



TEST PLAN

# **TP-337i4**

## **G.fast Certification Test Plan**

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## Executive Summary

This Broadband Forum Test Plan, TP-337i4, provides a set of functional, stability, and basic performance test cases and related pass/fail requirements for G.fast implementations according to ITU-T Recommendations G.9700 [1] and G.9701 [2].

The primary goal of TP-337i4 is to provide a set of test cases and framework to verify interoperability between a G.fast Transceiver Unit at the Optical Network Unit (FTU-O) (e.g., a Distribution Point Unit [DPU]) and one or more FTU at the Remote site (FTU-Rs) (e.g., Customer Premise Equipments [CPEs]).

TP-337i4 serves as the test plan, including pass/fail requirements for each test case, for the Broadband Forum G.fast Certification Program. Technical content in this test plan includes test setup information, equipment configuration requirements, test procedures, and pass/fail requirements for each test case.

For additional details about the G.fast Certification Program, including requirements for participation in the program or to view the list of currently certified devices, please refer to the [Broadband Forum website](#).

# 1 Purpose and Scope

## 1.1 Purpose

TP-337i4 provides a set of functional, stability, and basic performance test cases and related pass/fail requirements for G.fast implementations according to ITU-T Recommendations G.9700 [1] and G.9701 [2].

The primary goal of TP-337i4 is to provide a set of test cases and framework to verify interoperability between an FTU-O (e.g., a DPU) and one or more FTU-Rs (e.g., CPEs). The test cases are defined for a Device Under Test (DUT – either a DPU or CPE), tested against a Link Partner (either a CPE or DPU respectively). The DPU/CPE may be a reference design, however containing the necessary FTU-O/R and system functionality to execute this test plan (see e.g., section 4.2).

TP-337i4 serves as the test plan, including pass/fail requirements for each test case, for the Broadband Forum G.fast Certification Program. Additional documentation is available from the Broadband Forum about the G.fast Certification Program, including program benefits, participation requirements, number and type of equipment to be tested against, and logo usage guidelines. For additional details about the Broadband Forum’s certification programs, please refer to: <https://www.broadband-forum.org/testing-and-certification-programs>.

The reader is directed to the formal certification program documentation, which can be downloaded from the Broadband Forum’s public website, for a full description of the certification requirements and procedures.

Technical content in this test plan includes test setup information, equipment configuration requirements, test procedures, and pass/fail requirements for each test case. Specific manufacturer information for test and measurement equipment has not been included in this document, except in cases where the selection or use of alternate equipment could negatively impact the results of the testing.

## 1.2 Scope

This Test Plan is intended to provide a certification test plan for ITU-T Recommendation G.9700 “Fast access to subscriber terminals (G.fast) – Power spectral density specification” and G.9701 “Fast access to subscriber terminals (G.fast) – Physical layer specification”. This TP-337i4 is specifically conceived for the basic interoperability objectives of the Broadband Forum G.fast Certification Program.

TP-337i4 is intended to address a common set of basic test scenarios that can apply to different deployments around the world. The test scenarios have been developed based on deployment scenarios in the Fiber to the Distribution Point (FTTdp) architecture as defined by Broadband Forum in TR-301 [5]. Test cases included in TP-337i4 are intended to verify the interoperability between an FTU-O and an FTU-R (or multiple FTU-Rs) according to:

- Functionality of mandatory features within the ITU-T Recommendations G.9700 and G.9701,
- Basic performance between two or more transceivers,
- Stability and quality of the connection.

Operator-specific scenarios, including testing with loop types, lengths, or noise scenarios, that may be specific to a deployment, are outside the scope of TP-337i4. This Test Plan is applicable to both single-port and multi-port DPUs; test cases applicable only to multi-port DPUs are clearly identified as conditional test cases.

This test plan is also applicable to implementations requiring Reverse Power Feed (RPF) e.g., according to ETSI TS 101 548-1 [11].

This test plan is not intended to replace operator pre-deployment testing, which may include additional tests for a given deployment.

### **1.3 Compliance Requirements**

The tests contained in this document are intended to verify the interoperability between an FTU-R implementation and an FTU-O implementation, while also testing the DUT's compliance to the ITU-T specifications in some key functional areas, such as transmit power, upstream/downstream split ratios, etc. This test plan is not intended to validate completely a DUT's compliance to the ITU-T specifications. Instead, these other key aspects of the specification are tested for interoperability with the link partner.

### **1.4 Test Plan Passing Criteria**

The tests contained in this document are each marked with a test status, indicating: "mandatory," "conditional mandatory," or "optional." These terms are defined in section 2.3.

For the purpose of determining a summary result, such as indicating a device "passes TP-337i4 testing," the device SHALL pass all "mandatory" tests and all applicable "conditional mandatory" tests. "Optional" tests SHALL NOT impact the summary result. For the purposes of certification, this test plan only defines the requirements for each individual test case, while the certification program might require passing additional tests or testing with multiple link partners to achieve certification. For some tests, parameters are recorded for reporting purposes only. These parameters might be useful for debugging purposes.

For certification of devices supporting multiple ITU-T G.9701 profiles, additional testing requirements may apply.

#### **1.4.1 Test Plan Passing Criteria for Different ITU-T G.9701 Profiles**

This clause specifies test pass criteria for devices supporting either a single or multiple ITU-T G.9701 profiles defined in [2]: 106a, 106b, 106c, 212a and 212c.

For devices under test, DPU or CPE, the following rules SHALL apply for the required testing and certification listing. These rules guide the general flow of testing, while the individual test status (Mandatory, Conditional Mandatory, and Optional) still apply to each specific test case.

1. Devices supporting a single ITU-T G.9701 profile, either 106a, 106b, 212a, 106c, or 212c, MUST complete all applicable test cases using that single profile. The profile used for testing SHALL be listed as part of the certification record.
2. Devices supporting both ITU-T G.9701 profile 106a and profile 212a MUST complete all applicable test cases using profile 212a, and additionally MUST complete the following test cases using profile 106a. The certification record SHALL list both profiles as certified.
  - a. Tests 6.2.1 through 6.2.6,
  - b. Test 8.1.1,
  - c. Tests 8.2.1 through 8.2.2.
3. Devices supporting both ITU-T G.9701 profile 106c and profile 212c MUST complete all applicable test cases using profile 212c, and additionally MUST complete the following test cases using profile 106c. The certification record SHALL list both profiles as certified.
  - a. Tests 6.2.1 through 6.2.5,
  - b. Test 8.1.2.
4. Devices supporting both ITU-T G.9701 profile 106a and profile 106b, MUST complete all applicable test cases using profile 106b and additionally MUST complete the following test cases using profile 106a. The certification record SHALL list both profiles as certified.
  - a. Tests 6.2.1 through 6.2.6,
  - b. Test 8.1.1,
  - c. Tests 8.2.1 through 8.2.2.
5. Devices supporting each of ITU-T G.9701 profiles 106a, profile 106b and profile 212a, MUST complete all applicable test cases using profile 212a and additionally MUST complete the following test cases using profile 106a and MUST complete the following test cases using 106b. The certification record SHALL list all three profiles as certified.
  - a. Tests 6.2.1 through 6.2.6,
  - b. Test 8.1.1,
  - c. Tests 8.2.1 through 8.2.2.

Table 1 lists the test cases required per ITU-T G.9701 profile.

**Table 1 - Test cases required per ITU-T G.9701 profile**

Test Case	Test Cases Required per ITU-T G.9701 Profile	
	106a / 106b / 212a	106c / 212c
6.1 Inventory Data Test	M	M
6.2.1 PSD Limit Mask Test	M	M
6.2.2 Sub-carrier Masking Test	M	M
6.2.3 PSD Shaping Test	M	M
6.2.4 RFI Notching Test	M	M
6.2.5 UPBO Test	M	M



6.2.6 TIGA Test	C	N/A
6.3.1 TDD Inter-frame Gap Test	M	M
6.3.2 DS and US ratio configuration (Mds) Test	M	M
6.4 Accelerated MTBE Test	M	M
6.5 Discontinuous Operation Test	O	O
6.6 Bit Swap Test	M	M
6.7 SRA Downshift Test	M	M
6.8 SRA Upshift Test	M	M
6.9 FRA & SRA Upshift Test	M	M
6.10 RPA Test	M	M
6.11 RMC Bit Loading Configuration Test	M	M
6.12.1 Short Disconnect Test	M	M
6.12.2 Long Disconnect Test with LOS Failure	M	M
6.12.3 Long Disconnect Test with LOR Failure	M	M
6.13 Dying Gasp Test	O	O
6.14 Increased Bit Loading Test	M	M
6.15 Test Parameters Test	M	M
6.16 CPE Software Download Test	O	O
6.17 RMC Tone Masking Configuration Test	M	M
6.18 Robust Management Channel Recovery (RMCR) Test	O	O
7.1 SHINE Stability Test	M	M
7.2 REIN Stability Test	M	M
7.3 Fluctuating Broadband RFI Noise Present at Initialization Test	M	M
7.4 Stationary Broadband RFI Noise Present at Initialization Test	M	M
7.5 Fluctuating Broadband RFI Noise Present at Showtime Test	M	M
7.6 Stationary Broadband RFI Noise Present at Showtime Test	M	M
8.1.1 Single-line Basic Throughput Test over a copper wire pair	M	N/A
8.1.2 Single-line Basic Throughput Test over a coaxial cable	N/A	M
8.1.3 iDTA Test	O	O
8.2.1 Multi-line Basic Throughput Test over copper wire pairs	C	N/A
8.2.2 Multi-line Disorderly Shutdown Test over copper wire pairs	C	N/A

8.2.3 cDTA Test	O	N/A
9.2 Single-line HLOG Accuracy Test	M	M
9.3 Multi-line HLOG Accuracy Test over Copper Wire Pairs	C	N/A
<ul style="list-style-type: none"> <li>• M: Mandatory Test Case</li> <li>• C: Conditional Mandatory Test Case, refer to test case for specific condition/requirement.</li> <li>• O: Optional Test Case</li> <li>• N/A: Not Applicable Test Case</li> </ul>		

### 1.4.2 Test Plan Passing Criteria for Devices Requiring RPF

Devices requiring RPF SHOULD comply to ETSI TS 101 548-1 [11], and in such case the DUT and its Link Partner SHALL support the same power class (SR1, SR2, or SR3) according to section 7.2 of [11]. Other RPF technologies might exist, but are not considered in the context of this document.

Due to the nature of RPF, some test cases might be impacted when testing some reversely powered DPU devices, as detailed below.

If the DPU requires RPF for operation, all test cases SHALL apply, except 6.12.1, 6.12.2, 6.12.3, and 6.13, according to the requirements of section 1.4.1. The test report SHALL explicitly indicate the tests were not run and state the applicable reason.

If the DPU supports a local power supply, in addition to RPF, and that supply can be utilized during testing, all test cases SHALL apply according to section 1.4.1. The test report SHALL explicitly state the local power source that was used to complete the testing.

## 2 References and Terminology

### 2.1 Conventions

In this Test Plan, several words are used to signify the requirements of the specification. These words are always capitalized. More information can be found in RFC 2119 [3].

<b>SHALL</b>	This word, or the term “REQUIRED”, means that the definition is an absolute requirement of the specification.
<b>SHALL NOT</b>	This phrase means that the definition is an absolute prohibition of the specification.
<b>SHOULD</b>	This word, or the adjective “RECOMMENDED”, means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications need to be understood and carefully weighed before choosing a different course.
<b>SHOULD NOT</b>	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.
<b>MAY</b>	This word, or the adjective “OPTIONAL”, means that this item is one of an allowed set of alternatives. An implementation that does not include this option SHALL be prepared to inter-operate with another implementation that does include the option.

### 2.2 References

The following references are of relevance to this Test Plan. At the time of publication, the editions indicated were valid. All references are subject to revision; users of this Test Plan are therefore encouraged to investigate the possibility of applying the most recent edition of the references listed below.

A list of currently valid Broadband Forum Technical Reports is published at [www.broadband-forum.org](http://www.broadband-forum.org).

Document	Title	Source	Year
[1] <a href="#">G.9700</a>	<i>Fast Access to Subscriber Terminals (G.fast) – Power spectrum density specification</i>	ITU-T	2019

[2]	<a href="#">G.9701</a>	<i>Fast Access to Subscriber Terminals (G.fast) – Physical layer specification</i>	ITU-T	2019
[3]	<a href="#">RFC 2119</a>	<i>Key words for use in RFCs to Indicate Requirement Levels</i>	IETF	1997
[4]	<a href="#">TR-114 Issue 3 Amendment 4</a>	<i>VDSL2 Performance Test Plan – Issue 2</i>	Broadband Forum	2018
[5]	<a href="#">TR-301 Issue 2 Corrigendum 1</a>	<i>Fiber To The Distribution Point</i>	Broadband Forum	2019
[6]	<a href="#">G.227</a>	<i>Conventional Telephone Signal</i>	ITU-T	1998
[7]	<a href="#">RFC 791</a>	<i>Internet Protocol</i>	IETF	1981
[8]	<a href="#">TR-285 Corrigendum 2</a>	<i>Broadband Copper Cable Models</i>	Broadband Forum	2019
[9]	<a href="#">G.997.2</a>	<i>Physical Layer OAM for G.fast</i>	ITU-T	2019
[10]	<a href="#">TS 101 388</a>	<i>Asymmetric Digital Subscriber Line (ADSL) - European specific requirements - [ITU-T Recommendation G.992.1 modified]</i>	ETSI TC ATT M	2007
[11]	<a href="#">TS 101 548-1</a>	<i>European Requirements for Reverse Powering of Remote Access Equipment; Part 1: Twisted pair networks, V2.2.1</i>	ETSI TC ATT M	2018
[12]	<a href="#">TR-124 Issue 5</a>	<i>Functional Requirements for Broadband Residential Gateway Devices</i>	Broadband Forum	2016

### 2.3 Definitions

The following terminology is used throughout this Test Plan.

Conditional mandatory	Tests marked as “conditional mandatory” also include a conditional statement; which if met, indicates the test SHALL be considered as “mandatory.” If the conditional statement is not met, the test SHALL be considered as “optional” or “not applicable.”
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Link Partner	Applicable device to connect to the test setup opposite the Device Under Test (DUT). For example, if the DUT is a CPE device, the Link Partner is a DPU device.
Mandatory	Tests marked as “mandatory” SHALL be performed when completing testing according to this test plan.
Optional	Tests marked as “optional” MAY be completed at the request of the tester or equipment manufacturer.

## 2.4 Abbreviations

This Test Plan uses the following abbreviations:

AC	Alternating Current
AM	Amplitude Modulation
AGN	Additive Gaussian Noise
AWGN	Additive White Gaussian Noise
AWG	Arbitrary Waveform Generator
CPE	Customer Premises Equipment
DMT	Discrete Multi-Tone
DPU	Distribution Point Unit
DSL	Digital Subscriber Line
DTU	Data Transfer Unit
DUT	Device Under Test
ETR	Expected Throughput
FLR	Frame Loss Ratio
FM	Frequency Modulation
FRA	Fast Rate Adaptation
FTU	G.fast Transceiver Unit
FTU-O	FTU at the Optical Network Unit (i.e., operator end of the loop)
FTU-R	FTU at the Remote site (i.e., subscriber end of the loop)
GDR	Gamma Data Rate
G.fast	Fast access to subscriber terminals
HON	Higher Order Node
IL	Insertion Loss
LAN	Local Area Network
LOM	Loss of margin
LOR	Loss of RMC
LOS	Loss of signal

LPM	Limit PSD Mask
MAC	Media Access Control
MAE	Mean Absolute Error
MAXATP	Maximum Aggregate Transmit Power
MBW	Measurement Bandwidth
ME	Mean Error
MIB	Management Information Base
MTBE	Mean Time Between Error
NDR	Net Data Rate
NTP	Network Termination Point
OLR	On-line Reconfiguration
PSD	Power Spectral Density
psds/us	per sub-carrier downstream/upstream
REIN	Repetitive Impulse Noise
RF	Radio Frequency
RFI	Radio Frequency Interference
RMC	Robust Management Channel
RPA	RMC Parameter Adjustment
RPF	Reverse Power Feeding
SES	Severely Errored Second
SHINE	Single High Impulse Noise Event
SNRM	Signal to Noise Ratio Margin
SRA	Seamless Rate Adaptation
SSB-SC	Single-Sideband Suppressed-Carrier Modulation
TDD	Time Division Duplexing
TIGA	Transmitter Initiated Gain Adjustment
TXPSD	Transmitter Power Spectral Density
UAS	Unavailable Second
UDP	User Datagram Protocol
UPBO	Upstream Power Back-Off
VLAN	Virtual LAN
VTF	Voltage Transfer Function
WAN	Wide Area Network

### **3 Test Plan Impact**

#### **3.1 Energy Efficiency**

TP-337i4 has no impact on Energy Efficiency.

#### **3.2 IPv6**

TP-337i4 has no impact on IPv6.

#### **3.3 Security**

TP-337i4 has no impact on Security.

#### **3.4 Privacy**

Any issues regarding privacy are not affected by TP-337i4.

## 4 Equipment Features

### 4.1 Device Under Test (DUT) and Link Partner information

Table 2 and Table 3 are intended to provide test engineers and readers of the test report with sufficient information about the DUT and the Link Partner in order to assure repeatability of results and to allow for accurate comparisons of reported test results. Table 4 and Table 5 provide additional information about the powering of the DPU. Powering of the DPU is not within the scope of certification, and the details are provided for informational purposes only and can be omitted from the test report if the DPU is locally powered.

The information defined in the tables SHALL be provided to the test engineer prior to the start of the testing and SHALL be included as part of the test report. All fields SHALL be populated; if an item is not applicable to the DUT or Link Partner, the item MAY be marked as “Not Applicable.”

**Table 2 - DPU Information**

FTU-O ITU-T G.994.1 vendor ID (FTUO_GHS_VENDOR)	8 binary octets. See section 7.13.1.1/G.997.2.
FTU-O version number (FTUO_VERSION)	Up to 16 binary octets. See section 7.13.1.3/G.997.2.
DPU system vendor ID (DPU_SYSTEM_VENDOR)	8 binary octets. See section 7.13.2.1/G.997.2.
DPU system serial number (DPU_SYSTEM_SERIALNR)	Up to 32 ASCII characters. See section 7.13.2.3/G.997.2.
DPU uplink interface speed	e.g., 1 Gbit/s for 1000BASE-TX

**Table 3 - CPE Information**

FTU-R ITU-T G.994.1 vendor ID (FTUR_GHS_VENDOR)	8 binary octets. See section 7.13.1.2/G.997.2.
FTU-R version number (FTUR_VERSION)	Up to 16 binary octets. See section 7.13.1.4/G.997.2.
NT system vendor ID (NT_SYSTEM_VENDOR)	8 binary octets. See section 7.13.2.2/G.997.2.
NT system serial number (NT_SYSTEM_SERIALNR)	Up to 32 ASCII characters as: <NT serial number><space> <NT model><space> <NT firmware version> See section 7.13.2.4/G.997.2.
CPE LAN port interface speed	e.g., 1 Gbit/s for 1000BASE-TX



**Table 4 - DPU Powering Information**

DPU primary power source (local/RPF/remote)	
DPU RPF specification	
DPU RPF power class (SR1, SR2 or SR3) (see section 7.2 of ETSI TS 101 548-1 [11])	

**Table 5 - PSE Information (for RPF)**

PSE formfactor (1-box or 2-box solution)	
PSE Product Name & Model (2-box solution)	
PSE power class (SR1, SR2 or SR3) (see section 7.2 of ETSI TS 101 548-1 [11])	

#### 4.2 Management of the DUT and Link Partner

If the DUT is a DPU, the DUT SHALL support a DPU Northbound management protocol that allows the ability to configure and retrieve the G.997.2 managed objects used in this test plan. The management protocol is DUT vendor discretionary.

If the DUT is a CPE, the DUT is managed through the Distribution Point Unit Management Information Base (DPU-MIB) and the ITU-T G.9701 initialization/eoc/RMC. No Local Area Network (LAN)-side management protocol is required for the execution of this test plan, except as required to configure the CPE to pass Ethernet traffic between the G.fast and LAN interface(s).

## 5 Test Environments

This section contains all the specifications and information required for building the basic testing environment (e.g., test configurations, test setup characteristics, configuration settings of the Device Under Test (DUT) and the Link Partner, and setup of the simulated network environment) for G.fast test cases defined in this test plan. Test case-specific configuration settings are defined in their related section.

### 5.1 Test Configurations

#### 5.1.1 Ethernet/IP Traffic Setup

The CPE and DPU SHALL support means to pass Ethernet/IP traffic through the G.fast link.

The DPU and CPE each SHOULD support the following requirements to enable these tests. Figure 1 shows the basic setup for passing Ethernet/IP traffic through the DPU and CPE device in a single line test. Figure 2 shows the basic setup for passing Ethernet/IP traffic through the DPU and CPE devices in a multi-line test.

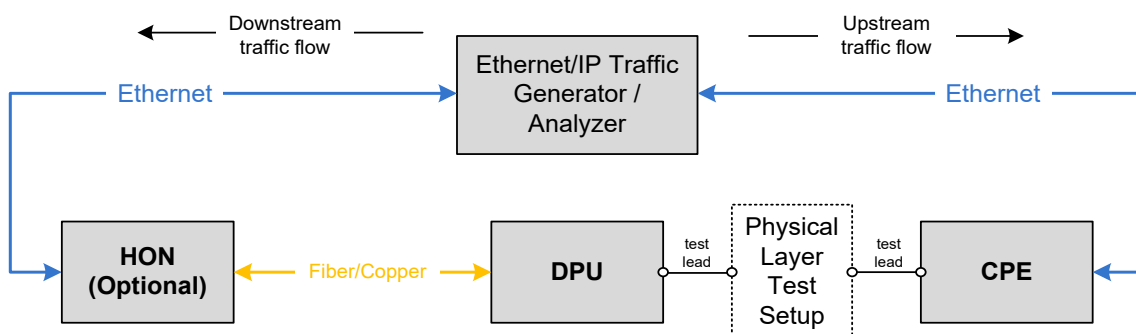
**Note:** The Physical Layer Test Setup shown in Figure 1 and Figure 2 contains any specific test setup(s) or equipment that may be required within the G.fast link, such as a wireline loop simulator, noise generator, spectrum analyzer, etc. (see section 5.1.3)

The DPU SHOULD support:

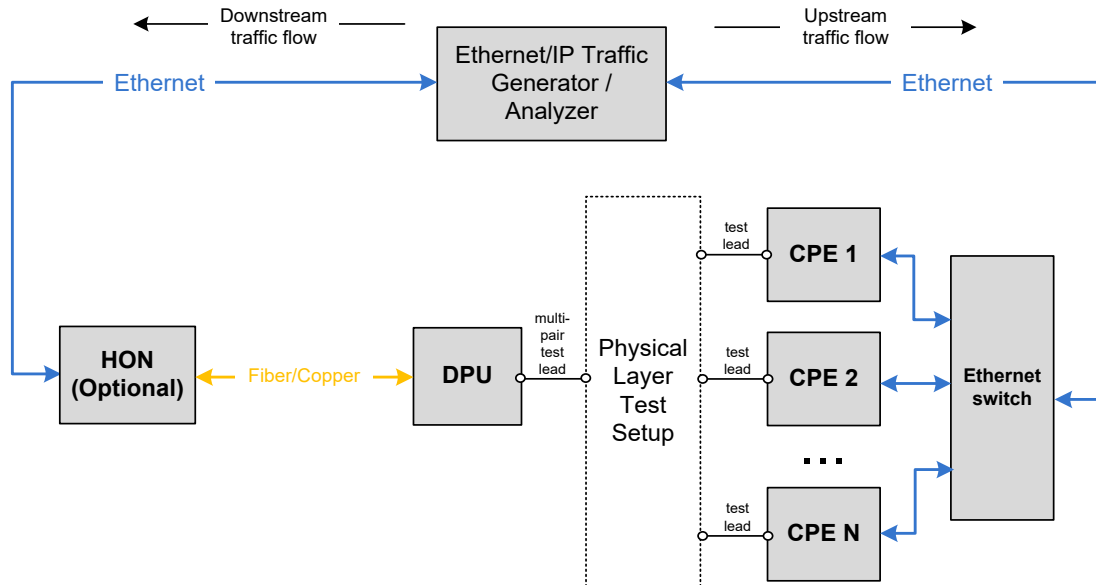
1. Forwarding of Ethernet traffic between the G.fast interface(s) and the northbound Ethernet interface, based on Media Access Control (MAC) learning or Virtual LAN (VLAN) markings.

The CPE SHOULD support at least one of the following configurations:

1. IPv4 Bridging between the Wide Area Network (WAN) and LAN ports, as defined in TR-124 Issue 5 [12], WAN.BRIDGE.1.
2. IPv4 Port Forwarding between the WAN and LAN ports, as defined in TR-124 Issue 5 [12], LAN.PFWD.1. The CPE SHALL be configured for forward IPv4 traffic for UDP Port 1024 between the WAN and LAN.



**Figure 1 - Test setup for Ethernet/IP traffic with single line test**



**Figure 2 - Test setup for Ethernet/IP traffic with multi-line test**

The test leads shown in Figure 1 and Figure 2 to connect the Physical Layer Test Setup to the DPU and CPE(s) SHALL be of 1 meter  $\pm$  2.5 cm length. For a multi-pair cable test setup, test leads SHALL be of type CAT5e or better. For a coaxial cable test setup, test leads SHALL be of type RG6 or better.

The Ethernet/IP Traffic Generator/Analyzer shown in Figure 1 and Figure 2 is not able to distinguish whether Ethernet frames are dropped in the DPU, the CPE, the High Order Node (HON), or the Ethernet switch. Hence, when verifying that no Ethernet frames are dropped in the DUT (e.g., in section 8.1.1), a background Frame Loss Ratio (FLR) of  $4e-7$ , with a minimum of 5 dropped frames, is allowed as to not fail the DUT for frames dropped outside its control.

**Note:** An FLR of  $4e-7$  corresponds with about 10 dropped downstream frames and 3 dropped upstream frames when running Ethernet traffic at a 1 Gbit/s aggregate net data rate at the default 4:1 downstream:upstream split ratio for 5 minutes, with a frame size distribution as defined in section 5.1.2. This FLR of  $4e-7$  accommodates the cascading of up to 4 Ethernet interfaces (as shown in Figure 2), each at an FLR of  $1e-7$ . A minimum of 5 dropped frames is allowed for the test to be statistically relevant given the measurement time.

For the test setup for Ethernet/IP traffic with multi-line test shown in Figure 2,

1. The purpose of the Ethernet Switch is to allow a single port to be used on the Ethernet traffic generator/analyzer for the CPE side testing. If multiple ports are used on the Ethernet traffic generator/analyzer, this switch may be eliminated.
2. If used, the Ethernet switch SHALL support a backplane switching speed so as not to limit the performance of the G.fast system, i.e., greater than the summation over all lines of the upstream and downstream G.fast net data rates.
3. The Ethernet connection between the switch and Ethernet traffic generator/analyzer link speed SHALL be 10 Gigabit Ethernet or better.

Test traffic SHALL be defined as Ethernet frames containing the headers shown in Table 6.

**Table 6 - Ethernet/IP test frame definition**

<b>Ethernet Frame Header</b>	<b>VLAN Tag</b>	<b>IPv4 Header</b>	<b>UDP Header</b>	<b>Data Payload</b>
MAC Destination/Source Addresses, etc.	Optional, downstream flow only	IPv4 Source/Destination Addresses, etc.	UDP Port, etc.	Pseudo-random bit pattern

The information listed in Table 7 SHALL be used to construct the Ethernet/IP frames used for testing. Fields not defined SHALL be calculated according to the appropriate standard (e.g., RFC791 [7] on IPv4) or SHOULD use well known and/or industry-default values. Frames received by the CPE LAN interface, for transmission in the upstream direction, SHALL NOT include a VLAN tag. Frames transmitted in the downstream direction MAY include a VLAN tag, if required by the HON and/or DPU.

**Table 7 - Ethernet/IP frame parameter values**

	<b>Downstream Flow</b>	<b>Upstream Flow</b>	<b>Description</b>
<b>Ethernet Frame Header</b>			
MAC Destination Address (Note 1)	MAC1	MAC2	Unicast MAC address, static for the duration of testing.
MAC Source Address	MAC2	MAC1	
<b>VLAN Tag (Optional)</b>			
TPID	0x8100	N/A	
VID	Based on equipment configuration.	N/A	
PCP	7	N/A	
DEI	0	N/A	
<b>IPv4 Header</b>			
IP Source	IP1	IP3 (Note 2)	Unicast IPv4 address. IP1 & IP2 SHOULD be globally routable, public IP addresses. IP3 MAY be a private IP address if the CPE is implementing port forwarding.
IP Destination	IP2 (Note 2)	IP1	
<b>UDP Header</b>			
UDP Source Port	1024	1024	
UDP Destination Port	1024	1024	
<b>Payload</b>			

Datagram Payload	PRBS	PRBS	Pseudo-random bit pattern filling remainder of frame bytes.
<p><b>Note 1:</b> The destination MAC address might be dependent on the configuration of the CPE.</p> <p><b>Note 2:</b> For CPE devices supporting Bridge Mode, IP2 SHALL equal IP3.</p>			

### 5.1.2 Ethernet Traffic Frame Sizes

The following describes the Ethernet traffic and frames sizes which SHALL be used within each test case described in this document, unless specified otherwise within the specific test case (e.g., where a single, fixed frame size is required).

A mix of Ethernet frame sizes SHALL be used during testing, with the mix of frames being evenly distributed according to the probabilities listed in Table 8.

**Table 8 - Frame Size Distribution within Ethernet Traffic**

Frame Size (bytes)	Probability
1566	0.050
1500	0.673
1024	0.088
256	0.014
70	0.175
<p><b>Note:</b> All Ethernet frame sizes being on the first byte of the Destination MAC Address and end on the last byte of the Frame Check Sequence (FCS).</p>	

To calculate the total number of frames per second to transmit through a connection of a given bit-rate, the following calculations SHALL be used.

$$\text{Average\_Frame\_Size\_of\_Mix} \left( \frac{\text{bytes}}{\text{frame}} \right) = \left[ \sum_{i=1}^M \text{frame\_probability}(i) \times \text{frame\_size}(i) \right]$$

For the Frame Size Distribution in Table 8, the Average\_Frame\_Size\_of\_Mix is 1194 bytes.

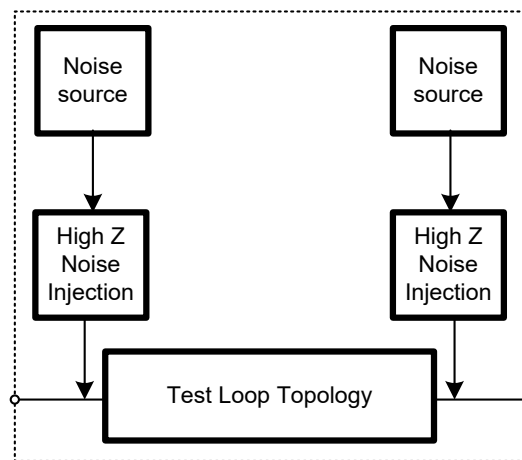
$$\text{Required\_Frame\_Rate} \left( \frac{\text{frames}}{\text{sec}} \right) = \left[ \frac{\text{Required\_Throughput} \times \frac{1}{8}}{\text{Average\_Frame\_Size\_of\_Mix}} \right],$$

where Required\_Throughput is in units of bits per second, and specified in each specific test case for a specific direction, upstream or downstream.

### 5.1.3 Physical Layer Test Setup

This section contains the specifications and information required for building the basic physical layer testing environment for G.fast test cases defined in this test plan. Different configurations and settings needed for specific test cases are defined in the related section.

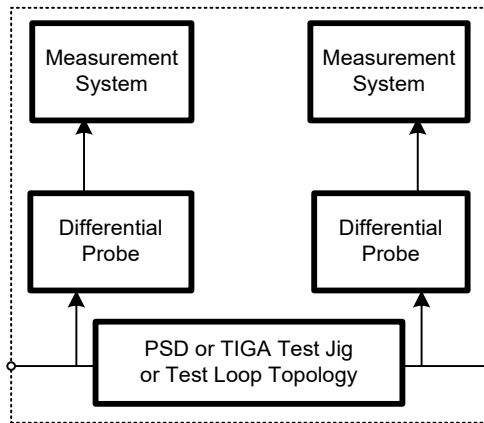
One instance of a physical layer test setup is shown in Figure 3, i.e., the instance for the test loop topology (defined in section 5.4.1) with noise injection. Where the noise is injected (at the DPU-side or at the CPE-side or at each side of the loop) is specified in each specific test case where noise injection is part of the test setup. If noise injection is not part of the test setup in a specific test case, then the High Z injection MAY still be connected to the test loop, but the noise source SHALL be switched off.



**Figure 3 - One instance of a Physical Layer Test Setup  
(test loop topology and noise injection)**

The requirements for High Impedance (Z) noise injector are specified in section 5.4.3. The requirements for the cable plant or line simulator are specified in section 5.4.1. The intended physical layer tests require one noise injection active per direction as there could be a different noise characteristic for DPU and for CPE.

Another instance of a physical layer test setup is shown in Figure 4, i.e., the instance for the PSD Test Jig (defined in section 5.4.2) or the TIGA Test Jig (defined in section 5.4.3) or the Test Loop Topology (defined in section 5.4.1) with a measurement system. The measurement point should be as close as possible to the G.fast interface at the DUT. The measurement system and where it is connected (at the DPU or at the CPE) is specified in each specific test case where a measurement system is part of the test setup.



**Figure 4 - One instance of a Physical Layer Test Setup (PSD or TIGA Test Jig or Test Loop Topology and measurement system)**

**5.2 Test Setup Characteristics**

Test results obtained as a result of testing performed in accordance with TP-337i4 SHALL contain the information described in sections 5.2.1 and 5.2.2.

**5.2.1 Temperature and Humidity**

The ranges of temperature and humidity of the test facility, over the entire time tests are conducted, SHALL be recorded in a manner similar to that shown in Table 9 and SHALL be included as part of the test report. The temperature SHOULD be within 21±5 °C. The humidity SHOULD be between 5% and 85%.

**Table 9 - Temperature and Humidity Range of Test Facility**

Parameter	High	Low
Temperature		
Humidity		

**5.2.2 Loops Environment Characteristics**

The test loops SHALL be recorded in a manner similar to that shown in Table 10 and SHALL be included as part of the test report.

**Table 10 - Loops used for Testing**

Loop	Cable type, wire gauge and length Cable or Crosstalk Emulator manufacturer and model number

A (coaxial or multi-pair) cable or multi-pair crosstalk emulator description SHALL be included as part of the test report. For a multi-pair cable, this description SHALL indicate the total number of pairs, the number and size of binders, and how each binder is structured. For a multi-pair crosstalk emulator, this description SHALL indicate the total number of pairs and any other information relevant to describe it.

**5.3 Device Under Test (DUT) and Link Partner Settings**

This section defines the values for all configuration parameters defined in G.997.2 with one default value per configuration parameter. Unless specified otherwise for an individual test case, the G.fast configuration parameter values defined in this section SHALL be used.

For a given service deployment, other configuration parameter values than these default values may be more appropriate.

**5.3.1 Profile Settings**

The profile SHALL be configured as defined in Table 11. The ITU-T G.9701 profiles are defined in Table 6-1 of ITU-T G.9701.

**Table 11 - ITU-T G.9701 profile configuration**

Configuration Parameter	ITU-T G.997.2 reference	Default value
ITU-T G.9701 profiles enabling (PROFILES)	7.1.0.1	Only one profile allowed (see section 1.4)

**5.3.2 Time Division Duplexing (TDD) Settings**

The TDD SHALL be configured as defined in Table 12.

**Table 12 - TDD configuration**

Configuration Parameter	ITU-T G.997.2 reference	Default value
Symbol periods per TDD frame (MF)	7.1.1.1	36
Symbol periods per TDD frame dedicated for downstream transmission (Mds)	7.1.1.2	28



Cyclic Extension (CE)	7.1.1.3	10
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### 5.3.3 Power and Spectrum Usage Settings

The power spectrum usage SHALL be configured as defined in Table 13.

**Table 13 - Power spectrum usage configuration**

Configuration Parameter	ITU-T G.997.2 reference	Default value
Downstream maximum aggregate transmit power (MAXATPds)	7.1.2.1	4 dBm (106a, 212a) 2 dBm (106c, 212c) 8 dBm (106b)
Upstream maximum aggregate transmit power (MAXATPus)	7.1.2.2	4 dBm (106a, 212a) 2 dBm (106c, 212c) 8 dBm (106b)
Downstream sub-carrier masking (CARMASKds)	7.1.2.3	No masked sub-carriers
Upstream sub-carrier masking (CARMASKus)	7.1.2.4	No masked sub-carriers
Downstream PSD mask (MIBPSDMASKds)	7.1.2.5	Limit PSD mask defined in ITU-T G.9700
Upstream PSD mask (MIBPSDMASKus)	7.1.2.6	Limit PSD mask defined in ITU-T G.9700
Downstream RMC sub-carrier masking (RMCCARMASKds)	7.1.2.16	No masked sub-carriers
Upstream RMC sub-carrier masking (RMCCARMASKus)	7.1.2.17	No masked sub-carriers
RFI bands (RFIBANDS)	7.1.2.7	No RFI bands (no PSD reduction)
International Amateur Radio bands (IARBANDS)	7.1.2.8	All IAR bands disabled (no PSD reduction)
Upstream power back-off reference PSD (UPBOPSDA)	7.1.2.9	40 dBm/Hz (Note 1)
Upstream power back-off reference PSD (UPBOPSDB)	7.1.2.10	0 dBm/Hz (Note 1)
Upstream electrical length (UPBOKL)	7.1.2.11	0 dB
Force electrical length (UPBOKLF)	7.1.2.12	false (not forced)
UPBO reference electrical length per band (UPBOKLREF)	7.1.2.13	0 (special value)
Class of downstream limit masks (CLASSMASKds)	7.1.2.14	Classmask_1 (Note 2)

Class of upstream limit masks (CLASSMASK <sub>us</sub> )	7.1.2.15	Classmask_1 (Note 2)
<p><b>Note 1:</b> These values imply that UPBO is disabled.</p> <p><b>Note 2:</b> If the DPU supports configuration of CLASSMASK, it MUST be configured at its default value (Classmask_1). If the DPU does not support configuration of CLASSMASK, then, G.9701 requires it operates according to Classmask_1.</p>		

### 5.3.4 Noise Margin (SNRM) Settings

The noise margins SHALL be configured as defined in Table 14.

**Table 14 - Noise margin configuration**

Configuration Parameter	G.997.2 reference	Default value
Downstream target noise margin (TARSNRM <sub>ds</sub> )	7.1.3.1	6 dB
Upstream target noise margin (TARSNRM <sub>us</sub> )	7.1.3.2	6 dB
Upstream maximum noise margin (MAXSNRM <sub>us</sub> )	7.1.3.3	511 (special value)
Downstream minimum noise margin (MINSNRM <sub>ds</sub> )	7.1.3.4	0 dB
Upstream minimum noise margin (MINSNRM <sub>us</sub> )	7.1.3.5	0 dB

### 5.3.5 Seamless Rate Adaptation (SRA) Settings

The SRA SHALL be configured as defined in Table 15.

**Table 15 - SRA configuration**

Configuration Parameter	G.997.2 reference	Default value
Downstream upshift noise margin (SRA-USNRM <sub>ds</sub> )	7.1.4.1	7 dB
Upstream upshift noise margin (SRA-USNRM <sub>us</sub> )	7.1.4.2	7 dB
Downstream minimum time interval for upshift SRA (SRA-UTIME <sub>ds</sub> )	7.1.4.3	8 seconds
Upstream minimum time interval for upshift SRA (SRA-UTIME <sub>us</sub> )	7.1.4.4	8 seconds
Downstream downshift noise margin (SRA-DSNRM <sub>ds</sub> )	7.1.4.5	5 dB
Upstream downshift noise margin (SRA-DSNRM <sub>us</sub> )	7.1.4.6	5 dB
Downstream minimum time interval for downshift SRA (SRA-DTIME <sub>ds</sub> )	7.1.4.7	2 seconds
Upstream minimum time interval for downshift SRA (SRA-DTIME <sub>us</sub> )	7.1.4.8	2 seconds

### 5.3.6 Fast Rate Adaptation (FRA) Settings

The FRA SHALL be configured as defined in Table 16.

**Table 16 - FRA configuration**

Configuration Parameter	G.997.2 reference	Default value
Downstream FRA time window (FRA-TIME <sub>ds</sub> )	7.1.5.1	8 logical frames
Upstream FRA time window (FRA-TIME <sub>us</sub> )	7.1.5.2	8 logical frames
Downstream FRA minimum percentage of degraded tones (FRA-NTONES <sub>ds</sub> )	7.1.5.3	50 %
Upstream FRA minimum percentage of degraded tones (FRA-NTONES <sub>us</sub> )	7.1.5.4	50 %
Downstream FRA number of uncorrectable DTU (FRA-RTXUC <sub>ds</sub> )	7.1.5.5	150
Upstream FRA number of uncorrectable DTU (FRA-RTXUC <sub>us</sub> )	7.1.5.6	150
Downstream vendor discretionary FRA triggering criteria (FRA-VENDISC <sub>ds</sub> )	7.1.5.7	false (disabled)
Upstream vendor discretionary FRA triggering criteria (FRA-VENDISC <sub>us</sub> )	7.1.5.8	false (disabled)

### 5.3.7 Robust Management Channel (RMC) Settings

The RMC SHALL be configured as defined in Table 17.

**Table 17 - RMC configuration**

Configuration Parameter	G.997.2 reference	Default value
Downstream target noise margin for RMC (TARSNRM-RMC <sub>ds</sub> )	7.1.6.1	9 dB
Upstream target noise margin (TARSNRM-RMC <sub>us</sub> )	7.1.6.2	9 dB
Downstream minimum noise margin for RMC (MINSNRM-RMC <sub>ds</sub> )	7.1.6.3	3 dB
Upstream minimum noise margin for RMC (MINSNRM-RMC <sub>us</sub> )	7.1.6.4	3 dB
Downstream maximum bit loading for RMC (MAXBL-RMC <sub>ds</sub> )	7.1.6.5	6 bits
Upstream maximum bit loading for RMC (MAXBL-RMC <sub>us</sub> )	7.1.6.6	6 bits

### 5.3.8 Vectoring Settings

If the DUT or Link Partner is a multi-port DPU supporting operation over a copper wire pair, then the vectoring SHALL be configured as defined in Table 18.

**Table 18 - Vectoring configuration for multi-port DPU**

Configuration Parameter	G.997.2 reference	Default value
FEXT cancellation enabling/disabling downstream (FEXT_TO_CANCEL_ENABLEds)	7.1.7.1	true (enabled)
FEXT cancellation enabling/disabling upstream (FEXT_TO_CANCEL_ENABLEus)	7.1.7.2	true (enabled)

### 5.3.9 Re-initialization Policy Settings

The re-initialization policy SHALL be configured as defined in Table 19.

**Table 19 - Re-initialization policy configuration**

Configuration Parameter	G.997.2 reference	Default value
Downstream <i>los</i> defect persistency (LOS_PERSISTENCYds)	7.1.8.1	0.2 seconds
Upstream <i>los</i> defect persistency (LOS_PERSISTENCYus)	7.1.8.2	0.2 seconds
Downstream <i>lom</i> defect persistency (LOM_PERSISTENCYds)	7.1.8.3	2 seconds
Upstream <i>lom</i> defect persistency (LOM_PERSISTENCYus)	7.1.8.4	2 seconds
Downstream <i>lor</i> defect persistency (LOR_PERSISTENCYds)	7.1.8.5	0.2 seconds
Upstream <i>lor</i> defect persistency (LOR_PERSISTENCYus)	7.1.8.6	0.2 seconds
Downstream re-initialization time threshold (REINIT_TIME_THRESHOLDds)	7.1.8.7	10 seconds
Upstream re-initialization time threshold (REINIT_TIME_THRESHOLDus)	7.1.8.8	10 seconds
Downstream low ETR threshold (LOW_ETR_THRESHOLDds)	7.1.8.9	20 seconds
Upstream low ETR threshold (LOW_ETR_THRESHOLDus)	7.1.8.10	20 seconds

### 5.3.10 Update of Test Parameters Settings

The update of test parameters settings SHALL be configured as defined in Table 20.

**Table 20 - Update of test parameters configuration**

Configuration Parameter	G.997.2 reference	Default value
Update request flag for near-end test parameters (UPDATE-NE-TEST)	7.1.9.1	false (no update forced)
Update request flag for far-end test parameters (UPDATE-FE-TEST)	7.1.9.2	false (no update forced)

### 5.3.11 Data Rates Settings

The data rates settings for the downstream channel and the data rates settings for the upstream channel SHALL be configured as defined in Table 21.

**Table 21 - Downstream and upstream channel data rates configuration**

Configuration Parameter	G.997.2 reference	Default value
Maximum Net Data Rate (MAXNDR)	7.2.1.1	3 000 000 kbit/s
Minimum Expected Throughput (MINETR)	7.2.1.2	518 kbit/s
Maximum Gamma Data Rate (MAXGDR)	7.2.1.3	3 000 000 kbit/s
Minimum Gamma Data Rate (MINGDR)	7.2.1.4	518 kbit/s

### 5.3.12 Retransmission Settings

The downstream retransmission settings and the upstream retransmission settings SHALL be configured as defined in Table 22.

**Table 22 - Downstream and upstream retransmission configuration**

Configuration Parameter	G.997.2 reference	Default value
Maximum delay (DELAYMAX)	7.2.2.1	10 msec
Minimum impulse noise protection against SHINE (INPMIN_SHINE)	7.2.2.2	0 symbol periods
SHINE ratio (SHINERATIO)	7.2.2.3	0 %
Minimum impulse noise protection against REIN (INPMIN_REIN)	7.2.2.4	0 symbol periods
REIN Inter-arrival time (IAT_REIN)	7.2.2.5	100 Hz
Minimum Reed-Solomon RFEC/NFEC ratio (RNRATIO)	7.2.2.6	0
RTX-TC testmode (RTX_TESTMODE)	7.2.2.7	false (disabled)

### 5.3.13 Data path settings

The data path settings SHALL be configured as defined in Table 23.

**Table 23 - Data path configuration**

Configuration Parameter	G.997.2 reference	Default value
TPS-TC testmode (TPS_TESTMODE)	7.3.1	false (disabled)
DRA testmode (DRA_TESTMODE)	7.3.2	false (disabled)

### 5.3.14 DTA settings

The DTA settings SHALL be configured as defined in Table 24.

**Table 24 - DTA configuration**

Configuration Parameter	G.997.2 reference	Default value
Annex X operation mode (ANNEX_X_MODE)	T.2.1.1	0 (AnnexX_FORBIDDEN) for 106a, 106b and 212a profiles 2 (AnnexX_FORCED) for 106c and 212c profiles
iDTA allowed (DTA_ALLOWED)	T.2.1.2	False (disallowed)
Annex D operation mode (ANNEX_D_MODE)	T.2.1.3	0 (AnnexD_FORBIDDEN)
cDTA allowed according to Annex D (CDTA_ALLOWED)	T.2.1.4	False (disallowed)
Preferred Mds for DTA (DTA_PREF_Mds)	T.2.2.1	28
Maximum step size for DTA changes (DTA_SMAX)	T.2.2.2	25
Minimum Mds for DTA (DTA_MIN_Mds)	T.2.2.3	5
Maximum Mds for DTA (DTA_MAX_Mds)	T.2.2.4	30
Minimum expected throughput for DTA (DTA_MINETRds/us)	T.2.2.5	0
Maximum net data rate for DTA (DTA_MAXNDRds/us)	T.2.2.6	3 000 000 kbit/s
cDTA procedure control (CDTA_PROC_CTRL)	T.2.2.7	0 (one or two step procedures)
Minimum time between DTA updates (DTA_MIN_TIME)	T.2.2.8	0 (0 seconds)

### 5.3.15 RMCR settings

The RMCR settings SHALL be configured as defined in Table 25.

**Table 25 - RMCR configuration**

<b>Configuration Parameter</b>	<b>G.997.2 reference</b>	<b>Default value</b>
RMCR_LOR_TRIGGERds	7.1.12.1	0 (disabled)
RMCR_LOR_TRIGGERus	7.1.12.1	0 (disabled)

## 5.4 Test Setup

For testing of DUT and Link Partner using RPF, the test setup SHALL support operation with power supplied towards the DPU by the PSE.

### 5.4.1 Test Loop Topologies

The end-to-end network extends from the DPU to the CPE.

An end-to-end network based on multi-pair cable includes the following segments: 1) Patch, 2) Multi-Pair Cable, 3) Isolated Drop Wire, 4) Network Termination Point (NTP), and 5) In Premises Wiring. For the convenience of test setups, this end-to-end network SHALL be partitioned into 2 separate topologies: the Multi-Pair Cable Test Loop Topology (defined in section 5.4.1.1) and the Home Network Bridged Tap Test Loop Topology (defined in section 5.4.1.2).

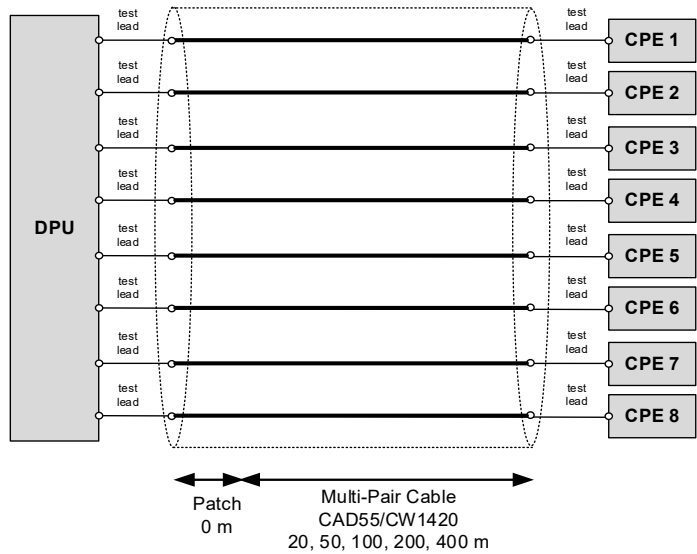
An end-to-end network based on coaxial cable includes the following segments: 1) Network-side diplexer, 2) Patch, 3) Coaxial Cable, and 4) Premises-side diplexer. For the convenience of test setups, this end-to-end network SHALL be partitioned into 2 separate topologies: coax configuration without diplexers (defined in section 5.4.1.3) and coax configuration with diplexers (defined in section 5.4.1.4).

#### 5.4.1.1 Multi-Pair Cable Test Loop Topology

The Multi-Pair Cable Test Loop Topology is shown in Figure 5. This topology is partitioned into two parts, i.e., the Patch and the Multi-Pair Cable. The Patch is the wiring of the loop that physically resides at the DP. For the purpose of this test plan, the Patch SHALL be a direct pass through (i.e., the Patch length SHALL be set to 0 meter). The Multi-Pair Cable SHALL be real cable or simulated cable.

The test setup of any Multi-Line test case is accommodated by this topology with an appropriate choice of Multi-Pair cable length(s).

Single-Line test cases SHALL use a single pair from the Multi-Pair Cable. All unused pairs SHALL be terminated at both sides of the loop with an 100 Ohm reference load.



**Figure 5 - Multi-Pair Cable Test Loop Topology**

Test leads to connect the Multi-Pair Cable to the DUT and link partner (see also Figure 1 and Figure 2) SHALL be 1 meter ± 2.5 cm in length and SHALL be of type CAT5e or better. At DPU side, the test leads MAY share the same cable, with crosstalk between the test leads. At CPE side, isolation between the test leads SHALL be as defined in section 5.4.5.6.

The “Multi-Pair Cable” is a path which is part of the general distribution network. For the purpose of this test plan, the “Multi-Pair Cable” SHALL be realized through the following cable type and cable lengths.

Multi-Pair Cable type:

- CAD55/CW1420

Multi-Pair Cable lengths (not including the test leads):

- 20 meters,
- 50 meters,
- 100 meters,
- 200 meters,
- 400 meters (Note).

The cable type CAD55 is a 4-pair cable of 0.5mm wire and 100 Ohm impedance, defined in TR-285 [8] Annex A. The Multi-Pair Cable (real cable or simulated cable) SHOULD have a similar characteristic as the cable model specified in TR-285 [8] Annex A. The equivalent real cable type is CW1420. For testing with up to 8 pairs with real cable, the Multi-Pair Cable SHALL consist of two 4-pair cables run in parallel adjacent to each other. The test report shall include access to the per pair attenuation and pair-to-pair crosstalk coupling of the multi-pair test loop used.

**Note:** The ITU-T G.9701 Recommendation is optimized to operate over wire-pairs up to approximately 250 m of 0.5 mm diameter. However, it is capable of operation over copper wire pairs up to at least 400 meters of 0.5 mm diameter, subject to some performance limitations. Therefore,



performance pass/fail criteria defined in this test plan are more relaxed at 400m than at the other loop lengths.

#### 5.4.1.1.1 Cable Accuracy

The CW1420 cable used for testing SHALL meet the following accuracy requirements. For tests requiring 8 wire pairs, both CW1420 cables SHALL meet the following accuracy requirements.

At least one pair SHALL achieve an  $MAE \leq 1\text{dB}$  for each of the loop lengths defined in section 5.4.1.1, where the MAE is defined in Equation (1) below. This pair SHALL be selected as the pair with an attenuation measurement falling closest to the arithmetic average (at all frequencies where the theoretical loop attenuation is less than  $A_{MAX}$ ) of the attenuation measurements of all 4 pairs within the CW1420 cable. The attenuation measurement SHALL be carried out in the in-band Limit PSD Mask (LPM) frequency range ( $f_{lr1}$ ,  $f_{lr2}$ ) defined in clause 7.2.1.1 of ITU-T G.9700 [1] (Note). It SHALL include everything (also connectors, e.g., RJ45) between the points where the test leads are connected to the physical layer test setup described in Figure 2.

**Note:** In-band LPM for 106 MHz profiles is defined for frequencies between 2 and 106 MHz and between 2 and 212 MHz for 212 MHz profiles.

$$MAE_{LoopX} = \frac{1}{N_i} \sum_{i \in \{A_{Ti} \leq A_{MAX}\}} |A_{Ri} - A_{Ti}|, \quad (1)$$

where

$A_{Ri}$  = Attenuation sample, in dB, of the measured loop X,  
 $A_{Ti}$  = Attenuation sample, in dB, of the theoretical loop X, and  
 $A_{MAX}$  SHALL be equal to 70dB.

The  $A_{Ti}$  values SHALL be calculated according to the models defined in TR-285.

The index “i” belongs to a set defined by the points necessary to measure the attenuation in steps of 50kHz or less and taking into account only those measurement points for which  $A_T \leq A_{MAX}$  dB.

$N_i$  is the number of elements in the above set.

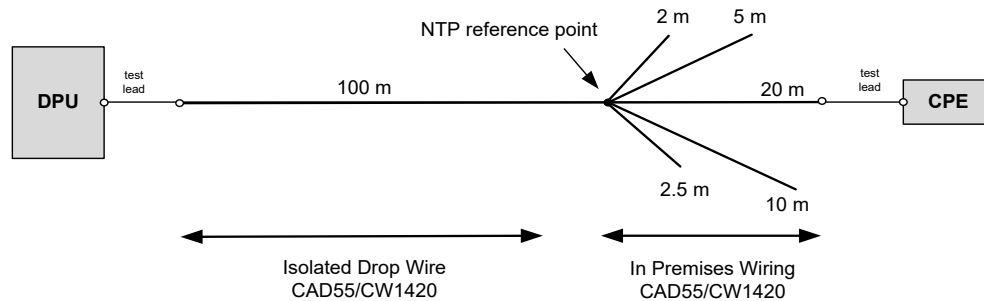
Due to the construction of the CW1420, it is expected the other pairs SHOULD have MAEs satisfying the following requirements for each of the loop lengths defined in section 5.4.1.1:

1. At least 2 of the 3 remaining pairs will have an  $MAE \leq 5$  dB.
2. The final remaining pair will have an  $MAE \leq 10$  dB.

All single pair testing defined within this test plan SHALL use the pair identified with an  $MAE \leq 1$  dB within the CW1420 cable, which SHALL meet the above accuracy requirements. Additionally, care SHOULD be taken in the construction of any physical cable plant to minimize the impacts of cross-talk between cables or loop lengths, which might negatively impact the operation of G.fast systems under test.

### 5.4.1.2 Home Network Bridged Tap Test Loop Topology

The Home Network Bridged Tap (HNBT) Test Loop Topology is shown in Figure 6. This topology is partitioned into two parts, i.e., the Isolated Drop Wire and the In Premises Wiring, separated by the Network Termination Point (NTP reference point). The In Premises Wiring topology SHALL be a star configuration consisting of 4 bridged taps and one branch to the CPE, all connected at the NTP.



**Figure 6 - Home Network Bridged Tap Test Loop Topology**

Test leads to connect the test loop to the DUT and link partner (see also Figure 1 and Figure 2) SHALL be 1 meter  $\pm$  2.5 cm in length and SHALL be of type CAT5e or better.

The “Isolated Drop Wire” (see Figure 6) represents the individual subscriber drop wires. For the purpose of this test plan, the “Isolated Drop Wire” SHALL be realized by using a single pair within the following cable type and cable lengths.

Isolated Drop Wire Cable Type:

- CAD55/CW1420

Isolated Drop Wire Cable length (not including the test lead):

- 100 meters

Any unused pairs within the cable SHALL be terminated with 100 Ohm reference impedances.

For the purpose of this test plan, the “In Premises Wiring” SHALL be realized using a single pair within the following cable type and cable lengths.

In Premises Wiring Cable Type:

- CAD55/CW1420

Bridged Tap Lengths from the NTP:

- 2 meters
- 2.5 meters
- 5 meters
- 10 meters

CPE Branch Length from the NTP (not including the test lead):

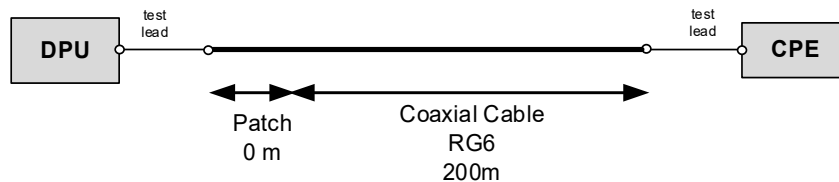
- 20 meters

Any unused pairs within the cable SHALL be terminated with 100 Ohm reference impedances.

Each bridged tap SHALL be unterminated. The crosstalk isolation between any of bridged taps and between any bridged tap and the branch to the CPE SHALL be as defined in section 5.4.5.6.

### 5.4.1.3 Coax Configuration Without Diplexers

The coax configuration without diplexers is shown in Figure 7. This topology is partitioned into two parts, i.e., the Patch and the Coaxial Cable. The Patch is the wiring of the loop that physically resides at the DP. For the purpose of this test plan, the Patch SHALL be a direct pass through (i.e., the Patch length SHALL be set to 0 meter). The Cable SHALL be real cable or simulated cable.



**Figure 7 - Coax configuration without diplexers.**

Test leads to connect the Coaxial Cable to the DUT and link partner (see also Figure 1 and Figure 2) SHALL be 1 meter  $\pm$  2.5 cm in length and SHALL be of type RG6 or better.

The “Coaxial Cable” is a path which is part of the general distribution network. For the purpose of this test plan, the “Coaxial Cable” SHALL be realized through the following cable type and cable lengths.

Coaxial Cable type:

- RG6

Coaxial Cable lengths (not including the test leads):

- 100 meters,
- 200 meters.

The RG6 type coax SHALL BE as defined in TR-285 Annex D. All connectors SHALL be F-type. Polyethylene foam SHALL be used for coax insulation; the center conductor may be copper-clad steel. The test report shall include access to the cable attenuation of the coaxial cable test loop used.

#### 5.4.1.3.1 Coax Cable Accuracy

The RG6 coaxial cable used for testing SHALL meet the following accuracy requirements.

The typical Insertion Loss (IL) is defined in TR-285 Amendment 1 [8] Annex D for the RG-6 Cable. The required range of accuracy is +/- 1 dB from the typical IL for frequency range below 100MHz and linearly interpolate to a bound of +/- 3dB from the typical IL for frequency at and above 200MHz as shown in Table 1 and Table 2. The measured IL (dB) of the RG6 cable used in the certification SHALL fall within the MIN IL (dB) and MAX IL (dB) range for each of the key frequency points listed in the tables below.

**Table 26 - Accuracy Requirements for 100m RG-6**

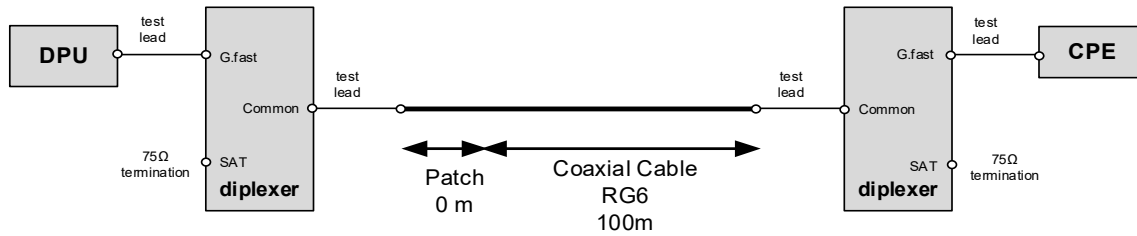
<b>100m RG-6</b>	<b>MIN IL (dB)</b>	<b>TYP IL (dB)</b>	<b>MAX IL (dB)</b>
1 MHz	0	0.66	1.66
10 MHz	0.97	1.97	2.97
50 MHz	3.59	4.59	5.59
100 MHz	5.56	6.56	7.56
200 MHz	6.18	9.18	12.18
400 MHz	11.10	14.10	17.10

**Table 27 - Accuracy Requirements for 200m RG-6**

<b>200m RG-6</b>	<b>MIN IL (dB)</b>	<b>TYP IL (dB)</b>	<b>MAX IL (dB)</b>
1 MHz	0.32	1.32	2.32
10 MHz	2.94	3.94	4.94
50 MHz	8.18	9.18	10.18
100 MHz	12.12	13.12	14.12
200 MHz	15.36	18.36	21.36
400 MHz	25.2	28.2	31.2

#### 5.4.1.4 Coax Configuration With Diplexers

The coax configuration with diplexers is shown in Figure 8. This topology is partitioned into two parts, i.e., the Patch and the Coaxial Cable. The Patch is the wiring of the loop that physically resides at the DP. For the purpose of this test plan, the Patch SHALL be a direct pass through (i.e., the Patch length SHALL be set to 0 meter). The Cable Cable SHALL be real cable or simulated cable.



**Figure 8 - Coax configuration with diplexers.**

Test leads to connect the diplexers to the DUT and link partner (see also Figure 1 and Figure 2) and to connect the Coaxial Cable to the diplexers SHALL be 1 meter ± 2.5 cm in length and SHALL be of type RG6 or better.

The “Coaxial Cable” is a path which is part of the general distribution network. For the purpose of this test plan, the “Coaxial Cable” SHALL be realized through the following cable type and cable lengths.

Coaxial Cable type:

- RG6

Coaxial Cable lengths (not including the test leads):

- 100 meters,

The RG6 type coax SHALL be as defined in TR-285 Annex D. Both diplexers SHALL have identical characteristics as defined in TR-285 Annex D. All connectors SHALL be F-type. Polyethylene foam SHALL be used for coax insulation; the center conductor may be copper-clad steel. The test report shall include access to the cable attenuation of the coaxial cable test loop used and to the attenuation of the diplexers used.

**5.4.1.4.1 Diplexer Accuracy**

The diplexers used for testing SHALL meet the following accuracy requirements.

Insertion Loss (IL in dB) between Common Port and G.fast Port:

- IL < 5 dB for 30 kHz < f < 430 kHz;
- IL > 40 dB for 2.1 MHz < f < 2.5 MHz;
- IL < 4 dB for 5 MHz < f < 6 MHz;
- IL < 2 dB for 6 MHz < f < 212 MHz;
- IL < 2.5 dB for 212 MHz < f < 806 MHz;
- IL > 40 dB for f > 950 MHz;

where IL is undefined for other frequencies.

Return Loss (RL in dB), with all unused ports terminated with 75 Ohms:

- Common Port: RL > 10 dB for 2.1 MHz < f < 2.5 MHz;

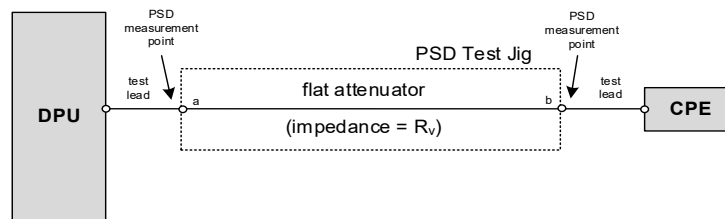
$RL > 10 \text{ dB}$  for  $5 \text{ MHz} < f < 212 \text{ MHz}$ ;  
 $RL > 10 \text{ dB}$  for  $950 \text{ MHz} < f < 2150 \text{ MHz}$ ;  
 where RL is undefined for other frequencies.

G.fast Port:  $RL > 8.5 \text{ dB}$  for  $5 \text{ MHz} > f > 20 \text{ MHz}$ ;  
 $RL > 10 \text{ dB}$  for  $20 \text{ MHz} > f > 212 \text{ MHz}$ .  
 where RL is undefined for other frequencies.

If Reverse Power Feed is used in a test, the diplexer SHALL pass DC current with a voltage drop of less than 0.5 Vdc and a maximum of 500 mA current between Common Port and G.fast Port. The diplexer SHALL block DC current between other ports.

### 5.4.2 PSD Test Jig

The PSD Test Jig is shown in Figure 9. The PSD Test Jig is a flat attenuator that allows the DUT to transmit at its full power (no power back off) and has the advantage of being very well matched to the design impedance  $R_v$ , which limits the reflection of power into the measurement.



**Figure 9 - PSD Test Jig**

With a multi-pair cable Physical Layer Test Setup,  $R_v = 100 \text{ Ohms}$ .  
 With a coaxial cable Physical Layer Test Setup,  $R_v = 75 \text{ Ohms}$ .

Test leads to connect the PSD Test Jig to the DUT and link partner (see also Figure 1 and Figure 2) SHALL be 1 meter  $\pm$  2.5 cm in length. Multi-pair test leads SHALL be of type CAT5e or better. Coaxial cable test leads SHALL be of type RG6 or better.

The PSD Test Jig SHALL have the following characteristics at the terminals a and b (see Figure 9). The test report shall include access to the attenuation of the PSD Test Jig used.

#### 5.4.2.1 Input Return Loss

The input return loss of the PSD Test Jig SHALL meet the following requirements:

- For  $f \leq 50 \text{ MHz}$ : Return Loss  $\geq 30 \text{ dB}$ ;
- For  $50 \text{ MHz} < f \leq 250 \text{ MHz}$ : Return Loss  $\geq 24 - 20 \log_{10}(f / 100 \text{ MHz})$ .

The input return loss at a given terminal SHALL be measured with an  $R_v$  reference load impedance at the other terminal. This requirement SHALL apply to both twisted pair (100 Ohm reference) and coax (75 Ohm reference) systems.

**Note:** The above requirement provides a maximum impedance mismatch within the measurement band (DC to 212MHz) of approximately  $\pm 5$  Ohms for a 100 Ohm reference impedance / system. This return loss requirement is based on a CAT6 RJ45 style connectors being used within the PSD Test Jig.

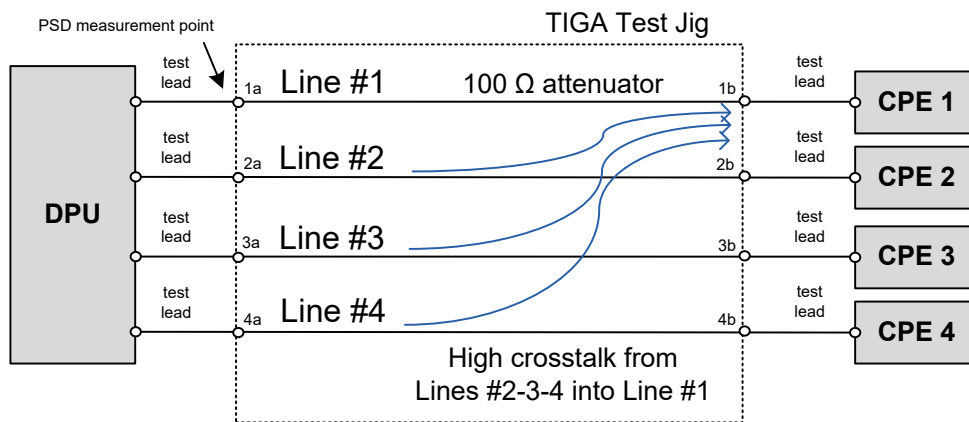
**5.4.2.2 Voltage Transfer Function**

For each direction  $a \rightarrow b$  and  $b \rightarrow a$ , the voltage transfer function (VTF) SHALL be between  $VTF\_MIN = -20dB$  and  $VTF\_MAX = -17dB$  for all frequencies from 138 kHz to 240 MHz.

The VTF SHALL be measured with an  $R_v$  reference source impedance at the transmit terminal and an  $R_v$  reference load impedance at the other terminal.

**5.4.3 TIGA Test Jig**

The TIGA Test Jig is shown in Figure 10 for the downstream direction. The TIGA Test Jig and measurement point are reversed for the upstream direction. The TIGA Test Jig allows the DUT to transmit at its full power (no power back off) and has the advantage of being well matched to the design impedance, which limits the reflection of power into the measurement. The TIGA Test Jig also allows insertion of FEXT at a level that triggers the Transmitter Initiated Gain Adjustment (TIGA) functionality (see section 6.2.5).



**Figure 10 - TIGA Test Jig for the downstream direction**

Test leads to connect the TIGA Test Jig to the DUT and link partner (see also Figure 1 and Figure 2) SHALL be 1 meter  $\pm$  2.5 cm in length and SHALL be of type CAT5e or better. At DPU side, the test leads MAY share the same cable, with crosstalk between the test leads. At CPE side, isolation between the test leads SHALL be as defined in section 5.4.5.6.

The TIGA Test Jig characteristics SHALL have the following characteristics amongst the 8 terminals 1a/2a/3a/4a and 1b/2b/3b/4b (see Figure 10). The test report shall include access to the attenuation and pair-to-pair crosstalk coupling of the TIGA Test Jig used.

#### 5.4.3.1 Input Return Loss

At each terminal [n]a and [n]b (with [n]=1 to 4), the input return loss (with the other terminals terminated with an 100 Ohm reference load) SHALL meet the following requirements:

- For  $f \leq 50$  MHz: Return Loss  $\geq 24$  dB;
- For  $50 \text{ MHz} < f \leq 250 \text{ MHz}$ : Return Loss  $\geq 18 - 20 \log_{10}(f / 100 \text{ MHz})$ .

The input impedance at a given terminal SHALL be measured with an 100 Ohm reference load impedance at all other terminals.

**Note 1:** The input impedance tolerance of the TIGA Test Jig is taken into account for ITU-T G.9700 PSD Limit Mask verification by allowing for a tolerance of 1dB above the PSD Limit Mask specified in ITU-T G.9700 (see section 6.2.6.7).

**Note 2:** The TIGA Test Jig cannot be used for the Transmit PSD verification tests defined in sections 6.2.1 to 6.2.5. A PSD Test Jig is defined for that purpose in section 5.4.2.

#### 5.4.3.2 Direct Path VTF

For each direction [n]a→[n]b and [n]b→[n]a (with [n]=1 to 4), the direct path voltage transfer function (VTF) SHALL be higher than the VTF\_MIN and lower than the VTF\_MAX defined in Table 28.

The direct path VTF SHALL be measured with an 100 Ohm reference source impedance at the transmit terminal and an 100 Ohm reference load impedance at all other terminals.

**Table 28 - MIN and MAX limits for direct path VTF**

f [kHz]	VTF_MIN [dB]	VTF_MAX [dB]
138	-20	-17
1000	-20	-17
10000	-23	-17
30000	-36	-17
60000	-36	-23
120000	-36	-23
240000	-39	-26

**Note:** Values between the breakpoints SHALL be interpolated on a linear VTF/ $\log_{10}(f)$  scale.



### 5.4.3.3 ELFEXT

For each direction  $[n]a \rightarrow [1]b$  and  $[n]b \rightarrow [1]a$  (with  $[n]=2$  to  $4$ ), the Equal Length Far-end Crosstalk (ELFEXT) SHALL be higher than the ELFEXT\_MIN and lower than the ELFEXT\_MAX defined in Table 29. The ELFEXT  $a \rightarrow b$  is defined as the  $[n]a \rightarrow [1]b$  FEXT VTF divided by the  $[1]a \rightarrow [1]b$  direct path VTF. The ELFEXT  $b \rightarrow a$  is defined as the  $[n]b \rightarrow [1]a$  FEXT VTF divided by the  $[1]b \rightarrow [1]a$  direct path VTF.

The FEXT VTF SHALL be measured with an 100 Ohm reference source impedance at the transmit terminal and an 100 Ohm reference load impedance at all other terminals.

**Table 29 - MIN and MAX limits for ELFEXT**

f [kHz]	ELFEXT_MIN [dB] Line#2 -> Line#1	ELFEXT_MAX [dB] Line#2 -> Line#1	ELFEXT_MIN [dB] Line#3 -> Line#1 Line#4 -> Line#1	ELFEXT_MAX [dB] Line#3 -> Line#1 Line#4 -> Line#1
138	N/A	-49	N/A	-49
1000	N/A	-32	N/A	-35
10000	-38	-12	-41	-15
30000	-9	-3	-12	-6
60000	-3	0	-6	-3
120000	0	3	-3	0
240000	3	6	0	3
<b>Note:</b> Values between the breakpoints SHALL be interpolated on a linear ELFEXT/ $\log_{10}(f)$ scale.				

### 5.4.3.4 NEXT VTF

For each terminal pair  $[n]a \rightarrow [1]a$  (with  $[n]=2$  to  $4$ ), the NEXT VTF SHALL be lower than -30dB.

The NEXT VTF SHALL be measured with an 100 Ohm reference source impedance at the transmit terminal and an 100 Ohm reference load impedance at all other terminals.

## 5.4.4 Noise Models

The following noise definitions are used for testing within this document, with a single noise definition applying to testing both 106 MHz and 212 MHz profiles.

### 5.4.4.1 Stationary Noise

#### 5.4.4.1.1 Flat Noise

Flat Noise is defined as Additive White Gaussian Noise (AWGN) that extends from 138 kHz to 240 MHz.

**Note:** The AWGN extends to 240 MHz so that it is not discontinuous at the 212 MHz boundary of the ITU-T G.9700/G.9701 signal spectrum.

The Flat Noise PSD levels are defined in the test setup section of the specific tests using Flat Noise.

Over the 138 kHz to 120 MHz frequency range, the Mean Absolute Error (MAE, see section 5.4.6.1) of the Flat Noise SHALL be less than or equal to 0.5 dB. Over the 120 MHz to 240 MHz frequency range, the MAE of the Flat Noise SHALL be less than or equal to 1 dB.

#### 5.4.4.1.2 Band-limited Noise

Band-limited Noise is defined as Additive Gaussian Noise (AGN) that extends from 2 MHz to 240 MHz with a PSD as defined in this section.

**Note 1:** The AGN extends to 240 MHz so that it is not discontinuous at the 212 MHz boundary of the ITU-T G.9700/G.9701 signal spectrum.

**Note 2:** The noise bands are only defined between 2 MHz and 106 MHz, due to the noises use within specific test cases with longer loops (i.e., 100m), where the noise bands combined with the loop attenuation would cause zero bits to be loaded within those bands thereby preventing the desired operation of the test cases. In the case of the BLN\_RPA noise files, it is extremely unlikely, given a 100m loop, a system would allocation RMC bits to tones above 106 MHz.

Six Band-limited Noises are defined (referred to as BLN-Type1 to BLN-Type6, see Figure 11 and Figure 12).

For Band-limited Noise of Type 1, the PSD (referred to as  $PSD_{BLN1}$ ) is defined as follows:

$$\begin{aligned}
 PSD_{BLN1} = & \quad -140 \text{ dBm/Hz for } 2 \text{ MHz} \leq f \leq 50 \text{ MHz} \\
 & \quad -119 \text{ dBm/Hz for } 50 \text{ MHz} < f \leq 60 \text{ MHz} && \text{(noise band 1)} \\
 & \quad -140 \text{ dBm/Hz for } 60 \text{ MHz} < f \leq 70 \text{ MHz} \\
 & \quad -119 \text{ dBm/Hz for } 70 \text{ MHz} < f \leq 80 \text{ MHz} && \text{(noise band 2)} \\
 & \quad -140 \text{ dBm/Hz for } 80 \text{ MHz} < f \leq 240 \text{ MHz}
 \end{aligned}$$

For Band-limited Noise of Type 2, the PSD (referred to as  $PSD_{BLN2}$ ) is defined as follows:

$$\begin{aligned}
 PSD_{BLN2} = & \quad -140 \text{ dBm/Hz for } 2 \text{ MHz} \leq f \leq 50 \text{ MHz} \\
 & \quad -139 \text{ dBm/Hz for } 50 \text{ MHz} < f \leq 60 \text{ MHz} && \text{(noise band 1)} \\
 & \quad -140 \text{ dBm/Hz for } 60 \text{ MHz} < f \leq 70 \text{ MHz} \\
 & \quad -99 \text{ dBm/Hz for } 70 \text{ MHz} < f \leq 80 \text{ MHz} && \text{(noise band 2)} \\
 & \quad -140 \text{ dBm/Hz for } 80 \text{ MHz} < f \leq 240 \text{ MHz}
 \end{aligned}$$

For Band-limited Noise of Type 3, the PSD (referred to as  $PSD_{BLN\_RPA\_1}$ ) is defined as follows:

$$\begin{aligned}
 PSD_{BLN\_RPA\_1} = & \quad -115 \text{ dBm/Hz for } 2 \text{ MHz} \leq f \leq 28 \text{ MHz} \\
 & \quad -140 \text{ dBm/Hz for } 28 \text{ MHz} < f \leq 240 \text{ MHz} && \text{(RPA noise band 1)}
 \end{aligned}$$

For Band-limited Noise of Type 4, the PSD (referred to as  $PSD_{BLN\_RPA\_2}$ ) is defined as follows:

$$PSD_{BLN\_RPA\_2} = \begin{cases} -140 \text{ dBm/Hz} & \text{for } 2 \text{ MHz} \leq f \leq 28 \text{ MHz} \\ -115 \text{ dBm/Hz} & \text{for } 28 \text{ MHz} < f \leq 54 \text{ MHz} \\ -140 \text{ dBm/Hz} & \text{for } 54 \text{ MHz} \leq f \leq 240 \text{ MHz} \end{cases} \quad (\text{RPA noise band 2})$$

For Band-limited Noise of Type 5, the PSD (referred to as  $PSD_{BLN\_RPA\_3}$ ) is defined as follows:

$$PSD_{BLN\_RPA\_3} = \begin{cases} -140 \text{ dBm/Hz} & \text{for } 2 \text{ MHz} \leq f \leq 54 \text{ MHz} \\ -115 \text{ dBm/Hz} & \text{for } 54 \text{ MHz} < f \leq 80 \text{ MHz} \\ -140 \text{ dBm/Hz} & \text{for } 80 \text{ MHz} \leq f \leq 240 \text{ MHz} \end{cases} \quad (\text{RPA noise band 3})$$

For Band-limited Noise of Type 6, the PSD (referred to as  $PSD_{BLN\_RPA\_4}$ ) is defined as follows:

$$PSD_{BLN\_RPA\_4} = \begin{cases} -140 \text{ dBm/Hz} & \text{for } 2 \text{ MHz} \leq f \leq 80 \text{ MHz} \\ -115 \text{ dBm/Hz} & \text{for } 80 \text{ MHz} < f \leq 120 \text{ MHz} \\ -140 \text{ dBm/Hz} & \text{for } 120 \text{ MHz} < f \leq 240 \text{ MHz} \end{cases} \quad (\text{RPA noise band 4})$$

Over the 2 MHz to 120 MHz frequency range (excluding a 500 kHz guard band centered around the noise step frequencies), the Mean Absolute Error (MAE, see section 5.4.6.1) of the Band-limited Noise SHALL be less than or equal to 0.5 dB. Over the 120 MHz to 240 MHz frequency range, the MAE of the Band-limited Noise SHALL be less than or equal to 1 dB.

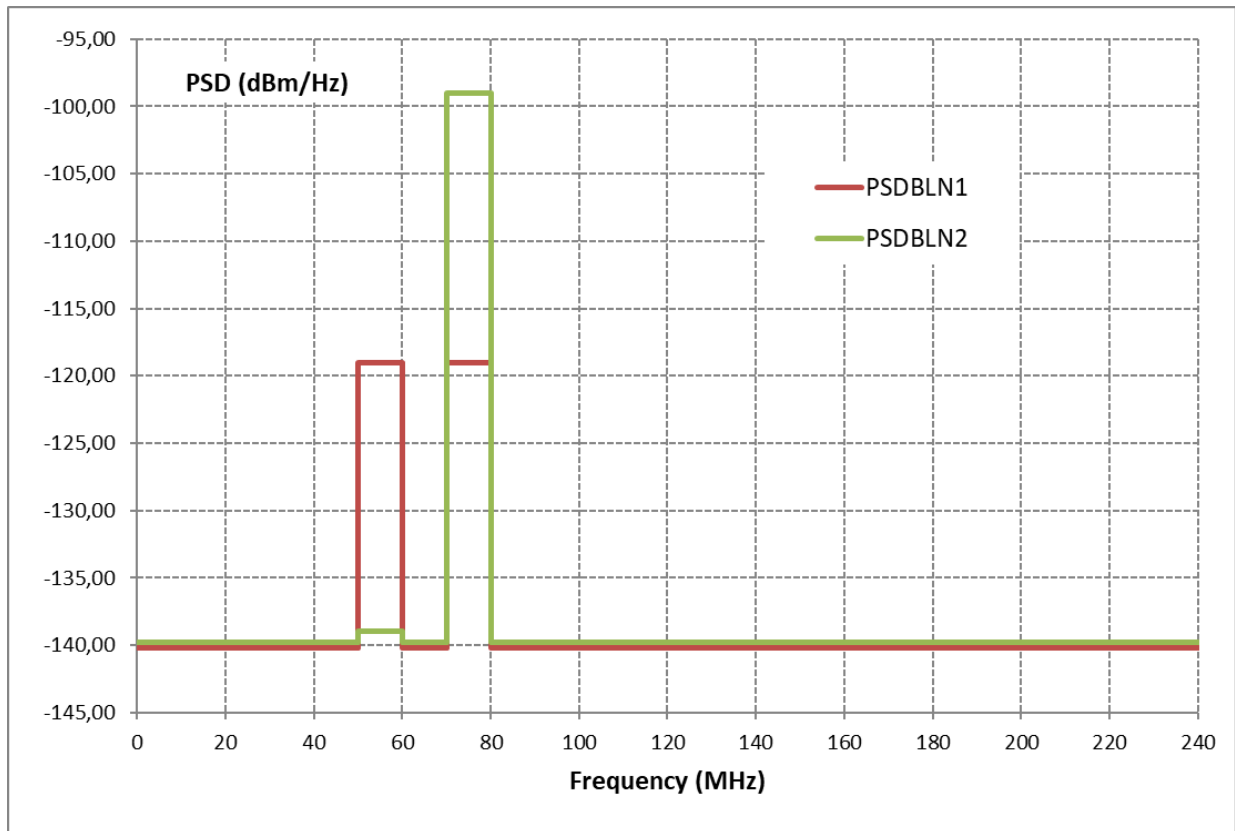
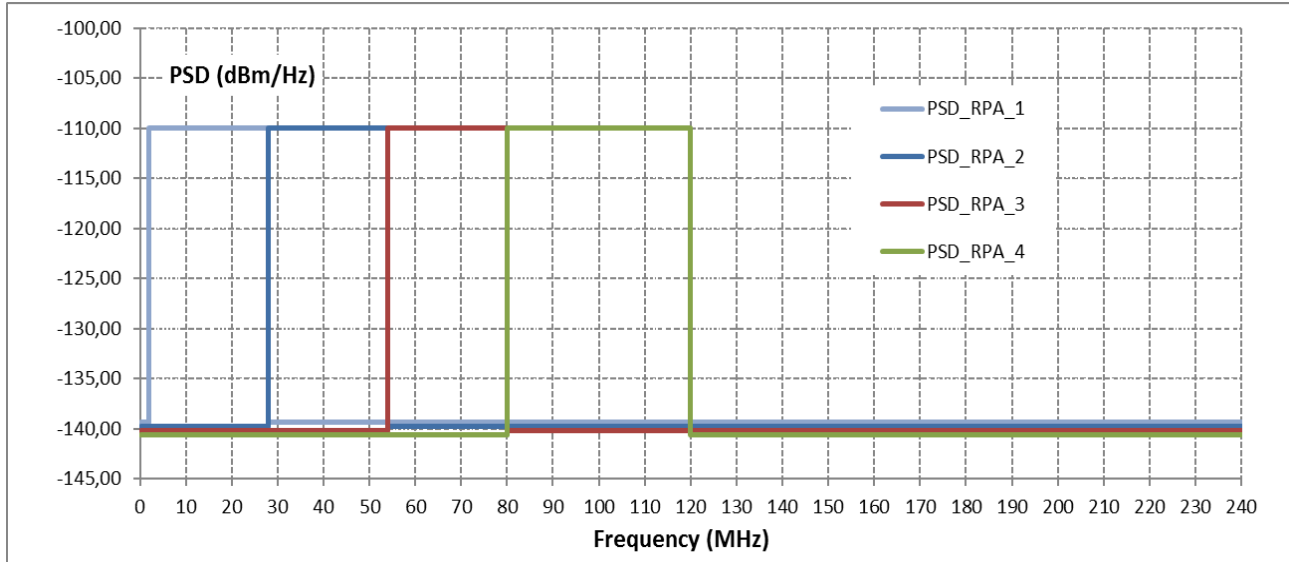


Figure 11 - PSD of the Band-limited Noise of Type 1 and 2.



**Figure 12 - PSD of the Band-limited Noise of Type 3 to 6.**

**5.4.4.2 RFI Noise**

Two RFI Noise signals are defined:

- Fluctuating Broadband RFI Noise (RFI below 30 MHz - defined in section 5.4.4.2.1);
- Stationary Broadband RFI Noise, defined as the composite of two signals:
  - RFI above 30 MHz – FM Broadcast (defined in section 5.4.4.2.2);
  - RFI above 30 MHz – TV Stations (defined in section 5.4.4.2.3).

The RFI noise is injected on top of Flat Noise. The Flat Noise PSD level is defined in the test setup section of the specific RFI test (see sections 7.3 and 7.4).

**5.4.4.2.1 RFI below 30 MHz - Fluctuating Broadband RFI**

**5.4.4.2.1.1 Signal Specification**

The set of RFI signals is referred to as:

$$\{\text{“RFI-CPE}_i(t)\}_{AM}, \text{ with } i = 1 \dots n,$$

where ‘i’ indicates the number of the loop on which the noise is injected and the subscript “AM” indicates the type of RFI.

For a given signal number *i*, the total RFI signal SHALL be defined as follows:

$$\text{RFI-CPE}_i(t) = \text{RFI}(t)$$

The signal set  $\{\text{“RFI-CPE}_i(t)\}_{AM}$  SHALL be injected in differential mode. When injected on more than one loop, the signal set  $\{\text{“RFI-CPE}_i(t)\}_{AM}$  SHALL be correlated (see section 5.4.5.5).

The Baseline Total RFI Signal, RFI(t), SHALL be composed of the 50 modulated RFI tones defined in Table 30. Of these 50 tones, exactly 45 tones SHALL correspond to RFI interferers which are AM broadcast interferers. Of these 50 tones, exactly 5 tones SHALL correspond to RFI interferers which are Amateur Radio interferers.

**Note:** The modulation on these tones is consistent with the Fluctuating Broadband RFI Model defined in section D.4.6 of TR-114 Issue 2 [4].

The tones representing the AM broadcast interferers SHALL each consist of double side band modulation. The tones representing the Amateur Radio interferers SHALL each consist of single-sideband suppressed-carrier modulation (SSB-SC).

Each tone SHALL be independently modulated with speech weighted noise, and is limited to 4.2 kHz, each noise source being independently modulated at the syllabic rate. Speech weighted noise SHALL be as defined in ITU-T G.227 [6], which is limited to 4.2 kHz. The target modulation index for each tone is 50%. Syllabic modulation SHALL be performed by periodically interrupting a continuous speech weighted noise source for a period of 150 ms every 200 ms. In the case of amateur band SSB signals, the carrier power column data SHOULD be interpreted as the power of the SSB signal during the on period of the syllabic rated modulation.

The modulating noise SHALL be fluctuating at the syllabic rate and SHALL be subject to fading at a rate and with a time profile representative of night time reception conditions. The fading between different carriers in the set SHALL be independent. In order to achieve the appropriate fading, the dual Arbitrary Waveform Generator (AWG) method specified in section D.4.6 of TR-114 Issue 2 [4] SHALL be used.

**Note:** This AWG method specifies that to achieve a fade of approximately 1000 seconds duration for carriers in the region of 1 MHz, one of the generators needs to produce a carrier at 1.000000001 MHz. This can be achieved using reference clocks of 10 MHz and 10.00000001 MHz to 2 AWGs, or by using one AWG with a pattern length of  $256 \times M$  samples (where  $M = 2^{20}$ ) and one with a pattern length of  $256 \times M - 8$  samples.

#### 5.4.4.2.1.2 Specifications of Carrier Power

Table 30 defines for each of the 50 RF tones, the frequency, the differential mode carrier power (into a 50 Ohm reference load), and whether the tone is an Amateur Radio Interferer.

**Table 30 - Differential Mode Carrier Powers for Total RFI Signal,  
RFI (t) - Fluctuating Broadband RFI Case**

RF Tone Number	Carrier Frequency ( $f_c$ ) (kHz)	Differential Mode Carrier Power (dBm)	Amateur Radio Interferer
1	99	-58	
2	270	-93	
3	333	-50	
4	531	-59	
5	630	-82	
6	711	-57	

7	801	-62	
8	855	-80	
9	909	-52	
10	999	-63	
11	1269	-83	
12	3250	-56	
13	3330	-71	
14	3365	-59	
15	3695	-75	Yes
16	3770	-90	Yes
17	4845	-80	
18	5035	-93	
19	5980	-56	
20	6005	-85	
21	6050	-85	
22	6095	-78	
23	6160	-89	
24	6180	-63	
25	7130	-71	Yes
26	7145	-90	Yes
27	7350	-92	
28	9495	-58	
29	9620	-74	
30	9685	-91	
31	9705	-93	
32	9820	-82	
33	11610	-92	
34	11720	-85	
35	11810	-82	
36	11915	-90	
37	12050	-90	
38	12185	-59	
39	13790	-70	
40	14115	-60	Yes
41	15140	-87	
42	15385	-87	
43	15735	-68	
44	17585	-65	
45	17625	-77	
46	17780	-78	
47	21670	-68	
48	21690	-92	
49	21755	-75	
50	23960	-86	

For each AM Broadcast Interferer, the peak power measured over the modulation band SHALL be within 0.5 dB of the carrier power defined in Table 30. The modulation band is defined as  $[f_c - 4.2 \text{ kHz}, f_c + 4.2 \text{ kHz}]$ .

For each Amateur Radio Interferer, the peak power measured over the modulation band SHALL be within 0.5 dB of the carrier power defined in Table 30. The modulation band is defined as  $[f_c, f_c + 4.2 \text{ kHz}]$ .

#### 5.4.4.2.2 RFI Above 30 MHz - FM Broadcast

The FM Broadcast RFI is to be considered as a set of RFI noises injected simultaneously on each loop. These are to represent multiple broadcast FM carriers.

##### 5.4.4.2.2.1 Signal Specification

The set of RFI signals is referred to as:

$$\{\text{“RFI-CPE}_i(t)\}_{\text{FM}}, \text{ with } i = 1 \dots n,$$

where ‘i’ indicates the number of the loop on which the noise is injected and the subscript ‘FM’ indicates the type of RFI.

For a given signal number  $i$ , the total RFI signal SHALL be defined as follows:

$$\text{RFI-CPE}_i(t) = \text{RFI}(t).$$

The signal set  $\{\text{“RFI-CPE}_i(t)\}_{\text{FM}}$  SHALL be injected in differential mode. When injected on more than one loop, the signal set  $\{\text{“RFI-CPE}_i(t)\}_{\text{FM}}$  SHALL be correlated (see section 5.4.5.5).

The Baseline Total RFI Signal,  $\text{RFI}(t)$ , SHALL be composed of the 11 broadcast FM signals defined in Table 31. Ten (10) of these signals are centered below 100 MHz. The 11th broadcast FM signal is placed between 100 MHz and 120 MHz. Its purpose is to provide a strong interferer which is out of band relative to ITU-T G.9701 operating below 106 MHz.

Each of the FM broadcast interferers in the set SHALL be independently modulated by a sinusoidal signal of frequency  $f_m$  of the form  $\beta \times \cos(2\pi \times f_m \times t)$ . The parameter  $\beta$  is the modulation index. The total FM broadcast interferer is then of the following form where  $f_c$  is the interferer center frequency:

$$\cos(2\pi \times f_c \times t + \beta \times \cos(2\pi \times f_m \times t)).$$

The bandwidth of the FM broadcast interferer is consistent with a 0.2 MHz spacing between adjacent FM broadcast carrier frequencies. The modulation band is defined as:

$$[f_c - \beta \times f_m, f_c + \beta \times f_m].$$

##### 5.4.4.2.2.2 Specification of Carrier Power and Signal Structure

Table 31 defines for each of the 11 broadcast FM signals, the signal structure (frequency, modulation frequency, and modulation index), and the differential mode carrier power (into a 50 Ohm reference load). The modulation frequency and modulation index are chosen so that the modulation bandwidth is less than 0.2 MHz. For each broadcast FM signal, the average power over the modulation bandwidth shall be within 0.5 dB of the carrier power defined in Table 31.

**Table 31 - Differential Mode Carrier Powers and Signal Structure for RFI Signal- FM Broadcast**

Description	Carrier Frequency (f <sub>c</sub> ) (MHz)	Modulation Frequency (f <sub>m</sub> ) (kHz)	Modulation Index (β)	Differential Mode Carrier Power (dBm)
1	88.3	15	5	-63
2	89.1	15	5	-68
3	89.9	15	5	-62
4	90.5	15	5	-66
5	91.3	15	5	-65
6	91.9	15	5	-65
7	92.7	15	5	-67
8	93.5	15	5	-64
9	95.3	15	5	-62
10	99.1	15	5	-60
11	107.9	15	5	-70

#### 5.4.4.2.3 RFI Above 30 MHz - TV Stations

This is to be considered as a set of RFI noises injected simultaneously on each loop. These are to represent digital TV signals.

##### 5.4.4.2.3.1 Signal Specification

The set of RFI signals is referred to as:

$$\{\text{“RFI-CPE}_i(t)\}_{\text{TV}}, \text{ with } i = 1 \dots n,$$

where ‘i’ indicates the number of the loop on which the noise is injected and the subscript ‘TV’ indicates the type of RFI.

For a given signal number  $i$ , the total RFI signal SHALL be defined as follows:

$$\text{RFI-CPE}_i(t) = \text{RFI}(t).$$

The signal set  $\{\text{“RFI-CPE}_i(t)\}_{\text{TV}}$  SHALL be injected in differential mode. When injected on more than one loop, the signal set  $\{\text{“RFI-CPE}_i(t)\}_{\text{TV}}$  SHALL be totally correlated, distributed from the same source.

The Baseline Total RFI Signal,  $\text{RFI}(t)$ , SHALL be composed of the 4 digital TV signals defined in Table 32.

Each of the TV signal interferers in the set SHALL be independently modulated with Gaussian Noise which SHALL be flat and SHALL begin 0.31 MHz from the start the modulation band and SHALL



end 0.31 MHz from the end of the modulation band. This allows for a guard band between adjacent TV channels.

#### 5.4.4.2.3.2 Specification of Carrier Power and Signal Structure

Table 32 defines for each of the 4 digital TV signals, the modulation band and the differential mode interferer power (into a 50 Ohm reference load). These values take into account common mode to differential mode conversion.

**Table 32 - Differential Mode Carrier Powers and Signal Structure for RFI Signal- TV**

Description	Modulation Band (MHz)	Diferential Mode Interferer Power (dBm)
TV Channel 2	54 - 60	-50.0
TV Channel 3	60 - 66	-52.2
TV Channel 4	66 - 72	-52.2
TV Channel 5	76 - 82	-54.0

For each digital TV signal, the average power measured over the modulation band SHALL be within 0.5 dB of the interferer power defined in Table 32.

#### 5.4.4.3 Impulse Noise

##### 5.4.4.3.1 REIN

Repetitive Impulse Noise (REIN) is defined as a repetition of an AWGN burst, with the time domain and frequency domain characteristics defined in following sub-sections.

##### 5.4.4.3.1.1 REIN Time Domain Characteristics

Two types of REIN are defined, with characteristics listed in Table 33.

**Table 33 - REIN time domain characteristics**

Parameter	Type 1	Type 2
burst duration	100 $\mu$ s	1ms
burst repetition	10ms (100Hz)	10ms (100Hz)

##### 5.4.4.3.1.2 REIN Frequency Domain Characteristics

During each REIN burst, the REIN PSD is defined as follows (see Figure 13):

$$PSD_{REIN}(f) = \begin{cases} -90 \text{ dBm/Hz}, & 138 \text{ kHz} \leq f < f_c \\ \max(-90 - 40 \times \log_{10}(f / f_c), -150) \text{ dBm/Hz}, & f_c \leq f < 240 \text{ MHz} \end{cases}$$

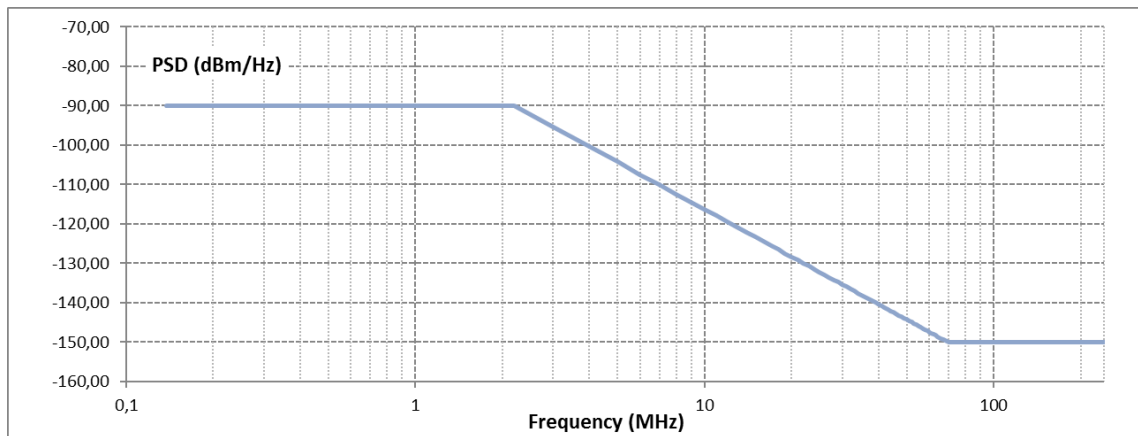
with  $f$  in Hz and  $f_c = 2.2 \times 10^6$  Hz.

Over the 138 kHz to 40 MHz frequency range, the MAE (see section 5.4.6.1) of the REIN PSD SHALL be less than or equal to 0.5 dB.

**Note:** An MAE up to 40 MHz corresponds with an MAE down to a noise level of about -140 dBm/Hz.

Outside the REIN burst, no REIN noise is generated.

The REIN noise is injected on top of Flat Noise as defined in section 5.4.4.1.1. The Flat Noise PSD level is defined in the test setup section of the specific REIN test (see section 7.2).



**Figure 13 - The PSD of a single REIN burst**

**5.4.4.3.2 SHINE**

SHINE is defined as a repetition of an AGN burst, with the time domain and frequency domain characteristics defined in following sub-sections.

**5.4.4.3.2.1 SHINE Time Domain Characteristics**

Four types of SHINE are defined (referred to as Type 1, Type 2, Type 3, and Type 4), with characteristics listed in Table 34.

**Table 34 - SHINE time domain characteristics**

Parameter	Type 1	Type 2	Type 3	Type 4
burst duration	4ms	100ms	800ms	10ms
burst repetition	1s	10s	20s	1s

#### **5.4.4.3.2.2 SHINE Frequency Domain Characteristics**

During each SHINE burst, the SHINE PSD SHALL be as Flat Gaussian Noise at a PSD level of -95 dBm/Hz over the 138 kHz to 240 MHz frequency range.

Over the 138 kHz to 120 MHz frequency range, the MAE (see section 5.4.6.1) of the SHINE PSD SHALL be less than or equal to 0.5 dB. Over the 120 MHz to 240 MHz frequency range, the MAE of the SHINE PSD SHALL be less than or equal to 1 dB.

Outside the SHINE burst, no SHINE noise is generated.

The SHINE noise is injected on top of Flat Noise as defined in section 5.4.4.1.1. The Flat Noise PSD level is defined in the test setup section of the specific SHINE test (see section 7.1).

### **5.4.5 Noise injection**

#### **5.4.5.1 Bandwidth**

The noise injector SHALL be capable of injecting Noise/Interference profiles with PSDs included in the spectral range extending from 138 kHz to 240 MHz.

#### **5.4.5.2 Simultaneous Noise/Interference Multi-line Injection**

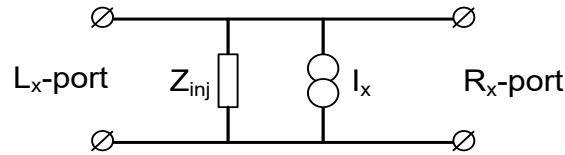
The noise injector SHALL allow simultaneous injection on N lines, where  $1 \leq N \leq 8$ , depending upon the specific test case.

#### **5.4.5.3 Modes of Injection**

Noise injection on each line SHALL be by Differential Mode.

#### **5.4.5.4 Impedance**

With the noise/interference considered as a current source, the Norton impedance of the noise-coupling circuit connected to the line ( $Z_{inj}$ ) SHALL be greater than 4000 Ohms at the point of injection, over the frequency range from 138 kHz to 240 MHz. This Norton impedance is illustrated in Figure 14 as  $Z_{inj}$ . The current source  $I_x$  is controlled by the noise source and by the parasitic shunt impedance  $Z_{inj}$  (see also ETSI TS 101 388 [10]).



**Figure 14 - Norton Equivalent Circuit Diagram**

#### 5.4.5.5 Noise/Interference on Different Lines

The noise injector SHALL allow G.fast tests to be carried out with the simultaneous injection of correlated noise/interference types on several lines. The term “correlated” means that all injected noise/interference signals are derived from the same single source, and all are within the PSD/power accuracy as specified for each individual noise/interference type.

The noise injector SHALL allow G.fast tests to be carried out with the simultaneous injection of groups of Independent Noise/Interference types and groups of Correlated Noise/Interference types on several lines.

#### 5.4.5.6 Isolation of Noise/Interference on Different Lines

Consider a port of the injector which is assigned to a specific line. For each pair of such ports the isolation between the two ports of the pair SHALL be at least 70 dB up to 240 MHz. Such isolation SHALL be defined in the following way. If a swept sine wave from a network analyzer is injected into the first port - with its voltage considered as a 0 dB reference - then the resulting measured output at the second port SHALL be at least 70 dB below the 0 dB reference, up to 240 MHz.

#### 5.4.5.7 Noise Floor

With noise/interference generator, the source of a noise/interference, in an idle state - no noise/interference being generated - the noise floor measured at the output of the injector SHALL be equal to or lower than -145 dBm/Hz and low enough to meet the MAE requirement for each individual noise/interference type. The test report shall include access to the noise floor over frequency of the noise injector used.

### 5.4.6 Test Equipment Requirements

#### 5.4.6.1 Accuracy of Noise Sources

Each noise SHALL be measured independently at the point of injection. This SHALL be done for one noise source at a time, using a NULL loop, with test leads present and terminated by a reference load impedance  $R_v$ . The measured noise will be impacted by the noise generator tolerance, the coupling circuit tolerance, cabling tolerance and noise pickup.

With a multi-pair cable Physical Layer Test Setup,  $R_v = 100$  Ohms.

With a coaxial cable Physical Layer Test Setup,  $R_v = 75$  Ohms.

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. The noise calibration frequency ranges  $f_1$  and  $f_2$  SHALL be as specified in section 5.4.4 for the specific noise source.

The Mean Absolute Error (MAE) for noise X is defined as:

$$MAE = \frac{1}{N} \sum_{i=0}^{N-1} |P_{Ri} - P_{Ti}|$$

The Mean Error (ME) for noise X is defined as:

$$ME = \frac{1}{N} \sum_{i=0}^{N-1} (P_{Ri} - P_{Ti})$$

**Note:** Positive error indicates excessive noise power.

where:

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

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

N is the number of power samples for a 10 kHz noise measurement resolution bandwidth.

The noise generator SHALL be compensated such that the absolute value of ME is minimized while maintaining an MAE as specified in section 5.4.4 for the specific noise source.

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

1. absolute amplitude accuracy
2. vertical linearity
3. frequency response of the measurement equipment used
4. tolerance of the calibration impedance.

#### 5.4.7 Management of the DUT and Link Partner

All configuration/management/status reporting of the FTU-O and FTU-R G.fast interface(s) SHALL be performed through the operation of the FTU-O interface, using the standard control parameters listed above in section 5.3. No configuration of the FTU-R interface shall be performed during this testing (the FTU-R interface(s) is considered a slave to the FTU-O configuration). The configuration of these parameters MAY be operated through the HON, DPU, CRAFT, or other appropriate interface. If a configuration parameter or status parameter is not available and is required for a specific test, that test SHALL be considered as failed.

**5.4.8 Minimum Port Interface Speed of the DUT and Link Partner**

If the DUT is a DPU, then the DUT SHALL support an uplink interface speed of 1 Gbit/s or better. The link partner is expected to have a LAN port interface speed of at least 1 Gbit/s.

If the DUT is a CPE, then the DUT SHALL support a LAN port interface speed of 1 Gbit/s or better. The link partner is expected to have an uplink interface speed of at least 1 Gbit/s.

## 6 Functional Tests

For each test in this section, reported items/measurements are verified in the expected results as applicable to the DUT. The Table 35 lists parameters (i.e., configuration parameters and reported items/measurements) referred to as “NE/FE” or “ds/us” in the expected results, and how these are applicable to a DPU and a CPE.

**Table 35 - Parameters as applicable to the DUT**

Parameter	If DUT is a DPU	If DUT is a CPE
MAXATPds/us	MAXATPds	MAXATPus
MREFPSDMASKds/us	MREFPSDMASKds	MREFPSDMASKus
MAXBL-RMCds/us	MAXBL-RMCus	MAXBL-RMCds
RMCCARMASKds/us	RMCCARMASKds	RMCCARMASKus
TARSNRM-RMCds/us	TARSNRM-RMCus	TARSNRM-RMCds
SRA-USNRMds/us	SRA-USNRMus	SRA-USNRMds
SRA-DSNRMds/us	SRA-DSNRMus	SRA-DSNRMds
NDRds/us	NDRus	NDRds
GDRds/us	GDRus	GDRds
FLRds/us	FLRus	FLRds
SNRMds/us	SNRMus	SNRMds
SNRM-RMCds/us	SNRM-RMCus	SNRM-RMCds
BITSpsds/us	BITSpsus	BITSpsds
BITSRMCpsds/us	BITSRMCpsus	BITSRMCpsds
BITSds/us	BITSus	BITSds
Lds/us	Lus	Lds
T_DTU_in_DMTds/us	T_DTU_in_DMTus	T_DTU_in_DMTds
EFBds/us	EFBus	EFBds
MTBEds/us	MTBEus	MTBEds
Tds/us_measured	Tds_measured	Tus_measured
CURR_24_NE/FE_[x]	CURR_24_NE_[x]	CURR_24_FE_[x]

The measurement systems documented in this section SHALL be calibrated with traceable and verifiable steps dependent on the specific measurement setup and test equipment. The test equipment calibration documentation SHALL be provided upon request.

### 6.1 Inventory Data and Profile Selection Test

#### 6.1.1 Purpose

The purpose of this test is to verify that the DUT inventory information retrieved from the DPU-MIB corresponds with the DUT vendor declared inventory information and verify that the actual profile of operation is the same as the configured profile.

### 6.1.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### 6.1.3 References

- ITU-T G.9701, clause 11.2.2.10.

### 6.1.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured according to the section 5.3.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.

### 6.1.5 Method of Procedure

1. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
2. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
3. Record the ITU-T G.9701 profile of operation (PROFILE).
4. Retrieve the FTU related inventory data for the DUT (x=O or R):
  - a. FTU-x ITU-T G.994.1 vendor ID (FTU<sub>x</sub>\_GHS\_VENDOR)
  - b. FTU-x version number (FTU<sub>x</sub>\_VERSION)
5. Retrieve the system related inventory data for the DUT (x=DPU or NT):
  - a. DUT system vendor ID (x\_SYSTEM\_VENDOR)
  - b. DUT system serial number (x\_SYSTEM\_SERIALNR)

### 6.1.6 Report

The following items/measurements SHALL be included in the report:

1. ITU-T G.9701 profile of operation as recorded in step 3.
2. FTU related inventory data for the DUT (FTU-x\_GHS\_VENDOR and FTU-x\_VERSION, with x=O or R).



3. System related inventory data for the DUT (`x_SYSTEM_VENDOR` and `x_SYSTEM_SERIALNR`, with `x=DPU` or `NT`).

### 6.1.7 Expected Results

1. The reported PROFILE parameter SHALL be identical to the configured PROFILES parameter (Table 11).
2. The retrieved FTU related inventory data for the DUT and the retrieved system related inventory data for the DUT SHALL be identical to the DUT vendor declared inventory data in either Table 2 (if the DUT is a DPU) or Table 3 (if the DUT is a CPE).

### 6.1.8 Estimated Test Time

The estimated test time for this test case is 10 minutes.

## 6.2 PSD Mask Tests

The following tests verify the signals transmitted by the DUT conform to the requirements defined in ITU-T G.9700 [1].

Figure 4 shows the specific setup required for the measurement of the G.fast signal. The measurement system for the purpose of PSD mask testing SHALL be connected at the DUT. Examples of measurement systems are given in Appendix I.

The measurement system output SHALL be the verifiable transmit PSD defined in Appendix III of ITU-T G.9700 (referred to as  $TXPSD(bw, f)$ ), with measurement bandwidth  $bw$  equal to the MBW defined in Table 8-1 of ITU-T G.9700. This Appendix provides a formal definition for Transmitter Power Spectral Density (TXPSD) for signals comprising a stream of symbols including quiet periods, such as those produced by time division duplexing DMT systems, e.g., G.fast. The TXPSD SHALL be measured over transmitted symbols only. Gap time, quiet symbols and idle symbols SHALL be excluded from the measurement.

The PSD Mask tests verify the PSD for the frequency bands using the measurement bandwidths as specified in Table 8-1 of ITU-T G.9700 over the frequency range defined in Table 36.

**Table 36 - PSD Frequency Range**

ITU-T G.9701 Profile	Start Frequency	Stop Frequency
106 MHz profile	500 kHz	212 MHz
212 MHz profile	500 kHz	300 MHz (Note 1,2)
<p><b>Note 1:</b> The value of 300 MHz is the maximum frequency in the measurement bandwidth settings for transmit PSD verification defined in clause 8 of ITU-T G.9700 [1].</p> <p><b>Note 2:</b> Measurement up to 250MHz is allowed for a measurement system per Appendix I Figure I-1, where the available digital storage oscilloscope is limited to 500 Msamples per second.</p>		

With the Physical Layer Test Setup (see Figure 4) terminated with impedance  $R_v$  at both the DPU-end and the CPE-end, and with the measurement system (see Figure 4) configured as during the measurement of the G.fast signal, the measurement system output (measuring the combination of the background noise present at the DUT side and the measurement system's internal noise floor) SHALL be less than -130 dBm/Hz over the frequency bands defined in Table 36. The noise floor SHALL be measured with both the DPU and CPE replaced with a reference load impedance  $R_v$ .

With a multi-pair cable Physical Layer Test Setup,  $R_v = 100$  Ohms.

With a coaxial cable Physical Layer Test Setup,  $R_v = 75$  Ohms.

## 6.2.1 PSD Limit Mask Test

### 6.2.1.1 Purpose

The purpose of this test is to verify that the signals transmitted by the DUT do not exceed the limit PSD mask (LPM) and maximum aggregate transmit power (MAXATP), when no additional spectral controls or restrictions have been configured.

### 6.2.1.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### 6.2.1.3 References

- ITU-T G.9700, clause 7.2.1.
- ITU-T G.9701, clause 7.3.1.

### 6.2.1.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 4.
2. The DUT and Link Partner SHALL be configured according to the section 5.3, except for the maximum aggregate transmit power (MAXATP), which SHALL be configured according to Table 37. No PSD shaping, sub-carrier masking, or RFI notching SHALL be configured on either the DUT or Link Partner.
3. The Measurement System SHALL be connected at the DUT side as shown in Figure 4, and SHALL be configured according to the requirements defined within clause 8 of ITU-T G.9700.
4. The PSD Test Jig as defined in section 5.4.2 SHALL be used for the testing.
5. The Ethernet/IP Traffic Generator/Analyzer SHALL be configured to transmit a continuous upstream and downstream flow of Ethernet frames (Note).

**Note:** Dropped frames do not impact the outcome of this test.

**Table 37 - Maximum aggregate transmit power (MAXATP)**

Case	ITU-T G.9701 Profile	MAXATPds	MAXATPus
1	106a or 212a	4 dBm	4 dBm
2	106a or 212a	-3 dBm	-3 dBm
1	106c or 212c	2 dBm	2dBm
2	106c or 212c	-5 dBm	-5 dBm
1	106b	+8dBm	+8dBm
2	106b	-3 dBm	-3 dBm
3	106b	+8 dBm	+4dBm

### 6.2.1.5 Method of Procedure

1. Configure the MAXATP parameters according to the first case in Table 37 for the ITU-T G.9701 profile being tested.
2. Allow the DUT and Link Partner to establish a G.fast connection through the PSD Test Jig.
3. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
4. Record the downstream and upstream net data rate (NDRds and NDRus).
5. Start the traffic generator in both the upstream and downstream directions with a required throughput equal to the minimum of (NDRus; CPE LAN port interface speed; DPU uplink interface speed) and the minimum of (NDRds; CPE LAN port interface speed; DPU uplink interface speed) respectively, in each direction.
6. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
7. Perform a transmit PSD measurement at the DUT side of the loop over the bands applicable to the ITU-T G.9701 profile identified in Table 36.
8. Perform a transmit power measurement at the DUT side of the loop over the  $f_{ir1} = 2$  MHz to  $f_{ir2} = 106$  or 212 MHz frequency band, as applicable.
9. Repeat steps 2 to 9 for the other MAXATP configuration cases listed in Table 37 for the ITU-T G.9701 profile being tested.

### 6.2.1.6 Report

For each of the MAXATP configuration cases specified in Table 37, the following items/measurements SHALL be included in the report:

1. The NDRds and NDRus recorded in step 4.
2. The measured PSD plot in dBm/Hz recorded in step 7.
3. The measured transmit power in dBm recorded in step 8.

### 6.2.1.7 Expected Results

The notation “ds/us” applies to the DUT as defined in Table 35.

For each of the cases specified in Table 37:

1. The measured PSD SHALL be equal to or lower than the Limit PSD Mask (LPM), as defined in clause 7.2.1 of ITU-T G.9700.
2. The measured transmit power SHALL be equal to or lower than the MAXATPds/us specified in Table 37 for the specific case.

### 6.2.1.8 Estimated Test Time

The estimated test time for this test case is 30 minutes.

## 6.2.2 Sub-carrier Masking Test

### 6.2.2.1 Purpose

The purpose of this test is to verify that the DUT is able to apply an arbitrary masking of sub-carriers to force no bit loading and reduced transmitted power over the masked carriers.

### 6.2.2.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### 6.2.2.3 References

- ITU-T G.9700, clauses 6.3 and 7.2.1.
- ITU-T G.9701, clause 7.3.1.3.

### 6.2.2.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 4.
2. The DUT and Link Partner SHALL be configured according to the section 5.3, except for the sub-carrier mask (CARMASK), which SHALL be configured on the DUT and the link partner according to Table 38 (Note 1). No PSD shaping, or RFI notching SHALL be configured on either the DUT or Link Partner.
3. The Measurement System SHALL be connected at the DUT side as shown in Figure 4, and SHALL be configured according to the requirements defined within clause 8 of ITU-T G.9700.
4. The PSD Test Jig as defined in section 5.4.2 SHALL be used for the testing.
5. The Ethernet/IP Traffic Generator/Analyzer SHALL be configured to transmit a continuous upstream and downstream flow of Ethernet frames (Note 2).

**Note 1:** If the DUT is a CPE, the FTU-R's Sub-carrier Mask (CARMASK) will be configured within the DPU-MIB.

**Note 2:** Dropped frames do not impact the outcome of this test.

**Table 38 - Sub-carrier mask (CARMASK)**

Sub-carrier Mask Index	Start Sub-carrier Index [sub-carrier (frequency)]	Stop Sub-carrier Index [sub-carrier (frequency)]
1	400 (20,700 kHz)	500 (25,875 kHz)
2	800 (41,400 kHz)	900 (46,575 kHz)
3	1200 (62,100 kHz)	1300 (67,275 kHz)
4	1600 (82,800 kHz)	1700 (87,975 kHz)
5 (Note)	2400 (124,200 kHz)	2500 (129,375 kHz)
<b>Note:</b> This entry applies only to testing of ITU-T G.9701 profiles 212a and 212c.		

### 6.2.2.5 Method of Procedure

1. Allow the DUT and Link Partner to establish a G.fast connection through the PSD Test Jig.
2. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
3. Record the downstream and upstream net data rate (NDRds and NDRus).
4. Start the traffic generator in both the upstream and downstream directions with a required throughput equal to the minimum of (NDRus; CPE LAN port interface speed; DPU uplink interface speed) and the minimum of (NDRds; CPE LAN port interface speed; DPU uplink interface speed) respectively, in each direction.
5. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
6. Record the downstream and upstream bit loading table (BITSpsds and BITSpsus).
7. Perform a PSD measurement at the DUT side of the loop over the bands applicable to the ITU-T G.9701 profile identified in Table 36.
8. Perform a transmit power measurement at the DUT side of the loop over the  $f_{tr1} = 2$  MHz to  $f_{tr2} = 106$  or 212 MHz frequency band, as applicable.

9. For the sub-carriers inside the CARMASK defined in Table 38, perform a sub-carrier PSD measurement at the DUT side (centered at frequency  $f = f_{sc} \times \text{sub-carrier index}$ , using an MBW = 10 kHz).

### 6.2.2.6 Report

The following items/measurements SHALL be included in the report:

1. The NDRds and NDRus recorded in step 3.
2. The BITSpsds and BITSpsus recorded in step 6.
3. The measured PSD plot in dBm/Hz recorded in step 7.
4. The measured transmit power in dBm recorded in step 8.
5. The measured sub-carrier PSD for the sub-carriers inside the CARMASK defined in Table 38 recorded in step 9.

### 6.2.2.7 Expected Results

1. The measured PSD SHALL be equal to or lower than the Limit PSD Mask (LPM), as defined in clause 7.2.1 of ITU-T G.9700.
2. The measured transmit power SHALL be equal to or lower than the value applicable to the ITU-T G.9701 profile, as specified in Table 7.1 of ITU-T G.9700 or Table X.1 of ITU-T G.9700.
3. For the sub-carriers inside the CARMASK defined in Table 38, the measured sub-carrier PSD SHALL be at least 10 dB lower than the Limit PSD Mask (LPM), as defined in ITU-T clause 7.2.1 of G.9700.
4. For the sub-carriers with index from 0 to 42 inclusive, and for the sub-carriers inside the CARMASK defined in Table 38 (Start and Stop sub-carriers inclusive), both the BITSpsds and BITSpsus SHALL be equal to 0.

### 6.2.2.8 Estimated Test Time

The estimated test time for this test case is 10 minutes.

## 6.2.3 PSD Shaping Test

### 6.2.3.1 Purpose

The purpose of this test is to verify that the DUT is able to apply an arbitrary PSD shaping. Within this test, this feature is also used to verify the configuration excluding the VDSL2 17MHz band, through the specific configuration values used for the PSD mask.

### 6.2.3.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### 6.2.3.3 References

- ITU-T G.9700, clauses 6.4 and 7.2.1.
- ITU-T G.9701, clause 7.3.1.1.

### 6.2.3.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 4.
2. The DUT and Link Partner SHALL be configured according to the section 5.3, except for the PSD shaping mask (MIBPSDMASK), which SHALL be configured on the DUT and the link partner according to Table 39 (Note 1). No sub-carrier masking, or RFI notching SHALL be configured on either the DUT or Link Partner.
3. The Measurement System SHALL be connected at the DUT side as shown in Figure 4, and SHALL be configured according to the requirements defined within clause 8 of ITU-T G.9700.
4. The PSD Test Jig as defined in section 5.4.2 SHALL be used for the testing.
5. The Ethernet/IP Traffic Generator/Analyzer SHALL be configured to transmit a continuous upstream and downstream flow of Ethernet frames (Note 2).

**Note 1:** If the DUT is a CPE, the FTU-R's PSD Shaping (MIBPSDMASK) will be configured within the DPU-MIB.

**Note 2:** Dropped frames do not impact the outcome of this test.

**Table 39 - PSD Shaping (MIBPSDMASK)**

PSD Shaping Mask Index	Sub-carrier Index	PSD Level (dBm/Hz)
1	39	-100.0
2	384	-100.0
3	387	-80.0
4	393	-65.0
5	568	-65.0
6	579	-73.0
7	2048	-76.0
8 (Note 3)	4096	-79.0

**Note 1:** This PSD Shape corresponds to a configuration for operation above 20 MHz.

**Note 2:** Additional break points, below sub-carrier index 39 or above sub-carrier index 2048, may be required for the device management interface. In these cases, the PSD level shall take the value of the breakpoint in the Table with the closest sub-carrier index.

**Note 3:** This break point applies only to testing of ITU-T G.9701 profiles 212a and 212c.

### 6.2.3.5 Method of Procedure

1. Allow the DUT and Link Partner to establish a G.fast connection through the PSD Test Jig.
2. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
3. Record the downstream and upstream net data rate (NDRds and NDRus).
4. Start the traffic generator in both the upstream and downstream directions with a required throughput equal to the minimum of (NDRus; CPE LAN port interface speed; DPU uplink interface speed) and the minimum of (NDRds; CPE LAN port interface speed; DPU uplink interface speed) respectively, in each direction.
5. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
6. Perform a PSD measurement at the DUT side of the loop over the bands applicable to the ITU-T G.9701 profile identified in Table 36.
7. Perform a transmit power measurement at the DUT side of the loop over the  $f_{tr1} = 2$  MHz to  $f_{tr2} = 106$  or 212 MHz frequency band, as applicable.

### 6.2.3.6 Report

The following items/measurements SHALL be included in the report:

1. The NDRds and NDRus recorded in step 3.
2. The measured PSD plot in dBm/Hz recorded in step 6.
3. The measured transmit power in dBm recorded in step 7.



### 6.2.3.7 Expected Results

The notation “ds/us” applies to the DUT as defined in Table 35.

1. The measured PSD SHALL be lower than the MREFPSDMASK<sub>ds/us</sub> as defined in Table 7-2 of ITU-T G.9701. The MREFPSDMASK<sub>ds/us</sub> SHALL be derived from the Limit PSD Mask (LPM), as defined in clause 7.2.1 of ITU-T G.9700, with the additional PSD shaping through the MIBPSDMASK defined in Table 39.
2. The measured transmit power SHALL be lower than the value applicable to the ITU-T G.9701 profile, as specified in Table 7.1 of ITU-T G.9700 or Table X.1 of ITU-T G.9700.

### 6.2.3.8 Estimated Test Time

The estimated test time for this test case is 10 minutes.

## 6.2.4 RFI Notching Test

### 6.2.4.1 Purpose

The purpose of this test is to verify that the DUT is able to apply a set of RFI notches for specific frequency bands in order to protect radio services; for example, amateur radio bands or broadcast radio bands.

### 6.2.4.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### 6.2.4.3 References

- ITU-T G.9700, clauses 6.5 and 7.2.1.
- ITU-T G.9701, clause 7.3.1.2.

### 6.2.4.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 4.
2. The DUT and Link Partner SHALL be configured according to the section 5.3, except for the notching mask (RFIBANDS and IARBANDS), which SHALL be configured according to Table 40 (Note 1). Each RFI notch is defined in terms of start subcarrier index  $SC_{start}$  and stop subcarrier index  $SC_{stop}$  (see clause 6.5 of ITU-T G.9700). No PSD shaping or sub-carrier masking, SHALL be configured on either the DUT or Link Partner.

3. The Measurement System SHALL be connected at the DUT side as shown in Figure 4, and SHALL be configured according to the requirements defined within clause 8 of ITU-T G.9700.
4. The PSD Test Jig as defined in section 5.4.2 SHALL be used for the testing.
5. The Ethernet/IP Traffic Generator/Analyzer SHALL be configured to transmit a continuous upstream and downstream flow of Ethernet frames (Note 2).

**Note 1:** If the DUT is a CPE, the FTU-R’s Notching Mask (RFIBANDS and IARBANDS) will be configured within the DPU-MIB.

**Note 2:** Dropped frames do not impact the outcome of this test.

**Table 40 - Notching Mask (RFIBANDS and IARBANDS)**

RFI Notch Index	RFIBAND $SC_{start}$ [sub-carrier (frequency)]	RFIBAND $SC_{stop}$ [sub-carrier (frequency)]	IARBAND Band start - Band stop [frequency ( $SC_{start} - SC_{stop}$ )]	Comment
1	N/A	N/A	24890-24990 kHz (480-484) (Note 1, 2)	Narrowband notch less than 1 MHz
2	N/A	N/A	50000-54000 kHz (965-1044) (Note 1, 2)	Wideband notch greater than 1 MHz
3	1690 (87,457.5 kHz) (Note 2)	2088 (108,054 kHz) (Note 2)	N/A	Wideband notch greater than 1 MHz
4 (Note 3)	N/A	N/A	144000-148000 kHz (2782 – 2861) (Note 1,2)	Wideband notch above 106 MHz
5 (Note 3)	3362 (173,983.5 kHz) (Note 2)	4095 (211,916.25 kHz) (Note 2)	N/A	Wideband notch above 106 MHz
<p><b>Note 1:</b> The sub-carrier start index <math>SC_{start}</math> and the sub-carrier stop index <math>SC_{stop}</math> are calculated from the band start and band stop frequencies as defined in clause 6.5 of ITU-T G.9700:</p> $SC_{start} = \text{floor}(\text{bandstartfrequency} / f_{SC} - 0.5)$ $SC_{stop} = \text{ceil}(\text{bandstopfrequency} / f_{SC} + 0.5)$ <p><b>Note 2:</b> The sub-carrier start index <math>SC_{start}</math> and the sub-carrier stop index <math>SC_{stop}</math> refer to the minimum set of sub-carriers (<math>SC_{start}</math> and <math>SC_{stop}</math> inclusive) to be turned off and refer to the frequency band (<math>SC_{start} \times f_{SC}</math> to <math>SC_{stop} \times f_{SC}</math>, with <math>f_{SC} = 51.75\text{kHz}</math>) over which the transmit PSD is to be verified, as defined in clause 6.5 of ITU-T G.9700.</p> <p><b>Note 3:</b> This entry applies only to testing of ITU-T G.9701 profiles 212a and 212c.</p>				

**6.2.4.5 Method of Procedure**

1. Allow the DUT and Link Partner to establish a G.fast connection through the PSD Test Jig.
2. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
3. Record the downstream and upstream net data rate (NDRds and NDRus).
4. Start the traffic generator in both the upstream and downstream directions with a required throughput equal to the minimum of (NDRus; CPE LAN port interface speed; DPU uplink interface speed) and the minimum of (NDRds; CPE LAN port interface speed; DPU uplink interface speed) respectively, in each direction.
5. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
6. Record the downstream and upstream bit loading table (BITSpsds and BITSpsus).
7. Perform a narrowband PSD measurement at the DUT side of the loop over the frequencies of Notch 1 ( $SC_{start} \times f_{SC}$  to  $SC_{stop} \times f_{SC}$ , with  $f_{SC}=51.75\text{kHz}$ ) from Table 40.
8. Perform a narrowband PSD measurement at the DUT side of the loop over the frequencies of Notch 2 ( $SC_{start} \times f_{SC}$  to  $SC_{stop} \times f_{SC}$ , with  $f_{SC}=51.75\text{kHz}$ ) from Table 40.
9. Calculate a wideband PSD at the DUT side of the loop over the frequencies of Notch 2 from Table 40, per the calculation method defined in clause 6.5 of ITU-T G.9700.
10. Perform a narrowband PSD measurement at the DUT side of the loop over the frequencies of Notch 3 ( $SC_{start} \times f_{SC}$  to  $SC_{stop} \times f_{SC}$ , with  $f_{SC}=51.75\text{kHz}$ ) from Table 40.
11. Calculate a wideband PSD at the DUT side of the loop over the frequencies of Notch 3 from Table 40, per the calculation method defined in clause 6.5 of ITU-T G.9700.
12. If the ITU-T G.9701 Profile uses frequencies above 106MHz, perform a narrowband PSD measurement at the DUT side of the loop over the frequencies of Notch 4 ( $SC_{start} \times f_{SC}$  to  $SC_{stop} \times f_{SC}$ , with  $f_{SC}=51.75\text{kHz}$ ) from Table 40.
13. If the ITU-T G.9701 Profile uses frequencies above 106MHz, calculate a wideband PSD at the DUT side of the loop over the frequencies of Notch 4 from Table 40, per the calculation method defined in clause 6.5 of ITU-T G.9700.
14. If the ITU-T G.9701 Profile uses frequencies above 106MHz, perform a narrowband PSD measurement at the DUT side of the loop over the frequencies of Notch 5 ( $SC_{start} \times f_{SC}$  to  $SC_{stop} \times f_{SC}$ , with  $f_{SC}=51.75\text{kHz}$ ) from Table 40.
15. If the ITU-T G.9701 Profile uses frequencies above 106MHz, calculate a wideband PSD at the DUT side of the loop over the frequencies of Notch 5 from Table 40, per the calculation method defined in clause 6.5 of ITU-T G.9700.

#### 6.2.4.6 Report

The following items/measurements SHALL be included in the report:

1. The NDRds and NDRus recorded in step 3.
2. The BITSpsds and BITSpsus recorded in step 6.
3. The measured PSD plots in dBm/Hz recorded in steps 7, 8, and 10.
4. The calculated PSD plots in dBm/Hz recorded in steps 9 and 11.

#### 6.2.4.7 Expected Results

1. The measured PSD SHALL be lower than the TXPSDM\_N PSD Mask for the narrowband measurement of Notch 1, as defined in clause 6.5 of ITU-T G.9700.

2. The measured PSD SHALL be lower than the TXPSDM\_N PSD Mask for the narrowband measurement of Notch 2, as defined in clause 6.5 of ITU-T G.9700.
3. The calculated PSD SHALL be lower than the TXPSDM\_W PSD Mask for the wideband calculation of Notch 2, as defined in clause 6.5 of ITU-T G.9700.
4. The measured PSD SHALL be lower than the TXPSDM\_N PSD Mask for the narrowband measurement of Notch 3, as defined in clause 6.5 of ITU-T G.9700.
5. The calculated PSD SHALL be lower than the TXPSDM\_W PSD Mask for the wideband calculation of Notch 3, as defined in clause 6.5 of ITU-T G.9700.
6. For the sub-carriers inside the RFIBANDs and IARBANDs defined in Table 40 ( $SC_{start}$  and  $SC_{stop}$  sub-carriers inclusive), both the BITSpsds and BITSpsus SHALL be equal to 0.
7. If the G.9701 Profile uses frequencies above 106MHz, the measured PSD SHALL be lower than the TXPSDM\_N PSD Mask for the narrowband measurement of Notch 4, as defined in ITU-T G.9700 clause 6.5.
8. If the G.9701 Profile uses frequencies above 106MHz, the calculated PSD SHALL be lower than the TXPSDM\_W PSD Mask for the wideband calculation of Notch 4, as defined in ITU-T G.9700 clause 6.5.
9. If the G.9701 Profile uses frequencies above 106MHz, the measured PSD SHALL be lower than the TXPSDM\_N PSD Mask for the narrowband measurement of Notch 5, as defined in ITU-T G.9700 clause 6.5.
10. If the G.9701 Profile uses frequencies above 106MHz, the calculated PSD SHALL be lower than the TXPSDM\_W PSD Mask for the wideband calculation of Notch 5, as defined in ITU-T G.9700 clause 6.5.

#### 6.2.4.8 Estimated Test Time

The estimated test time for this test case is 10 minutes.

### 6.2.5 UPBO Test

#### 6.2.5.1 Purpose

The purpose of this test is to verify that the signals transmitted by the DUT do not exceed the calculated upstream Transmit PSD Mask (PSDMASK), which includes the transmit PSD reductions due to UPBO. The UPBO configuration parameters are communicated to the FTU-R by the FTU-O during initialization and are required for the correct calculation of the Transmit PSD Mask. Additionally, the FTU-R needs to accurately estimate the electrical length (kl0) of the channel to calculate the appropriate Transmit PSD Mask.

#### 6.2.5.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### 6.2.5.3 References

- ITU-T G.9701, clause 7.3.1.4.
- ITU-T G.9701, clause 7.3.1.

### 6.2.5.4 Test Setup

1. The DUT and Link Partner (either DPU or CPE) SHALL be connected to the test setup shown in Figure 1 and Figure 4. The transmit PSD measurement SHALL be made at the CPE.
2. The DUT and Link Partner SHALL be configured according to the section 5.3, except for the UPBO configuration parameters listed in Table 41. No PSD shaping, sub-carrier masking, or RFI notching SHALL be configured on either the DUT or Link Partner.
3. The Measurement System SHALL be configured according to the requirements defined within clause 8 of ITU-T G.9700.
4. The PSD Test Jig as defined in section 5.4.2 SHALL be used for the testing.
5. The Ethernet/IP Traffic Generator/Analyzer SHALL be configured transmit a continuous upstream and downstream flow of Ethernet frames (Note).

**Note:** Dropped frames do not impact the outcome of this test.

**Table 41 - Configuration for UPBO test**

UPBO Configuration Parameter	G.997.2 reference	Value
Upstream power back-off reference PSD (UPBOPSDA)	7.1.2.9	70 dBm/Hz
Upstream power back-off reference PSD (UPBOPSDB)	7.1.2.10	5.5 dBm/Hz

### 6.2.5.5 Method of Procedure

1. Allow the DUT and Link Partner to establish a G.fast connection through the PSD Test Jig.
2. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
3. Record the downstream and upstream net data rate (NDRds and NDRus).
4. Start the traffic generator in both the upstream and downstream directions with a required throughput equal to the minimum of (NDRus; CPE LAN port interface speed; DPU uplink interface speed) and the minimum of (NDRds; CPE LAN port interface speed; DPU uplink interface speed) respectively, in each direction.
5. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
6. Record the FTU-O estimated upstream power back-off electrical length (UPBOKLE) and the FTU-R estimated upstream power back-off electrical length (UPBOKLE-R).
7. Perform a PSD measurement at the CPE side of the loop over the bands applicable to the ITU-T G.9701 profile identified in Table 36.
8. Perform a transmit power measurement at the CPE side of the loop over the  $f_{lr1} = 2$  MHz to  $f_{lr2} = 106$  or 212 MHz frequency band, as applicable.

### 6.2.5.6 Report

The following items/measurements SHALL be included in the report:

1. The PSD\_ATTEN (f) recorded in section 5.4.2 (Note 1).
2. The  $k_{10}$  calculated as defined in clause 7.3.1.4.2.1 of ITU-T G.9701, with  $\text{loss}(f) = \text{PSD\_ATTEN}(f)$ , and the average taken over all sub-carriers with index 43 to 2047 for ITU-T G.9701 profile 106a, 106b and 106c and with index 43 to 4095 for G.9701 profile 212a and 212c (referred to as  $k_{10\_reference}$ ) (Note 2).
3. The NDRs and NDRs recorded in step 3.
4. The UPBOKLE and UPBOKLE-R recorded in step 6.
5. The measured PSD plot in dBm/Hz recorded in step 7.
6. The measured transmit power recorded in step 8.

**Note 1:** Because the PSD Test Jig input impedance is matched to the load impedance,  $\text{PSD\_ATTEN}(f) = -\text{VTF}(f)$ , with  $\text{PSD\_ATTEN}(f)$  the insertion loss in dB as a function of frequency and  $\text{VTF}(f)$  the voltage transfer function defined in section 5.4.2. The test setup calibration includes a measurement of the PSD Test Jig's  $\text{VTF}(f)$ .

**Note 2:** A flat attenuator with  $\text{PSD\_ATTEN} = 20$  dB results in a  $k_{10\_reference} = 3.4$  dB for ITU-T G.9701 profile 106a, 106b and 106c and 2.5dB for ITU-T G.9701 profile 212a and 212c.

### 6.2.5.7 Expected Results

1. The measured PSD SHALL be lower than the MREFPSDMASK<sub>us</sub> as defined in Table 7-2 of ITU-T G.9701. The MREFPSDMASK<sub>us</sub>(f) SHALL be derived from the Limit PSD Mask (LPM), as defined in clause 7.2.1 of ITU-T G.9700, with the additional PSD shaping through the UPBOMASK as defined in clause 7.3.1.4.2.2 with  $k_{10} = \text{UPBOKLE}$ .
2. The measured transmit power SHALL be lower than the value applicable to the ITU-T G.9701 profile, as specified in Table 7.1 of ITU-T G.9700 or Table X.1 of ITU-T G.9700.
3. The UPBOKLE-R value and the UPBOKLE value SHALL be within 2 dB of the  $k_{10\_reference}$  value.

### 6.2.5.8 Estimated Test Time

The estimated test time for this test case is 10 minutes.

## 6.2.6 TIGA Test

### 6.2.6.1 Purpose

The purpose of this test is to verify that the signals transmitted by the DUT do not exceed the limit PSD mask (LPM), when high-crosstalk lines join the pre-coded group. This test applies only if the DPU supports operation over a copper wire pair and supports multiple ports.

### 6.2.6.2 Certification Requirement

- FTU-O: Conditional mandatory, with the condition that the DPU supports operation over a copper wire pair and supports more than 1 port.
- FTU-R: Conditionally mandatory, with the condition that the CPE supports operation over a copper wire pair.

### 6.2.6.3 References

- ITU-T G.9701, clause 13.2.2.1.

### 6.2.6.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 10.
2. The DUT and Link Partner SHALL be configured according to the section 5.3. No PSD shaping, sub-carrier masking, or RFI notching SHALL be configured on either the DUT or Link Partner.
3. The Measurement System SHALL be configured according to the requirements defined within clause 8 of ITU-T G.9700.
4. The TIGA Test Jig as defined in section 5.4.3 SHALL be used for the testing.
5. The Ethernet/IP Traffic Generator/Analyzer SHALL be configured to transmit a continuous upstream and downstream flow of Ethernet frames (Note).

**Note:** Dropped frames do not impact the outcome of this test.

### 6.2.6.5 Method of Procedure

1. Allow the DUT and Link Partner to establish a G.fast connection through the TIGA Test Jig on line #1. The lines #2, #3 and #4 remain in the L3 state.
2. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
3. Record the downstream and upstream net data rate (NDRds and NDRus).
4. Start the traffic generator in both the upstream and downstream directions with a required throughput equal to the minimum of (NDRus; CPE LAN port interface speed; DPU uplink interface speed) and the minimum of (NDRds; CPE LAN port interface speed; DPU uplink interface speed) respectively, in each direction.
5. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
6. Perform a PSD measurement at the DUT side of line #1 over the bands applicable to the ITU-T G.9701 profile identified in Table 36.
7. Perform a transmit power measurement at the DUT side of line#1 over the  $f_{tr1} = 2$  MHz to  $f_{tr2} = 106$  or 212 MHz frequency band, as applicable.
8. Record the full initialization counter (CURR\_24\_FULL\_INITS) and the fast initialization counter (CURR\_24\_FAST\_INITS) for line #1.
9. Record the Successful TIGA counter (CURR\_24\_TIGA) for line #1.

10. Record the near-end and far-end Errored Seconds counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end Severely Errored Seconds counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), and the near-end and far-end Unavailable Seconds counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS) for line #1.
11. Repeat steps 2, 6 and 7 (if the DPU supports fewer than 4 lines total, repeat until all lines of the DPU are used / connected):
  - a. First with joining line #2 in presence of line #1, lines #3 and #4 remain in the L3 state;
  - b. Then with joining line #3 in presence of line #1 and #2, line #4 remains in the L3 state;
  - c. Then with joining line #4 in presence of line #1, #2, and #3.
12. Record the full initialization counter (CURR\_24\_FULL\_INITS) and the fast initialization counter (CURR\_24\_FAST\_INITS) for line #1.
13. Record the Successful TIGA counter (CURR\_24\_TIGA) for line #1.
14. Record the near-end and far-end Errored Seconds counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end Severely Errored Seconds counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), and the near-end and far-end Unavailable Seconds counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS) for line #1.

#### 6.2.6.6 Report

The following items/measurements SHALL be included in the report:

1. The NDRds and NDRus recorded in step 3.
2. The CURR\_24\_FULL\_INITS and CURR\_24\_FAST\_INITS counters recorded in steps 8 and 12.
3. The CURR\_24\_TIGA counter recorded in steps 9 and 13.
4. The CURR\_NE\_24\_ES and CURR\_FE\_24\_ES counters, the CURR\_NE\_24\_SES and CURR\_FE\_24\_SES counters, and the CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS counters recorded in steps 10 and 14.
5. The four measured PSD plots in dBm/Hz recorded in step 6.
6. The four measured transmit power values in dBm recorded in step 7.

#### 6.2.6.7 Expected Results

The notation “NE/FE” applies to the DUT as defined in Table 35.

From before until after joining lines #2, #3 and #4:

1. The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
2. The CURR\_24\_FAST\_INITS counter increase SHALL be 0.
3. The CURR\_24\_TIGA counter increase SHALL be  $\geq 1$ .
4. The CURR\_NE/FE\_24\_ES counter increase SHALL be 0.
5. The CURR\_NE/FE\_24\_SES counter increase SHALL be 0.
6. The CURR\_NE/FE\_24\_UAS counter increase SHALL be 0.

The measured PSD SHALL be lower than the Limit PSD Mask (LPM) plus 1 dB, as defined in clause 7.2.1 of ITU-T G.9700 for each of the four PSD measurements.



**Note:** The input impedance tolerance of the TIGA Test Jig is taken into account for ITU-T G.9700 PSD Limit Mask verification by allowing for a tolerance of 1dB above the PSD Limit Mask specified in ITU-T G.9700 (see section 5.4.3).

Each of the four measured transmit power values SHALL be lower than the value applicable to the ITU-T G.9701 profile, as specified in Table 7.1 of ITU-T G.9700.

### 6.2.6.8 Estimated Test Time

The estimated test time for this test case is 30 minutes.

## 6.3 TDD Operations

### 6.3.1 TDD Inter-frame Gap Test

#### 6.3.1.1 Purpose

The purpose of this test is to verify that the DUT maintains a proper gap time between the start and stop of each TDD transmission, as observed at its interface. The test performed over a number of different loop lengths to assure the introduced delay does not negatively impact the gap time. The loop may be simulated/modeled or may be real cable, but it SHALL introduce a propagation delay related to its length.

#### 6.3.1.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

#### 6.3.1.3 References

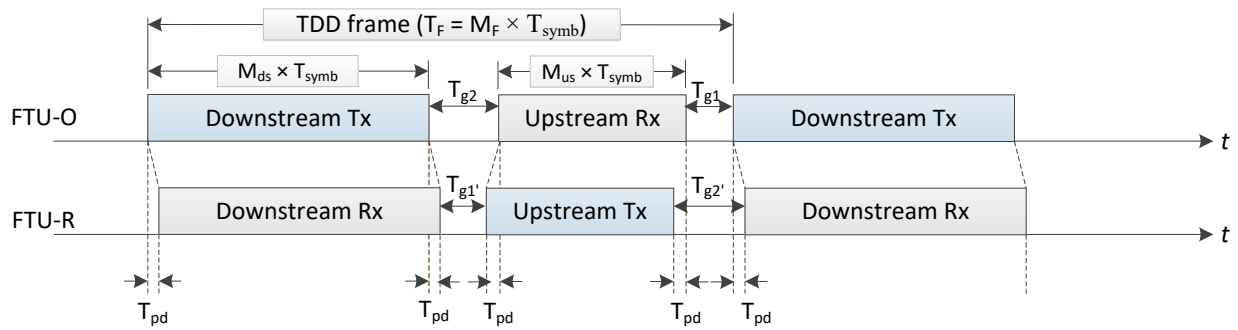
- ITU-T G.9701, clause 10.5.

#### 6.3.1.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 4.
2. The measurement system SHALL be a Digital Storage Oscilloscope and SHALL be connected at the DUT side of the loop.
3. The DUT and Link Partner SHALL be configured according to the section 5.3.
4. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the loop lengths of 20 and 200 meters as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the loop length of 100 meters as defined in section 5.4.1.3 SHALL be used.

**6.3.1.5 Method of Procedure**

1. Allow the DUT and Link Partner to establish a G.fast connection through the 20m loop.
2. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
3. Enable the testmodes (enable TPS\_TESTMODE and DRA\_TESTMODE).
4. Wait 10 seconds to allow the DUT and Link Partner to enter test modes.
5. Use the digital storage oscilloscope to capture 9 TDD frame periods (containing 8 complete TDD frames).
6. Measure the average gap times  $T_{g1}$  (at the DPU side), and  $T_{g1'}$  (at the CPE side), as the average of the gap times for each of the captured TDD frames (see Figure 15 and clause 10.5 of ITU-T G.9701).
7. Repeat steps 1 to 7 for the 200m loop.



**Figure 15 – TDD frame structure**

**6.3.1.6 Report**

For each of the test loops, the following items/measurements SHALL be included in the report:

1. The  $T_{g1}$  and  $T_{g1'}$  gap times measured in step 6.

**6.3.1.7 Expected Results**

For each of the test loops:

1. The average measured gap time  $T_{g1'}$  SHALL fall in the range of 6.5-0.75  $\mu$ s to 11.2  $\mu$ s.
2. The average measured gap time  $T_{g1}$  SHALL be greater than or equal to 6.5-0.75  $\mu$ s.

**Note:** The 0.75  $\mu$ s accounts for measurement uncertainty due to windowing techniques.

**6.3.1.8 Estimated Test Time**

The estimated test time for this test case is 10 minutes.

## 6.3.2 DS and US Ratio Configuration (Mds) Test

### 6.3.2.1 Purpose

The purpose of this test is to verify that the DUT adheres to the split of downstream/upstream transmission time/rate as configured in the DPU-MIB.

The number of symbols per TDD frame dedicated for downstream transmission ( $M_{ds}$ ) determines the downstream transmission time ratio ( $DS_{ratio} = M_{ds} / (M_{ds} + M_{us})$ ) and the upstream transmission time ratio ( $US_{ratio} = M_{us} / (M_{ds} + M_{us})$ ). There are  $M_F$  symbol periods per TDD frame period, with  $M_{ds} + M_{us} = M_F - 1$ , since one symbol period per TDD frame is used as a gap time. With configuration according to the section 5.3, the TDD frame period is 750  $\mu s$  and the symbol period is  $750/36 = 20.83 \mu s$ .

This verification is done by comparing:

- the measured downstream and upstream transmission times;
- the configured downstream and upstream transmission times.

### 6.3.2.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### 6.3.2.3 References

- ITU-T G.9701, clause 10.5.

### 6.3.2.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 4.
2. The measurement system SHALL be a digital storage oscilloscope and SHALL be connected at the DUT.
3. The DUT and Link Partner SHALL be configured according to the section 5.3, except for the  $M_{ds}$  parameter listed in Table 42.
4. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.

**Table 42 - Mds configurations**

Case	$M_F$	$M_{ds}$	$M_{us}$	DSratio	USratio
1	36	32	3	91.4%	8.6%
2	36	28	7	80.0%	20.0%
3	36	16	19	45.7%	54.3%

### 6.3.2.5 Method of Procedure

1. Configure the Mds parameter according to the first case in Table 42.
2. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
3. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
4. Record the NDR in downstream and upstream directions (referred to as NDRds and NDRus).
5. Enable the testmodes (enable TPS\_TESTMODE and DRA\_TESTMODE).
6. Wait 10 seconds to allow the DUT and Link Partner to enter test modes.
7. Use the digital storage oscilloscope to capture 9 TDD frame periods (containing 8 complete TDD frames).
8. Measure the average number of symbols transmitted in the downstream and upstream directions (referred to as  $M_{ds\_measured}$  and  $M_{us\_measured}$ , respectively), as the average of the number of symbols transmitted per captured TDD frame, rounded to the nearest integer.
9. Repeat steps 1 through 8 for each of the other Mds configuration cases specified in Table 42.

### 6.3.2.6 Report

The following items/measurements SHALL be included in the report for each of the cases specified in Table 42:

1. The  $M_{ds\_measured}$  measured in step 8.
2. The  $M_{us\_measured}$  measured in step 8
3. The NDRds and NDRus recorded in step 4 (Note).

**Note:** Because the bit loading may be different in downstream and upstream directions, the ratios  $NDRds/(NDRds+NDRus)$  and  $NDRus/(NDRds+NDRus)$  may be different from DSratio and USratio, respectively.

### 6.3.2.7 Expected Results

For each of the cases specified in Table 42:

1. The  $M_{ds\_measured}$  SHALL be equal to  $M_{ds}$ .
2. The  $M_{us\_measured}$  SHALL be equal to  $M_{us}$ .

### 6.3.2.8 Estimated Test Time

The estimated test time for this test case is 10 minutes.

## 6.4 Accelerated MTBE Test

### 6.4.1 Purpose

The purpose of this test is to verify through the accelerated MTBE test whether the DUT is able to sustain the minimum MTBE defined in ITU-T G.9701. The RTX\_TESTMODE (no retransmission), TPS\_TESTMODE (maximum (dummy) data rate), and DRA\_TESTMODE (TTRds=Mds; TTRus=Mus) defined in ITU-T G.9701 are used for accelerating the test time.

### 6.4.2 Certification Requirement

- FTU-O: Mandatory
- FTU-R: Mandatory

### 6.4.3 References

- ITU-T G.9701, clause 9.8.3.1.

### 6.4.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured per section 5.3, except for the configuration parameters listed in Table 43.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.
4. The Noise Generator SHALL be configured to inject Flat Noise as defined in section 5.4.4.1.1, at a level of -120 dBm/Hz, at the DUT side of the loop.

**Table 43 - Configuration for accelerated MTBE test**

<b>SRA and FRA Configuration Parameter</b>	<b>G.997.2 reference</b>	<b>Value</b>
Downstream minimum time interval for downshift SRA (SRA-DTIME <sub>ds</sub> )	7.1.4.7	16383 seconds
Upstream minimum time interval for downshift SRA (SRA-DTIME <sub>us</sub> )	7.1.4.8	16383 seconds
Downstream FRA minimum percentage of degraded tones (FRA-NTONES <sub>ds</sub> )	7.1.5.3	0 (special value)
Upstream FRA minimum percentage of degraded tones (FRA-NTONES <sub>us</sub> )	7.1.5.4	0 (special value)
Downstream FRA number of uncorrectable DTU (FRA-RTXUC <sub>ds</sub> )	7.1.5.5	0 (special value)
Upstream FRA number of uncorrectable DTU (FRA-RTXUC <sub>us</sub> )	7.1.5.6	0 (special value)
<b>Note:</b> These configurations imply that during the MTBE test, no SRA and no FRA are initiated by either FTU.		

#### 6.4.5 Method of Procedure

1. Inject Flat Noise at the DUT side of the loop.
2. Allow the DUT and Link Partner to establish the G.fast connection through the loop.
3. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments.
4. Record the full initialization counter (CURR\_24\_FULL\_INITS) and fast initialization counter (CURR\_24\_FAST\_INITS).
5. Record the downstream and upstream net data rate (NDR<sub>ds</sub> and NDR<sub>us</sub>) and the downstream and upstream signal to noise ratio (SNRM<sub>ds</sub> and SNRM<sub>us</sub>).
6. If the signal to noise margin (SNRM<sub>ds</sub> if the DUT is a CPE, SNRM<sub>us</sub> if the DUT is a DPU) is higher than 2 dB, increase the noise level injected at the DUT side of the loop by 1 dB, otherwise increase with 0.25 dB.
7. Wait 60 seconds.
8. Repeat steps 5 and 6 until the SNRM (SNRM<sub>ds</sub> if the DUT is a CPE, SNRM<sub>us</sub> if the DUT is a DPU) has been decreased below 1.25 dB.
9. Record the downstream and upstream net data rate (NDR<sub>ds</sub> and NDR<sub>us</sub>) and the downstream and upstream signal to noise ratio (SNRM<sub>ds</sub> and SNRM<sub>us</sub>).
10. Record the downstream and upstream bit loading table (BITSps<sub>ds</sub> and BITSps<sub>us</sub>).
11. Record the downstream and upstream number of bytes per FEC codeword (DTU-NFEC<sub>ds</sub> and DTU-NFEC<sub>us</sub>) and downstream and upstream number of FEC codewords per DTU (DTU-Q<sub>ds</sub> and DTU-Q<sub>us</sub>).
12. Enable the testmodes (enable RTX\_TESTMODE, TPS\_TESTMODE, and DRA\_TESTMODE).
13. Wait 10 seconds to allow the DUT and Link Partner to enter test modes.
14. Record the downstream and upstream error free bits counters (EFB-C24H<sub>ds</sub> and EFB-C24H<sub>us</sub>), the near-end and far-end uncorrected DTU counters (CURR\_NE\_24\_RTXUC

- and CURR\_FE\_24\_RTXUC), and the near-end and far-end retransmitted DTU counters (CURR\_NE\_24\_RTXTX and CURR\_FE\_24\_RTXTX).
15. Wait 5 minutes for the test to run (measurement\_time = 300 seconds).
  16. Record the full initialization counter (CURR\_24\_FULL\_INITS) and fast initialization counter (CURR\_24\_FAST\_INITS).
  17. Record the downstream and upstream error free bits counter (EFB-C24Hds and EFB-C24Hus), the near-end and far-end uncorrected DTU counters (CURR\_NE\_24\_RTXUC and CURR\_FE\_24\_RTXUC), and the near-end and far-end retransmitted DTU counters (CURR\_NE\_24\_RTXTX and CURR\_FE\_24\_RTXTX).
  18. Disable the testmodes (disable RTX\_TESTMODE, TPS\_TESTMODE, and DRA\_TESTMODE).

### 6.4.6 Report

The following items/measurements SHALL be included in the report:

1. The SNRMds and SNRMus recorded in steps 4 and 8.
2. The NDRds and NDRus recorded in steps 4 and 8.
3. The CURR\_24\_FULL\_INITS and CURR\_24\_FAST\_INITS counters recorded in steps 4 and 16.
4. The CURR\_NE\_24\_RTXTX, CURR\_NE\_24\_RTXUC, CURR\_FE\_24\_RTXTX, and CURR\_FE\_24\_RTXUC counters recorded in steps 14 and 17 (the increase is referred to as NE\_RTXTX, NE\_RTXUC, FE\_RTXTX, and FE\_RTXUC, respectively).
5. The EFB-C24Hds and EFB-C24Hus recorded in step 14 and 17 (the increase is referred to as EFBds and EFBus, respectively).
6. The number of data bits loaded over a downstream symbol (LDds) and over an upstream symbol (LDus), with  $L_D$  calculated as defined in clause 10.2.1.3 of ITU-T G.9701, for each of the BITSpsds and BITSpsus recorded in step 9.
7. The DTU duration in DMT symbols:
 
$$T_{DTU\_in\_DMTds} = (DTU-Qds \times DTU-NFECds) / \text{floor}(LDds/8)$$

$$T_{DTU\_in\_DMTus} = (DTU-Qus \times DTU-NFECus) / \text{floor}(LDus/8)$$
8. The symbol rate:
 
$$f_{DMT} = 51750 \times 2 / (2 + 10 / 64) \text{ Hz} = 48000 \text{ Hz}.$$
9. The Mean Time Between Error Events (MTBE): MTBEds = MTBEus = 14400 seconds.
10. The measurement time: measurement\_time = 300 seconds.
11. The maximum number of near-end and far-end uncorrected DTUs over the measurement time (referred to as max\_NE\_RTXUC and max\_FE\_RTXUC):

$$\max\_NE\_RTXUC = \frac{\text{measurement\_time}}{\sqrt{\frac{MTBEus \times T_{DTU\_in\_DMTus}}{f_{DMT}}}}$$

$$\max\_FE\_RTXUC = \frac{\text{measurement\_time}}{\sqrt{\frac{MTBEds \times T_{DTU\_in\_DMTds}}{f_{DMT}}}}$$

### 6.4.7 Expected Results

The notations “ds/us” and “NE/FE” apply to the DUT as defined in Table 35.

From before to after the measurement period:

1. The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
2. The CURR\_24\_FAST\_INITS counter increase SHALL be 0.

Over the measurement period:

3.  $0.25 \leq T\_DTU\_in\_DMTds/us \leq 4$
4.  $(65536 \times EFBds/us)/measurement\_time > 95\%$  of NDRds/us
5. NE\_RTXX = 0
6. FE\_RTXX = 0
7.  $NE/FE\_RTXUC \leq max\_NE/FE\_RTXUC$ .

If a first run of this test leads to a failure, this SHALL be recorded in the test report and a second run of this test SHALL be performed. Test data SHALL be recorded and reported for both test runs. The test result SHALL be recorded as the result of the second test run.

### 6.4.8 Estimated Test Time

The estimated test time for this test case is 15 minutes.

## 6.5 Discontinuous Operation Test

### 6.5.1 Purpose

The purpose of this test is to verify that the DUT can correctly enter and exit discontinuous operation according to the volume of traffic applied on a single line. The transient transmission signals are captured at the interface of DUT. Signal levels equal to the line noise level are expected during the interval(s) of quiet symbols.

### 6.5.2 Certification Requirement

- FTU-O: Optional
- FTU-R: Optional

### 6.5.3 References

- ITU-T G.9701, clause 10.7 and Appendix VI.



### 6.5.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 4.
2. The measurement system SHALL be a Digital Storage Oscilloscope and SHALL be connected at the DUT.
3. The DUT and Link Partner SHALL be configured according to the section 5.3.
4. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.
5. The Ethernet/IP Traffic Generator/Analyzer SHALL be configured to transmit a continuous upstream and downstream flow of Ethernet frames, using a 1024 byte fixed frame size in each direction.

### 6.5.5 Method of Procedure

1. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
2. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
3. Record the downstream and upstream net data rate (NDRds and NDRus).
4. Start the traffic generator in both the upstream and downstream directions at a required throughput equal to a percentage (see Table 44 case 1) of the NDR in each direction.
5. Wait 30 seconds for the system to stabilize.
6. Use the digital storage oscilloscope to capture 9 TDD frame periods (containing 8 complete TDD frames).
7. Measure the average number of symbols transmitted in the downstream and upstream directions (referred to as Nds\_measured and Nus\_measured, respectively) as the average of the number of symbols transmitted per captured TDD frame.
8. Repeat steps 3 through 7 for other upstream and downstream traffic settings listed in Table 44.

**Table 44 - Downstream and upstream traffic settings**

Case	Downstream (% of NDR)	Upstream (% of NDR)	Downstream Tx duration (Tds in symbols)	Upstream Tx duration (Tus in symbols)
1	0	0	$1 \leq Nds_{\text{measured}} \leq 3$	$1 \leq Nus_{\text{measured}} \leq 3$
2	25	25	$6 \leq Nds_{\text{measured}} \leq 8$	$1 \leq Nus_{\text{measured}} \leq 3$
3	50	50	$13 \leq Nds_{\text{measured}} \leq 15$	$3 \leq Nus_{\text{measured}} \leq 5$
4	75	75	$20 \leq Nds_{\text{measured}} \leq 22$	$5 \leq Nus_{\text{measured}} \leq 6$

**Note:** When sending traffic at 100% of NDR, all of the symbol periods (default is Mds = 28 and Mus = 7) are used to transmit data symbols.

### 6.5.6 Report

For each of the traffic cases in Table 44, the following items/measurements SHALL be included in the report:

1. The NDRds recorded in step 3.
2. The NDRus recorded in step 3.
3. The Nds\_measured as measured in step 7.
4. The Nus\_measured as measured in step 7.

### **6.5.7 Expected Results**

The notation “ds/us” applies to the DUT as defined in Table 35.

With ds/us as applicable to the DUT:

1. The Nds/us\_measured SHALL be within the bounds for the corresponding configuration, defined in Table 44.

### **6.5.8 Estimated Test Time**

The estimated test time for this test case is 10 minutes.

## **6.6 Bit swap or SRA Test**

### **6.6.1 Purpose**

The purpose of this test is to verify that the DUT supports the reallocation of data capacity under varying noise, using monitored tones and bit swap or SRA OLR types.

### **6.6.2 Certification Requirement**

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### **6.6.3 References**

ITU-T G.9701, clause 10.2.1.4, 13.2.1.1 and 13.2.1.2.

### **6.6.4 Test Setup**

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.

2. The DUT and Link Partner SHALL be configured according to the section 5.3, except for the SRA configuration parameters listed in Table 45.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.
4. The noise generator SHALL be configured to inject a Band-limited Noise as defined in section 5.4.4.1.2 at both sides of the loop.

**Table 45 - Configuration for bit swap test**

<b>SRA Configuration Parameter</b>	<b>G.997.2 reference</b>	<b>Value</b>
Downstream minimum time interval for upshift SRA (SRA-UTIME <sub>ds</sub> )	7.1.4.3	16383 seconds
Upstream minimum time interval for upshift SRA (SRA-UTIME <sub>us</sub> )	7.1.4.4	16383 seconds
Downstream minimum time interval for downshift SRA (SRA-DTIME <sub>ds</sub> )	7.1.4.7	16383 seconds
Upstream minimum time interval for downshift SRA (SRA-DTIME <sub>us</sub> )	7.1.4.8	16383 seconds

### 6.6.5 Method of Procedure

1. Inject a Band-limited Noise of Type 1 at both sides of the loop.
2. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
3. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
4. Record the downstream and upstream bit loading (BITSps<sub>ds</sub> and BITSps<sub>us</sub>).
5. Record the full initialization counter (CURR\_24\_FULL\_INITS) and the fast initialization counter (CURR\_24\_FAST\_INITS).
6. Record the near-end and far-end successful bit swap counters (CURR\_NE\_24\_BSW and CURR\_FE\_24\_BSW) and the near-end and far-end Successful Autonomous SRA counters (CURR\_NE\_24\_SRA and CURR\_FE\_24\_SRA).
7. Record the near-end and far-end SES counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES) and the near-end and far-end UAS counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS).
8. Change the injected noise gradually to Band-limited Noise of Type 2 by decreasing the noise in band 1 by 2dB and then within 1 second increasing the noise in band 2 by 2dB for 10 times every 2 seconds (total noise change per band of 20dB) at both sides of the loop.
9. Wait 60 seconds.
10. Record the downstream and upstream bit loading (BITSps<sub>ds</sub> and BITSps<sub>us</sub>).
11. Record the full initialization counter (CURR\_24\_FULL\_INITS) and the fast initialization counter (CURR\_24\_FAST\_INITS).
12. Record the near-end and far-end successful bit swap counters (CURR\_NE\_24\_BSW and CURR\_FE\_24\_BSW) and the near-end and far-end Successful Autonomous SRA counters (CURR\_NE\_24\_SRA and CURR\_FE\_24\_SRA).

13. Record the near-end and far-end SES counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES) and the near-end and far-end UAS counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS).
14. Change the injected noise gradually to the initial Band-limited Noise of Type 1 by decreasing the noise in band 2 by 2dB and then within 1 second increasing the noise in band 1 by 2dB for 10 times every 2 seconds (total noise change per band of 20dB) at both sides of the loop.
15. Wait 60 seconds
16. Record the downstream and upstream bit loading (BITSpsds and BITSpsus).
17. Record the full initialization counter (CURR\_24\_FULL\_INITS) and the fast initialization counter (CURR\_24\_FAST\_INITS).
18. Record the near-end and far-end successful bit swap counters (CURR\_NE\_24\_BSW and CURR\_FE\_24\_BSW) and the near-end and far-end Successful Autonomous SRA counters (CURR\_NE\_24\_SRA and CURR\_FE\_24\_SRA).
19. Record the near-end and far-end SES counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES) and the near-end and far-end UAS counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS).

### 6.6.6 Report

The following items/measurements SHALL be included in the report:

1. The BITSpsds and BITSpsus recorded in steps 4, 10 and 16;
2. The number of data bits loaded over a downstream symbol (LDds) and over an upstream symbol (LDus), with  $L_D$  calculated as defined in clause 10.2.1.3 of ITU-T G.9701, for each of the BITSpsds and BITSpsus recorded in steps 4, 10 and 16;
3. The downstream bit loading (BITSds) and upstream bit loading (BITSus) over the frequency bands where the noise is removed or increased, calculated as  $\sum \text{BITSps}_i$  over the sub-carriers in that frequency band, for each of the BITSpsds and BITSpsus recorded in steps 4, 10 and 16;
4. The number of downstream monitored sub-carriers (MONSCds) and the number of upstream monitored sub-carriers (MONSCus) that exist in the frequency range of noise band 2, calculated as the count of sub-carriers with  $\text{BITSpsds/us}=0$ , for each of the BITSpsds and BITSpsus recorded in steps 4, 10 and 16;
5. The CURR\_24\_FULL\_INITS and CURR\_24\_FAST\_INITS counters recorded in steps 5, 11 and 17;
6. The CURR\_NE\_24\_BSW and CURR\_FE\_24\_BSW counters and the near-end and far-end Successful Autonomous SRA counters (CURR\_NE\_24\_SRA and CURR\_FE\_24\_SRA) recorded in steps 6, 12 and 18.
7. The CURR\_NE\_24\_SES and CURR\_FE\_24\_SES, and CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS counters recorded in steps 7, 13 and 19.

### 6.6.7 Expected Results

The notations “ds/us” and “NE/FE” apply to the DUT as defined in Table 35.

For each noise change, from before the noise change until after the noise change:

1. The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
2. The CURR\_24\_FAST\_INITS counter increase SHALL be 0.
3. The total increase of the CURR\_NE\_24\_BSW and CURR\_NE\_24\_SRA counters SHALL be  $\geq 1$ . The total increase of the CURR\_FE\_24\_BSW and CURR\_FE\_24\_SRA counters SHALL be  $\geq 1$ .
4. The CURR\_NE/FE\_24\_SES counter increase SHALL be  $\leq 1$ .
5. The CURR\_NE/FE\_24\_UAS counter increase SHALL be 0.
6. The BITSds/us in the frequency band where the noise is removed SHALL increase.
7. The BITSds/us in the frequency band where the noise is added SHALL decrease.
8. The MONSCds/us in the frequency range of noise band 2 after the noise is added SHALL increase.
9. The MONSCds/us in the frequency range of noise band 2 after the noise is removed SHALL decrease.

From before the first noise change until after the second noise change:

10. The value of BDds/us SHALL NOT drop by more than 5%, where  $BD = \text{floor}(LD / 8)$ .

### 6.6.8 Estimated Test Time

The estimated test time for this test case is 10 minutes.

## 6.7 SRA Downshift Test

### 6.7.1 Purpose

The purpose of this test is to verify that the DUT is able to decrease the Net Data Rate (NDR), based on the external noise on the line increasing slowly over time. The NDR downshift is triggered with an increase of the noise present on the line.

### 6.7.2 Certification Requirement

- FTU-O: Mandatory
- FTU-R: Mandatory

### 6.7.3 References

- ITU-T G.9701, clause 13.2.1.1.

#### 6.7.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured per section 5.3.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.
4. The Noise Generator SHALL be configured to inject Flat Noise as defined in section 5.4.4.1.1 at both sides of the loop.

#### 6.7.5 Method of Procedure

1. Inject Flat Noise at a PSD level of -120 dBm/Hz at both sides of the loop.
2. Allow the DUT and Link Partner to establish the G.fast connection through the loop.
3. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments.
4. Record the downstream and upstream net data rate (NDRds and NDRus), the downstream and upstream signal to noise ratio margin (SNRMds and SNRMus).
5. Record the full initialization counter (CURR\_24\_FULL\_INITS) and the fast initialization counter (CURR\_24\_FAST\_INITS).
6. Record the near-end and far-end Successful Autonomous SRA counters (CURR\_NE\_24\_SRA and CURR\_FE\_24\_SRA).
7. Record the near-end and far-end CV counters (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV), the near-end and far-end Errored Seconds counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end Severely Errored Seconds counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), and the near-end and far-end Unavailable Seconds counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS).
8. Increase the Flat Noise PSD level by 1 dB at both sides of the loop.
9. Wait 10 seconds.
10. Repeat steps 8 and 9 until the Flat Noise PSD level has been increased by a total of 6 dB.
11. Wait an additional 20 seconds to ensure the DPU has retrieved the far end status parameters.
12. Record the downstream and upstream net data rate (NDRds and NDRus), the downstream and upstream signal to noise ratio margin (SNRMds and SNRMus).
13. Record the full initialization counter (CURR\_24\_FULL\_INITS) and the fast initialization counter (CURR\_24\_FAST\_INITS).
14. Record the near-end and far-end Successful Autonomous SRA counters (CURR\_NE\_24\_SRA and CURR\_FE\_24\_SRA).
15. Record the near-end and far-end CV counters (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV), the near-end and far-end Errored Seconds counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end Severely Errored Seconds counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), and the near-end and far-end Unavailable Seconds counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS).

### 6.7.6 Report

The following items/measurements SHALL be included in the report:

1. The NDRds and NDRus, SNRMds and SNRMus recorded in step 4 and 12.
2. The CURR\_24\_FULL\_INITS and CURR\_24\_FAST\_INITS counters recorded in steps 5 and 13.
3. The CURR\_NE\_24\_SRA and CURR\_FE\_24\_SRA counters recorded in steps 6 and 14;
4. The CURR\_NE\_24\_CV and CURR\_FE\_24\_CV, CURR\_NE\_24\_ES and CURR\_FE\_24\_ES, CURR\_NE\_24\_SES and CURR\_FE\_24\_SES, and CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS counters recorded in steps 7 and 15.

### 6.7.7 Expected Results

The notations “ds/us” and “NE/FE” apply to the DUT as defined in Table 35.

From before the noise increase until after the noise increase:

1. The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
2. The CURR\_24\_FAST\_INITS counter increase SHALL be 0.
3. The CURR\_NE/FE\_24\_SRA counter increase SHALL be  $\geq 1$ .
4. The CURR\_NE/FE\_24\_CV counter increase SHALL be 0.
5. The CURR\_NE/FE\_24\_ES counter increase SHALL be 0.
6. The CURR\_NE/FE\_24\_SES counter increase SHALL be 0.
7. The CURR\_NE/FE\_24\_UAS counter increase SHALL be 0.
8. The NDRds/us SHALL decrease.

Both before and after the noise increase:

9. The SNRMds/us SHALL be within the bounds of the configured SRA downshift margin (SRA-DSNRMds/us) and SRA upshift margin (SRA-USNRMds/us), inclusively.

### 6.7.8 Estimated Test Time

The estimated test time for this test case is 15 minutes.

## 6.8 SRA Upshift Test

### 6.8.1 Purpose

The purpose of this test is to verify that the DUT is able to increase the net data rate (NDR), based on the external noise on the line decreasing slowly over time. The NDR upshift is triggered with a decrease of the noise present on the line.

## 6.8.2 Certification Requirement

- FTU-O: Mandatory
- FTU-R: Mandatory

## 6.8.3 References

- ITU-T G.9701, clause 13.2.1.1.

## 6.8.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured per section 5.3.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.
4. The Noise Generator SHALL be configured to inject Flat Noise as defined in section 5.4.4.1.1 at both sides of the loop.

## 6.8.5 Method of Procedure

1. Inject Flat Noise at a PSD level of -120 dBm/Hz at both sides of the loop.
2. Allow the DUT and Link Partner to establish the G.fast connection through the loop.
3. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments.
4. Record the downstream and upstream net data rate (NDRds and NDRus), downstream and upstream signal to noise ratio margin (SNRMds and SNRMus).
5. Record the full initialization counter (CURR\_24\_FULL\_INITS) and the fast initialization counter (CURR\_24\_FAST\_INITS).
6. Record the near-end and far-end Successful Autonomous SRA counters (CURR\_NE\_24\_SRA and CURR\_FE\_24\_SRA)
7. Record the near-end and far-end CV counters (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV), the near-end and far-end Errored Seconds counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end Severely Errored Seconds (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), and the near-end and far-end Unavailable Seconds counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS).
8. Decrease the Flat Noise level by 1 dB at both sides of the loop.
9. Wait 16 seconds.
10. Repeat steps 8 and 9 until the Flat Noise PSD level has been decreased by a total of 6 dB.
11. Wait an additional 20 seconds to ensure the DPU has retrieved the far end status parameters.
12. Record the downstream and upstream net data rate (NDRds and NDRus), the downstream and upstream signal to noise ratio margin (SNRMds and SNRMus).



13. Record the full initialization counter (CURR\_24\_FULL\_INITS) and the fast initialization counter (CURR\_24\_FAST\_INITS).
14. Record the near-end and far-end Successful Autonomous SRA counters (CURR\_NE\_24\_SRA and CURR\_FE\_24\_SRA).
15. Record the near-end and far-end CV counters (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV), the near-end and far-end Errored Seconds counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end Severely Errored Seconds (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), and the near-end and far-end Unavailable Seconds counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS).

### 6.8.6 Report

The following items/measurements SHALL be included in the report:

1. The NDRds and NDRus, SNRMds and SNRMus recorded in step 4 and 12.
2. The CURR\_24\_FULL\_INITS and CURR\_24\_FAST\_INITS counters recorded in steps 5 and 13.
3. The CURR\_NE\_24\_SRA and CURR\_FE\_24\_SRA counters recorded in steps 6 and 14;
4. The CURR\_NE\_24\_CV and CURR\_FE\_24\_CV, CURR\_NE\_24\_ES and CURR\_FE\_24\_ES, CURR\_NE\_24\_SES and CURR\_FE\_24\_SES, and CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS counters recorded in steps 7 and 15.

### 6.8.7 Expected Results

The notations “ds/us” and “NE/FE” apply to the DUT as defined in Table 35.

From before the noise decrease until after the noise decrease:

1. The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
2. The CURR\_24\_FAST\_INITS counter increase SHALL be 0.
3. The CURR\_NE/FE\_24\_SRA counter increase SHALL be  $\geq 1$ .
4. The CURR\_NE/FE\_24\_CV counter increase SHALL be 0.
5. The CURR\_NE/FE\_24\_ES counter increase SHALL be 0.
6. The CURR\_NE/FE\_24\_SES counter increase SHALL be 0.
7. The CURR\_NE/FE\_24\_UAS counter increase SHALL be 0.
8. The NDRds/us SHALL increase.

Both before and after the noise decrease:

9. The SNRMds/us SHALL be within the bounds of the configured SRA downshift margin (SRA-DSNRMds/us) and SRA upshift margin (SRA-USNRMds/us), inclusively.

### 6.8.8 Estimated Test Time

The estimated test time for this test case is 15 minutes.

## 6.9 FRA & SRA Upshift Test

### 6.9.1 Purpose

The purpose of this test is to verify that the DUT is capable of rapidly performing bit loading reduction in a specified portion of frequency spectrum in both the upstream and downstream directions, based on sudden noise increase.

The noise changes and the related DUT actions are illustrated in Figure 16. In stage 1, a high noise is applied. In stage 2, a low noise is applied, leading to the DUT initiating an SRA to increase the net data rate. In stage 3, the high noise level is applied again, leading to the DUT initiating an FRA to significantly reduce the net data rate, followed by the DUT initiating an SRA to restore a net data rate that should be about the same net data rate as in stage 1.

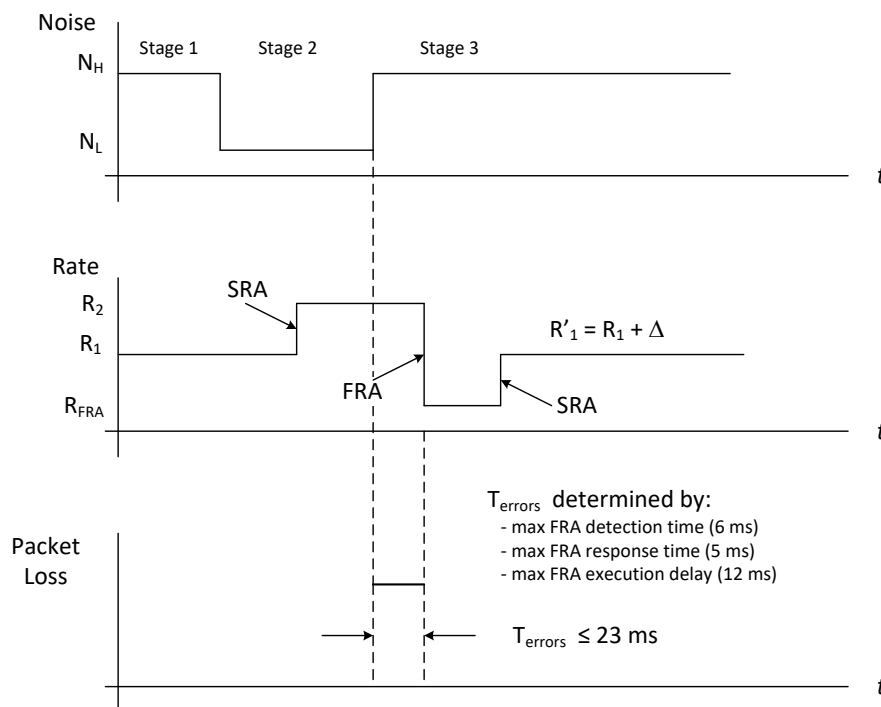


Figure 16 - Illustration of the noise changes and related transceiver actions.

### 6.9.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### 6.9.3 References

- ITU-T G.9701, clauses 13.2.1.1 and 13.3.1.1.

#### 6.9.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured per section 5.3, except for the FRA configuration parameters listed in Table 46.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 20m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.
4. The Noise Generator SHALL be configured to inject Flat Noise as defined in section 5.4.4.1.1, either at a PSD level of -113 dBm/Hz (Low Noise) or -101 dBm/Hz (High Noise), at the CPE-side of the loop (Note).

**Note:** With a transmit PSD level of -76 dBm/Hz, the Low Noise and High Noise facilitate an SNR of approximately 34 dB and 22 dB respectively.

**Table 46 - Configuration for FRA & SRA Upshift test**

FRA Configuration Parameter	G.997.2 reference	Value
Downstream FRA number of uncorrectable DTU (FRA-RTXUCds)	7.1.5.5	1
Upstream FRA number of uncorrectable DTU (FRA-RTXUCus)	7.1.5.6	1
Downstream lom defect persistency (LOM_PERSISTENCYds)	7.1.8.3	4 seconds
Upstream lom defect persistency (LOM_PERSISTENCYus)	7.1.8.4	4 seconds

The FRA-RTXUC value in Table 46 is chosen specifically to ensure that FRA is triggered during this test.

#### 6.9.5 Method of Procedure

1. Inject the High Noise.
2. Allow the DUT and Link Partner to establish the G.fast connection through the loop.
3. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
4. Record the downstream and upstream net data rate (NDRds and NDRus), and the downstream and upstream signal to noise ratio margin (SNRMds and SNRMus).
5. Record the full initialization counter (CURR\_24\_FULL\_INITS) and the fast initialization counter (CURR\_24\_FAST\_INITS).
6. Record the near-end and far-end Successful FRA counters (CURR\_NE\_24\_FRA and CURR\_FE\_24\_FRA) and the near-end and far-end Successful SRA counters (CURR\_NE\_24\_SRA and CURR\_FE\_24\_SRA).
7. Record the near-end and far-end CV counters (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV), the near-end and far-end errored seconds counters (CURR\_NE\_24\_ES and

- CURR\_FE\_24\_ES), the near-end and far-end severely errored seconds counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), and the near-end and far-end unavailable seconds counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS).
8. Decrease the injected Flat Noise PSD level to the Low Noise PSD level.
  9. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
  10. Record the downstream and upstream net data rate (NDRds and NDRus), and the downstream and upstream signal to noise ratio margin (SNRMds and SNRMus).
  11. Record the full initialization counter (CURR\_24\_FULL\_INITS) and the fast initialization counter (CURR\_24\_FAST\_INITS).
  12. Record the near-end and far-end Successful FRA counters (CURR\_NE\_24\_FRA and CURR\_FE\_24\_FRA), and the near-end and far-end Successful SRA counters (CURR\_NE\_24\_SRA and CURR\_FE\_24\_SRA).
  13. Record the near-end and far-end CV counters (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV), the near-end and far-end errored seconds counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end severely errored seconds counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), and the near-end and far-end unavailable seconds counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS).
  14. Instantaneously increase the injected Flat Noise PSD level to the High Noise PSD level (Note).
  15. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
  16. Record the downstream and upstream net data rate (NDRds and NDRus), and the downstream and upstream signal to noise ratio margin (SNRMds and SNRMus).
  17. Record the full initialization counter (CURR\_24\_FULL\_INITS) and the fast initialization counter (CURR\_24\_FAST\_INITS).
  18. Record the near-end and far-end Successful FRA counters (CURR\_NE\_24\_FRA and CURR\_FE\_24\_FRA), and the near-end and far-end Successful SRA counters (CURR\_NE\_24\_SRA and CURR\_FE\_24\_SRA).
  19. Record the near-end and far-end CV counters (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV), the near-end and far-end ES counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end severely errored seconds counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), and the near-end and far-end unavailable seconds counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS).

**Note:** Increasing the noise level instantaneously (i.e., as quickly as feasible) by 12 dB should cause errors in transmission, observable via code violations and errored seconds. The FRA mechanism should adapt relatively quickly (compared to SRA) to the abrupt large change in noise.

### 6.9.6 Report

The following items/measurements SHALL be included in the report:

1. The NDRds and NDRus, and the SNRMds and SNRMus as recorded in steps 4, 10, and 16.
2. The CURR\_24\_FULL\_INITS and CURR\_24\_FAST\_INITS counters recorded in steps 5, 11, and 17.
3. The CURR\_NE\_24\_FRA and CURR\_FE\_24\_FRA counters, and the CURR\_NE\_24\_SRA and CURR\_FE\_24\_SRA counters recorded in steps 6, 12, and 18.

4. Record the CURR\_NE\_24\_CV and CURR\_FE\_24\_CV counters, the CURR\_NE\_24\_ES and CURR\_FE\_24\_ES counters, the CURR\_NE\_24\_SES and CURR\_FE\_24\_SES counters, and the CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS counters recorded in steps 7, 13, and 19.

### 6.9.7 Expected Results

The notations “ds/us” and “NE/FE” apply to the DUT as defined in Table 35.

Each of the SNRMds/us values, at stage 1, stage 2, and stage 3, SHALL be within the bounds of the configured SRA downshift margin (SRA-DSNRMs/us) and SRA upshift margin (SRA-USNRMs/us), inclusively.

From before the noise decrease (stage 1) until after the noise decrease (stage 2):

1. The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
2. The CURR\_24\_FAST\_INITS counter increase SHALL be 0.
3. The CURR\_NE/FE\_24\_FRA counter increase SHALL be 0.
4. The CURR\_NE/FE\_24\_SRA counter increase SHALL be  $\geq 1$ .
5. The CURR\_NE/FE\_24\_CV counter increase SHALL be 0.
6. The CURR\_NE/FE\_24\_ES counter increase SHALL be 0.
7. The CURR\_NE/FE\_24\_SES counter increase SHALL be 0.
8. The CURR\_NE/FE\_24\_UAS counter increase SHALL be 0.
9. The NDRds/us SHALL increase.

From before the noise increase (stage 2) until after the noise increase (stage 3):

1. The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
2. The CURR\_24\_FAST\_INITS counter increase SHALL be 0.
3. The CURR\_NE/FE\_24\_FRA counter increase SHALL be  $\geq 1$ .
4. The CURR\_NE/FE\_24\_SRA counter increase SHALL be  $\geq 1$ .
5. The CURR\_NE/FE\_24\_CV counter increase SHALL be  $\leq 5$ .
6. The CURR\_NE/FE\_24\_ES counter increase SHALL be  $\leq 2$ .
7. The CURR\_NE/FE\_24\_SES counter increase SHALL be 0.
8. The CURR\_NE/FE\_24\_UAS counter increase SHALL be 0.
9. The NDRds/us SHALL decrease.

### 6.9.8 Estimated Test Time

The estimated test time for this test case is 10 minutes.

## 6.10 RPA Test

### 6.10.1 Purpose

The purpose of this test is to verify that the DUT is capable of adjusting RMC parameters if the external noise changes over time. The RMC parameter adjustment (RPA) is triggered when the SNR margin of the RMC (either SNRM-RMCds or SNRM-RMCus) is lower than the minimum SNR margin of the RMC (MINSNRM-RMCds or MINSNRM-RMCus).

### 6.10.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### 6.10.3 References

- ITU-T G.9701, clause 13.2.1.3.

### 6.10.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured according to section 5.3, except for the configuration parameters listed in Table 47 .
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.
4. The Noise Generator SHALL be configured to inject Flat Noise as defined in section 5.4.4.1.1, at a PSD level of -120 dBm/Hz, into each side of the loop.

**Table 47 - Configuration for RPA test**

<b>Configuration Parameter</b>	<b>G.997.2 reference</b>	<b>Value</b>
Downstream target noise margin for RMC (TARSNRM-RMCds)	7.1.6.1	12 dB
Upstream target noise margin for RMC (TARSNRM-RMCus)	7.1.6.2	12 dB
Downstream minimum noise margin for RMC (MINSNRM-RMCds)	7.1.6.3	10 dB
Upstream minimum noise margin for RMC (MINSNRM-RMCus)	7.1.6.4	10 dB

### 6.10.5 Method of Procedure

1. Allow the DUT and Link Partner to establish a G.fast connection through the loop.

2. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
3. Record the downstream and upstream signal-to-noise ratio margin for the RMC (SNRM-RMCds and SNRM-RMCus).
4. Record the downstream and upstream sub-carrier set and bit allocation for the RMC (BITS-RMCpsds and BITS-RMCpsus).
5. Record the full re-initialization counter (CURR\_24\_FULL\_INITS) and the fast re-initialization counter (CURR\_24\_FAST\_INITS).
6. Record the near-end and far-end Successful RPA counters (CURR\_NE\_24\_RPA and CURR\_FE\_24\_RPA).
7. Determine the band containing the largest number of RMC bits from the following bands: Band 1: 38-541, Band 2: 541-1043, Band 3: 1043-1545, Band 4: 1545-2048 (sub-carriers), for both the upstream and downstream RMC channels, as BandRMCus and BandRMCds.
8. Inject the corresponding band limited noises: with PSD referred to as  $PSD_{BLN\_RPA\_n}$  for  $n=BandRMCds$  at the CPE side of the loop, and with PSD referred to as  $PSD_{BLN\_RPA\_n}$  for  $n=BandRMCus$  at the DPU side of the loop (Note).
9. At the CPE-side of the loop, if the injected band limited noise has been increased by a total of less than  $Round(SNRM-RMCds - MINSNRM-RMCds - 2)$  dB, increase the band limited noise level injected at the CPE-side of the loop by 1 dB.
10. At the DPU-side of the loop, if the injected band limited noise has been increased by a total of less than  $Round(SNRM-RMCus - MINSNRM-RMCus - 2)$  dB, increase the band limited noise level injected at the DPU-side of the loop by 1 dB.
11. Wait for 5 seconds.
12. Repeat steps 9, 10 and 11 until the injected band limited noise has been increased by at least a total of  $Round(SNRM-RMCds - MINSNRM-RMCds - 2)$  dB at the CPE-side of the loop and at least by a total of  $Round(SNRM-RMCus - MINSNRM-RMCus - 2)$  dB at the DPU-side of the loop.
13. Wait 60 seconds.
14. Record the downstream and upstream signal-to-noise ratio margin for the RMC (SNRM-RMCds and SNRM-RMCus).
15. Record the downstream and upstream sub-carrier set and bit allocation for the RMC (BITSRMCpsds and BITSRMCpsus).
16. Record the full re-initialization counter (CURR\_24\_FULL\_INITS) and the fast re-initialization counter (CURR\_24\_FAST\_INITS).
17. Record the near-end and far-end Successful RPA counters (CURR\_NE\_24\_RPA and CURR\_FE\_24\_RPA).

If steps 9 and 10 above both require a 1 dB noise increase, the noise SHALL be increased simultaneously at both ends of the loop.

**Note:** The initial injection of the band limited noise represents a 5dB increase in the noise within that band and might cause an FRA to occur. However, this increase is below the configured minimum SNRM-RMC margin and should not cause a *loss of RMC (lor)* failure.

### 6.10.6 Report

The following items/measurements SHALL be included in the report:

1. The SNRM-RMCds and SNRM-RMCus recorded in step 3 and step 14.
2. The BITSRMCpsds and BITSRMCpsus recorded in steps 4 and 15.
3. The CURR\_24\_FULL\_INITS and CURR\_24\_FAST\_INITS counters recorded in steps 5 and 16.
4. The CURR\_NE\_24\_RPA and CURR\_FE\_24\_RPA counters recorded in steps 6 and 17.

### 6.10.7 Expected Results

The notations “ds/us” and “NE/FE” apply to the DUT as defined in Table 35.

From before the noise increase until after the noise increase (with NE/FE and ds/us as applicable to the DUT):

1. The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
2. The CURR\_24\_FAST\_INITS counter increase SHALL be 0.
3. The CURR\_NE/FE\_24\_RPA increase SHALL be  $\geq 1$ .
4. The RMC bit loading (BITSRMCpsds/us) shall change between steps 4 and 14, where the RMC bit loading consists of an array of (sub-carrier index, RMC bits) pairs.

### 6.10.8 Estimated Test Time

The estimated test time for this test case is 10 minutes.

## 6.11 RMC Bit Loading Configuration Test

### 6.11.1 Purpose

The purpose of this test is to verify that the DUT is capable to perform accurately the RMC bit loading configuration.

### 6.11.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### 6.11.3 References

- ITU-T G.9701, clause 10.2.



### 6.11.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured according to section 5.3, except for the RMC bit loading parameters, which SHALL be configured according to Table 48.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.

**Table 48 - RMC bit loading configurations**

Case	Downstream maximum bit loading for RMC (MAXBL-RMCds)	Upstream maximum bit loading for RMC (MAXBL-RMCus)
1	6 bits	6 bits
2	5 bits	3 bits
3	2 bits	2 bits

### 6.11.5 Method of Procedure

1. Configure the RMC bit loading parameters according to case 1 in Table 48.
2. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
3. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
4. Record the downstream and upstream signal-to-noise ratio margin for the RMC (SNRM-RMCds and SNRM-RMCus), and the downstream and upstream sub-carrier set and bit allocation for the RMC (BITSRMCpsds and BITSRMCpsus).
5. Repeat Steps 1-5 for each of the other cases specified in Table 48.

### 6.11.6 Report

For each of the cases specified in Table 48, the following items/measurements SHALL be included in the report:

1. The SNRM-RMCds and SNRM-RMCus recorded in step 4.
2. The BITSRMCpsds and BITSRMCpsus recorded in step 4.

### 6.11.7 Expected Results

The notation “ds/us” applies to the DUT as defined in Table 35.

For each of the cases in Table 48:

1. The BITSRMCpsds/us SHALL meet the bounds of the MAXBL-RMCds/us specified in Table 48 for the specific case.

2. The SNRM-RMCds/us SHALL be  $\geq$  TARSNRM-RMCds/us – 1 dB.

### 6.11.8 Estimated Test Time

The estimated test time for this test case is 10 minutes.

## 6.12 Re-initialization Policy Test

### 6.12.1 Short Disconnect Test

#### 6.12.1.1 Purpose

The purpose of this test is to verify that the DUT supports the re-initialization policy for a loop disconnect that is shorter than the *los* and *lor* defect persistency and hence does not cause a re-initialization.

#### 6.12.1.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

#### 6.12.1.3 References

ITU-T G.9701, clauses 12.1.4.2 and 12.1.4.3.

#### 6.12.1.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured according to the section 5.3.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.

#### 6.12.1.5 Method of Procedure

1. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
2. Wait 10 seconds.

3. Record the failed fast initialization counter (CURR\_24\_FAILEDFAST\_INITS) and the fast initialization counter (CURR\_24\_FAST\_INITS), and the failed full initialization counter (CURR\_24\_FAILEDFULL\_INITS) and the full initialization counter (CURR\_24\_FULL\_INITS).
4. Record the near-end and far-end loss-of-signal failure counter (CURR\_NE\_24\_LOS and CURR\_FE\_24\_LOS), the near-end and far-end loss-of-RMC failure counter (CURR\_NE\_24\_LOR and CURR\_FE\_24\_LOR), and the near-end and far-end loss-of-margin failure counter (CURR\_NE\_24\_LOM and CURR\_FE\_24\_LOM).
5. Record the near-end and far-end errored seconds counter (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end severely errored seconds counter (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), the near-end and far-end unavailable seconds counter (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS), the near-end and far-end loss-of-signal seconds counter (CURR\_NE\_24\_LOSS and CURR\_FE\_24\_LOSS), and the near-end and far-end loss-of-RMC seconds counter (CURR\_NE\_24\_LORS and CURR\_FE\_24\_LORS).
6. Record the near-end and far-end CV counter (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV), uncorrected DTU counter (CURR\_NE\_24\_RTXUC and CURR\_FE\_24\_RTXUC) and the near-end and far-end retransmitted DTU counter (CURR\_NE\_24\_RTXTX and CURR\_FE\_24\_RTXTX).
7. Disconnect simultaneously both wires of the loop at the DUT-side for 0.1 sec.
8. Wait 20 seconds.
9. Record the failed fast initialization counter (CURR\_24\_FAILEDFAST\_INITS) and the fast initialization counter (CURR\_24\_FAST\_INITS), and the failed full initialization counter (CURR\_24\_FAILEDFULL\_INITS) and the full initialization counter (CURR\_24\_FULL\_INITS).
10. Record the near-end and far-end loss-of-signal failure counter (CURR\_NE\_24\_LOS and CURR\_FE\_24\_LOS), the near-end and far-end loss-of-RMC failure counter (CURR\_NE\_24\_LOR and CURR\_FE\_24\_LOR), and the near-end and far-end loss-of-margin failure counter (CURR\_NE\_24\_LOM and CURR\_FE\_24\_LOM).
11. Record the near-end and far-end errored seconds counter (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end severely errored seconds counter (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), the near-end and far-end unavailable seconds counter (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS), the near-end and far-end loss-of-signal seconds counter (CURR\_NE\_24\_LOSS and CURR\_FE\_24\_LOSS), and the near-end and far-end loss-of-RMC seconds counter (CURR\_NE\_24\_LORS and CURR\_FE\_24\_LORS).
12. Record the near-end and far-end CV counter (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV), uncorrected DTU counter (CURR\_NE\_24\_RTXUC and CURR\_FE\_24\_RTXUC) and the near-end and far-end retransmitted DTU counter (CURR\_NE\_24\_RTXTX and CURR\_FE\_24\_RTXTX).
13. Repeat steps 1-10 for a total of 5 disconnects.

The wires disconnect in steps 6 above requires very specific timing and SHALL be performed using a machine timed relay.

### 6.12.1.6 Report

The following items/measurements SHALL be included in the report:

1. The CURR\_24\_FAILEDFAST\_INITS and CURR\_24\_FAST\_INITS counters, and the CURR\_24\_FAILEDFULL\_INITS and CURR\_24\_FULL\_INITS counters recorded in steps 3 and 9.
2. The CURR\_NE\_24\_LOS and CURR\_FE\_24\_LOS counters, the CURR\_NE\_24\_LOR and CURR\_FE\_24\_LOR counters, and the CURR\_NE\_24\_LOM and CURR\_FE\_24\_LOM counters recorded in steps 4 and 10.
3. The CURR\_NE\_24\_ES and CURR\_FE\_24\_ES counters, the CURR\_NE\_24\_SES and CURR\_FE\_24\_SES counters, the CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS counters, the CURR\_NE\_24\_LOSS and CURR\_FE\_24\_LOSS counters, and the CURR\_NE\_24\_LORS and CURR\_FE\_24\_LORS counters recorded in steps 5 and 11.
4. The CURR\_NE\_24\_CV and CURR\_FE\_24\_CV counters, the CURR\_NE\_24\_RTXUC and CURR\_FE\_24\_RTXUC counters and the CURR\_NE\_24\_RTXTX and CURR\_FE\_24\_RTXTX counters recorded in steps 6 and 12.

### 6.12.1.7 Expected Results

The notation “NE/FE” applies to the DUT as defined in Table 35.

From before until after the loop disconnect at the DUT-side, for at least 3 out of 5 disconnects:

1. The CURR\_24\_FAST\_INITS counter increase SHALL be 0.
2. The CURR\_24\_FAILEDFAST\_INITS counter increase SHALL be 0.
3. The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
4. The CURR\_24\_FAILEDFULL\_INITS counter increase SHALL be 0.
5. The CURR\_NE/FE\_24\_UAS counter increase SHALL be 0.
6. The CURR\_NE/FE\_24\_LOSS counter increase SHALL be  $\geq 1$ .
7. The CURR\_NE/FE\_24\_LORS counter increase SHALL be  $\geq 1$ .
8. The CURR\_NE/FE\_24\_ES counter increase SHALL be  $\geq 1$ .
9. The CURR\_NE/FE\_24\_SES counter increase SHALL be  $\geq 1$ .
10. The CURR\_NE/FE\_24\_LOS counter increase SHALL be 0.
11. The CURR\_NE/FE\_24\_LOR counter increase SHALL be 0.
12. The CURR\_NE/FE\_24\_LOM counter increase SHALL be 0.
13. The CURR\_NE/FE\_24\_CV counter increase SHALL be  $\leq 4$ .
14. The CURR\_NE/FE\_24\_RTXUC counter increase SHALL be  $\geq 13$ .
15. The CURR\_NE/FE\_24\_RTXTX counter increase SHALL be  $\geq 80$ .

### 6.12.1.8 Estimated Test Time

The estimated test time for this test case is 10 minutes.

## 6.12.2 Long disconnect Test with LOS failure

### 6.12.2.1 Purpose

The purpose of this test is to verify that the DUT supports the re-initialization policy for a loop disconnect that is longer than the *los* defect persistency and shorter than the *lor* defect persistency, and hence causes a re-initialization triggered by a LOS failure.

### 6.12.2.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### 6.12.2.3 References

ITU-T G.9701, clauses 12.1.4.2 and 12.1.4.3.

### 6.12.2.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured according to the section 5.3, except for the re-initialization policy configuration in Table 49.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.

**Table 49 - Configuration for re-initialization upon LOS test**

Configuration Parameter	G.997.2 reference	Default value
Downstream lor defect persistency (LOR_PERSISTENCY <sub>ds</sub> )	7.1.8.5	2 seconds
Upstream lor defect persistency (LOR_PERSISTENCY <sub>us</sub> )	7.1.8.6	2 seconds

### 6.12.2.5 Method of Procedure

1. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
2. Wait 10 seconds.
3. Record the failed fast initialization counter (CURR\_24\_FAILEDFAST\_INITS) and the fast initialization counter (CURR\_24\_FAST\_INITS), and the failed full initialization counter (CURR\_24\_FAILEDFULL\_INITS) and the full initialization counter (CURR\_24\_FULL\_INITS).

4. Record the near-end and far-end loss-of-signal failure counter (CURR\_NE\_24\_LOS and CURR\_FE\_24\_LOS), the near-end and far-end loss-of-RMC failure counter (CURR\_NE\_24\_LOR and CURR\_FE\_24\_LOR), and the near-end and far-end loss-of-margin failure counter (CURR\_NE\_24\_LOM and CURR\_FE\_24\_LOM).
5. Record the near-end and far-end errored seconds counter (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end severely errored seconds counter (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), the near-end and far-end unavailable seconds counter (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS), the near-end and far-end loss-of-signal seconds counter (CURR\_NE\_24\_LOSS and CURR\_FE\_24\_LOSS), and the near-end and far-end loss-of-RMC seconds counter (CURR\_NE\_24\_LORS and CURR\_FE\_24\_LORS).
6. Disconnect simultaneously both wires of the loop at the DUT-side for 0.5 sec.
7. Wait 30 seconds.
8. Record the failed fast initialization counter (CURR\_24\_FAILEDFAST\_INITS) and the fast initialization counter (CURR\_24\_FAST\_INITS), and the failed full initialization counter (CURR\_24\_FAILEDFULL\_INITS) and the full initialization counter (CURR\_24\_FULL\_INITS).
9. Record the near-end and far-end loss-of-signal failure counter (CURR\_NE\_24\_LOS and CURR\_FE\_24\_LOS), the near-end and far-end loss-of-RMC failure counter (CURR\_NE\_24\_LOR and CURR\_FE\_24\_LOR), and the near-end and far-end loss-of-margin failure counter (CURR\_NE\_24\_LOM and CURR\_FE\_24\_LOM).
10. Record the near-end and far-end errored seconds counter (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end severely errored seconds counter (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), the near-end and far-end unavailable seconds counter (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS), the near-end and far-end loss-of-signal seconds counter (CURR\_NE\_24\_LOSS and CURR\_FE\_24\_LOSS), and the near-end and far-end loss-of-RMC seconds counter (CURR\_NE\_24\_LORS and CURR\_FE\_24\_LORS).
11. Repeat steps 1-10 for a total of 5 disconnects.

The wires disconnect in step 6 above requires very specific timing and SHALL be performed using a machine timed relay.

#### 6.12.2.6 Report

The following items/measurements SHALL be included in the report:

1. The CURR\_24\_FAILEDFAST\_INITS and CURR\_24\_FAST\_INITS counters, and the CURR\_24\_FAILEDFULL\_INITS and CURR\_24\_FULL\_INITS counters recorded in steps 3 and 8.
2. The CURR\_NE\_24\_LOS and CURR\_FE\_24\_LOS counters, the CURR\_NE\_24\_LOR and CURR\_FE\_24\_LOR counters, and the CURR\_NE\_24\_LOM and CURR\_FE\_24\_LOM counters recorded in steps 4 and 9.
3. The CURR\_NE\_24\_ES and CURR\_FE\_24\_ES counters, the CURR\_NE\_24\_SES and CURR\_FE\_24\_SES counters, the CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS counters, the CURR\_NE\_24\_LOSS and CURR\_FE\_24\_LOSS counters, and the CURR\_NE\_24\_LORS and CURR\_FE\_24\_LORS counters recorded in steps 5 and 10.

### 6.12.2.7 Expected Results

The notation “NE/FE” applies to the DUT as defined in Table 35.

From before until after the loop disconnect at the DUT-side, for at least 3 out of 5 disconnects:

1. The CURR\_24\_FAST\_INITS counter increase SHALL be 1.
2. The CURR\_24\_FAILEDFAST\_INITS counter increase SHALL be 0.
3. The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
4. The CURR\_24\_FAILEDFULL\_INITS counter increase SHALL be 0.
5. The CURR\_NE/FE\_24\_UAS counter increase SHALL be  $\geq 1$  and  $\leq 15$ .
6. The CURR\_NE/FE\_24\_LOSS counter increase SHALL be 0.
7. The CURR\_NE/FE\_24\_LORS counter increase SHALL be 0.
8. The CURR\_NE/FE\_24\_ES counter increase SHALL be  $\leq 1$ .
9. The CURR\_NE/FE\_24\_SES counter increase SHALL be 0.
10. The CURR\_NE\_24\_LOS counter increase SHALL be 1. This metric applies only if the DPU is the DUT.
11. The CURR\_NE\_24\_LOR counter increase SHALL be 0. This metric applies only if the DPU is the DUT.
12. The CURR\_NE\_24\_LOM counter increase SHALL be 0. This metric applies only if the DPU is the DUT.

**Note:** The LOSS, LORS, ES, and SES counters are inhibited upon UAS.

### 6.12.2.8 Estimated Test Time

The estimated test time for this test case is 10 minutes.

## 6.12.3 Long disconnect Test with LOR failure

### 6.12.3.1 Purpose

The purpose of this test is to verify that the DUT supports the re-initialization policy for a loop disconnect that is shorter than the *los* defect persistency and longer than the *lor* defect persistency, and hence causes a re-initialization triggered by a LOR failure.

### 6.12.3.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### 6.12.3.3 References

ITU-T G.9701, clauses 12.1.4.2 and 12.1.4.3.

### 6.12.3.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured according to the section 5.3, except for the re-initialization policy configuration in Table 50.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.

**Table 50 - Configuration for re-initialization upon LOR test**

Configuration Parameter	G.997.2 reference	Default value
Downstream <i>los</i> defect persistency (LOS_PERSISTENCY <sub>ds</sub> )	7.1.8.1	2 seconds
Upstream <i>los</i> defect persistency (LOS_PERSISTENCY <sub>us</sub> )	7.1.8.2	2 seconds

### 6.12.3.5 Method of Procedure

1. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
2. Wait 10 seconds.
3. Record the failed fast initialization counter (CURR\_24\_FAILEDFAST\_INITS) and the fast initialization counter (CURR\_24\_FAST\_INITS), and the failed full initialization counter (CURR\_24\_FAILEDFULL\_INITS) and the full initialization counter (CURR\_24\_FULL\_INITS).
4. Record the near-end and far-end loss-of-signal failure counter (CURR\_NE\_24\_LOS and CURR\_FE\_24\_LOS), the near-end and far-end loss-of-RMC failure counter (CURR\_NE\_24\_LOR and CURR\_FE\_24\_LOR), and the near-end and far-end loss-of-margin failure counter (CURR\_NE\_24\_LOM and CURR\_FE\_24\_LOM).
5. Record the near-end and far-end errored seconds counter (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end severely errored seconds counter (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), the near-end and far-end unavailable seconds counter (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS), the near-end and far-end loss-of-signal seconds counter (CURR\_NE\_24\_LOSS and CURR\_FE\_24\_LOSS), and the near-end and far-end loss-of-RMC seconds counter (CURR\_NE\_24\_LORS and CURR\_FE\_24\_LORS).
6. Disconnect simultaneously both wires of the loop at the DUT-side for 0.5 sec.
7. Wait 30 seconds.
8. Record the failed fast initialization counter (CURR\_24\_FAILEDFAST\_INITS) and the fast initialization counter (CURR\_24\_FAST\_INITS), and the failed full initialization counter (CURR\_24\_FAILEDFULL\_INITS) and the full initialization counter (CURR\_24\_FULL\_INITS).



9. Record the near-end and far-end loss-of-signal failure counter (CURR\_NE\_24\_LOS and CURR\_FE\_24\_LOS), the near-end and far-end loss-of-RMC failure counter (CURR\_NE\_24\_LOR and CURR\_FE\_24\_LOR), and the near-end and far-end loss-of-margin failure counter (CURR\_NE\_24\_LOM and CURR\_FE\_24\_LOM).
10. Record the near-end and far-end errored seconds counter (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end severely errored seconds counter (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), the near-end and far-end unavailable seconds counter (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS), the near-end and far-end loss-of-signal seconds counter (CURR\_NE\_24\_LOSS and CURR\_FE\_24\_LOSS), and the near-end and far-end loss-of-RMC seconds counter (CURR\_NE\_24\_LORS and CURR\_FE\_24\_LORS).
11. Repeat steps 1-10 for a total of 5 disconnects.

The wires disconnect in steps 6 above requires very specific timing and SHALL be performed using a machine timed relay.

### 6.12.3.6 Report

The following items/measurements SHALL be included in the report:

1. The CURR\_24\_FAILEDFAST\_INITS and CURR\_24\_FAST\_INITS counters, and the CURR\_24\_FAILEDFULL\_INITS and CURR\_24\_FULL\_INITS counters recorded in steps 3 and 8.
2. The CURR\_NE\_24\_LOS and CURR\_FE\_24\_LOS counters, the CURR\_NE\_24\_LOR and CURR\_FE\_24\_LOR counters, and the CURR\_NE\_24\_LOM and CURR\_FE\_24\_LOM counters recorded in steps 4 and 9.
3. The CURR\_NE\_24\_ES and CURR\_FE\_24\_ES counters, the CURR\_NE\_24\_SES and CURR\_FE\_24\_SES counters, the CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS counters, the CURR\_NE\_24\_LOSS and CURR\_FE\_24\_LOSS counters, and the CURR\_NE\_24\_LORS and CURR\_FE\_24\_LORS counters recorded in steps 5 and 10.

### 6.12.3.7 Expected Results

The notation “NE/FE” applies to the DUT as defined in Table 35.

From before until after the loop disconnect at the DUT-side, for at least 3 out of 5 disconnects:

1. The CURR\_24\_FAST\_INITS counter increase SHALL be 1.
2. The CURR\_24\_FAILEDFAST\_INITS counter increase SHALL be 0.
3. The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
4. The CURR\_24\_FAILEDFULL\_INITS counter increase SHALL be 0.
5. The CURR\_NE/FE\_24\_UAS counter increase SHALL be  $\geq 1$  and  $\leq 15$ .
6. The CURR\_NE/FE\_24\_LOSS counter increase SHALL be 0.
7. The CURR\_NE/FE\_24\_LORS counter increase SHALL be 0.
8. The CURR\_NE/FE\_24\_ES counter increase SHALL be  $\leq 1$ .
9. The CURR\_NE/FE\_24\_SES counter increase SHALL be 0.

10. The CURR\_NE\_24\_LOS counter increase SHALL be 0. This metric applies only if the DPU is the DUT.
11. The CURR\_NE\_24\_LOR counter increase SHALL be 1. This metric applies only if the DPU is the DUT.
12. The CURR\_NE\_24\_LOM counter increase SHALL be 0. This metric applies only if the DPU is the DUT.

**Note:** The LOSS, LORS, ES, and SES counters are inhibited upon UAS.

### 6.12.3.8 Estimated Test Time

The estimated test time for this test case is 10 minutes.

## 6.13 Dying Gasp Test

### 6.13.1 Purpose

If the DUT is a CPE, then the purpose of this test is to verify that the DUT supports sending the dying gasp to the DPU.

If the DUT is a DPU, then the purpose of this test is to verify that the DUT supports receiving the dying gasp from the CPE and supports conveying the dying gasp over the DPU Northbound management protocol.

### 6.13.2 Certification Requirement

- FTU-O: Optional.
- FTU-R: Optional.

Purpose of the test is for DUT=FTU-R to verify dying gasp is sent to the DPU.

Purpose of test is for DUT=FTU-O to verify dying gasp is received and conveyed onto the management system.

### 6.13.3 References

ITU-T G.9701, clause 11.3.3.2

### 6.13.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.

2. The DUT and Link Partner SHALL be configured according to the section 5.3, except for the re-initialization policy configuration in Table 49.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.

### 6.13.5 Method of Procedure

1. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
2. Wait 10 seconds.
3. Record the near-end loss-of-signal failure (LOS) and far-end loss-of-power failure (LPR-FE).
4. Disconnect the AC mains power at the CPE.
5. Wait 10 seconds.
6. Record the near-end loss-of-signal failure (LOS) and far-end loss-of-power failure (LPR-FE).
7. Connect the AC mains power at the CPE.
8. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
9. Wait 10 seconds.
10. Record the near-end loss-of-signal failure (LOS) and far-end loss-of-power failure (LPR-FE).
11. Disconnect simultaneously both wires of the loop at the CPE-side.
12. Wait 10 seconds.
13. Record the near-end loss-of-signal failure (LOS) and far-end loss-of-power failure (LPR-FE).
14. Connect simultaneously both wires of the loop at the CPE-side.
15. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
16. Wait 10 seconds.
17. Record the near-end loss-of-signal failure (LOS) and far-end loss-of-power failure (LPR-FE).

### 6.13.6 Report

The following items/measurements SHALL be included in the report:

1. The LOS failures recorded in steps 3, 6, 10, 13, and 17.
2. The LPR-FE failures recorded in steps 3, 6, 10, 13, and 17.

### 6.13.7 Expected Results

Before disconnecting AC mains power:	LOS = FALSE, LPR-FE = FALSE;
After disconnecting AC mains power:	LOS = TRUE, LPR-FE = TRUE;
After reconnecting AC mains power:	LOS = FALSE, LPR-FE = FALSE;
After disconnecting the loop:	LOS = TRUE, LPR-FE = FALSE;

After reconnecting the loop: LOS = FALSE, LPR-FE = FALSE.

### 6.13.8 Estimated Test Time

The estimated test time for this test case is 10 minutes.

## 6.14 Increased Bit Loading Test

### 6.14.1 Purpose

The purpose of this test is to verify that the DUT is capable to allocate an increased bit loading of up to 14 bits to a subcarrier.

### 6.14.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### 6.14.3 References

- ITU-T G.9701, clause 10.2.1.4.2.

### 6.14.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured according to section 5.3, except for the configuration for the testing of profiles 212a and 212c in Table 51. The DUT and Link Partner SHALL be configured according to section 5.3, except for the configuration parameter listed in Table 49.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 50m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.45.4.1.3 SHALL be used.

**Table 51 - Configuration for the increased bit loading test**

<b>Configuration Parameter</b>	<b>G.997.2 reference</b>	<b>Default value</b>
Downstream sub-carrier masking (CARMASKds)	7.1.2.3	Start Sub-carrier Index: 1025 End Sub-carrier Index: 2047 (for 106MHz profiles) or 4095 (for 212MHz profiles)
Upstream sub-carrier masking (CARMASKus)	7.1.2.4	Start Sub-carrier Index: 1025 End Sub-carrier Index: 2047 (for 106MHz profiles) or 4095 (for 212MHz profiles)
Downstream upshift noise margin (SRA-USNRMds)	7.1.4.1	4 dB
Upstream upshift noise margin (SRA-USNRMus)	7.1.4.2	4 dB
Downstream target noise margin (TARSNRMds)	7.1.3.1	3 dB
Upstream target noise margin (TARSNRMus)	7.1.3.2	3 dB
Downstream downshift noise margin (SRA-DSNRMds)	7.1.4.5	2 dB
Upstream downshift noise margin (SRA-DSNRMus)	7.1.4.6	2 dB

**Note:** TARSNRM of 3dB should allow operational conditions in which the DUT can possibly allocate 14 bits over a sufficient range of subcarriers.

#### 6.14.5 Method of Procedure

1. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
2. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
3. Record downstream and upstream bit loading (BITSpsds and BITSpsus).

#### 6.14.6 Report

The following items/measurements SHALL be included in the report:

1. The BITSpsds and BITSpsus recorded in step 3.

#### 6.14.7 Expected Results

The notation “ds/us” applies to the DUT as defined in Table 35.

1. For each subcarrier, the BITSpsds/us SHALL be from 0 to 14, inclusive.
2. At least 1 subcarrier shall have BITSpsds/us equal to 14.

### 6.14.8 Estimated Test Time

The estimated test time for this test case is 10 minutes.

## 6.15 Test Parameters Test

### 6.15.1 Purpose

The purpose of this test is to verify that the DUT supports measurement and reporting of the test parameters quiet line noise (QLN), active line noise (ALN), insertion loss (HLOG), and signal attenuation (SATN).

### 6.15.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### 6.15.3 References

- ITU-T G.9701, clause 11.4.1.2.
- ITU-T G.997.2, clause 7.10.

### 6.15.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured according to section 5.3.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.

### 6.15.5 Method of Procedure

1. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
2. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
3. If required by the DPU, set Update request flag for far-end test parameters (UPDATE-FE-TEST) to TRUE for Far-end test parameter group 1 (FE-G1) and Far-end test parameter group 2 (FE-G2) (NOTE).
4. Wait 5 minutes for the test parameters to be updated.

5. Record the following test parameters:
  - Downstream insertion loss per sub-carrier group: HLOGMTds, HLOGGds, HLOGds;
  - Upstream insertion loss per sub-carrier group: HLOGMTus, HLOGGus, HLOGpsus;
  - Downstream quiet line noise per sub-carrier group: QLNMTds, QLNGds, QLNpsds;
  - Upstream quiet line noise per sub-carrier group: QLNMTus, QLNGus, QLNpsus;
  - Active line noise per sub-carrier group: ALNMT, ALNG, ALNps;
  - Signal attenuation: SATNds, SATNus.

**Note:** The DPU may implement an autonomous update process (see G.997.2 clause 7).

### 6.15.6 Report

The following items/measurements SHALL be included in the report:

1. HLOGMTds, HLOGGds and HLOGpsds recorded in step 5;
2. HLOGMTus, HLOGGus and HLOGpsus recorded in step 5;
3. QLNMTds, QLNGds and QLNpsds recorded in step 5;
4. QLNMTus, QLNGus and QLNpsus recorded in step 5;
5. ALNMT, ALNG and ALNps recorded in step 5;
6. SATNds and SATNus recorded in step 5.

### 6.15.7 Expected Results

1. HLOGMTds, HLOGGds and HLOGpsds values SHALL comply within the valid values as specified in clauses 7.10.7.1, 7.10.7.2 and 7.10.7.3 of G.997.2 respectively.
2. HLOGMTus, HLOGGus and HLOGpsus values SHALL comply within the valid values as specified in clauses 7.10.7.4, 7.10.7.5 and 7.10.7.6 of G.997.2 respectively.
3. QLNMTds, QLNGds and QLNpsds values SHALL comply within the valid values as specified in clauses 7.10.9.1, 7.10.9.2 and 7.10.9.3 of G.997.2 respectively.
4. QLNMTus, QLNGus and QLNpsus values SHALL comply within the valid values as specified in clauses 7.10.9.4, 7.10.9.5 and 7.10.9.6 of G.997.2 respectively.
5. ALNMTds, ALNGds and ALNpsds values SHALL comply within the valid values as specified in clauses 7.10.10.1, 7.10.10.2 and 7.10.10.3 of G.997.2 respectively.
6. SATNds and SATNus values SHALL comply within the valid values as specified in clauses 7.10.15.1 and 7.10.15.2 of G.997.2 respectively.

### 6.15.8 Estimated Test Time

The estimated test time for this test case is 10 minutes.

## 6.16 CPE Software Download Test

### 6.16.1 Purpose

The purpose of this test is to verify that the DUT supports Software Download to the CPE, followed by the “activate” or “commit” of the downloaded software, as defined in ITU-T G.9701 Annex S and ITU-T G.997.2 Annex S.

### 6.16.2 Certification Requirement

- DPU: Optional.
- CPE: Optional.

### 6.16.3 References

- ITU-T G.9701, Annex S.
- ITU-T G.997.2, Annex S.

### 6.16.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured according to section 5.3.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.

### 6.16.5 Method of Procedure

This method of procedure targets to walk the CPE software image through a sequence of states (see Figure S.3/G.9701):

- Either S1 or S3 -> S2 -> S3 -> S4 -> S3 -> S4' -> S3'
- Or S1' or S3' -> S2' -> S3' -> S4' -> S3' -> S4 -> S3

In steps 7, 15, 22, 31, 37 and 46, the CPE software image state (NT\_SW\_STATE, being one of S1, S1', S3, S3', S4, S4') is derived from the recorded NT\_SW\_ACTIVE\_0/1, NT\_SW\_COMMITTED\_0/1 and NT\_SW\_VALID\_0/1 as defined in Figure S.3/G.9701.

If in step 7, 15, 22, 31, 37 or 46, the CPE software image state (NT\_SW\_STATE) is not per the expected result (see section 6.16.7), the test procedure SHALL end, and the test SHALL be recorded as *failed*.

This test supports two approaches to CPE software download:



- One-step download: CPE software image is downloaded directly to the CPE from a URI external to the DPU (see step 9);
- Two-step download: CPE software image is first downloaded to the DPU from a URI external to the DPU, and then CPE software image is downloaded to the CPE from a URI internal to the DPU (see steps 3 and 9).

The test is executed as one-step or two-step download, depending on the DPU capability.

The managed objects used in this test listed in Table S.1 of G.997.2 Annex S should be accessed through their equivalents in the software management protocol (see section 4.2). If the DPU proactively retrieves the CPE software image attributes, then steps 5, 13, 20, 29, 35 and 44 are skipped (no need to force an update of the attributes).

1. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
2. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
3. For the two-step download, download a CPE software image (with different version attribute than the committed software image) onto the DPU at a known Uniform Resource Identifier (URI).
4. Wait 10 seconds.
5. Force an update of the CPE software image attributes of the software image 0 and 1 through UPDATE\_NT\_SW\_ATTR0 and UPDATE\_NT\_SW\_ATTR1.
6. Wait 10 seconds.
7. Record the NT\_SW\_VERSION0/1, NT\_SW\_COMMITTED0/1, NT\_SW\_ACTIVE0/1, NT\_SW\_VALID0/1, and the derived NT\_SW\_STATE.
8. If NT\_SW\_COMMITTED0 is *true* then set  $n=0$  and  $\bar{n}=1$ , else set  $n=1$  and  $\bar{n}=0$ .
9. Configure the location (Uniform Resource Identifier) of the CPE software image file to be downloaded to the CPE through NT\_SW\_IMAGEFILE $\bar{n}$ .
10. Wait 10 seconds.
11. Force the start of the download of the CPE software image file to the CPE through setting NT\_SW\_DOWNLOAD $\bar{n} = true$ .
12. Wait until the CPE software image download is complete, i.e., until the DPU has reset the NT\_SW\_DOWNLOAD $\bar{n}$  (its value changed back to *false*) immediately after the download is complete (with success or failure), up to a maximum of 10 minutes.
13. Force an update of the CPE software image attributes of the software image 0 and 1 through UPDATE\_NT\_SW\_ATTR0 and UPDATE\_NT\_SW\_ATTR1.
14. Wait 10 seconds.
15. Record the NT\_SW\_VERSION0/1, NT\_SW\_COMMITTED0/1, NT\_SW\_ACTIVE0/1, NT\_SW\_VALID0/1, NT\_SW\_DOWNLOAD\_RES $\bar{n}$ , and the derived NT\_SW\_STATE.
16. Wait 10 seconds.
17. Force “activate” of the CPE software image through NT\_SW\_ACTIVATE $\bar{n}$ .
18. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
19. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
20. Force an update of the CPE software image attributes of the software image 0 and 1 through UPDATE\_NT\_SW\_ATTR0 and UPDATE\_NT\_SW\_ATTR1.
21. Wait 10 seconds.
22. Record the NT\_SW\_VERSION0/1, NT\_SW\_COMMITTED0/1, NT\_SW\_ACTIVE0/1, NT\_SW\_VALID0/1, NT\_SW\_ACTIVATE\_RES $\bar{n}$ , and the derived NT\_SW\_STATE.

23. Wait 10 seconds.
24. Disconnect the AC mains power at the CPE.
25. Wait 10 seconds.
26. Connect the AC mains power at the CPE.
27. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
28. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
29. Force an update of the CPE software image attributes of the software image 0 and 1 (through UPDATE\_NT\_SW\_ATTR0 and UPDATE\_NT\_SW\_ATTR1).
30. Wait 10 seconds.
31. Record the NT\_SW\_VERSION0/1, NT\_SW\_COMMITTED0/1, NT\_SW\_ACTIVE0/1, NT\_SW\_VALID0/1, and the derived NT\_SW\_STATE.
32. Wait 10 seconds.
33. Force “commit” of the CPE software image through NT\_SW\_COMMIT $\bar{n}$ .
34. Wait 10 seconds.
35. Force an update of the CPE software image attributes of the software image 0 and 1 through UPDATE\_NT\_SW\_ATTR0 and UPDATE\_NT\_SW\_ATTR1.
36. Wait 10 seconds.
37. Record the NT\_SW\_VERSION0/1, NT\_SW\_COMMITTED0/1, NT\_SW\_ACTIVE0/1, NT\_SW\_VALID0/1, NT\_SW\_COMMIT\_RES $\bar{n}$ , and the derived NT\_SW\_STATE.
38. Wait 10 seconds.
39. Disconnect the AC mains power at the CPE.
40. Wait 10 seconds.
41. Connect the AC mains power at the CPE.
42. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
43. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
44. Force an update of the CPE software image attributes of the software image 0 and 1 (through UPDATE\_NT\_SW\_ATTR0 and UPDATE\_NT\_SW\_ATTR1).
45. Wait 10 seconds.
46. Record the NT\_SW\_VERSION0/1, NT\_SW\_COMMITTED0/1, NT\_SW\_ACTIVE0/1, NT\_SW\_VALID0/1, and the derived NT\_SW\_STATE.

### 6.16.6 Report

The following items/measurements SHALL be included in the report:

1. NT\_SW\_VERSION\_B = NT\_SW\_VERSION $n$  recorded in step 7 (version active after boot).
2. NT\_SW\_STATE\_B as recorded in step 7 (state after boot).
3. NT\_SW\_VERSION\_D = NT\_SW\_VERSION $\bar{n}$  recorded in step 15 (version of downloaded CPE software image).
4. NT\_SW\_DOWNLOAD\_RES = NT\_SW\_DOWNLOAD\_RES $\bar{n}$  recorded in step 15 (result of download).
5. NT\_SW\_STATE\_D as recorded in step 15 (state after download).
6. NT\_SW\_ACTIVATE\_RES = NT\_SW\_ACTIVATE\_RES $\bar{n}$  recorded in step 21 (result of activate).

7. NT\_SW\_STATE\_A as recorded in step 21 (state after activate).
8. NT\_SW\_STATE\_AR as recorded in step 31 (state after activate and reboot).
9. NT\_SW\_COMMIT\_RES = NT\_SW\_COMMIT\_RES $\bar{n}$  recorded in step 37 (result of commit).
10. NT\_SW\_STATE\_C as recorded in step 37 (state after commit).
11. NT\_SW\_STATE\_CR as recorded in step 46 (state after commit and reboot).

### 6.16.7 Expected Results

After boot:

1. NT\_SW\_VERSION\_B SHALL be a string of 14 binary octets.
2. NT\_SW\_STATE\_B SHALL be S1, S1', S3 or S3'.

After download:

3. NT\_SW\_VERSION\_D SHALL BE a string of 14 binary octets.
4. NT\_SW\_VERSION\_D SHALL BE different from NT\_SW\_VERSION\_B.
5. NT\_SW\_DOWNLOAD\_RES SHALL be 0 (Command processed successfully (CRC correct)).
6. If NT\_SW\_STATE\_B is S1 or S3, then NT\_SW\_STATE\_D SHALL be S3.  
If NT\_SW\_STATE\_B is S1' or S3', then NT\_SW\_STATE\_D SHALL be S3'.

After activate:

7. NT\_SW\_ACTIVATE\_RES SHALL be 0 (Command processed successfully).
8. If NT\_SW\_STATE\_D is S3, then NT\_SW\_STATE\_A SHALL be S4.  
If NT\_SW\_STATE\_D is S3', then NT\_SW\_STATE\_A SHALL be S4'.

After activate and reboot:

9. If NT\_SW\_STATE\_A is S4, then NT\_SW\_STATE\_AR SHALL be S3.  
If NT\_SW\_STATE\_A is S4', then NT\_SW\_STATE\_AR SHALL be S3'.

After commit:

10. NT\_SW\_COMMIT\_RES SHALL be 0 (Command processed successfully).
11. If NT\_SW\_STATE\_AR is S3, then NT\_SW\_STATE\_C SHALL be S4'.  
If NT\_SW\_STATE\_AR is S3', then NT\_SW\_STATE\_C SHALL be S4.

After commit and reboot:

12. If NT\_SW\_STATE\_C is S4, then NT\_SW\_STATE\_CR SHALL be S3.  
If NT\_SW\_STATE\_C is S4', then NT\_SW\_STATE\_CR SHALL be S3'.

### 6.16.8 Estimated Test Time

The estimated test time for this test case is 30 minutes.

## 6.17 RMC Tone Masking Configuration Test

### 6.17.1 Purpose

The purpose of this test is to verify that the DUT is capable to perform accurately the RMC tone masking configuration.

### 6.17.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### 6.17.3 References

- ITU-T G.9701, Clauses 12.3.3.2.1, 12.3.4.2.7, 13.2.1.3.1 and 13.3.1.2.3.

### 6.17.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured according to section 5.3, except for the RMC tone masking parameters, which SHALL be configured according to Table 52 for both the downstream and upstream direction.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.

**Table 52 – RMC sub-carrier mask (RMCCARMASKds/us)**

Sub-carrier Mask Index	Start Sub-carrier Index [sub-carrier (frequency)]	Stop Sub-carrier Index [sub-carrier (frequency)]
1	39 (2018.25 kHz)	386 (19975.5 kHz)
2	967 (50042.25 kHz)	1352 (69966 kHz)

Note: This RMC sub-carrier mask corresponds to a configuration for RMC operation above 20 MHz and outside the 50-70 MHz frequency band.

### 6.17.5 Method of Procedure

1. Configure the RMC sub-carrier masking parameters according to Table 52.
2. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
3. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.

4. Record the downstream and upstream sub-carrier set and bit allocation for the RMC (BITSRMCpsds and BITSRMCpsus).

### 6.17.6 Report

The following items/measurements SHALL be included in the report:

1. The BITSRMCpsds and BITSRMCpsus recorded in step 4.

### 6.17.7 Expected Results

The notation “ds/us” applies to the DUT as defined in Table 35.

1. All reported RMC sub-carriers (as in the BITSRMCpsds/us) shall be outside the masked RMC sub-carrier bands (RMCCARMASKds/us as defined in Table 52, with start/stop sub-carrier being included in the band).

### 6.17.8 Estimated Test Time

The estimated test time for this test case is 10 minutes.

## 6.18 Robust Management Channel Recovery (RMCR) Test

### 6.18.1 Purpose

The purpose of this test case is to verify the FTU-O and FTU-R are able to perform the RMCR operations to recover the RMC.

Note: This test case requires both transceivers implement the optional RMCR procedures described in ITU-T G.9701.

### 6.18.2 Certification Requirement

- FTU-O: Optional.
- FTU-R: Optional.

### 6.18.3 References

- ITU-T G.9701, Clause 13.3.1.2.

### 6.18.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured according to section 5.3, except for the RMCR test configuration parameters, which SHALL be configured according to Table 53 for both the downstream and upstream direction.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.
4. The Noise Generator SHALL be configured to inject a SHINE Type 3 Noise as defined in section 5.4.4.3.2 at the DUT side of the loop.

**Table 53 – RMCR test configuration values**

Configuration Parameter	G.997.2 reference	Default value
LOS_PERSISTENCYds	7.1.8.1	2 seconds
LOS_PERSISTENCYus	7.1.8.2	2 seconds
LOR_PERSISTENCYds	7.1.8.5	2 seconds
LOR_PERSISTENCYus	7.1.8.6	2 seconds
RMCR_LOR_TRIGGERds	7.1.12.1	0.4 seconds
RMCR_LOR_TRIGGERus	7.1.12.1	0.4 seconds

### 6.18.5 Method of Procedure

1. Configure the RMCR configuration parameters according to Table 53.
2. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
3. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
4. Record the following parameters for the line: CURR\_NE/FE\_24\_LOS, CURR\_NE/FE\_24\_LOR, CURR\_NE/FE\_24\_LOM, CURR\_NE/FE\_24\_UAS, CURR\_24\_FULL\_INITS, CURR\_24\_FULL\_INITS, CURR\_24\_FAILEDFULL\_INITS, CURR\_24\_FAILEDFAST\_INITS, CURR\_NE/FE\_24\_RMCR.
5. Record the downstream and upstream sub-carrier set and bit allocation for the RMC (BITS-RMCpsds and BITS-RMCpsus).
6. Inject the SHINE Type 3 noise at the DUT side of the loop, for the 240 second test time (12 SHINE impulses).
7. Record the following parameters for the line: CURR\_NE/FE\_24\_LOS, CURR\_NE/FE\_24\_LOR, CURR\_NE/FE\_24\_LOM, CURR\_NE/FE\_24\_UAS, CURR\_24\_FULL\_INITS, CURR\_24\_FULL\_INITS, CURR\_24\_FAILEDFULL\_INITS, CURR\_24\_FAILEDFAST\_INITS, CURR\_NE/FE\_24\_RMCR.
8. Record the downstream and upstream sub-carrier set and bit allocation for the RMC (BITS-RMCpsds and BITS-RMCpsus).

### 6.18.6 Report

The following items/measurements SHALL be included in the report:

1. The CURR\_24\_FAST\_INITS and CURR\_24\_FAILEDFAST\_INITS counters and the CURR\_24\_FULL\_INITS and CURR\_24\_FAILEDFULL\_INITS counters recorded in steps 4 and 7.
2. The CURR\_NE\_24\_LOS and CURR\_FE\_24\_LOS counters, the CURR\_NE\_24\_LOR and CURR\_FE\_24\_LOR counters, the CURR\_NE\_24\_LOM and CURR\_FE\_24\_LOM counters, and the CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS counters recorded in steps 4 and 7.
3. The CURR\_NE/FE\_24\_RMCR counter recorded in steps 4 and 7.
4. The BITS-RMCpsds and BITS-RMCpsus recorded in steps 5 and 8.

### 6.18.7 Expected Results

The notations “ds/us” and “NE/FE” apply to the DUT as defined in Table 35.

1. The increase in CURR\_NE/FE\_24\_LOS, CURR\_NE/FE\_24\_LOR, CURR\_NE/FE\_24\_LOM, CURR\_NE/FE\_24\_UAS, CURR\_24\_FULL\_INITS, CURR\_24\_FULL\_INITS, CURR\_24\_FAILEDFULL\_INITS, CURR\_24\_FAILEDFAST\_INITS from step 4 to step 7 SHALL be zero.
2. The RMC bit loading (BITS-RMCpsds/us) shall change from step 5 to step 8, where the RMC bit loading consists of an array of (sub-carrier index, RMC bits) pairs.
3. The CURR\_NE\_24\_RMCR increase from step 4 to step 7 SHALL be  $\geq 1$ .
4. The CURR\_FE\_24\_RMCR increase from step 4 to step 7 SHALL be  $\geq 1$ .

### 6.18.8 Estimated Test Time

The estimated test time for this test case is 10 minutes.

## 7 Stability Tests

### 7.1 SHINE stability Test

#### 7.1.1 Purpose

The purpose of this test is to verify that the DUT is able to maintain physical layer and traffic stability under noise burst conditions.

The characteristics of SHINE noise Type 1, SHINE noise Type 2, SHINE noise Type 3, and SHINE noise Type 4 are defined in section 5.4.4.3.2. The SHINE noise Type 1, Type 2, Type 3, and Type 4 SHALL be injected for  $T_{\text{meas}} = 60, 120, 240, \text{ and } 60$  sec respectively. The SHINE type 1 and SHINE

type 4 are expected to be corrected completely, the SHINE type 2 and SHINE type 3 are expected to have frame loss for the duration of the SHINE impulse.

### 7.1.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### 7.1.3 References

- ITU-T G.9701, clauses 9.8.3.3, 11.4.2.4, 11.4.2.5, and 13.3.1.1.1.1.

### 7.1.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured according to the section 5.3, except for the Re-initialization policy settings and Retransmission settings, which SHALL be configured according to Table 54 and Table 55 respectively, and except for the FRA settings with SHINE type 4, which SHALL be configured according to Table 56.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used, except for the SHINE type 4 that SHALL use the 200m loop. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used, except for the SHINE type 4 that SHALL use the 200m loop.
4. The Noise Generator SHALL be configured to inject Flat Noise as defined in section 5.4.4.1.1, at a PSD of -140 dBm/Hz at the DUT side of the loop and to inject a SHINE Noise as defined in section 5.4.4.3.2 at the DUT side of the loop.
5. The Ethernet/IP Traffic Generator/Analyzer SHALL be configured to transmit a continuous upstream and downstream flow of Ethernet frames.

**Table 54 - Re-initialization policy configurations for SHINE stability test**

Configuration Parameter	Value
LOS_PERSISTENCYds	2 seconds
LOS_PERSISTENCYus	2 seconds
LOR_PERSISTENCYds	2 seconds
LOR_PERSISTENCYus	2 seconds



**Table 55 - Retransmission configurations for SHINE stability test**

Configuration Parameter	Value
INPMIN_SHINE	400 symbol periods
SHINERATIO	2 %
INPMIN_REIN	52 symbol periods
DELAYMAX	16 msec

**Table 56 - FRA configurations for SHINE type 4**

Configuration Parameter	Value
Downstream FRA time window (FRA-TIME <sub>d</sub> s)	24 logical frames
Upstream FRA time window (FRA-TIME <sub>u</sub> s)	24 logical frames

### 7.1.5 Method of Procedure

1. Inject Flat Noise at the DUT side of the loop.
2. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
3. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
4. Record the downstream ETR (ETR<sub>d</sub>s) and upstream ETR (ETR<sub>u</sub>s).
5. Record the full re-inits counter (CURR\_24\_FULL\_INITS), and fast re-inits counter (CURR\_24\_FAST\_INITS).
6. Record the near-end and far-end FRA counters (CURR\_NE\_24\_FRA and CURR\_FE\_24\_FRA), CV counters (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV), near-end and far-end ES counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), near-end and far-end SES counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), near-end and far-end UAS counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS), and near-end and far-end RTXUC counters (CURR\_NE\_24\_RTXUC and CURR\_FE\_24\_RTXUC).
7. Start the traffic generator in both the upstream and downstream directions at a required throughput equal to 50% of ETR in each direction.
8. Inject SHINE noise Type 1 at the DUT side of the loop for T<sub>meas</sub> seconds, on top of the Flat Noise.
9. Stop the traffic generator in both the upstream and downstream directions.
10. Wait 60 seconds to allow the PM counters to be updated.
11. Record the full re-inits counter (CURR\_24\_FULL\_INITS), and fast re-inits counter (CURR\_24\_FAST\_INITS).
12. Record the near-end and far-end FRA counters (CURR\_NE\_24\_FRA and CURR\_FE\_24\_FRA), CV counters (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV), near-end and far-end ES counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), near-end and far-end SES counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), near-end and far-end UAS counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS), and near-end and far-end RTXUC counters (CURR\_NE\_24\_RTXUC and CURR\_FE\_24\_RTXUC).
13. Record the total number of frames transmitted and received in the upstream and downstream directions.

14. Repeat steps 1-13 for SHINE noise Type 2, SHINE noise Type 3, and SHINE noise Type 4. For SHINE noise Type 4, DUT and Link Partner SHALL be re-configured as defined in the Test Setup (section 7.1.4), before repeating steps 1-13.

### 7.1.6 Report

The following items/measurements SHALL be included in the report:

1. The CURR\_24\_FAST\_INITS counters, and the CURR\_24\_FULL\_INITS counters recorded in steps 6 and 10 for each SHINE type.
2. The CURR\_NE\_24\_FRA and CURR\_FE\_24\_FRA counters, the CURR\_NE\_24\_CV and CURR\_FE\_24\_CV counters, the CURR\_NE\_24\_ES and CURR\_FE\_24\_ES counters, the CURR\_NE\_24\_SES and CURR\_FE\_24\_SES counters, and the CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS counters recorded in steps 7 and 11 for each SHINE type.
3. For SHINE type 1 and SHINE type 4, the CURR\_NE\_24\_RTXUC and CURR\_FE\_24\_RTXUC counters.
4. The total number of frames transmitted and received in the upstream and downstream directions recorded in step 13 and the derived frame loss ratio for each direction (FLRds and FLRus) for each SHINE type.

### 7.1.7 Expected Results

The notations “ds/us” and “NE/FE” apply to the DUT as defined in Table 35.

From before the SHINE injection until after the SHINE injection:

1. For SHINE type 1:
  - The CURR\_24\_FAST\_INITS counter increase SHALL be 0.
  - The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
  - The CURR\_NE/FE\_24\_CV counter increase SHALL be 0.
  - The CURR\_NE/FE\_24\_ES counter increase SHALL be 0.
  - The CURR\_NE/FE\_24\_SES counter increase SHALL be 0.
  - The CURR\_NE/FE\_24\_UAS counter increase SHALL be 0.
  - The CURR\_NE/FE\_24\_FRA counter increase SHALL be 0.
  - The CURR\_NE/FE\_24\_RTXUC counter increase SHALL be 0.
  - The number of dropped ds/us (i.e., transmitted minus received) frames SHALL NOT exceed 5, or the FLRds/us SHALL NOT exceed the background FLR defined in section 5.1.1.
2. For SHINE type 2:
  - The CURR\_24\_FAST\_INITS counter increase SHALL be 0.
  - The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
  - The CURR\_NE/FE\_24\_ES counter increase SHALL be  $\leq 24$ .
  - The CURR\_NE/FE\_24\_SES counter increase SHALL be  $\leq 24$ .
  - The CURR\_NE/FE\_24\_UAS counter increase SHALL be 0.

- The FLRds/us SHALL NOT exceed 1.5%.
3. For SHINE type 3:
    - The CURR\_24\_FAST\_INITS counter increase SHALL be 0.
    - The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
    - The CURR\_NE/FE\_24\_ES counter increase SHALL be  $\leq 24$ .
    - The CURR\_NE/FE\_24\_SES counter increase SHALL be  $\leq 24$ .
    - The CURR\_NE/FE\_24\_UAS counter increase SHALL be 0.
    - The FLRds/us SHALL NOT exceed 5.5%.
  4. For SHINE type 4:
    - The CURR\_24\_FAST\_INITS counter increase SHALL be 0.
    - The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
    - The CURR\_NE/FE\_24\_CV counter increase SHALL be 0.
    - The CURR\_NE/FE\_24\_ES counter increase SHALL be 0.
    - The CURR\_NE/FE\_24\_SES counter increase SHALL be 0.
    - The CURR\_NE/FE\_24\_UAS counter increase SHALL be 0.
    - The CURR\_NE/FE\_24\_FRA counter increase SHALL be 0.
    - The CURR\_NE/FE\_24\_RTXUC counter increase SHALL be 0.
    - The number of dropped ds/us (i.e., transmitted minus received) frames SHALL NOT exceed 5, or the FLRds/us SHALL NOT exceed the background FLR defined in section 5.1.1.

### 7.1.8 Estimated Test Time

The estimated test time for this test case is 20 minutes.

## 7.2 REIN Stability Test

### 7.2.1 Purpose

This test assesses DUT physical layer and traffic stability under repetitive noise burst conditions (REIN). Because retransmission is a mandatory capability for a G.fast transceiver, this impulse noise protection mechanism is tested. The REIN noise is injected after the link has trained. After a stabilization period the error metrics SHALL be recorded for the measurement period.

The characteristics of REIN noise type1 and REIN noise type 2 are defined in section 5.4.4.3.1. The REIN noise Type 1 and Type 2 SHALL be injected for  $T_{\text{meas}} = 60$  sec.

### 7.2.2 Certification Requirement

- FTU-O: Mandatory.

- FTU-R: Mandatory.

### 7.2.3 References

- ITU-T G.9701, clauses 9.8.3.3, 11.4.2.6, and 11.4.2.7.

### 7.2.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured according to the section 5.3 except for the Retransmission settings, which SHALL be configured according to Table 55.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.
4. The Noise Generator SHALL be configured to inject Flat Noise as defined in section 5.4.4.1.1, at a PSD of -140 dBm/Hz at the DUT side of the loop and to inject REIN Noise as defined in section 5.4.4.3.1 at the DUT side of the loop.
5. The Ethernet/IP Traffic Generator/Analyzer SHALL be configured to transmit a continuous upstream and downstream flow of Ethernet frames.

### 7.2.5 Method of Procedure

1. Inject Flat Noise at the DUT side of the loop.
2. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
3. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
4. Record the downstream ETR (ETRs) and upstream ETR (ETRs).
5. Record the full re-inits counter (CURR\_24\_FULL\_INITS), and fast re-inits counter (CURR\_24\_FAST\_INITS).
6. Record the near-end and far-end CV counters (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV), near-end and far-end ES counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), near-end and far-end SES counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), and near-end and far-end UAS counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS).
7. Start the traffic generator in both the upstream and downstream directions at a required throughput equal to 90% of the ETR in each direction.
8. Inject the REIN noise type 1 as defined in section 5.4.4.3.1 at the DUT side of the loop for  $T_{meas}$  seconds, on top of the Flat Noise.
9. Stop the traffic generator in both the upstream and downstream directions.
10. Wait 60 seconds to allow the PM counters to be updated.
11. Record the full re-inits counter (CURR\_24\_FULL\_INITS), and fast re-inits counter (CURR\_24\_FAST\_INITS).
12. Record the near-end and far-end CV counters (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV), near-end and far-end ES counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), near-end

and far-end SES counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), and near-end and far-end UAS counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS).

13. Record the total number of frames transmitted and received in the upstream and downstream directions.
14. Repeat steps 6-13 for REIN Noise type 2.

### 7.2.6 Report

The following items/measurements SHALL be included in the report:

1. The CURR\_24\_FAST\_INITS counters, and the CURR\_24\_FULL\_INITS counters recorded in steps 6 and 10 for each REIN type.
2. The CURR\_NE\_24\_CV and CURR\_FE\_24\_CV counters, the CURR\_NE\_24\_ES and CURR\_FE\_24\_ES counters, the CURR\_NE\_24\_SES and CURR\_FE\_24\_SES counters, and the CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS counters recorded in steps 7 and 11 for each REIN type.
3. The total number of frames transmitted and received in the upstream and downstream directions recorded in step 13 and the derived frame loss ratio in each direction (FLRds and FLRus) for each REIN type.

### 7.2.7 Expected Results

The notations “ds/us” and “NE/FE” apply to the DUT as defined in Table 35.

For each REIN type, from before the REIN injection until after the REIN injection:

1. The CURR\_24\_FAST\_INITS counter increase SHALL be 0.
2. The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
3. The CURR\_NE/FE\_24\_CV counter increase SHALL be 0.
4. The CURR\_NE/FE\_24\_ES counter increase SHALL be 0.
5. The CURR\_NE/FE\_24\_SES counter increase SHALL be 0.
6. The CURR\_NE/FE\_24\_UAS counter increase SHALL be 0.
7. The number of dropped ds/us (i.e., transmitted minus received) frames SHALL NOT exceed 5, or the FLRds/us SHALL NOT exceed the background FLR defined in section 5.1.1.

### 7.2.8 Estimated Test Time

The estimated test time for this test case is 10 minutes.

## 7.3 Fluctuating Broadband RFI Noise Present at Initialization Test

### 7.3.1 Purpose

This test verifies the stability of the G.fast link in the downstream and upstream direction, when RFI noise is injected at the CPE while the FTU-O and FTU-R initialize and after they reach the Showtime state.

### 7.3.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### 7.3.3 References

- ITU-T G.9701, clause 11.4.2.8.

### 7.3.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured according to the section 5.3, except for the RNRATIO configuration parameter listed in Table 57. No sub-carrier masking, or RFI notching SHALL be configured on either the DUT or Link Partner.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.
4. The Noise Generator SHALL be configured to inject Flat noise as defined in section 5.4.4.1.1, at a PSD level of -140 dBm/Hz at both sides of the loop and to inject Fluctuating Broadband RFI Noise as defined in section 5.4.4.2.1 at the CPE-side of the loop.
5. The Ethernet/IP Traffic Generator/Analyzer SHALL be configured to transmit a continuous upstream and downstream flow of Ethernet frames.

**Table 57 - Configuration for RFI Noise test**

<b>Downstream and upstream RNRATIO Configuration Parameter</b>	<b>G.997.2 reference</b>	<b>Value</b>
Minimum Reed-Solomon RFEC/NFEC ratio (RNRATIO)	7.2.2.6	8

### 7.3.5 Method of Procedure

1. Inject Flat Noise at both sides of the loop and inject Fluctuating Broadband RFI Noise at the CPE-side of the loop on top of the Flat Noise.
2. Allow the DUT and Link Partner to establish the G.fast connection through the loop.
3. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments.
4. Record the full re-inits counter (CURR\_24\_FULL\_INITS) and the fast re-inits counter (CURR\_24\_FAST\_INITS).
5. Record the near-end and far-end CV counters (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV), the near-end and far-end ES counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end SES counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), and the near-end and far-end UAS counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS).
6. Record the downstream ETR (ETRs) and upstream ETR (ETRs).
7. Send traffic in both the upstream and downstream directions at a required throughput equal to 90% of the ETR in each direction for 120 seconds.
8. Record the full re-inits counter (CURR\_24\_FULL\_INITS) and the fast re-inits counter (CURR\_24\_FAST\_INITS).
9. Record the near-end and far-end CV counters (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV), the near-end and far-end ES counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end SES counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), and the near-end and far-end UAS counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS).
10. Record the total number of frames transmitted and received in the upstream and downstream directions.

### 7.3.6 Report

The following items/measurements SHALL be included in the report:

1. The CURR\_24\_FAST\_INITS counters, and the CURR\_24\_FULL\_INITS counters recorded in steps 4 and 8.
2. The CURR\_NE\_24\_CV and CURR\_FE\_24\_CV counters, the CURR\_NE\_24\_ES and CURR\_FE\_24\_ES counters, the CURR\_NE\_24\_SES and CURR\_FE\_24\_SES counters, and the CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS counters recorded in steps 5 and 9.
3. The total number of frames transmitted and received in the upstream and downstream directions recorded in step 10 and the derived frame loss ratio in each direction (FLRs and FLRs).

### 7.3.7 Expected Results

The notations “ds/us” and “NE/FE” apply to the DUT as defined in Table 35.

From before the steady state period until after the steady state period:

1. The CURR\_NE/FE\_24\_CV counter increase SHALL be  $\leq 1$ .
2. The CURR\_NE/FE\_24\_ES counter increase SHALL be  $\leq 1$ .
3. The CURR\_NE/FE\_24\_SES counter increase SHALL be 0.
4. The CURR\_NE/FE\_24\_UAS counter increase SHALL be 0.
5. The CURR\_24\_FAST\_INITS counter increase SHALL be 0.
6. The CURR\_24\_FULL\_INITS counter increase SHALL be 0.

7. The number of dropped ds/us (i.e., transmitted minus received) frames SHALL NOT exceed 5, or the FLRds/us SHALL NOT exceed the background FLR defined in section 5.1.1.

### 7.3.8 Estimated Test Time

The estimated test time for this test case is 5 minutes.

## 7.4 Stationary Broadband RFI Noise Present at Initialization Test

### 7.4.1 Purpose

This test verifies the stability of the G.fast link in the downstream and upstream direction, when RFI noise is injected at the CPE while the FTU-O and FTU-R initialize and after they reach the Showtime state.

### 7.4.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### 7.4.3 References

- ITU-T G.9701, clause 11.4.2.8.

### 7.4.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured according to the section 5.3, except for the RNRATIO configuration parameter listed in Table 57. No sub-carrier masking, or RFI notching SHALL be configured on either the DUT or Link Partner.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.
4. The Noise Generator SHALL be configured to inject Flat noise as defined in section 5.4.4.1.1, at a PSD level of -140 dBm/Hz at both sides of the loop and to inject Stationary Broadband RFI Noise as defined in section 5.4.4.2.2 and 5.4.4.2.3 at the CPE-side of the loop.
5. The Ethernet/IP Traffic Generator/Analyzer SHALL be configured to transmit a continuous upstream and downstream flow of Ethernet frames.



### 7.4.5 Method of Procedure

1. Inject Flat Noise at both sides of the loop and inject Stationary Broadband RFI Noise at the CPE-side of the loop on top of the Flat Noise.
2. Allow the DUT and Link Partner to establish the G.fast connection through the loop.
3. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments.
4. Record the full re-inits counter (CURR\_24\_FULL\_INITS) and the fast re-inits counter (CURR\_24\_FAST\_INITS).
5. Record the near-end and far-end CV counters (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV), the near-end and far-end ES counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end SES counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), and the near-end and far-end UAS counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS).
6. Record the downstream ETR (ETRs) and upstream ETR (ETRs).
7. Send traffic in both the upstream and downstream directions at a required throughput equal to 90% of the ETR in each direction for 120 seconds.
8. Record the full re-inits counter (CURR\_24\_FULL\_INITS) and the fast re-inits counter (CURR\_24\_FAST\_INITS).
9. Record the near-end and far-end CV counters (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV), the near-end and far-end ES counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end SES counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), and the near-end and far-end UAS counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS).
10. Record the total number of frames transmitted and received in the upstream and downstream directions.

### 7.4.6 Report

The following items/measurements SHALL be included in the report:

1. The CURR\_24\_FAST\_INITS counters, and the CURR\_24\_FULL\_INITS counters recorded in steps 4 and 8.
2. The CURR\_NE\_24\_CV and CURR\_FE\_24\_CV counters, the CURR\_NE\_24\_ES and CURR\_FE\_24\_ES counters, the CURR\_NE\_24\_SES and CURR\_FE\_24\_SES counters, and the CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS counters recorded in steps 5 and 9.
3. The total number of frames transmitted and received in the upstream and downstream directions recorded in step 10 and the derived frame loss ratio in each direction (FLRs and FLRs).

### 7.4.7 Expected Results

The notations “ds/us” and “NE/FE” apply to the DUT as defined in Table 35.

From before the steady state period until after the steady state period:

1. The CURR\_NE/FE\_24\_CV counter increase SHALL be  $\leq 1$ .
2. The CURR\_NE/FE\_24\_ES counter increase SHALL be  $\leq 1$ .
3. The CURR\_NE/FE\_24\_SES counter increase SHALL be 0.
4. The CURR\_NE/FE\_24\_UAS counter increase SHALL be 0.

5. The CURR\_24\_FAST\_INITS counter increase SHALL be 0.
6. The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
7. The number of dropped ds/us (i.e., transmitted minus received) frames SHALL NOT exceed 5, or the FLRds/us SHALL NOT exceed the background FLR defined in section 5.1.1.

#### **7.4.8 Estimated Test Time**

The estimated test time for this test case is 5 minutes.

### **7.5 Fluctuating Broadband RFI Noise Present at Showtime Test**

#### **7.5.1 Purpose**

This test verifies the stability of the G.fast link in the downstream and upstream direction, when RFI noise is injected at the CPE after the FTU-O and FTU-R reach the Showtime state.

#### **7.5.2 Certification Requirement**

- FTU-O: Mandatory.
- FTU-R: Mandatory.

#### **7.5.3 References**

- ITU-T G.9701, clause 11.4.2.8.

#### **7.5.4 Test Setup**

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured according to the section 5.3, except for the RNRATIO configuration parameter listed in Table 57. No sub-carrier masking, or RFI notching SHALL be configured on either the DUT or Link Partner.
3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.
4. The Noise Generator SHALL be configured to inject Flat Noise as defined in section 5.4.4.1.1, at a PSD level of -140 dBm/Hz, at both sides of the loop and to inject Fluctuating Broadband RFI Noise as defined in section 5.4.4.2.1 at the CPE-side of the loop.
5. The Ethernet/IP Traffic Generator/Analyzer SHALL be configured to transmit a continuous upstream and downstream flow of Ethernet frames.

### 7.5.5 Method of Procedure

1. Inject Flat Noise at both sides of the loop.
2. Allow the DUT and Link Partner to establish the G.fast connection through the loop.
3. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments.
4. Record the full re-inits counter (CURR\_24\_FULL\_INITS) and the fast re-inits counter (CURR\_24\_FAST\_INITS).
5. Record the near-end and far-end SES counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), and the near-end and far-end UAS counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS).
6. Inject Fluctuating Broadband RFI Noise at the CPE-side of the loop on top of the Flat Noise.
7. Wait 30 seconds to allow the DUT and Link Partner to perform any adjustments.
8. Record the near-end and far-end CV counters (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV) and the near-end and far-end ES counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES).
9. Record the downstream ETR (ETRs) and upstream ETR (ETRs).
10. Send traffic in both the upstream and downstream directions at a required throughput equal to 90% of the ETR in each direction for 120 seconds.
11. Record the full re-inits counter (CURR\_24\_FULL\_INITS) and the fast re-inits counter (CURR\_24\_FAST\_INITS).
12. Record the near-end and far-end CV counters (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV), the near-end and far-end ES counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end SES counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), and the near-end and far-end UAS counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS).
13. Record the total number of frames transmitted and received in the upstream and downstream directions.

### 7.5.6 Report

The following items/measurements SHALL be included in the report:

1. The CURR\_24\_FAST\_INITS counters, and the CURR\_24\_FULL\_INITS counters recorded in steps 4 and 11.
2. The CURR\_NE\_24\_CV and CURR\_FE\_24\_CV counters, and the CURR\_NE\_24\_ES and CURR\_FE\_24\_ES counters recorded in steps 8 and 12.
3. The CURR\_NE\_24\_SES and CURR\_FE\_24\_SES counters, and the CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS counters, recorded in steps 5 and 12.
4. The total number of frames transmitted and received in the upstream and downstream directions recorded in step 13 and the derived frame loss ratio in each direction (FLRs and FLRs).

### 7.5.7 Expected Results

The notations “ds/us” and “NE/FE” apply to the DUT as defined in Table 35.

From before the noise change until after the noise change:

1. The CURR\_24\_FAST\_INITS counter increase SHALL be 0.
2. The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
3. The CURR\_NE/FE\_24\_CV counter increase SHALL be  $\leq 1$ .
4. The CURR\_NE/FE\_24\_ES counter increase SHALL be  $\leq 1$ .
5. The CURR\_NE/FE\_24\_SES counter increase SHALL be  $\leq 2$ .
6. The CURR\_NE/FE\_24\_UAS counter increase SHALL be 0.
7. The number of dropped ds/us (i.e., transmitted minus received) frames SHALL NOT exceed 5, or the FLRds/us SHALL NOT exceed the background FLR defined in section 5.1.1.

### 7.5.8 Estimated Test Time

The estimated test time for this test case is 5 minutes.

## 7.6 Stationary Broadband RFI Noise Present at Showtime Test

### 7.6.1 Purpose

This test verifies the stability of the G.fast link in the downstream and upstream direction, when RFI noise is injected at the CPE after the FTU-O and FTU-R reach the Showtime state.

### 7.6.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### 7.6.3 References

- ITU-T G.9701, clause 11.4.2.8.

### 7.6.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured according to the section 5.3, except for the RNRATIO configuration parameter listed in Table 57. No sub-carrier masking, or RFI notching SHALL be configured on either the DUT or Link Partner.

3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.
4. The Noise Generator SHALL be configured to inject Flat Noise as defined in section 5.4.4.1.1, at a PSD level of -140 dBm/Hz, at both sides of the loop and to inject Stationary Broadband RFI Noise as defined in section 5.4.4.2.2 and 5.4.4.2.3 at the CPE-side of the loop.
5. The Ethernet/IP Traffic Generator/Analyzer SHALL be configured to transmit a continuous upstream and downstream flow of Ethernet frames.

### 7.6.5 Method of Procedure

1. Inject Flat Noise at both sides of the loop.
2. Allow the DUT and Link Partner to establish the G.fast connection through the loop.
3. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments.
4. Record the full re-inits counter (CURR\_24\_FULL\_INITS) and the fast re-inits counter (CURR\_24\_FAST\_INITS).
5. Record the near-end and far-end SES counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), and the near-end and far-end UAS counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS).
6. Inject Stationary Broadband RFI Noise at the CPE-side of the loop on top of the Flat Noise.
7. Wait 30 seconds to allow the DUT and Link Partner to perform any adjustments.
8. Record the near-end and far-end CV counters (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV) and the near-end and far-end ES counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES).
9. Record the downstream ETR (ETRs) and upstream ETR (ETRs).
10. Send traffic in both the upstream and downstream directions at a required throughput equal to 90% of the ETR in each direction for 120 seconds.
11. Record the full re-inits counter (CURR\_24\_FULL\_INITS) and the fast re-inits counter (CURR\_24\_FAST\_INITS).
12. Record the near-end and far-end CV counters (CURR\_NE\_24\_CV and CURR\_FE\_24\_CV), the near-end and far-end ES counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end SES counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), and the near-end and far-end UAS counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS).
13. Record the total number of frames transmitted and received in the upstream and downstream directions.

### 7.6.6 Report

The following items/measurements SHALL be included in the report:

1. The CURR\_24\_FAST\_INITS counters, and the CURR\_24\_FULL\_INITS counters recorded in steps 4 and 11.
2. The CURR\_NE\_24\_CV and CURR\_FE\_24\_CV counters, the CURR\_NE\_24\_ES and CURR\_FE\_24\_ES counters recorded in steps 8 and 12.
3. The CURR\_NE\_24\_SES and CURR\_FE\_24\_SES counters, and the CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS counters, recorded in steps 5 and 12.

4. The total number of frames transmitted and received in the upstream and downstream directions recorded in step 13 and the derived frame loss ratio in each direction (FLRds and FLRus).

### 7.6.7 Expected Results

The notations “ds/us” and “NE/FE” apply to the DUT as defined in Table 35.

From before the noise change until after the noise change:

1. The CURR\_24\_FAST\_INITS counter increase SHALL be 0.
2. The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
3. The CURR\_NE/FE\_24\_CV counter increase SHALL be  $\leq 1$ .
4. The CURR\_NE/FE\_24\_ES counter increase SHALL be  $\leq 1$ .
5. The CURR\_NE/FE\_24\_SES counter increase SHALL be  $\leq 2$ .
6. The CURR\_NE/FE\_24\_UAS counter increase SHALL be 0.
7. The number of dropped ds/us (i.e., transmitted minus received) frames SHALL NOT exceed 5, or the FLRds/us SHALL NOT exceed the background FLR defined in section 5.1.1.

### 7.6.8 Estimated Test Time

The estimated test time for this test case is 5 minutes.

## 8 Performance Tests

### 8.1 Single-line Performance Tests

#### 8.1.1 Single-line Basic Throughput Test Over a Copper Wire Pair

##### 8.1.1.1 Purpose

The purpose of this test is to verify that the DUT can establish a stable link of sufficient performance and stability to pass data traffic over a copper wire pair at the required data rates with the Link Partner.

##### 8.1.1.2 Certification Requirement

- FTU-O: Conditionally mandatory, with the condition that the DPU supports operation over a copper wire pair.
- FTU-R: Conditionally mandatory, with the condition that the CPE supports operation over a copper wire pair.

##### 8.1.1.3 References

- ITU-T G.9701, clause 1.

##### 8.1.1.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured per section 5.3.
3. The loops with lengths listed in Table 58 and as defined in section 5.4.1 SHALL be used for the testing.
4. The Ethernet/IP Traffic Generator/Analyzer SHALL be configured to transmit a continuous upstream and downstream flow of Ethernet frames.

**Table 58 - Single-line performance copper wire pairs loops and requirements**

Loop length (m)	Aggregate net data rate (Mbit/s) for operation according to profile		
	106a	106b	212a
20	750	750	1450
50	650	650	1200
100	575	575	950
200	325	325	325
300	200	200	200
400	125	125	125
<b>HNBT (Note)</b>	450	450	450

**Note:** The home network bridged tap (HNBT) test loop topology is specified in section 5.4.1.2. Different instantiations of this bridged tap topology may exhibit large variations in insertion loss characteristics. The pass/fail criterion is set accordingly.

### 8.1.1.5 Method of Procedure

1. Allow the DUT and Link Partner to establish a G.fast connection through the first loop listed in Table 58.
2. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
3. Record the downstream and upstream net data rate (NDRds and NDRus), downstream and upstream gamma data rate (GDRds and GDRus), downstream and upstream signal to noise ratio margin (SNRMds and SNRMus), and downstream and upstream actual aggregate transmit power (ACTATPds and ACTATPus).
4. Start the traffic generator in both the upstream and downstream directions with a required throughput equal to 90% of the minimum of (GDRus; DPRus - DPReoc; CPE LAN port interface speed; DPU uplink interface speed), where  $DPRus = NDRus + 1 \text{ Mbit/s}$ ,  $DPReoc = 32 \text{ Mbit/s}$  for a 212 MHz profile and  $16 \text{ Mbit/s}$  for a 106 MHz profile, and 90% of the minimum of (GDRds; CPE LAN port interface speed; DPU uplink interface speed) respectively, in each direction (see section 5.4.8). If  $DPRus < DPReoc$ , the required upstream throughput rate SHALL equal 1 Mbit/s.
5. Let the traffic run for 5 minutes.
6. Record the total number of frames transmitted and received in the upstream and downstream directions.
7. Repeat steps 1 through 6 for each of the other loops listed in Table 58.

### 8.1.1.6 Report

The following items/measurements SHALL be included in the report:

1. The NDRds, NDRus, GDRds, GDRus, SNRMds, SNRMus, ACTATPds and ACTATPus recorded in step 3 for each loop length.
2. The required frame rate (derived from the required throughput used in step 4, as defined in section 5.1.2) for each direction and for each loop length.



3. The total number of frames transmitted and received in the upstream and downstream directions recorded in step 6 and the derived frame loss ratio in each direction (FLRds and FLRus).

### 8.1.1.7 Expected Results

The notation “ds/us” applies to the DUT as defined in Table 35.

For each loop length in Table 58:

1. The aggregate net data rate (i.e., NDRds+NDRus) SHALL be equal to or higher than the required aggregate net data rate indicated in Table 58 for the specific loop length.
2. The GDRds/us SHALL be  $\geq 0.99 \times \min(\text{NDRds/us}; \text{DPU uplink port interface speed})$ .
3. The SNRMds/us SHALL be equal to or higher than the configured SRA downshift margin (SRA-DSNRMds/us).
4. The number of dropped downstream (i.e., transmitted minus received) frames SHALL NOT exceed 5, or the FLRds SHALL NOT exceed the background FLR defined in section 5.1.1.
5. The number of dropped upstream (i.e., transmitted minus received) frames SHALL NOT exceed 5, or the FLRus SHALL NOT exceed the background FLR defined in section 5.1.1.

For G.9701 profile 106b, for the 400m loop length in Table 58:

6. ACTATPds SHALL be  $\geq 6$  dBm.
7. ACTATPus SHALL be  $\geq 5$  dBm.

### 8.1.1.8 Estimated Test Time

The estimated test time for this test case is 45 minutes.

## 8.1.2 Single-line Basic Throughput Test Over a Coaxial Cable

### 8.1.2.1 Purpose

The purpose of this test is to verify that the DUT can establish a stable link of sufficient performance and stability to pass data traffic over a coaxial cable at the required data rates with the Link Partner.

### 8.1.2.2 Certification Requirement

- FTU-O: Conditionally mandatory, with the condition that the DPU supports operation over a coaxial cable.
- FTU-R: Conditionally mandatory, with the condition that the CPE supports operation over a coaxial cable.

### 8.1.2.3 References

- ITU-T G.9701, clause 1.

### 8.1.2.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1 and Figure 3.
2. The DUT and Link Partner SHALL be configured per section 5.3.
3. The loops with lengths listed in Table 59 and as defined in section 5.4.1 SHALL be used for the testing.
4. The Ethernet/IP Traffic Generator/Analyzer SHALL be configured to transmit a continuous upstream and downstream flow of Ethernet frames.

**Table 59 - Single-line performance for coaxial cable loops and requirements**

Loop length (m)	Aggregate net data rate (Mbit/s) for operation according to profile	
	106c	212c
200 without diplexer	600	1200
100 with diplexer	600	1200

### 8.1.2.5 Method of Procedure

1. Allow the DUT and Link Partner to establish a G.fast connection through the first loop listed in in Table 59.
2. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
3. Record the downstream and upstream net data rate (NDRds and NDRus), downstream and upstream gamma data rate (GDRds and GDRus), downstream and upstream signal to noise ratio margin (SNRMds and SNRMus).
4. Start the traffic generator in both the upstream and downstream directions with a required throughput equal to 90% of the minimum of (GDRus; DPRus - DPReoc; CPE LAN port interface speed; DPU uplink interface speed), where  $DPRus = NDRus + 1 \text{ Mbit/s}$ ,  $DPReoc = 32 \text{ Mbit/s}$  for a 212 MHz profile and  $16 \text{ Mbit/s}$  for a 106 MHz profile, and 90% of the minimum of (GDRds; CPE LAN port interface speed; DPU uplink interface speed) respectively, in each direction (see section 5.4.8). If  $DPRus < DPReoc$ , the required upstream throughput rate SHALL equal 1 Mbit/s.
5. Let the traffic run for 5 minutes.
6. Record the total number of frames transmitted and received in the upstream and downstream directions.
7. Repeat steps 1 through 6 for each of the other loops listed in in Table 59.

### 8.1.2.6 Report

The following items/measurements SHALL be included in the report:

1. The NDRds, NDRus, GDRds, GDRus, SNRMds, SNRMus recorded in step 3 for each loop length.
2. The required frame rate (derived from the required throughput used in step 4, as defined in section 5.1.2) for each direction and for each loop length.
3. The total number of frames transmitted and received in the upstream and downstream directions recorded in step 6 and the derived frame loss ratio in each direction (FLRds and FLRus).

### 8.1.2.7 Expected Results

The notation “ds/us” applies to the DUT as defined in Table 35.

For each loop length in Table 59:

1. The aggregate net data rate (i.e., NDRds+NDRus) SHALL be equal to or higher than the required aggregate net data rate indicated in Table 59 or the specific loop length.
2. The GDRds/us SHALL be  $\geq 0.99 \times \text{NDRds/us}$ .
3. The SNRMds/us SHALL be equal to or higher than the configured SRA downshift margin (SRA-DSNRMds/us).
4. The number of dropped downstream (i.e., transmitted minus received) frames SHALL NOT exceed 5, or the FLRds SHALL NOT exceed the background FLR defined in section 5.1.1.
5. The number of dropped upstream (i.e., transmitted minus received) frames SHALL NOT exceed 5, or the FLRus SHALL NOT exceed the background FLR defined in section 5.1.1.

### 8.1.2.8 Estimated Test Time

The estimated test time for this test case is 45 minutes.

## 8.1.3 iDTA Test

### 8.1.3.1 Purpose

The purpose of this test is to verify that the DUT supports coordinated Dynamic Time Allocation (iDTA) in a crosstalk-free environment. This test is applicable to DTU and CPE combinations operating over coax and to DPU and CPE combinations operating over twisted pair where the DPU supports operation in a crosstalk-free environment. The crosstalk-free environment is defined in ITU-T G.9701 Annex X Clause X.2.1.

### 8.1.3.2 Certification Requirement

- DPU: Optional for DPU devices operating over coax and for DPU devices operating over twisted pair in a crosstalk-free environment.

- CPE: Optional.

### 8.1.3.3 References

- ITU-T G.9701, Annex T, Annex X.
- ITU-T G.997.2, Annex T.

### 8.1.3.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 1.
2. The DUT and Link Partner SHALL be configured according to the section 5.3, except that the value of Mds SHALL be configured to the value of Preferred Mds for DTA (DTA\_PREF\_Mds) as listed in Table 60.

NOTE - This implies iDTA is not used at the start of the testing procedure.

3. For the testing of ITU-T G.9701 profiles 106a, 106b and 212a, the 100m loop as defined in section 5.4.1.1 SHALL be used. For the testing of ITU-T G.9701 profiles 106c and 212c, the 100m loop as defined in section 5.4.1.3 SHALL be used.
4. The Ethernet/IP Traffic Generator/Analyzer SHALL be configured to transmit a continuous stream of Ethernet frames upstream or downstream, where the required traffic data rates are defined in the procedure below.

**Table 60 - Configuration parameters for the iDTA test case**

Configuration Parameter	G.997.2 reference	Default value
Annex X operation mode (ANNEX_X_MODE)	T.2.1.1	2 (AnnexX_FORCED)
iDTA allowed (DTA_ALLOWED)	T.2.1.2	True (allowed)
Annex D operation mode (ANNEX_D_MODE)	T.2.1.3	0 (Annex D_FORBIDDEN)
cDTA allowed according to Annex D (CDTA_ALLOWED)	T.2.1.4	False (disallowed)
Preferred Mds for DTA (DTA_PREF_Mds)	T.2.2.1	18
Maximum step size for DTA changes (DTA_SMAX)	T.2.2.2	2
Minimum Mds for DTA (DTA_MIN_Mds)	T.2.2.3	5
Maximum Mds for DTA (DTA_MAX_Mds)	T.2.2.4	30
Minimum expected throughput for DTA (DTA_MINETRds/us)	T.2.2.5	0
Maximum net data rate for DTA (DTA_MAXNDRds/us)	T.2.2.6	3000000
cDTA procedure control (CDTA_PROC_CTRL)	T.2.2.7	0 (one or two step procedures)
Minimum time between DTA updates (DTA_MIN_TIME)	T.2.2.8	5 (50 milli-seconds)

### 8.1.3.5 Method of Procedure

1. Allow the DUT and Link Partner to establish a G.fast connection through the loop.

2. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
3. Record whether the DTU supports Annex X (ANNEX\_X\_SUPPORT\_FTU\_O), whether the CPE supports Annex X (ANNEX\_X\_SUPPORT\_FTU\_R), whether ANNEX X is enabled (ANNEX\_X\_ENABLED) and whether iDTA is enabled (IDTA\_ENABLED).
4. Record the downstream and upstream net data rate (NDRds and NDRus) as usNDR\_1 and dsNDR\_1.
5. Configure the traffic generator in both the upstream and downstream directions with a required upstream throughput equal to 90% of the minimum of (GDRus; DPRus - DPRoc; CPE LAN port interface speed; DPU uplink interface upstream speed), where  $DPRus = NDRus + 1 \text{ Mbit/s}$ ,  $DPRoc = 32 \text{ Mbit/s}$  for a 212 MHz profile and 16 Mbit/s for a 106 MHz profile, and downstream throughput equal to 1 Mbit/s (see section 5.4.8). If  $DPRus < DPRoc$ , the required upstream throughput rate SHALL equal 1 Mbit/s. Record the configured upstream throughput rate as USR\_1.
6. Run the traffic for 60 seconds, then record the total number of frames transmitted and received for the upstream direction and calculate the upstream frame loss rate as FLRus\_1.
7. Configure the traffic generator in both the upstream and downstream directions with a required downstream throughput equal to 90% of the minimum of (GDRds; CPE LAN port interface speed; DPU uplink interface downstream speed) and upstream throughput equal to 1 Mbit/s (see section 5.4.8). Record the configured downstream throughput rate as DSR\_1.
8. Run the traffic for 60 seconds, then record the total number of frames transmitted and received for the downstream direction and calculate the upstream frame loss rate as FLRds\_1.
9. Reconfigure the DUT and Link Partner according to the section 5.3, except that the DTA settings SHALL be configured as listed in Table 60.
10. Allow the DUT and Link Partner to establish a G.fast connection through the loop.
11. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
12. Record whether the DTU supports Annex X (ANNEX\_X\_SUPPORT\_FTU\_O), whether the CPE supports Annex X (ANNEX\_X\_SUPPORT\_FTU\_R), whether ANNEX X is enabled (ANNEX\_X\_ENABLED) and whether iDTA is enabled (IDTA\_ENABLED).
13. Record the downstream and upstream net data rate (NDRds and NDRus) as usNDR\_2 and dsNDR\_2.
14. Record the near-end and far-end Errored Seconds counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end Severely Errored Seconds counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), the near-end and far-end Unavailable Seconds counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS), the full re-inits counter (CURR\_24\_FULL\_INITS) and fast re-inits counter (CURR\_24\_FAST\_INITS) for each of the  $N$  lines.
15. Configure the traffic generator in both the upstream and downstream directions with a required upstream throughput equal to the minimum of ( $1.25 * USR_1$ ; 90% of CPE LAN port interface speed; 90% of DPU uplink interface upstream speed) and downstream throughput equal to 1 Mbit/s (see section 5.4.8).
16. Run the traffic for 60 seconds, then record the total number of frames transmitted and received for the upstream direction and calculate the upstream frame loss rate as FLRus\_2.
17. Configure the traffic generator in both the upstream and downstream directions with a required downstream throughput equal to the minimum of ( $1.25 * DSR_1$ ; 90% of CPE

- LAN port interface speed; DPU uplink interface downstream speed) and upstream throughput equal to 1 Mbit/s (see section 5.4.8).
18. Run the traffic for 60 seconds, then record the total number of frames transmitted and received for the downstream direction and calculate the downstream frame loss rate as FLRds\_2.
  19. Configure the traffic generator in both the upstream and downstream directions with a required upstream throughput equal to the minimum of (1.25 \* USR\_1; 90% of CPE LAN port interface speed; DPU uplink interface upstream speed) and downstream throughput equal to 1 Mbit/s (see section 5.4.8).
  20. Run the traffic for 60 seconds, then record the total number of frames transmitted and received for the upstream direction and calculate the upstream frame loss rate as FLRus\_3.
  21. Configure the traffic generator in both the upstream and downstream directions with a required downstream throughput equal to the minimum of (1.25 \* DSR\_1; 90% of CPE LAN port interface speed; 90% of DPU uplink interface downstream speed) and upstream throughput equal to 1 Mbit/s (see section 5.4.8).
  22. Run the traffic for 60 seconds, then record the total number of frames transmitted and received for the downstream direction and calculate the downstream frame loss rate as FLRds\_3.
  23. Record the near-end and far-end Errored Seconds counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end Severely Errored Seconds counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), the near-end and far-end Unavailable Seconds counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS), the full re-inits counter (CURR\_24\_FULL\_INITS) and fast re-inits counter (CURR\_24\_FAST\_INITS) for each of the *N* lines.

NOTE - Care should be taken to ensure the traffic running in the direction opposite the direction being measured (i.e., the downstream direction while upstream is being tested) is kept to a low data rate.

### 8.1.3.6 Report

The following items/measurements SHALL be included in the report:

1. The ANNEX\_X\_SUPPORT\_FTU\_O, ANNEX\_X\_SUPPORT\_FTU\_R, the ANNEX\_X\_ENABLED and IDTA\_ENABLED as recorded in steps 3 and 12;
2. The usNDR1, dsNDR1, usNDR2 and dsNDR2 as recorded in steps 4 and 13;
3. The USR\_1 and DSR\_1 as recorded in steps 5 and 7 respectively;
4. The FLRus\_1, FLRds\_1, FLRus\_2, FLRds\_2, FLRus\_3, FLRds\_3 as recorded in steps 6, 8, 16, 18, 20, and 22 respectively;
5. The CURR\_NE\_24\_ES and CURR\_FE\_ES counters, the CURR\_NE\_24\_SES and CURR\_FE\_SES counters, the CURR\_NE\_24\_UAS and CURR\_FE\_UAS counters, the CURR\_24\_FULL\_INITS and CURR\_24\_FAST\_INITS counters as recorded in step 14 and 23;

### 8.1.3.7 Expected Results

1. The reported usNDR\_2 SHALL be greater than 125% of the reported usNDR\_1.
2. The reported dsNDR\_2 SHALL be greater than 125% of the reported dsNDR\_1.
3. The number of dropped ds/us (i.e., transmitted minus received) frames SHALL NOT exceed 5, or the FLRds/us (FLRus\_1, FLRds\_2) SHALL NOT exceed the background FLR defined in section 5.1.1.

In step 3:

4. The ANNEX\_X\_SUPPORT\_FTU\_O SHALL be *true* (supported);
5. The ANNEX\_X\_SUPPORT\_FTU\_R SHALL be *true* (supported);
6. The ANNEX\_X\_ENABLED SHALL be *false* ;
7. The IDTA\_ENABLED SHALL be *false* (disabled);

In step 12:

8. The ANNEX\_X\_SUPPORT\_FTU\_O SHALL be *true* (supported);
9. The ANNEX\_X\_SUPPORT\_FTU\_R SHALL be *true* (supported);
10. The ANNEX\_X\_ENABLED SHALL be *true* ;
11. The IDTA\_ENABLED SHALL be *true* (enabled);

From step 14 until step 23 of the cDTA test procedure:

12. The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
13. The CURR\_24\_FAST\_INITS counter increase SHALL be 0.
14. The CURR\_NE/FE\_24\_ES counter increase SHALL be 0.
15. The CURR\_NE/FE\_24\_SES counter increase SHALL be 0.
16. The CURR\_NE/FE\_24\_UAS counter increase SHALL be 0.
17. The number of dropped ds/us (i.e., transmitted minus received) frames SHALL NOT exceed 5, or the FLRds/us (FLRus\_2, FLRds\_2, FLRus\_3, FLRds\_3) SHALL NOT exceed the background FLR defined in section 5.1.1.

### 8.1.3.8 Estimated Test Time

The estimated test time for this test case is 15 minutes.

## 8.2 Multi-line Performance Tests Over Copper Wire Pairs

These tests apply only if the DPU supports operation over a copper wire pair and supports multiple ports. The number of ports/pairs used for multi-line testing (represented by  $N$ ) SHALL require the DPU be fully loaded, up to a maximum of 8 ports (4 port DPU is tested with 4 CPE, 8 port DPU is tested with 8 CPE, 16 port DPU is tested with 8 CPE). The DPU ports (for DPU with more than 8 ports) used for testing SHALL be randomly selected by the test lab, at the start of a certification test run (not changed in between link partners).

**Note 1:** For DPU certification, a mix of CPEs, selected by the test lab within the G.fast Certification Program guidelines (OD-362), connected to all lines of the DPU, is used for multi-line testing.

**Note 2:** For multi-line testing for CPE certification, all lines of the DPU involved in the test have the same type of CPE connected.

## 8.2.1 Multi-line Basic Throughput Test over Copper Wire Pairs

### 8.2.1.1 Purpose

The purpose of this test is to verify that the DUT can establish  $N$  stable links of sufficient performance and stability to pass data traffic at the required data rates with the Link Partner. The required net data rates within the expected results for this test require the devices to implement vectoring. This test is performed with all devices connecting over a mix of loop lengths, also known as non co-located CPE devices.

### 8.2.1.2 Certification Requirement

- FTU-O: Conditional mandatory, with the condition that the DPU supports operation over a copper wire pair and supports more than 1 port.
- FTU-R: Conditionally mandatory, with the condition that the CPE supports operation over a copper wire pair.

### 8.2.1.3 References

- ITU-T G.9701, clause 1.

### 8.2.1.4 Test Setup

1. The DUT and Link Partners (either CPEs or DPU) SHALL be connected to the test setup shown in Figure 2 and Figure 3.
2. The multi-pair loop SHALL consist of a mix of the 20m, 50m, 100m and 200m loops defined in section 5.4.1.1 for G.9701 profiles 106a and 212a or a mix of the 50m, 100m, 200m, and 400m loops defined in section 5.4.1.1 for G.9701 profile 106b.
3. For G.9701 profiles 106a and 212a, the DUT and Link Partners SHALL be connected as follows:
  - a. If the DPU has 2 ports, then the test SHALL be run twice, once with a 20m loop and a 50m loop, and once with a 100m loop and 200m loop.
  - b. If the DPU has 3 ports, then three different loops SHALL be randomly selected by the test lab from the full mix of 20, 50, 100 and 200m loops.
  - c. If the DPU has 4 ports, the full mix of 20, 50, 100 and 200m loops SHALL be used.
  - d. For larger DPUs, the full mix of 20, 50, 100 and 200m loops SHALL be repeated starting from the shortest loop on the next available port, with up to 8 loops used for multi-line testing.

For G.9701 profile 106b, the DUT and Link Partners SHALL be connected as follows:

- a. If the DPU has 2 ports, then the test SHALL be run twice, once with a 50m loop and a 100m loop, and once with a 200m loop and 400m loop.



- b. If the DPU has 3 ports, then three different loops SHALL be randomly selected by the test lab from the full mix of 50, 100, 200 and 400m loops.
  - c. If the DPU has 4 ports, the full mix of 50, 100, 200 and 400m loops SHALL be used.
  - d. For larger DPUs, the full mix of 50, 100, 200 and 400m loops SHALL be repeated starting from the shortest loop on the next available port, with up to 8 loops used for multi-line testing.
4. The DUT and Link Partner SHALL be configured per section 5.3.
  5. The Ethernet/IP Traffic Generator/Analyzer SHALL be configured as follows:
    - a. For each test loop length that is used once in the test, the related line SHALL be the “High Rate Line”. For each loop length that is used twice in the test, one line SHALL be randomly selected by the test lab as the “High Rate Line”. The “High Rate Line” SHALL be used to carry a higher rate Ethernet traffic during the test for that loop length.
    - b. The generator/analyzer SHALL be configured to transmit a continuous upstream and downstream flow of Ethernet frames over the High Rate Line.
    - c. The generator/analyzer SHALL be configured to transmit a continuous upstream and downstream flow of Ethernet frames at a required throughput of 1 Mbit/s over all lines except the High Rate Line.

**Table 61 - Multi-line performance loops and requirements**

Loop length (m)	Aggregate net data rate (Mbit/s) for operation according to profile		
	106a	106b	212a
20	500	N/A	1000
50	500	500	900
100	500	500	700
200	200	200	200
400	N/A	75	N/A

**Note:** The required throughput is only transmitted on one randomly selected line in the vectored group to avoid exceeding the bandwidth of the DPU fiber/copper uplink. All other lines in the group SHALL carry traffic at a required throughput of 1 Mbit/s during the test.

**8.2.1.5 Method of Procedure**

1. Force all *N* lines to L3 (AdminState=DOWN for each of the *N* lines).
2. Record the near-end Unavailable Seconds counters (CURR\_NE\_24\_UAS) for each of the *N* lines.
3. Allow the DUT and Link Partner (either CPE or DPU) to establish a G.fast connection through each of the *N* loops (AdminState=UP for each of the *N* lines).
4. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
5. Record the near-end Unavailable Seconds counters (CURR\_NE\_24\_UAS), the full re-inits counter (CURR\_24\_FULL\_INITS) and fast re-inits counter (CURR\_24\_FAST\_INITS) for each of the *N* lines.

6. Record the downstream and upstream net data rate (NDRds and NDRus), downstream and upstream gamma data rate (GDRds and GDRus), downstream and upstream signal to noise ratio margin (SNRMds and SNRMus), for each of the  $N$  lines.
7. Start the traffic generator in both the upstream and downstream directions on each of the  $N$  lines. The traffic stream on High Rate Line (as selected in step 5a of the test setup) SHALL have a required throughput equal to 90% of the minimum of (GDRus; DPRus - DPReoc; CPE LAN port interface speed; DPU uplink interface speed), where DPRus = NDRus + 1 Mbit/s, DPReoc = 32 Mbit/s for a 212 MHz profile and 16 Mbit/s for a 106 MHz profile, and 90% of the minimum of (GDRds; CPE LAN port interface speed; DPU uplink interface speed) respectively, in each direction (see section 5.4.8). If DPRus < DPReoc, the required upstream throughput rate SHALL equal 1 Mbit/s.
8. All the traffic to run for 5 minutes.
9. Repeat steps 7 to 8 for each loop length selected in step 3 of the test setup.
10. Record the total number of frames transmitted and received in the upstream and downstream directions for each of the  $N$  lines.
11. Record the full re-inits counter (CURR\_24\_FULL\_INITS), and fast re-inits counter (CURR\_24\_FAST\_INITS) for each of the  $N$  lines.

### 8.2.1.6 Report

The following items/measurements SHALL be included in the report:

1. The CURR\_NE\_24\_UAS counter recorded in steps 2 and 5 for each of the  $N$  lines.
2. The CURR\_24\_FULL\_INITS and CURR\_24\_FAST\_INITS counters recorded in steps 3 and 10 for each of the  $N$  lines.
3. The NDRds, NDRus, GDRds, GDRus, SNRMds, SNRMus recorded in step 4 for each of the  $N$  lines.
4. The total number of frames transmitted and received in the upstream and downstream directions and the derived frame loss ratio in each direction (FLRds and FLRus) for each of the  $N$  lines.

### 8.2.1.7 Expected Results

The notation “ds/us” applies to the DUT as defined in Table 35.

For each of the  $N$  lines:

1. The CURR\_NE\_24\_UAS counter increase SHALL be  $\leq 60$  (Note).
2. The aggregate net data rate (i.e., NDRds+NDRus) SHALL be equal to or higher than the required aggregate net data rate indicated in Table 61 for the specific loop length.
3. The GDRds/us SHALL be  $\geq 0.80 \times$  NDRds/us.
4. The SNRMds/us for each line SHALL be equal to or higher than the configured SRA downshift margin (SRA-DSNRMds/us).
5. The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
6. The CURR\_24\_FAST\_INITS counter increase SHALL be 0.

7. The number of dropped downstream (i.e., transmitted minus received) frames SHALL NOT exceed 5, or the FLRds SHALL NOT exceed the background FLR defined in section 5.1.1.
8. The number of dropped upstream (i.e., transmitted minus received) frames SHALL NOT exceed 5, or the FLRus SHALL NOT exceed the background FLR defined in section 5.1.1.

**Note:** The near-end UAS counter increase between line state changing to AdminState=UP and the near-end transceiver reaching showtime represents the line init time.

### 8.2.1.8 Estimated Test Time

The estimated test time for this test case is 60 minutes.

## 8.2.2 Multi-line Disorderly Shutdown Test Over Copper Wire Pairs

### 8.2.2.1 Purpose

The purpose of this test is to verify that the DUT is able to sustain with the Link Partner *N-1* stable links when a disorderly shutdown occurs on one line. This test is performed with all devices connecting over a mix of loop lengths, also known as non co-located CPE devices.

### 8.2.2.2 Certification Requirement

- FTU-O: Conditional mandatory, with the condition that the DPU supports operation over a copper wire pair and supports more than 1 port.
- FTU-R: Conditionally mandatory, with the condition that the CPE supports operation over a copper wire pair.

### 8.2.2.3 References

- None.

### 8.2.2.4 Test Setup

The test setup SHALL be identical to the test setup defined for the multi-line basic throughput test in section 8.2.1.4.

### 8.2.2.5 Method of Procedure

1. Allow the DUT and Link Partner to establish *N* G.fast connections through the *N* loops.
2. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.

3. Start the traffic generator in both the upstream and downstream directions.
4. Allow the traffic to run for 1 minute.
5. Record the fast re-init counter (CURR\_24\_FAST\_INITS) and full re-init counter (CURR\_24\_FULL\_INITS) for each of the  $N$  lines.
6. Record the near-end and far-end unavailable seconds counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS) for each of the  $N$  lines.
7. Disconnect line  $\#n$  at the CPE, with  $n$  randomly selected by the test lab.
8. Wait 10 seconds
9. Reconnect line  $\#n$  at the CPE.
10. Allow the DUT and Link Partner to establish a G.fast connection through line  $\#n$ .
11. Wait 60 seconds to allow the DUT and Link Partner on line  $\#n$  to perform any adjustments to the link.
12. Record the fast re-inits counter (CURR\_NE\_24\_FAST\_INITS) and full re-inits counter (CURR\_24\_FULL\_INITS) for each of the  $N$  lines.
13. Record the near-end and far-end unavailable seconds counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS) for each of the  $N$  lines.
14. Disconnect the AC mains power at the CPE on line  $\#m$ , with  $m$  randomly selected by the test lab, with  $m \neq n$ .
15. Wait 10 seconds.
16. Connect the AC mains power at the CPE on line  $\#m$ .
17. Allow the DUT and Link Partner to establish a G.fast connection through line  $\#m$ .
18. Wait 60 seconds to allow the DUT and Link Partner on line  $\#m$  to perform any adjustments to the link.
19. Record the fast re-init counter (CURR\_24\_FAST\_INITS) and full re-inits counter (CURR\_24\_FULL\_INITS) for each of the  $N$  lines.
20. Record the near-end and far-end unavailable seconds counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS) for each of the  $N$  lines.

### 8.2.2.6 Report

The following items/measurements SHALL be included in the report:

1. The CURR\_24\_FAST\_INITS and CURR\_24\_FULL\_INITS counters, as recorded in steps 5, 12, and 19.
2. The CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS counters, as recorded in steps 6, 13, and 20.

### 8.2.2.7 Expected Results

The notation “NE/FE” applies to the DUT as defined in Table 35.

From before disconnecting line  $\#n$  at the CPE until after reconnecting line  $\#n$  at the CPE, on all lines except line  $\#n$ :

1. The CURR\_24\_FAST\_INITS counter increase SHALL be 0.
2. The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
3. The CURR\_NE/FE\_UAS counter increase SHALL be 0.

From before disconnecting AC power at the CPE on line #*m* until after reconnect AC power at the CPE on line #*m*, on all lines except line #*m*:

1. The CURR\_24\_FAST\_INITS counter increase SHALL be 0.
2. The CURR\_24\_FULL\_INITS counter increase SHALL be 0.
3. The CURR\_NE/FE\_UAS counter increase SHALL be 0.

### 8.2.2.8 Estimated Test Time

The estimated test time for this test case is 5 minutes.

## 8.2.3 cDTA Test

### 8.2.3.1 Purpose

The purpose of this test is to verify that the DUT supports coordinated Dynamic Time Allocation (cDTA) across a vectored group in a crosstalk environment. This test is applicable to a DPU and CPE operating over Twisted Pair (TP) only.

### 8.2.3.2 Certification Requirement

- DPU: Optional for DPU operating over TP.
- CPE: Optional for CPE operating over TP.

### 8.2.3.3 References

- ITU-T G.9701, Annex D, Annex T.
- ITU-T G.997.2, Annex T.

### 8.2.3.4 Test Setup

1. The DUT and Link Partner (either CPE or DPU) SHALL be connected to the test setup shown in Figure 2.
2. The multi-pair loop SHALL consist of a mix of the 20m, 50m, 100m and 200m loops defined in section 5.4.1.1 for G.9701 profiles 106a and 212a or a mix of the 50m, 100m, 200m, and 400m loops defined in section 5.4.1.1 for G.9701 profile 106b.
3. The DUT and Link Partner SHALL be configured according to the section 5.3, except that the value of Mds SHALL be configured to the value of Preferred Mds for DTA (DTA\_PREF\_Mds) as listed in Table 62.

NOTE - This implies cDTA is not used at the start of the testing procedure.

4. The Ethernet/IP Traffic Generator/Analyzer SHALL be configured as follows:
  - a. Over line\_A, the generator/analyzer SHALL be configured to transmit a continuous upstream and downstream flow of Ethernet frames. In downstream, at a required

throughput of 1 Mbit/s, the required upstream throughput is specified in the procedure steps below.

- b. Over line\_B, the generator/analyzer SHALL be configured to transmit a continuous upstream and downstream flow of Ethernet frames. In upstream, at a required throughput of 1 Mbit/s, the required downstream throughput is specified in the procedure steps below.

**Table 62 - Configuration parameters for the cDTA test case**

Configuration Parameter	G.997.2 reference	Default value
Annex X operation mode (ANNEX_X_MODE)	T.2.1.1	0 (AnnexX_FORBIDDEN)
iDTA allowed (DTA_ALLOWED)	T.2.1.2	False (disallowed)
Annex D operation mode (ANNEX_D_MODE)	T.2.1.3	2 (AnnexD_FORCED)
cDTA allowed according to Annex D (CDTA_ALLOWED)	T.2.1.4	True (allowed)
Preferred Mds for DTA (DTA_PREF_Mds)	T.2.2.1	18
Maximum step size for DTA changes (DTA_SMAX)	T.2.2.2	2
Minimum Mds for DTA (DTA_MIN_Mds)	T.2.2.3	10
Maximum Mds for DTA (DTA_MAX_Mds)	T.2.2.4	31
Minimum expected throughput for DTA (DTA_MINETRds/us)	T.2.2.5	0
Maximum net data rate for DTA (DTA_MAXNDRds/us)	T.2.2.6	3000000
cDTA procedure control (CDTA_PROC_CTRL)	T.2.2.7	0 (one or two step procedures)
Minimum time between DTA updates (DTA_MIN_TIME)	T.2.2.8	5 (50 milli-seconds)

### 8.2.3.5 Method of Procedure

1. Allow the DUT and Link Partner(s) to establish a G.fast connection through the *N* loops.
2. Wait 60 seconds to allow the DUT and Link Partner(s) to perform any adjustments to the *N* links.
3. Record whether the DTU supports Annex D (ANNEX\_D\_SUPPORT\_FTU\_O), whether the CPE supports Annex D (ANNEX\_D\_SUPPORT\_FTU\_R), whether ANNEX D is enabled (ANNEX\_D\_ENABLED) and the actual type of the cDTA procedure (CDTA\_PROC\_ACT).
4. Record the downstream and upstream net data rate (NDRds and NDRus) as usNDR\_1 and dsNDR\_1, for each of the *N* lines.
5. Randomly select two lines (record as line\_A and line\_B), where the loop length for each line SHALL be different.
6. Configure the traffic generator connected to the first random line (line\_A) in both the upstream and downstream directions with a required upstream throughput equal to 90% of the minimum of (GDRus; DPRus - DPREoc; CPE LAN port interface speed; DPU uplink interface upstream speed), where DPRus = NDRus + 1 Mbit/s, DPREoc = 32 Mbit/s for a 212 MHz profile and 16 Mbit/s for a 106 MHz profile, and downstream throughput equal to 1 Mbit/s (see section 5.4.8). If DPRus < DPREoc, the required upstream throughput rate SHALL equal 1 Mbit/s. Record the configured upstream throughput rate as USR\_1.

7. Run the traffic over line\_A for 60 seconds, then record the total number of frames transmitted and received for the upstream direction and calculate the upstream frame loss rate as FLRus\_1.
8. Configure the traffic generator connected to the second random line (line\_B) in both the upstream and downstream directions with a required downstream throughput equal to 90% of the minimum of (GDRds; CPE LAN port interface speed; DPU uplink interface downstream speed) and upstream throughput equal to 1 Mbit/s (see section 5.4.8). Record the configured downstream throughput rate as DSR\_1.
9. Run the traffic over line\_B for 60 seconds, then record the total number of frames transmitted and received for the downstream direction and calculate the downstream frame loss rate as FLRds\_1.
10. Reconfigure the DUT and Link Partner(s) according to the section 5.3, except that the DTA settings SHALL be configured as listed in Table 62.
11. Allow the DUT and Link Partner(s) to establish a G.fast connection through the *N* loops.
12. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the *N* links.
13. Record whether the DTU supports Annex D (ANNEX\_D\_SUPPORT\_FTU\_O), whether the CPE supports Annex D (ANNEX\_D\_SUPPORT\_FTU\_R), whether ANNEX D is enabled (ANNEX\_D\_ENABLED) and the actual type of the cDTA procedure (CDTA\_PROC\_ACT).
14. Record the downstream and upstream net data rate (NDRds and NDRus) as usNDR\_2 and dsNDR\_2, for each of the *N* lines.
15. Record the near-end and far-end Errored Seconds counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end Severely Errored Seconds counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), the near-end and far-end Unavailable Seconds counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS), the full re-inits counter (CURR\_24\_FULL\_INITS) and fast re-inits counter (CURR\_24\_FAST\_INITS) for each of the *N* lines.
16. Configure the traffic generator connected to the first random line (line\_A) in both the upstream and downstream directions with a required upstream throughput equal to the minimum of (1.25\*USR\_1; 90% of CPE LAN port interface speed; 90% of DPU uplink interface upstream speed) and downstream throughput equal to 1 Mbit/s (see section 5.4.8).
17. Run the traffic over line\_A for 60 seconds, then record the total number of frames transmitted and received for the upstream direction and calculate the upstream frame loss rate as FLRus\_2.
18. Configure the traffic generator connected to the second random line (line\_B) in both the upstream and downstream directions with a required downstream throughput equal to the minimum of (1.25\*DSR\_1; 90% of CPE LAN port interface speed; 90% of DPU uplink interface downstream speed) and upstream throughput equal to 1 Mbit/s (see section 5.4.8).
19. Run the traffic over line\_B for 60 seconds, then record the total number of frames transmitted and received for the downstream direction and calculate the downstream frame loss rate as FLRds\_2.
20. Configure the traffic generator connected to the first random line (line\_A) in both the upstream and downstream directions with a required upstream throughput equal to the minimum of (1.25\*USR\_1; 90% of CPE LAN port interface speed; 90% of DPU uplink interface upstream speed) and downstream throughput equal to 1 Mbit/s (see section 5.4.8).

21. Run the traffic over line\_A for 60 seconds, then record the total number of frames transmitted and received for the upstream direction and calculate the upstream frame loss rate as FLRus\_3.
22. Configure the traffic generator connected to the second random line (line\_B) in both the upstream and downstream directions with a required downstream throughput equal to the minimum of (1.25\*DSR\_1; 90% of CPE LAN port interface speed; 90% of DPU uplink interface downstream speed) and upstream throughput equal to 1 Mbit/s (see section 5.4.8).
23. Run the traffic over line\_B for 60 seconds, then record the total number of frames transmitted and received for the downstream direction and calculate the downstream frame loss rate as FLRds\_3.
24. Record the near-end and far-end Errored Seconds counters (CURR\_NE\_24\_ES and CURR\_FE\_24\_ES), the near-end and far-end Severely Errored Seconds counters (CURR\_NE\_24\_SES and CURR\_FE\_24\_SES), the near-end and far-end Unavailable Seconds counters (CURR\_NE\_24\_UAS and CURR\_FE\_24\_UAS), the full re-inits counter (CURR\_24\_FULL\_INITS) and fast re-inits counter (CURR\_24\_FAST\_INITS) for each of the *N* lines.

NOTE - Care should be taken to ensure the traffic running in the direction opposite the direction being measured (i.e., the downstream direction while upstream is being tested) is kept to a low data rate.

### 8.2.3.6 Report

The following items/measurements SHALL be included in the report:

1. The ANNEX\_D\_SUPPORT\_FTU\_O, ANNEX\_D\_SUPPORT\_FTU\_R, the ANNEX\_D\_ENABLED and CDTA\_PROC\_ACT as recorded in steps 3 and 13, for each of the *N* lines;
2. The usNDR1, dsNDR1, usNDR2 and dsNDR2 as recorded in steps 4 and 14, for each of the *N* lines;
3. The USR\_1 and DSR\_1 as recorded in steps 6 and 8 respectively;
4. The FLRus\_1, FLRds\_1, FLRus\_2, FLRds\_2, FLRus\_3, FLRds\_3 as recorded in steps 7, 9, 17, 19, 21, and 23 respectively;
5. The CURR\_NE\_24\_ES and CURR\_FE\_ES counters, the CURR\_NE\_24\_SES and CURR\_FE\_SES counters, the CURR\_NE\_24\_UAS and CURR\_FE\_UAS counters, the CURR\_24\_FULL\_INITS and CURR\_24\_FAST\_INITS counters as recorded in step 15 and 24, for each of the *N* lines;

### 8.2.3.7 Expected Results

1. The reported usNDR\_2 SHALL be greater than 125% of the reported usNDR\_1 for all *N* lines.
2. The reported dsNDR\_2 SHALL be greater than 125% of the reported dsNDR\_1 for all *N* lines.



3. The number of dropped ds/us (i.e., transmitted minus received) frames SHALL NOT exceed 5, or the FLRds/us (FLRus\_1, FLRds\_2) SHALL NOT exceed the background FLR defined in section 5.1.1.

In step 3:

4. The ANNEX\_D\_SUPPORT\_FTU\_O SHALL be *true* (supported) for all *N* lines;
5. The ANNEX\_D\_SUPPORT\_FTU\_R SHALL be *true* (supported) for all *N* lines;
6. The ANNEX\_D\_ENABLED SHALL be *false* for all *N* lines;
7. The CDTA\_PROC\_ACT SHALL be 0 (disabled) for all *N* lines;

In step 13:

8. The ANNEX\_D\_SUPPORT\_FTU\_O SHALL be *true* (supported) for all *N* lines;
9. The ANNEX\_D\_SUPPORT\_FTU\_R SHALL be *true* (supported) for all *N* lines;
10. The ANNEX\_D\_ENABLED SHALL be *true* for all *N* lines;
11. The CDTA\_PROC\_ACT SHALL be 1 (one-step procedure) or 2 (two-step procedure) for all *N* lines;

From step 15 until step 24 of the cDTA test procedure:

12. The CURR\_24\_FULL\_INITS counter increase SHALL be 0 for all *N* lines.
13. The CURR\_24\_FAST\_INITS counter increase SHALL be 0 for all *N* lines.
14. The CURR\_NE/FE\_24\_ES counter increase SHALL be 0 for all *N* lines.
15. The CURR\_NE/FE\_24\_SES counter increase SHALL be 0 for all *N* lines.
16. The CURR\_NE/FE\_24\_UAS counter increase SHALL be 0 for all *N* lines.
17. The number of dropped ds/us (i.e., transmitted minus received) frames SHALL NOT exceed 5, or the FLRds/us (FLRus\_2, FLRds\_2, FLRus\_3, FLRds\_3) SHALL NOT exceed the background FLR defined in section 5.1.1.

### 8.2.3.8 Estimated Test Time

The estimated test time for this test case is 30 minutes.

## 9 Test Parameter Accuracy

The purpose of this section is to include tests to verify the accuracy of test parameters.

### 9.1 Definition of accuracy metrics

#### 9.1.1 HLOG Mean Absolute Error (MAE\_HLOG)

For both the downstream and upstream direction, the HLOG Mean Absolute Error (MAE\_HLOG) for a loop is defined as:

$$MAE\_HLOG_{LoopX} = \frac{1}{N_i} \sum_{i \in \{SNR_{ps_i} > SNR_{min}, f_i \geq f_{min}, f_i \leq f_{max}\}} |HLOG_{ps_i} - HLOG_{REF_{ps_i}}|,$$

where:

- $f_i = i \times HLOGG \times 51.75$  kHz;
- $SNR_{ps_i}$  is the  $SNR_{psds_i}$  or  $SNR_{psus_i}$  sample, in dB, for loop X and frequency  $f_i$ . The  $SNR_{ps}$  is downsampled (if  $SNRG < HLOGG$ ) or linearly interpolated (if  $SNRG > HLOGG$ ) on the frequency grid of  $HLOG_{ps}$ ;
- $HLOG_{ps_i}$  is the reported  $HLOG_{psds_i}$  or  $HLOG_{psus_i}$  sample, in dB, for loop X and frequency  $f_i$ ;
- $HLOG_{REF_{ps_i}}$  = Reference sample, in dB, for loop X and frequency  $f_i$  (measured with a Network Analyzer on a frequency grid of 50kHz and linearly interpolated on the frequency grid of  $HLOG_{ps}$ , taking into account the subcarrier group size  $HLOGG$  (see ITU-T G9701 clause 11.4.1.2.1));
- $SNR_{min} = 12$ dB;
- Minimum frequency for MAE calculation  $f_{min} = 4$  MHz;
- Maximum frequency for MAE calculation  $f_{max} = 80$  MHz for the 106a and 106b profiles;
- Maximum frequency for MAE calculation  $f_{max} = 80$  MHz for the 106c profile;
- Maximum frequency for MAE calculation  $f_{max} = 160$  MHz for the 212a profile;
- Maximum frequency for MAE calculation  $f_{max} = 160$  MHz for the 212c profile;
- $N_i$  is the number of  $HLOG_{ps}$  samples meeting the summation criterion.

### 9.2 Single-line HLOG Accuracy Test

#### 9.2.1 Purpose

The purpose of this test is to verify that the DUT and Link Partner measure and report per subcarrier HLOG ( $HLOG_{ps}$ ) values that satisfy the accuracy requirements.

The  $HLOG_{ps}$  accuracy is influenced by the FTU-O, FTU-R and VCE. The reported  $HLOG_{ps}$  values are compared to the insertion loss values measured by a network analyzer on the same wire pair. The

values measured by the network analyzer are considered the reference values. The pass/fail criteria are based on the MAE deviation of the reported values versus the reference values.

### 9.2.2 Certification Requirement

- FTU-O: Mandatory.
- FTU-R: Mandatory.

### 9.2.3 References

- ITU-T G.9701, clause 11.4.1.2.1.
- ITU-T G.997.2, clause 7.10.

### 9.2.4 Test Setup

1. The DUT and Link Partners (either CPEs or DPU) SHALL be connected to the test setup shown in Figure 1.
2. The DUT and Link Partners SHALL be configured according to section 5.3.
3. The DUT and Link Partner SHALL be connected with the 100m copper pair loop defined in section 5.4.1.1 (if the DUT supports operation over a copper pair) and with the 100m coaxial cable loop defined in section 5.4.1.3 (if the DUT supports operation over a coaxial cable).
4. The reference insertion loss for the loop has been measured by the test lab with a Network Analyzer, according to ITU-T G.9701 clause 11.4.1.2.1.

### 9.2.5 Method of Procedure

1. Allow the DUT and Link Partner (either CPE or DPU) to establish a G.fast connection through the loop;
2. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
3. If required by the DPU, set Update request flag for far-end test parameters (UPDATE-FE-TEST) to TRUE for Far-end test parameter group 1 (FE-G1) and Far-end test parameter group 2 (FE-G2) (NOTE).
4. Wait 5 minutes for the test parameters to be updated.
5. Record the following test parameters:
  - Downstream signal to noise ratio SNRMTds, SNRGds, and SNRpsds;
  - Upstream signal to noise SNRMTus, SNRGus, and SNRpsus;
  - Downstream insertion loss per sub-carrier group: HLOGMTds, HLOGGds, and HLOGpsds;
  - Upstream insertion loss per sub-carrier group: HLOGMTus, HLOGGus, and HLOGpsus.
6. Calculate the HLOG Mean Absolute Error (MAE\_HLOG) as defined in section 9.1.1, for both the downstream (MAE\_HLOGds) and upstream (MAE\_HLOGus) direction.

**Note:** The DPU may implement an autonomous update process (see G.997.2 clause 7).

## 9.2.6 Report

The following items/measurements SHALL be included in the report:

1. SNRMTds, SNRGds, and SNRpsds recorded in step 6;
2. SNRMTus, SNRGus, and SNRpsus recorded in step 6;
3. HLOGMTds, HLOGGds, and HLOGpsds recorded in step 6;
4. HLOGMTus, HLOGGus, and HLOGpsus recorded in step 6;
5. MAE\_HLOGds and MAE\_HLOGus as calculated in step 7.

## 9.2.7 Expected Results

1. MAE\_HLOGds SHALL be  $\leq 6$  dB;
2. MAE\_HLOGus SHALL be  $\leq 6$  dB.

## 9.2.8 9.1.7 Estimated Test Time

The estimated test time for this test case is 10 minutes.

## 9.3 Multi-line HLOG Accuracy Test over Copper Wire Pairs

### 9.3.1 Purpose

The purpose of this test is to verify that the DUT and Link Partner(s) measure and report per subcarrier HLOG (HLOGps) values that satisfy the accuracy requirements.

The HLOGps accuracy is influenced by the FTU-O, FTU-R and VCE. The reported HLOGps values are compared to the insertion loss values measured by a network analyzer on the same wire pair, for each of the pairs. The values measured by the network analyzer are considered the reference values. The pass/fail criteria are based on the MAE deviation of the reported values versus the reference values.

### 9.3.2 Certification Requirement

- FTU-O: Conditional mandatory, with the condition that the DPU supports operation over a copper wire pair and supports more than 1 port.
- FTU-R: Conditionally mandatory, with the condition that the CPE supports operation over a copper wire pair.

### 9.3.3 References

- ITU-T G.9701, clause 11.4.1.2.1.
- ITU-T G.997.2, clause 7.10.

### 9.3.4 Test Setup

This test is performed with all devices connected over a mix of loop lengths, also known as non co-located CPE devices. The test SHALL be run over  $N$  pairs. If the DPU supports more than 4 ports, then  $N=4$ , otherwise  $N$  equals the number of ports supported by the DPU ( $N=2$  or  $N=3$ ).

The HLOG-ps data is reported on the first  $N$  pairs of the Multi-Pair Cable Test Loop Topology (CAD55 / CW1420) defined in section 5.4.1.1, with  $N \leq 4$  ports active and vectoring active. These  $N$  pairs are part of one CAD/CW1420 4-pair binder, where the Multi-pair Cable Test Loop Topology (CAD55 / CW1420) is a setup with two CAD/CW1420 4-pair binders. The remaining  $4-N$  pairs of the first binder and the 4 pairs of the second binder are terminated with 100 Ohm at both ends.

1. The DUT and Link Partners (either CPEs or DPU) SHALL be connected to the test setup shown in Figure 2.
2. The DUT and Link Partners SHALL be configured according to section 5.3.
3. The multi-pair loop SHALL consist of a mix of the 20m, 50m, 100m, 200m and 400m loops defined in section 5.4.1.1.
4. The DUT and Link Partners SHALL be connected with the multi-pair loop, consisting of the loop lengths defined in Table 63. If the DPU supports more than 4 ports, the multi-pair loop SHALL be connected on 4 ports randomly selected by the test lab.
5. The reference insertion loss for each of the  $N$  pairs has been measured by the test lab with a Network Analyzer, according to ITU-T G.9701 clause 11.4.1.2.1.

**Table 63 – Loop lengths per profile and number of loops (N)**

	<b>106a</b>	<b>106b</b>	<b>212a</b>
<b>N=2</b>	50m, 200m	100m, 400m	20m, 100m
<b>N=3</b>	50m, 100m, 200m	100m, 200m, 400m	20m, 50m, 100m
<b>N=4</b>	20m, 50m, 100m, 200m	50m, 100m, 200m, 400m	20m, 50m, 100m, 200m

### 9.3.5 Method of Procedure

1. Force all  $N$  lines to L3 (AdminState=DOWN for each of the  $N$  lines).
2. Allow the DUT and Link Partner (either CPE or DPU) to establish a G.fast connection through each of the  $N$  loops (AdminState=UP for each of the  $N$  lines).
3. Wait 60 seconds to allow the DUT and Link Partner to perform any adjustments to the link.
4. If required by the DPU, for each of the  $N$  lines, set Update request flag for far-end test parameters (UPDATE-FE-TEST) to TRUE for Far-end test parameter group 1 (FE-G1) and Far-end test parameter group 2 (FE-G2) (NOTE).
5. Wait 5 minutes for the test parameters to be updated.

6. For each of the  $N$  lines, record the following test parameters:
  - Downstream signal to noise ratio SNRMTds, SNRGds, and SNRpsds;
  - Upstream signal to noise SNRMTus, SNRGus, and SNRpsus;
  - Downstream insertion loss per sub-carrier group: HLOGMTds, HLOGGds, and HLOGpsds;
  - Upstream insertion loss per sub-carrier group: HLOGMTus, HLOGGus, and HLOGpsus.
7. For each of the  $N$  loops, calculate the HLOG Mean Absolute Error (MAE\_HLOG) as defined in section 9.1.1, for both the downstream (MAE\_HLOGds) and upstream (MAE\_HLOGus) direction.

**Note:** The DPU may implement an autonomous update process (see G.997.2 clause 7).

### 9.3.6 Report

For each of the  $N$  loops, the following items/measurements SHALL be included in the report:

1. SNRMTds, SNRGds, and SNRpsds recorded in step 6;
2. SNRMTus, SNRGus, and SNRpsus recorded in step 6;
3. HLOGMTds, HLOGGds, and HLOGpsds recorded in step 6;
4. HLOGMTus, HLOGGus, and HLOGpsus recorded in step 6;
5. MAE\_HLOGds and MAE\_HLOGus as calculated in step 7.

### 9.3.7 Expected Results

For each of the  $N$  loops:

1. MAE\_HLOGds SHALL be  $\leq 6$  dB;
2. MAE\_HLOGus SHALL be  $\leq 6$  dB.

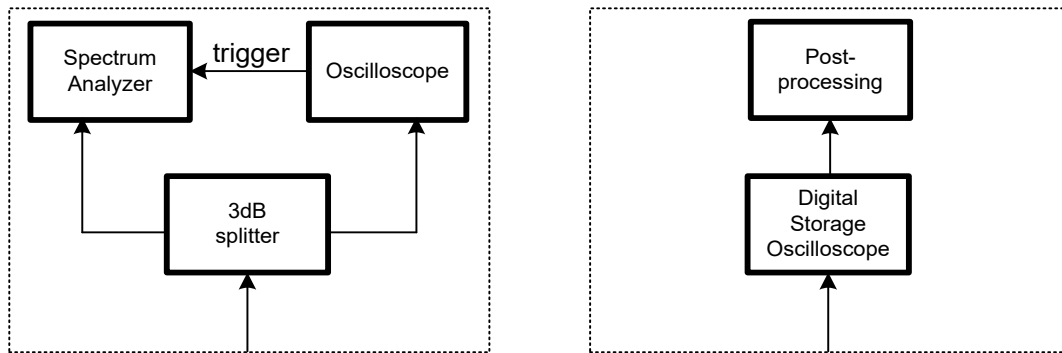
### 9.3.8 Estimated Test Time

The estimated test time for this test case is 10 minutes.

### Appendix I Example Measurement Systems for PSD Mask Testing

This Appendix provides some examples of measurement systems for the purpose of PSD mask testing (see section 6.2).

Example measurement systems for the purpose of PSD mask testing are a time-gated spectrum analyzer or a digital storage oscilloscope with post-processing, as shown in Figure I-1.



**Figure I-1 - Example measurement systems for PSD mask testing.**

If the measurement system uses a time gated spectrum analyzer, the spectrum analyzer is set to continuous sweep mode, due to the absence of trigger signal, when measuring the noise floor of the test setup.

## Appendix II Summary of the Tests and the Estimated Test Times

This Appendix provides a summary of the tests and the estimated test times.

The summary of the tests and the estimated test times are listed in Table II-1. The tests are each marked with a test status, indicating: “M” for “mandatory,” “CM” for “conditional mandatory,” or “O” for “optional.” These terms are defined in section 2.3.

**Table II-1 – Summary of the tests and the estimated test times**

Reference	Test name	FTU-O	FTU-R	Estimated test time (minutes)
6.1	Inventory Data and Profile Selection Test	M	M	10
6.2.1	PSD Limit Mask Test	M	M	30
6.2.2	Sub-carrier Masking Test	M	M	10
6.2.3	PSD Shaping Test	M	M	10
6.2.4	RFI Notching Test	M	M	10
6.2.5	UPBO Test	M	M	10
6.2.6	TIGA Test	CM	CM	30
6.3.1	TDD Inter-frame Gap Test	M	M	10
6.3.2	DS and US Ratio Configuration (Mds) Test	M	M	10
6.4	Accelerated MTBE Test	M	M	15
6.5	Discontinuous Operation Test	O	O	10
6.6	Bit swap or SRA Test	M	M	10
6.7	SRA Downshift Test	M	M	15
6.8	SRA Upshift Test	M	M	15
6.9	FRA & SRA Upshift Test	M	M	10
6.10	RPA Test	M	M	10
6.11	RMC Bit Loading Configuration Test	M	M	10
6.12.1	Short Disconnect Test	M	M	10
6.12.2	Long disconnect Test with LOS failure	M	M	10
6.12.3	Long disconnect Test with LOR failure	M	M	10
6.13	Dying Gasp Test	O	O	10
6.14	Increased Bit Loading Test	M	M	10
6.15	Test Parameters Test	M	M	10
6.16	CPE Software Download Test	O	O	30
6.17	RMC Tone Masking Configuration Test	M	M	10
6.18	Robust Management Channel Recovery (RMCR) Test	O	O	10



7.1	SHINE stability Test	M	M	20
7.2	REIN Stability Test	M	M	10
7.3	Fluctuating Broadband RFI Noise Present at Initialization Test	M	M	5
7.4	Stationary Broadband RFI Noise Present at Initialization Test	M	M	5
7.5	Fluctuating Broadband RFI Noise Present at Showtime Test	M	M	5
7.6	Stationary Broadband RFI Noise Present at Showtime Test	M	M	5
8.1.1	Single-line Basic Throughput Test Over a Copper Wire Pair	CM	CM	45
8.1.2	Single-line Basic Throughput Test Over a Coaxial Cable	CM	CM	45
8.1.3	iDTA Test	O	O	15
8.2.1	Multi-line Basic Throughput Test over Copper Wire Pairs	CM	CM	60
8.2.2	Multi-line Disorderly Shutdown Test Over Copper Wire Pairs	CM	CM	5
8.2.3	cDTA Test	O	O	30
9.2	Single-line HLOG Accuracy Test	M	M	10
9.3	Multi-line HLOG Accuracy Test over Copper Wire Pairs	CM	CM	10
<b>Estimated total test time for TP-337i4</b>				<b>605</b>

End of Broadband Forum Test Plan TP-337i4