

TR-067  
ADSL Interoperability Test Plan

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## Table of Contents

<b>1. REVISION HISTORY</b> .....	<b>7</b>
<b>2. INTRODUCTION</b> .....	<b>9</b>
2.1. INTEROPERABILITY .....	9
2.2. INTERPRETATION OF KEY WORDS .....	9
2.3. SCOPE .....	10
<b>3. REFERENCES</b> .....	<b>10</b>
<b>4. TEST TOOLS REQUIREMENTS AND CALIBRATION</b> .....	<b>10</b>
4.1. ACCURACY OF LOOP SIMULATORS AND NOISE SOURCES .....	11
4.1.1. <i>Loop Simulators</i> .....	11
4.1.2. <i>Noise Sources</i> .....	12
4.1.3. <i>Cabling</i> .....	13
<b>5. COMMON TEST INFORMATION</b> .....	<b>14</b>
5.1. MAXIMUM RATES FOR DSLAMS .....	14
5.2. COMPATIBILITY MATRIX/DEFINITIONS .....	14
5.3. REGIONAL PREFERENCES .....	14
5.4. RECORDING TEMPERATURE AND HUMIDITY .....	14
5.5. SYNC STATE DEFINITION .....	15
<b>6. EQUIPMENT FEATURES</b> .....	<b>15</b>
6.1. DSLAM .....	15
6.2. CPE .....	17
6.3. EXPECTED RESULTS .....	18
<b>7. TEST CONFIGURATIONS</b> .....	<b>19</b>
<b>8. PHYSICAL LAYER TEST CASES</b> .....	<b>23</b>
8.1. ADSL FUNCTIONALITY TESTS .....	25
8.1.1. <i>Basic Functional Bit Swap Test</i> .....	25
8.1.2. <i>Verification of CRC error reporting by ATU-R (Basic CRC Functionality Test)</i> .....	26
8.1.3. <i>Check ADSL Diagnostic Tools</i> .....	27
8.1.4. <i>Dying gasp</i> .....	27
8.1.5. <i>Modular connector pins</i> .....	27
8.1.6. <i>Ethernet Connector Pinout</i> .....	27
8.1.7. <i>Upstream Power Cutback</i> .....	28
8.1.8. <i>ATU-R Register Reporting via EOC</i> .....	28
8.1.9. <i>Request Downstream Power Cutback</i> .....	28
8.2. SUDDEN APPLICATION OF RFI .....	29
8.3. DSL NOISE SPIKES/SURGES TESTS .....	30
8.4. STRESS TEST .....	31
8.5. ELECTRICAL COMPATIBILITY TESTS .....	32
8.5.1. <i>Analog Front End Power</i> .....	32
8.5.2. <i>PSD Measurement</i> .....	32
8.5.3. <i>Longitudinal Balance – LCL</i> .....	33
8.5.4. <i>Longitudinal Balance – LOV</i> .....	34
<b>9. HIGHER LAYER TEST CASES</b> .....	<b>35</b>
9.1. ATM CONNECTIVITY TESTS .....	35
9.1.1. <i>Loopback at ATU-R</i> .....	35
9.1.2. <i>Maximum number of VC's</i> .....	35

9.1.3.	<i>Maximum VPI/VCI Range</i> .....	35
9.1.4.	<i>Default VPI/VCI</i> .....	36
9.1.5.	<i>QoS Support for CBR / UBR Traffic (test if implemented)</i> .....	36
9.1.6.	<i>QoS Support for rtVBR / UBR Traffic (test if implemented)</i> .....	37
9.1.7.	<i>QoS Support for nrtVBR / UBR Traffic (test if implemented)</i> .....	38
9.1.8.	<i>F5 OAM Support</i> .....	38
9.2.	LAYER 3 ETHERNET OR USB INTERFACE RFC 2684 [10] BRIDGED MODE.....	39
9.2.1.	<i>Packet Throughput Test</i> .....	39
9.2.2.	<i>Packet Latency Tests</i> .....	41
9.3.	RFC 2516 [11] PPPoE END-TO-END CONNECTIVITY TEST.....	43
9.3.1.	<i>PPPoE</i> .....	44
9.4.	RFC 2364 [12] PPPoA END-TO-END CONNECTIVITY TEST .....	44
9.4.1.	<i>PPPoA</i> .....	45
9.5.	RFC 2684 [10] END-TO-END CONNECTIVITY TEST.....	46
9.5.1.	<i>Verify IP Bridged</i> .....	46
9.6.	USABILITY TEST.....	46
9.6.1.	<i>PC Re-boot</i> .....	46
9.6.2.	<i>Power Cycle Test</i> .....	46
9.6.3.	<i>Link Cycle Test</i> .....	47
9.6.4.	<i>Verify 10/100 Ethernet Auto-negotiation (802.3u)</i> .....	47
<b>ANNEX A</b>	<b>PHYSICAL LAYER TEST CASES FOR SYSTEMS USING G.992.1 ANNEX A [1].</b>	<b>49</b>
A.1	NORTH AMERICAN TEST SET.....	49
A.1.1	<i>CPE Margin verification tests</i> .....	50
A.1.1.7.	<i>CO Margin Verification (Optional)</i> .....	54
A.1.2	<i>ANSI T1-413 [4] Operation</i> .....	55
A.1.3	<i>Operation in the Presence of Impulse Noise Events (G.996.1 [2], Test Impulse 1)</i> .....	55
A.1.4	<i>Verification of downstream fine gain values</i> .....	56
A.1.5	<i>Loop Tests with Ports Set for Adaptive Rate</i> .....	56
A.1.6	<i>Loop Tests with Ports Set For Fixed Rate</i> .....	60
A.1.7	<i>CSA #4 Standard Loop</i> .....	61
A.1.8	<i>ANSI 13 Standard Loop</i> .....	61
A.1.9	<i>Bridged Tap Tests</i> .....	62
A.2	EUROPEAN TEST SET .....	65
A.2.1	<i>CPE Margin verification tests</i> .....	65
A.2.2	<i>Verification of Downstream Fine Gain Values</i> .....	66
A.2.3	<i>Loop Tests with Ports Set for Adaptive Rate</i> .....	67
A.2.4	<i>Loop Tests with Ports Set For Fixed Rate</i> .....	69
<b>ANNEX B</b>	<b>PHYSICAL LAYER TEST CASES FOR SYSTEMS USING G.992.1 ANNEX B.....</b>	<b>72</b>
B.1	ANNEX B SPECIFIC TEST SETUP INFORMATION.....	73
B.1.1	<i>Test setup for loop tests</i> .....	73
B.2	EUROPEAN TEST SET .....	74
B.2.1	<i>CPE Margin verification tests</i> .....	75
B.2.2	<i>CO Margin Verification (Optional)</i> .....	77
B.2.3	<i>Verification of Downstream Fine Gain Values</i> .....	79
B.2.4	<i>Loop Tests with Ports Set for Adaptive Rate</i> .....	80
B.2.5	<i>Loop Tests with Ports Set For Fixed Rate</i> .....	82
<b>ANNEX C</b>	<b>PHYSICAL LAYER TEST CASES FOR SYSTEMS USING G.992.1 ANNEX C .....</b>	<b>86</b>
<b>APPENDIX W: EFFECT OF THE STATISTICAL VARIABILITY IN CPE MANUFACTURING (INFORMATIVE)</b> .....		<b>87</b>
<b>ANNEX X ATTENUATION OF THEORETICAL LOOP MODELS (NORMATIVE)</b> .....		<b>89</b>

<b>APPENDIX Y: TEST EVENT METHODOLOGY (INFORMATIVE)</b> .....	<b>111</b>
Y.1 INTRODUCTION .....	111
Y.2 INITIAL MODEM TESTING .....	111
Y.2.1 Verification of Upstream PSD Level .....	111
Y.2.2 Verification of CRC Reporting by the Modem.....	112
Y.2.3 Verification of Downstream Fine Gain Values .....	112
Y.2.4 Checkpoint 1.....	112
Y.2.5 Verification of Reported Downstream Noise Margin.....	112
Y.2.6 Checkpoint 2.....	112
Y.2.7 Collection of Data Rates and Reported Noise Margins .....	112
Y.2.8 Checkpoint 3.....	112
Y.3 INITIAL DATA RATE REQUIREMENTS.....	112
Y.3.1 Modem Segregation.....	112
Y.3.2 Candidate Modem Selection.....	113
Y.3.3 Data Rates.....	113
Y.4 REFINEMENT OF DATA RATE REQUIREMENTS .....	113
Y.5 APPENDIX: TEST DESCRIPTIONS .....	115
Y.5.1 Upstream PSD Level .....	115
Y.5.2 CRC Reporting .....	116
Y.5.3 Downstream Fine Gains.....	117
Y.5.4 Checkpoint 1.....	118
Y.5.5 Downstream Noise Margin.....	119
Y.5.6 Checkpoint 2.....	120
Y.5.7 Checkpoint 3.....	120
Y.6 APPENDIX: DEFINITIONS .....	120
Y.6.1 Best Performing.....	120
Y.6.2 Closest to Passing .....	121
Y.6.3 STANDARD CONFIGURATION .....	121
Y.6.4 APPROPRIATE REPORTED NOISE MARGINS .....	122
Y.7 APPENDIX: OPEN TEST EVENT CALIBRATION PLAN.....	122
Y.7.1 Test Lab Calibration .....	122
Y.7.2 Test Equipment.....	122
Y.7.3 Test System Benchmarking .....	124
Y.7.4 Selection of DSLAM port and test equipment.....	125
Y.7.5 Full System Bench Mark.....	125

## List of Figures

Figure 1: Test setup for loop tests for ADSL external modems .....	19
Figure 2: Test setup for throughput tests for ADSL external modems with Ethernet interfaces .....	19
Figure 3: Test set-up for ATM-25 modems.....	20
Figure 4: Test set-up for Ethernet modems .....	20
Figure 5: Test set-up for USB modems .....	21
Figure 7: Test set-up for European Annex A test with splitters .....	22
Figure 8: Test set-up for European Annex B tests with splitters .....	22
Figure 9: 40 dB attenuator for tests 8.5.1 and 8.5.2.....	32
Figure 10: Measurement Method for Longitudinal Conversion Loss (Sample Setup) .....	33
Figure 11: Measurement Method for Longitudinal Output Voltage (LOV) .....	34
Figure 12: Test setup for PPPoE testing with Ethernet modems .....	43
Figure 13: Test setup for PPPoE testing with USB modems.....	43
Figure 14: Test setup for PPPoE testing with PCI modems .....	44
Figure 15: Test setup for PPPoA testing with Ethernet modems.....	44
Figure 16: Test setup for PPPoA testing with USB modems .....	45
Figure 17: Test setup for PPPoA testing with PCI modems .....	45
Figure B.1: structure of the ADSL/ISDN and ADSL/'ISDN or POTS' universal splitter .....	73

Figure W.1 PDF of the individual rates $R_i$ , and the Rate-requirement $R_r$ .....	88
Figure Y.1: Data rate reduction corresponding to 1dB performance degradation.....	114
Figure Y.2: Test Set-up .....	123

## 1. Revision History

Table 1.1: Revision history

Date (MM/DD/YYYY)	Version	Major Changes	Editor(s)
02/13/2003	0.0	Initial creation per agreement in Dallas, based on TR-048 and contribution 2003.22.00, PD-11v3	Jurgen Content, Alcatel Bell NV. Steve Aspell, SBC Technology
02/24/2003	0.1	Editorial clean-up of version 0.0	Jurgen Content, Alcatel Bell NV.
03/17/2003	1.0	Editorial changes	Jurgen Content, Alcatel Bell NV.
03/18/2003	2.0	Accepted changes from T&I conf call on March 18, 2003	Jurgen Content, Alcatel Bell NV.
05/07/2003	3.0	Included accepted contributions from the Lisbon meeting	Jurgen Content, Alcatel Bell NV.
08/07/03	4.0	All changes agreed from the Lisbon meeting and items accepted from conference calls on July 29, 2003.	William Causey, Texas Instruments Inc
08/13/03	4.1	Editorial changes and corrections. Added test cases accepted at the San Francisco meeting in December 2002.	William Causey, Texas Instruments Inc
09/05/03	5.0	Included all changes agreed to from the Boston meeting. Some editorial corrections added as needed. Working Text was sent to Straw Ballet with straw ballet comments submitted by the November, 2003 quarterly meeting.	William Causey, Texas Instruments Inc
11/13/03	5.1	Includes agreed changes from the Paris meeting also including some simple editing fixes based on straw comments.	William Causey, Texas Instruments Inc
11/21/03	5.2	Same as version 5.1 with sections modified in table format matching the table format done in TR-048.	William Causey, Texas Instruments Inc
12/10/03	5.2.1	Merged all the changes agreed from the teleconference calls held on November 25 and December 2, 2003.	William Causey, Texas Instruments Inc
1/19/04	5.2.2	All changes agreed upon from the January 13 <sup>th</sup> conference call. (Also converted section 8.1.2 into table format.)	William Causey, Texas Instruments Inc
1/31/04	5.2.3	Changes based on changes agreed from the January 27 <sup>th</sup> conference call.	William Causey, Texas Instruments Inc

2/4/04	5.3	Changes accepted on the February 3 <sup>rd</sup> conference call. Changes covered sections 9.2 – 9.6.3. All changes to WT-085 accepted and change bars dropped in this version. This version was added as an update.	William Causey, Texas Instruments Inc
2/5/04	5.3.1	Changes made based on the February 5 <sup>th</sup> conference call.	Herman Verbueken, Alcatel
2/11/04	6.0	Correlated the unresolved comments the straw comment spreadsheet with the new line numbers in this version of WT-085. Bumped the version number up to 6.0 as agreed in the February 3 <sup>rd</sup> conference call.	William Causey, Texas Instruments Inc
2/24/04	6.1	Agreed changes based from the February 19 <sup>th</sup> conference call. Changed section 9.6.4 based on contribution 2004.017. Added fine gain measurement tests for the European Annex A and Annex B. Added additional margin verification tests in Annex B. Made so agreed editing changes based on the conference call.	William Causey, Texas Instruments Inc
3/2/04	6.2	Agreed changes based on Tuesday agreements from comment resolution and contributions.	William Causey, Texas Instruments Inc
3/3/04	6.3	All final agreed edit changes. All changes accepted and document made clean of all changes for a full review	William Causey, Texas Instruments Inc
3/3/04	6.4	Changes in throughput requirements in section 9.2 back to match TR-048 and change to the stress test in section 8.4. Editing modifications throughout document.	William Causey, Texas Instruments Inc
3/4/04	6.5	Updated editing changes in the document and all change indications accepted	William Causey, Texas Instruments Inc
3/15/04	7.0	Updated test 8.5.1 the Analog Front End Measurement based on the results of a liaison to the ITU on this measurement. Editing corrections based on locations for references for test setup information. Also removed the line numbering.	William Causey, Texas Instruments Inc
4/3/04	8.0	Editorial and spelling corrections throughout the document.	William Causey, Texas Instruments Inc



## 2. Introduction

This document describes interoperability test cases required for ADSL reference systems consisting of DSLAMs and CPE modems. The origin of this document comes from TR-048 and this document may be considered a second version.

### 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 shall 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", means that the definition is an absolute prohibition of the specification.
- ***Should***: This word, or the adjective "recommended", means that there may exist valid reasons in particular circumstances to ignore 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" means that there may exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
- ***May***: This word, or the adjective "optional", means that 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 and ISDN 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 the maximum allowable power. ATU-C equipment unable to provide this transmit power is considered to be out of the scope of this interoperability test plan. The performance points may differ from the performance requirements of ANSI T1.413 [4], ITU-T G.992.1 [1] and ETSI TS101 388[7]. 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 test.

## 3. References

Listed below are standards referenced throughout this ADSL interoperability test document. If there is no date indicated use the latest version of the specified standard.

- [1] ITU-T Recommendation G.992.1, *Asymmetric digital subscriber line (ADSL) transceivers*.
- [2] ITU-T Recommendation G.996.1 (1999), *Test procedures for digital subscriber line (DSL) transceivers*.
- [3] ITU-T G.997.1, *Physical Layer Management for Digital Subscriber Line (DSL) Transceivers*.
- [4] ANSI T1.413 (1998), *Network to Customer Installation Interfaces - Asymmetric Subscriber Line (ADSL) Metallic Interface*.
- [5] ANSI T1.417 issue 2, *Spectrum Management for Loop Transmission Systems*.
- [6] ITU-T Recommendation G.117 (1996), *Transmission aspects of unbalance about earth*.
- [7] ETSI TS 101 388 V1.3.1 (2002 – 2003), *ADSL – European Specific Requirements*.
- [8] ETSI TS 101 952-1 V1.1.1 (04/2002) - *Specification of ADSL splitters for European deployment*.
- [9] IEEE 802.3u, *Fast Ethernet*.
- [10] RFC 2684, *Multi-protocol Encapsulation over ATM Adaptation Layer 5 (AAL5)*.
- [11] RFC 2516, *Method for Transmitting PPP over Ethernet. (PPPoE)*.
- [12] RFC 2364, *PPP over AAL5 (PPPoA)*.
- [13] RFC 1242, *Benchmarking terminology for network interconnection devices*.
- [14] RFC 2544, *Benchmarking terminology for network interconnection devices (Test methodology)*.

## 4. Test Tools Requirements and Calibration

- Loop simulator
- 1 traffic simulator/analyzer with matching network interfaces
- 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 must 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 or IP traffic directly from the DSLAM.

## 4.1. Accuracy of Loop simulators and noise sources

### 4.1.1. Loop Simulators

#### a) Attenuation

##### North American

Loop attenuation which corresponds to the Insertion Loss  $10\log|H(f)|^2$ , is expressed as a positive number in dB, and shall be calculated from the RLCG parameters using two-port ABCD modeling methodology as specified in ANSI T1.417 [5] Section B.3.1 (for both straight loops and loops with bridged taps). The RLCG cable parameters shall be calculated using the coefficients in ITU-T Rec. G.996.1 [2] Table 5: Coefficients for calculation of  $R$  and  $L$  (24 and 26 AWG PIC at 70° F).

The attenuation values of theoretical loops models are given in Annex X

##### European

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 ETSI TS 101 388 [7]. The RLCG cable parameters shall be calculated using the coefficients in ITU-T Rec. G.996.1 [2] Table 9: Coefficients for calculation of  $R$  and  $L$  (PE cable at 20 degrees Celsius).

The attenuation values of theoretical loops models are given in Annex X

For the loop simulator used in testing, the simulated loop attenuation shall be measured over the frequency band  $[f1, f2]$ , given by table 4.1.1.1 for the different annexes. At least one measurement shall be made per 10 kHz interval. The Mean Error (ME) 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.

Table 4.1.1.1: Calibration frequency boundaries

	Annex A	Annex B
f1	20kHz	120kHz
f2	1104kHz	1104kHz

Mean Absolute Error (MAE) and Mean Error (ME) for loop X are given by:

$$\text{MAE}_{\text{loop X}} = \frac{1}{N} \sum_{i \in \{A_{Ti} \leq 90 \text{ dB}\}} |A_{Ri} - A_{Ti}|$$

$$\text{ME}_{\text{loop X}} = \frac{1}{N} \sum_{i \in \{A_{Ti} \leq 90 \text{ dB}\}} (A_{Ri} - A_{Ti})$$

[positive error = too much attenuation]

$A_{Ri}$  = Attenuation sample, in dB, of the measured loop X

$A_{Ti}$  = Attenuation sample, in dB, of the theoretical loop X

The index “i” belongs to a set defined by the points necessary to measure the attenuation in steps of 10 kHz or less and taking into account only those points for which  $A_{Ti} \leq 90$  dB. N is the number of elements in the above set.

The loop simulator shall be compensated by adjusting the loop length such that the absolute value of ME is minimized while maintaining an MAE less than 0.5 dB. 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% variation from the theoretical amplitude and phase Measured with the appropriate termination impedance. For North American noises this is 100ohms, for European noises, this shall be according ETSI TS 101 388, section 5.1 [7].

#### **d) Phase**

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

### **4.1.2. 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. For North American cases both ATUs are replaced by a 100 Ohm ( $\pm 1\%$ ) resistor. For European cases the methodology in ETSI TS 101 388 [7] section 5.1.4.1 shall be used. The measured noise will be impacted by the noise generator tolerance, the coupling circuit tolerance, cabling tolerance and noise pickup.

For the noise source used in testing, the simulated noise level shall be measured over the frequency band [f1, f2], given by table 4.1.2.1 for the different annexes. At least one measurement shall be made per 10 kHz interval. The Mean Error (ME) and Mean Absolute Error (MAE) of the measured simulated noise level values (in dBm/Hz), relative to the theoretical noise level values (in dBm/Hz), shall be calculated.

Table 4.1.2.1: Calibration frequency boundaries

	Annex A	Annex B
f1	20 kHz	120 kHz
f2	1104 kHz	1104 kHz

Mean Absolute Error (MAE) and Mean Error (ME) for noise X are given by:

$$\text{MAE}_{\text{noise } X} = \frac{1}{M} \sum_{i \in \left\{ P_{Ti} \geq -140 \text{ dBm} / \text{Hz} \right\}} |P_{Ri} - P_{Ti}|$$

$$\text{ME}_{\text{noise } X} = \frac{1}{M} \sum_{i \in \left\{ P_{Ti} \geq -140 \text{ dBm} / \text{Hz} \right\}} (P_{Ri} - P_{Ti})$$

[positive error = too much noise power]

$P_{Ri}$  = power sample, in dBm/Hz, of the generated noise X  
 $P_{Ti}$  = power sample, in dBm/Hz, of the theoretical noise X

The index “i” belongs to a set defined by the points necessary to measure the noise power in steps of 10 kHz or less and taking into account only those points for which  $P_{Ti} \geq -140$  dBm/Hz.

N is the number of elements in the above set.

#### 4.1.2.1. Noise Impairment Accuracy

All noise impairments used in this specification shall comply with the following specifications. The theoretical noise level shall have a Gaussian amplitude distribution to 5 sigma.

The noise generator shall be compensated such that the absolute value of ME is minimized while maintaining an MAE less than 0.5 dB.

Note: For noise calibration, there is measurement uncertainty that can not be compensated for, consisting of the following contributions:

- absolute amplitude accuracy, vertical linearity and frequency response of the measurement equipment used;
- tolerance of the calibration impedance.

#### 4.1.3. 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 shall be contained within the compensation process described above in section 4.1.1 (Loop Simulators).

## 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[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.

### 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%.

Table 5.4.1: Temperature and Humidity

<i>Parameter</i>	<i>High</i>	<i>Low</i>
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**

The listed tables 6.1.1 and 6.2.1 must be filled with the requested information before starting the tests in order to have all the information about the EUT and to have a reproducible test environment.

### **6.1. DSLAM**

Table 6.1.1: DSLAM Features (Informative)

<b>Test Item</b>	<b>Results</b>
<b>DSLAM General Information</b>	
Vendor information (product name and revision)	
HW Version	
SW Version	
Line Card Type, Version	
Industry Standards Supported	
Chipset (Vendor, HW and Firmware)	
<b>ADSL Characteristics</b>	
supported max rates - downstream	
supported max rates - upstream	
possible coding options	
Used duplex procedure (FDD, EC)	
frequency usage (bin allocation) downstream	
allowed usage Upstream bins (option below #33)	
Support of S = 1/2	
Support of framing modes	
Support of trellis	
Support of bit swap	
Support of fast path	
Support of interleaved path	
Dying Gasp detection	
Power Cut Back implemented? (yes/no)	
<b>ATM Characteristics</b>	
Maximum Number of VCCs per DSLAM port	
F5 OAM Support	
VPI/VCI Ranges	
<b>Splitter Characteristics</b>	
Vendor information	
Type ( <i>POTS, 2B1QISDN, 4B3T ISDN, ...</i> )	
HW version	



## 6.2. CPE

Table 6.2.1: CPE Features Tables (Informative)

Test Item	Results
<b>CPE General Information</b>	
vendor information (product name and revision)	
Industry Standards Supported	
HW version	
SW version	
serial number	
Modem form (interfaces)	
PCI/USB driver version	
Chipset (Vendor, HW and Firmware)	
<b>ADSL Characteristics</b>	
supported max rates - downstream	
supported max rates – upstream	
possible coding options	
used duplex procedure (FDD, EC)	
allowed frequency usage downstream	
used Upstream bins (option below #33)	
Support of S = ½	
support of framing modes	
support of trellis	
Support of bit swap	
Support of fast path	
latency channel supported (fast, interleaved, max. interleaver depth)	
Power Cut Back implemented? (yes/no)	
dying gasp (yes/no)	
<b>ATM Characteristics</b>	
Maximum No. of VC's	
VPI/VCI Ranges	
F4/F5 OAM Loopback, optional CC, AIS, RDI	
supported Qos classes	
ILMI supported (yes/no)	
<b>Protocols</b>	
RFC 2684 IP Bridging	
RFC 2684 IP Routing	
Bridge Filter	
LLC-SNAP	
VC-MUX	
DHCP Client / Server	
NAT	
PAT	

RFC 2364 PPPoA	
RFC 2516 PPPoE	
PAP / CHAP	
Classical IP RFC 1577	
Max number of active connections	
Other supported protocols	
<b>Splitter Characteristics</b>	
Vendor information	
Type ( <i>POTS, 2B1QISDN, 4B3T ISDN,...</i> )	
HW version	

### 6.3. Expected Results

The results columns of tables 6.1.1 and 6.2.1 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 8: high-impedance couplings may be integrated in noise sources, and high impedance is defined as in G.996.1 Figure 3.*

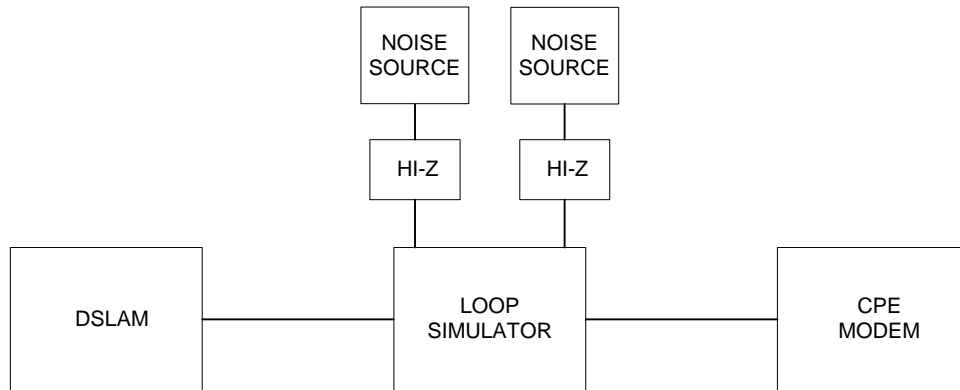


Figure 1: Test setup for loop tests for ADSL external modems

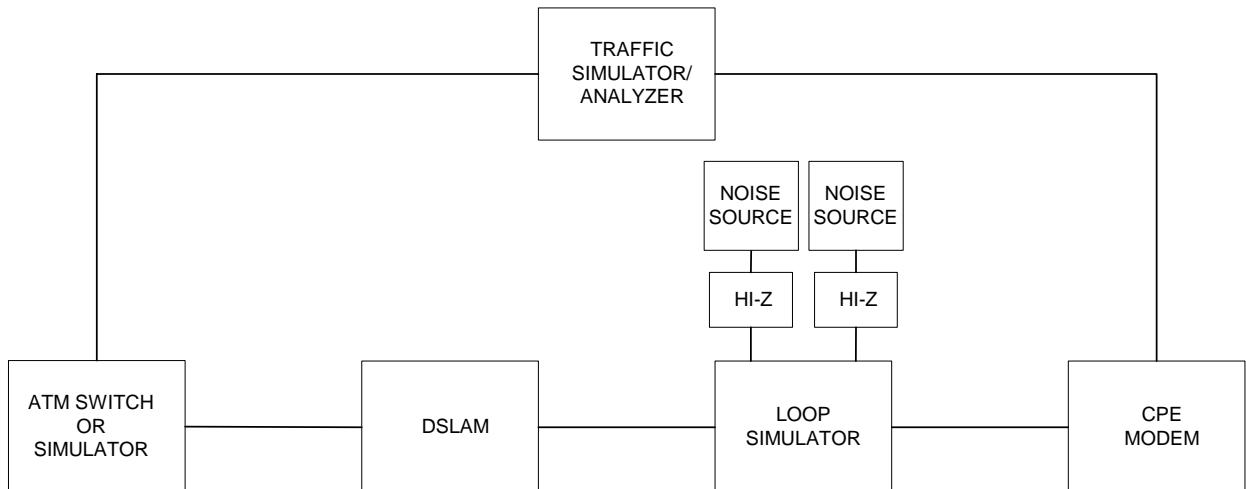


Figure 2: Test setup for throughput tests for ADSL external modems with Ethernet interfaces

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.

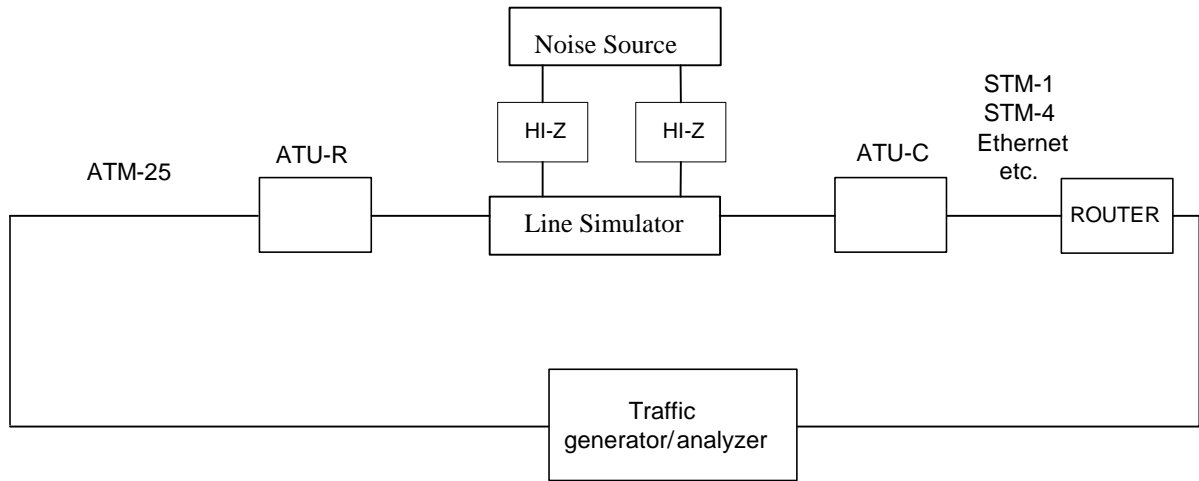


Figure 3: Test set-up for ATM-25 modems

Notes for Figure 3:

- Specify a single VPI/VCI.
- The router is optional

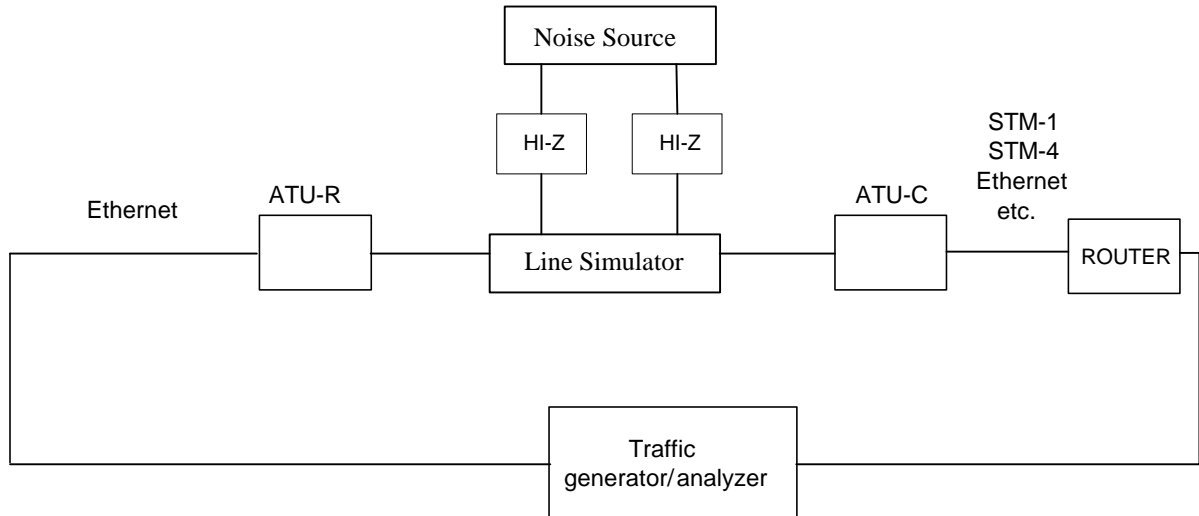


Figure 4: Test set-up for Ethernet modems

Note for Figure 4:

- The modem must be set to a bridged configuration.
- The router is optional

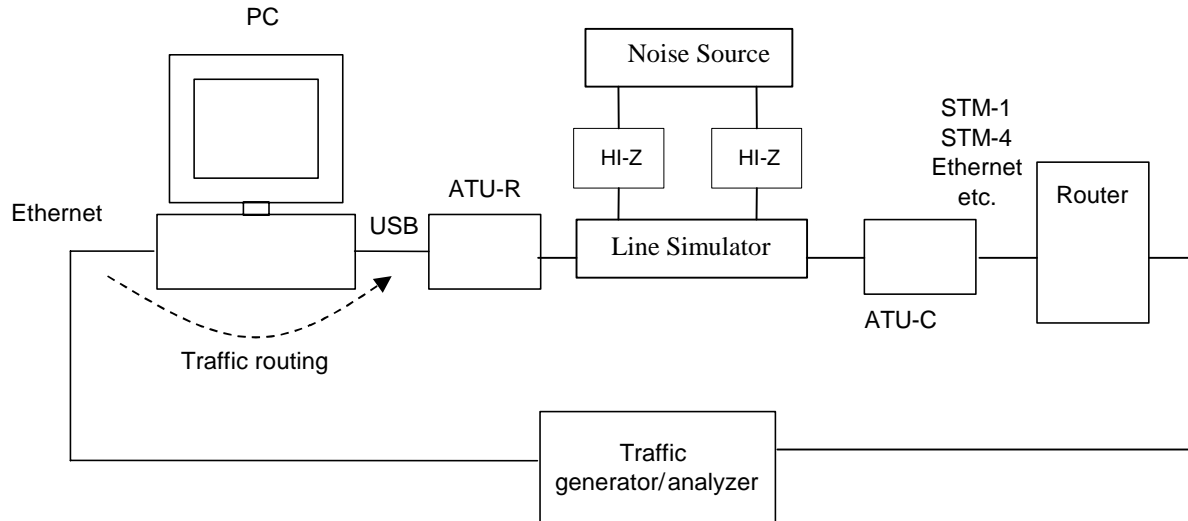


Figure 5: Test set-up for USB modems

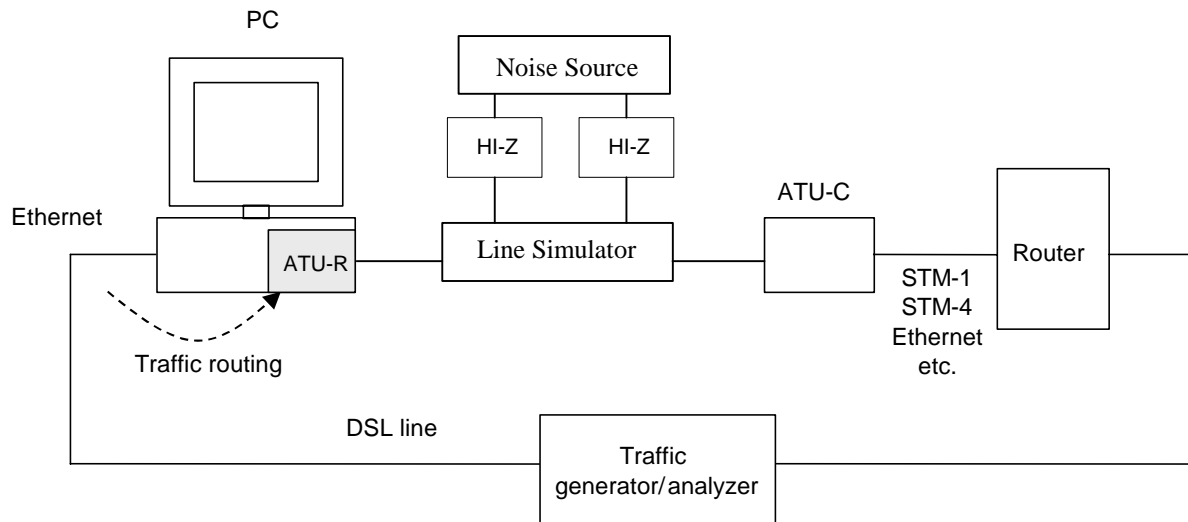


Figure 6: Test set-up for PCI (internal) modems

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.

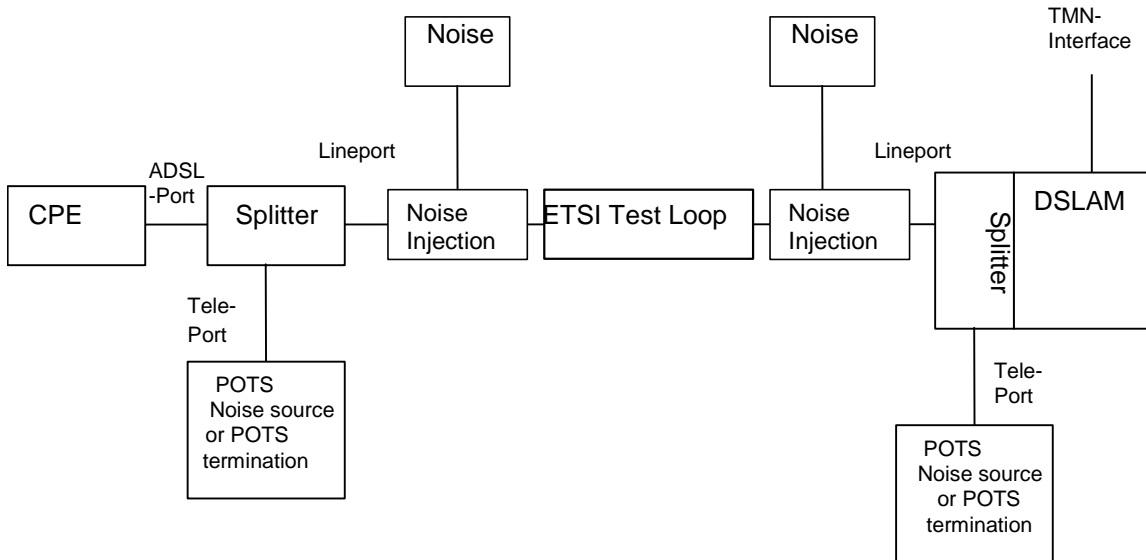


Figure 7: Test set-up for European Annex A test with splitters

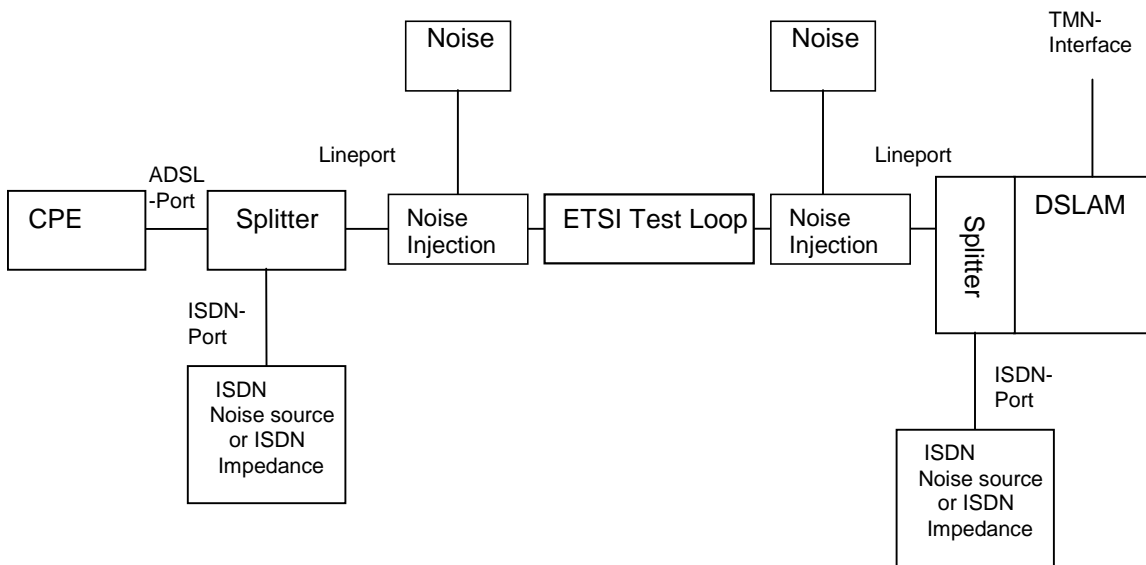


Figure 8: Test set-up for European Annex B tests with splitters

## 8. Physical Layer Test Cases

The loop simulators shall be calibrated relative to the nominal attenuation as defined in chapter 4, section 4.1.1. Noise shall be injected through a high impedance network as specified in G.996.1 [2], with simultaneous noise injection at both ends of the loop. The noise injection shall be calibrated as defined in chapter 4, section 4.1.2.

*Note: Although 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 higher.*

DSLAM Port Settings Common to All Loop Tests:

- Latency setting                      Fast path or 16ms interleaved path
- Target noise margin                6 dB
- Minimum noise margin            0 dB
- Maximum noise margin            16 dB for all rate reach tests, include fixed rate tests.
- Maximum noise margin            31dB for all other tests, e.g., margin verification tests, CRC verification tests.
- Rate negotiation                    Rate adaptive mode
- Trellis coding                        Allowed

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 [1] or ETSI TS 101 952 [8] 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.

Tests will be performed at consecutive loops lengths identified in tables of the region-specific annexes. The tests are initiated by placing the line from the DSLAM out of service (OOS). Then the loop simulator is set with the appropriate noise impairments and loop length, after which the line from the DSLAM is, placed in-service (IS). At each test point, the modem must train within **a total of 60** seconds, starting from the time that the ATU-C was placed IS. Following at least sixty seconds after the train has occurred; the bi-directional rates and noise margins shall be recorded. After it has reached its final train state, the modem shall remain in showtime for the duration of the tests.

The line from the DSLAM shall then be placed OOS, the loop simulator loop length incremented to the next test point loop length, the line from the DSLAM placed back IS, modem trained, and the data shall be recorded. This sequence shall continue until all loop lengths defined in the table are complete.

The modem shall not be power cycled, rebooted or otherwise reinitialized between loop length increments.

It is required that the modem trains in every loop reach test. A failure to train in any test will result in a failure of that section. This is required to eliminate the possibility of any modem with interoperability 'holes' from passing the requirements contained within this document.

At times, the training process may result in a "False Train" condition. This situation occurs when the modem initially indicates that it is trained but within a short time frame (< 60 seconds) goes into a retrain sequence.

If a false train occurs and the second train has not completed within the initial 60 second window, a result of zero will be recorded into the result for that test point and the whole section will be marked as a fail.

To obtain a result for each individual test, each test shall be performed once. In rate-adaptive testing, any test point that fails to meet the requirement in downstream direction by 96 kbps or less or in the upstream direction by 32 kbps 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 and the whole section will be marked as a fail.

ADSL systems shall be tested according to tests specified for the different regions and annexes. See table below for reference.

Table 8.1: Pointer to physical layer test cases

	Annex A		Annex B	Annex C
	North America	Europe	Europe	Japan
WT-085 annex A	A1	A2		
WT-085 annex B			B	
HATS-DE-101-V2				C



## 8.1. ADSL Functionality Tests

*9 individual tests – 9 must be passed*

### 8.1.1. Basic Functional Bit Swap Test

Table 8.1.1.1: Basic Functional Bit Swap Test

Test Configuration	<ol style="list-style-type: none"> <li>1. See Figure 2</li> <li>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.</li> <li>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.</li> <li>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 <math>\pm 1\%</math> 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.</li> <li>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).</li> </ol>
Method of Procedure	<ol style="list-style-type: none"> <li>1. Randomly select a value, <math>n</math>, 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 for Annex A or #96 for Annex B) or any unpopulated tones.</li> <li>2. Record and report the value of <math>n</math> used.</li> <li>3. Connect ATU-R and ATU-C as per test configuration details with the tone disturber <math>n</math> selected in step 1 applied at the ATU-R and set to –110dBm.</li> <li>4. Activate management port to record the downstream bits per tone map.</li> <li>5. Increase the tone power to –75dBm power and repeat step 4. Observe any downstream bit swap operation without retraining of the modems or change in the downstream net data rate.</li> <li>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.</li> <li>7. Randomly select a value, <math>n</math>, in the range 10 – 20 for Annex A or 40 – 50 for Annex B, ensuring that the tone <math>n</math> has assigned bits as described in the upstream bits per tone map. Avoid use of the pilot tone (#16 for Annex A) or any unpopulated tones.</li> <li>8. Record and report the value of <math>n</math> used.</li> <li>9. Connect ATU-R and ATU-C as per test configuration details with the tone disturber <math>n</math> selected in step 7 applied at the ATU-C and set to –110dBm.</li> <li>10. Activate management port to record the upstream bits per tone map.</li> <li>11. Increase the tone power to –75dBm power and repeat step 10. Observe any upstream bit swap operation without retraining of the modems or change in the upstream net data rate.</li> <li>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.</li> </ol>
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.

**8.1.2. Verification of CRC error reporting by ATU-R** (Basic CRC Functionality Test)

Table 8.1.2.1: Verification of CRC error reporting

Purpose	CRC error counts are the basis of margin verification tests; it is necessary to verify if the ATU-R accurately counts and reports CRC errors.
Method of Procedure	The following mandatory test procedure verifies CRC error reporting: <ol style="list-style-type: none"> <li>1. Configure CPE and DSLAM according to the description in the title of a margin verification test. (The target noise margin is set to 6dB.)</li> <li>2. Connect CPE and DSLAM under a loop and noise condition that will be used for margin verification tests.</li> <li>3. Force a new initialization and wait for modems to sync. Wait for 2 minutes after initialization for bitswaps to settle.</li> <li>4. Force “micro-interruption” of the loop at CPE side with duration of 1ms. (On a commonly used loop simulator, choose: Micro-interruption applied at CPE side, micro-interrupt duration = 1ms). It is expected that a micro-interruption will result in at least one reported downstream CRC error.</li> <li>5. Repeat the step above every 10 seconds, for a total test time of 120 seconds (i.e. a total of 12 micro-interruptions are issued). (On a commonly used loop simulator, choose: Signal Period = 10 sec, Test Interval = 120 sec).</li> </ol>
Test Loops	<b>North American Required Test Loops</b> <ol style="list-style-type: none"> <li>1. 13 kft with 24 HDSL</li> <li>2. 16 kft with 24 DSL</li> <li>3. 12 kft with 5 T1 adjacent</li> <li>4. 17 kft with -130 dBm/Hz AWGN</li> <li>5. 12 kft + 750 ft BT with -120 dBm/Hz AWGN</li> <li>6. 12 kft + 1000 ft BT with -140 dBm/Hz AWGN</li> <li>7. 17.5 kft + 500 ft BT with -140 dBm/Hz AWGN</li> </ol>
Expected Result	If each micro-interruption does not result in at least one reported downstream CRC error, then the ATU-R has <b>failed</b> the basic CRC functionality test. That is, at least 12 reported downstream CRC errors are expected to pass this test.

### 8.1.3. Check ADSL Diagnostic Tools

Table 8.1.3.1: 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. Verify the following results match the results on the DSLAM: <ul style="list-style-type: none"> <li>▪ upstream train rate</li> <li>▪ downstream train rate</li> <li>▪ upstream noise margin</li> <li>▪ downstream noise margin</li> <li>▪ loop attenuation for up- and downstream</li> <li>▪ upstream cell rate</li> <li>▪ downstream cell rate</li> <li>▪ DSL performance monitoring</li> </ul>
Expected Result	The results reported from the ATU-C shall match the results reported from the ATU-R.

### 8.1.4. Dying gasp

Table 8.1.4.1: Dying gasp

Test Configuration	See Figure 1
Method of Procedure	<ul style="list-style-type: none"> <li>▪ Establish an ADSL circuit between the DSLAM and the ATU-R, and then cut the power to the ATU-R (or pull the USB cable for a bus powered USB modem). This condition will simulate a power outage.</li> </ul>
Expected Result	<ul style="list-style-type: none"> <li>▪ The DSLAM will indicate a loss of power on the specific line the ATU-R was connected.</li> </ul>

### 8.1.5. Modular connector pins

Table 8.1.5.1: Modular connector pins

Test Configuration	See Figure 1
Method of Procedure	<ul style="list-style-type: none"> <li>▪ Verify that ADSL signal is connected to pins 3 and 4 of RJ-14 connector.</li> </ul>
Expected Result	<ul style="list-style-type: none"> <li>▪ ATU-R is connected via pins 3 and 4.</li> </ul>

### 8.1.6. Ethernet Connector Pinout

Table 8.1.6.1: Ethernet Connector Pinout

Test Configuration	See Figure 1
Method of Procedure	<ul style="list-style-type: none"> <li>▪ Verify Ethernet connector pinout is such that a straight through cable is used between computer and modem.</li> </ul>
Expected Result	<ul style="list-style-type: none"> <li>▪ ATU-R Ethernet port is configured for straight through connection to the computer.</li> </ul>

### 8.1.7. Upstream Power Cutback

Table 8.1.7.1: Upstream Power Cutback

Test Configuration	See Figure 1 <ul style="list-style-type: none"> <li>▪ Configure a DSLAM port for an adaptive data rate, with a maximum data rate of 256 kbps upstream. Use the fast mode. Set the maximum noise margin to 12 dB. Initialize a modem on a zero-length loop. Connect ATU-R and ATU-C with a stable connection at 0ft 26AWG or 0 km ETSI-1 with -140dBm/Hz AWGN noise added at both the ATU-C and ATU-R ends.</li> </ul>
Method of Procedure	<ul style="list-style-type: none"> <li>▪ Query the management system to obtain the upstream power.</li> </ul>
Expected Result	<ul style="list-style-type: none"> <li>▪ The reported value shall not exceed +2 dBm.</li> </ul>

### 8.1.8. ATU-R Register Reporting via EOC

Table 8.1.8.1: ATU-R Register Reporting via EOC

Test Configuration	See Figure 1
Method of Procedure	<ol style="list-style-type: none"> <li>1. Set up a bi-directional connection on a known VPI/VCI, e.g., VP=1 and VC=32</li> <li>2. Initiate an Element Management Information Request from the DSLAM to the modem for the following registers:</li> <li>3. "ATU-R vendor ID" (Register #0)</li> <li>4. "ATU-R version number minus one" (Register #1)</li> <li>5. "ATU-R serial number" (Register #2)</li> <li>6. Read out the information provided by the ATU-R.</li> </ol>
Expected Result	The information as provided by the ATU-R shall be as specified in ITU-T G.992.1. section 9.4 [1] (defined in ITU-T G.997.1 section 7.4.4.[3])

### 8.1.9. Request Downstream Power Cutback

Table 8.1.9.1: Request Downstream Power Cutback

Test Configuration	See Figure 4
Method of Procedure	<ol style="list-style-type: none"> <li>1. Configure the Line Simulator for a Null loop</li> <li>2. Apply white noise at a level of -140 dBm/Hz</li> <li>3. Provision the Maximum Noise Margin to 10 dB</li> <li>4. Provision the Maximum Downstream Data Rate to 1.472 Mb/s</li> <li>5. Provision the Maximum Upstream Data Rate to 256 kb/s</li> <li>6. Set up a bi-directional connection on a known VPI/VCI</li> <li>7. Query the management system (or the DSLAM directly) for the total downstream power</li> </ol>
Expected Result	The total downstream power shall be 0 dBm or less.

*Note: This is an equipment compliance test only. Service providers are free to set the operating parameters affecting power cutback based on the nature of their services and their network operations.*

## 8.2. Sudden Application of RFI

**Purpose:** A test that more closely replicates the very rapid increases in amplitude of RFI that occur on real circuits. When the RFI is applied it is expected the bits will be swapped away from the tone affected by the RFI signal.

*Note: This test is designed to be a stress test that goes beyond the functional test of section 8.1.1. Though the used signal has some similarity to RFI signals that can be found in the field, the user of this test shall bear in mind that real narrow band interference arising in the copper plant may significantly differ with respect to its time and frequency statistical behavior.*

Table 8.2.1: Sudden Application of RFI

Test Configuration	<ol style="list-style-type: none"> <li>1. See Figure 1</li> <li>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.</li> <li>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.</li> <li>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 <math>\pm 1\%</math> 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.</li> </ol>
Method of Procedure	<ol style="list-style-type: none"> <li>1. Randomly select an integer 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 for Annex A or #96 for Annex B) or any unpopulated tones.</li> <li>2. Record and report the value of n used.</li> <li>3. Connect the ATU-R and ATU-C as per test configuration details. The frequency of the interfering tone shall be set to <math>n \times 4.3125</math> kHz. The power of the interfering tone shall be -110 dBm or less.</li> <li>4. Activate the management port to record the downstream bits per tone map.</li> <li>5. Increase the power of the interfering tone to -50 dBm.</li> <li>6. Observe any downstream bit swap operation without retraining of the modems or change in the downstream net data rate. After 2 minutes verify the payload or CRC errors have stopped. (There may be some initial errors seen when the signal is first inserted on the line.)</li> <li>7. Randomly select an integer value, n, in the range 10 – 20 for Annex A or 40 – 50 for Annex B, ensuring that the tone n has assigned bits as described in the upstream bits per tone map. Avoid use of the pilot tone (#16 for Annex A) or any unpopulated tones.</li> <li>8. Record and report the value of n used.</li> <li>9. Connect the ATU-R and ATU-C as per test configuration details. The frequency of the interfering tone shall be set to <math>n \times 4.3125</math> kHz. The power of the interfering tone shall be -110 dBm or less.</li> <li>10. Activate the management port to record the upstream bits per tone map.</li> <li>11. Increase the tone power to -50dBm.</li> <li>12. Observe any upstream bit swap operation without retraining of the modems or change in the upstream net data rate. After 2 minutes verify the payload or CRC errors have stopped. (There may be some initial errors seen when the signal is first inserted on the line.)</li> </ol>
Expected Result	The bit swap protocol re-deploys the allocation of bits among the sub-carriers with no retrain of the modems and the modems are error free ( $BER < 1E-7$ ) after 2 minutes.

### 8.3. DSL Noise Spikes/Surges Tests

The purpose of these tests is to verify that the xDSL modem will return to normal functionality, after being submitted to strong and sudden spikes or surges of noise on the line. The data passing through the modem is allowed to have errors temporarily. The errors shall be recorded, but there is no limit on the amount of errors in the expected result. The recorded errors shall be the sum of upstream and downstream errors. The modem is even allowed to retrain, which shall be recorded also. Both the ATU-R and ATU-C shall be stressed during this test.

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

Table 8.3.1: DSL Noise Spikes/Surges Tests

Test Configuration	<ul style="list-style-type: none"> <li>• The test configuration shall be as shown in figures 3 to 8 in Section 7.</li> <li>• As this is a physical layer test, the CPE can be set up for RFC 2684<sup>2</sup> bridging/routing, or PPP bridging/routing, the DSLAM should be setup with MAX DN/MAX UP in fast mode.</li> <li>• Set up the loop simulators for a MID-CSA #6 loop (26 AWG at 6000 feet) or ETSI loop #1 1800 m.</li> </ul>
Method of Procedure	<ol style="list-style-type: none"> <li>1. Set CO side impairments to: <ul style="list-style-type: none"> <li>• -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.</li> <li>• Continuously running</li> </ul> </li> <li>2. Allow the CPE and DSLAM to train.</li> <li>3. Do a “clear counters” command on the DSLAM, if available.</li> <li>4. Note the margins on both ends of the connection.</li> <li>5. Verify there are no CRC errors.</li> <li>6. Verify that traffic is being transmitted and received by the traffic generator/analyzer.</li> <li>7. 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.</li> <li>8. Turn on the CPE side impairments for one second.</li> <li>9. 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.</li> <li>10. 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.</li> <li>11. Also verify that no other abnormal conditions appear on the line; <i>e.g.</i>, rise in error ratios, rise in CRCs.</li> <li>12. Record the results in the Table 8.3.2.</li> <li>13. Repeat steps 8 – 13 increasing the duration of the noise spike by one second until the last noise spike spans 10 seconds. If the CPE retrains at any time verify that the CPE syncs with the DSLAM within 60 seconds and the traffic resumes as normal.</li> </ol>
Expected Result	The xDSL modem shall recover (potentially with retraining occasionally), irrespective of the spikes or surges of noise that hit the DSL line. Neither the ability to train nor the ability to pass traffic at any OSI layer shall be impacted by a single spike or surge or multiple spikes or surges.

Note: Errors shall be counted during and after noise is applied. Errors shall be recorded only in the case of no retrain.

Table 8.3.2: DSL Noise Spikes/Surges Tests

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									

**8.4. Stress Test**

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

*1 individual test – 1 must be passed*

Table 8.4.1: Stress Test

Test Configuration	<ul style="list-style-type: none"> <li>The test configuration shall be as shown in figures 3 to 8 in Section 7.</li> <li>The CPE may be set up for RFC 2684 bridging/routing, or PPP bridging/routing, the DSLAM should be setup to train in Rate Adaptive at Startup mode at Maximum Rate down/up in fast mode.</li> <li>Set up the loop simulators for a 26 AWG at 12000 feet or ETSI loop#1 at 3600m. (On this loop, the modems are expected to train without excess margin).</li> <li>Inject -130 dBm/Hz white noise disturber at both ends of the loop.</li> </ul>
Method of Procedure	<ol style="list-style-type: none"> <li>Train the CPE with the DSLAM.</li> <li>Wait for 1 minute after initialization.</li> <li>Check reported margin and document as initial_reported_margin.</li> <li>Increase the noise level by initial_reported_margin - 1 dB.</li> <li>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).</li> <li>Run one over night BER test (8 hour minimum).</li> </ol>
Expected Result	<ul style="list-style-type: none"> <li>The connection between the CPE shall not lose sync with the DSLAM at any time during the overnight test. Any retrain will constitute a failure for this section.</li> <li>The BER shall be less than 1.5e-7 for the entire test.</li> </ul>

Note: The Bit Error Rate Testing (BERT) will be approximated using the CRC error counts as defined in section A.1.1, Table A.1.1.1.

### 8.5. Electrical Compatibility Tests

4 individual tests – 4 must be passed

To perform the tests described in sections 8.5.3 and 8.5.4 there are two test modes that should be available in the device under test: "Online Quiet and Continuously Sending." If the two test modes are not available, other means must be used to verify the expected results.

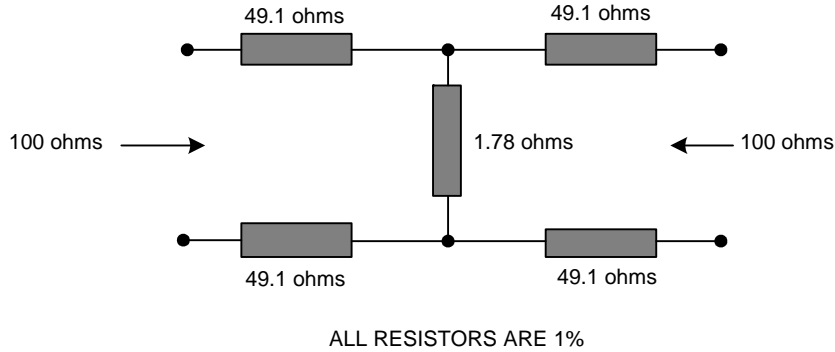


Figure 9: 40 dB attenuator for tests 8.5.1 and 8.5.2

#### 8.5.1. Analog Front End Power

Table 8.5.1.1: Analog Front End Power

Test Configuration	DSLAM connected to CPE through a 40 dB flat attenuator, with 100 Ohms impedance towards DSLAM and CPE. See Figure 9.
Method of Procedure	<ol style="list-style-type: none"> <li>1. Connect Modem to test setup.</li> <li>2. Configure Modem for Maximum Data Rate down/up.</li> <li>3. Train modem.</li> <li>4. Measure the total power generated into 100 Ohms over the signal passband defined in G.992.1 [1], averaged over a measurement period of at least 2 seconds.</li> </ol>
Expected Result	Transmit Power as measured on the U-interface (line interface) falls within the limits specified in: <ul style="list-style-type: none"> <li>• Annex A → ITU-T G.992.1 Annex A [1]</li> <li>• Annex B → ETSI TS 101 388 [7] resp. ITU-T G.992.1 Annex B [1]</li> </ul>

#### 8.5.2. PSD Measurement

Table 8.5.2.1: PSD Measurement

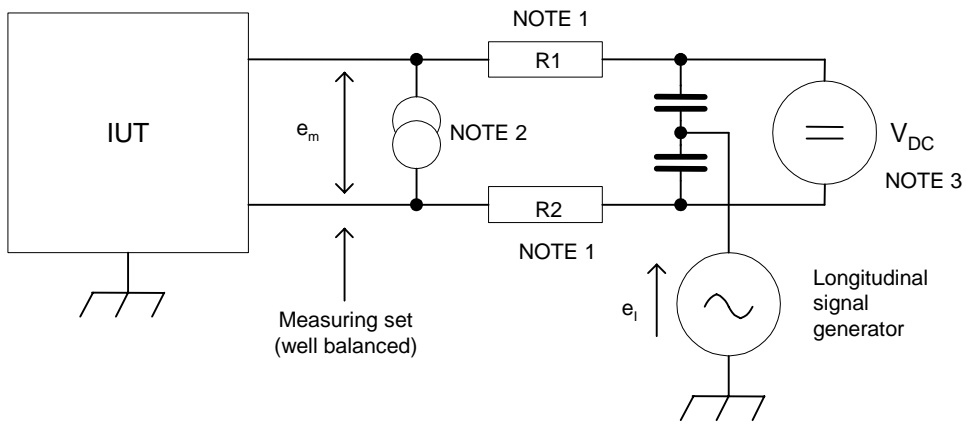
Test Configuration	DSLAM connected to CPE through a 40 dB flat attenuator, with 100 Ohms impedance towards DSLAM and CPE. See Figure 9.
Method of Procedure	<ol style="list-style-type: none"> <li>1. Connect Modem to test setup.</li> <li>2. Configure Modem for Maximum Data Rate down/up.</li> <li>3. Train modem.</li> <li>4. Measure the total power generated into 100 Ohms over the signal passband defined in G.992.1 [1], averaged over a measurement period of at least 2 seconds.</li> </ol>
Expected Result	Each PSD falls within the limits specified in: <ul style="list-style-type: none"> <li>▪ Annex A =&gt; ITU-T G.992.1 Annex A [1]</li> <li>▪ Annex B =&gt; ETSI TS 101 388 [7] resp. ITU-T G.992.1 Annex B [1].</li> </ul>



8.5.3. Longitudinal Balance – LCL

Table 8.5.3.1: Longitudinal Balance - LCL

Test Configuration	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). See figure 10
Method of Procedure	<ol style="list-style-type: none"> <li>1. Set up test according to figure 10</li> <li>2. Activate test mode “online quiet.”</li> <li>3. Measure Longitudinal Conversion Loss as specified in G.117 [6] in the frequency range: <ul style="list-style-type: none"> <li>▪ Annex A: 25 kHz up to 1104 kHz</li> <li>▪ Annex B: 120 kHz up to 1104 kHz</li> </ul> </li> </ol>
Expected Result	Balance $\geq$ 40 dB



- NOTE 1: These resistors have to be matched:  $R1=R2=100/2\Omega$  and  $R1/R2=1 \pm 0.1\%$ .
- 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  $100/2\Omega$  in series with a capacitance of  $0.33\mu F$ .

Figure 10: Measurement Method for Longitudinal Conversion Loss (Sample Setup)

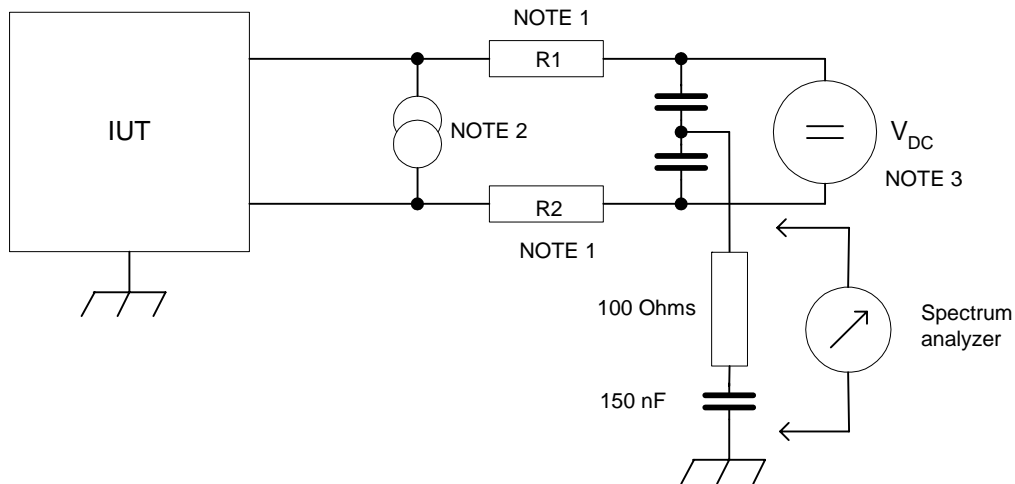
Note: The longitudinal conversion loss is given by:  $LCL = 20 \log (e_i/e_m)$  [dB]:

- Where  $e_i$  is the applied longitudinal voltage referenced to the building ground and
- $e_m$  is the resultant metallic voltage appearing across the line interface of the device under test (terminated by  $100\Omega$ ).

8.5.4. Longitudinal Balance – LOV

Table 8.5.4.1: Longitudinal Balance - LOV

Test Configuration	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. See figure 11
Method of Procedure	<ol style="list-style-type: none"> <li>1. Set up test according to figure 11</li> <li>2. Activate test mode “continuously sending.”</li> <li>3. Measure Longitudinal Output Voltage as specified in G.117 [6].</li> </ol>
Expected Result	<p>The observed LOV shall have an rms voltage of below <math>-46</math> dBV, measured in a power bandwidth of <b>10 kHz</b>, centered over any frequency in the range from <b>5.1 kHz</b> to <math>f_{max}</math>, and averaged in any one second period. Compliance with this limitation is required with a longitudinal terminating impedance having value <math>Z_L(\omega) = R_L + 1/(j\omega C_L)</math>.</p> <ul style="list-style-type: none"> <li>▪ <math>F_{max} = 415</math> kHz for CPE test (upstream)</li> <li>▪ <math>F_{max} = 1825</math> kHz for CO test (downstream)</li> <li>▪ <math>R_L = 100</math> Ohms</li> <li>▪ <math>C_L = 150</math> nF</li> </ul>



NOTE 1: These resistors have to be matched:  $R1=R2=R_r/2$  and  $R1/R2=1 \pm 0.1\%$ .  
 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 11: Measurement Method for Longitudinal Output Voltage (LOV)

## 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)

#### 9.1.1. Loopback at ATU-R

Table 9.1.1.1: Loopback at ATU-R

Test Configuration	<ul style="list-style-type: none"> <li>▪ See Figure 2</li> <li>▪ 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</li> </ul>
Method of Procedure	<ol style="list-style-type: none"> <li>1. 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.</li> <li>2. The ATM Cells from generator/analyzer (bit error rate tester or BERT) are filled with an S-PRBS9 or O.191 test cell sequence, or a RFC 2544 [14]-formatted frame sequence.</li> <li>3. 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).</li> </ol>
Expected Result	<ul style="list-style-type: none"> <li>▪ The ATU-R is looped back, BER is less than <math>10^{-7}</math> when using S-PRBS9, or CER is less than <math>3.84e^{-5}</math> if using either O.191 test cells or the RFC 2544 [14] test methodology.</li> </ul>

#### 9.1.2. Maximum number of VC's

Table 9.1.2.1: Maximum number of VC's

Test Configuration	<ul style="list-style-type: none"> <li>▪ See Figure 2</li> <li>▪ 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</li> </ul>
Method of Procedure	<ul style="list-style-type: none"> <li>▪ 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.</li> </ul>
Expected Result	<ul style="list-style-type: none"> <li>▪ 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).</li> </ul>

#### 9.1.3. Maximum VPI/VCI Range

Table 9.1.3.1: Maximum VPI/VCI Range

Test Configuration	<ul style="list-style-type: none"> <li>▪ See Figure 2</li> <li>▪ 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</li> </ul>
Method of Procedure	<ul style="list-style-type: none"> <li>▪ Configure VPI/VCI just within the published range, and just outside the published range.</li> </ul>
Expected Result	<ul style="list-style-type: none"> <li>▪ Capability to choose VPI/VCI falls within the intersection of the published ranges for the DSLAM or and the ATU-R.</li> </ul>

#### 9.1.4. Default VPI/VCI

Table 9.1.4.1: Default VPI/VCI

Test Configuration	<ul style="list-style-type: none"> <li>▪ See Figure 2</li> <li>▪ 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</li> </ul>
Method of Procedure	<ul style="list-style-type: none"> <li>▪ Having the ATU-R/CPE in its default configuration, cross connect a circuit in this default VPI/VCI and pass cells over the circuit.</li> </ul>
Expected Result	<ul style="list-style-type: none"> <li>▪ Cells must be passed across the circuit using the default VPI/VCI value from the CPE General Information table.</li> </ul>

#### 9.1.5. QoS Support for CBR / UBR Traffic (test if implemented)

Table 9.1.5.1: QOS support for CBR / UBR Traffic (if implemented)

Test Configuration	<ul style="list-style-type: none"> <li>▪ See Figure 2.</li> <li>▪ 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).</li> <li>▪ The loop simulator may be bypassed.</li> <li>▪ The noise generator may be removed.</li> </ul>
Method of Procedure	<ul style="list-style-type: none"> <li>▪ Only run this test if CBR functionality is implemented on both the DSLAM and ATU-R/CPE. Configure the test network as follows: <ol style="list-style-type: none"> <li>1. 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.</li> <li>2. 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.</li> <li>3. Configure both channels on the Traffic Simulator / Analyzer for O.191 or RFC 2544 [14] generation and analysis.</li> <li>4. Configure the ATU-R to loop back traffic.</li> </ol> </li> </ul>
Expected Result	<ul style="list-style-type: none"> <li>▪ O.191 or RFC 2544 [14] analysis shall show that only UBR traffic is discarded and that all of the CBR traffic is delivered, <u>if UBR and CBR are implemented.</u></li> </ul>

**9.1.6. QoS Support for rtVBR / UBR Traffic** (test if implemented)

Table 9.1.6.1: QoS Support for rtVBR / UBR Traffic (if implemented)

Test Configuration	<ul style="list-style-type: none"> <li>▪ See Figure 2.</li> <li>▪ 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).</li> <li>▪ The loop simulator may be bypassed.</li> <li>▪ The noise generator may be removed.</li> </ul>
Method of Procedure	<p><u>Only run this test if rtVBR functionality is implemented on both the DSLAM and ATU-R/CPE.</u></p> <p>Configure the test network as follows:</p> <ol style="list-style-type: none"> <li>1. 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.</li> <li>2. 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.</li> <li>3. Configure both channels on the Traffic Simulator / Analyzer for O.191 or RFC 2544 [14] generation and analysis.</li> <li>4. Configure the ATU-R to loop back traffic.</li> </ol>
Expected Result	<ul style="list-style-type: none"> <li>▪ O.191 or RFC 2544 [14] 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.</li> </ul>

### 9.1.7. QoS Support for nrtVBR / UBR Traffic (test if implemented)

Table 9.1.7.1: QoS Support for nrtVBR / UBR Traffic (if implemented)

Test Configuration	<ul style="list-style-type: none"> <li>▪ See Figure 2.</li> <li>▪ 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).</li> <li>▪ The loop simulator may be bypassed.</li> <li>▪ The noise generator may be removed.</li> </ul>
Method of Procedure	<p><u>Only run this test if rtVBR functionality is implemented on both the DSLAM and ATU-R/CPE.</u></p> <p>Configure the test network as follows:</p> <ol style="list-style-type: none"> <li>1. 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.</li> <li>2. 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.</li> <li>3. Configure both channels on the Traffic Simulator / Analyzer for O.191 or RFC 2544 [14] generation and analysis.</li> <li>4. Configure the ATU-R to loop back traffic.</li> </ol>
Expected Result	<ul style="list-style-type: none"> <li>▪ O.191 or RFC 2544 [14] analysis shall show that some UBR and some nrtVBR cells are delivered, <u>if nrtVBR and UBR are implemented.</u></li> </ul>

### 9.1.8. F5 OAM Support

Table 9.1.8.1: F5 OAM Support

Test Configuration	<ul style="list-style-type: none"> <li>▪ See Figure 2.</li> <li>▪ 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).</li> <li>▪ The loop simulator may be bypassed.</li> <li>▪ The noise generator may be removed.</li> </ul>
Method of Procedure	<ol style="list-style-type: none"> <li>1. Configure the test network for a bi-directional connection on a known VPI/VCI (e.g., VP=0 and VC=35).</li> <li>2. Send an F5 OAM segment loopback cell from the network to the CPE.</li> </ol>
Expected Result	<ul style="list-style-type: none"> <li>▪ Confirm that a response cell is received from the network.</li> </ul>

**9.2. Layer 3 Ethernet or USB Interface RFC 2684 [10] 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[4]/G.992.1 [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 [13], 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.

The Packet Throughput results in the following tables includes trailer overhead for AAL5 CPCS-PDU.

*42 individual tests – 42 tests must be passed*

Table 9.2.1.1: Packet Throughput Test

Methodology	<p><i>The throughput test specified here satisfies the terminology criteria of RFC 1242 [13] and the test methodology specified in RFC 2544 [14] [14]. From RFC 1242 [13], throughput is “the maximum rate at which none of the offered frames are dropped by the device.” From RFC 2544 [14], 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 is 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 [13] Section 3.5).</i></p>
Test Configuration	<ul style="list-style-type: none"> <li>• The configuration shall be as shown in figures 3 to 6.</li> <li>• 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) with white noise (–140 dBm/Hz) at injected at <b>both</b> the upstream and downstream ends of the loop.</li> </ul>

Method of Procedure	<ol style="list-style-type: none"> <li>1. Provision the DSLAM at the maximum bit rates as shown in the throughput tables 9.2.1.2 – 9.2.1.4.</li> <li>2. Set the CPE modem for bridged mode with LLC encapsulation.</li> <li>3. Let the CPE train.</li> <li>4. Record the modem up and down stream train rates and noise margins in the tables below.</li> <li>5. Setup traffic generator/analyzer to send frames in one direction with destination MAC address equal to the unicast source MAC address of frames sent in the opposite direction.</li> <li>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.</li> <li>7. Record analyzer throughput rate results as frames per second.</li> <li>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 7 and 8. If the count of received frames is less than the count of offered frames, decrease the rate of the offered stream and repeat steps 7 and 8.</li> <li>9. Divide the analyzer frames per second by the maximum FPS for the connect rate and frame size.</li> <li>10. Record as percentage of maximum connect rate.</li> </ol>
Expected Result	<p>Based on the throughput tables: 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</p>

Table 9.2.1.2: Throughput Test Results: Connect Rates DS: 384 kbps 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				

Table 9.2.1.3: Throughput Test Results: Connect Rates DS: 1536 kbps 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				



Table 9.2.1.4: Throughput Test Results: Connect Rates DS: 8000 kbps 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				

### 9.2.2. Packet Latency Tests

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

*10 individual tests – 10 must be passed*

This test takes two forms. First, a test (table 9.2.2.1) will be done at a specified train rate and various frame sizes. Second, a test (table 9.2.2.3) will be performed at a single frame size and various train rates.

Methodology: Latency is tested as defined in RFC 1242 [13].

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.)

Table 9.2.2.1: Latency Test – Single Train Rate with Multiple Frame Sizes

Test Configuration	<ul style="list-style-type: none"> <li>• Test configuration shall be as shown in figures 4 to 6.</li> <li>• 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) with white noise (–140 dBm/Hz) at injected at <b>both</b> the upstream and downstream ends of the loop.</li> <li>• Set DSLAM rate to 384/128 kbps down/up.</li> </ul>
Method of Procedure	<ol style="list-style-type: none"> <li>1. Set CPE to bridge mode.</li> <li>2. Let the CPE train.</li> <li>3. Setup the traffic generator/analyzer to perform a latency test for the selected frame length.</li> <li>4. Record traffic generator/analyzer latency test results in table 9.2.2.2.</li> <li>5. Repeat for the 7 different frame lengths as shown in table below.</li> <li>6. Reset equipment.</li> </ol>
Expected Result	Round trip average latency times shall be less than 255 ms.

Table 9.2.2.2: Latency Test Results with Multiple Frame Sizes

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

Table 9.2.2.3: Latency Test – Single Frame Size with Multiple Train Rates

Test Configuration	<ul style="list-style-type: none"> <li>• Test configuration shall be as shown in figures 4 to 6.</li> <li>• 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) with white noise (–140 dBm/Hz) at injected at <b>both</b> the upstream and downstream ends of the loop.</li> <li>• Frame size shall be 1280 bytes.</li> </ul>
Method of Procedure	<ol style="list-style-type: none"> <li>1. Set CPE to bridge mode.</li> <li>2. Train at specified bit rate defined in table 9.2.2.4.</li> <li>3. Setup the traffic generator/analyzer to perform a latency test for the selected train rate.</li> <li>4. Record traffic generator/analyzer latency test results.</li> <li>5. Repeat for the different train rates as specified in the table 9.2.2.4.</li> <li>6. Reset equipment.</li> </ol>
Expected Result	Round trip average latency times shall be less than 255 ms.

Table 9.2.2.4: Latency Test Results with Multiple Train Rates

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

### 9.3. RFC 2516 [11] PPPoE End-to-End Connectivity Test

*1 individual test – 1 must be passed*

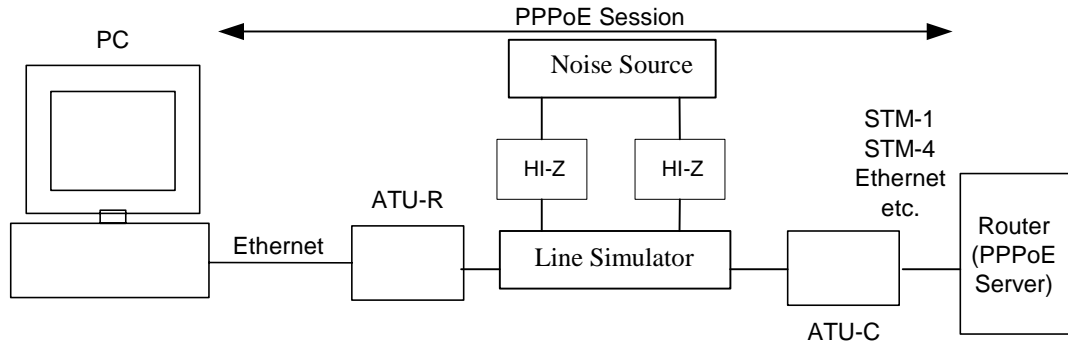


Figure 12: Test setup for PPPoE testing with Ethernet modems

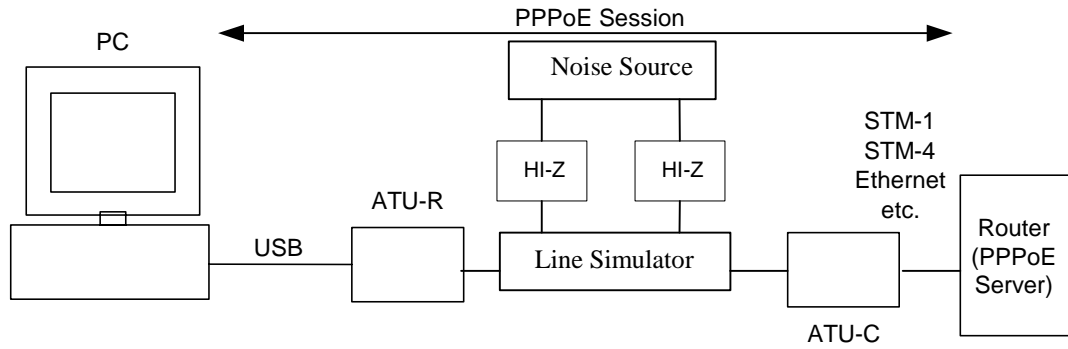


Figure 13: Test setup for PPPoE testing with USB modems

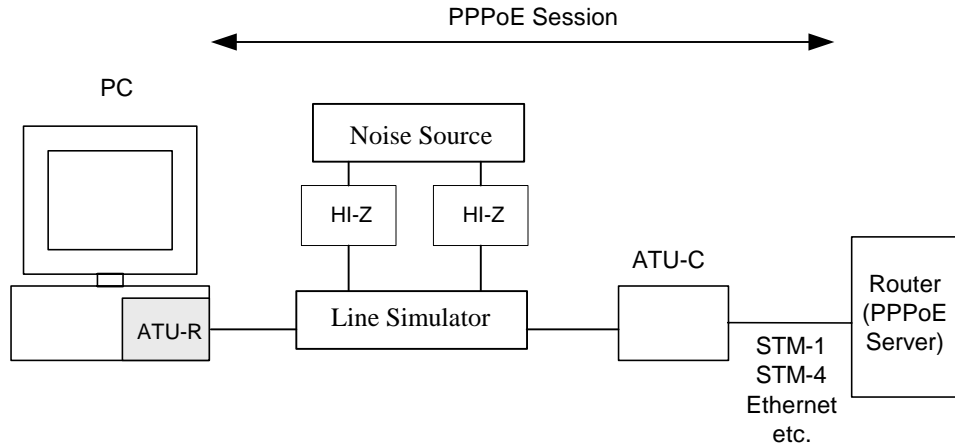


Figure 14: Test setup for PPPoE testing with PCI modems

**9.3.1. PPPoE**

Table 9.3.1.1: PPPoE

Test Configuration	<ul style="list-style-type: none"> <li>▪ See Figure 12, 13 or 14 (as applicable)</li> </ul>
Method of Procedure	<ol style="list-style-type: none"> <li>1. Terminate PPPoE session between the computer and the router.</li> <li>2. Verify connectivity by passing traffic over this PPPoE session.</li> <li>3. Tear down the PPPoE session.</li> </ol>
Expected Result	<ul style="list-style-type: none"> <li>▪ Transmitted packets are received.</li> <li>▪ The PPPoE session has been torn down correctly.</li> </ul>

**9.4. RFC 2364 [12] PPPoA End-to-End Connectivity Test**

*1 individual test – 1 must be passed*

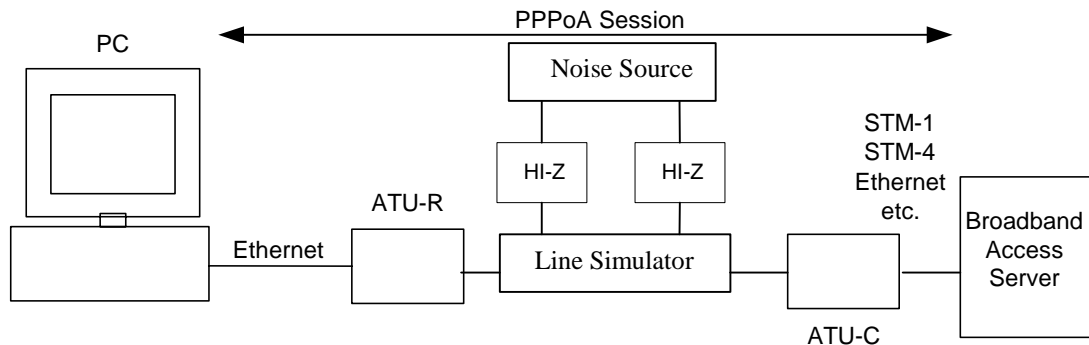


Figure 15: Test setup for PPPoA testing with Ethernet modems

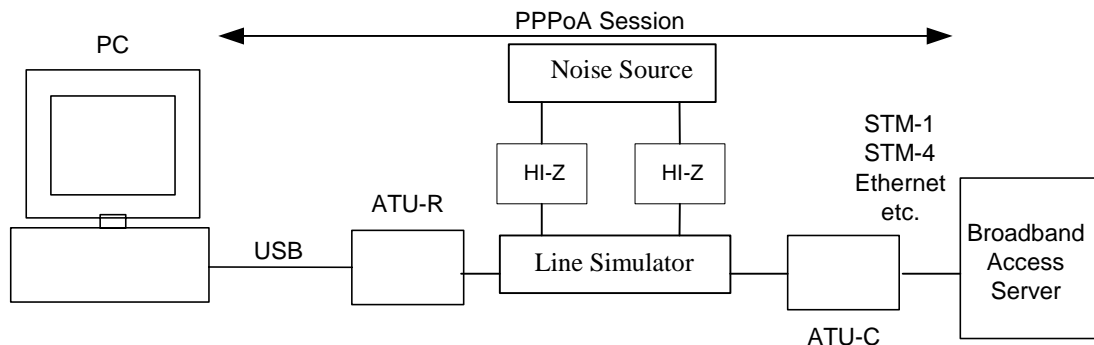


Figure 16: Test setup for PPPoA testing with USB modems

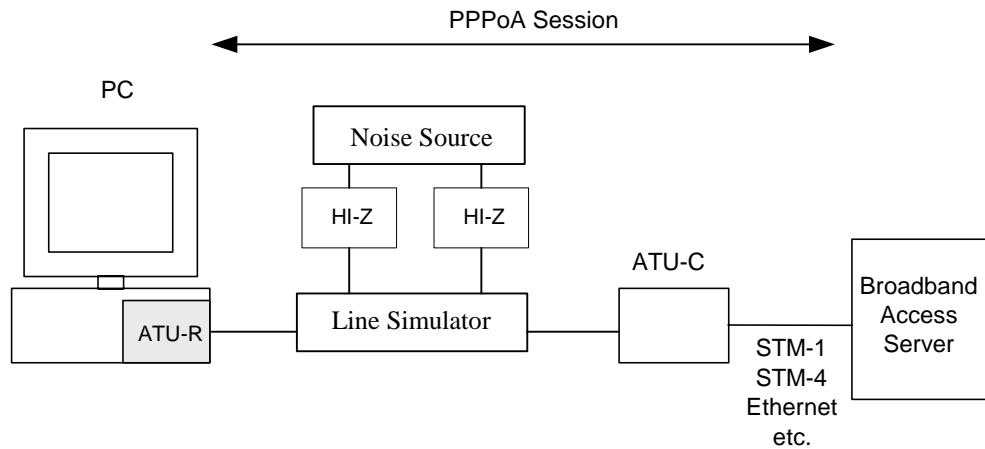


Figure 17: Test setup for PPPoA testing with PCI modems

9.4.1. PPPoA

Table 9.4.1.1: PPPoA

Test Configuration	<ul style="list-style-type: none"> <li>▪ See Figure 15, 16, or 17 (as applicable)</li> </ul>
Method of Procedure	<ol style="list-style-type: none"> <li>1. Terminate PPPoA session between the computer and the broadband access server.</li> <li>2. Verify connectivity by passing traffic over this PPPoA session.</li> <li>3. Tear down the PPPoA session.</li> </ol>
Expected Result	<ul style="list-style-type: none"> <li>▪ Transmitted packets are received.</li> <li>▪ The PPPoA session has been torn down correctly.</li> </ul>

## 9.5. RFC 2684 [10] End-to-End Connectivity Test

*1 individual test – 1 must be passed*

### 9.5.1. Verify IP Bridged

Table 9.5.1.1: Verify IP Bridged RFC 2684 [10]

Test Configuration	▪ See Figure 2, applicable to Ethernet modem only
Method of Procedure	<ol style="list-style-type: none"> <li>1. Configure the test environment including the ATU-R and the computer so that the ATU-R/CPE Ethernet port terminates a bridge section.</li> <li>2. The second termination of the bridge section should be implemented at an appropriate device within the testing environment (<i>e.g.</i>, DSLAM, PoP).</li> <li>3. Pass IP packets over the complete bridge section and verify the proper reception at the destination (<i>e.g.</i>, PoP, Host PC).</li> </ol>
Expected Result	Transmitted packets are received.

## 9.6. Usability Test

### 9.6.1. PC Re-boot

*1 individual test – 1 must be passed*

Table 9.6.1.1: 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.

### 9.6.2. Power Cycle Test

*1 individual test - 1 must be passed*

Table 9.6.2.1: Power Cycle Test

Test Configuration	See Figure 4 or 5 (no loop length, bridge tap nor noise injected)
Method of Procedure	<ol style="list-style-type: none"> <li>1. Connect Modem to test setup.</li> <li>2. Configure Modem for Maximum Data Rate down/up.</li> <li>3. Train modem.</li> <li>4. Follow procedure to establish a data link, if necessary.</li> <li>5. Send arbitrary data (verify received).</li> <li>6. Disconnect power from modem for 30 seconds.</li> <li>7. Allow modem to train.</li> <li>8. Follow procedure to re-establish the data link.</li> <li>9. Re-connect power cable.</li> <li>10. Send arbitrary data (verify received).</li> </ol>
Expected Result	Modem re-powers. Link re-covers and modem passes data.

### 9.6.3. Link Cycle Test

*1 individual test – 1 must be passed*

Table 9.6.3.1: Link Cycle Test (*Note: This test does not apply to a USB powered CPE.*)

Test Configuration	See Figure 4 or 5 (no loop length, bridge tap nor noise injected).
Method of Procedure	<ol style="list-style-type: none"> <li>1. Connect Modem to test setup.</li> <li>2. Configure Modem for Maximum Data Rate down/up.</li> <li>3. Train modem.</li> <li>4. Send arbitrary data (verify received).</li> <li>5. Disconnect link cable (Ethernet or USB) from modem for 30 seconds.</li> <li>6. Re-connect link cable.</li> <li>7. -establish data link if necessary.</li> <li>8. Send arbitrary data (verify received).</li> </ol>
Expected Result	Link re-covers and modem passes data.

### 9.6.4. Verify 10/100 Ethernet Auto-negotiation (802.3u)

Purpose: Test a CPE which supports Auto-negotiation based on IEEE 802.3 [9].

*13 individual tests -13 must be passed*

Table 9.6.4.1: Verify 10/100 Ethernet Auto-negotiation (802.3u) [9]

Test Configuration	<p>See Figure 4 (no loop length, bridge tap nor noise injected), applicable to Ethernet modem with 10/100 Mbps Auto-negotiation capability only.</p> <ul style="list-style-type: none"> <li>• The Link partner connected to the DUT must have configurable MII AN-Advertisement ( register 4 ) and Control ( register 0 ) registers or equivalent.</li> <li>• Need to be able to read from status register what type of Ethernet connection was made for each test.</li> </ul>
Method of Procedure for each test case. (9.6.4.1 – 9.6.4.13)	<ol style="list-style-type: none"> <li>1. Set the CPE MII registers to enable Auto-Negotiation.</li> <li>2. Advertise 10/100 Full and Half Duplex capabilities on the link partner to the DUT.</li> <li>3. Disconnect the Ethernet cable to the CPE.</li> <li>4. Set the AN advertisement registers as per the test requirement for the link partner (as per the test table below.)</li> <li>5. Connect the Ethernet cable and wait for the link light to illuminate.</li> <li>6. Check the status register in the CPE and compare to the pass criteria for the test.</li> <li>7. Start a bi-directional data flow across the link.</li> <li>8. Allow this to run for 1 minute. Check Ethernet stats looking for errors on each end of the link.</li> </ol>
Expected Result	No Errors shall be detected on either side of the link to pass each test. The CPE must match the pass/fail requirements for each test as listed in the Table 9.6.4.2 on the following page.

Table 9.6.4.2: Expected Results Table

Test	Link Partner Advertisement capabilities	DUT Link Status after Auto-Neg completes	Pass/Fail
9.6.4.1	10 FDX/HDX	10 FDX	Pass
9.6.4.2	10 FDX	10 FDX	Pass
9.6.4.3	10 HDX	10 HDX	Pass
9.6.4.4	100 FDX/HDX	100 FDX	Pass
9.6.4.5	100 FDX	100 FDX	Pass
9.6.4.6	100 HDX	100 HDX	Pass
9.6.4.7	10/100 FDX/HDX	100 FDX	Pass
9.6.4.8	10/100 FDX	100 FDX	Pass
9.6.4.9	10/100 HDX	100 HDX	Pass
9.6.4.10	NA 10 HDX	10 HDX	Pass
9.6.4.11	NA 10 FDX	10 HDX	Fail
9.6.4.12	NA 100 FDX	100 HDX	Fail
9.6.4.13	NA 100 HDX	100 HDX	Pass



## **Annex A Physical Layer Test Cases for systems using G.992.1 Annex A [1].**

### **A.1 North American Test set**

Listed are three known sources of variability that need to be taken into account when verifying the interoperability of a CPE and DSLAM combination.

#### 1. CPE Variability

For a modem type to be considered compliant, unit(s) submitted for compliance testing shall pass the performance requirements in this section. Taking into account the statistical variability in the manufacturing process, it is expected that the large majority of randomly-selected units will pass these requirements. (See Appendix W)

#### 2. Test Environment Variability

The rate requirements in this section take into account a 0.5dB variability in the test environment.

#### 3. Bridged Tap Noise Injection Variability

The noise injection method of the present version of the document for [CSA\_4], [ANSI\_13] and [BT] sections may lead to:

- results differing from those on real loops,
- lower repeatability of results (due to, for example, varying noise floor and impedance) from test environment to test environment even if they are compliant to this document.

The impact on the rate requirements contained herein and ways to improve test conditions are under study. A future version of this document may address this issue.

#### Note:

Modems passing this test are not necessarily meeting the spectrum compatibility as defined by T1.417 for North America, or any other similar requirement specification. Users of this document should carry on additional testing to ensure spectral compatibility before deployment.

### A.1.1 CPE Margin verification tests

Because of the significant dependency of achievable data rates on the noise margin, margin verification tests are performed across several loop and noise scenarios of this test plan to ensure that chipset vendors do not optimize modem performance for some specific test loops.

Since CRC error counts are the basis of margin verification tests, it is necessary to verify if the ATU-R accurately counts and reports CRC errors. A mandatory test procedure to verify CRC error reporting is required and defined in section 8.1.2.

The following test descriptions show the loop and noise conditions for margin verification tests. Brief explanation of Tables A1.1.1 – A1.1.5 below:

Each test (e.g. A.1.1.1) is specified by the type and level of the injected noise and by the type and length of the loop. The **title** of each test specifies the type and level of the injected noise (e.g. 24HDSL + AWGN at -140dBm/Hz).

**Column 1** of each table specifies the loop type (e.g. 26AWG) and loop length (e.g. 13kft).

**Column 2** specifies the required test time in order to observe approximately 10 CRC error events at a target BER of 1e-7. To allow for modem connections with slightly lower than the anticipated data rates, the test durations below are rounded up in increments of 5 minutes.

**Column 3** mentions the anticipated DS rate for the specified loop/noise case and asks for the insertion of the measured DS rate. The anticipated DS rate is obtained from the current WT-085 requirements or from measurements if the loop/noise scenario is not part of WT-085. (Note: The anticipated DS rates do not necessarily reflect the performance objectives for specific loop and noise conditions, which are specified in the appropriate section of loop tests.)

It is required that the achieved DS rate shall be recorded twice: first at the start of the margin verification test (see step 3 in Table A1.1.6) and also at the end of the margin verification test (see step 10 in Table A1.1.6). This helps capture a potential modem retrain and connection at lower DS rates due to the increase in injected noise level.

**Column 4** asks for the insertion of the measured DS CRC count after the injected noise level has been increased by (initial\_reported\_margin - 1) dB. Measurement of initial\_reported\_margin shall be done from the DSLAM.

**Column 5** asks for the computation of the estimated BER from the number of observed CRC error events according to Table A1.3.0. If the estimated BER < 1.5e-7, then the test PASSES, else it FAILS.

**Column 6** asks for the insertion of "PASS" or "FAIL".

Table A.1.1.1: The Equations for estimating BER

<i>Modem configuration</i>	<i>Equations for estimating BER</i>
<i>Fast path</i>	$\text{BER} = \frac{\text{Number of bit errors}}{\text{Number of transmitted bits}} \cong \frac{15 * \text{CRC\_error\_count}}{\text{data\_rate} * 1000 * \text{test\_time} * 60}$
<i>Interleaved path, high latency</i>	$\text{BER} = \frac{\text{Number of bit errors}}{\text{Number of transmitted bits}} \cong \frac{40 * \text{CRC\_error\_count}}{\text{data\_rate} * 1000 * \text{test\_time} * 60}$

A.1.1.1. 24HDSL and AWGN at -140dBm/Hz impairments. Noise injection according to section A.1.5.2. DSLAM Port settings according to section 8, using fast mode.

Table A.1.1.1.1: Margin Verification on test loop from section A.1.5.2

Loop length (kft) 26AWG	Test time (minutes)	Anticipated DS rate: <b>&gt;= 1088 kbps</b>  Achieved DS rate (test start)  Achieved DS rate (test end)	Measured DS CRC count, after injected noise level has been raised by (initial_reported_margin - 1) dB	Estimated BER, based on equations in Table A.1.1.1  If: Estimated_BER < 1.5e-7 then PASS else FAIL	Pass / Fail
13	30				

A.1.1.2. 24DSL and AWGN at -140dBm/Hz impairments. Noise injection according to section A.1.5.3. DSLAM Port settings according to section 8, using fast mode.

Table A.1.1.2.1: Margin Verification on test loop from section A.1.5.3

Loop length (kft) 26AWG	Test time (minutes)	Anticipated DS rate: <b>&gt;= 416 kbps</b>  Achieved DS rate (test start)  Achieved DS rate (test end)	Measured DS CRC count, after injected noise level has been raised by (initial_reported_margin - 1) dB	Estimated BER, based on equations in Table A.1.1.1  If: Estimated_BER < 1.5e-7 then PASS else FAIL	Pass / Fail
16	60				

A.1.1.3. 5T1 and AWGN at -140dBm/Hz impairments. Noise injection according to section A.1.5.4. DSLAM Port settings according to section 8, using fast mode.

Table A.1.1.3.1: Margin Verification on test loop from section A.1.5.4

Loop length (kft) 26AWG	Test time (minutes)	Anticipated DS rate: <b>&gt;= 864 kbps</b>  Achieved DS rate (test start)  Achieved DS rate (test end)	Measured DS CRC count, after injected noise level has been raised by (initial_reported_margin - 1) dB	Estimated BER, based on equations in Table A.1.1.1  If: Estimated_BER < 1.5e-7 then PASS else FAIL	Pass / Fail
12	30				

- A.1.1.4. AWGN at **-130 dBm/Hz** impairment. Noise injection according to section A.1.5.1 with AWGN level at **-130 dBm/Hz** (not -140dBm/Hz). The higher noise level helps ensure that the injected noise dominates the receiver noise floor at the CPE. DSLAM Port settings according to section 8, using fast mode.

Table A.1.1.4.1: Margin Verification on test loop from section A.1.5.1

Loop length (kft) 26AWG	Test time (minutes)	Anticipated DS rate: <b>&gt;= 224 kbps</b>  Achieved DS rate (test start)  Achieved DS rate (test end)	Measured DS CRC count, after injected noise level has been raised by (initial_reported_margin - 1) dB	Estimated BER, based on equations in Table A.1.1.1  If: Estimated_BER < 1.75e-7 then PASS else FAIL	Pass / Fail
17	55				

## NOTE:

Due to the low, achievable DS data rates under this loop and noise condition, the observation of 10 error events would require approximately 110 minutes (at BER ~ 1e-7). To accelerate testing, the desired number of observed error events is reduced to 5. To remain consistent with previous confidence levels of estimated BER, the range of allowed estimated BER is increased from 1.5-e7 to **1.75e-7**.

- A.1.1.5. Bridged tap loop with AWGN at **-120 dBm/Hz** impairment. Noise injection according to section A.1.9 with AWGN level at **-120 dBm/Hz** (not -140dBm/Hz). The higher noise level helps ensure that the injected noise dominates the receiver noise floor at the CPE. DSLAM Port settings according to section 8, using fast mode.

Table A.1.1.5.1: Margin Verification on bridge tap test loop from section A.1.9.2

Loop type 26AWG with 24AWG bridged tap	Test time (minutes)	Anticipated DS rate: <b>&gt;= 864 kbps</b>  Achieved DS rate (test start)  Achieved DS rate (test end)	Measured DS CRC count, after injected noise level has been raised by (initial_reported_margin - 1) dB	Estimated BER, based on equations in Table A.1.1.1  If: Estimated_BER < 1.5e-7 then PASS else FAIL	Pass / Fail
12kft loop with 750ft tap	25				

## A.1.1.6. Test methodology / Procedure on DS Margin verification at the CPE.

Table A.1.1.6.1: Test methodology / Procedure on DS Margin verification at the CPE.

Test Configuration	<p>The loop and noise conditions for the individual margin verification tests are described in item B below.</p> <p>The pass/fail criterion is the bit error ratio (BER) at the physical layer. Since CPEs are not required to provide internal BER monitoring capabilities, CRC error counts are used to estimate BER at the physical layer. [As shown in Table A1.1, it is assumed that one CRC error corresponds to 15 bit errors in fast mode. In high interleaved mode, one CRC error is assumed to correspond to 40 bit errors.]</p>
Details of Test Procedure	<ol style="list-style-type: none"> <li>1. Configure CPE and DSLAM according to the description in the title of the margin verification test (set minimum margin to 0dB)</li> <li>2. Connect CPE and DSLAM to first test loop option, with the noise injected at the specified reference power level. This power level is considered the 0 dB noise power level for that type of noise.</li> <li>3. Force a new initialization and wait for modems to sync.</li> <li>4. Wait for 3 minutes after initialization for bitswaps to settle.</li> <li>5. Check reported margin and document as <b>initial_reported_margin</b></li> <li>6. Increase the noise power level by 1 dB on the CPE side only.</li> <li>7. Wait for 1 minute.</li> <li>8. Repeat steps 6 and 7 until the noise power is increased by (<b>initial_reported_margin</b> – 1) dB.</li> <li>9. At this point the power level of the noise is at the (<b>initial_reported_margin</b> – 1) dB level.</li> <li>10. Execute a BER test for specified duration. Record the CRC count at the start and the end of the BER test. Actual number of CRCs is the difference between these two counts. Document the measured BER.</li> <li>11. Repeat steps 2 to 10 for every test loop.</li> </ol> <ul style="list-style-type: none"> <li>• 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.</li> </ul>
Expected Result	<p>The CPE modem passes the margin verification test, if for every test loop: Estimated BER &lt; 1.5e-7</p> <p>The CPE modem passes the margin verification test if the BER criterion is met for every test loop.</p>

## A.1.1.7. CO Margin Verification (Optional)

Table A.1.1.7.1: Margin Verification for DSLAM

Test Configuration	<p>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.</p> <p>Category I:</p> <ol style="list-style-type: none"> <li>1. Section A.1.5.2 (HDSL): Any length with Expected Upstream Rate between 96 and 608 kbps</li> <li>2. Section A.1.5.3 (DSL (ISDN)): Any length with Expected Upstream Rate between 96 and 608 kbps</li> </ol> <p>Category II:</p> <ol style="list-style-type: none"> <li>1. Section A.1.9 (Bridged tap): Any length with Expected Upstream Rate between 96 and 608 kbps with tap length of at least 250 feet</li> </ol> <ul style="list-style-type: none"> <li>• Bit Error Rate Testing (BERT) will be approximated using the CRC error counts as defined in section Table A.1.1.1.</li> </ul>
Method of Procedure	<ol style="list-style-type: none"> <li>1. Configure CPE and DSLAM as for Section A.1.5 tests and in Fast mode.</li> <li>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.</li> <li>3. Force a new initialization and wait for modems to sync as for Section A.1.5 tests.</li> <li>4. Wait 3 minutes after initialization for bitswaps to settle.</li> <li>5. Check reported margin and document.</li> <li>6. Increase the noise power level by 1 dB on the DSLAM side only.</li> <li>7. Wait 1 minute.</li> <li>8. Repeat steps 6 and 7 until the noise power is increased by target noise margin – 2dB.</li> <li>9. At this point the power level of the noise is at the target noise margin – 2 dB level.</li> <li>10. Execute a BER test for 110 minutes. Document the measured BER.</li> <li>11. Repeat steps 2 to 10 for the second, third and fourth test loop.</li> </ol> <p>If the measured BER result falls in the interval <math>1.5E-7 &lt; BER &lt; 5E-7</math> for a specific loop option, that BER test (steps 4 to 10) shall be repeated a single time for that loop option.</p> <p>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.</p>
Expected Result	<p>Reported Margin: The CO modem passes the reported margin criteria, if for all 4 test loops: target noise margin + 2 dB <math>\geq</math> upstream reported margin <math>\geq</math> target noise margin – 2dB</p> <p>Measured Margin The CO modem passes the measured margin criteria, if for all 4 test loops: BER measured <math>&lt; 1.5E-7</math> (Note: This corresponds with a modem actual margin <math>\geq</math> tested margin = target noise margin – 2 dB)</p> <p>The CO modem passes the margin verification test if both the reported margin criteria and the measured margin criteria are passed.</p>

### A.1.2 ANSI T1-413 [4] Operation

Table A.1.2.1: ANSI T1.413 [4] Operation

Test Configuration	<ul style="list-style-type: none"> <li>▪ See Figure 1</li> <li>▪ Configure a DSLAM port for full rate fast operation, ANSI T1-413 only mode Connect ATU-R and ATU-C with a stable connection at 0ft 26AWG with – 140dBm/Hz AWGN noise added at both the ATU-C and ATU-R ends.</li> </ul>
Method of Procedure	<ul style="list-style-type: none"> <li>▪ Query the management system to obtain the operating mode.</li> </ul>
Expected Result	<ul style="list-style-type: none"> <li>▪ The modem shall connect in ANSI T1-413 [4] mode in less than 60 seconds.</li> </ul>

### A.1.3 Operation in the Presence of Impulse Noise Events (G.996.1 [2], Test Impulse 1)

Table A.1.3.1: Operation in the Presence of Impulse Noise Events ([2], Test Impulse 1)

Test Configuration	<p>This test is a standard based on G.992.1 [1] Section F.2.2 and G.996.1 [2] Section 5.1.3.1 using CSA Loop #6.</p> <ol style="list-style-type: none"> <li>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).</li> <li>2. Set the upstream and downstream target noise margins to 6 dB. Train the ADSL system to MAX UP and MAX DN, with interleaved operation.</li> </ol> <ul style="list-style-type: none"> <li>• Bit Error Rate Testing (BERT) will be approximated using the CRC error counts as defined in section A.1.1 Table A.1.1.1.</li> </ul>
Method of Procedure	<ol style="list-style-type: none"> <li>1. Inject a 20 HDSL disturber and –140 dBm/Hz white noise disturber at the CO end of the loop.</li> <li>2. Train the modems in interleaved mode.</li> <li>3. Lower the 20 HDSL disturber from the reference level by 4 dBm.</li> <li>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.</li> <li>5. Note the amplitude in millivolts at which half of the impulses caused errors.</li> <li>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%.</li> <li>7. Repeat steps 4 through 6 using ADSL c2 impulses.</li> <li>8. Calculate the probability that a second will be errored using the formula in G.996.1[2].</li> <li>9. Repeat steps 1 through 8, injecting the 20 HDSL disturber, white noise, and impulses at the customer end of the loop.</li> </ol>
Expected Result	<p>The probability of errored seconds (ES) shall be less than 0.14% for tests at both ends of the loop.</p>

### A.1.4 Verification of downstream fine gain values

Table A.1.4.1: Verification of downstream fine gain values

Test Configuration	From the DSLAM read the fine gain values requested during initialization for the following test loops:
Method of Procedure	<ol style="list-style-type: none"> <li>1. 12 kft with -140 dBm/Hz AWGN</li> <li>2. 18 kft with -140 dBm/Hz AWGN</li> <li>3. 11 kft with -140 dBm/Hz AWGN (16ms interleaved path, instead of fast path)</li> <li>4. 17 kft with -140 dBm/Hz AWGN (16ms interleaved path, instead of fast path)</li> <li>5. 9 kft with 5 T1 adjacent</li> <li>6. 15 kft with 5 T1 adjacent</li> <li>7. 15 kft with 24 DSL</li> <li>8. 16 kft with 24 DSL</li> <li>9. 12 kft with 24 HDSL</li> <li>10. 13 kft with 24 HDSL</li> <li>11. CSA4 with 5 T1 adjacent</li> <li>12. 9 kft + 500 ft BT with -140 dBm/Hz AWGN</li> <li>13. 12 kft + 250 ft BT with -140 dBm/Hz AWGN</li> <li>14. 12 kft + 750 ft BT with -140 dBm/Hz AWGN</li> <li>15. 15 kft + 500 ft BT with -140 dBm/Hz AWGN</li> <li>16. 15 kft + 900 ft BT with -140 dBm/Hz AWGN</li> <li>17. 17.5 kft + 500 ft BT with -140 dBm/Hz AWGN</li> <li>18. 17.5 kft + 1000 ft BT with -140 dBm/Hz AWGN</li> </ol> <p>Note that <math>g_i</math> rms is defined (for all options) as:</p> $g_i \text{ rms} = 10 \log_{10} \left( \frac{1}{ A } \sum_{i \in A} g_i^2 \right)$ <p>where A is the set of subchannels under consideration and  A  is the number of subchannels in A</p>
Expected Result to Pass	<p>The downstream fine gain values have to meet the following criteria on each test point:</p> <ol style="list-style-type: none"> <li>1. Maximum <math>g_i</math> (over nonzero <math>g_i</math>) <math>\leq +2.503</math> dB.</li> <li>2. Minimum <math>g_i</math> (over nonzero <math>g_i</math>) <math>\geq -14.5</math> dB.</li> <li>3. <math>g_i</math> rms value over used tones (<math>b_i &gt; 0</math>) <math>\leq 0.7</math> dB.</li> <li>4. <math>g_i</math> rms value over monitored tones (<math>b_i = 0</math> &amp; <math>g_i &gt; 0</math>) <math>\leq 0</math> dB.</li> <li>5. Over the 138 to 1104 kHz band, <math>g_i</math> rms value <math>\leq 0.0</math> dB</li> </ol>

### A.1.5 Loop Tests with Ports Set for Adaptive Rate

Tests shall be performed according to the general procedure described in section 8.

In addition to achieving the required rate, both downstream and upstream noise margin values are to be considered in determining the result of an individual section.

It is acknowledged that achieving a desired noise margin is primarily the responsibility of the receiver. That is, the DSLAM is primarily responsible for achieving desired upstream noise margins, while the CPE (modem) is primarily responsible for achieving desired downstream noise margins.

The following chart outlines the Pass/Fail criteria.



Table A.1.5.1: Noise margin chart

Reported Noise Margin (dB)	Requirement
< 4	On no test point
>= 4 and < 5	On at most 10% of the test points
>= 5	On at least 90% of the test points
>= 6	On at least 75% of the downstream test points

All measurements shall be from the DSLAM.

Violation of any of the requirements in the Noise Margin Chart shall constitute a test section failure.

Overall pass/fail criteria for each adaptive rate test section is then as follows:

- If any reported noise margin is less than 4dB, then the ATU-C/ATU-R pair fails the *noise margin* requirements of that section.
- If more than 10% of the reported noise margins are less than 5dB in a section, then the ATU-C/ATU-R pair fails the *noise margin* requirements of that section.
- If more than 25% of the reported downstream noise margins are less than 6dB in a section, then the ATU-C/ATU-R pair fails the *noise margin* requirements of that section.
- If more than 10% of the data rates are less than the data rate requirements in a section, then the ATU-C/ATU-R pair fails the *data rate* requirements of that section.
- If the ATU-C/ATU-R pair passes *both the data rate and noise margin* requirements, it passes the section; otherwise, it fails the section.

The following table lists the number of test points per section corresponding to the 10% and 25% limits mentioned above.

Table A.1.5.2: Reported Margin Requirements

Section Number	Number of test points in section	10% limit	25% limit (applies to down-stream margins only)
A.1.5.1	80	8	10
A.1.5.2	12	1	2
A.1.5.3	14	1	2
A.1.5.4	12	1	2
A.1.7	8	1	1
A.1.8	8	1	1
A.1.9.1	8	1	1
A.1.9.2	20	2	3
A.1.9.3	28	3	4
A.1.9.4	28	3	4

**A.1.5.1 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

Table A.1.5.1.1: White Noise Impairment Only

Loop Length (kft, 26 (AWG))	Fast Mode								Interleaved Mode							
	Upstream				Downstream				Upstream				Downstream			
	Sync Rate (kbps)			Noise Margin, Reported (dB)	Sync Rate (kbps)			Noise Margin, Reported (dB)	Sync Rate (kbps)			Noise Margin, Reported (dB)	Sync Rate (kbps)			Noise Margin, Reported (dB)
	Expected	Measured	Pass/Fail		Expected	Measured	Pass/Fail		Expected	Measured	Pass/Fail		Expected	Measured	Pass/Fail	
0	800				8000				800				7616			
1	800				8000				800				7616			
2	800				8000				800				7616			
3	800				8000				800				7616			
4	800				8000				800				7616			
5	800				8000				800				7616			
6	800				8000				800				7616			
7	800				8000				800				7616			
8	800				8000				800				7616			
9	800				7648				800				7616			
10	800				6464				800				6528			
11	800				5216				800				5216			
12	800				4032				800				4064			
13	768				3008				768				3040			
14	672				2240				704				2336			
15	608				1600				640				1696			
16	512				1088				544				1216			
17	416				704				448				832			
17.5	352				576				384				672			
18	320				448				352				512			

### A.1.5.2 24 HDSL Impairment

*Note :The tests points presented in this annex are intended to stress CPE modems, but the user of this test should bear in mind that real deployment conditions could be significantly different, for example due to crosstalk mixes that depend on the nature of deployed systems, their deployment distance, their location on the loop and various other similar parameters. For example, tests involving HDSL type of crosstalk are not considering the usual spectrum compatibility based deployment length of 9 kft on AWG26 loops, and tests beyond that deployment length should take into account the non-collocation effect.*

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*

Table A.1.5.2.1: 24 HDSL Impairment

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	Pass/Fail		Expected	Measured	Pass/Fail	
0	800				8000			
3	800				8000			
6	704				8000			
9	448				6016			
12	160				2016			
13	96				1088			

### A.1.5.3 24 DSL Impairment

Set noise generators for 24 DSL (ISDN) Impairment [DSL Impairment in G.996.1[2]] and white noise at  $-140$  dBm/Hz, CO and CPE ends.

*14 individual tests – 13 must be passed*

Table A.1.5.3.1: 24 DSL Impairment

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	Pass/Fail		Expected	Measured	Pass/Fail	
0	800				8000			
3	800				8000			
6	800				8000			
9	704				7200			
12	448				3136			
15	192				832			
16	96				416			

**A.1.5.4 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*

Table A.1.5.4.1: 5 T1 Adjacent Binder Impairment

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	Pass/Fail		Expected	Measured	Pass/Fail	
0	800				8000			
3	800				8000			
6	800				5824			
9	800				2336			
12	800				864			
15	576				256			

**A.1.6 Loop Tests with Ports Set For Fixed Rate**

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

**Pass/fail criteria:** If any reported noise margin is less than 6dB, then the ATU-C/ATU-R pair fails that section.

256 kbps downstream, 128 kbps upstream

*16 individual tests – 16 shall be passed*

Table A.1.6.1: Loop Tests with Ports Set for Fixed Rate

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						

**A.1.7 CSA #4 Standard Loop**

*8 individual tests – 7 must be passed*

Tests shall be performed according to the general procedure described in section 8.

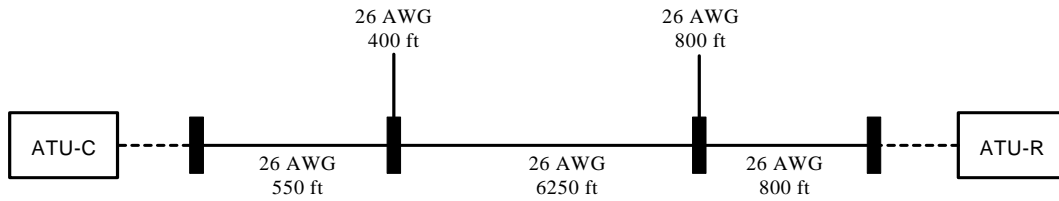


Table A.1.7.1: CSA #4 Standard Loop

Disturber Type	Fast Mode						
	Upstream				Downstream		
	Sync Rate (kbps)		Noise Margin, Reported (dB)	Pass /Fail	Sync Rate (kbps)		Pass /Fail
	Expected	Measured			Expected	Measured	
White Noise	800				8000		
24 HDSL	512				6464		
5 T1	800				2208		
24 DSL (ISDN)	736				7584		

**A.1.8 ANSI 13 Standard Loop**

*8 individual tests- 7 must be passed*

Tests shall be performed according to the general procedure described in section 8.

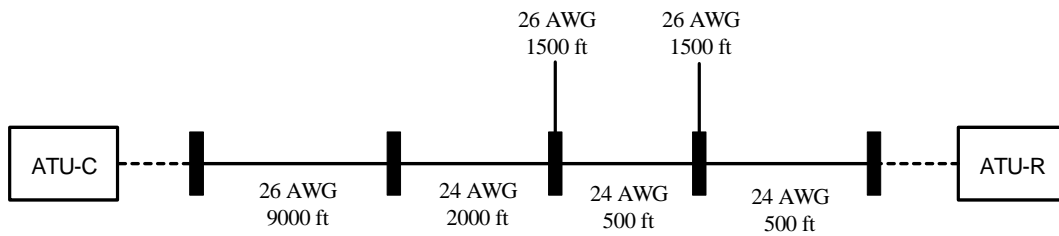


Table A.1.8.1: ANSI 13 Standard Loop

Disturber Type	Fast Mode						
	Upstream				Downstream		
	Sync Rate (kbps)		Noise Margin, Reported	Pass /Fail	Sync Rate (kbps)		Pass /Fail
	Expected	Measured			Expected	Measured	
White Noise	704				3008		
24 HDSL	64				1312		
5 T1	704				512		
24 DSL (ISDN)	288				2432		

**A.1.9 Bridged Tap Tests**

**A.1.9.1 9 kft Bridged Tap Tests**

White noise disturber at both ends of the total loop at -140 dBm/Hz, Fast mode.  
 8 individual tests – 7 must be passed

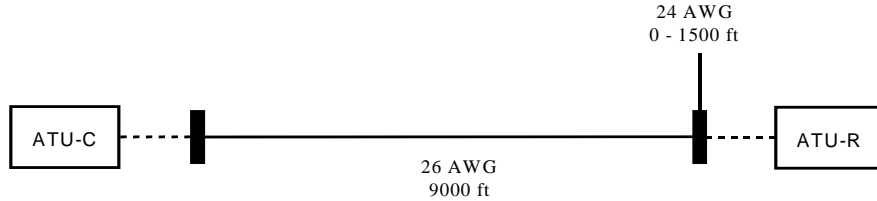


Table A.1.9.1.1: 9,000 Foot Loop

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			Expected	Measured		
150	800				7040			
250	800				7168			
350	800				7520			
500	800				7360			

**A.1.9.2 12 kft Bridged Tap Tests**

20 individual tests – 18 must be passed

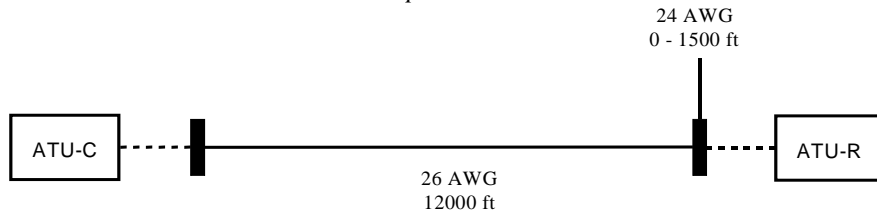
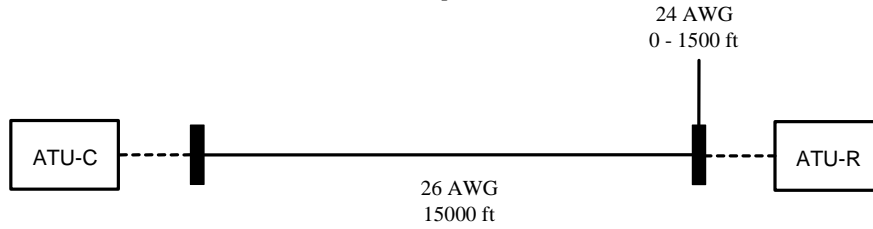


Table 1.9.2.1: 12,000 Foot Loop

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			Expected	Measured		
0	800				4064			
50	800				4064			
150	800				3968			
250	800				3360			
350	800				3584			
500	800				3712			
750	800				3648			
1000	736				3584			
1250	704				3744			
1500	704				3808			

**A.1.9.3 15 kft Bridged Tap Tests**

*28 individual tests – 25 must be passed*

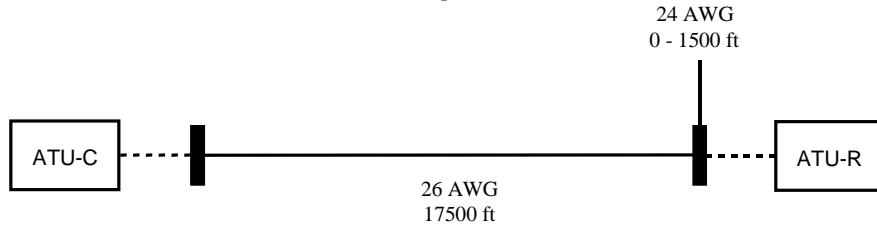


**Table A.1.9.3.1: 15,000 Foot Loop**

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			Expected	Measured		
0	608				1568			
50	608				1600			
150	608				1536			
200	576				1472			
300	576				1248			
400	576				1216			
500	544				1216			
600	544				1248			
700	544				1280			
800	512				1312			
900	480				1280			
1000	480				1248			
1250	416				1344			
1500	416				1376			

**A.1.9.4 17.5 kft Bridged Tap Tests**

*28 individual tests – 25 must be passed*



**Table A.1.9.4.1: 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			Expected	Measured		
0	352				576			
50	352				576			
150	352				544			
200	352				512			
300	352				448			
400	352				416			
500	352				320			
600	320				288			
700	288				256			
800	288				256			
900	256				352			
1000	256				352			
1250	192				416			
1500	192				448			



## A.2 European Test set

### A.2.1 CPE Margin verification tests

Because of the significant dependency of achievable data rates on the noise margin, margin verification tests are performed across several loop and noise scenarios of this test plan to ensure that chipset vendors do not optimize modem performance for some specific test loops.

Since CRC error counts are the basis of margin verification tests, it is necessary to verify if the ATU-R accurately counts and reports CRC errors. A mandatory test procedure to verify CRC error reporting is required and defined in section 8.1.2.

The following test descriptions show the loop and noise conditions for margin verification tests. An explanation of the various table entries can be found in Annex A1.1.

A.2.1.1. Noise FB impairments. Noise injection according to section A.2.3.2. DSLAM Port settings according to WT-085 section A.2.3.2, using fast mode.

Table A.2.1.1.1: Noise FB Impairment Margin Verification at 1500 meters

Loop length (m) 0.4mm	Test time (minutes)	Anticipated DS rate: <b>&gt;= 6144 kbps</b>  Achieved DS rate (test start)  Achieved DS rate (test end)	Measured DS CRC count, after injected noise level has been raised by (initial_reported_margin - 1) dB	Estimated BER, based on equations in Table A.1.1.1  If: Estimated_BER < 1.5e-7 then PASS else FAIL	Pass / Fail
1500	5				

A.2.1.2. Noise FB impairments. Noise injection according to section A.2.3.2. DSLAM Port settings according to WT-085 section A.2.3.2, using 16ms interleaved mode.

Table A.2.1.2.1: Noise FB Impairment Margin Verification at 2850 meters

Loop length (m) 0.4mm	Test time (minutes)	Anticipated DS rate: <b>&gt;= 1504 kbps</b>  Achieved DS rate (test start)  Achieved DS rate (test end)	Measured DS CRC count, after injected noise level has been raised by (initial_reported_margin - 1) dB	Estimated BER, based on equations in Table A.1.1.1  If: Estimated_BER < 1.75e-7 then PASS else FAIL	Pass / Fail
2850	45				

For a detailed description of the margin verification test methodology / procedure, see section A.1.1.6.

## A.2.2 Verification of Downstream Fine Gain Values

Table A.2.2.1: Verification of downstream fine gain values

Test Configuration	From the DSLAM read the fine gain values requested during initialization for the following test loops:
Method of Procedure	<ol style="list-style-type: none"> <li>1. 3000 m with -140 dBm/Hz AWGN</li> <li>2. 5000 m with -140 dBm/Hz AWGN</li> <li>3. 3000 m with -140 dBm/Hz AWGN (16ms interleaved path, instead of fast path)</li> <li>4. 4500 m with -140 dBm/Hz AWGN (16ms interleaved path, instead of fast path)</li> <li>5. 1750 m with Noise FB</li> <li>6. 3000 m with Noise FB</li> <li>7. 1500 m with Noise FB (16ms interleaved path, instead of fast path)</li> <li>8. 2500 m with Noise FB (16ms interleaved path, instead of fast path)</li> </ol> <p>Note that <math>g_i</math> rms is defined (for all options) as:</p> $g_i \text{ rms} = 10 \log_{10} \left( \frac{1}{ A } \sum_{i \in A} g_i^2 \right)$ <p>where A is the set of subchannels under consideration and  A  is the number of subchannels in A</p>
Expected Result to Pass	<p>The downstream fine gain values have to meet the following criteria on each test point:</p> <ol style="list-style-type: none"> <li>1. Maximum <math>g_i</math> (over nonzero <math>g_i</math>) <math>\leq +2.503</math> dB.</li> <li>2. Minimum <math>g_i</math> (over nonzero <math>g_i</math>) <math>\geq -14.5</math> dB.</li> <li>3. <math>g_i</math> rms value over used tones (<math>b_i &gt; 0</math>) <math>\leq 0.7</math> dB.</li> <li>4. <math>g_i</math> rms value over monitored tones (<math>b_i = 0</math> &amp; <math>g_i &gt; 0</math>) <math>\leq 0</math> dB.</li> <li>5. Over the 138 to 1104 kHz band, <math>g_i</math> rms value <math>\leq 0.0</math> dB</li> </ol>

### A.2.3 Loop Tests with Ports Set for Adaptive Rate

Tests shall be performed according to the general procedure described in section 8 and based on references listed in section 3.

In addition to achieving the required rate, both downstream and upstream noise margin values are to be considered in determining the result of an individual section.

It is acknowledged that achieving a desired noise margin is primarily the responsibility of the receiver. That is, the DSLAM is primarily responsible for achieving desired upstream noise margins, while the CPE (modem) is primarily responsible for achieving desired downstream noise margins.

The following chart outlines the Pass/Fail criteria.

Table A.2.3.1: Noise margin chart

Reported Noise Margin (dB)	Requirement
< 4	On no test point
>= 4 and < 5	On at most 10% of the test points
>= 5	On at least 90% of the test points
>= 6	On at least 75% of the downstream test points

All measurements shall be from the DSLAM.

Violation of any of the requirements in the Noise Margin Chart shall constitute a test section failure.

Overall pass/fail criteria for each adaptive rate test section is then as follows:

- If any reported noise margin is less than 4dB, then the ATU-C/ATU-R pair fails the *noise margin* requirements of that section.
- If more than 10% of the reported noise margins are less than 5dB in a section, then the ATU-C/ATU-R pair fails the *noise margin* requirements of that section.
- If more than 25% of the reported downstream noise margins are less than 6dB in a section, then the ATU-C/ATU-R pair fails the *noise margin* requirements of that section.
- If more than 10% of the data rates are less than the data rate requirements in a section, then the ATU-C/ATU-R pair fails the *data rate* requirements of that section.
- If the ATU-C/ATU-R pair passes *both the data rate and noise margin* requirements, it passes the section; otherwise, it fails the section.

The following table lists the number of test points per section corresponding to the 10% and 25% limits mentioned above.

Table A.2.3.2: Reported Margin Requirements

Section Number	Number of test points in section	10% limit	25% limit (applies to down-stream margins only)
A.2.3.1	44	4	6
A.2.3.2	32	3	4

### A.2.3.1 White Noise Impairment Only

- 6 dB target noise margin
- fast and interleaved mode of operation
- adaptive rate
- trellis coding optional

Set noise generator G4 to apply white noise disturber at both ends of the total loop at -140 dBm/Hz.

*44 individual tests – 40 tests must be passed*

Table A.2.3.1.1: White Noise Impairment Only

Loop Length (m, ETSI loop #1)	Fast Mode								Interleaved Mode								
	Upstream				Downstream				Upstream				Downstream				
	Sync Rate (kbps)			Noise Margin, Reported (dB)	Sync Rate (kbps)			Noise Margin, Reported (dB)	Sync Rate (kbps)			Noise Margin, Reported (dB)	Sync Rate (kbps)			Noise Margin, Reported (dB)	
	Expected	Measured	Pass/Fail		Expected	Measured	Pass/Fail		Expected	Measured	Pass/Fail		Expected	Measured	Pass/Fail		
0	800				8000				800					7616			
500	800				8000				800					7616			
1000	800				8000				800					7616			
1500	800				8000				800					7616			
2000	800				8000				800					7616			
2500	800				8000				800					7616			
3000	800				6144				800					6304			
3500	736				3968				800					4192			
4000	672				2592				704					2848			
4500	544				1504				576					1696			
5000	320				768				352					928			

### A.2.3.2 Noise FB Impairment

- 6 dB target noise margin
- fast and interleaved mode of operation
- adaptive rate
- trellis coding optional

Set noise generator G1 and G2 for ETSI FB noise:

At CO side:

G1 = X.LT.FB as defined in TS 101 388 [7], section. 5.3.4.1.3, table 12, with NEXT coupling function.

G2 = X.NT.FB as defined in TS 101 388 [7], section. 5.3.4.1.3, table 13, with FEXT coupling function.

At CPE side:

G1 = X.NT.FB as defined in TS 101 388 [7], section. 5.3.4.1.3, table 13, with NEXT coupling function.

G2 = X.LT.FB as defined in TS 101 388 [7], section. 5.3.4.1.3, table 12, with FEXT coupling function.

Set noise generator G4 to apply white noise disturber at both ends of the total loop at -140 dBm/Hz.

All measurements with noise model FB shall be done with the noise model FB calculated for 3000 m loop #1.

32 individual tests – 29 tests must be passed

Table A.2.3.2.1: Noise FB Impairment in Fast Mode

Loop Length (m, ETSI loop #1)	Fast Mode							
	Upstream				Downstream			
	Sync Rate (kbps)			Noise Margin, Reported (dB)	Sync Rate (kbps)			Noise Margin, Reported (dB)
	Expected	Measured	Pass/Fail		Expected	Measured	Pass/Fail	
0	800				5984			
500	800				7328			
1250	768				7296			
1500	736				6368			
1750	704				5568			
2000	640				4704			
2500	512				2368			
3000	384				544			

Table A.2.3.2.2: Noise FB Impairment in Interleaved Mode

Loop Length (m, ETSI loop #1)	Interleaved Mode							
	Upstream				Downstream			
	Sync Rate (kbps)			Noise Margin, Reported (dB)	Sync Rate (kbps)			Noise Margin, Reported (dB)
	Expected	Measured	Pass/Fail		Expected	Measured	Pass/Fail	
0	800				6144			
500	800				7488			
1250	800				7392			
1500	768				6660			
1750	736				5984			
2000	672				5024			
2500	544				2944			
3000	416				1024			

## A.2.4 Loop Tests with Ports Set For Fixed Rate

### Pass/fail criteria for fixed rate tests in this section:

1. If upstream or downstream reported noise margin on any test point is  $\geq 4\text{dB}$  and  $< 6\text{dB}$ , then this test point shall be re-tested 3 times. If a re-test is performed, then the maximum reported downstream noise margin achieved during testing shall be recorded as reported noise margin for this test point, along with the associated upstream noise margin provided that this is  $\geq 6\text{dB}$ .
2. If the final upstream or downstream reported noise margin (from step 1 above) is less than  $6\text{dB}$  on any test point, then the ATU-C/ATU-R pair fails that section.

**A.2.4.1 Noise FB Impairment**

- 6 dB target noise margin
- fast and interleaved mode of operation
- fixed rate
- trellis coding optional

Set noise generator G1 and G2 for ETSI FB noise as specified in the previous section A.2.3.2.

**a) Rate: 832 kbps downstream, 192 kbps upstream**

*10 individual tests – 10 shall be passed*

Table A.2.4.1.1: Fixed Rate 832/192 kbps

loop length (m, loop#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						
500						
1000						
2000						
2900				Max. loop length requirement for fast mode, test not to perform		
3000	Max. loop length requirement for interleaved mode, test not to perform					

**b) Rate: 1504 kbps downstream, 320 kbps upstream**

*10 individual tests – 10 shall be passed*

Table A.2.4.1.2: Fixed Rate 1504/320 kbps

loop length (m, loop#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						
500						
1000						
2000						
2750				Max. loop length requirement for fast mode, test not to perform		
2900	Max. loop length requirement for interleaved mode, test not to perform					

**c) Rate: 4832 kbps downstream, 640 kbps upstream**  
*8 individual tests – 8 shall be passed*

Table A.2.4.1.3: Fixed Rate 4832/640 kbps

loop length (m, loop#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						
750						
1250						
1950				Max. loop length requirement for fast mode, test not to perform		
2100	Max. loop length requirement for interleaved mode, test not to perform					

## **Annex B Physical Layer Test Cases for systems using G.992.1 Annex B.**

This Annex contains a set of tests and requirements specific for ADSL systems according to the recommendations ETSI TS 101 388 [7] for ADSL over ISDN with Frequency Division Duplexing (FDD). Test plan details, especially performance tests, for ADSL over ISDN Systems using echo cancellation are actually not considered and are for further study or TBD.

The ADSL system will be tested to be interoperable according to ETSI TS 101 388 [7]. Some of the performance requirements specified herein exceeds those of the previously mentioned standards. These higher requirements were provided by the service provider furnishing primary input to this document.



## B.1 Annex B specific test setup information

In addition to the general part of this document the following configurations have to be considered.

All tests shall be done with splitters inserted in the line on both the ATU-C and ATU-R side. The vendor of the EUT (DSLAM, MODEM) shall deliver together with the EUT a splitter that complies with the common recommendations (here: ETSI TS 101 952-1 [8], Sub-Part 3: specification of ADSL/ISDN splitters and/or ETSI TS 101 952-1 [8], Sub-Part 4: ADSL/ISDN or POTS' universal splitter). The splitter manufacturer and design (external, integrated or splitter line card) is left to the EUT vendor.

The functional model of the used splitters shall conform to the following figure:

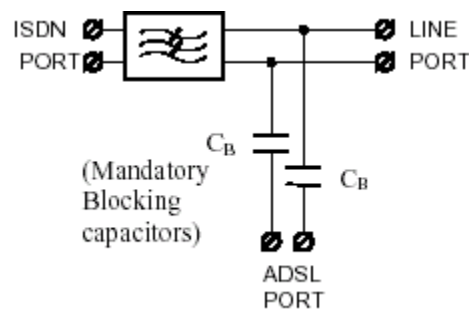


Figure B.1: structure of the ADSL/ISDN and ADSL/ISDN or POTS' universal splitter

This structure of the splitter is a proposal for an external splitter. If the splitter functionality is integrated into the linecard, then the blocking capacitors are not mandatory.

### B.1.1 Test setup for loop tests

The CPE and the DSLAM are connected via a line simulator. On both sides of the simulator a noise source shall be inserted in the setup. The noise source can be integrated in the simulator or an external arbitrary waveform generator. The noise injection method shall be according ETSI TS 101 388 [7]. The line simulator has to simulate the loops defined by ETSI TS 101 388 [7].

Noise Generator settings:

Set G1 and G2 to for **noise model FB**:

At CO side:

- G1 = X.LT.FB as defined in ETSI TS 101 388 [7], section 5.3.4.1.4, table 14, with NEXT coupling function
- G2 = X.NT.FB as defined in ETSI TS 101 388 [7], section 5.3.4.1.4, table 15, with FEXT coupling function

At CPE side:

- G1 = X.NT.FB as defined in ETSI TS 101 388 [7], section 5.3.4.1.4, table 15, with NEXT coupling function
- G2 = X.LT.FB as defined in ETSI TS 101 388 [7], section 5.3.4.1.4, table 14, with FEXT coupling function

Note: To reduce test time only one noise level is used for the tests in chapter B.2.4.2 and chapter B.2.5.2. All measurements with noise model FB shall be done with the noise model FB calculated for 2875m loop #1 (ETSI performance requirement for 768 kbps downstream and 128 kbps upstream, see ETSI TS 101 388[7], tables 38 and 39 for FDD ADSL over ISDN down- and upstream).

For **white noise** set generator G4 at both ends of the total loop at  $-140$  dBm/Hz.

For the **line sharing noise** generator G8 according to ETSI TS 101 388 [7] is used.

If G8 is implemented in the above mentioned noise generator, through the noise injection circuit, the ISDN port of the splitter has to be terminated with the appropriate ISDN impedance.

If G8 is not implemented in the above mentioned noise generator, G8 has to be realized according to ETSI TS 101 388 [7], Annex F. In this case the ISDN port of the splitter has to be used for injecting the line sharing noise.

## B.2 European Test set

The tests of the physical layer correspond to ETSI TS 101 388 [7]. Loop simulators shall simulate cable characteristics specified in said standard. The loop simulators shall be calibrated relative to the nominal attenuation as defined in the *section 4.1.1*. Noise shall be injected as specified in ETSI TS 101 388 [7], with simultaneous noise injection at both ends of the loop. Possible differences from this are stated in the test cases.

The simultaneous used generators shall be G1 (NEXT noise), G2 (FEXT noise), G4 (white noise) and G8 (Same Pair ISDN/line sharing noise). The model for G1 and G2 shall be FB. (Note: Although ETSI TS 101 388 [7] 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 significantly higher. Also to reduce test time only one noise model is proposed.) The noise injection shall be calibrated as defined in ETSI TS 101 388 [7].

For all tests Same Pair ISDN Noise shall be injected at both ends of the loop.

Tests shall be performed according to the general procedure described in section 8.

In addition to achieving the required rate, both downstream and upstream noise margin values are to be considered in determining the result of an individual section.

It is acknowledged that achieving a desired noise margin is primarily the responsibility of the receiver. That is, the DSLAM is primarily responsible for achieving desired upstream noise margins, while the CPE (modem) is primarily responsible for achieving desired downstream noise margins.

The following chart outlines the Pass/Fail criteria.

Table B.2.1: Noise margin chart

Reported Noise Margin (dB)	Requirement
< 5	On no test point
>= 5 and < 6	On at most 10% of the test points
>= 6	On at least 90% of the test points

All measurements shall be from the DSLAM.

Violation of any of the requirements in the Noise Margin Chart shall constitute a test section failure.

Overall pass/fail criteria for each section (either adaptive rate or fixed rate tests) are then as follows:

- If any reported noise margin is less than 5dB, then the ATU-C/ATU-R pair fails the *noise margin* requirements of that section.
- If more than 10% of the reported noise margins are less than 6dB in a section, then the ATU-C/ATU-R pair fails the *noise margin* requirements of that section.
- If more than 10% of the data rates are less than the data rate requirements in a section, then the ATU-C/ATU-R pair fails the *data rate* requirements of that section.
- If the ATU-C/ATU-R pair passes *both the data rate and noise margin* requirements, it passes the section; otherwise, it fails the section.

The following table lists the number of test points per section corresponding to the 10% limit mentioned above.

Table B.2.2: Reported Margin Requirements

Section Number	Number of test points in section	10% limit
B.2.4.1	38	4
B.2.4.2	48	5
B.2.5.1	22	2
B.2.5.2	38	4
B.2.5.3	$0 \leq x \leq 10$	1

### B.2.1 CPE Margin verification tests

Because of the significant dependency of achievable data rates on the noise margin, margin verification tests are performed across several loop and noise scenarios of WT-085 to ensure that chipset vendors do not optimize modem performance for some specific test loops.

Since CRC error counts are the basis of margin verification tests, it is necessary to verify if the ATU-R accurately counts and reports CRC errors. A mandatory test procedure to verify CRC error reporting is required and defined in section 8.1.2.

B.2.1.1. The following test descriptions show the loop and noise conditions for margin verification tests.

An explanation of the various table entries can be found in Annex A1.1.Noise FB impairments.

Settings as defined in section B.1.1, using fast mode.

Table B.2.1.1.1: Noise FB Impairments at 1500 meters (fast mode)

Loop length (m) 0.4mm	Test time (minutes)	Anticipated DS rate: <b>&gt;= 6400 kbps</b>  Achieved DS rate (test start)  Achieved DS rate (test end)	Measured DS CRC count, after injected noise level has been raised by (initial_reported_margin - 1) dB	Estimated BER, based on equations in Table A.1.1.1  If: Estimated_BER < 1.5e-7 then PASS else FAIL	Pass / Fail
1500	5				

B.2.1.2. Noise FB impairments. Settings as defined in section B.1.1, using fast mode.

Table B.2.1.2.1: Noise FB Impairments at 2500 meters (fast mode).

Loop length (m) 0.4mm	Test time (minutes)	Anticipated DS rate: <b>&gt;= 2080 kbps</b>  Achieved DS rate (test start)  Achieved DS rate (test end)	Measured DS CRC count, after injected noise level has been raised by (initial_reported_margin - 1) dB	Estimated BER, based on equations in Table A.1.1.1  If: Estimated_BER < 1.5e-7 then PASS else FAIL	Pass / Fail
2500	15				

B.2.1.3. Noise FB impairments. Settings as defined in section B.1.1, using 16ms interleaved mode.

Table B.2.1.3.1: Noise FB Impairment at 2850 meters (interleaved mode).

Loop length (m) 0.4mm	Test time (minutes)	Anticipated DS rate: <b>&gt;= 768 kbps</b>  Achieved DS rate (test start)  Achieved DS rate (test end)	Measured DS CRC count, after injected noise level has been raised by (initial_reported_margin - 1) dB	Estimated BER, based on equations in Table A.1.1.1  If: Estimated_BER < 1.75e-7 then PASS else FAIL	Pass / Fail
2850	45				

NOTE:

Due to the low, achievable DS data rates under this loop and noise condition, the observation of 10 error events would require approximately 90 minutes (at BER ~ 1e-7). To accelerate testing, the desired number of observed error events is reduced to 5. To remain consistent with previous confidence levels of estimated BER, the range of allowed estimated BER is increased from 1.5-e7 to **1.75e-7**.

B.2.1.4. Select one test loop from: ETSI Loop #3-7 with either Noise Impairment FA or FC, using 16ms interleaved mode. The noise injection is defined as specified in TS 101 388 [7]. (Optional test)

Table B.2.1.4.1: First Selected Test Loop.

ETSI Loop Selected	Test time (minutes) Calculate based on connect rate.	Achieved DS rate (test start)  Achieved DS rate (test end)	Measured DS CRC count, after injected noise level has been raised by (initial_reported_margin - 1) dB	Estimated BER, based on equations in Table A.1.1.1  If: Estimated_BER < 1.5e-7 then PASS else FAIL	Pass / Fail
Loop Selected					

Note:

The table for section B.2.1.4 is an example table. The specific test loop selected and noise shape used should be indicated in the table. The connect rate and also test time calculated should be indicated in the table B.2.1.4.1.

B.2.1.5. Select one test loop from: ETSI Loop #3-7 with either Noise Impairment FA or FC, using 16ms interleaved mode. (Second optional test, to differ from the loop in section B.2.1.4)

Table B.2.1.5.1: Second Selected Test Loop.

ETSI Loop Selected	Test time (minutes) Calculate based on connect rate.	Achieved DS rate (test start)  Achieved DS rate (test end)	Measured DS CRC count, after injected noise level has been raised by (initial_reported_margin - 1) dB	Estimated BER, based on equations in Table A.1.1.1  If: Estimated_BER < 1.5e-7 then PASS else FAIL	Pass / Fail
Loop Selected					

Note:

The table for section B.2.1.5 is an example table. The specific test loop selected and noise shape used should be indicated in the table. The connect rate and also test time calculated should be indicated in the table B.2.1.5.1.

## B.2.2 CO Margin Verification (Optional)

B.2.2.1 Noise FB impairments. Settings as defined in section B.1.1, using fast mode.

Table B.2.2.1.1: Upstream Margin Test with Noise FB Impairment at 1500 meters (fast mode)

Loop length (m) 0.4mm	Test time (minutes)	Anticipated US rate: >= 640 kbps  Achieved US rate (test start)  Achieved US rate (test end)	Measured US CRC count, after injected noise level has been raised by (initial_reported_margin - 1) dB	Estimated BER, based on equations in Table A.1.1.1  If: Estimated_BER < 1.5e-7 then PASS else FAIL	Pass / Fail
1500	40				

B.2.2.2 Noise FB impairments. Settings as defined in section B.1.1, using 16ms interleaved mode.

Table B.2.2.2.1: Upstream Margin Test with Noise FB Impairment at 2000 meters (interleaved mode)

Loop length (m) 0.4mm	Test time (minutes)	Anticipated US rate: >= 480 kbps  Achieved US rate (test start)  Achieved US rate (test end)	Measured US CRC count, after injected noise level has been raised by (initial_reported_margin - 1) dB	Estimated BER, based on equations in Table A.1.1.1  If: Estimated_BER < 1.5e-7 then PASS else FAIL	Pass / Fail
2000	70				

B.2.2.3 Noise FB impairments. Settings as defined in section B.1.1, using fast mode.

Table B.2.2.3.1: Upstream Margin Tests with Noise FB Impairment at 2500 meters (fast mode)

Loop length (m) 0.4mm	Test time (minutes)	Anticipated US rate: >= 224 kbps  Achieved US rate (test start)  Achieved US rate (test end)	Measured US CRC count, after injected noise level has been raised by (initial_reported_margin - 1) dB	Estimated BER, based on equations in Table A.1.1.1  If: Estimated_BER < 1.75e-7 then PASS else FAIL	Pass / Fail
2500	60				

Note:

Due to the low, achievable DS data rates under this loop and noise condition, the observation of 10 error events would require approximately 90 minutes (at BER ~ 1e-7). To accelerate testing, the desired number of observed error events is reduced to 5. To remain consistent with previous confidence levels of estimated BER, the range of allowed estimated BER is increased from 1.5-e7 to 1.75e-7.

B.2.2.4. Select one test loop from: ETSI Loop #3-7 with either Noise Impairment FA or FC, using 16ms interleaved mode. The noise injection is defined as specified in TS 101 388 [7].

Table B.2.2.4.1: Upstream Margin Tests for First Selected ETSI Loop #3 – 7 (interleaved mode)

ETSI Loop Selected	Test time (minutes) Calculate based on connect rate.	Achieved DS rate (test start)  Achieved DS rate (test end)	Measured DS CRC count, after injected noise level has been raised by (initial_reported_margin - 1) dB	Estimated BER, based on equations in Table A.1.1.1  If: Estimated_BER < 1.5e-7 then PASS else FAIL	Pass / Fail
Loop Selected					

Note:

The table for section B.2.2.4 is an example table. The specific test loop selected and noise shape used should be indicated in the table. The connect rate and also test time calculated should be indicated in the table B.2.2.4.1.

B.2.2.5. Select one test loop from: ETSI Loop #3-7 with either Noise Impairment FA or FC, using 16ms interleaved mode. (Second test loop, to differ from the loop in section B.2.2.4)

Table B.2.2.5.1: Upstream Margin Tests for Second Selected ETSI Loop #3 – 7 (interleaved mode)

ETSI Loop Selected	Test time (minutes) Calculate based on connect rate.	Achieved DS rate (test start)  Achieved DS rate (test end)	Measured DS CRC count, after injected noise level has been raised by (initial_reported_margin - 1) dB	Estimated BER, based on equations in Table A.1.1.1  If: Estimated_BER < 1.5e-7 then PASS else FAIL	Pass / Fail
Loop Selected					

Note:

The table for section B.2.2.5 is an example table. The specific test loop selected and noise shape used should be indicated in the table. The connect rate and also test time calculated should be indicated in the table B.2.2.5.1.

For a detailed description of the margin verification test methodology / procedure, see section A.1.1.6

### B.2.3 Verification of Downstream Fine Gain Values

Table B.2.3.1: Verification of downstream fine gain values

Test Configuration	From the DSLAM read the fine gain values requested during initialization for the following test loops:
Method of Procedure	<ol style="list-style-type: none"> <li>1. 2500 m with -140 dBm/Hz AWGN</li> <li>2. 3800 m with -140 dBm/Hz AWGN</li> <li>3. 3000 m with -140 dBm/Hz AWGN (16ms interleaved path, instead of fast path)</li> <li>4. 4000 m with -140 dBm/Hz AWGN (16ms interleaved path, instead of fast path)</li> <li>5. 1250 m with Noise FB</li> <li>6. 2875 m with Noise FB</li> <li>7. 1500 m with Noise FB (16ms interleaved path, instead of fast path)</li> <li>8. 2875 m with Noise FB (16ms interleaved path, instead of fast path)</li> </ol> <p>Note that <math>g_i</math> rms is defined (for all options) as:</p> $g_i \text{ rms} = 10 \log_{10} \left( \frac{1}{ A } \sum_{i \in A} g_i^2 \right)$ <p>where A is the set of subchannels under consideration and  A  is the number of subchannels in A</p>
Expected Result to Pass	<p>The downstream fine gain values have to meet the following criteria on each test point:</p> <ol style="list-style-type: none"> <li>1. Maximum <math>g_i</math> (over nonzero <math>g_i</math>) <math>\leq +2.503</math> dB.</li> <li>2. Minimum <math>g_i</math> (over nonzero <math>g_i</math>) <math>\geq -14.5</math> dB.</li> <li>3. <math>g_i</math> rms value over used tones (<math>b_i &gt; 0</math>) <math>\leq 0.7</math> dB.</li> <li>4. <math>g_i</math> rms value over monitored tones (<math>b_i = 0</math> &amp; <math>g_i &gt; 0</math>) <math>\leq 0</math> dB.</li> <li>5. Over the 138 to 1104 kHz band, <math>g_i</math> rms value <math>\leq 0.0</math> dB</li> </ol>

**B.2.4 Loop Tests with Ports Set for Adaptive Rate**

See Section 8 for the physical layer setup and test procedures.

**B.2.4.1 White Noise Impairment Only**

Set noise generator G4 to apply white noise disturber at both ends of the total loop at -140 dBm/Hz.

*38 individual tests – 34 tests must be passed*

Table B.2.4.1.1: White Noise Impairment Only in fast mode

Loop Length [m, loop#1]	Fast Mode							
	Upstream				Downstream			
	Sync Rate (kbps)			Noise Margin, Reported (dB)	Sync Rate (kbps)			Noise Margin, Reported (dB)
	Expected	Measured	Pass/Fail		Expected	Measured	Pass/Fail	
0	768				7616			
500	768				7616			
1000	768				7616			
1500	768				7616			
2000	768				7616			
2500	768				6144			
3000	576				3648			
3500	384				1760			
3800	288				608			

Table B.2.4.1.2: White Noise Impairment only in interleave mode

Loop Length [m, loop#1]	Interleaved Mode							
	Upstream				Downstream			
	Sync Rate (kbps)			Noise Margin, Reported (dB)	Sync Rate (kbps)			Noise Margin, Reported (dB)
	Expected	Measured	Pass/Fail		Expected	Measured	Pass/Fail	
0	768				7616			
500	768				7616			
1000	768				7616			
1500	768				7616			
2000	768				7616			
2500	768				6144			
3000	672				4096			
3500	480				2208			
3750	384				1184			
4000	288				320			



**B.2.4.2 Noise FB impairment**

Set noise generators G1, G2, G4 and G8 for model FB impairment as defined in section B.1.1.

*48 individual tests – 44 must be passed*

Table B.2.4.2.1: Noise FB Impairment in fast mode

Loop Length [m, loop# 1]	Fast Mode							
	Upstream				Downstream			
	Sync Rate (kbps)			Noise Margin, Reported (dB)	Sync Rate (kbps)			Noise Margin, Reported (dB)
	Expected	Measured	Pass/Fail		Expected	Measured	Pass/Fail	
0	768				4864			
250	768				5792			
500	768				6752			
750	768				7136			
1000	768				7200			
1250	736				6976			
1500	672				6496			
1750	576				5408			
2000	480				4320			
2500	256				2176			
2750	128				1120			
2875	64				192			

Table B.2.4.2.2: Noise FB Impairment in interleaved mode

Loop Length [m, loop# 1]	Interleaved Mode							
	Upstream				Downstream			
	Sync Rate (kbps)			Noise Margin, Reported (dB)	Sync Rate (kbps)			Noise Margin, Reported (dB)
	Expected	Measured	Pass/Fail		Expected	Measured	Pass/Fail	
0	768				4864			
250	768				5792			
500	768				6752			
750	768				7136			
1000	768				7200			
1250	768				6976			
1500	704				6624			
1750	608				5824			
2000	512				4800			
2500	320				2528			
2750	192				1504			
2875	128				768			

**B.2.5 Loop Tests with Ports Set For Fixed Rate**

See Section 8 for the physical layer setup and test procedures.

**B.2.5.1 White Noise Impairment Only**

Set noise generator G4 to apply white noise disturber at both ends of the total loop at -140 dBm/Hz.

**a) Rate: 864 kbps downstream, 160 kbps upstream**

*12 individual tests – 12 shall be passed*

Table B.2.5.1.1: White Noise Fixed Rate 864/160 kbps

loop length (m, loop#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						
500						
1000						
2000						
3000						
3600				Max. loop length requirement for fast mode, test not to perform		
3700	Max. loop length requirement for interleaved mode, test not to perform					

**b) 4096 kbps downstream, 384 kbps upstream**

*10 individual tests – 10 shall be passed*

Table B.2.5.1.2: White Noise Fixed Rate 4096/384 kbps

loop length (m, loop#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						
500						
1000						
2000						
2900				Max. loop length requirement for fast mode, test not to perform		
3000	Max. loop length requirement for interleaved mode, test not to perform					

**B.2.5.2 European noise FB Impairments**

Set noise generators G1, G2, G4 and G8 for model FB impairment, Same Pair ISDN and white noise at -140 dBm/Hz, CO and CPE ends, as defined in section B.1.1.

**a) Rate: 864 kbps downstream, 160 kbps upstream**

*10 individual tests – 10 shall be passed*

Table B.2.5.2.1: Noise FB Impairment on Fixed Rate 864/160 kbps

loop length (m, loop#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						
500						
1000						
2000						
2650				Max. loop length requirement for fast mode, test not to perform		
2750	Max. loop length requirement for interleaved mode, test not to perform					

**b) 2048 kbps downstream, 256 kbps upstream**

*10 individual tests – 10 shall be passed*

Table B.2.5.2.2: Noise FB Impairment on Fixed Rate 2048/256 kbps

loop length (m, loop#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						
500						
1000						
2000						
2400				Max. loop length requirement for fast mode, test not to perform		
2500	Max. loop length requirement for interleaved mode, test not to perform					

- c) **4096 kbps downstream, 384 kbps upstream**  
*10 individual tests – 10 shall be passed*

Table B.2.5.2.3: Noise FB Impairment on Fixed Rate 4096/384 kbps

loop length (m, loop#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						
500						
1000						
1500						
1950				Max. loop length requirement for fast mode, test not to perform		
2050	Max. loop length requirement for interleaved mode, test not to perform					

- d) **6144 kbps downstream, 640 kbps upstream**  
*8 individual tests – 8 shall be passed*

Table B.2.5.2.4: Noise FB Impairment on Fixed Rate 6144/640 kbps

loop length (m, loop#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)
750						
1000						
1250						
1400				Max. loop length requirement for fast mode, test not to perform		
1500	Max. loop length requirement for interleaved mode, test not to perform					

Note: because of the lower performance on short loops, the test should start at 750 m.

**B.2.5.3 Target noise margin consideration**

To ensure the consideration of the desired target noise margin for fixed rate operation during/after synchronization the noise margin for the maximum loop length for the below described scenario has to be recorded.

The defined requirement is a CPE connecting with the target noise margin. For this test the maximum loop length achieved is not a pass/fail consideration.

Table B.2.5.3.1: Target noise margin consideration

Test Configuration	<ol style="list-style-type: none"> <li>1. Fixed Rate set to: 4096 kbps downstream, 384 kbps upstream, interleaved mode.</li> <li>2. Set noise generators for model FB impairment as defined in section B1.1.</li> </ol>
Method of Procedure	<ol style="list-style-type: none"> <li>1. Start test at 2100 m (50 m above fixed rate performance objective in section).</li> <li>2. Allow to train for 60 seconds to achieve showtime.</li> <li>3. Record the upstream and downstream reported noise margin in the table below. (Read the margin one minute after show time is reached.)</li> <li>4. Increase the loop length 50 meters and follow steps 2 – 3, until the modem fails to connect.</li> <li>5. After the first length for which the modem fails to connect attempt the next incremented loop length. (50 meters greater than the failing loop length of step 4.) If the CPE connects record the reported upstream and downstream margin.</li> </ol>
Expected Result to Pass	If the modem reaches showtime for a certain loop length, then the related reported noise margin must meet the pass/fail criteria as stated in section B.2.

Table B.2.5.3.2: Target noise margin consideration Results table

loop length (m, loop#1)	Interleaved Mode			
	Modem Trained (Y/N)?	Upstream Noise Margin, Reported (dB)	Downstream Noise Margin, Reported (dB)	Pass / Fail
<b>2100</b>				
<b>2150</b>				
<b>2200</b>				
<b>2250</b>				
<b>2300</b>				
...				
...				
...				

## **Annex C Physical Layer Test Cases for systems using G.992.1 Annex C**

Please refer to the latest version of **HATS-DE-101-V2** entitled “DSL Layer Interoperability Test Plan (ITU-T G.992.1/G.992.2 Annex C)”. **HATS-DE-101-V2** can be found at <http://www.ciaj.or.jp/hats/tilc/dsl-e/dsl-testplan.html>. (The English version of the DSL-TILC Web site will be made when it is available.)

*Note: The test cases for G.992.1 Annex C have been developed by DSL-TILC.  
By referring to **HATS-DE-101-V2** the DSL-Forum adopts the test plan of DSL-TILC.*

## Appendix W: Effect of the Statistical Variability in CPE Manufacturing (Informative)

This section gives information on the effect of statistical variability in CPE manufacturing variation on the statistics involved with the methodology, how the “expected” data rate requirements were determined for section A.1 “North American Test Set”.

### Methodology

This section describes the essentials of the methodology, how the “expected” data rate requirements were determined for section A.1 “North American Test Set”. Only the essentials needed for understanding the statistics in the next section are given. Full details of the test methodology can be found in Annex Y “Test Methodology for Deriving Performance Requirements for WT-085 (North America) v2.0”.

A number of CPE’s have been submitted by CPE vendors to a test event, open to service providers and vendors. It is assumed that these modems represent randomly selected samples from a production lot. Based on the methodology in Annex Y, a selection of 2 candidate modem-types was established, which correspond with the best 2 modem-types that are fully standard compliant. Preliminary data rates were measured, and that modem-type was selected with the lowest data rate. This was done for each test point and for upstream and downstream direction independently.

In a further refinement process, 4 units of the selected modem-type were measured and data rates recorded. The final data rate requirements have been established, by taking picking the rates of 4 units, and determining picking the lowest of these 4 rates.

### Statistical Analysis

In this section, the analysis is given of the statistics of the rate-requirement ( $R_r$ ) which is determined by taking the lowest rates out of  $N$  rates ( $R_i$ :  $I=1 \dots N$ ) obtained from different units. It can be assumed that the manufacturing variance on equipment corresponds with a Gaussian distribution of the rates  $R$ .

The probability density function (PDF) of the rate-requirement is given by below equation:

$$\begin{aligned} Prob(R_r) = & Prob(R_1=R_r) * Prob(R_1 < All other R_i) + \\ & Prob(R_2=R_r) * Prob(R_2 < All other R_i) + \\ & \dots \\ & Prob(R_N=R_r) * Prob(R_N < All other R_i) + \end{aligned}$$

Therefore:

$$PDF(R_r) = N * PDF\_gaussian(R_r) * (CDF\_gaussian(R_r))^{(N-1)}$$

This is illustrated in Figure 1. In this figure the distributions are plotted in function of the “normalized  $R$ ”:

$$Normalized\_R = (R - R\_mean) / R\_sigma$$

With

$$R\_mean = \text{mean value of rates } R\text{-distribution}$$

$$R\_sigma = \text{variance of rates } R\text{-distribution.}$$

The solid curve gives the Gaussian PDF of the individual rates  $R_i$ . The dashed curve gives the PDF of the rate-requirement  $R_r$  for  $N=4$  as in [Annex Y].

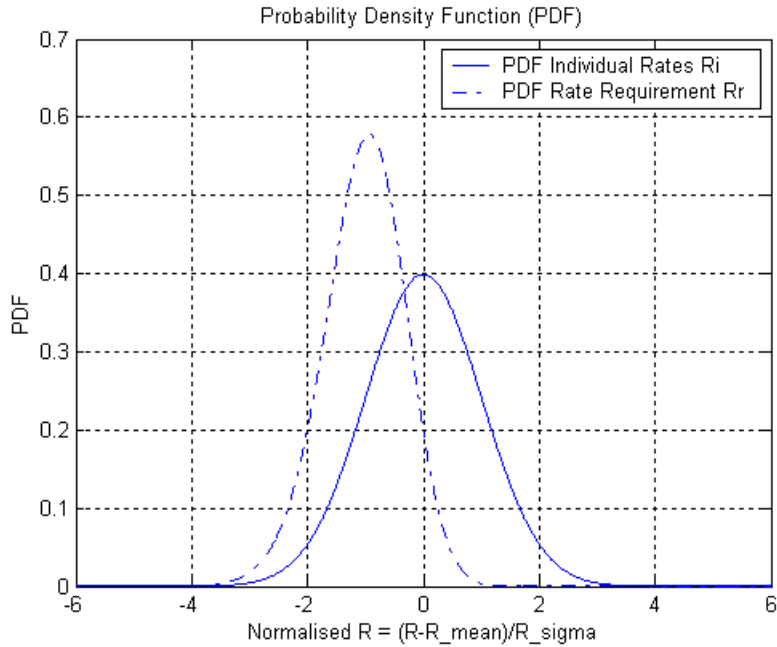


Figure W.1 PDF of the individual rates  $R_i$ , and the Rate-requirement  $R_r$ .

The overlapping part in Figure 1 correspond with modem-units for which  $R_i < R_r$ , i.e. the part of the production lot which could show a fail on the performance tests, although the modem-type is compliant to this TR.

The probability that this occurs can be calculated as:

$$Failprobability = \int_{-\infty}^{+\infty} Prob(R_r) * Prob(R_i < R_r) * dR_r$$

This probability has been evaluated, with results showing that the large majority, (but not all) of randomly-selected units will pass the rate requirements.



## Annex X Attenuation of theoretical loop models (normative)

This annex contains the attenuation of the theoretical loop models used for the tests described in this document.

Attenuation, expressed in dB, is calculated from the RLCG parameters using two-port ABCD modeling methodology as specified in ANSI T1.417 [5] Section B.3.1 (for both straight loops and loops with bridged taps). The RLCG cable parameters used are derived using the coefficients from ITU-T Rec. G.996.1[2], Section 6.1.1, Table 5: *Coefficients for calculation of R and L (24 and 26 AWG PIC at 70° F)* and Section 6.1.2 Table 9: *Coefficients for calculation of R and L (PE Cables)*.

This calculation was done using for  $\mathbf{R}_{out}$  and  $\mathbf{R}_{in}$  a purely resistive value of 100 ohms for North American loops and 100 ohms for European loops.

Table X.1 AWG26 straight loops

Freq [Hz]	Attenuation [dB]																		
	1 kft	2 kft	3 kft	4 kft	5 kft	6 kft	7 kft	8 kft	9 kft	10 kft	11 kft	12 kft	13 kft	14 kft	15 kft	16 kft	17 kft	17.5 kft	18 kft
1.00E+04	3.04	5.29	7.13	8.74	10.24	11.72	13.22	14.76	16.35	17.97	19.61	21.27	22.93	24.58	26.24	27.89	29.54	30.36	31.19
2.00E+04	3.04	5.34	7.33	9.27	11.27	13.38	15.55	17.75	19.95	22.15	24.33	26.51	28.69	30.86	33.04	35.22	37.40	38.49	39.58
3.00E+04	3.05	5.42	7.63	9.96	12.43	14.96	17.50	20.03	22.53	25.04	27.54	30.04	32.55	35.06	37.57	40.07	42.58	43.83	45.08
4.00E+04	3.07	5.53	8.00	10.67	13.44	16.21	18.95	21.67	24.40	27.13	29.86	32.59	35.32	38.05	40.78	43.51	46.24	47.61	48.97
5.00E+04	3.08	5.66	8.38	11.31	14.26	17.16	20.04	22.93	25.82	28.72	31.61	34.51	37.40	40.29	43.19	46.08	48.97	50.42	51.87
6.00E+04	3.11	5.80	8.75	11.85	14.89	17.90	20.91	23.93	26.95	29.97	32.99	36.01	39.02	42.04	45.06	48.08	51.10	52.61	54.12
7.00E+04	3.13	5.96	9.10	12.29	15.40	18.50	21.63	24.75	27.87	30.99	34.11	37.23	40.35	43.47	46.59	49.71	52.83	54.39	55.95
8.00E+04	3.16	6.13	9.41	12.65	15.83	19.03	22.25	25.45	28.66	31.86	35.07	38.27	41.48	44.68	47.89	51.10	54.30	55.90	57.51
9.00E+04	3.20	6.30	9.68	12.96	16.22	19.51	22.79	26.07	29.35	32.63	35.91	39.19	42.47	45.75	49.03	52.31	55.59	57.23	58.87
1.00E+05	3.24	6.47	9.91	13.23	16.58	19.93	23.28	26.63	29.98	33.32	36.67	40.02	43.37	46.72	50.07	53.42	56.76	58.44	60.11
1.10E+05	3.28	6.64	10.11	13.49	16.91	20.33	23.74	27.15	30.56	33.97	37.38	40.80	44.21	47.62	51.03	54.44	57.86	59.56	61.27
1.20E+05	3.33	6.79	10.30	13.75	17.23	20.70	24.17	27.64	31.12	34.59	38.06	41.53	45.01	48.48	51.95	55.42	58.89	60.63	62.37
1.30E+05	3.38	6.94	10.47	14.00	17.53	21.06	24.59	28.12	31.65	35.18	38.71	42.24	45.77	49.30	52.83	56.37	59.90	61.66	63.43
1.40E+05	3.43	7.08	10.64	14.24	17.82	21.41	25.00	28.59	32.17	35.76	39.35	42.94	46.52	50.11	53.70	57.29	60.87	62.67	64.46
1.50E+05	3.49	7.21	10.82	14.48	18.11	21.76	25.40	29.05	32.69	36.33	39.98	43.62	47.26	50.91	54.55	58.19	61.84	63.66	65.48
1.60E+05	3.55	7.33	10.99	14.71	18.40	22.10	25.80	29.50	33.20	36.90	40.60	44.30	48.00	51.69	55.39	59.09	62.79	64.64	66.49
1.70E+05	3.61	7.45	11.17	14.93	18.69	22.44	26.19	29.95	33.70	37.46	41.21	44.97	48.72	52.48	56.23	59.99	63.74	65.62	67.50
1.80E+05	3.67	7.56	11.34	15.16	18.97	22.78	26.59	30.40	34.21	38.02	41.83	45.64	49.45	53.26	57.07	60.88	64.69	66.59	68.50
1.90E+05	3.74	7.67	11.52	15.38	19.25	23.11	26.98	30.85	34.71	38.58	42.44	46.31	50.17	54.04	57.90	61.77	65.63	67.57	69.50
2.00E+05	3.80	7.77	11.70	15.61	19.53	23.45	27.37	31.29	35.21	39.13	43.05	46.98	50.90	54.82	58.74	62.66	66.58	68.54	70.50
2.10E+05	3.87	7.88	11.87	15.83	19.81	23.79	27.76	31.74	35.72	39.69	43.67	47.64	51.62	55.60	59.57	63.55	67.52	69.51	71.50
2.20E+05	3.93	7.99	12.03	16.06	20.09	24.12	28.16	32.19	36.22	40.25	44.28	48.31	52.34	56.38	60.41	64.44	68.47	70.49	72.50
2.30E+05	4.00	8.10	12.20	16.29	20.37	24.46	28.55	32.63	36.72	40.81	44.90	48.98	53.07	57.16	61.24	65.33	69.42	71.46	73.51
2.40E+05	4.07	8.21	12.37	16.51	20.65	24.80	28.94	33.08	37.22	41.37	45.51	49.65	53.80	57.94	62.08	66.22	70.37	72.44	74.51
2.50E+05	4.13	8.33	12.53	16.74	20.94	25.13	29.33	33.53	37.73	41.93	46.12	50.32	54.52	58.72	62.92	67.11	71.31	73.41	75.51
2.60E+05	4.20	8.44	12.70	16.96	21.22	25.47	29.72	33.98	38.23	42.48	46.74	50.99	55.25	59.50	63.75	68.01	72.26	74.39	76.51
2.70E+05	4.26	8.56	12.87	17.18	21.49	25.80	30.11	34.42	38.73	43.04	47.35	51.66	55.97	60.28	64.59	68.90	73.21	75.36	77.52
2.80E+05	4.32	8.68	13.04	17.41	21.77	26.14	30.50	34.87	39.23	43.60	47.96	52.33	56.69	61.06	65.42	69.79	74.15	76.33	78.52
2.90E+05	4.39	8.80	13.21	17.63	22.05	26.47	30.89	35.31	39.73	44.15	48.58	53.00	57.42	61.84	66.26	70.68	75.10	77.31	79.52
3.00E+05	4.45	8.91	13.38	17.86	22.33	26.81	31.28	35.76	40.23	44.71	49.19	53.66	58.14	62.61	67.09	71.56	76.04	78.28	80.52
3.10E+05	4.51	9.02	13.55	18.08	22.61	27.14	31.67	36.20	40.73	45.26	49.79	54.33	58.86	63.39	67.92	72.45	76.98	79.25	81.51
3.20E+05	4.56	9.14	13.72	18.30	22.89	27.47	32.06	36.64	41.23	45.82	50.40	54.99	59.57	64.16	68.75	73.33	77.92	80.21	82.50
3.30E+05	4.62	9.25	13.88	18.52	23.16	27.80	32.44	37.09	41.73	46.37	51.01	55.65	60.29	64.93	69.57	74.21	78.85	81.18	83.50
3.40E+05	4.68	9.36	14.05	18.74	23.44	28.13	32.83	37.53	42.22	46.92	51.61	56.31	61.00	65.70	70.40	75.09	79.79	82.14	84.48
3.50E+05	4.73	9.46	14.21	18.96	23.71	28.46	33.21	37.96	42.71	47.46	52.22	56.97	61.72	66.47	71.22	75.97	80.72	83.09	85.47
3.60E+05	4.78	9.57	14.37	19.18	23.99	28.79	33.60	38.40	43.21	48.01	52.82	57.62	62.43	67.23	72.04	76.84	81.64	84.05	86.45
3.70E+05	4.84	9.68	14.54	19.40	24.26	29.12	33.98	38.84	43.69	48.55	53.41	58.27	63.13	67.99	72.85	77.71	82.57	85.00	87.43
3.80E+05	4.89	9.79	14.70	19.62	24.53	29.44	34.36	39.27	44.18	49.10	54.01	58.92	63.84	68.75	73.66	78.57	83.49	85.94	88.40
3.90E+05	4.94	9.89	14.87	19.83	24.80	29.77	34.73	39.70	44.67	49.63	54.60	59.57	64.54	69.50	74.47	79.44	84.40	86.89	89.37
4.00E+05	4.99	10.00	15.03	20.05	25.07	30.09	35.11	40.13	45.15	50.17	55.19	60.21	65.23	70.25	75.28	80.30	85.32	87.83	90.34
4.10E+05	5.04	10.11	15.19	20.26	25.34	30.41	35.48	40.56	45.63	50.71	55.78	60.85	65.93	71.00	76.08	81.15	86.22	88.76	91.30
4.20E+05	5.09	10.22	15.35	20.48	25.60	30.73	35.86	40.98	46.11	51.24	56.37	61.49	66.62	71.75	76.87	82.00	87.13	89.69	92.26
4.30E+05	5.14	10.33	15.51	20.69	25.87	31.05	36.23	41.41	46.59	51.77	56.95	62.13	67.31	72.49	77.67	82.85	88.03	90.62	93.21
4.40E+05	5.19	10.43	15.67	20.90	26.13	31.36	36.60	41.83	47.06	52.30	57.53	62.76	67.99	73.23	78.46	83.69	88.92	91.54	94.16

Freq [Hz]	Attenuation [dB]																		
	1 kft	2 kft	3 kft	4 kft	5 kft	6 kft	7 kft	8 kft	9 kft	10 kft	11 kft	12 kft	13 kft	14 kft	15 kft	16 kft	17 kft	17.5 kft	18 kft
4.50E+05	5.25	10.54	15.82	21.11	26.39	31.68	36.96	42.25	47.54	52.82	58.11	63.39	68.68	73.96	79.25	84.53	89.82	92.46	95.10
4.60E+05	5.30	10.65	15.98	21.32	26.66	31.99	37.33	42.67	48.00	53.34	58.68	64.02	69.35	74.69	80.03	85.37	90.70	93.37	96.04
4.70E+05	5.35	10.75	16.14	21.53	26.92	32.31	37.69	43.08	48.47	53.86	59.25	64.64	70.03	75.42	80.81	86.20	91.59	94.28	96.98
4.80E+05	5.40	10.86	16.29	21.73	27.17	32.62	38.06	43.50	48.94	54.38	59.82	65.26	70.70	76.14	81.58	87.02	92.46	95.19	97.91
4.90E+05	5.45	10.96	16.45	21.94	27.43	32.92	38.42	43.91	49.40	54.89	60.39	65.88	71.37	76.86	82.35	87.85	93.34	96.08	98.83
5.00E+05	5.50	11.06	16.60	22.14	27.69	33.23	38.77	44.32	49.86	55.40	60.95	66.49	72.03	77.58	83.12	88.66	94.21	96.98	99.75
5.10E+05	5.56	11.16	16.76	22.35	27.94	33.54	39.13	44.73	50.32	55.91	61.51	67.10	72.70	78.29	83.89	89.48	95.07	97.87	100.67
5.20E+05	5.61	11.26	16.91	22.55	28.20	33.84	39.49	45.13	50.78	56.42	62.07	67.71	73.36	79.00	84.64	90.29	95.93	98.76	101.58
5.30E+05	5.66	11.36	17.06	22.75	28.45	34.14	39.84	45.53	51.23	56.92	62.62	68.31	74.01	79.71	85.40	91.10	96.79	99.64	102.49
5.40E+05	5.71	11.46	17.21	22.95	28.70	34.44	40.19	45.94	51.68	57.43	63.17	68.92	74.66	80.41	86.15	91.90	97.64	100.52	103.39
5.50E+05	5.77	11.56	17.36	23.15	28.95	34.74	40.54	46.33	52.13	57.92	63.72	69.51	75.31	81.11	86.90	92.70	98.49	101.39	104.29
5.60E+05	5.82	11.66	17.51	23.35	29.20	35.04	40.89	46.73	52.58	58.42	64.27	70.11	75.95	81.80	87.64	93.49	99.33	102.26	105.18
5.70E+05	5.87	11.76	17.66	23.55	29.44	35.34	41.23	47.13	53.02	58.91	64.81	70.70	76.60	82.49	88.38	94.28	100.17	103.12	106.07
5.80E+05	5.92	11.86	17.80	23.75	29.69	35.63	41.58	47.52	53.46	59.41	65.35	71.29	77.23	83.18	89.12	95.06	101.01	103.98	106.95
5.90E+05	5.97	11.96	17.95	23.94	29.93	35.93	41.92	47.91	53.90	59.89	65.89	71.88	77.87	83.86	89.85	95.85	101.84	104.83	107.83
6.00E+05	6.02	12.06	18.10	24.14	30.18	36.22	42.26	48.30	54.34	60.38	66.42	72.46	78.50	84.54	90.58	96.62	102.66	105.68	108.70
6.10E+05	6.07	12.15	18.24	24.33	30.42	36.51	42.60	48.69	54.77	60.86	66.95	73.04	79.13	85.22	91.31	97.40	103.49	106.53	109.57
6.20E+05	6.12	12.25	18.39	24.52	30.66	36.80	42.93	49.07	55.21	61.34	67.48	73.62	79.76	85.89	92.03	98.17	104.30	107.37	110.44
6.30E+05	6.17	12.35	18.53	24.72	30.90	37.08	43.27	49.45	55.64	61.82	68.01	74.19	80.38	86.56	92.75	98.93	105.12	108.21	111.30
6.40E+05	6.22	12.44	18.67	24.91	31.14	37.37	43.60	49.83	56.07	62.30	68.53	74.76	81.00	87.23	93.46	99.69	105.93	109.04	112.16
6.50E+05	6.26	12.54	18.82	25.10	31.37	37.65	43.93	50.21	56.49	62.77	69.05	75.33	81.61	87.89	94.17	100.45	106.73	109.87	113.01
6.60E+05	6.31	12.63	18.96	25.28	31.61	37.94	44.26	50.59	56.92	63.24	69.57	75.90	82.22	88.55	94.88	101.20	107.53	110.70	113.86
6.70E+05	6.36	12.72	19.10	25.47	31.85	38.22	44.59	50.97	57.34	63.71	70.09	76.46	82.83	89.21	95.58	101.96	108.33	111.52	114.70
6.80E+05	6.40	12.82	19.24	25.66	32.08	38.50	44.92	51.34	57.76	64.18	70.60	77.02	83.44	89.86	96.28	102.70	109.12	112.33	115.54
6.90E+05	6.45	12.91	19.38	25.84	32.31	38.78	45.24	51.71	58.18	64.64	71.11	77.58	84.04	90.51	96.98	103.44	109.91	113.14	116.38
7.00E+05	6.49	13.00	19.52	26.03	32.54	39.06	45.57	52.08	58.59	65.11	71.62	78.13	84.64	91.16	97.67	104.18	110.70	113.95	117.21
7.10E+05	6.54	13.09	19.65	26.21	32.77	39.33	45.89	52.45	59.01	65.57	72.13	78.68	85.24	91.80	98.36	104.92	111.48	114.76	118.04
7.20E+05	6.58	13.19	19.79	26.40	33.00	39.61	46.21	52.81	59.42	66.02	72.63	79.23	85.84	92.44	99.05	105.65	112.26	115.56	118.86
7.30E+05	6.63	13.28	19.93	26.58	33.23	39.88	46.53	53.18	59.83	66.48	73.13	79.78	86.43	93.08	99.73	106.38	113.03	116.35	119.68
7.40E+05	6.67	13.37	20.07	26.76	33.46	40.15	46.85	53.54	60.24	66.93	73.63	80.32	87.02	93.71	100.41	107.10	113.80	117.15	120.49
7.50E+05	6.72	13.46	20.20	26.94	33.68	40.42	47.16	53.90	60.64	67.38	74.12	80.86	87.60	94.34	101.08	107.83	114.57	117.94	121.31
7.60E+05	6.76	13.55	20.34	27.12	33.91	40.69	47.48	54.26	61.05	67.83	74.62	81.40	88.19	94.97	101.76	108.54	115.33	118.72	122.11
7.70E+05	6.81	13.64	20.47	27.30	34.13	40.96	47.79	54.62	61.45	68.28	75.11	81.94	88.77	95.60	102.43	109.26	116.09	119.50	122.92
7.80E+05	6.85	13.73	20.60	27.48	34.35	41.23	48.10	54.97	61.85	68.72	75.60	82.47	89.35	96.22	103.09	109.97	116.84	120.28	123.72
7.90E+05	6.89	13.82	20.74	27.65	34.57	41.49	48.41	55.33	62.25	69.17	76.08	83.00	89.92	96.84	103.76	110.68	117.59	121.05	124.51
8.00E+05	6.94	13.91	20.87	27.83	34.79	41.76	48.72	55.68	62.64	69.61	76.57	83.53	90.49	97.46	104.42	111.38	118.34	121.82	125.31
8.10E+05	6.98	13.99	21.00	28.01	35.01	42.02	49.02	56.03	63.04	70.04	77.05	84.06	91.06	98.07	105.08	112.08	119.09	122.59	126.09
8.20E+05	7.03	14.08	21.13	28.18	35.23	42.28	49.33	56.38	63.43	70.48	77.53	84.58	91.63	98.68	105.73	112.78	119.83	123.35	126.88
8.30E+05	7.07	14.17	21.26	28.35	35.45	42.54	49.63	56.73	63.82	70.91	78.01	85.10	92.19	99.29	106.38	113.47	120.57	124.11	127.66
8.40E+05	7.11	14.25	21.39	28.53	35.66	42.80	49.94	57.07	64.21	71.35	78.48	85.62	92.76	99.89	107.03	114.17	121.30	124.87	128.44
8.50E+05	7.16	14.34	21.52	28.70	35.88	43.06	50.24	57.42	64.60	71.78	78.96	86.14	93.32	100.50	107.67	114.85	122.03	125.62	129.21
8.60E+05	7.20	14.43	21.65	28.87	36.09	43.32	50.54	57.76	64.98	72.21	79.43	86.65	93.87	101.09	108.32	115.54	122.76	126.37	129.98
8.70E+05	7.25	14.51	21.78	29.04	36.31	43.57	50.84	58.10	65.37	72.63	79.90	87.16	94.43	101.69	108.96	116.22	123.49	127.12	130.75
8.80E+05	7.29	14.60	21.90	29.21	36.52	43.83	51.13	58.44	65.75	73.06	80.36	87.67	94.98	102.29	109.59	116.90	124.21	127.86	131.52
8.90E+05	7.33	14.68	22.03	29.38	36.73	44.08	51.43	58.78	66.13	73.48	80.83	88.18	95.53	102.88	110.23	117.58	124.93	128.60	132.28

Freq [Hz]	Attenuation [dB]																		
	1 kft	2 kft	3 kft	4 kft	5 kft	6 kft	7 kft	8 kft	9 kft	10 kft	11 kft	12 kft	13 kft	14 kft	15 kft	16 kft	17 kft	17.5 kft	18 kft
9.00E+05	7.38	14.77	22.16	29.55	36.94	44.33	51.72	59.12	66.51	73.90	81.29	88.68	96.08	103.47	110.86	118.25	125.64	129.34	133.03
9.10E+05	7.42	14.85	22.28	29.72	37.15	44.58	52.02	59.45	66.89	74.32	81.75	89.19	96.62	104.05	111.49	118.92	126.35	130.07	133.79
9.20E+05	7.46	14.93	22.41	29.88	37.36	44.83	52.31	59.79	67.26	74.74	82.21	89.69	97.16	104.64	112.11	119.59	127.06	130.80	134.54
9.30E+05	7.50	15.02	22.53	30.05	37.57	45.08	52.60	60.12	67.63	75.15	82.67	90.19	97.70	105.22	112.74	120.25	127.77	131.53	135.29
9.40E+05	7.54	15.10	22.66	30.22	37.77	45.33	52.89	60.45	68.01	75.57	83.12	90.68	98.24	105.80	113.36	120.92	128.47	132.25	136.03
9.50E+05	7.59	15.18	22.78	30.38	37.98	45.58	53.18	60.78	68.38	75.98	83.58	91.18	98.78	106.38	113.97	121.57	129.17	132.97	136.77
9.60E+05	7.63	15.26	22.90	30.54	38.19	45.83	53.47	61.11	68.75	76.39	84.03	91.67	99.31	106.95	114.59	122.23	129.87	133.69	137.51
9.70E+05	7.67	15.35	23.03	30.71	38.39	46.07	53.75	61.43	69.11	76.80	84.48	92.16	99.84	107.52	115.20	122.88	130.57	134.41	138.25
9.80E+05	7.71	15.43	23.15	30.87	38.59	46.31	54.04	61.76	69.48	77.20	84.92	92.65	100.37	108.09	115.81	123.53	131.26	135.12	138.98
9.90E+05	7.75	15.51	23.27	31.03	38.80	46.56	54.32	62.08	69.85	77.61	85.37	93.13	100.90	108.66	116.42	124.18	131.95	135.83	139.71
1.00E+06	7.79	15.59	23.39	31.19	39.00	46.80	54.60	62.41	70.21	78.01	85.81	93.62	101.42	109.22	117.03	124.83	132.63	136.53	140.43
1.01E+06	7.83	15.67	23.51	31.36	39.20	47.04	54.88	62.73	70.57	78.41	86.26	94.10	101.94	109.79	117.63	125.47	133.31	137.24	141.16
1.02E+06	7.87	15.75	23.63	31.52	39.40	47.28	55.16	63.05	70.93	78.81	86.70	94.58	102.46	110.35	118.23	126.11	133.99	137.94	141.88
1.03E+06	7.91	15.83	23.75	31.68	39.60	47.52	55.44	63.37	71.29	79.21	87.14	95.06	102.98	110.90	118.83	126.75	134.67	138.63	142.59
1.04E+06	7.95	15.91	23.87	31.83	39.80	47.76	55.72	63.68	71.65	79.61	87.57	95.53	103.50	111.46	119.42	127.38	135.35	139.33	143.31
1.05E+06	7.99	15.99	23.99	31.99	39.99	48.00	56.00	64.00	72.00	80.00	88.01	96.01	104.01	112.01	120.02	128.02	136.02	140.02	144.02
1.06E+06	8.02	16.07	24.11	32.15	40.19	48.23	56.27	64.32	72.36	80.40	88.44	96.48	104.52	112.56	120.61	128.65	136.69	140.71	144.73
1.07E+06	8.06	16.15	24.23	32.31	40.39	48.47	56.55	64.63	72.71	80.79	88.87	96.95	105.03	113.11	121.19	129.28	137.36	141.40	145.44
1.08E+06	8.10	16.22	24.34	32.46	40.58	48.70	56.82	64.94	73.06	81.18	89.30	97.42	105.54	113.66	121.78	129.90	138.02	142.08	146.14
1.09E+06	8.14	16.30	24.46	32.62	40.78	48.94	57.10	65.25	73.41	81.57	89.73	97.89	106.05	114.21	122.36	130.52	138.68	142.76	146.84
1.10E+06	8.18	16.38	24.58	32.77	40.97	49.17	57.37	65.56	73.76	81.96	90.16	98.35	106.55	114.75	122.95	131.14	139.34	143.44	147.54

Table X.2: CSA#4, ANSI#13 loops

Freq [Hz]	Attenuation [dB]	
	CSA#4	ANSI#13
1.00E+04	14.48	20.76
2.00E+04	17.62	26.68
3.00E+04	20.11	30.94
4.00E+04	22.03	34.25
5.00E+04	23.60	37.07
6.00E+04	24.94	39.71
7.00E+04	26.14	42.29
8.00E+04	27.29	44.75
9.00E+04	28.40	46.74
1.00E+05	29.53	47.91
1.10E+05	30.70	48.26
1.20E+05	31.92	48.08
1.30E+05	33.20	47.70
1.40E+05	34.52	47.31
1.50E+05	35.86	47.04
1.60E+05	37.15	46.95
1.70E+05	38.27	47.04
1.80E+05	39.06	47.31
1.90E+05	39.48	47.76

Freq [Hz]	Attenuation [dB]	
	CSA#4	ANSI#13
2.00E+05	39.61	48.37
2.10E+05	39.58	49.14
2.20E+05	39.52	50.08
2.30E+05	39.51	51.20
2.40E+05	39.60	52.51
2.50E+05	39.82	54.02
2.60E+05	40.17	55.69
2.70E+05	40.62	57.43
2.80E+05	41.18	59.05
2.90E+05	41.85	60.37
3.00E+05	42.60	61.22
3.10E+05	43.44	61.58
3.20E+05	44.34	61.55
3.30E+05	45.27	61.31
3.40E+05	46.22	61.04
3.50E+05	47.13	60.84
3.60E+05	47.94	60.78
3.70E+05	48.58	60.88
3.80E+05	49.01	61.14
3.90E+05	49.22	61.53
4.00E+05	49.27	62.06
4.10E+05	49.21	62.72
4.20E+05	49.11	63.48
4.30E+05	49.02	64.35
4.40E+05	48.97	65.32
4.50E+05	48.99	66.36
4.60E+05	49.08	67.45
4.70E+05	49.25	68.53
4.80E+05	49.49	69.56
4.90E+05	49.81	70.48
5.00E+05	50.20	71.21
5.10E+05	50.66	71.74
5.20E+05	51.15	72.07
5.30E+05	51.67	72.27
5.40E+05	52.20	72.39
5.50E+05	52.69	72.50
5.60E+05	53.11	72.64
5.70E+05	53.44	72.84
5.80E+05	53.65	73.11
5.90E+05	53.74	73.44
6.00E+05	53.74	73.85
6.10E+05	53.67	74.32
6.20E+05	53.57	74.87
6.30E+05	53.46	75.49
6.40E+05	53.37	76.17

Freq [Hz]	Attenuation [dB]	
	CSA#4	ANSI#13
6.50E+05	53.31	76.91
6.60E+05	53.29	77.71
6.70E+05	53.30	78.56
6.80E+05	53.35	79.44
6.90E+05	53.44	80.32
7.00E+05	53.57	81.19
7.10E+05	53.73	82.01
7.20E+05	53.92	82.75
7.30E+05	54.14	83.38
7.40E+05	54.39	83.88
7.50E+05	54.66	84.28
7.60E+05	54.96	84.60
7.70E+05	55.28	84.86
7.80E+05	55.62	85.10
7.90E+05	55.99	85.34
8.00E+05	56.38	85.62
8.10E+05	56.79	85.95
8.20E+05	57.23	86.33
8.30E+05	57.69	86.78
8.40E+05	58.18	87.30
8.50E+05	58.69	87.88
8.60E+05	59.23	88.53
8.70E+05	59.79	89.24
8.80E+05	60.38	89.99
8.90E+05	60.99	90.78
9.00E+05	61.62	91.58
9.10E+05	62.27	92.36
9.20E+05	62.93	93.08
9.30E+05	63.58	93.73
9.40E+05	64.23	94.28
9.50E+05	64.86	94.73
9.60E+05	65.44	95.07
9.70E+05	65.99	95.34
9.80E+05	66.48	95.55
9.90E+05	66.91	95.74
1.00E+06	67.30	95.94
1.01E+06	67.64	96.15
1.02E+06	67.96	96.41
1.03E+06	68.26	96.71
1.04E+06	68.57	97.06
1.05E+06	68.89	97.47
1.06E+06	69.23	97.92
1.07E+06	69.59	98.43
1.08E+06	69.98	98.98
1.09E+06	70.40	99.55

Freq [Hz]	Attenuation [dB]	
	CSA#4	ANSI#13
1.10E+06	70.85	100.15

Table X.3: Bridge tap loops: 9kft straight segment

Freq [Hz]	Attenuation dB			
	Tap 150 ft	Tap 250 ft	Tap 350 ft	Tap 500 ft
1.00E+04	16.36	16.38	16.39	16.41
2.00E+04	19.99	20.02	20.05	20.10
3.00E+04	22.59	22.63	22.68	22.76
4.00E+04	24.47	24.53	24.59	24.70
5.00E+04	25.91	25.98	26.06	26.20
6.00E+04	27.05	27.13	27.22	27.41
7.00E+04	27.98	28.07	28.19	28.41
8.00E+04	28.77	28.88	29.01	29.28
9.00E+04	29.48	29.60	29.75	30.07
1.00E+05	30.11	30.25	30.43	30.82
1.10E+05	30.71	30.86	31.07	31.53
1.20E+05	31.27	31.44	31.68	32.23
1.30E+05	31.82	32.01	32.28	32.93
1.40E+05	32.35	32.56	32.87	33.64
1.50E+05	32.88	33.11	33.47	34.38
1.60E+05	33.40	33.66	34.06	35.13
1.70E+05	33.92	34.20	34.66	35.93
1.80E+05	34.44	34.75	35.27	36.77
1.90E+05	34.95	35.30	35.88	37.65
2.00E+05	35.47	35.85	36.51	38.60
2.10E+05	35.99	36.40	37.16	39.61
2.20E+05	36.51	36.96	37.81	40.70
2.30E+05	37.03	37.53	38.49	41.87
2.40E+05	37.55	38.09	39.18	43.14
2.50E+05	38.07	38.67	39.89	44.51
2.60E+05	38.60	39.24	40.63	45.96
2.70E+05	39.12	39.83	41.39	47.47
2.80E+05	39.64	40.42	42.18	48.95
2.90E+05	40.17	41.01	42.99	50.26
3.00E+05	40.69	41.61	43.85	51.21
3.10E+05	41.21	42.22	44.74	51.67
3.20E+05	41.74	42.83	45.67	51.68
3.30E+05	42.26	43.45	46.65	51.39
3.40E+05	42.78	44.08	47.68	50.98
3.50E+05	43.31	44.71	48.77	50.58
3.60E+05	43.83	45.36	49.91	50.23
3.70E+05	44.35	46.02	51.12	49.97
3.80E+05	44.87	46.68	52.38	49.79
3.90E+05	45.39	47.36	53.69	49.68

Freq [Hz]	Attenuation dB			
	Tap 150 ft	Tap 250 ft	Tap 350 ft	Tap 500 ft
4.00E+05	45.91	48.06	55.03	49.65
4.10E+05	46.43	48.76	56.34	49.68
4.20E+05	46.95	49.48	57.56	49.76
4.30E+05	47.47	50.23	58.56	49.89
4.40E+05	47.99	50.98	59.27	50.06
4.50E+05	48.50	51.76	59.61	50.27
4.60E+05	49.02	52.57	59.65	50.51
4.70E+05	49.54	53.40	59.47	50.77
4.80E+05	50.06	54.25	59.18	51.05
4.90E+05	50.57	55.13	58.86	51.36
5.00E+05	51.09	56.05	58.56	51.68
5.10E+05	51.60	57.00	58.29	52.01
5.20E+05	52.12	57.99	58.08	52.36
5.30E+05	52.64	59.01	57.93	52.72
5.40E+05	53.16	60.08	57.83	53.09
5.50E+05	53.67	61.18	57.78	53.47
5.60E+05	54.19	62.31	57.77	53.85
5.70E+05	54.71	63.47	57.81	54.25
5.80E+05	55.23	64.62	57.88	54.65
5.90E+05	55.76	65.75	57.99	55.06
6.00E+05	56.28	66.80	58.12	55.47
6.10E+05	56.81	67.72	58.28	55.89
6.20E+05	57.33	68.45	58.46	56.32
6.30E+05	57.86	68.94	58.67	56.75
6.40E+05	58.39	69.18	58.89	57.18
6.50E+05	58.93	69.22	59.13	57.63
6.60E+05	59.47	69.10	59.38	58.07
6.70E+05	60.01	68.90	59.65	58.53
6.80E+05	60.55	68.66	59.93	58.99
6.90E+05	61.10	68.41	60.22	59.46
7.00E+05	61.65	68.18	60.51	59.93
7.10E+05	62.21	67.98	60.82	60.42
7.20E+05	62.77	67.81	61.13	60.91
7.30E+05	63.33	67.67	61.45	61.41
7.40E+05	63.91	67.58	61.78	61.92
7.50E+05	64.48	67.51	62.11	62.45
7.60E+05	65.07	67.48	62.44	62.99
7.70E+05	65.66	67.48	62.78	63.54
7.80E+05	66.26	67.51	63.13	64.11
7.90E+05	66.87	67.57	63.47	64.70
8.00E+05	67.49	67.64	63.82	65.30
8.10E+05	68.11	67.74	64.18	65.93
8.20E+05	68.75	67.86	64.53	66.58
8.30E+05	69.40	68.00	64.89	67.26
8.40E+05	70.06	68.15	65.26	67.97



Freq [Hz]	Attenuation dB			
	Tap 150 ft	Tap 250 ft	Tap 350 ft	Tap 500 ft
8.50E+05	70.73	68.32	65.62	68.70
8.60E+05	71.41	68.50	65.99	69.46
8.70E+05	72.11	68.69	66.35	70.25
8.80E+05	72.82	68.90	66.73	71.06
8.90E+05	73.55	69.11	67.10	71.89
9.00E+05	74.30	69.34	67.47	72.74
9.10E+05	75.06	69.57	67.85	73.57
9.20E+05	75.85	69.81	68.23	74.37
9.30E+05	76.65	70.06	68.61	75.12
9.40E+05	77.47	70.32	68.99	75.79
9.50E+05	78.31	70.58	69.38	76.34
9.60E+05	79.17	70.84	69.76	76.76
9.70E+05	80.05	71.12	70.15	77.04
9.80E+05	80.94	71.39	70.55	77.20
9.90E+05	81.84	71.67	70.94	77.26
1.00E+06	82.74	71.96	71.34	77.25
1.01E+06	83.63	72.24	71.74	77.21
1.02E+06	84.50	72.53	72.14	77.14
1.03E+06	85.32	72.83	72.55	77.08
1.04E+06	86.08	73.12	72.96	77.02
1.05E+06	86.74	73.42	73.38	76.99
1.06E+06	87.28	73.72	73.80	76.98
1.07E+06	87.69	74.03	74.22	77.00
1.08E+06	87.97	74.33	74.65	77.04
1.09E+06	88.11	74.64	75.09	77.11
1.10E+06	88.14	74.95	75.53	77.20

Table X.4: Bridge tap loops: 12kft straight segment

Freq [Hz]	Attenuation dB								
	Tap 50 ft	Tap 150 ft	Tap 250 ft	Tap 350 ft	Tap 500 ft	Tap 750 ft	Tap 1000 ft	Tap 1250 ft	Tap 1500 ft
1.00E+04	21.27	21.29	21.30	21.31	21.33	21.38	21.42	21.48	21.54
2.00E+04	26.52	26.55	26.58	26.61	26.66	26.76	26.88	27.02	27.19
3.00E+04	30.06	30.10	30.15	30.19	30.27	30.44	30.65	30.91	31.23
4.00E+04	32.61	32.66	32.72	32.78	32.90	33.13	33.45	33.86	34.38
5.00E+04	34.53	34.59	34.66	34.74	34.89	35.21	35.66	36.28	37.06
6.00E+04	36.04	36.10	36.18	36.28	36.46	36.89	37.51	38.40	39.53
7.00E+04	37.26	37.34	37.43	37.55	37.77	38.32	39.17	40.41	41.95
8.00E+04	38.31	38.39	38.50	38.63	38.90	39.60	40.75	42.45	44.27
9.00E+04	39.23	39.32	39.44	39.59	39.92	40.80	42.34	44.56	46.17
1.00E+05	40.06	40.16	40.29	40.47	40.86	41.98	44.01	46.66	47.12
1.10E+05	40.84	40.94	41.10	41.30	41.76	43.17	45.82	48.39	47.16
1.20E+05	41.58	41.69	41.86	42.10	42.64	44.42	47.74	49.29	46.84
1.30E+05	42.29	42.41	42.60	42.87	43.52	45.74	49.68	49.32	46.55
1.40E+05	42.98	43.12	43.32	43.64	44.40	47.18	51.30	48.96	46.43

Freq [Hz]	Attenuation dB								
	Tap 50 ft	Tap 150 ft	Tap 250 ft	Tap 350 ft	Tap 500 ft	Tap 750 ft	Tap 1000 ft	Tap 1250 ft	Tap 1500 ft
1.50E+05	43.67	43.81	44.04	44.40	45.31	48.75	52.20	48.59	46.50
1.60E+05	44.35	44.50	44.75	45.16	46.23	50.46	52.30	48.38	46.73
1.70E+05	45.02	45.18	45.47	45.92	47.19	52.27	51.97	48.35	47.09
1.80E+05	45.69	45.87	46.18	46.70	48.20	54.08	51.57	48.47	47.55
1.90E+05	46.36	46.55	46.89	47.48	49.25	55.63	51.28	48.73	48.10
2.00E+05	47.03	47.23	47.61	48.28	50.36	56.60	51.15	49.09	48.74
2.10E+05	47.70	47.92	48.33	49.09	51.54	56.89	51.17	49.54	49.45
2.20E+05	48.37	48.60	49.06	49.91	52.79	56.70	51.32	50.05	50.24
2.30E+05	49.05	49.29	49.79	50.75	54.14	56.35	51.57	50.64	51.13
2.40E+05	49.72	49.98	50.52	51.61	55.57	56.02	51.92	51.27	52.10
2.50E+05	50.39	50.67	51.26	52.49	57.10	55.81	52.33	51.97	53.19
2.60E+05	51.06	51.36	52.01	53.39	58.72	55.72	52.81	52.71	54.39
2.70E+05	51.73	52.05	52.76	54.32	60.40	55.75	53.33	53.52	55.70
2.80E+05	52.40	52.74	53.51	55.27	62.04	55.89	53.89	54.39	57.05
2.90E+05	53.07	53.43	54.27	56.25	63.52	56.11	54.50	55.33	58.32
3.00E+05	53.74	54.12	55.04	57.27	64.64	56.41	55.13	56.35	59.35
3.10E+05	54.41	54.81	55.81	58.33	65.27	56.76	55.80	57.46	60.01
3.20E+05	55.07	55.50	56.59	59.43	65.44	57.17	56.50	58.66	60.33
3.30E+05	55.74	56.18	57.37	60.57	65.31	57.62	57.24	59.94	60.44
3.40E+05	56.40	56.87	58.16	61.77	65.07	58.11	58.01	61.25	60.51
3.50E+05	57.06	57.56	58.97	63.02	64.83	58.62	58.82	62.51	60.62
3.60E+05	57.72	58.24	59.77	64.33	64.65	59.16	59.68	63.58	60.82
3.70E+05	58.37	58.93	60.59	65.69	64.55	59.72	60.58	64.36	61.11
3.80E+05	59.02	59.61	61.42	67.12	64.52	60.31	61.54	64.80	61.49
3.90E+05	59.67	60.29	62.26	68.59	64.58	60.91	62.57	65.01	61.95
4.00E+05	60.32	60.97	63.12	70.09	64.71	61.52	63.66	65.09	62.48
4.10E+05	60.97	61.65	63.98	71.57	64.90	62.16	64.82	65.16	63.08
4.20E+05	61.61	62.33	64.87	72.94	65.14	62.81	66.04	65.28	63.75
4.30E+05	62.25	63.01	65.77	74.11	65.43	63.47	67.29	65.47	64.48
4.40E+05	62.88	63.68	66.68	74.96	65.76	64.15	68.50	65.73	65.27
4.50E+05	63.52	64.36	67.62	75.47	66.13	64.85	69.61	66.07	66.13
4.60E+05	64.14	65.03	68.58	75.66	66.52	65.57	70.51	66.47	67.06
4.70E+05	64.77	65.71	69.56	75.64	66.94	66.30	71.14	66.93	68.06
4.80E+05	65.40	66.38	70.57	75.50	67.37	67.06	71.51	67.44	69.09
4.90E+05	66.02	67.05	71.61	75.34	67.83	67.85	71.69	68.00	70.14
5.00E+05	66.63	67.72	72.68	75.19	68.31	68.67	71.78	68.60	71.14
5.10E+05	67.25	68.39	73.78	75.08	68.79	69.52	71.85	69.25	72.02
5.20E+05	67.86	69.06	74.92	75.02	69.29	70.40	71.94	69.94	72.72
5.30E+05	68.47	69.72	76.10	75.02	69.80	71.33	72.09	70.68	73.22
5.40E+05	69.07	70.39	77.31	75.06	70.32	72.30	72.29	71.47	73.56
5.50E+05	69.68	71.06	78.56	75.16	70.85	73.32	72.55	72.31	73.80
5.60E+05	70.28	71.73	79.85	75.31	71.39	74.38	72.86	73.21	74.02
5.70E+05	70.87	72.40	81.15	75.49	71.93	75.49	73.22	74.15	74.25
5.80E+05	71.47	73.06	82.45	75.71	72.48	76.62	73.62	75.13	74.52
5.90E+05	72.06	73.73	83.73	75.96	73.03	77.75	74.07	76.13	74.86

Freq [Hz]	Attenuation dB								
	Tap 50 ft	Tap 150 ft	Tap 250 ft	Tap 350 ft	Tap 500 ft	Tap 750 ft	Tap 1000 ft	Tap 1250 ft	Tap 1500 ft
6.00E+05	72.65	74.40	84.92	76.24	73.59	78.84	74.54	77.11	75.24
6.10E+05	73.23	75.07	85.99	76.55	74.16	79.84	75.05	78.03	75.69
6.20E+05	73.81	75.74	86.86	76.88	74.73	80.67	75.59	78.82	76.20
6.30E+05	74.39	76.42	87.49	77.22	75.30	81.31	76.16	79.45	76.75
6.40E+05	74.97	77.09	87.88	77.59	75.88	81.74	76.75	79.92	77.36
6.50E+05	75.54	77.77	88.06	77.97	76.47	82.00	77.38	80.24	78.03
6.60E+05	76.11	78.45	88.08	78.36	77.05	82.14	78.03	80.47	78.74
6.70E+05	76.68	79.13	88.02	78.77	77.65	82.22	78.71	80.67	79.50
6.80E+05	77.24	79.81	87.92	79.19	78.25	82.28	79.43	80.87	80.31
6.90E+05	77.81	80.50	87.81	79.62	78.86	82.36	80.18	81.09	81.15
7.00E+05	78.37	81.19	87.72	80.05	79.47	82.47	80.97	81.35	82.01
7.10E+05	78.92	81.88	87.65	80.49	80.09	82.62	81.80	81.66	82.85
7.20E+05	79.48	82.58	87.62	80.94	80.72	82.81	82.67	82.01	83.64
7.30E+05	80.03	83.28	87.62	81.40	81.36	83.03	83.57	82.41	84.34
7.40E+05	80.58	83.99	87.66	81.86	82.01	83.30	84.49	82.85	84.92
7.50E+05	81.12	84.71	87.73	82.33	82.67	83.60	85.42	83.33	85.38
7.60E+05	81.67	85.42	87.84	82.80	83.34	83.93	86.33	83.85	85.74
7.70E+05	82.21	86.15	87.97	83.27	84.03	84.29	87.19	84.41	86.04
7.80E+05	82.75	86.88	88.13	83.75	84.73	84.68	87.95	85.00	86.30
7.90E+05	83.29	87.62	88.32	84.23	85.45	85.09	88.59	85.64	86.57
8.00E+05	83.82	88.37	88.53	84.71	86.19	85.52	89.09	86.31	86.86
8.10E+05	84.35	89.13	88.76	85.20	86.95	85.97	89.46	87.02	87.19
8.20E+05	84.88	89.90	89.01	85.68	87.73	86.43	89.73	87.77	87.56
8.30E+05	85.41	90.68	89.28	86.17	88.54	86.91	89.93	88.55	87.97
8.40E+05	85.93	91.47	89.56	86.67	89.38	87.41	90.10	89.36	88.43
8.50E+05	86.46	92.27	89.86	87.16	90.24	87.92	90.27	90.17	88.93
8.60E+05	86.98	93.08	90.17	87.65	91.13	88.45	90.45	90.96	89.48
8.70E+05	87.50	93.91	90.49	88.15	92.04	89.00	90.66	91.71	90.06
8.80E+05	88.01	94.75	90.82	88.65	92.98	89.56	90.91	92.39	90.69
8.90E+05	88.53	95.60	91.16	89.15	93.94	90.13	91.18	92.98	91.36
9.00E+05	89.04	96.48	91.52	89.65	94.91	90.73	91.49	93.46	92.06
9.10E+05	89.55	97.37	91.87	90.15	95.87	91.34	91.83	93.84	92.78
9.20E+05	90.06	98.27	92.24	90.65	96.80	91.97	92.20	94.15	93.50
9.30E+05	90.56	99.20	92.61	91.16	97.67	92.63	92.61	94.41	94.21
9.40E+05	91.07	100.15	92.99	91.67	98.46	93.31	93.04	94.64	94.88
9.50E+05	91.57	101.11	93.38	92.17	99.14	94.01	93.49	94.87	95.49
9.60E+05	92.07	102.09	93.77	92.69	99.68	94.74	93.97	95.13	96.02
9.70E+05	92.57	103.09	94.16	93.20	100.08	95.49	94.48	95.40	96.46
9.80E+05	93.06	104.10	94.56	93.71	100.37	96.27	95.02	95.71	96.83
9.90E+05	93.56	105.12	94.96	94.23	100.55	97.07	95.58	96.05	97.15
1.00E+06	94.05	106.15	95.36	94.75	100.66	97.90	96.16	96.42	97.44
1.01E+06	94.54	107.16	95.77	95.27	100.74	98.73	96.78	96.83	97.73
1.02E+06	95.03	108.15	96.18	95.79	100.79	99.56	97.42	97.27	98.02
1.03E+06	95.51	109.09	96.60	96.32	100.85	100.38	98.09	97.75	98.33
1.04E+06	96.00	109.96	97.01	96.85	100.91	101.15	98.78	98.26	98.68

Freq [Hz]	Attenuation dB								
	Tap 50 ft	Tap 150 ft	Tap 250 ft	Tap 350 ft	Tap 500 ft	Tap 750 ft	Tap 1000 ft	Tap 1250 ft	Tap 1500 ft
1.05E+06	96.48	110.74	97.43	97.38	101.00	101.86	99.50	98.80	99.05
1.06E+06	96.96	111.41	97.85	97.92	101.11	102.49	100.24	99.37	99.47
1.07E+06	97.44	111.93	98.27	98.46	101.24	103.02	100.99	99.98	99.92
1.08E+06	97.92	112.32	98.69	99.01	101.40	103.44	101.73	100.61	100.40
1.09E+06	98.40	112.59	99.11	99.56	101.58	103.76	102.46	101.27	100.93
1.10E+06	98.87	112.74	99.54	100.12	101.79	104.00	103.15	101.94	101.48

Table X.5: Bridge tap loops: 15kft straight segment

Freq [Hz]	Attenuation dB												
	Tap 50ft	Tap 150ft	Tap 200ft	Tap 300ft	Tap 400ft	Tap 500ft	Tap 600ft	Tap 700ft	Tap 800ft	Tap 900ft	Tap 1000ft	Tap 1250ft	Tap 1500ft
1.00E+04	26.24	26.26	26.26	26.28	26.29	26.30	26.32	26.34	26.35	26.37	26.39	26.44	26.51
2.00E+04	33.05	33.08	33.10	33.12	33.16	33.19	33.23	33.27	33.31	33.36	33.41	33.56	33.73
3.00E+04	37.58	37.62	37.64	37.69	37.74	37.79	37.86	37.92	38.00	38.08	38.17	38.43	38.75
4.00E+04	40.81	40.86	40.88	40.94	41.01	41.09	41.17	41.27	41.38	41.50	41.64	42.06	42.57
5.00E+04	43.21	43.27	43.31	43.38	43.47	43.57	43.68	43.81	43.97	44.14	44.34	44.96	45.74
6.00E+04	45.09	45.16	45.20	45.29	45.39	45.52	45.67	45.84	46.05	46.29	46.57	47.45	48.59
7.00E+04	46.62	46.70	46.75	46.85	46.98	47.13	47.32	47.55	47.82	48.15	48.53	49.77	51.31
8.00E+04	47.92	48.01	48.06	48.18	48.33	48.52	48.75	49.05	49.40	49.84	50.37	52.07	53.89
9.00E+04	49.07	49.16	49.22	49.35	49.53	49.76	50.05	50.42	50.89	51.47	52.18	54.40	56.01
1.00E+05	50.11	50.21	50.27	50.42	50.63	50.91	51.27	51.74	52.35	53.12	54.06	56.70	57.17
1.10E+05	51.07	51.18	51.25	51.43	51.67	52.00	52.44	53.04	53.83	54.84	56.05	58.63	57.40
1.20E+05	51.99	52.11	52.18	52.38	52.67	53.06	53.61	54.36	55.38	56.67	58.16	59.71	57.25
1.30E+05	52.88	53.00	53.09	53.31	53.64	54.11	54.79	55.73	57.03	58.65	60.27	59.91	57.14
1.40E+05	53.75	53.88	53.97	54.23	54.61	55.17	55.99	57.18	58.81	60.72	62.06	59.72	57.20
1.50E+05	54.60	54.74	54.84	55.13	55.57	56.24	57.25	58.73	60.73	62.71	63.13	59.52	57.43
1.60E+05	55.44	55.60	55.71	56.03	56.54	57.33	58.56	60.41	62.75	64.28	63.40	59.48	57.83
1.70E+05	56.28	56.45	56.57	56.93	57.51	58.46	59.96	62.21	64.71	65.10	63.23	59.61	58.35
1.80E+05	57.12	57.30	57.43	57.83	58.51	59.63	61.46	64.14	66.32	65.23	63.00	59.90	58.98
1.90E+05	57.96	58.15	58.29	58.74	59.52	60.84	63.06	66.11	67.25	65.04	62.87	60.32	59.70
2.00E+05	58.79	59.00	59.16	59.66	60.55	62.12	64.78	67.96	67.51	64.83	62.91	60.85	60.50
2.10E+05	59.63	59.85	60.02	60.58	61.60	63.47	66.62	69.38	67.38	64.73	63.09	61.46	61.38
2.20E+05	60.47	60.70	60.89	61.51	62.68	64.89	68.53	70.16	67.18	64.78	63.41	62.15	62.34
2.30E+05	61.31	61.55	61.76	62.45	63.80	66.40	70.42	70.36	67.05	64.96	63.83	62.90	63.39
2.40E+05	62.15	62.41	62.63	63.40	64.94	68.00	72.09	70.25	67.05	65.27	64.35	63.70	64.53
2.50E+05	62.98	63.26	63.51	64.36	66.13	69.70	73.31	70.08	67.18	65.68	64.93	64.56	65.79
2.60E+05	63.82	64.12	64.38	65.33	67.36	71.49	73.95	69.97	67.43	66.18	65.57	65.47	67.15
2.70E+05	64.66	64.98	65.26	66.31	68.64	73.32	74.11	69.98	67.78	66.73	66.26	66.44	68.62
2.80E+05	65.50	65.83	66.14	67.30	69.97	75.14	74.02	70.10	68.22	67.35	66.99	67.48	70.14
2.90E+05	66.33	66.69	67.02	68.31	71.37	76.78	73.89	70.33	68.72	68.01	67.76	68.59	71.58
3.00E+05	67.17	67.54	67.90	69.33	72.83	78.07	73.81	70.66	69.29	68.71	68.56	69.77	72.78
3.10E+05	68.00	68.40	68.79	70.37	74.36	78.86	73.83	71.06	69.90	69.44	69.39	71.05	73.61
3.20E+05	68.83	69.25	69.67	71.43	75.96	79.19	73.94	71.53	70.55	70.20	70.26	72.42	74.08
3.30E+05	69.66	70.11	70.56	72.50	77.63	79.24	74.15	72.06	71.23	70.99	71.16	73.86	74.36
3.40E+05	70.49	70.96	71.45	73.60	79.35	79.16	74.45	72.63	71.94	71.80	72.10	75.33	74.59

Freq [Hz]	Attenuation dB												
	Tap 50ft	Tap 150ft	Tap 200ft	Tap 300ft	Tap 400ft	Tap 500ft	Tap 600ft	Tap 700ft	Tap 800ft	Tap 900ft	Tap 1000ft	Tap 1250ft	Tap 1500ft
3.50E+05	71.31	71.81	72.34	74.72	81.08	79.08	74.82	73.24	72.67	72.64	73.07	76.76	74.87
3.60E+05	72.13	72.66	73.22	75.86	82.74	79.06	75.25	73.88	73.43	73.50	74.09	78.00	75.23
3.70E+05	72.95	73.51	74.11	77.03	84.23	79.12	75.73	74.54	74.21	74.39	75.16	78.93	75.69
3.80E+05	73.76	74.35	75.01	78.24	85.40	79.26	76.26	75.24	75.00	75.31	76.28	79.54	76.23
3.90E+05	74.58	75.19	75.90	79.48	86.17	79.48	76.82	75.95	75.81	76.25	77.47	79.91	76.85
4.00E+05	75.38	76.04	76.79	80.76	86.56	79.77	77.41	76.67	76.64	77.24	78.73	80.15	77.55
4.10E+05	76.19	76.88	77.69	82.07	86.69	80.12	78.03	77.42	77.49	78.26	80.05	80.39	78.31
4.20E+05	76.99	77.71	78.59	83.44	86.68	80.53	78.68	78.17	78.36	79.32	81.42	80.66	79.13
4.30E+05	77.79	78.55	79.49	84.85	86.65	80.97	79.34	78.94	79.25	80.44	82.83	81.01	80.02
4.40E+05	78.58	79.38	80.39	86.30	86.63	81.46	80.02	79.73	80.17	81.61	84.20	81.43	80.97
4.50E+05	79.37	80.22	81.30	87.81	86.67	81.98	80.71	80.52	81.10	82.84	85.46	81.92	81.99
4.60E+05	80.16	81.05	82.21	89.35	86.77	82.53	81.41	81.33	82.07	84.12	86.52	82.48	83.08
4.70E+05	80.94	81.87	83.13	90.92	86.94	83.10	82.13	82.15	83.08	85.46	87.30	83.09	84.22
4.80E+05	81.72	82.70	84.04	92.47	87.16	83.70	82.85	82.98	84.11	86.82	87.83	83.76	85.42
4.90E+05	82.49	83.52	84.97	93.97	87.43	84.31	83.59	83.83	85.20	88.16	88.17	84.47	86.62
5.00E+05	83.26	84.35	85.90	95.34	87.76	84.94	84.33	84.69	86.33	89.42	88.41	85.23	87.77
5.10E+05	84.03	85.17	86.83	96.49	88.13	85.58	85.08	85.57	87.51	90.52	88.63	86.03	88.80
5.20E+05	84.80	85.99	87.78	97.35	88.53	86.23	85.84	86.48	88.73	91.38	88.88	86.88	89.65
5.30E+05	85.55	86.81	88.73	97.92	88.97	86.89	86.60	87.40	90.01	92.00	89.17	87.77	90.30
5.40E+05	86.31	87.63	89.69	98.23	89.44	87.56	87.37	88.35	91.31	92.41	89.52	88.71	90.79
5.50E+05	87.06	88.45	90.66	98.37	89.93	88.24	88.16	89.33	92.62	92.69	89.93	89.70	91.19
5.60E+05	87.81	89.26	91.64	98.41	90.45	88.92	88.95	90.34	93.89	92.91	90.39	90.74	91.55
5.70E+05	88.56	90.08	92.63	98.42	90.98	89.61	89.74	91.39	95.05	93.13	90.90	91.83	91.93
5.80E+05	89.30	90.89	93.63	98.44	91.54	90.31	90.55	92.48	96.05	93.38	91.45	92.96	92.35
5.90E+05	90.03	91.71	94.65	98.49	92.10	91.01	91.37	93.60	96.83	93.68	92.04	94.11	92.83
6.00E+05	90.77	92.52	95.69	98.58	92.68	91.71	92.21	94.78	97.39	94.02	92.66	95.24	93.37
6.10E+05	91.50	93.34	96.74	98.71	93.27	92.42	93.05	95.99	97.77	94.41	93.32	96.30	93.96
6.20E+05	92.22	94.15	97.81	98.88	93.87	93.14	93.92	97.23	98.04	94.85	94.00	97.23	94.61
6.30E+05	92.94	94.97	98.90	99.10	94.47	93.86	94.80	98.48	98.26	95.33	94.71	98.01	95.31
6.40E+05	93.66	95.79	100.01	99.35	95.09	94.58	95.70	99.71	98.47	95.85	95.45	98.61	96.06
6.50E+05	94.38	96.61	101.14	99.64	95.71	95.30	96.62	100.88	98.70	96.41	96.21	99.08	96.87
6.60E+05	95.09	97.43	102.30	99.96	96.34	96.03	97.57	101.93	98.97	96.99	97.01	99.45	97.72
6.70E+05	95.80	98.25	103.48	100.32	96.97	96.77	98.55	102.82	99.28	97.60	97.83	99.79	98.62
6.80E+05	96.50	99.07	104.69	100.70	97.60	97.51	99.56	103.52	99.64	98.23	98.69	100.13	99.57
6.90E+05	97.21	99.90	105.93	101.10	98.24	98.26	100.60	104.03	100.03	98.89	99.58	100.49	100.55
7.00E+05	97.90	100.73	107.19	101.52	98.88	99.01	101.67	104.39	100.47	99.57	100.51	100.89	101.55
7.10E+05	98.60	101.56	108.48	101.96	99.53	99.77	102.78	104.66	100.94	100.27	101.48	101.33	102.53
7.20E+05	99.29	102.39	109.79	102.42	100.18	100.54	103.92	104.87	101.44	100.99	102.48	101.82	103.46
7.30E+05	99.98	103.23	111.10	102.89	100.83	101.31	105.09	105.07	101.96	101.74	103.52	102.36	104.29
7.40E+05	100.66	104.08	112.41	103.38	101.48	102.10	106.27	105.28	102.52	102.51	104.58	102.93	105.01
7.50E+05	101.35	104.93	113.69	103.88	102.14	102.89	107.44	105.52	103.09	103.31	105.64	103.55	105.60
7.60E+05	102.02	105.78	114.91	104.39	102.79	103.70	108.57	105.79	103.69	104.13	106.69	104.20	106.10
7.70E+05	102.70	106.64	116.02	104.91	103.45	104.52	109.63	106.11	104.30	104.98	107.68	104.90	106.53
7.80E+05	103.37	107.51	116.99	105.43	104.11	105.35	110.57	106.46	104.93	105.86	108.58	105.63	106.93

Freq [Hz]	Attenuation dB												
	Tap 50ft	Tap 150ft	Tap 200ft	Tap 300ft	Tap 400ft	Tap 500ft	Tap 600ft	Tap 700ft	Tap 800ft	Tap 900ft	Tap 1000ft	Tap 1250ft	Tap 1500ft
7.90E+05	104.04	108.38	117.79	105.97	104.77	106.21	111.35	106.84	105.58	106.78	109.35	106.39	107.33
8.00E+05	104.71	109.26	118.39	106.51	105.44	107.08	111.98	107.26	106.25	107.72	109.98	107.20	107.75
8.10E+05	105.37	110.15	118.81	107.06	106.10	107.97	112.44	107.70	106.94	108.70	110.48	108.04	108.21
8.20E+05	106.03	111.05	119.08	107.61	106.77	108.88	112.78	108.17	107.64	109.71	110.88	108.92	108.71
8.30E+05	106.69	111.96	119.24	108.17	107.44	109.82	113.03	108.66	108.36	110.73	111.21	109.83	109.25
8.40E+05	107.34	112.87	119.33	108.73	108.11	110.78	113.24	109.18	109.10	111.75	111.51	110.77	109.84
8.50E+05	108.00	113.80	119.39	109.29	108.78	111.78	113.43	109.71	109.85	112.76	111.81	111.70	110.47
8.60E+05	108.65	114.75	119.43	109.86	109.46	112.79	113.62	110.26	110.64	113.71	112.12	112.63	111.14
8.70E+05	109.29	115.70	119.49	110.43	110.14	113.84	113.83	110.83	111.44	114.58	112.46	113.51	111.86
8.80E+05	109.94	116.67	119.56	111.00	110.82	114.91	114.07	111.41	112.27	115.34	112.83	114.32	112.62
8.90E+05	110.58	117.65	119.65	111.58	111.51	115.99	114.34	112.01	113.13	115.97	113.23	115.03	113.41
9.00E+05	111.21	118.65	119.77	112.16	112.20	117.09	114.64	112.61	114.01	116.49	113.66	115.64	114.23
9.10E+05	111.85	119.67	119.91	112.73	112.89	118.17	114.97	113.23	114.92	116.90	114.13	116.14	115.08
9.20E+05	112.48	120.70	120.08	113.31	113.59	119.23	115.32	113.87	115.86	117.23	114.63	116.58	115.93
9.30E+05	113.11	121.75	120.27	113.90	114.29	120.22	115.71	114.51	116.82	117.53	115.16	116.96	116.76
9.40E+05	113.74	122.82	120.49	114.48	115.00	121.14	116.12	115.17	117.80	117.81	115.71	117.32	117.56
9.50E+05	114.37	123.91	120.73	115.06	115.72	121.93	116.55	115.85	118.78	118.09	116.29	117.67	118.29
9.60E+05	114.99	125.01	120.99	115.65	116.45	122.60	117.00	116.53	119.75	118.39	116.90	118.05	118.94
9.70E+05	115.61	126.13	121.28	116.23	117.18	123.13	117.47	117.24	120.67	118.71	117.53	118.44	119.51
9.80E+05	116.23	127.27	121.58	116.82	117.92	123.53	117.95	117.95	121.54	119.07	118.18	118.87	120.00
9.90E+05	116.84	128.41	121.89	117.40	118.67	123.84	118.45	118.69	122.31	119.45	118.86	119.34	120.44
1.00E+06	117.46	129.55	122.23	117.99	119.44	124.07	118.96	119.44	122.98	119.86	119.57	119.83	120.85
1.01E+06	118.07	130.69	122.57	118.58	120.21	124.26	119.49	120.22	123.54	120.30	120.31	120.36	121.26
1.02E+06	118.68	131.80	122.93	119.16	121.00	124.44	120.02	121.02	123.99	120.76	121.07	120.92	121.67
1.03E+06	119.28	132.86	123.30	119.75	121.80	124.61	120.57	121.83	124.35	121.25	121.86	121.52	122.10
1.04E+06	119.89	133.85	123.69	120.34	122.62	124.80	121.13	122.68	124.66	121.76	122.67	122.15	122.56
1.05E+06	120.49	134.75	124.08	120.93	123.46	125.00	121.69	123.54	124.93	122.30	123.51	122.81	123.06
1.06E+06	121.09	135.53	124.48	121.51	124.32	125.23	122.27	124.43	125.19	122.86	124.36	123.50	123.59
1.07E+06	121.69	136.18	124.89	122.10	125.19	125.48	122.85	125.34	125.46	123.43	125.23	124.22	124.16
1.08E+06	122.28	136.68	125.31	122.69	126.09	125.76	123.45	126.26	125.74	124.03	126.09	124.97	124.76
1.09E+06	122.87	137.06	125.74	123.28	127.00	126.06	124.05	127.19	126.03	124.65	126.94	125.75	125.40
1.10E+06	123.47	137.33	126.17	123.87	127.94	126.38	124.66	128.11	126.35	125.29	127.74	126.54	126.07

Table X.6: Bridge tap loops: 17.5kft straight segment

Freq [Hz]	Attenuation dB												
	Tap 50ft	Tap 150ft	Tap 200ft	Tap 300ft	Tap 400ft	Tap 500ft	Tap 600ft	Tap 700ft	Tap 800ft	Tap 900ft	Tap 1000ft	Tap 1250ft	Tap 1500ft
1.00E+04	30.37	30.38	30.39	30.40	30.41	30.43	30.44	30.46	30.48	30.50	30.52	30.57	30.63
2.00E+04	38.50	38.53	38.54	38.57	38.60	38.64	38.68	38.72	38.76	38.81	38.86	39.00	39.17
3.00E+04	43.85	43.89	43.91	43.96	44.01	44.06	44.12	44.19	44.26	44.34	44.43	44.70	45.02
4.00E+04	47.63	47.68	47.71	47.77	47.84	47.91	48.00	48.10	48.21	48.33	48.47	48.88	49.40
5.00E+04	50.45	50.51	50.54	50.61	50.70	50.80	50.92	51.05	51.20	51.38	51.58	52.19	52.98
6.00E+04	52.64	52.71	52.75	52.84	52.94	53.07	53.22	53.39	53.60	53.84	54.12	55.00	56.14
7.00E+04	54.43	54.50	54.55	54.65	54.78	54.93	55.12	55.35	55.62	55.95	56.33	57.58	59.11
8.00E+04	55.94	56.02	56.07	56.19	56.34	56.53	56.77	57.06	57.42	57.86	58.38	60.08	61.91

Freq [Hz]	Attenuation dB												
	Tap 50ft	Tap 150ft	Tap 200ft	Tap 300ft	Tap 400ft	Tap 500ft	Tap 600ft	Tap 700ft	Tap 800ft	Tap 900ft	Tap 1000ft	Tap 1250ft	Tap 1500ft
9.00E+04	57.27	57.36	57.42	57.55	57.73	57.96	58.25	58.62	59.09	59.68	60.38	62.61	64.21
1.00E+05	58.48	58.58	58.64	58.80	59.00	59.28	59.64	60.11	60.72	61.49	62.43	65.08	65.54
1.10E+05	59.60	59.71	59.78	59.96	60.20	60.53	60.97	61.57	62.36	63.37	64.58	67.16	65.93
1.20E+05	60.67	60.79	60.86	61.07	61.35	61.74	62.29	63.04	64.06	65.35	66.84	68.39	65.93
1.30E+05	61.71	61.83	61.91	62.14	62.47	62.94	63.61	64.56	65.85	67.47	69.09	68.74	65.96
1.40E+05	62.71	62.85	62.94	63.20	63.57	64.14	64.96	66.15	67.78	69.69	71.03	68.69	66.16
1.50E+05	63.71	63.85	63.95	64.24	64.68	65.35	66.35	67.84	69.84	71.82	72.24	68.63	66.54
1.60E+05	64.69	64.85	64.96	65.28	65.78	66.58	67.81	69.66	72.00	73.53	72.65	68.73	67.08
1.70E+05	65.67	65.84	65.96	66.32	66.90	67.84	69.35	71.60	74.10	74.49	72.62	69.00	67.74
1.80E+05	66.65	66.82	66.96	67.36	68.03	69.15	70.98	73.67	75.84	74.76	72.52	69.43	68.51
1.90E+05	67.62	67.81	67.96	68.41	69.18	70.51	72.73	75.78	76.92	74.70	72.54	69.99	69.36
2.00E+05	68.60	68.80	68.96	69.46	70.35	71.92	74.59	77.76	77.31	74.63	72.71	70.65	70.30
2.10E+05	69.57	69.79	69.96	70.52	71.54	73.41	76.56	79.32	77.32	74.67	73.03	71.40	71.32
2.20E+05	70.55	70.78	70.97	71.59	72.76	74.97	78.61	80.24	77.25	74.85	73.49	72.23	72.42
2.30E+05	71.52	71.77	71.98	72.67	74.01	76.61	80.63	80.58	77.26	75.18	74.05	73.11	73.60
2.40E+05	72.50	72.76	72.99	73.76	75.30	78.36	82.45	80.61	77.40	75.63	74.70	74.06	74.89
2.50E+05	73.48	73.76	74.00	74.85	76.63	80.19	83.81	80.57	77.67	76.18	75.42	75.06	76.28
2.60E+05	74.46	74.75	75.02	75.96	77.99	82.12	84.58	80.61	78.06	76.81	76.20	76.11	77.79
2.70E+05	75.43	75.75	76.03	77.08	79.41	84.10	84.88	80.75	78.55	77.51	77.03	77.22	79.40
2.80E+05	76.41	76.74	77.05	78.22	80.89	86.05	84.94	81.01	79.13	78.26	77.90	78.39	81.05
2.90E+05	77.38	77.74	78.07	79.36	82.42	87.83	84.94	81.38	79.77	79.06	78.81	79.64	82.63
3.00E+05	78.36	78.73	79.09	80.52	84.02	89.25	85.00	81.85	80.48	79.90	79.75	80.96	83.97
3.10E+05	79.33	79.73	80.12	81.70	85.68	90.19	85.15	82.39	81.22	80.77	80.72	82.38	84.93
3.20E+05	80.30	80.72	81.14	82.89	87.42	90.66	85.41	83.00	82.01	81.67	81.73	83.88	85.55
3.30E+05	81.26	81.71	82.16	84.10	89.23	90.84	85.76	83.66	82.83	82.59	82.76	85.46	85.97
3.40E+05	82.23	82.70	83.19	85.34	91.09	90.90	86.19	84.37	83.68	83.54	83.84	87.07	86.33
3.50E+05	83.19	83.69	84.21	86.59	92.95	90.96	86.69	85.11	84.55	84.52	84.95	88.63	86.75
3.60E+05	84.14	84.67	85.24	87.87	94.75	91.08	87.26	85.89	85.44	85.51	86.10	90.01	87.25
3.70E+05	85.10	85.65	86.26	89.18	96.37	91.27	87.88	86.69	86.35	86.54	87.31	91.08	87.84
3.80E+05	86.05	86.63	87.29	90.52	97.68	91.55	88.54	87.52	87.28	87.59	88.57	91.83	88.51
3.90E+05	86.99	87.61	88.32	91.90	98.58	91.90	89.24	88.36	88.23	88.67	89.89	92.32	89.27
4.00E+05	87.93	88.59	89.35	93.31	99.11	92.32	89.97	89.22	89.20	89.79	91.28	92.70	90.10
4.10E+05	88.87	89.56	90.38	94.76	99.37	92.81	90.72	90.10	90.18	90.94	92.73	93.07	90.99
4.20E+05	89.81	90.53	91.41	96.26	99.50	93.34	91.49	90.99	91.18	92.14	94.24	93.48	91.95
4.30E+05	90.74	91.50	92.44	97.80	99.60	93.92	92.29	91.89	92.20	93.39	95.78	93.96	92.97
4.40E+05	91.66	92.47	93.48	99.39	99.72	94.54	93.10	92.81	93.25	94.69	97.28	94.51	94.05
4.50E+05	92.58	93.43	94.51	101.02	99.89	95.19	93.92	93.73	94.32	96.05	98.68	95.14	95.20
4.60E+05	93.50	94.39	95.55	102.69	100.12	95.87	94.75	94.67	95.42	97.47	99.86	95.82	96.42
4.70E+05	94.41	95.35	96.60	104.39	100.41	96.58	95.60	95.62	96.55	98.93	100.78	96.57	97.70
4.80E+05	95.32	96.30	97.65	106.07	100.76	97.30	96.45	96.58	97.72	100.42	101.43	97.36	99.02
4.90E+05	96.22	97.26	98.70	107.70	101.17	98.04	97.32	97.56	98.93	101.90	101.90	98.20	100.35
5.00E+05	97.12	98.21	99.76	109.20	101.62	98.79	98.19	98.55	100.18	103.28	102.27	99.09	101.63
5.10E+05	98.02	99.16	100.82	110.47	102.11	99.56	99.06	99.56	101.49	104.51	102.62	100.02	102.79
5.20E+05	98.91	100.10	101.89	111.47	102.65	100.34	99.95	100.59	102.85	105.50	102.99	100.99	103.77

Freq [Hz]	Attenuation dB												
	Tap 50ft	Tap 150ft	Tap 200ft	Tap 300ft	Tap 400ft	Tap 500ft	Tap 600ft	Tap 700ft	Tap 800ft	Tap 900ft	Tap 1000ft	Tap 1250ft	Tap 1500ft
5.30E+05	99.79	101.05	102.97	112.16	103.21	101.13	100.84	101.64	104.25	106.24	103.41	102.01	104.54
5.40E+05	100.67	101.99	104.05	112.59	103.80	101.92	101.74	102.71	105.68	106.78	103.89	103.07	105.16
5.50E+05	101.55	102.93	105.15	112.86	104.42	102.73	102.64	103.82	107.11	107.18	104.42	104.19	105.67
5.60E+05	102.42	103.87	106.25	113.02	105.06	103.53	103.56	104.95	108.50	107.53	105.01	105.35	106.16
5.70E+05	103.29	104.81	107.36	113.16	105.72	104.35	104.48	106.12	109.79	107.87	105.64	106.57	106.67
5.80E+05	104.15	105.75	108.49	113.30	106.39	105.17	105.41	107.33	110.91	108.24	106.31	107.82	107.21
5.90E+05	105.01	106.69	109.63	113.47	107.08	105.99	106.35	108.58	111.81	108.66	107.02	109.09	107.81
6.00E+05	105.87	107.62	110.79	113.68	107.78	106.82	107.31	109.88	112.49	109.12	107.76	110.34	108.47
6.10E+05	106.72	108.56	111.96	113.93	108.49	107.65	108.28	111.21	113.00	109.64	108.54	111.52	109.18
6.20E+05	107.56	109.50	113.15	114.22	109.21	108.48	109.26	112.57	113.39	110.19	109.34	112.58	109.95
6.30E+05	108.41	110.43	114.36	114.56	109.94	109.32	110.26	113.94	113.72	110.80	110.17	113.47	110.77
6.40E+05	109.24	111.37	115.59	114.93	110.67	110.16	111.28	115.29	114.05	111.43	111.03	114.19	111.64
6.50E+05	110.08	112.31	116.84	115.34	111.41	111.00	112.32	116.58	114.40	112.10	111.91	114.78	112.56
6.60E+05	110.91	113.24	118.12	115.78	112.15	111.85	113.39	117.75	114.79	112.80	112.83	115.27	113.54
6.70E+05	111.73	114.18	119.42	116.25	112.90	112.70	114.48	118.76	115.22	113.53	113.77	115.72	114.56
6.80E+05	112.55	115.12	120.74	116.75	113.65	113.56	115.61	119.57	115.69	114.28	114.74	116.18	115.62
6.90E+05	113.37	116.06	122.10	117.26	114.41	114.42	116.76	120.20	116.20	115.05	115.75	116.66	116.72
7.00E+05	114.19	117.01	123.48	117.80	115.17	115.29	117.95	120.68	116.75	115.85	116.80	117.17	117.83
7.10E+05	115.00	117.96	124.88	118.36	115.93	116.17	119.18	121.05	117.33	116.67	117.88	117.73	118.93
7.20E+05	115.80	118.91	126.30	118.93	116.69	117.05	120.43	121.38	117.95	117.50	118.99	118.34	119.97
7.30E+05	116.60	119.86	127.73	119.52	117.45	117.94	121.71	121.69	118.59	118.37	120.14	118.98	120.92
7.40E+05	117.40	120.82	129.15	120.12	118.22	118.83	123.01	122.02	119.25	119.25	121.32	119.67	121.75
7.50E+05	118.20	121.78	130.54	120.73	118.99	119.74	124.29	122.37	119.94	120.16	122.49	120.40	122.45
7.60E+05	118.99	122.74	131.87	121.35	119.76	120.66	125.53	122.76	120.65	121.09	123.65	121.17	123.06
7.70E+05	119.77	123.71	133.10	121.98	120.53	121.59	126.70	123.18	121.38	122.05	124.75	121.97	123.60
7.80E+05	120.56	124.69	134.18	122.62	121.30	122.54	127.75	123.64	122.12	123.05	125.76	122.81	124.11
7.90E+05	121.34	125.68	135.08	123.27	122.07	123.50	128.65	124.14	122.88	124.07	126.64	123.69	124.62
8.00E+05	122.11	126.67	135.80	123.92	122.84	124.48	129.38	124.66	123.66	125.13	127.39	124.61	125.16
8.10E+05	122.89	127.67	136.33	124.57	123.62	125.49	129.96	125.22	124.45	126.22	128.00	125.56	125.72
8.20E+05	123.66	128.67	136.70	125.23	124.39	126.51	130.40	125.80	125.26	127.33	128.51	126.55	126.33
8.30E+05	124.42	129.69	136.97	125.90	125.17	127.55	130.77	126.40	126.09	128.46	128.95	127.57	126.98
8.40E+05	125.19	130.72	137.17	126.57	125.95	128.63	131.08	127.02	126.94	129.59	129.36	128.61	127.68
8.50E+05	125.95	131.75	137.34	127.24	126.73	129.72	131.37	127.66	127.80	130.71	129.76	129.65	128.42
8.60E+05	126.70	132.80	137.49	127.92	127.52	130.85	131.67	128.32	128.69	131.77	130.18	130.68	129.20
8.70E+05	127.45	133.86	137.65	128.59	128.30	132.00	131.99	128.99	129.60	132.74	130.62	131.67	130.02
8.80E+05	128.20	134.94	137.83	129.27	129.09	133.18	132.34	129.68	130.54	133.61	131.10	132.59	130.89
8.90E+05	128.95	136.03	138.02	129.95	129.88	134.37	132.71	130.38	131.50	134.35	131.60	133.40	131.78
9.00E+05	129.69	137.13	138.24	130.64	130.68	135.57	133.12	131.09	132.49	134.97	132.14	134.12	132.71
9.10E+05	130.43	138.25	138.49	131.32	131.47	136.76	133.55	131.82	133.51	135.48	132.72	134.73	133.66
9.20E+05	131.17	139.39	138.77	132.00	132.28	137.91	134.01	132.56	134.55	135.92	133.32	135.26	134.62
9.30E+05	131.91	140.54	139.06	132.69	133.09	139.02	134.50	133.31	135.62	136.32	133.95	135.75	135.55
9.40E+05	132.64	141.72	139.39	133.37	133.90	140.03	135.01	134.07	136.70	136.70	134.61	136.21	136.45
9.50E+05	133.37	142.91	139.73	134.06	134.72	140.93	135.55	134.85	137.78	137.09	135.29	136.67	137.29
9.60E+05	134.09	144.11	140.10	134.75	135.55	141.70	136.10	135.64	138.85	137.49	136.00	137.15	138.04



Freq [Hz]	Attenuation dB												
	Tap 50ft	Tap 150ft	Tap 200ft	Tap 300ft	Tap 400ft	Tap 500ft	Tap 600ft	Tap 700ft	Tap 800ft	Tap 900ft	Tap 1000ft	Tap 1250ft	Tap 1500ft
9.70E+05	134.81	145.34	140.48	135.43	136.38	142.33	136.67	136.44	139.88	137.92	136.73	137.65	138.71
9.80E+05	135.53	146.57	140.88	136.12	137.23	142.84	137.26	137.26	140.84	138.37	137.49	138.18	139.30
9.90E+05	136.25	147.82	141.30	136.81	138.08	143.24	137.86	138.10	141.72	138.85	138.27	138.74	139.85
1.00E+06	136.96	149.06	141.73	137.50	138.94	143.58	138.47	138.95	142.49	139.37	139.08	139.34	140.36
1.01E+06	137.68	150.29	142.18	138.18	139.82	143.87	139.10	139.83	143.14	139.90	139.91	139.97	140.86
1.02E+06	138.38	151.50	142.64	138.87	140.71	144.15	139.73	140.72	143.69	140.47	140.78	140.63	141.38
1.03E+06	139.09	152.67	143.11	139.56	141.61	144.42	140.38	141.64	144.16	141.06	141.66	141.33	141.91
1.04E+06	139.79	153.76	143.59	140.24	142.53	144.71	141.03	142.58	144.57	141.67	142.58	142.05	142.47
1.05E+06	140.49	154.76	144.09	140.93	143.47	145.01	141.70	143.55	144.94	142.30	143.51	142.81	143.06
1.06E+06	141.19	155.63	144.59	141.62	144.42	145.33	142.37	144.53	145.30	142.96	144.47	143.60	143.69
1.07E+06	141.89	156.38	145.09	142.30	145.39	145.68	143.06	145.54	145.66	143.64	145.43	144.42	144.36
1.08E+06	142.58	156.98	145.61	142.99	146.39	146.06	143.75	146.56	146.03	144.33	146.39	145.27	145.06
1.09E+06	143.27	157.46	146.13	143.68	147.40	146.45	144.45	147.58	146.43	145.05	147.33	146.14	145.80
1.10E+06	143.96	157.82	146.66	144.36	148.43	146.87	145.15	148.60	146.85	145.79	148.24	147.03	146.57

Table X.7: 0.4mm loop 250 to 2400 m

Freq [Hz]	Attenuation [dB]																	
	250	500	750	1000	1250	1400	1500	1750	1800	1950	2000	2100	2150	2200	2250	2300	2350	2400
1.00E+04	2.61	4.62	6.27	7.70	9.00	9.75	10.24	11.45	11.69	12.42	12.66	13.16	13.40	13.65	13.90	14.16	14.41	14.66
2.00E+04	2.61	4.64	6.37	7.97	9.56	10.54	11.21	12.92	13.27	14.33	14.68	15.40	15.76	16.12	16.48	16.84	17.20	17.56
3.00E+04	2.62	4.68	6.52	8.35	10.28	11.49	12.31	14.39	14.81	16.06	16.48	17.32	17.74	18.15	18.57	18.98	19.40	19.81
4.00E+04	2.62	4.73	6.71	8.80	11.02	12.38	13.30	15.59	16.04	17.40	17.85	18.76	19.21	19.66	20.10	20.55	21.00	21.45
5.00E+04	2.63	4.79	6.93	9.25	11.67	13.13	14.10	16.50	16.98	18.41	18.88	19.83	20.31	20.78	21.26	21.74	22.21	22.69
6.00E+04	2.65	4.87	7.17	9.67	12.22	13.73	14.73	17.21	17.70	19.19	19.69	20.68	21.18	21.67	22.17	22.67	23.17	23.67
7.00E+04	2.66	4.95	7.41	10.04	12.66	14.20	15.22	17.78	18.29	19.83	20.34	21.37	21.89	22.40	22.92	23.43	23.95	24.46
8.00E+04	2.68	5.05	7.64	10.36	13.01	14.58	15.63	18.26	18.79	20.37	20.90	21.96	22.49	23.02	23.54	24.07	24.60	25.12
9.00E+04	2.70	5.15	7.86	10.63	13.31	14.91	15.99	18.69	19.23	20.85	21.39	22.46	23.00	23.54	24.08	24.62	25.16	25.70
1.00E+05	2.72	5.25	8.06	10.85	13.57	15.21	16.31	19.07	19.62	21.27	21.81	22.91	23.46	24.01	24.56	25.11	25.66	26.21
1.10E+05	2.74	5.36	8.24	11.05	13.81	15.49	16.62	19.41	19.97	21.65	22.20	23.32	23.88	24.44	25.00	25.56	26.12	26.68
1.20E+05	2.77	5.47	8.40	11.23	14.05	15.76	16.90	19.73	20.30	22.00	22.57	23.71	24.27	24.84	25.41	25.98	26.55	27.11
1.30E+05	2.79	5.58	8.55	11.40	14.28	16.01	17.16	20.04	20.61	22.34	22.92	24.07	24.65	25.23	25.80	26.38	26.95	27.53
1.40E+05	2.82	5.69	8.68	11.56	14.50	16.25	17.42	20.34	20.92	22.67	23.26	24.43	25.01	25.60	26.18	26.76	27.35	27.93
1.50E+05	2.86	5.80	8.80	11.73	14.71	16.48	17.66	20.63	21.22	23.00	23.59	24.77	25.36	25.96	26.55	27.14	27.73	28.33
1.60E+05	2.89	5.90	8.92	11.90	14.92	16.71	17.91	20.91	21.51	23.31	23.91	25.11	25.71	26.31	26.91	27.51	28.11	28.71
1.70E+05	2.92	6.00	9.03	12.07	15.12	16.93	18.15	21.19	21.80	23.63	24.23	25.45	26.06	26.67	27.27	27.88	28.49	29.10
1.80E+05	2.96	6.10	9.15	12.24	15.31	17.16	18.40	21.47	22.09	23.94	24.55	25.79	26.40	27.02	27.63	28.25	28.87	29.48
1.90E+05	3.00	6.19	9.27	12.41	15.51	17.39	18.64	21.75	22.38	24.25	24.87	26.12	26.74	27.37	27.99	28.62	29.24	29.86
2.00E+05	3.04	6.27	9.39	12.57	15.72	17.62	18.88	22.04	22.67	24.56	25.19	26.46	27.09	27.72	28.35	28.98	29.62	30.25
2.10E+05	3.08	6.35	9.51	12.73	15.92	17.84	19.12	22.32	22.96	24.87	25.51	26.79	27.43	28.07	28.71	29.35	29.99	30.63
2.20E+05	3.13	6.43	9.64	12.89	16.12	18.07	19.36	22.60	23.25	25.19	25.84	27.13	27.78	28.43	29.07	29.72	30.37	31.02
2.30E+05	3.17	6.51	9.77	13.05	16.33	18.29	19.60	22.88	23.54	25.50	26.16	27.47	28.12	28.78	29.43	30.09	30.75	31.40
2.40E+05	3.22	6.59	9.90	13.21	16.53	18.52	19.85	23.16	23.83	25.82	26.48	27.81	28.47	29.13	29.80	30.46	31.13	31.79
2.50E+05	3.26	6.67	10.02	13.37	16.73	18.75	20.09	23.45	24.12	26.13	26.81	28.15	28.82	29.49	30.16	30.83	31.51	32.18
2.60E+05	3.31	6.74	10.15	13.54	16.94	18.98	20.34	23.73	24.41	26.45	27.13	28.49	29.17	29.85	30.53	31.21	31.89	32.57

Freq [Hz]	Attenuation [dB]																	
	250	500	750	1000	1250	1400	1500	1750	1800	1950	2000	2100	2150	2200	2250	2300	2350	2400
2.70E+05	3.36	6.82	10.27	13.70	17.14	19.21	20.58	24.02	24.71	26.77	27.46	28.83	29.52	30.21	30.90	31.58	32.27	32.96
2.80E+05	3.40	6.90	10.40	13.87	17.35	19.44	20.83	24.31	25.00	27.09	27.79	29.18	29.87	30.57	31.26	31.96	32.66	33.35
2.90E+05	3.45	6.98	10.52	14.04	17.55	19.67	21.07	24.59	25.30	27.41	28.11	29.52	30.22	30.93	31.63	32.34	33.04	33.74
3.00E+05	3.50	7.06	10.64	14.20	17.76	19.90	21.32	24.88	25.59	27.73	28.44	29.87	30.58	31.29	32.00	32.71	33.43	34.14
3.10E+05	3.55	7.15	10.76	14.37	17.97	20.13	21.57	25.17	25.89	28.05	28.77	30.21	30.93	31.65	32.37	33.09	33.81	34.53
3.20E+05	3.59	7.23	10.88	14.53	18.17	20.36	21.82	25.46	26.19	28.37	29.10	30.56	31.29	32.01	32.74	33.47	34.20	34.93
3.30E+05	3.64	7.32	11.01	14.69	18.38	20.59	22.06	25.75	26.48	28.69	29.43	30.90	31.64	32.38	33.11	33.85	34.59	35.32
3.40E+05	3.69	7.41	11.13	14.86	18.58	20.82	22.31	26.03	26.78	29.01	29.76	31.25	31.99	32.74	33.48	34.23	34.97	35.72
3.50E+05	3.73	7.49	11.26	15.02	18.79	21.05	22.56	26.32	27.08	29.34	30.09	31.60	32.35	33.10	33.85	34.61	35.36	36.11
3.60E+05	3.78	7.58	11.38	15.19	19.00	21.28	22.80	26.61	27.37	29.66	30.42	31.94	32.70	33.46	34.23	34.99	35.75	36.51
3.70E+05	3.82	7.66	11.51	15.36	19.20	21.51	23.05	26.90	27.67	29.98	30.75	32.29	33.06	33.83	34.60	35.37	36.13	36.90
3.80E+05	3.87	7.75	11.63	15.52	19.41	21.74	23.30	27.19	27.97	30.30	31.08	32.63	33.41	34.19	34.97	35.74	36.52	37.30
3.90E+05	3.91	7.83	11.76	15.69	19.62	21.97	23.55	27.48	28.26	30.62	31.41	32.98	33.76	34.55	35.34	36.12	36.91	37.69
4.00E+05	3.95	7.92	11.88	15.85	19.82	22.20	23.79	27.76	28.56	30.94	31.73	33.32	34.12	34.91	35.70	36.50	37.29	38.09
4.10E+05	4.00	8.00	12.00	16.01	20.03	22.43	24.04	28.05	28.85	31.26	32.06	33.67	34.47	35.27	36.07	36.87	37.68	38.48
4.20E+05	4.04	8.08	12.13	16.18	20.23	22.66	24.28	28.34	29.15	31.58	32.39	34.01	34.82	35.63	36.44	37.25	38.06	38.87
4.30E+05	4.08	8.16	12.25	16.34	20.43	22.89	24.53	28.62	29.44	31.90	32.71	34.35	35.17	35.99	36.81	37.63	38.44	39.26
4.40E+05	4.12	8.24	12.37	16.50	20.64	23.12	24.77	28.91	29.73	32.21	33.04	34.69	35.52	36.35	37.17	38.00	38.83	39.65
4.50E+05	4.16	8.32	12.49	16.67	20.84	23.35	25.02	29.19	30.02	32.53	33.36	35.03	35.87	36.70	37.54	38.37	39.21	40.04
4.60E+05	4.20	8.40	12.61	16.83	21.04	23.57	25.26	29.47	30.32	32.84	33.69	35.37	36.22	37.06	37.90	38.74	39.59	40.43
4.70E+05	4.24	8.48	12.73	16.99	21.25	23.80	25.50	29.75	30.61	33.16	34.01	35.71	36.56	37.41	38.26	39.12	39.97	40.82
4.80E+05	4.28	8.56	12.85	17.15	21.45	24.02	25.74	30.04	30.90	33.47	34.33	36.05	36.91	37.77	38.63	39.49	40.34	41.20
4.90E+05	4.31	8.64	12.98	17.31	21.65	24.25	25.98	30.32	31.18	33.79	34.65	36.39	37.25	38.12	38.99	39.85	40.72	41.59
5.00E+05	4.35	8.72	13.10	17.47	21.85	24.47	26.22	30.60	31.47	34.10	34.97	36.72	37.60	38.47	39.35	40.22	41.10	41.97
5.10E+05	4.39	8.80	13.22	17.63	22.05	24.70	26.46	30.88	31.76	34.41	35.29	37.06	37.94	38.82	39.71	40.59	41.47	42.35
5.20E+05	4.43	8.88	13.34	17.79	22.24	24.92	26.70	31.15	32.04	34.72	35.61	37.39	38.28	39.17	40.06	40.95	41.84	42.74
5.30E+05	4.47	8.96	13.46	17.95	22.44	25.14	26.94	31.43	32.33	35.03	35.93	37.72	38.62	39.52	40.42	41.32	42.22	43.12
5.40E+05	4.50	9.04	13.57	18.11	22.64	25.36	27.17	31.71	32.61	35.33	36.24	38.05	38.96	39.87	40.77	41.68	42.59	43.49
5.50E+05	4.54	9.12	13.69	18.26	22.84	25.58	27.41	31.98	32.90	35.64	36.55	38.38	39.30	40.21	41.13	42.04	42.96	43.87
5.60E+05	4.58	9.20	13.81	18.42	23.03	25.80	27.64	32.26	33.18	35.95	36.87	38.71	39.63	40.56	41.48	42.40	43.32	44.25
5.70E+05	4.62	9.28	13.93	18.58	23.23	26.02	27.88	32.53	33.46	36.25	37.18	39.04	39.97	40.90	41.83	42.76	43.69	44.62
5.80E+05	4.66	9.36	14.04	18.73	23.42	26.24	28.11	32.80	33.74	36.55	37.49	39.37	40.30	41.24	42.18	43.12	44.06	44.99
5.90E+05	4.69	9.43	14.16	18.89	23.62	26.45	28.34	33.07	34.02	36.85	37.80	39.69	40.64	41.58	42.53	43.47	44.42	45.37
6.00E+05	4.73	9.51	14.27	19.04	23.81	26.67	28.58	33.34	34.30	37.16	38.11	40.02	40.97	41.92	42.88	43.83	44.78	45.74
6.10E+05	4.77	9.59	14.39	19.20	24.00	26.88	28.81	33.61	34.57	37.45	38.42	40.34	41.30	42.26	43.22	44.18	45.14	46.10
6.20E+05	4.81	9.66	14.50	19.35	24.19	27.10	29.03	33.88	34.85	37.75	38.72	40.66	41.63	42.60	43.56	44.53	45.50	46.47
6.30E+05	4.85	9.74	14.62	19.50	24.38	27.31	29.26	34.14	35.12	38.05	39.03	40.98	41.95	42.93	43.91	44.88	45.86	46.84
6.40E+05	4.89	9.82	14.73	19.65	24.57	27.52	29.49	34.41	35.39	38.35	39.33	41.30	42.28	43.26	44.25	45.23	46.22	47.20
6.50E+05	4.93	9.89	14.85	19.80	24.76	27.74	29.72	34.67	35.67	38.64	39.63	41.61	42.61	43.60	44.59	45.58	46.57	47.56
6.60E+05	4.96	9.96	14.96	19.95	24.95	27.95	29.94	34.94	35.94	38.93	39.93	41.93	42.93	43.93	44.93	45.93	46.93	47.92
6.70E+05	5.00	10.04	15.07	20.10	25.14	28.16	30.17	35.20	36.21	39.23	40.23	42.25	43.25	44.26	45.26	46.27	47.28	48.28
6.80E+05	5.04	10.11	15.19	20.25	25.32	28.36	30.39	35.46	36.48	39.52	40.53	42.56	43.57	44.59	45.60	46.61	47.63	48.64
6.90E+05	5.08	10.19	15.30	20.40	25.51	28.57	30.62	35.72	36.74	39.81	40.83	42.87	43.89	44.91	45.93	46.96	47.98	49.00
7.00E+05	5.12	10.26	15.41	20.55	25.69	28.78	30.84	35.98	37.01	40.10	41.12	43.18	44.21	45.24	46.27	47.30	48.33	49.35
7.10E+05	5.16	10.34	15.52	20.70	25.88	28.99	31.06	36.24	37.28	40.38	41.42	43.49	44.53	45.56	46.60	47.64	48.67	49.71

Freq [Hz]	Attenuation [dB]																	
	250	500	750	1000	1250	1400	1500	1750	1800	1950	2000	2100	2150	2200	2250	2300	2350	2400
7.20E+05	5.20	10.41	15.63	20.85	26.06	29.19	31.28	36.50	37.54	40.67	41.71	43.80	44.84	45.89	46.93	47.97	49.02	50.06
7.30E+05	5.23	10.48	15.74	20.99	26.25	29.40	31.50	36.75	37.80	40.95	42.01	44.11	45.16	46.21	47.26	48.31	49.36	50.41
7.40E+05	5.27	10.56	15.85	21.14	26.43	29.60	31.72	37.01	38.06	41.24	42.30	44.41	45.47	46.53	47.59	48.64	49.70	50.76
7.50E+05	5.31	10.63	15.96	21.28	26.61	29.80	31.93	37.26	38.33	41.52	42.59	44.72	45.78	46.85	47.91	48.98	50.04	51.11
7.60E+05	5.35	10.70	16.06	21.43	26.79	30.01	32.15	37.51	38.59	41.80	42.88	45.02	46.09	47.17	48.24	49.31	50.38	51.45
7.70E+05	5.38	10.78	16.17	21.57	26.97	30.21	32.37	37.76	38.84	42.08	43.16	45.32	46.40	47.48	48.56	49.64	50.72	51.80
7.80E+05	5.42	10.85	16.28	21.71	27.15	30.41	32.58	38.02	39.10	42.36	43.45	45.62	46.71	47.80	48.88	49.97	51.06	52.14
7.90E+05	5.45	10.92	16.39	21.86	27.33	30.61	32.80	38.27	39.36	42.64	43.73	45.92	47.02	48.11	49.20	50.30	51.39	52.49
8.00E+05	5.49	10.99	16.49	22.00	27.50	30.81	33.01	38.51	39.61	42.92	44.02	46.22	47.32	48.42	49.52	50.62	51.73	52.83
8.10E+05	5.53	11.06	16.60	22.14	27.68	31.00	33.22	38.76	39.87	43.19	44.30	46.52	47.63	48.73	49.84	50.95	52.06	53.17
8.20E+05	5.56	11.13	16.71	22.28	27.86	31.20	33.43	39.01	40.12	43.47	44.58	46.81	47.93	49.04	50.16	51.27	52.39	53.50
8.30E+05	5.60	11.20	16.81	22.42	28.03	31.40	33.64	39.25	40.38	43.74	44.86	47.11	48.23	49.35	50.47	51.60	52.72	53.84
8.40E+05	5.63	11.27	16.92	22.56	28.21	31.59	33.85	39.50	40.63	44.01	45.14	47.40	48.53	49.66	50.79	51.92	53.05	54.18
8.50E+05	5.66	11.34	17.02	22.70	28.38	31.79	34.06	39.74	40.88	44.29	45.42	47.69	48.83	49.97	51.10	52.24	53.37	54.51
8.60E+05	5.70	11.41	17.12	22.84	28.55	31.98	34.27	39.98	41.13	44.56	45.70	47.98	49.13	50.27	51.41	52.56	53.70	54.84
8.70E+05	5.73	11.48	17.23	22.98	28.73	32.18	34.48	40.23	41.38	44.82	45.97	48.27	49.42	50.57	51.72	52.87	54.02	55.17
8.80E+05	5.77	11.55	17.33	23.11	28.90	32.37	34.68	40.47	41.62	45.09	46.25	48.56	49.72	50.88	52.03	53.19	54.35	55.50
8.90E+05	5.80	11.62	17.43	23.25	29.07	32.56	34.89	40.71	41.87	45.36	46.52	48.85	50.01	51.18	52.34	53.50	54.67	55.83
9.00E+05	5.83	11.68	17.54	23.39	29.24	32.75	35.09	40.94	42.11	45.63	46.80	49.14	50.31	51.48	52.65	53.82	54.99	56.16
9.10E+05	5.87	11.75	17.64	23.52	29.41	32.94	35.30	41.18	42.36	45.89	47.07	49.42	50.60	51.78	52.95	54.13	55.31	56.48
9.20E+05	5.90	11.82	17.74	23.66	29.58	33.13	35.50	41.42	42.60	46.15	47.34	49.71	50.89	52.07	53.26	54.44	55.62	56.81
9.30E+05	5.93	11.89	17.84	23.79	29.75	33.32	35.70	41.65	42.84	46.42	47.61	49.99	51.18	52.37	53.56	54.75	55.94	57.13
9.40E+05	5.97	11.95	17.94	23.93	29.92	33.51	35.90	41.89	43.09	46.68	47.88	50.27	51.47	52.66	53.86	55.06	56.26	57.45
9.50E+05	6.00	12.02	18.04	24.06	30.08	33.69	36.10	42.12	43.33	46.94	48.14	50.55	51.75	52.96	54.16	55.37	56.57	57.77
9.60E+05	6.03	12.09	18.14	24.20	30.25	33.88	36.30	42.36	43.57	47.20	48.41	50.83	52.04	53.25	54.46	55.67	56.88	58.09
9.70E+05	6.06	12.16	18.24	24.33	30.41	34.07	36.50	42.59	43.80	47.46	48.67	51.11	52.33	53.54	54.76	55.98	57.19	58.41
9.80E+05	6.10	12.22	18.34	24.46	30.58	34.25	36.70	42.82	44.04	47.71	48.94	51.39	52.61	53.83	55.06	56.28	57.50	58.73
9.90E+05	6.13	12.29	18.44	24.59	30.74	34.44	36.90	43.05	44.28	47.97	49.20	51.66	52.89	54.12	55.35	56.58	57.81	59.04
1.00E+06	6.16	12.35	18.54	24.72	30.91	34.62	37.09	43.28	44.51	48.23	49.46	51.94	53.17	54.41	55.65	56.88	58.12	59.36
1.01E+06	6.20	12.42	18.64	24.85	31.07	34.80	37.29	43.51	44.75	48.48	49.72	52.21	53.45	54.70	55.94	57.18	58.43	59.67
1.02E+06	6.23	12.48	18.73	24.98	31.23	34.98	37.48	43.73	44.98	48.73	49.98	52.48	53.73	54.98	56.23	57.48	58.73	59.98
1.03E+06	6.26	12.55	18.83	25.11	31.40	35.16	37.68	43.96	45.22	48.99	50.24	52.76	54.01	55.27	56.52	57.78	59.04	60.29
1.04E+06	6.29	12.61	18.93	25.24	31.56	35.35	37.87	44.19	45.45	49.24	50.50	53.03	54.29	55.55	56.81	58.08	59.34	60.60
1.05E+06	6.33	12.68	19.02	25.37	31.72	35.52	38.06	44.41	45.68	49.49	50.76	53.30	54.57	55.83	57.10	58.37	59.64	60.91
1.06E+06	6.36	12.74	19.12	25.50	31.88	35.70	38.26	44.63	45.91	49.74	51.01	53.56	54.84	56.12	57.39	58.67	59.94	61.22
1.07E+06	6.39	12.80	19.22	25.63	32.04	35.88	38.45	44.86	46.14	49.99	51.27	53.83	55.11	56.40	57.68	58.96	60.24	61.52
1.08E+06	6.42	12.87	19.31	25.75	32.20	36.06	38.64	45.08	46.37	50.23	51.52	54.10	55.39	56.68	57.96	59.25	60.54	61.83
1.09E+06	6.46	12.93	19.41	25.88	32.35	36.24	38.83	45.30	46.60	50.48	51.78	54.36	55.66	56.95	58.25	59.54	60.84	62.13
1.10E+06	6.49	12.99	19.50	26.01	32.51	36.41	39.02	45.52	46.82	50.73	52.03	54.63	55.93	57.23	58.53	59.83	61.13	62.44

Table X.8: 0.4mm loop 2450 to 5000 m

Freq [Hz]	Attenuation [dB]																
	2450	2500	2650	2700	2750	2850	2875	2900	3000	3500	3600	3700	3750	3800	4000	4500	5000
1.00E+04	14.92	15.18	15.95	16.21	16.48	17.00	17.14	17.27	17.80	20.49	21.04	21.58	21.85	22.12	23.21	25.92	28.63
2.00E+04	17.92	18.29	19.37	19.73	20.09	20.82	21.00	21.18	21.90	25.48	26.20	26.92	27.27	27.63	29.06	32.64	36.22
3.00E+04	20.23	20.64	21.88	22.29	22.70	23.53	23.73	23.94	24.76	28.88	29.71	30.53	30.95	31.36	33.01	37.14	41.26
4.00E+04	21.90	22.35	23.70	24.14	24.59	25.49	25.72	25.94	26.84	31.34	32.24	33.14	33.59	34.04	35.84	40.34	44.84
5.00E+04	23.16	23.64	25.07	25.55	26.03	26.98	27.22	27.46	28.41	33.19	34.14	35.09	35.57	36.05	37.96	42.73	47.50
6.00E+04	24.16	24.66	26.16	26.65	27.15	28.15	28.40	28.65	29.64	34.62	35.61	36.61	37.10	37.60	39.59	44.57	49.55
7.00E+04	24.98	25.49	27.03	27.54	28.06	29.09	29.34	29.60	30.63	35.77	36.80	37.82	38.34	38.85	40.91	46.05	51.19
8.00E+04	25.65	26.18	27.76	28.29	28.82	29.87	30.13	30.40	31.45	36.73	37.78	38.84	39.37	39.89	42.00	47.28	52.55
9.00E+04	26.24	26.77	28.39	28.93	29.47	30.55	30.82	31.09	32.17	37.56	38.63	39.71	40.25	40.79	42.95	48.34	53.73
1.00E+05	26.76	27.31	28.96	29.50	30.05	31.15	31.43	31.70	32.80	38.29	39.39	40.49	41.04	41.59	43.79	49.28	54.78
1.10E+05	27.23	27.79	29.47	30.03	30.59	31.70	31.98	32.26	33.38	38.97	40.09	41.20	41.76	42.32	44.56	50.14	55.73
1.20E+05	27.68	28.25	29.95	30.52	31.09	32.22	32.50	32.79	33.92	39.60	40.74	41.87	42.44	43.01	45.28	50.95	56.63
1.30E+05	28.10	28.68	30.41	30.99	31.56	32.71	33.00	33.29	34.44	40.20	41.35	42.51	43.08	43.66	45.96	51.72	57.48
1.40E+05	28.52	29.10	30.85	31.44	32.02	33.19	33.48	33.77	34.94	40.78	41.95	43.12	43.71	44.29	46.63	52.47	58.31
1.50E+05	28.92	29.51	31.29	31.88	32.47	33.66	33.95	34.25	35.43	41.35	42.54	43.72	44.32	44.91	47.28	53.20	59.12
1.60E+05	29.31	29.91	31.71	32.31	32.91	34.11	34.41	34.72	35.92	41.92	43.12	44.32	44.92	45.52	47.92	53.92	59.92
1.70E+05	29.71	30.31	32.14	32.75	33.35	34.57	34.87	35.18	36.39	42.47	43.69	44.91	45.51	46.12	48.55	54.63	60.71
1.80E+05	30.10	30.71	32.56	33.18	33.79	35.02	35.33	35.64	36.87	43.03	44.26	45.49	46.11	46.73	49.19	55.35	61.51
1.90E+05	30.49	31.11	32.98	33.61	34.23	35.48	35.79	36.10	37.35	43.59	44.83	46.08	46.70	47.33	49.82	56.06	62.30
2.00E+05	30.88	31.51	33.40	34.04	34.67	35.93	36.25	36.56	37.83	44.14	45.40	46.67	47.30	47.93	50.46	56.77	63.09
2.10E+05	31.27	31.91	33.83	34.47	35.11	36.39	36.71	37.03	38.30	44.70	45.98	47.26	47.90	48.54	51.09	57.49	63.88
2.20E+05	31.66	32.31	34.25	34.90	35.55	36.84	37.17	37.49	38.78	45.26	46.55	47.85	48.50	49.14	51.73	58.21	64.68
2.30E+05	32.06	32.71	34.68	35.33	35.99	37.30	37.63	37.96	39.27	45.82	47.13	48.44	49.10	49.75	52.37	58.93	65.48
2.40E+05	32.45	33.12	35.11	35.77	36.43	37.76	38.09	38.42	39.75	46.38	47.71	49.04	49.70	50.37	53.02	59.65	66.29
2.50E+05	32.85	33.52	35.54	36.21	36.88	38.22	38.56	38.89	40.24	46.95	48.29	49.64	50.31	50.98	53.67	60.38	67.09
2.60E+05	33.25	33.93	35.97	36.65	37.32	38.68	39.02	39.36	40.72	47.52	48.88	50.24	50.92	51.60	54.31	61.11	67.91
2.70E+05	33.65	34.33	36.40	37.09	37.77	39.15	39.49	39.84	41.21	48.09	49.46	50.84	51.53	52.21	54.96	61.84	68.72
2.80E+05	34.05	34.74	36.83	37.53	38.22	39.61	39.96	40.31	41.70	48.66	50.05	51.44	52.14	52.83	55.62	62.58	69.53
2.90E+05	34.45	35.15	37.26	37.97	38.67	40.08	40.43	40.78	42.19	49.23	50.64	52.05	52.75	53.46	56.27	63.31	70.35
3.00E+05	34.85	35.56	37.70	38.41	39.12	40.55	40.90	41.26	42.68	49.81	51.23	52.65	53.37	54.08	56.93	64.05	71.17
3.10E+05	35.25	35.97	38.14	38.86	39.58	41.02	41.38	41.74	43.18	50.38	51.82	53.26	53.98	54.70	57.58	64.79	71.99
3.20E+05	35.66	36.39	38.57	39.30	40.03	41.49	41.85	42.21	43.67	50.96	52.41	53.87	54.60	55.33	58.24	65.53	72.81
3.30E+05	36.06	36.80	39.01	39.74	40.48	41.95	42.32	42.69	44.16	51.53	53.01	54.48	55.22	55.95	58.90	66.27	73.63
3.40E+05	36.46	37.21	39.44	40.19	40.93	42.42	42.80	43.17	44.66	52.11	53.60	55.09	55.83	56.58	59.56	67.01	74.46
3.50E+05	36.87	37.62	39.88	40.63	41.39	42.89	43.27	43.65	45.15	52.68	54.19	55.70	56.45	57.20	60.22	67.75	75.28
3.60E+05	37.27	38.03	40.32	41.08	41.84	43.36	43.74	44.12	45.65	53.26	54.78	56.31	57.07	57.83	60.87	68.49	76.10
3.70E+05	37.67	38.44	40.75	41.52	42.29	43.83	44.22	44.60	46.14	53.84	55.37	56.91	57.68	58.45	61.53	69.23	76.92
3.80E+05	38.08	38.85	41.19	41.97	42.74	44.30	44.69	45.08	46.63	54.41	55.97	57.52	58.30	59.08	62.19	69.97	77.74
3.90E+05	38.48	39.27	41.62	42.41	43.20	44.77	45.16	45.55	47.13	54.99	56.56	58.13	58.91	59.70	62.84	70.70	78.56
4.00E+05	38.88	39.68	42.06	42.85	43.65	45.23	45.63	46.03	47.62	55.56	57.15	58.74	59.53	60.32	63.50	71.44	79.38
4.10E+05	39.28	40.08	42.49	43.29	44.10	45.70	46.10	46.50	48.11	56.13	57.74	59.34	60.14	60.95	64.15	72.18	80.20
4.20E+05	39.68	40.49	42.92	43.73	44.55	46.17	46.57	46.98	48.60	56.70	58.32	59.94	60.76	61.57	64.81	72.91	81.02
4.30E+05	40.08	40.90	43.36	44.17	44.99	46.63	47.04	47.45	49.09	57.27	58.91	60.55	61.37	62.18	65.46	73.65	81.83

Freq [Hz]	Attenuation [dB]																
	2450	2500	2650	2700	2750	2850	2875	2900	3000	3500	3600	3700	3750	3800	4000	4500	5000
4.40E+05	40.48	41.31	43.79	44.61	45.44	47.09	47.51	47.92	49.57	57.84	59.50	61.15	61.98	62.80	66.11	74.38	82.64
4.50E+05	40.88	41.71	44.22	45.05	45.89	47.56	47.97	48.39	50.06	58.41	60.08	61.75	62.58	63.42	66.76	75.11	83.45
4.60E+05	41.27	42.12	44.65	45.49	46.33	48.02	48.44	48.86	50.55	58.98	60.66	62.35	63.19	64.03	67.40	75.83	84.26
4.70E+05	41.67	42.52	45.07	45.92	46.77	48.48	48.90	49.33	51.03	59.54	61.24	62.94	63.79	64.65	68.05	76.56	85.07
4.80E+05	42.06	42.92	45.50	46.36	47.22	48.94	49.36	49.79	51.51	60.10	61.82	63.54	64.40	65.26	68.69	77.28	85.87
4.90E+05	42.46	43.32	45.92	46.79	47.66	49.39	49.83	50.26	51.99	60.66	62.40	64.13	65.00	65.87	69.33	78.00	86.67
5.00E+05	42.85	43.72	46.35	47.22	48.10	49.85	50.29	50.72	52.47	61.22	62.97	64.72	65.60	66.47	69.97	78.72	87.47
5.10E+05	43.24	44.12	46.77	47.65	48.54	50.30	50.74	51.18	52.95	61.78	63.55	65.31	66.20	67.08	70.61	79.44	88.27
5.20E+05	43.63	44.52	47.19	48.08	48.97	50.75	51.20	51.64	53.43	62.34	64.12	65.90	66.79	67.68	71.24	80.15	89.06
5.30E+05	44.01	44.91	47.61	48.51	49.41	51.20	51.65	52.10	53.90	62.89	64.69	66.48	67.38	68.28	71.88	80.87	89.85
5.40E+05	44.40	45.31	48.03	48.93	49.84	51.65	52.11	52.56	54.37	63.44	65.25	67.07	67.97	68.88	72.51	81.57	90.64
5.50E+05	44.79	45.70	48.44	49.36	50.27	52.10	52.56	53.02	54.85	63.99	65.82	67.65	68.56	69.48	73.14	82.28	91.43
5.60E+05	45.17	46.09	48.86	49.78	50.70	52.55	53.01	53.47	55.31	64.54	66.38	68.23	69.15	70.07	73.76	82.99	92.21
5.70E+05	45.55	46.48	49.27	50.20	51.13	52.99	53.46	53.92	55.78	65.08	66.94	68.80	69.73	70.66	74.39	83.69	92.99
5.80E+05	45.93	46.87	49.68	50.62	51.56	53.43	53.90	54.37	56.25	65.63	67.50	69.38	70.32	71.26	75.01	84.39	93.76
5.90E+05	46.31	47.26	50.09	51.04	51.98	53.88	54.35	54.82	56.71	66.17	68.06	69.95	70.90	71.84	75.63	85.08	94.54
6.00E+05	46.69	47.64	50.50	51.46	52.41	54.32	54.79	55.27	57.18	66.71	68.62	70.52	71.48	72.43	76.24	85.78	95.31
6.10E+05	47.06	48.03	50.91	51.87	52.83	54.75	55.23	55.71	57.64	67.25	69.17	71.09	72.05	73.01	76.86	86.47	96.08
6.20E+05	47.44	48.41	51.31	52.28	53.25	55.19	55.67	56.16	58.09	67.78	69.72	71.66	72.62	73.59	77.47	87.15	96.84
6.30E+05	47.81	48.79	51.72	52.69	53.67	55.62	56.11	56.60	58.55	68.31	70.27	72.22	73.20	74.17	78.08	87.84	97.60
6.40E+05	48.18	49.17	52.12	53.10	54.09	56.05	56.55	57.04	59.01	68.84	70.81	72.78	73.76	74.75	78.68	88.52	98.36
6.50E+05	48.55	49.55	52.52	53.51	54.50	56.49	56.98	57.48	59.46	69.37	71.36	73.34	74.33	75.32	79.29	89.20	99.12
6.60E+05	48.92	49.92	52.92	53.92	54.92	56.91	57.41	57.91	59.91	69.90	71.90	73.90	74.89	75.89	79.89	89.88	99.87
6.70E+05	49.29	50.30	53.32	54.32	55.33	57.34	57.84	58.35	60.36	70.42	72.44	74.45	75.46	76.46	80.49	90.55	100.62
6.80E+05	49.66	50.67	53.71	54.73	55.74	57.77	58.27	58.78	60.81	70.95	72.97	75.00	76.02	77.03	81.09	91.22	101.36
6.90E+05	50.02	51.04	54.11	55.13	56.15	58.19	58.70	59.21	61.25	71.47	73.51	75.55	76.57	77.59	81.68	91.89	102.11
7.00E+05	50.38	51.41	54.50	55.53	56.55	58.61	59.13	59.64	61.70	71.98	74.04	76.10	77.13	78.16	82.27	92.56	102.85
7.10E+05	50.74	51.78	54.89	55.92	56.96	59.03	59.55	60.07	62.14	72.50	74.57	76.64	77.68	78.72	82.86	93.22	103.58
7.20E+05	51.10	52.15	55.28	56.32	57.36	59.45	59.97	60.49	62.58	73.01	75.10	77.19	78.23	79.27	83.45	93.88	104.32
7.30E+05	51.46	52.51	55.66	56.72	57.77	59.87	60.39	60.92	63.02	73.53	75.63	77.73	78.78	79.83	84.03	94.54	105.05
7.40E+05	51.82	52.88	56.05	57.11	58.17	60.28	60.81	61.34	63.46	74.04	76.15	78.27	79.33	80.38	84.62	95.19	105.77
7.50E+05	52.17	53.24	56.43	57.50	58.56	60.70	61.23	61.76	63.89	74.54	76.67	78.80	79.87	80.93	85.20	95.85	106.50
7.60E+05	52.53	53.60	56.82	57.89	58.96	61.11	61.64	62.18	64.32	75.05	77.19	79.34	80.41	81.48	85.77	96.50	107.22
7.70E+05	52.88	53.96	57.20	58.28	59.36	61.52	62.06	62.60	64.76	75.55	77.71	79.87	80.95	82.03	86.35	97.14	107.94
7.80E+05	53.23	54.32	57.58	58.66	59.75	61.92	62.47	63.01	65.18	76.05	78.23	80.40	81.49	82.57	86.92	97.79	108.66
7.90E+05	53.58	54.67	57.96	59.05	60.14	62.33	62.88	63.42	65.61	76.55	78.74	80.93	82.02	83.11	87.49	98.43	109.37
8.00E+05	53.93	55.03	58.33	59.43	60.53	62.74	63.29	63.84	66.04	77.05	79.25	81.45	82.55	83.65	88.06	99.07	110.08
8.10E+05	54.27	55.38	58.71	59.81	60.92	63.14	63.69	64.25	66.46	77.54	79.76	81.98	83.08	84.19	88.62	99.70	110.78
8.20E+05	54.62	55.73	59.08	60.19	61.31	63.54	64.10	64.65	66.89	78.04	80.27	82.50	83.61	84.73	89.19	100.34	111.49
8.30E+05	54.96	56.08	59.45	60.57	61.70	63.94	64.50	65.06	67.31	78.53	80.77	83.02	84.14	85.26	89.75	100.97	112.19
8.40E+05	55.30	56.43	59.82	60.95	62.08	64.34	64.90	65.47	67.72	79.02	81.27	83.53	84.66	85.79	90.31	101.60	112.89
8.50E+05	55.65	56.78	60.19	61.33	62.46	64.73	65.30	65.87	68.14	79.50	81.77	84.05	85.18	86.32	90.86	102.22	113.58
8.60E+05	55.99	57.13	60.56	61.70	62.84	65.13	65.70	66.27	68.56	79.99	82.27	84.56	85.70	86.84	91.42	102.85	114.28
8.70E+05	56.32	57.47	60.92	62.07	63.22	65.52	66.10	66.67	68.97	80.47	82.77	85.07	86.22	87.37	91.97	103.47	114.97
8.80E+05	56.66	57.82	61.29	62.44	63.60	65.91	66.49	67.07	69.38	80.95	83.26	85.58	86.73	87.89	92.52	104.09	115.65

Freq [Hz]	Attenuation [dB]																
	2450	2500	2650	2700	2750	2850	2875	2900	3000	3500	3600	3700	3750	3800	4000	4500	5000
8.90E+05	56.99	58.16	61.65	62.81	63.98	66.30	66.89	67.47	69.79	81.43	83.76	86.08	87.25	88.41	93.07	104.70	116.34
9.00E+05	57.33	58.50	62.01	63.18	64.35	66.69	67.28	67.86	70.20	81.91	84.25	86.59	87.76	88.93	93.61	105.31	117.02
9.10E+05	57.66	58.84	62.37	63.55	64.72	67.08	67.67	68.26	70.61	82.38	84.74	87.09	88.27	89.44	94.15	105.92	117.70
9.20E+05	57.99	59.18	62.73	63.91	65.10	67.46	68.06	68.65	71.02	82.85	85.22	87.59	88.77	89.96	94.69	106.53	118.37
9.30E+05	58.32	59.51	63.09	64.28	65.47	67.85	68.44	69.04	71.42	83.33	85.71	88.09	89.28	90.47	95.23	107.14	119.04
9.40E+05	58.65	59.85	63.44	64.64	65.84	68.23	68.83	69.43	71.82	83.80	86.19	88.58	89.78	90.98	95.77	107.74	119.72
9.50E+05	58.98	60.18	63.79	65.00	66.20	68.61	69.21	69.81	72.22	84.26	86.67	89.08	90.28	91.49	96.30	108.34	120.38
9.60E+05	59.30	60.52	64.15	65.36	66.57	68.99	69.60	70.20	72.62	84.73	87.15	89.57	90.78	91.99	96.83	108.94	121.05
9.70E+05	59.63	60.85	64.50	65.72	66.93	69.37	69.98	70.58	73.02	85.19	87.63	90.06	91.28	92.50	97.36	109.54	121.71
9.80E+05	59.95	61.18	64.85	66.07	67.30	69.74	70.36	70.97	73.42	85.65	88.10	90.55	91.77	93.00	97.89	110.13	122.37
9.90E+05	60.27	61.51	65.20	66.43	67.66	70.12	70.73	71.35	73.81	86.11	88.57	91.04	92.27	93.50	98.42	110.72	123.03
1.00E+06	60.60	61.83	65.54	66.78	68.02	70.49	71.11	71.73	74.20	86.57	89.05	91.52	92.76	93.99	98.94	111.31	123.68
1.01E+06	60.92	62.16	65.89	67.13	68.38	70.86	71.48	72.11	74.59	87.03	89.52	92.00	93.25	94.49	99.46	111.90	124.33
1.02E+06	61.23	62.48	66.23	67.48	68.73	71.23	71.86	72.48	74.98	87.48	89.98	92.48	93.73	94.98	99.98	112.48	124.98
1.03E+06	61.55	62.81	66.58	67.83	69.09	71.60	72.23	72.86	75.37	87.94	90.45	92.96	94.22	95.48	100.50	113.07	125.63
1.04E+06	61.87	63.13	66.92	68.18	69.44	71.97	72.60	73.23	75.76	88.39	90.91	93.44	94.70	95.97	101.02	113.65	126.28
1.05E+06	62.18	63.45	67.26	68.53	69.80	72.34	72.97	73.61	76.14	88.84	91.38	93.91	95.18	96.45	101.53	114.22	126.92
1.06E+06	62.49	63.77	67.60	68.87	70.15	72.70	73.34	73.98	76.53	89.29	91.84	94.39	95.66	96.94	102.04	114.80	127.56
1.07E+06	62.81	64.09	67.94	69.22	70.50	73.06	73.70	74.35	76.91	89.73	92.30	94.86	96.14	97.42	102.55	115.37	128.19
1.08E+06	63.12	64.41	68.27	69.56	70.85	73.43	74.07	74.71	77.29	90.18	92.75	95.33	96.62	97.91	103.06	115.94	128.83
1.09E+06	63.43	64.72	68.61	69.90	71.20	73.79	74.43	75.08	77.67	90.62	93.21	95.80	97.09	98.39	103.57	116.51	129.46
1.10E+06	63.74	65.04	68.94	70.24	71.54	74.15	74.80	75.45	78.05	91.06	93.66	96.26	97.56	98.87	104.07	117.08	130.09

## **Appendix Y: Test Event Methodology (*Informative*)**

### **Y.1 Introduction**

This Annex describes the test methodology that was used to derive the performance requirements for North America (Annex A.1). All modems were submitted by modem vendors to an independent test lab and were assigned a unique identifier (by the independent testing lab). The modems then underwent the test sequence and test methodology described in this Annex. The test process is summarized as follows:

1. Initial modem testing (section Y.2).
2. Selection of candidate modems and generation of initial data rate requirements (section Y.3).
3. Refinement of the data rate requirements to take into account performance variability of the modems and variability in the test environment configuration variation (section Y.4).
4. Final verification and selection of data rate requirements.

The test process is designed such that modems from at least 2 chipset vendors will be used to generate the final data rate requirements.

### **Y.2 Initial Modem Testing**

The initial testing to find candidate modems for generating data rates is designed as a series of checkpoints, where:

- Each checkpoint allows modems which satisfy the proposed passing criteria to proceed.
- Each checkpoint also allows for a relaxation of the passing criteria such that a sufficient number of modems which did not satisfy the proposed passing criteria can proceed. The relaxation of passing criteria is only performed if not sufficient modems cleanly passed the checkpoint to generate final data rate requirements. The details of the relaxation are described below.

The flow of this section of the test procedure is as follows:

1. Verification of upstream PSD level (information only)
2. Verification of CRC reporting by the modem
3. Verification of downstream fine gain values
4. Checkpoint 1
5. Verify downstream noise margin
6. Checkpoint 2
7. Collect data rates and reported noise margins
8. Checkpoint 3

Because a chipset vendor can participate with up to 3 modem vendors, a total of 4 modems need to pass checkpoint 2 to guarantee that the data rate requirements can be based on modems from two chipset vendors.

#### **Y.2.1 Verification of Upstream PSD Level**

Perform tests according to section Y.5.1

### ***Y.2.2 Verification of CRC Reporting by the Modem***

Perform tests according to section Y.5.2

### ***Y.2.3 Verification of Downstream Fine Gain Values***

Perform tests according to section Y.5.3.

### ***Y.2.4 Checkpoint 1***

Modems which pass sections Y.2.2 (CRC reporting) and Y.2.3 (fine gains) proceed to section Y.2.4. If not a sufficient number of modems passes the above sections, then the passing criteria will be relaxed according to Appendix section Y.5.4. Note that "sufficient number" is also defined in section Y.5.4.

### ***Y.2.5 Verification of Reported Downstream Noise Margin***

Perform tests according to Appendix section Y.5.5.

### ***Y.2.6 Checkpoint 2***

Modems which pass section Y.2.5 (downstream noise margin verification) proceed to section Y.2.7. If less than 4 modems pass the section for noise margin verification, then the passing criteria will be relaxed according to section Y.5.6.

### ***Y.2.7 Collection of Data Rates and Reported Noise Margins***

Conduct performance measurements according to sections A.1.4 to A.1.9 (excluding A.1.5) and record data rates and reported noise margins. Configure the modems to the standard configuration in section Y.6.3.2. Reported noise margins shall be recorded one minute after the modems have reached Showtime. Modems must reach Showtime within 60 seconds (otherwise the recorded rate is 0).

### ***Y.2.8 Checkpoint 3***

If there are not at least 2 modems from different chipset vendors which have appropriate reported noise margins, then the passing criteria will be relaxed according to section Y.5.7. The term "appropriate noise margin" is defined in section Y.6.4.

## ***Y.3 Initial Data Rate Requirements***

### ***Y.3.1 Modem Segregation***

Based on the results of section Y.2 (which guarantees that there will be at least 4 modems and 2 chipset vendors), modems are segregated into 3 groups:



- Group 1: Modems which passed checkpoints 1, 2 and 3 cleanly.
- Group 2: Modems which required exactly one of the following:
  - a. the passing criteria of checkpoint 2 to be relaxed, or
  - b. the passing criteria of checkpoint 3 to be relaxed.
- Group 3: All other modems.

### ***Y.3.2 Candidate Modem Selection***

The following selection criterion is applied to determine which modems are used for generating data rates:

1. If there are at least 2 chipset vendors represented in group 1, then the candidate modems (for defining data rate requirements) are:
  - a. The 2 best performing modems.
  - b. If 2 different chipset vendors are not represented in the 2 best performing modems (in this case at least one more modem from a different chipset vendor exists in group 1), then the third candidate modem is the best performing modem from a different chipset vendor in group 1.
  - c. If two different chipset vendors are represented, then the third best modem in group 1 is added as the third candidate modem (if a third modem exists in group 1).
2. If there is exactly 1 chipset vendor represented in group 1, then the candidate modems are:
  - a. The one or two (if available) best performing modems from group 1.
  - b. The closest to passing modem from group 2 from another chipset vendor. If no such modem exists, then the closest to passing modem from group 3 from another chipset vendor.
3. If no modems are in group 1, then the candidate modems are:
  - a. The three closest to passing modems from two different chipset vendors, taken first from group 2, then group 3 if an insufficient number is in group 2.

Note: The "best performing" is defined as in section Y.6.1, and "closest to passing" is defined in section Y.6.2.

### ***Y.3.3 Data Rates***

From the set of candidate CPE's, pick the lowest data rate (for upstream and downstream direction) on each test point as the preliminary data rate requirement. Record the reported noise margin associated with that preliminary data rate requirement and the unique CPE identifier associated with that preliminary data rate requirement.

## ***Y.4 Refinement of Data Rate Requirements***

### ***Refinement for variation in test setup***

The procedure in this section is proposed only for determining the new performance requirements, not for qualifying a modem at the operators' test labs. In this section the initial data rates from section Y.3 are refined to take into account performance variability of the modem and test environment.

For those modems that were used to determine the preliminary data rate requirements in section Y.3 (i.e. the candidate modems), take performance measurements according to section Y.2.7 on 3 additional

modems as shown in Table Y.1. Xn refers to the nth modem of vendor X. The availability of 4 modems for each modem vendor is assumed. The DSLAM port and the test equipment shall remain unchanged w.r.t. the measurements of section Y2.7. Test setup 1 refers to the performance numbers already generated in section Y.2.7.

**Table Y.1:** Data rate refinement configurations.

	CPE
Test setup 1 (already completed)	X1
Test setup 2	X2
Test setup 3	X3
Test setup 4	X4

Among all modems tested (i.e. four modems of each candidate modem type from section Y.3), determine the lowest data rate (for upstream and downstream direction) on each test point. The lowest data rate on each test point then becomes the revised data rate requirement for that test point. Also, record the reported noise margin associated with each revised data rate requirement.

Finally, allowing for variability in the test environment, the revised data rate requirements (described in the previous paragraph) are reduced by an amount corresponding to 0.5 dB performance degradation on each test point. The following paragraphs describe how the amount of data rate corresponding to 0.5 dB performance degradation is determined.

Figure Y.1 and Table Y.2 shows the amount of data rate reduction corresponding to 1dB performance degradation.

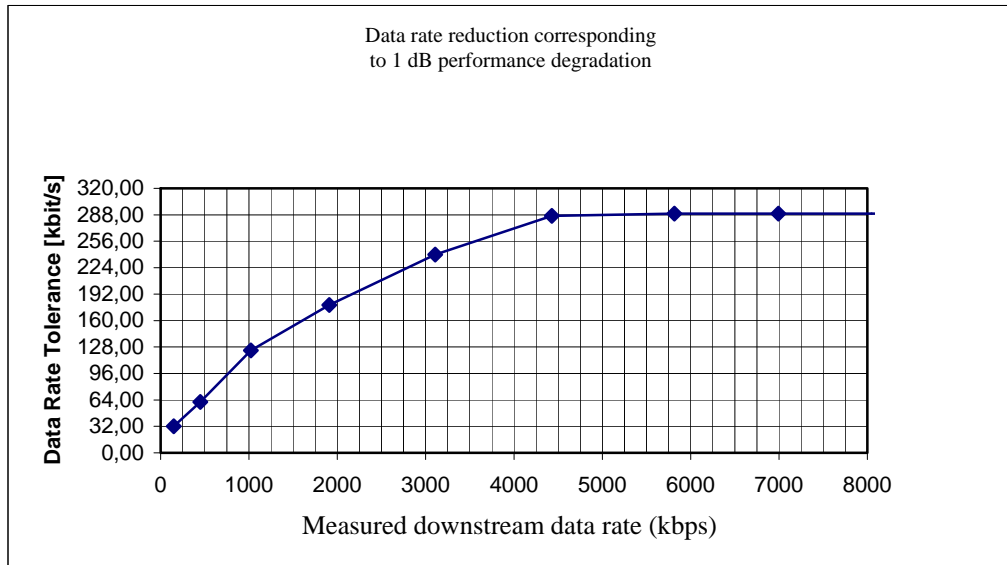


Figure Y.1: Data rate reduction corresponding to 1dB performance degradation  
(This is a function of the measured data rate)

Table Y.2: Data rate reduction corresponding to 1dB performance degradation.

Measured Downstream Data Rate (kbps)	Data Rate Adjustment (kbps) corresponding to 1dB
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

The amount of data rate reduction is computed by linearly interpolating the adjustment values given in Table Y.2 and multiplying the result by 0.5 (corresponding to 0.5 dB). The data rate adjustment value is rounded to the closest multiple of 32 kbps. If the measured data rate is the maximum downstream data rate supported by the DSLAM, then no data rate adjustment is performed.

The same data rate adjustment is applied to measured upstream data rates. However, since for upstream all the available tones are used for all loop lengths and measured data rates, the upstream data rate adjustment for 0.5 dB performance degradation corresponds to 32 kbps (after rounding), irrespective of the measured data rate. If the measured data rate is the maximum upstream data rate supported by the DSLAM, then no data rate adjustment is performed.

## ***Y.5 Appendix: Test Descriptions***

For each of the proposed tests in section Y.2, the following 4 items are described:

1. Configuration.
2. Test points.
3. Test procedure.
4. Pass/fail criteria.

### ***Y.5.1 Upstream PSD Level***

*(This specific test was not run at the plugfest event.)*

#### **Y.5.1.1 Configuration**

Configure the modems to the standard configuration in section Y.6.1.3.

#### **Y.5.1.2 Test Points**

There are a total of  $N_{fg} = 18$  test points. These are the same test points as for fine gain verification tests.

1. 12 kft with -140 dBm/Hz AWGN
2. 18 kft with -140 dBm/Hz AWGN
3. 11 kft with -140 dBm/Hz AWGN (16ms interleaved path, instead of fast path)

4. 17 kft with -140 dBm/Hz AWGN (16ms interleaved path, instead of fast path)
5. 9 kft with 5 T1 adjacent
6. 15 kft with 5 T1 adjacent
7. 15 kft with 24 DSL
8. 16 kft with 24 DSL
9. 12 kft with 24 HDSL
10. 13 kft with 24 HDSL
11. CSA4 with 5 T1 adjacent
12. 9 kft + 500 ft BT with -140 dBm/Hz AWGN
13. 12 kft + 250 ft BT with -140 dBm/Hz AWGN
14. 12 kft + 750 ft BT with -140 dBm/Hz AWGN
15. 15 kft + 500 ft BT with -140 dBm/Hz AWGN
16. 15 kft + 900 ft BT with -140 dBm/Hz AWGN
17. 17.5 kft + 500 ft BT with -140 dBm/Hz AWGN
18. 17.5 kft + 1000 ft BT with -140 dBm/Hz AWGN

### **Y.5.1.3 Test Procedure**

The upstream PSD verification tests are performed at the same time as the fine gain verification tests (section Y.5.3) and thus do not require additional test or setup time. The DSLAM shall report the measured upstream power on subcarriers 7-18 during R-REVERB1 on each test point.

### **Y.5.1.4 Pass/Fail Criteria**

The measured upstream power is not compared against a pass/fail criterion. The measured upstream power is reported for information purposes and allows a relative comparison of measured upstream power on each test point with respect to the average of the upstream power of all modems under test.

## ***Y.5.2 CRC Reporting***

### **Y.5.2.1 Configuration**

Configure the modems to the standard configuration in section Y.6.3.1.

### **Y.5.2.2 Test Points**

There are a total of  $N_{cr} = 7$  test points.

1. 13 kft with 24 HDSL
2. 16 kft with 24 DSL
3. 12 kft with 5 T1 adjacent
4. 17 kft with -130 dBm/Hz AWGN
5. 12 kft + 750 ft BT with -120 dBm/Hz AWGN
6. 12 kft + 1000 ft BT with -140 dBm/Hz AWGN
7. 17.5 kft + 500 ft BT with -140 dBm/Hz AWGN

### **Y.5.2.3 Test Procedure**

The test procedure is as defined as follows:

1. Let  $n = 1$ .
2. Select a loop and noise condition according to test point  $n$  above.
3. Force a new initialization between CPE and DSLAM and wait for modems to sync. Wait for 2 minutes after initialization for bitswaps to settle.
4. Force a “micro interruption” of the loop at the CPE side with duration of 1ms. On a commonly used loop simulator choose: Micro interruption applied at CPE side, micro interrupt duration = 1ms. A micro interruption should result in at least one reported downstream CRC error.
5. Repeat step 4 every 10 seconds, for a total test time of 120 seconds (i.e. a total of 12 micro-interruptions are issued). On a commonly used loop simulator, choose: Signal Period = 10 sec, Test Interval = 120 sec.
6. If each micro interruption does not result in at least one reported downstream CRC error, then the ATU-R has failed the basic CRC functionality test.
7. Let  $n = n + 1$ . If  $n \leq N_{\text{crc}}$  then go to 2.
8. Record the results in Table Y.3.

The total estimated test time is ~4 minutes per test, 7 tests =  $4 \times 7 = 28$  minutes per CPE.

**Table Y.3:** Micro interruption test results.

	Number of Reported CRC Errors per each micro interruption
Test point 1	
Test point 2	
Test point 3	
Test point 4	
Test point 5	
Test point 6	
Test point 7	

#### **Y.5.2.4 Pass/Fail Criteria**

Each test (1 through  $N_{\text{crc}}$ ) must yield at least 12 reported downstream CRC errors.

### ***Y.5.3 Downstream Fine Gains***

#### **Y.5.3.1 Configuration**

Configure the modems to the standard configuration in section Y.6.3.1.

#### **Y.5.3.2 Test Points**

There are a total of  $N_{\text{fg}} = 18$  test points.

1. 12 kft with -140 dBm/Hz AWGN
2. 18 kft with -140 dBm/Hz AWGN
3. 11 kft with -140 dBm/Hz AWGN (16ms interleaved path, instead of fast path)
4. 17 kft with -140 dBm/Hz AWGN (16ms interleaved path, instead of fast path)
5. 9 kft with 5 T1 adjacent
6. 15 kft with 5 T1 adjacent
7. 15 kft with 24 DSL

8. 16 kft with 24 DSL
9. 12 kft with 24 HDSL
10. 13 kft with 24 HDSL
11. CSA4 with 5 T1 adjacent
12. 9 kft + 500 ft BT with -140 dBm/Hz AWGN
13. 12 kft + 250 ft BT with -140 dBm/Hz AWGN
14. 12 kft + 750 ft BT with -140 dBm/Hz AWGN
15. 15 kft + 500 ft BT with -140 dBm/Hz AWGN
16. 15 kft + 900 ft BT with -140 dBm/Hz AWGN
17. 17.5 kft + 500 ft BT with -140 dBm/Hz AWGN
18. 17.5 kft + 1000 ft BT with -140 dBm/Hz AWGN

### Y.5.3.3 Test Procedure

The DSLAM shall report the fine gain values requested during initialization.  
The total estimated test time is ~1 minute per test, 17 tests = 17 minutes per CPE.

### Y.5.3.4 Pass/Fail Criteria

Note that  $g_i$  rms is defined (for all options) as:

$$g_i \text{ rms} = 10 \log_{10} \left( \frac{1}{|A|} \sum_{i \in A} g_i^2 \right)$$

where A is the set of subchannels under consideration and |A| is the number of subchannels in A.  
The downstream fine gain values have to meet the following criteria on each test point:

6. Maximum  $g_i$  (over nonzero  $g_i$ )  $\leq +2.5$  dB.
7. Minimum  $g_i$  (over nonzero  $g_i$ )  $\geq -14.5$  dB.
8.  $g_i$  rms value over used tones ( $b_i > 0$ )  $\leq 0.7$  dB.
9.  $g_i$  rms value over monitored tones ( $b_i = 0$  &  $g_i > 0$ )  $\leq 0$  dB.
10. Over the 138 to 1104 kHz band,  $g_i$  rms value  $\leq 0.0$  dB.

### Y.5.4 Checkpoint 1

If not at least four modems (four is tentatively considered a “sufficient number”) pass this checkpoint cleanly, then the passing criteria are relaxed as follows.

For each modem that does not pass this checkpoint, perform the following computation:

1. Let F\_CRC = Number of failed CRC verification tests  
Let F\_FG = Number of failed fine gain verification tests
2. Delta1 = F\_CRC + F\_FG

Let at least the 4 modems with the smallest values of Delta1 proceed through Checkpoint 1. (Note: Modems that pass all tests up to Checkpoint 1 have Delta1=0.)

Clarification of how Checkpoint 1 is applied:

The number of modems allowed to proceed through this checkpoint to section Y.2.5 will solely determine

the total test time. The number of modems allowed to proceed through this checkpoint does not have an impact on the selection of the best performing modems in section Y.3.

As explained in Section Y.3.1, all modems are classified based on whether they meet specified pass/fail criteria. Section Y.3.2 then ensures that only the best modems (i.e. from group 1, only if necessary from group 2, and only if necessary from group 3) are chosen as candidate modems for generating data rate requirements.

The motivation for letting more than the minimum of two modems from two chipset vendors proceed through Checkpoint 1 is as follows:

A modem which passes sections Y.2.1 - Y.2.3 (and thus passes Checkpoint 1 cleanly) and later fails Checkpoint 2 or Checkpoint 3 will be classified as “group 2” modem (see Section Y.3.1). However, if a modem passes Checkpoint 1 cleanly and later fails Checkpoint 2 and Checkpoint 3 it will be classified as “group 3” modem (see Section Y.3.1).

At the same time, also modems that do not pass Checkpoint 1 (i.e. modems for which the passing criteria in Checkpoint 1 were relaxed) are classified as “group 3” modems (see Section Y.3.1).

If (and only if) there are not at least two modems from two chipset vendors in group 1 and/or group 2 after checkpoint 3, then the “closest to passing” modems from group 3 are determined (see Section Y.3.2).

If a large number of modems pass Checkpoint 1 cleanly, then the likelihood is high that at least two modems from two chipset vendors will end up in groups 1 or 2.

However, if only few (e.g. 2-3) modems pass Checkpoint 1 cleanly, then the likelihood is high that there will not be two modems from two chipset vendors in groups 1 or 2, rather there will be several modems ending up in group 3.

In this case, to ensure that modems which passed Checkpoint 1 cleanly and failed both Checkpoints 2 and 3 are compared properly against other modems from group 3 (which failed Checkpoint 1), a sufficient number of modems which failed Checkpoint 1 are allowed to proceed.

”Four” is tentatively considered a “sufficient number”. If necessary (i.e. only one or no modem falls in groups 1 or 2), the count of “4” can be increased.

The test methodology is designed such that the best modems from 2 different chipset vendors will be used to generate the final data rate requirements (see section Y.3.2).

### ***Y.5.5 Downstream Noise Margin***

#### **Y.5.5.1 Configuration**

Configure the modems to the standard configuration in section Y.6.3.1.

#### **Y.5.5.2 Test Points**

There are a total of  $N_{nm} = 5$  test points.

1. 13 kft with 24 HDSL
2. 16 kft with 24 DSL
3. 12 kft with 5 T1 adjacent
4. 17 kft with -130 dBm/Hz AWGN
5. 12 kft + 750 ft BT with -120 dBm/Hz AWGN

**Y.5.5.3 Test Procedure**

Perform tests according to section A.1.1.  
The total estimated test time is ~3.5 hours (210 minutes) per CPE.

**Y.5.5.4 Pass/Fail Criteria**

A modem has to pass the margin verification test on every test point.

**Y.5.6 Checkpoint 2**

If less than 4 modems pass the section for downstream noise margin verification, then the passing criteria are relaxed as follows. For each modem that does not pass this checkpoint, perform the following computation:

Let  $\Delta_2$  = Number of failed noise margin verification tests

Let at least the 4 modems with the smallest values of  $\Delta_2$  proceed through Checkpoint 2. (Note: Modems that pass all downstream noise margin verification tests have  $\Delta_2=0$ .)

**Y.5.7 Checkpoint 3**

If there are not at least 2 modems from different chipset vendors which have appropriate reported noise margins, then the passing criteria are relaxed as follows. For each modem that does not pass this checkpoint, perform the following computation:

1. Let  $N_4$  = Number of test points (upstream or downstream) with less than 4dB reported noise margin.  
Let  $N_5$  = Number of test points (upstream or downstream) with  $\geq 4$ dB and  $< 5$ dB reported noise margin, beyond the allowed 10% limit.  
Let  $N_6$  = Number of test points with less than 6dB reported downstream noise margin (among the 109 downstream test points), beyond the allowed 25% limit.
2.  $\Delta_3 = N_4 + N_5 + N_6$

Pick the 4 modems with the smallest value of  $\Delta_3$ . (Note: Modems that have appropriate reported noise margins have  $\Delta_3=0$ .)

**Y.6 Appendix: Definitions****Y.6.1 Best Performing**

Compare the upstream and downstream data rate for each test point to the reference rate. The reference rate is defined as the data rate requirement in TR-048. Sum the percentage increase or decrease w.r.t. the reference rate for each test point, with the upstream direction at half the weight of the downstream direction, over all of the test points in sections A.1.4. through A.1.9 (excluding A.1.5) and divide by the number of test points.

A modem is considered to perform better than another modem if its resulting percentage score is higher.



**Y.6.2 Closest to Passing**

Let  $\Delta_{23} = \Delta_2 + \Delta_3$   
 Let  $\Delta_{123} = \Delta_1 + \Delta_2 + \Delta_3$

The modem closest to passing in group 2 is the modem with the smallest value of  $\Delta_{23}$ . (Note: Modems in group 2 have either  $\Delta_2=0$  or  $\Delta_3=0$ .)

The modem closest to passing in group 3 is the modem with the smallest value of  $\Delta_{123}$ .

Modems that pass all checkpoints without relaxation have  $\Delta_{123} = \Delta_{23} = 0$ .

**Y.6.3 Standard Configuration****Y.6.3.1 Default Standard Configuration**

Latency setting	Fast path
Target noise margin	6 dB
Minimum margin	0 dB
Maximum margin	31 dB
Rate negotiation	Rate adaptive mode
Trellis coding	Allowed

**Y.6.3.2 Standard Configuration for collection of data rates and reported noise margins (see section Y.2.7)**

Latency setting	Fast path or 16ms interleaved path
Target noise margin	6 dB
Minimum margin	0 dB
Maximum margin	16 dB
Rate negotiation	Rate adaptive mode
Trellis coding	Allowed

### Y.6.4 Appropriate Reported Noise Margins

A modem is said to have *appropriate* reported noise margins if it satisfies the requirements of Table Y.3.

**Table Y.3:** Requirements for *appropriate* reported noise margin

Reported Noise Margin (dB)	Requirement
< 4	On no test point
>= 4 and < 5	On at most 10% of the test points
>= 5	On at least 90% of the test points
>= 6	On at least 75% of the downstream test points

Table Y.4 lists the number of test points per section corresponding to the 10% and 25% limits in Table Y.3.

**Table Y.4:** Number of test points per section corresponding to 10% and 25% limits

Section Number	10% limit	25% limit (downstream margins only)
A.1.4.1	8	10
A.1.4.2	1	2
A.1.4.3	1	2
A.1.4.4	1	2
A.1.7	1	1
A.1.8	1	1
A.1.9.1	1	1
A.1.9.2	2	3
A.1.9.3	3	4
A.1.9.4	3	4

## Y.7 Appendix: Open Test Event Calibration Plan

Prior to the initiation of testing at the Open Test Event the Test Lab, Test Equipment and DSLAM will be calibrated. In addition to the calibration, benchmark testing will be done using a known repeatable modem to demonstrate the repeatability of the test system (this benchmark testing is being done to ensure confidence in the test setup and is in no way meant to influence the out come of this event). The resulting data will be made available to the TOC and participants in the Open Test Event.

### Y.7.1 Test Lab Calibration

The noise floor of the test lab will be measured to the limits of the available test equipment to check for RFI and other interferers. The laboratory setup will follow the guidelines of section 4.1.3.

### Y.7.2 Test Equipment

#### Y.7.2.1 Wireline Simulator

The Wireline simulator is calibrated using the procedure defined in section 4.1. In addition to this procedure the calibration of the loop simulator will also target to achieve a mean error as close to 0 as possible.

MAE indicates that the attenuation curve for the simulated loop fits closely to the theoretical curve. ME value indicates the whether the area under the actual attenuation curve is smaller or larger than the area under the theoretical curve.

Ensuring MAE and ME are as low as possible will yield the most accurate / repeatable results.

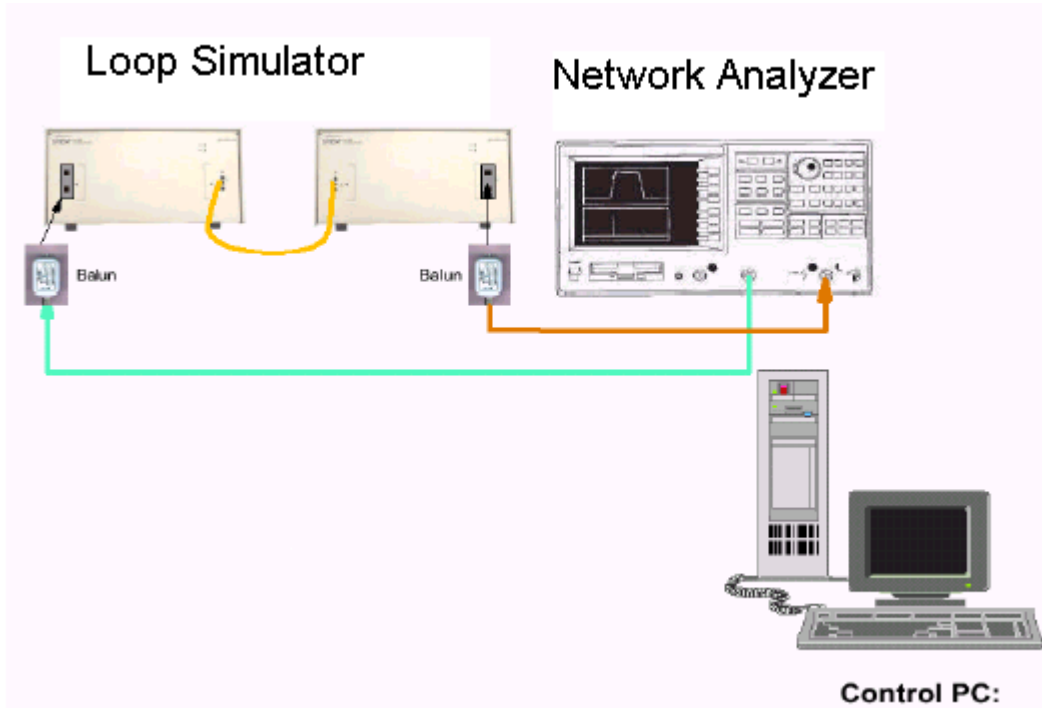


Figure Y.2: Test Set-up

### Measurements

Loop attenuation values are measured on a Spectrum/Network Analyzer, connected to the loop simulator as shown in the test set-up. All equipment is automated via a calibration script, which runs on the Control PC. The script also calculates and reports the Mean Error values and Mean Absolute Error values for all loops.

The analyzer is connected to side 'A' and 'B' of the loop simulator via a Wide-band transformer.

### Method for Calculating Mean Error

The Mean Error (ME) of a simulated loop is measured and calculated over the range  $[f1, f2]$ , where frequency  $f1$  is 20 kHz. The frequency  $f2$  is the frequency at which the loop attenuation is 90dB or 1.104 MHz, whichever is the lowest. One measurement is taken every 10 kHz. The ME is calculated as follows:

$$\text{Mean Error} = N^{-1} \sum_{i=1}^{i=N} (\text{Actual Attenuation}_i \text{ (dB)} - \text{Theoretical Attenuation}_i \text{ (dB)})$$

For an individual point (i), if actual loop attenuation is higher than theoretical (too much attenuation), the mean attenuation error shall be represented by a positive value in dB. If actual loop attenuation is lower than theoretical (too little attenuation), the mean attenuation error shall be represented by a negative value in dB.

N is determined by the number of points necessary to measure the attenuation in steps of 10 kHz. The Actual Attenuation Values are measured using the network analyzer.

The theoretical values are calculated from the RLCG parameters using two-port ABCD modeling methodology as specified in ANSI T1.417 Section B.3.1. The RLCG cable parameters are specified in ITU-T Rec. G.996.1 (June 1999)(PIC cable at 70 degrees Fahrenheit for North America.

#### **Y.7.2.2 Noise Generator**

The noise generators will be calibrated to the requirements of section 4.1.

#### **Y.7.2.3 Network/Spectrum Analyzer**

The network/spectrum analyzers used for the Open Test Event will be calibrated to the manufactures specification and will have valid calibration certificates.

### ***Y.7.3 Test System Benchmarking***

#### **Y.7.3.1 Port-to-port variance & trial-to-trial variance**

To demonstrate the port-to-port variance on the DSLAM and the trial-to-trial variance of the CPE used in the benchmarking, each port of the DSLAM card that will be used in the official testing will be tested for 25 iterations over 11 kft with -140 dBm/Hz White Noise. This test will be done in fast mode and conducted as specified in Annex A.1.4.1. 11 kft is chosen as the expected result is in the knee of the performance curve where the device under test is most susceptible to variance (as shown in BroadbandForum2002-306). -140 White Noise is chosen as this is the lowest power noise used which yields the widest dynamic range and again the DUT is most susceptible to variance.

Using 25 iterations across 12 ports (there are 12 ports per DSLAM card) limits the test time to approximately 5 hours. The DSLAM ports are ranked according to their achieved average (over the 25 iterations) downstream data rate.

Repeat the above tests for upstream performance. Each port of the same DSLAM card will be tested for 25 iterations over 18 kft with -140 dBm/Hz White Noise. This test will be done in fast mode and conducted as specified in Annex A.1.4.1. 18 kft is chosen as the DSLAM tends to achieve its lowest receiver noise floor on the longest loops.

The candidate DSLM port for the Open Test Event is chosen as the 9-th best-performing DSLAM port (75% criterion) in the list of 12 ports ranked according to average downstream performance.

If multiple DSLAM ports achieve average downstream data rates within ~60kbps to the average downstream data rate of the candidate port, then the candidate DSLAM port is chosen from this group of ports as the one whose average upstream data rate is lower than that of 75% of the ports.

#### **Y.7.3.2 Test equipment variance**

Two sets of loop simulators and noise generators will be used in the Open Test Event. One will be used for the official testing and the other will be made available to the participants for pre-testing and as back up. This test will use the same loop and noise condition and the same CPE as the previous test. However, in this case the DSLAM port will remain constant (port 1) and the 50 iterations will be done across the permutations of test equipment as shown in the table below.

<b>Wireline Simulator</b>	<b>Noise Generator</b>
1	1
1	2
2	1
2	2

The lowest-performing test equipment combination (of Wireline simulator and noise generator) is the combination which yields the lowest average (over the 50 iterations) downstream data rate.

#### **Y.7.4 Selection of DSLAM port and test equipment**

The DSLAM will be configured as specified in Annex A.1. For the purposes of the Open Test Event, the candidate DSLAM port identified in section Y.7.3.1 will be used for the testing. Further, the lowest-performing test equipment combination identified in section Y.7.3.2 will be used for the testing.

#### **Y.7.5 Full System Bench Mark**

A complete run of the full Open Test Event Methodology will be run using the known repeatable CPE, the identified DSLAM port and the identified test equipment. The purpose of this test is to prove-in the automation & methodology.

