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TR-048

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ADSL Interoperability Test Plan

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Abstract:
Tests and requirements demonstrate interoperability of ADSL modems with various DSLAMs included in the reference model. The key items of loop reach, data handling performance, and electrical compatibility are tested to demonstrate compliance with deployment based requirements. This working text contains tests and requirements for North American and European deployment.

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1 Revision History

Table 1: Revision History

Date (M/D/Y)	Version	Major Changes	Editor(s)
3/15/01	1.0	Initial creation per agreement in Vancouver, B.C., based on contribution 2001.103	Steve Aspell, SBC Technology Resources, Inc. Ron Brost, SBC Technology Resources, Inc. Tom Starr, SBC Technology Resources, Inc. James Viator, Bell South Telecommunications Michael Brusca, Verizon Communications Ashley Pickering, BTexact Pete Youngberg, Sprint
4/13/01	2.0	Eliminated redundant DSLAM configuration information from Section 8, other editorial changes.	Ron Brost
5/4/01	3.0	Added one entry each to Tables 7.2.3 and 7.2.4; moved Sections 8.4 through 8.11 to new Section 10; eliminated redundant loop simulator setup information from former Section 8.4.1 Step 3 (now Section 10.1.1 Step 3); other editorial changes.	Steve Aspell and Ron Brost
6/7/01	4.0	Added reference to Section 6 of G.992.1 to Section 5.1; changed title of Section 10.2 to “Operation in the Presence of Impulse Noise Events (G.996.1, Test Impulse 1); added table of cluster descriptions and regional preferences.	Ron Brost
7/16/01	5.0	Deleted no noise tests from Section 7; added requirement to Section 7 to have multiple trials for loop tests; changed title of Section 7.2; major reorganization of Section 8, including the addition of Figures 3, 4, 5, and 6; added Test 10.2.2; deleted Test 10.8.2; added Method of Procedure language to Test 10.6.2; other misc. changes.	Ron Brost

7/27/01	6.0	Sectionalized existing Section 2, and added Scope sub-section; updated performance requirement numbers in Section 7.2.1; corrected downstream performance numbers in Section 7.4.2 that had been previously transposed; added paragraph to the beginning of Section 10.5 before tests; deleted Test 10.5.3 that had been in Ver. 5; changed tests 10.5.1 and 10.5.2 from Ver. 5 to tests 10.5.5 and 10.5.6; added new tests 10.5.1-10.5.4; added Figures 8 and 9; added test report template in Annex B	Steve Aspell and Ron Brost
9/12/01	7.0	Added line numbering; edited scope statement; removed requirement for testing noise margin in Section 7; changed requirement for performing Section 7 loop test multiple times (repeat failed tests instead of performing each test multiple times); divided Section 7.3 into North American and European sections; added tests in Section 7.6; edited DSLAM provisioning values in Section 8 so they apply to all of Section 8, instead of just Section 8.1; edited tests in Section 8.1; specified frame size of 1280 bytes in Test 8.2.5; edited QoS tests in Section 9; deleted existing Tests 9.1.6 and 9.1.7, and added new Tests 9.1.6 through 9.1.9; added details to test 9.2.1; edited Section 10.1; edited Test 10.2.2; added details to Test 10.6.2; deleted Section 10.8 (modem sync time); added table of attenuation values to Annex A; deleted Annex B (test report template); other misc. changes	Steve Aspell and Ron Brost
9/19/01	8.0	Rearranged document sections so that document is more clearly divided between physical layer and higher layer major sections	Steve Aspell and Ron Brost

12/17/01, 2/1/02, 2/11/02, 2/13/02, 2/14/04	8.5.5	Numerous changes based on straw ballot comments: added descriptions column to feature tables; edited figures to include high impedance baluns; changed “actual” to “reported” for tests in which noise margin is informational only; edited bridged tap test figure to indicate loop simulators; changed test requirements in bridged tap tests so that zero length tap requirements match requirements for regular loop tests; added noise margin columns in bridged tap test tables; edited tables in European Fixed Rte tests; edited bit swap test; edited DSL Noise Spike/Surge test; edited Impulse Noise Test; added ETSI loop reference in addition to CSA loop reference in numerous locations; added BERT testing options to several tests; edited margin verification test; edited throughput tests to indicate testing in one direction at a time; added figures 12-17; edited PPPoE and PPPoA tests; changed Annex A in its entirety; added Annex B; numerous editorial edits	Steve Aspell and Ron Brost
2/15/02	8.5.6	Edited Test 8.6.1; edited test in Section 8.9.1; changed Tests 8.10.1 and 8.10.2; added figure for 40 dB attenuator; edited Test 8.11.1; other minor edits	Ron Brost
2/26-28/02	9.0	Created new version in preparation for letter ballot submission. Edited language regarding test cells in Test 9.1.1; edited noise calibration procedures in Annex A; changed the diagram in Section 8.4, other minor edits there; added Fine Adjusted columns in Sections 8.1, 8.3, 8.4, and 8.5.2; edited figures 10, 11, and 12; other minor edits.	Ron Brost

2 Introduction

This document describes interoperability test cases required for ADSL reference systems consisting of DSLAMs and CPE modems.

2.1 Interoperability

A CPE modem and a DSLAM are dynamically interoperable if they implement a common and compatible set of features, functions and options and can demonstrate satisfactory mutual communication in a real network architecture environment as performance test conditions are varied and exercised. The term "compatible" is used to mean that there are no conflicting requirements that will prevent the ADSL system from achieving interoperability.

Systems are tested for Dynamic Interoperability on both standard loops and on a set of additional loops. ADSL Termination equipment (ATU-R and/or ATU-C) will be required to be tested according to the tests stated in this document. An interoperability statement with respect to this technical report is only applicable for ATU-R/ATU-C combinations that have been tested against each other using the tests specified in this document.

Throughout this document, the term “DSLAM” is understood to refer to the functionality of the ATU-C. The terms “CPE”, “CPE modem” and “modem” are understood to refer to the functionality of the ATU-R, unless stated otherwise. ATU-C functionality may be provided by DSLAM units or digital loop carrier based (DLC) remote terminal units.

2.2 Interpretation of Key Words

This document uses several words to signify the specification requirements. This section defines these words as they should be interpreted. The key words "must", "must not", "required", "shall", "shall not", "should", "should not", "recommended", "may", and "optional" in this document are to be interpreted as described below.

- *Must*: This word, or the terms "required" or "shall", mean that the definition is an absolute requirement of the specification.

- *Must Not*: This phrase, or the phrase "shall not", mean that the definition is an absolute prohibition of the specification.

- *Should*: This word, or the adjective "recommended", mean that there may exist valid reasons in particular circumstances to ignore a particular 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" mean 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", mean that an item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because the vendor feels that it enhances the product while another vendor may omit the same item. An implementation that does not include a particular option must be prepared to interoperate with another implementation which does include the option, though perhaps with reduced functionality. In the same vein, an implementation that does include a particular option must be prepared to interoperate with another implementation which does not include the option (except, of course, for the feature the option provides).

2.3 Scope

This test plan facilitates ADSL over POTS CPE / DSLAM interoperability testing. This test plan embodies operators' definitions of ADSL interoperability (between one DSLAM and one CPE at a time). The test plan focuses on physical layer testing, and also validation and verification of selected higher layer functionality. The test plan defines dynamic interoperability (performance) as expected by leading carriers, specifying simulated network conditions under which interoperability is required. The performance points in this test plan are based on ATU-C equipment, capable of providing 20.4 dBm transmit power over the frequency band from 25.875 kHz to 1104 kHz. ATU-C equipment unable to provide this transmit power is considered to be out of the scope of this interoperability test. The performance points may differ from the performance requirements of ANSI T1.413-1998 and ITU-T G.992.1. It does not fully replace all operators' pre-deployment testing.

This test plan defines tests for various physical layer functionalities and some higher layer functionalities. A pass/fail indication result is provided for each functionality tested.

3 Standards Referenced for Dynamic Interoperability Testing

ADSL reference systems will be tested to be interoperable according to the ANSI T1.413-1998 (Issue II) or ITU-T Annex A of G.992.1 (G.dmt) standards.

Some of the performance requirements specified herein exceed those of the previously mentioned standards. These higher requirements were provided by the service providers furnishing primary input to this document, and were agreed upon by those service providers.

4 Test Tools Requirements

- Loop simulator (see Annex A)
- 1 traffic simulator/analyzer with ATM and 10BASE-T capabilities
- ATM switch/router
- PC with USB/Ethernet interface
- Noise sources for both ends of the line (loop simulator integral noise sources or arbitrary waveform generators)

All these tools are part of configurations identified in figures 3, 4, 5 and 6. The ATM switch/router and PC used for throughput testing should have adequate performance such that they do not affect the measured throughput over the ADSL link. The ATM Switch or Simulator may be removed if traffic simulator/analyzer in use is capable of terminating the ATM traffic directly from the DSLAM.

5 Common Test Information

5.1 Maximum Rates for DSLAMs

Throughout this document, the variables MAX UP and MAX DN appear. When encountered, substitute for them the maximum possible net data rate (Section 6 of G.992.1) for the DSLAM being used in the test. The terms “variable rate” and “adaptive rate” are also used and should be taken as maximum possible net data rate.

5.2 Compatibility Matrix/Definitions

A modem must achieve at least the minimum required performance in each test to claim interoperability with the DSLAMs it is tested against. When a modem is tested against a set of DSLAMs, it must achieve the minimum required performance in each test against each DSLAM.

5.3 Regional Preferences

This document serves as an international framework for ADSL interoperability testing. Although there is a common understanding on interoperability needs, regional preferences occur due to different evolutions in telecommunication networks all over the world. The following matrix provides an overview of the requirements in specific regions of the world. This selection matrix should not prevent world-wide interoperability, but it should help to reduce the testing effort when a "device under test" is intended to be used only in one or in a few specific countries. Several clusters are introduced to address the specific regions:

Cluster A	Cluster A is intended to represent typical networks as they are present in the North American hemisphere.
Cluster B	Cluster B is intended to represent typical networks as they are present in the European hemisphere.

Note: None of the clusters above is restricted to networks of the given region. For networks outside the specific regions, a cluster can also apply. Furthermore, even networks in a given region can differ from the related cluster.

Requirement		Applies for Cluster A networks	Applies for Cluster B networks
7	Test Configurations	X	X
8	Physical Layer Test Cases		
8.1	Loop Tests with Ports Set for Adaptive Rate		
8.1.1	White Noise Impairment Only	X	X
8.1.2	24 HDSL Impairment	X	X
8.1.3	24 DSL (ISDN) Impairment	X	X
8.1.4	5T1 Adjacent Binder Impairment	X	X
8.2	Loop Tests with Ports Set For Fixed Rate		
8.2.1	North American Fixed Rate Tests	X	
8.2.2	European Fixed Rate Tests		X
8.3	Full Rate Standard Loop Tests		
8.3.1	CSA #4 Standard Loop	X	X
8.3.2	ANSI 13 Standard Loop	X	
8.4	Bridged Tap Tests	X	X
8.5	European Impairments		
8.5.1	European Impairments with Ports Set for Variable Rate		X
8.5.2	European Impairments with Ports Set for Fixed Rate		X
8.6	ADSL Functionality Tests	X	X
8.7	DSL Noise Spikes/Surges Tests	X	

Requirement		Applies for Cluster A networks	Applies for Cluster B networks
8.8	Operation in the Presence of Impulse Noise Events (G.996.1, Test Impulse 1)	X	
8.8.1	North American Impulse Noise Test	X	
8.9	Stress Tests	X	X
8.10	Electrical Compatibility Tests	X	X
8.11	Reporting of ADSL Line Conditions	X	X
9	Higher Layer Test Cases		
9.1	ATM Connectivity Tests	X	X
9.2	Layer 3 Ethernet or USB Interface RFC 2684 bridged mode		
9.2.1	Packet Throughput Test	X	X
9.2.2	Packet Latency Tests	X	X
9.3	PPPoE End-to-End Connectivity Test	X	X
9.4	PPPoA End-to-End Connectivity Test	X	X
9.5	RFC 2364 End-to-End Connectivity Test	X	X
9.6	Usability Test	X	X

5.4 Recording Temperature and Humidity

The ranges of temperature and humidity of the test facility over the entire time of all the tests herein shall be recorded in a manner similar to that shown here. The acceptable range of temperatures shall be between 15 °C/59 °F and 35 °C/95 °F. The humidity shall be between 5% and 85%.

Parameter	***High***	***Low***
Temperature		
Humidity		

5.5 Sync State Definition

The modem sync state shall be defined as achieving showtime and capable of transferring data.

6 Equipment Features

6.1 Equipment Description

Record the specifications claimed by the manufacturer of the reference system. All data rates requested are to be ‘net data rate’ as defined in or ITU-T Annex A of G.992.1 (G.dmt). The data recorded will be used in the test report to specifically define the combination of devices tested (ATU-C/ATU-R).

Table 2: DSLAM Features Table (Informative)

Test Item	*Results*
Make	
Model Number	
Network Interface	
DSLAM Firmware Version	
Chipset Hardware Version	
Chipset Firmware Version	
Line Card Type	
Line Card Version	
Line Card Firmware Version	
Supported max net data rate - downstream	
Supported max net data rate - upstream	
Maximum Number of VCCs	
F5 OAM Support	
VPI/VCI Ranges	

Table 3: CPE Features Tables (Informative)

CPE General Information

Test Item	*Results*	*Description*
CPE Make/Model/Rev.		*Product name / model / revision*
Serial Number		*CPE Serial number*
Software Version		*CPE SW version*
Chip Set Make/Model/Rev.		*Chipset name / model / revision*
Firmware Revision		*Firmware revision*
Modem Form		*Ethernet, USB, PCI, ATMF25*
PCI/USB Driver Version		*PCI/USB driver version*

ADSL Characteristics

Supported max net data rate - downstream		*DS maximum bitrate in kbps*
Supported max net data rate - upstream		*US maximum bitrate in kbps*
Rate Adaptation		*Adaptive and/or fixed rate*
Echo Cancellation		*Yes/No*
Power Boost/Cut		*Yes/No*
T1.413-1998 Mode		*Yes/No*
G.992.1 Annex A Mode		*Yes/No*
Fast Mode		*Yes/No*
Interleaved Mode		*Yes/No*
Dying Gasp		*Yes/No*
Test mode online quiet		*Yes/No*
Test mode continuously sending		*Yes/No*

ATM Characteristics

Maximum No. of VC's		*Maximum number of VC's*
VPI/VCI Ranges		*VPI/VCI ranges*
SVC		*Yes/No*
SAR		*PC or Modem*
Multicast Support		*Yes/No*
F4/F5 OAM Loopback		*Yes/No (OAM segment or end-to-end)*
UBR Supported		*Yes/No*
CBR Supported		*Yes/No*
VBR.rt Supported		*Yes/No*
VBR.nrt Supported		*Yes/No*
ILMI		*Yes/No*

Protocols

RFC 1483 or 2684 IP Bridging		*RFC 1483 or RFC 2684 or no*
RFC 1483 or 2684 IP Routing		*RFC 1483 or RFC 2684 or no*
Bridge Filter		*Yes/No*
LLC-SNAP		*Yes/No*
VC-MUX		*Yes/No*
DHCP Client		*Yes/No*
DHCP Server		*Yes/No*
NAT		*Yes/No*
PAT		*Yes/No*
RFC 2364 PPPoA		*Yes/No (precise Embedded or Host client)*
RFC 2516 PPPoE		*Yes/No (precise Embedded or Host client)*
PAP		*Yes/No*
CHAP		*Yes/No*
Classical IP RFC 1577		*Yes/No*
Max number of active connect.		*For router only*
Other supported protocols		

6.2 Expected Results

The *Results* columns of tables 2 and 3 shall be completed to indicate whether each feature is included with the DSLAM or CPE modem. The information to complete the tables shall be available with the equipment.

7 Test Configurations

Note for Figures 1 through 6: high-impedance couplings may be integrated in noise sources, and high impedance is defined as in G.996.1 Figure 3.

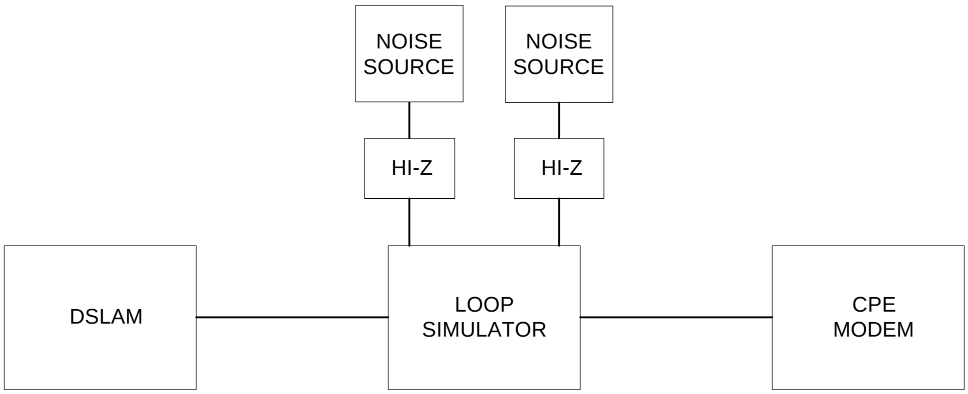


Figure 1: Test setup for loop tests for ADSL external modems

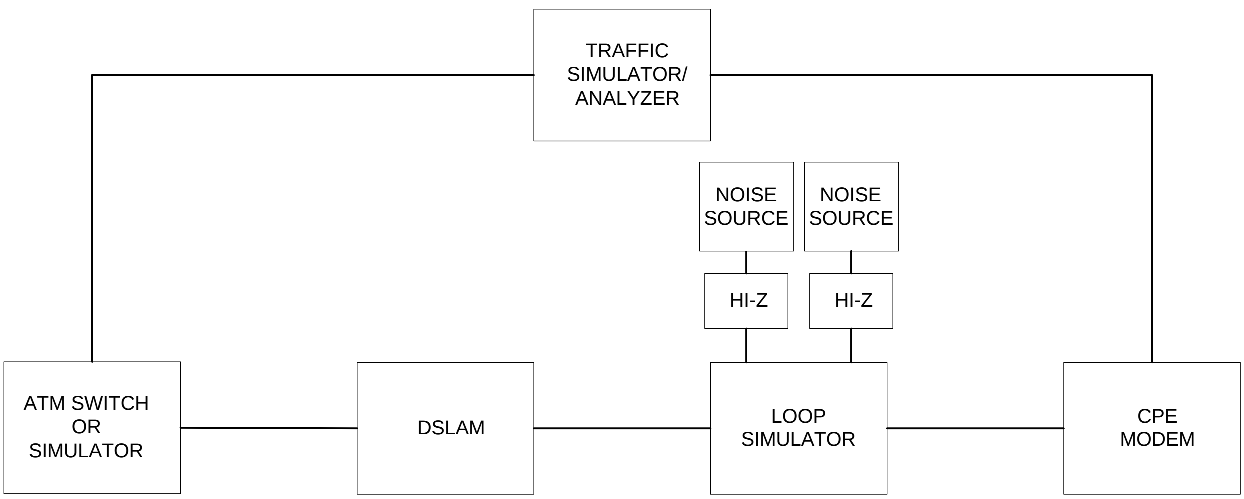


Figure 2: Test setup for throughput tests for ADSL external modems with Ethernet interfaces

Note for Figure 2: The ATM Switch or Simulator may be removed if traffic simulator/analyzer in use is capable of terminating the ATM traffic directly from the DSLAM.

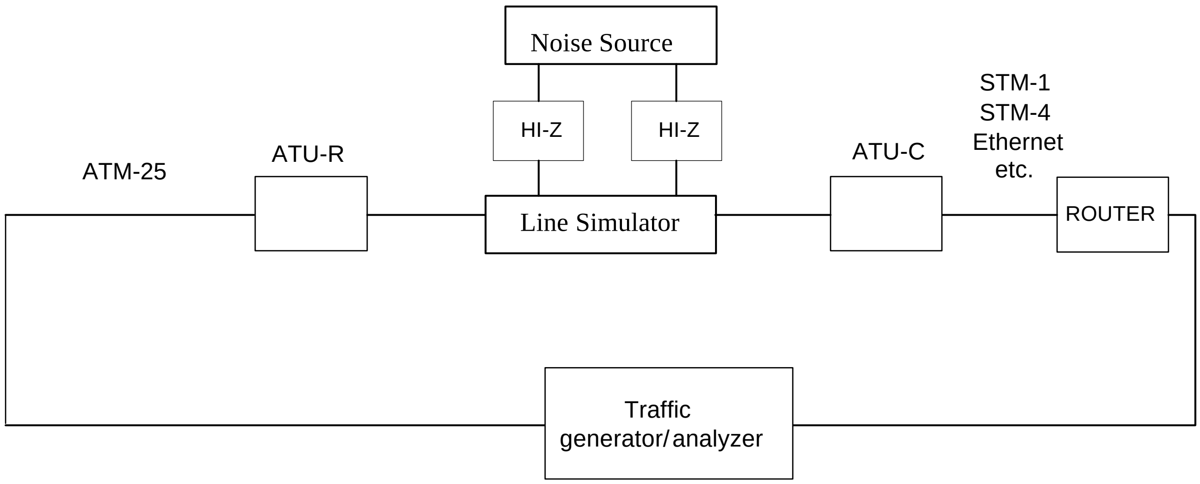


Figure 3: Test set-up for ATM-25 modems

Notes for Figure 3:
- Specify a single VCI/VPI.
- The router is optional

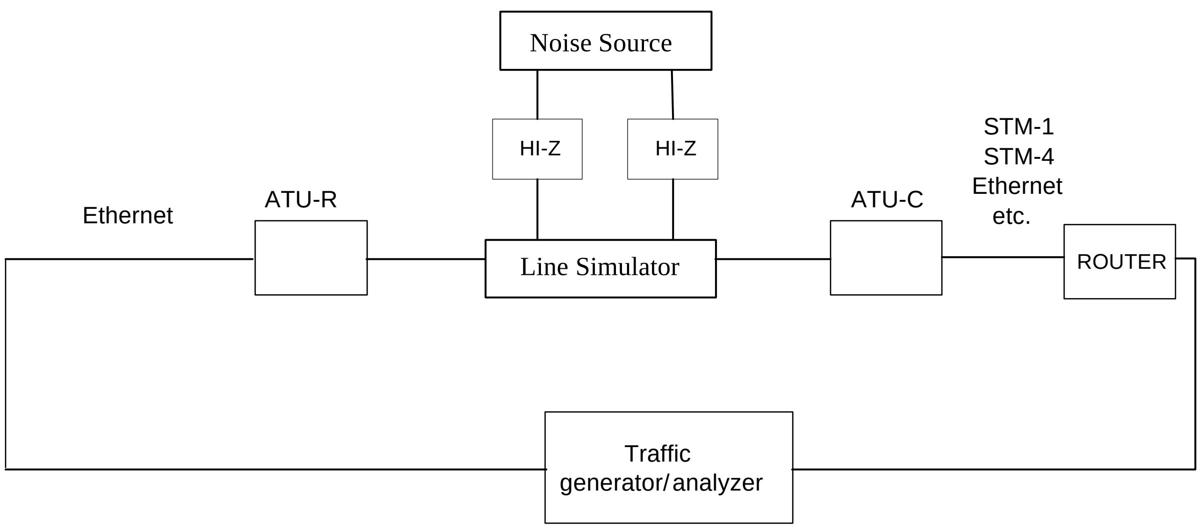


Figure 4: Test set-up for Ethernet modems

Note for Figure 4:
- The modem must be set to a bridged configuration.
- The router is optional

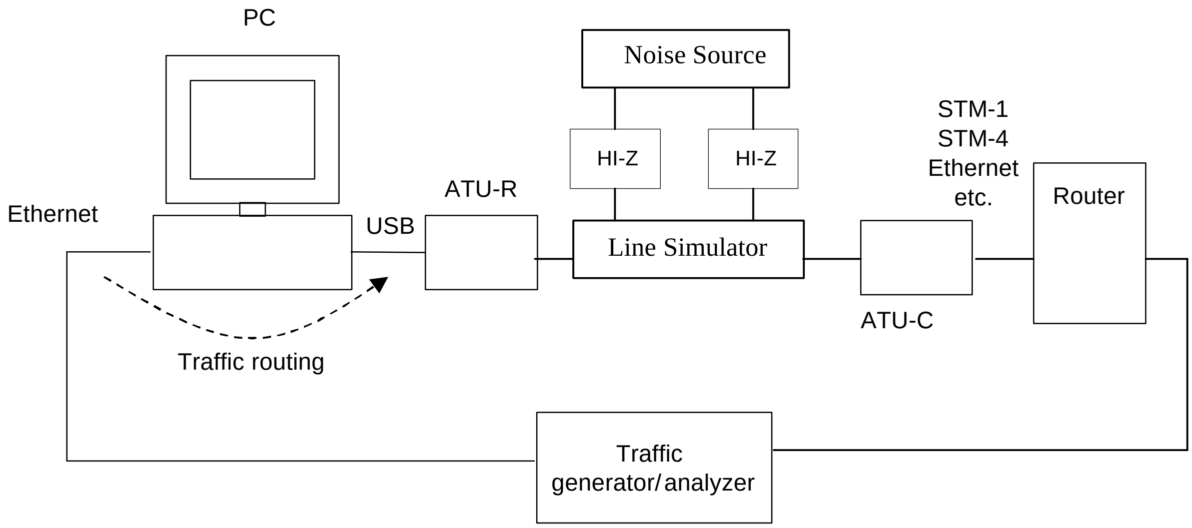


Figure 5: Test set-up for USB modems

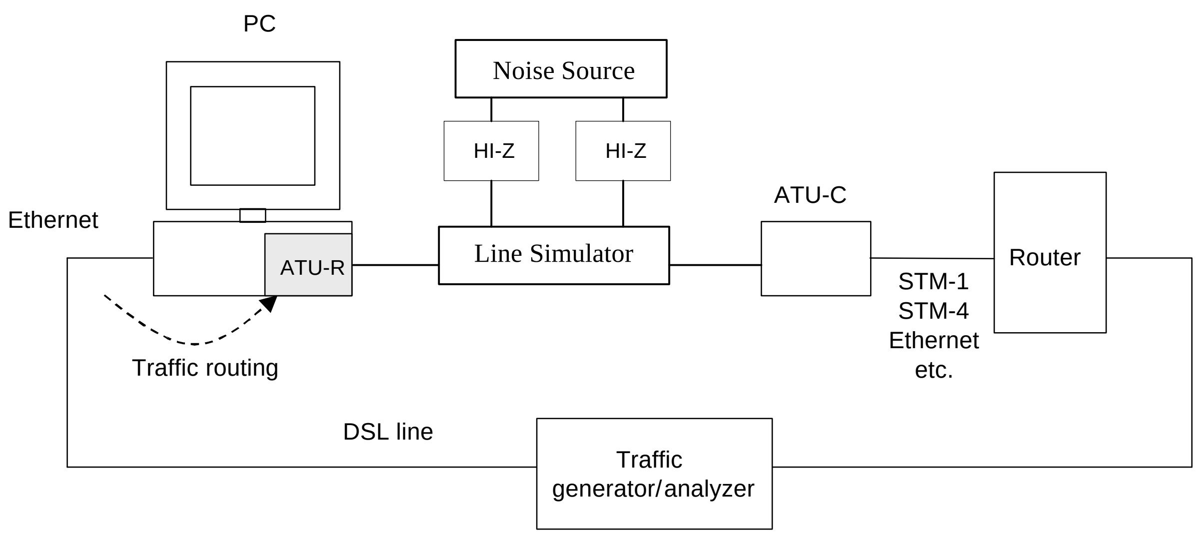


Figure 6: Test set-up for PCI (internal) modems

Notes for Figure 5 and Figure 6:

- The PC must have a separate Ethernet interface or Ethernet card installed.
- The Ethernet card and the corresponding port on the traffic generator/analyzer should be configured with IP addresses on the same network.
- The PC should be set-up to route traffic between the Ethernet interface and the USB interface (see below). Note that the PPP session through the modem needs to be initiated before this can be done, if PPP is to be used.
- With suitable choice of PC it is assumed that its effects on performance are negligible.
- The traffic generator/analyzer is used to measure end to end throughput, latency and packet loss in exactly the same way as for other modem types (*e.g.*, Ethernet).
- The PC setup examples below only apply to Windows PCs: (Note that the choice of PC impacts performance and that this impact should be restricted.)

- On the PC, enable IP routing by adding ***EnableRouting "1"*** to ***HKEY_local_machine\system\currentcontrolset\services\VxD\MSTCP*** of the Windows registry.
- Add a route on the PC to the traffic generator/analyzer port which is connected to the router by using ***route add <network address> mask <network mask> <ip address>*** from DOS.
- Add a static route on the router to the Ethernet port of the traffic generator/analyzer connected to the PC.

8 Physical Layer Test Cases

Loop simulators shall simulate cable characteristics specified in ITU-T Rec. G.996.1 for 70 degrees Fahrenheit. The loop simulators shall be calibrated relative to the nominal attenuation as defined in Annex A.1. Noise shall be injected through a high impedance network as specified in G.996.1, with simultaneous noise injection at both ends of the loop. The noise injection shall be calibrated as defined in Annex A.2. (Note: Although G.996.1 crosstalk models are intended for injection at a single end of the loop, noise in this document is injected on both ends simultaneously in order to reduce testing time. It is understood that noise levels on short loops can be up to 3 dB higher.)

DSLAM Port Settings Common to All Loop Tests:

- Variable rate (except sections 8.2 and 8.5.2)
- Autodetect between T1.413-1998 and G.dmt per G.992.1 Annex A
- Trellis code is allowed
- The target noise margin shall be set to 6 dB upstream and downstream
- Framing mode 3 is allowed
- Interleaved mode shall be tested with maximum interleave delay = 16 ms
- The minimum noise margin shall be set to 0 dB
- Rate adaptive mode shall be used unless a fixed rate is indicated
- No limitation of maximum noise margin (set at least to 30 dB)

The CO splitter used shall be the splitter integral to the DSLAM, if that option exists. Otherwise, an external CO splitter as specified in Annex E of G.992.1 shall be used.

USB modems and NIC modems will be connected via an Ethernet card in a computer that has the minimum configuration per the modem’s manufacturer.

ATM switch included for DSLAM termination and IP return traffic.

8.1 Loop Tests with Ports Set for Adaptive Rate

To obtain a result for each individual test, each test shall be performed once. Any test point that fails to meet the requirement by 96 kbps or less shall be re-tested 3 times. If a re-test is performed, then the maximum downstream value achieved during testing, along with the associated upstream rate, shall be recorded. If a circuit fails to sync within 60 seconds, a result of zero will be recorded into the result for that test point.

Note: passing criteria is sync rates, noise margins are for informational purposes. Noise margins shall be read one minute (or longer) after modem training.

Note: the fine data rate adjustment is added to the measured data rate and the total is compared with the expected data rate to determine whether the modem passes or fails the test.

8.1.1 White Noise Impairment Only

Apply white noise disturber at both ends of the total loop at –140 dBm/Hz.

80 individual tests – 72 tests must be passed

Loop Length (kft, 26 AWG)	Fast Mode									
	Upstream					Downstream				
	Sync Rate (kbps)				Noise Margin, Reported (dB)	Sync Rate (kbps)				Noise Margin, Reported (dB)
	Expected	Measured	Fine Adjustment	Pass/Fail		Expected	Measured	Fine Adjustment	Pass/Fail	
0	800					8000				
1	800					8000				
2	800					8000				
3	800					8000				
4	800					8000				
5	800					8000				
6	800					8000				
7	800					8000				
8	800					7360				
9	800					6432				
10	800					5408				
11	768					4224				
12	704					3200				
13	608					2336				
14	512					1696				
15	416					1184				
16	320					800				
17	256					512				
17.5	224					384				
18	160					288				

Loop Length (kft, 26 AWG)	Interleaved									
	Upstream					Downstream				
	Sync Rate (kbps)				Noise Margin, Reported (dB)	Sync Rate (kbps)				Noise Margin, Reported (dB)
	Expected	Measured	Fine Adjustment	Pass/Fail		Expected Actual	Measured	Fine Adjustment	Pass/Fail	
0	800					7616				
1	800					7616				
2	800					7616				
3	800					7616				
4	800					7616				
5	800					7616				
6	800					7616				
7	800					7616				
8	800					7360				
9	800					6528				
10	800					5408				
11	800					4256				
12	800					3488				
13	736					2592				
14	640					1824				
15	576					1408				
16	480					960				
17	384					608				
17.5	384					480				
18	352					416				

8.1.2 24 HDSL Impairment

Set noise generators for 24 HDSL impairment and white noise at –140 dBm/Hz, CO and CPE ends.
12 individual tests – 11 must be passed

Loop Length (kft, 26 AWG)	Fast Mode									
	Upstream					Downstream				
	Sync Rate (kbps)				Noise Margin, Reported (dB)	Sync Rate (kbps)				Noise Margin, Reported (dB)
	Expected	Measured	Fine Adjustment	Pass/Fail		Expected	Measured	Fine Adjustment	Pass/Fail	
0	800					8000				
3	800					8000				
6	672					8000				
9	416					5472				
12	160					1952				
13	96					1184				

8.1.3 24 DSL Impairment

Set noise generators for 24 DSL (ISDN) Impairment [DSL Impairment in G.996.1] and white noise at –140 dBm/Hz, CO and CPE ends.
14 individual tests – 13 must be passed

Loop Length (kft, 26 AWG)	Fast Mode									
	Upstream					Downstream				
	Sync Rate (kbps)				Noise Margin, Reported (dB)	Sync Rate (kbps)				Noise Margin, Reported (dB)
	Expected	Measured	Fine Adjustment	Pass/Fail		Expected	Measured	Fine Adjustment	Pass/Fail	
0	800					8000				
3	800					8000				
6	800					8000				
9	672					6272				
12	416					2880				
15	160					928				
16	64					576				

8.1.4 5 T1 Adjacent Binder Impairment

Set noise generators for 5 T1 adjacent binder impairment and white noise at –140 dBm/Hz, CO and CPE ends.

12 individual tests – 11 must be passed

Loop Length (kft, 26 AWG)	Fast Mode									
	Upstream					Downstream				
	Sync Rate (kbps)				Noise Margin, Reported (dB)	Sync Rate (kbps)				Noise Margin, Reported (dB)
	Expected	Measured	Fine Adjustment	Pass/Fail		Expected	Measured	Fine Adjustment	Pass/Fail	
0	800					8000				
3	800					8000				
6	800					5216				
9	800					1824				
12	736					608				
15	480					64				

8.2 Loop Tests with Ports Set For Fixed Rate

To obtain a result for each individual loop length, each test shall be run once. If a circuit syncs within 60 seconds, that is considered passing for that loop length. Noise margins shall be read one minute (or longer) after modem training.

Apply white noise disturber at both ends of the total loop at –140 dBm/Hz.

8.2.1 North American Fixed Rate Tests

256 kbps downstream, 128 kbps upstream

16 individual tests – 16 shall be passed

Loop Length (kft, 26 AWG)	Fast Mode			Interleaved Mode		
	Modem Trained (Y/N)?	Upstream Noise Margin, Reported (dB)	Downstream Noise Margin, Reported (dB)	Modem Trained (Y/N)?	Upstream Noise Margin, Reported (dB)	Downstream Noise Margin, Reported (dB)
0						
3						
6						
9						
12						
15						
17						
17.5						

8.2.2 European Fixed Rate Tests

576 kbps downstream, 128 kbps upstream

12 individual tests – 12 shall be passed

Loop Length (km, ETSI-1)	Fast Mode			Interleaved Mode		
	Modem Trained (Y/N)?	Upstream Noise Margin, Reported (dB)	Downstream Noise Margin, Reported (dB)	Modem Trained (Y/N)?	Upstream Noise Margin, Reported (dB)	Downstream Noise Margin, Reported (dB)
0						
0.9						
1.8						
2.7						
3.6						
4.5						

1536 kbps downstream, 384 kbps upstream

12 individual tests – 12 shall be passed

Loop Length (km, ETSI-1)	Fast Mode			Interleaved Mode		
	Modem Trained (Y/N)?	Upstream Noise Margin, Reported (dB)	Downstream Noise Margin, Reported (dB)	Modem Trained (Y/N)?	Upstream Noise Margin, Reported (dB)	Downstream Noise Margin, Reported (dB)
0						
0.9						
1.8						
2.7						
3.6						
4.2						

8.3 Full Rate Standard Loop Tests

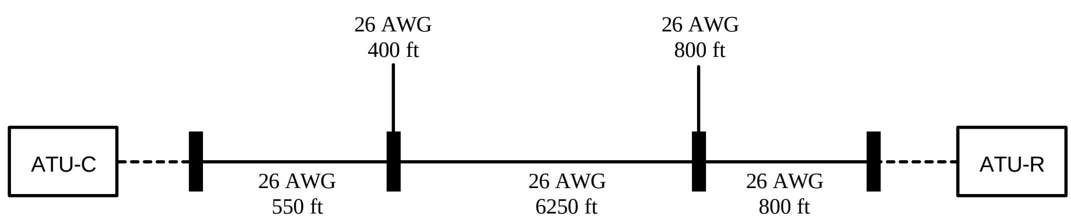
To obtain a result for each individual test, each test shall be performed once. Any test point that fails to meet the requirement by 96 kbps or less shall be re-tested 3 times. The maximum value of the re-tests shall be recorded. If a circuit fails to sync within 60 seconds, a result of zero will be recorded into the result for that trial. Noise margins shall be read one minute (or longer) after modem training.

Note: the fine data rate adjustment is added to the measured data rate and the total is compared with the expected data rate to determine whether the modem passes or fails the test.

Always apply white noise disturber at both ends of the total loop at –140 dBm/Hz.

8.3.1 CSA #4 Standard Loop

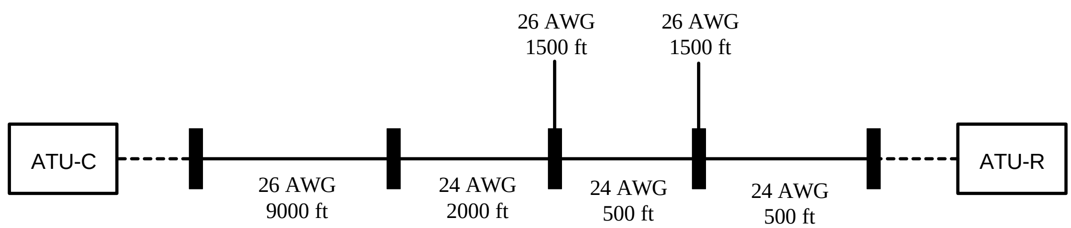
8 individual tests – 7 must be passed



Disturber Type	Fast Mode									
	Upstream					Downstream				
	Sync Rate (kbps)			Noise Margin, Reported (dB)	Pass /Fail	Sync Rate (kbps)			Noise Margin, Reported (dB)	Pass /Fail
	Expected	Measured	Fine Adjustment			Expected	Actual			
White Noise	800					7136				
24 HDSL	480					6080				
5 T1	800					1568				
24 DSL (ISDN)	736					6624				

8.3.2 ANSI 13 Standard Loop

8 individual tests- 7 must be passed



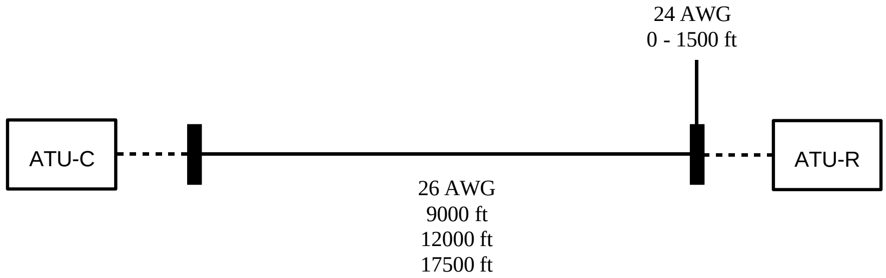
Disturber Type	Fast Mode									
	Upstream					Downstream				
	Sync Rate (kbps)			Noise Margin, Reported (dB)	Pass /Fail	Sync Rate (kbps)			Noise Margin, Reported (dB)	Pass /Fail
	Expected	Measured	Fine Adjustment			Expected	Measured	Fine Adjustment		
White Noise	608					2272				
24 HDSL	64					1376				
5 T1	576					288				
24 DSL (ISDN)	288					2240				

8.4 Bridged Tap Tests

To obtain a result for each individual test, each test shall be performed once. Any test point that fails to meet the requirement by 96 kbps or less shall be re-tested 3 times. The maximum value of the re-tests shall be recorded. If a circuit fails to sync within 60 seconds, a result of zero will be recorded into the result for that trial. Noise margins shall be read one minute (or longer) after modem training.

Apply white noise disturber at both ends of the total loop at –140 dBm/Hz.

48 individual tests – 43 must be passed



The simulated straight loop shall be 26 AWG. The simulated bridged tap shall be 24 AWG. The loop simulator(s) shall be calibrated relative to this nominal attenuation as defined in Annex A.1. The noise injection shall be calibrated as defined in Annex A.2.

Note: the fine data rate adjustment is added to the measured data rate and the total is compared with the expected data rate to determine whether the modem passes or fails the test.

- White noise disturber at both ends of the total loop, at –140 dBm/Hz
- Fast mode

9,000 Foot Loop

Tap Length (feet)	Upstream Sync Rates (kbps) Expected	Upstream Sync Rates (kbps) Measured	Upstream Sync Rates (kbps) Fine Adjustment	Upstream Noise Margin, Reported (dB)	Pass/ Fail	Downstream Sync Rates (kbps) Expected	Downstream Sync Rates (kbps) Measured	Downstream Sync Rates (kbps) Fine Adjustment	Downstream Noise Margin, Reported (dB)	Pass/ Fail
0	800					6432				
50	800					6272				
150	800					5152				
250	800					5216				
350	800					5376				
500	800					5600				
750	800					5760				
1000	800					5664				
1250	800					5664				
1500	800					5632				

12,000 Foot Loop

Tap Length (feet)	Upstream				Pass/ Fail	Downstream				Pass/ Fail
	Sync Rates (kbps)			Noise Margin, Reported (dB)		Sync Rates (kbps)			Noise Margin, Reported (dB)	
	Expected	Measured	Fine Adjustment			Expected	Measured	Fine Adjustment		
0	704					3200				
50	704					3168				
150	704					2752				
250	704					2080				
350	704					2112				
500	704					2336				
750	704					2464				
1000	672					2528				
1250	640					2528				
1500	640					2464				

17,500 Foot Loop

Tap Length (feet)	Upstream				Pass/ Fail	Downstream				Pass/ Fail
	Sync Rates (kbps)			Noise Margin, Reported (dB)		Sync Rates (kbps)			Noise Margin, Reported (dB)	
	Expected	Measured	Fine Adjustment			Expected	Measured	Fine Adjustment		
0	224					384				
50	224					352				
150	224					256				
200	224					224				

8.5 European Full Rate Tests

8.5.1 European Impairments with Ports Set for Variable Rate

To obtain a result for each individual test, each test shall be performed once. Any test point that fails to meet the requirement by 96 kbps or less shall be re-tested 3 times. The maximum value of the re-tests shall be recorded. If a circuit fails to sync within 60 seconds, a result of zero will be recorded into the result for that trial.
Note: passing criteria is sync rates, noise margins are for informational purposes. Noise margins shall be read one minute (or longer) after modem training.

Note: the fine data rate adjustment is added to the measured data rate and the total is compared with the expected data rate to determine whether the modem passes or fails the test.

- 6 dB target margin
- Fast and interleaved modes of operation
- Variable rate

14 individual tests – 14 must be passed

Loop (see G.996.1)	Loop Insertion Loss @ 300kHz	Nominal length ‘X’ (Km)	Down Net Data Rate (kbps)	Actual Down Net Data Rate (kbps)	Fine Adjusted Down Net Data Rate (kbps)	Reported Down Noise Margin (dB)	Pass/ Fail	Up Net Data Rate (kbps)	Actual Up Net Data Rate (kbps)	Fine Adjusted Up Net Data Rate (kbps)	Reported Up Noise Margin (dB)	Pass/ Fail	Noise @ ATU-C	Noise @ ATU-R
ETSI-0	0 dB	0	6144					640					AWGN @ -140 dBm/Hz	AWGN @ -140 dBm/Hz
ETSI-1	40 dB	2.80	4896					320					Euro-K	ETSI-A
ETSI-1	50 dB	3.50	2144					128					Euro-K	ETSI-A
ETSI-1	20 dB	1.40	6144					640					ETSI-B	ETSI-B
ETSI-1	30 dB	2.15	2048					512					ETSI-B	ETSI-B
ETSI-1	60 dB	4.20	576					128					ETSI-A	ETSI-A
ETSI-1	60 dB	4.20	1536					512					AWGN @ -140 dBm/Hz	AWGN @ -140 dBm/Hz

8.5.2 European Impairments with Ports Set for Fixed Rate

- 6 dB target margin
- Fast and interleaved modes of operation
- Fixed rate

Method of procedure

1. Provision the DSLAM with ports set for fixed rate at the downstream and upstream bit rates as specified.
2. Set up ETSI-1 loop simulator at the loop length as indicated in the table and inject the noise simultaneously at both ends of the loop.
3. Let the CPE train.
4. Check upstream and downstream noise margins and document them.

The passing criteria is that for the defined loop length and the required data rate specified in the tables, there is a minimum of 6 dB noise margin both for the downstream and upstream channel.

Note that the loop definitions (insertion loss @ 300 kHz and loop length) are equivalent and either may be used.
10 individual tests – 10 must be passed

Loop (see G.996.1)	Loop Under Test		Noise Margin					Fixed Down Net Data Rate (kbps)	Fixed Up Net Data Rate (kbps)	Noise @ ATU-C	Noise @ ATU-R
	Insertion Loss @ 300 kHz	Loop Length (km)	Minimum	Fast Mode		Interleaved Mode					
				Reported (DS/US)	Pass/Fail	Reported (DS/US)	Pass/Fail				
ETSI-1	40 dB	2.80	6 dB					4896	320	Euro-K	ETSI-A
ETSI-1	50 dB	3.50	6 dB					2144	128	Euro-K	ETSI-A
ETSI-1	20 dB	1.40	6 dB					6144	640	ETSI-B	ETSI-B
ETSI-1	30 dB	2.15	6 dB					2048	512	ETSI-B	ETSI-B
ETSI-1	60 dB	4.20	6 dB					576	128	ETSI-A	ETSI-A

8.6 ADSL Functionality Tests

5 individual tests – 5 must be passed

Test 8.6.1	Bit Swap Test
Test Configuration	1. See Figure 2 2. Configure the DSLAM for rate adaptive fast channel mode of operation with the maximum downstream net data rate limited to 6432kbits/s and the maximum upstream net data rate limited to 800kbits/s, using a target noise margin of 6dB. These are the minimum compliance limits specified for Section 8.1.1. 3. Connect ATU-R and ATU-C with a stable connection at 9000ft 26AWG or 2.7km ETSI-1 with –140dBm/Hz AWGN noise added at both the ATU-C and ATU-R ends. 4. All single frequency tone amplitudes that are applied are referenced in terms of power levels (dBm) at the injection point on the loop, calibrated with the ATU-R and ATU-C modems replaced with calibrated 100 Ohm ±1% resistors. Measurements performed into a 1kHz resolution bandwidth. Note that with a 1kHz resolution bandwidth the power spectral density value will be 30dB (in dBm/Hz) less than the power level (in dBm), limited by the noise floor of the test equipment used for calibration. 5. To allow the tone power to be negligible during ADSL synchronization the source should be able to provide –110dBm power in the interferer tone with low background noise in the region 25.875kHz to 2208kHz. Some arbitrary waveform generators may provide too much power at minimum settings (spectrum and vector analyzers are alternatives).

Method of Procedure	1. Randomly select a value, *n*, in the range 70-100, ensuring that the tone selected has assigned bits as described in the downstream bits per tone map. Avoid use of the pilot tone #64 or any unpopulated tones. 2. Record and report the value of *n* used. 3. Connect ATU-R and ATU-C as per test configuration details with the tone disturber *n* selected in step 1 applied at the ATU-R and set to –110dBm. 4. Activate management port to record the downstream bits per tone map. 5. Increase the tone power to –75dBm power and repeat step 3. Observe any downstream bit swap operation without retraining of the modems or change in the downstream net data rate. 6. Continue to increase the tone power in 5dBm steps until downstream bit swap operation or retrain of the modems occurs. Record this tone power value in the report. 7. Randomly select a value, *n*, in the range 10 - 20, ensuring that the tone *n* has assigned bits as described in the upstream bits per tone map. Avoid use of the pilot tone #16 or any unpopulated tones. 8. Record and report the value of *n* used. 9. Connect ATU-R and ATU-C as per test configuration details with the tone disturber *n* selected in step 7 applied at the ATU-C and set to –110dBm. 10. Activate management port to record the upstream bits per tone map. 11. Increase the tone power to –75dBm power and repeat step 3. Observe any upstream bit swap operation without retraining of the modems or change in the upstream net data rate. 12. Continue to increase the tone power in 5dBm steps until upstream bit swap operation or retrain of the modems occurs. Record this value in the report.
Expected Result	The bit swap protocol re-deploys the allocation of bits among the sub-carriers with no retrain of the modems or change in the net data rates.

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Test 8.6.2	**Check ADSL Diagnostic Tools**
Test Configuration	See Figure 1
Method of Procedure	Use the software supplied by the ATU-R vendor to see operational parameters of the ATU-R, or use a web browser, whichever is recommended by the vendor.
Expected Result	The following can be seen by one of these methods: upstream train rate, downstream train rate, upstream noise margin, downstream noise margin, upstream cell rate, downstream cell rate. The results reported from the ATU-C shall match the results reported from the ATU-R. Tools will be used to the extent available.

Test 8.6.3	**Dying gasp**
Test Configuration	See Figure 1
Method of Procedure	Establish an ADSL circuit between the DSLAM and the ATU-R, and then remove the input power from the ATU-R by disconnecting AC (or USB cable for a bus powered USB modem) from the ATU-R. This condition will simulate a power outage.
Expected Result	The ATU-R sends a Dying Gasp indication to the DSLAM.

Test 8.6.4	**Modular connector pins**
Test Configuration	See Figure 1
Method of Procedure	Verify that ADSL signal is connected to pins 3 and 4 of RJ-14 connector.
Expected Result	ATU-R is connected via pins 3 and 4.

Test 8.6.5	**Ethernet Connector Pinout**
Test Configuration	See Figure 1
Method of Procedure	Verify Ethernet connector pinout is such that a straight through cable is used between computer and modem.
Expected Result	ATU-R Ethernet port is configured for straight through connection to the computer.

8.7 DSL Noise Spikes/Surges Tests

The purpose of these tests is to verify that xDSL functionality is not impacted by sudden spikes or surges of noise on the line. The errors recorded shall be the sum of upstream and downstream errors. Both the ATU-R and ATU-C will be stressed during this test.

8.7.1 Test Configuration

The test configuration shall be as shown in figures 3 to 6 in Section 7.

8.7.2 Test Description

- Train at MAX DN/MAX UP down/up in fast mode
- Set up the loop simulators for a MID-CSA #6 loop (26 AWG at 6000 feet, ETSI equivalent 1800 m)

1) As this is a physical layer test, the CPE can be set up for RFC 1483[2] bridging/routing, or

[2] RFC 1483 has been obsoleted by RFC 2684.

PPP bridging/routing.

2) Set CO side impairments to:
   - –75.0 dBm HDSL NEXT with the total power in the frequency range of 0 to 1.544 MHz, and –140.0 dBm/Hz white noise
   - Continuously running
3) Allow the CPE and DSLAM to train.
4) Do a "clear counters" command on the DSLAM, if available.
5) Note the margins on both ends of the connection.
6) Verify there are no CRC errors.
7) Verify that traffic is being transmitted and received by the traffic generator/analyzer.
8) Set CPE side impairments to 24 HDSL NEXT with the total power in the frequency range of 0 to 1.544 MHz, and –90.0 dBm/Hz white noise.
9) Turn on the CPE side impairments for one second.
10) After 1 second, observe whether the traffic sent by the traffic generator/analyzer is received by the traffic generator/analyzer. If traffic stops, wait adequate time to determine if the traffic resumes.
11) Verify that the traffic is received by the traffic generator/analyzer once noise is backed off. Note that it is expected that during the noise surge there may be a short interruption of the data stream.
12) Also verify that no other abnormal conditions appear on the line; *e.g.*, rise in error ratios, rise in CRCs.
13) Repeat steps 9 – 12 and add one second of time to the noise surge per session.
14) Perform these steps until you reach 10 seconds or the CPE retrains. When the CPE retrains, verify that traffic resumes as normal, traffic should resume within 60 s.

8.7.3 Results

10 individual tests – 10 must be passed (recovery or retrain after noise condition)

Trial	**Seconds per Noise Spike**	**Downstream Margin Before Noise Applied**	**Upstream Margin Before Noise Applied**	**Downstream Margin After Noise Applied**	**Upstream Margin After Noise Applied**	**Corrected Superframes**	**Uncorrected Superframes**	**ES Events**	**Traffic Resumed?**	**CPE Retrain?**
1	1									
2	2									
3	3									
4	4									
5	5									
6	6									
7	7									
8	8									
9	9									
10	10									

8.7.4 Expected Results

Despite how many spikes or surges of noise to hit the DSL line, the line shall always recover gracefully, or retrain if conditions deteriorate sufficiently. Neither the ability to train nor the ability to pass traffic at any OSI layer shall be impacted by a single spike/surge or multiple spike/surges. Errors shall be counted during and after noise is applied. Only record errors in the case of no retrain.

375 8.8 Operation in the Presence of Impulse Noise Events (G.996.1, Test Impulse 1)

Test 8.8.1	**Impulse noise test for North America loops**
Test Configuration	This test is a standard based on G.992.1 Section F.2.2 and G.996.1 Section 5.1.3.1 using CSA Loop #6. 1. Connect the CPE to the DSLAM through a loop simulator. Set the loop simulator to CSA Loop #6 (9000 feet of 26 AWG wire) or ETSI-1 loop (2700 meters of 0.4 mm wire). 2. Set the upstream and downstream target margins to 6 dB. Train the ADSL system to MAX UP and MAX DN, with interleaved operation. Bit Error Rate Testing (BERT) may be done with any of these possible solutions, with the recommendation that testing be accurate: • ATM test equipment. • Using HEC or CRC error counts to calculate the approximate BER. • Internal BER capabilities available within some products. • Any other software or hardware capable of testing bit error rate.
Method of Procedure	1. Inject a 20 HDSL disturber and –140 dBm/Hz white noise disturber at the CO end of the loop. 2. Train the modems in fast mode. 3. Lower the 20 HDSL disturber from the reference level by 4 dBm. 4. Inject 15 ADSL c1 impulses (defined in G.996.1) spaced at least 1 second apart into the circuit at the CO end of the loop simulator. Repeat, varying the amplitude, until about half of the impulses cause errored seconds. 5. Note the amplitude in millivolts at which half of the impulses caused errors. 6. Where a DSLAM imposes minimum counter periods (for example 15 minutes) then the application of impulses should be maintained at least 1 second apart, but the test can be performed for longer, applying more than 15 impulses. For half the applied pulses to cause an error apply the limit: 0.5 X number of impulses +/- 5%. 7. Repeat steps 4 through 6 using ADSL c2 impulses. 8. Calculate the probability that a second will be errored using the formula in G.996.1. 9. Repeat steps 1 through 8, injecting the 20 HDSL disturber, white noise, and impulses at the customer end of the loop.
Expected Result	The probability of errored seconds (ES) shall be less than 0.14% for tests at both ends of the loop.

376 8.9 Stress Tests

377 The purpose of this test is to try and force instability and/or failure to the CPE/Drivers in a non-destructive test.

8.9.1 Test Description

- Configure to train in Rate Adaptive at Startup mode at Maximum Rate down/up.
- Set up the loop simulators for a 26 AWG at 12000 feet or ETSI-1 loop (0.4 mm at 3.6 km).
- Inject –140 dBm/Hz white noise disturber at both ends of the loop.
- Train the CPE in fast mode at 6 dB noise margin.
- Increase the noise level by 6 dB.
- Configure the traffic generator/analyzer to provide MAC frames as a payload source for the duration of the test. The engineer will need to adjust the rate of the MAC frames to an acceptable level such that dropped frames due to LAN-based collisions or otherwise are negligible. Record these rates and the MAC frame size used for the test (suggested default 1024 bytes including FCS).
- Run one over night BER test (8 hour minimum).

Bit Error Rate Testing (BERT) may be done with any of these possible solutions, with the recommendation that the test be accurate:

- ATM test equipment.
- Using HEC or CRC error counts to calculate the approximate BER.
- Internal BER capabilities available within some products.
- Any other software or hardware capable of testing bit error rate.

The test setup is identical to the setup in Section 8.1.1 for testing Fast Mode Maximum Rate down/up over 12 kft 26 AWG. On this loop, the modems are expected to train without excess margin. The injected noise level is increased with 6 dB, followed by a BER measurement over a measurement period of minimum 8 hours.

Expected Results

1 individual test – 1 must be passed

The BER shall be less than 10^{-7} for the entire test. This test is Pass/Fail only.

8.10 Electrical Compatibility Tests

4 individual tests – 4 must be passed

To perform the tests described in this section, two test modes should be available in the device under test:

- Test Mode “continuously sending:” In this test mode, the device under test shall continuously generate signals at it maximum power and maximum spectrum without being connected to a counterpart modem. The modem shall send a pseudo-random data sequence of 2^{15}-1 or higher.
- Test mode “online quiet:” In this test mode, the device under test shall be in a condition where the line interface is powered up, but not transmitting and signal (= inactive, driving 0 V).

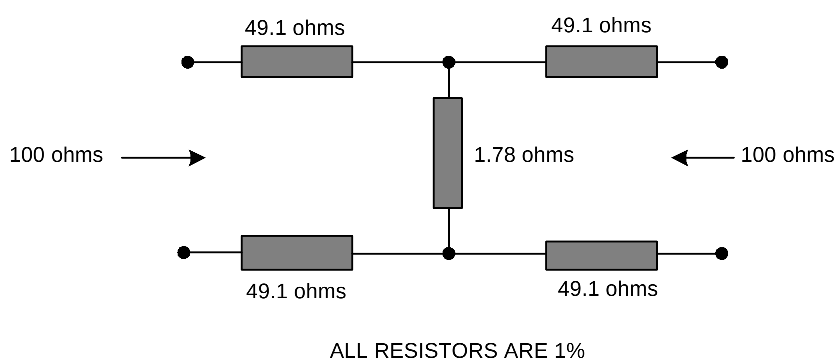

Figure 7: 40 dB attenuator for tests 8.10.1 and 8.10.2

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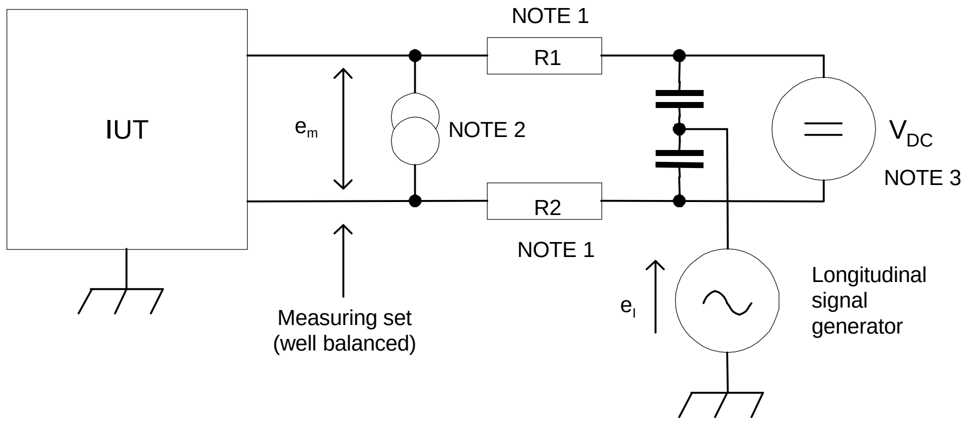
Test 8.10.1	**Analog Front End Power**
Test Configuration	DSLAM connected to CPE through a 40 dB flat attenuator, with 100 Ohms impedance towards DSLAM and CPE.
Method of Procedure	1. Connect Modem to test setup. 2. Configure Modem for Maximum Data Rate down/up. 3. Train modem. 4. Measure the total power generated into 100 Ohms over the signal passband defined in G.992.1, averaged over a measurement period of at least 2 seconds.
Expected Result	Analog Front End Power within the limits specified in Annex A of ITU-T G.992.1.

419

Test 8.10.2	**PSD Measurements**
Test Configuration	DSLAM connected to CPE through a 40 dB flat attenuator, with 100 Ohms impedance towards DSLAM and CPE.
Method of Procedure	1. Connect Modem to test setup. 2. Configure Modem for Maximum Data Rate down/up. 3. Train modem. 4. Measure the PSD generated into 100 Ohms over the signal passband defined in G.992.1, averaged over a measurement period of at least 2 seconds.
Expected Result	Power Spectral Density within the limits defined in Annex A of ITU-T G.992.1.

420

Test 8.10.3	**Longitudinal Balance – LCL**
Test Configuration	See Figure 8
Method of Procedure	1. Set up test according to Figure 8. 2. Activate test mode “online quiet.” 3. Measure Longitudinal Conversion Loss as specified in G.117 in the frequency range specified in G.992.1.
Expected Result	Balance ≥ 40 dB between 25 kHz and 1104 kHz.



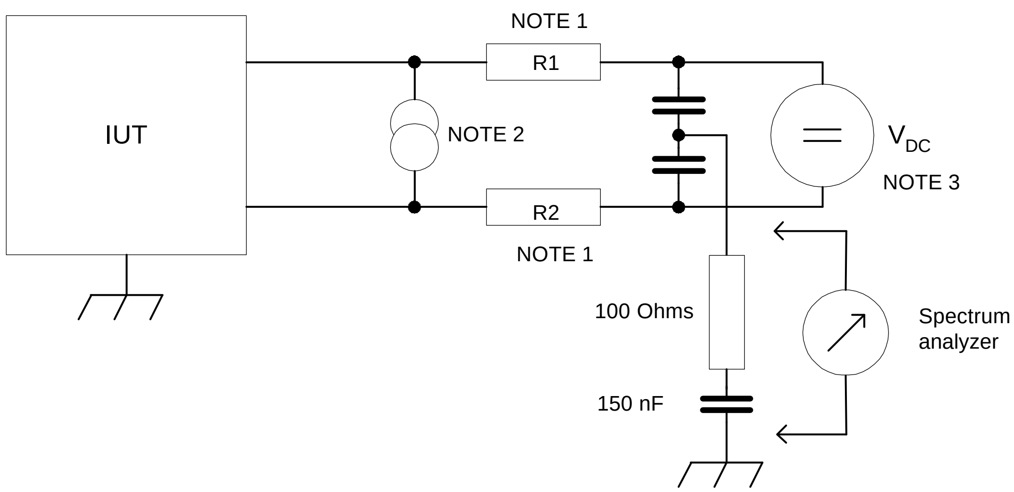
NOTE 1: These resistors have to be matched: R1=R2=100/2 Ω and R1/R2=1 +/-0.1%.
NOTE 2: For LTU test only if remote power feeding is supplied.
NOTE 3: For NTU test only if remote power feeding is required.
NOTE 4: During regenerator test (where required) each wire on the side which is not under test has to be connected to ground by a terminating impedance having the value of 100/2 Ω in series with a capacitance of 0.33 µF.

Figure 8: Measurement Method for Longitudinal Conversion Loss (Sample Setup)

The longitudinal conversion loss is given by: LCL = 20 log (el/em) [dB]:

- Where el is the applied longitudinal voltage referenced to the building ground and
- em is the resultant metallic voltage appearing across the line interface of the device under test (terminated by 100 Ω).

Test 8.10.4	**Longitudinal Balance – LOV**
Test Configuration	See Figure 9
Method of Procedure	1. Set up test according to Figure 9. 2. Activate test mode “continuously sending.” 3. Measure Longitudinal Output Voltage as specified in G.117.
Expected Result	The observed LOV shall have an rms voltage of below –46 dBV, measured in a power bandwidth of **10 kHz**, centered over any frequency in the range from **5.1 kHz** to $\mathbf{f_{max}}$, and averaged in any one second period. Compliance with this limitation is required with a longitudinal terminating impedance having value $Z_L(\omega) = R_L+1/(j\omega x C_L)$. Fmax = 415 kHz for CPE test (upstream) Fmax = 1825 kHz for CO test (downstream) R_L = 100 Ohms C_L= 150 nF



NOTE 1: These resistors have to be matched: $R1=R2=R_T/2$ and R1/R2=1 +/-0.1%.
NOTE 2: For LTU test only if remote power feeding is supplied.
NOTE 3: For NTU test only if remote power feeding is required DC blocking capacitors=C_B.

Figure 9: Measurement Method for Longitudinal Output Voltage (LOV)

8.11 Reporting of ADSL Line Conditions

1 individual test – 1must be passed

Test 8.11.1	**Margin Verification for CPE**
Test Configuration	To ensure vendors do not optimize for some specific test loops, the test engineer will randomly select one individual test from Category I, and will also perform the test in Category II. Category I: 1. Section 8.1.2 (HDSL): Any length with Expected Downstream Rate between 900 and 7000 kbps 2. Section 8.1.3 (DSL (ISDN)): Any length with Expected Downstream Rate between 900 and 7000 kbps 3. Section 8.1.4 (T1adj): Any length with Expected Downstream Rate between 900 and 7000 kbps Category II: 1. Section 8.4 (Bridged tap): Any length with Expected Downstream Rate between 900 and 7000 kbps with tap length of at least 250 feet Bit Error Rate Testing (BERT) may be done with any of these possible solutions. However, the test engineer shall calculate the measured BER back to bit-pipe BER as this is used in the pass/fail criterion. The test engineer shall take the extra measurement errors into account for the pass/fail decision. It is recommended that the testing be accurate. • ATM test equipment. • Using HEC error counts, CRC error counts or Idle Cell Payload error counts to calculate the approximate BER. These error counters are defined in ITU-T G.997.1. • Internal BER capabilities available within some products. • Any other software or hardware capable of testing bit error rate.
Method of Procedure	1. Configure CPE and DSLAM as for Section 8.1 tests and in Fast mode. 2. Connect CPE and DSLAM to first test loop option, with the noise injected at the appropriate reference power level. This power level is considered the 0 dB margin level for that type of noise. 3. Force a new initialization and wait for modems to sync as for Section 8.1 tests. 4. Wait 3 minutes after initialization for bitswaps to settle. 5. Check reported margin and document. 6. Increase the noise power level by 1 dB on the CPE side only. 7. Wait 1 minute. 8. Repeat steps 6 and 7 until the noise power is increased by target_margin – 1dB. 9. At this point the power level of the noise is at the target_margin – 1 dB level. 10. Execute a BER test for 45 minutes. Document the

	measured BER. 11. Repeat steps 2 to 10 for the second, third and fourth test loop. If the measured BER result falls in the interval 1.5E-7 < BER < 5E-7 for a specific loop option, that BER test (steps 4 to 10) shall be repeated a single time for that loop option. In order for the BER result to be valid, the modems should not have re-initialized during steps 4 to 10. If a re-initialization has occurred, the test for that loop option shall be repeated once.
Expected Result	Reported Margin: The CPE modem passes the reported margin criteria, if for all 4 test loops: target margin + 3dB >= downstream reported margin >= target margin – 1dB Note: The 3 dB upper tolerance assumes a "good" implementation of the Rate Negotiation at ATU-C side. Measured Margin: The CPE modem passes the measured margin criteria, if for all 4 test loops: BER measured < 1.5E-7 (Note: This corresponds with a modem actual margin >= tested margin = target margin – 1 dB) The CPE modem passes the margin verification test if both the reported margin criteria and the measured margin criteria are passed.

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Test 8.11.2	Margin Verification for DSLAM (optional)
Test Configuration	To ensure vendors do not optimize for some specific test loops, the test engineer will randomly select one individual test from Category I, and will also perform the test in Category II. Category I: 1. Section 8.1.2 (HDSL): Any length with Expected Upstream Rate between 96 and 608 kbps 2. Section 8.1.3 (DSL (ISDN)): Any length with Expected Upstream Rate between 96 and 608 kbps Category II: 1. Section 8.4 (Bridged tap): Any length with Expected Upstream Rate between 96 and 608 kbps with tap length of at least 250 feet Bit Error Rate Testing (BERT) may be done with any of these possible solutions. However, the test engineer shall calculate the measured BER back to bit-pipe BER as this is used in the pass/fail criterion. The test engineer shall take the extra measurement errors into account for the pass/fail decision. It is recommended that the testing be accurate. • ATM test equipment. • Using HEC error counts, CRC error counts or Idle Cell Payload error counts to calculate the approximate BER. These error counters are defined in ITU-T G.997.1. • Internal BER capabilities available within some products. • Any other software or hardware capable of testing bit error rate.
Method of Procedure	1. Configure CPE and DSLAM as for Section 8.1 tests and in Fast mode. 2. Connect CPE and DSLAM to first test loop option, with the noise injected at the appropriate reference power level. This power level is considered the 0 dB margin level for that type of noise. 3. Force a new initialization and wait for modems to sync as for Section 8.1 tests. 4. Wait 3 minutes after initialization for bitswaps to settle. 5. Check reported margin and document. 6. Increase the noise power level by 1 dB on the DSLAM side only. 7. Wait 1 minute. 8. Repeat steps 6 and 7 until the noise power is increased by target_margin – 2dB. 9. At this point the power level of the noise is at the target_margin – 2 dB level. 10. Execute a BER test for 110 minutes. Document the measured BER. 11. Repeat steps 2 to 10 for the second, third and fourth test loop.

	If the measured BER result falls in the interval 1.5E-7 < BER < 5E-7 for a specific loop option, that BER test (steps 4 to 10) shall be repeated a single time for that loop option. In order for the BER result to be valid, the modems should not have re-initialized during steps 4 to 10. If a re-initialization has occurred, the test for that loop option shall be repeated once.
Expected Result	Reported Margin: The CO modem passes the reported margin criteria, if for all 4 test loops: target margin + 2 dB >= upstream reported margin >= target margin – 2dB Measured Margin The CO modem passes the measured margin criteria, if for all 4 test loops: BER measured < 1.5E-7 (Note: This corresponds with a modem actual margin >= tested margin = target margin – 2 dB) The CO modem passes the margin verification test if both the reported margin criteria and the measured margin criteria are passed.

9 Higher Layer Test Cases

9.1 ATM Connectivity Tests

Test configuration is not specified; any configuration suitable for ATM testing may be used.

9 individual tests – 8 must be passed (all except Test 9.1.5)

Test 9.1.1	**Loopback at ATU-R**
Test Configuration	• See Figure 2 • The ATM switch or simulator may be removed if traffic simulator/analyzer in use is capable of terminating the ATM traffic directly from the DSLAM
Method of Procedure	Set up a bi-directional connection on a known VPI/VCI, *e.g.,* VP=0 and VC=35. The ATU-R shall loopback this VPI/VCI on the ATM level. The ATM Cells from generator/analyzer (bit error rate tester or BERT) are filled with a S-PRBS9 or O.191 test cell sequence, or a RFC 2544-formatted frame sequence. The downstream channel is loaded up to the capacity of the upstream channel using flat rate distribution (*i.e.,* constant bit rate, CBR, with cell rate matched to the physical data rate).
Expected Result	The ATU-R is looped back, BER is less than 10^{-7} when using S-PRBS9, or CER is less than $3.84e^{-5}$ if using either O.191 test cells or the RFC 2544 test methodology.

Test 9.1.2	**Maximum number of VC’s**
Test Configuration	• See Figure 1 • The ATM switch or simulator may be removed if traffic simulator/analyzer in use is capable of terminating the ATM traffic directly from the DSLAM
Method of Procedure	Cross connect VC’s between the ATU-R and the ATU-C until 16 VC’s are successfully configured or until the system will not accept any more, whatever is less.
Expected Result	Maximum number of VC’s is the same as that published in the ATU-R, or DSLAM documentation, or 16, whichever is less (for a DSLAM, the maximum number of VC’s is considered to be the maximum number per port).

Test 9.1.3	**Maximum VPI/VCI Range**
Test Configuration	• See Figure 1 • The ATM switch or simulator may be removed if traffic simulator/analyzer in use is capable of terminating the ATM traffic directly from the DSLAM
Method of Procedure	Configure VPI/VCI just within the published range, and just outside the published range.
Expected Result	Capability to choose VPI/VCI falls within published range for the DSLAM or the ATU-R modem, whichever is more restrictive.

Test 9.1.4	**Default VPI/VCI**
Test Configuration	• See Figure 2 • The ATM switch or simulator may be removed if traffic simulator/analyzer in use is capable of terminating the ATM traffic directly from the DSLAM.
Method of Procedure	Having the ATU-R/CPE in its default configuration, cross connect a circuit in this default VPI/VCI and pass cells over the circuit.
Expected Result	Cells must be passed across the circuit using the default VPI/VCI value from the CPE General Information table.

Test 9.1.5	**SVC Support (Optional)**
Test Configuration	• See Figure 2 • The ATM switch or simulator may be removed if traffic simulator/analyzer in use is capable of terminating the ATM traffic directly from the DSLAM.
Method of Procedure	Configure a SVC and verify NSAP ATM addressing and native E.164 addressing. (NOTE: Extra details of this method of procedure are required for reproducible test results.)
Expected Result	NSAP ATM addressing and E.164 addressing work.

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Test 9.1.6	**QoS Support for CBR / UBR Traffic**
Test Configuration	• See test network in Figure 2. • The ATM switch or simulator may be removed if traffic simulator/analyzer in use is capable of terminating the ATM traffic directly from the DSLAM (unless a back-to-back connection proves to be critical or unstable). • The loop simulator may be bypassed. • The noise generator may be removed.
Method of Procedure	Only run this test if CBR functionality is implemented on both the DSLAM and ATU-R/CPE. • Configure the test network as follows: • Set up a bi-directional connection on a known VPI/VCI (*e.g.*, VP=1 and VC=35) for CBR traffic. For this connection configure the DSLAM, setting the peak traffic rate (in kbps) or the peak cell rate PCR (in ATM cells/s) equal to the maximum ATU-R upstream data rate achieved during synchronization. • Set up a bi-directional connection on a separate known VPI/VCI (*e.g.*, VP=2 and VC=35) for UBR traffic. For this connection configure the DSLAM, setting the peak traffic rate (in kbps) or the peak cell rate PCR (in ATM cells/s) equal to the maximum ATU-R downstream data rate achieved during synchronization. • Configure both channels on the Traffic Simulator / Analyzer for O.191 or RFC 2544 generation and analysis. • Configure the ATU-R to loop back traffic.
Expected Result	O.191 or RFC 2544 analysis shall show that only UBR traffic is discarded and that all of the CBR traffic is delivered, if UBR and CBR are implemented.

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Test 9.1.7	**QoS Support for rtVBR / UBR Traffic**
Test Configuration	• See test network in Figure 2. • The ATM switch or simulator may be removed if traffic simulator/analyzer in use is capable of terminating the ATM traffic directly from the DSLAM (unless a back-to-back connection proves to be critical or unstable). • The loop simulator may be bypassed. • The noise generator may be removed.
Method of Procedure	Only run this test if rtVBR functionality is implemented on both the DSLAM and ATU-R/CPE. • Configure the test network as follows: • Set up a bi-directional connection on a known VPI/VCI (*e.g.*, VP=1 and VC=35) for rtVBR traffic. Set the peak traffic rate equal to the maximum ATU-R upstream data rate and the sustained traffic rate equal to half the maximum ATU-R upstream data rate. • Set up a bi-directional connection on a separate known VPI/VCI (*e.g.*, VP=2 and VC=35) for UBR traffic. Set the traffic rate equal to the maximum ATU-R downstream data rate. • Configure both channels on the Traffic Simulator / Analyzer for O.191 or RFC 2544 generation and analysis. • Configure the ATU-R to loop back traffic.
Expected Result	O.191 or RFC 2544 analysis shall show that all of the cells in the rtVBR data stream are delivered, if rtVBR and UBR are implemented. Additionally, a portion of the UBR data stream shall be delivered.

Test 9.1.8	**QoS Support for nrtVBR / UBR Traffic**
Test Configuration	• See test network in Figure 2. • The ATM switch or simulator may be removed if traffic simulator/analyzer in use is capable of terminating the ATM traffic directly from the DSLAM (unless a back-to-back connection proves to be critical or unstable). • The loop simulator may be bypassed. • The noise generator may be removed.
Method of Procedure	Only run this test if nrtVBR functionality is implemented on both the DSLAM and ATU-R/CPE. • Configure the test network as follows: • Set up a bi-directional connection on a known VPI/VCI (*e.g.*, VP=1 and VC=35) for nrtVBR traffic. Set the peak traffic rate equal to the maximum ATU-R upstream data rate and the sustained traffic rate equal to half the maximum ATU-R upstream data rate. • Set up a bi-directional connection on a separate known VPI/VCI (*e.g.*, VP=2 and VC=35) for UBR traffic. Set the traffic rate equal to the maximum ATU-R downstream data rate. • Configure both channels on the Traffic Simulator / Analyzer for O.191 or RFC 2544 generation and analysis. • Configure the ATU-R to loop back traffic.
Expected Result	O.191 or RFC 2544 analysis shall show that some UBR and some nrtVBR cells are delivered, if nrtVBR and UBR are implemented.

Test 9.1.9	**F5 OAM Support**
Test Configuration	• See test network in Figure 2. • The ATM switch or simulator may be removed if traffic simulator/analyzer in use is capable of terminating the ATM traffic directly from the DSLAM (unless a back-to-back connection proves to be critical or unstable). • The loop simulator may be bypassed. • The noise generator may be removed.
Method of Procedure	• Configure the test network for a bi-directional connection on a known VPI/VCI (*e.g.*, VP=0 and VC=35). • Send an F5 OAM segment loopback cell from the network to the CPE.
Expected Result	Confirm that a response cell is received from the network.
Method of Procedure	• Send an F5 OAM end-to-end loopback cell from the network to the CPE.
Expected Result	Confirm that a response cell is received from the network.

9.2 Layer 3 Ethernet or USB Interface RFC 2684 bridged mode

Provision the DSLAM with a fixed set of values:

- Margin up and down: 6dB
- Data Path: Fast
- FEC redundancy: Off (if configurable)
- Trellis Coding: enabled
- Bit swapping: enabled
- Payload scrambling: enabled
- Operational Mode: Autodetect (T1.413-1998/G.992.1 Annex A)

9.2.1 Packet Throughput Test

The purpose of this test is to verify the throughput for a selected list of provisioned line rates (down/up) using IP Frame transfers of varying length.

The packet or frame size is defined in RFC 1242, section 3.5, Data Link Frame Size, and states "The number of octets in the frame from the first octet following the preamble to the end of the FCS, if present, or to the last octet of the data if there is no FCS". This specifically defines the packet or frame size in terms of the MAC frame, and hence is not the IP packet size.

Methodology:

The throughput test specified here satisfies the terminology criteria of RFC 1242 and the test methodology specified in RFC 2544. From RFC 1242, throughput is "the maximum rate at which none of the offered frames are dropped by the device." From RFC 2544, the methodology to measure throughput is to "Send a specific number of frames at a specific rate through the DUT and then count the frames that are transmitted by the DUT." If the count of offered frames is equal to the count of received frames, the rate of the offered stream is raised and the test is rerun. If fewer frames are received than were transmitted, the rate of the offered stream is reduced and the test is rerun. In this test specification, the number of frames transmitted from one end of the ADSL link are compared with the number of frames received at the far end of the ADSL link.
The frame size is payload only. Throughput shall be measured for MAC frame length (see RFC 1242 Section 3.5).
*White noise shall be injected into the loop at **both** upstream and downstream ends at a power level of –140 dBm/Hz.*
(The errors recorded shall be the sum of upstream and downstream errors. To pass an individual test, HEC errors shall be zero, excluding HEC errors related to modem training.)

9.2.1.1 Test Configuration

The configuration shall be as shown in figures 3 to 6.

9.2.1.2 Test Description

1. Set up the loop simulators for a MID –CSA #6 loop (26 AWG at 6000 feet) or ETSI-1 loop (0.4 mm at 1800 m).
2. Provision the DSLAM at the maximum bit rates as shown in the tables below.
3. Set the CPE modem for bridged mode with LLC encapsulation.
4. Let the CPE train.
5. Record the modem up and down stream train rates and noise margins in the tables below.
6. Setup traffic generator/analyzer to perform throughput test for selected frame length and connect rate. Test for the throughput in the downstream direction. Reduce the throughput rate of the upstream direction to 90% of the maximum theoretical value sustainable by the ADSL net data rate. Record the downstream throughput rate for compliance purposes and the upstream throughput rate for information only. Repeat the test for throughput in the opposite direction

using 90% of the maximum downstream theoretical ADSL net data rate. The test shall be run for 60 seconds.

7. Record analyzer throughput rate results as frames per second.
8. If the count of received frames is equal to the count of offered frames, increase the rate of the offered stream and repeat steps 6 and 7. If the count of received frames is less than the count of offered frames, decrease the rate of the offered stream and repeat steps 6 and 7.
9. Divide the analyzer frames per second by the maximum FPS for the connect rate and frame size.
10. Record as percentage of maximum connect rate.

9.2.1.3 Test Results

42 individual tests – 42 tests must be passed

1. Throughput Test Results

Connect Rate DS: 384 kbps
Connect Rate US: 128 kbps

Analyzer Recorded FPS			Max FPS		% of Max		Margin	
Frame Size	DS	US	DS	US	DS	Us	DS	US
64			452	150				
128			226	75				
256			150	50				
512			75	25				
1024			41	13				
1280			32	10				
1518			28	9				

2. Throughput Test Results

Connect Rate DS: 1536 kbps
Connect Rate US: 384 kbps

Analyzer Recorded FPS			Max FPS		% of Max		Margin	
Frame Size	DS	US	DS	US	DS	Us	DS	US
64			1811	452				
128			905	226				
256			603	150				
512			301	75				
1024			164	41				
1280			129	32				
1518			113	28				

3. Throughput Test Results

Connect Rate DS: 8000 kbps
Connect Rate US: 800 kbps

Analyzer Recorded FPS			Max FPS		% of Max		Margin	
Frame Size	DS	US	DS	US	DS	Us	DS	US
64			9434	943				
128			4717	471				
256			3144	314				
512			1572	157				
1024			857	85				
1280			673	67				
1518			589	59				

9.2.1.4 Expected Results

The percentage of frames achievable for all DSL modems (Ethernet and USB) is 85%. For PCI and USB modems, 85% is passing, since their performance will be affected by the efficiency of the PC drivers and the OS on which they are installed. This 85% also assumes the downstream connect rate does not exceed the USB bus maximum. In that case, the USB max will dictate the Max FPS recorded.

9.2.2 Packet Latency Tests

The purpose of this test is to measure the round trip time of the given transmission chain.

This test takes two forms. First, a test will be done at a specified train rate and various frame sizes. Second, a test will be performed at a single frame size and various train rates.
Methodology: Latency is tested as defined in RFC 1242.
The traffic generator sends a burst of frames at a specified frame size over the ADSL link at a specified throughput rate. In the middle of the burst stream it inserts one frame with an identifying trigger (tag). The time when the trigger frame is fully transmitted is the Transmit Timestamp. The time the traffic analyzer recognizes the trigger frame is the Receive Timestamp. The Latency is calculated as follows:
(Receive Timestamp) minus (Transmit Timestamp) = Latency
(NOTE: Round trip delay is the sum of upstream latency and downstream latency.)

9.2.2.1 Latency Test – Single Train Rate with Multiple Frame Sizes

9.2.2.1.1 Test Configuration/Description

1. Test configuration shall be as shown in figures 4 to 6.
2. Set modem to bridge mode.
3. Set up the loop simulator for a MID-CSA #6 loop (26 AWG at 6000 feet) or ETSI-1 loop (0.4 mm at 1800 m).
4. Train at 384/128 kbps down/up.
5. Setup the traffic generator/analyzer to perform a latency test for the selected frame length.
6. Record traffic generator/analyzer latency test results.
7. Repeat for the 7 different frame lengths as shown in table below.
8. Reset equipment.

9.2.2.1.2 Results

7 individual tests – 7 must be passed

Packet Size	Round Trip Times in mS		
	Min.	Ave.	Max.
64			
128			
256			
512			
1024			
1280			
1518			

9.2.2.1.3 Expected results

Round trip average latency times shall be less than 255 ms.

9.2.2.2 Latency Test – Single Frame Size with Multiple Train Rates

9.2.2.2.1 Test Configuration/Description

Frame size shall be 1280 bytes.

1. Set modem to bridge mode.
2. Set up the loop simulator for a MID-CSA #6 loop (26 AWG at 6000 feet) or ETSI-1 loop (0.4 mm at 1800 m).
3. Train at specified bit rate.
4. Setup the traffic generator/analyzer to perform a latency test for the selected train rate.
5. Record traffic generator/analyzer latency test results.
6. Repeat for the different train rates as shown in the table below.
7. Reset equipment.

9.2.2.2.2 Results

3 individual tests – 3 must be passed

Trained Rate	Round Trip Times in mS		
	Min.	Ave.	Max.
384/128 kbps			
1536/384 kbps			
MAX DN/MAX UP			

9.2.2.2.3 Expected results

Round trip average latency times shall be less than 255 ms.

9.3 PPPoE End-to-End Connectivity Test

1 individual test – 1 must be passed

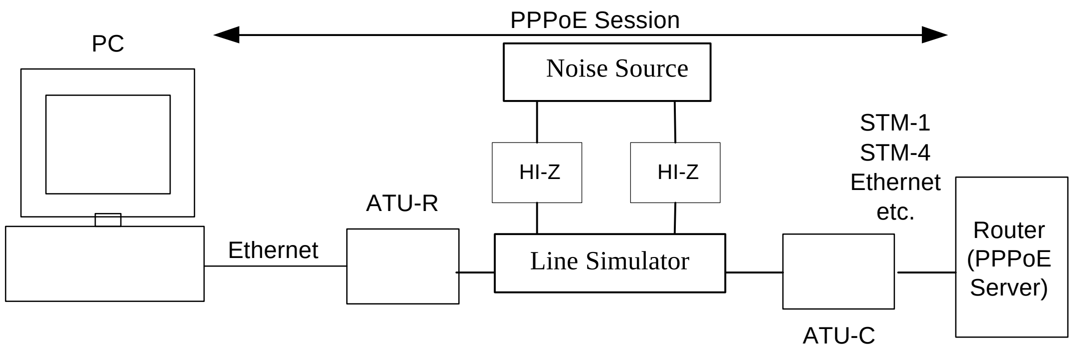


Figure 10: Test setup for PPPoE testing with Ethernet modems

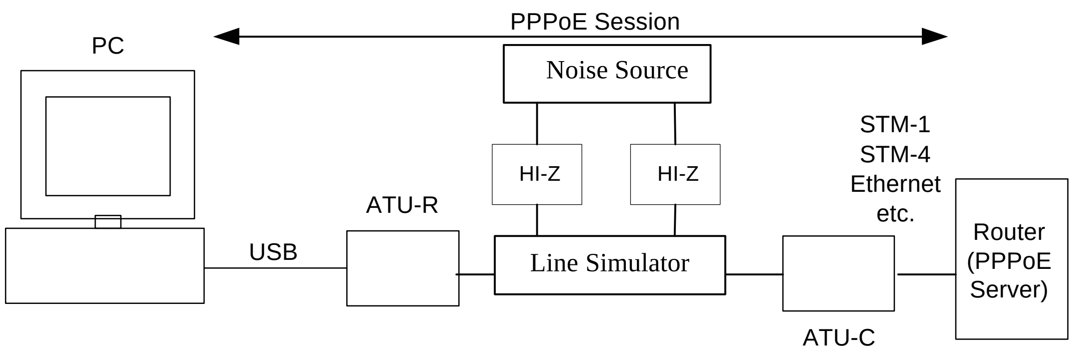


Figure 11: Test setup for PPPoE testing with USB modems

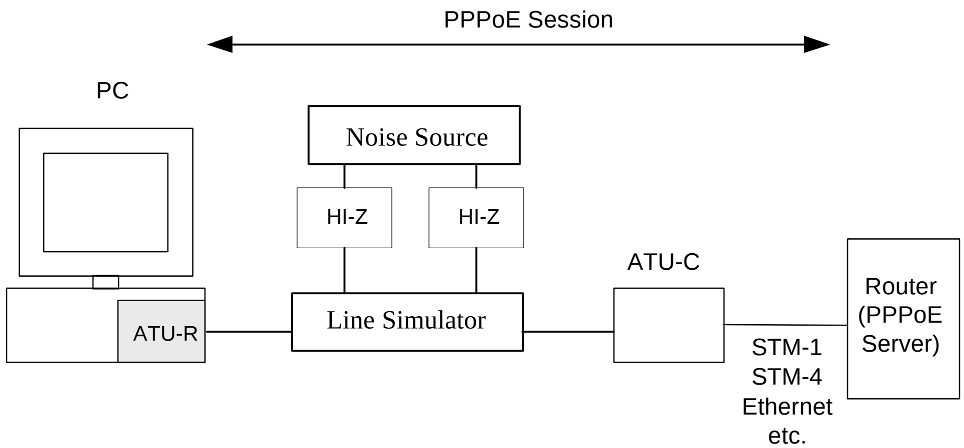


Figure 12: Test setup for PPPoE testing with PCI modems

Test 9.3.1	**PPPoE**
Test Configuration	See Figure 10, 11, or 12 (as applicable)
Method of Procedure	Terminate PPPoE session between the computer and the router. Verify connectivity by passing traffic over this PPPoE session.
Expected Result	Transmitted packets are received.

9.4 PPPoA End-to-End Connectivity Test

1 individual test – 1 must be passed

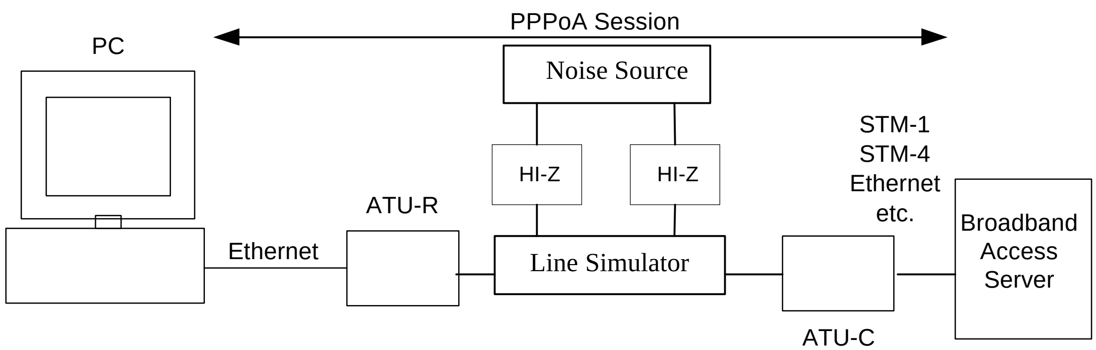


Figure 13: Test setup for PPPoA testing with Ethernet modems

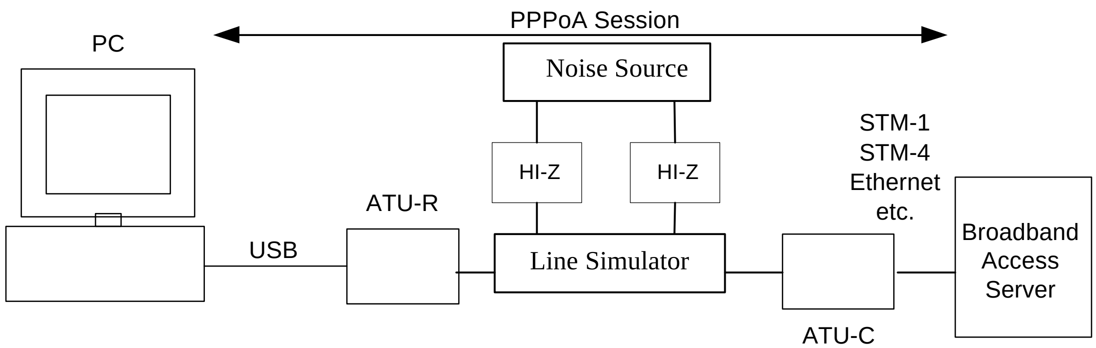


Figure 14: Test setup for PPPoA testing with USB modems

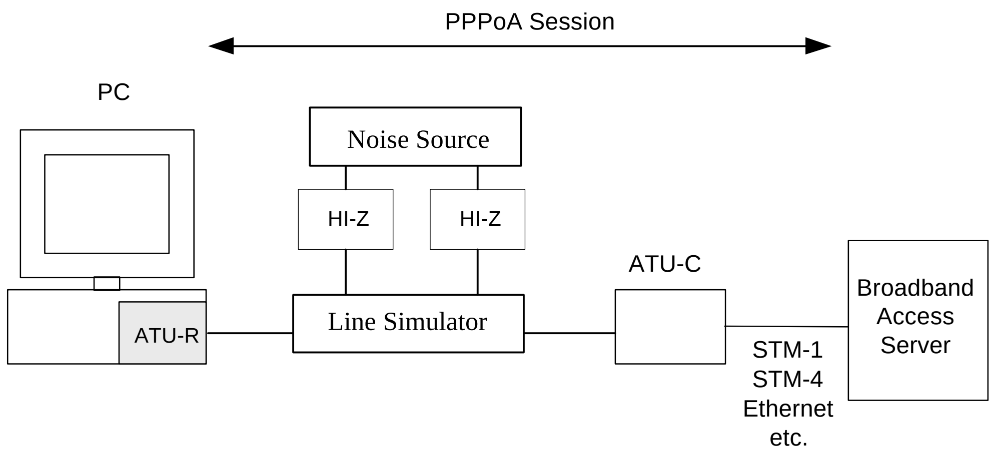


Figure 15: Test setup for PPPoA testing with PCI modems

Test 9.4.1	**PPPoA**
Test Configuration	See Figure 13, 14, or 15 (as applicable)
Method of Procedure	Terminate PPPoA session between the computer and the broadband access server. Verify connectivity by passing traffic over this PPPoA session.
Expected Result	Transmitted packets are received.

9.5 RFC 2684 End-to-End Connectivity Test

1 individual test – 1 must be passed

Test 9.5.1	**Verify IP Bridged**
Test Configuration	See Figure 2, applicable to Ethernet modem only
Method of Procedure	Configure the test environment including the ATU-R and the computer so that the ATU-R/CPE Ethernet port terminates a bridge section. The second termination of the bridge section should be implemented at an appropriate device within the testing environment (*e.g.*, DSLAM, PoP). Pass IP packets over the complete bridge section and verify the proper reception at the destination (*e.g.*, PoP, Host PC).
Expected Result	Transmitted packets are received.

9.6 Usability Test

1 individual test – 1 must be passed

Test 9.6.1	**PC Re-boot**
Test Configuration	See Figure 2, only applies to PCI NIC, USB modems
Method of Procedure	From a freshly installed operating system, quantify the number of reboots required to install all drivers on a PC.
Expected Result	No more than two reboots are required.

Annex A: Accuracy of Loop Simulators and Noise Sources (Normative)

A.1 Loop Simulators

a) Attenuation

Loop attenuation which corresponds to the Insertion Loss $10\log|H(f)|^2$, is expressed in dB, and shall be calculated from the RLCG parameters using two-port ABCD modeling methodology as specified in ANSI T1.417 Section B.3.1 (for both straight loops and loops with bridged taps). The RLCG cable parameters shall be as specified in ITU-T Rec. G.996.1 (June 1999) (PIC cable at 70 degrees Fahrenheit for North American test loops, PE cable at 20 degrees Celsius for European test loops).

For the loop simulator used in testing, the simulated loop attenuation shall be measured over the frequency band [f1, f2], where frequency f1 shall be 20 kHz. The frequency f2 shall be the frequency at which the nominal loop attenuation is 90dB (under review) (see Note below) or the passband upper bound frequency (138 kHz upstream or 1104 kHz downstream), whichever is the lowest. At least one measurement shall be made per 10 kHz interval. The Mean Error and Mean Absolute Error (MAE) of the measured simulated loop attenuation values (in dB), relative to the theoretical loop attenuation values (in dB), shall be calculated.

Mean Absolute Error (MAE) is given by:

$$MAE = N^{-1} \sum_{i=1}^{i=N} \left| (\text{Actual Attenuation}_i \text{ (dB)} - \text{Theoretical Attenuation}_i \text{ (dB)}) \right|$$

N is determined by the number of points necessary to measure the attenuation in steps of 10 kHz or less.

The loop simulator shall be compensated by adjusting the loop length such that the MAE is minimized. After compensation, the MAE shall be less than 0.5 dB. The Mean Error for the compensated wireline shall be calculated. This accuracy requirement shall apply for all test loops.

NOTE: The ADSL equipment uses the full ADSL bandwidth up to 1.1 MHz (tone 255) for loop lengths up to about 11 kft for straight 26 AWG loop with –140 dBm/Hz AWGN noise. This corresponds to an expected ADSL signal bandwidth, reaching to the 1.1 MHz frequency with a loop attenuation of 90 dB. This corresponds with the received signal being 10 dB above the –140 dBm/Hz AWGN level.

b) Average noise floor

The average noise floor in the Wireline Simulator shall be lower than -150dBm/Hz within the ADSL band.

c) Impedance

The Impedance of the Wireline Simulator shall have less than 10% (5% was under review) variation from the theoretical amplitude and phase. Measured with 100 Ohm termination impedance.

d) Phase

The Phase of the Wireline Simulator shall have a total phase with less than 10% variation from the total theoretical phase.

A.2 Noise Sources

Each noise shall be measured independently at the ATU terminal. This shall be done for one noise source at a time, using a zero-length loop, with both ATUs replaced by a 100 Ohm (±1%) resistor. The measured noise will be impacted by the noise generator tolerance, the coupling circuit tolerance, cabling tolerance and noise pickup (see Annex A.4).

For the noise source used in testing, the simulated noise level shall be measured over the frequency band 12 kHz to 2.208 MHz, with at least one measurement per 10 kHz interval. The MAE and Mean Error of the noise level values (in dB), relative to the nominal noise level values (in dB), shall be calculated over the same frequency band [f1, f2] as for the Mean and MAE loop attenuation range.

The noise shall be compensated by slightly adjusting the level, such that the MAE is minimized. The Mean Error of the noise with the compensated noise shall be calculated.

A.2.1 White Noise

In tests with white noise only, the theoretical noise level shall be defined as a flat PSD level of –140 dBm/Hz over the frequency range of 12 kHz to 2208 kHz, with a Gaussian amplitude distribution to 5 sigma.

The MAE of this noise shall be less than 1.0 dB if test setup does not allow to compensate for minimum MAE.
The MAE of this noise shall be less than 0.5 dB if test setup allows to compensate for minimum MAE.

A.2.2 24 HDSL, 24 DSL (ISDN), and 5 T1 Adjacent Binder + European Noises

In tests with disturbers added on top of white noise, the theoretical noise level shall be defined as the reference disturber shapes defined in G.996.1 (June 1999), added to a flat PSD level of –140 dBm/Hz over the frequency range of 12 kHz to 2208 kHz. Noises shall be Gaussian with a Crest Factor of greater than 5.

The measured noise level shall be within a maximum tolerance from the theoretical noise level. The measured noise level tolerance shall be as follows:

Tolerance of Measured Noise Level Relative to Theoretical Noise Level	
Disturber Type	MAE
HDSL	< 0.5 dB
DSL (ISDN)	< 0.5 dB
T1 Adjacent Binder	< 0.5 dB
ETSI A	< 0.5 dB
ETSI B	< 0.5 dB
Euro-K	< 0.5 dB

A.3 Fine Data Rate Adjustment

This paragraph describes a methodology how to finely adjust the measured data rates as a function of the tolerances of the Loop simulator and Noise source.

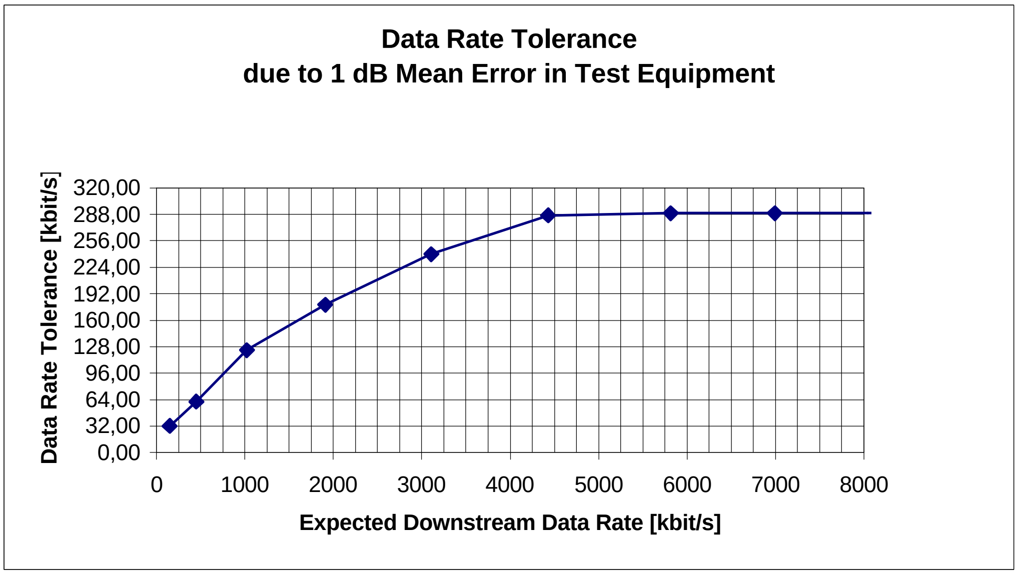
If Loop Attenuation is higher than specified (too much attenuation), the mean attenuation error shall be represented by a positive value in dB.
If the Noise Level is higher than specified (too much noise), the mean noise level error shall be represented by a positive value in dB.
The mean error of the Test Equipment shall be defined as the sum of the mean attenuation error and the mean noise level error.
The measured data rate shall be finely adjusted for the mean error of the Test Equipment, using the method below, with a proportional rule. The data rate tolerance value (*i.e.,* the fine adjustment) is rounded to the closest increment of 32 kbps. The fine adjustment can be a positive or negative value.

Both the measured data rate and the fine adjustment shall be reported in the test report.

The fine data rate adjustment is added to the measured data rate and the total is compared with the expected data rate to determine whether the modem passes or fails the test.

A.3.1 Calculation of Data Rate Fine Adjustment

The fine adjustment is calculated from the figure and table below. The mean error is the mean error over the [f1,f2] bandwidth.



Expected Downstream Data Rate (kbps)	Data Rate Fine Adjustment (kbps)
148	32.00
448	61.33
1020	124.00
1908	178.67
3108	240.00
4428	286.67
5816	289.33
6992	289.33
8000	289.33

If the measured data rate is the maximum data rate supported by the modem, then no fine adjustment shall be performed (*i.e.*, fine adjustment value is set to 0).

Example:

- Test case where the expected data rate is 2304 kbps.
- The measured data rate is 2240 kbps.
- The Loop Attenuation mean error is +0.4 dB (too much attenuation).
- The Noise Level mean error is +0.2 dB (too much noise).
- The mean error of the Test equipment is 0.4 + 0.2 = 0.6dB.
- From the table, using linear interpolation, the data rate tolerance is: (2304 - 1908)/(3108 - 1908)*(240 - 178.67) + 178.67 = 198.9 kbps for an attenuation error of 1 dB
- The error due to 0.6 dB is 0.6 * 198.9 = 119.3 kbps
- This value is then rounded, to the closest 32 kbps increment, giving a data rate tolerance value of 128 kbps.
- The total of 2240 + 128 = 2368 kbps is compared with the expected data rate of 2304 kbps.
- It is determined that the modem passes the test.

The same fine adjustment shall be applied to upstream measured data rates. However, since for upstream all the available tones are used for all loop lengths and measured data rates, the measured upstream data rate fine adjustment due to 1 dB mean error in Test Equipment shall be 32 kbps, irrespective of the measured data rate.

The methodology described above compensates for tolerance in the spectrum analyzer. The same spectrum analyzer shall be used to measure the loop attenuation and the noise level. The impact of the spectrum analyzer tolerance on the mean loop attenuation error is compensated by its impact on the mean noise level error.

A.4 Cabling

Cabling, switches and other equipment are needed to connect the DSLAM, the loop simulator, the noise generator and the ATU-R. Care must be taken in order that the minimum noise is coupled into this cabling, so the wiring should be kept short as practically possible. Recommended cables are Cat5 UTP and STP. Since the length is typically short (*e.g.*, 5 to 10 feet) this does not influence the measurements. STP is only required when there is high EMI in the vicinity (typically from engines, air conditioning units) or for longer cables coming from the DSLAM. If the test is performed in a large operational lab (where also other work is done) then consider this lab as a high-noise environment.

One should take care that the shielding is connected in an appropriate way. Connect the shield to the loop simulator ground only (one sided grounding). A badly connected shield can even make the performance worse. In case of doubt, use the unshielded twisted pair.

Computer screens and power supplies radiate in the frequency bands used by ADSL. These devices should be placed at a distance from the setup or even be switched off. This noise may be generated by either internal or external power supplies. When the pickup noise levels are greater than -140 dBm/Hz, they will limit the ADSL performance and influence the test results.

The ATU-R and ATU-C and their wiring should be physically separated, since when testing on long loops, crosstalk can occur between the cabling. Generally, starting from attenuation levels of 70 dB and greater, special care must be taken for the wiring to avoid crosstalk.

To obtain the maximum accuracy the cables, switches and any other equipment used in the link between the DSLAM and the Remote modem should be contained within the compensation process described in Annex A.1 (Loop Simulators).

Annex B: ETSI to AWG conversion charts (Informative)

The following table is composed of three main columns listing each various correspondence between ETSI-1 and 26 AWG loops using as pivot parameter (first, fourth, and seventh column) the loop length in km, the loop length in kft, and the attenuation in dB, respectively.

- 1 km = 3.28 kft
- Attenuation/km for ETSI-1 loop @ 20 degrees C = 14.2 dB
- Attenuation/km for 26 AWG loop @ 20 degrees C = 14.6 dB

Correspondence between attenuation of ETSI-1 and 26 AWG loops for European lengths			Correspondence between attenuation of 26 AWG and ETSI-1 loops for American lengths			Correspondence between lengths of ETSI-1 and 26 AWG loops for given loop attenuations		
	Loop Type			Loop Type			Loop Type	
	ETSI-1	26 AWG		26 AWG	ETSI-1		ETSI-1	26 AWG
Loop length (km)	Attenuation (dB)	Attenuation (dB)	Loop length (kft)	Attenuation (dB)	Attenuation (dB)	Loop Atten. (dB)	Length (km)	Length (kft)
0.5	7	7	1	5	4	2	0.1	0.4
1	14	15	2	9	9	4	0.3	0.9
1.4	20	20	3	14	13	6	0.4	1.3
1.5	21	22	4	18	17	8	0.6	1.8
2	28	29	5	23	22	10	0.7	2.2
2.15	30	31	6	27	26	12	0.8	2.7
2.5	36	37	7	32	30	15	1.1	3.4
2.8	40	41	8	36	34	20	1.4	4.5
3	43	44	9	41	39	25	1.8	5.6
3.5	50	51	10	45	43	30	2.1	6.7
4	57	58	11	50	47	35	2.5	7.9
4.2	60	61	12	54	52	40	2.8	9.0
4.5	64	66	13	59	56	45	3.2	10.1
			14	63	60	50	3.5	11.2
			15	68	65	55	3.9	12.4
			16	72	69	60	4.2	13.5
			17	77	73	65	4.6	14.6
			17.5	79	75	70	4.9	15.7
			18	81	77	75	5.3	16.8
						80	5.6	18.0