TECHNICAL REPORT

TR-138

Accuracy Tests for Test Parameters

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TR Issue History

Issue Number	Approval Date	Publication Date	Issue Editor	Changes
1	November 2009		Frank Van der Putten, Alcatel	Original
Issue 1 Amendment 1	8 September 2014	25 September 2014	Massimo Sorbara, Ikanos Communications	Additional tests: UER, LATN, and SATN

Comments or questions about this Technical Report should be directed to help@broadband-forum.org.

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Executive Summary

This document contains an amendment to issue 1 of TR-138.

TR-138i1a1 contains additional tests on accuracy of test parameters to the existing material in TR-138 Issue 1. The additional tests include the following:

- Line Attenuation (LATN) for G.992.3 and G.992.5 in Section 6.5.1
- Line Attenuation (LATN) for G.993.2 in Section 6.5.2
- Signal Attenuation (SATN) for G.992.3 and G.992.5 in Section 6.6.1
- Signal Attenuation (SATN) for G.993.2 in Section 6.6.2, and
- Un-calibrated Echo Response (UER) in Single Ended Loop Testing (SELT) for G.992.3, G.992.5, and G.993.2 in Section 6.10

1 Purpose and Scope

See *Section 1/TR-138 Issue 1*.

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 could exist valid reasons in particular circumstances to ignore this item, but the full implications need to be understood and carefully weighed before choosing a different course.
SHOULD NOT	This phrase, or the phrase "NOT RECOMMENDED" means that there could exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications need to 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.

The reference list in *Section 2.2/TR-138 Issue 1 is replaced with the following:*

Document	Title	Source	Year
[1] RFC2119	*Key words for use in RFCs to Indicate Requirement Levels*	IETF	1997
[2] G.992.3 Amendment 5	*Asymmetric digital subscriber line transceivers 2 (ADSL2)*	ITU-T	2012

[3]	G.993.2 Amendment 2	*Very-high speed digital subscriber line transceivers 2 (VDSL2)*	ITU-T	2012
[4]	G.997.1	*Physical layer management for digital subscriber line (DSL) transceivers*	ITU-T	2012
[5]	TR-100 Issue 2	*ADSL2/ADSL2plus Performance Test Plan*	BBF	2012
[6]	TR-114 Issue 2	*VDSL2 Performance Test Plan*	BBF	2012
[7]	TR-138	*Accuracy Tests for Test Parameters*	BBF	2009
[8]	G.992.5	*Asymmetric digital subscriber line transceivers 2 (ADSL2) – Extended bandwidth (ADSL2plus)*	ITU-T	2009
[9]	G.996.2	*Single-ended line testing for digital subscriber lines (DSL)*	ITU-T	2009

2.3 Definitions

This Technical Report amendment contains no new definitions.

2.4 Abbreviations

See *Section 2.4/TR-138 Issue 1*

This Technical Report uses the following additional abbreviation:

UER	Un-calibrated Echo Response

2.5 G.997.1 Parameters

Parameter	**Section in G.997.1**
ACTPSD	7.5.1.21, 7.5.1.22
GAINSps	7.5.1.29.3, 7.5.1.29.4
LATN	7.5.1.9, 7.5.1.10
MREFPSD	7.5.1.29.7, 7.5.1.29.8
RMSGI	7.5.1.21, 7.5.1.22
SATN	7.5.1.11, 7.5.1.12
TSSps	7.5.1.29.5, 7.5.1.29.6

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.

3.4 Privacy

Any issues regarding privacy are not affected by TR-138i1a1

6 Test Parameter Accuracy Tests

Update section 6.5 for LATN with the following:

-----*begin text* -----

6.5 LATN

6.5.1 LATN for G.992.3 and G.992.5

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

In order to minimize variability in measured results, the wireline and noise simulators SHALL have loop and noise characteristics as defined in Section 3/TR-100 [5]. They SHOULD meet the accuracy requirements specified in Section 3/TR-100 [5] for attenuation, phase and impedance.

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

Table 6-1 provides the test environment configuration for G.992.3 and G.992.5.

The method of procedure is defined in Table 6-11.

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

Purpose	Verify accuracy of reported LATN, 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 LATN_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 value as follows: $\text{LATN\_reference\_us} = -10 \times \log_{10}\left(\frac{\sum_{k=n3}^{n4}\left\lvert \text{H\_reference\_us}(k)\right\rvert^{2}}{NSC\_U}\right)$. where *NSC_U* is the number of sub-carriers in the upstream band and equals $n4-n3+1$ where *n*3 and *n*4 are the indices of the first and the last sub-carriers of this band, respectively. H_reference_us(*k*) is calculated for each tone in the upstream band as $\left\lvert \text{H\_reference\_us}(k)\right\rvert^{2} = 10^{\text{HLOGps\_reference\_us}(k)/10}$ where $\text{HLOGps\_reference\_us}(k) = \text{PSDps\_UC2}(k) - (\text{REFPSDus} + \text{log\_tssi}(k))$, REFPSDus is obtained from ACTPSDus and RMSGIus; and tssi(*k*) is obtained from TSSpsus. PSDps_UC2(*k*) SHALL be measured by the spectrum analyzer at the U-C2 reference point. If one or more H_reference values could not be measured because they are out of the PSD mask passband, then the LATN_reference_us SHALL be calculated as an average of H_reference values over a number of subcarriers *NSC_U’* that is less than *NSC_U*, where *NSC_U’* is the number of valid upstream H_reference values. f. Calculate the downstream reference value as follows: $\text{LATN\_reference\_ds} = -10 \times \log_{10}\left(\frac{\sum_{k=n1}^{n2}\left\lvert \text{H\_reference\_ds}(k)\right\rvert^{2}}{NSC\_D}\right)$ where *NSC_D* is the number of sub-carriers in the downstream band = $n2-n1+1$ where *n*1 and *n2* are the indices of the first and the last sub-carriers of this band, respectively. H_reference_ds(*k*) is calculated for each tone in the downstream band as

	$\lvert \mathrm{H\_reference\_ds}(k) \rvert^2 = 10^{\mathrm{HLOGps\_reference\_ds}(k)/10}$ with HLOGps_reference_ds(k) defined as: For G.992.3: $\mathrm{HLOGps\_reference} - \mathrm{ds}(k) = \mathrm{PSDps\_UR2}(k) - (\mathrm{REFPSDds} + \mathrm{log\_tssi}(k))$ For G.992.5: $\mathrm{HLOGps\_reference\_ds}(k) = \mathrm{PSDps\_UR2}(k) - (\mathrm{REFPSDds} + \mathrm{ceiled\_log\_tssi}(k))$ where REFPSDds is obtained from ACTPSDds and RMSGIds and tssi(k) is obtained from TSSpsds. PSDps_UR2(k) SHALL be measured by the spectrum analyzer at the U-R2 reference point. If one or more H_reference values could not be measured because they are out of the PSD mask passband then the LATN_reference_ds value SHALL be calculated as an average of H_reference values over a number of subcarriers *NSC_D'* that is less than *NSC_D*, where *NSC_D'* is the number of valid downstream H_reference values. 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 2)	Record the reported values of LATN 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 LATNus and LATNds.
Expected Result	1. LATNds value SHALL be different from the special value defined in Section 8.12.3.4/G.992.3 [2]; 2. |LATNds - LATN_reference_ds| ≤ 3.5dB (see NOTE 1); 3. LATNus value SHALL be different from the special value defined in Section 8. 12.3.4/G.992.3 [2]; 4. |LATNus - LATNreference_us| ≤ 3.5 dB (see NOTE 1). NOTE 1 – Includes 0.5 dB to accommodate for test equipment tolerance.

6.5.2 LATN pb for G.993.2

Figure 6-1 illustrates the test environment for testing the accuracy of the loop attenuation per band (LATN-pb), when configured with the DUT attached.

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 [6]. They SHOULD meet the accuracy requirements as specified in Section 7/TR-114[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 a 100 Ω termination to determine LATN_reference.

Table 6-3 provides the test environment configuration for G.993.2.

The method of procedure for G.993.2 is defined in Table 6-12.

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

Purpose	Verify accuracy of reported LATN-pb, after diagnostics mode or after initialization.
Test Configuration	See Table 6-3. A test SHALL be performed over each of the test loops listed in Table 6-3. The AWGN noise level SHALL be set to –140 dBm/Hz to be injected near the DUT.
Method of Procedure (step 1)	Determine the LATN _reference value 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. Calculate the upstream reference value. For each band the upstream LATNpb(m) reference value for the m^{th} upstream band is defined as $$\text{LATN\_reference\_us}(m) = -10 \times \log_{10}\left(\frac{\sum_{k=n1}^{n2} \left\|\text{H\_reference\_us}(k \times \Delta f)\right\|^2}{N\_U(m)}\right)$$ where *N_U(m)* is the number of sub-carriers in the m^{th} upstream band and equals $n2-n1+1$ where $n1$ and $n2$ are the indices of the first and the last sub-carriers of this band, respectively. H_reference_us($k \times \Delta f$) is calculated as:

	$\left\lvert \mathrm{H\_reference\_us}(k \times \Delta f) \right\rvert^2 = 10^{\mathrm{HLOG\_reference\_us}(k \times \Delta f)/10}$ with HLOG_reference_us(k × Δf) = MREFPSDus(k × Δf) - PSD_UO2(k × Δf), where MREFPSDus is upstream MEDLEY reference PSD and PSD_UO2(k × Δf) is the PSD measured by the spectrum analyzer at the U-O2 reference point. If one or more H_reference_us(k×Δf)) values could not be measured because they are out of the transmitter SUPPORTEDCARRIERS set (see G.993.2[3] clause 11.4.1.1.1), then the LATN_ reference_us(m) value SHALL be calculated as an average of H(f) values over the number of sub-carriers for which valid values of H(f) are available., f. Calculate the downstream reference value. For each band the downstream LATNpb(m) reference value for the m'th downstream band is defined as $\mathrm{LATN\_reference\_ds}(m) = -10 \times \log_{10}\left(\frac{\sum_{k=n1}^{n2} \left\lvert \mathrm{H\_reference\_ds}(k \times \Delta f) \right\rvert^2}{N\_D(m)} \right)$ where $N\_D(m)$ is the number of sub-carriers in the m^{th} downstream band and equals $n2-n1+1$ where $n1$ and $n2$ are the indices of the first and the last sub-carriers of this band, respectively. The value of H_reference_ds(k × Δf) is calculated as $\left\lvert \mathrm{H\_reference\_ds}(k \times \Delta f) \right\rvert^2 = 10^{\mathrm{HLOG\_reference\_ds}(k \times \Delta f)/10}$ with $\mathrm{HLOG\_reference\_ds}(k \times \Delta f) = \mathrm{MREFPSDds}(k \times \Delta f) - \mathrm{PSD\_UR2}(k \times \Delta f)$, where MREFPSDds is the downstream MEDLEY reference PSD, and PSD_UR2(k×Δf) is the PSD measured by the spectrum analyzer at the U-R2 reference point. If one or more H_reference_ds(k×Δf) values could not be measured because they are out of the transmitter SUPPORTEDCARRIERS set (see G.993.2[3] clause 11.4.1.1.1), then the LATN_reference_ds(m) value SHALL be calculated as an average of the H(f) values over the number of sub-carriers for which valid values of H(f) are available. 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	Record the values of LATN as follows:

Procedure (step 2)	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 LATNus and LATNds in each frequency band
Expected results	1. LATNds value SHALL be different from the special value defined in Section 11.4.1.1.4/G.993.2 [3]; 2. |LATNds - LATN_reference_ds(*m*)| ≤ 3.5 dB in all frequency bands m (see NOTE 1); 3. LATNus value SHALL be different from the special values defined in Section 11.4.1.1.1/G.993.2[3]; 4. |LATNus - LATN_reference_us(*m*)| ≤ 3.5 dB in all frequency bands m. (see NOTE 1). NOTE 1 – Includes 0.5 dB to accommodate for test equipment tolerance.

----- *end text* -----

6.6 SATN

Update section 6.6 for SATN with the following:

----- *begin text* -----

6.6.1 SATN for G.992.3 and G.992.5

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

In order to minimize variability in measured results, the wireline and noise simulators SHALL have loop and noise characteristics as defined in Section 3/TR-100 [5]. They SHOULD meet the accuracy requirements specified in Section 3/TR-100 [5] for attenuation, phase and impedance.

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

Table 6-1 provides the test environment configuration for G.992.3 and G.992.5.

The method of procedure is defined in Table 6-13.

Table 6-13 – SATN Method of Procedure for G.992.3 and G.992.5

Purpose	Verify accuracy of reported SATN, 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 SATN_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 value. The upstream SATN reference value is defined as follows: $\mathrm{SATN\_reference\_us} = \mathrm{TXpower\_dBm\_reference\_us} - \mathrm{RXpower\_dBm\_reference\_us}$ where the TXpower_dBm_reference_us is given by ACTATPus and the RXpower_dBm_reference_us by $10 \times \log_{10}(\Delta \mathrm{f}) + 10 \times \log_{10}\left(\sum_{i \in \mathrm{MEDLEYus}} \left(10^{\frac{\mathrm{PSDps\_UC2}(i)}{10}} \right) \right)$ where PSDps_UC2(*i*) is the upstream PSD measured at the U-C2 reference point, after initialization of the line up to an R-REVERB state, in which state the ATU-R is frozen and the ATU-C is subsequently replaced by a R_N = 100 Ω. f. Calculate the downstream reference value. The downstream SATN reference value is defined as follows: $\mathrm{SATN\_reference\_ds} = \mathrm{TXpower\_dBm\_reference\_ds} - \mathrm{RXpower\_dBm\_reference\_ds}$ where the TXpower_dBm_reference_ds is given by ACTATPds and the RXpower_dBm_reference_ds by $10 \times \log_{10}(\Delta \mathrm{f}) + 10 \times \log_{10}\left(\sum_{i \in \mathrm{MEDLEYus}} \left(10^{\frac{\mathrm{PSDps\_UR2}(i)}{10}} \right) \right)$ where PSDps_UR2(*i*) is the downstream PSD measured at the U-R2 reference point, after initialization of the line up to a C-REVERB state, in which state the ATU-C is frozen and the ATU-R subsequently replaced by an R_N = 100 Ω. 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 2)	Record the reported values of SATN 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 SATNus and SATNds.
Expected result	The following requirements SHALL apply: 1. SATNds value SHALL be different from the special value defined in Section 8.12.3.5/G.992.3 [2]; 2. |SATNds - SATN_reference_ds| ≤ 4.5dB (see NOTE 1); 3. SATNus value SHALL be different from the special value defined in Section 8. 12.3.5/G.992.3 [2]; 4. |SATNus - SATNreference_us| ≤ 4.5 dB (see NOTE 1). NOTE 1 – Includes 0.5 dB to accommodate for test equipment tolerance. It also includes 1 dB additional inaccuracy to accommodate for the ACTATP taken as an alternative for the TXpower_dBm_ reference in calculation of the SATN_reference.

6.6.2 SATN pb for G.993.2

Figure 6-1 illustrates the test environment for testing the accuracy of the signal attenuation per band (SATN-pb), when configured with the DUT attached.

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 [6]. They SHOULD meet the accuracy requirements as specified in Section 7/TR-114[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 100Ω termination to determine SATN_reference.

Table 6-3 provides the test environment configuration for G.993.2.

The method of procedure for SATN in G.993.2 is defined in Table 6-14.

Table 6-14 – SATN-pb Method of Procedure for G.993.2

Purpose	Verify accuracy of reported SATN-pb, after diagnostics mode or after initialization.
Test Configuration	See Table 6-3. A test SHALL be performed over each of the test loops listed in Table 6-3. The AWGN noise level SHALL be set to –140 dBm/Hz to be injected near the DUT.
Method of Procedure (step 1)	Determine the SATN_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. Calculate the upstream reference value for each band. The reference value for the m^{th} upstream band is defined as: $\text{SATN\_reference\_us}(m) = \text{TXpower\_dBm\_reference\_us}(m) - \text{RXpower\_dBm\_reference\_us}(m)$. The TXpower_dBm_reference_us(*m*) is defined as: $\text{TXpower\_dBm\_reference\_us}(m) = 10 \times \log_{10} \Delta f + 10 \times \log_{10}\left(\sum_{i \in \text{MEDLEYus} \cap \text{US}(m))} \left(10^{\frac{\text{MREFPSD}[i]}{10}} \times g_i^2 \right) \right)$ where MEDLEYus ∩ US(*m*) denotes all sub-carriers of the MEDLEYus set that fall into the *m*th upstream band, MREFPSD[*i*] is the value of MREFPSDus for sub-carrier *i* in dBm/Hz, g_i is as defined in clause 11.4.1.1.5 of ITU-T G.993.2 [3], and Δ*f* is the sub-carrier spacing in Hz. The RXpower_dBm_reference_us (*m*) is defined as: $\text{RXpower\_dBm\_reference\_us}(m) = 10 \times \log_{10}(\Delta \text{f}) + 10 \times \log_{10}\left(\sum_{i \in \text{MEDLEYus} \cap \text{US}(m))} \left(10^{\frac{\text{PSD\_UO2}(\text{i} \times \Delta \text{f})}{10}} \right) \right)$, where PSD_UO2(*i* × Δ*f*) is the PSD measured at the U-O2 reference point with the VTU-R connected to the loop and frozen in the R-P-MEDLEY stage of initialization with the SOC in the R-IDLE state,

	and with the VTU-O replaced by an R_N=100 Ohm resistance terminating the loop. f. Calculate the downstream reference value for each band. The reference value for the m^{th} downstream band is defined as: $\text{SATN\_reference\_ds}(m) = \text{TXpower\_dBm\_reference\_ds}(m) - \text{RXpower\_dBm\_reference\_ds}(m)$. The TXpower_dBm_reference_ds(m) is defined as: $\text{TXpower\_dBm\_reference\_ds}(m) = 10\times\log_{10}(\Delta f) + 10\times\log_{10}\left(\sum_{i\in\text{MEDLEYds}\cap\text{DS}(m))}\left(10^{\frac{\text{MREFPSD}[i]}{10}}\times g_i^2\right)\right)$ where MEDLEYds ∩ DS(m) denotes all sub-carriers of the MEDLEYds set that fall into the m^{th} downstream band, MREFPSD[i] is the value of MREFPSDds for sub-carrier i in dBm/Hz, g_i is as defined in Section 11.4.1.1.5 ITU-T G.993.2 [3],, and Δf is the sub-carrier spacing in Hz. RXpower_dBm_reference_ds (m) is defined as: $\text{RXpower\_dBm\_reference\_us}(m) = 10\times\log_{10}(\Delta\text{f}) + 10\times\log_{10}\left(\sum_{i\in\text{MEDLEYus}\cap\text{US}(m))}\left(10^{\frac{\text{PSD\_UR2}(\text{i}\times\Delta\text{f})}{10}}\right)\right)$, where PSD_UR2(i × Δf) is the PSD measured at the U-R2 reference point with the VTU-O connected to the loop and frozen in the O-P-MEDLEY stage of initialization with the SOC in the O-IDLE state, and with the VTU-R replaced by a R_N=100 Ohm resistance terminating the loop. NOTE – The feature to freeze a VTU in the MEDLEY stage of initialization exists solely to allow a test bed to be constructed for the purpose of measuring the reference values. It applies only to specific transceivers serving as the 'transmit transceiver' of the test environment, and is not a requirement for compliance.
Method of Procedure (step 2)	Record the values of SATN 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 SATNus and SATNds in each frequency band.
Expected Results	1. SATNds value SHALL be different from the special value defined in Section 11.4.1.1.5/G.993.2 [3];

	2. |SATNds - SATN_reference_ds(*m*)| ≤ 3.5 dB in all frequency bands *m* (see NOTE 1); 3. SATNus value SHALL be different from the special value defined in Section 11.4.1.1.5/G.993.2 [3]; 4. |SATNus - SATN_reference_us(*m*)| ≤ 3.5 dB in all frequency bands *m*. (see NOTE 1). NOTE 1 – Includes 0.5 dB to accommodate for test equipment tolerance.

-----*end text* -----

Add new section 6.10 on accuracy testing of SELT parameters.

---- *begin text* -----

6.10 SELT

The purpose of this single line-ended test (SELT) is to define a method for measuring the uncalibrated echo response (UER) and set a goal on its deviation from the reference UER. After a stimulus signal is applied to the line card, the UER is measured and computed as a combination of the AFE response (AFER) and the line response (COPPER CHANNEL RESPONSE, e.g. CCR). AFER is the echo component caused by reflections in the analog front end of the line card and the CCR is the echo from the twisted pair transmission line attached to the line card. In the next step, after a calibration procedure (a so-called SHORT-OPEN-LOAD calibration), or a vector of correction coefficients, is applied, the adjusted UER determines the line card CCR (LCCR).

The network analyzer provides both the stimulus signal and measures the UER, i.e. it functions just as a line card. Since quality network analyzers provide standard methods for removing the effect of the analyzer’s front-end electronics from the echo measurement, they are used to determine the reference CCR of the test loop (RCCR).

Figure 6-5 illustrates the test environment for testing the accuracy of the uncalibrated echo response (UER), when configured with the Device Under Test (DUT) attached. The DUT is generally a line card that performs the SELT test and calculates the UER.

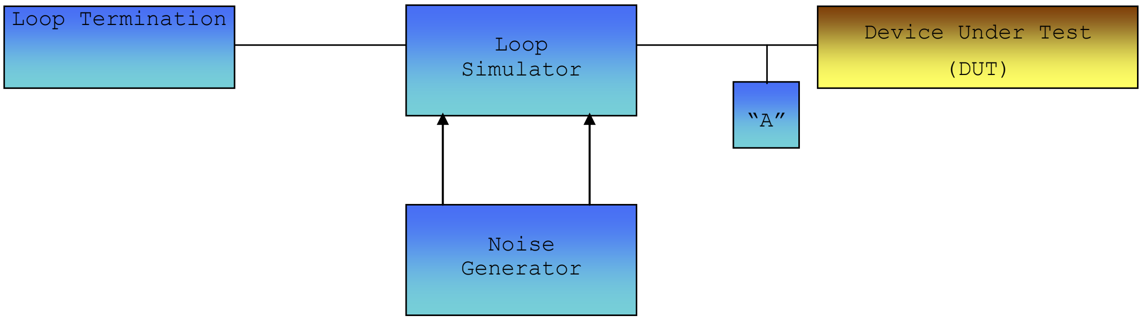
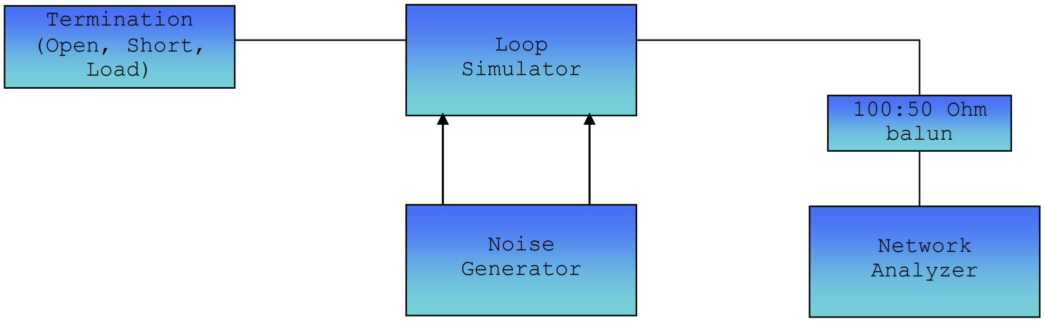


Figure 6-5 – Test environment with the DUT attached

For the SELT test for G.992.3 and G.992.5, in order to minimize variability in measured results, the wire-line and noise simulators SHALL have loop and noise characteristics as defined in Section 3/TR-100 [5]. They SHOULD meet the accuracy requirements specified in Section 3/TR-100 [5] for attenuation, phase and impedance, however, calibration is not required.

For the SELT test for G.993.2, in order to minimize variability in measured results, the wireline and noise simulators SHALL have loop and noise characteristics as defined in Section 7/TR-114 [6]. They SHOULD meet the accuracy requirements specified in Section 7/TR-114 [6] for attenuation, phase and impedance, however, calibration is not required.

Figure 6-6 illustrates the Test Environment when configured with a network analyzer and a 100 Ω load termination to determine the reference UER.



NOTE - The unbalanced side of the balun might be of other impedances than 50 Ohm, as long as it matches the network analyzer

Figure 6-6 – Test environment with network analyzer attached

The 100:50-Ohm balun SHALL comply with the requirements below in a frequency range from 25.875 kHz to 2.2MHz for G992.3 and G. 992.5, and to 30 MHz for G.993.2:

- Impedance at the balanced side SHALL match the loop impedance within 10%
- Insertion loss SHALL be < 1.5dB
- Non-linear distortion SHALL be < -40dBc when subjected to 0dBm source power on 25.875kHz

6.10.1 SELT for G.992.3 and G.992.5

Table 6-15 provides the test environment configuration for G.992.3 and G.992.5.

Table 6-15 – Configuration of Test Environment for G.992.3 and G.992.5

Test loop (see NOTE 1)	Loop type	Loop length (no bridge taps)
1	26 AWG	1000 ft
2	26 AWG	2000 ft
3	26 AWG	3000 ft
4	26 AWG	4000 ft
5	26 AWG	5000 ft
6	26 AWG	6000 ft
7	26 AWG	7000 ft
8	26 AWG	8000 ft
9	26 AWG	9000 ft
10	26 AWG	10000 ft
11	26 AWG	11000 ft
12	26 AWG	12000 ft
13	26 AWG	13000 ft
14	26 AWG	14000 ft
15	26 AWG	15000 ft
16	26 AWG	16000 ft
Common Line Settings		As defined in Table 7-1/TR-100 [5].
General Test Profile		The Low delay profile F-1/0 from Table 7-2/TR-100 [5].
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 [5].
NOTE - Other loop types and loop lengths MAY be used if resulting in the same insertion loss at 300 kHz.		

The method of procedure to determine the LCCR is defined in Table 6-16.

Based on the outcome of HLOG test described in Section 6.2.1, the frequency f_max(loop) that has 45 dB of loss on the loop under test SHALL be defined. Therefore, the UER accuracy requirements apply only on loops in frequency and impedance ranges defined in Section 6.2.1. In order to meet these requirements, the loop simulator and transmitting transceiver SHALL be configured as defined in Table 6-15. For shorter loops where 45 dB of loss is not measurable, the f_max(loop) is set to 2.2 MHz.

Table 6-16 – UER(f) DUT Method of Procedure for G.992.3 and G.992.5

Purpose	Verify accuracy of reported channel parameter UER from the DUT.
Test Configuration	See Table 6-15. A test SHALL be performed over each of the test loops listed in Table 6-15 each with a termination of an OPEN, SHORT and LOAD.
Method of Procedure (step 1)	a. There is no "standard" for calibration procedure for a DUT. Rather the SELT standard [9] refers to calibration coefficients that are "computed and stored" as part of the DUT product and applied to the UER. A DUT calibration SHALL not be recorded here. The DUT will output UER coefficients that are calibrated to a 100 Ω resistive load at the interface reference point "A" in Figure 6-5 or the vendor SHALL supply a recommended algorithm for calibrating the DUT to the reference point.
Method of Procedure (step 2)	a. Set the line simulator to the first loop listed in Table 6-15. b. Set the noise generator to -140 dBm/Hz.
Method of Procedure (step 3)	a. Use an OPEN as the termination in Figure 6-6. b. Execute the UER measurements and record the RCCR data. c. Use an OPEN as the termination in Figure 6-5. d. Execute the UER measurements and record the LCCR data for OPEN loop.
Method of Procedure (step 4)	a. Use an SHORT as the termination in Figure 6-6. b. Execute the UER measurements and record the RCCR data. c. Use an SHORT as the termination in Figure 6-5. d. Execute the UER measurements and record the LCCR data for SHORT loop.
Method of Procedure (step 5)	a. Use a 100 Ohm LOAD as the termination in Figure 6-6. b. Execute the UER measurements and record the RCCR data. c. Use a 100 Ohm LOAD as the termination in Figure 6-5. d. Execute the UER measurements and record the LCCR data for LOAD loop.
Method of Procedure (step 6)	Repeat Steps 2-5 for each loop in Table 6-15
Expected Result	For the index "i" denoting the *i*-th frequency of the set of measured frequencies, the χ^2 (normalized) is given as: $\chi^2 = \frac{1}{nmax - nmin + 1} \times \sum_{i=nmin}^{nmax} \frac{\lVert L(i) - R'(i) \rVert^2}{\lVert R(i) \rVert^2}$, where *nmin* and *nmax* represent the limits of the range of frequencies of the measurements, and *L*(*i*) and *R*(*i*) are complex values defined as:

<table>
<tr><td></td><td>$L(i) = LCCR(i) + \beta$
$R(i) = RCCR(i) + \beta$
$R'(i) = k \times (RCCR(i) + \beta)$
$\beta = 1 + j,$
where j is the imaginary constant equal to $j = \sqrt{-1}$.

Parameter *k* is a vendor discretionary real value that optimizes (i.e. minimizes) the value of χ^2.

The test is passed if for each loop, and for the given *k*, the $\chi^2 < 0.02$.</td></tr>
<tr><td colspan="2">NOTE 1 – See Section A.2.2.1/G.996.2 [9] for more information regarding numerical representation of the UER.

NOTE 2 - For each loop under test, the accuracy value of UER is defined for all frequencies up to and including f_max(loop) using a regression analysis χ^2 test.

It should be noted that the information content of impedance mismatch effects from the UER depends on the integrity of the shape of the curves of the real (Re) and imaginary (Im) parts of the LCCR data, but not on an overall scale factor, referred to as “k”. Therefore, until the requirements specify a calibrated echo response, an overall scaling factor is allowed so that the Real and Imaginary components of LCCR and RCCR are related as:
• LCCR(Re) ~ RCCR(Re), and
• LCCR(Im) ~ RCCR(Im), and also,
• LCCR(Re) = k*RCCR(Re), and
• LCCR(Im) = k*RCCR(Im).</td></tr>
</table>

6.10.2 SELT for G.993.2

Table 6-17 provides the test environment configuration for G.993.2.

Table 6-17 - Configuration of Test Environment for G.993.2

Test # (see NOTE 1)	**Loop type**	**Loop length (no bridge taps)**
1	26 AWG	500 ft
2	26 AWG	1000 ft
3	26 AWG	2000 ft
4	26 AWG	3000 ft
5	26 AWG	4000 ft
6	26 AWG	5000 ft
VDSL2 Band-profiles for testing		ANNEX A profile AA8d, as defined in Table 6-1/TR-114 [6], or One of the following ANNEX B profiles: BA8b, BA12a, BA17a, BB8b or BB12a, or BB17a, as defined in Table 6-1/TR-114 [6].
Common Line Settings		As defined in Table 6-2/TR-114 [6].
General Line Settings		As defined in Table 6-3/TR-114 [6].
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 [6]. Specific line settings RA_I_096_056 and RA_F_150_150 are defined in Table 6-4/TR-114 [6]. Profile-line combinations are defined in Section 6.2.3./TR-114 [6].
NOTE - Other loop types and loop lengths MAY be used if resulting in the same insertion loss at 1 MHz.		

The method of procedure to determine the LCCR is defined in Table 6-18.

Based on the outcome of HLOG test described in Section 6.2.2, the frequency f_max(loop) that has 45 dB of loss on the loop under test SHALL be defined. Therefore, the UER accuracy requirements apply only on loops in frequency and impedance ranges defined in Section 6.2.2. In order to meet these requirements, the loop simulator and transmitting transceiver SHALL be configured as defined in Table 6-17. For shorter loops where 45 dB of loss is not measurable, the f_max(loop) is set to 17 MHz.

Table 6-18 – UER Method of Procedure for G.993.2

Purpose	Verify accuracy of reported UER from the DUT.
Test Configuration	See Table 6-17. A test SHALL be performed over each of the test loops listed in Table 6-17 each with a termination of an OPEN, SHORT and LOAD.
Method of Procedure (step 1)	There is no standard calibration procedure for a DUT. Rather the SELT part of ITU-T Recommendation (G.996.2) [9] refers to calibration coefficients that are "computed and stored" as part of the DUT product and applied to the UER. A DUT calibration SHALL not be recorded here. The DUT will output UER coefficients that are calibrated to a 100 Ω resistive load at the interface reference point "A" in Figure 6-5 or the vendor SHALL supply a recommended algorithm for calibrating the DUT to the reference point.
Method of Procedure (step 2)	a. Set the line simulator to the first loop in Table 6-17. b. Set the noise generator to -140 dBm/Hz.
Method of Procedure (step 3)	a. Use an OPEN as the termination in Figure 6-6. b. Execute the UER measurements and record the RCCR data. c. Use an OPEN as the termination in Figure 6-5. d. Execute the UER measurements and record the LCCR data for OPEN loop.
Method of Procedure (step 4)	a. Use an SHORT as the termination in Figure 6-6. b. Execute the UER measurements and record the RCCR data. c. Use an SHORT as the termination in Figure 6-5. d. Execute the UER measurements and record the LCCR data for SHORT loop.
Method of Procedure (step 5)	a. Use a 100 Ohm LOAD as the termination in Figure 6-6. b. Execute the UER measurements and record the RCCR data. c. Use a 100 Ohm LOAD as the termination in Figure 6-5. d. Execute the UER measurements and record the LCCR data for LOAD loop.
Method of Procedure (step 6)	Repeat Steps 2-5 for each loop in Table 6-17.
Expected Result	For the index "i" denoting the *i*-th frequency of the set of measured frequencies, the χ^2 (normalized) is given as: $\chi^2 = \frac{1}{nmax - nmin + 1} \times \sum_{i=nmin}^{nmax} \frac{\left\| L(i) - R'(i) \right\|^2}{\left\| R(i) \right\|^2}$, where *nmi*n and *nmax* represent the limits of the range of frequencies

<table>
<tr><td></td><td>of the measurements, and $L(i)$ and $R(i)$ are complex values defined as:
$L(i) = LCCR(i) + \beta$
$R(i) = RCCR(i) + \beta$
$R'(i) = k \times (RCCR(i) + \beta)$
$\beta = 1 + j,$
where j is the imaginary constant equal to $j = \sqrt{-1}$.

Parameter k is a vendor discretionary real value that optimizes (i.e. minimizes) the value of χ^2 .

The test is passed if for each loop, and for the given k, the $\chi^2 < 0.02$.</td></tr>
<tr><td colspan="2">NOTE 1 – See Section A.2.2.1/G.996.2 [9] for more information regarding numerical representation of the UER.

NOTE 2 - For each loop under test, the accuracy value of UER is defined for all frequencies up to and including f_max(loop) using a regression analysis χ^2 test.

It should be noted that the information content of impedance mismatch effects from the UER depends on the integrity of the shape of the curves of the real (Re) and imaginary (Im) parts of the LCCR data, but not on an overall scale factor, referred to as “k”. Therefore, until the requirements specify a calibrated echo response, an overall scaling factor is allowed so that the Real and Imaginary components of LCCR and RCCR are related as:
• LCCR(Re) ~ RCCR(Re), and
• LCCR(Im) ~ RCCR(Im), and also,
• LCCR(Re) = k*RCCR(Re), and
• LCCR(Im) = k*RCCR(Im).</td></tr>
</table>

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End of Broadband Forum Technical Report TR-138