both have accuracy requirements defined in G.992.3, G.992.5 and G.993.2 and which have been identified by the Broadband Forum as being of special importance in DSL testing and operations support.

1 Purpose and Scope

1.1 Purpose

TR-138 provides accuracy tests for test parameters that are defined in the ITU-T Physical Layer Recommendations G.992.3 (ADSL2 transceivers), G.992.5 (ADSL2plus transceivers) and G.993.2 (VDSL2 transceivers), and that are also listed in G.997.1 (Physical Layer Operations, Administration, and Maintenance). The test parameters covered in this document represent the subset of the transceiver test parameters from G.997.1 that both have accuracy requirements defined in G.992.3 and G.993.2 and which have been identified by the Broadband Forum as being of special importance in DSL testing and operations support.

1.2 Scope

A number of test and configuration parameters which instrument and control the G.992.3, G.992.5 and G.993.2 PHY Layers in the G.PLOAM CO MIB (defined in ITU-T Recommendation G.997.1) have been identified as being of special importance for both the testing and the operational management of transceivers supporting one or more of these PHY layers. In order for these parameters to be both tested and used to their best advantage, the accuracy ranges of the reported values must be specified.

TR-138 provides a list of the identified G.997.1 test parameters and references to accuracy ranges that are both useful and technically feasible in the actual environment of DSL transceivers that would be deployed in the field.

A testing reference model and methodology is described. The general structure of the accuracy tests is to set up a known state for the test at the U-x2 reference point (U-C2 and U-R2 as defined in Figure 5-4/G.992.3 and U-O2 and U-R2 as defined in Figure 5.4/G.993.2) and then extract the reported test parameter values from the transceivers. An accuracy test is described for each of the listed test parameters. The purpose of these tests is to validate the correct reporting of test parameters by the transceiver.

2 References and Terminology

2.1 Conventions

In this Technical Report, several words are used to signify the requirements of the specification. These words are always capitalized. More information can be found be in RFC 2119 [1].

SHALL	This word, or the term "REQUIRED", means that the definition is an absolute requirement of the specification.
SHALL NOT	This phrase means that the definition is an absolute prohibition of the specification.
SHOULD	This word, or the adjective "RECOMMENDED", means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications must be understood and carefully weighed before choosing a different course.
SHOULD NOT	This phrase, or the phrase "NOT RECOMMENDED" means that there may exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
MAY	This word, or the adjective "OPTIONAL", means that this item is one of an allowed set of alternatives. An implementation that does not include this option SHALL be prepared to inter-operate with another implementation that does include the option.

2.2 References

The following references are of relevance to this Technical Report. At the time of publication, the editions indicated were valid. All references are subject to revision; users of this Technical Report are therefore encouraged to investigate the possibility of applying the most recent edition of the references listed below.
A list of currently valid Broadband Forum Technical Reports is published at www.broadband-forum.org.

[1] RFC2119	*Key words for use in RFCs to Indicate Requirement Levels*	IETF	1997
[2] G.992.3	*Asymmetric digital subscriber line transceivers 2 (ADSL2)*	ITU-T Recommendation	2009

[3] G.993.2 (revision 2006 and amendments 1, 2 and 3)	*Very-high speed digital subscriber line transceivers 2 (VDSL2)*	ITU-T Recommendation	2008
[4] G.996.1	*Test procedures for DSL transceivers*	ITU-T Recommendation	2001
[5] G.997.1	*Physical layer management for digital subscriber line (DSL) transceivers*	ITU-T Recommendation	2009
[6] TR-100 (including Corrigendum 1)	*ADSL2/ADSL2plus Performance Test Plan*	Broadband Forum	2007
[7] TR-114	*VDSL2 Performance Test Plan*	Broadband Forum	2009

2.3 Definitions

This Technical Report contains no new definitions.

2.4 Abbreviations

This Technical Report uses the following abbreviations:

CO	Central Office
DUT	Device Under Test
MIB	Management Information Base
OAM	Operations, Administration, and Maintenance

3 Technical Report Impact

3.1 Energy Efficiency

TR-138 has no impact on Energy Efficiency.

3.2 IPv6

TR-138 has no impact on IPv6.

3.3 Security

TR-138 has no impact on Security.

4 G.997.1 Test Parameters and Values

The following Table 4-1 lists the Test Parameters in G.992.3, G.992.5 and G.993.2, the reference to G.997.1 where the parameter is defined, and reference to the sections in G.992.3 and G.993.2 where the accuracy requirements for the test parameters are defined.

Table 4-1 - G.997.1 test parameters

Parameter	Description	Reference in G.997.1 [5]	Accuracy Requirement Reference in G.992.3 [2]	Accuracy Requirement Reference in G.993.2 [3]	Test in this document
HLINpsus HLINpsds	Upstream and Downstream H(f) linear representation	7.5.1.26.9 7.5.1.26.3	For Further Study	For further study	For further study (6.1)
HLOGpsus HLOGpsds	Upstream and Downstream H(f) logarithmic representation	7.5.1.26.12 7.5.1.26.6	8.12.5.1.1	11.4.1.2.1.2	6.2
LATNus LATNds	Upstream and Downstream Line Attenuation	7.5.1.10 7.5.1.9	For Further Study	For further study	For further study (6.5)
QLNpsus QLNpsds	Upstream and Downstream Quiet Line Noise per DMT Subcarrier	7.5.1.27.6 7.5.1.27.3	8.12.5.2	11.4.1.2.2	6.3
SATNus SATNds	Upstream and Downstream Signal Attenuation	7.5.1.12 7.5.1.11	For Further Study	For further study	For further study (6.6)
SNRMus SNRMds	Upstream and Downstream Signal-to-Noise Ratio Margin	7.5.1.16 7.5.1.13	For Further Study	For further study	For further study (6.7)
SNRpsus SNRpsds	Upstream and Downstream SNR(f)	7.5.1.28.6 7.5.28.3	8.12.5.3	11.4.1.2.3	6.4

ACTATPus ACTATPds	Upstream and Downstream Actual Aggregate Transmit Power	7.5.1.25 7.5.1.24	8.12.5.8	11.4.1.2.8	6.9
ATTNDRus ATTNDRds	Upstream and Downstream Maximum Attainable Data Rate	7.5.1.20 7.5.1.19	For Further Study	For further study	For further study (6.8)

5 Testing Reference Model and Methodology

The purpose of these tests is to validate the correct reporting by the transceiver of the test parameters defined in G.992.3, G.992.5 and G.993.2. The specific tests in Section 6 test whether a test parameter is properly reported. The general structure of the accuracy tests in this Technical Report set up a known state for the test at the U-x2 reference point, and the tests then validate that the reported test parameter values are consistent with what is expected given that known state.

NOTE - A complete definition of the known state at the U-x2 reference point is of critical importance to the success of these tests. Even more so than other functional tests, these test conditions define a controlled experiment for validating the accuracy of the reported results of a particular test parameter. Repeatability is a prime concern as it is expected that reported results will be consistent when the test is repeated several times. Complete definition of the known condition in each test's method of procedure will require detailed specification of values such as the:

- Test Loop
- Noise Condition on the Loops
- The Configured State of the Transceiver
    - Operating mode Annex (for ADSL) or Regional Annex (for VDSL2)
    - Profile (for VDSL2)

Perhaps more so than for other functional PHY layer tests, these test parameter accuracy tests involve values that are of importance throughout the management environment. The known states are explicit descriptions of conditions at the U-x2 reference point of a transceiver pair. However, the observation of values of the particular test parameters could be made at a number of points in a management reference model and errors in equipment between the transceiver and the point where the observation of the value is made could be the source of an inaccuracy.

Although the scope of this Technical Report and the specifics of the test Methods of Procedures are oriented solely toward tests of the values as reported by the DSL transceiver, these Methods of Procedure could be extended in the future by work in the Broadband Forum or by others to verify accuracy of reported parameters at additional management interfaces. Not only could testers monitor the values of the test parameters at these various points, but they may be specifically concerned with the question of whether the reported values are consistent at all of these points as well as with the values expected given the known state of the U-x2 reference point. Figure 5-1 illustrates various reference points in a DSL management model, where accuracy could be of interest.

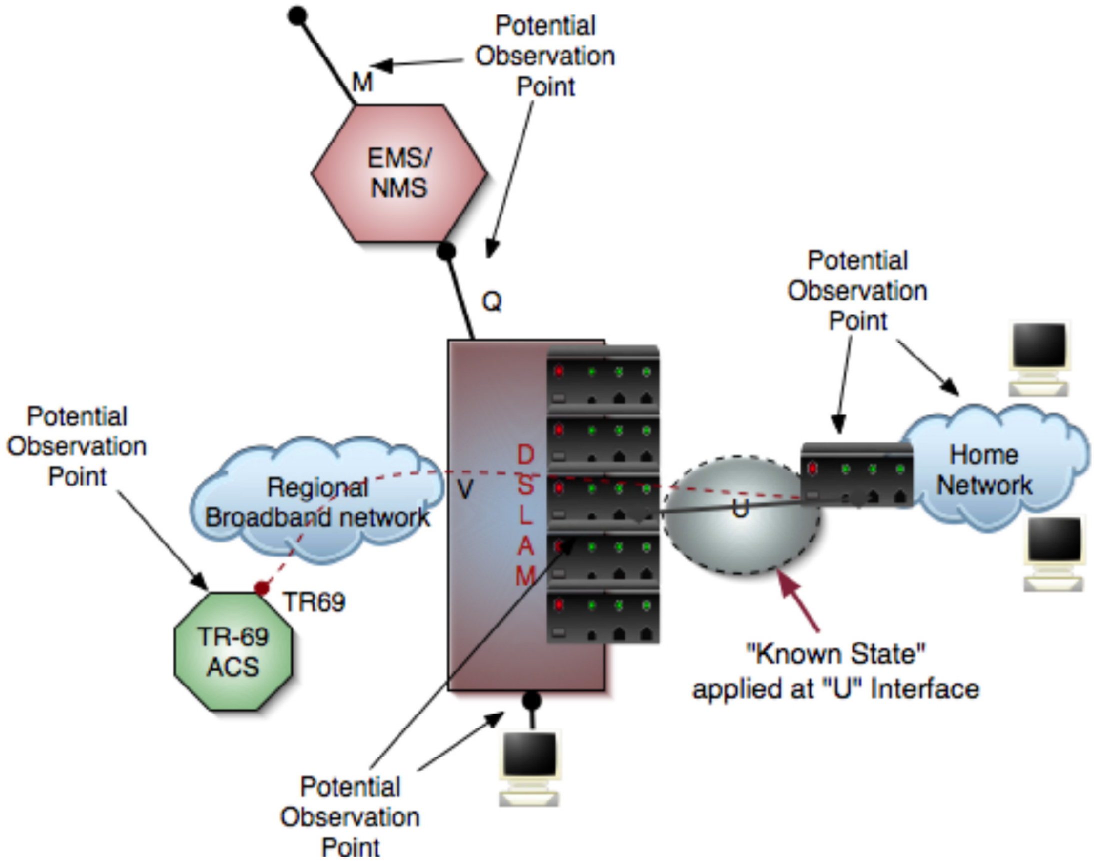

Figure 5-1 - Management Plane Reference Model and Measurement Points for PLOAM Validation Tests.

Section 6 provides test environment, method of procedure and configuration for validating the test parameters. Test parameters may change over time and thus they may be tested for three different conditions:

- Only when the transceiver initializes.
- Both when the transceiver initializes and during Showtime when conditions change.
- During diagnostics mode.

Table 5-1 indicates for which categories a particular test would be applicable to each test parameter.

Table 5-1 – Test Parameters and Test Mode Matrix

Test Parameter Tested	Set Only During Initialization	Changes During Showtime	Diagnostics Mode
HLIN	X		X
HLOG	X		X
QLN	X		X
SNR		X	X
SATN		X	X
LATN	X		X
SNRM		X	X
ATTNDR		X	X
ACTATP		X	X

6 Test Parameter Accuracy Tests

6.1 HLIN

For further study.

6.2 HLOG

6.2.1 HLOG for G.992.3 and G.992.5

Figure 6-1 illustrates the test environment for testing the accuracy of the channel parameter HLOG, when configured with the Device Under Test (DUT) attached.

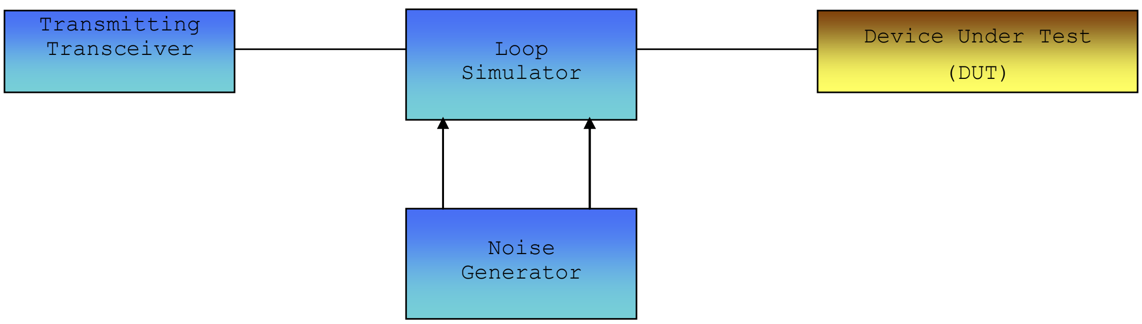

Figure 6-1 – Test environment with the DUT attached

The wireline and noise simulators SHALL have loop and noise characteristics as defined in Section 3/TR-100[6]. They SHOULD meet the accuracy requirements specified in Section 3/TR-100[6] for attenuation, phase and impedance, however, calibration is not required.

Figure 6-2 illustrates the Test Environment when configured with a spectrum analyzer and 100 Ω termination to determine HLOGps_reference.

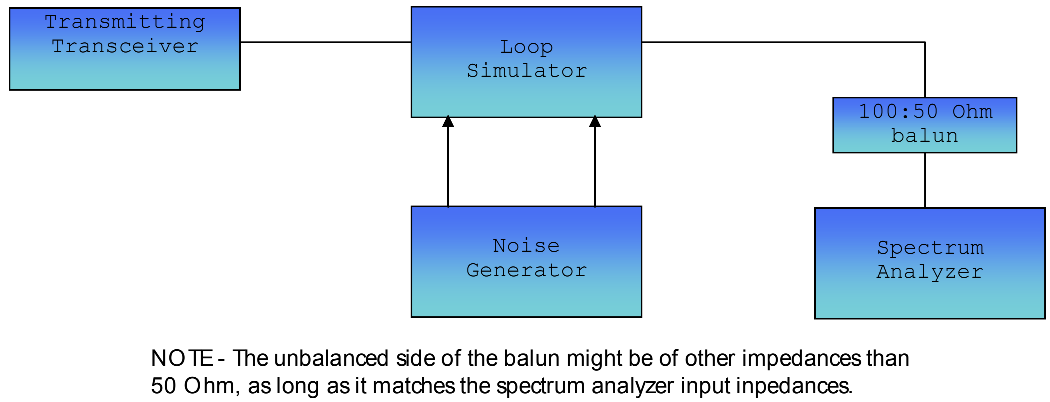

Figure 6-2 - Test environment with spectrum analyzer attached

The HLOG accuracy requirements apply only on loops having a loop impedance within the loop impedance range defined in Section 8.12.5/G.992.3. In order to meet this loop impedance range, the loop simulator and transmitting transceiver SHALL be configured as defined in Table 6-1.

This test is subject to the requirements from Section 8.12.5.1.1/G.992.3 and Section 8.12.5/G.992.5.

The impedance of the Loop (Z_{loop}) and Transmitting Transceiver SHALL be measured by use of a Network Analyzer configured to measure the impedance of a system using a transmission reflection testset probe. The test instrument SHALL be connected to the test bed (that is the transmitting transceiver combined with the loop simulator) with a 100/50 balun. During the measurement, the transmitting transceiver is frozen in a QUIET state. Reported results for the real and imaginary parts or for the magnitude of the impedance (see Table 6-3 method of procedure, step 1e) SHALL be multiplied by the impedance conversion factor of the balun.

NOTE - The balun's impedance at the balanced side SHOULD match as close as possible the theoretical impedance of the loop in the range of interest.

Figure 6-3 illustrates the test setup for measuring Z_{loop}.in the HLOG test.

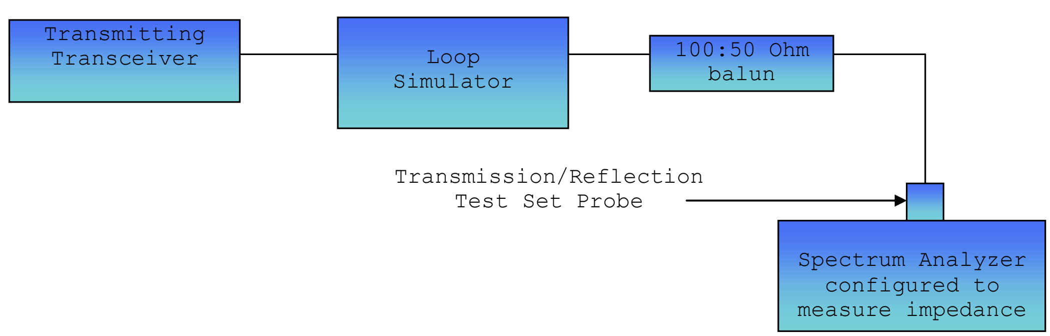

Figure 6-3 - Test setup for measuring Z_{loop}.

Table 6-1 - Configuration of Test Environment for G.992.3 and G.992.5

Test # (see NOTE 1)	Loop type	Loop length (kfeet, no bridge taps)	Noise impairment (see NOTE 2, 3)
1	26 AWG	5	White Noise (AWGN)
2	26 AWG	7	White Noise (AWGN)
3	26 AWG	12	White Noise (AWGN)
Common Line Settings		As defined in Table 7-1/TR-100 [6].	
General Test Profile		The Low delay profile F-1/0 from Table 7-2/TR-100 [6].	
Specific Test Profile		One of the following (at the DUT vendor's choice): G.992.3: A2_RA_F_16000k or B2_RA_F_16000k, G.992.5: A2P_RA_F_30000k or B2P_RA_F_30000k, as defined in Table 7-3/TR-100 [6].	
NOTE 1 - Other loop types and loop lengths may be used if resulting in the same insertion loss at 300 kHz. NOTE 2 – Noise levels are defined within the test method of procedure. NOTE 3 – Shaped noise impairment is for further study.			

Table 6-2 – Sub-carrier range for which the accuracy requirements apply (according to ITU-T G.992.3 Amendment 4 section 8.12.5.1)

Downstream	**Annex A, I**	**Annex L**	**Annex B, J, M**	
G.992.3	46-208	46-104	92-208	
G.992.5	46-463	N/A	92-463	
Upstream	**Annex A, I**	**Annex L (Mask 1)**	**Annex B**	**Annex J, M**
G.992.3	11-23	11-17	36-53	11-53
G.992.5	11-23	N/A	36-53	11-53
NOTE 1 – Accuracy requirements do not apply to sub-carriers in the BLACKOUTset. NOTE 2 - Accuracy requirements outside these specified ranges are for further study.				

The method of procedure is defined in Table 6-3.

Table 6-3 – HLOG Method of Procedure for G.992.3 and G.992.5.

Purpose	Verify accuracy of reported HLOG, after diagnostics or after initialization.
Test Configuration	See Table 6-1. A test SHALL be performed over each of the test loops listed in Table 6-1. The AWGN noise level SHALL be set to –140 dBm/Hz to be injected near the DUT.
Method of Procedure (step 1)	Determine the Impedance of the test environment – Z_{loop} as follows: a. Attach the DUT to the reference test environment (Figure 6-1). b. Start Initialization, freezing the transmitting transceiver in a QUIET State c. Remove the DUT. d. Attach a reflectance-based impedance measurement device to replace the DUT to measure Z_{loop}, according to test setup shown in Figure 6-3. e. Measure the Z_{loop} impedance. f. Record the impedance magnitude and imaginary component. NOTE - The requirement to freeze the transmitting transceiver in a QUIET state applies only to the transmitting transceiver in the test bed and not to the DUT.
Method of Procedure (step 2)	Determine the HLOGps_reference as follows: a. Attach the DUT to the reference environment. b. Start Initialization, freezing the transmitting transceiver in a REVERB State. c. Remove the DUT. d. Attach a spectrum analyzer to the reference environment with a 100 Ω termination (Figure 6-2). e. Calculate the upstream reference as follows: HLOGps_reference_us(i) = PSDps_UC2(i) – (REFPSDus + log_tssi(i)) where REFPSDus is obtained from ACTPSDus and RMSGIus (see Section 7.5.1.22/G.997.1) and tssi(i) is obtained from TSSpsus (see Section 7.5.1.29.6/G.997.1). PSDps_UC2(i) SHALL be measured by the spectrum analyzer at the U-C2 reference point. f. Calculate the downstream reference as follows: For G.992.3: HLOGps_reference_ds(i) = PSDps_UR2(i) – (REFPSDds + log_tssi(i)) For G.992.5: HLOGps_reference_ds(i) = PSDps_UR2(i) – (REFPSDds + ceiled_log_tssi(i)) where REFPSDds is obtained from ACTPSDds and RMSGIds (see Section 7.5.1.21/G.997.1) and tssi(i) is obtained from TSSpsus (see Section 7.5.1.29.5/G.997.1). PSDps_UR2(i) SHALL be measured by the spectrum analyzer at the U-R2 reference point. g. The above measurements SHALL be made within 10 minutes of measuring the Z_{loop} for the test environment defined in Table 6-1. NOTE - The requirement to freeze the transmitting transceiver in REVERB state applies only to the transmitting transceiver in the test bed and not to the DUT.

Method of Procedure (step 3)	Record the reported values of HLOG as follows: a. Replace the spectrum analyzer with the DUT b. Allow the Transmitting Transceiver and the DUT to go through initialization (in either diagnostics mode or normal initialization.) c. Record the reported values of SNRpsus and SNRpsds (Section 7.5.1.28.6 and Section 7.5.1.28.3/G.997.1). d. Record the reported values of HLOGpsus and HLOGpsds (Section 7.5.1.26.12 and Section 7.5.1.26.6/G.997.1). e. The above measurements SHALL be made within 10 minutes of measuring the Z_{loop} for the test environment defined in Table 6-1.

<table>
<tr>
<td>Expected result</td>
<td>
For downstream sub-carriers where the HLOGpsds accuracy requirements apply (sub-carriers in Table 6-2), and for which the loop impedance (Z_{loop}) falls within the following ranges as defined in §8.12.5.1.1/G.992.3 Amendment 4 (see NOTE 1):
• Z_{loop} impedance magnitude is between 100 Ω and 120 Ω;
• Z_{loop} impedance imaginary component is between –20 Ω and 0 Ω;
and
• SNRpsds ≥ 12 dB;
• HLOGps_reference_ds is above –90 dB,

the following requirements SHALL apply:
1. HLOGpsds value SHALL be different from the special value defined in Section 8.12.3.1/G.992.3;
2. |HLOGpsds - HLOGps_reference_ds| ≤ 3.5 dB (see NOTE 2);
3. The mean absolute error of the HLOGpsds values SHALL be reported.

For downstream sub-carriers where the HLOGpsds accuracy requirements do not apply, the HLOGpsds values different from the special value defined in Section 8.12.3.1/G.992.3 SHALL be reported.

For upstream sub-carriers where the HLOGpsus accuracy requirements apply (sub-carriers in Table 6-2), and for which the loop impedance (Z_{loop}) falls within the following ranges as defined in §8.12.5.1.1/G.992.3 Amendment 4 (see NOTE 1):
• Z_{loop} impedance magnitude is between 100 Ω and 120 Ω;
• Z_{loop} impedance imaginary component is between –20 Ω and 0 Ω;
and
• SNRpsus ≥ 12 dB;
• HLOGps_reference_us is above –90 dB,

the following requirements SHALL apply:
1. HLOGpsus value SHALL be different from the special value defined in Section 8.12.3.1/G.992.3;
2. |HLOGpsus - HLOGps_reference_us| ≤ 3.5 dB (see NOTE 2);
3. The mean absolute error of the HLOGpsus values SHALL be reported.

For upstream sub-carriers where the HLOGpsus accuracy requirements do not apply, the HLOGpsus values different from the special value defined in Section 8.12.3.1/G.992.3 SHALL be reported.

NOTE 1 – Accuracy requirements for HLOGps for frequencies where the loop impedance (Z_{loop}) falls outside this range are for further study at the ITU-T, and no pass/fail criteria on the accuracy of HLOG measurements SHALL apply. Nevertheless, the HLOGps measurements SHALL still be reported for the sub-carriers defined in Table 6-2.

NOTE 2 – Includes 0.5 dB to accommodate for test equipment tolerance.
</td>
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</table>

6.2.2 HLOG for G.993.2

Figure 6-1 illustrates the test environment for testing the accuracy of the channel parameter HLOG, when configured with the DUT attached.

The wireline and noise simulators SHALL have loop and noise characteristics as defined in Section 7/TR-114[7]. They SHOULD meet the accuracy requirements as specified in Section 7/TR-114[7] for attenuation, phase and impedance, however, calibration is not required.

Figure 6-2 illustrates the test environment when configured with a spectrum analyzer and 100 Ω termination to determine HLOGps_reference.

The HLOG accuracy requirements apply only on loops with an impedance within the impedance range defined in Section 11.4.1.2/G.993.2. In order to meet this loop impedance range, the loop simulator and transmitting transceiver SHALL be configured as defined in Table 6-4.

This test is subject to the requirements from Section 11.4.1.1.1/G.993.2.

The impedance of the Loop (Z_{loop}) and Transmitting Transceiver SHALL be measured by use of a Network Analyzer configured to measure the impedance of a system using a transmission reflection test set probe. The test instrument SHALL be connected to the test bed (that is the transmitting transceiver combined with the loop simulator) with a 100/50 balun. During the measurement the transmitting transceiver is frozen in a QUIET State. Reported results for the real and imaginary parts or for the magnitude of the impedance (see Table 6-6 method of procedure, step 1e) SHALL be multiplied by the impedance conversion factor of the balun.

NOTE - The balun's impedance at the balanced side SHOULD match as close as possible the theoretical impedance of the loop in the range of interest.

Figure 6-3 illustrates the test setup for measuring Z_{loop} in the HLOG test.

Table 6-4 - Configuration of Test Environment for G.993.2

Test # (see NOTE 1)	Loop type	Loop length (no bridge taps)	Noise impairment (see NOTE 2, 3)
1	26 AWG	750 ft	White Noise (AWGN)
2	26 AWG	1500 ft	White Noise (AWGN)
3	26 AWG	2000 ft	White Noise (AWGN)
VDSL2 Band-profiles for testing		ANNEX A profile AA8d, as defined in Table 6-1/TR-114 [7], or One of the following ANNEX B profiles: BA8b, BA12a, BA17a, BB8b or BB12a, or BB17a, as defined in Table 6-1/TR-114 [7].	
Common Line Settings		As defined in Table 6-2/TR-114 [7].	
General Line Settings		As defined in Table 6-3/TR-114 [7].	
Profile-line combination		One of the following (at the DUT vendor's choice): AA8d_RA_I_096_056, or x_RA_F_150_150, where x represents one of the following VDSL2 band-profiles: BA8b, BA12a, BA17a, BB8b, BB12a, or BB17a. VDSL2 band-profiles are defined in Table 6-1/TR-114 [7]. Specific line settings RA_I_096_056 and RA_F_150_150 are defined in Table 6-4/TR-114 [7]. Profile-line combinations are defined in Section 6.2.3./TR-114 [7].	
NOTE 1 - Other loop types and loop lengths may be used if resulting in the same insertion loss at 1 MHz. NOTE 2 – Noise levels are defined within the test method of procedure. NOTE 3 – Shaped noise impairment is for further study.			

Table 6-5 – Sub-carrier range for which the accuracy requirements apply (according to ITU-T G.993.2 Amendment 3 section 11.4.1.2.1.1)

Downstream (profiles 8a, 8b, 8c, 8d, 12a, 12b and 17a)	
Annex A, Masks D-32, D-48, and D-64 of Table A-8/G.993.2-Amendment 1	92-869 and 1206-1971
Annex A Mask D-128 of Table A-8/G.993.2-Amendment 1	184-869 and 1206-1971
Annex B Band Plan 998 of Table B-1/G.993.2-Amendment 1	92-869 and 1206-1971
Annex B Band Plan 997 of Table B-1/G.993.2-Amendment 1	92-695 and 1183-1634

Annex C, Masks in Table C-1, C-2, C-5 and C-6/G.993.2 -Amendment 1	92-869 and 1206-1971
Annex C, Masks in Table C-9/G.993.2-Amendment 1	214-869 and 1206-1971
Upstream	
Annex A	870-1205 (profiles 8a, 8b, 8c and 8d) 870-1205 and 1972-2782 (profiles 12a, 12b and 17a)
B Band Plan 998 of Table B-1/G.993.2-Amendment 1	
Annex C	
Annex B Band Plan 997 of Table B-1/G.993.2-Amendment 1	696-1182 and 1635-2047 (profiles 8a, 8b and 8d) 696-1182 (profile 8c) 696-1182 and 1635-2782 (profiles 12a, 12b and 17a)
NOTE 1 – Accuracy requirements SHALL NOT apply to sub-carriers in the BLACKOUTset. NOTE 2 – Accuracy requirements SHALL NOT apply to sub-carrier groups that contain sub-carriers in the RFI bands or that contain any of the 15 sub-carriers adjacent to each side of the RFI bands. NOTE 3 - Accuracy requirements for Annex B band plans 998ADE and HPE are for further study. NOTE 4 - Accuracy requirements for Profile 30a are for further study. NOTE 5 - Accuracy requirements outside these specified ranges are for further study.	

The method of procedure is defined in Table 6-6.

Table 6-6 – HLOG Method of Procedure for G.993.2

Purpose	Verify accuracy of reported HLOG, after diagnostics mode or after initialization.
Test Configuration	See Table 6-4. A test SHALL be performed over each of the test loops listed in Table 6-4. The AWGN noise level SHALL be set to –140 dBm/Hz to be injected near the DUT.

Method of Procedure (step 1)	Determine the Impedance of the test environment – Z_{loop} as follows: a. Attach the DUT to the test environment (Figure 6-1). b. Start Initialization, freezing the transmitting transceiver in a QUIET State. c. Remove the DUT. d. Attach a reflectance-based impedance measurement device to replace the DUT to measure Z_{loop}, according to test setup shown in Figure 6-3. e. Measure the Z_{loop} impedance. NOTE - The requirement to freeze the transmitting transceiver in a QUIET state applies only to the transmitting transceiver in the test bed and not to the DUT.
Method of Procedure (step 2)	Determine the HLOGps_reference as follows: a. Attach the DUT to the reference environment b. Start Initialization, freezing the transmitting transceiver in the O-P-MEDLEY stage of initialization with the SOC in the O-IDLE state in determination of the downstream reference value, and in the R-P-MEDLEY stage of initialization with the SOC in the R-IDLE state in determination of the upstream reference value. c. Remove the DUT. d. Attach a spectrum analyzer to the reference environment with a 100 Ω termination (Figure 6-2). e. Measure the spectrum. f. Calculate the upstream reference as follows: The upstream Hlog(f) reference value for frequency k × G × Δf SHALL be defined as HLOG_reference_us(k × G × Δf) = MREFPSDus(k × G × Δf) - PSD_UO2(k × G × Δf), where MREFPSDus is obtained from the MIB (see Section 7.5.1.29.8/G.997.1), and PSD_UO2(k × G × Δf) is the PSD measured by the spectrum analyzer at the U-O2 reference point. g. Calculate the downstream reference as follows: The downstream Hlog(f) reference value for frequency k × G × Δf SHALL be defined as HLOG_reference_ds(k × G × Δf) = MREFPSDds(k × G × Δf) - PSD_UR2(k × G × Δf), where MREFPSDds is obtained from the MIB (see Section 7.5.1.29.7/G.997.1), and PSD_UR2(k × G × Δf) is the PSD measured by the spectrum analyzer at the U-R2 reference point. h. The above measurements SHALL be made within 10 minutes of measuring the Z_{loop} for the test environment defined in Table 6-1. NOTE - The requirement to freeze the transmitting transceiver in the O-P-MEDLEY or R-P-MEDLEY state applies only to the transmitting transceiver in the test bed and not to the DUT.

Method of Procedure (step 3)	Record the values of HLOG as follows: a. Replace the spectrum analyzer with the DUT. b. Allow the transmitting transceiver and the DUT to go through initialization (in either diagnostics mode or normal initialization). c. Record the reported values of HLOGpsus and HLOGpsds (Section 7.5.1.26.12 and Section 7.5.1.26.6/G.997.1). d. Record the reported values of SNRpsus and SNRpsds (Section 7.5.1.28.6 and Section 7.5.1.28.3/G.997.1). e. The above measurements SHALL be made within 10 minutes of measuring the Z_{loop} for the test environment defined in Table 6-4.

<table>
<tr><td>Expected results</td><td>For downstream sub-carriers where the HLOGpsds accuracy requirements apply (sub-carriers in Table 6-5), for which the loop impedance (Z_{loop}) falls within the following ranges as defined in §11.4.1.2.1.1/G.993.2 Amendment 3 (see NOTE 1):
• Z_{loop} impedance magnitude is between 100 Ω and 120 Ω;
• Z_{loop} impedance imaginary component is between –20 Ω and 0 Ω;
and
• SNRpsds ≥ 12 dB;
• HLOGps_reference_ds is above –90 dB,

the following requirements SHALL apply:
1. HLOGpsds value SHALL be different from the special value defined in Section 11.4.1.1.1/G.993.2;
2. |HLOGpsds - HLOGps_reference_ds| ≤ 3.5 dB (see NOTE 2);
3. The mean absolute error of the HLOGpsds values SHALL be reported.

For downstream sub-carriers for which the HLOGpsds accuracy requirements do not apply, the HLOGpsds values different from the special value defined in Section 11.4.1.1.1/G.993.2 SHALL be reported.

For upstream sub-carriers where the HLOGpsus accuracy requirements apply (sub-carriers in Table 6-5), for which the loop impedance (Z_{loop}) falls within the following ranges as defined in §11.4.1.2.1.1/G.993.2 Amendment 3 (see NOTE 1):
• Z_{loop} impedance magnitude is between 100 Ω and 120 Ω;
• Z_{loop} impedance imaginary component is between –20 Ω and 0 Ω;
and
• SNRpsus ≥ 12 dB;
• HLOGps_reference_us is above –90 dB,

the following requirements SHALL apply:
1. HLOGpsus value SHALL be different from the special values defined in Section 11.4.1.1.1/G.993.2;
2. |HLOGpsus - HLOGps_reference_us| ≤ 3.5 dB (see NOTE 2);
3. The mean absolute error of the HLOGpsus values SHALL be reported.

For upstream sub-carriers for which the HLOGpsus accuracy requirements do not apply, the HLOGpsus values different from the special value defined in Section 11.4.1.1.1/G.993.2 SHALL be reported.

NOTE 1 – Accuracy requirements for HLOGps for frequencies where the loop impedance (Z_{loop}) falls outside this range are for further study at the ITU-T, and no pass/fail criteria on the accuracy of HLOG measurements SHALL apply. Nevertheless, the HLOGps measurements SHALL still be reported for the sub-carriers defined in Table 6-5.

NOTE 2 – Includes 0.5 dB to accommodate for test equipment tolerance.</td></tr>
</table>

6.3 QLN

6.3.1 QLN for G.992.3 and G.992.5

The reference environment's requirements and design are identical to those for the HLOG. Figure 6-1 and Figure 6-2 illustrate the configuration of the reference environments and Table 6-1 describes the specific configuration of the test environment (including transmitting transceiver requirements and test loop configuration to meet the impedance requirements of Section 8.12.5.2/G.992.3). However, the Noise PSDs are measured on a quiet loop to determine the reference values. A noise generator is used to insert an appropriate noise profile into the wire line simulator.

In order to minimize variability in measured results, the wireline and noise simulators SHALL meet the accuracy requirements as specified in Section 3/TR-100 [6] for attenuation, phase and impedance, however, calibration is not required.

This test is subject to the requirements from Section 8.12.5.2/G.992.3.

The Z_{loop} (the impedance of the Loop and Transmitting Transceiver) SHALL be measured as described in Section 6.2.1.

The method of procedure is defined in Table 6-7.

Table 6-7 – QLN Method of Procedure for G.992.3 and G.992.5

Purpose	Verify accuracy of reported QLNps, after diagnostics mode and after initialization.
Test Configuration	See Table 6-1. A test SHALL be performed over each of the test loops listed in Table 6-1. The AWGN noise level SHALL be set to -120dBm/Hz AWGN for testing QLNpsds and to -100dBm/Hz AWGN for testing QLNpsus, to be injected near the DUT.

Method of procedure (step 1)	Determine the Impedance of the test environment – Z_{loop} – as follows: a. Attach the DUT to the reference test environment (Figure 6-1). b. Start Initialization, freezing the transmitting transceiver in a QUIET State. c. Remove the DUT. d. Attach a reflectance-based impedance measurement device to replace the DUT to measure Z_{loop}, according to the test setup shown in Figure 6-3. e. Measure the Z_{loop} impedance. f. Record the impedance magnitude and imaginary component. NOTE - The requirement to freeze the transmitting transceiver in a QUIET state applies only to the transmitting transceiver in the test bed and not to the DUT.
Method of Procedure (step 2)	Determine the QLN reference as follows: a. Attach the DUT to the reference environment. b. Apply the specified noise environment to the wireline simulator near the DUT. c. Start Initialization, freezing the transmitting transceiver in a QUIET State. d. Remove the DUT. e. Attach a spectrum analyzer to the reference environment with a 100 Ω termination (Figure 6-2). f. Measure QLNps_reference_us(i) values as the upstream PSD at the U-C2 reference point (PSDps_UC2(i)). g. Measure QLNps_reference_ds(i) values as the downstream PSD at the U-R2 reference point (PSDps_UR2(i)). h. The above measurements SHALL be made within 10 minutes of measuring the Z_{loop} for the test environment defined in Table 6-1. NOTE - The requirement to freeze the transmitting transceiver in a QUIET state applies only to the transmitting transceiver in the test bed and not to the DUT.
Method of Procedure (step 3)	Record the reported values of QLN as follows: a. Replace spectrum analyzer with the DUT. b. Allow the Transmitting Transceiver and the DUT to go through initialization (in either diagnostics mode or normal initialization). c. Record the reported values of QLNpsus and QLNpsds (Section 7.5.1.27.6/G.997.1 and Section 7.5.1.27.3/G.997.1). d. The above measurements SHALL be made within 10 minutes of measuring the Z_{loop} for the test environment defined in Table 6-1.

<table>
<tr>
<td>Expected Result</td>
<td>For downstream sub-carriers where the QLNpsds accuracy requirements apply (sub-carriers in Table 6-2), for which the loop impedance (Z_{loop}) falls within the following ranges as defined in §8.12.5.1.1/G.992.3 Amendment 4 (see NOTE 1):
• Z_{loop} impedance magnitude is between 100 Ω and 120 Ω;
• Z_{loop} impedance imaginary component is between –20 Ω and 0 Ω;
and
• QLNps_reference_ds is above –130 dB,

the following requirements SHALL apply:
1. QLNpsds value SHALL be different from the special value defined in Section 8.12.3.2/G.992.3;
2. |QLNpsds - QLNps_reference_ds| ≤ 3.5 dB (see NOTE 2)

To account for sinusoidal noise sources internal to the ATU-R, the QLNpsds requirement does not apply to up to 5 groups of 3 adjacent downstream subcarriers, which can be selected at the ATU-R vendor's discretion.

For downstream sub-carriers where the QLNpsds accuracy requirements do not apply, the QLNpsds values different from the special value defined in Section 8.12.3.2/G.992.3 SHALL be reported.

For upstream sub-carriers where the QLNpsus accuracy requirements apply (sub-carriers in Table 6-2), for which the loop impedance (Z_{loop}) falls within the following ranges as defined in §8.12.5.1.1/G.992.3 Amendment 4 (see NOTE 1):
• Z_{loop} impedance magnitude is between 100 Ω and 120 Ω;
• Z_{loop} impedance imaginary component is between –20 Ω and 0 Ω;
and
• QLNps_reference_us is above –110 dB,

the following requirements SHALL apply:
1. QLNpsus value SHALL be different from the special value defined in Section 8.12.3.2/G.992.3;
2. |QLNpsus - QLNps_reference_us| ≤ 3.5 dB (see NOTE 2);

For upstream sub-carriers where the QLNpsus accuracy requirements do not apply, the QLNpsus values different from the special value defined in Section 8.12.3.2/G.992.3 SHALL be reported.

NOTE 1 – Accuracy requirements for QLNps for frequencies where the loop impedance (Z_{loop}) falls outside this range are for further study at the ITU-T, and no pass/fail criteria on the accuracy of QLN measurements SHALL apply. Nevertheless, the QLNps measurements SHALL still be reported for the sub-carriers defined in Table 6-2.

NOTE 2 – Includes 0.5 dB to accommodate for test equipment tolerance.</td>
</tr>
</table>

6.3.2 QLN for G.993.2

The reference environment's requirements and design are identical to those for the HLOG. Figure 6-1 and Figure 6-2 illustrate the configuration of the reference environments and Table 6-1 describes the specific configuration of the test environment (including transmitting transceiver requirements and test loop configuration to meet the impedance requirements of Section 11.4.1.2.1.1/G.993.2). However, the Noise PSDs are measured on a quiet loop to determine the reference values. A noise generator is used to insert an appropriate noise profile into the wire line simulator.

In order to minimize variability in measured results, the wireline and noise simulators SHALL meet the accuracy requirements as specified in Section 7/TR-114 [7] for attenuation, phase and impedance, however, no calibration is needed.

This test is subject to the requirements from Section 11.4.1.1.2/G.993.2.

The Z_{loop} (the impedance of the Loop and Transmitting Transceiver) SHALL be measured as described in Section 6.2.2.

The method of procedure is defined in Table 6-8.

Table 6-8 – QLN Method of Procedure for G.993.2

Purpose	Verify accuracy of reported QLNps, after diagnostics mode and after initalizaton.
Test Configuration	See Table 6-4. A test SHALL be performed over each of the test loops listed in Table 6-4. The AWGN noise level SHALL be set to -120dBm/Hz AWGN for testing QLNpsds and to -100dBm/Hz AWGN for testing QLNpsus, to be injected near the DUT.

Method of procedure (step 1)	Determine the Impedance of the test environment – Z_{loop} - as follows: a. Attach the DUT to the reference test environment (Figure 6-1). b. Start Initialization, freezing the transmitting transceiver in a QUIET State. c. Remove the DUT. d. Attach a reflectance-based impedance measurement device to replace the DUT to measure Z_{loop} , according to the test setup shown in Figure 6-3. e. Measure the Z_{loop} impedance. f. Record the impedance magnitude and imaginary component. NOTE - The requirement to freeze the transmitting transceiver in a QUIET state applies only to the transmitting transceiver in the test bed and not to the DUT.
Method of Procedure (step 2)	Determine the QLN reference as follows: a. Attach the DUT to the reference environment. b. Apply the specified noise environment to the wireline simulator near the DUT. c. Start Initialization, freezing the transmitting transceiver in a QUIET State. d. Remove the DUT. e. Attach a spectrum analyzer to the reference environment with a 100 Ω Termination (Figure 6-2). f. Measure QLNps_reference_us(k × G × Δf) values as the upstream PSD at the U-O2 reference point (PSDps_UO2(i), with averaging of the PSDps values in dBm/Hz over the sub-carrier group. g. Measure QLNps_reference_ds(k × G × Δf) values as the upstream PSD at the U-R2 reference point (PSDps_UR2(i), with averaging of the PSDps values in dBm/Hz over the sub-carrier group). h. The above measurements SHALL be made within 10 minutes of measuring the Z_{loop} for the test environment defined in Table 6-4. NOTE - The requirement to freeze the transmitting transceiver in a QUIET state applies only to the transmitting transceiver in the test bed and not to the DUT.
Method of Procedure (step 3)	Record the reported values of QLN as follows: a. Replace spectrum analyzer with the DUT. b. Allow the Transmitting Transceiver and DUT to go through initialization (in either diagnostics mode or normal initialization). c. Record the reported values of QLNpsus and QLNpsds (Section 7.5.1.27.6/G.997.1 and Section 7.5.1.27.3/G.997.1). d. The above measurements SHALL be made within 10 minutes of measuring the Z_{loop} for the test environment defined in Table 6-4.
Expected Result	For downstream sub-carriers where the QLNpsds accuracy requirements apply (sub-carriers in Table 6-5), for which the loop impedance (Z_{loop}) falls within the following ranges as defined in §11.4.1.2.1.1/G.993.2 Amendment 3 (see NOTE 1): • Z_{loop} impedance magnitude is between 100 Ω and 120 Ω; • Z_{loop} impedance imaginary component is between –20 Ω and 0 Ω; and

	• QLNps_reference_ds is above –130 dB, the following requirements SHALL apply: 1. QLNpsds value SHALL be different from the special value defined in Section 11.4.1.1.2/G.993.2; 2. |QLNpsds - QLNps_reference_ds| ≤ 3.5 dB (see NOTE 2); 3. The sample variance of the QLNpsds value (measured within a 10 minute measurement window, and under the same loop, noise, temperature, and configuration settings) ≤ 0.5dB. To account for sinusoidal noise sources internal to the VTU-R, this requirement does not apply to up to 5 clusters of N consecutive sub-carrier groups per 2.2MHz bandwidth, which can be selected at the VTU-R vendor's discretion, with N = 1 + ceil(W/ G) and W = 12. For downstream sub-carriers where the QLNpsds accuracy requirements do not apply, the QLNpsds values different from the special value defined in Section 11.4.1.1.2/G.993.2 SHALL be reported. For upstream sub-carriers where the QLNpsus accuracy requirements apply (sub-carriers in Table 6-5), for which the loop impedance (Z_{loop}) falls within the following ranges as defined in §11.4.1.2.1.1/G.993.2 Amendment 3 (see NOTE 1): • Z_{loop} impedance magnitude is between 100 Ω and 120 Ω; • Z_{loop} impedance imaginary component is between –20 Ω and 0 Ω; and • QLNps_reference_us is above –110 dB, the following requirements SHALL apply: 1. QLNpsus value SHALL be different from the special value defined in Section 11.4.1.1.2/G.993.2; 2. |QLNpsus - QLNps_reference_us| ≤ 3.5 dB (see NOTE 2); 3. The sample variance of the QLNpsus value (measured within a 10 minute measurement window, and under the same loop, noise, temperature, and configuration settings) ≤ 0.5dB. To account for sinusoidal noise sources internal to the VTU-O, this requirement does not apply to up to 10 clusters of N consecutive sub-carrier groups per 2.2MHz bandwidth, which can be selected at the VTU-O vendor's discretion, with N = 1 + ceil(W/ G) and W = 12. For upstream sub-carriers where the QLNpsus accuracy requirements do not apply, the QLNpsus values different from the special value defined in Section 11.4.1.1.2/G.993.2 SHALL be reported. NOTE 1 – Accuracy requirements for QLNps for frequencies where the loop impedance (Z_{loop}) falls outside this range are for further study at the ITU-T, and no pass/fail criteria on the accuracy of QLN measurements SHALL apply. Nevertheless, the QLNps measurements SHALL still be reported for the sub-

	carriers defined in Table 6-5. NOTE 2 – Includes 0.5 dB to accommodate for test equipment tolerance.

6.4 SNR

6.4.1 SNR for G.992.3 and G.992.5

Figure 6-1 illustrates the test environment when configured with the DUT attached for actually determining the reported values of SNRps under changing noise conditions.

In order to minimize variability in measured results the wireline and noise simulators SHALL meet the accuracy requirements as specified in Section 3/TR-100 [6] for attenuation, phase and impedance (not implying a need for calibration).

Figure 6-2 illustrates the Test Environment when configured with a spectrum analyzer and 100 Ω terminations to determine Noise_PSD_T1 and Noise_PSD_T2.

This test is subject to the requirements from Section 8.12.5.3/G.992.3.

Noise_PSDps, the stationary noise PSD present on the line at the U-C2 and U-R2 reference points SHALL be measured by the same method as is used to measure the QLNps_reference, described in Section 6.3.1.

The method of procedure is defined in Table 6-9.

Table 6-9 – SNR Method of Procedure for G.992.3 and G.992.5

Purpose	Verify accuracy of reported SNRps, after diagnostics mode or after initialization.
Test Configuration	See Table 6-1. A test SHALL be performed over each of the test loops listed in Table 6-1. Noise_Profile_T1 SHALL be -118dBm/Hz AWGN for SNRpsds and -98dBm/Hz AWGN for SNRpsus, to be injected near the DUT. Noise_Profile_T2 SHALL be -115dBm/Hz AWGN for SNRpsds and -95dBm/Hz AWGN for SNRpsus, to be injected near the DUT. NOTE –Noise changes SHOULD be applied gradually over time, and not simultaneously at the U-C2 and U-R2 reference point, as not to force a re-initialization of the line.
Method of procedure (step 1)	Determine the Noise_PSDps_T1 as follows: a. Attach a spectrum analyzer to the reference noise environment (see Figure 6-2) with a 100 Ω termination. b. Apply the specified Noise_Profile_T1 to the wireline simulator. c. Measure Noise_PSDps_UR2_T1 at the U-R2 reference point. d. Measure Noise_PSDps_UC2_T1 at the U-C2 reference point. NOTE - The Noise_PSDps present on the line at the U-C2 and U-R2 reference points SHALL be measured by the same method as is used to measure the QLNps_reference.
Method of procedure (step 2)	Determine the SNRps_T1 and SNRps_T2 as follows (see NOTE 1): a. Attach the DUT to the reference test environment (see Figure 6-1). b. Apply the Noise_Profile_T1 to the wireline simulator near the DUT. c. Initialize the transceiver pair to reach Showtime. Wait 2 minutes for bitswap to settle. d. Record the reported values of GAINSpsus_T1 per Section 7.5.1.29.4/G.997.1 and GAINSpsds_T1 per Section 7.5.1.29.3/G.997.1. e. Record the reported values of SNRpsus_T1 per Section 7.5.1.28.6/G.997.1 and SNRpsds_T1 per Section 7.5.1.28.3/G.997.1. f. Record the reported values of GAINSpsus_T1' per Section 7.5.1.29.4/G.997.1 and GAINSpsds_T1' per Section 7.5.1.29.3/G.997.1. g. Record the reported values of BITSpsus_T1 per Section 7.5.1.29.2/G.997.1 and BITSpsds_T1 per Section 7.5.1.29.1/G.997.1. h. If GAINSpsus_T1 ≠ GAINSpsus_T1' for more than 50 % of the upstream sub-carriers where the SNRpsus accuracy requirements apply, then repeat upstream recording from step d. Upon failing 3 upstream recordings, the test result SHALL be reported in the test report as "invalid" (see NOTE 2). If GAINSpsds_T1 ≠ GAINSpsds_T1' for more than 50 % of the downstream sub-carriers where the SNRpsds accuracy requirements apply, then repeat downstream recording from step d. Upon failing 3 downstream recordings, the test result SHALL be reported in the test report as "invalid" (see NOTE 2). i. Apply the Noise_Profile_T2.

	j. Wait 1 minute for bitswap to settle. k. Record the reported values of GAINSpsus_T2 per Section 7.5.1.29.4/G.997.1 and GAINSpsds_T2 per Section 7.5.1.29.3/G.997.1. l. Record the reported values of SNRpsus_T2 per Section 7.5.1.28.6/G.997.1 and SNRpsds_T2 per Section 7.5.1.28.3/G.997.1. m. Record the reported values of GAINSpsus_T2' per Section 7.5.1.29.4/G.997.1 and GAINSpsds_T2' per Section 7.5.1.29.3/G.997.1. n. Record the reported values of BITSpsus_T2 per Section 7.5.1.29.2/G.997.1 and BITSpsds_T2 per Section 7.5.1.29.1/G.997.1. o. If GAINSpsus_T2 ≠ GAINSpsus_T2' for more than 50 % of the upstream sub-carriers where the SNRpsus accuracy requirements apply, then repeat upstream recording from step k. Upon failing 3 upstream recordings, the test result SHALL be reported in the test report as "invalid" (see NOTE 2). If GAINSpsds_T2 ≠ GAINSpsds_T2' for more than 50 % of the downstream sub-carriers where the SNRpsds accuracy requirements apply, then repeat downstream recording from step k. Upon failing 3 downstream recordings, the test result SHALL be reported in the test report as "invalid" (see NOTE 2). NOTE 1 - The optional OLR functionality (SRA, DRR) SHALL NOT be used. If the ATUs can deactivate the bit swapping mechanism, steps f, h, m and o may be omitted. This feature may apply only to a specific transceiver serving as the "transmitting transceiver", and is not a requirement for compliance to G.992.3 and G.992.5 Recommendation. NOTE 2 – An "invalid" test result means the test could not be performed and SHALL NOT be interpreted as a "fail".
Method of procedure (step 3)	Determine the Noise_PSDps_T2 as follows: a. Attach a spectrum analyzer to the reference noise environment (see Figure 6-2) with a 100 Ω termination. b. Measure Noise_PSDps_UR2_T2 at the U-R2 reference point. c. Measure Noise_PSDps_UC2_T2 at the U-C2 reference point. NOTE - The Noise_PSDps present on the line at the U-C2 and U-R2 reference points SHALL be measured by the same method as is used to measure the QLNps_reference.
Method of procedure (step 4)	Determine the downstream and upstream SNR reference value as difference between the measured Noise_PSDps_T1 and Noise_PSDps_T2 values: a. ΔSNRps_reference_ds(i) = Noise_PSDps_UR2_T1(i) – Noise_PSDps_UR2_T2(i). b. ΔSNRps_reference_us(i) = Noise_PSDps_UC2_T1(i) – Noise_PSDps_UC2_T2(i).
Expected Result	For at least 95% of the downstream sub-carriers where the SNRpsds accuracy requirements apply, i.e.: • subcarrier is at least 50 kHz away from the lower and higher passband edges; • BITSpsds_T1 > 0 and BITSpsds_T2 > 0; • Noise_PSDps_UR2_T1 and Noise_PSDps_UR2_T2 > –120 dBm/Hz ; • (SNRpsds_T1-GAINSpsds_T2) and (SNRpsds_T1-GAINSpsds_T2) <

	40 dB, and where: ▪ (GAINSpsds_T1=GAINSpsds_T1') and ▪ (GAINSpsds_T2=GAINSpsds_T2'), the following requirements SHALL apply: 1. If the line does not reinitialize over a time period T1 to T2: |(SNRpsds_T2–GAINSpsds_T2) – (SNRpsds_T1–GAINSpsds_T1) – ΔSNRps_reference_ds| ≤ 1.3 dB (see NOTE 1); 2. Statistical sample variance of (SNRpsds-GAINSpsds) (all samples taken over a 10-minute time interval, without line re-initialization in this time interval, and under the same loop, noise, temperature and configuration settings) SHALL be ≤ 0.5 (see NOTE 2). For at least 95% of the upstream sub-carriers where the SNRpsus accuracy requirements apply, i.e.: ▪ subcarrier is at least 50 kHz away from the lower and higher passband edges; ▪ BITSpsus_T1 > 0 and BITSpsus_T2 > 0; ▪ Noise_PSDps_UC2_T1 and Noise_PSDps_UC2_T2 > –100 dBm/Hz; ▪ (SNRpsus_T1-GAINSpsus_T1) and (SNRpsus_T2-GAINSpsus_T2) < 40 dB; and where: ▪ (GAINSpsus_T1=GAINSpsus_T1') and ▪ (GAINSpsus_T2=GAINSpsus_T2'), the following requirements SHALL apply: 1. If the line does not reinitialize over a time period T1 to T2: |(SNRpsus_T2–GAINSpsus_T2) – (SNRpsus_T1–GAINSpsus_T1) – ΔSNRps_reference_us| ≤ 1.3 dB (see NOTE 1); 2. Statistical sample variance of (SNRpsus-GAINSpsus) (all samples taken over a 10-minute time interval, without line re-initialization in this time interval, and under the same loop, noise, temperature and configuration settings) SHALL be ≤ 0.5 (see NOTE 2). NOTE 1 – Includes 0.5 dB to accommodate for test equipment tolerance. NOTE 2 – For each sample of (SNRps-GAINSps), the GAINSps SHALL be recorded before and after the recording of the SNRps. Only if these GAINSps values are equal, the SNRps-GAINSps value SHALL be included in the sample variance calculation.

6.4.2 SNR for G.993.2

Figure 6-1 illustrates the test environment when configured with the DUT attached for actually determining the reported values of SNRps under changing noise conditions.

In order to minimize variability in measured results the wireline and noise simulators SHALL meet the accuracy requirements as specified in Section 7/TR-114 [7] for attenuation, phase and impedance (not implying a need for calibration).

Figure 6-2 illustrates the test environment when configured with a spectrum analyzer and 100 Ω terminations to determine Noise_PSD_T1 and Noise_PSD_T2.

This test is subject to the requirements from Section 11.4.1.1.3/G.993.2.

Noise_PSDps, the stationary noise PSD present on the line at the U-O2 and U-R2 reference points SHALL be measured by the same method as is used to measure the QLNps_reference, described in Section 6.3.2.

The method of procedure is defined in Table 6-10.

Table 6-10 – SNR Method of Procedure for G.993.2

Purpose	Verify accuracy of reported SNRps, after diagnostics mode or after initialization.
Test Configuration	See Table 6-4. A test SHALL be performed over each of the test loops listed in Table 6-4. Noise_Profile_T1 SHALL be -118dBm/Hz AWGN for SNRpsds and -98dBm/Hz AWGN for SNRpsus, to be injected near the DUT. Noise_Profile_T2 SHALL be -115dBm/Hz AWGN for SNRpsds and -95dBm/Hz AWGN for SNRpsus, to be injected near the DUT. NOTE –Noise changes SHOULD be applied gradually over time, and not simultaneously at the U-O2 and U-R2 reference point, as not to force a re-initialization of the line.
Method of procedure (step 1)	Determine the Noise_PSDps_T1 as follows: a. Attach a spectrum analyzer to the reference noise environment (see Figure 6-2) with a 100 Ω termination. b. Apply the specified Noise_Profile_T1 to the wireline simulator. c. Measure Noise_PSDps_UR2_T1 at the U-R2 reference point. d. Measure Noise_PSDps_UO2_T1 at the U-O2 reference point. NOTE - The Noise_PSDps present on the line at the U-O2 and U-R2 reference points SHALL be measured by the same method as is used to measure the QLNps_reference.
Method of procedure (step 2)	Determine the SNRps_T1 and SNRps_T2 as follows (see NOTE 1): a. Attach the DUT to the reference test environment (see Figure 6-1). b. Apply the Noise_Profile_T1 to the wireline simulator near the DUT. c. Initialize the transceiver pair to reach Showtime. Wait 2 minutes for

	bitswap to settle. d. Record the reported values of GAINSpsus_T1per Section 7.5.1.29.4/G.997.1 and GAINSpsds_T1 per Section 7.5.1.29.3/G.997.1. e. Record the reported values of SNRpsus_T1 per Section 7.5.1.28.6/G.997.1 and SNRpsds_T1 per Section 7.5.1.28.3/G.997.1. f. Record the reported values of GAINSpsus_T1’ per Section 7.5.1.29.4/G.997.1 and GAINSpsds_T1’ per Section 7.5.1.29.3/G.997.1. g. Record the reported values of BITSpsus_T1per Section 7.5.1.29.2/G.997.1 and BITSpsds_T1 per Section 7.5.1.29.1/G.997.1). h. If GAINSpsus_T1 ≠ GAINSpsus_T1’ for more than 50 % of the upstream sub-carrier groups (see NOTE 2) where the SNRpsus accuracy requirements apply, then repeat upstream recording from step d. Upon failing 3 upstream recordings, the test result SHALL be reported in the test report as “invalid” (see NOTE 3). If GAINSpsds_T1 ≠ GAINSpsds_T1’ for more than 50 % of the downstream sub-carrier groups (see NOTE 2) where the SNRpsds accuracy requirements apply, then repeat downstream recording from step d. Upon failing 3 downstream recordings, the test result SHALL be recorded in the test report as “invalid” (see NOTE 3). i. Apply the Noise_Profile_T2. j. Wait 1 minute for bitswap to settle. k. Record the reported values of GAINSpsus_T2per Section 7.5.1.29.4/G.997.1 and GAINSpsds_T2 per Section 7.5.1.29.3/G.997.1. l. Record the reported values of SNRpsus_T2 per Section 7.5.1.28.6/G.997.1 and SNRpsds_T2 per Section 7.5.1.28.3/G.997.1 m. Record the reported values of GAINSpsus_T2’ per Section 7.5.1.29.4/G.997.1 and GAINSpsds_T2’ per Section 7.5.1.29.3/G.997.1. n. Record the reported values of BITSpsus_T2per Section 7.5.1.29.2/G.997.1 and BITSpsds_T2 per Section 7.5.1.29.1/G.997.1. o. If GAINSpsus_T2 ≠ GAINSpsus_T2’ for more than 50 % of the upstream sub-carrier groups (see NOTE 2) where the SNRpsus accuracy requirements apply, then repeat upstream recording from step k. Upon failing 3 upstream recordings, the test result SHALL be reported in the test report as “invalid” (see NOTE 3). If GAINSpsds_T2 ≠ GAINSpsds_T2’ for more than 50 % of the downstream sub-carrier groups (see NOTE 2) where the SNRpsds accuracy requirements apply, then repeat downstream recording from step k. Upon failing 3 downstream recordings, the test result SHALL be reported in the test report as “invalid” (see NOTE 3). NOTE 1 - The optional OLR functionality (SRA, DRR) SHALL NOT be used. If the VTUs can deactivate the bit swapping mechanism, steps f, h, m and o may be omitted. This feature may apply only to a specific transceiver serving as the “transmitting transceiver”, and is not a requirement for compliance to the G.993.2 Recommendation. NOTE 2 - GAINSps values SHALL be averaged in dB over the sub-carrier group. NOTE 3 – An “invalid” test result means the test could not be performed and SHALL NOT be interpreted as a “fail”.

Method of procedure (step 3)	Determine the Noise_PSDps_T2 as follows: a. Attach a spectrum analyzer to the reference noise environment (see Figure 6-2) with a 100 Ω termination. b. Measure Noise_PSDps_UR2_T2 at the U-R2 reference point. c. Measure Noise_PSDps_UO2_T2 at the U-O2 reference point. NOTE - The Noise_PSDps present on the line at the U-O2 and U-R2 reference points SHALL be measured by the same method as is used to measure the QLNps_reference.
Method of procedure (step 4)	Determine the downstream and upstream SNR reference value as difference between the measured Noise_PSDps_T1 and Noise_PSDps_T2 values: a. ΔSNRps_reference_ds(k × G × Δf) = Noise_PSDps_UR2_T1(k × G × Δf) – Noise_PSDps_UR2_T2(k × G × Δf) b. ΔSNRps_reference_us(k × G × Δf) = Noise_PSDps_UO2_T1(k × G × Δf) – Noise_PSDps_UO2_T2(k × G × Δf)
Expected Result	For at least 95% of the downstream sub-carrier groups where theSNRpsds accuracy requirements apply, i.e., :: ▪ Sub-carriers in the sub-carrier group are at least 50kHz away from the lower and higher passband edge; ▪ BITSpsds_T1 >0 and BITSpsds_T2 > 0 on at least one sub-carrier in the sub-carrier group; ▪ Noise_PSDps_UR2_T1(k × G × Δf) and Noise_PSDps_UR2_T2(k × G × Δf) > –110 dBm/Hz; ▪ (SNRpsds_T1-GAINSpsds_T1) and (SNRpsds_T2-GAINSpsds_T2) < 40 dB (see NOTE 1), and where: ▪ (GAINSpsds_T1=GAINSpsds_T1') and ▪ (GAINSpsds_T2=GAINSpsds_T2') (see NOTE 1), the following requirements SHALL apply: 1. If the line does not reinitialize over a time period T1 to T2: |(SNRpsds_T2–GAINSpsds_T2) – (SNRpsds_T1–GAINSpsds_T1) – ΔSNRps_reference_ds| ≤ 1.3 dB (see NOTE 1, 2); 2. Statistical sample variance of (SNRpsds-GAINSpsds) (all samples taken over a 10-minute time interval, without line re-initialization in this time interval, and under the same loop, noise, temperature and configuration settings) SHALL be ≤ 0.5 (see NOTE 1, 3). For at least 95% of the upstream sub-carrier groups where the SNRpsus accuracy requirements apply, i.e., : ▪ Sub-carriers in the sub-carrier group are at least 50kHz away from the lower and higher passband edge; ▪ BITSpsus_T1 > 0 and BITSpsus_T2 > 0 on at least one sub-carrier

	in the sub-carrier group; ▪ Noise_PSDps_UO2_T1(k × G × Δf) and Noise_PSDps_UO2_T2(k × G × Δf) > –120 dBm/Hz; ▪ (SNRpsus_T1-GAINSpsus_T1) and (SNRpsus_T2-GAINSpsus_T2) < 40 dB (see NOTE 1), and where: ▪ (GAINSpsus_T1=GAINSpsus_T1') and ▪ (GAINSpsus_T2=GAINSpsus_T2') (see NOTE 1), the following requirements SHALL apply: 1. If the line does not reinitialize over a time period T1 to T2: |(SNRpsus_T2–GAINSpsus_T2) – (SNRpsus_T1–GAINSpsus_T1) – ΔSNRps_reference_us| ≤ 1.3 dB (see NOTE 1, 2); 2. Statistical sample variance of (SNRpsus-GAINSpsus) (all samples taken over a 10-minute time interval, without line re-initialization in this time interval, and under the same loop, noise, temperature and configuration settings) SHALL be ≤ 0.5 (see NOTE 1, 3). NOTE 1 - GAINSps values SHALL be averaged in dB over the sub-carrier group. NOTE 2 – Includes 0.5 dB to accommodate for test equipment tolerance. NOTE 3 – For each sample of (SNRps-GAINSps), the GAINSps SHALL be recorded before and after the recording of the SNRps. Only if these GAINSps values are equal, the SNRps-GAINSps value SHALL be included in the sample variance calculation.

6.5 LATN

For further study.

6.6 SATN

For further study.

6.7 SNRM

For further study.

6.8 ATTNDR

For further study.

6.9 ACTATP

6.9.1 ACTATP for G.992.3 and G.992.5

The reference environment's requirements and design are identical to those for the HLOG. Figure 6-1 illustrates the configuration of the reference environments and Table 6-1 describes the specific configuration of the test environment (including transmitting transceiver requirements, test loop configuration and noise environment). No noise is inserted.

Figure 6-4 illustrates the Test Environment with a test instrument (e.g., spectrum analyzer or power meter) and 100 Ω termination to determine ACTATP_reference_UC2 and ACTATP_reference_UR2.

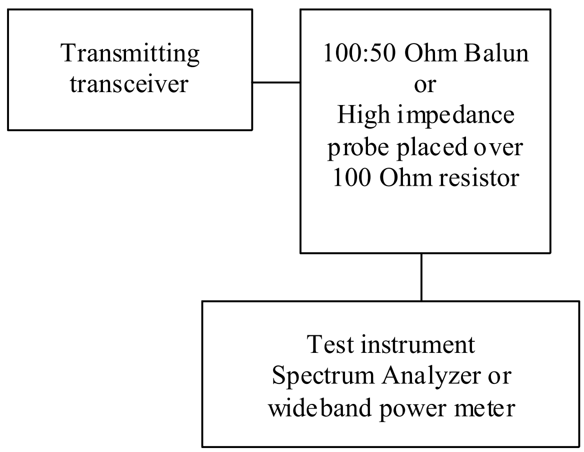

Figure 6-4 - Test environment for transmitted power using a test instrument, e.g. spectrum analyzer or wideband power meter.

This test is subject to the requirements from Section 8.12.5.8/G.992.3.

The method of procedure is defined in Table 13.

Table 6-11 – ACTATP Method of Procedure for G.992.3 and G.992.5

Purpose	Verify accuracy of reported near-end ACTATP after initialization.
Test Configuration	See Table 6-1. A test SHALL be performed over each of the test loops listed in Table 6-1.

Method of Procedure (step 1)	Record the reported values of near-end ACTATP as follows: a. Attach the DUT to the reference environment (Figure 6-4). b. Allow the Transmitting Transceiver and the DUT to go through initialization (in either diagnostics mode or normal initialization). c. Record the reported values of ACTATPds and ACTATPus (Section 7.5.1.24/G.997.1 and Section 7.5.1.25/G.997.1).
Method of Procedure (step 2a)	Determine the ATU-C near-end ACTATP reference as follows: a. Freeze the ATU-C DUT in Showtime state (i.e., disable the retrain trigger) and subsequently connect to an RN=100 Ω. If the power can be measured within a 4 second period (see NOTE 2), it is not needed to freeze the DUT in Showtime. b. ACTATP SHALL be measured in one of the following ways: • with high-impedance differential probe or high impedance test instrument placed over a 100 Ω resistor; or • with the test instrument 50 Ω input impedance over a wideband 100/50 balun transformer. c. Measure the ATU-C near-end ACTATP reference value (ACTATP_reference_UC2) as the downstream power at the U-C2 reference point.
Method of Procedure (step 2b)	Determine the ATU-R near-end ACTATP reference as follows: a. Freeze the ATU-R DUT in Showtime state (i.e. disable the retrain trigger) and subsequently connect to an RN=100 Ω. If the power can be measured within a 4 second period (see NOTE 2) it is not needed to freeze the DUT in Showtime. b. ACTATP SHALL be measured in one of the following ways: • with high-impedance differential probe or high impedance test instrument placed over a 100 Ω resistor, or • with the test instrument 50 Ω input impedance over a wideband 100/50 balun transformer c. Measure the ATU-R near-end ACTATP reference value (ACTATP_reference_UR2) as the upstream power at the U-R2 reference point.
Expected Result	a. For downstream the following requirement SHALL apply: |ACTATPds - ACTATP_reference_UC2| ≤ 1.5 dB (see NOTE 1) b. For upstream the following requirement SHALL apply: |ACTATPus - ACTATP_reference_UR2| ≤ 1.5 dB (see NOTE 1) NOTE 1 – Includes 0.5 dB to accommodate for test equipment tolerance.
NOTE 2 – The minimum persistent LOS/LOF failure time defined in G.992.3 Annex D is 4 seconds.	

6.9.2 ACTATP for G.993.2

The reference environment's requirements and design are identical to those for the HLOG. Figure 6-1 illustrates the configuration of the reference environments and Table 6-1 describes the specific configuration of the test environment (including transmitting transceiver requirements, test loop configuration and noise environment).

Figure 6-4 illustrates the Test Environment with a test instrument (e.g. spectrum analyzer or power meter) and 100 Ω termination to determine ACTATP_reference_UO2 and ACTATP_reference_UR2.

This test is subject to the requirements from Section 11.4.1.1.8/G.993.2.

The method of procedure is defined in Table 6-12.

Table 6-12 – ACTATP Method of Procedure for G.993.2

Purpose	Verify accuracy of reported near-end ACTATP after initialization.
Test Configuration	See Table 6-4. A test SHALL be performed over each of the test loops listed in Table 6-4.
Method of Procedure (step 1)	Record the reported values of near-end ACTATP as follows: a. Attach the DUT to the reference environment (Figure 6-1). b. Allow the Transmitting Transceiver and the DUT to go through initialization (in either diagnostics mode or normal initialization). c. Record the reported values of ACTATPds and ACTATPus (Section 7.5.1.24/G.997.1 and Section 7.5.1.25/G.997.1).
Method of Procedure (step 2a)	Determine the VTU-O near-end ACTATP reference as follows: a. Freeze the VTU-O DUT in Showtime state (i.e. disable the retrain trigger) and subsequently connect to an RN=100 Ω. If the power can be measured within a 4 second period (see NOTE 2), it is not needed to freeze the DUT in Showtime. b. ACTATP SHALL be measured in one of the following ways: • with high-impedance differential probe or high impedance test instrument placed over a 100 Ω resistor, or • with test instrument 50 Ω input impedance over a wideband 100/50 balun transformer c. Measure the VTU-O near-end ACTATP reference value (ACTATP_reference_UO2) as the downstream power at the U-O2 reference point.

Method of Procedure (step 2b)	Determine the VTU-R near-end ACTATP reference as follows: a. Freeze the VTU-R DUT in Showtime state (i.e. disable the retrain trigger) and subsequently connect to an RN=100 Ω. If the power can be measured within a 4 second period (see NOTE 2) it is not needed to freeze the DUT in Showtime. b. ACTATP SHALL be measured in one of the following ways: • with high-impedance differential probe or high impedance test instrument placed over a 100 Ω resistor, or • with the test instrument 50 Ω input impedance over a wideband 100/50 balun transformer c. Measure the VTU-R near-end ACTATP reference value (ACTATP_reference_UR2) as the upstream power at the U-R2 reference point.
Expected Result	a. For downstream the following requirements SHALL apply: |ACTATPds - ACTATP_reference_UO2| ≤ 1.5 dB (see NOTE 1) The sample variance of the VTU-O near-end ACTATP_ds measurements (all samples taken over a 10 minutes time interval, without line re-initialization and bit/gain-swaps in this time interval, and under the same loop, noise, temperature, and configuration settings) ≤ 0.5dB. b. For upstream the following requirement SHALL apply: |ACTATPus - ACTATP_reference_UR2| ≤ 1.5 dB (see NOTE 1) The sample variance of the VTU-R near-end ACTATP_us measurements (all samples taken over a 10 minutes time interval, without line re-initialization and bit/gain-swaps in this time interval, and under the same loop, noise, temperature, and configuration settings) ≤ 0.5dB. NOTE 1 – Includes 0.5 dB to accommodate for test equipment tolerance.
NOTE 2 – The minimum persistent LOS/LOF failure time defined in clause 12.1.4/G.993.2 is 4 seconds.	

End of Broadband Forum Technical Report TR-138